





VTCT

USP186 - Applied anatomy for exercise, fitness, health and wellbeing

LO1 Understand the structure and function of the skeletal system in relation to exercise, health and fitness programming

Content and Assessment Criteria

- Know the anatomical reference points (see also USP182)
- Know the anatomical planes of movement (see also USP182)
- Know the functions of the skeleton (see also USP182)
- Know the bones of the axial and appendicular skeleton (see also USP182)
- Know the classifications of different bones (see also USP182)
- Know the stages of bone growth and the structures of a long bone (see also USP182)

Content and Assessment Criteria

- Structure of the spine in relation to posture and range of motion (see also USP182)
- Know the skeletal structures of the pelvic girdle (see also USP182)
- Know the joint classifications and structure (see also USP182)
- Know the different types of synovial joints, their location, range of motion and joint actions (see also USP182)
- Know the exercise and movement considerations in relation to the skeletal system

Summary of the skeletal system

- Main framework of approximately 206 bones, which form joints
- Different functions – shape, support, attachment, locomotion
- Many synovial or freely moveable joints – ligaments, tendons and cartilage
- Different bone classifications – long, short, flat
- Bone structure and growth – periosteum, growth plates, bone cells
- Different types of joint and joint actions
- The spine – posture and posture types

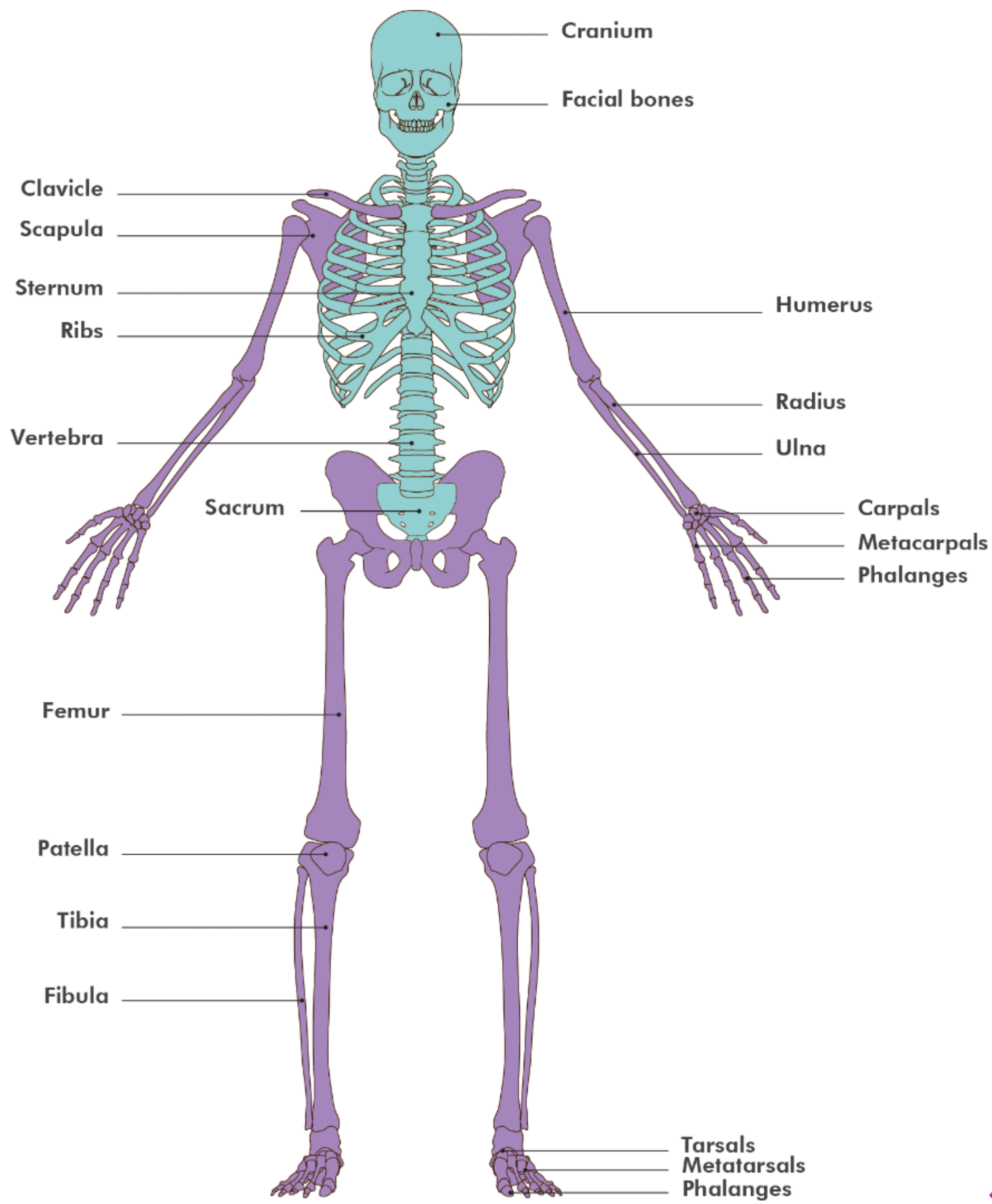
The skeleton

Appendicular skeleton

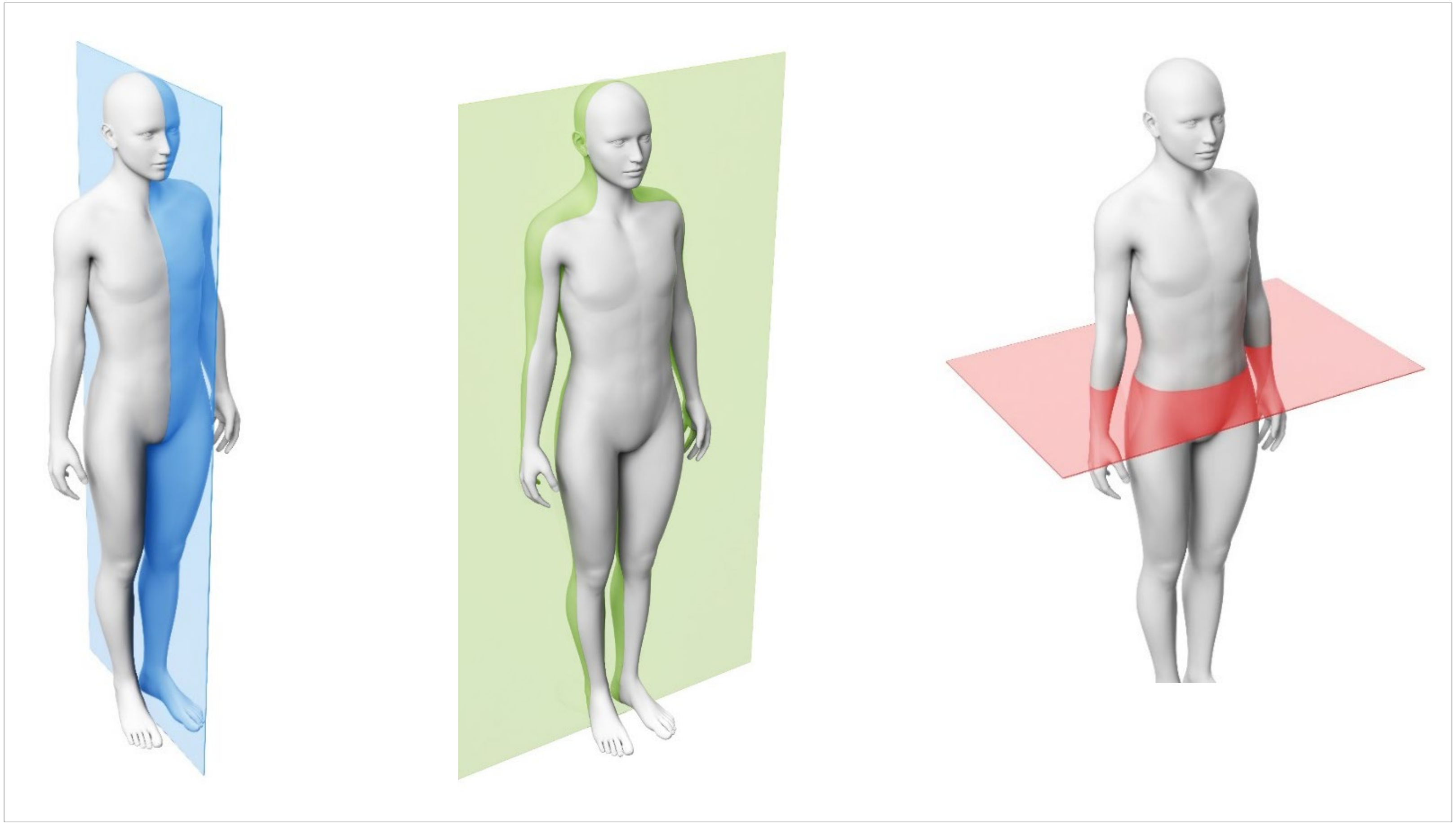
- Pelvic girdle
- Shoulder girdle
- Bones of the arms, legs, hands and feet

Axial skeleton

- Skull
- Spine
- Ribcage
- Sternum



Movement planes review



Sagittal Frontal Transverse

Sagittal or median plane

- Vertical plane that dissects the body into left and right sides
- Bilateral axis movements: flexion and extension

Frontal or coronal plane

- Vertical plane that dissects the body into front and back
- Anterior/Posterior axis movements: adduction, abduction, lateral flexion, eversion and inversion

Transverse (horizontal) plane

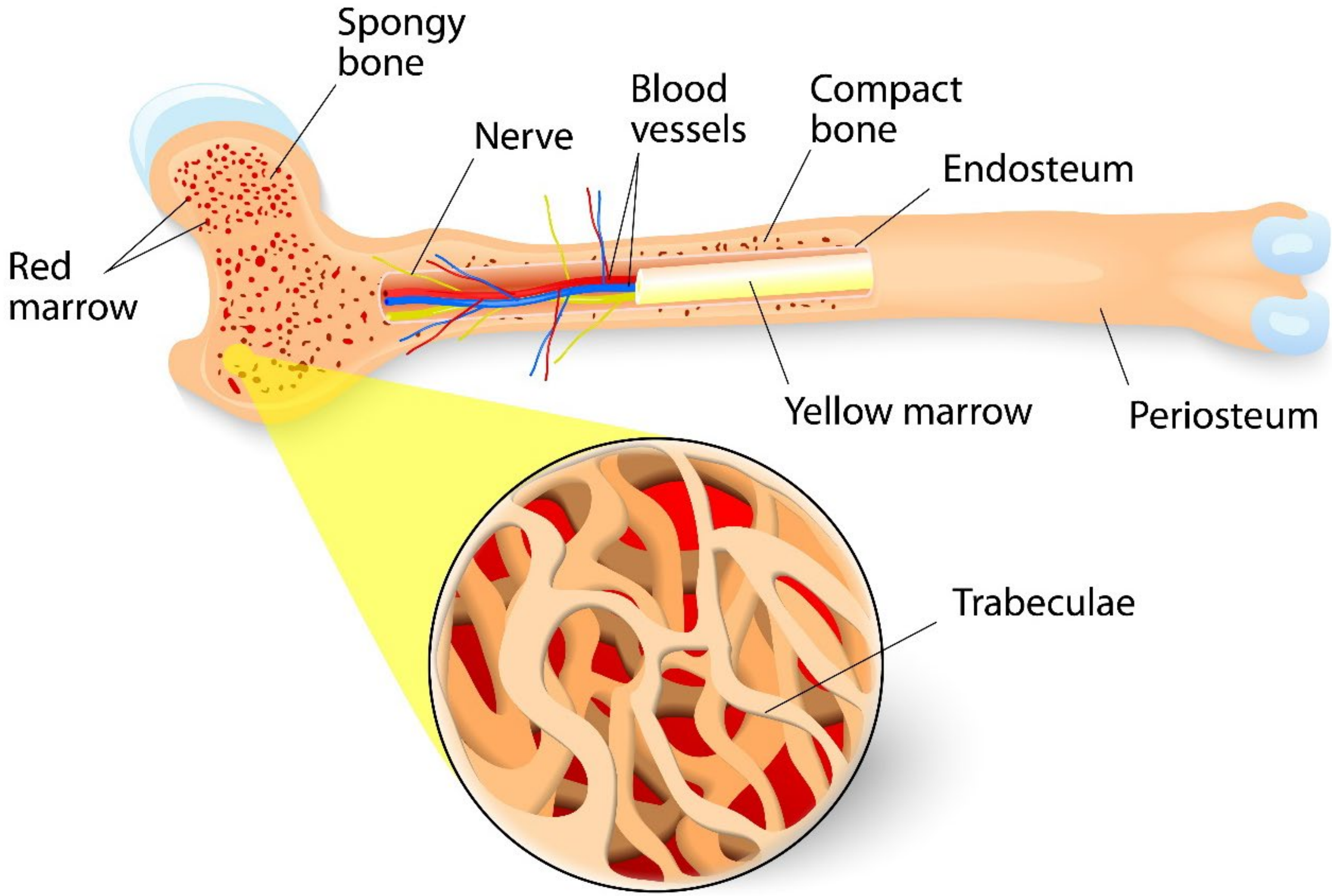
- Horizontal plane that dissects the body into upper and lower
- Vertical axis movements: internal rotation, external rotation, horizontal flexion and extension

Activity

Identify the planes of movement the following joints are moving through in the following exercises:

- The elbow during a bicep curl
- The shoulder during a lateral raise
- The hip during the downward phase of a squat
- The spine during lateral flexion of the spine

Bone anatomy



Structure of a long bone

- **Periosteum**
  A tough, connective tissue sheath covering the outer section of the bone
- **Articular cartilage**
  Hyaline cartilage covers the end of the bone
- **Epiphysis**
  The two end sections of the bone
- **Diaphysis**
  The main shaft (length) of the bone
- **Metaphysis**
  Where the epiphysis joins the diaphysis in a mature bone
- **Epiphyseal plates**
  The growth plates

Structure of a long bone

- **Endosteum**
  A layer of connective tissue that lines the inner surface of the bone

- **Compact bone**
  The solid, dense bone tissue otherwise known as cortical bone that forms the external layer of all bones. Provides protection and support and resists stresses placed on long bones

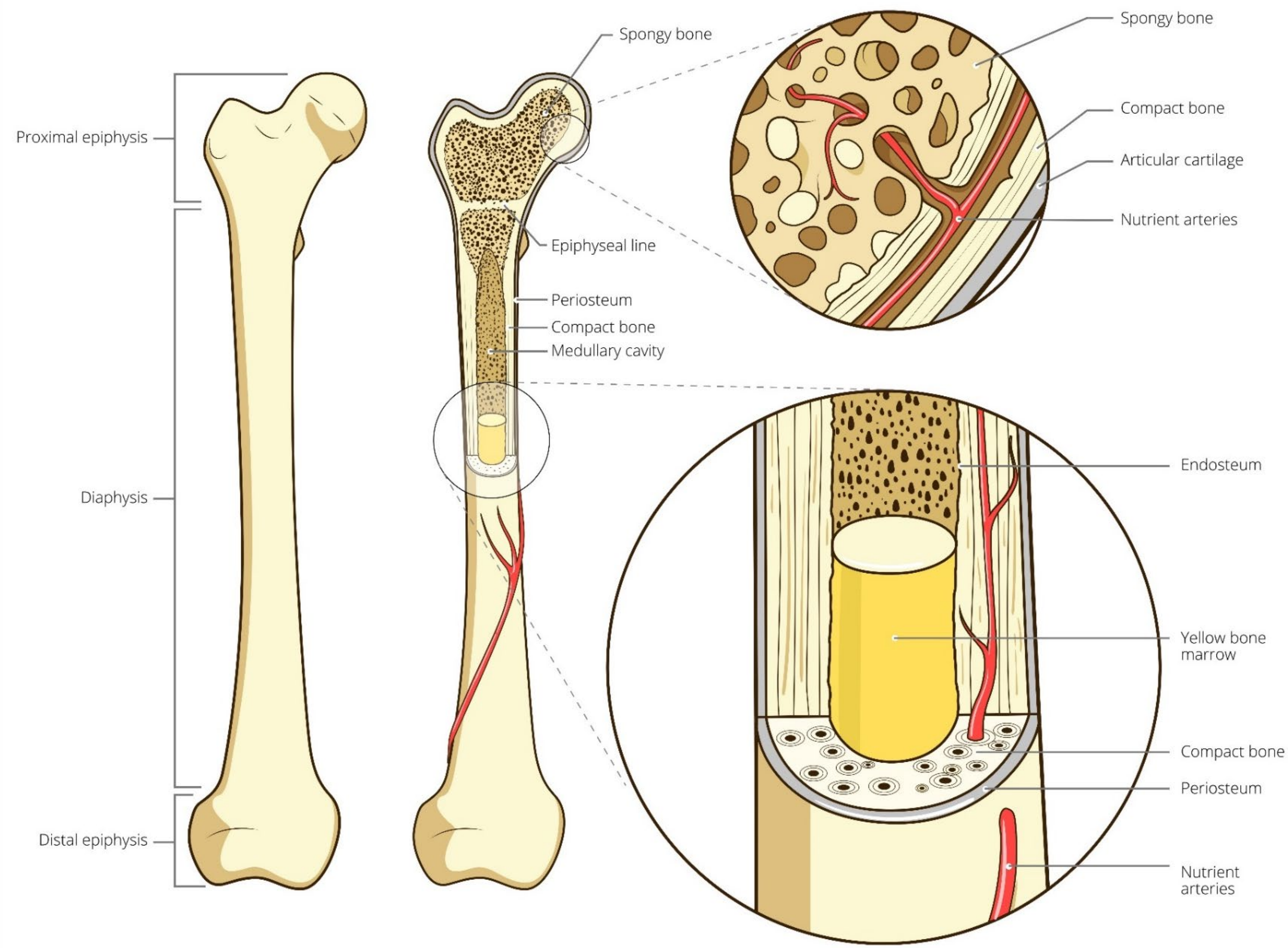
- **Cancellous bone**
  Also called trabecular bone or spongy bone. This type of bone tissue makes up most of the bone tissue of short, flat and irregular bones and the epiphysis of long bones

- **Red marrow**
  Found in cancellous bone tissue

- **Medullary cavity**
  The marrow cavity. Contains yellow bone marrow

- **Yellow marrow**
  Found in the medullary cavity and functions for the storage of fat

Bone structure



Activity

Name the structures:

- The fibrous connective tissue covering the bone
  -
- The main bone shaft
  -
- The two ends of the bone
  -
- The cartilage covering of the ends of the bone
  -
- The growth plates
  -
- The marrow found in the medullary cavity
  -

Bone formation and growth

- **Osteoblasts** – bone building cells
- **Osteoclasts** – bone clearing cells
- **Ossification** – the process of bone growth
- **Osteoporosis** – disease caused by loss of bone mass

Bone formation and growth

Ossification:

- Ossification begins around the 6^{th} or 7^{th} week of embryonic life
- Bone formation follows one of two patterns
  - Intramembranous ossification
  - Endochondral ossification
- Both methods involve replacing the pre-existing connective tissue with bone tissue

Bone formation and growth

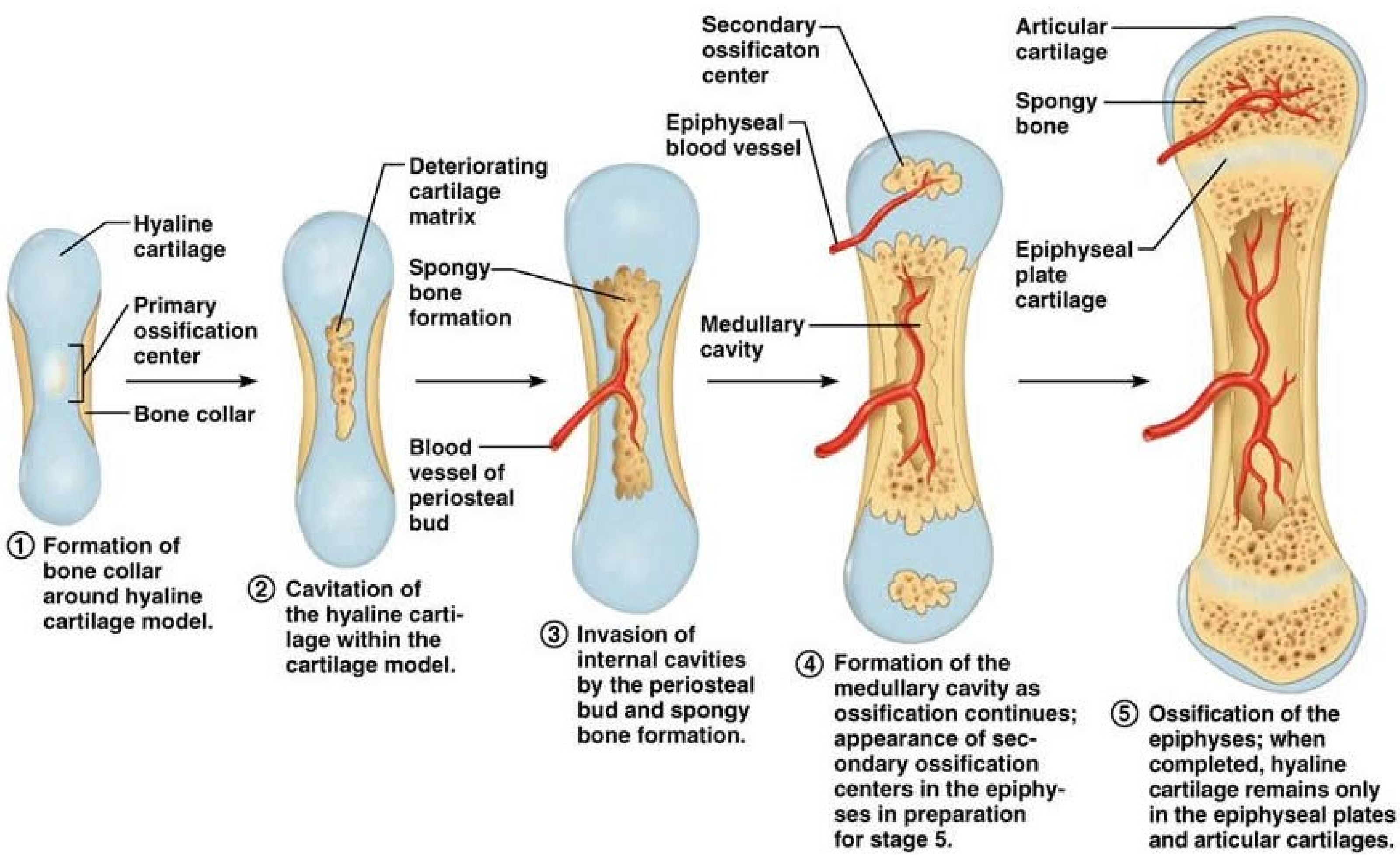
Intramembranous ossification:

- Refers to the formation of bone directly on or within loose fibrous connective tissue membranes
- Loose fibrous connective tissue membranes are replaced by bone
- Typically occurs in the flat bones of the skull, mandible and clavicles

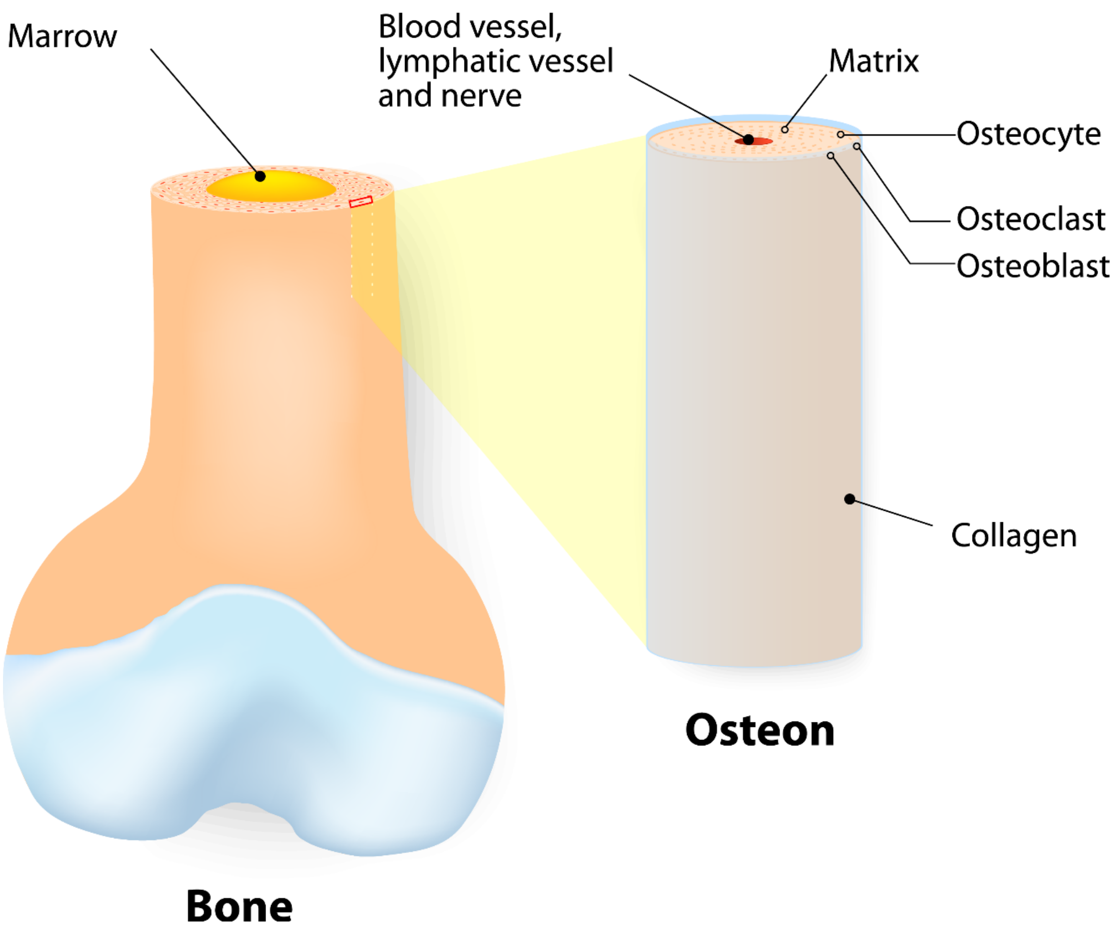
Endochondral ossification:

- Refers to the formation of bone in hyaline cartilage
- Most bones in the body are formed this way but but is best observed in long bones
- The slide below depicts this process of bone formation and growth

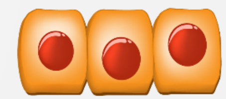
Bone formation and growth



Internal structure of a bone

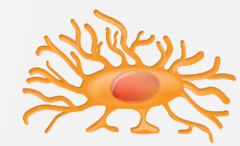


Osteoblast



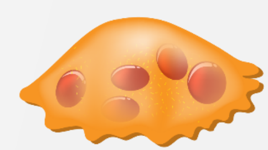
synthesize bone

Osteocyte



are formed
from osteoblasts

Osteoclast



breaks down
bone tissue

Factors affecting bone growth

- Age
- Gender
- Ethnicity
- Diet and nutrition
- Physical activity
- Hormones
- Medications
- Sunlight
- Vitamin D
- Calcium

Fracture and repair of bone

A fracture is a break in a bone. There are 4 general steps that occur in the repair of bone fracture

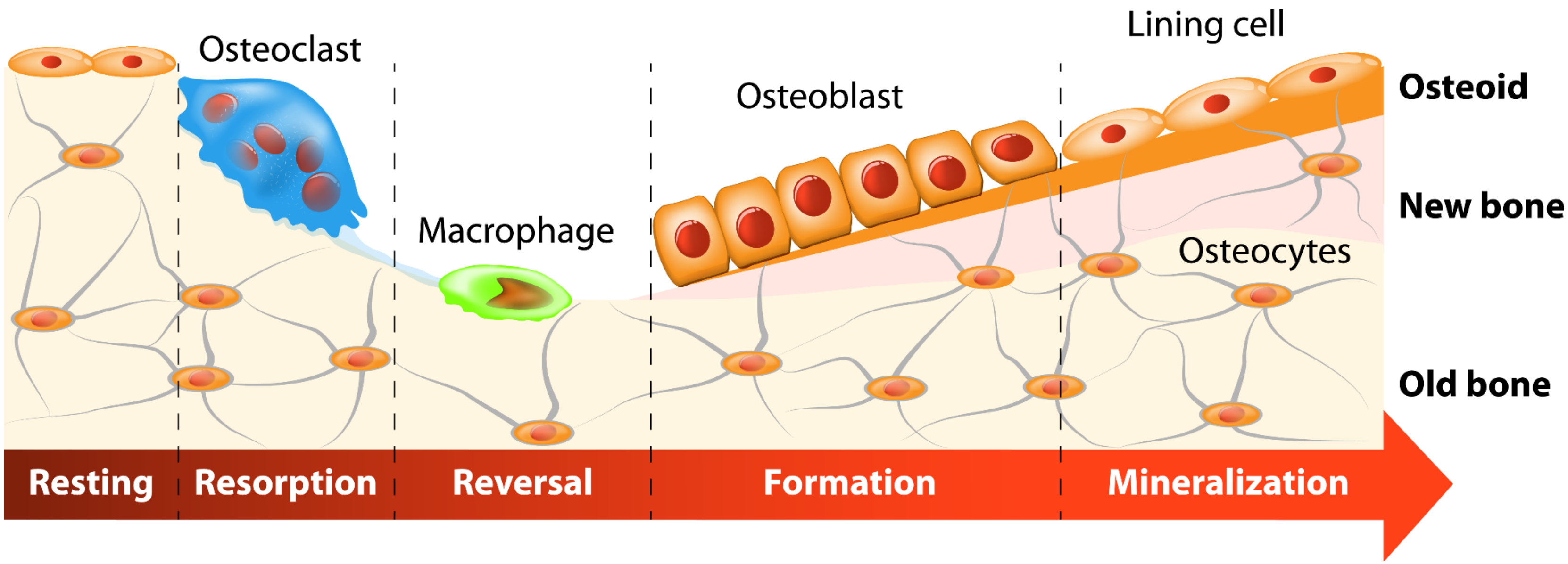
1. As a result of a fracture bleeding occurs at the site and leads to a clot called a ***fracture hematoma.*** Usually occurring 6-8hours after fracture

2. Blood capillaries enter the the fracture hematoma. Osteoblasts invade the area and fibroblast cells start to lay down collagen. This leads to a ***fibrocartilage callus formation*** that bridges the broken ends of the bone. This lasts for around 3 weeks

3. Osteoblasts start to produce spongy bone tissue leading to an area of ***hard callus*** formation. This can take 3-4 months

4. The final phase is ***remodelling***. Osteoclasts remove dead bone cells and compact bone replaces spongy bone

The bone remodelling process

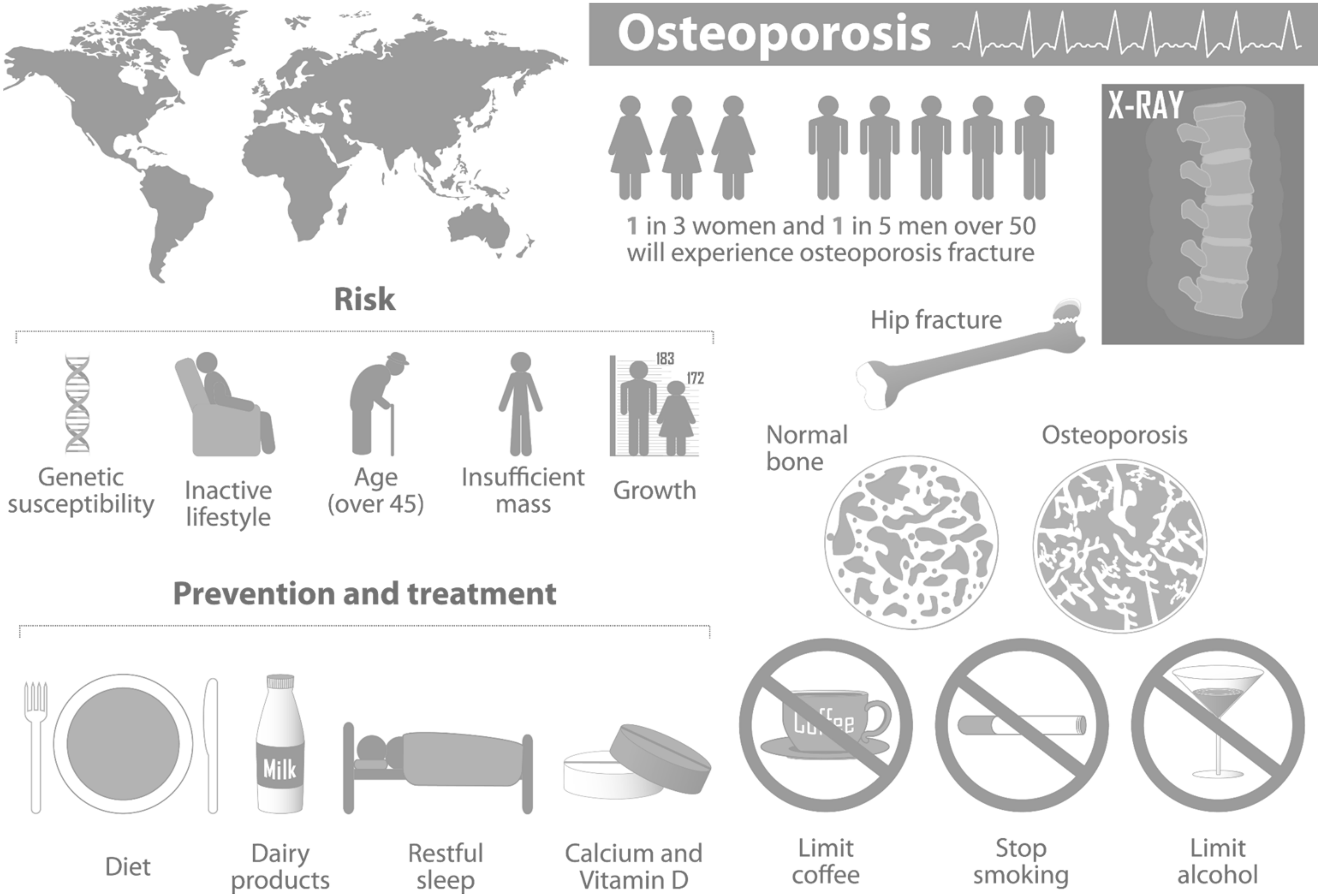


Growth spurts

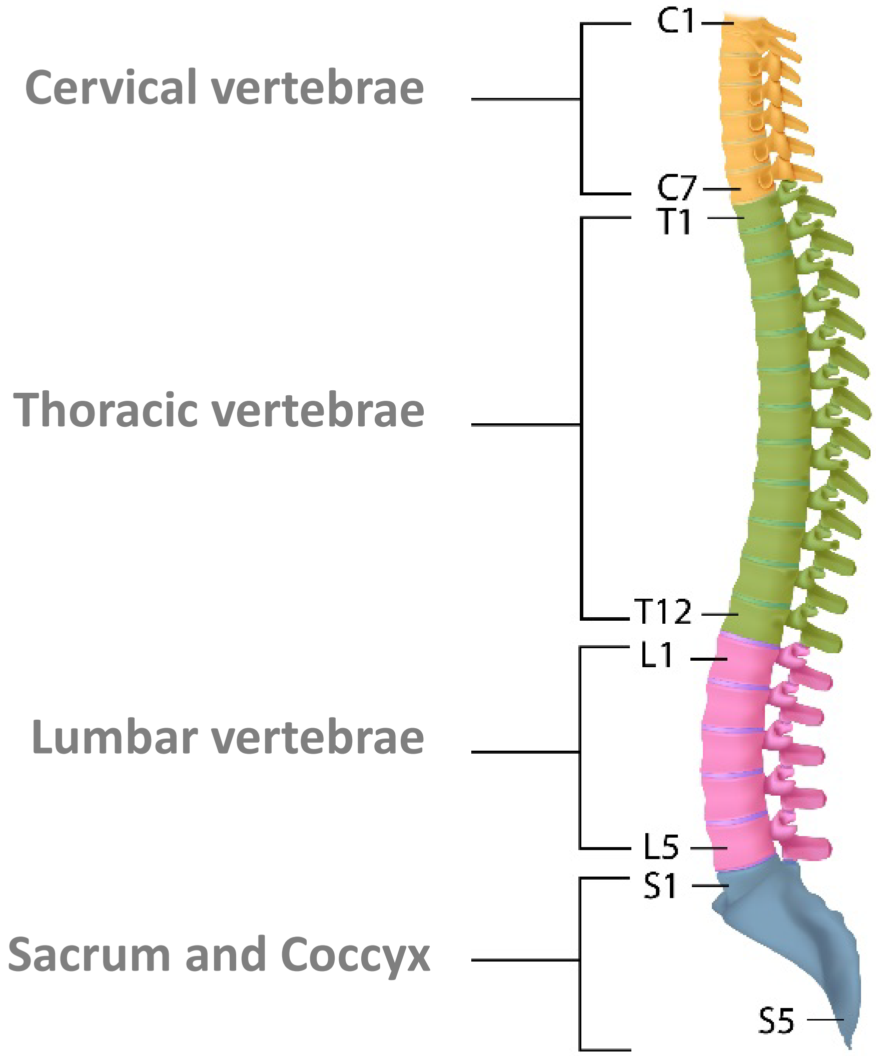
During a child's maturation their bones will suddenly develop at a rapid rate. This is known as a growth spurt.

Growths spurts happen at different rates and ages, but commonly:

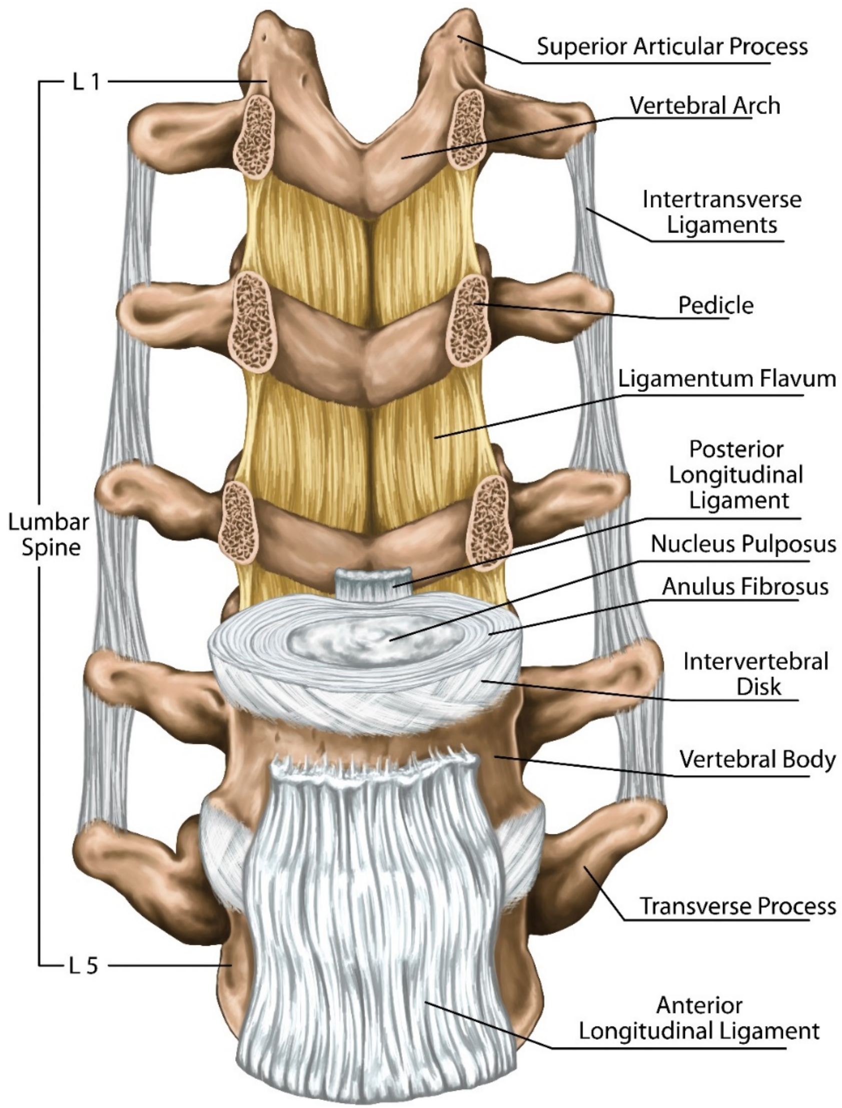
- Girls tend to grow fastest at 12 to 13 ending at 18
- Boys tend to grow fastest at 14 to 15 ending at 20


Osteoporosis
X-RAY
1 in 3 women and 1 in 5 men over 50
will experience osteoporosis fracture
Hip fracture
Risk
Genetic susceptibility
Inactive lifestyle
Age (over 45)
Insufficient mass
183
172
Growth
Normal bone
Osteoporosis
Prevention and treatment
Diet
Milk
Dairy products
Restful sleep
Calcium and Vitamin D
Limit coffee
Stop smoking
Limit alcohol

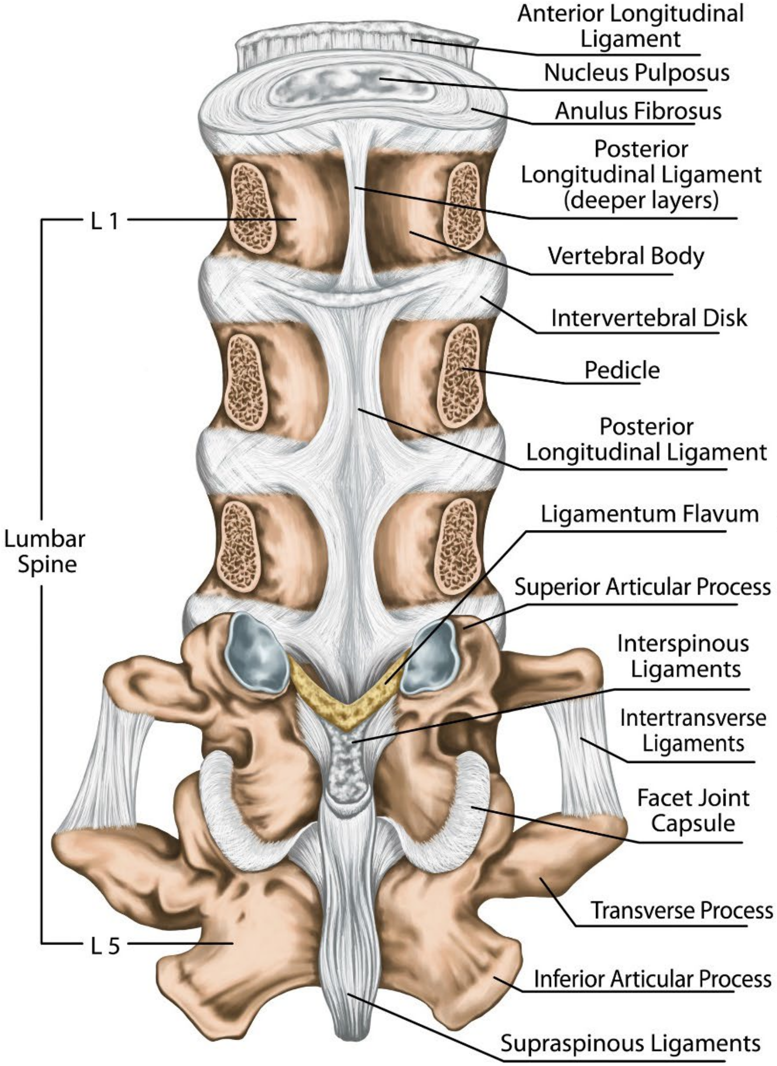
Neutral spine

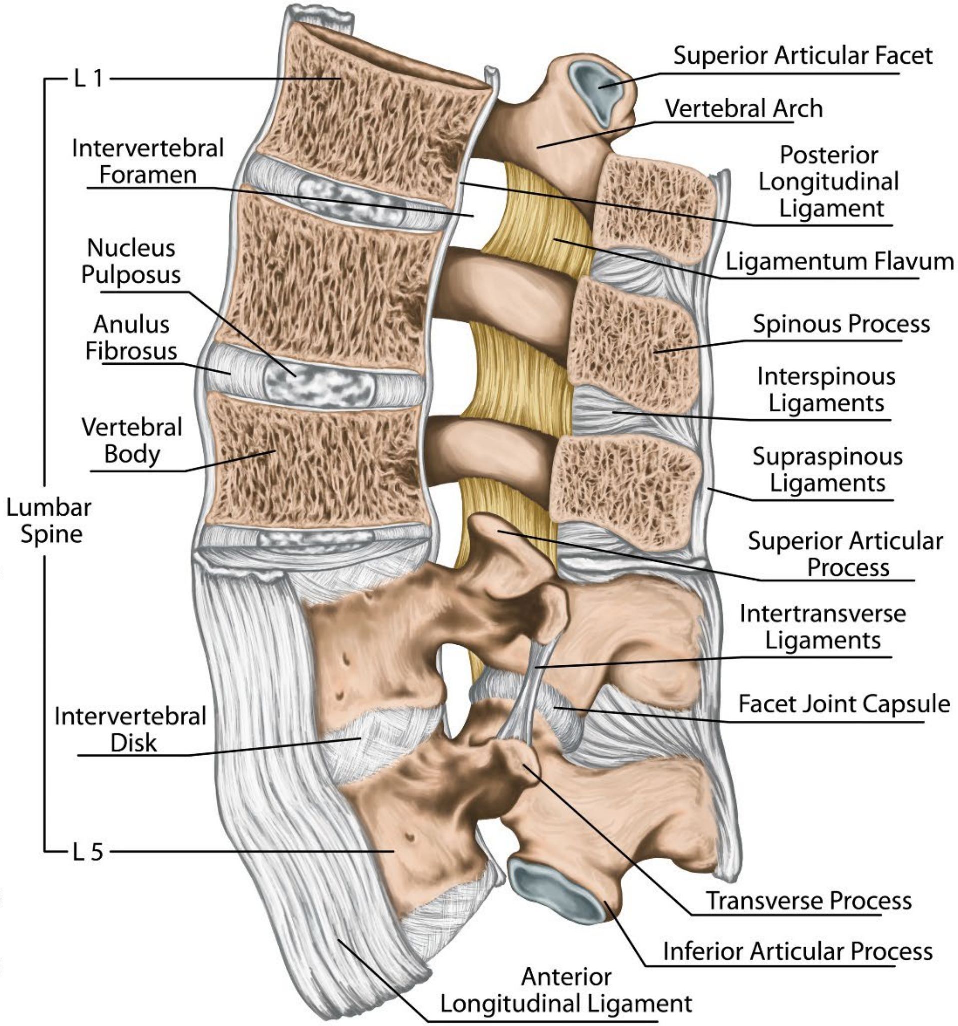


Stabilising ligaments



Stabilising ligaments





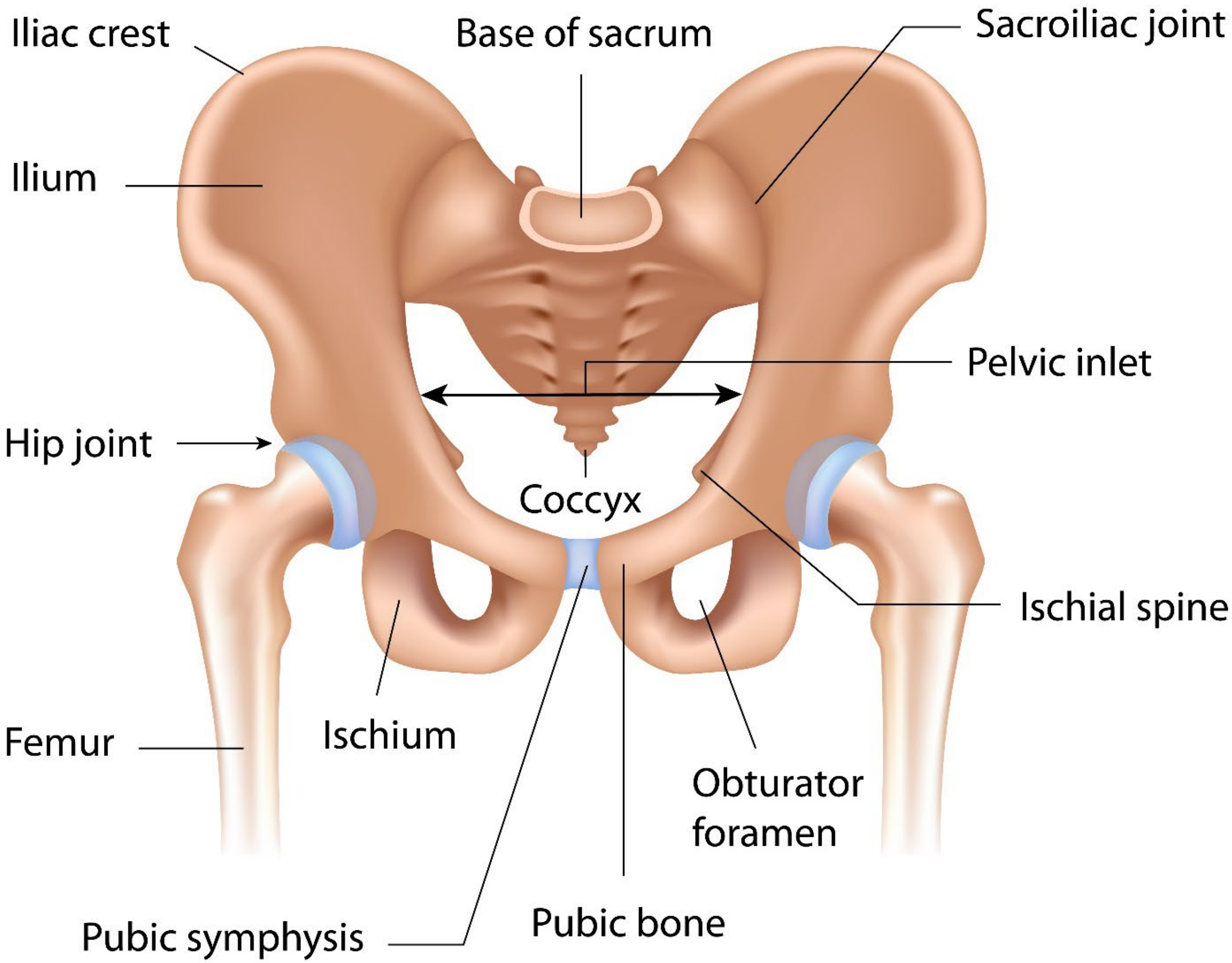
Posture types

Posture type	Weak/long muscles	Short/strong muscles	Action
Hyperlordosis	• Hamstrings • Gluteals • Abdominals	• Back extensors (possibly) • Hip flexors	• Stretch short muscles • Strengthen weaker muscles
Hyperkyphosis	• Lower and middle trapezius • Rhomboids • Neck flexors	• Neck extensors • Pectorals • Anterior deltoid • Upper trapezius	
Flat back	• Hip flexors • Back may be long but not necessarily weak	• Hamstrings	
Sway back	• Hip flexor • External obliques • Upper back extensors • Neck flexors	• Hamstrings, • Internal oblique • Lumbar extensors (may be strong, but not short)	
Scoliosis	• One side convex	• Other side of the concave	

Potential problems associated with postural deviations

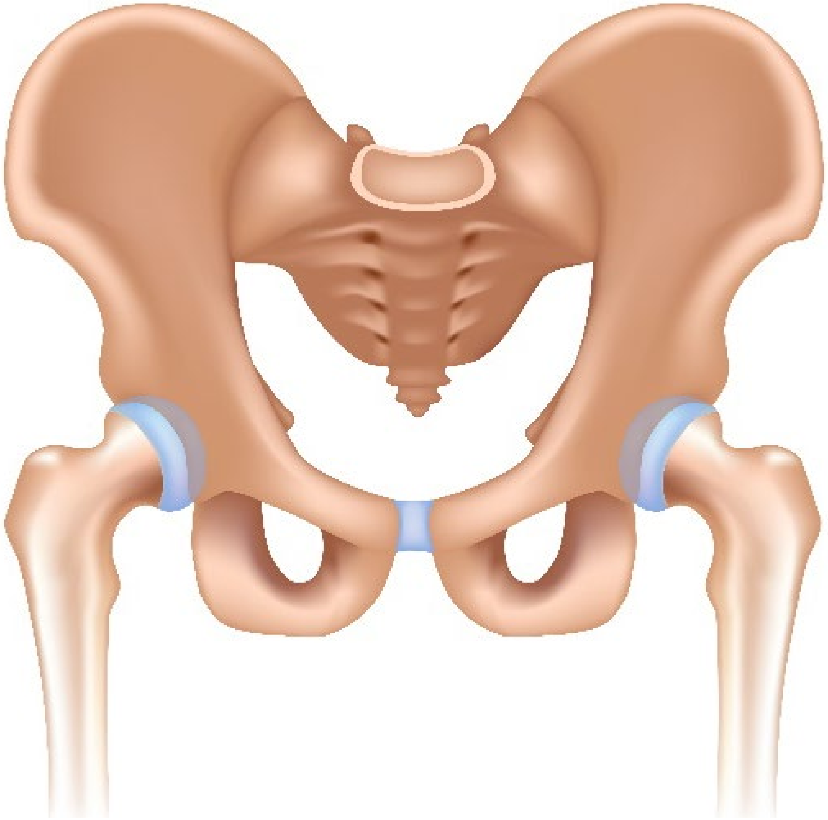
- Muscle imbalances
- Compensatory movements
- Inefficient movement patterns
- Joint and muscle pain
- Back pain

The pelvic girdle



Sacroiliac joint (SIJ)

- Between sacrum and iliac bones
- Considered to be both movable (synovial) and immoveable (fibrous) components
- It is generally considered that motion occurs at the SIJ
- Movements at the SIJ can seem complex but the most commonly referred to are the anterior and posterior rotations in the sagittal plane



Ligaments of the pelvic girdle

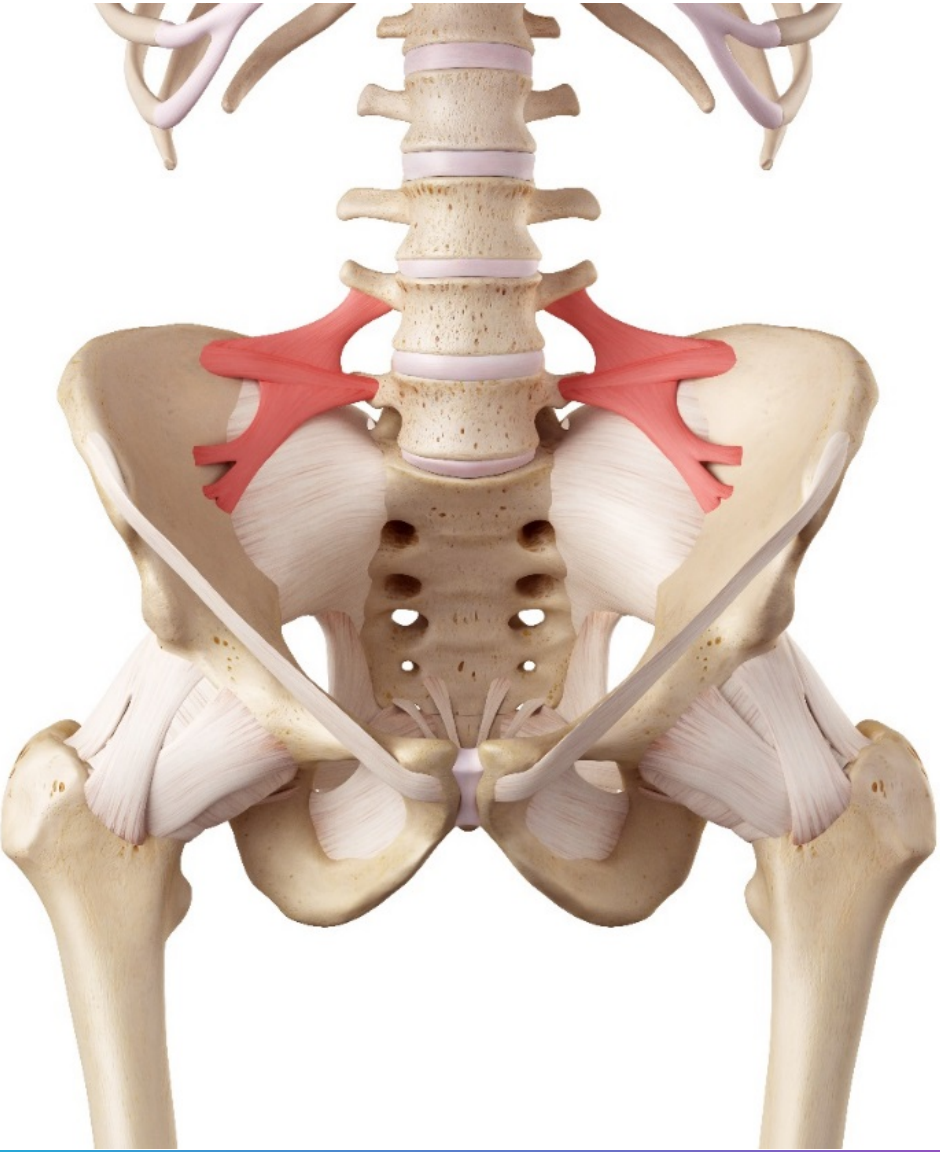
Ligaments:

- Iliolumbar
- Sacrospinous
- Sacrotuberous
- Anterior and posterior sacroiliac

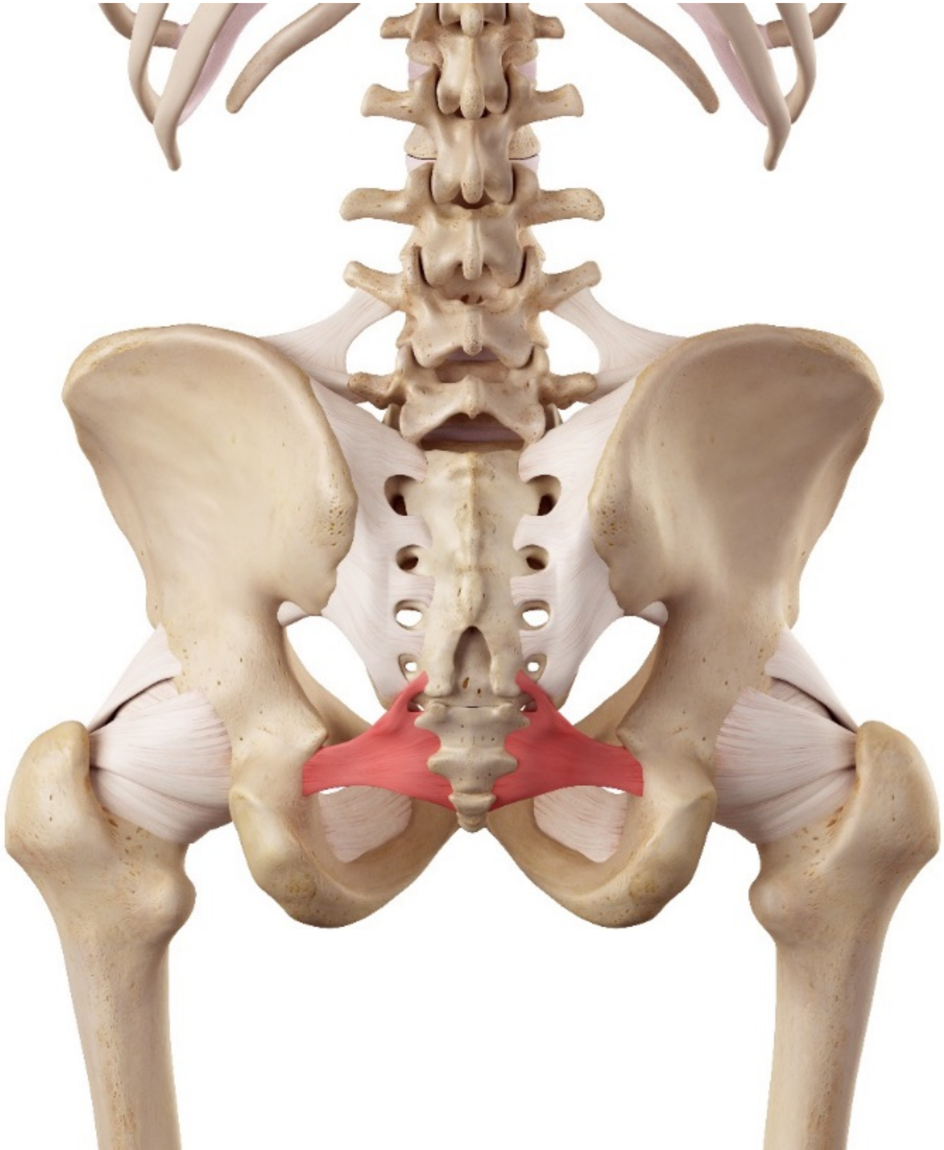
Articulations:

- Pubis symphysis articulation (cartilaginous)
- Sacroiliac articulation

Iliolumbar ligament

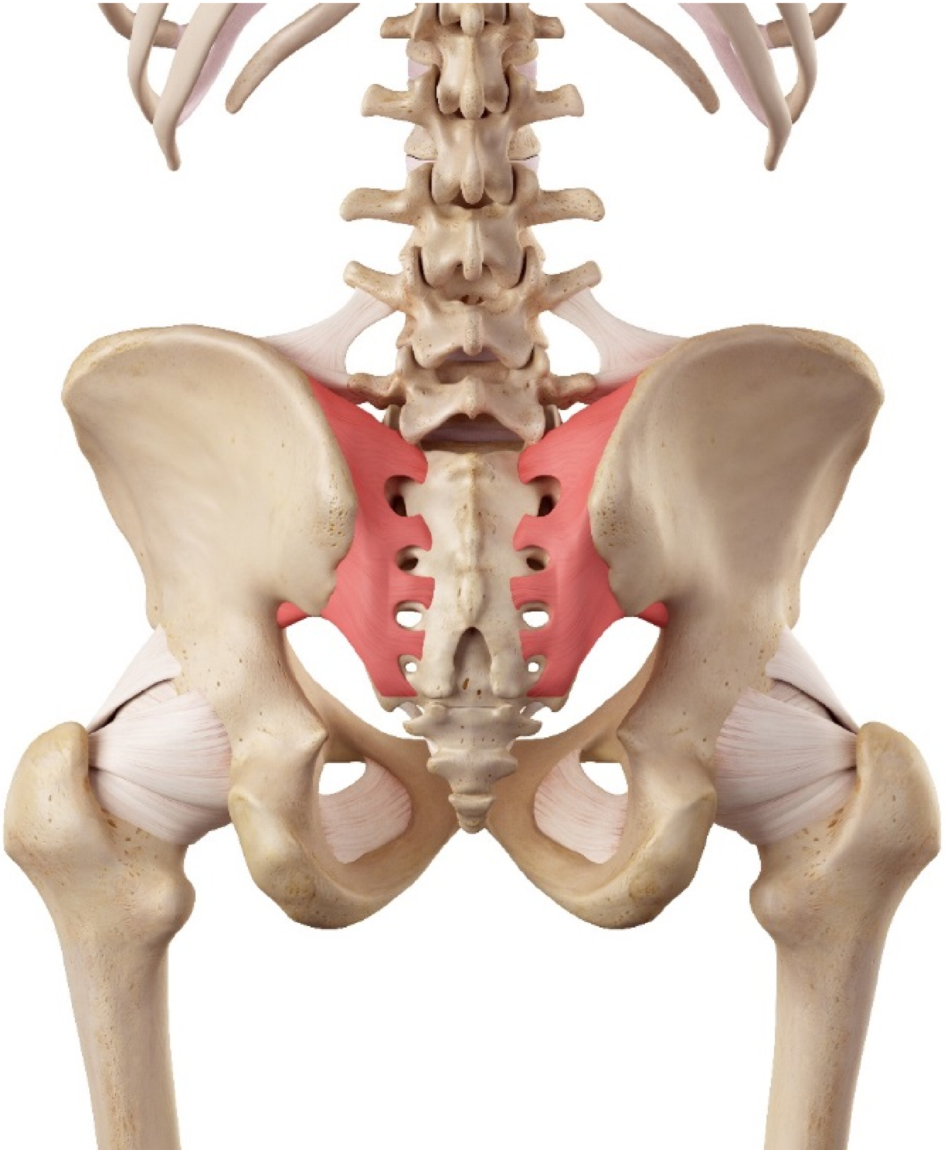


Sacrospinous ligament

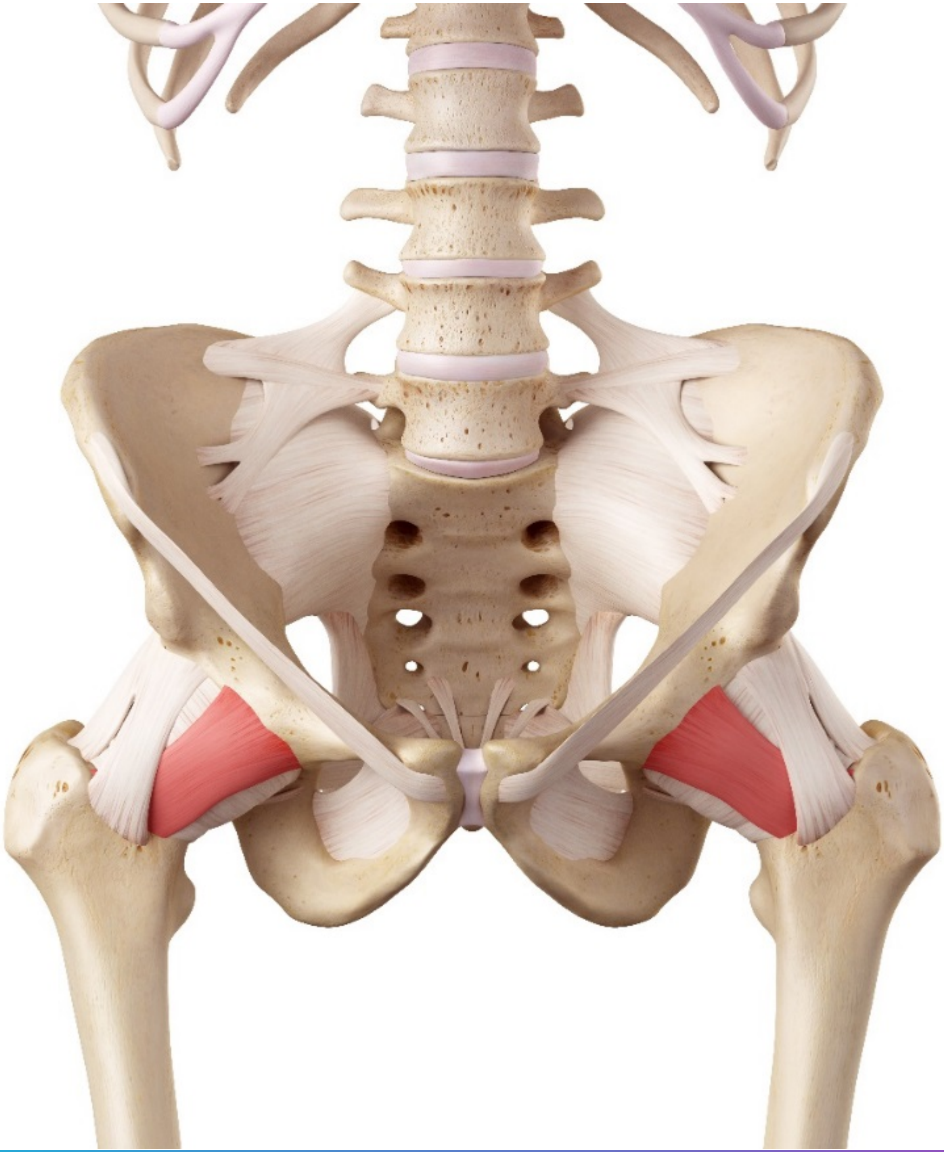


Sacrotuberous ligament

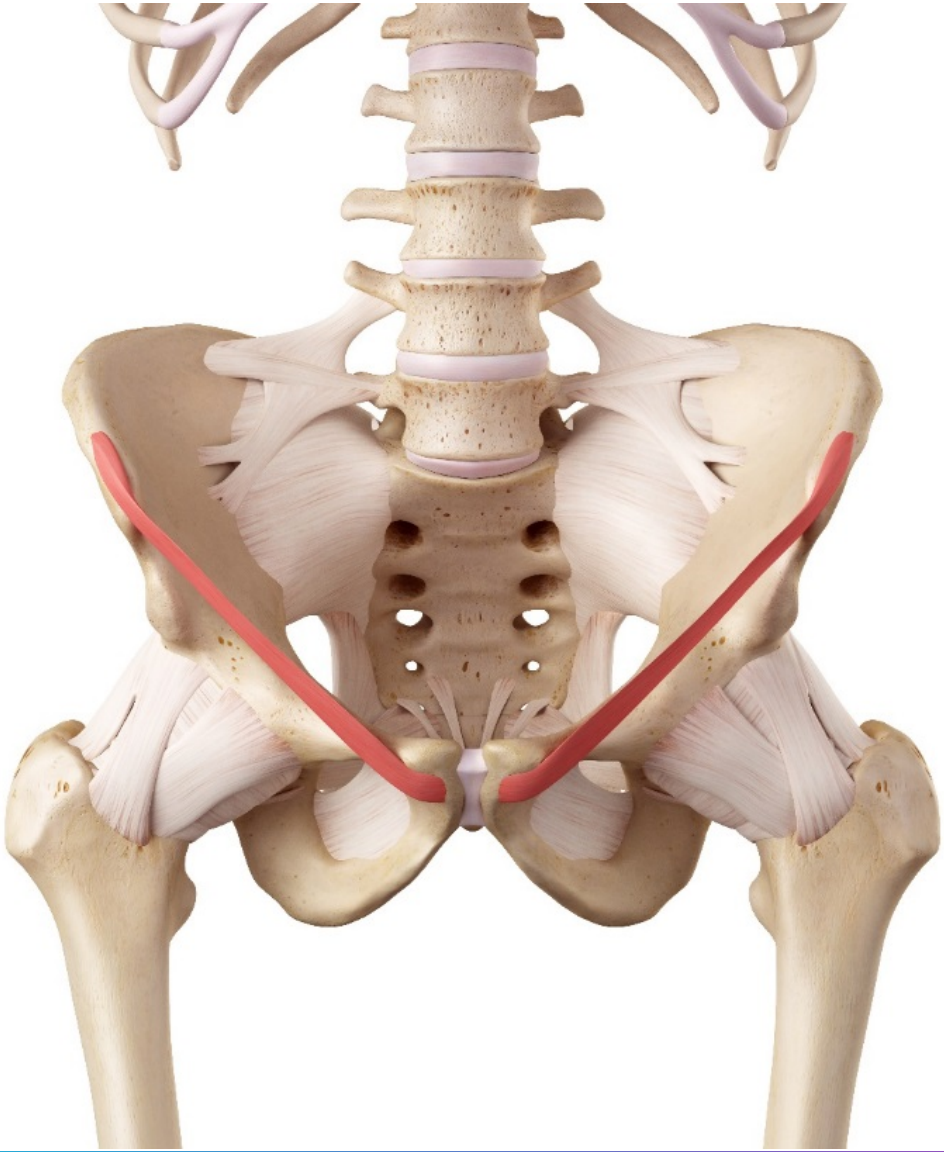
Sacroiliac ligament



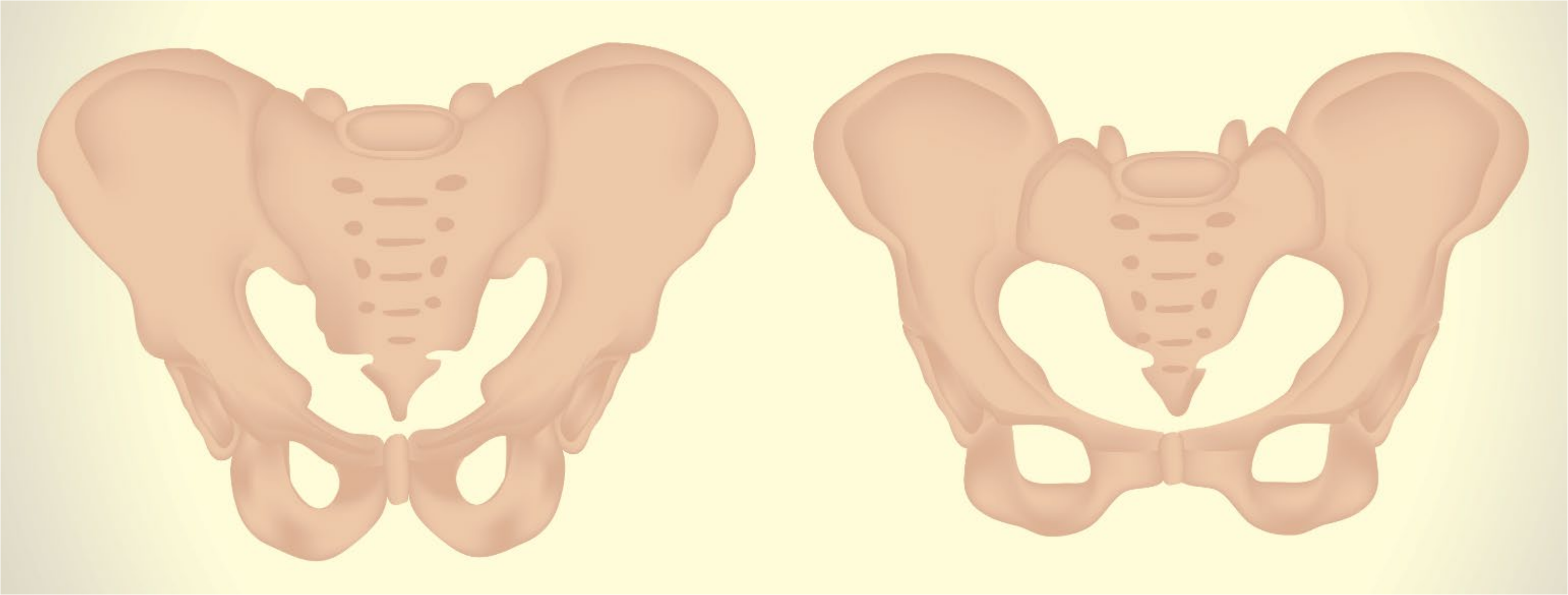
Pubofemoral ligament



Inguinal ligament



Male and female pelvis



Male pelvis **Female pelvis**

Activity

Identify three possible risk factors to bones, joints or ligaments when engaging in physical activity or exercise and discuss how these risk factors can be minimised.

Risk factors and injuries

Fractures

- Ligament sprains
- Cartilage damage
- Joint dislocations

Factors contributing to injury risk

- Poor technique
- Excessive loads in resistance training
- Fatigue
- Falls and trips in a gym environment
- Lack of observation and client monitoring
- Overtraining/Lack of rest

Immediate/short term effects

Skeletal:

- Increased blood circulated to bones and joints
- Increased synovial fluid in the joints (lubrication)
- Increased joint mobility
- Connective tissue compliance at joints
- Cartilage nourishment

Long term adaptations

Skeletal:

- Improved bone mineral density
- Improved development of peak bone mass in formative years (up to age 30)
- Maintenance of bone mass pre-menopause
- Reduces rate of bone loss post-menopause
- Reduced risk of osteoporosis
- Increased release of synovial fluid into the joints
- Healthier hyaline cartilage
  (which can assist with the management of osteoarthritis)

Long term adaptations

Skeletal:

- Maintenance or improved joint mobility and range of motion
- Stronger ligaments and other joint connective tissues
- Reduced risk of joint injury
- Improved posture
- Reduced risk of falls and bone fractures in older adults with osteoporosis
- Reduced risk of low back pain

Levers and lever systems

Levers

- Allow movement to occur
- Muscles contract and pull on the bones to allow movement at the different joints

Three types

- 1st class lever
- 2nd class lever
- 3rd class lever

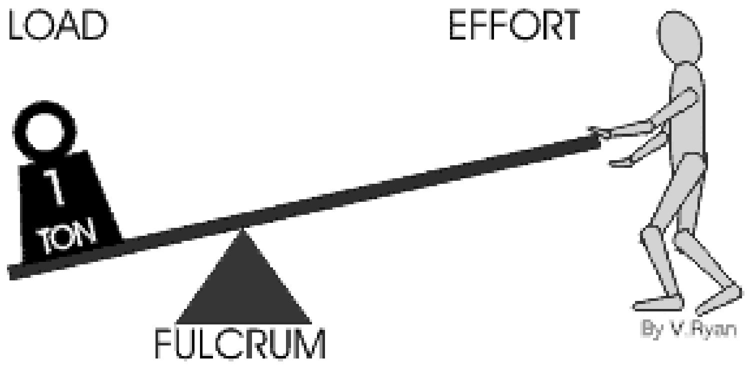
Levers and lever systems

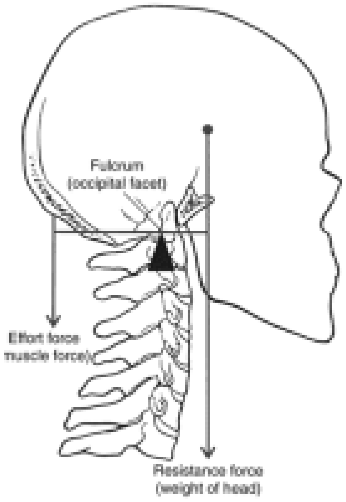
Levers

- Lever – simple rigid bar (bones)
- Fulcrum – point around which the lever rotates (a joint)
- Force arm – area between the fulcrum and point of force (effort)
- Load arm – area between the fulcrum and the load
- Effort – muscular force

1st class lever

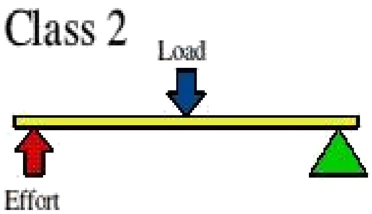
- **Fulcrum between the load and force arm**





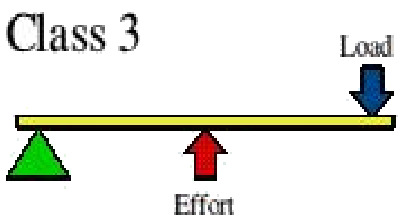
2nd class lever

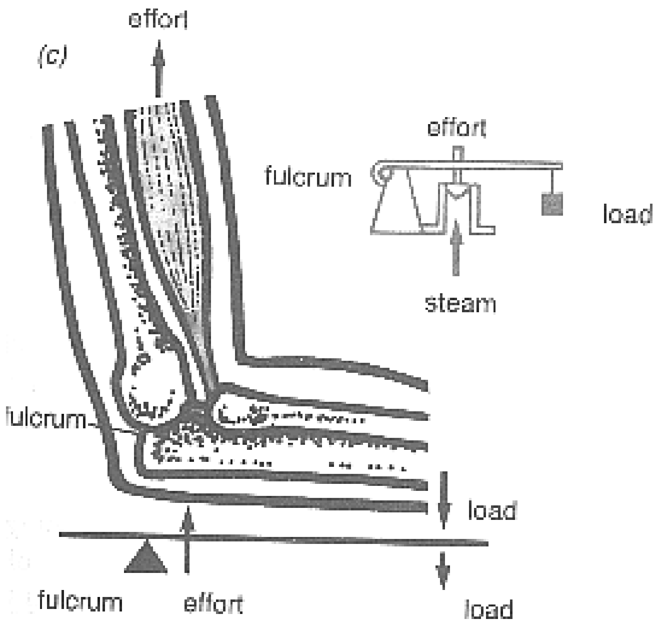
- Fulcrum at one end and applied force at the other, the load sits between them
- Wheelbarrow
- Lifting up on to toes



3rd class lever

- Fulcrum at one end, the load at the other with the applied force between them





Activity

What is biomechanics and what do we mean by the following?

- Centre of gravity
- Momentum
- Force
- Length – tension relationship
- Open and closed chain kinetic movements

Biomechanics

The study of forces acting on and generated within a body

- The application of physics to the study of motion
- Important for studying movement
- Force – any action that tends to maintain or alter the motion of a body or object for example, a tackle or gravity
- Centre of gravity (COG) – the point in an object where its weight is balanced
  - In the anatomical position – usually around S2
  - Slightly higher in men
  - As we move it will change
  - Knowing an objects COG will help aid stability

Biomechanics

The study of forces acting on and generated within a body

- Momentum – motion of a body which is the product of its mass and its velocity
  - Linear
  - Angular

- Length-tension relationships – represents the force a muscle is capable of generating while held at a series of discrete lengths
  - The length-tension relationship states that isometric tension generation in skeletal muscle is related to the amount of overlap between actin and myosin filaments

- Open chain exercises – exercises where the hand or foot is free to move (leg extension)

- Closed chain exercises – exercises where the hand or foot is fixed (squat)

Learning check quiz

- Outline the difference between a 1^{st} and 2^{nd} class lever
- Identify two long term training adaptations to the skeletal system
- Outline the position and function of the sacroiliac ligament
- What is the main difference between a male and female pelvic girdle?
- Identify and describe the function of two ligaments that support the spine
- Outline the difference between an osteoclast and an osteoblast
- Identify the plane of motion that the humerus goes through during a lying chest press exercise







VTCT

USP186 - Functional anatomy

LO2 Understand the structure and function of the muscular system in relation to exercise, health, and fitness programming

Content and Assessment Criteria

- Types of muscle tissue
- Basic structure of skeletal muscle
- Name and location of skeletal muscles
- Function of muscle
- Muscle contraction and action
- Skeletal muscle fibre types and their characteristics
- Stabilising muscles of the spine

The muscular system

The muscular tissue is characterised by properties that allow movement.

Characteristics of muscle tissue

Characteristics:

- **Excitability**
  The ability to receive and respond to stimuli by producing electrical stimuli called action potential (impulses)

- **Conductivity**
  The ability of a muscle cell to propagate or conduct action potentials along its membrane

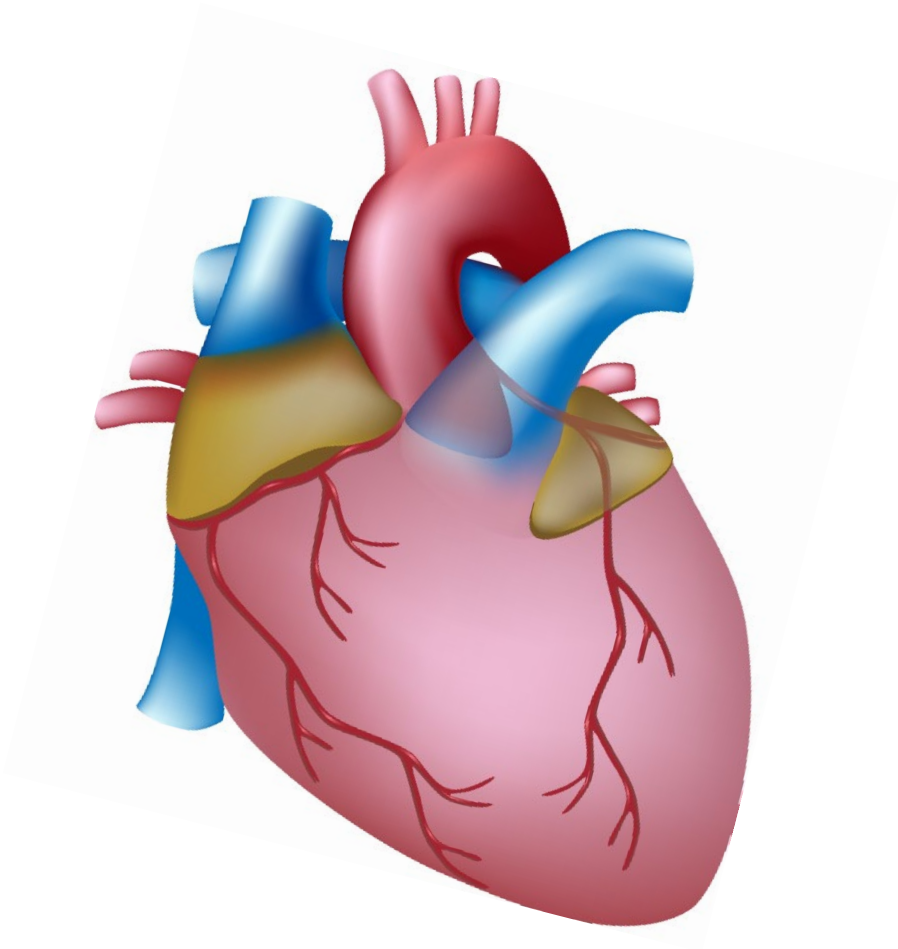
- **Contractility**
  The ability to shorten (contract) thus generating force

- **Extensibility**
  The ability to be stretched or extended without damage to the tissue

- **Elasticity**
  The ability to recoil and return to its starting length after contraction or extension

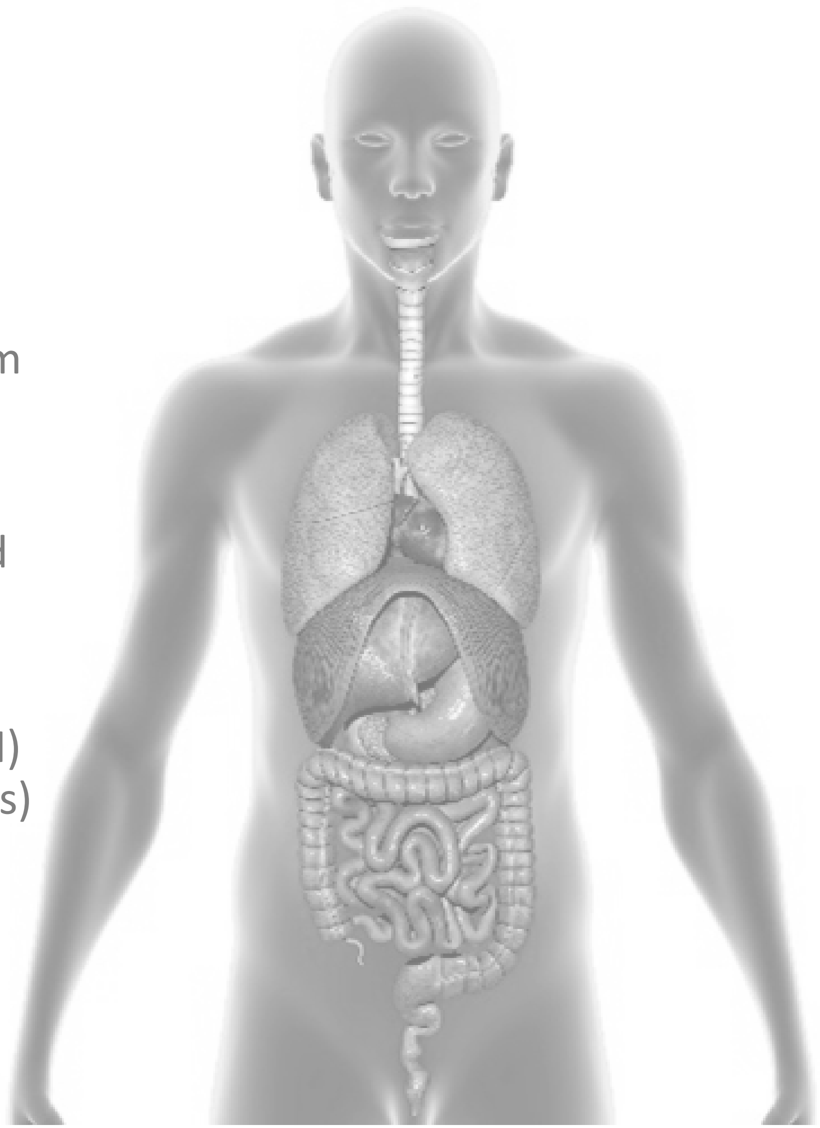
Characteristics of cardiac muscle

- Involuntary
- No conscious control
- Found in the chamber walls of the heart
- Works continuously
- Controlled by the sinoatrial node (SAN)



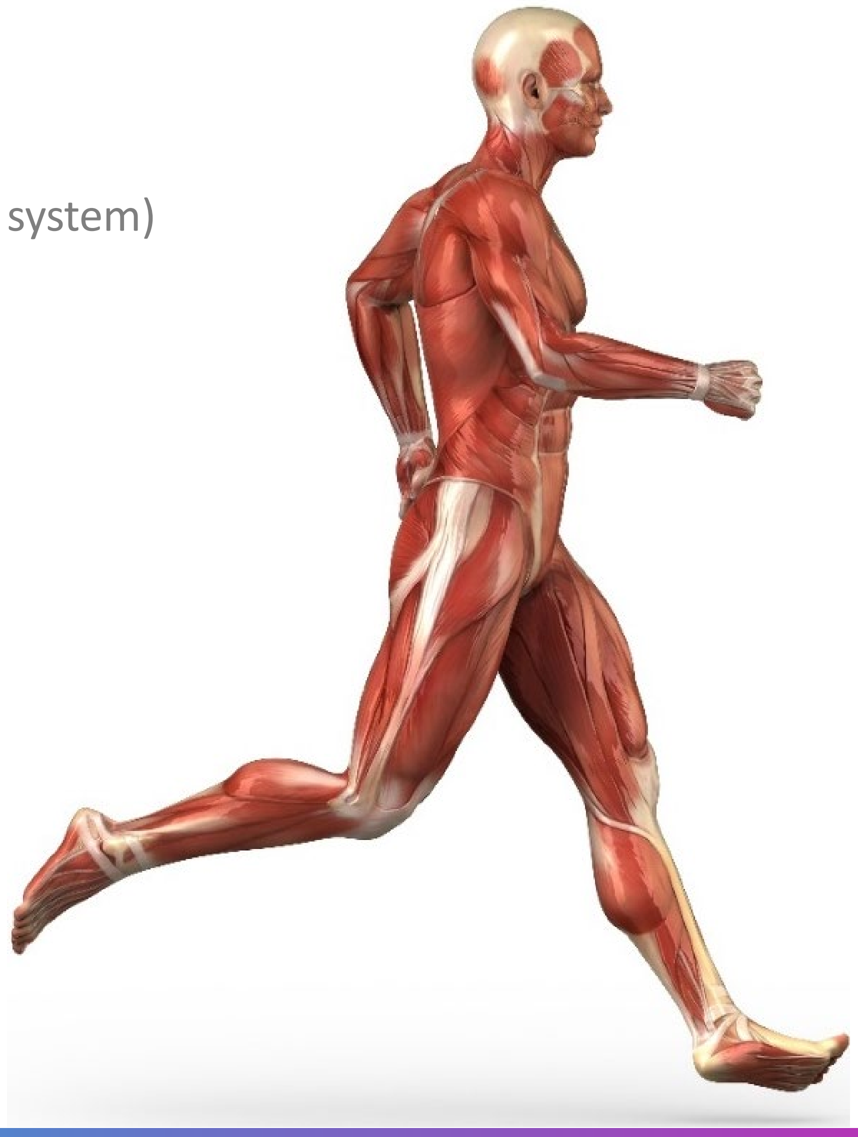
Characteristics of smooth muscle

- Involuntary
- No conscious control
- Operated by autonomic nervous system
- Found in the reproductive system, digestive system, the blood vessels and the urinary system
- The smooth muscle of the digestive (GI) tract contracts to move food (peristalsis)

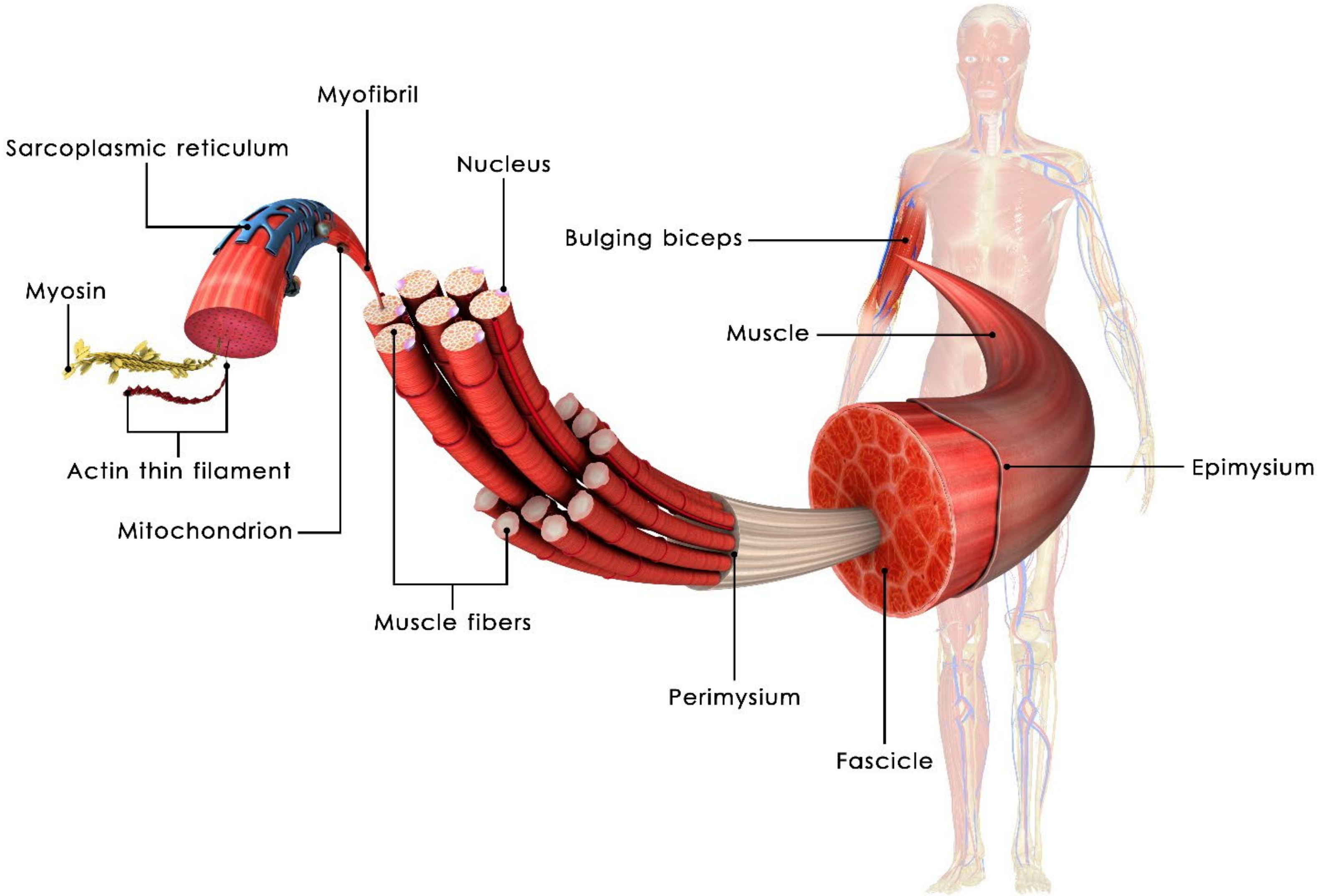


Characteristics of skeletal muscle

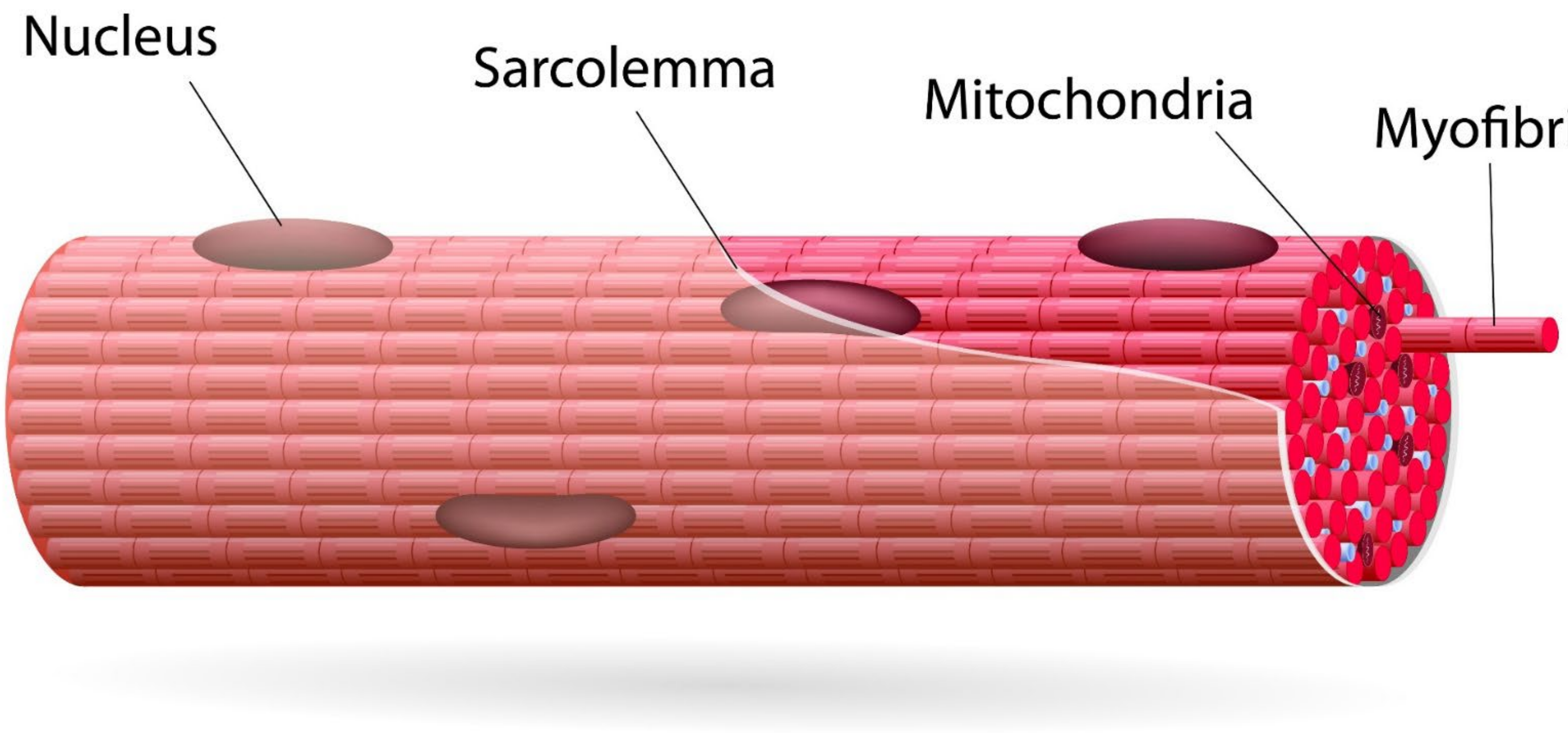
- Voluntary
- Conscious control (Somatic nervous system)
- Striated
- Tendons attach muscle to bone
- Muscle contraction = locomotion
- Extensible/Elastic
- Adaptable (hypertrophy/atrophy)



Muscle structure



Muscle fibre



Muscle connective tissue

Skeletal muscles interact with the deep fascia of the connective tissue system.

- Aponeurotic fascia refers to the connective tissue sheaths that cover and keep in place a group of muscles, for example, thoracolumbar fascia
- Epimysial fascia refers to the connective tissue layers that surround and support a muscle and its fibres
  - They allow the fibres to glide effectively during contraction and relaxation
- All the connective tissue within a muscle is interconnected and constitutes the passive elastic component of a muscle
  - Epimysium – surrounds the whole muscle
  - Perimysium – surrounds individual fascicles
  - Endomysium – surrounds individual muscle fibres

Sliding filament theory

The discharge of an action potential from a motor nerve signals the release of calcium from the sarcoplasmic reticulum into the myofibril, causing tension development in muscle.

Sliding filament theory of muscular contraction

- Resting phase
- Excitation-contraction coupling phase
- Contraction phase
- Recharge phase
- Relaxation phase

Sliding filament theory

Resting phase

- Under normal resting conditions most of the calcium within the muscle is stored within the sarcoplasmic reticulum therefore very few myosin cross bridges are bound to actin

Excitation-contraction coupling phase

- When the sarcoplasmic reticulum is stimulated to release calcium ions, calcium binds to a protein called troponin
- Troponin displaces tropomyosin which then allows the myosin cross bridges to attach to the actin filaments

Contraction phase (power stroke)

- Adenosine triphosphate (ATP) is broken down to adenosine diphosphate (ADP) and energy which is used to pull the actin filaments towards the centre of the sarcomere

Sliding filament theory

Recharge phase

- Continued muscle shortening occurs as long as the binding of calcium to troponin, cross bridge formation, power stroke, dissociation of myosin and actin and the subsequent recoupling is repeated
- Calcium and ATP must be present for this to occur

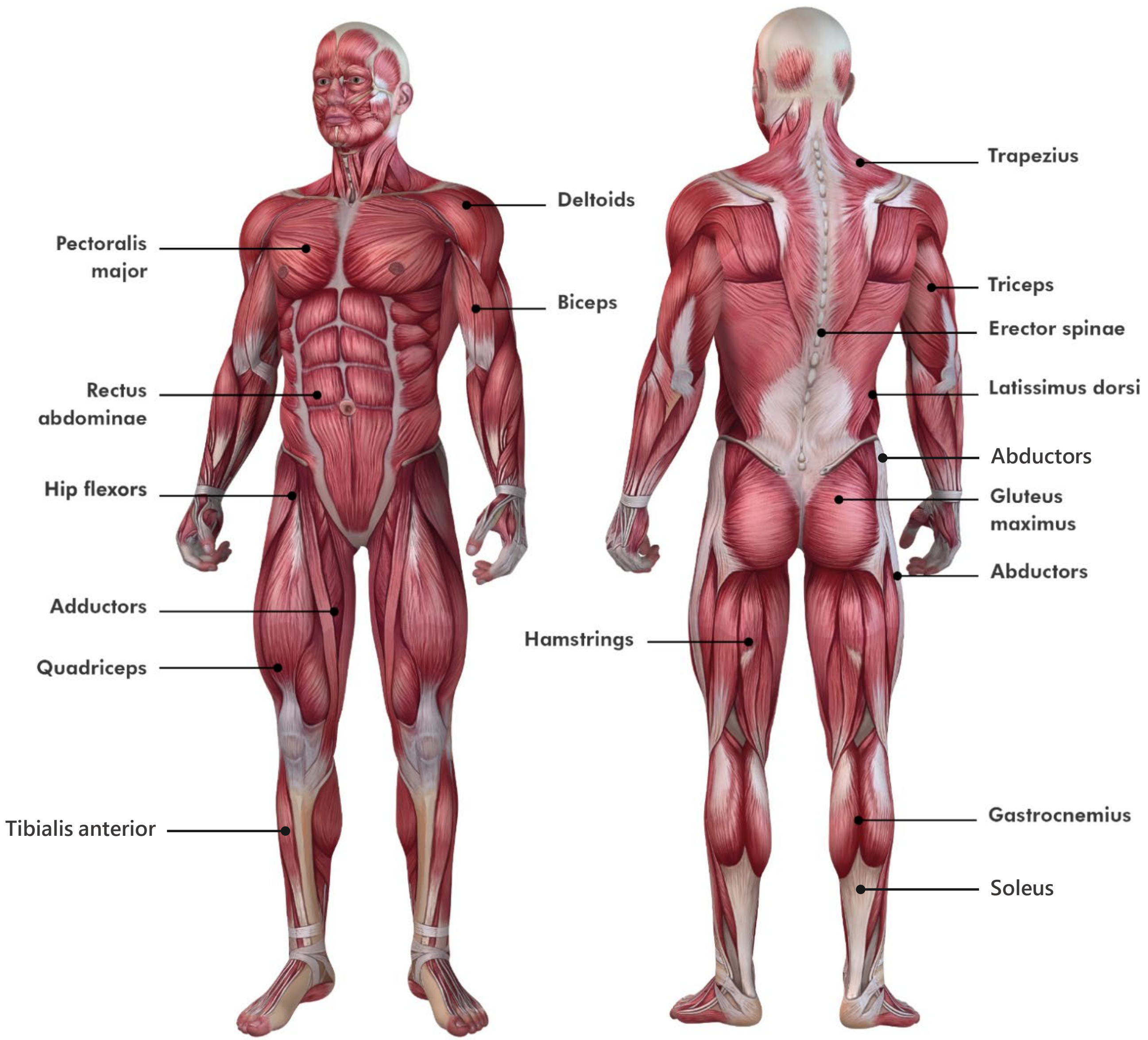
Relaxation phase

- Relaxation occurs when the stimulation of the motor nerve stops
- Calcium is pumped back into the sarcoplasmic reticulum
- The level of calcium drops preventing the cross bridge formation from occurring

Muscle fibre type review

Characteristic	Type I	Type IIa	Type IIb
Motor neuron size	Small	Large	Large
Nerve conduction velocity	Slow	Fast	Fast
Contraction speed	Slow	Fast	Fast
Fatigue resistance	High	Intermediate	Low
Force production	Low	Intermediate	High
Power output	Low	Intermediate	High
Endurance	High	Intermediate	Low
Capillary density	High	Intermediate	Low
Mitochondrial density	High	Intermediate	Low
Colour	Red	White/red	White

Major muscles review



Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Supraspinatus	Supraspinous fossa of the scapula	Greater tubercle of the humerus	Initiates abduction of the shoulder joint
Infraspinatus	Infraspinous fossa of the scapula	Greater tubercle of the humerus	Lateral rotation of the shoulder joint
Teres minor	Upper 2/3 of lateral boarder of the scapula	Greater tubercle of the humerus	Lateral rotation of the shoulder joint
Subscapularis	Subscapular fossa of the scapula (anterior)	Lesser tubercle of the humerus	Medial rotation of the shoulder joint

Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Deltoids	Lateral 1/3 of clavicle Acromion Spine of scapula	Deltoid tuberosity of the humerus	Abduction Flexion Extension of the shoulder joint
Latissimus dorsi	Inferior angle of scapula	Bicipital groove of the humerus (intertrabecular groove)	Shoulder extension Shoulder adduction Shoulder medial rotation
Teres major	Inferior angle of scapula and lower 1/3 of the lateral boarder of scapula	Lesser tubercle of the humerus	Shoulder extension Shoulder adduction Shoulder medial rotation

Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Coracobrachialis	Coracoid process	Mid shaft of humerus	Shoulder flexion Weak shoulder adduction
Pectoralis major	Medial aspect of the clavicle Sternum Cartilage of ribs 1-6	Greater tubercle of humerus	Adduction, Medial rotation and Horizontal flexion of the shoulder joint

Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Trapezius	Occiput Spinous processes C7 – T12	Lateral 1/3 clavicle Acromion Spine of scapula	Upper – elevate scapula Mid – retract scapula Lower – depress the scapula
Levator scapula	Transverse processes of C1-C4	Medial boarder of scapula and superior angle of scapula	Elevate scapula
Rhomboid major	Spinous processes of T2 – T5	Medial boarder of scapula	Retract scapula
Rhomboid minor	Spinous processes of C7 – T1	Upper part of medial boarder	Retract scapula

Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Pec minor	Ribs 3,4,5	Coracoid process	Protraction of the scapula
Serratus anterior	Upper 8 ribs	Anterior surface of medial boarder of scapula	Protraction of the scapula Stabilisation of the scapula

Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Rectus femoris	Anterior inferior iliac spine (AIIS)	Tibial tuberosity via patellar tendon	Knee extension Hip flexion
Vastus medialis	Medial lip of the linea aspera	Tibial tuberosity via patellar tendon	Knee extension
Vastus lateralis	Lateral lip of linea aspera, gluteal tuberosity and greater trochanter of the femur	Tibial tuberosity via patellar tendon	Knee extension
Vastus intermedius	Anterior and lateral shaft of femur	Tibial tuberosity via patellar tendon	Knee extension
Sartorius	Anterior superior iliac spine (ASIS)	Upper medial shaft of the tibia	Hip flexion, Abduction and Lateral rotation

Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Biceps femoris	Long head – ischial tuberosity Short head – lateral lip of linea aspera	Head of fibula	Knee flexion Hip extension
Semitendinosis	Ischial tuberosity	Proximal medial shaft of the tibia (pes anserine)	Knee flexion Hip extension
Semimembranosus	Ischial tuberosity	Posterior aspect of the medial tibial condyle	Knee flexion Hip extension
Popliteus	Lateral condyle of femur	Proximal posterior tibia	Knee flexion and medial rotation
Gastrocnemius	Posterior surface of medial and lateral femoral condyles	Calcaneus via Achilles tendon	Knee flexion Ankle plantar flexion
Plantaris	Lateral supracondylar line of the femur	Calcaneus via Achilles tendon	Weak knee flexion Weak ankle plantar flexion

Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Gluteus maximus	Sacrum, coccyx, iliac crest	Gluteal line of the femur and iliotibial tract	Extension, adduction and external (lateral) rotation of the hip
Adductor longus	Pubic bone	Middle 1/3 of the posterior femur	Adduction of the hip
Rectus abdominus	5-7th costal cartilage and xiphoid process	Pubic symphysis	Flexion of the trunk
Erector spinae	3 sets of muscles (iliocostalis, longissimus & spinalis): with different origins and insertions work as a group and as individual muscles		Extend and laterally flex the spine
Psoas major	Transverse processes of L1 to L5, and T12	Lesser trochanter of femur	Flexion of the hip

Common muscle origin, insertions and actions (not exhaustive)

Muscle	Origin	Insertion	Action
Biceps brachii	Long head: supraglenoid tubercle of the scapula Short head: coracoid process	Radial tuberosity	Elbow flexion Elbow supination Shoulder joint flexion
Brachioradialis	Lateral supracondylar ridge of humerus	Styloid process of radius	Elbow flexion
Brachialis	Distal anterior humerus	Coronoid tubercle of ulna	Elbow flexion
Triceps	Long head: infraglenoid tubercle of the scapula Lateral head: posterior proximal humerus Medial head: posterior distal humerus	Olecranon process of the ulna	Elbow extension Shoulder joint extension

Activity

- Select a muscle from the following regions:
  - Upper body
  - Trunk
  - Lower body
- Find an exercise that works the muscle as a prime mover
- Name the antagonist muscle
- Name the fixator and synergist

Patterns of muscle dysfunction

- Prolonged stress on skeletal muscles can lead to adaptations to different muscle types

- Muscles have been categorised according to their function and responses to stress for example:

    - Stabilisers and mobilisers
    - Local and global
    - Phasic and tonic (postural)

- Whichever category is used it is generally accepted that some muscles are prone to shorten while others are prone to become inhibited/weaken

- These can lead to patterns of imbalance leading to instability at joints

- Examples of patterns of imbalance as some muscles weaken and others shorten can be seen on the next slide

Patterns of muscle dysfunction

Underactive stabiliser muscle	Overactive synergist	Shortened antagonist
Gluteus medius	TFL/QL	Hip adductors
Gluteus maximus	Erector spinae/hamstrings	Hip flexors
Transversus abdominus	Rectus abdominus	Lumbar spine extensors
Lower trapezius	Levator scapula/ upper trapezius	Pectoralis major
Serratus anterior	Pectoralis major/minor	Rhomboids

As some muscles weaken and lengthen, their synergist will overwork while the antagonist can shorten.

Patterns of muscle dysfunction

Postural and phasic muscles

- Postural muscles tend to become shortened and tight for example:
  - Upper trapezius
  - Erector spinae
  - Pectoralis major
- Phasic muscles tend to weaken and lengthen for example:
  - Middle and lower trapezius
  - Gluteal muscles
  - Serratus anterior

Stabilising muscles of the spine

Local stabilisers of the spine: tend to become weak

- Lumbar multifidus
- Transversus abdominis
- Diaphragm
- Pelvic floor muscles
- Internal obliques

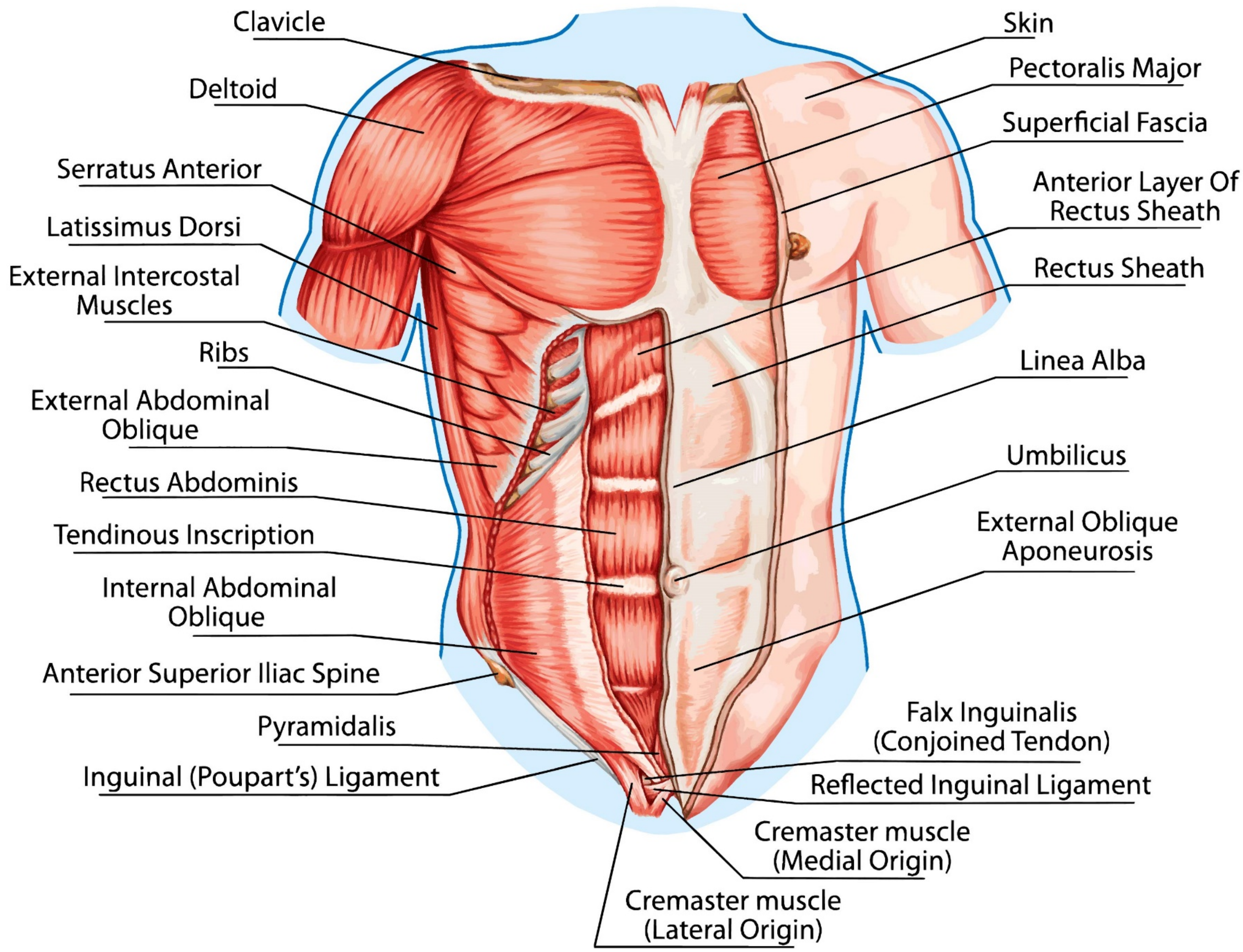
Global stabilisers of the spine: can become weak but can become overactive or synergistically dominant

- External obliques
- Gluteus medius
- Gluteus minimus
- Some fibres of the erector spinae
- Quadratus lumborum

Stabilising muscles of the spine

Global mobilisers of the spine: tend to become overactive and short/tight

- Rectus abdominus
- Anterior fibres of psoas major
- Latissimus dorsi
- Rectus femoris


Clavicle
Deltoid
Serratus Anterior
Latissimus Dorsi
External Intercostal Muscles
Ribs
External Abdominal Oblique
Rectus Abdominis
Tendinous Inscription
Internal Abdominal Oblique
Anterior Superior Iliac Spine
Pyramidalis
Inguinal (Poupart's) Ligament
Skin
Pectoralis Major
Superficial Fascia
Anterior Layer Of Rectus Sheath
Rectus Sheath
Linea Alba
Umbilicus
External Oblique Aponeurosis
Falx Inguinalis (Conjoined Tendon)
Reflected Inguinal Ligament
Cremaster muscle (Medial Origin)
Cremaster muscle (Lateral Origin)

Reasons for insufficient stabilisation

- Heredity
- Medical conditions
- Lifestyle
- Ageing
- Muscle imbalances
- Injury

Potential effects of abdominal adiposity and poor posture

- Inefficient movement patterns
- Compensatory movements
- Muscle imbalances
- Instability
- Poor alignment
- Change of centre of gravity

Posture types

<table>
<tr><th>Posture type</th><th>Weak/long muscles</th><th>Short/strong muscles</th><th>Action</th></tr>
<tr><td>Hyperlordosis</td><td>• Hamstrings
• Gluteals
• Abdominals</td><td>• Back extensors (possibly)
• Hip flexors</td><td rowspan="5">• Stretch short muscles
• Strengthen weaker muscles</td></tr>
<tr><td>Hyperkyphosis</td><td>• Lower and middle trapezius
• Rhomboids
• Neck flexors</td><td>• Neck extensors
• Pectorals
• Anterior deltoid
• Upper trapezius</td></tr>
<tr><td>Flat back</td><td>• Hip flexors
• Back may be long but not necessarily weak</td><td>• Hamstrings</td></tr>
<tr><td>Sway back</td><td>• Hip flexor
• External obliques
• Upper back extensors
• Neck flexors</td><td>• Hamstrings,
• Internal oblique
• Lumbar extensors (may be strong, but not short)</td></tr>
<tr><td>Scoliosis</td><td>• One side convex</td><td>• Other side of the concave</td></tr>
</table>

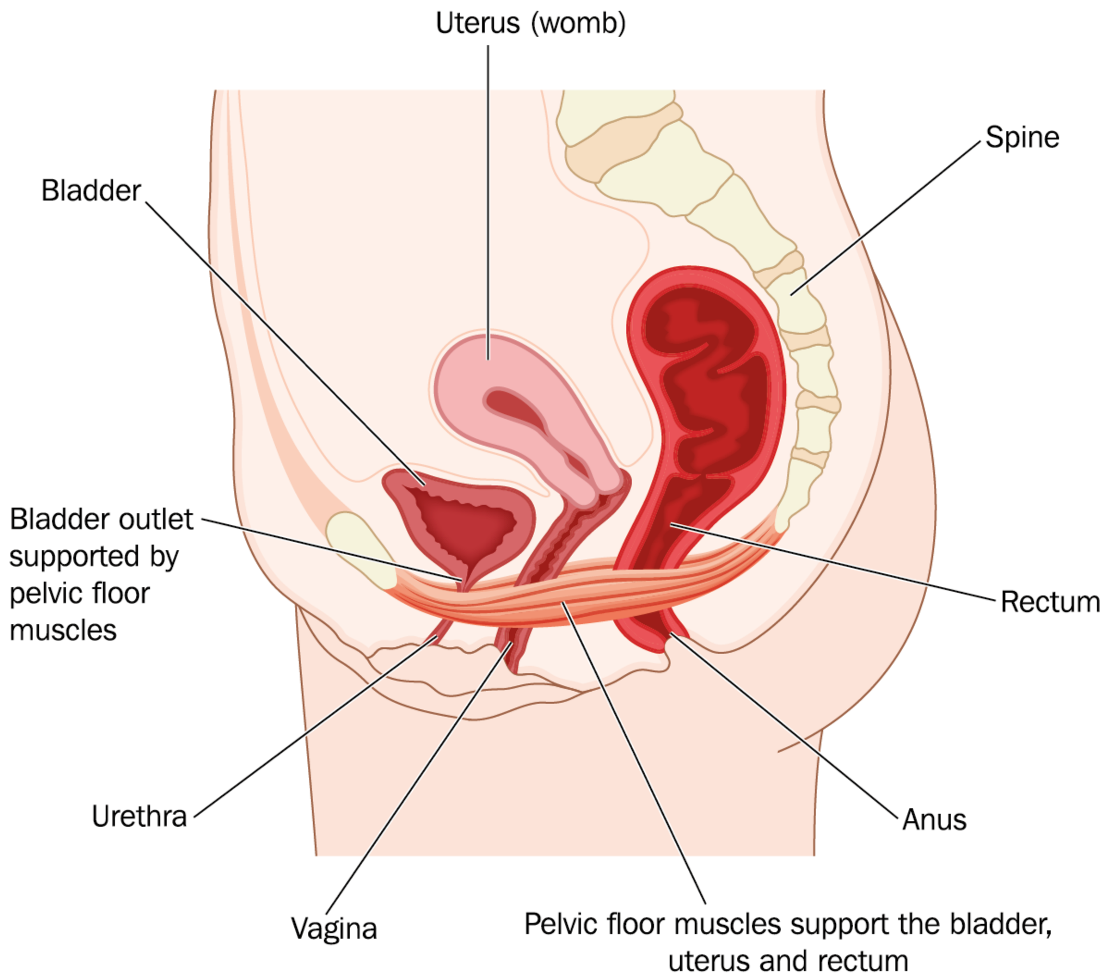
Activity

What local muscular changes may occur due to insufficient stabilisation?

Muscle changes

- Muscles lengthened
- Muscles shortened
- Weak/Inactive muscles
- Overactive/Strong muscles
- Imbalanced kinetic chain
- Synergistic dominance

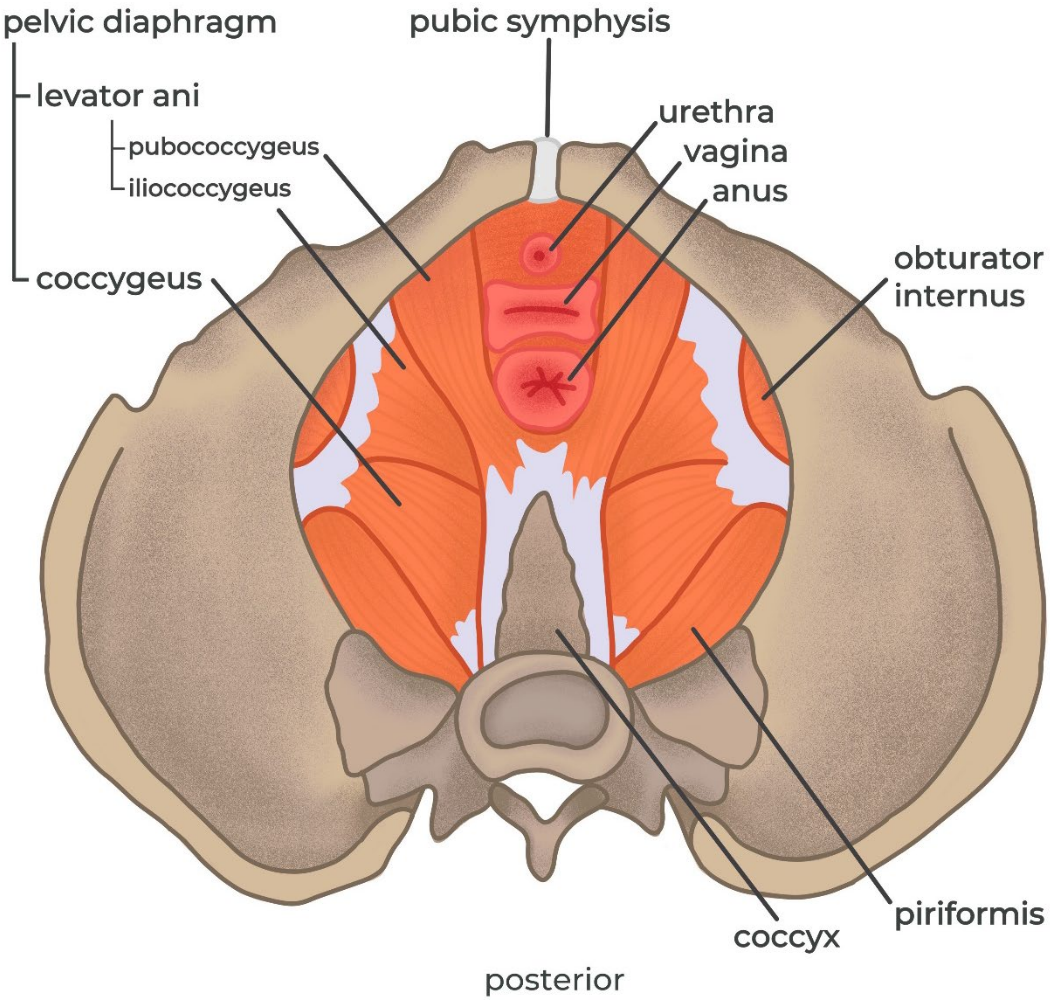
Pelvic floor



Pelvic floor - structure and functions

- Small group of muscles
  - Levator ani
  - Pubococcygeus
  - Puborectalis
  - iliococcygeus
- Base of pelvis
- Muscular hammock like structure
- Support the pelvic organs, for example, the bladder
- Prevent stress incontinence
- Assist childbirth
- Assist excretion and urination

Pelvic floor muscles



Learning check quiz

- Describe the three types of muscle tissue

- Where would you locate the following muscles:
  - Gastrocnemius
  - Adductors
  - Trapezius

Learning check quiz

- What joint actions are brought about by the following muscles:
  - Hamstrings
  - Triceps
  - Pectorals major







VTCT

USP186 - Applied anatomy for exercise, fitness, health and wellbeing

LO3 Understand the structure and function of the circulatory system in relation to exercise, health and fitness programming

Content and Assessment Criteria

- Know the structure and function of the cardiovascular system
- Know the structure and function of the heart
- Know the structure of the heart
- Know how blood flows through the four chambers of the heart and different circulatory systems
- Know the composition of blood
- Know the structure and functions of blood vessels
- Know the effects of disease processes on the blood vessels and the effect on blood pressure

The circulatory system

The circulatory system review

The main structures include:

- **The heart (cardio)**
  A cardiac muscle pump that contracts rhythmically to move blood from the veins at low pressure to the arteries at high pressure

- **The blood vessels (vascular system)**
  Arteries, arterioles, capillaries, venules and veins. Its main functions are to:
  - distribute blood to various organs
  - exchange materials in tissues
  - transform pulsate flow from the heart to a more continuous flow

- **The blood**
  The blood contains a variety of materials including water, salts, dissolved proteins, nutrients and a variety of different cell types

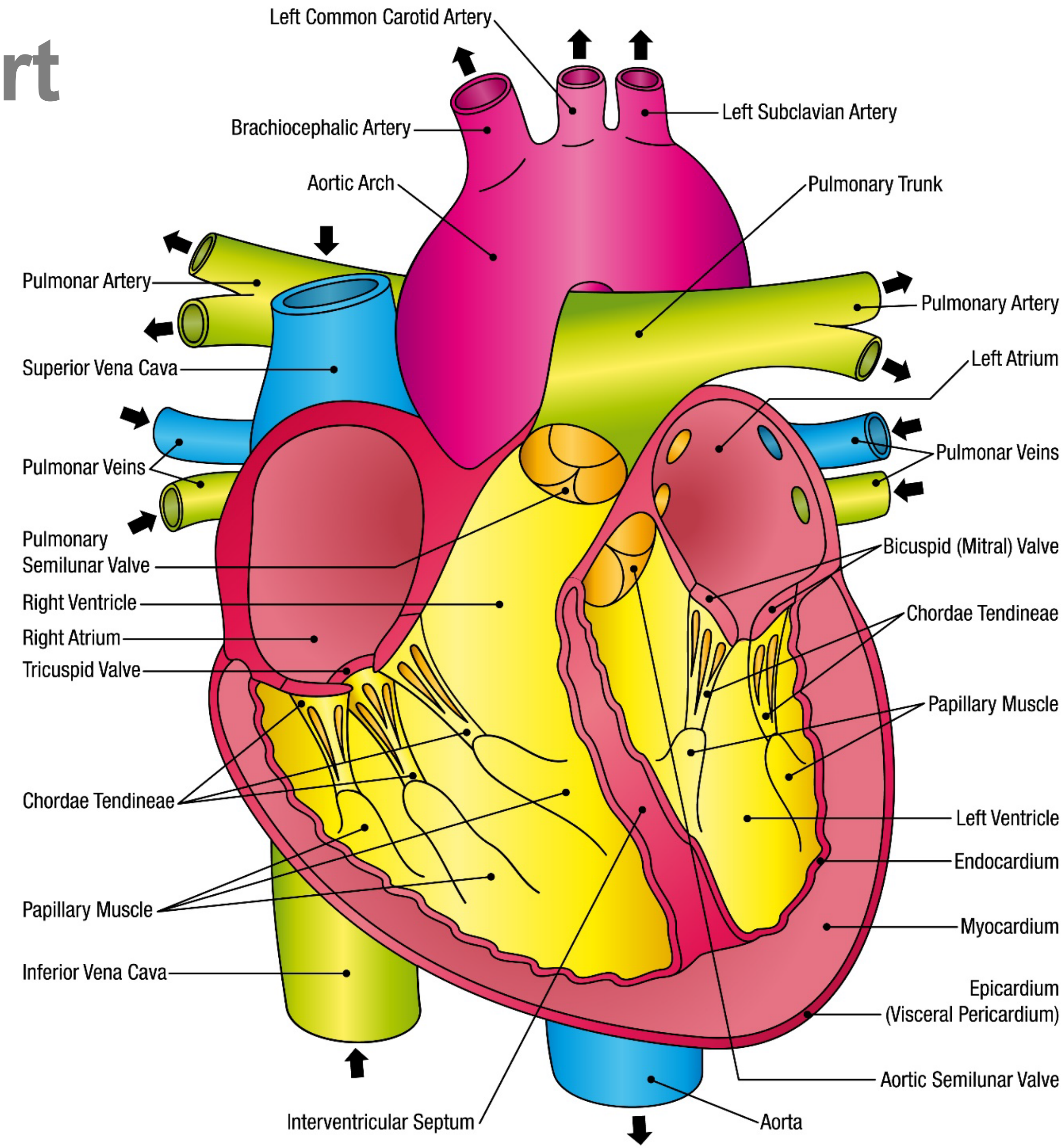
Structure and function of the heart

- Four chambered structure
- The heart is located in the middle of the thoracic cavity, orientated obliquely with its apex pointing down to the left
- The heart is suspended in a tough fibrous sac called the ***pericardium***
- The heart consists of three types of muscle tissue, atrial muscle, ventricular muscle and specialised muscle tissue that co-ordinates electrical signals through the heart
- Three layers form the heart wall
  - The ***epicardium*** is the outer most layer (connective tissue layer)
  - The ***myocardium*** is the central layer of ***cardiac muscle*** (responsible for the pumping action)
  - The ***endocardium*** is the innermost layer composed of endothelium cells and a thin layer of connective tissue

Structure and function of the heart

- Connective tissue separates muscle tissue of the atria from that of the ventricles
- The ***interatrial septum*** is a layer of connective tissue that separates the atria
- The ***intraventricular septum*** is a layer of connective tissue that separates the two ventricles
- The period of contraction of the heart muscle is called ***systole***
- The period of relaxation is called ***diastole***

The heart


Left Common Carotid Artery
Brachiocephalic Artery
Left Subclavian Artery
Aortic Arch
Pulmonary Trunk
Pulmonar Artery
Pulmonary Artery
Superior Vena Cava
Left Atrium
Pulmonar Veins
Pulmonar Veins
Pulmonary
Semilunar Valve
Bicuspid (Mitral) Valve
Right Ventricle
Right Atrium
Chordae Tendineae
Tricuspid Valve
Papillary Muscle
Chordae Tendineae
Left Ventricle
Endocardium
Papillary Muscle
Myocardium
Inferior Vena Cava
Epicardium
(Visceral Pericardium)
Aortic Semilunar Valve
Interventricular Septum
Aorta

The heart valves

Atrio-ventricular valves:

- Bicuspid valve – left atrium and ventricle
- Tricuspid valve – right atrium and ventricle

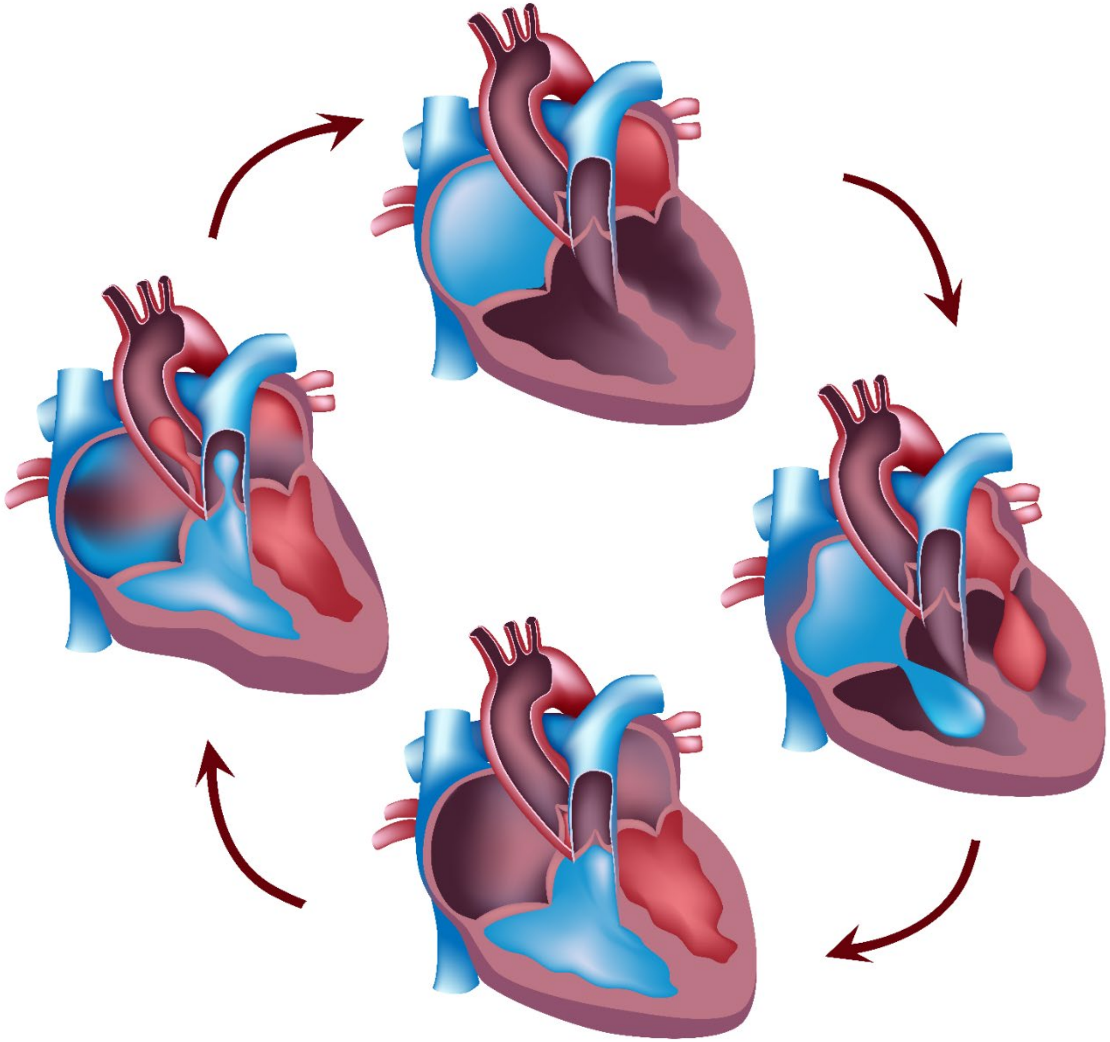
Semi-lunar valves:

- Aortic – left ventricle and aorta
- Pulmonary – right ventricle and pulmonary artery

Function of valves:

- Control blood flow through heart chambers
- Prevent backflow of blood

Operation of the heart valves



Activity

Name the valve that prevents back flow:

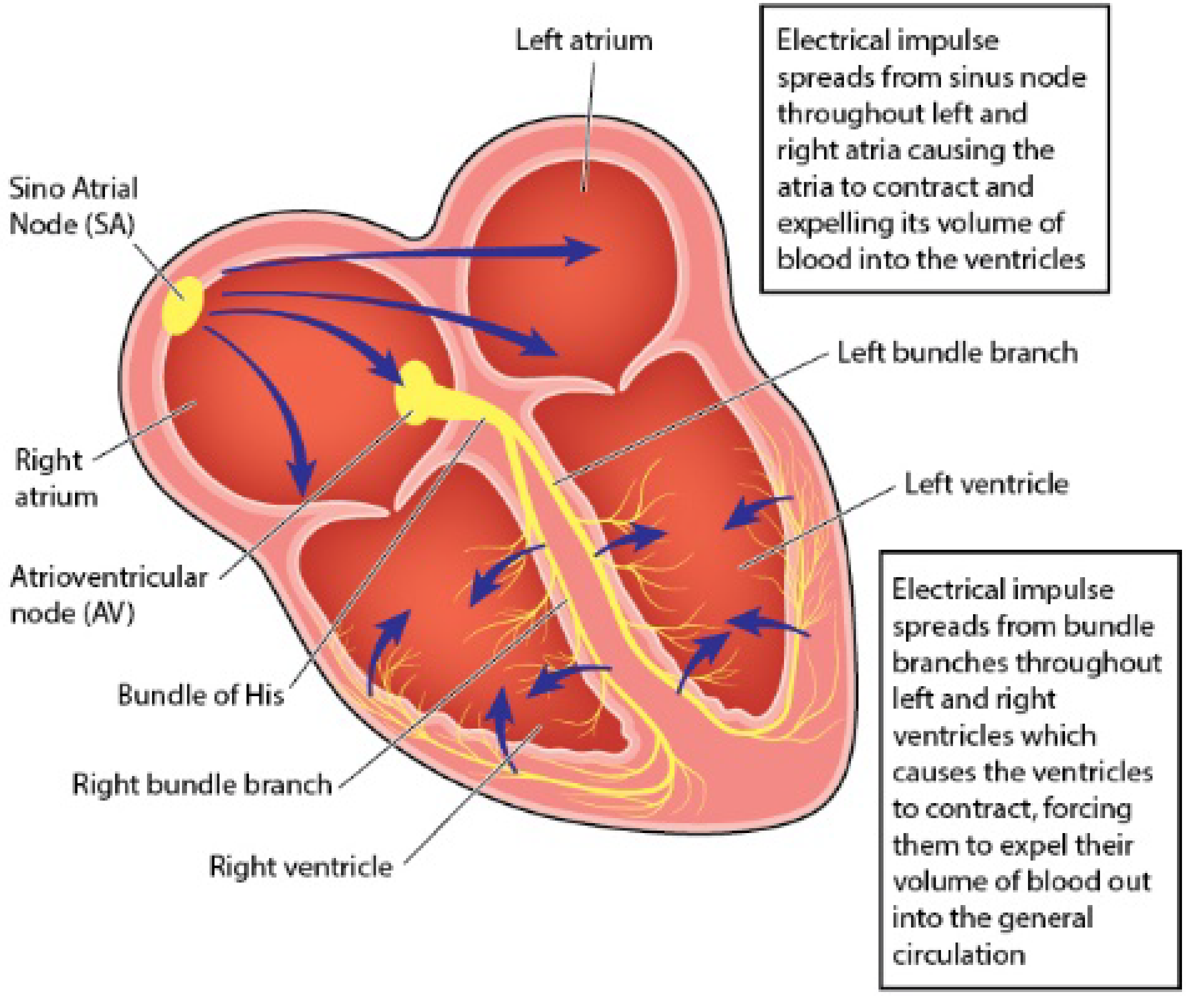
- From the left ventricle to the left atrium
- From the right ventricle to the right atrium
- From the aorta to the left ventricle
- From the pulmonary artery to the right ventricle

Cardiac conduction

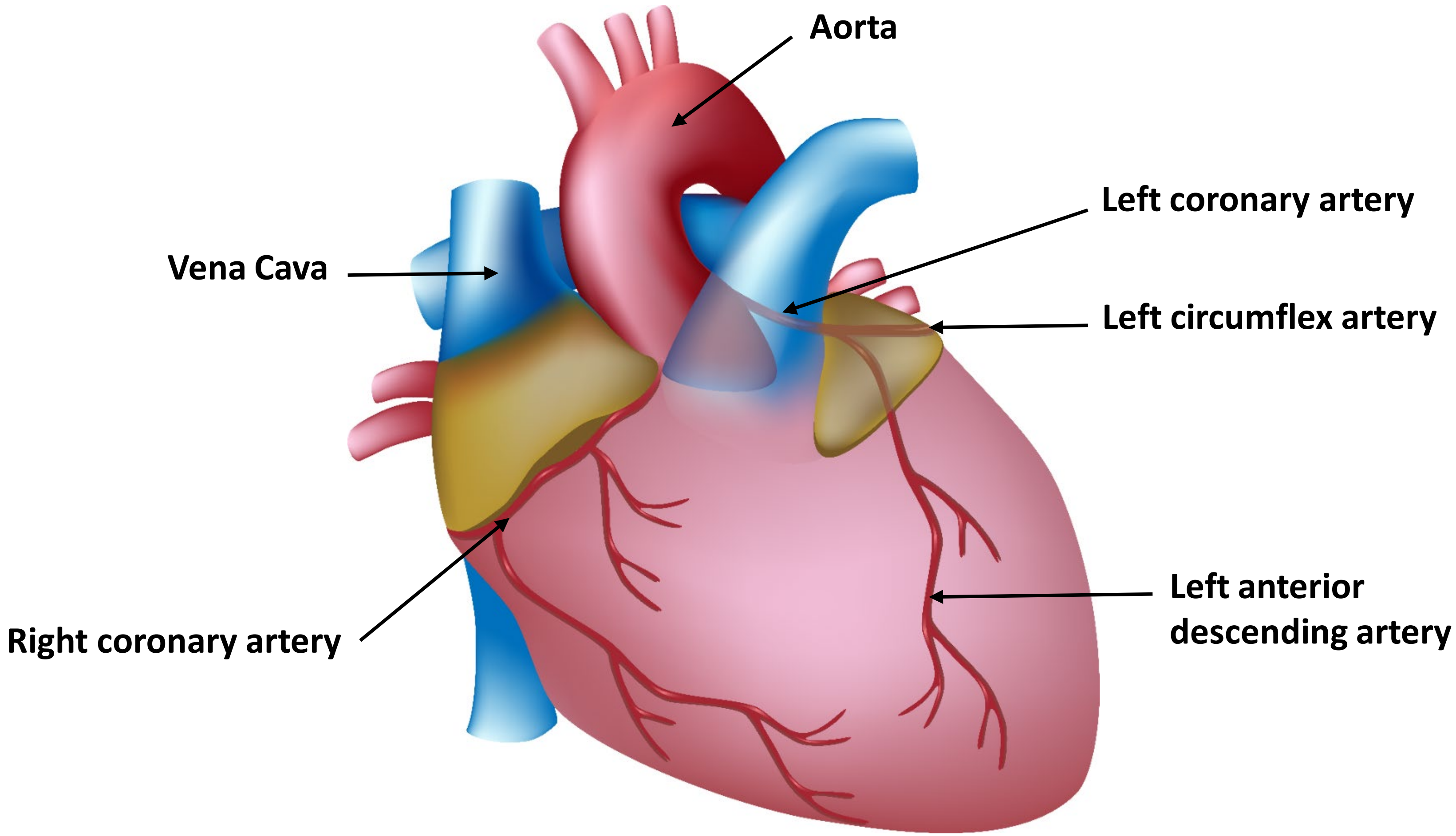
An automatic electrical system controls the contraction of the heart

- Normal cardiac excitation begins in the ***sinoatrial node (SA)*** located in the right atrial wall, just below the superior vena cava
- An action potential is conducted from the SA node through the atrial tissue that leads to atrial contraction
- The action potential spreads to the ***atrioventricular node (AV)*** located in the septa between the two atria
- The action potential then enters the AV bundle ***(bundle of His)*** and then the right and left bundle branches within the intraventricular septa
- Finally special fibres called ***Purkinje fibres*** conduct the action potential to the ventricular myocardium for ventricular contraction

Cardiac conduction system



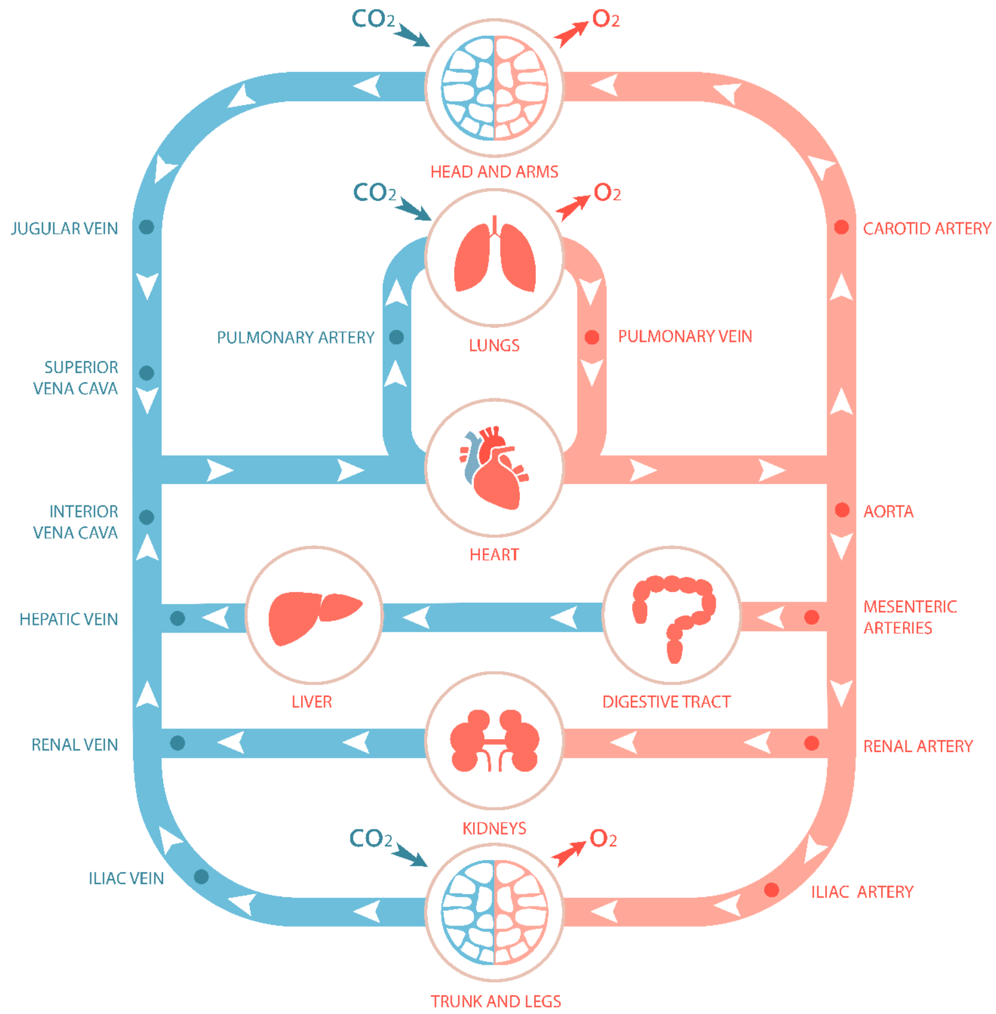
Coronary circulation



Coronary circulation

- Circulation of blood to the heart
- Oxygenated blood
- Root of aorta, aortic sinuses, epicardial coronary arteries
- Left coronary artery
- Circumflex artery
- Left anterior descending artery
- Right coronary artery, anastomoses, marginal arteries
- Cardiac veins, right atrium

Pulmonary and systemic circulation review

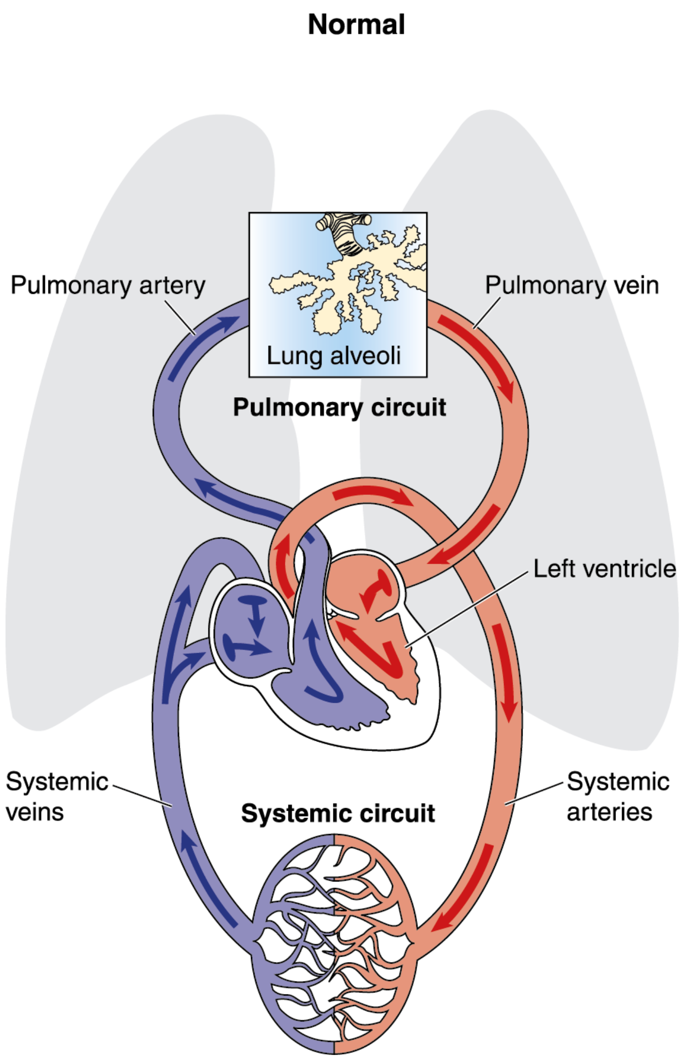


Activity

Describe the flow of blood through the pulmonary and systemic circulation naming the structures that it passes through

- From the left ventricle to the left atrium
- From the right ventricle to the right atrium
- From the aorta to the left ventricle
- From the pulmonary artery to the right ventricle

Pulmonary and systemic circulation



Functional considerations

Cardiac output is the flow produced by the heart:

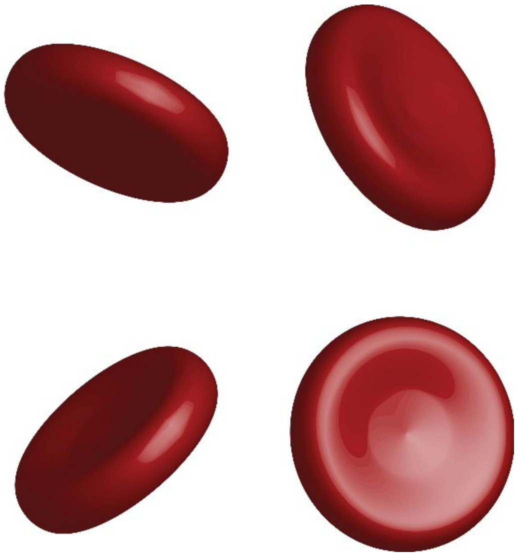
- Each beat of the heart ejects a volume of blood, ***stroke volume (SV)***
- ***Heart rate (HR)*** is the number of heart beats per minute
- ***Cardiac output (CO)*** is the average flow of blood into the aorta and is calculated as the product of heart rate and stroke volume

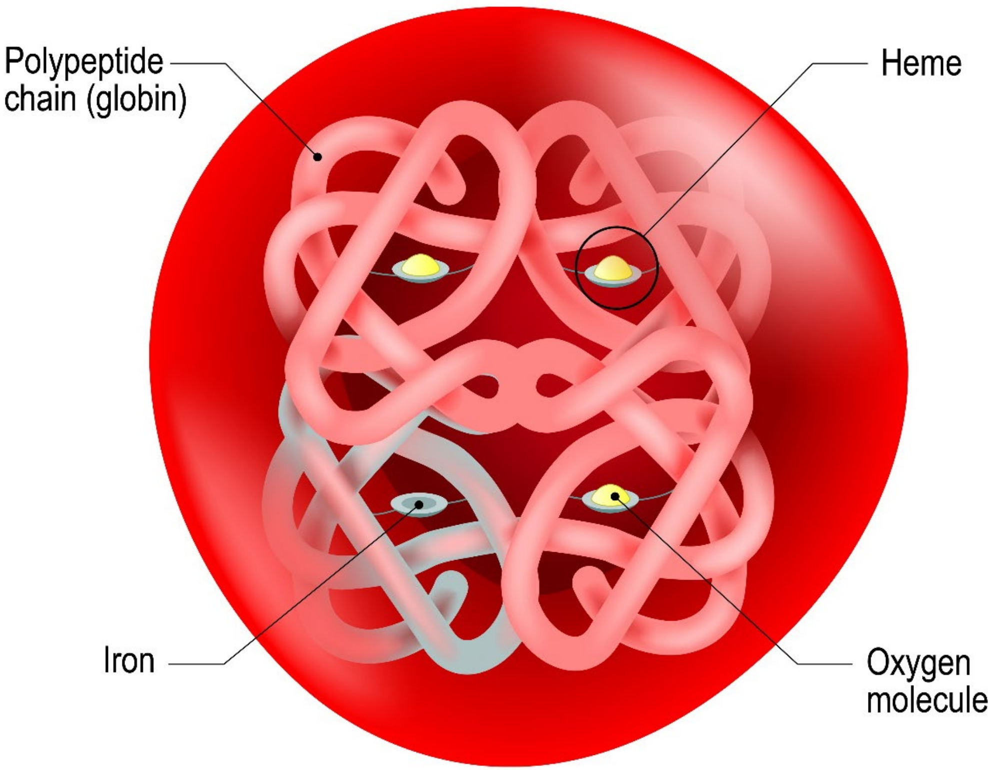
CO = SV x HR

Composition of blood

- Blood consists of cells suspended in plasma
- Water makes up approximately 92% of the mass of plasma
- Plasma also consists of electrolytes, for example, sodium and potassium, and proteins, for example, fibrinogen and albumin
- Red blood cells or ***erythrocytes*** are the most abundant cell in the blood
- Erythrocytes have a distinctive biconcave shape and have no nuclei
- Haemoglobin is a protein that gives the cell its red colour
- Haemoglobin contains a protein and a ***heme*** group that contains the iron that is responsible for haemoglobin's ability to bind to oxygen
- The average lifespan of an erythrocyte is approximately 120 days

Erythrocytes





Composition of blood

White blood cells or ***leukocytes*** include:

- **Neutrophils**
  Responsible for phagocytosis and destruction of bacteria
- **Eosinophils**
  Destroy some parasites and combat the effect of histamine in allergic reactions
- **Basophils**
  Releases histamine, heparin and serotonin in allergic reactions
- **Monocytes**
  Involved in phagocytosis
- **Lymphocytes**
  Kills infectious microbes and mediates the immune response
- **Platelets**
  Forms platelet plugs in homeostasis and blood clotting

Blood vessels review

All arteries carry **oxygenated** blood **EXCEPT** for the pulmonary artery, which carries **deoxygenated** blood to the lungs.

Arteries – Away

- Carry blood away from heart
- Have thick muscular walls
- Carry blood under high pressure

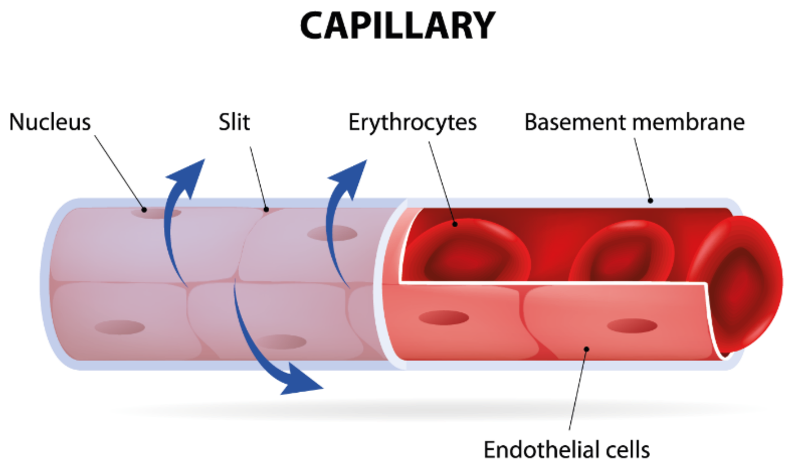
Veins – the ve-in (way in)

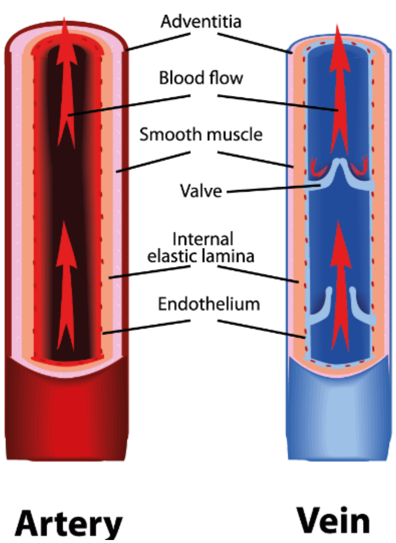
- Carry blood to the heart
- Have thinner muscular walls
- Have non-return valves
- Carry blood under lower pressure

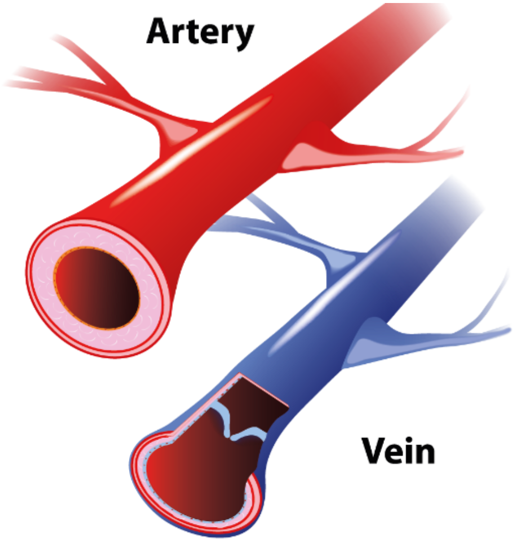
Capillaries

- Smallest blood vessels
- One cell thick to allow diffusion
- Gaseous exchange

Blood vessels





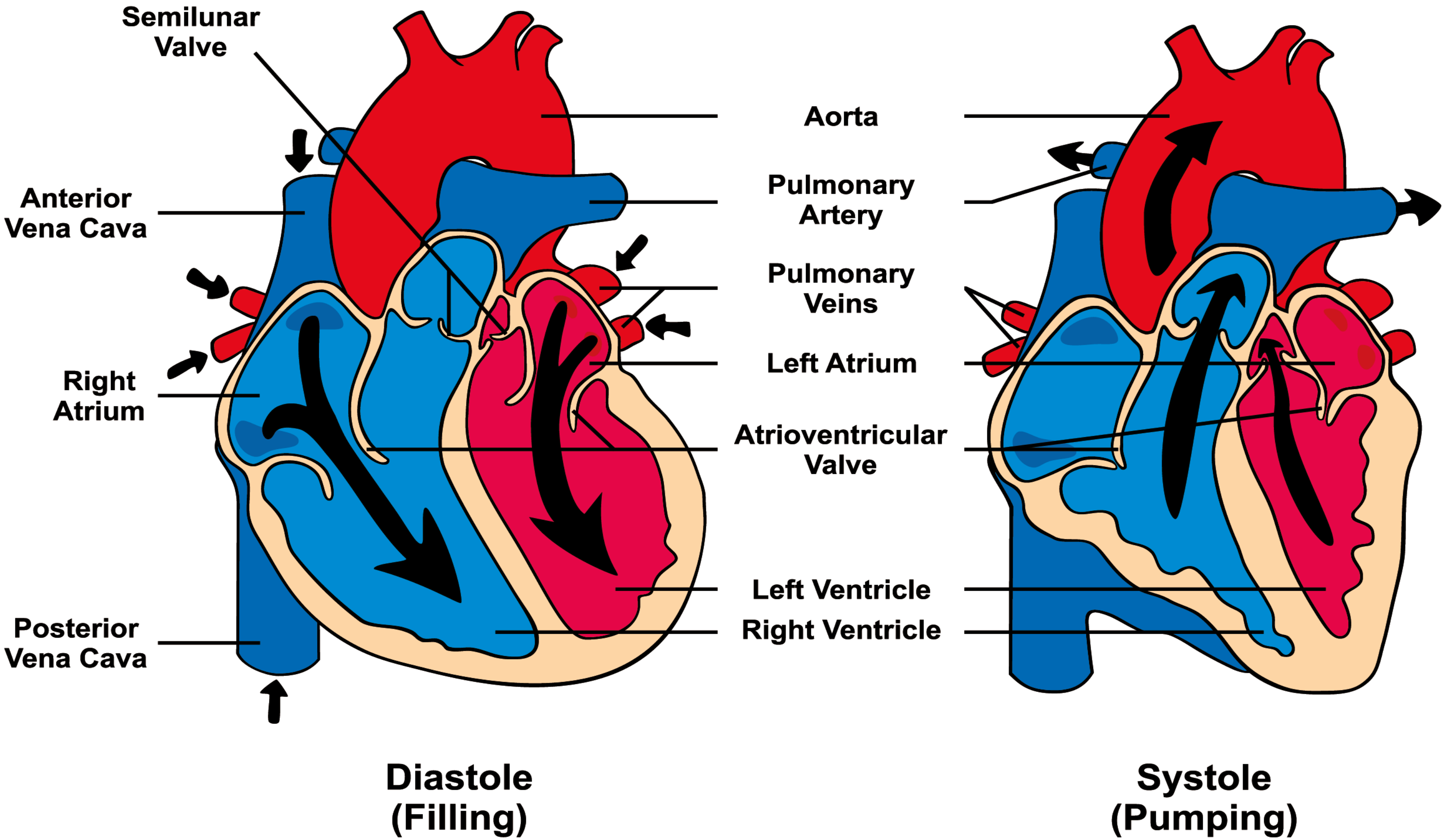


Blood pressure

A measure of the force that the blood applies to the walls of the arteries as it flows through them.

- Measured in millimetres of mercury (mmHg)
- Two numerical readings:
  - **Systolic blood pressure** (SBP) contracting and pumping blood
  - **Diastolic blood pressure** (DBP) relaxing and filling with blood
- The relationship between BP and risk for a cardiovascular event is continuous, consistent and independent of other risk factors
- For individuals aged 40-70 each increment of 20mm Hg is systolic BP and 10mm Hg diastolic BP doubles the risk of CVD

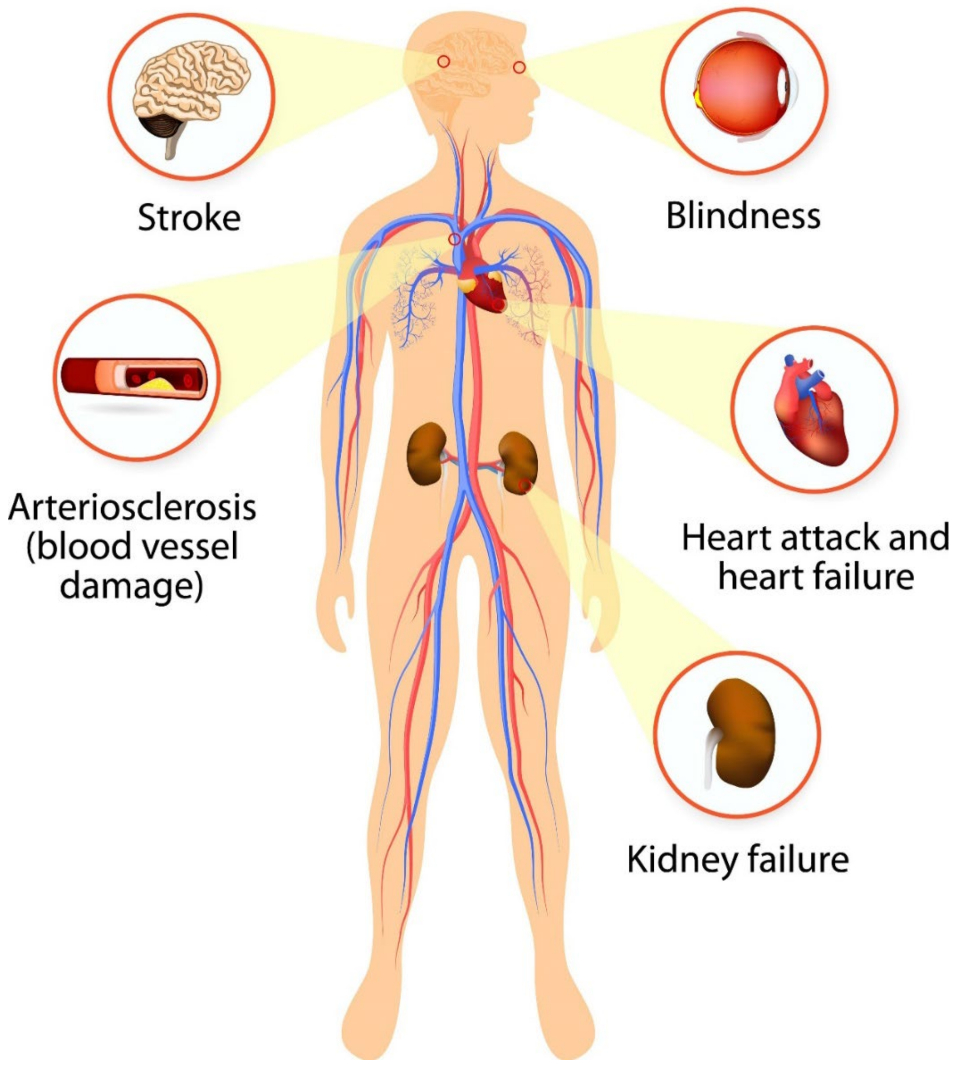
Diastole and Systole of the heart



Blood pressure classifications

Classification category	Systolic (mmHg)	Diastolic (mmHg)
Normal	< 120	< 80
Prehypertension	120-139	80-89
Stage 1 hypertension	140-159	90-99
Stage 2 hypertension	> 160	> 100
		ACSM (2018)

Hypertension and health risks



- Cardiovascular disease (CVD)
- Stroke
- Coronary heart disease (CHD)
- Coronary artery disease
- Kidney disease
- Loss of vision

Homeostasis and the circulatory system

Inflammation is the net response of the body to tissue injury.

- There are 5 cardinal signs of inflammation:
  - Redness
  - Heat
  - Swelling
  - Pain
  - Loss of function

- The process of inflammation includes complex vascular and blood cell interactions including:
  - Vasoconstriction and vasodilation of local blood vessels
  - Blood clotting
  - Innate immune response including white blood cell activity (phagocytosis)

Disease processes

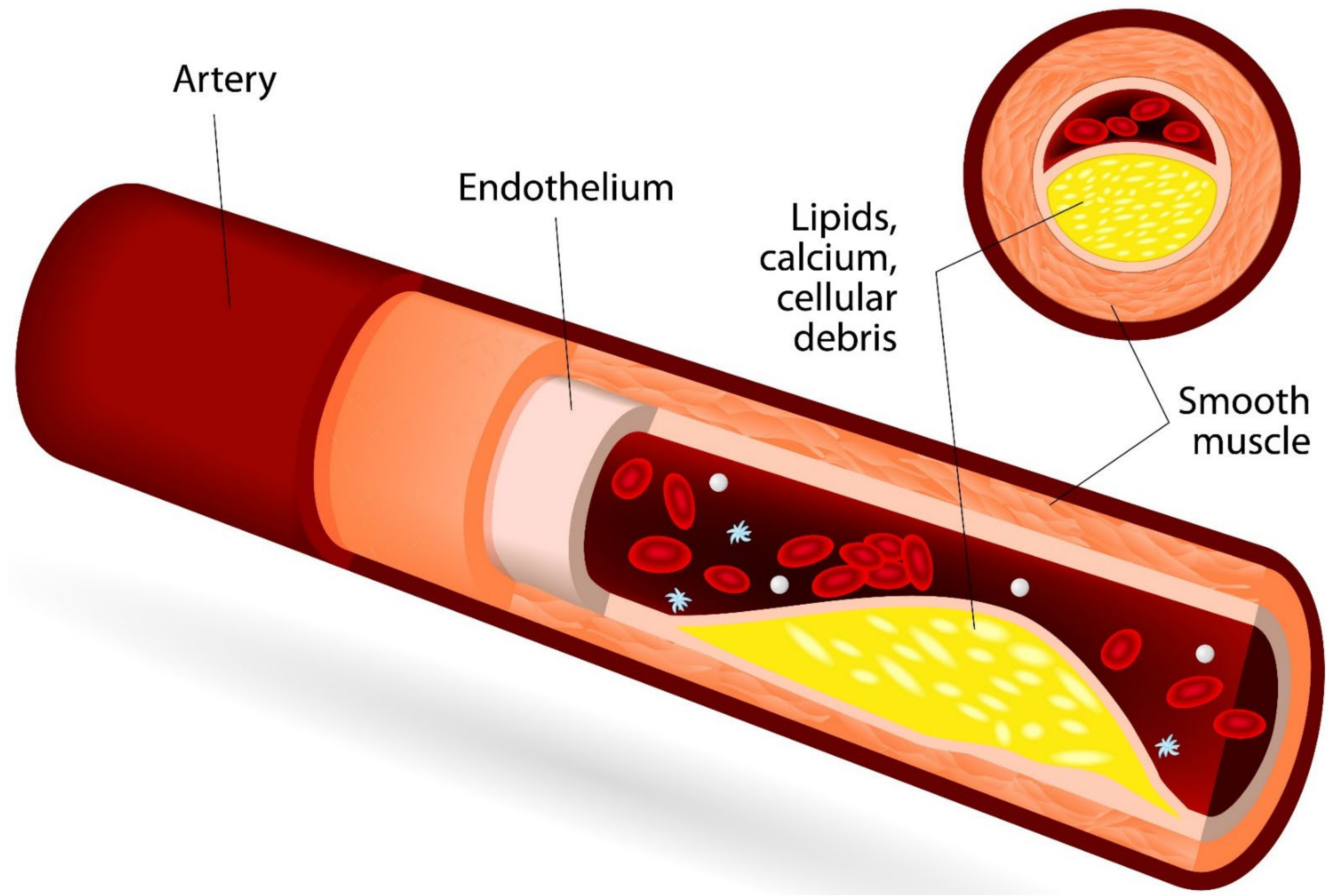
Arteriosclerosis – hardening of the arteries

- The arteries become thick and stiff
- Sometimes restricting blood flow to the organs and tissues

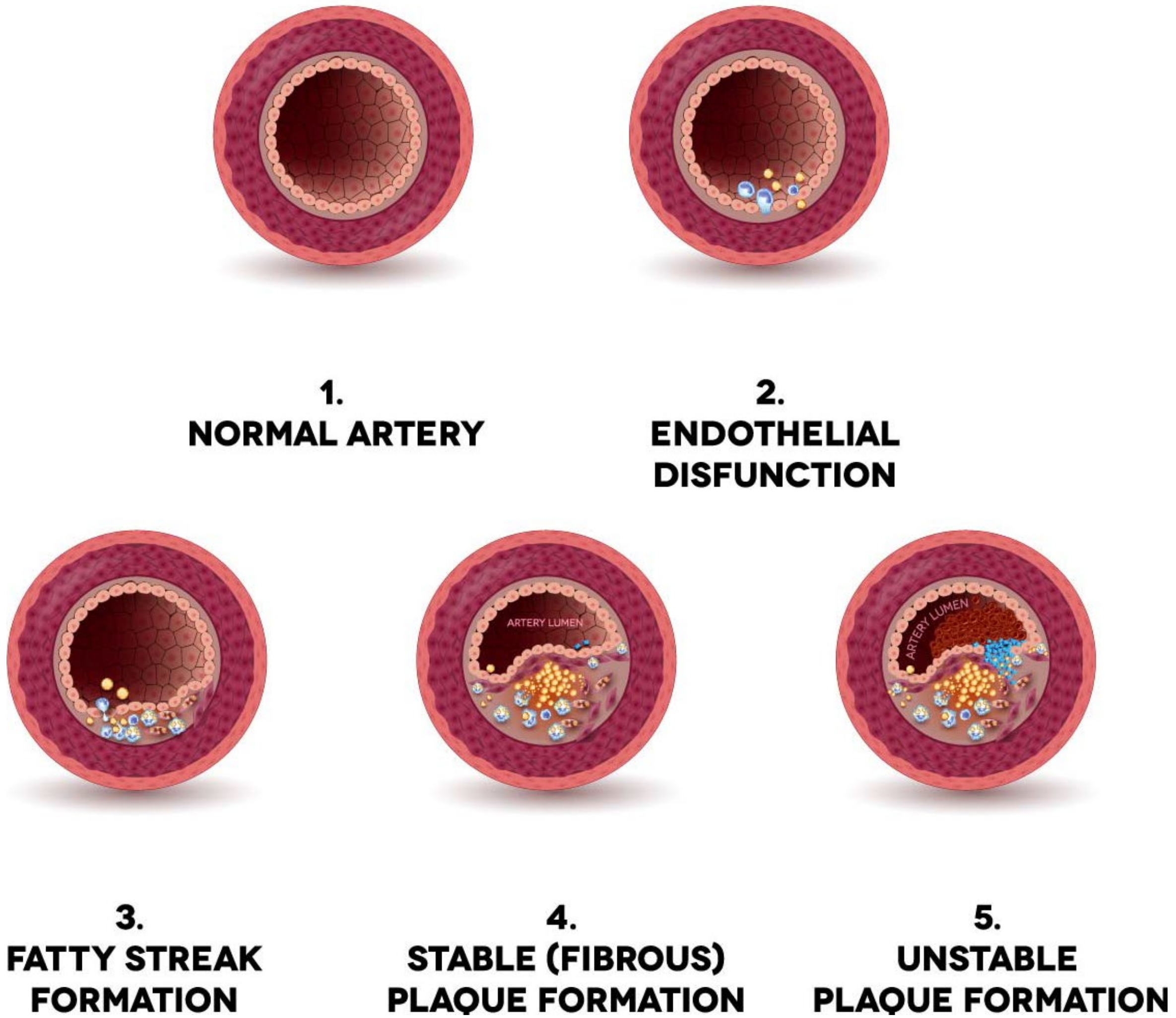
Atherosclerosis – a specific type of arteriosclerosis

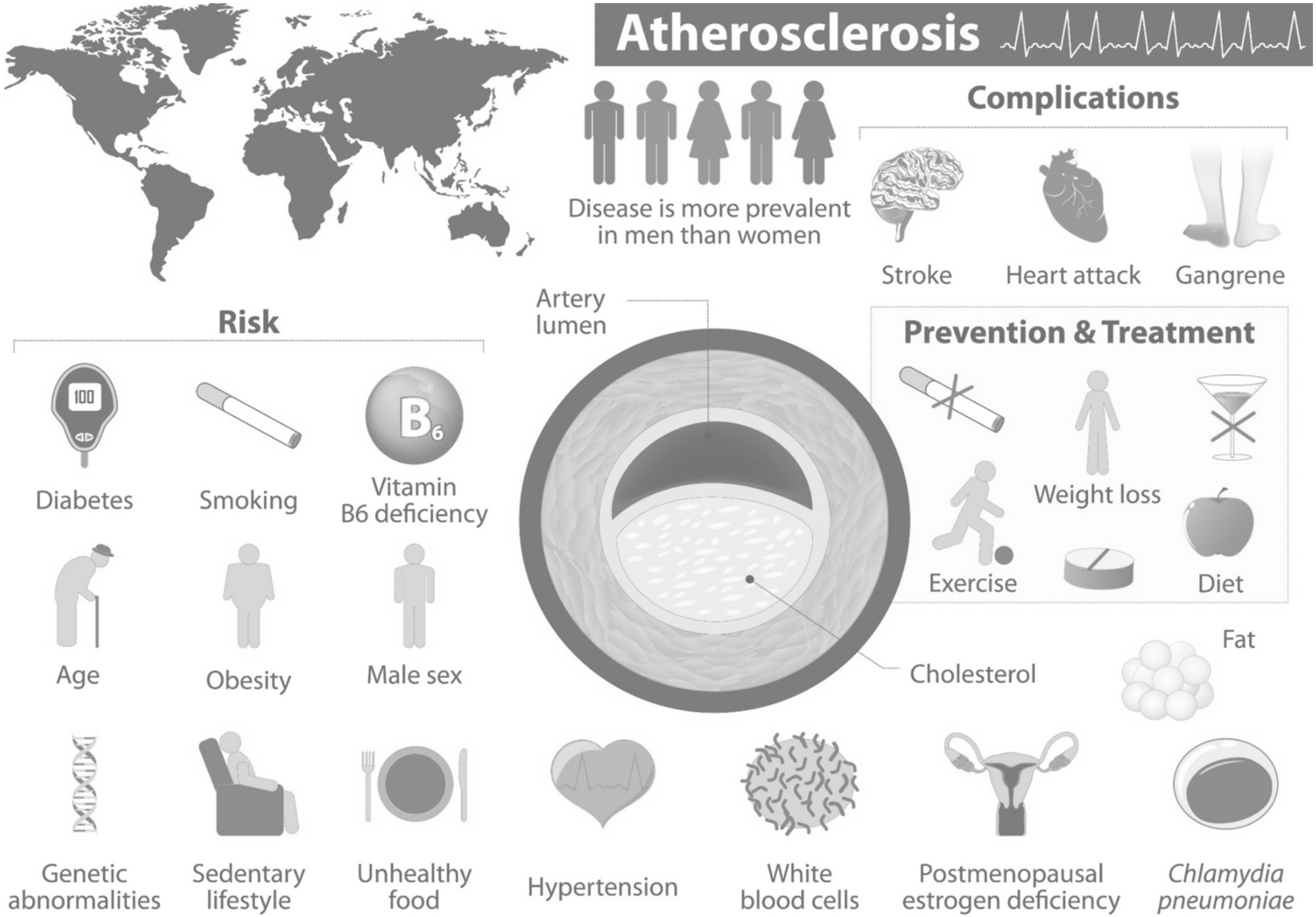
- Build up of fats, cholesterol and other substances in and on the artery walls (plaques)
- Can restrict blood flow
- Plaques can burst and trigger a blood clot
- Can affect arteries anywhere in the body

Atherosclerosis



Atherosclerosis




Atherosclerosis
Disease is more prevalent in men than women
Complications
Stroke
Heart attack
Gangrene
Risk
Diabetes
Smoking
Vitamin B6 deficiency
Age
Obesity
Male sex
Artery lumen
Cholesterol
Prevention & Treatment
Weight loss
Exercise
Diet
Fat
Genetic abnormalities
Sedentary lifestyle
Unhealthy food
Hypertension
White blood cells
Postmenopausal estrogen deficiency
Chlamydia pneumoniae

Exercise and blood pressure

Short term:

- No change in diastolic pressure
- Progressive increase in systolic pressure during CV training
- Rapid and greater increase in systolic blood pressure (SBP) during resistance training
- Reduced blood pressure for up to 24 hours after physical activity

Long term:

- Reduction in resting blood pressure
- Improved regulation of blood pressure

Cardiovascular exercise benefits review

- Increased heart strength and efficiency
- Increased capillary network
- Increased stroke volume and cardiac output
- Increased elasticity of blood vessels
- Improved blood flow distribution
- Improved blood cholesterol profile
- Reduced blood pressure
- Improved ability to tolerate heat
- Reduced risk of cardiovascular diseases, for example, a stroke

Cardiovascular exercise risks

- Overexertion
- Aggravation of cardiovascular contraindications to exercise
- Overtraining
- Overuse injuries

Learning check quiz

Answer TRUE or FALSE

- The largest artery in the body is the aorta
- The main artery that leaves the right ventricle is the aorta
- The pulmonary vein carries oxygenated blood to the heart
- The vena cava is part of the pulmonary circulatory system
- The pulmonary artery carries deoxygenated blood
- Circulation between the heart and body is systemic circulation
- All arteries carry blood away from the heart
- All veins carry deoxygenated blood
- The pulmonary artery is the only artery that carries deoxygenated blood
- Veins carry blood under high pressure

USP186 - Applied anatomy for exercise, fitness, health and wellbeing

LO4 Understand the structure and function of the respiratory system in relation to exercise, health and fitness programming

Content and Assessment Criteria

- Know the structure and function of the respiratory system
- Know the muscles involved in breathing and the passage of air through the respiratory system
- Know the process of gaseous exchange

Structure and function of the respiratory system

Respiration is the exchange of gases between the atmosphere, blood and cells and occurs in three main steps:

Pulmonary ventilation:

- Breathing involves the inspiration and expiration of air between the atmosphere and lungs

External respiration:

- The exchange of gases between the air spaces of the lungs and the pulmonary capillaries

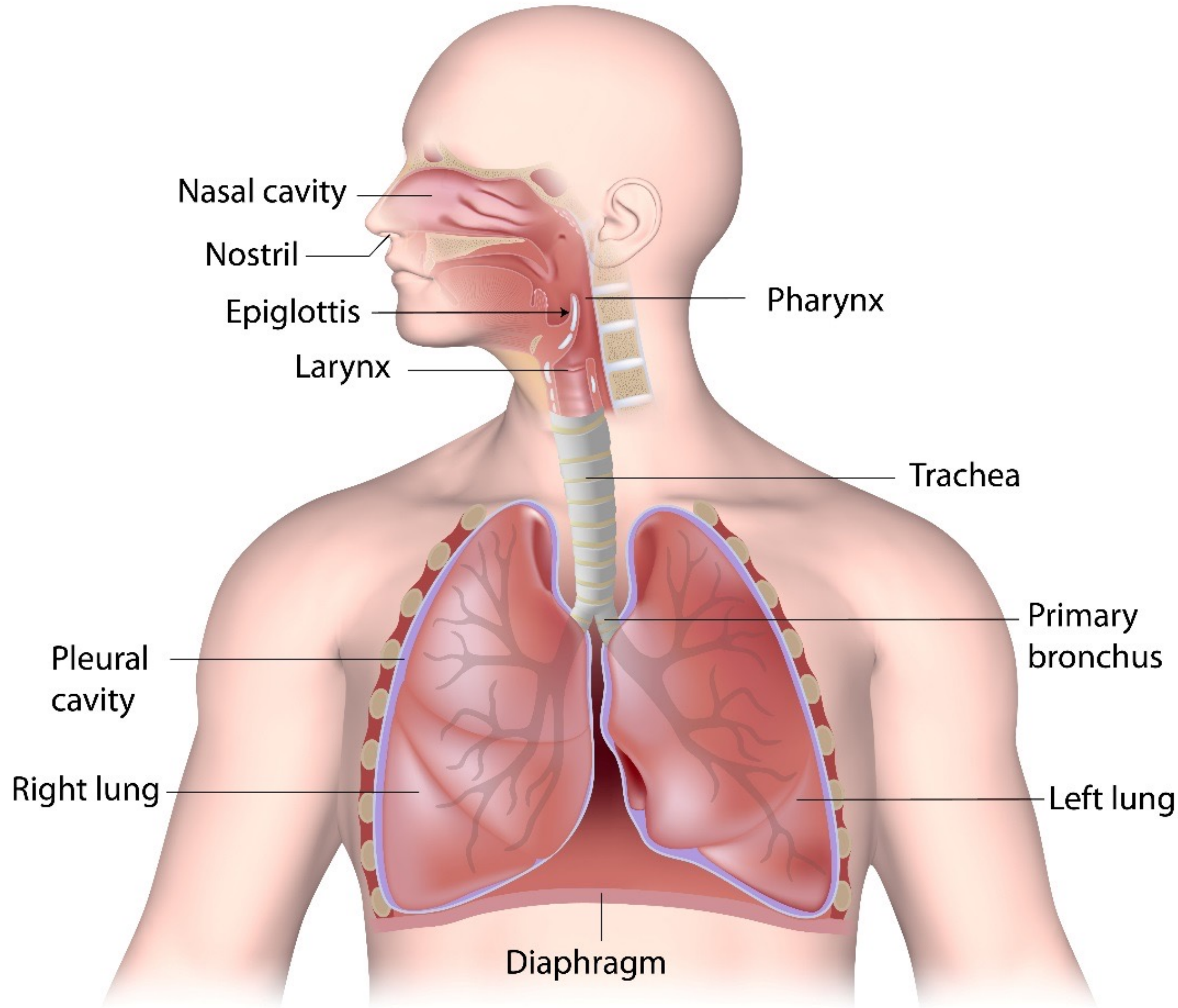
- O_2 is delivered to the blood and CO_2 is lost from the blood

Structure and function of the respiratory system

Internal respiration:

- The exchange of gases between the systemic capillaries and the tissue cells
- The cells consume O_2 and give off CO_2 during metabolic reactions (cellular respiration)
- Blood loses O_2 and gains CO_2

Respiratory system structures review



Structures of the respiratory system

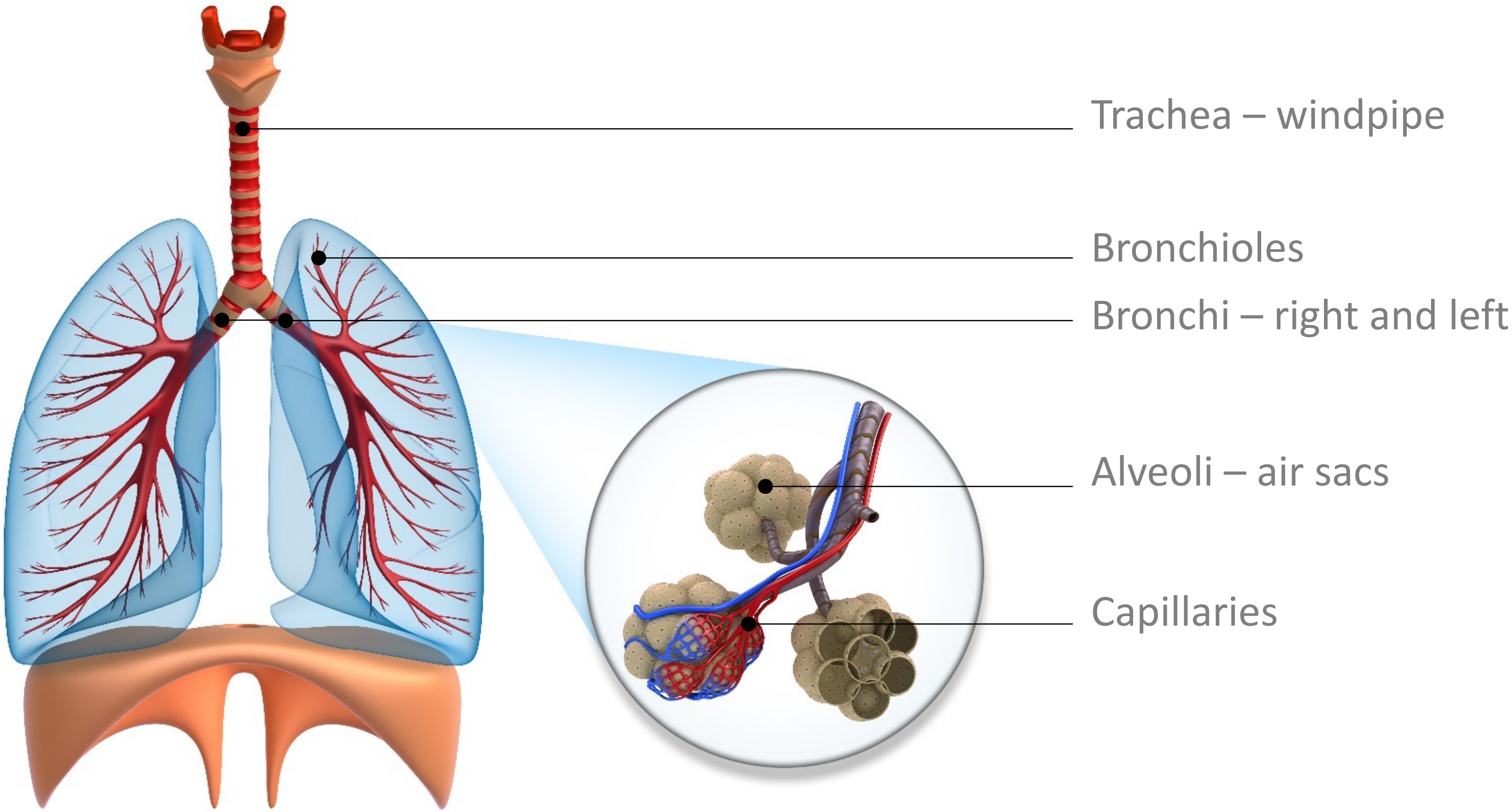
Structurally the respiratory system has two portions:

Upper respiratory system:
- Nose, nasal passage and pharynx

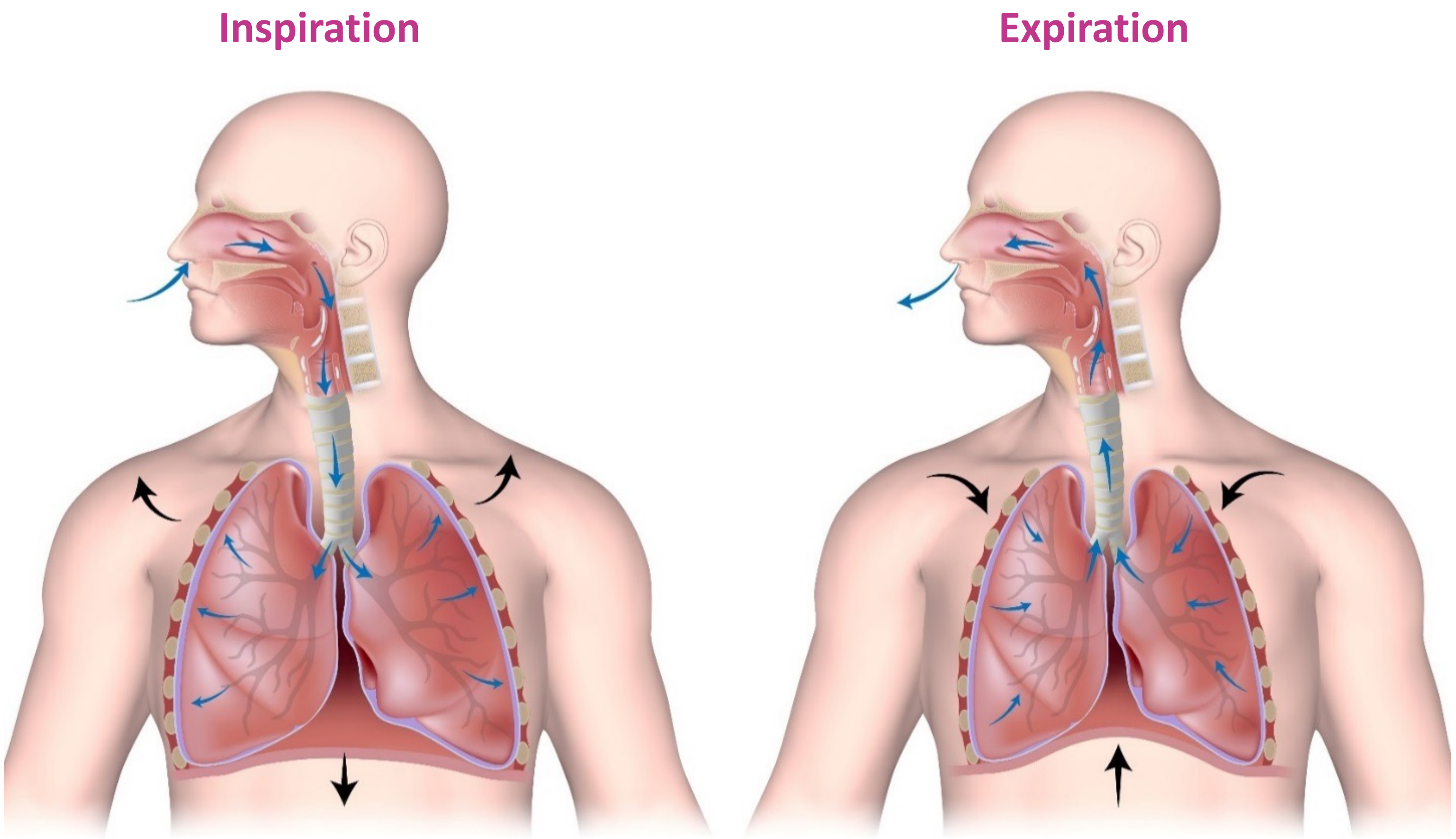
Lower respiratory tract:
- Larynx, trachea bronchi and lungs

The lungs are paired cone shaped organs lying in the thoracic cavity:
- A pleural membrane encloses and protects the lungs
- A pleural cavity contains a lubricating fluid that reduces friction between the membranes to facilitate breathing
- Each lung is divided into lobes
- The left lung contains two lobes and the right lung has three
- The right lung is also thicker, broader and shorter than the left to accommodate the position of the liver

The structure of the lungs review



Mechanics of breathing



Mechanics of breathing

Skeletal muscles power inspiration

- The diaphragm is the major muscle driving normal inspiration
- When the diaphragm contracts it expands the thoracic cavity at the expense of the abdominal cavity
- The increase in the volume of the thoracic cavity allows air from the atmosphere to flow into the lungs
- External intercostal muscles expand the thoracic cage upward and outward
- This reduces pressure within the lungs and facilitates air flowing into the lungs

Accessory muscles aid in forceful inspiration

- The sternocleidomastoid and scalene muscles elevate the sternum and 1st two ribs respectively
- Some texts also suggest the pectoralis minor muscle is also involved
- These muscles are recruited during high levels of inspiration such as strenuous exercise (forced inspiration)

Mechanics of breathing

Resting expiration is passive:

- During inspiration the inspiratory muscles store mechanical energy in the elastic lungs and chest wall system
- When the inspiratory muscles relax the lungs and chest wall recoil, leading to contraction of the thoracic cavity
- This increases intrathoracic pressure and forces air out out of the lungs

Abdominal muscles aid in forced expiration:

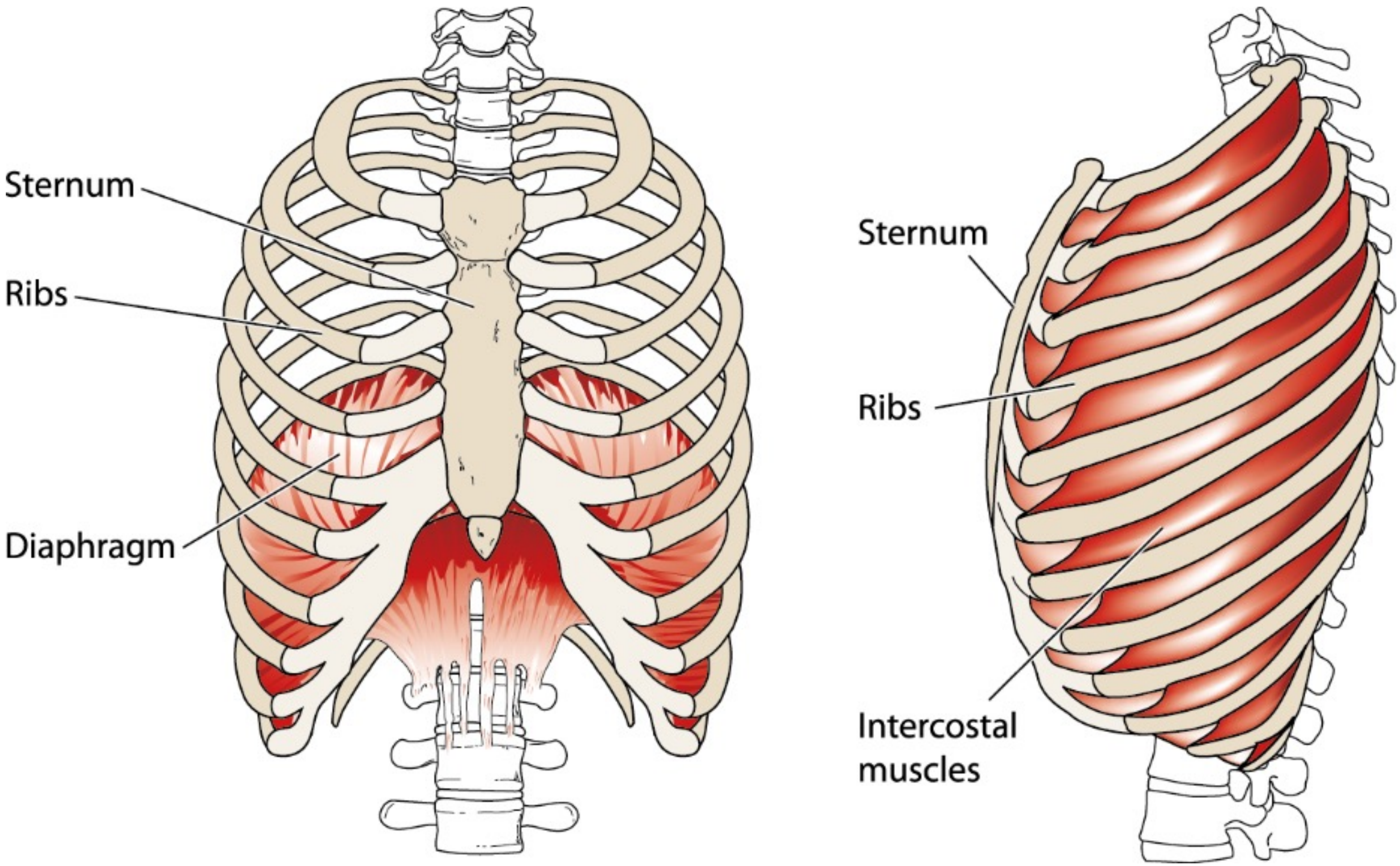
- Contraction of the abdominal muscles compresses the contents of the abdominal cavity, thereby reducing the volume of the thoracic cavity
- These muscles include the internal intercostals, rectus abdominus, external and internal obliques and the transverse abdominus
- These muscles assist expiration during strenuous breathing

Lung volumes

Several useful lung volumes and capacities can be identified, these are:

- Tidal volume TV – the amount of air breathed in during normal breathing (appx 0.5l)
- Inspiratory reserve volume IRV – additional volume that can be inspired at the end of normal tidal inspiration (appx 0.3l)
- Expiratory reserve volume ERV – additional volume that can be expired after normal tidal expiration (appx 1.1l)
- Residual volume RV – the volume remaining in the lungs after maximum expiration (appx 1.2l)
- Inspiratory capacity IC – volume of air that can be inspired after normal tidal expiration. IC = IRV + TV
- Vital capacity VC – is the largest volume of air that can be expired from a maximal inspiration. VC = ERV + TV + IRV
- Total lung capacity TLC – maximum volume of air that the respiratory system can hold and is the sum of all 4 lung volumes (appx 6l)

Muscles involved in breathing

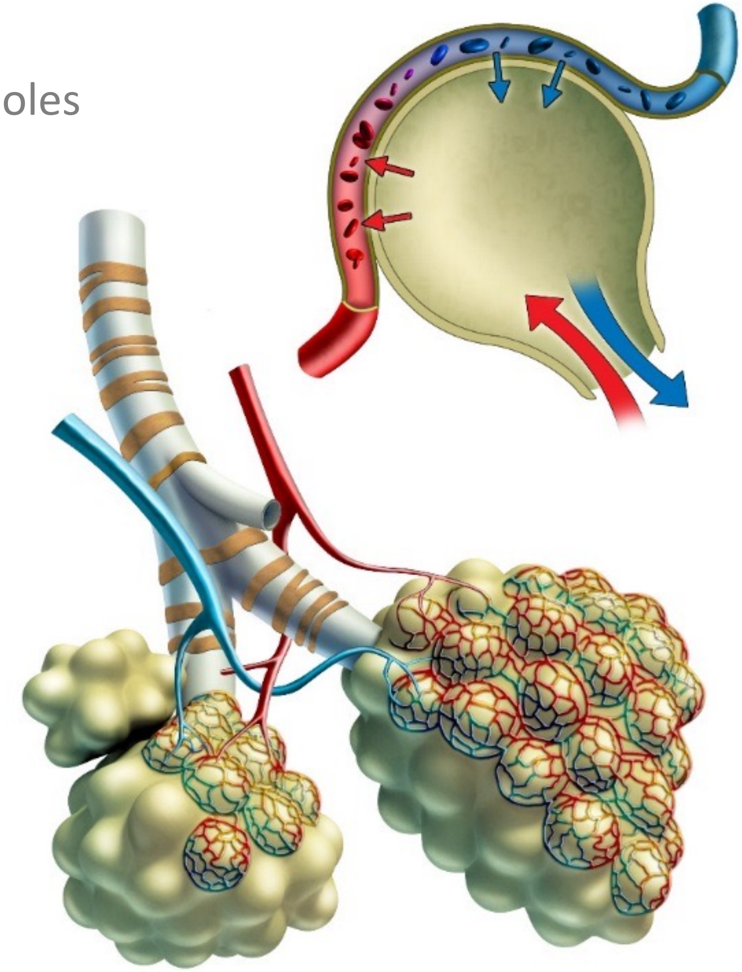


Composition of air

Gas	Inhaled air	Exhaled air	Difference
Nitrogen	79%	79%	none
Oxygen	21%	17%	↓ 4%
Carbon dioxide	< 1%	4%	↑ 4%

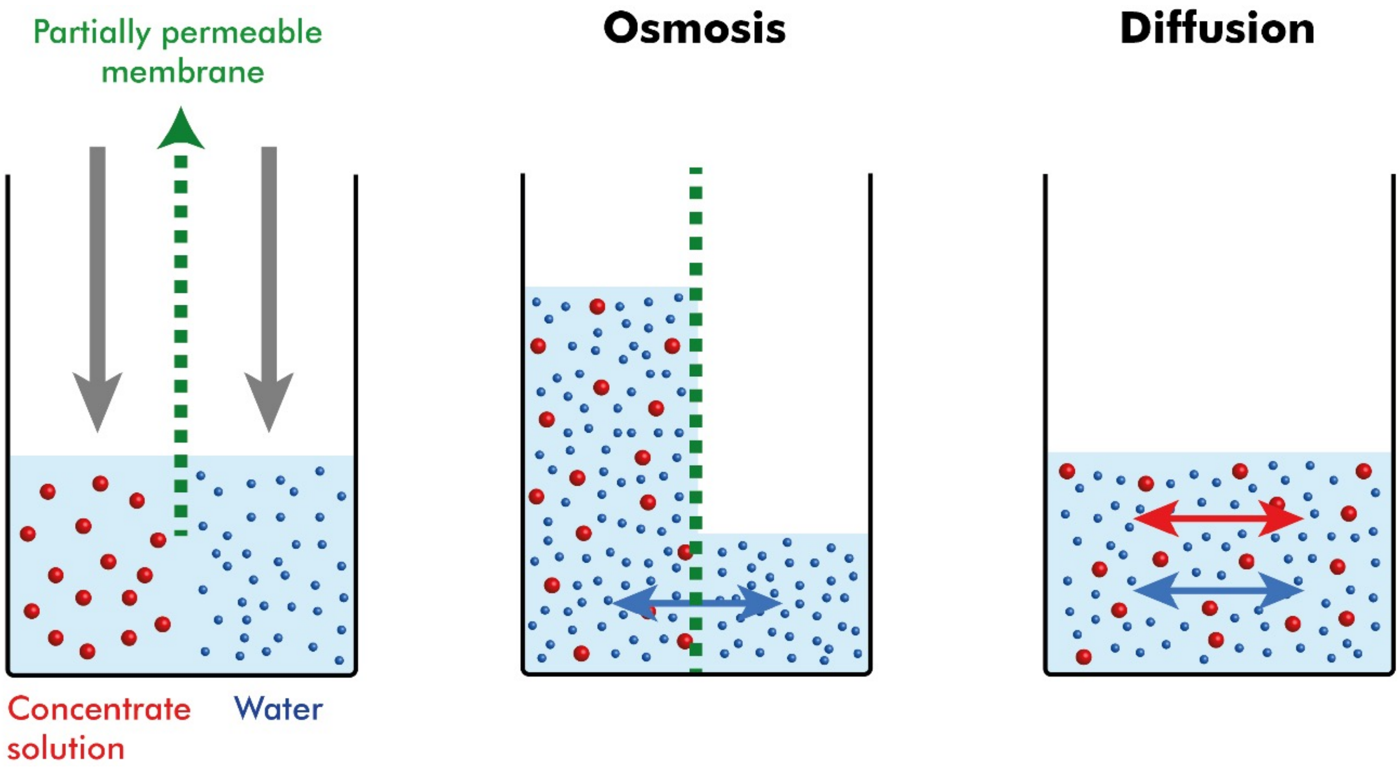
Gaseous exchange in alveoli review

- Air sacs at the terminal end of bronchioles
- Surrounded by capillaries
- Site of gaseous exchange
- Diffusion of gases



Diffusion

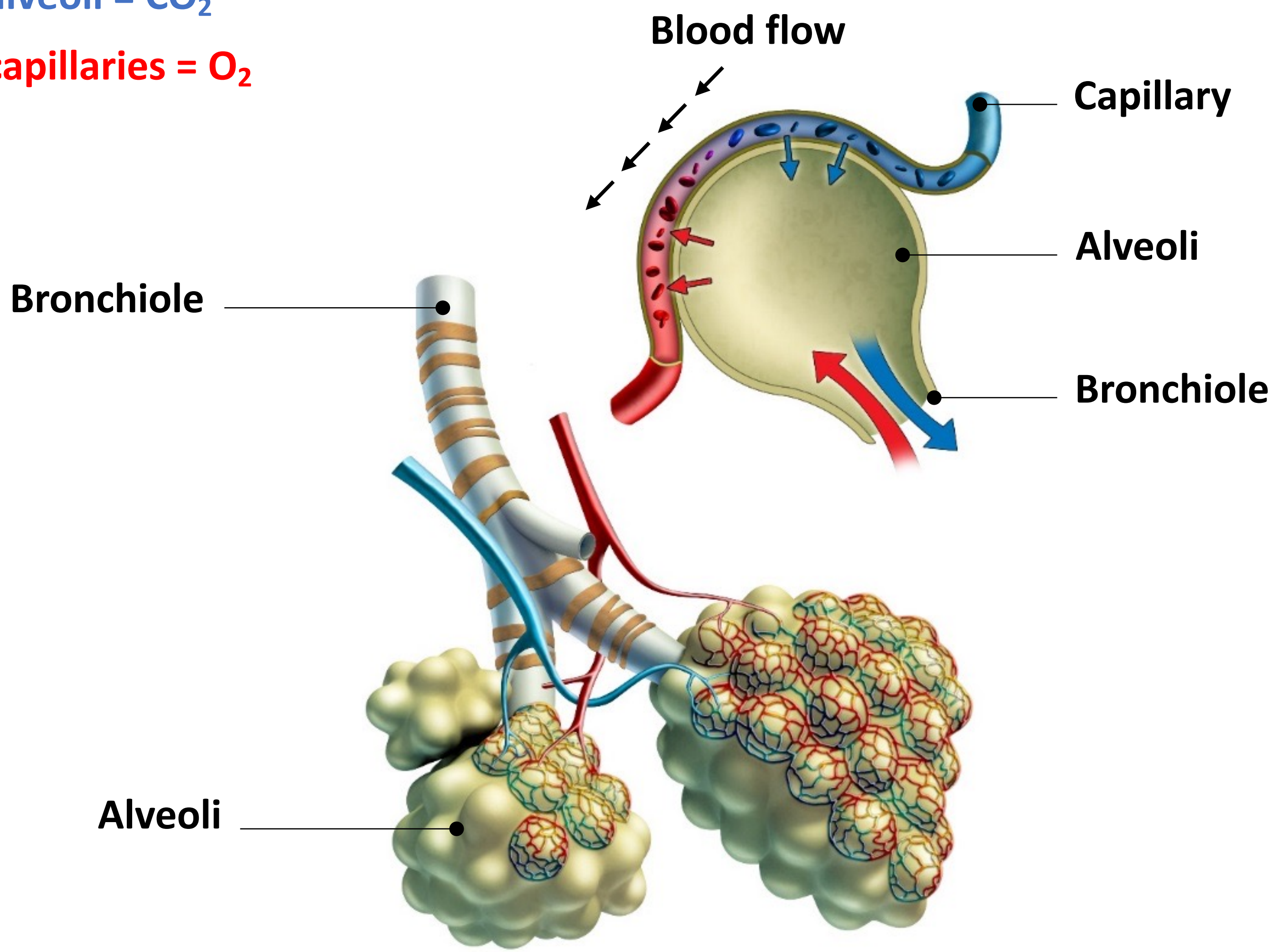
The movement of a substance from an area of high concentration to an area of low concentration.



Gaseous exchange

To alveoli = CO_2

To capillaries = O_2



Pulmonary ventilation:
pressure changes

- The pressure of a specific gas in mixture is called the ***partial pressure***
- Partial pressures are important when determining the movement of O_2 and CO_2 between the atmosphere and the lungs and the blood and body cells
- Gases diffuse from an area of high partial pressure to the area where partial pressure is less (diffusion)
- The partial pressure of oxygen in alveolar air is about 104 mm Hg, whereas the partial pressure of the oxygenated pulmonary venous blood is about 100 mm Hg
- When ventilation is sufficient, oxygen enters the alveoli at a high rate, and the partial pressure of oxygen in the alveoli remains high
- Without the large difference in partial pressure between the alveoli and the blood, oxygen does not diffuse efficiently across the respiratory membrane

Learning check

- Outline the three main steps of respiration
- Identify the structures in the upper and lower respiratory tracts
- List the muscles involved in normal inspiration and forced expiration
- Outline the main difference between the left and right lung
- Describe the following
    - Tidal volume
    - Vital capacity
- Explain how gases are exchanged at the lungs

VTCT

USP186 - Applied anatomy for exercise, fitness, health and wellbeing

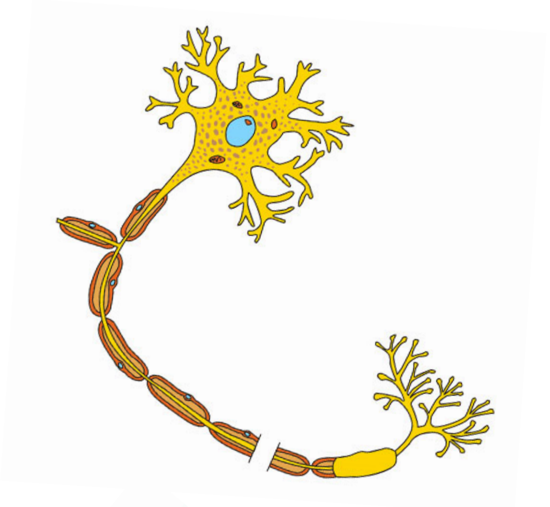
LO5 Understand the structure and function of the nervous system in relation to exercise, health and fitness programming

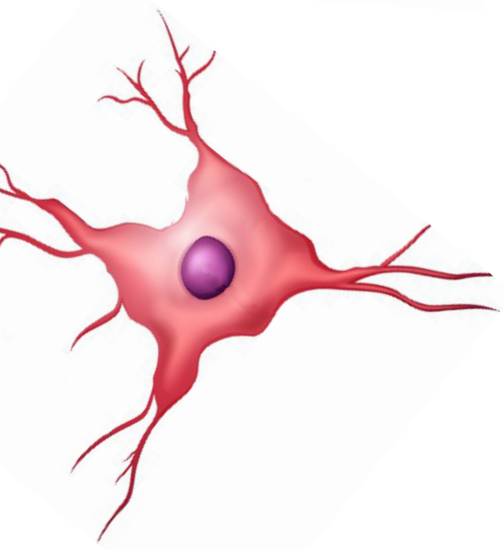
Content and Assessment Criteria

- Know the roles and functions of the different components of the nervous system
- Know the characteristics of different types of nerves
- Know the relationship between the nervous system and principles of muscle contraction and motor unit recruitment
- Know how exercise enhances neuromuscular activity and improves motor fitness

The nervous system review

- The body's main control and communication centre
- Works closely with the endocrine system
- Maintain homeostasis
- Ensures the body functions efficiently
- Communicates messages via a network of neurons/nerves





Function of the nervous system review

Three key roles:

- **Sensory**
  To gather information and detect changes in the body’s internal environment and in the external environment

- **Integrative**
  To analyse and interpret the changes it senses and select the appropriate response

- **Motor**
  To respond to the changes by signalling the required action, for example, the secretion of hormones from the endocrine glands, or by initiating muscle contraction

Structure of the nervous system

- The central nervous system (CNS) is composed of the brain and spinal cord
- Nerve fibres leading to the CNS are called ***afferent*** fibres
- ***Efferent*** nerve fibres are those nerve fibres that lead away from the CNS and comprise the ***peripheral nervous system (PNS)***
- ***Sensory afferent*** nerves bring sensory information from the periphery to the CNS and are the incoming arm of the PNS
- The outgoing or **efferent** arm represents the other half and can also be described as ***motor nerves***

Structure of the nervous system

The peripheral nervous system (PNS) can also be subdivided into:

- **Autonomic**
  Controls involuntary **(unconscious)** functions, such as smooth muscle contraction, for example, digestion

- **Somatic**
  Controls voluntary **(conscious)** functions, such as skeletal muscle contraction and movement, for example, standing, walking, lifting a weight

Autonomic system

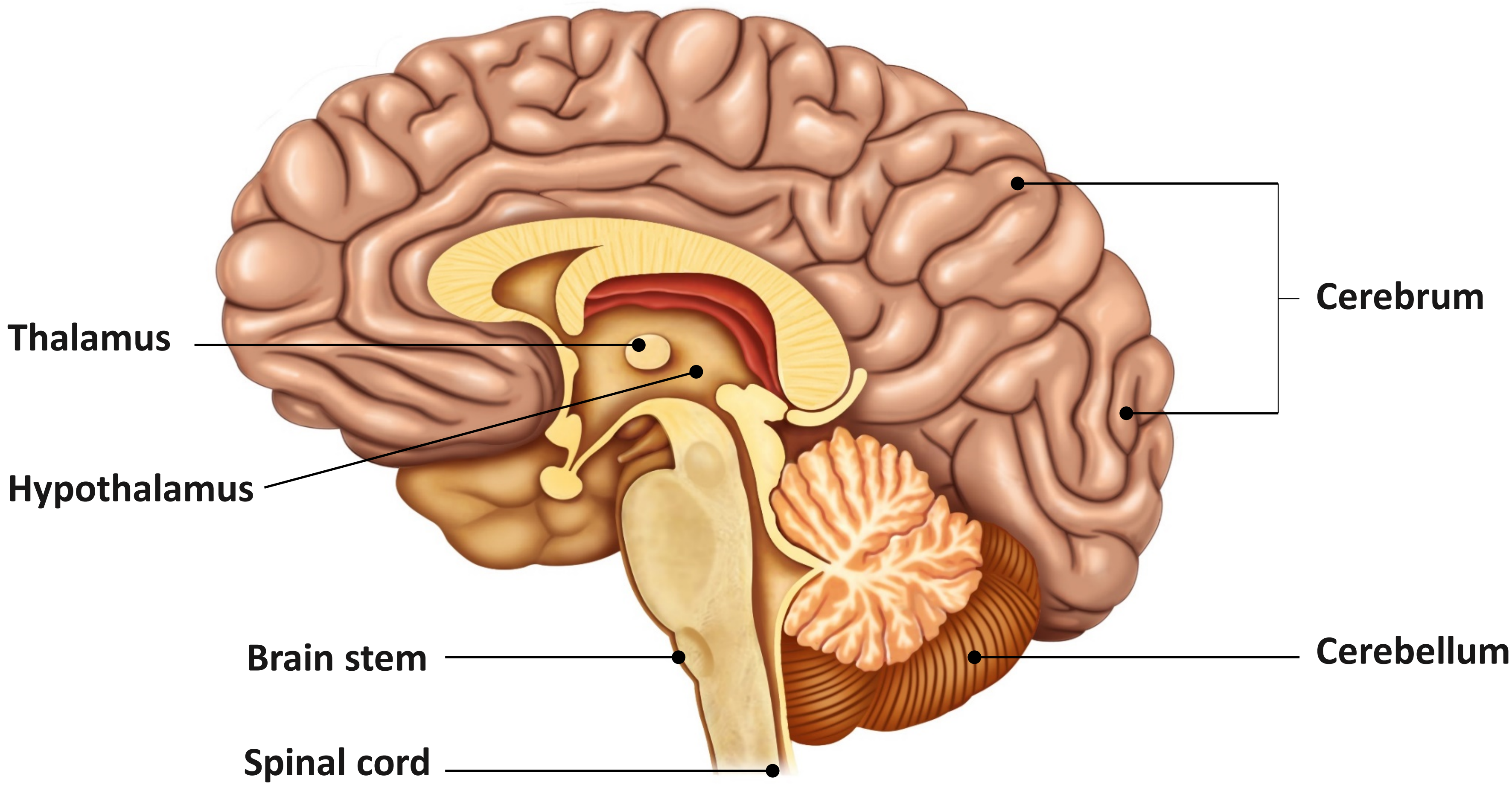
Has three subdivisions:

- **Sympathetic branch**
  Generally **speeds** things up, for example, increases heart rate and breathing rate

- **Parasympathetic branch**
  Generally **slows** things down, for example, reduces heart rate and breathing rate

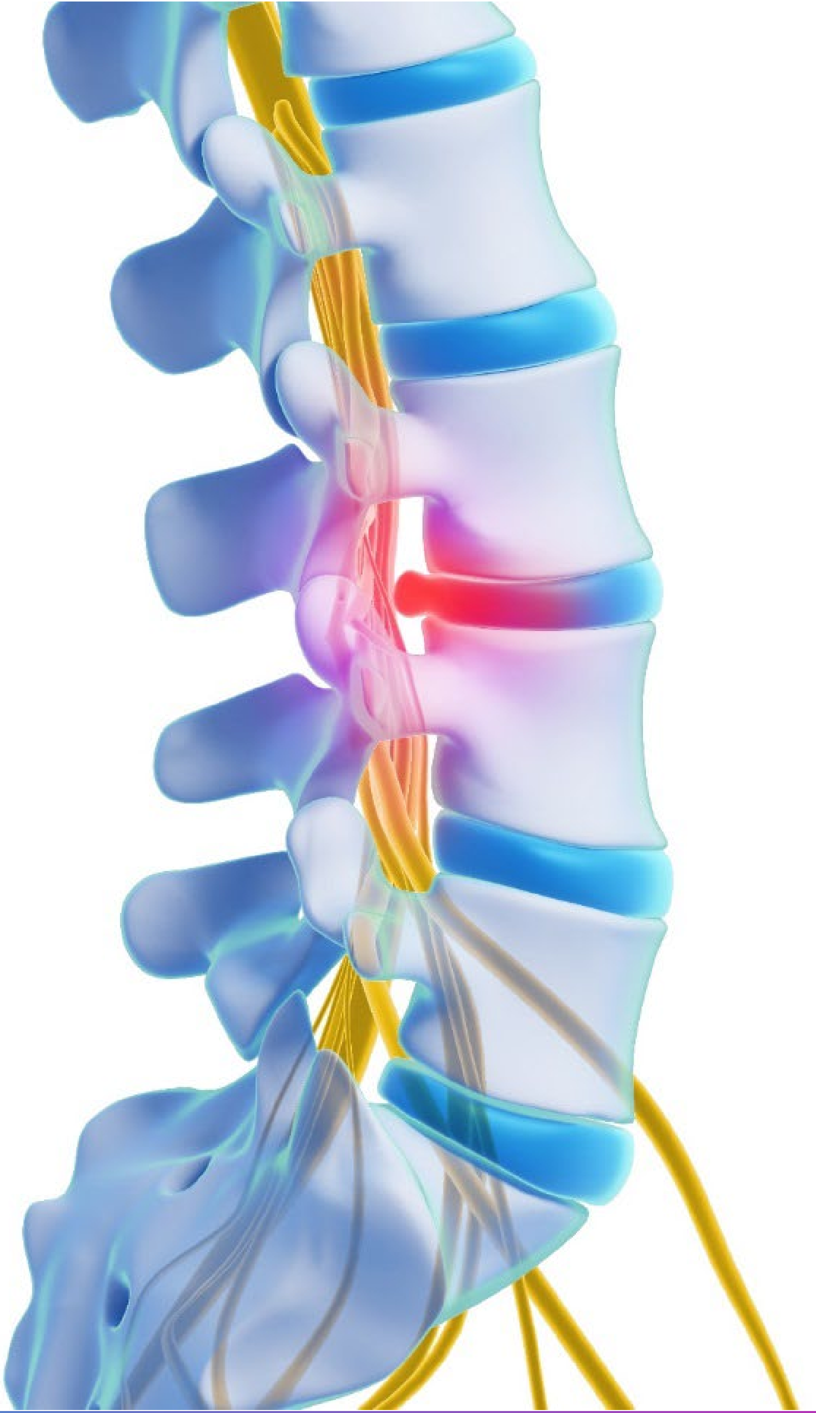
- **Enteric branch**
  A network of neurons that link the CNS with the digestive tract

The brain

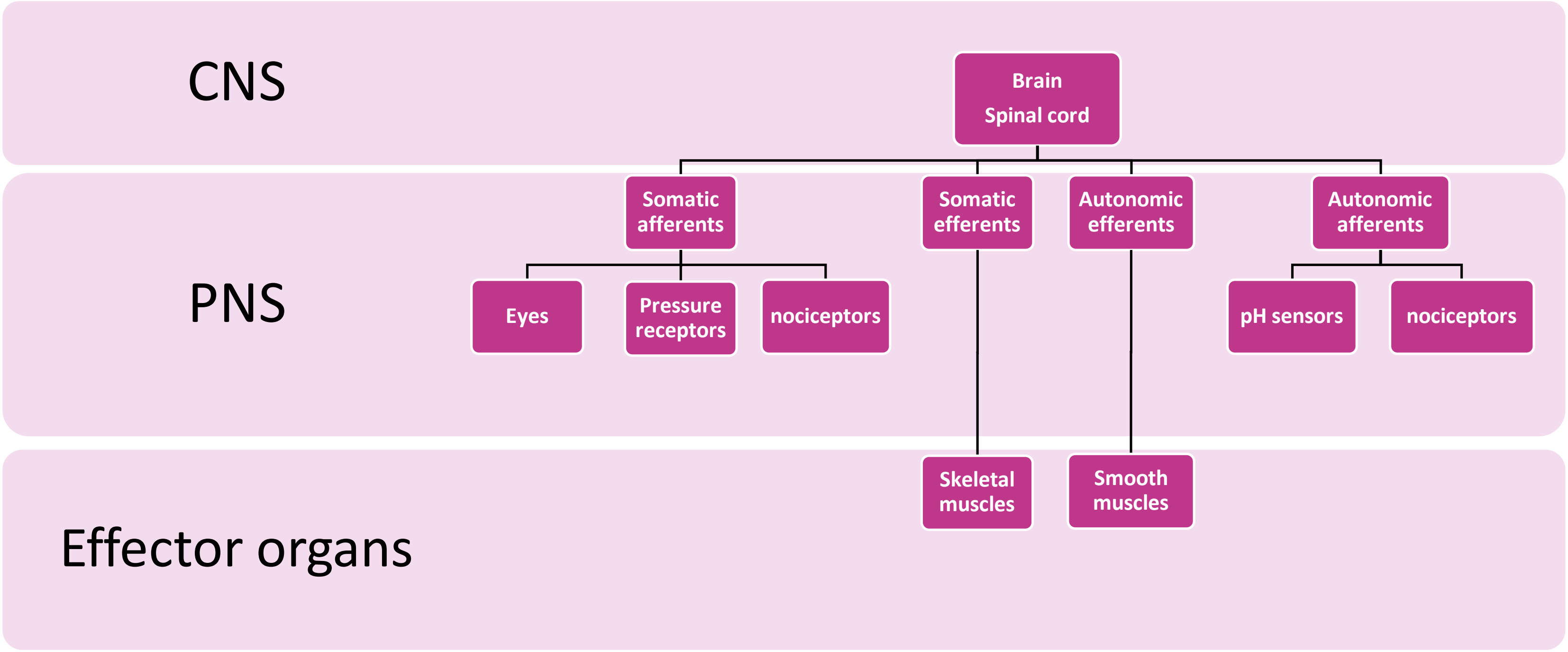

Thalamus
Hypothalamus
Brain stem
Spinal cord
Cerebrum
Cerebellum

The spinal cord

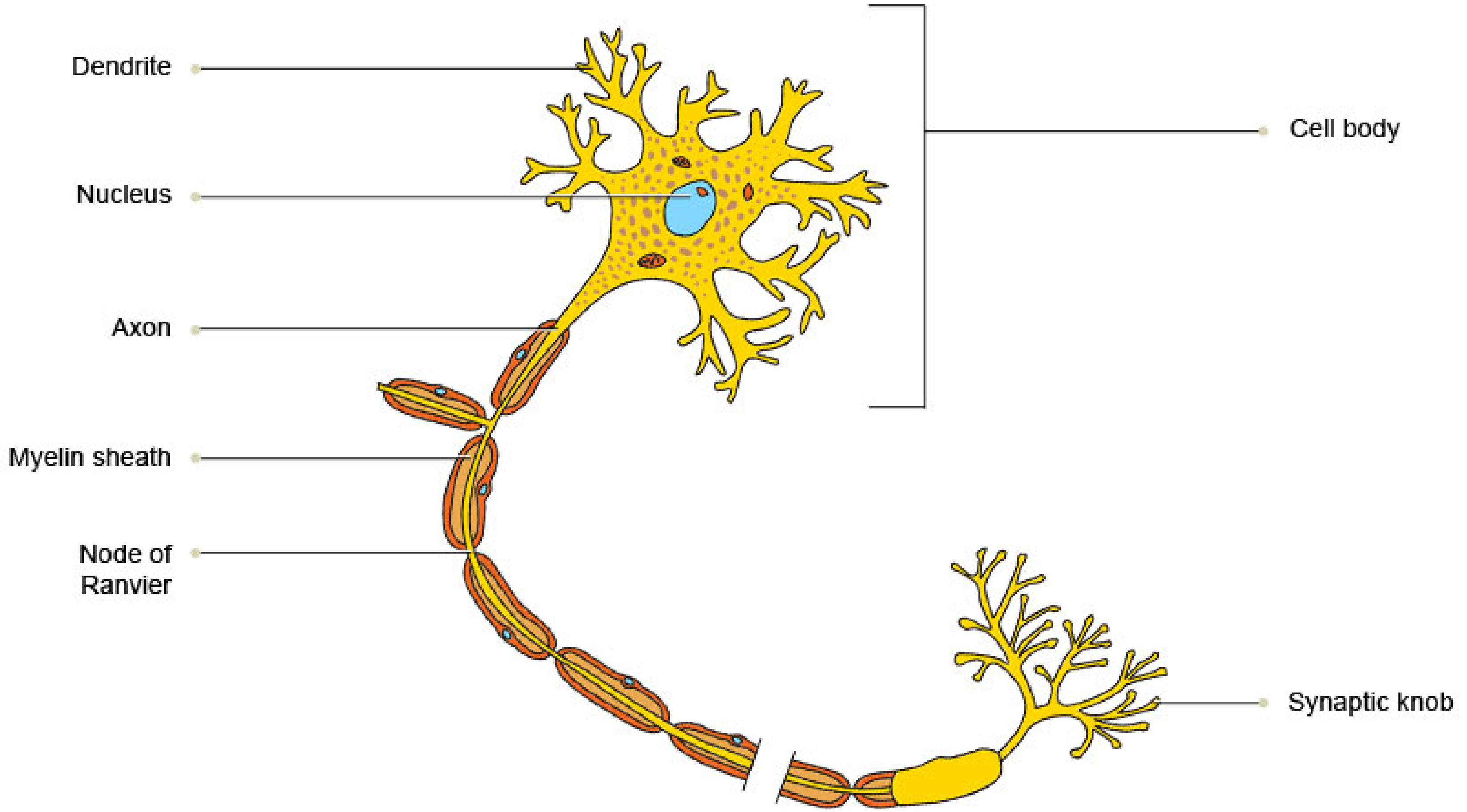
- Extends from the brain stem
- Runs through the vertebral canal
- Protected by the vertebrae
- There are 31 pairs of spinal nerves
- There are 12 pairs of cranial nerves



General organisation of the nervous system



Structure of a typical neuron



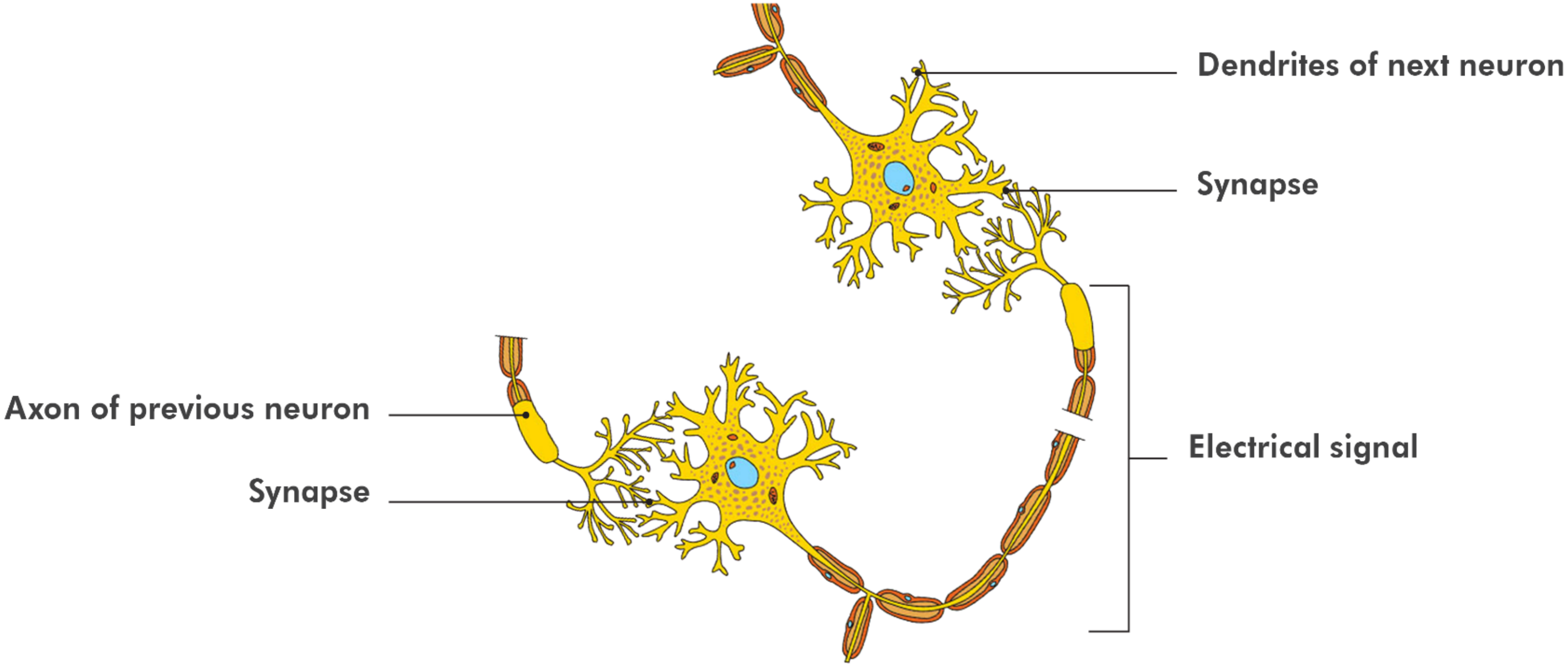
Structure of a typical neuron

Most neurons have three parts:

- **Cell body** – contains the nucleus, cytoplasm and organelles
- **Dendrites** – the receiving or input portion of a typical nerve cell
- **Axon** – this propagates nerve impulses to an effector cell such as a muscle
    - The axon may branch many times to form terminal axons that end either on other neurons or effector cells
    - This region of communication is referred to as a synapse
    - The particular type of synapse formed between a motor neurone and skeletal muscle is called the neuromuscular junction

Action potential

Electrical signals that travel from one neuron to the next or to a target organ.



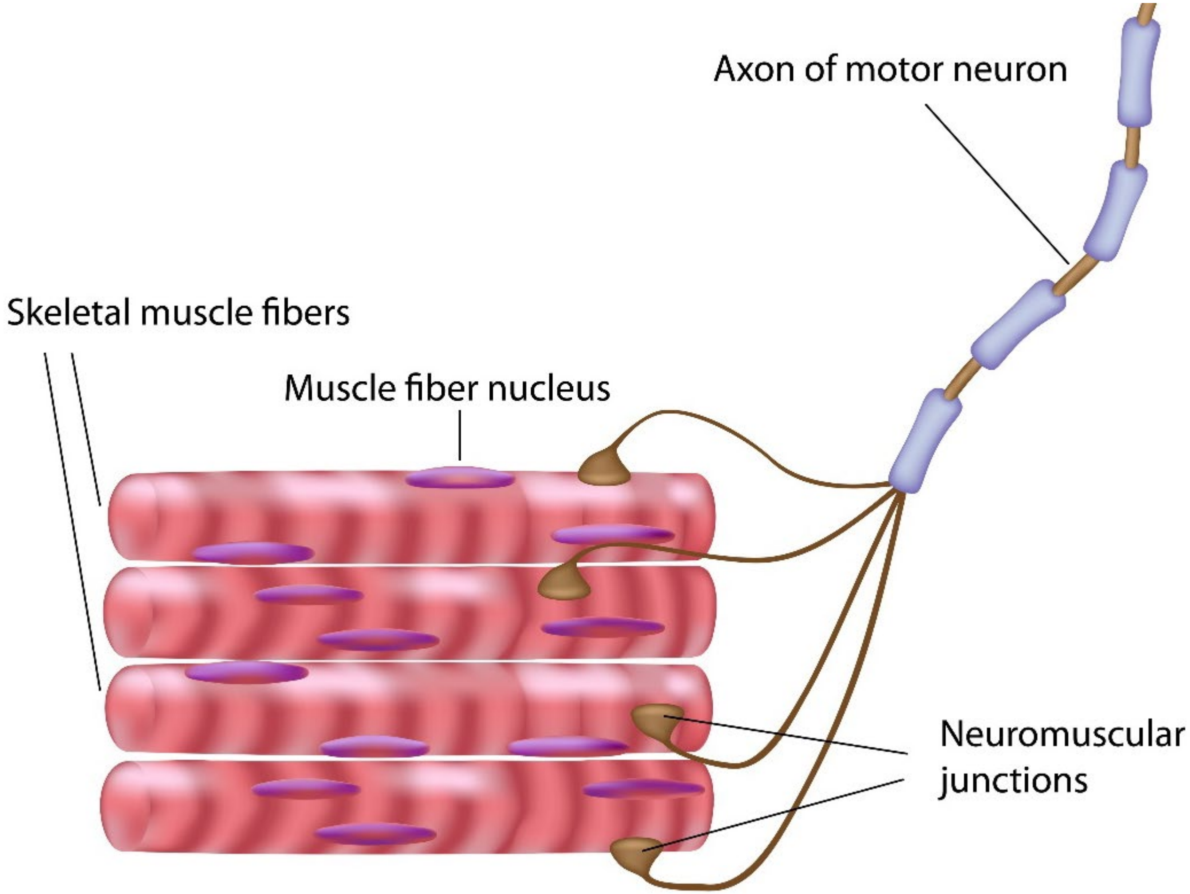
Structure of a typical neuron

Other neuronal structures include:

- **Myelin sheath** – a lipid and protein covering layer around axons of many PNS and CNS neurons
- **Nodes of Ranvier** – a space between sections of a myelin sheath that help to speed up the propagation of a nerve impulse
- **Neuroglia** – cells of the nervous system that perform supportive functions
  - Astrocytes – metabolises neurotransmitters, links neurons and blood vessels
  - Oligodendrocytes – helps produce myelin sheaths
  - Microcytes – protect the CNS from disease

Motor unit

A motor nerve and all the muscle fibres it stimulates.



All or none law

- When a neuron receives an impulse, all the muscle fibres within the motor unit are activated
- The motor unit will only activate the fibres it controls
- For other muscle fibres to be activated, more neurons and motor units would need to be activated

Muscle proprioceptors and stretch reflexes

- **Muscle spindles**
  Detect changes in muscle length

- **Golgi tendon organs**
  Detect changes in muscle tension

- **Stretch reflex**
  Muscle spindle activates to cause a reflex contraction of the stretched muscle as a protective function to prevent over-lengthening

- **Inverse stretch reflex**
  Golgi tendon organs are activated when a muscle contracts and pulls on the tendon (reflecting the force of the muscle). This stimulates a reflexive relaxation of the muscle initiating the contraction – thereby reducing the risk of high forces injuring a muscle

Muscle proprioceptors and stretch reflexes

Reciprocal inhibition:

- Sherrington's law of reciprocal inhibition states that there is a neurologic inhibition of an antagonist when an agonist is working
- For example when we contract the biceps to flex the elbow the triceps will be neurologically inhibited
- Co-contraction is an exception to this rule when agonist and antagonist can work together, for example, when you make a fist both the flexors and extensors co-contract
- Reciprocal inhibition is also used to facilitate stretching
  - When a client actively contracts a muscle group the opposite muscle will relax
  - This allows greater stretching of the relaxed muscle as it is in a relatively more relaxed state

Motor unit recruitment

Factors affecting recruitment:

- Specific movement pattern
- High and low firing threshold
- Skill and experience of participant
- All or none law:
  - stimulus is above threshold; individual muscle fibres fully contract
  - stimulus is below threshold; muscle fibres do not contract
- Strength of muscle contraction

Size principle:

- Small motor units (type I)
- Large motor units (type II)

Exercise and neuromuscular connections

- Improved neuromuscular connections and transmissions
- Improved motor fitness – specific to type of training, for example, power, balance, speed, reaction time, coordination
- Resistance training – improved motor unit recruitment and synchronisation

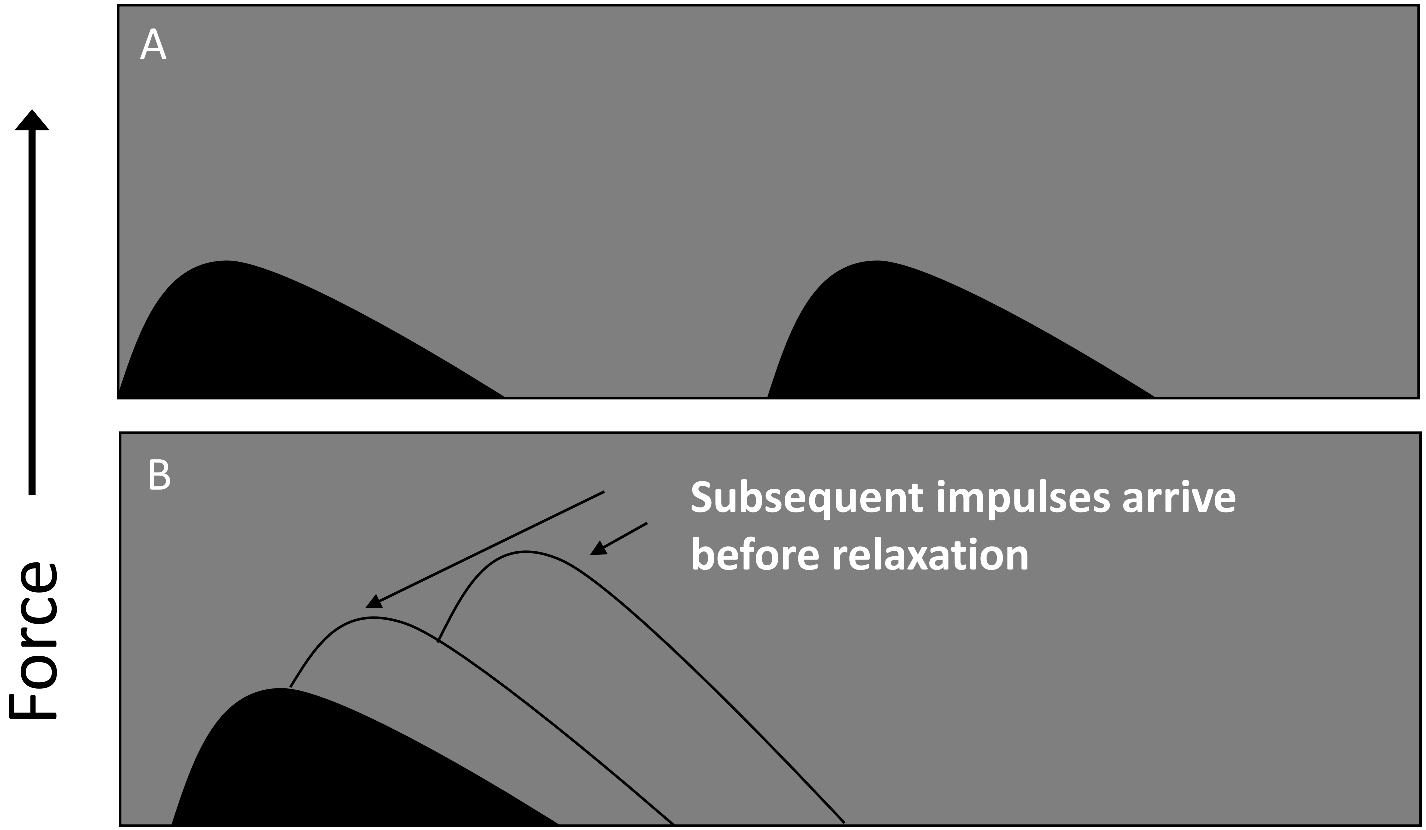
Neural factors affecting the development of strength and power

- **Motor unit recruitment**
  - During a physical task motor units will sequentially recruit from weakest to strongest as the force increases
  - Resistance training has been shown to increase the number of motor units recruited per muscle group
- **Motor unit synchronisation**
  - Motor units fire in a synchronous manner in order to produce smooth muscular contractions
  - Resistance training improves the synchronised summation of forces which in turn can improve force production

Neural factors affecting the development of strength and power

- **Frequency of nervous stimulation**
  - Resistance training can also increase the frequency at which muscles are stimulated
  - By increasing the speed of stimulation to each motor unit, the nervous system can initiate contractions in a muscle before the first contraction has dissipated
  - This can result in the summation of forces to improve strength (see diagram on next slide)

Increased frequency of stimulation



A = infrequent nervous impulses
B = increased frequency of impulses

Exercise and neuromuscular connections

Other benefits of nervous system training effects:

- Improved reaction times
- Improved balance and co-ordination
- Improved balance
- Links to improved agility
- Improved stability for example, spinal stability

Learning check

- Describe the role and functions of the nervous system
- Describe difference between afferent and efferent nerve fibres
- Describe the ‘all or none law’/motor unit recruitment
- Describe the function of the Golgi tendon organs
- Explain the concept of reciprocal inhibition
- Describe how exercise can enhance neuromuscular connections and improve motor fitness

VTCT

USP186 - Applied anatomy for exercise, fitness, health and wellbeing

LO6 Understand the structure and function of the endocrine system in relation to exercise, health and fitness programming

Content and Assessment Criteria

- Know the functions of the endocrine system
- Know the names of the major glands, their locations and hormones excreted
- Know the functions of hormones

Comparisons of the nervous and endocrine system in the regulation of homeostasis

Characteristic	Nervous system	Endocrine system
Mechanism of control	Neurotransmitters and nerve impulses	Hormones delivered to tissues
Cells affected	Muscles, glands, other nerve cells	Almost all body cells
Resulting action	Muscular contraction, glandular secretion	Changes in metabolic activity
Speed of action	Milliseconds	Seconds, hours, days
Duration of action	Briefer	Longer

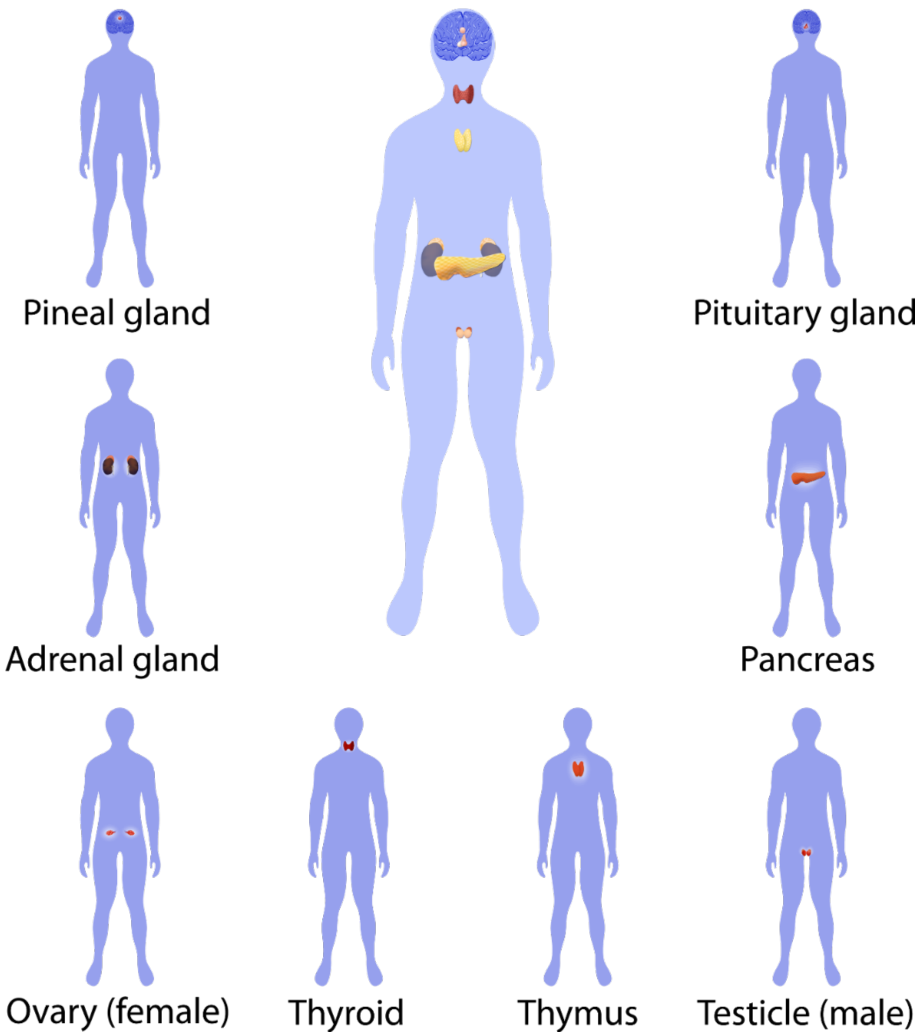
Functions of the endocrine system

- Help maintain homeostasis
- Production of hormones
- Regulate chemical composition and volume of the internal environment
- Help regulate metabolism and energy balance
- Regulate certain activities of the immune system
- Contribute to the basic process of reproduction, growth and development

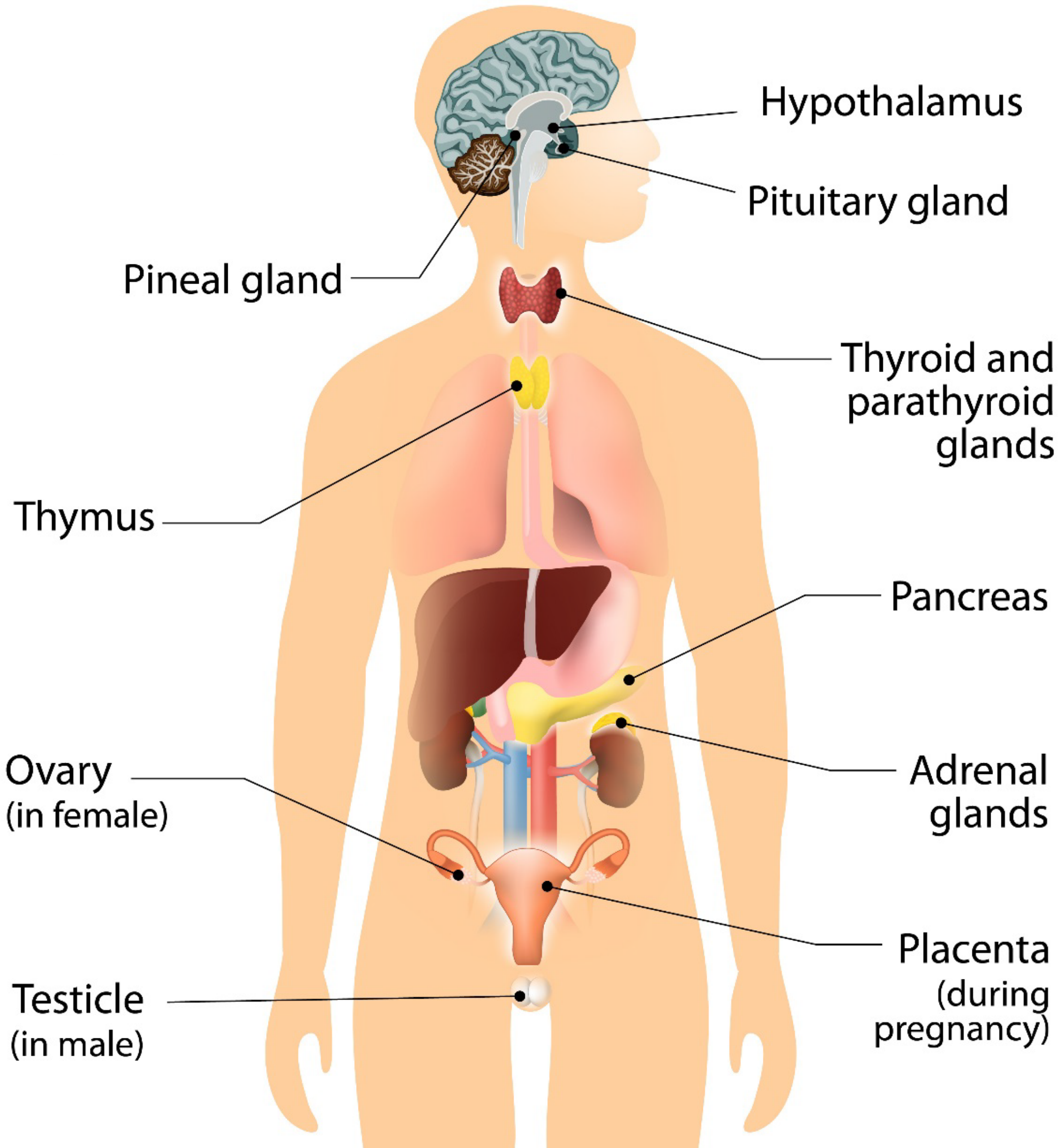
Endocrine system structures

Major endocrine glands:

- Hypothalamus
- Pituitary
- Pineal
- Pancreas
- Thyroid
- Parathyroid
- Adrenal
- Testes
- Ovaries



Endocrine system



Hypothalamus

Brain structure with key role in communication between the nervous and endocrine systems.

- Located inferior to the two lobes of the thalamus and connected to the pituitary gland
- Receives input from several areas of the brain
- The hypothalamus and pituitary glands play important roles in regulating all aspects of endocrine system functions

Pituitary gland

Located at the base of the brain.

The ‘master gland’.

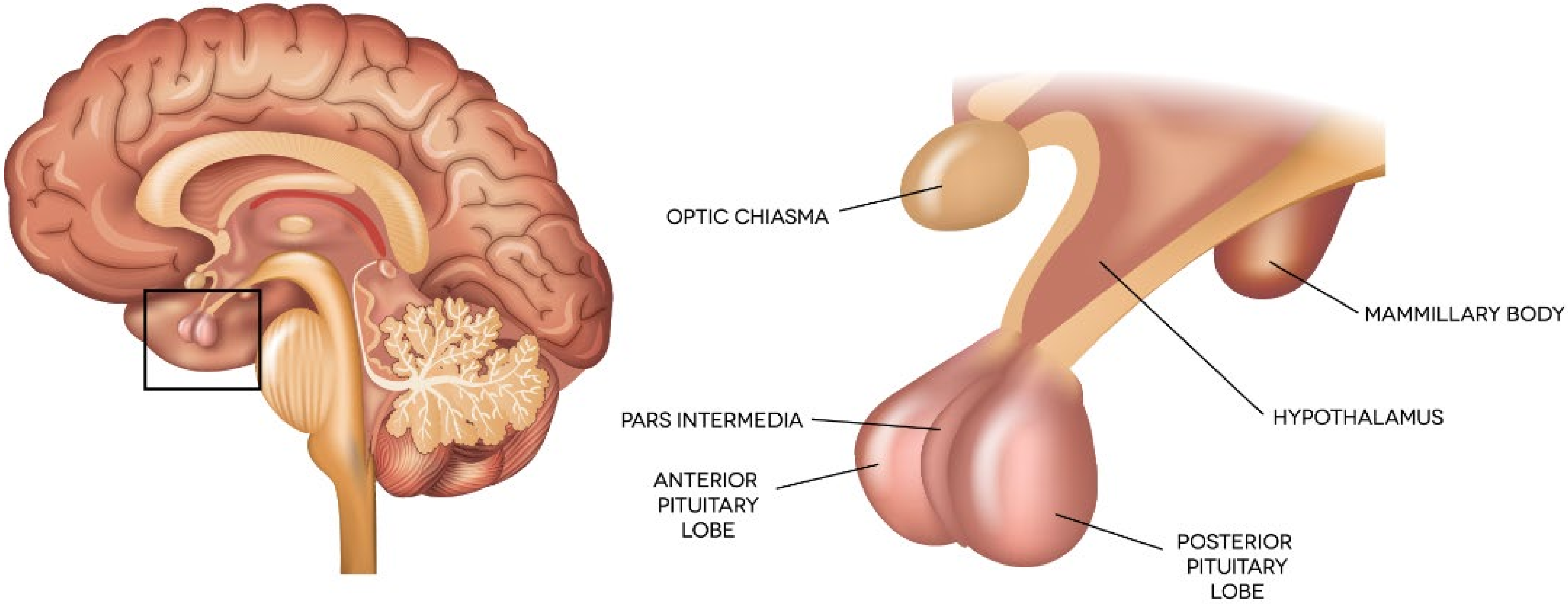
Releases different hormones and regulates many body activities:

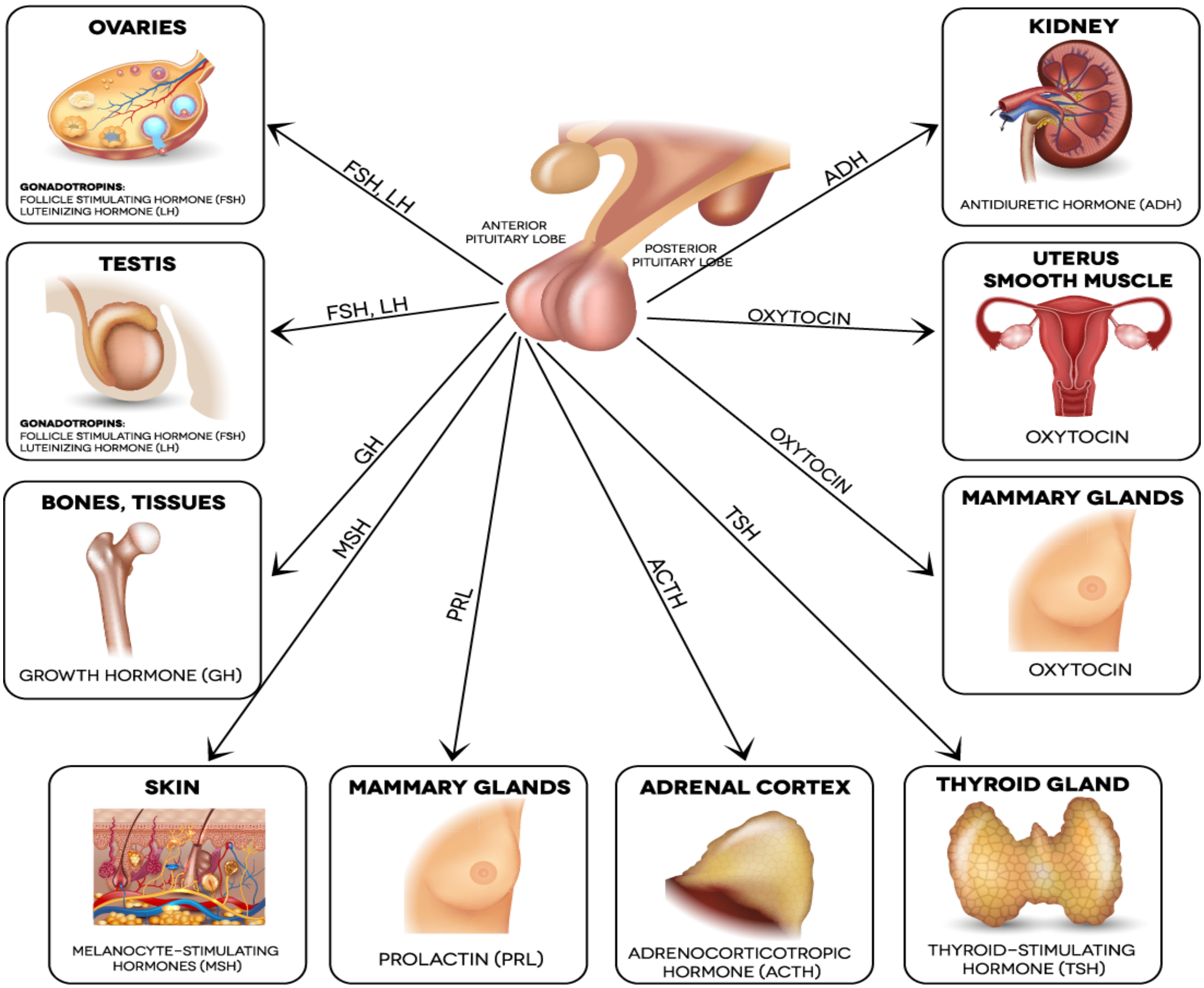
- **Growth hormones (somatotropin)**
  To increase the rate of growth of the skeleton and skeletal muscles

- **Trophic hormones**
  Hormones that trigger secretion of hormones from other glands

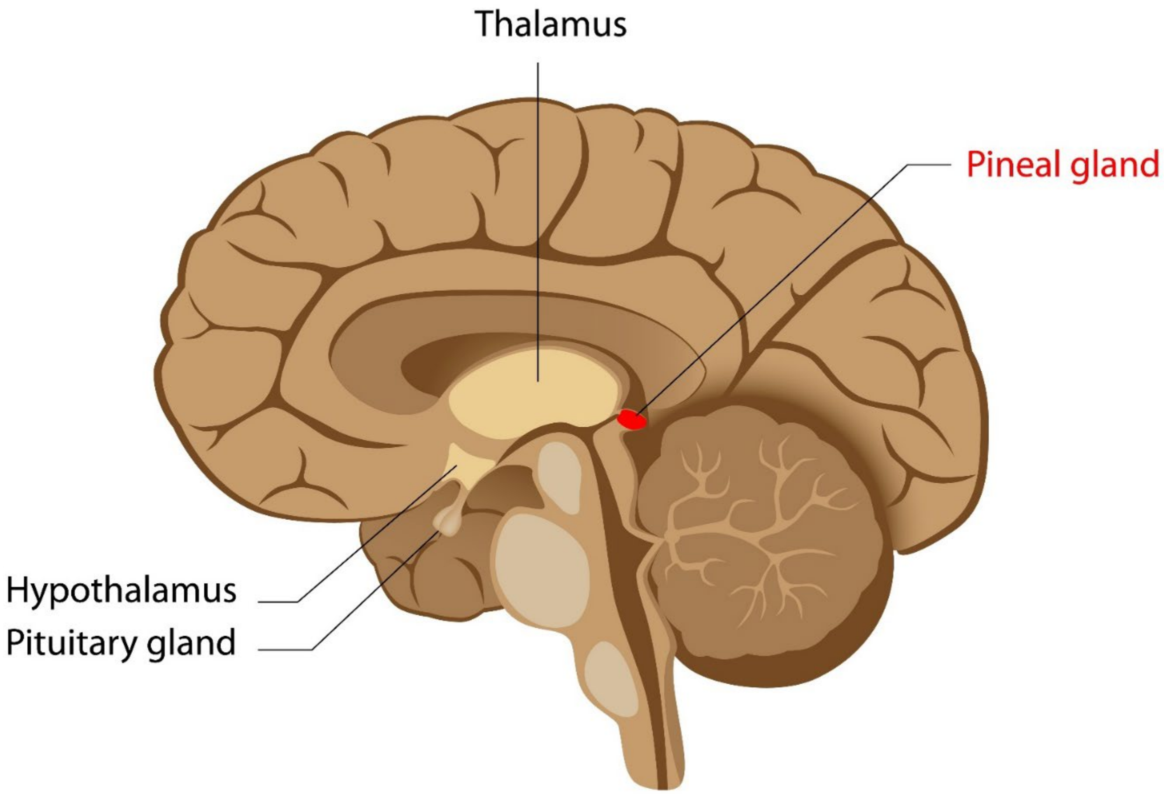
Pituitary gland

- The anterior pituitary gland secretes the majority of pituitary hormones that regulate a wide range of bodily activities from growth to reproduction
- The posterior pituitary gland secretes two hormones – oxytocin and antidiuretic hormone




OVARIES
GONADOTROPINS:
FOLLICLE STIMULATING HORMONE (FSH)
LUTEINIZING HORMONE (LH)
TESTIS
GONADOTROPINS:
FOLLICLE STIMULATING HORMONE (FSH)
LUTEINIZING HORMONE (LH)
BONES, TISSUES
GROWTH HORMONE (GH)
KIDNEY
ANTIDIURETIC HORMONE (ADH)
UTERUS
SMOOTH MUSCLE
OXYTOCIN
MAMMARY GLANDS
OXYTOCIN
ANTERIOR
PITUITARY LOBE
POSTERIOR
PITUITARY LOBE
FSH, LH
FSH, LH
GH
MSH
PRL
ACTH
TSH
ADH
OXYTOCIN
OXYTOCIN
SKIN
MELANOCYTE-STIMULATING
HORMONES (MSH)
MAMMARY GLANDS
PROLACTIN (PRL)
ADRENAL CORTEX
ADRENOCORTICOTROPIC
HORMONE (ACTH)
THYROID GLAND
THYROID-STIMULATING
HORMONE (TSH)

Pineal gland



Secretes ***melatonin*** which functions to regulate sleep patterns

Thyroid gland

Positioned at either side of the trachea below the larynx. Controlled by the hypothalamus:

- **Calcitonin**
  Lowers blood calcium levels and is responsible for accelerating calcium absorption by bones

- **Triiodothyronine and thyroxin**
  Regulate metabolism, growth and development and activity of the nervous system, has an effect on ‘energy levels’ and weight management

Parathyroid glands

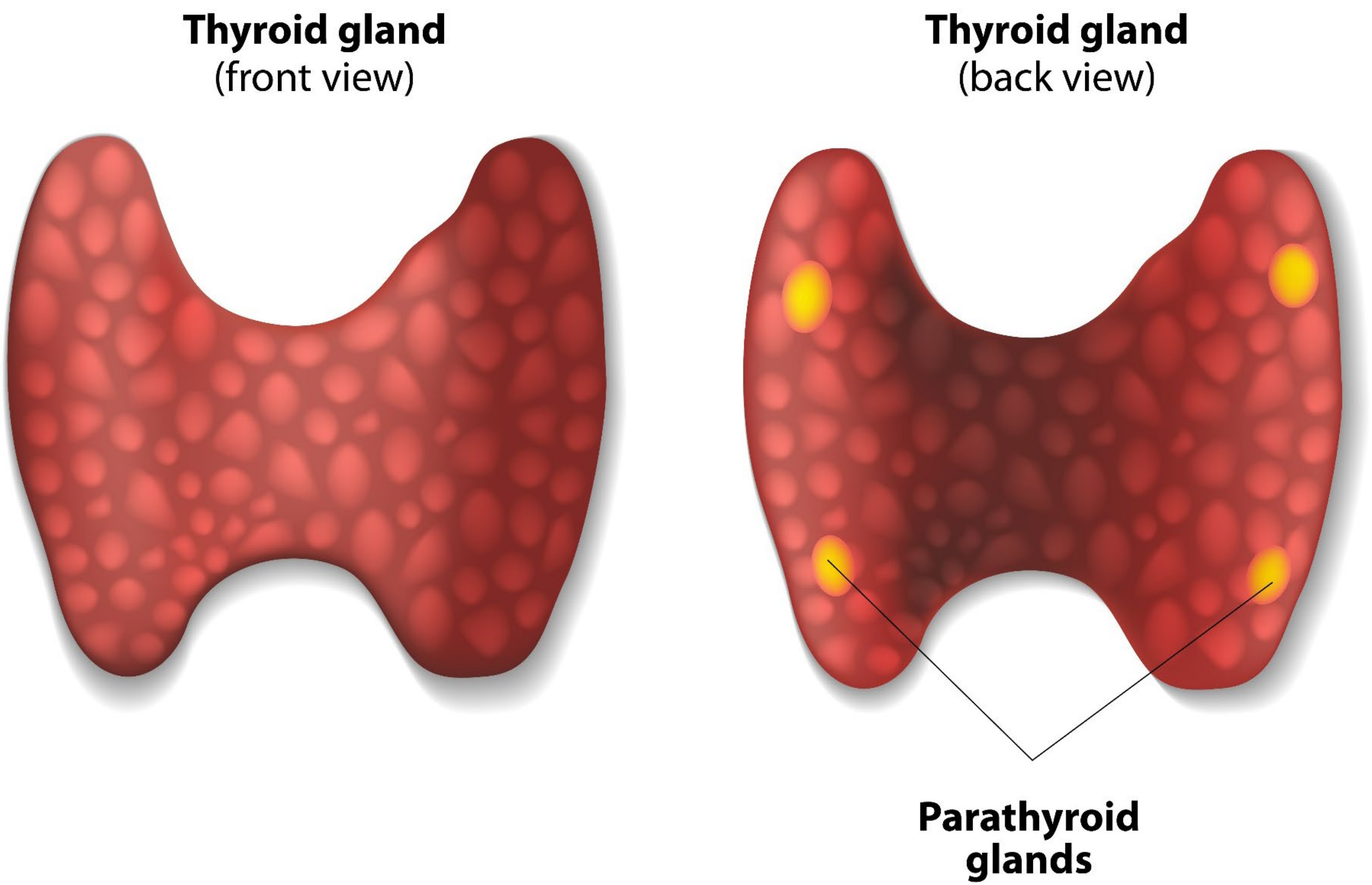
Back of the thyroid gland.

Secrete parathyroid hormones when blood calcium levels are low, which aim to:

- Increase the rate of calcium absorption from the gastrointestinal tract and into the blood
- Stimulate the activity of osteoclasts to break down bone to release calcium to maintain blood calcium levels

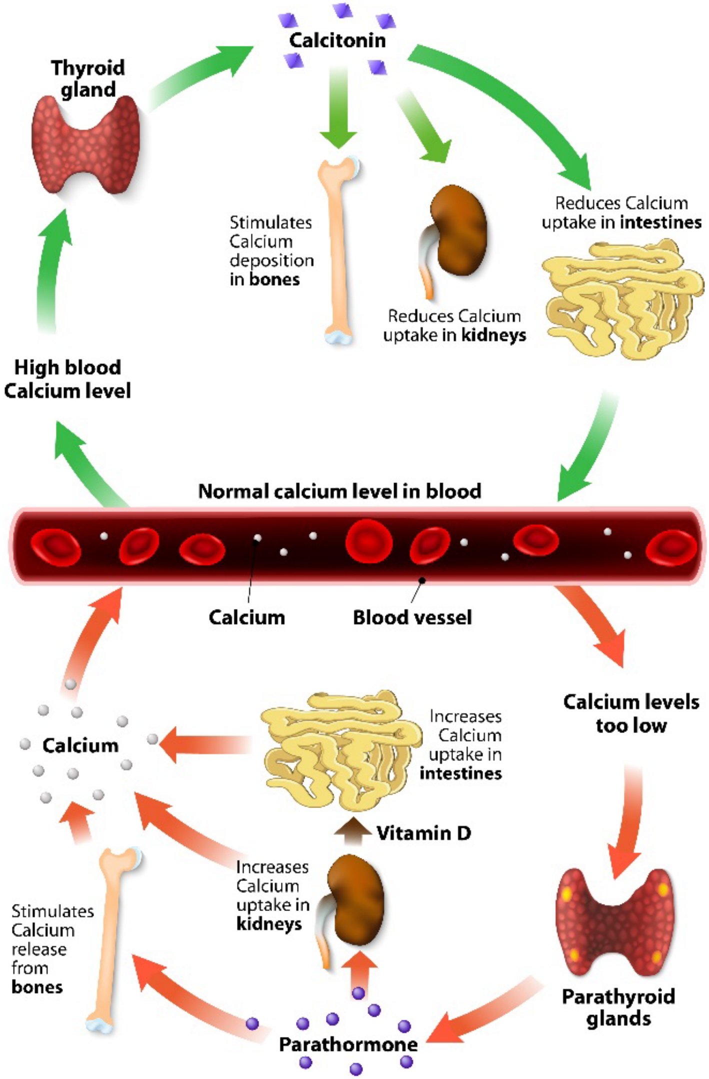
This can have a negative effect on bone density.

Thyroid and Parathyroid

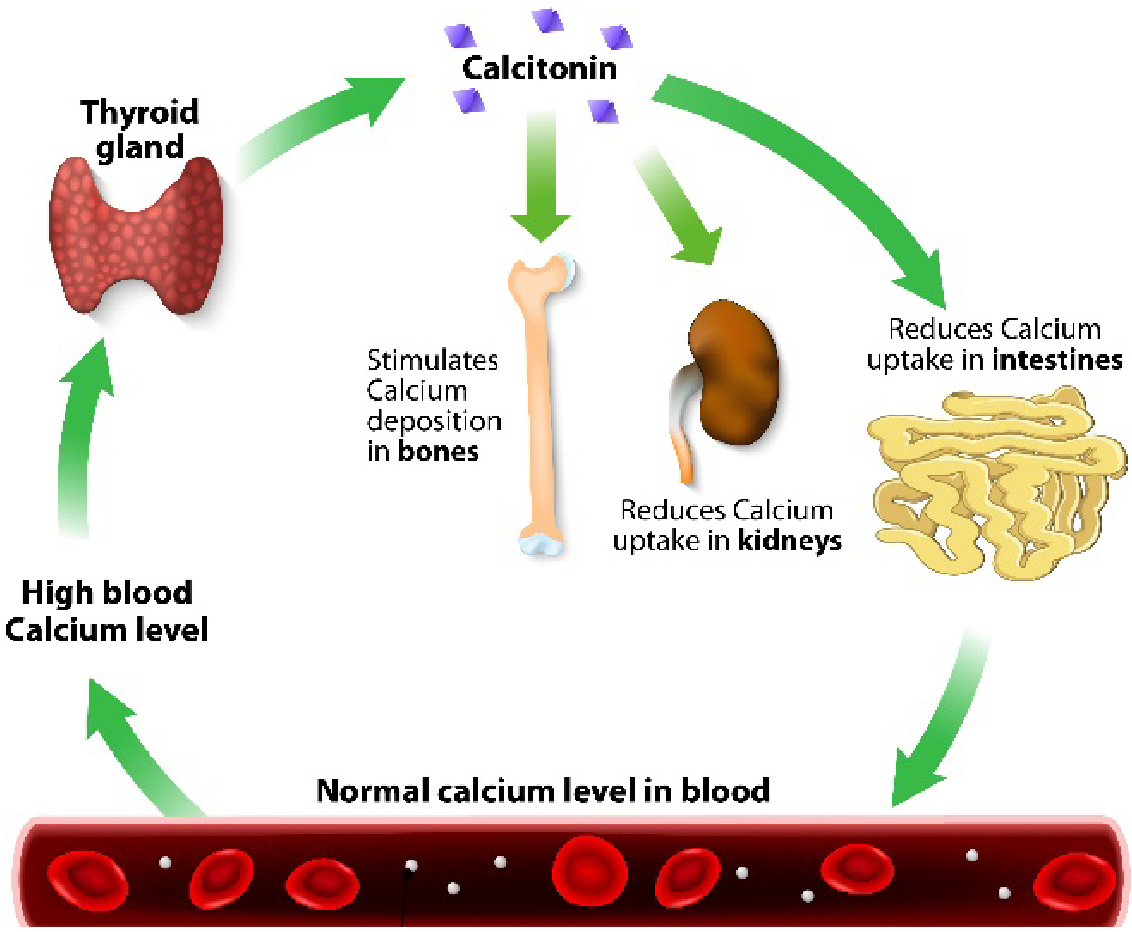


Parathyroid hormone

- Parathyroid glands
- Regulate blood calcium levels
- Increase calcium levels by acting on kidneys, bones and the intestines

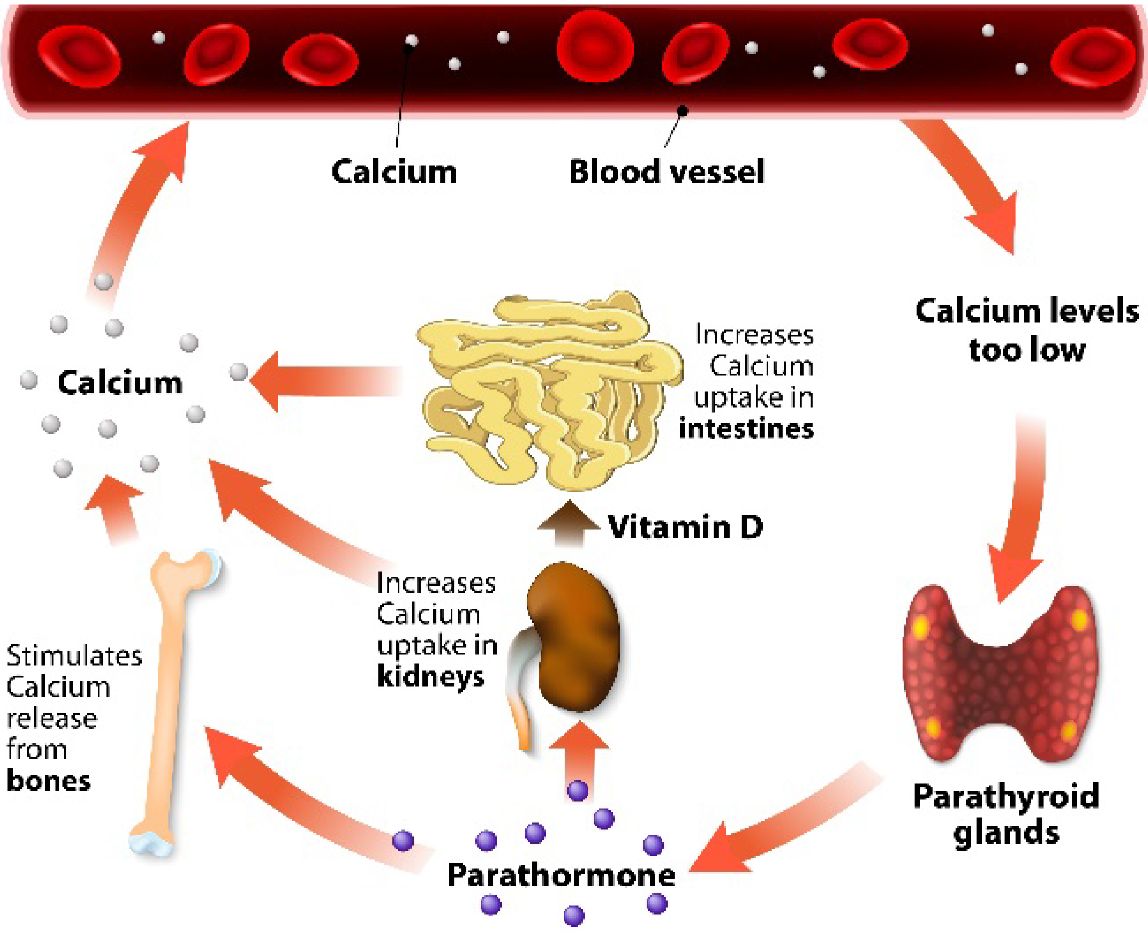


Calcitonin



Calcitonin
Thyroid gland
Stimulates Calcium deposition in bones
Reduces Calcium uptake in kidneys
Reduces Calcium uptake in intestines
High blood Calcium level
Normal calcium level in blood

Calcitonin


Calcium
Blood vessel
Calcium levels too low
Increases Calcium uptake in intestines
Calcium
Vitamin D
Increases Calcium uptake in kidneys
Stimulates Calcium release from bones
Parathyroid glands
Parathormone

Adrenal glands

Top of the kidneys.

The adrenal medulla (central portion) produces the catecholamine hormones which initiate ‘fight or flight’:

- Adrenaline (epinephrine)
- Noradrenaline (norepinephrine)

The adrenal cortex (outer portion) produces corticosteroids:

- Cortisol – controls metabolism and provides resistance to stress, promotes gluconeogenesis
- Aldosterone – increases blood sodium levels

Corticosteroids

Cortisol

- Role in metabolism
- Role in the immune response
- Role in stress response
- Secreted by adrenal glands
- Has a diffuse effect on many cells of the body

Released in response to:

- Physical stress
  - Activity, exercise, illness or injury
- Psychological stress
  - **Short term**
    Increases resilience, prepares the body for action
  - **Long term**
    Can suppress the immune system and increase the risk of chronic health conditions

The catecholamines

Adrenaline and noradrenaline

- Secreted by adrenal glands
- Mediate fight-or-flight response
- Affect heart rate, blood pressure and respiratory rate
- Divert blood away from the skin and gut towards the muscles
- Increase blood flow to the brain

FIGHT **FLIGHT** **FREEZE**

The ovaries

- Significant role during puberty
- Affect bone growth
- Storage and release of eggs for reproduction
- Secrete reproductive hormones (oestrogen and progesterone)
  - **Oestrogen and progesterone**
    Develop female characteristics, regulate the menstrual cycle and maintain pregnancy
  - **Relaxine**
    Relaxes pelvic ligaments to facilitate childbirth

The testes

Positioned inside the scrotum.

- Significant role during puberty
- Affect bone growth
- Produce sperm
- Secrete testosterone
  - Develops male characteristics (facial and body hair)
  - Increases potential for muscle hypertrophy/growth (greater muscle mass)

The pancreas

Positioned slightly inferior and posterior to the stomach.

An endocrine and exocrine gland:

- As an exocrine gland it releases digestive enzymes into the small intestine to assist digestion

- As an endocrine gland it produces insulin and glucagon

Insulin and glucagon

- Secreted by the pancreas
- Regulate blood glucose level

Insulin lowers blood glucose

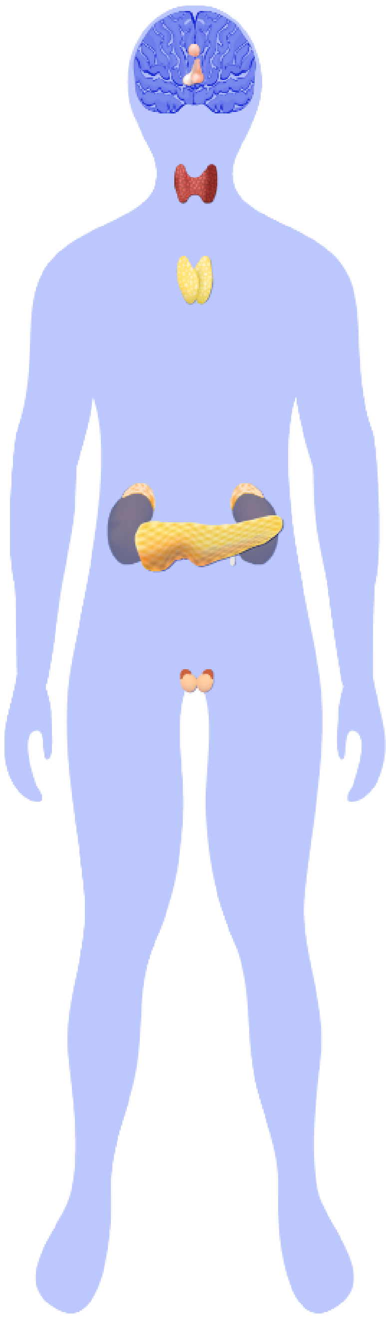
- Stimulates blood glucose uptake by cells of the liver, muscles and adipose tissue

Glucagon raises blood glucose

- Stimulates the liver to break down stored glycogen and release glucose into the blood

Activity

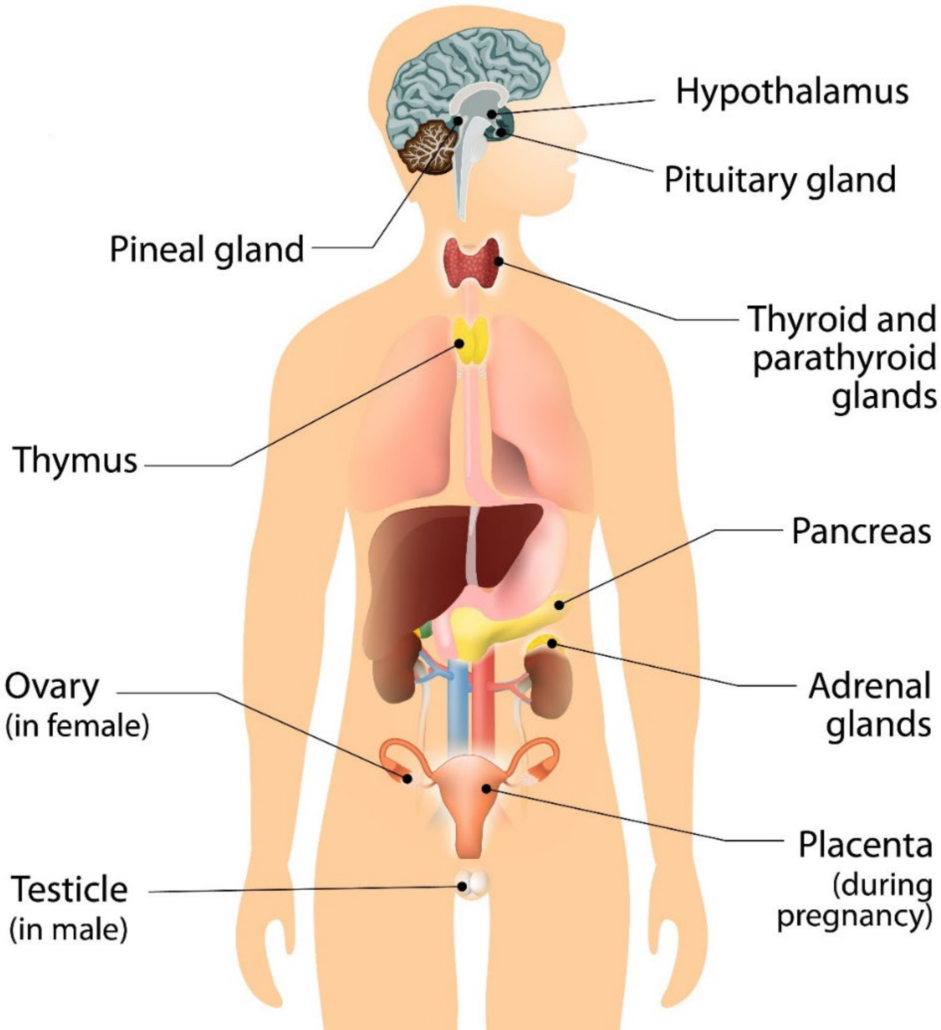
Locate the major glands and name the hormone they release.



Learning check

Match the gland to the hormone(s) listed:

- Oestrogen
- Testosterone
- Insulin
- Glucagon
- Adrenaline
- Cortisol



VTCT

USP186 - Applied anatomy for exercise, fitness, health and wellbeing

LO7 Understand the roles and function of the energy systems in relation to exercise, health and fitness programming

Content and Assessment Criteria

- Know the macronutrients and their role in the production of energy

- Know the energy systems used during exercise and the by-products of different systems

Macronutrients review

- **Carbohydrates**
  For example bread, pasta, break down into glucose. Glycogen is stored in muscles and liver

- **Proteins**
  For example meat, fish, break down into amino acids, growth and repair of muscle, used for energy when other nutrients are depleted

- **Lipids**
  For example cheese, butter, break down into fatty acids in presence of oxygen, stored as adipose tissue, protection, energy store

Adenosine triphosphate (ATP)

- A molecule that is involved in the body's energy production

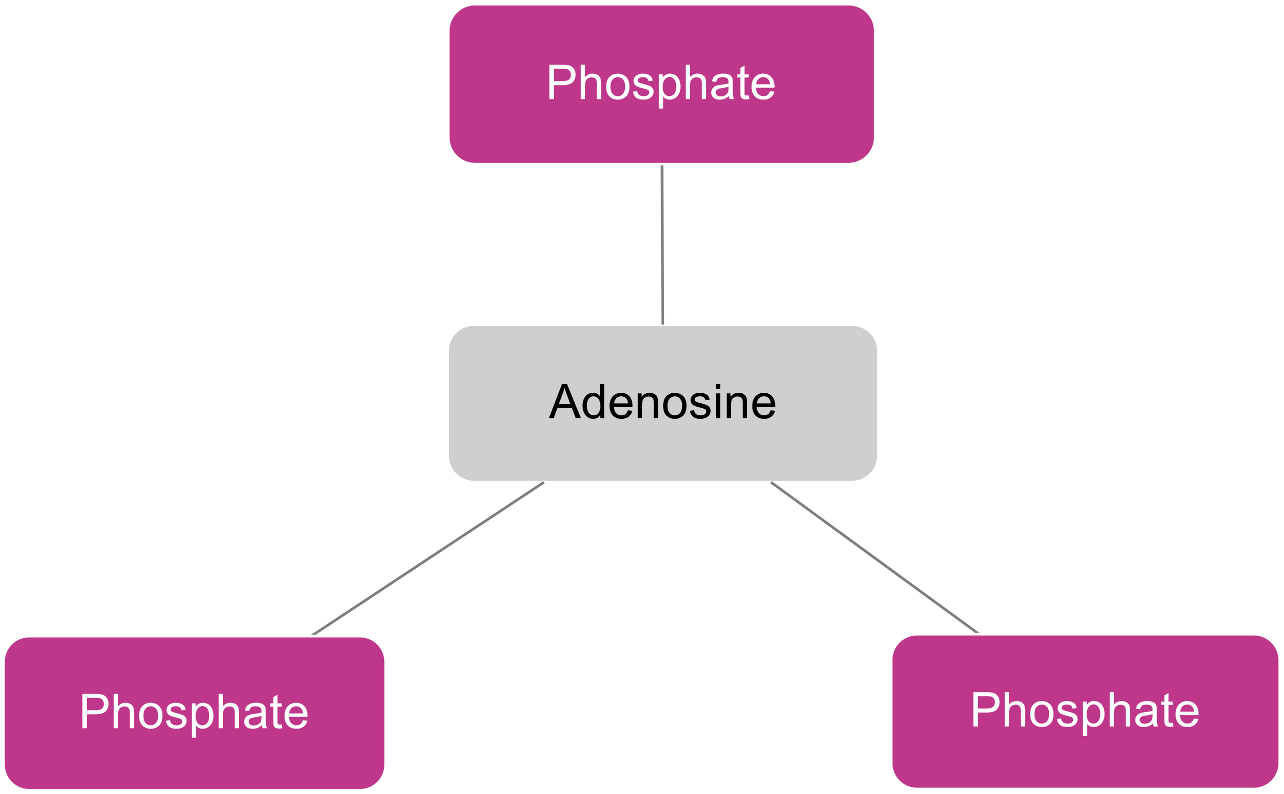
- Limited stores, has to be remade

- The break down of ATP = energy for all body processes

- Re-made via THREE energy systems and breakdown of:
  - Carbohydrate, fat and protein (nutrients)

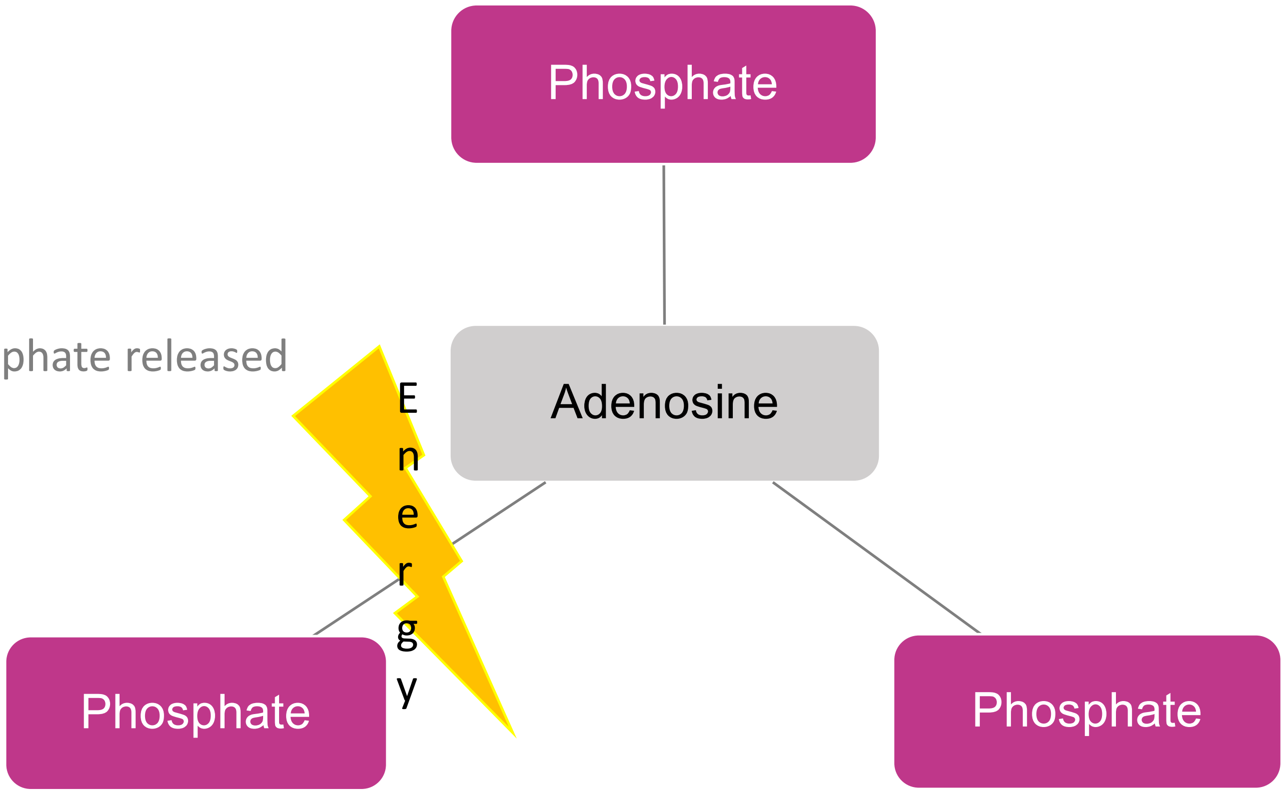
Adenosine triphosphate (ATP)

ONE adenosine molecule and **THREE** phosphate molecules.



Adenosine triphosphate (ATP)

- ATP broken down to create energy
- Phosphate released



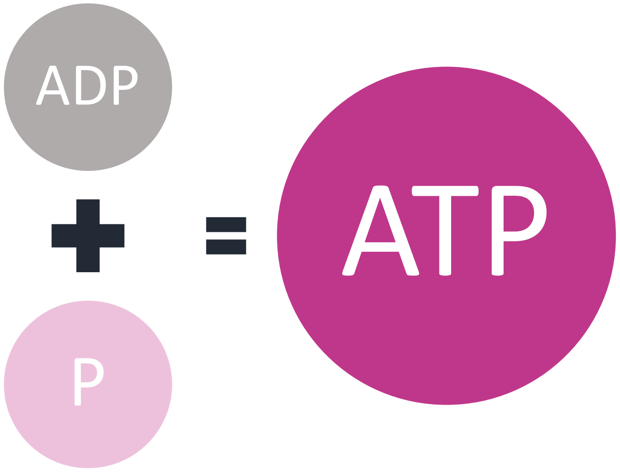
- Adenosine diphosphate (ADP)

Re-synthesis of Adenosine triphosphate (ADP) to ATP

- Phosphocreatine or creatine phosphate system (anaerobic)
- Lactate or anaerobic glycolysis system (anaerobic)
- Aerobic or oxygen system (aerobic)

Creatine phosphate (CP) system

- CP supplies a phosphate group to ADP to form ATP
- Without oxygen
- No nutrients used, for example, fat or carbohydrate
- Immediate use
- Stores last for around 8-15 seconds
- Explosive, very high intensity activities, for example, 100 metre sprint, powerlift



Anaerobic

Creatine phosphate system

ADP + CP = ATP + Creatine

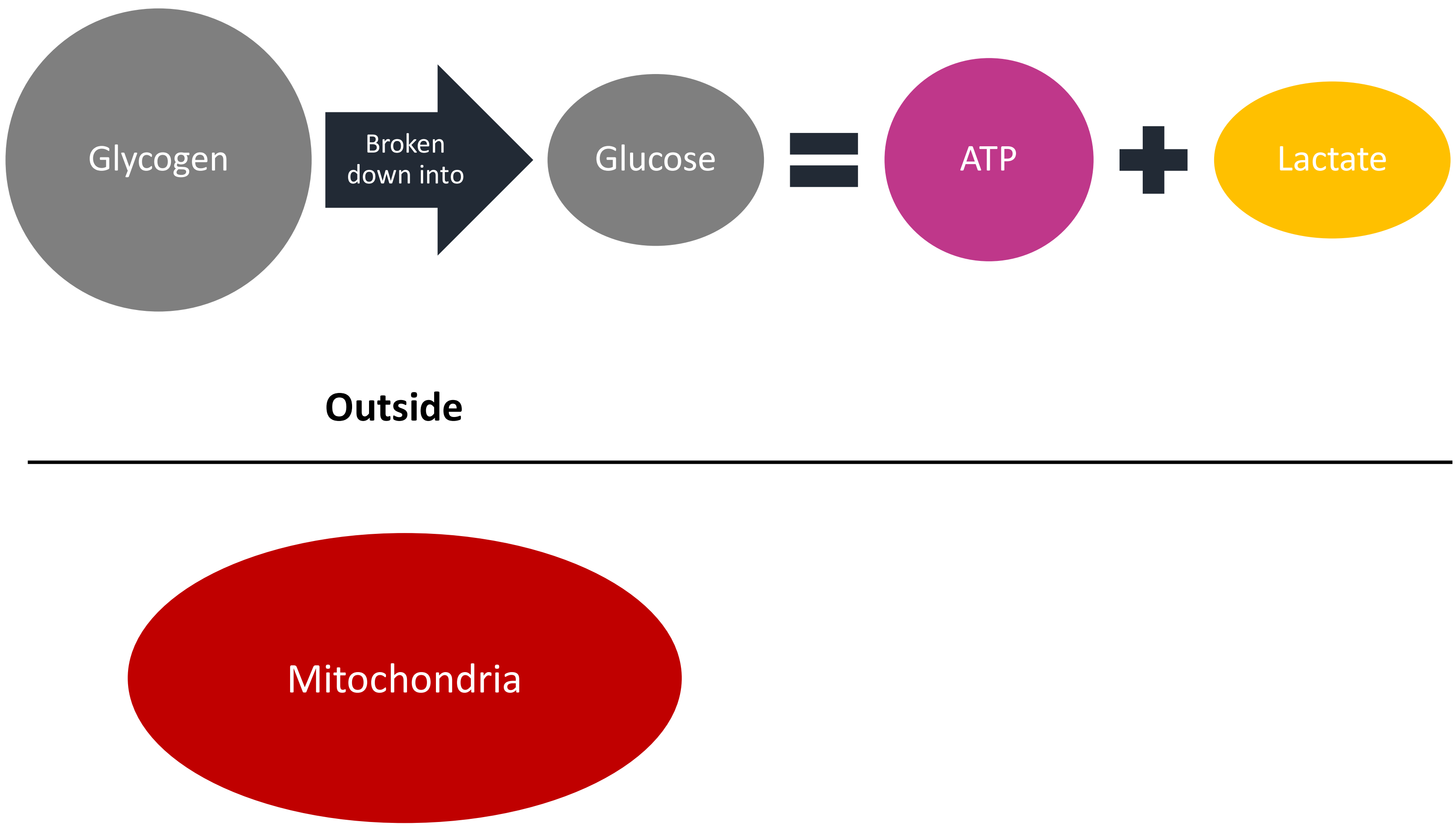
- Eventually resynthesized
- Fully restored after around 5-8 minutes of rest

Anaerobic glycolysis

- Glycogen (stored carbohydrate) used to remake ATP
- Glycogen broken down into glucose
- Without oxygen
- By-product is lactate
- High-intensity activities up to three minutes, for example, 400 metre sprint
- Oxidation one glucose molecule provides a net gain of 2 ATP’s are produced through this system

Anaerobic

Lactate system



Aerobic

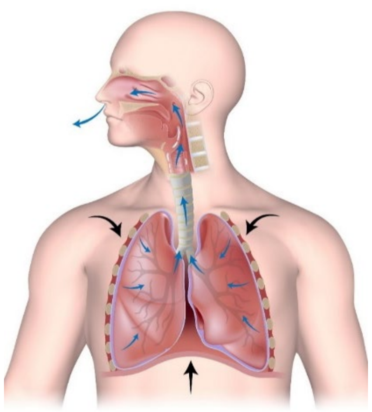
Oxygen system

- Uses carbohydrates (glycogen and glucose), fats (fatty acids) and proteins (only when required)
- With oxygen
- By-products:
  - Carbon dioxide (CO_2) – removed via expiration
  - Water (H_2O) – removed via perspiration (sweat)
- Long lasting – provided CV system can meet demands
- Sustained, long duration activities, for example, marathon running
- This system can yield 34-36 ATP's from one molecule of glucose

Aerobic

Oxygen system

Expiration



Oxygen | Glycogen | Fatty acids → Mitochondria = ATP + CO_2 + H_2O

Energy systems	Creatine phosphate	Lactate/lactic acid/anaerobic glycolysis system	Aerobic
Time to engage	Very quick	Quick	Slower
Use of oxygen	Anaerobic	Anaerobic	Aerobic
Fuel	Phosphocreatine	Glycogen	Glycogen, fat, protien
ATP production	Very limited ATP	Limited ATP	Unlimited ATP
By-products	Creatine	Lactate	Carbon dioxide and water – easily removed
Duration	Short 8-15 seconds	1-3 minutes intense activity	Long Beyond 3 minutes
Intensity	Very high (95-100% maximum)	High (60-95% maximum)	Low to moderate (up to 60% maximum)
Recovery	Fast 30 seconds to 5 minutes	Slower 20 minutes to 2 hours – dispersal of lactic acid	Slower Replenish fuel stores by eating
Muscle fibre type	Type IIb	Type IIa	Type I

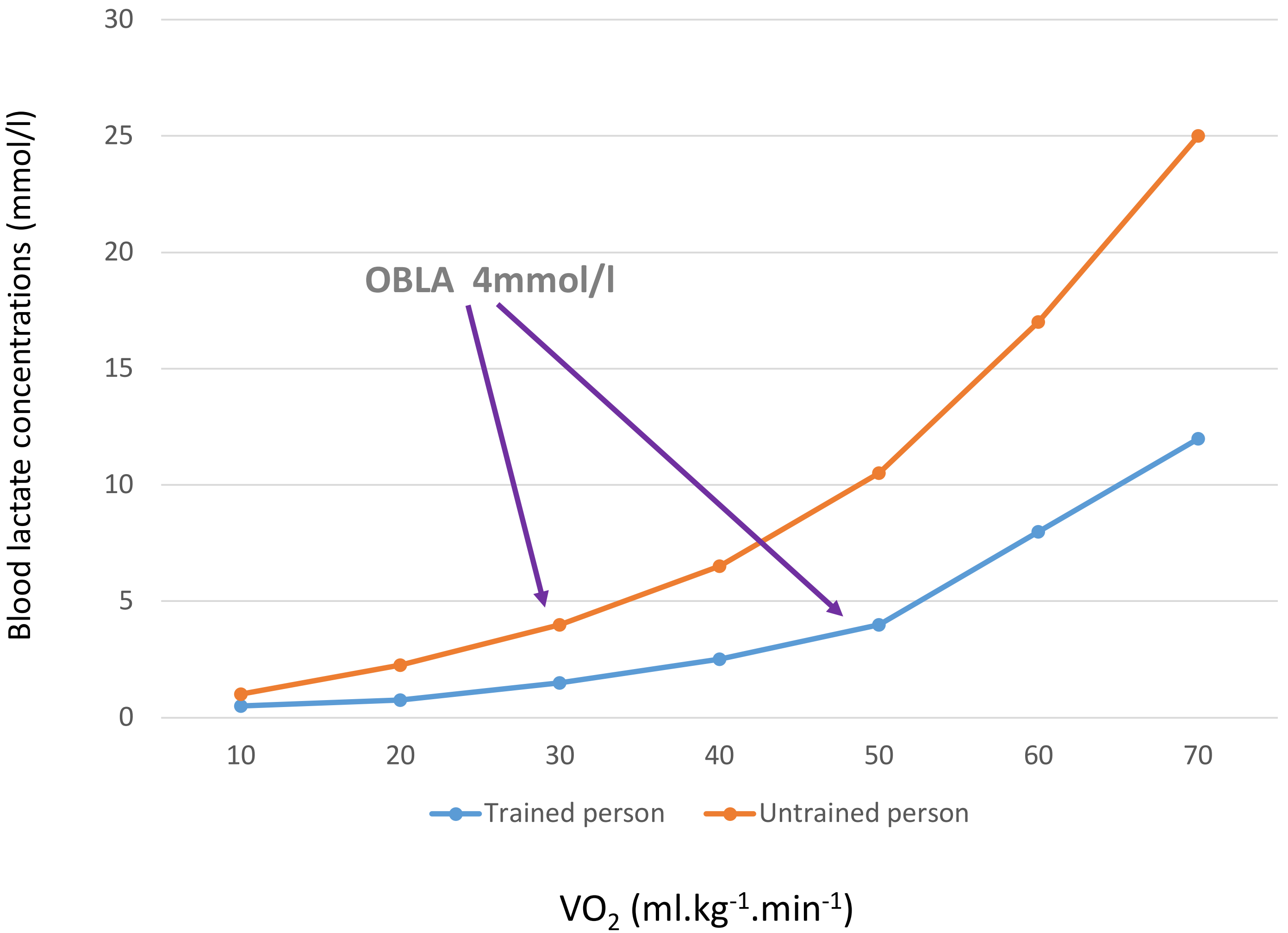
Use of fats as an energy source

- Fats can also be used for energy through the oxidative/aerobic energy system
- Triglycerides stored in fat cells are broken down into fatty acids and glycerol
- Free fatty acids can enter the blood stream, circulate and enter the muscle
- Free fatty acids enter the mitochondria of the muscle cell and then the Krebs cycle
- A series of reactions take place in which free fatty acids are broken down
- The breakdown of a single triglyceride can lead to the formation of over 300 ATP's

High intensity exercise

- At high intensity of exercise glucose and glycogen are the preferred fuel source
- Muscle cells burn glucose for energy but glycogen is stored in the muscle and liver
- Glycogen stores can be broken down to provide glucose for muscle activity
- Blood lactate levels rise progressively with increases in exercise intensity
- The point at which blood lactate begins to rise above resting levels is also known as 'lactate threshold'
- Lactate threshold represents a greater increased reliance on anaerobic energy production. This typically begins around the 60% of max O_2 uptake level but may be earlier in untrained individuals
- A second increase in lactate accumulation has been noted at higher levels of intensity and is known as the onset of blood lactate (OBLA)
- OBLA occurs at blood lactate concentrations of 4mmol/l or more

Lactate threshold and onset of blood lactate for a trained and untrained individual



Fatigue: possible causes

Fatigue can be described as a transient loss of work capacity resulting from preceding work.

Substrate depletion:

- Fatigue during exercise may be partially due to a decrease in the stores of phosphagen's due to high intensity exercise (for example, ATP and CP)
- Creatine phosphate stores may be completely depleted at very intense exercise to exhaustion, leading to a reduction in work capacity
- Limited stores of glycogen are available for exercise and the rate of glycogen depletion is related to exercise intensity
- When glycogen becomes low, it can no longer sustain ATP levels and may lead to muscular fatigue

Fatigue: possible causes

Fatigue can be described a s a transient loss of work capacity resulting from preceding work.

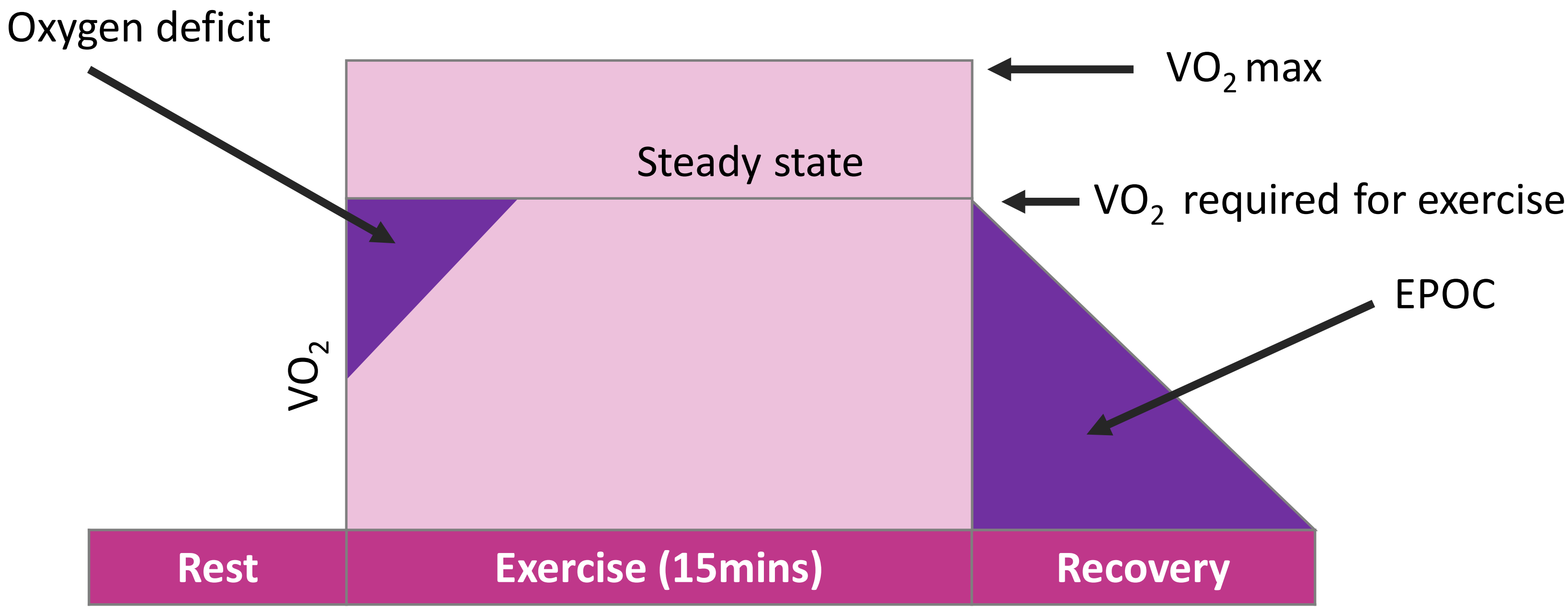
Metabolic acidosis:

- Fatigue during exercise often correlates with high concentrations of ‘lactate’
- However more recently the influence of lactate production leading to fatigue has been questioned
- High intensity exercise may lead to ‘metabolic acidosis’
- Metabolic acidosis has been known to increase hydrogen ions (H^+) and reduce muscle and blood pH
- This reduction in pH is said to interfere with the muscles’ ability to contract and or reduce glycolytic reactions

Oxygen uptake and the aerobic/ anaerobic contributions to exercise

- Oxygen uptake represents a person's ability to take in and use O_2 at the working muscles for energy
- During low intensity exercise O_2 uptake increases until a steady state of O_2 uptake is reached
- At the start of the exercise some of the energy may be obtained through anaerobic systems as the aerobic system responds slowly to the initial increase in exercise demand
- This anaerobic contribution to energy production is referred to as 'oxygen deficit'
- After exercise oxygen uptake remains above resting levels for a period of time
- This post exercise oxygen uptake has been termed 'oxygen debt' or 'excess post exercise oxygen consumption (EPOC)
- EPOC represents the oxygen uptake after exercise required to restore the body to pre-exercise conditions

Oxygen uptake and the aerobic/ anaerobic contributions to exercise



Low intensity steady state exercise metabolism

EPOC = excess post exercise oxygen consumption

Anaerobic training adaptations

- Improved anaerobic enzyme activity
- Increased metabolic energy stores
  - ATP
  - CP
  - Stored glycogen
- Improved tolerance to metabolic acidosis
- Improved anaerobic power

Aerobic training adaptations

- Improved aerobic power / capacity
- Increased metabolic energy stores
  - ATP
  - Stored glycogen
  - Stored triglycerides
  - Myoglobin stores
- Improved removal of lactic acid
- Helps to delay onset of blood lactate (OBLA)

Learning check

- Describe how carbohydrates, fats and proteins are used in the production of energy/adenosine triphosphate

- Explain the use of the three energy systems during aerobic and anaerobic exercise







VTCT

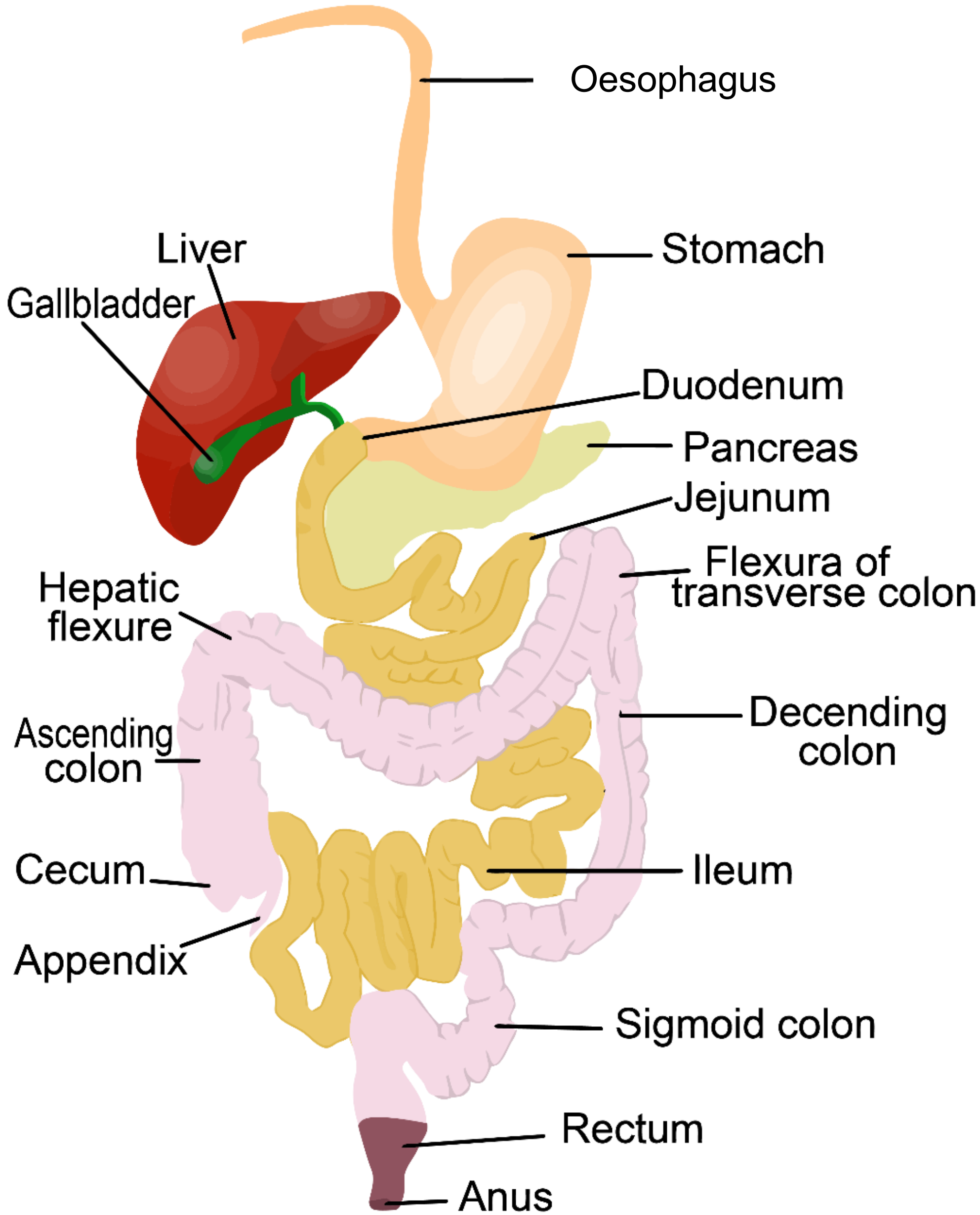
USP126 - Applied anatomy for exercise, fitness, health and wellbeing

LO8 Know the structure and function of the digestive system

Content and Assessment Criteria

- Know the structure of the digestive system
- Know the functions of the digestive system
- Know how the macronutrients are digested and absorbed
- Know the role of dietary fibre in the maintenance of gut function

Digestive system review



Organs of the digestive system can be divided into two main groups

Gastrointestinal (GI) tract structures.

A continuous tract that extends from the mouth to the anus which include:

- Mouth
- Pharynx
- Oesophagus
- Stomach
- Small intestine
- Large intestine

Organs of the digestive system can be divided into two main groups

Accessory structures which include:

- Teeth
- Tongue
- Salivary glands
- Liver
- Gallbladder
- Pancreas

Overview of digestive system functions

- **Ingestion** – taking in food into the mouth
- **Secretion** – the release of water, acid buffers and enzymes into the lumen of the tract (appx 9L/day)
- **Mixing and propulsion** – contraction and relaxation of smooth muscle tissue in the walls of the GI tract mix up the food and secretions and propel them through the digestive tract
- **Digestion** – both mechanical and chemical processes are used to break down food into smaller fragments
  - **Mechanical digestion** – mechanical manipulation of the food including use of the teeth and peristalsis to further break down the food
  - **Chemical digestion** – a series of chemical reactions that break down large macronutrients into smaller molecules for absorption

Overview of digestive system functions

- **Absorption**
  Food and fluids are eventually absorbed into the lumen of the GI tract. These nutrients then pass to the blood and lymph for circulation to the cells of the body

- **Defecation**
  The elimination of variable amounts of indigestible substances and bacteria from the GI tract through the anus

The journey of food

Food takes around 24 hours to travel through the GI tract.

- Chewing
- Peristalsis
- Digestion
- Absorption
- Elimination

Functions of the mouth pharynx and oesophagus in digestion

Formation of a bolus

- When food is taken into the mouth it is ***masticated*** or chewed and moved around the mouth
- It is mixed with saliva and formed onto a soft ***bolus***
- Salivary amylase is secreted to break down starches into smaller particles

Swallowing

- After mastication and formation of a bolus the mouth and tongue push the bolus towards the pharynx
- Muscles of the pharynx propel the bolus into the oesophagus
- Peristaltic waves of contraction force the swallowed bolus of food towards the stomach

Functions of the stomach in digestion

Stomach

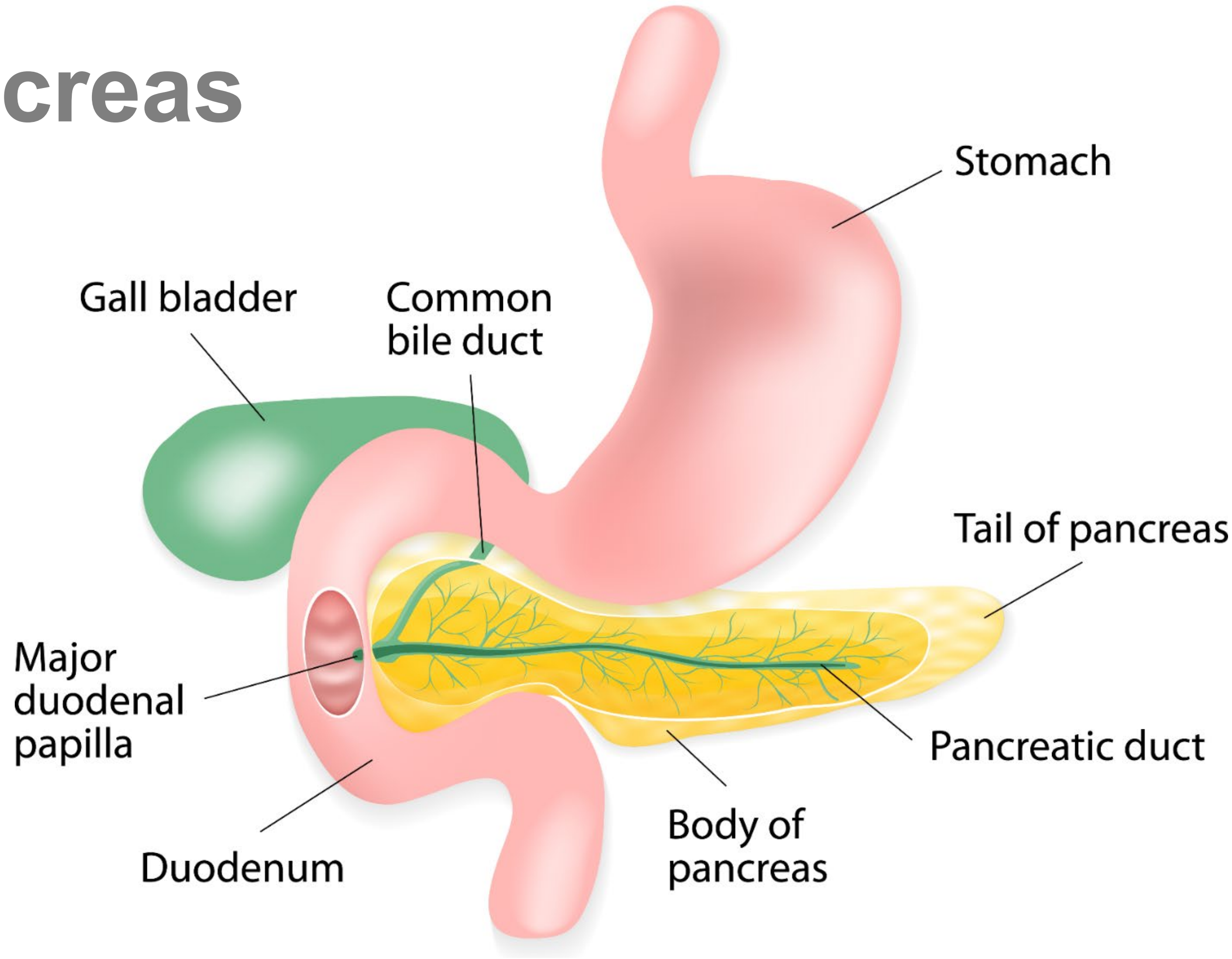
- Mechanical mixing macerates food to produce **chyme**
- Gastric juices are secreted to continue with the chemical digestion
    - Hydrochloric acid (HCl) is secreted into the stomach, HCl:
        - Kills bacteria
        - Provides an environment for protein digestion
    - Gastric lipase is secreted to break down fats
    - The stomach walls secrete mucus which helps to protect the walls of the stomach from an acidic environment

Small intestine and digestion

Small intestine (duodenum, jejunum and ileum)

- Mechanical digestion continues through **segmentation** and **peristalsis**
  - **Segmentation –** mixing of chyme with digestive juices in preparation for absorption
  - **Peristalsis –** propels the chyme through the intestinal tract
- Chemical digestion – the completion of the digestion of carbohydrates, proteins and fats
  - Pancreatic amylase breaks down CHO's not already broken down
  - Pancreatic juices continue to secrete enzymes that break down proteins into amino acids
  - Bile salts emulsify fats and pancreatic lipase brakes them down into fatty acids and monoglycerides

Pancreas



- Secretes pancreatic juice containing enzymes that assist breakdown of carbohydrates, protein and fat in small intestine
- Secretes pancreatic enzymes – trypsin, amylase, lipase

Nutrient break down

Through the process of digestion, the different nutrients are broken down:

- **Carbohydrates** are broken down into **glucose**
- **Proteins** are broken down into **amino acids**
- **Fats** are broken down into **monoglycerides** and **fatty acids**

Revision activity

Describe the following processes:

- Chewing
- Peristalsis
- Digestion
- Absorption
- Elimination

Enzymes

Enzyme	Nutrient broken down	Secreted by and acts in
Amylase	Carbohydrates	Secreted: salivary glands and pancreas Acts in: mouth (salivary amylase), small intestine (pancreatic amylase)
Pepsin	Proteins	Secreted: stomach Acts in: stomach
Lipase	Fats	Secreted: pancreas Acts in: small intestine, Gastric lipase acts in the stomach
Trypsin	Proteins	Secreted: pancreas Acts in: small intestine

Absorption

Carbohydrate absorption:

- All carbohydrates are absorbed as monosaccharides in the small intestine
- These monosaccharides pass through the wall of the small intestine into the blood capillaries in structures called villi
- Absorbed carbohydrates can then be transported to cells

Protein absorption:

- Most proteins are absorbed as amino acids in the duodenum and jejunum
- Amino acids move through the walls of the small intestine and into the blood capillaries of the villi
- Proteins can then be transported for general circulation

Absorption

Lipid absorption:

- Absorption of lipids takes place in the small intestine
- Lipids exit the small intestine into structures called lacteals, in contrast to carbohydrates and proteins
- From here they are transported by way of the lymphatic system to the circulatory system

Absorption

Water absorption:

- All water absorbed in the GI tract occurs by osmosis
- Although most water absorption occurs in the small intestine a small amount is absorbed by the large intestine.
- The absorption of water from the small intestine is important for the maintenance of osmotic balance in the blood
- Water in the large intestine is also important for defecation
- Excessive water absorption from the large intestine may lead to constipation
- Hydration is therefore important for all digestive functions

Liver

- Secretion of bile to emulsify fat and assist breakdown and absorption of fats

Large intestine

- Final stage of digestive process
- Partial breakdown of cellulose (soluble fibre), reabsorption of the water from undigested food. Undigested food fibre forms faeces and passes to the rectum

Role of dietary fibre in the maintenance of gut function

- Soluble fibre – dissolves in the water of the digestive system
  - May assist with reducing cholesterol in the blood
  - Increasing dietary intake of soluble fibre can help to reduce constipation
  - Sources of soluble fibre – oats, fruit, vegetables, golden linseeds
- Insoluble fibre or non-starch polysaccharide (NSP) – does not dissolve in water
  - Passes through the gut without being broken down
  - Helps other foods transit through the digestive system more easily
  - Prevents digestive problems and keeps the bowels healthy
  - Sources of insoluble fibre – fruit, oats, nuts, seeds, root vegetables, cereals and wholemeal bread

Timescales for digestion

- Food will initially travel relatively quickly through the digestive system
- Within 6 to 8 hours, it has usually moved its way through the stomach, small intestine, and large intestine
- Once in the large intestine, partially digested food can sit for more than a day while it's broken down even more
- Digestion rate can be determined by what is eaten
  - Meat and fish – contain complex protein and fat, can take up to 2 days to digest fully
  - Fruit and vegetable – contain more fibre, usually digest in less than a day
  - Processed foods – a few hours
- Approximately 24 to 72 hours to move through the whole digestive tract (the specific time will depend on the quantity and types of foods eaten

Learning check quiz

What is the role of the following components of the digestive system?

- Mouth
- Oesophagus
- Stomach
- Liver
- Pancreas
- Gall bladder and bile ducts
- Small intestine
- Large intestine

VTCT

USP186 - Applied anatomy for exercise, fitness, health and wellbeing

LO9 Understand the effects of exercise, health and fitness programming on the body systems

Content and Assessment Criteria

- Know effects of exercise, health and fitness programming on the skeletal system
- Know effects of exercise, health and fitness programming on the neuromuscular system
- Know effects of exercise, health and fitness programming on the cardiovascular and respiratory system
- Know effects of exercise, health and fitness programming on the energy systems
- Know effects of exercise, health and fitness programming on the digestive system

Learning check

Skeletal system

- What can you remember about the skeletal system?

Summary of the skeletal system

- Main framework of approximately 206 bones, which form joints
- Different functions – shape, support, attachment, locomotion
- Many synovial or freely moveable joints – ligaments, tendons and cartilage
- Different bone classifications – long, short, flat
- Bone structure and growth – periosteum, growth plates, bone cells
- Types of joint and joint actions
- The spine – posture and posture types

Activity

How does the skeletal system respond to exercise?

- Consider:
  - Bone development
  - Posture
  - Joint range of movement

Immediate/short term effects

Skeletal:

- Increase blood circulated to bones and joints
- Increased synovial fluid in the joints (lubrication)
- Increased joint mobility
- Connective tissue compliance at joints
- Cartilage nourishment

Long term adaptations

Skeletal:

- Improved bone mineral density
- Improved development of peak bone mass in formative years (up to age 30)
- Maintenance of bone mass pre-menopause
- Reduced rate of bone loss post-menopause
- Reduced risk of osteoporosis
- Increased release of synovial fluid into the joints
- Healthier hyaline cartilage
  (which can assist with the management of osteoarthritis)

Long term adaptations

- Maintenance or Improved joint mobility and range of motion
- Stronger ligaments and other joint connective tissues
- Reduced risk of joint injury
- Improved posture
- Reduced risk of falls and bone fractures in older adults with osteoporosis
- Reduced risk of low back pain

Activity

List some associated risks of an acute bout of exercise on the skeletal system.

- Consider:
  - Posture
  - Type of activity
  - Fitness levels
  - Untrained vs trained individuals
  - Warm up/cool down

Associated risks

Exercise related risks on the skeletal system are generally related to overuse, injury, inaccurate technique or health and safety issues. Some of these effects are listed below

- Ligament damage
- Cartilage damage
- Fractures
- Postural adaptations

Learning check

Neuromuscular system

- What can you remember about the structure and function of the neuromuscular system?

Summary of the neuromuscular system

- Different types of muscle tissue – cardiac, smooth and skeletal
- Different levels of control – sinoatrial node, involuntary, voluntary
- Skeletal muscle structure – connective tissues, muscle fibres, myofibrils, actin and myosin
- Sliding filament theory
- Principles of muscle work – attach to bones, work in pairs
- Muscle contraction – concentric, eccentric, isometric
- Roles during movement – prime mover, antagonist, etc.
- Muscle contraction and joint action – flexion, extension, etc.
- Different fibre types – slow twitch, fast twitch

Neuromuscular adaptations: short term

- Muscle fibre recruitment and force production mechanisms and relationships
- Muscle temperature increases
- Increased metabolic activity
- Increased demand for oxygen
- Increased dilation of capillaries within the muscle
- Increased pliability of muscle and connective tissue (greater extensibility)
- Neuromuscular pathways engaged

Neuromuscular adaptations: long term

- Hypertrophy of muscle fibres (increase in size – due to increased number of myosin and actin within muscle)
- Increased muscle strength and/or endurance depending on training history
- Improved flexibility of muscle tissue and ROM at the joints following flexibility training
- Increased muscle tone and metabolic activity
- Increased capillarisation of muscles following endurance training – greater potential for delivery of oxygen and nutrients and removal of waste products improves endurance
- Increased tolerance to lactate accumulation following anaerobic training

Neuromuscular adaptations: long term

- Increased size and number of mitochondria in type I and IIa muscle fibres to enable greater aerobic energy production following endurance training
- Increased myoglobin in type I and IIa muscle fibres following endurance training
- Improved posture – provided training approach is balanced
- Improved proprioception – spatial and body awareness
- Improved skill-related fitness (motor fitness)

Neuromuscular adaptations: long term

- Enhancements to neuromuscular activity and motor fitness
  - Resistance training adaptations (improved motor unit recruitment)
  - Motor skills training adaptations
    - growth of new nervous system connections,
    - increased frequency of nerve impulses to motor units,
    - improved synchronous motor unit recruitment,
- Benefits of improved neuromuscular co-ordination
  - Improved movement efficiency and economy,
  - improved accuracy of movement patterns

Associated risks

- Potential for lactate build up in muscle or metabolic acidosis
- Metabolic acidosis-related fatigue
- Exercise muscle soreness
- Delayed onset muscle soreness (DOMS) may be experienced (1-2 days after training)
- Increased risk for muscle and connective tissue injury

Delayed onset muscle soreness

- Muscle soreness
- Tightness and stiffness in the muscles
- Usually experienced 1-2 days after a training session
- Can last up to three days

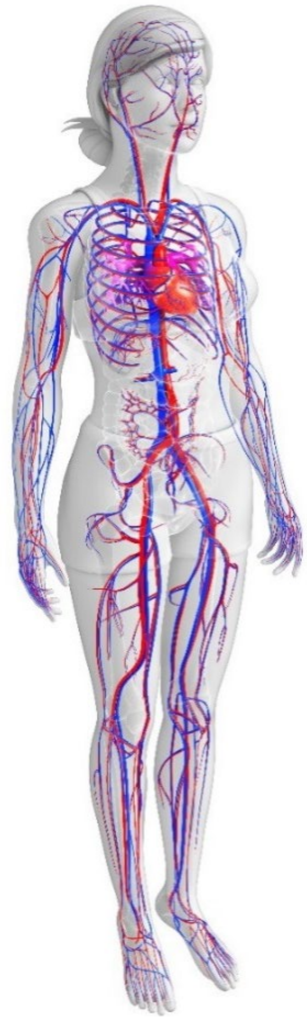
Activities that may cause DOMS

- New to exercise/beginner/low fitness
- Unaccustomed to exercise or a type of exercise
- Increase training intensity
- Increased eccentric muscle work
- Unfamiliar eccentric contractions

Learning check

Cardiovascular system

- What can you remember about the cardiovascular system?



Summary of the Cardiovascular system

- The heart, blood vessels, blood
- Location and structure of the heart
- Heart valves
- Blood flow through heart and body
- Pulmonary, systemic and coronary circulation
- Blood vessel structure
- Blood pressure

Immediate/short term effects

Cardiovascular:

- Heart rate increases
- Increased circulation to working muscles
  - Stroke volume
  - Cardiac output
- Increase in systolic blood pressure
- Vasodilation of blood vessels
- Vascular shunt

Exercise and blood pressure

Short term:

- No change in diastolic pressure (DBP)
- Progressive increase in systolic pressure (SBP) during CV training
- Rapid and greater increase in SBP during resistance training
- Reduced BP for up to 24 hours after physical activity

Long term:

- Reduction in resting blood pressure
- Improved regulation of blood pressure

Long term adaptations

- Stronger heart (increased mass of myocardium – cardiac muscle). The left ventricle thickens (cardiac hypertrophy)
- Increased resting, submaximal and maximal stroke volume
- Increased maximal cardiac output
- Improved blood flow to working muscles – combination of increased capillary network and reduced peripheral resistance of blood vessels
- Increased blood volume
- Decreased resting heart rate (heart rate at rest)

Long term adaptations

- Lower working heart rate at same intensity or effort
- Increased size and number of mitochondria in myocardium
- Increased number of capillaries in muscles
- Increased elasticity of blood vessels
- Improved cholesterol profile
- Increased potential for oxygen delivery to muscles
- Increased potential for removal of waste products from the muscles

Long term adaptations

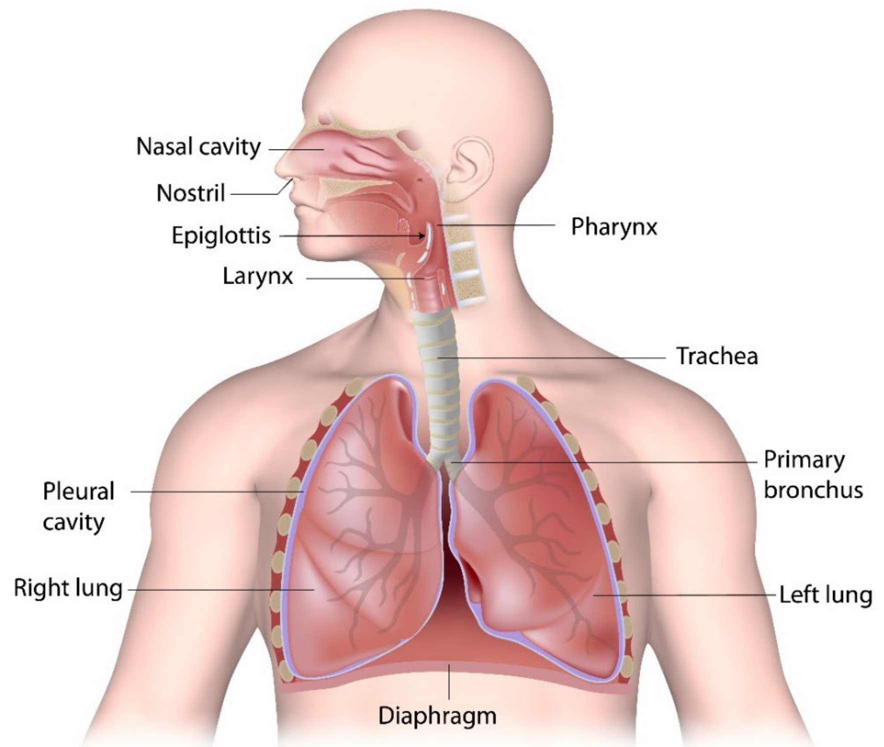
- Reduced recovery times
- Reduction in resting blood pressure, improved regulation of blood pressure
- Improved ability to tolerate heat
- Improved aerobic fitness
- Reduced risk of cardiovascular diseases

Blood pooling

- May occur if vigorous exercise stops suddenly
- Blood may pool in the extremities
- Leading to dizziness and fainting
- Cool down gradually to lower heart rate
- Keep legs moving until heart rate lowered and volume of blood circulated has reduced
- This will assist the return of venous blood to the heart and brain
- The veins have less muscular walls

Learning check

What can you remember about the respiratory system?



Summary of the Respiratory system

- Structure and function of the lungs
- Respiration
- Composition of air
- Mechanics of breathing
- The journey of air through the body
- Gaseous exchange
- Lung volumes

Lung volumes

- **Spirometry**
  The study of lung function. Lung function can be affected by age, gender, size and stature and other lifestyle factors, for example, smoking

- **Tidal volume (TV)**
  The amount of air inhaled/exhaled in one breath

- **Minute ventilation (MV)**
  The amount of air inhaled/exhaled in one minute

- **Vital capacity**
  The greatest volume of air that can be expelled from the lungs after taking a maximal inhalation

- **Residual volume**
  The volume of air left in the lungs after forced expiration

Short term responses

- Increased tidal volume
- Increased breathing rate and depth
- Increased gaseous exchange
- Increase in respiratory muscle action

Long term adaptations

- Increased number (and therefore surface area) of alveoli
- Increased minute ventilation
- Increased strength of respiratory muscles
- Increased vital capacity
- Increased tidal volume
- Reduced resting respiratory rate
- Improved potential for gaseous exchange

Learning check

Energy systems

- What can you remember about the energy systems?

Summary of the Energy systems

- Adenosine triphosphate
- Re-synthesised via THREE energy system:
  - ATP-CP – anaerobic
  - Glycolysis – anaerobic
  - Oxygen – aerobic
- Different fuels
  - Phosphocreatine
  - Carbohydrate, fat and protein (nutrients)
- Different waste products

Energy systems	Creatine phosphate	Lactate	Aerobic
Time to engage	Very quick	Quick	Slower
Use of oxygen	Anaerobic	Anaerobic	Aerobic
Fuel	Phosphocreatine	Glycogen	Glycogen and fat
ATP production	Very limited ATP	Limited ATP	Unlimited ATP
By-products	Creatine	Lactate	Carbon dioxide and water - easily removed
Duration	Short Around 8-15 seconds	1-3 minutes intense activity	Long Beyond 3 minutes
Intensity	Very high (95-100% maximum)	High (60-95% maximum)	Low to moderate (up to 60% maximum)
Recovery	Fast 30 seconds to 5 minutes	Slower 20 minutes to 2 hours - dispersal of lactic acid	Slower Replenish fuel stores by eating
Muscle fibre type	Type IIb	Type IIa	Type I

Aerobic adaptations

- Increased efficiency of the heart and lungs
- Stronger heart muscle, increased stroke volume
- Lower resting heart rate and lower working heart rate for a given intensity
- Increased number of red blood cells and capillarisation in the muscles
- Increased size and number of mitochondria
- More efficient gaseous exchange in the lungs and at a muscular level
- Increased oxygen uptake
- Improved efficiency of oxygen use at a muscular level
- Improved removal of metabolic waste products

Anaerobic adaptations

- Increased stores of creatine phosphate
- Increased capacity to store muscle glycogen
- Increased muscle fibre diameter
- Greater force production capacity of muscle fibres
- Increased efficiency of lactic acid removal from the muscles
- Improved resistance to fatigue during high-stress, anaerobic exercise
- Improved recovery after high-intensity exercise

Fatigue

Possible causes

- Depletion of energy stores (ATP)
- Depletion of substrate (for example, CHO stores)
- Metabolic acidosis (H+ ion accumulation)
- Reduced motor unit recruitment

Effects of exercise on the digestive system

- Diversion of blood flow away from intestines and digestive organs during exercise caused by sympathetic nervous system dominance and blood shunting
- Slowing of digestive processes too much during exercise due to reduced blood flow; upper digestive system discomfort and vomiting if large meals are eaten shortly before exercising
- Exercise speeds up transit time of faeces and prevents constipation, reducing risk of colon cancer and other diseases of large intestine
- Some types of exercise, for example, long distance running, can cause lower abdominal cramps and diarrhoea as water is not absorbed form the large intestine
- Exercise has been known to reduce or alleviate constipation

Overtraining

Excessive training volume and frequency can lead to decrements in performance with or without physiological and psychological signs.

This is referred to as **overtraining**.

Markers associated with anaerobic overtraining:

- Underperformance
- Persistent fatigue
- Disordered sleep patterns
- Loss of appetite
- Increased sense of effort

Overtraining

Markers associated with aerobic overtraining (not exhaustive):

- Decreased performance
- Reduced percentage of body fat
- Decreased max oxygen uptake
- Altered blood pressure
- Increased submaximal exercise HR
- Increased muscle soreness
- Decreased muscle glycogen

Overtraining

Possible causes of overtraining:

- Increased training volume
- Increased training intensity
- Training monotony
- High number of competitions
- Lack of appropriate rest

Quiz

State **two immediate responses** and **two long term adaptations** of exercise on the following systems:

- Musculoskeletal system
- Energy systems
- Cardiovascular system
- Respiratory system

USP186 - Applied anatomy for exercise, fitness, health and wellbeing

LO10 Understand the life course of the anatomical and physiological systems of the body

Content and Assessment Criteria

- Describe the life course of the musculoskeletal system, including relevant tendon, ligament, muscle, joint and bone mineral density changes, and their implications for exercise, plus specific implications for working with:
  - Young people in the 13-18 age range
  - Antenatal and postnatal women
  - Older people (50+)
  - Disabled people

Effects of ageing review

Neuromuscular changes	Effects
• Less fast twitch muscle fibres • Reduced motor neurons • Decreased neuromuscular transmission • Fewer capillaries • Alterations in connective tissue structure and function • Decline in vision • Decline in hearing • Decline in cognitive function	• Reduced: - Muscular endurance, strength and power - Movement speed - Range of motion and flexibility - Co-ordination and balance - Reduced ROM and flexibility - Postural stability - Short-term memory

Effects of ageing review

Cardiovascular and respiratory changes	Effects
• Reduced efficiency of cardiovascular and respiratory systems • Reduced stroke volume and cardiac output • Reduced intake and utilisation of oxygen • Increased blood pressure • Less capillaries • Less elastic vessels • Increased risk of CVD	• Lower maximal and target heart rate • Decreased anaerobic threshold • Reduced tolerance to high intensity exercise • Fatigue quicker • Increased recovery time

Effects of ageing review

Skeletal changes	Effects
• Reduced bone density • Loss of bone mass • Reduced synovial fluid production • Degenerative changes to joint cartilage	• Bones more susceptible to fracture • Increased risk of osteoporosis • Joints less mobile and stiffer • Reduced shock absorption capacity in the joints • Increased risk of osteoarthritis

Source: Lawrence, 2008

Activity

How would an exercise session and structure need to be modified to accommodate these changes and effects?

Special considerations for exercise programming (ACSM 2018)

- Intensity and duration of PA should be light at the beginning, in particular for older adults who are highly deconditioned, functionally limited, or have chronic conditions that affect their ability to perform physical tasks
- Progression of PA should be individualized and tailored to tolerance and preference; a conservative approach may be necessary for the older adults who are highly deconditioned or physically limited
- Muscular strength decreases rapidly with age, especially for those aged >50 yr. Although resistance training is important across the lifespan, it becomes more important with increasing age
- For strength training involving use of selected machines or free weights, initial training sessions should be supervised and monitored by personnel who are sensitive to the special needs of older adults
- Older adults may particularly benefit from power training because this element of muscle fitness declines most rapidly with ageing and insufficient power has been associated with a greater risk of accidental falls

Special considerations for exercise programming (ACSM 2018)

- Moderate intensity PA should be encouraged for individuals with cognitive decline given the known benefits of PA on cognition. Individuals with significant cognitive impairment can engage in PA but may require individualised assistance
- Structured PA sessions should end with an appropriate cool down, particularly among individuals with CVD. The cool down should include a gradual reduction of effort and intensity and, optimally, flexibility exercises
- Incorporation of behavioural strategies such as social support, self-efficacy, the ability to make healthy choices, and perceived safety may all enhance participation in regular exercise
- The exercise professional should also provide regular feedback, positive reinforcement, and other behavioural/programmatic strategies to enhance adherence

Ante and post natal

Pregnancy

- Healthy pregnant women without exercise contra-indications are encouraged to exercise throughout pregnancy (ACSM 2018)
- There are a number of benefits of exercising during pregnancy
  - Prevention of excessive gestational weight gain
  - Prevention of gestational diabetes mellitus
  - Decreased risk of pre-eclampsia
  - Decreased incidence/symptoms of low back pain
  - Decreased risk of urinary incontinence
  - Prevention/improvement of depressive symptoms
  - Maintenance of fitness
  - Prevention of postpartum weight retention

Trimester and postnatal changes review

First	Second	Third	Postnatal
• 0-3 months • Weight gain 1-3 kg • Morning sickness • Breasts and uterus enlarge • Hormonal changes for example increased relaxin	• 3-6 months • Weight gain 6-8 kg • Postural changes • Abdominal muscles stretch and lengthen • Centre of gravity (CoG) changes	• 6-9 months • Weight gain 3-4 kg • Tired more easily • Pelvic floor under more stress • Joints less stable • Increased lordosis • Balance affected by CoG changes	• Hormone levels high • Weaker pelvic floor • Pelvic girdle less stable • Diastasis recti • Abdominals weaker

Contra-indications for exercise during pregnancy (ACSM 2018)

Relative contra-indications

- Severe anaemia
- Unevaluated maternal cardiac dysrhythmia
- Chronic bronchitis
- Poorly controlled Type 1 diabetes mellitus
- Extreme morbid obesity
- Extreme underweight
- History of extremely sedentary lifestyle
- Intrauterine growth restriction in current pregnancy
- Poorly controlled hypertension
- Orthopaedic limitations
- Poorly controlled seizure disorder
- Poorly controlled hyperthyroidism
- Heavy smoker

Contra-indications for exercise during pregnancy (ACSM 2018)

Absolute contra-indications

- Hemodynamically significant heart disease
- Restrictive lung disease
- Incompetent cervix/cerclage
- Multiple gestation at risk for premature labour
- Persistent second or third trimester bleeding
- Placenta previa after 26 weeks of gestation
- Premature labour during the current pregnancy
- Ruptured membranes
- Pre-eclampsia/pregnancy-induced hypertension

Special considerations (ACSM 2018)

- Physical activity (PA) in the supine position should be avoided or modified after week 16 of pregnancy
- Due to the weight of the growing foetus, exertion or prolonged periods in the supine position may reduce venous return and subsequent cardiac output
- Women who are pregnant should avoid exercising in a hot humid environment, be well hydrated at all times, and dress appropriately to avoid heat stress
- Women should increase caloric intake to meet the caloric costs of pregnancy and exercise. Intake above or below recommended levels with concomitant changes in weight gain during pregnancy may be associated with adverse maternal and foetal outcomes

Special considerations (ACSM 2018)

- PA may help regulate weight gain during pregnancy. However, women who exercise above recommended levels should be monitored to ensure adequate caloric intake and weight gain

- Women who are pregnant and severely obese or have gestational diabetes mellitus or hypertension should consult their physician before beginning an exercise program

Post-natal return to exercise

Post-natal

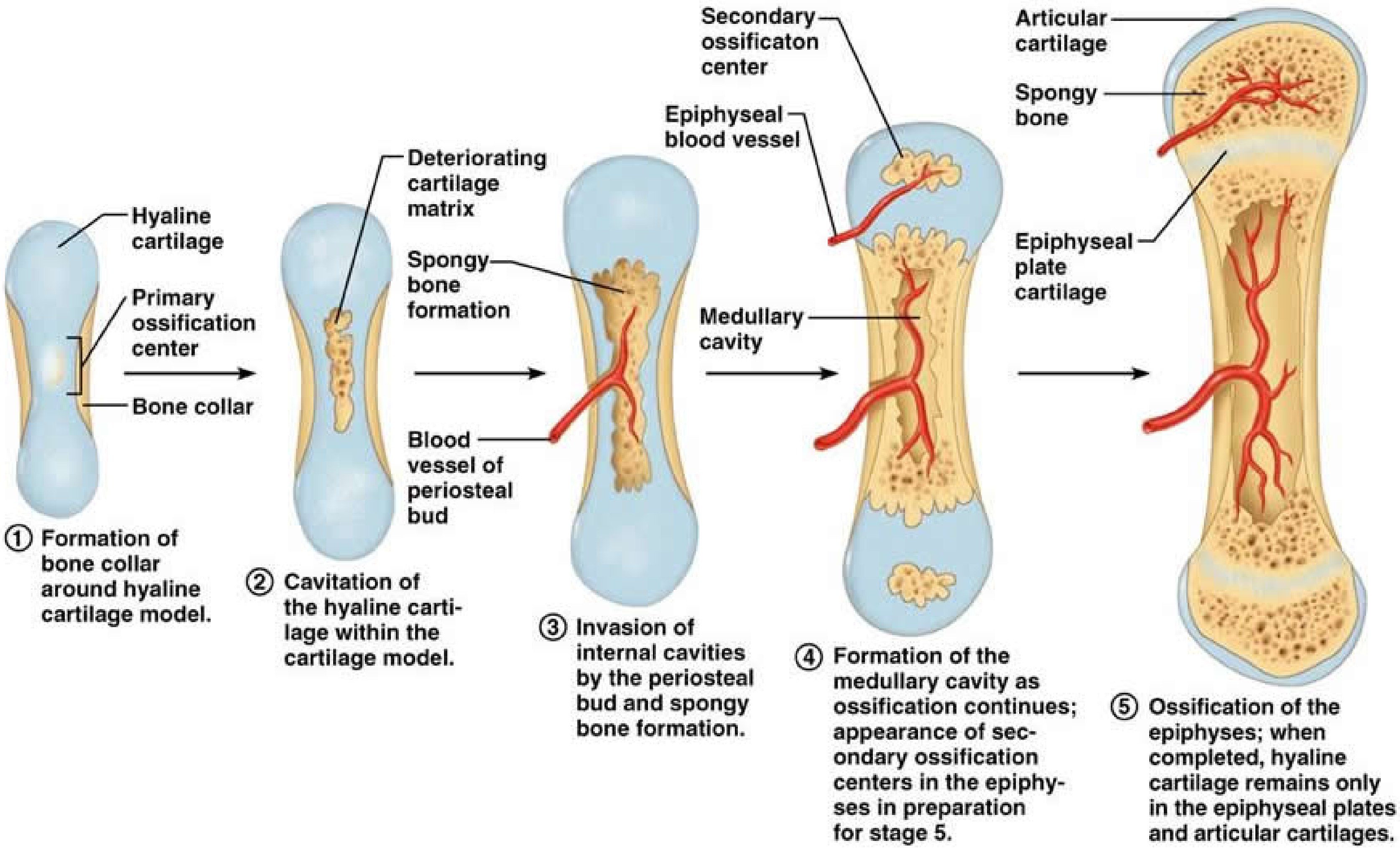
- 4-6 weeks after normal delivery
- 8-10 weeks after caesarean delivery
- Build gradually
- Light to moderate intensity activity does not interfere with breast feeding

Young adults (13-18)

- Mentally and physically less mature than adults
- Higher heart rate
- Lower stroke volume
- Lower cardiac output
- Lower blood pressure

Growth spurt

- **Girls**
  - Starts between the ages of 10 and 12
  - Fastest growth period around age 12 to 13
  - Ending around age 18
- **Boys**
  - Starts between the ages of 12 and 14
  - Fastest growth period around age 14 to 15
  - Ending around age 20
- Growth cartilage more vulnerable
- Growth plate fractures more common
  - Boys age 14-16
  - Girls age 11-13


Hyaline cartilage
Primary ossification center
Bone collar
① Formation of bone collar around hyaline cartilage model.
Deteriorating cartilage matrix
Spongy bone formation
Blood vessel of periosteal bud
② Cavitation of the hyaline cartilage within the cartilage model.
③ Invasion of internal cavities by the periosteal bud and spongy bone formation.
Secondary ossificaton center
Epiphyseal blood vessel
Medullary cavity
④ Formation of the medullary cavity as ossification continues; appearance of secondary ossification centers in the epiphyses in preparation for stage 5.
Articular cartilage
Spongy bone
Epiphyseal plate cartilage
⑤ Ossification of the epiphyses; when completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages.

Considerations

- Safeguarding legislation where appropriate
- Growth related issues and injuries
- Thermoregulation
- Self-esteem and confidence
- Overtraining and body image issues
- Medical conditions
- Obesity
- Immaturity
- Reduced coordination and motor skills
- Flexibility

Key safety guidelines

- Safeguarding legislation where appropriate
- Longer and more gradual warm up and cool down
- Lower impact, intensity, repetitions, resistance
- Less complex
- Focus on technique
- Adapt stretch positions and range of motion
- Stretch to the point of mild tension, avoid ballistic stretching
- Maintain hydration
- Be mindful of behaviour and regard to safety (ground rules)
- Be mindful of body image issues (eating disorders are a contra-indication)

Key safety guidelines

- Avoid exercising in hot and humid conditions
- Can participate in strength training under supervision
(8-15 repetitions to point of moderate fatigue)
- Children with medical conditions require specialist and adapted programme
(for example, asthma, obesity, cerebral palsy, diabetes)
- Inactive or obese young adults should work towards physical activity guidelines

Disabled people

- Estimated 10 million registered disabled people in the UK
- Registered disabilities include:
  - Deaf or partially hearing
  - Blind or partially sighted
  - Down’s syndrome
  - Cerebral palsy
  - Chronic health conditions (for example, stroke, obesity, cancer, arthritic conditions)
  - Mental health conditions (for example, severe depression, post traumatic stress disorder)
  - Limb amputation
  - Fibromyalgia

Effects

- **Neurological**
  For example, muscular dystrophy – decline in the central nervous system (CNS) function, muscles become weaker

- **Mental**
  For example, severe depression, PTSD – affects outlook on life, reduces motivation and energy levels, suicide risk

- **Sensory (visual, auditory)**
  Sensory nerves damage can affect sight, hearing and physical/touch sensation, For example, inability to detect pressure against the skin can result in a pressure sore

- **Progressive**
  For example, multiple sclerosis, worsen over time

- **Asymmetrical**
  For example, stroke and cerebral palsy – affect different sides of the body

General guidelines

- Stay active
- Maintain general fitness levels to decrease rate of decline
- Consider effects of medication
- Signpost any rapid decline in function to GP
- Consideration to pressure sores (wheelchair users)
- Consider imbalances
- Aim to improve functioning
- Consider range of movement, assisted movement and support

Activity

How would an exercise session and structure need to be modified to accommodate these changes and effects?

Key safety guidelines

- Promote inclusion
- Specific needs will determine exercise selection
- General guidelines:
  - Reduce intensity – simplify, slower, less repetitions, lower resistance, appropriate range of motion
  - Modifying exercise positions, increase support and balance
  - Use alternative modalities, for example, water-based or chair-based
  - Consider accessibility and health and safety
  - Adapt teaching and communication style, for example hearing or visually impaired

Learning check

Outline three physical or physiological changes and three safety considerations for exercise for the following population groups:

- Young people
- Antenatal and postnatal women
- Older adults
- Disabled people