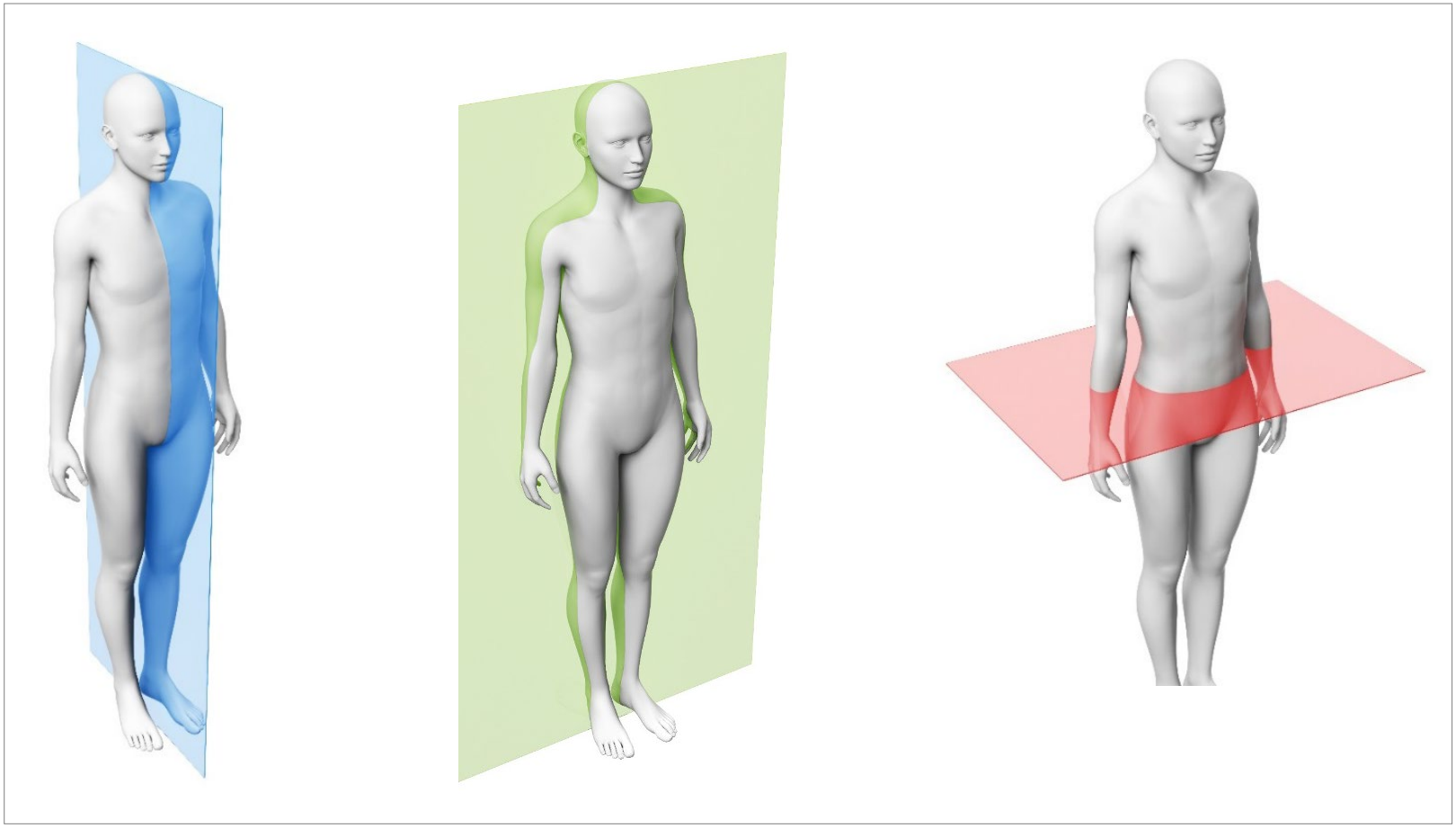
USP182 - Anatomy and physiology for exercise and fitness professionals

LO1 Know the structure and function of the skeletal system in relation to exercise

Content and Assessment Criteria

- Structure
- Function
- Basic awareness of anatomical position and reference points
- Stages of bone growth
- Joint classifications
- Joint movements
- Exercise and movement considerations

Movement planes



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

Anatomical terms

- **Anterior (or ventral)**
  Describes the front or direction toward the front of the body
- **Posterior (or dorsal)**
  Describes the back or direction toward the back of the body
- **Superior (or cranial)**
  Describes a position above or higher than another part of the body
- **Inferior (or caudal)**
  Describes a position below or lower than another part of the body
- **Lateral**
  Describes the side or direction toward the side of the body
- **Medial**
  Describes the middle or direction toward the middle of the body

Anatomical terms

- **Proximal**
  Describes a position in a limb that is nearer to the point of attachment or the trunk of the body

- **Distal**
  Describes a position in a limb that is farther from the point of attachment or the trunk of the body

- **Superficial**
  Describes a position closer to the surface of the body

- **Deep**
  Describes a position farther from the surface of the body

The skeleton

- The framework that gives the body structure
- 206 bones
- Bones connect to form joints
- Ligaments connect bone to bone
- Cartilage covers the end of the bones
- Tendons attach muscle to bone

Functions of the skeleton

- **Shape and support**
  A bony support framework
- **Attachment**
  Muscles, tendons and ligaments
- **Locomotion**
  Bones act as levers and muscles pull on bones
- **Production**
  Red and white blood cells
- **Protection**
  Different structures protect vital organs
- **Storage**
  Minerals, for example calcium

Activity

Name the skeletal structures that protect the following:

- Brain
- Spinal cord
- Reproductive organs
- Heart and lungs

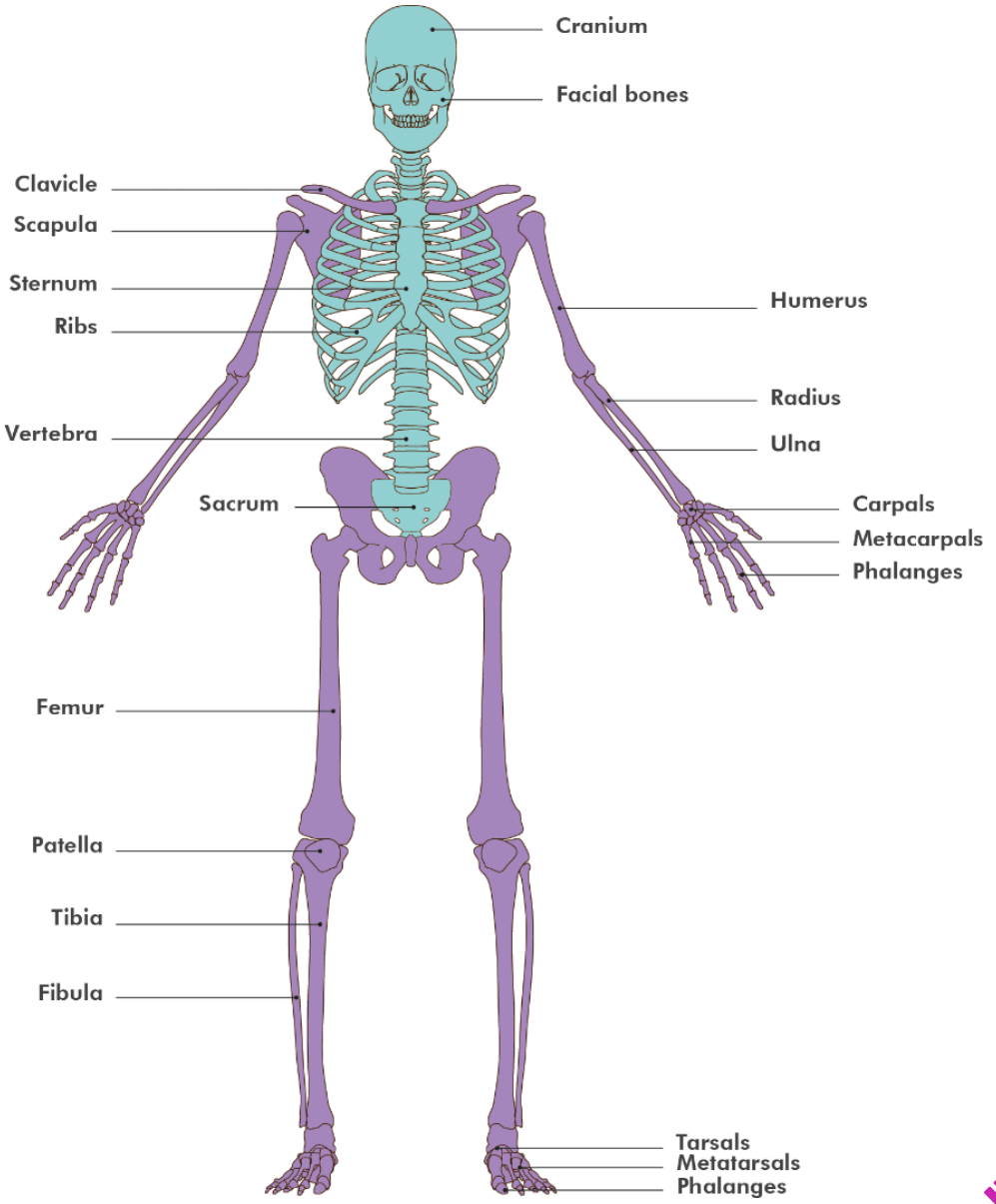
The skeleton

Appendicular skeleton

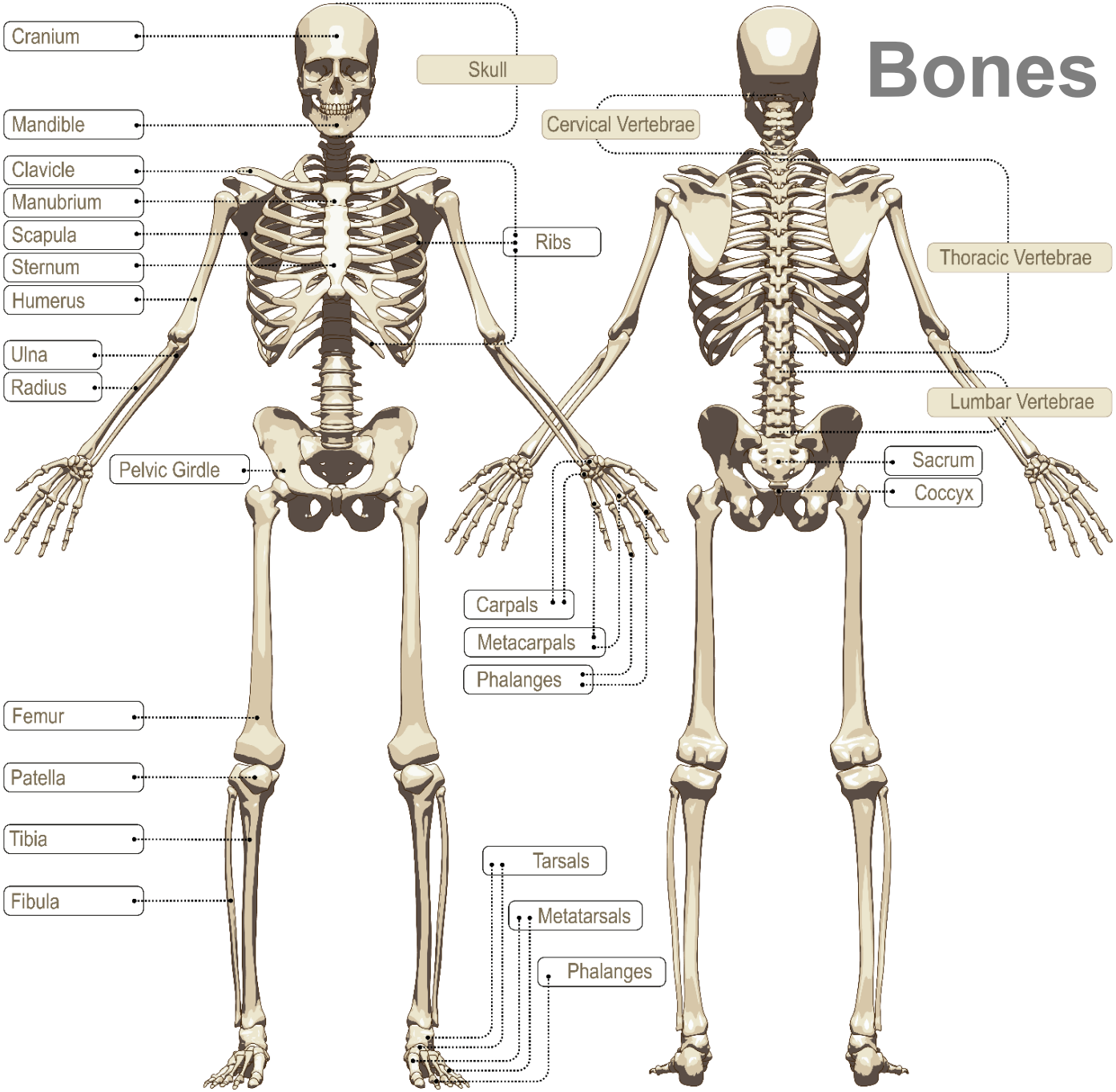
- Pelvic girdle
- Shoulder girdle
- Bones of the arms, legs, hands and feet

Axial skeleton

- Skull
- Spine
- Ribcage
- Sternum



Bones


Cranium
Skull
Mandible
Cervical Vertebrae
Clavicle
Manubrium
Scapula
Sternum
Humerus
Ribs
Thoracic Vertebrae
Ulna
Radius
Lumbar Vertebrae
Pelvic Girdle
Sacrum
Coccyx
Carpals
Metacarpals
Phalanges
Femur
Patella
Tibia
Fibula
Tarsals
Metatarsals
Phalanges

Classifications of bone

Classified by shape:

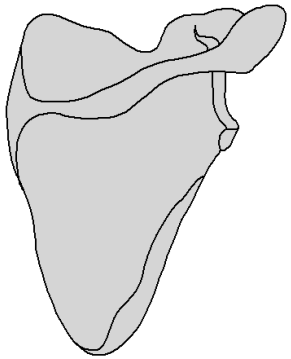
- Long – femur
- Short – carpals
- Flat – scapula
- Irregular – vertebrae

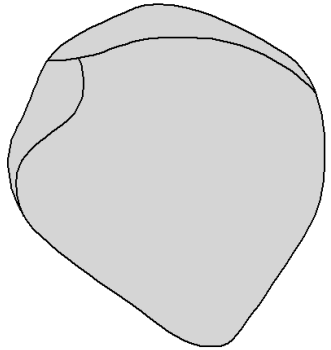
Not classified by shape:

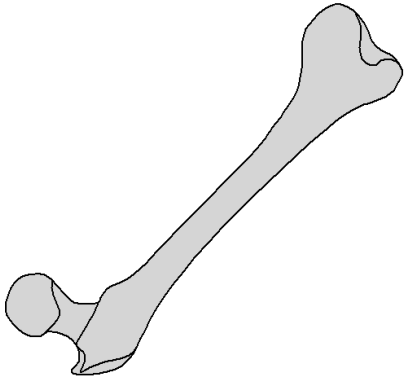
- Sesamoid bones – small bones within tendons, for example, the patella
- Wormian or sutural bones – small bones between the joints of some cranial bones

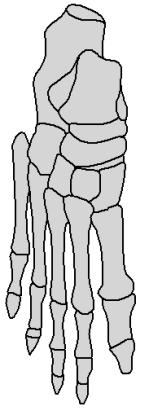
Activity

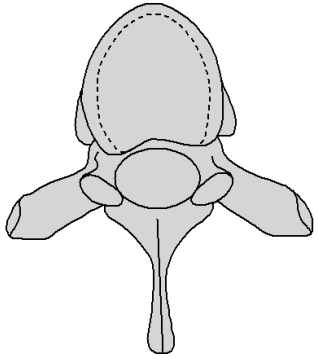
Name the types of bone pictured.





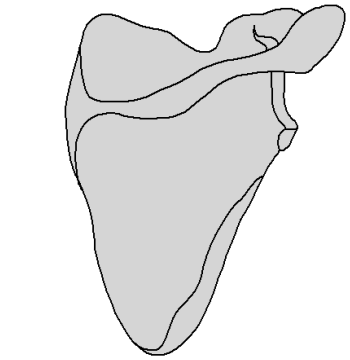


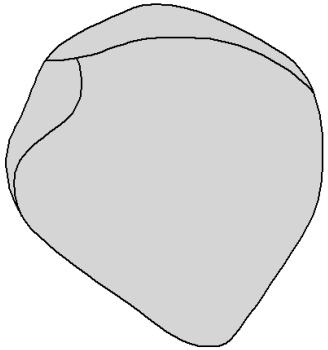


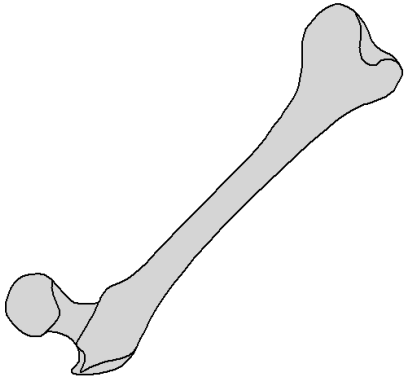


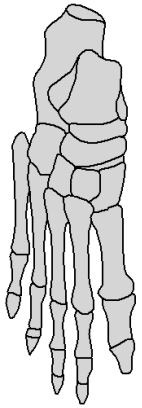
Types of bones

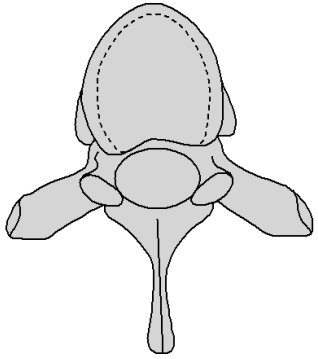
- Long
- Short
- Flat
- Irregular
- Sesamoid









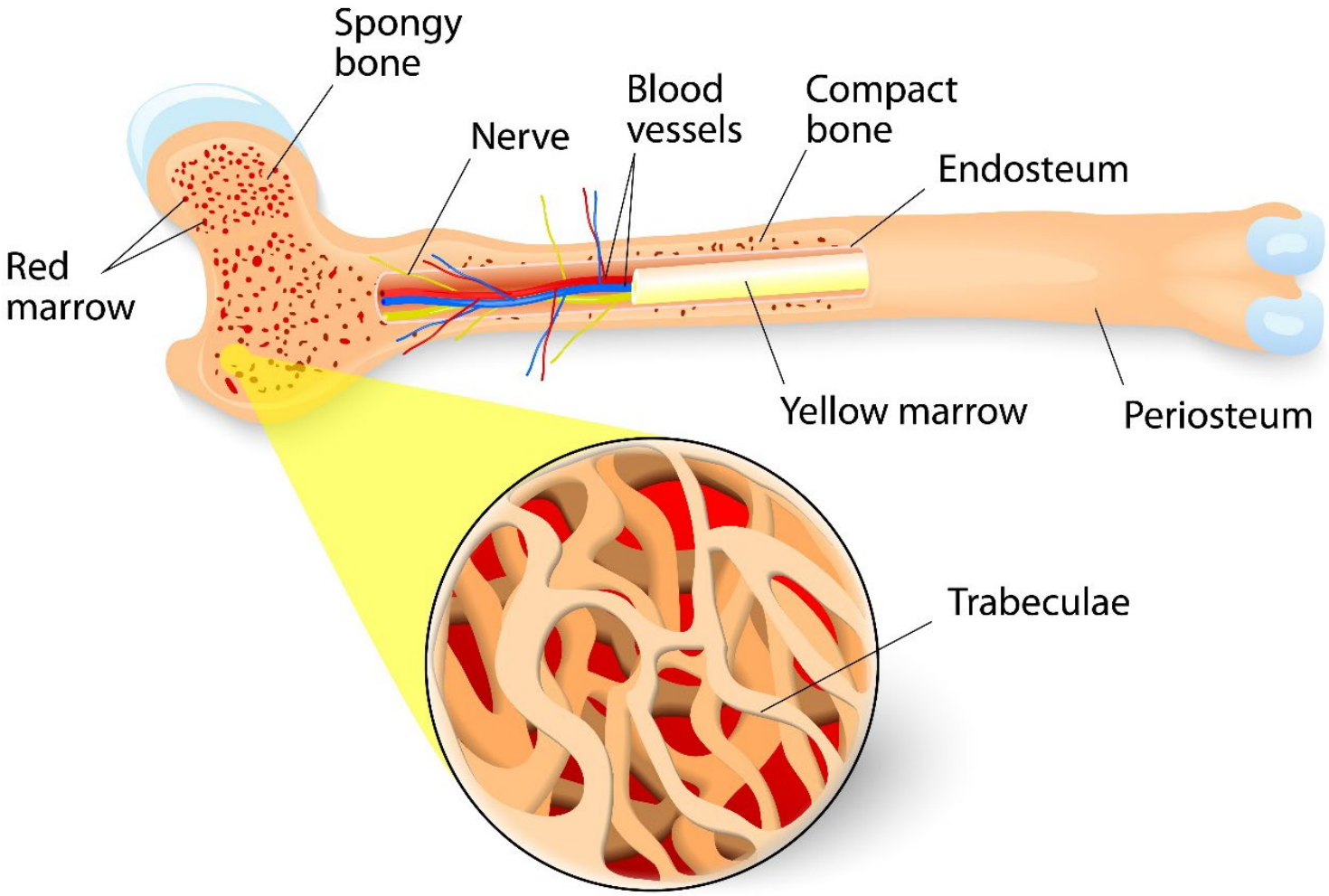


Activity

What type of bones are each of the following?

- The phalanges
- The radius
- The tarsals
- The femur
- The scapula
- The knee cap
- The vertebrae

Bone anatomy



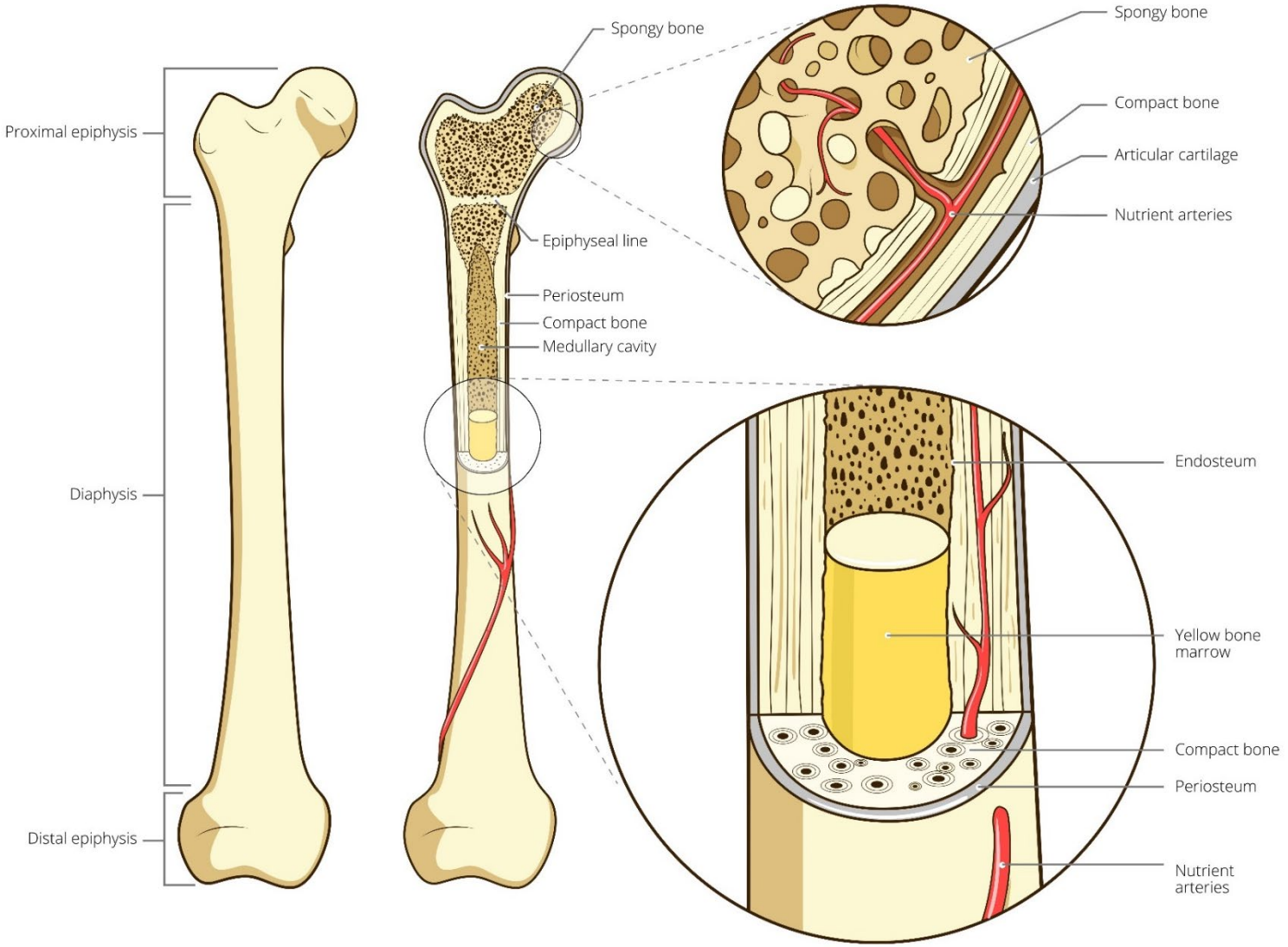
Structure of a long bone

- **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
- **Cancellous bone**
  Also called trabecular bone or spongy bone, is the light, porous bone found at the ends of long bones
- **Red marrow**
  Found in cancellous bone tissue
- **Medullary cavity**
  The marrow cavity
- **Yellow marrow**
  Found in the medullary cavity and functions for the storage of fat

Bone structure

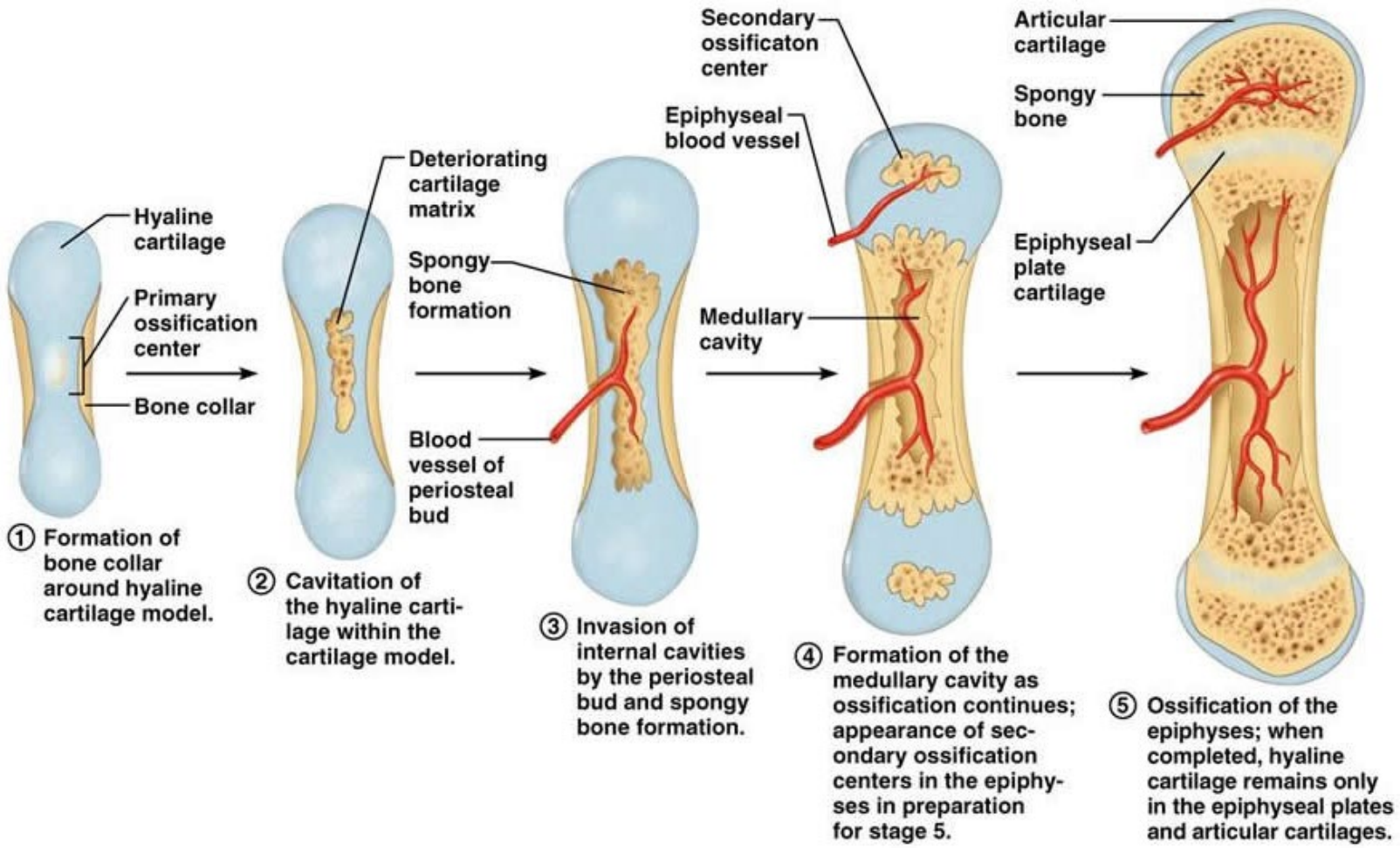


Activity

Name the structures:

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

Bone formation and growth



Factors affecting bone growth

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

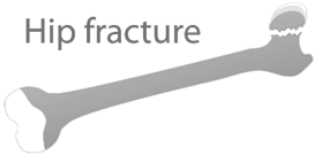
Osteoporosis

1 in 3 women and 1 in 5 men over 50 will experience osteoporosis fracture

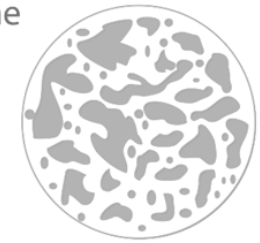
Risk

Genetic susceptibility | Inactive lifestyle | Age (over 45) | Insufficient mass | Growth

Hip fracture



Normal bone



Osteoporosis

Prevention and treatment

Diet

Dairy products

Restful sleep

Calcium and Vitamin D

Limit coffee

Stop smoking

Limit alcohol

Joints

‘The junction where two or more bones meet’

Three main types:

- **Fixed joints**
  Joints that are linked together usually by a fibrous connective tissue

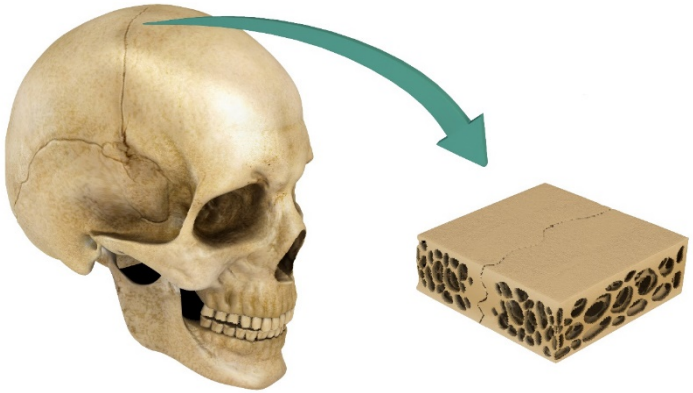
- **Cartilaginous joints**
  Joints that are connected entirely by cartilage

- **Synovial joints**
  Connections between two bones which are separated by an articular cavity

Fixed/Fibrous joints

'Linked together by fibrous connective tissue'

'Allow no movement, or very little movement'



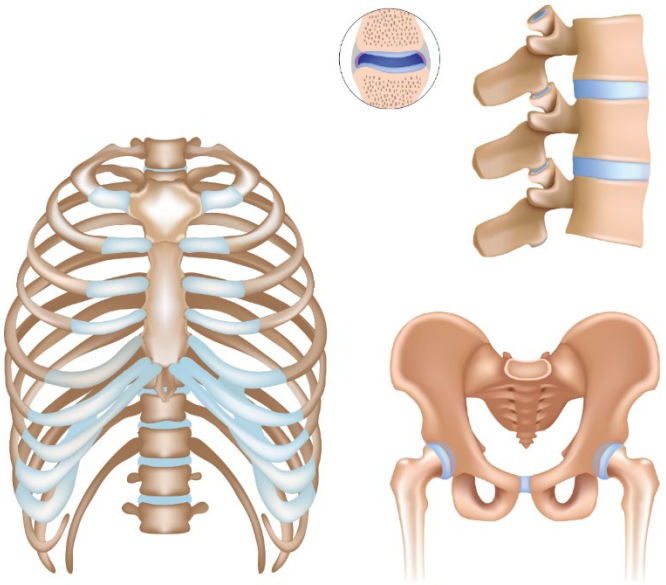
Three types:

- **Sutures**
  Bones joined by a layer of dense fibrous connective tissue, for example, between the bones of the skull

- **Gomphoses**
  A cone shaped peg, fits into a socket, for example, the teeth and adjoining bones

- **Syndesmosis**
  Two adjacent bones are linked by a ligament or interosseous membrane, for example, the radius and ulna

Cartilaginous joints



'No joint cavity, connected by cartilage.'

'Allow very little movement or no movement.'

Two types:

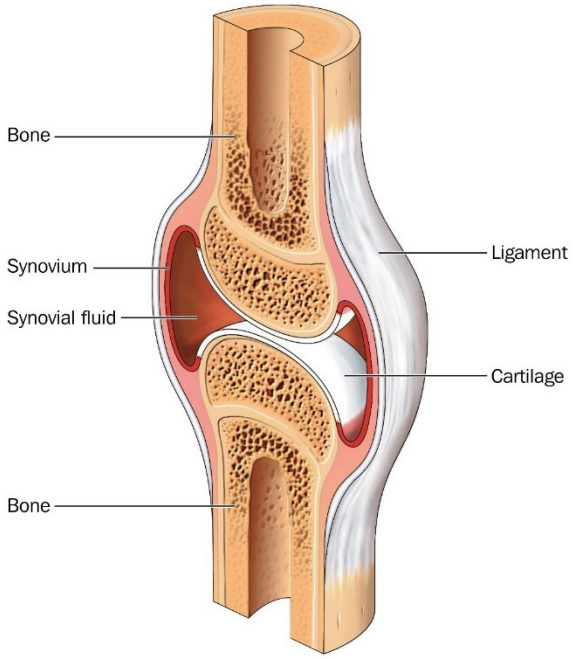
Synchrondrosis:

- Connected by hyaline cartilage, which has ossified, for example, the first rib and the sternum
- No movement

Symphysis:

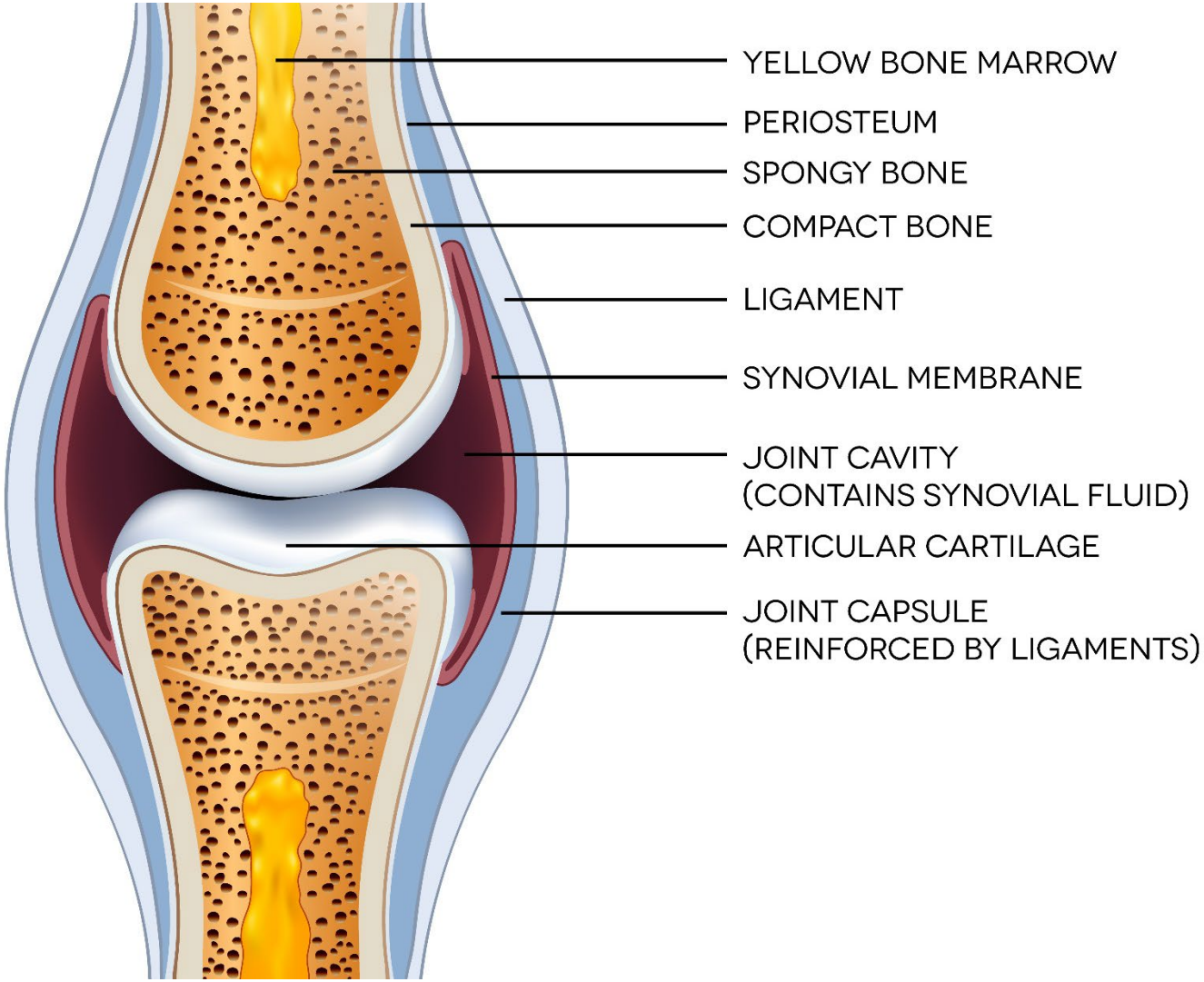
- Connected by fibrocartilage, for example, between the vertebral bones and also the pubis symphysis
- There is slight movement

Synovial joints

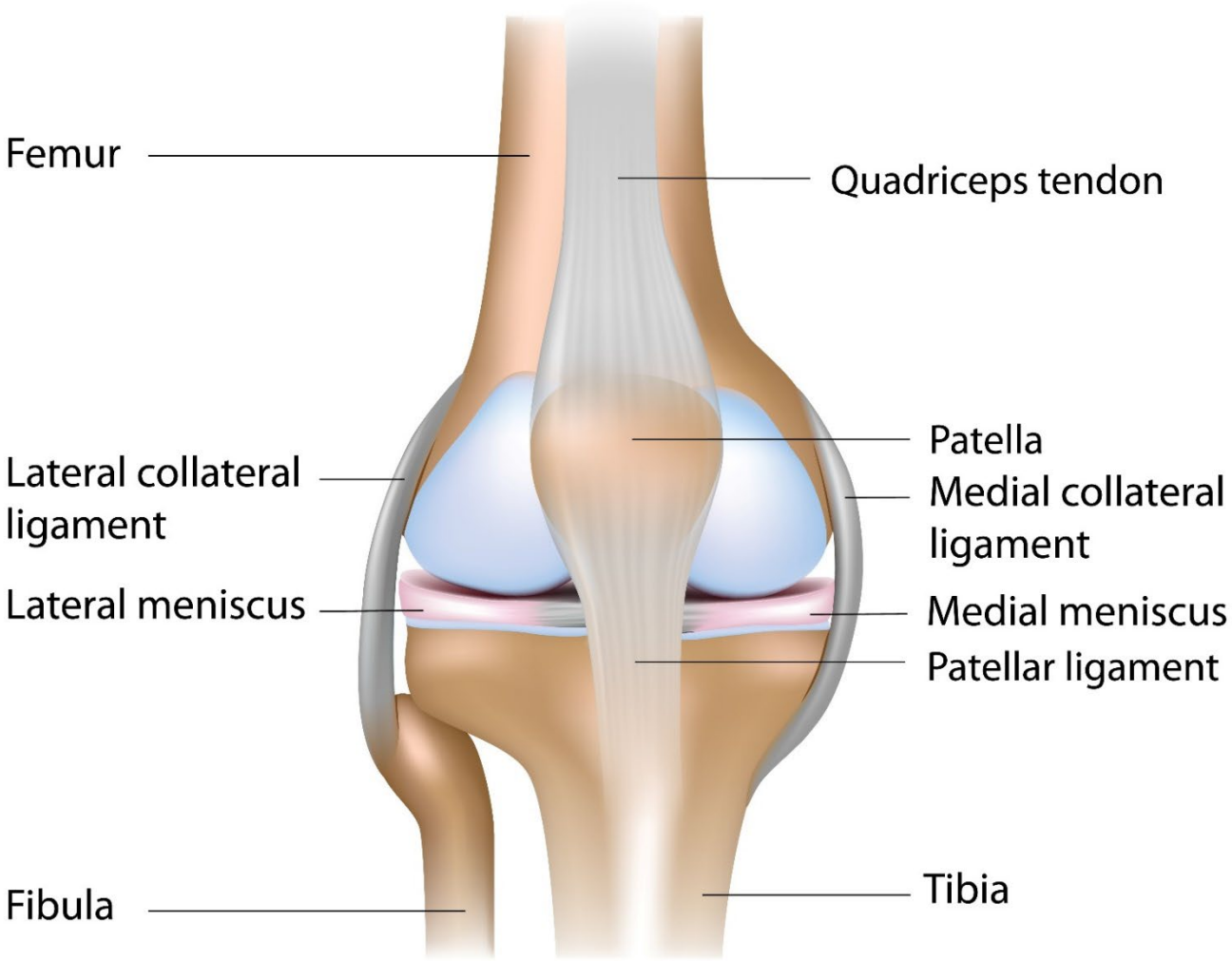


- Freely movable
- Whole joint surrounded by a capsule
- Synovial cavity or joint cavity between bones
- Cartilage covers ends of the bones
- Bone ends are covered with hyaline (articular) cartilage
- Bones connected and stabilised by ligaments
- Capsule contains a synovial membrane that secretes synovial fluid
- Synovial fluid lubricates the joints

Synovial joints



Anterior view of the right knee

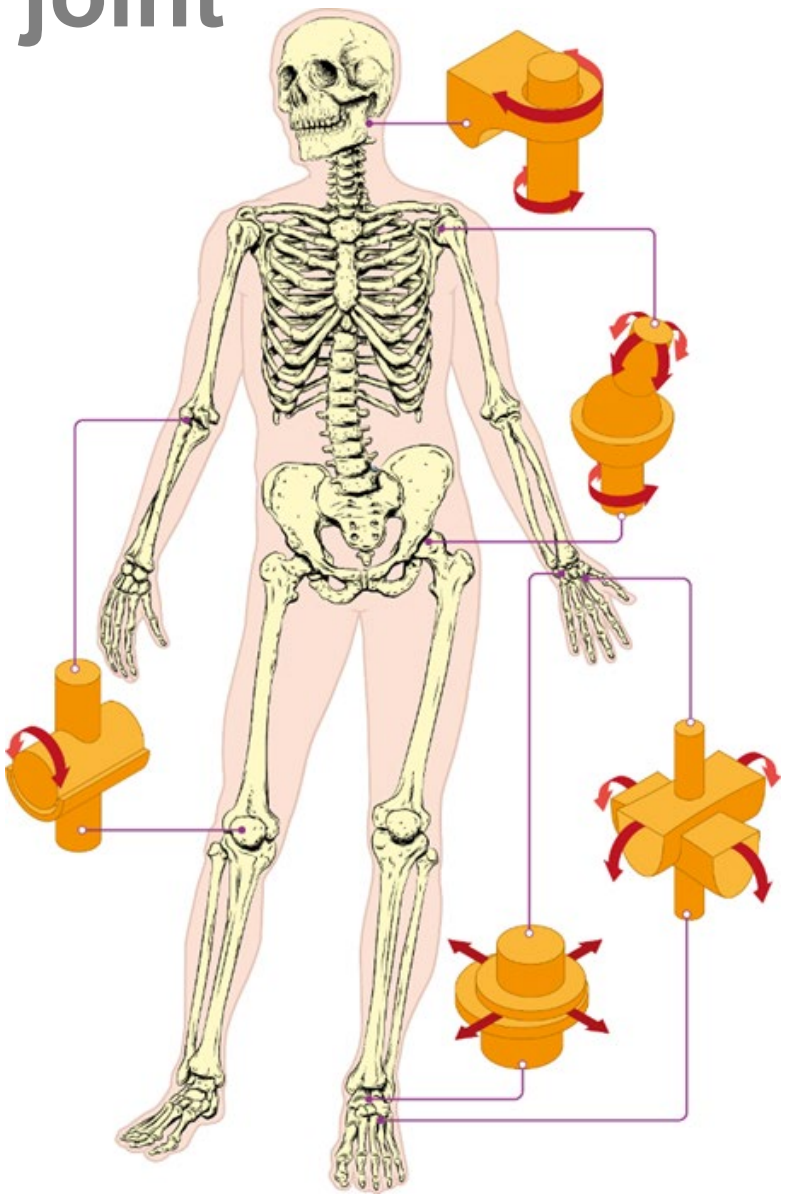


Ligaments

- Connect bone to bone
- Stabilise joints
- Restrict excessive joint movements
- Poor blood supply
- Collagen (less extensible)
- Elastin (more extensible)

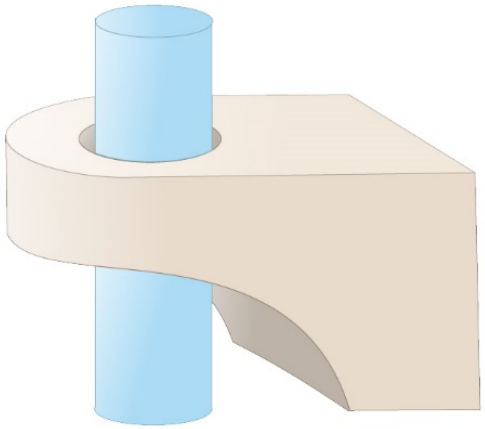
Types of synovial joint

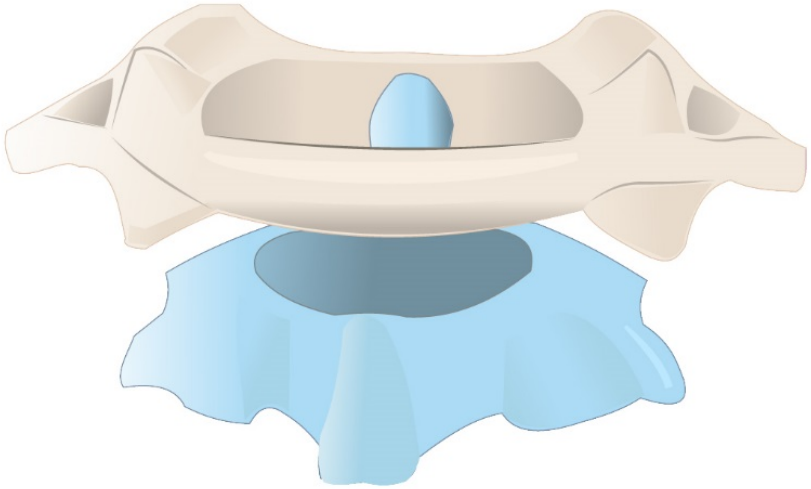
- Pivot
- Ball and Socket
- Hinge
- Condyloid (Ellipsoid)
- Saddle
- Plane (Gliding)



Pivot joints

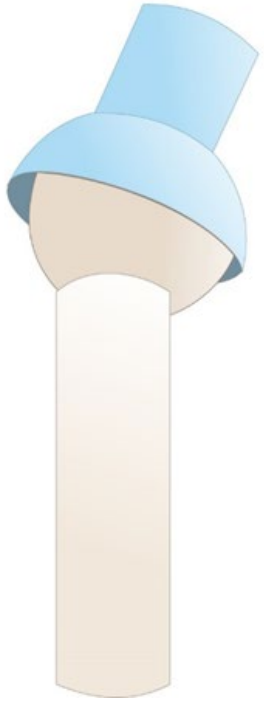
- Allow rotation
- Movement plane (the transverse plane)
- Uniaxial or monaxial
- The atlas and axis (cervical vertebrae C1 and C2)

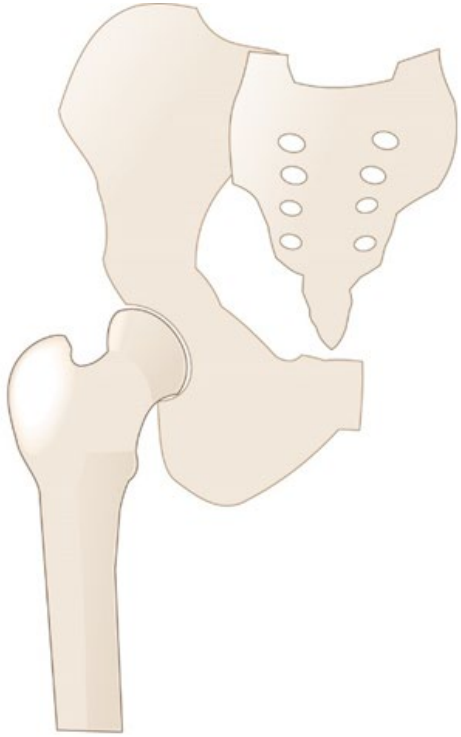




Ball and socket

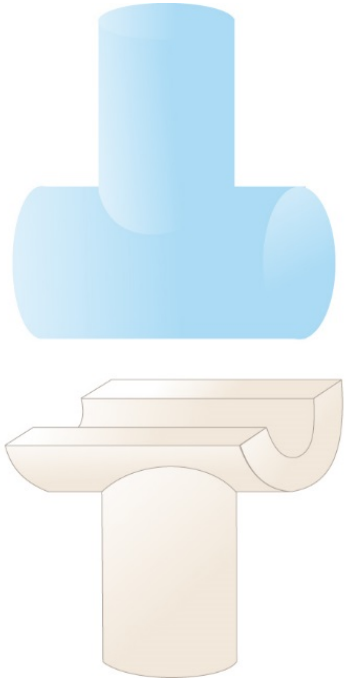
- Triaxial or multiaxial
- Move in all three movement planes (the sagittal plane, frontal plane and transverse plane)
- Hip and shoulder

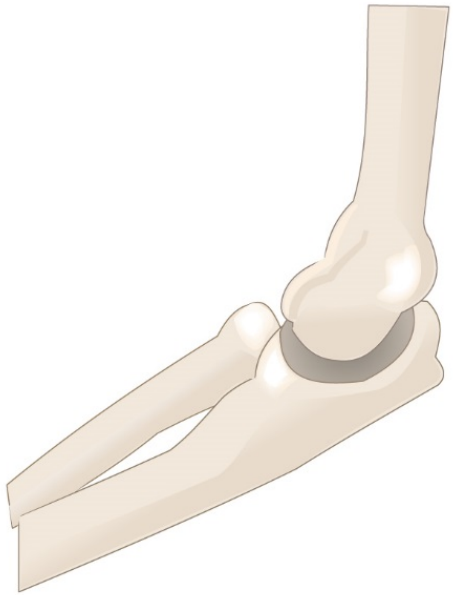




Hinge joints

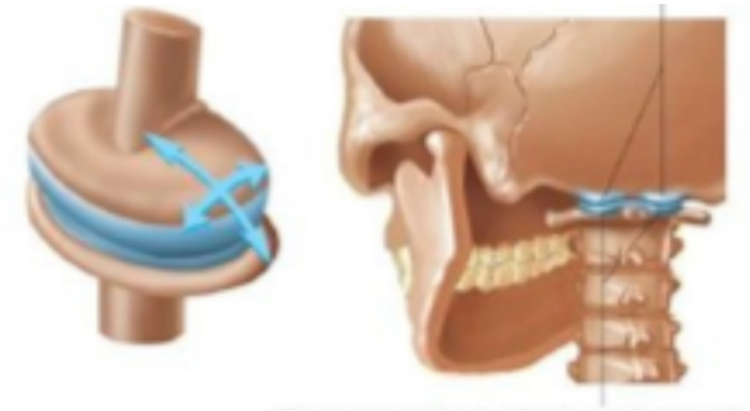
- Knee and elbow
- Uniaxial
- Move in one plane





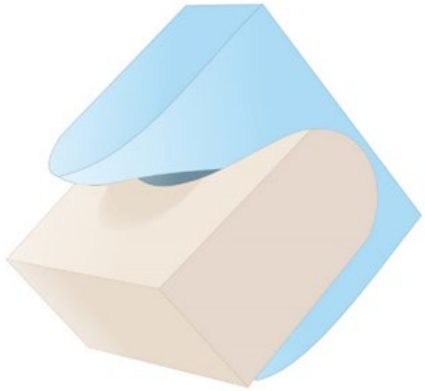
Condyloid (Ellipsoid) joints

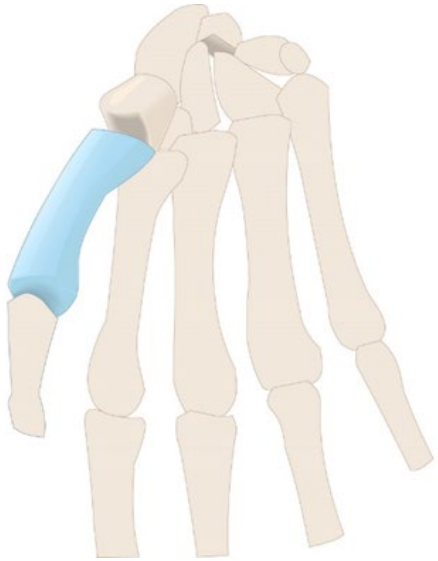
- Allow movements side to side and back and forth
- Move in two movement planes (the frontal and sagittal planes)
- Biaxial
- The wrist, which allows flexion, extension, abduction and adduction



Saddle joints

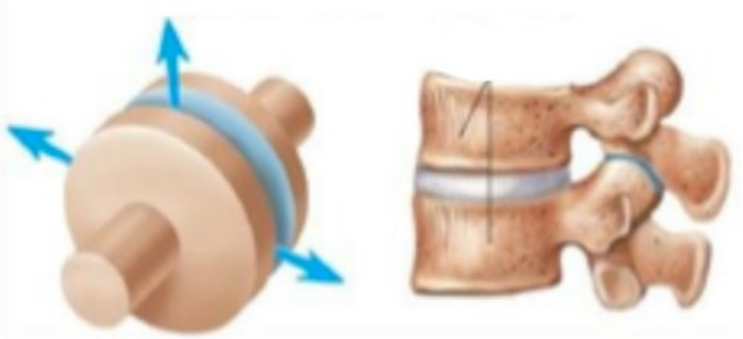
- Modified ellipsoid joints
- Move side to side and back and forth
- Biaxial
- The joint between the metacarpal of the thumb





Plane or gliding joint

- Allow movement back and forth and side to side over another surface
- Do not move around a point of axis – nonaxial
- No rotation
- Carpals, tarsals, scapula and clavicle



Activity

Identify the synovial joint classification for the following:

- Elbow
- Hip
- Knee
- Thumb
- Shoulder
- Wrist
- Ankle
- Atlas and axis

Joint actions

- Extension
- Flexion
- Adduction
- Abduction
- Dorsi flexion
- Plantar flexion
- Circumduction
- Lateral flexion
- Rotation
- Pronation
- Supination
- Eversion
- Inversion

Activity

Identify a sporting movement of your choice.
(For example, kicking a ball or upward phase of a squat – keep it simple)

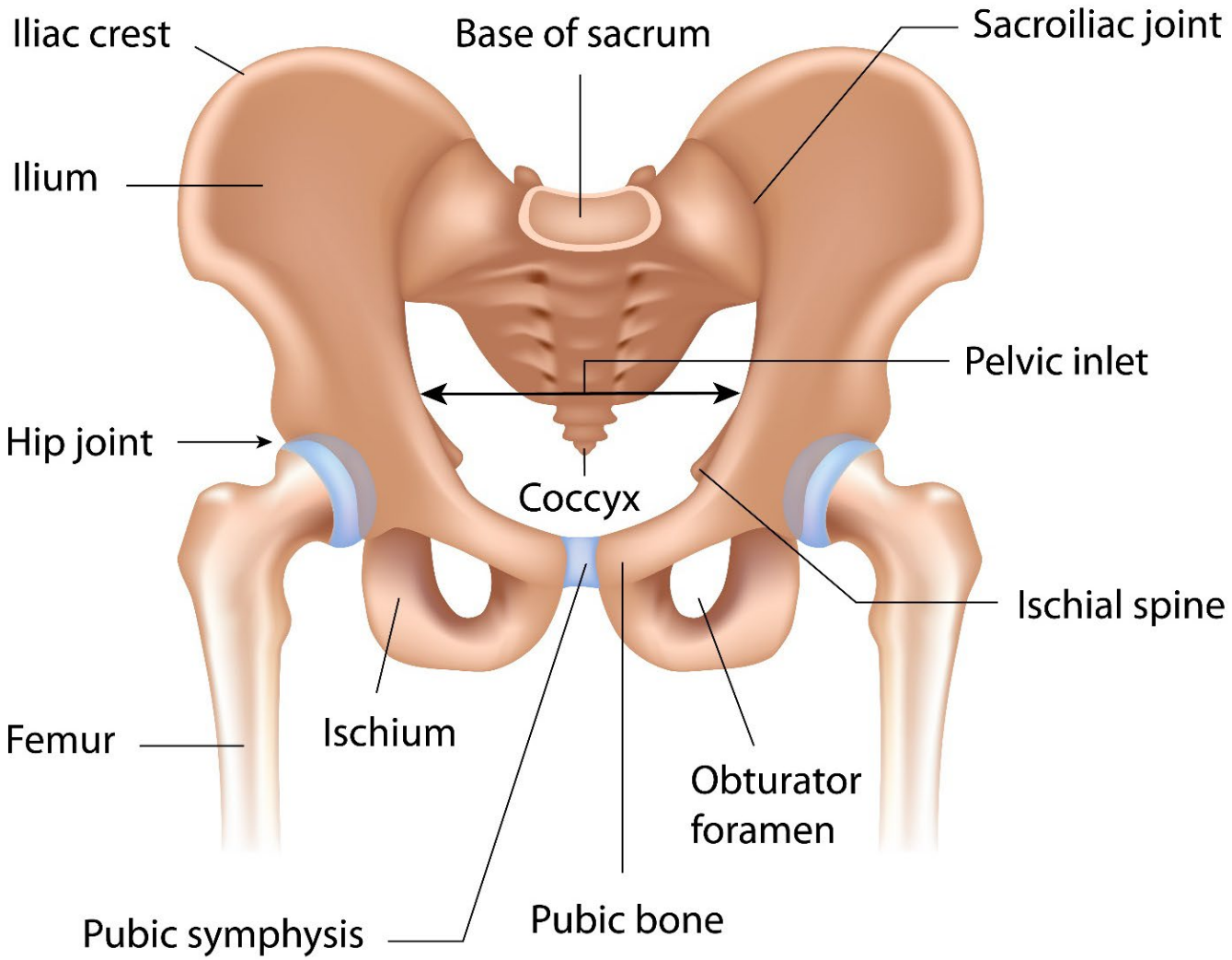
- Name the joint or joints moving in the action
- Name the joint or joint actions

Quiz

Which joints allow the following movements?

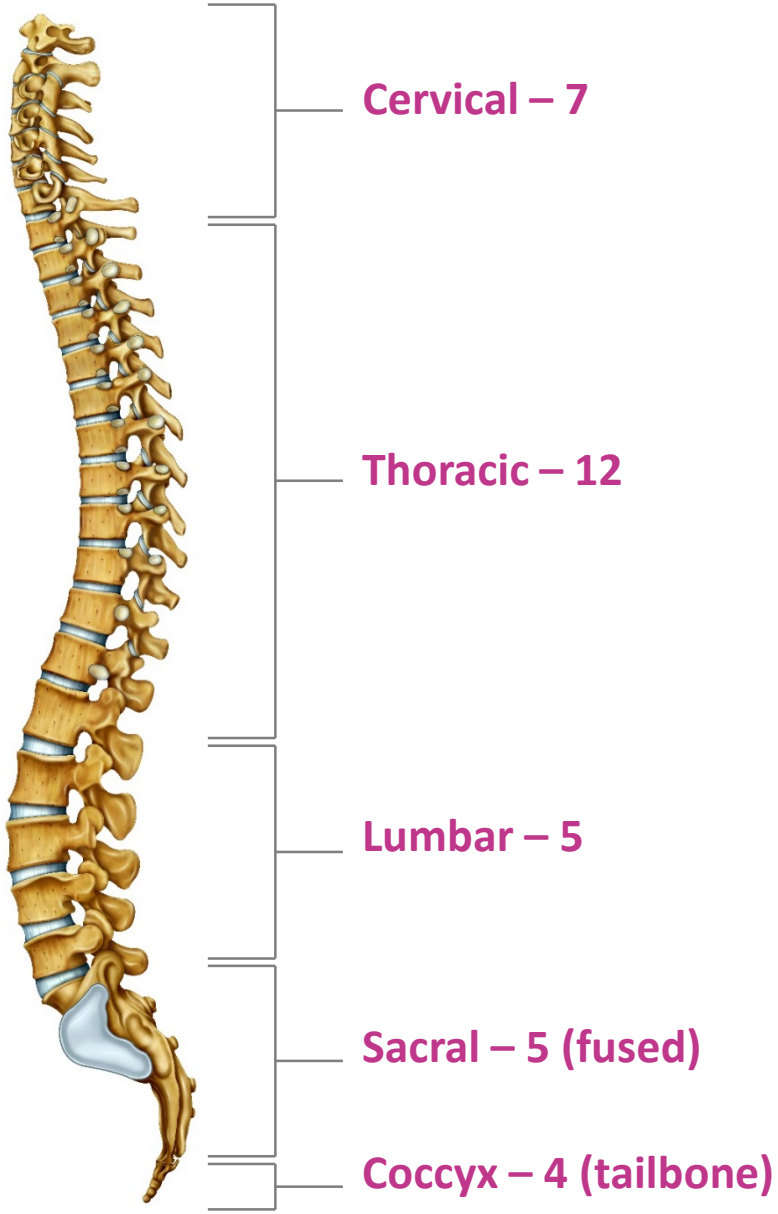
- Extension
- Flexion
- Adduction
- Abduction
- Dorsi flexion
- Plantar flexion
- Circumduction
- Lateral flexion
- Rotation
- Pronation
- Supination
- Eversion
- Inversion

The pelvic girdle



The spine

- 33 bones
- 7 cervical
- 12 thoracic
- 5 lumbar
- 5 sacral (fused)
- 4 coccygeal (fused)



Movement of the spine

Cervical spine

- The atlas and the axis form a pivot joint allowing rotation
- Flexion, extension and lateral flexion

Thoracic spine

- Flexion, extension, lateral flexion and rotation

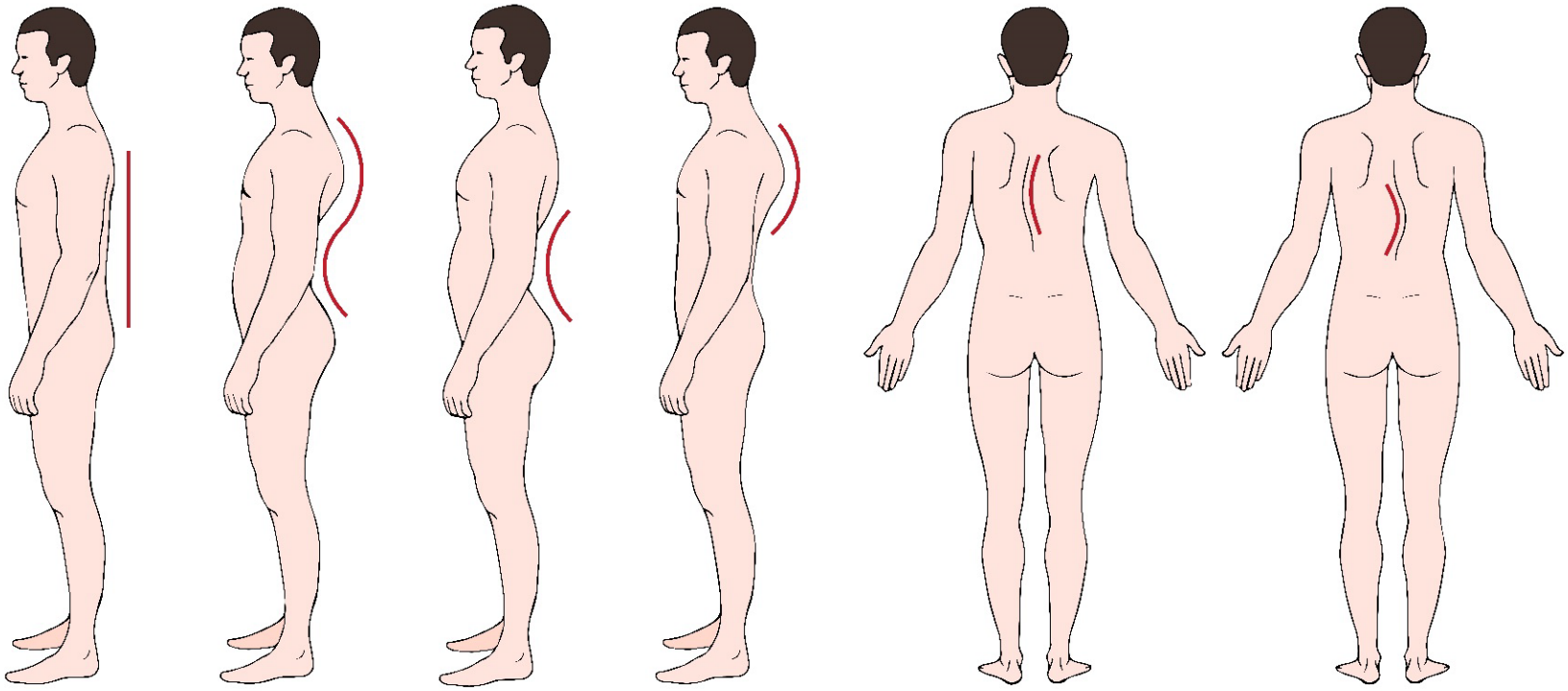
Lumbar spine

- Flexion, extension, lateral flexion and limited rotation

Sacral and coccygeal

- No movement

Postural deviations



Activity

How will exercise, movement and sport impact on the skeletal system?

Consider:

- Joint actions in specific activities
- Potential for overuse injuries
- Effects of exercise on the skeletal system in the long and short term

Learning check quiz

- Name and give an example of a long bone
- Name and give an example of a flat bone
- Which bones form the axial skeleton?
- Name two bones that form the appendicular skeleton
- Name the functions of the skeleton
- What are the different types of joints?

Learning check quiz

- Describe the structure of a synovial joint
- Name four types of synovial joint
- Which movements occur at the following joints:
  - Knee
  - Hip
  - Spine
  - Shoulder
  - Shoulder girdle
  - Elbow
  - Ankle
- List the main planes of motion

USP182 - Anatomy and physiology for exercise and fitness professionals

LO2 Know the structure and function of the muscular system in relation to exercise

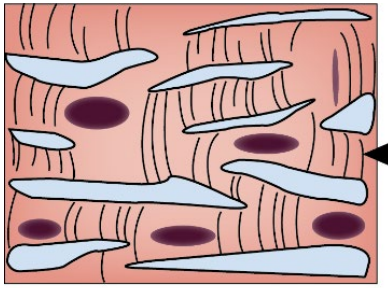
Content and Assessment Criteria

- 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 pelvic floor

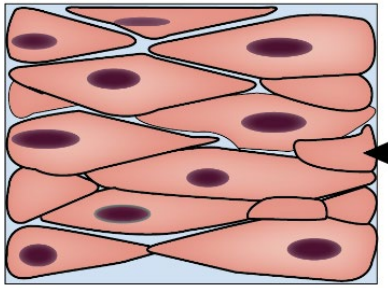
The muscular system

The muscular tissue is characterised by properties that allow movement.

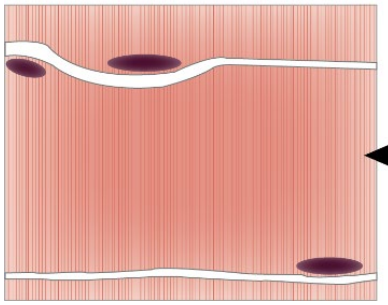
Types of muscle tissue



Cardiac (myocardium)
For example, the heart



Smooth
For example, the digestive system



Skeletal (striated)
For example, the hamstrings or triceps

Characteristics of muscle tissue

Four characteristics:

- **Excitability**
  The ability to receive and respond to stimuli

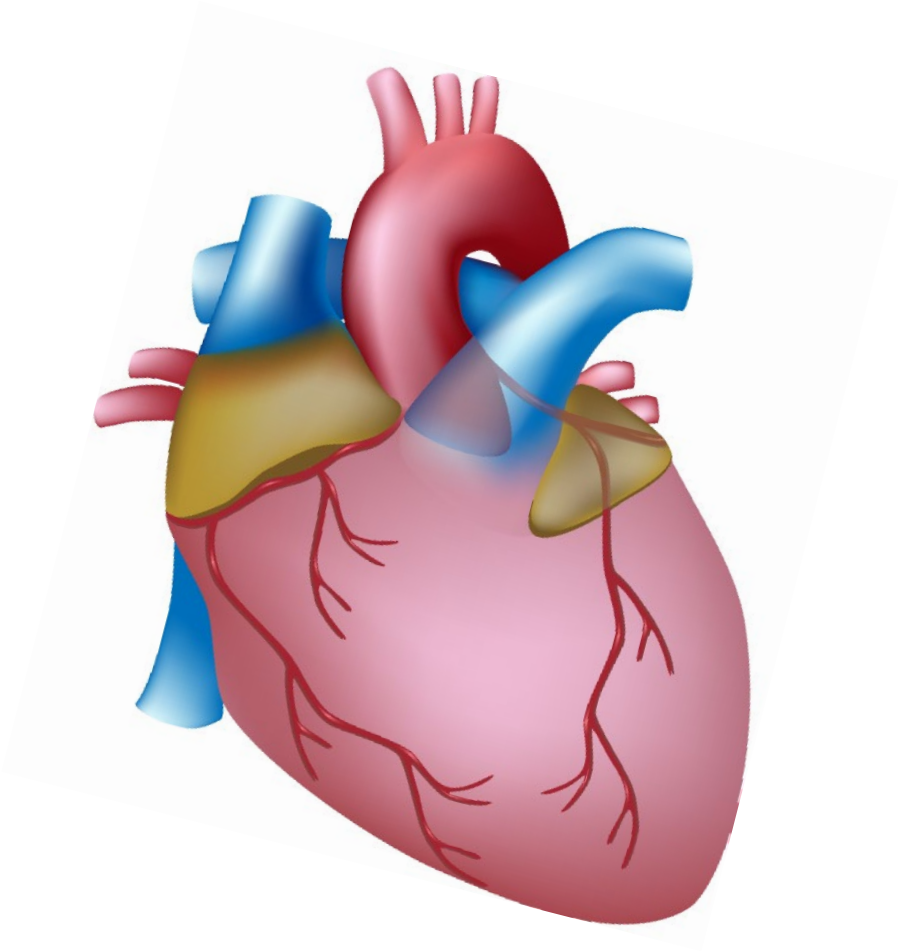
- **Contractility**
  The ability to shorten

- **Extensibility**
  The ability to be stretched or extended

- **Elasticity**
  The ability to recoil and return to its starting length

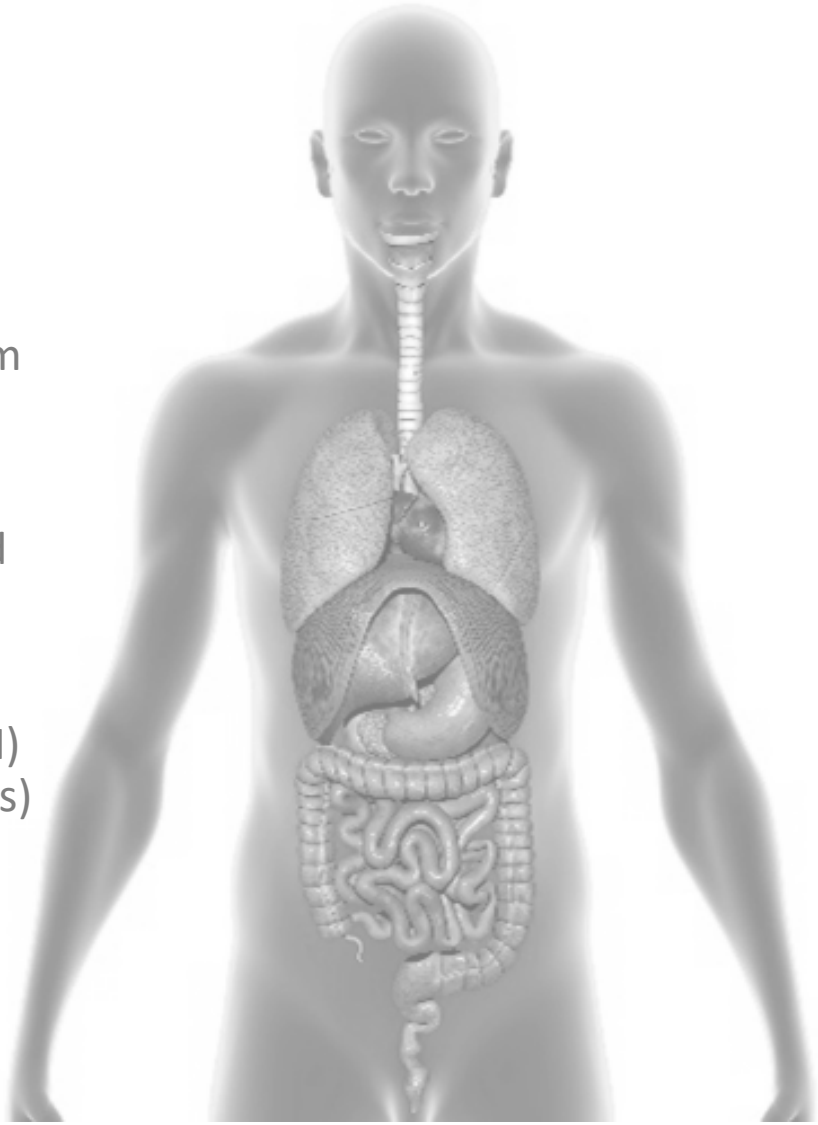
Characteristics of cardiac muscle

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



Characteristics of smooth muscle

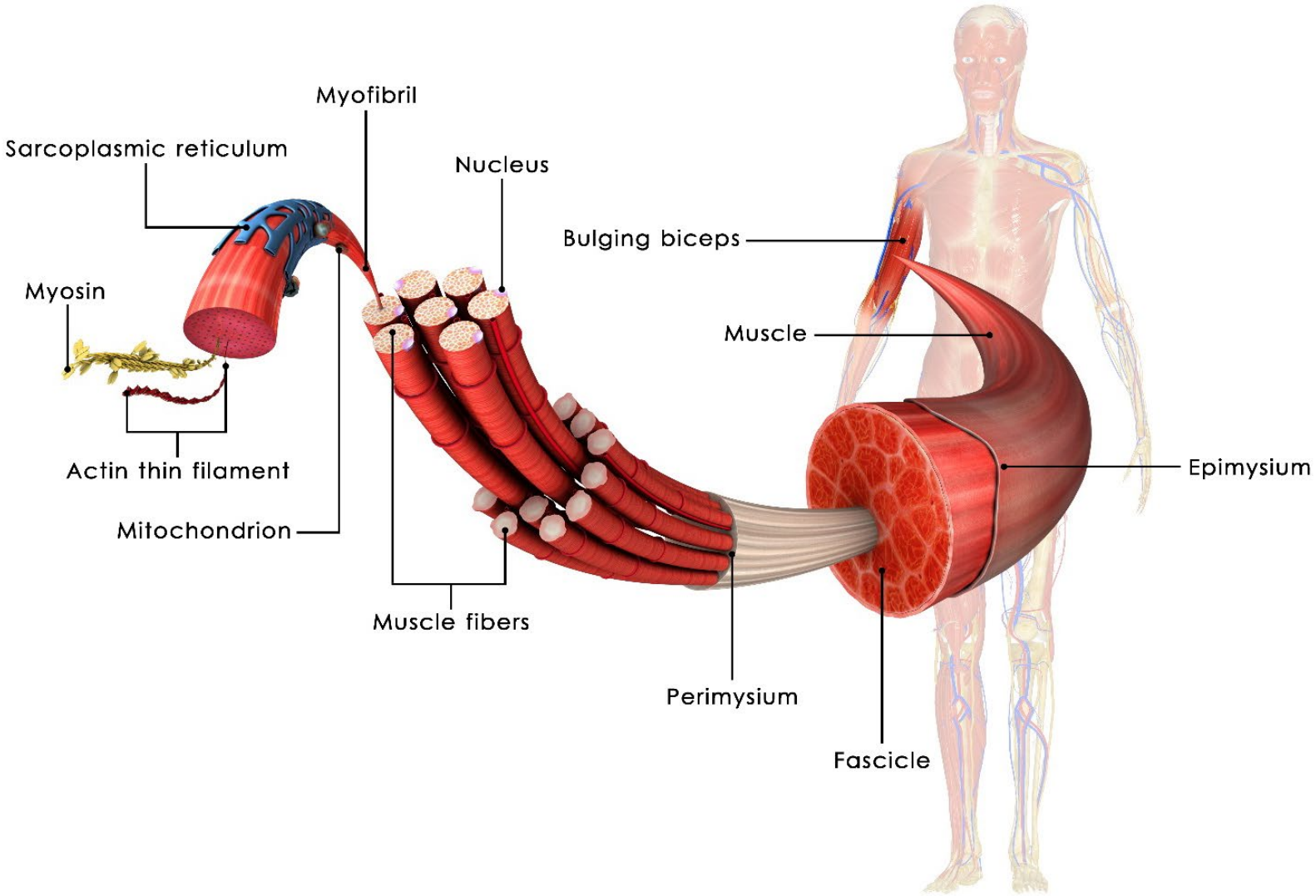
- Involuntary
- No conscious control
- Operated by autonomic nervous system
- Found in the reproductive system, digestive system, the blood vessels and the urinary system
- The smooth muscle of the digestive (GI) tract contracts to move food (peristalsis)



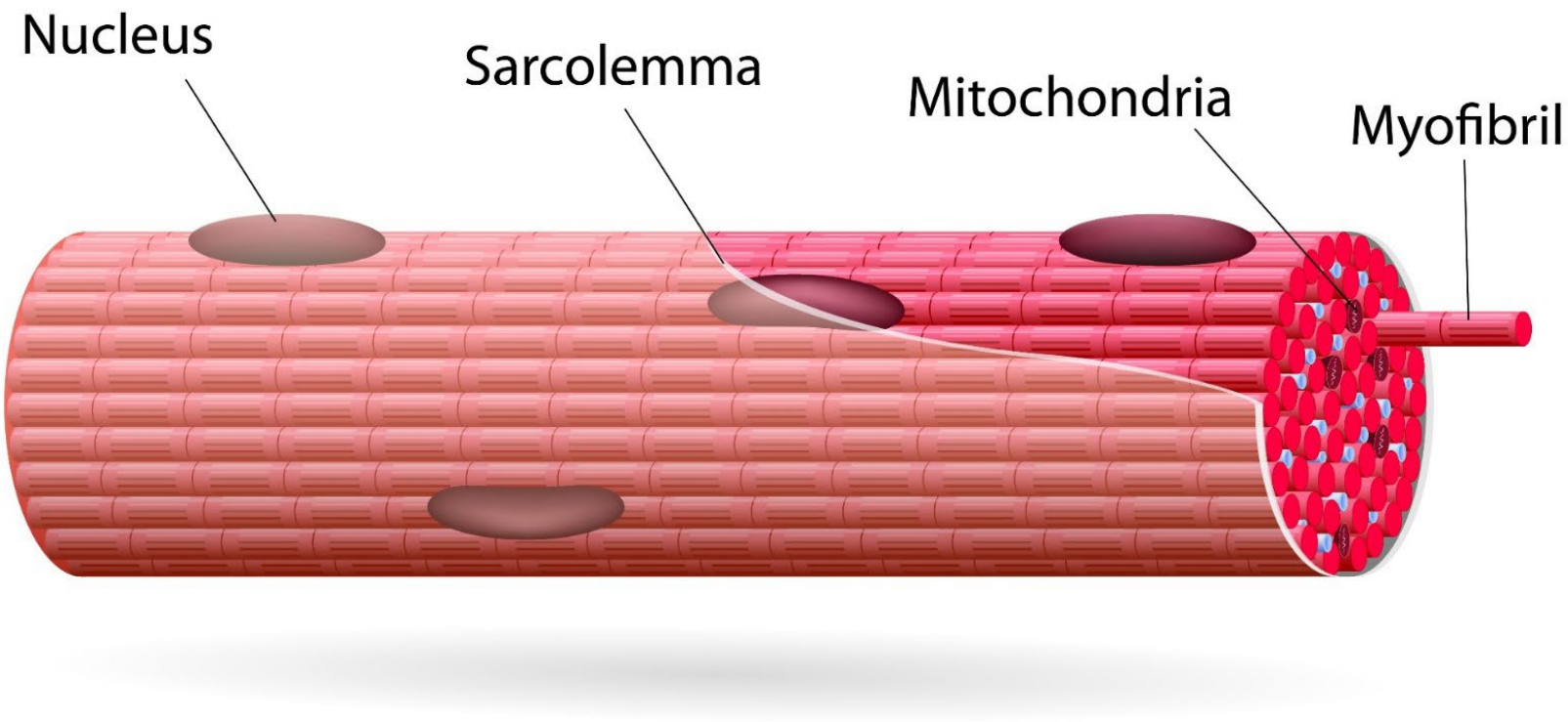
Characteristics of skeletal muscle

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

Muscle structure

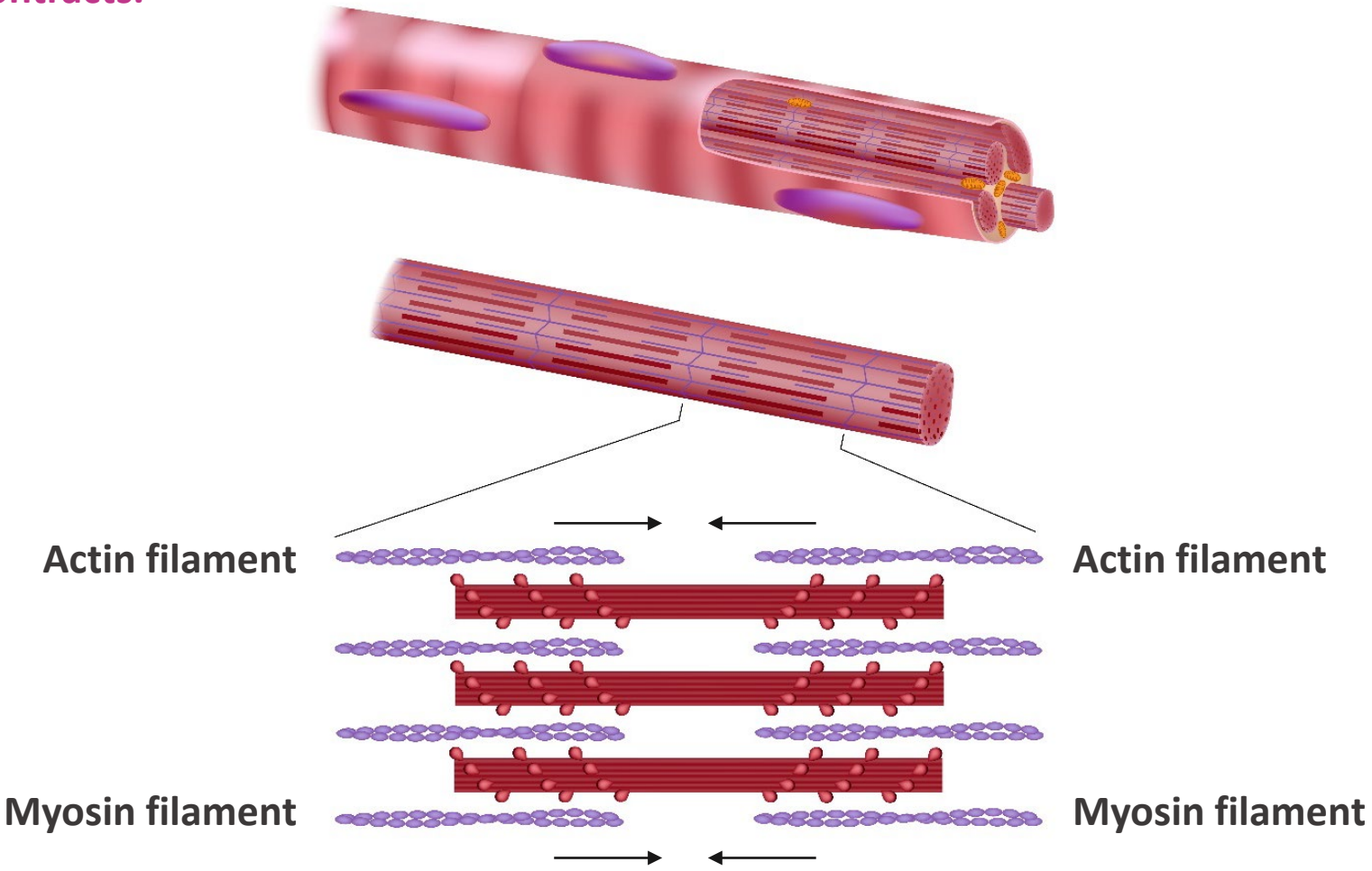


Muscle fibre



Sliding filament theory

Myosin connects to and pulls actin filaments. The filaments slide and the muscle contracts.



Type I fibres (slow oxidative)

- Slower to contract, slower to tire
- Fatigue resistant
- Red in colour
- Re-synthesise ATP using oxygen
- High in mitochondria and myoglobin
- Endurance training and events
- Used in activities with long duration and low intensity
- Dominant system at rest

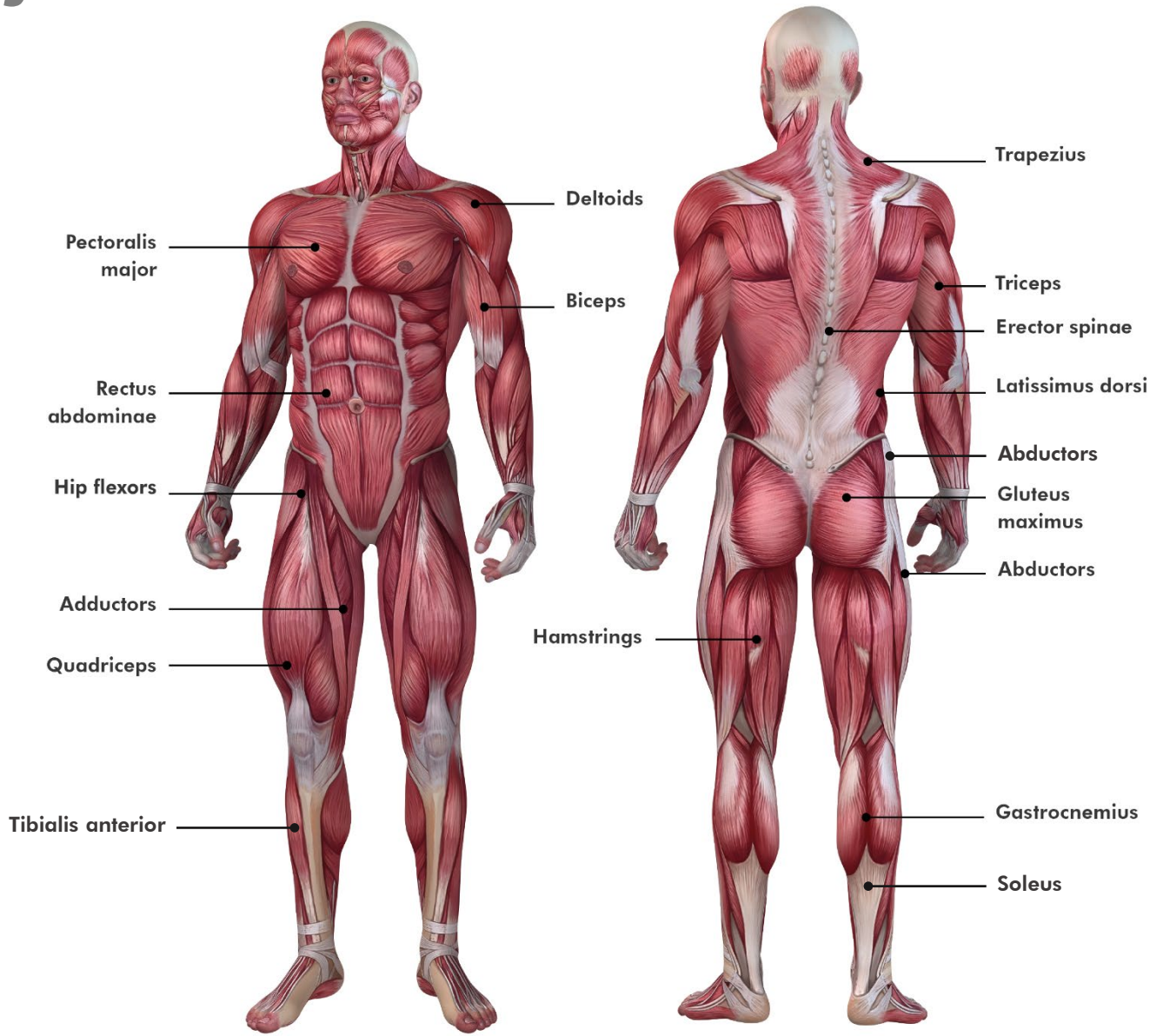
Type II A fibres

- Fast Oxidative Glycolytic (FOG)
- Can utilise energy through anaerobic and aerobic processes
- They also have more mitochondria than type II B
- Pink in colour
- Adapt specifically to different types of training to behave more like type I or type II B fibres

Type II B fibres

- Fast Glycolytic (FG)
- Fastest contraction and quickest to fatigue
- Low oxidative capacity and low in mitochondria
- White in colour
- Used in short burst, high intensity and explosive movements
- Power lifting
- Sprinting

Major muscles



Principles of muscular actions

- Attach to bones (levers) – origin and insertion
- Cross joints
- Contract and pull on bones
  - Contract and shorten – concentric (Isotonic)
  - Contract and lengthen – eccentric (Isotonic)
  - Contract with no movement – isometric
- Bring about specific joint actions
- Work in pairs
  - One muscle contracts – prime mover
  - Opposite muscle relaxes – antagonist

Origin and insertions

Skeletal muscles attach to bones.

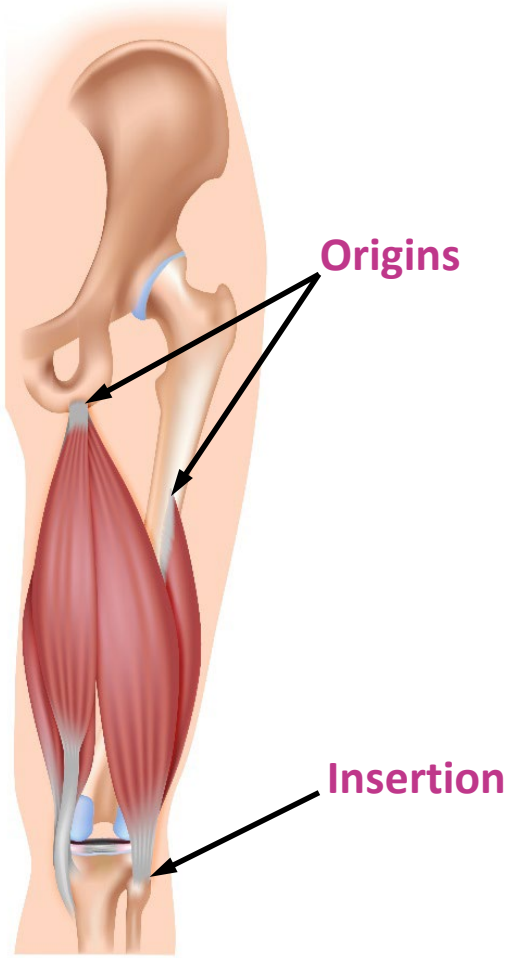
Two attachment points – the origin and insertion.

Origin:

- Closer to the midline
- Proximal attachment
- Fixed during muscular contraction

Insertion:

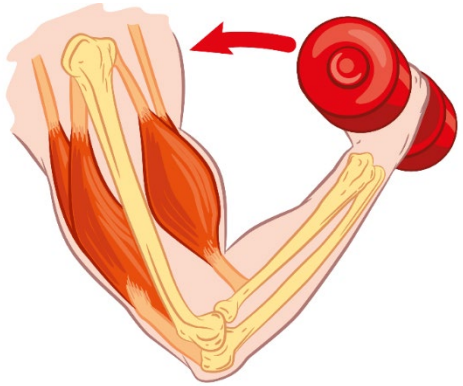
- Further away from the midline
- Distal attachment
- Causes movement of distal bone



Muscle contractions

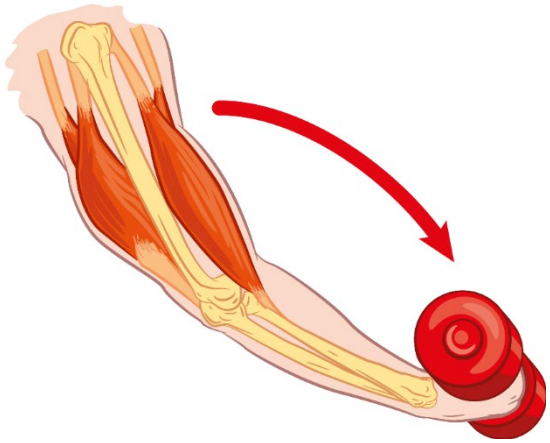
Concentric (positive contraction)

- Generates force to overcome gravity and lift a resistance
- Fibres shorten
- Isotonic



Eccentric (negative contraction)

- Generates force to control and lower a resistance
- Fibres lengthen
- Isotonic



Isometric (static)

- Generates force without movement
- Fibres stay the same length

Muscle roles during movement

- **Agonist or prime mover**
  The main muscle creating the action

- **Antagonist**
  The opposite movement to the agonist

- **Synergist**
  The muscle that assists or modifies agonist movement

- **Fixator**
  The muscle that stabilises movement at another joint

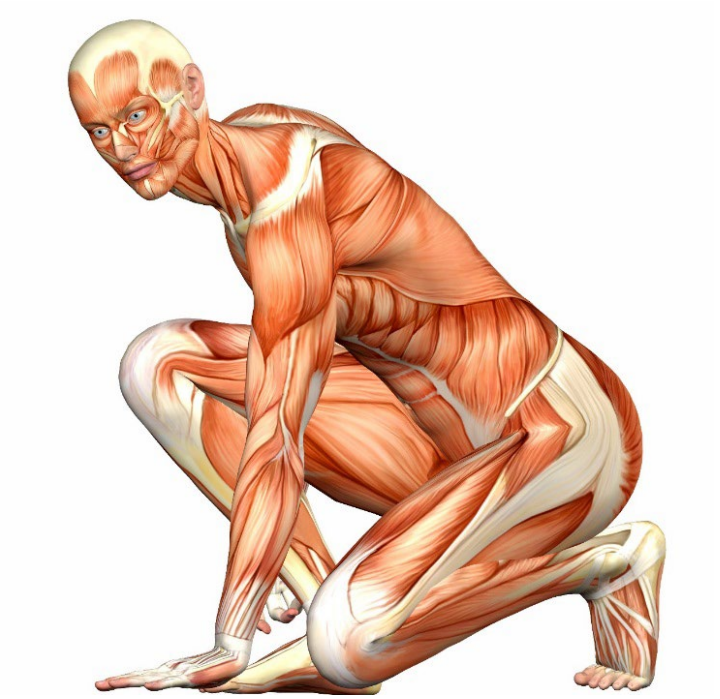
Activity

- 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

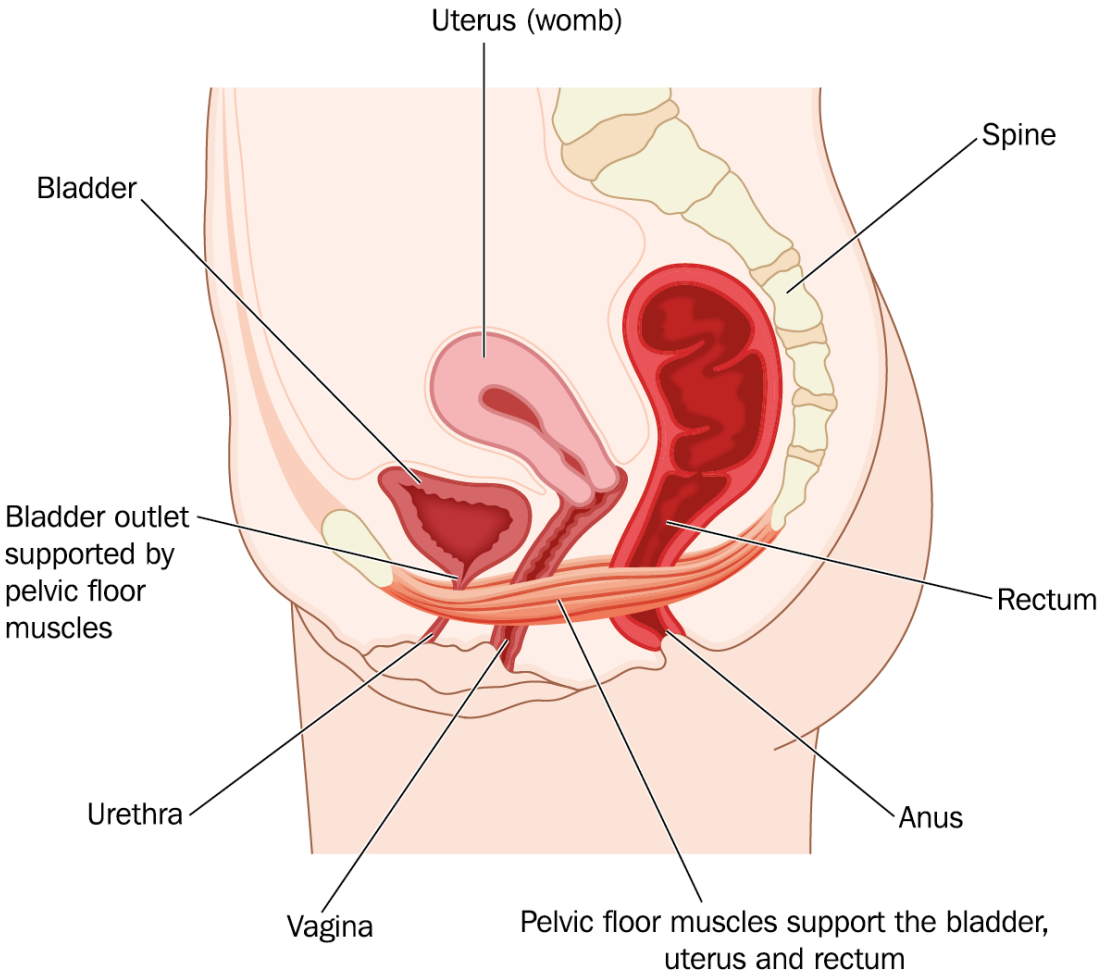
Activity

Which muscle contracts concentrically to create the joint actions?

- Knee flexion
- Hip Extension
- Elbow extension
- Hip adduction
- Shoulder adduction
- Spine rotation
- Spine flexion
- Ankle plantar flexion
- Shoulder girdle retraction



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

Learning check quiz

- Describe the three types of muscle tissue
- Where would you locate the following muscles:
  - Gastrocnemius
  - Adductors
  - Trapezius
- Describe the different muscle fibre types, their characteristics and types of sports which emphasise specific types

Learning check quiz

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

- Describe the following:
  - Isotonic
  - Eccentric
  - Antagonist
  - Fixator

VTCT

USP182 - Anatomy and physiology for exercise and fitness professionals

LO3 Know the structure and function of the circulatory system in relation to exercise

Content and Assessment Criteria

- Know the location of the heart
- Know the function of the heart
- Know the structure of the heart
- Know how blood flows through the four chambers of the heart
- Know systemic and pulmonary circulation
- Know the structure and functions of blood vessels
- Know blood pressure and blood pressure classifications
- Know the effects of disease and the benefits of exercise on the circulatory system

The circulatory system

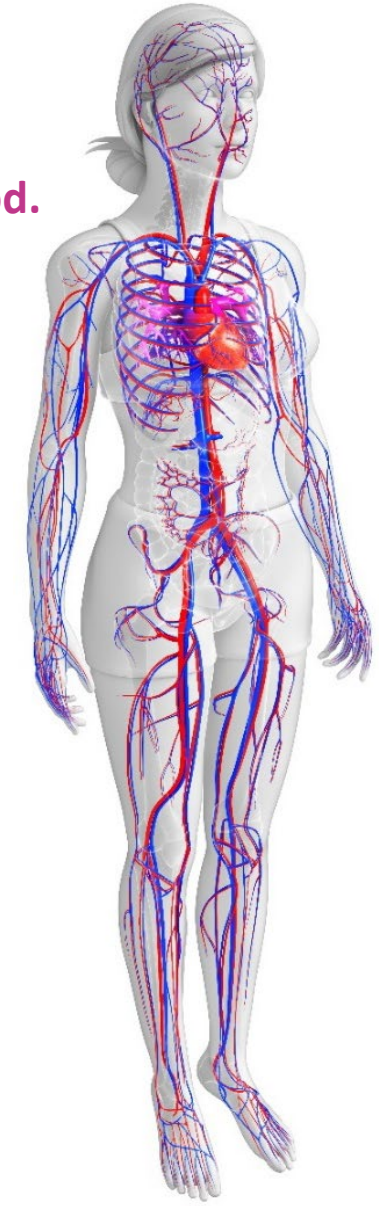
The circulatory system is responsible for the circulation of blood.

The main structures include:

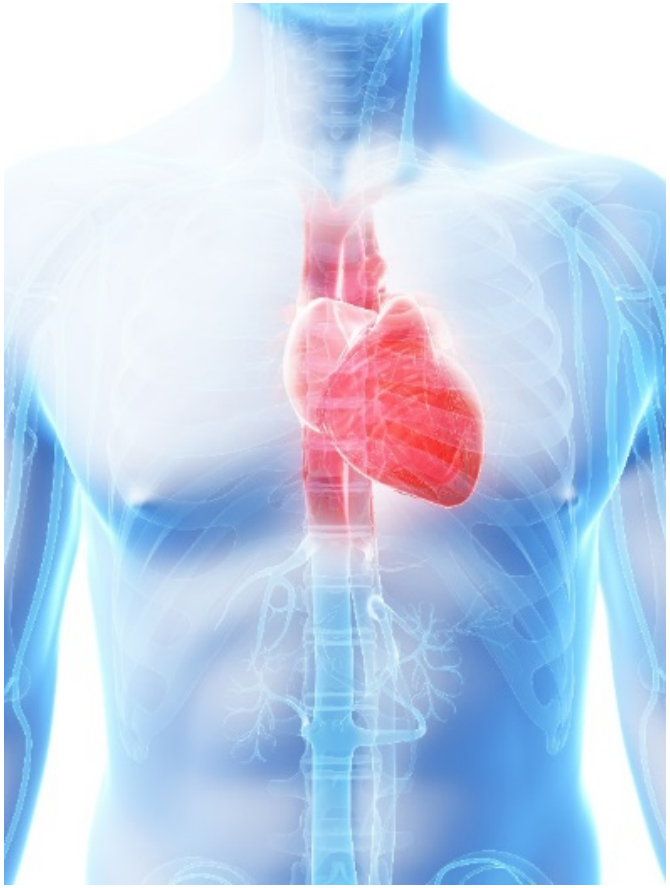
- **The heart (cardio)**
  A cardiac muscle pump

- **The blood vessels (vascular)**
  Arteries, arterioles, capillaries, venules and veins

- **The blood**
  Fluid containing water nutrients, proteins, and cells



The location of the heart



- Located in the thoracic cavity
- Between the right and left lungs
- Protected by the rib cage
- Posterior to the sternum/just left of centre
- Size of a clenched fist
- Muscular pump

Structure and function of the heart

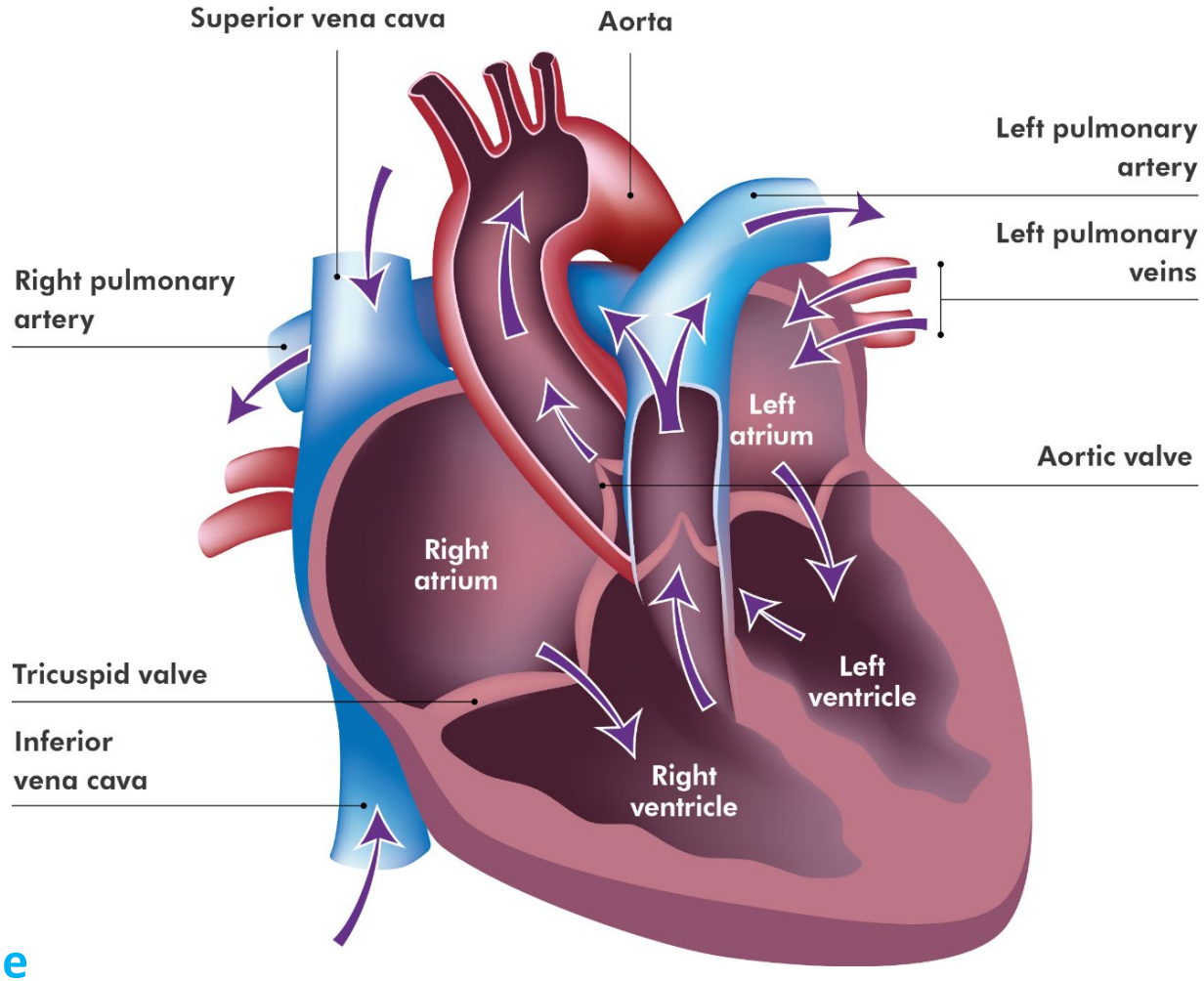
- **Four chambers**
  - Upper chambers – atria
  - Lower chambers – ventricles

- **Two sides**
  - Left side – oxygenated blood
  - Right side – deoxygenated blood

- **Circulates blood**
  - Oxygenated to the body (systemic)
  - Deoxygenated to the lungs (pulmonary)

The heart

Left side



Right side

Blood flow through the heart

- Oxygenated blood from lungs to:
  - Left atrium
  - Left ventricle

- To body via the aorta

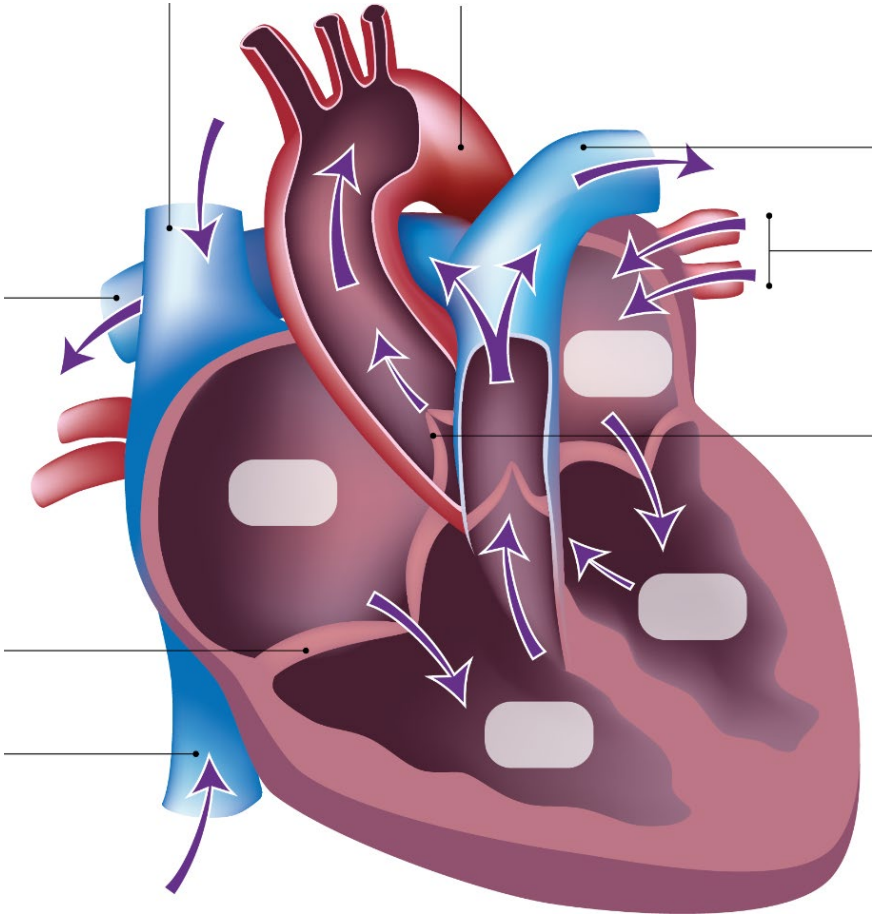
- Back to heart from the body via vena cava to:
  - Right atrium
  - Right ventricle

- Deoxygenated blood to lungs

Activity

Name the structures

Name the type of blood (oxygenated or deoxygenated)



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

Pulmonary circulation

Between the heart and lungs

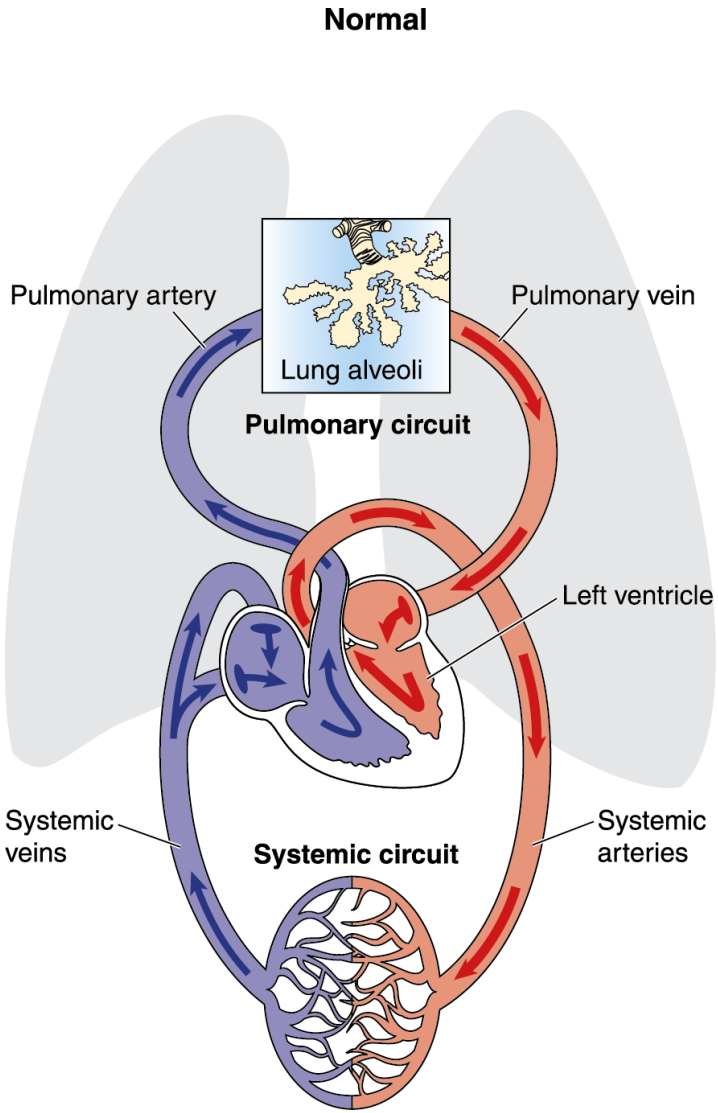
- Right ventricle
- Pulmonary artery
- Pulmonary vein
- Left atrium

Systemic circulation

Between the heart and body

- Left ventricle
- Aorta, arteries, arterioles
- Capillaries, venules, veins
- Vena cava
- Right atrium

Pulmonary and systemic circulation



Blood vessels

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

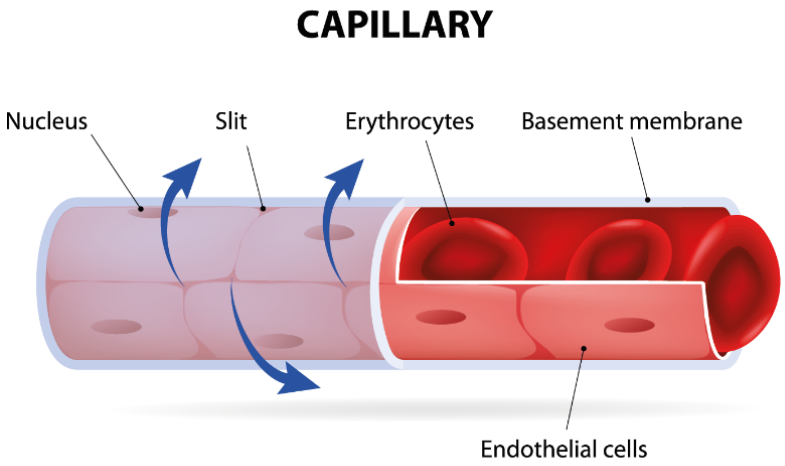
Veins – the ve-in (way in)

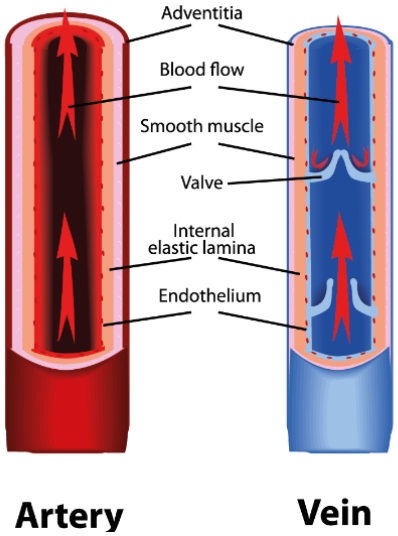
- Carry blood to the heart
- Have thinner muscular walls
- Have non-return valves
- Carry blood under lower pressure

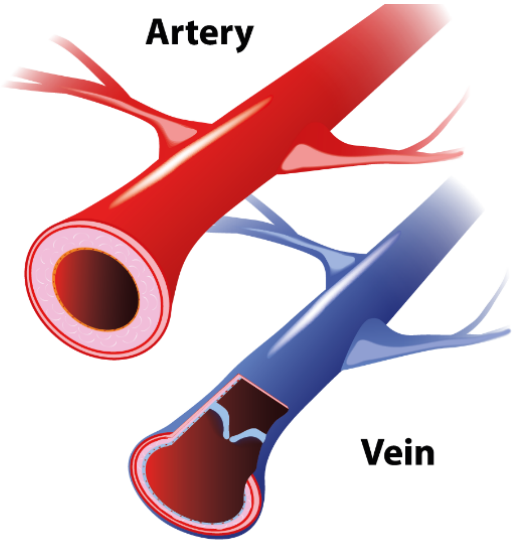
Capillaries

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

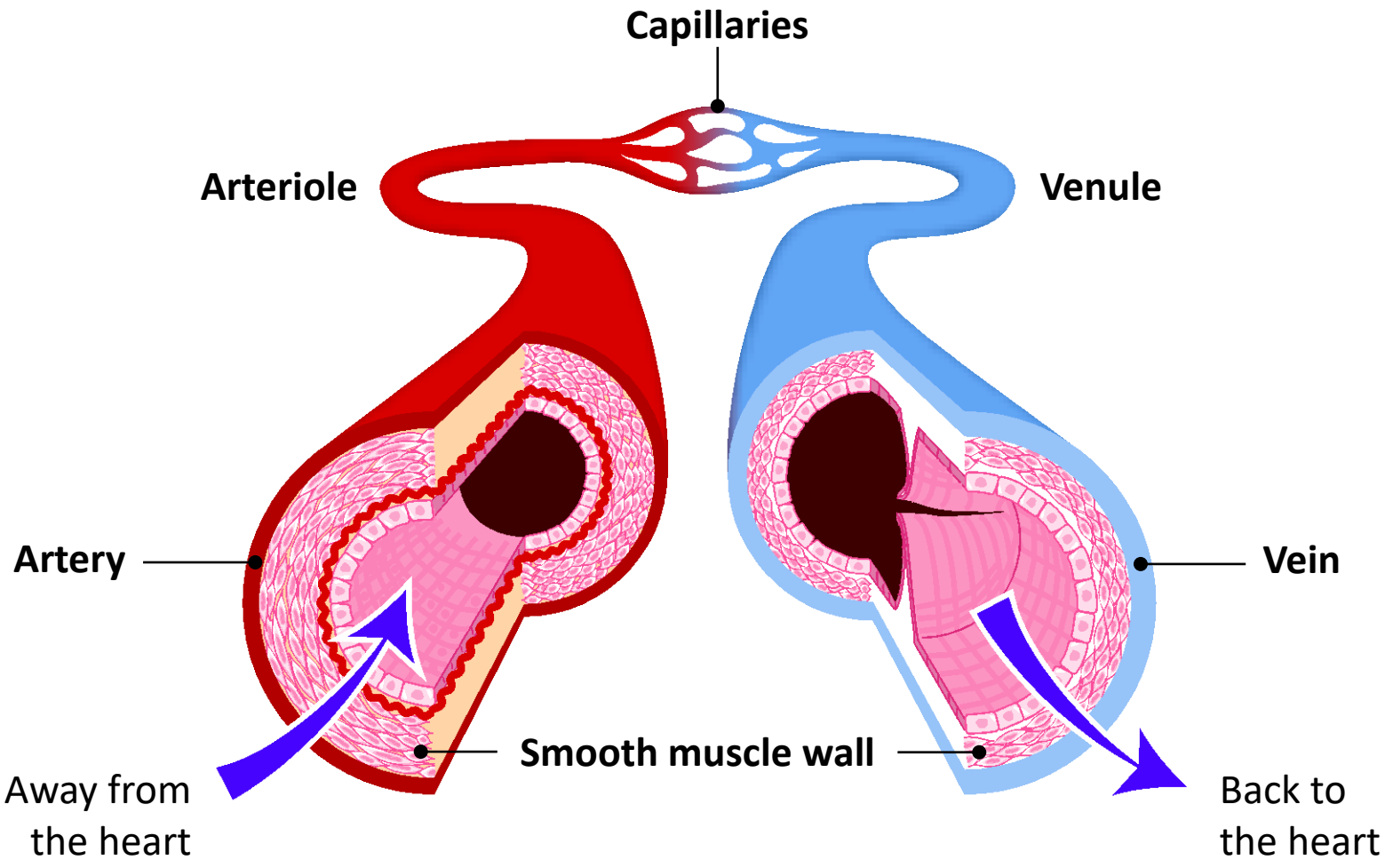
Blood vessels



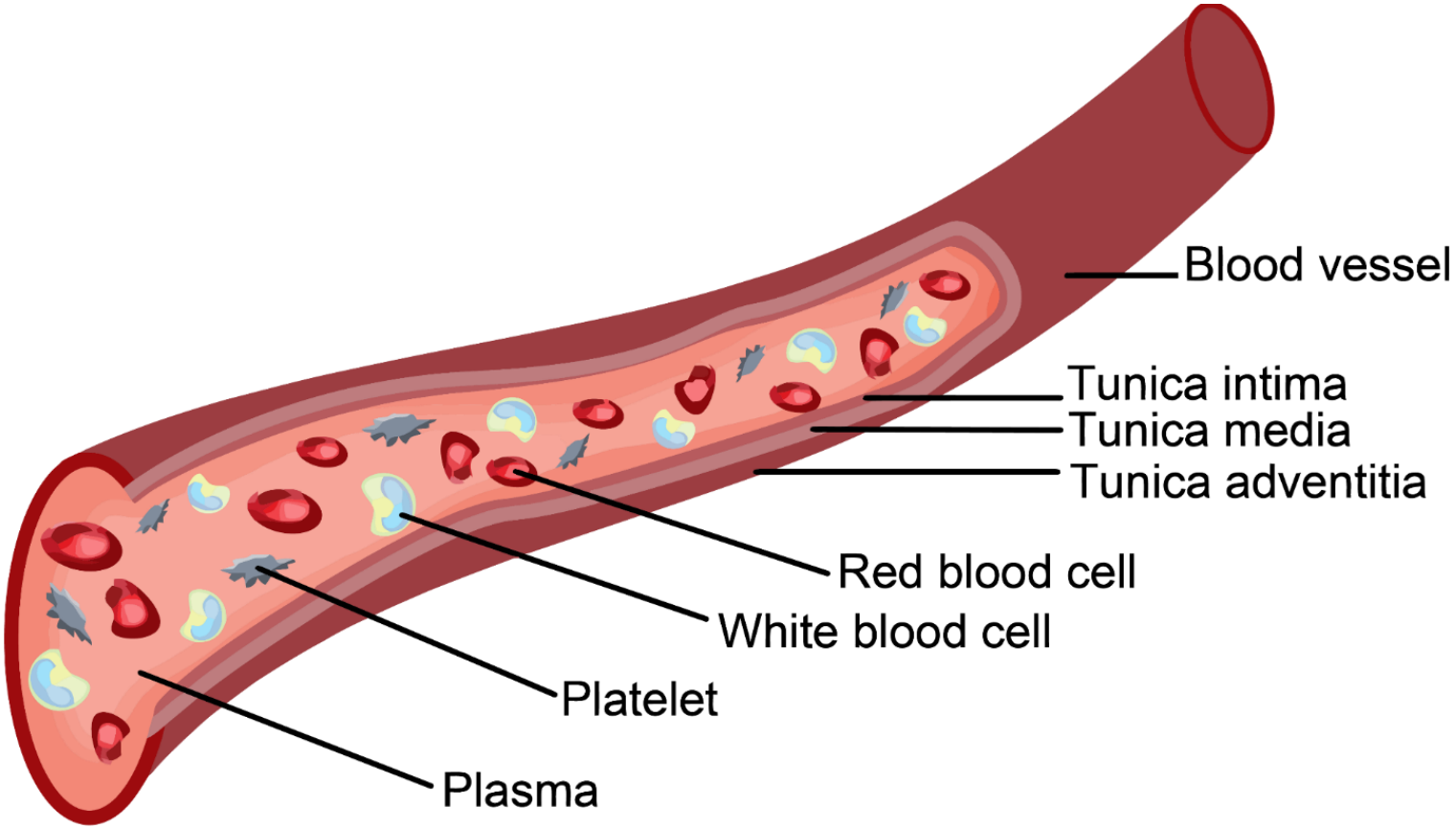




Blood vessels



Composition of the blood



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

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	160-179	100-109
		ACSM (2014, p46)

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

Disease is more prevalent in men than women

Complications

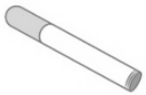
Stroke

Heart attack

Gangrene

Risk

Diabetes



Smoking

Vitamin B6 deficiency

Age

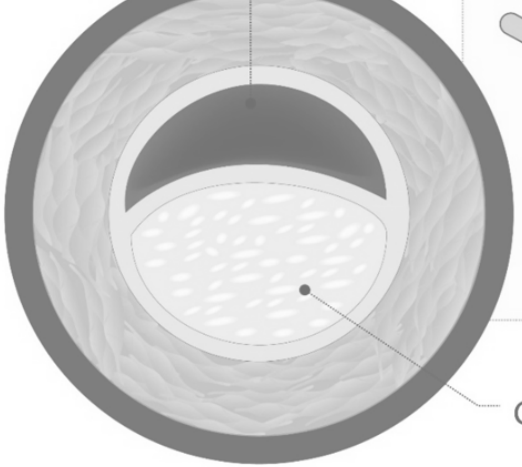
Obesity

Male sex

Genetic abnormalities

Sedentary lifestyle

Unhealthy food



Prevention & Treatment

Weight loss

Exercise

Diet

Fat

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 (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

Cardiovascular exercise benefits

- 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 contra-indications 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

USP182 - Anatomy and physiology for exercise and fitness professionals

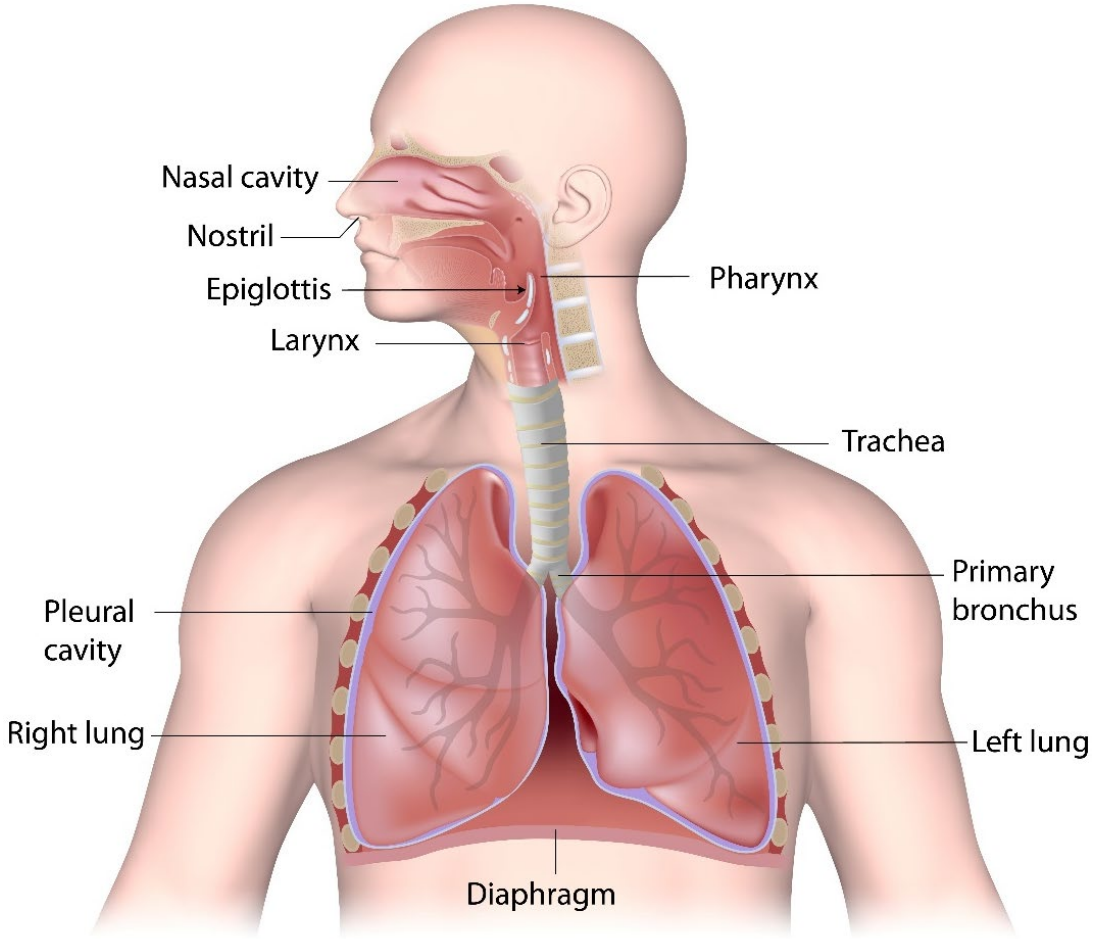
LO4 Know structure and function of the respiratory system in relation to exercise

Assessment criteria

- Know the location of the lungs
- Know the function of the lungs
- Know the structure of the lungs
- Know the main muscles involved in breathing
- Know the passage of air flow through the respiratory tract
- Know the process of gaseous exchange of oxygen and carbon dioxide in the lungs

Location of lungs

The lungs are located in the rib cage or thoracic cavity.



Function of the lungs and respiratory system

The lungs and respiratory system work with the cardiovascular system to ensure the body receives oxygen and removes carbon dioxide.

The respiratory system:

- Takes in oxygen from the atmosphere
- Releases carbon dioxide into the atmosphere

The cardiovascular system:

- Circulates oxygen to the cells of the body
- Collects carbon dioxide from the cells of the body

All cells need oxygen to survive and perform their various activities.

Composition of air

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

Respiratory system structures

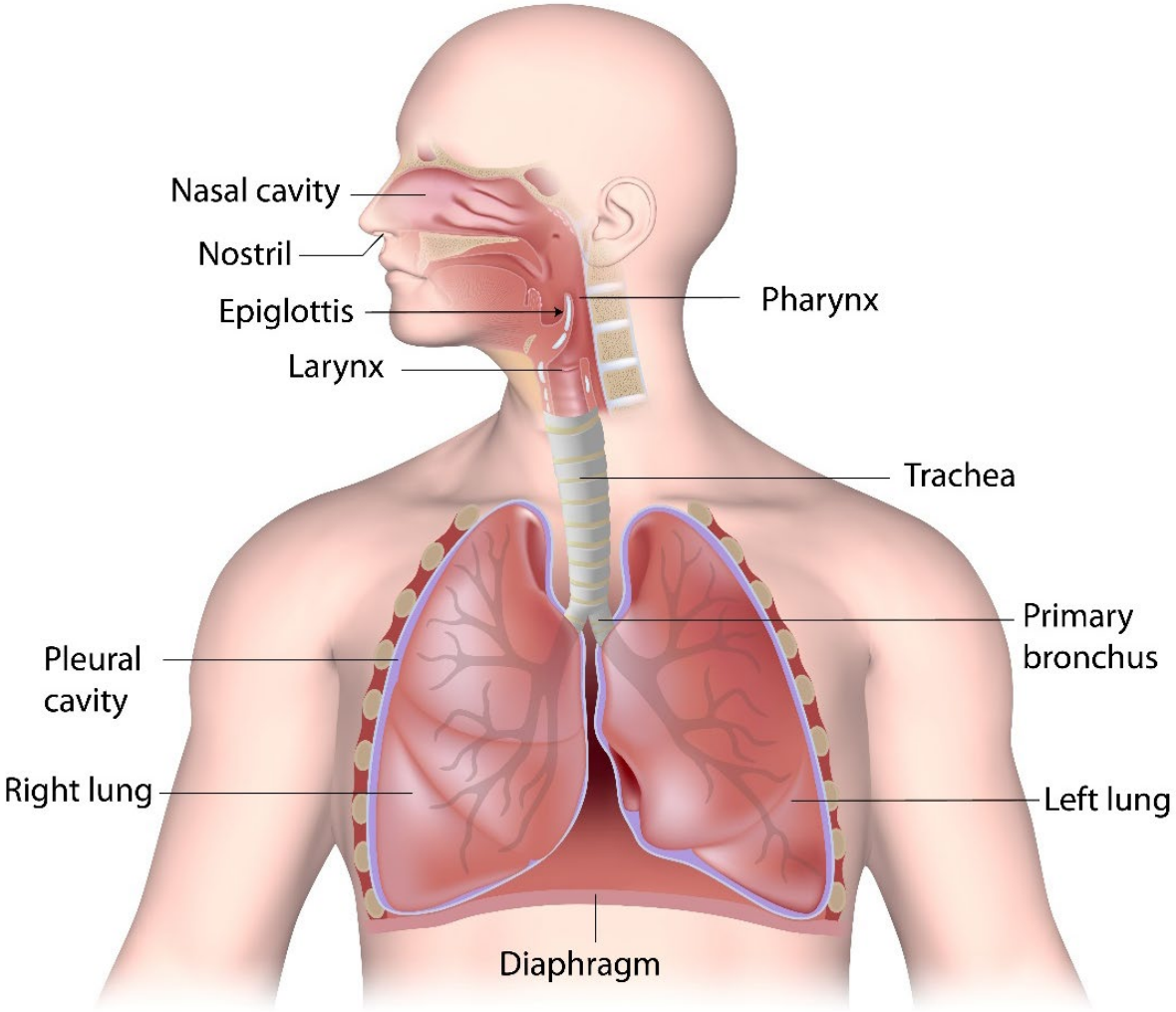
The upper respiratory system:

- The nose
- The mouth
- The pharynx
- The larynx

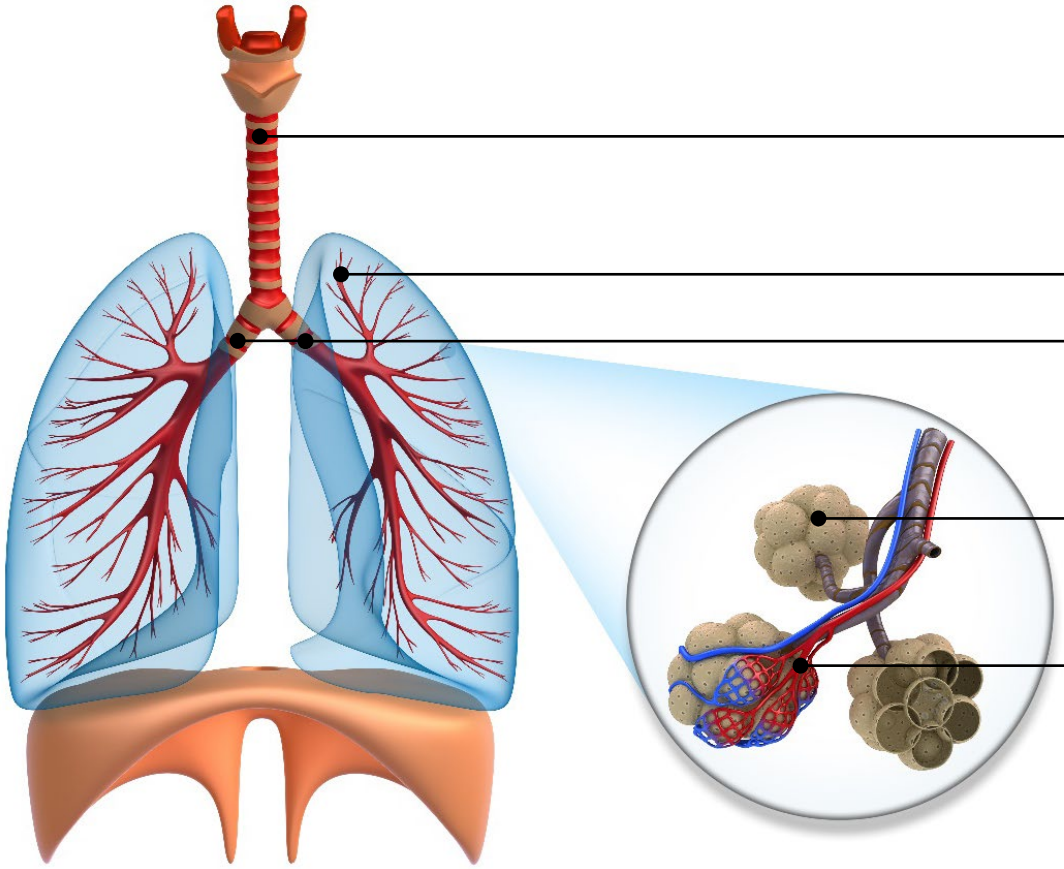
The lower respiratory system:

- The trachea
- The bronchi (right bronchus and left bronchus)
- The bronchioles
- The alveoli (surrounded by capillaries)

Respiratory system structures



The structure of the lungs



Trachea – windpipe

Bronchioles

Bronchi – right and left

Alveoli – air sacs

Capillaries

Activity

Place your hands on your rib cage.

Breathe in and out.

- What happens to the rib cage when you breathe in?

- What happens to the rib cage when you breathe out?

Mechanics of breathing

Breathe in – Inspiration

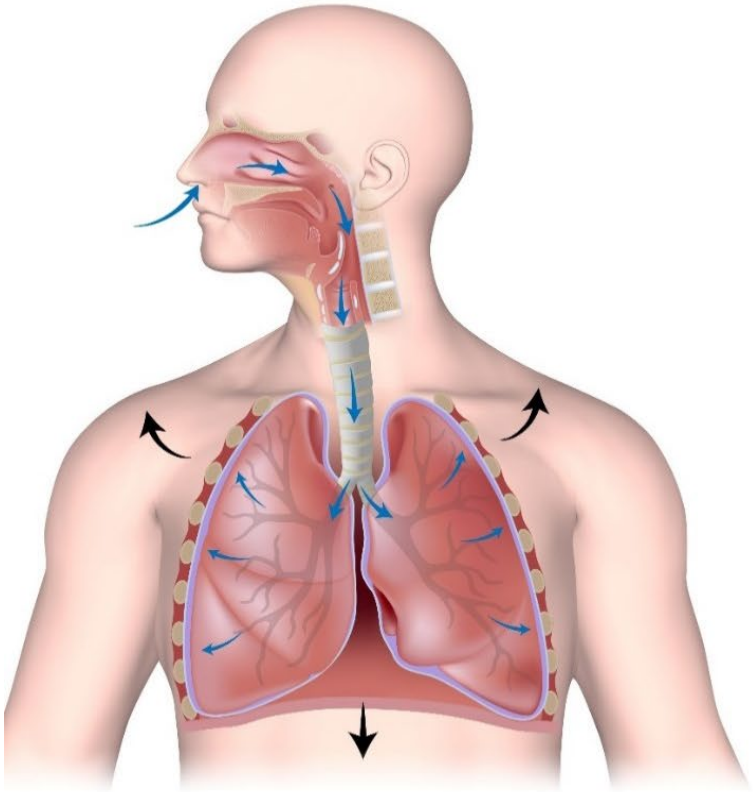
- Rib cage expands
- Diaphragm contracts and lowers (descends)
- Intercostal muscles contract
- Lungs inflate (fill with air)

Breathe out – Expiration

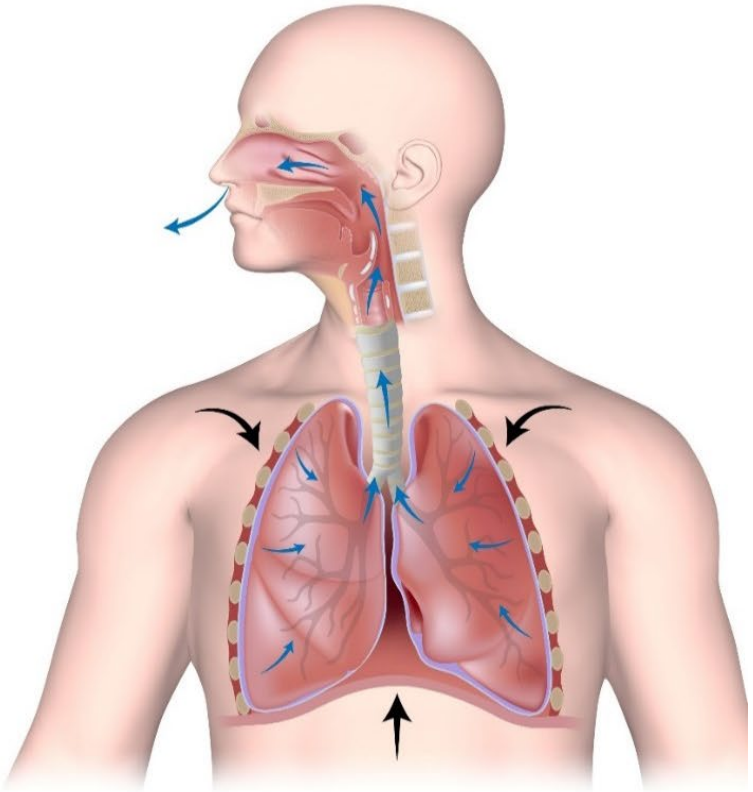
- Rib cage returns to normal
- Diaphragm relaxes and rises (ascends)
- Lungs deflate (air removed)

Mechanics of breathing

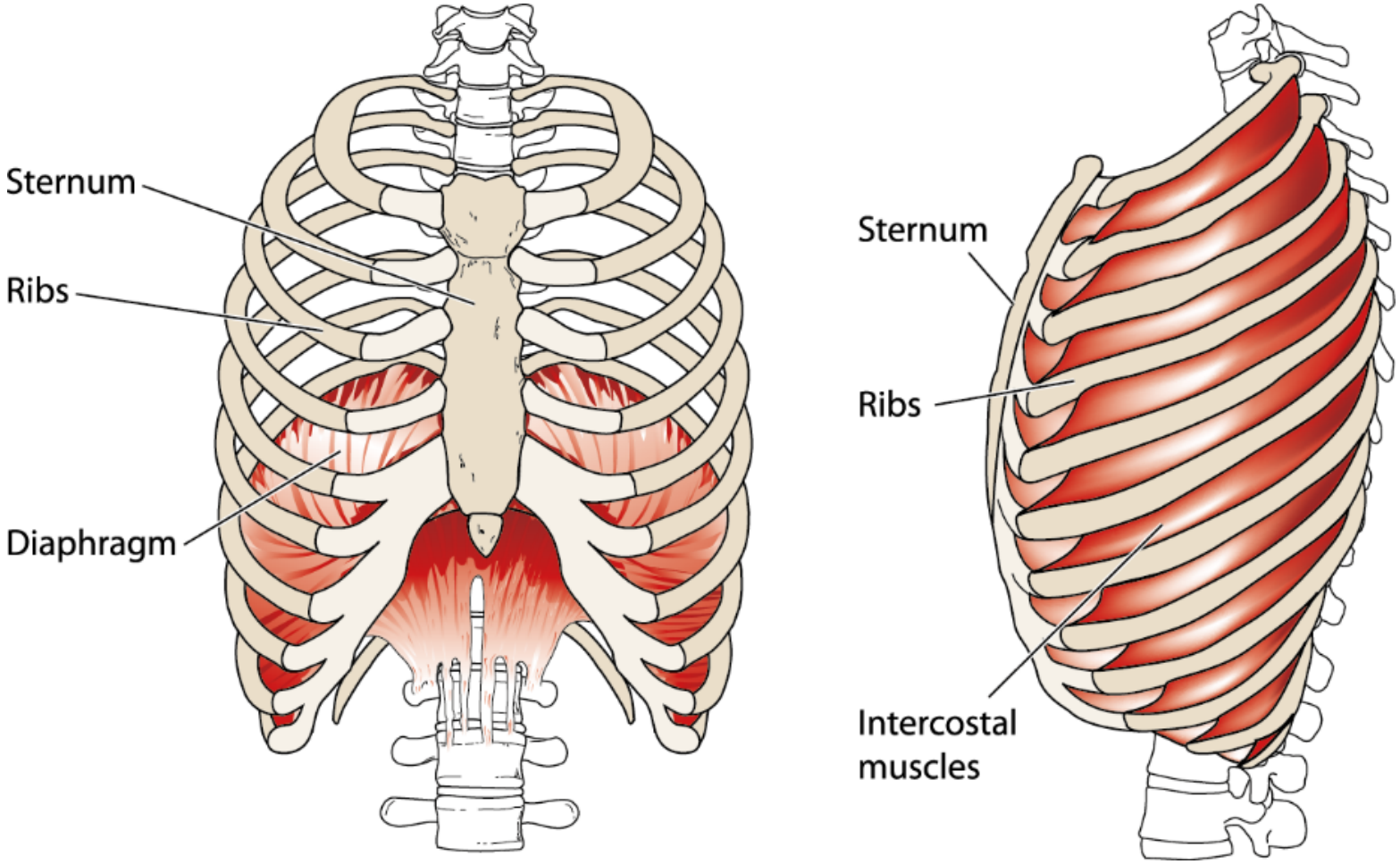
Inspiration



Expiration



Muscles involved in breathing



Accessory breathing muscles

Help increase intake of oxygen when the demand increases.

- Abdominals help draw the rib cage down and out
- Sternocleidomastoid and scalenes help draw the rib cage up and out

The journey of air to the body

Breathe in

- Nose and mouth
- Pharynx and larynx
- Trachea
- Bronchus, bronchioles
- Alveoli

Gaseous exchange occurs in the lungs

- Oxygenated blood circulated from the lungs to the heart
- Pulmonary vein enters left atrium, moves to left ventricle
- Circulated to body via aorta, arteries, arterioles, capillaries

Oxygen reaches the cells

The journey of air from the body

Gaseous exchange – body cells

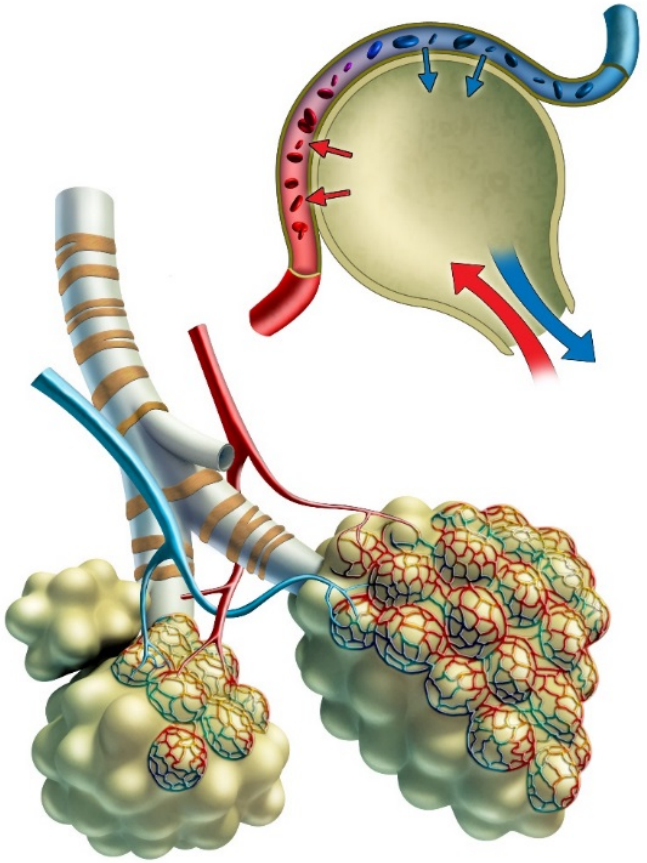
- Cells receive oxygen and release carbon dioxide into capillaries
- Deoxygenated blood travels to the heart, via vena cava
- Circulated to the lungs

Gaseous exchange in lungs

- Alveoli receive carbon dioxide from capillaries and release oxygen into capillaries
- Pulmonary vein brings oxygenated blood back to the heart

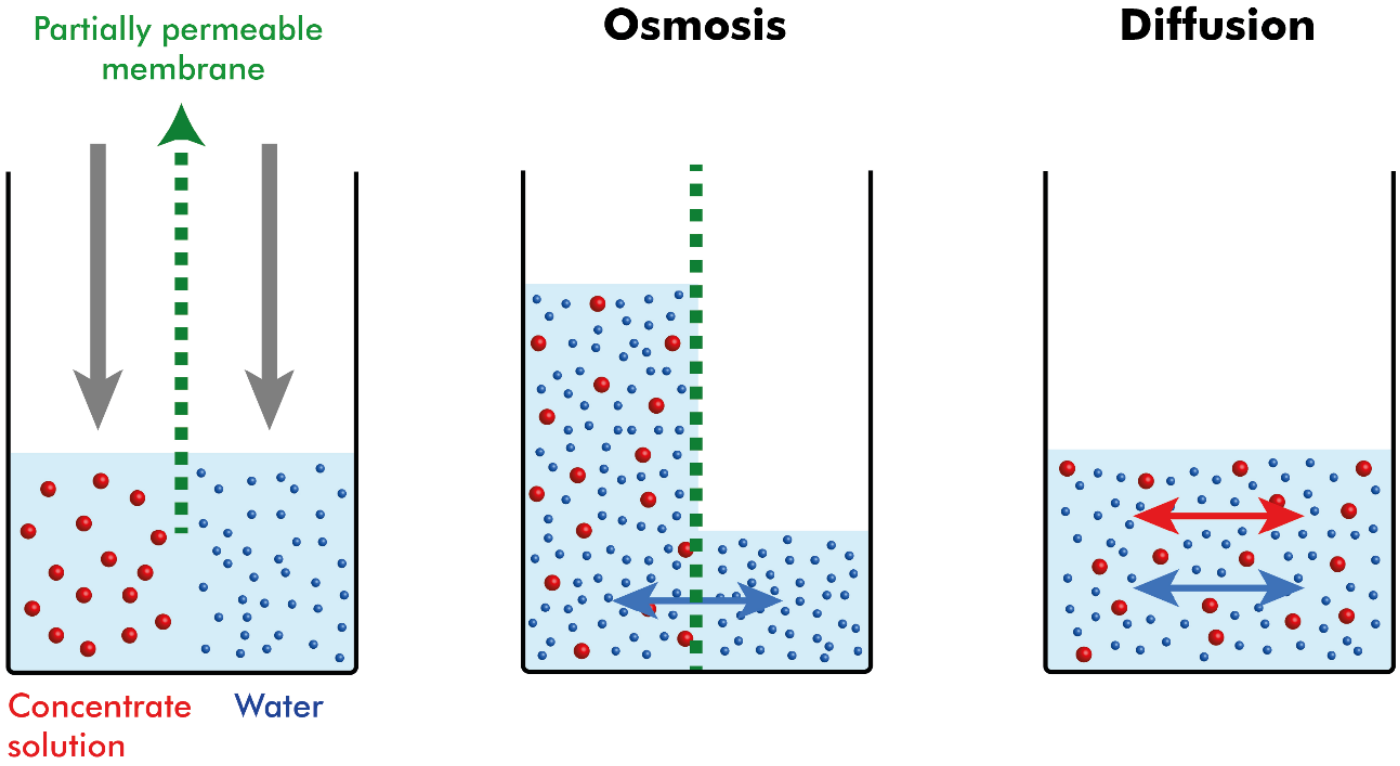
Gaseous exchange in alveoli

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



Diffusion

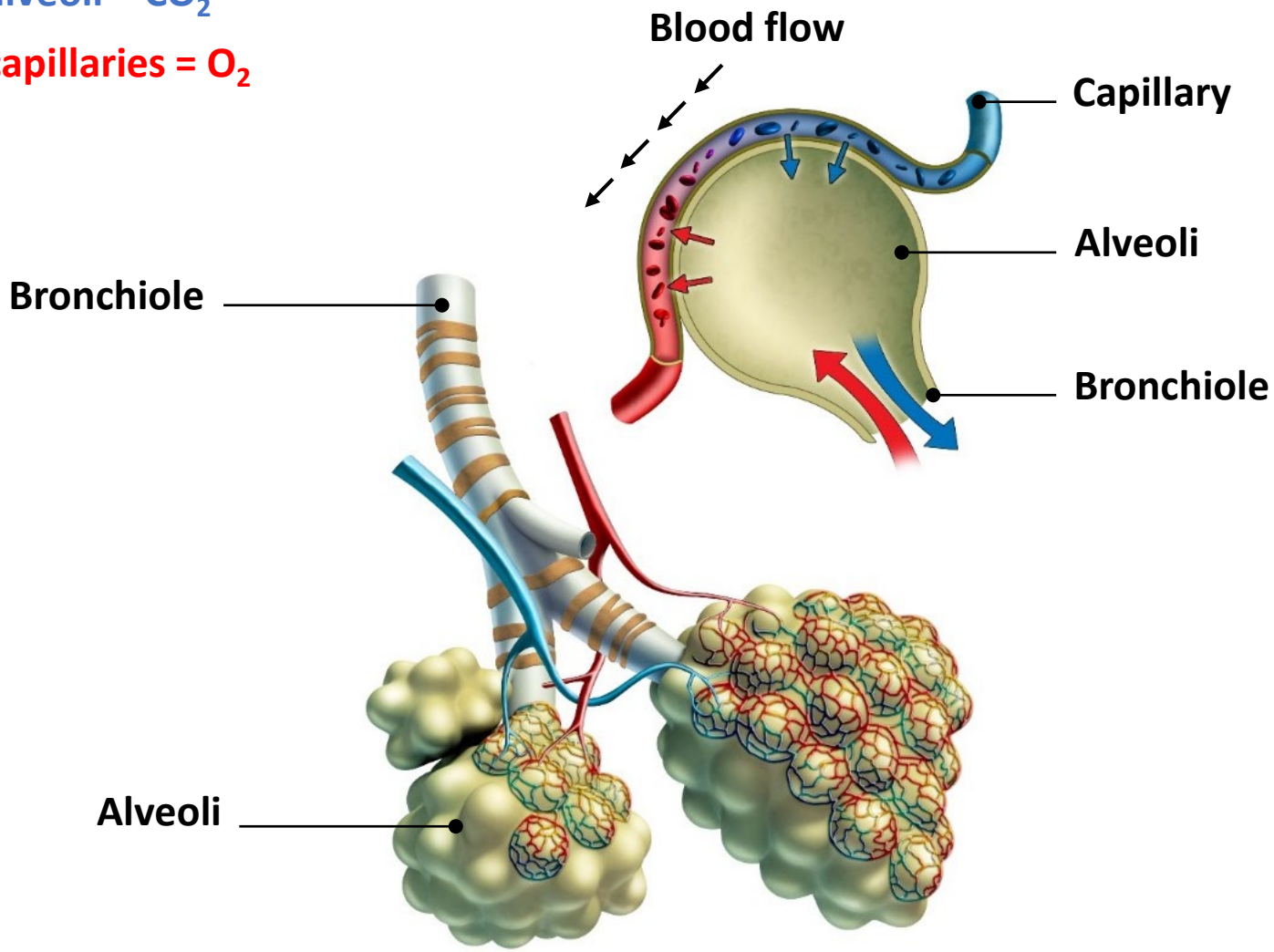
The movement of a substance from an area of high concentration to an area of low concentration.



Gaseous exchange

To alveoli = CO_2

To capillaries = O_2



Activity

- Explain how oxygen enters the body and how it travels around the body
- Name the structures of the respiratory systems it will move through

Learning check

- Identify the location of the lungs
- Describe the function of the lungs
- Describe the structure of the lungs
- Identify the main muscles involved in breathing
- Describe the passage of air through the respiratory tract
- Describe the process of gaseous exchange of oxygen and carbon dioxide in the lungs

VTCT

USP182 - Anatomy and physiology for exercise and fitness professionals

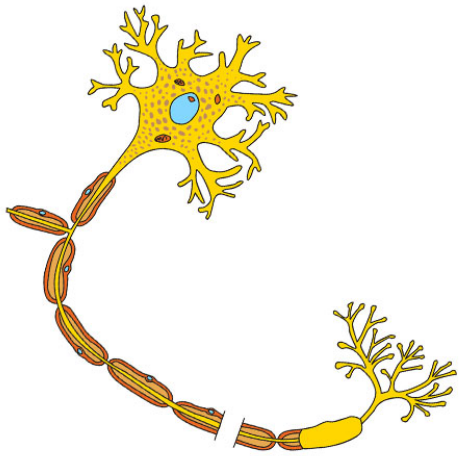
LO5 Know the structure and function of the nervous system in relation to exercise

Assessment criteria

- Know the role and functions of the nervous system
- Know the relationship between the nervous system and principles of muscle contraction and motor unit recruitment
- Know the role of exercise on neuromuscular activity and motor fitness

The nervous system

- 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

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

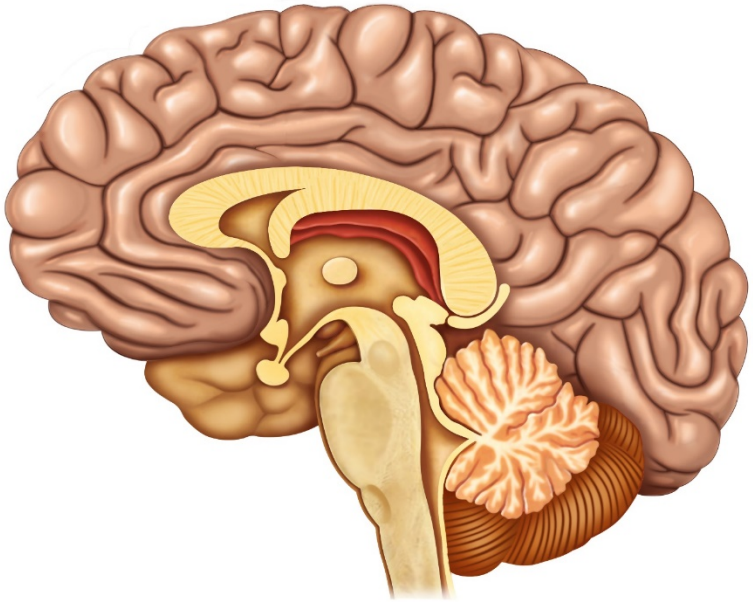
Two main divisions.

Central nervous system (CNS)

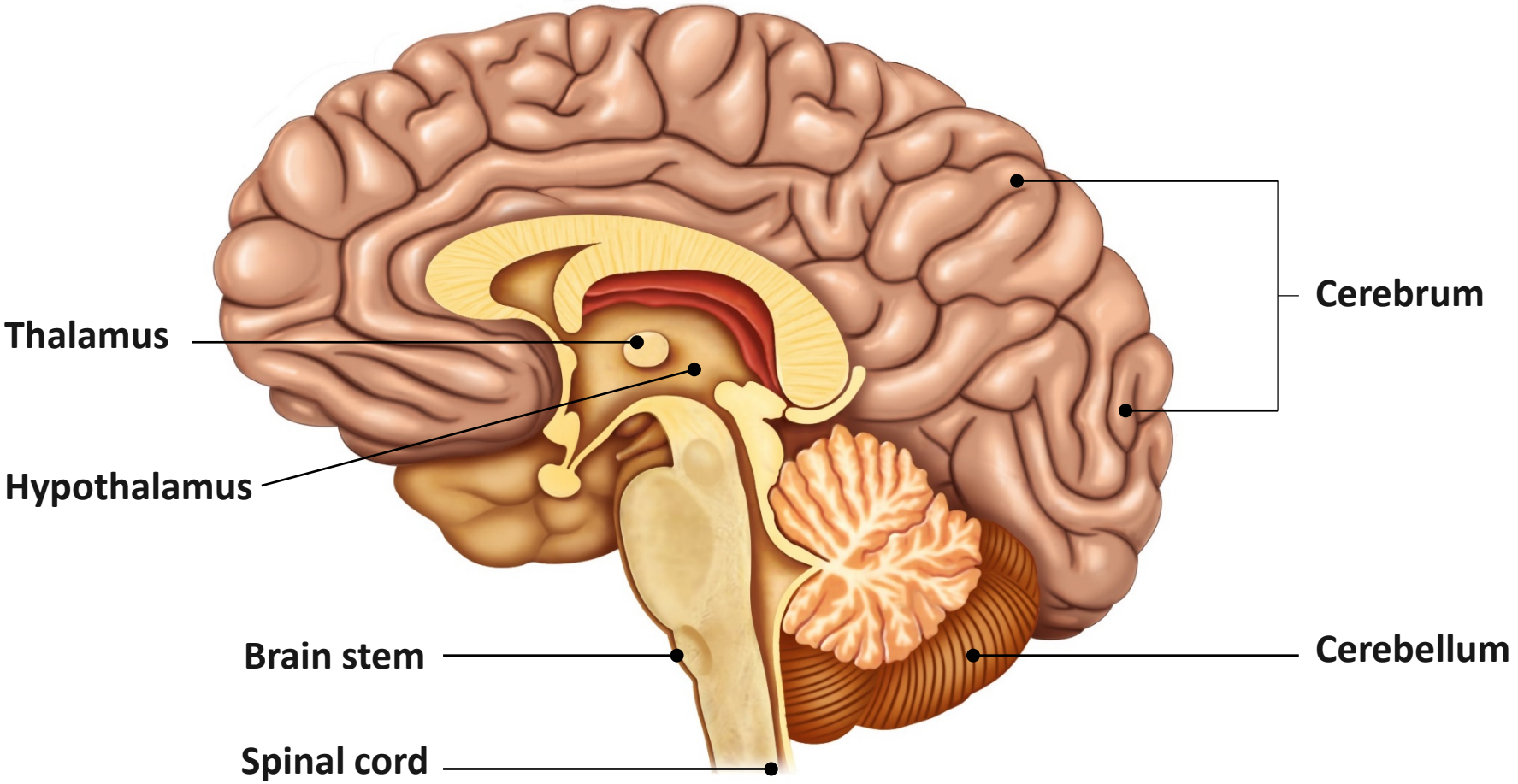
- Brain
- Spinal cord

Peripheral nervous system (PNS)

- The nerves that lie outside the spinal cord
- Sensory neurons
- Motor neurons



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

The peripheral system

Has two subdivisions:

- **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 two 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

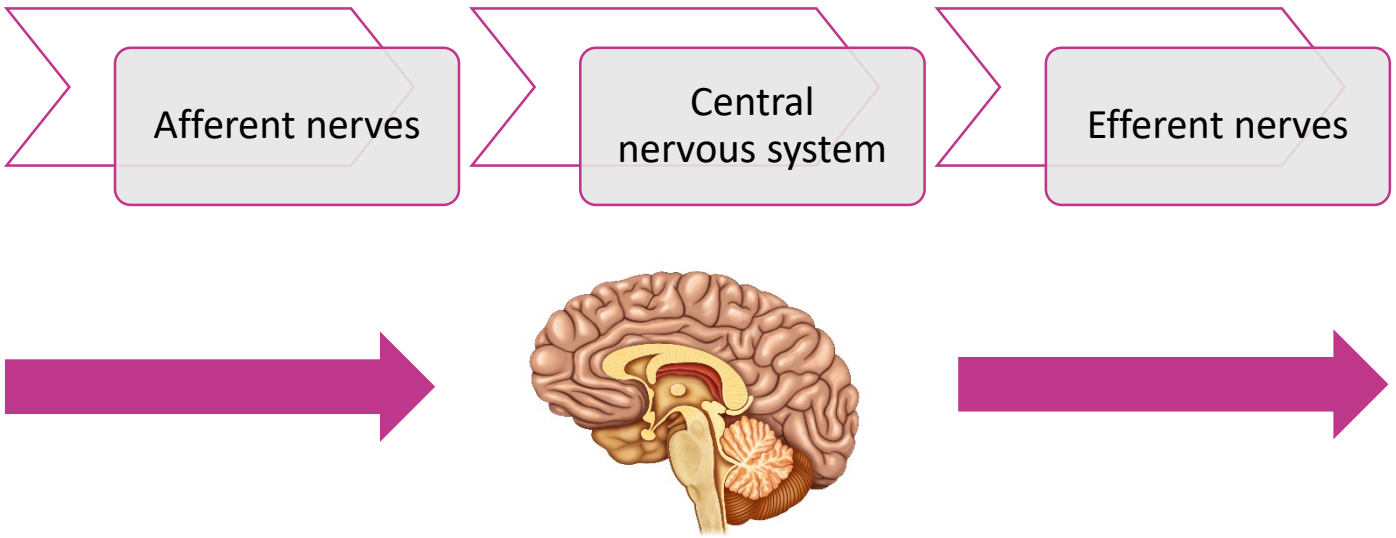
Activity

Describe each of the following:

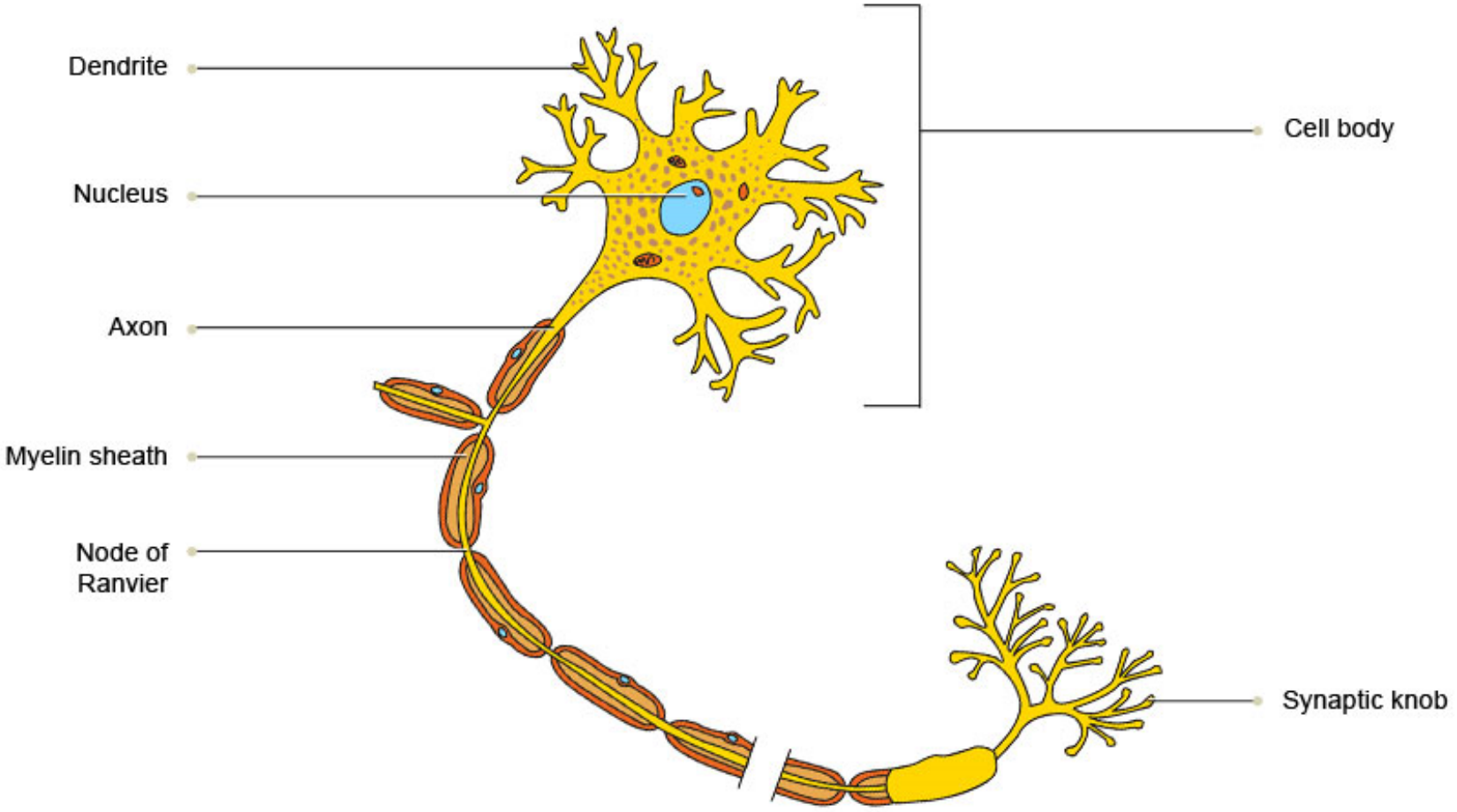
- The central nervous system
- The peripheral nervous system
- The somatic nervous system
- The autonomic nervous system
- The sympathetic nervous system
- The parasympathetic nervous system

Nerves

- **Afferent** (sensory neurons) from the body to the CNS
- **Efferent** (motor neurons) from the CNS to the body
- **Interneurons** (relay neurons) communication between sensory or motor nerves and the CNS

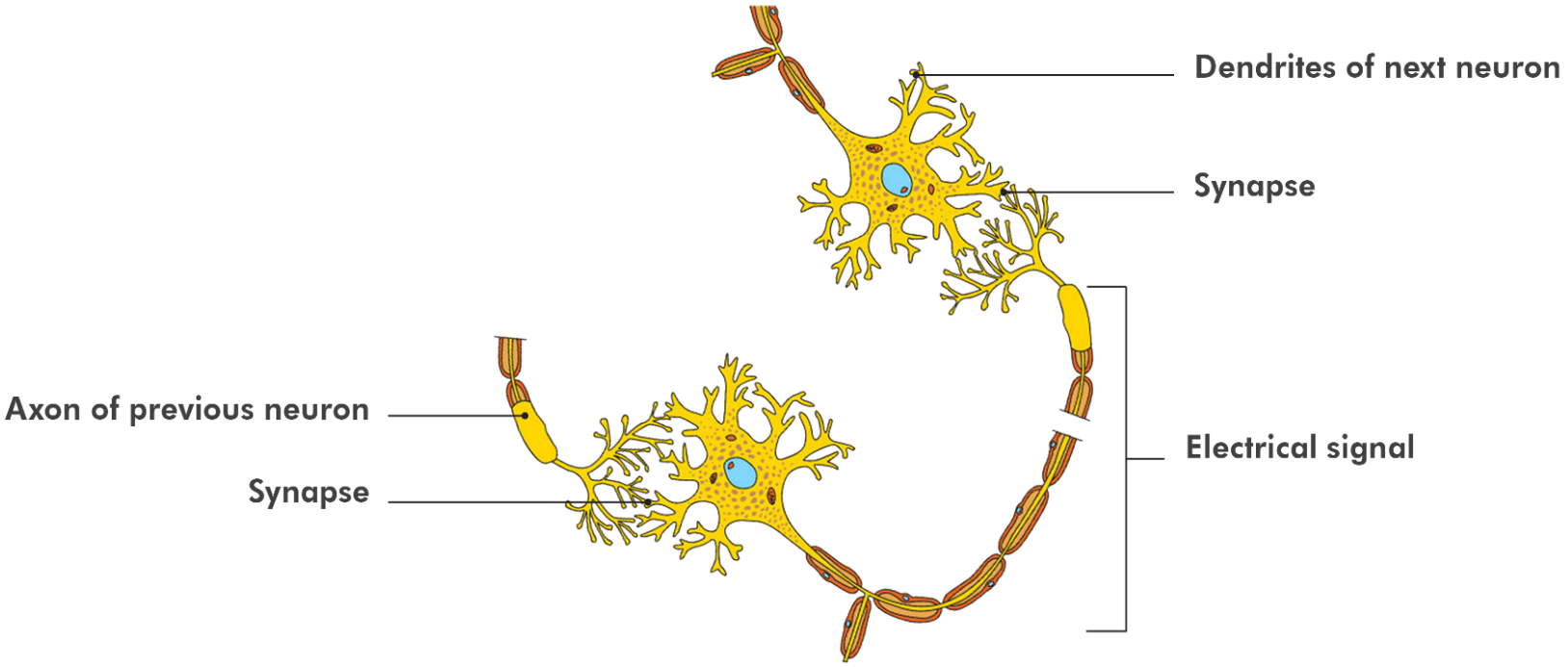


Structure of a neuron



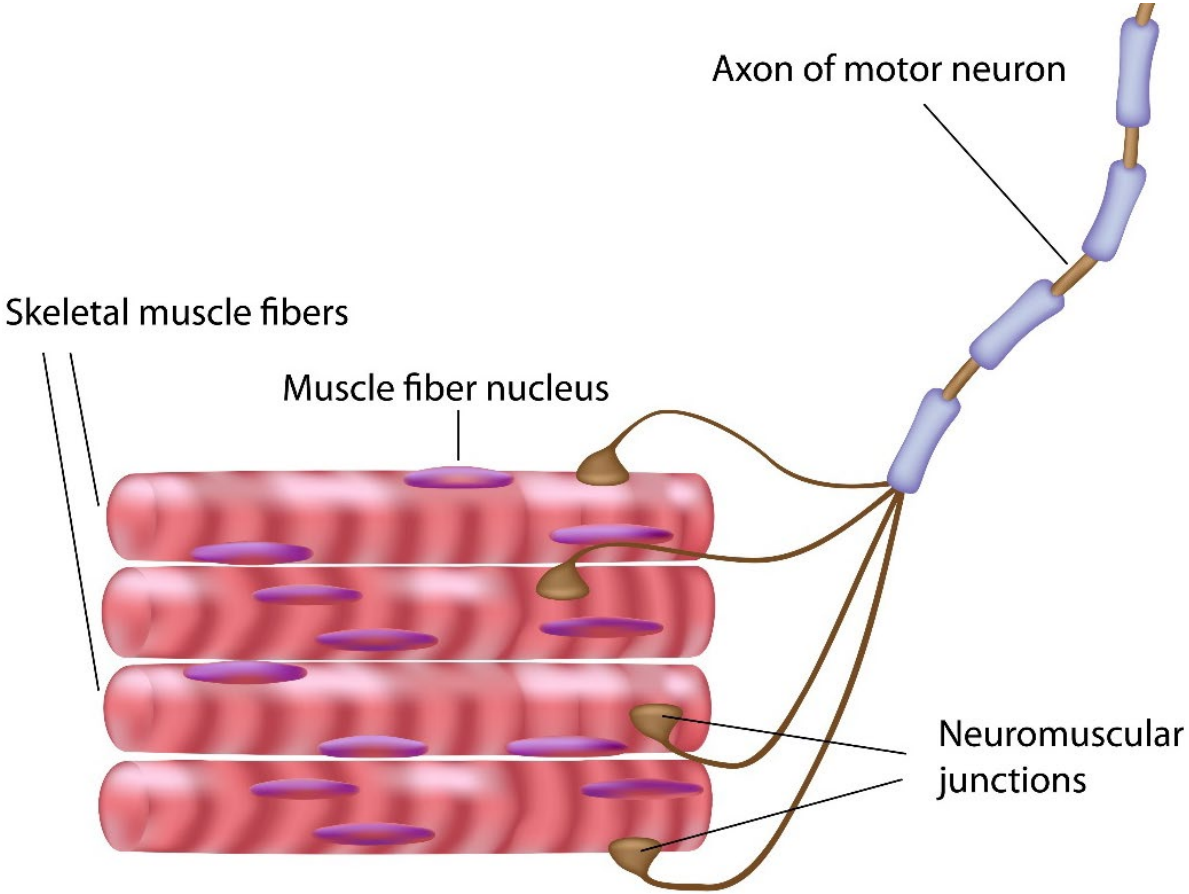
Action potential

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



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

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

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

- **Stretch reflex**
  Muscle spindles activate 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

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

Learning check

- Describe the role and functions of the nervous system
- Describe the principles of muscle contraction
- Describe the ‘all or none law’/motor unit recruitment
- Describe how exercise can enhance neuromuscular connections and improve motor fitness

USP182 - Anatomy and physiology for exercise and fitness professionals

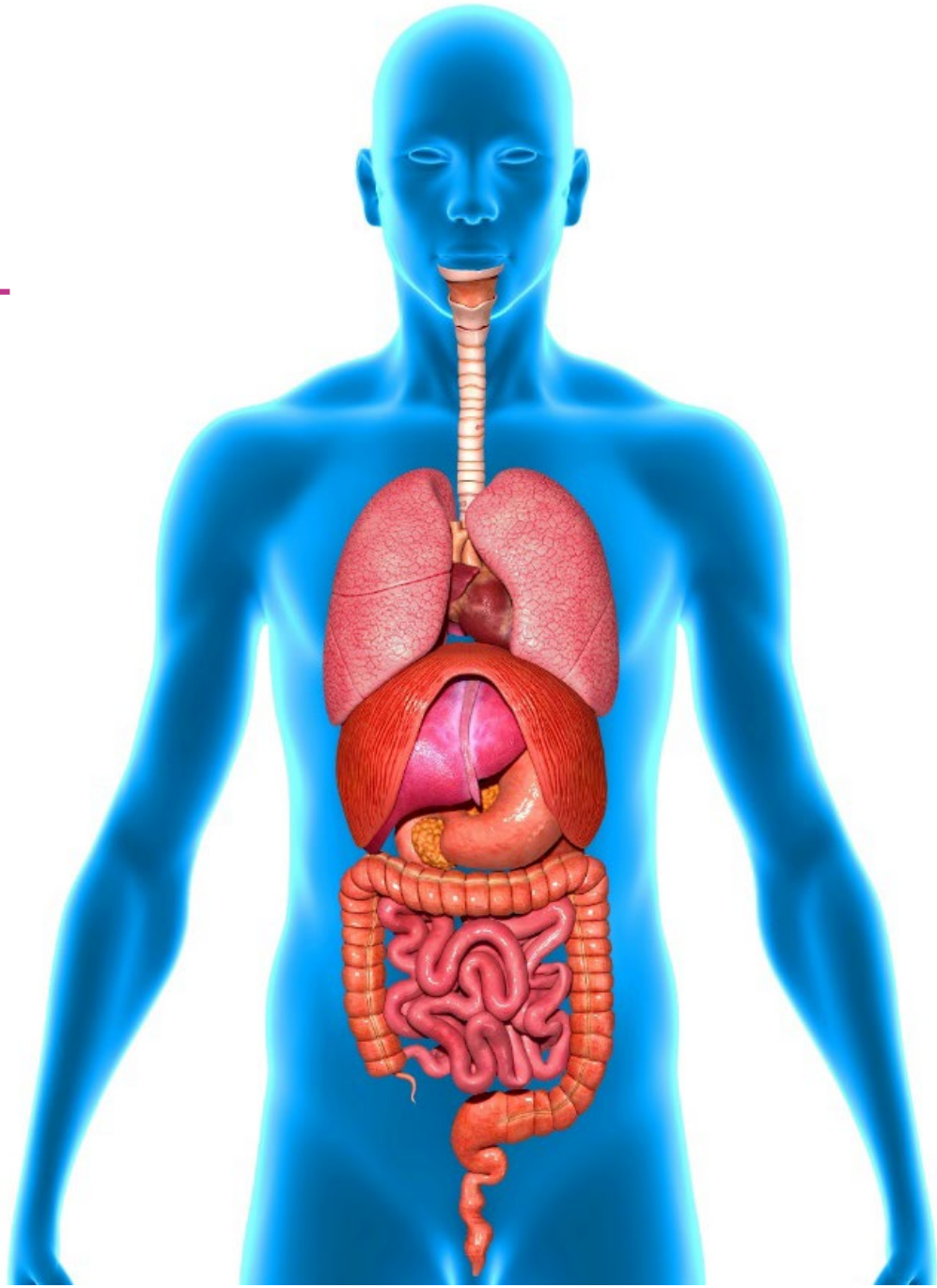
LO6 Know the structure and function of the digestive system

Content and Assessment Criteria

- Know the structure and function of the digestive system
- Know how macronutrients are digested and absorbed
- Know the role of dietary fibre in the maintenance of gut function
- Know the timescales for digestion
- Know the importance of fluid

Activity

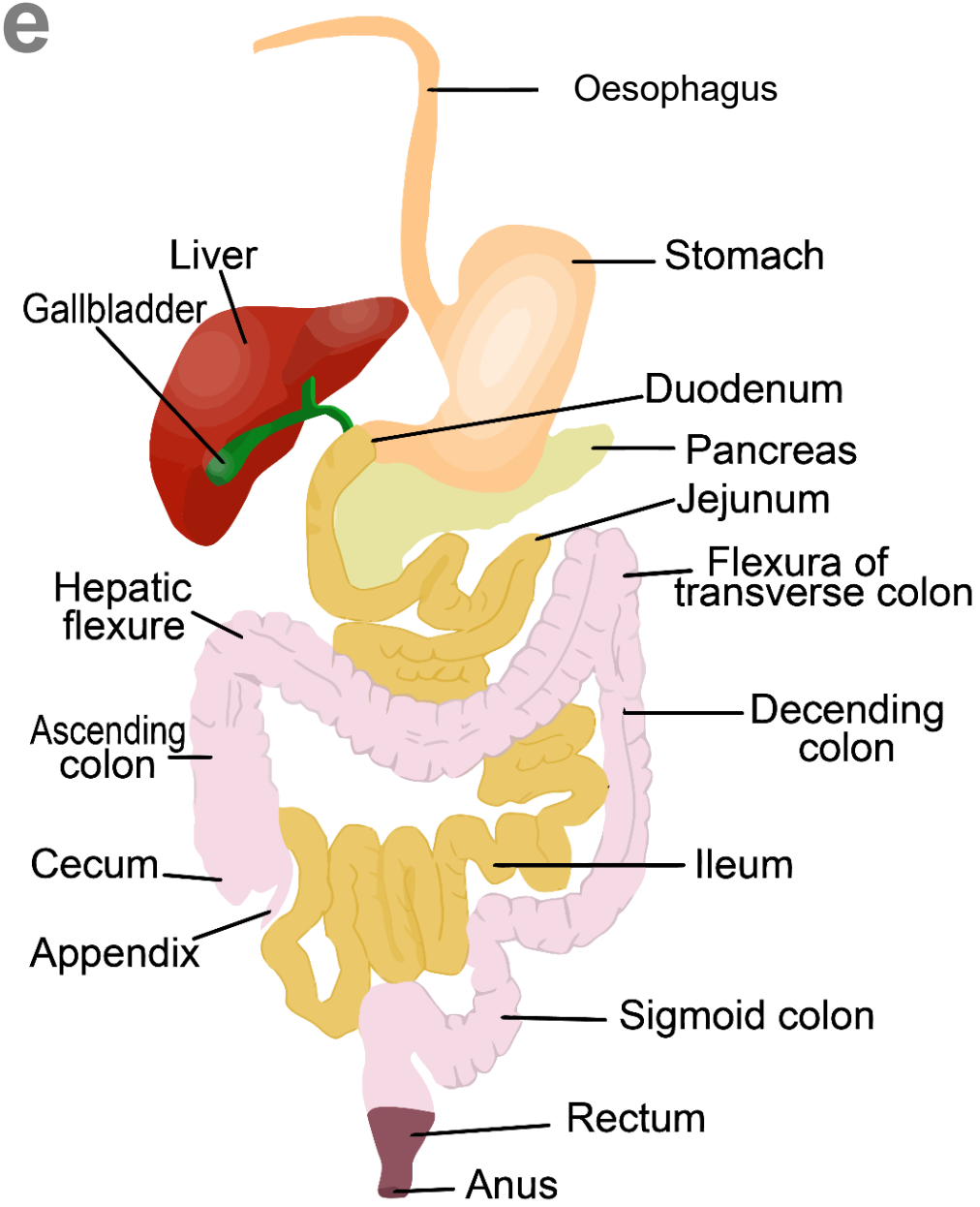
Can you name some of the structures, that form part of the digestive system, in the diagram?



Digestive system structures

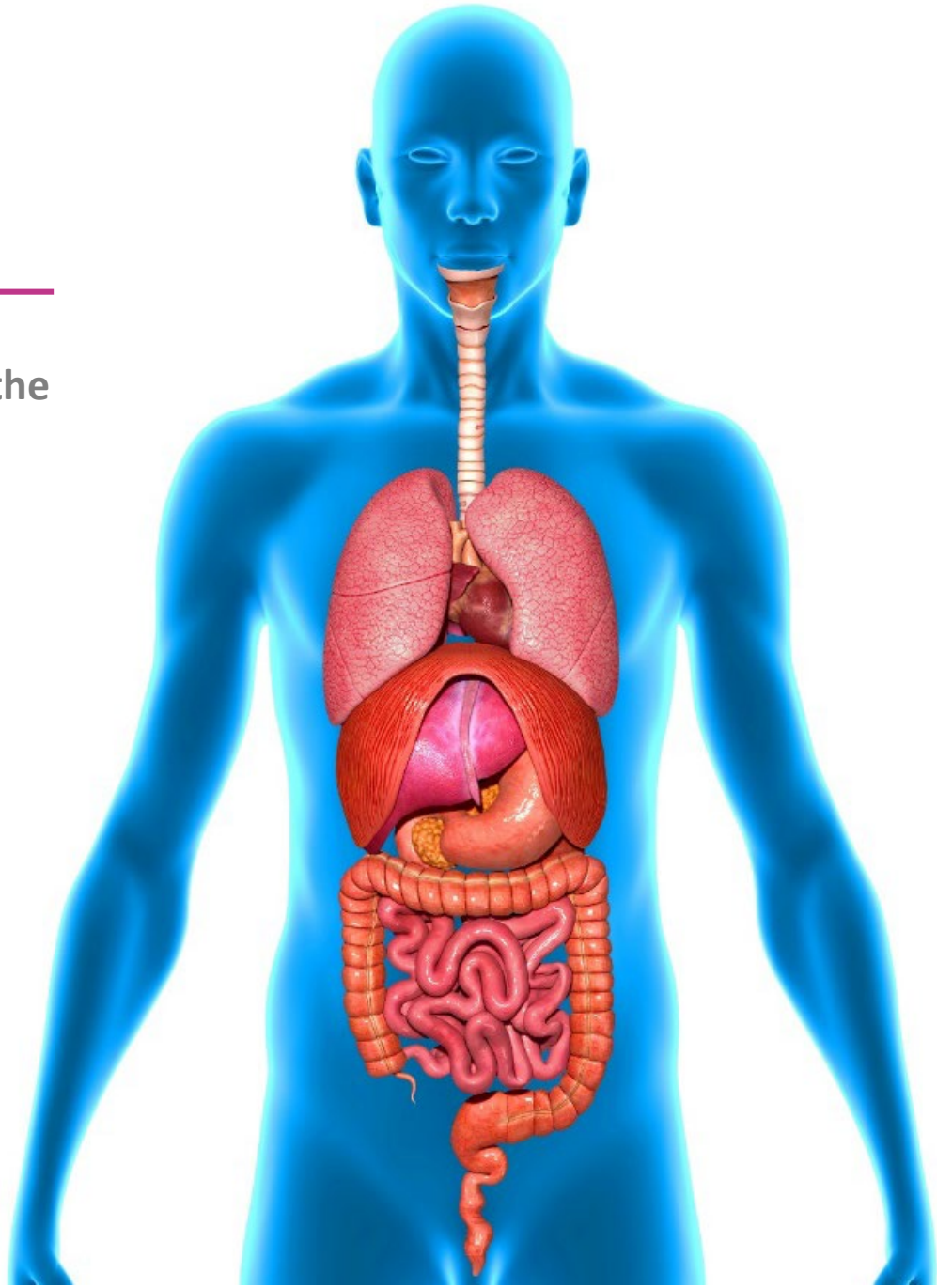
- Mouth (including, the teeth, tongue and salivary glands)
- Pharynx
- Oesophagus
- Stomach
- Liver
- Pancreas
- Gall bladder and bile ducts
- Small intestine (including the duodenum, jejunum and ileum)
- Large intestine
- Rectum and anus

Digestive system



Activity

What is the main function of the digestive system?



Digestive system functions

- The intake and digestion of food
- The absorption of nutrients
- The excretion of waste

Digestive processes

- **Ingestion**
  Eating and taking food into the body
- **Movement**
  Journey of food through the GI tract
- **Digestion** – Food broken down
  - **Mechanical digestion**
    For example, mastication (chewing)
  - **Chemical digestion**
    For example, the action of enzymes
- **Absorption**
  Nutrients are moved to the body's transport systems and travel to the body cells
- **Defecation**
  waste products are eliminated

The journey of food

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

- Chewing
- Peristalsis
- Digestion
- Absorption
- Elimination

Chewing and peristalsis

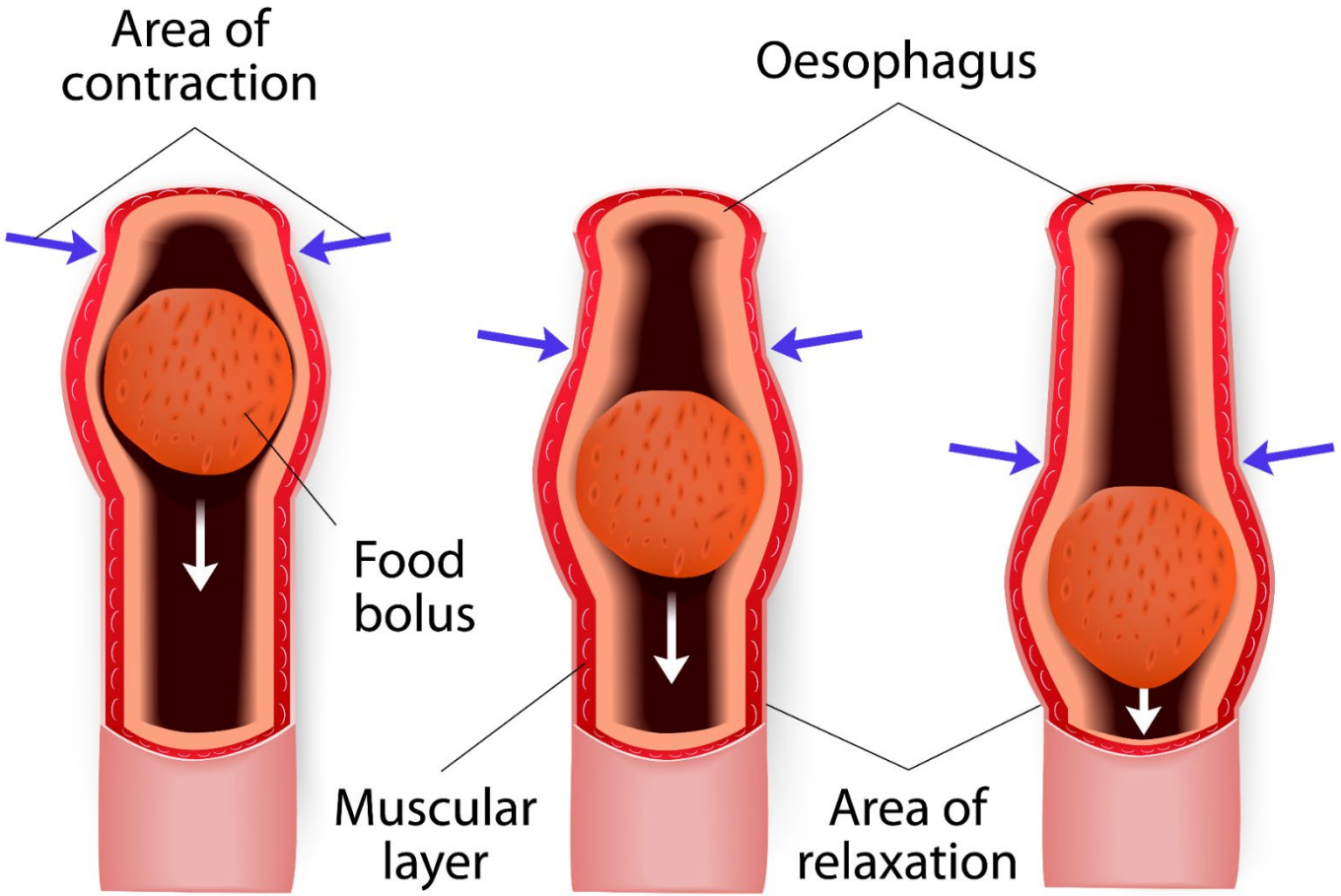
Chewing

- Food is crushed by the teeth (mastication)
- Broken down by the salivary enzymes
- Swallowed and enters the oesophagus (gullet)

Peristalsis

- Waves of involuntary muscular contractions
- Move food through the oesophagus, towards the stomach

Peristalsis



Digestion

Stomach

- Mechanical mixing macerates food to produce **chyme**
- 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 (duodenum, jejunum and ileum)

- Mechanical digestion continues
- Chemical digestion – the completion of the digestion of carbohydrates, proteins and fats

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 **fatty acids**

Absorption and elimination

- Digested food moves to large intestine/colon
- The nutrients (fats, carbohydrates, proteins) already broken down
- Absorbed through the intestinal walls
- Transported via bloodstream
- Waste products move to the rectum
- Excreted as faeces

Revision activity

Describe the following processes:

- Chewing
- Peristalsis
- Digestion
- Absorption
- Elimination

Enzymes

Enzyme	Nutrient broken down	Secreted by and acts in
Salivary amylase	Carbohydrates	Secreted: salivary glands Acts in: mouth and oesophagus
Pepsin	Proteins	Secreted: stomach Acts in: stomach
Lipase	Fats	Secreted: pancreas Acts in: small intestine
Trypsin	Proteins	Secreted: pancreas Acts in: small intestine

Revision activity

- **Where are the following enzymes released?**
- **What nutrient do they break down?**
  - Trypsin
  - Salivary amylase
  - Pepsin
  - Lipase

Fibre

4 kcal per gram

- Complex carbohydrate

- Adds bulk, roughage to the diet

- Assists movement of food through digestive system
- Assists removal of waste

- Found in vegetables, fruits and whole grains

Fibre

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 – 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

Timescales for digestion

- 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 – can take up to 2 days to digest
  - Fruit and vegetable – usually digest in less than a day
  - Processed foods – a few hours

- Approximately 24 to 72 hours to move through the whole digestive tract

Importance of fluid

- Assist with the removal of waste from the body
- Enables the transport and absorption of nutrients around the body
- Can help prevents constipation
- Supports chemical reactions – chemical reactions in all cells take place in water

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

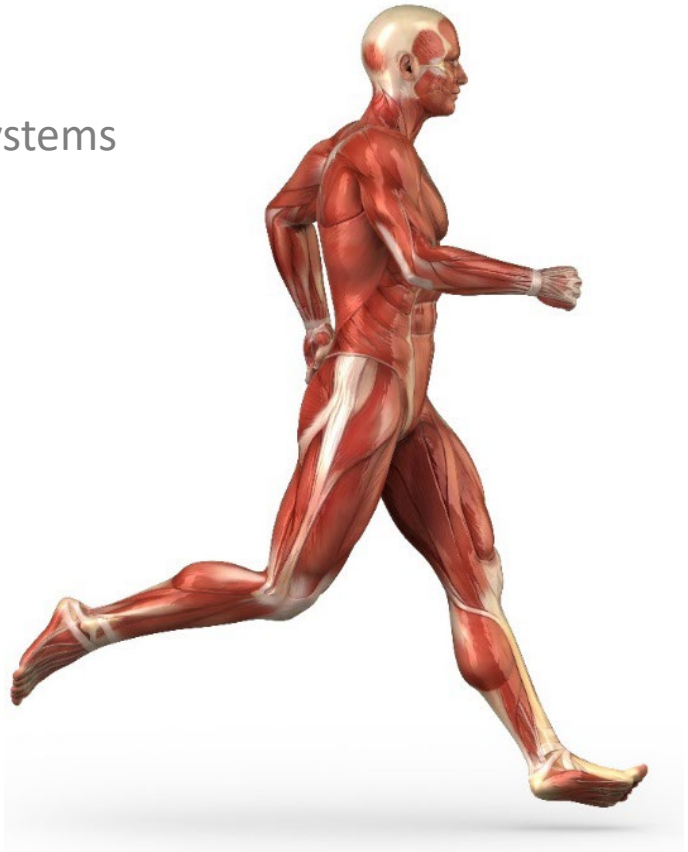
VTCT

USP182 - Anatomy and physiology for exercise and fitness professionals

LO7 Know the roles and function of the energy systems in relation to physical activity and exercise

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
- Know the effects of exercise on the energy systems



Macronutrients

- **Carbohydrates**
  For example bread, pasta, break down into glucose, glycogen storage 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

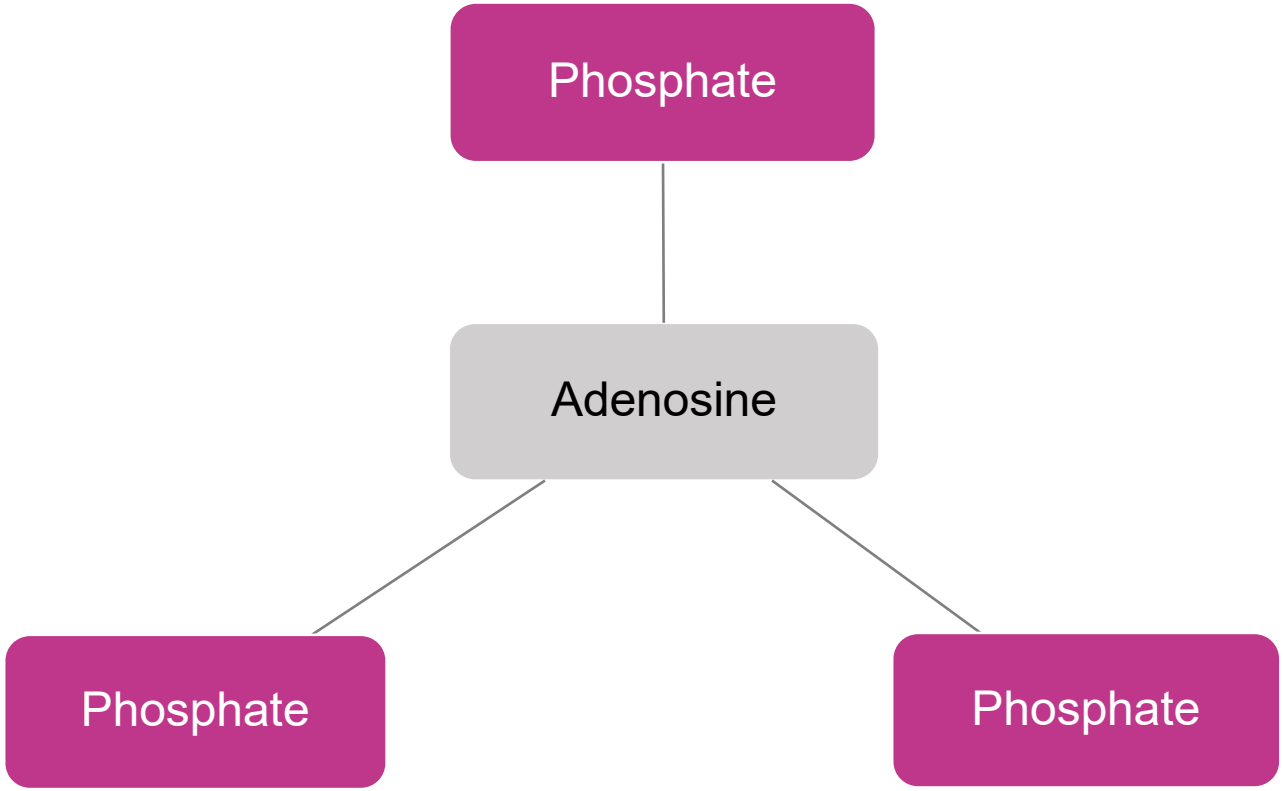
- **Lipids**
  For example cheese, butter, break down into fatty acids in presence of oxygen, stored as adipose tissue, protection, energy store

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)

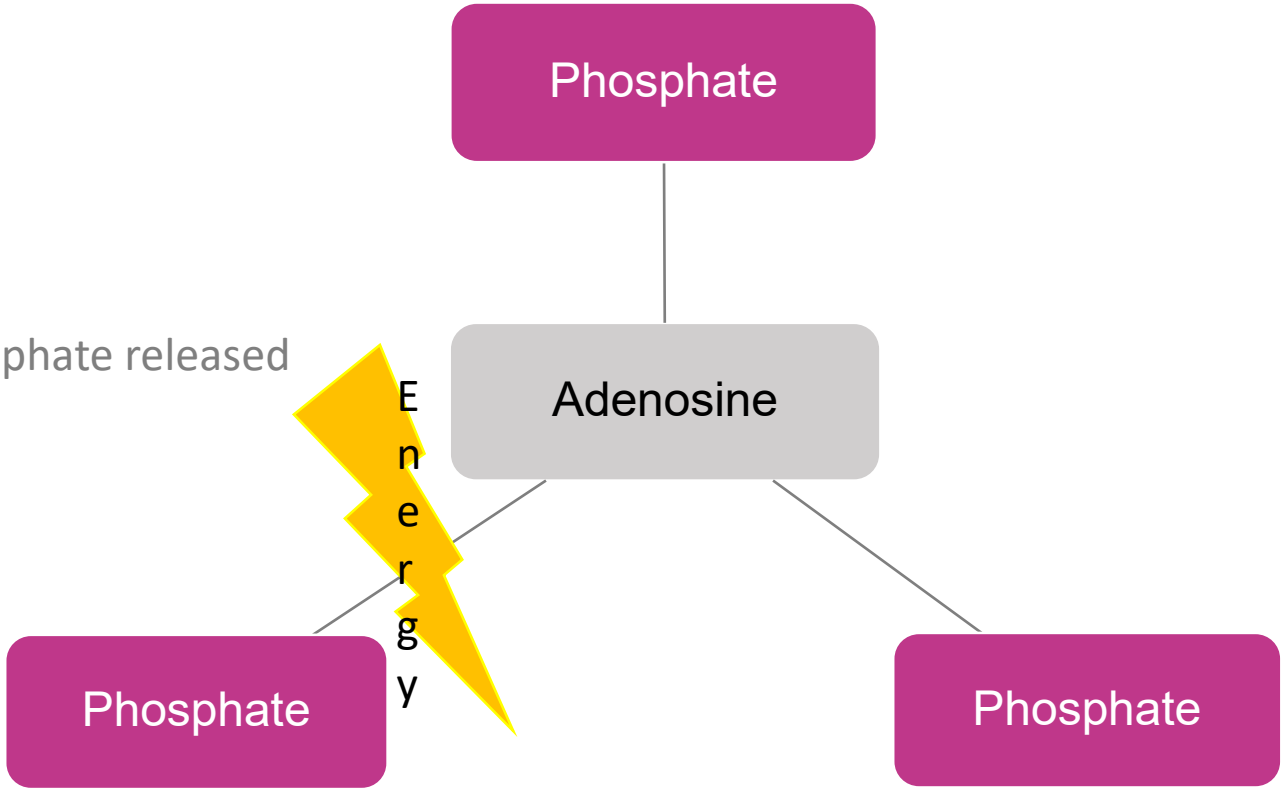
Adenosine triphosphate (ATP)

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



Adenosine triphosphate (ATP)

- ATP broken down to create energy



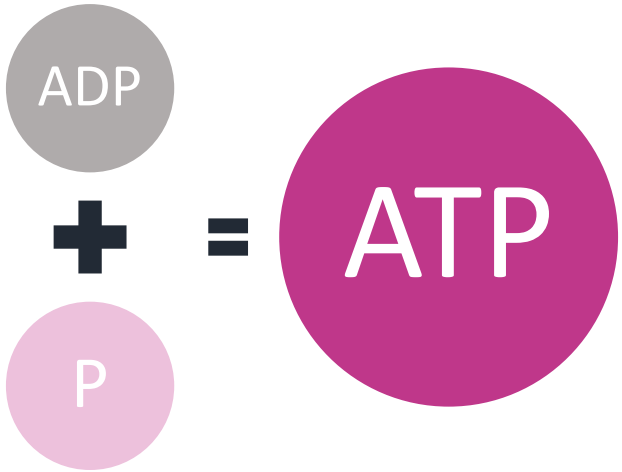
- Phosphate released
- Adenosine diphosphate (ADP)

Re-synthesis of ADP to ATP

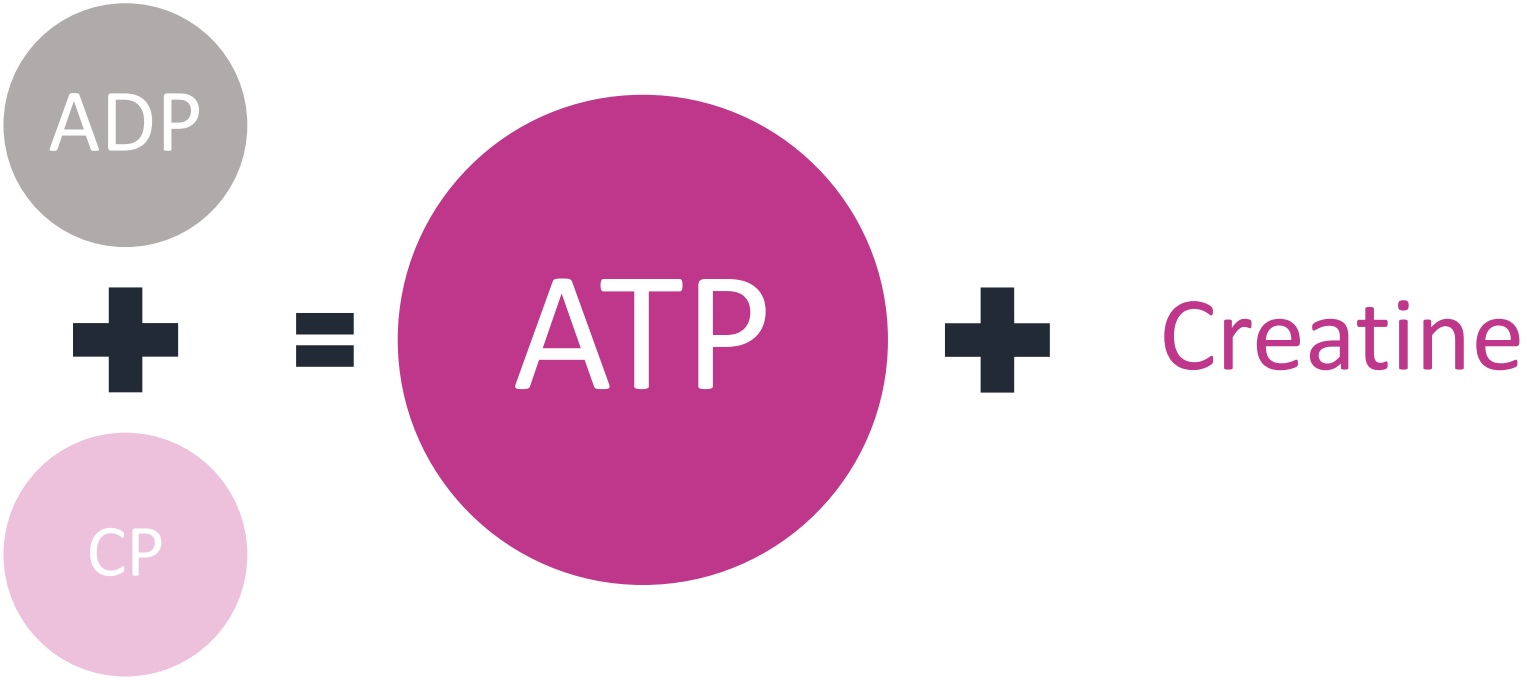
- Phosphocreatine or creatine phosphate system (anaerobic)
- Lactate or anaerobic glycolysis system (anaerobic)
- Aerobic or oxygen system (aerobic)

Creatine phosphate system

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



Creatine phosphate system

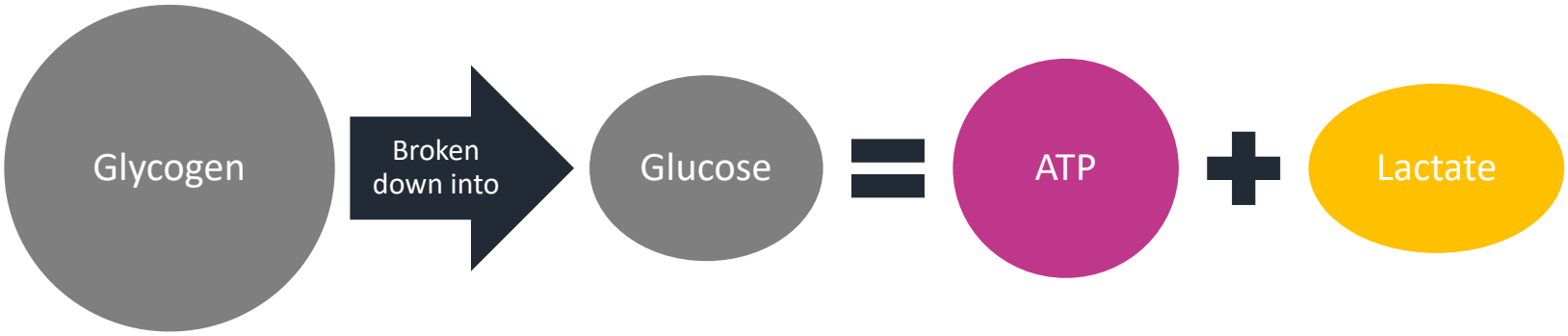


- Eventually resynthesized
- Fully restored after around 5-8 minutes of rest

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

Lactate system



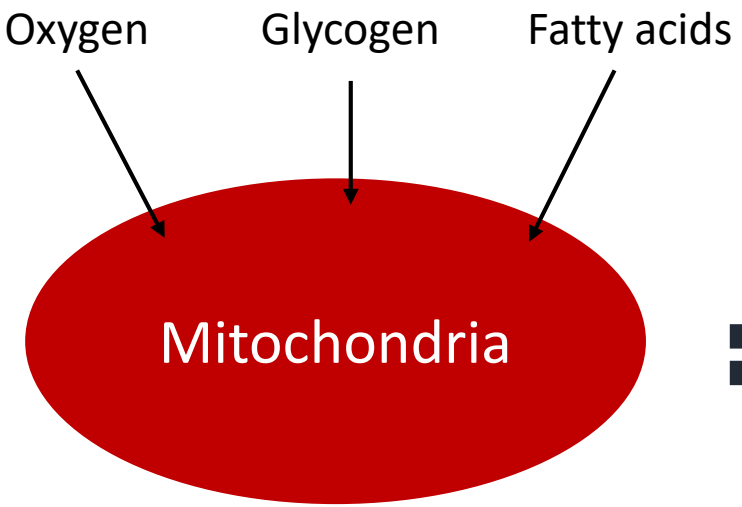
Outside

Mitochondria

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

Oxygen system



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ATP

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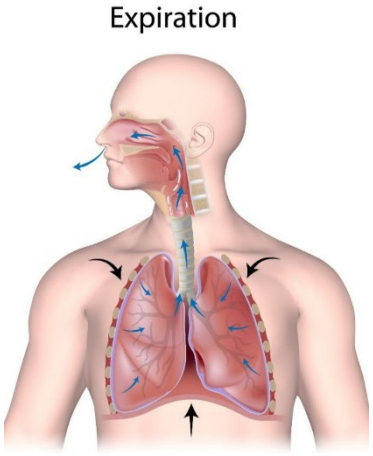

CO_2

H_2O

Key points

- All systems are always active
- Intensity of task or activity and duration determines predominant system
- Aerobic system takes longer to engage
- High intensity anaerobic work may lead to metabolic fatigue
- High intensity training sessions may need appropriate recovery, for example, rests between heavy sets or rest intervals in cardio training

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 Up to 10 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

Anaerobic training adaptations

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

Aerobic training adaptations

- Improved aerobic power
- 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

USP182 - Anatomy and physiology for exercise and fitness professionals

LO8 Know the life course of the anatomical and physiological systems of the body

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

Older adults

- The ageing process is highly individual
- People age at different rates
- Progressive decline in functioning of body systems
- Effects to: mobility, independence, risk of chronic health conditions, level of frailty and risk of falls
- Activity assists functioning
- Effects generally start around the age of 50
- By age 65, effects more apparent around

Effects of ageing

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 - Coordination and balance - Postural stability - Short-term memory

Effects of ageing

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

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?

Key safety guidelines

- Longer and more gradual warm-up and cool down
- More mobility exercises and build range of motion gradually
- Slower pace and more time for transitions and changing position
- More stable and balanced exercise positions
- Less complex moves and lower impact
- Build intensity more gradually and lower working intensity
- Focus on correct alignment and technique
- Layer instructions
- Lighter resistance, less repetitions and sets, and more rest
- Strengthen postural muscles and pelvic floor muscles
- Strengthen fracture sites for osteoporosis (wrist, hip and spine)

Ante and post natal

Trimester and postnatal changes

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

Activity

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

Key safety guidelines

Antenatal

- If inactive, work towards physical activity guidelines
- Avoid contact sports
- Avoid exercising in supine position after 16 weeks
- Avoid prone exercises
- Avoid exercising in hot, humid environments
- Avoid heavy isometric exercise
- Avoid complex balance challenged or uncontrolled exercises
- Avoid high impact work

Key safety guidelines

Postnatal return to exercise

- 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

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

Activity

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

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 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 (e.g. 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 partial hearing
  - Blind or partial 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