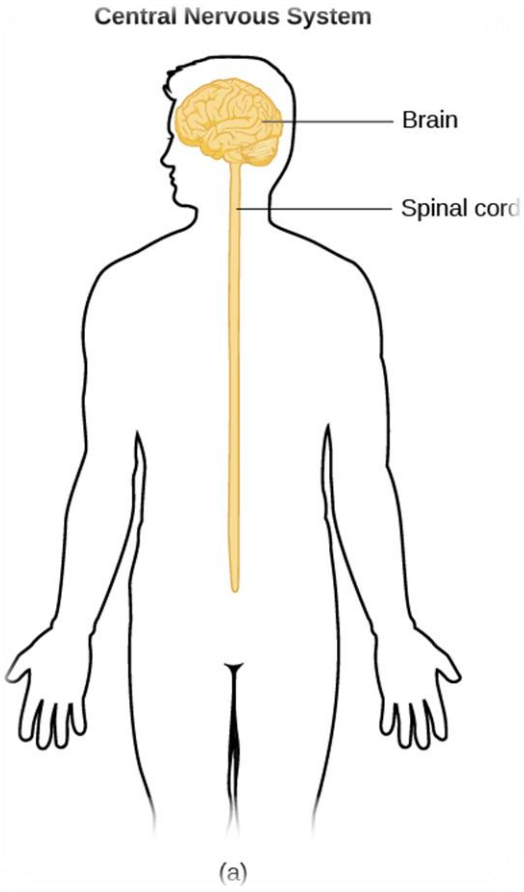
1-Central Nervous System

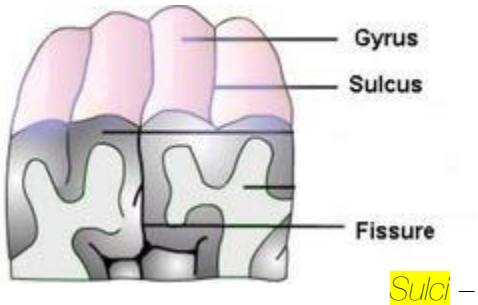
Function

Acts as the control centre for all bodily functions. It functions as the transmitter & receiver as well as the pathway for information flow, while determining how the body responds to changes in its internal & external environment.

Location

Brain & Spinal Cord





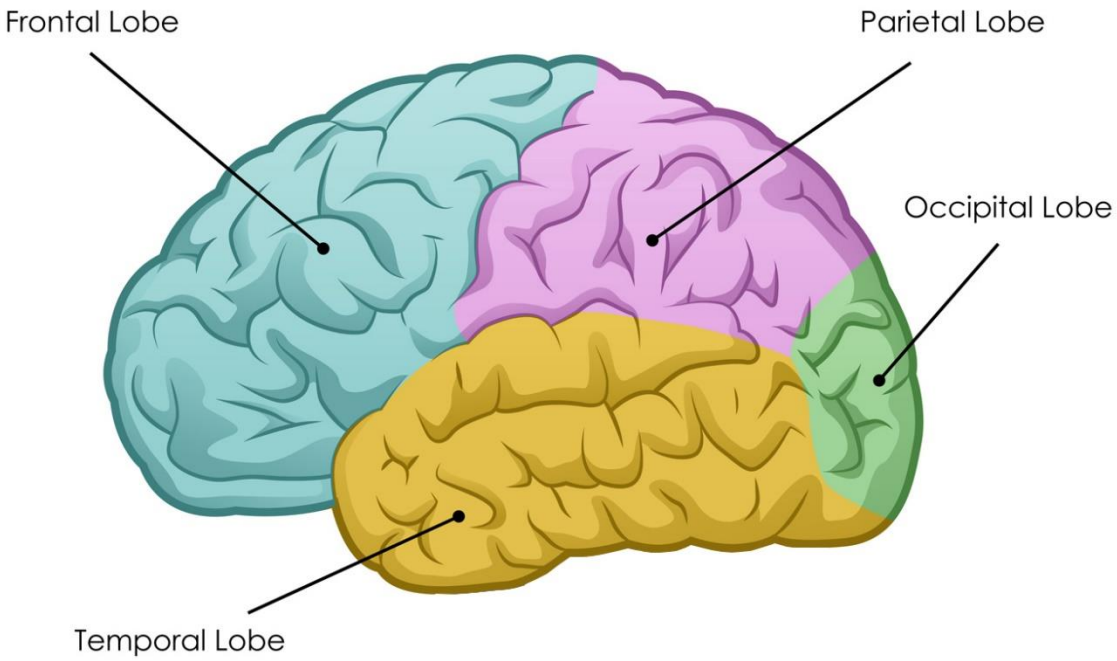
The Brain

Sulci – shallow downfolds found between the gyrus.

Fissure – deep downfolds found between the gyrus.

Gyri (Gyrus) – Also known as convolutions, the ridges on the brain due to the folding.

The Cerebrum



Cerebrum – Biggest part of the brain. Its outer surface is known as the cerebral cortex, which is grey matter with a 2-4 mm thickness. White matter is underneath the cerebral cortex while deep into the cerebrum is the basal ganglia which is grey matter.

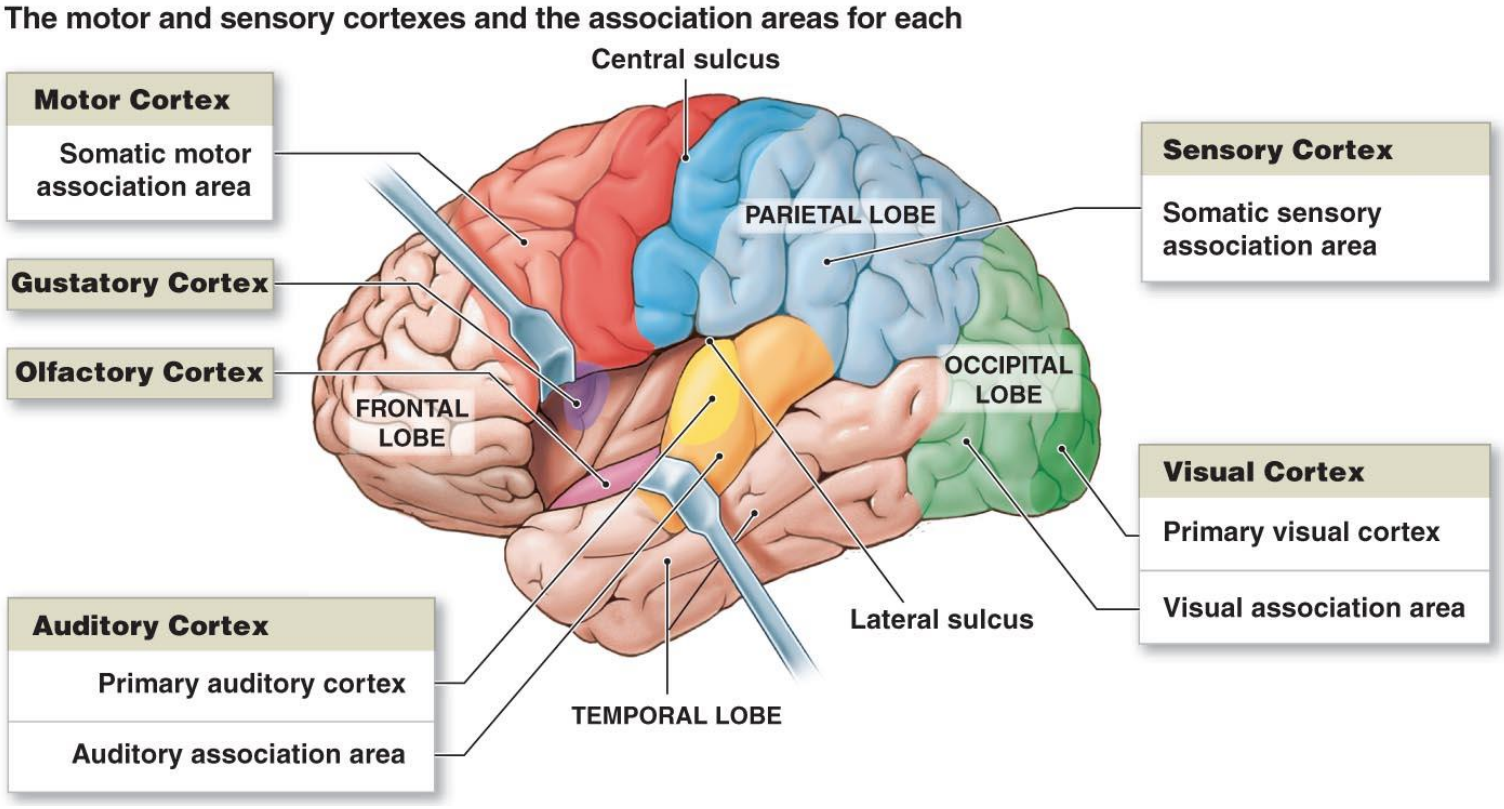
Cerebral Cortex – Consists of grey matter, is in folded patterns which increases surface area allowing the cortex to contain 70% of all the neurons in the CNS.

Areas of the Cortex

Sensory Areas – Interprets impulses from receptors.

Motor Areas – Controls muscular movements.

Association Areas – Coordinates intellectual & emotional processes.



Four Lobes

Frontal – Contains the premotor & primary motor areas responsible for voluntary control of muscles. Responsible for judgment, emotions, motivation & memory (high order thinking). Frontal lobe damage will affect language, verbal skills & positive emotions, non-verbal communication & negative emotions.

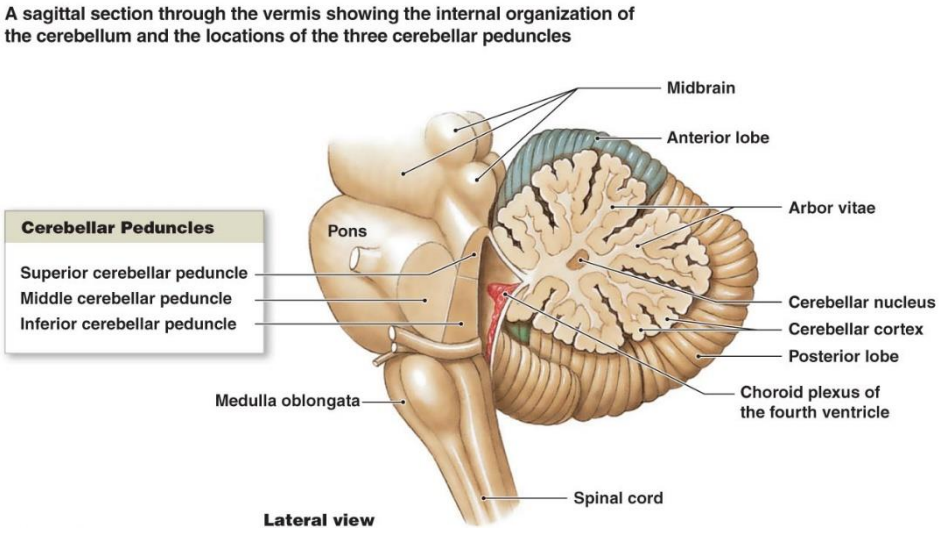
Parietal – Contains the primary sensory strip & sensory association areas. Damage to this region makes it difficult to interpret sensory inputs from the skin.

Temporal – The temporal lobe contains the olfactory (smell) & auditory (hearing) areas. Damage to this area causes disturbance of auditory sensation & perception, an inability to pay attention to what is seen or heard, impaired ability to comprehend language, impaired factual & long term memory.

Occipital – The occipital lobe contains the visual areas. Damage to this area may result in cortical blindness.

The Cerebellum

Cerebellum – Second largest part of the brain, found under the rear of the cerebrum. It has a series of parallel ridges on its surface. The outer folded part is grey matter while the inner branches are white matter.

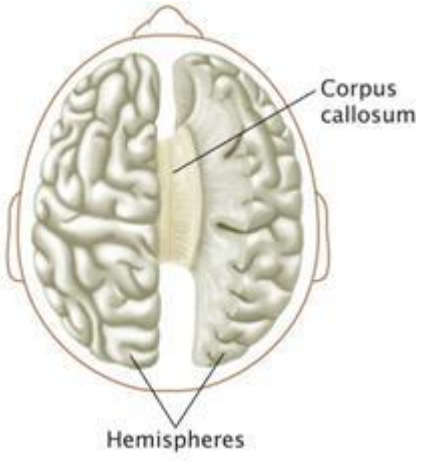


Function – The cerebellum is responsible for the fine coordination of voluntary muscle movements. Its function occurs below conscious level. It receives sensory information from the inner ear & stretch receptors for maintaining posture as well as balance. Without the cerebellum movement, would still occur but it would not be as smooth & coordinated.

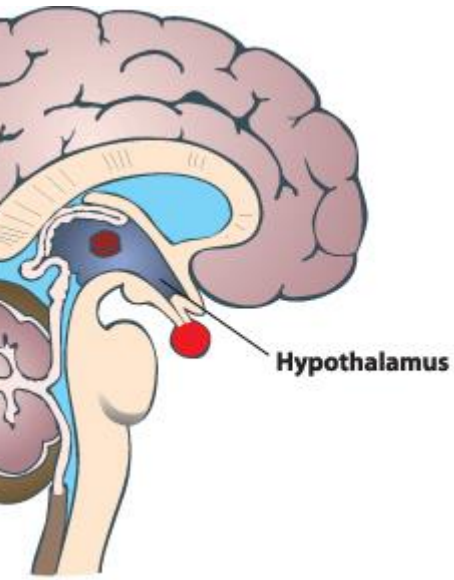
The Corpus Callosum

Corpus callosum – A wide band of nerve fibres that lies underneath the cerebrum at the base of the longitudinal fissure.

Function – Allows the hemispheres to communicate with each other.



The Hypothalamus



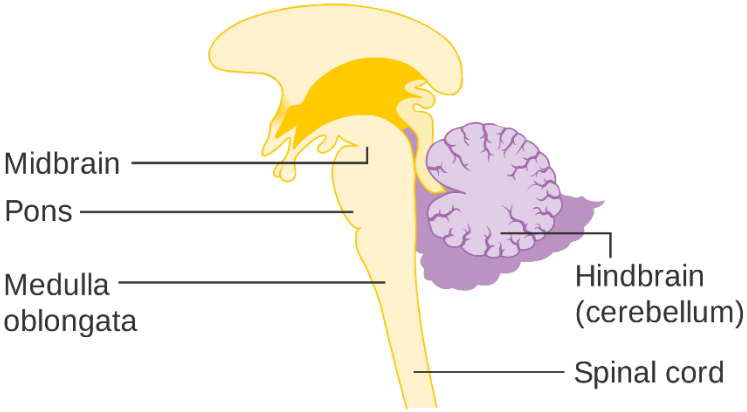
Hypothalamus – found in the middle of the brain

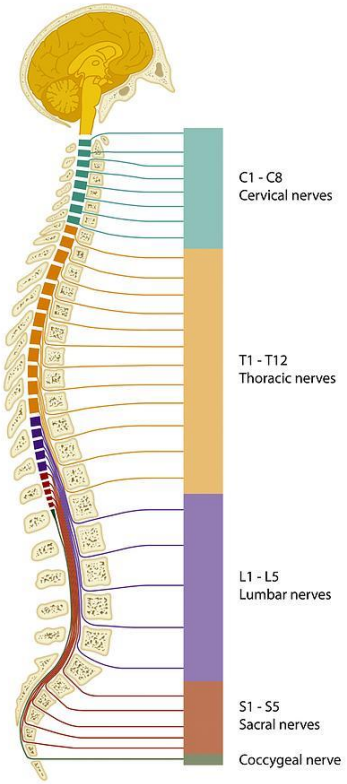
Function – Regulates heart rate, blood pressure, secretion of digestive juices, movements of the alimentary canal, diameter of pupil, body temperature, water & food intake, sleep patterns, emotional response & secretion of hormones & coordination of endocrine system. Through the pituitary gland, the hypothalamus regulates metabolism, growth, reproduction & response to stress.

The Medulla

Medulla – 3 cm long, located just above the point where the spinal cord enters the skull. The medulla contains cardiac, respiratory & vasomotor centres.

Function – The cardiac centre **regulates** the rate & force of the heartbeat. The respiratory centre **regulates** rate & depth of breathing. The vasomotor centre **regulates** the diameter of blood vessels. The medulla can also control the reflexes of swallowing, sneezing, coughing & vomiting.



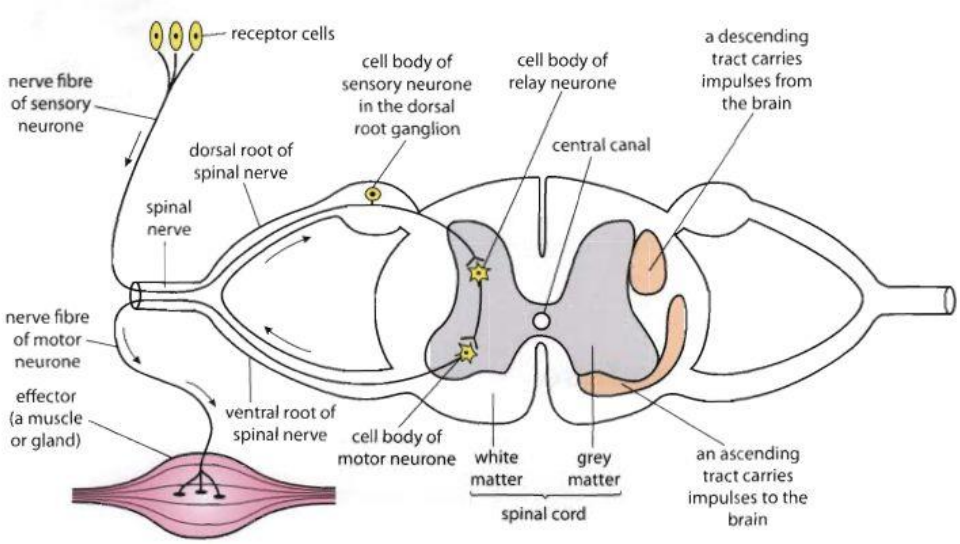


The Spinal cord

Spinal Cord – The spinal cord is an extension of the medulla oblongata from the brain. The cord runs down through the vertebral canal from the foramen magnum to the second lumbar vertebra.

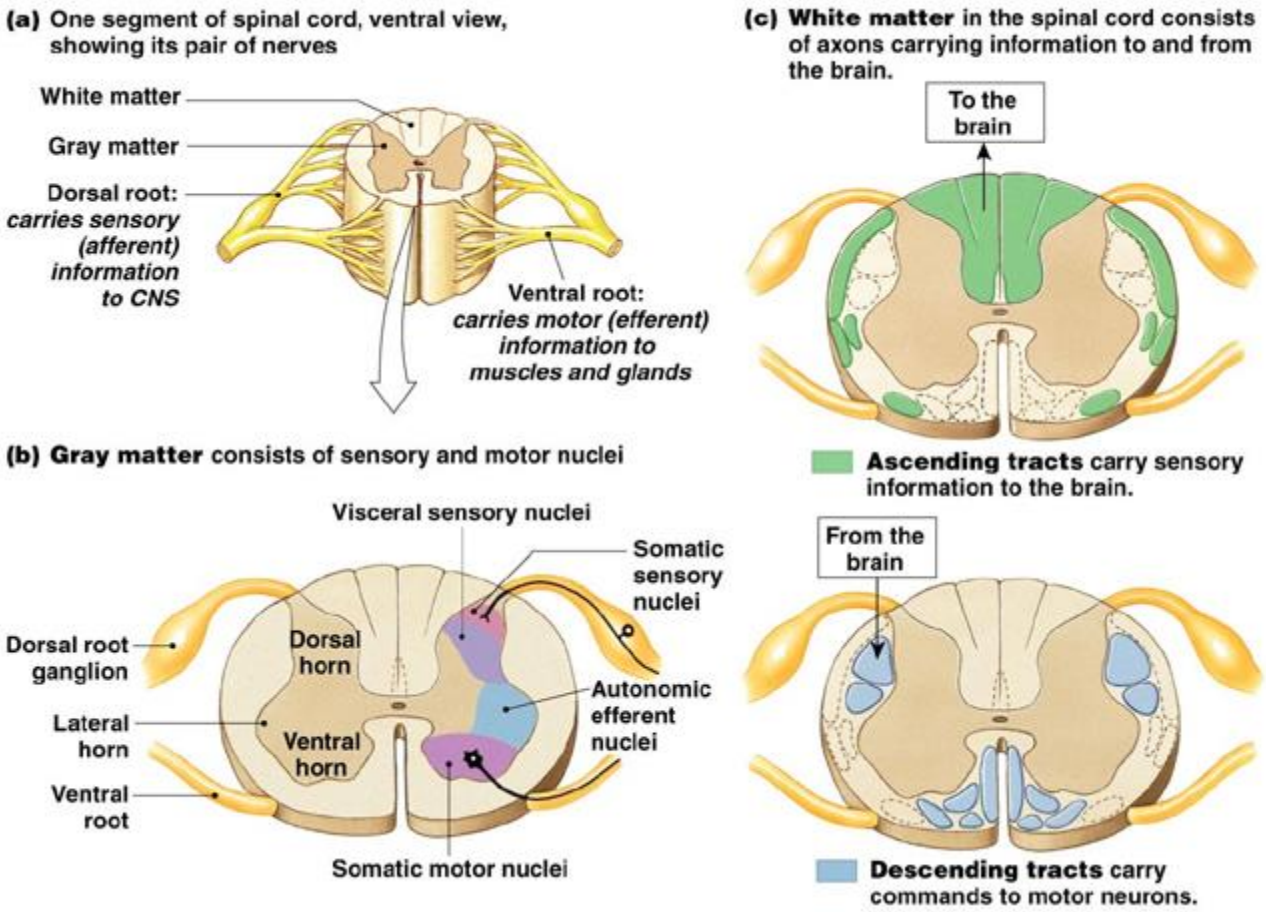
Structure – The spinal canal is made up of grey matter which forms a H shape & is surrounded by white matter. The spinal cord is protected with the three meningeal layers. The outer most layer (Dura mater) is not joined to the bone which allows the flexibility of the spinal cord when bending of the spine occurs. The white matter hosts the myelinated nerve fibres known as the ascending tract **(body to brain)** & descending tract **(brain to body)**.

Function – The spinal cord has 3 main functions. Carries sensory impulses to the brain (along ascending tracts). Carriers motor impulses away from the brain (along descending tracts) & initiates certain reflexes without an impulse from the brain.



Grey Matter – Contains unmyelinated nerve fibres.

White matter – Contains cell bodies & myelinated fibres.



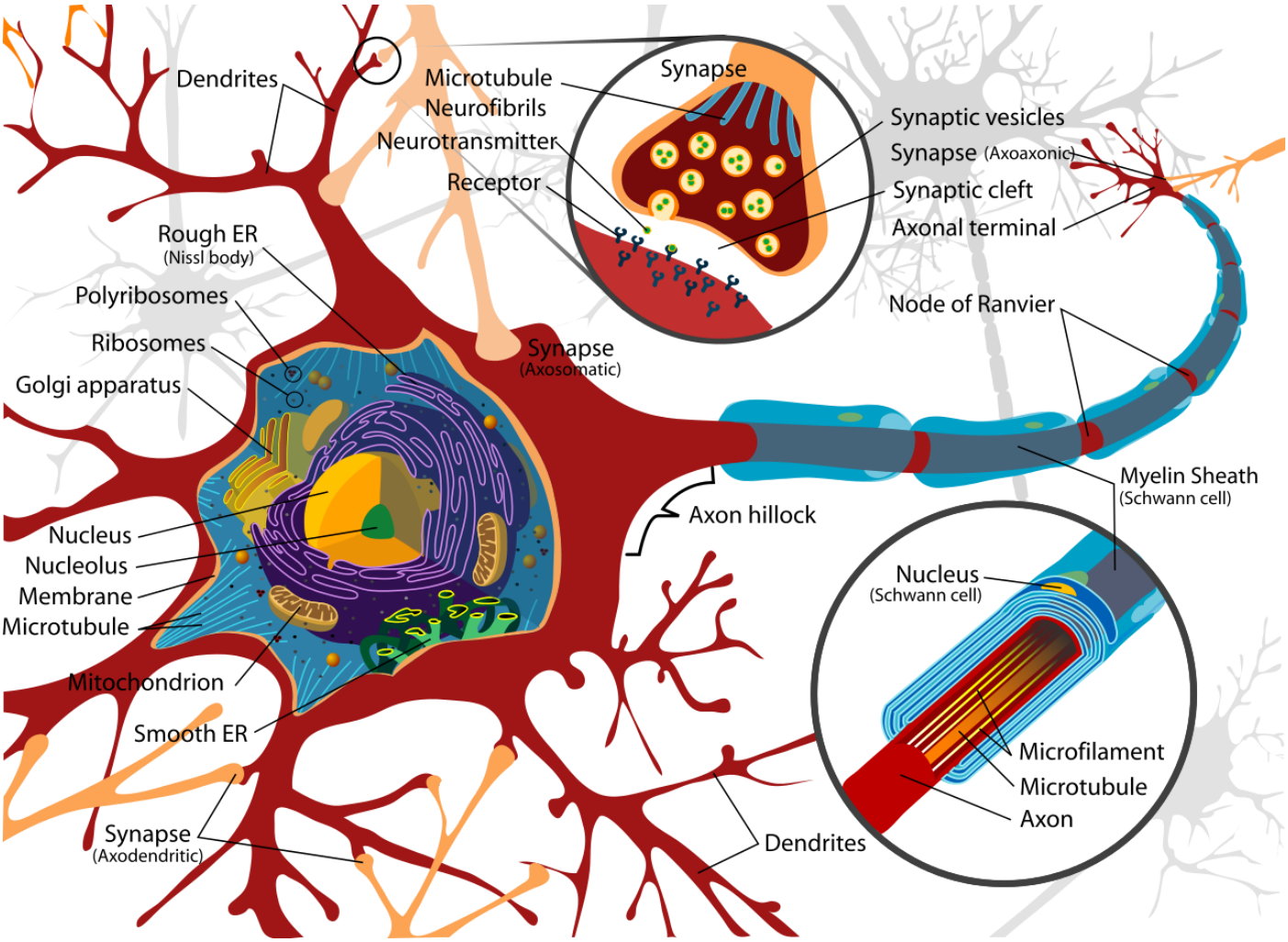
Protection of CNS

Both the brain & spinal cord can be damaged, so to guarantee damage does not occur. Three structures exist in the human body to protect the CNS. Both the brain & spinal cord is surrounded by skeleton, the cranium for the brain & the spinal column for the spinal cord. Both are covered in the three layers of the meningeal membranes. Both are immersed in cerebrospinal fluid (CSF), which acts as a shock absorber.

Structure	Function
Cerebral cortex	Higher order functions e.g. thinking, reasoning, memory, learning, conscious awareness of surroundings
Corpus callosum	Communication between the two hemispheres
Cerebellum	Coordination of fine contractions of muscles allowing fine movements & maintaining posture & balance
Hypothalamus	Homeostasis e.g. regulation of heart, digestive system, appetite etc.
Medulla Oblongata	Regulates the heart, breathing & diameter of blood vessels
Spinal Cord	Pathway for communication between CNS to effectors

Neurons

Neurons – Basic structural & functional units of the nervous system. Neurons are highly specialised cells, they generate electrochemical impulses & carry information around the body.



Dendrites – Carry impulses toward cell body.

Cell body – Processes impulses received & begins nerve transmission.

Axon – Carries electrochemical impulse away from cell body.

Myelin Sheath – Insulates & protects axon also increases impulse speed. A white, fatty sheath surrounding the axon of most neurons. Nerve fibres with a myelin sheath are said to be myelinated.

Motor End Plate/Axon terminal – Stimulates the effector which is a muscle, gland or another neuron.

Nodes of Ranvier – Impulses jump from node to node speeding up transmission.

Schwann Cell – Produces myelin sheath.

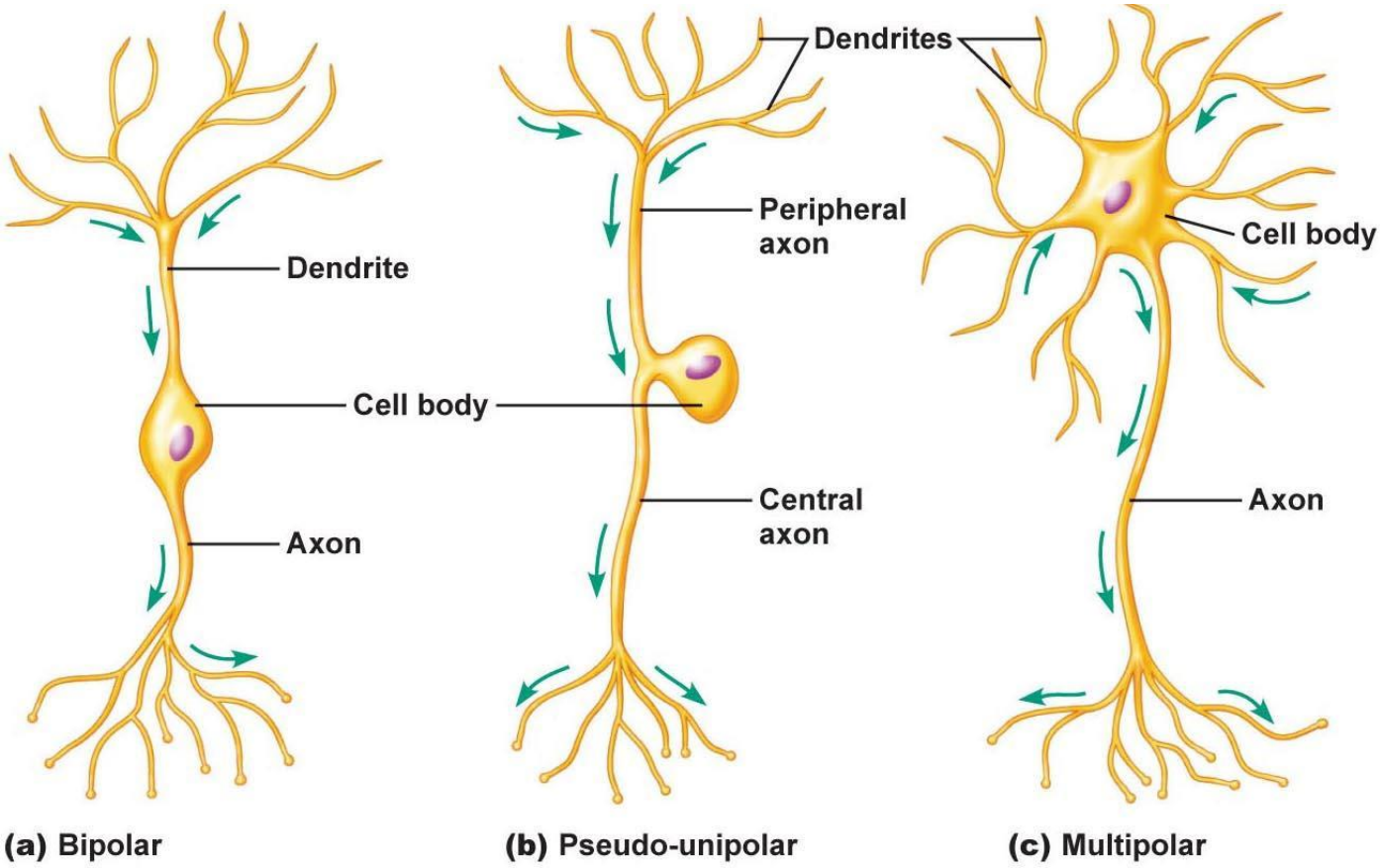
Neurilemma – Involved in repair of injured axons.

Nucleus – Controls neuron activities.

Filament – Carries impulse to motor end plate/axon terminal.

Neuron Types

Neuron	Function	Structure classification	Location
Motor	Carries nerve impulse from the CNS to the effector Passes through the **ventral** root of the spinal nerves At a neuromuscular junction, neurotransmitter acetylcholine is released causing muscle movement	Multipolar	The cell body is located in the spinal cord & axons outside the spinal cord to directly control the effector (muscles & glands)
Sensory	Carries nerve impulses from receptors to CNS Passes through **dorsal** root of the spinal nerves Sensory receptors occur at end of dendrites	Bipolar, Unipolar	The cell bodies of the sensory neurons leading to the spinal cord are located in the dorsal root ganglia. The axon extends in both directions, axon from receptors & an axon to the spinal cord.
Interneuron/Relay	Connect sensory neurons to motor neurons & other interneurons Integrates sensory input & initiates motor output	Multipolar	Cell bodies in grey matter between motor & sensory neurons



Nerve Impulses

A nerve impulse is an electrical signal that travels along an axon. There is an electrical difference between the inside of the axon & its surrounding. When the nerve is activated, there is a sudden change in the charge across the wall of the axon, caused by the movement of ions in & out of the neuron. Impulses move through axons like dominoes as they are transferred through the action potentials along the axons.

Action potential – Rapid depolarisation & repolarisation of the membrane of the nerve fibre, which typically lasts millisecond.

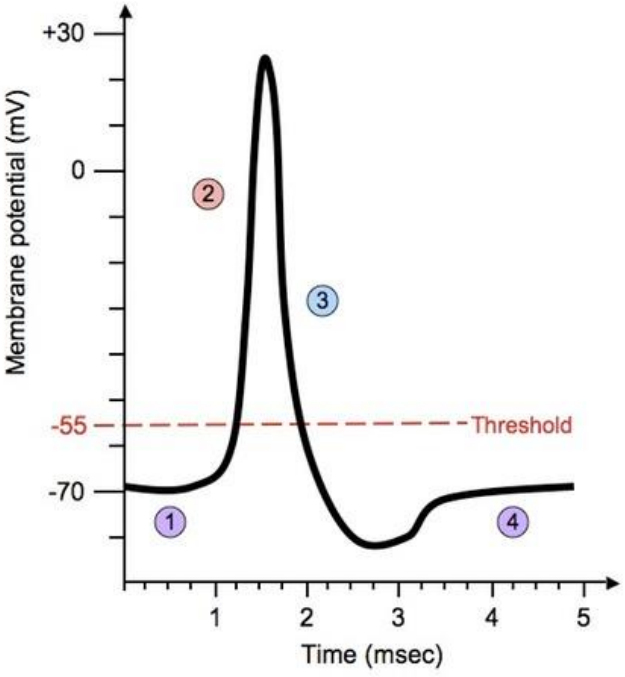
Neuron membrane potential – In the cell membrane there is a charge of -70 mV (resting membrane potential) while outside the cell membrane there is a positive charge. This difference in charges is the membrane potential & the membrane is considered to be polarised.

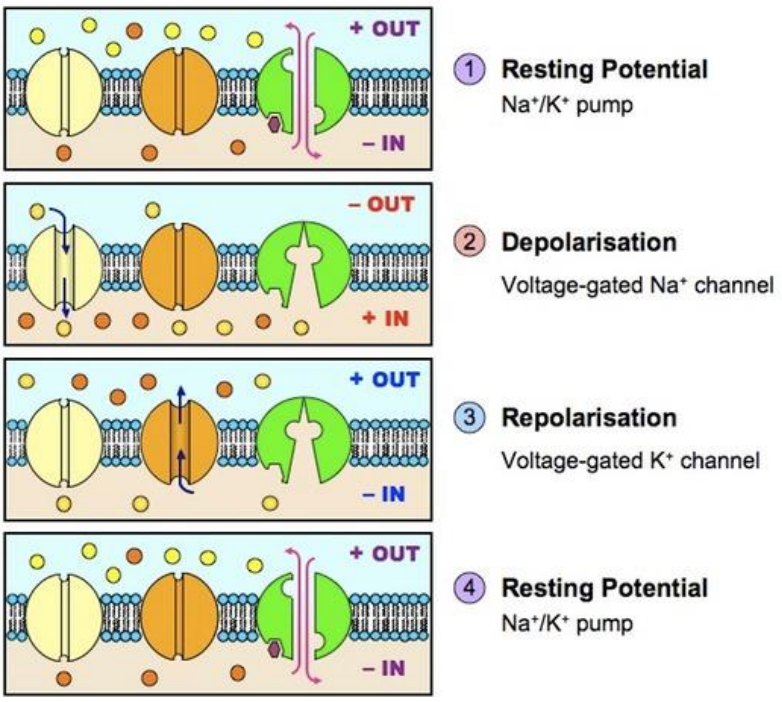
Refractory period – During which an action potential cannot occur again at the same place on the axon. This prevents the impulse from travelling backwards.

Process

Depolarisation – This occurs when dendrites are stimulated with an impulse 15 mV or more allowing for the threshold to be passed. Now with the threshold passed, the inside membrane is at -55 mV. Na^+ ions enter through the cell membrane, this rush into the membrane is caused due to the high concentration of Na^+ to the low concentration inside the membrane *concentration gradient* & the membrane becoming more permeable to Na^+ ions. The influx of Na^+ ions causes the polarity of the membrane to become positively charged at 30mV. **This is known as depolarisation**.

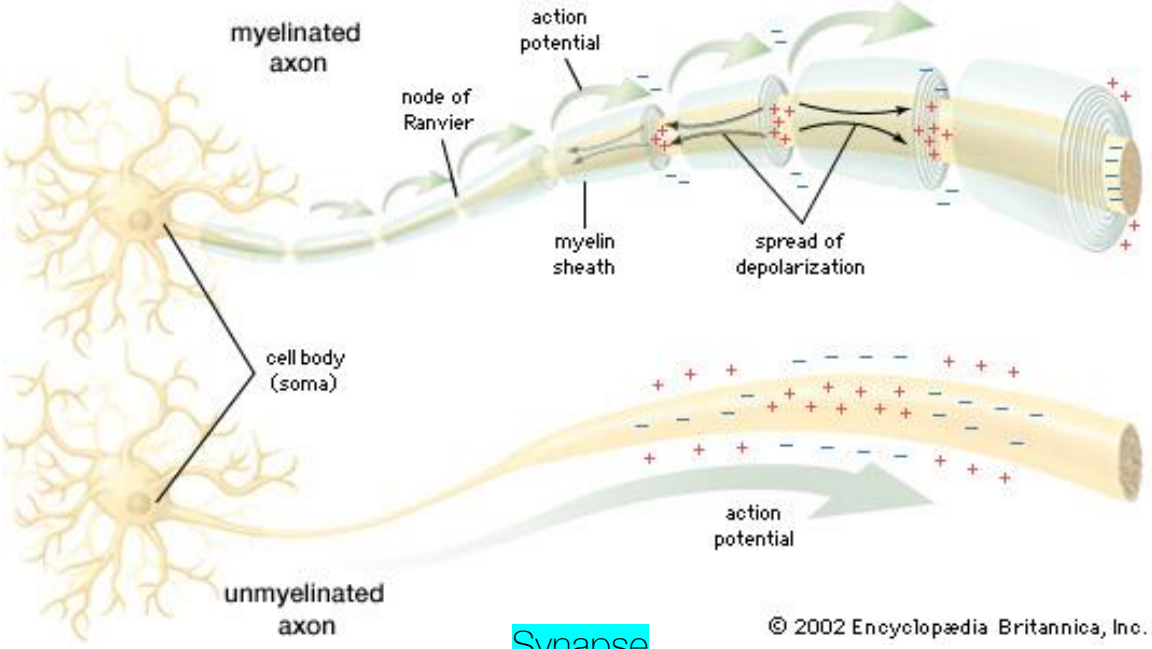
Repolarisation – After depolarisation, K^+ ions exit the cell membrane resulting in the charge to go down back to -70 mV, the resting membrane potential is reached. Na^+/K^+ pumps work to maintain the resting membrane potential by transporting both Na^+ & K^+ ions in & out.





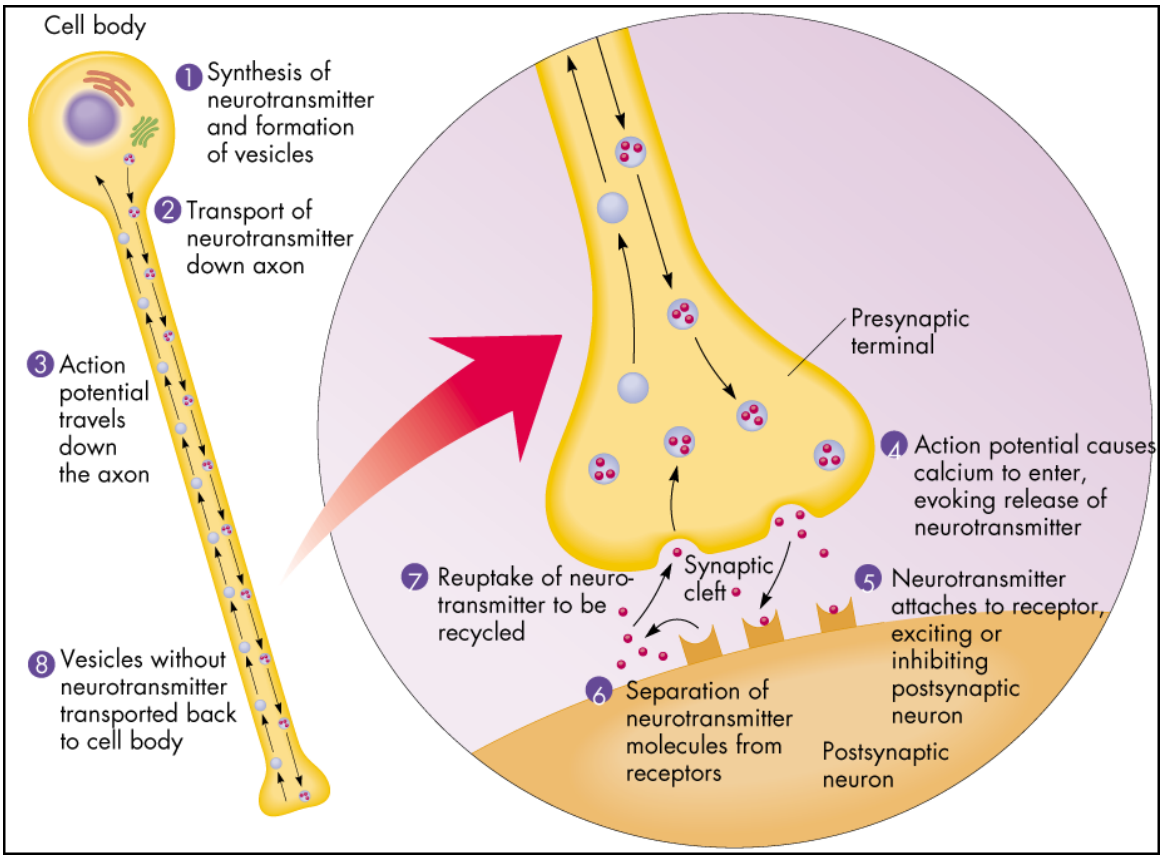
Conduction of Nerve Impulse

	Saltatory	Continuous
Myelin sheath	Yes	None
Speed	65 km/h to 500 km/h	7 km/h
Action potential	Between nodes of Ranvier	Along the axon



Synapse

A synapse is the junction between two neurons. The junction between a neuron & muscle tissue is called the neuromuscular junction. Nerve impulse transmission occurs because special neurotransmitter chemicals are released into the synaptic cleft, which separates the two nerve cells. Acetylcholine & noradrenaline are the neurotransmitters of the peripheral nervous system.



Receptors

Receptors – Structures that are able to detect changes in the body's internal or external environment

Sense Organs – Where receptor cells of a particular type are grouped together

Receptors may be specialised cells or nerve endings (dendrites) of sensory neurons

Receptor	Stimuli	Location
Thermoreceptors	Temperature internally & externally	Skin (peripheral) & Hypothalamus (central)
Osmoreceptors	Solute concentrations in blood plasma (osmotic pressure)	Hypothalamus
Chemoreceptors	Chemicals detected by the nose & mouth. Oxygen, carbon dioxide & pH in blood	Nose, tongue, medulla, carotid & aortic bodies
Pain receptors	Damage to tissue & cells	All around body except the brain
Touch receptors	Light touch, pressure & vibrations	Skin (Epidermis & Dermis)

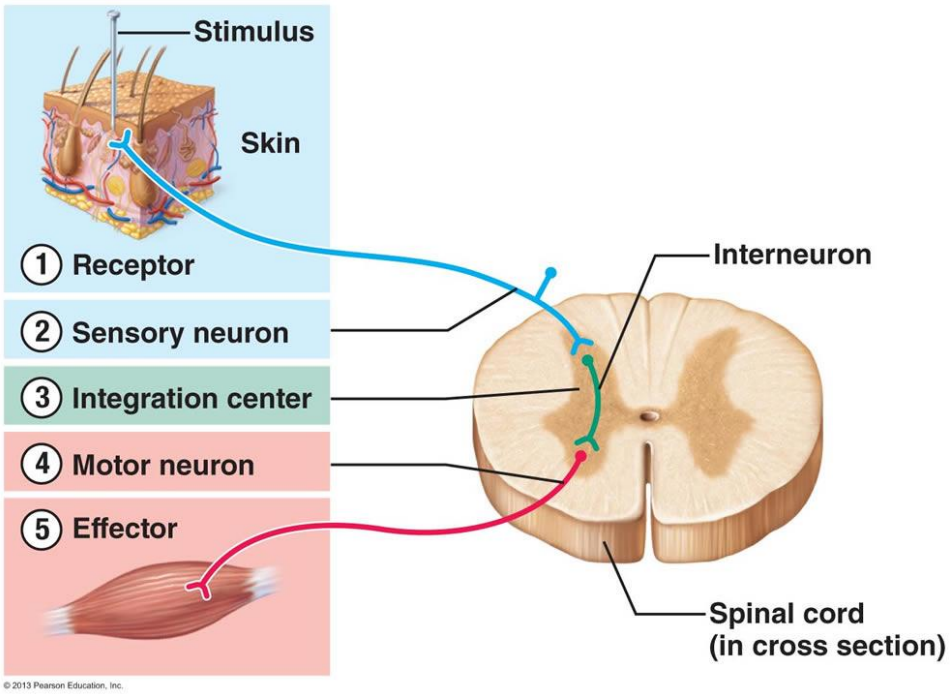
Reflexes

Innate reflex – Rapid, involuntary/automatic response to a stimulus. Some reflexes involve the unconscious parts of the brain but most are coordinated by the spinal cord (Spinal reflex).

Acquired reflex – Complex motor patterns/responses which are learned through constant repetition e.g. maintaining balance while riding a bike or catching a ball.

All **innate reflexes** are triggered by a stimulus, occur without conscious thought, are rapid due to small number of neurons involved & are stereotyped meaning they occur in the same way each time.

Reflex Arc



Peripheral Nervous System

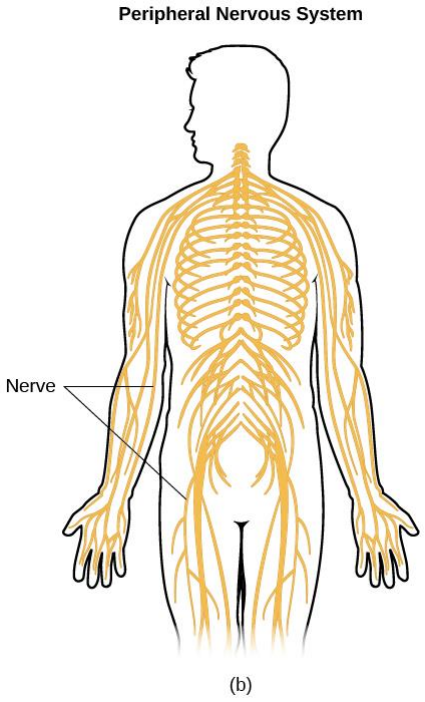
Structure – 12 pairs of cranial nerves & 31 pairs of spinal nerves.

Afferent/Sensory division – Carries sensory impulses from receptors to CNS. Impulses detected by neurons in the skin & muscles are part of the Somatic sensory, while impulses detected by neurons in internal organs are part of the Visceral sensory.

Efferent/Motor division – Carries nerve impulses from the CNS to effectors. The efferent division is broken down into the somatic & autonomic divisions.

Somatic division – Carries nerve impulses from the CNS to skeletal muscles.

Autonomic division – Carries nerve impulses from the CNS to glands & involuntary muscles.

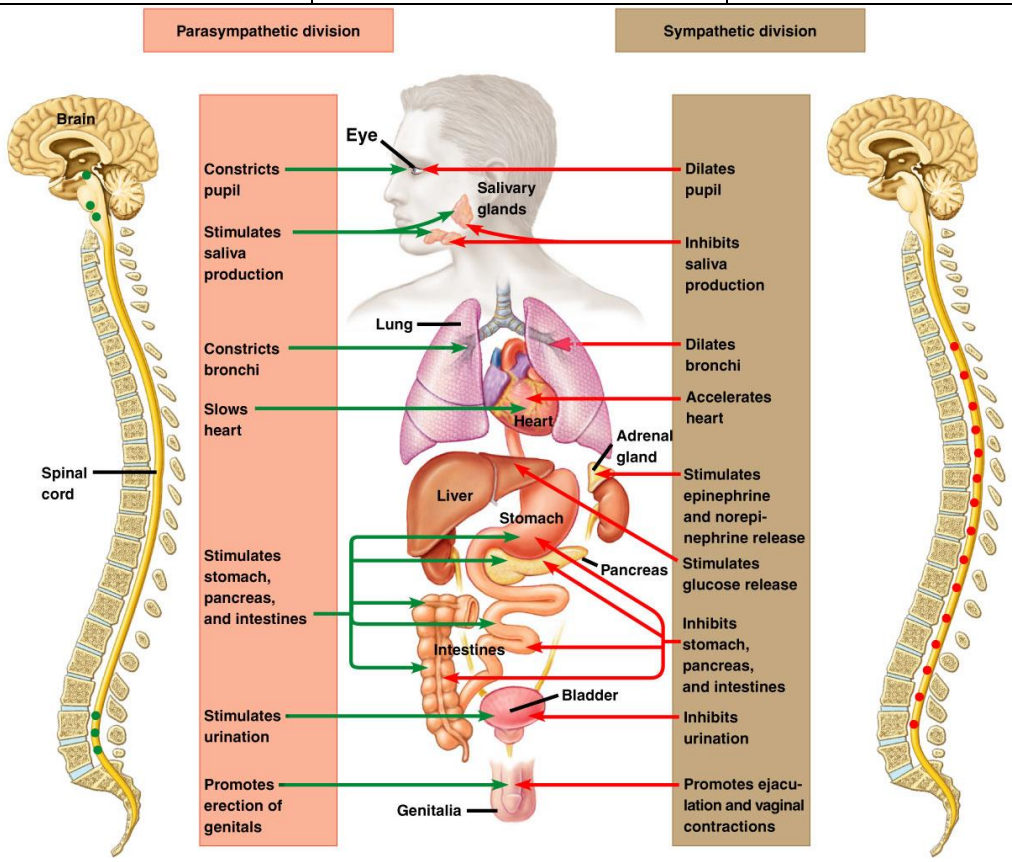


Characteristic	Autonomic division	Somatic division
Effectors	Involuntary muscles & glands	Voluntary muscles
Function	Homeostasis	Response to external environment
Pathway to effector	Two motor neurons from CNS to synapse in a ganglion to effector	One motor neuron from CNS to effector
Neurotransmitter at effector	Acetylcholine & noradrenaline	Acetylcholine
Control	Involuntary	Voluntary
Nerve sets to effector	Two sets/sympathetic & parasympathetic	One set
Effect on effector	Excitation or inhibition	Always excitation

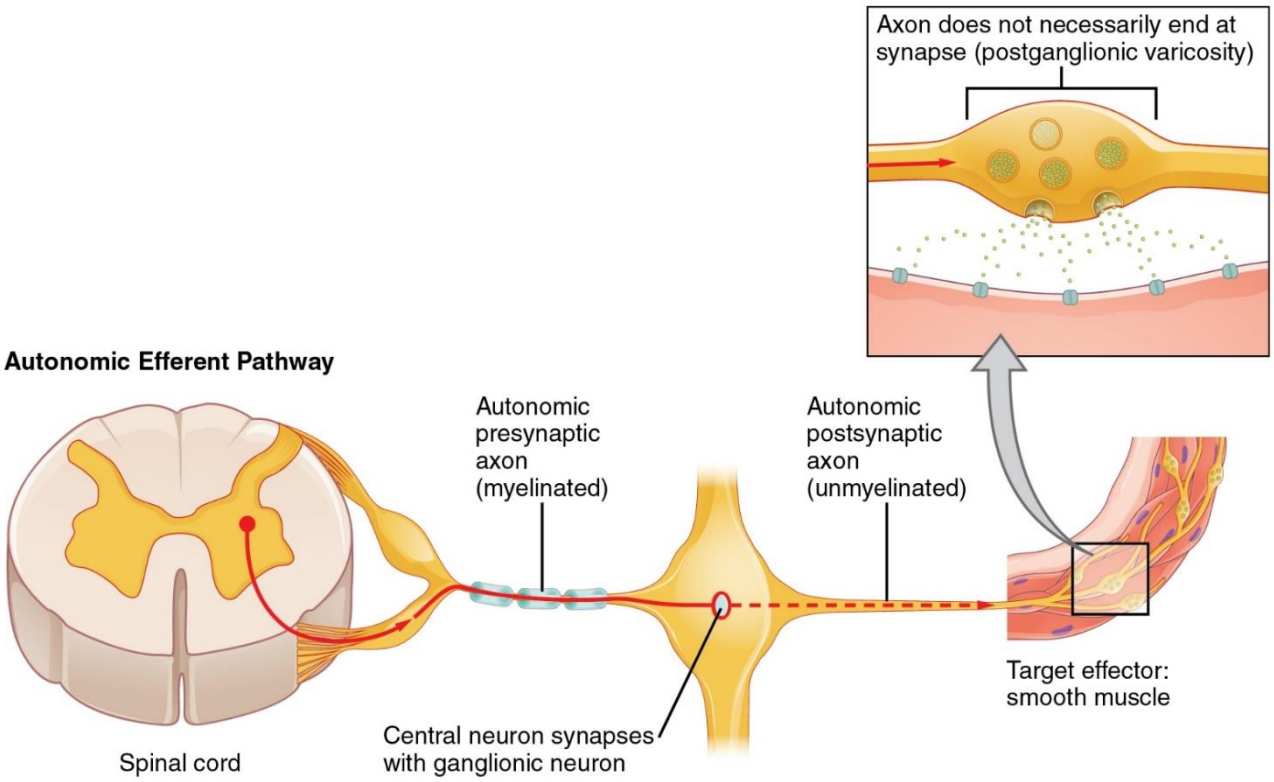
Peripheral Nervous System

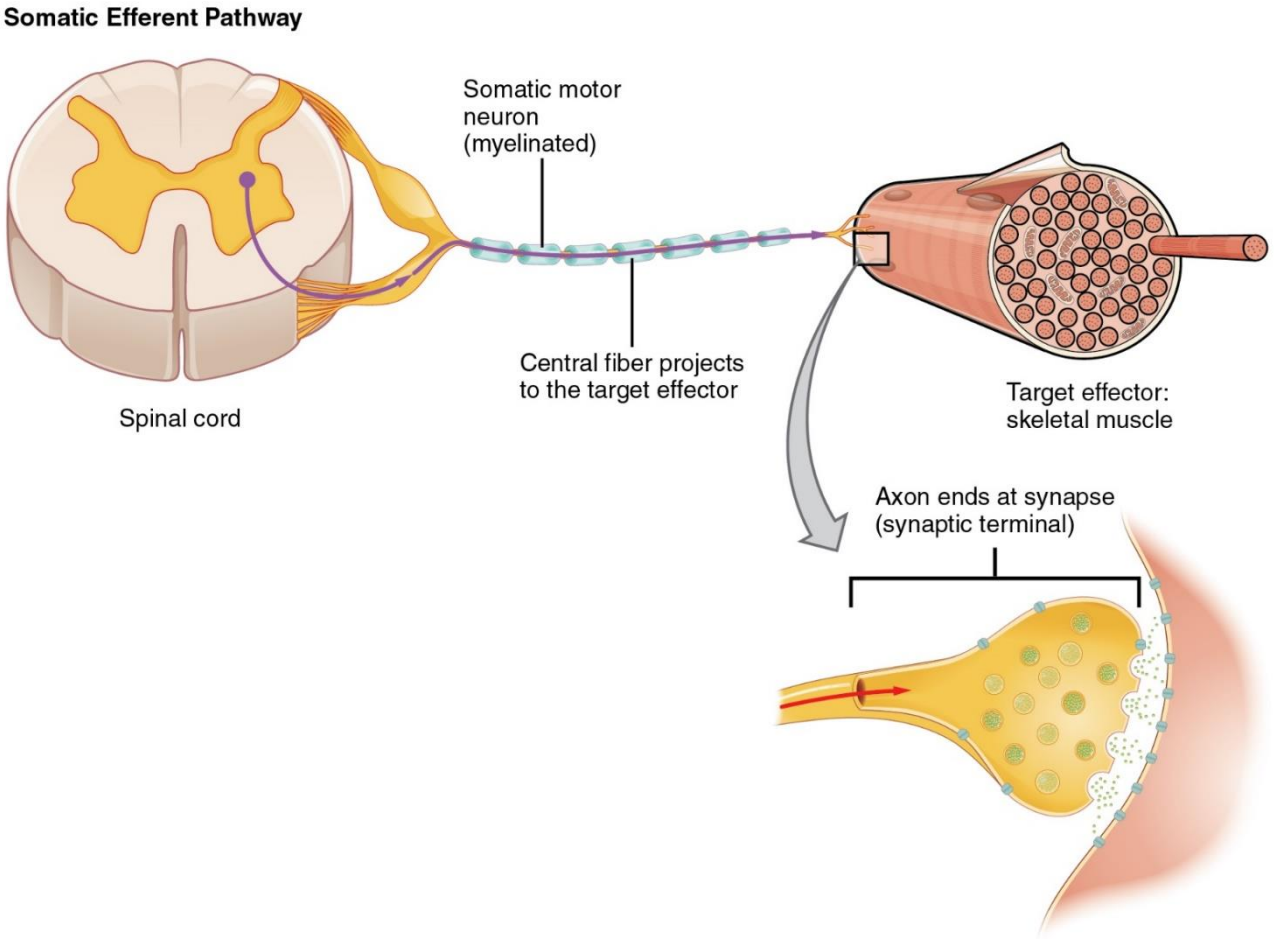
The autonomic division is broken down into the parasympathetic & sympathetic divisions. The sympathetic division enables the body to respond to stress (fight or flight response) throws the body out of homeostatic balance. The neurotransmitter at the effector is noradrenaline. The parasympathetic division is involved with normal body functioning (maintains homeostatic balance). The neurotransmitter at the effector is acetylcholine.

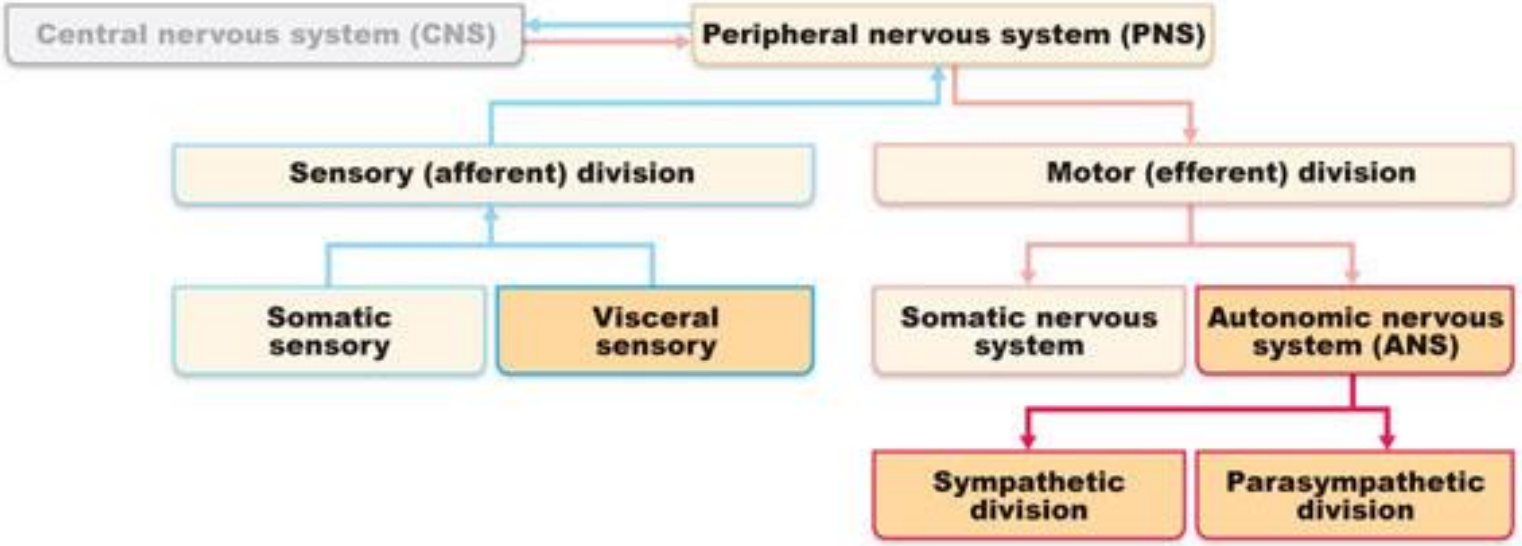
Effector	Sympathetic	Parasympathetic
Adrenal glands	Increased adrenaline production	None
Heart	Increased cardiac output (HR & SV)	Decreased cardiac output
Bronchioles (smooth muscles lining)	Dilation	Constricts airways, decreased breathing rate
Sweat glands	Sweating	None
Iris of the eye	Dilation of pupils	Constriction of pupils
Erector pili muscles	Goose bumps or piloerection	None
Liver	Increased fat & glycogen conversion to glucose (glycogenolysis)	Increased conversion of glucose into glycogen (glycogenesis) & fats
Alimentary canal (smooth muscle)	Decreased contractions/ peristalsis	Increased contractions/ peristalsis
Alimentary canal (glands e.g. salivary)	Secretions decreased	Stimulates secretion
Anal & urethral sphincters	sphincters contract	sphincters relax
Cutaneous Arterioles (smooth muscles lining)	Vasoconstriction	Little effect
Visceral arterioles	Vasoconstriction	Little effect
Skeletal muscle arterioles	Vasodilation	No effect



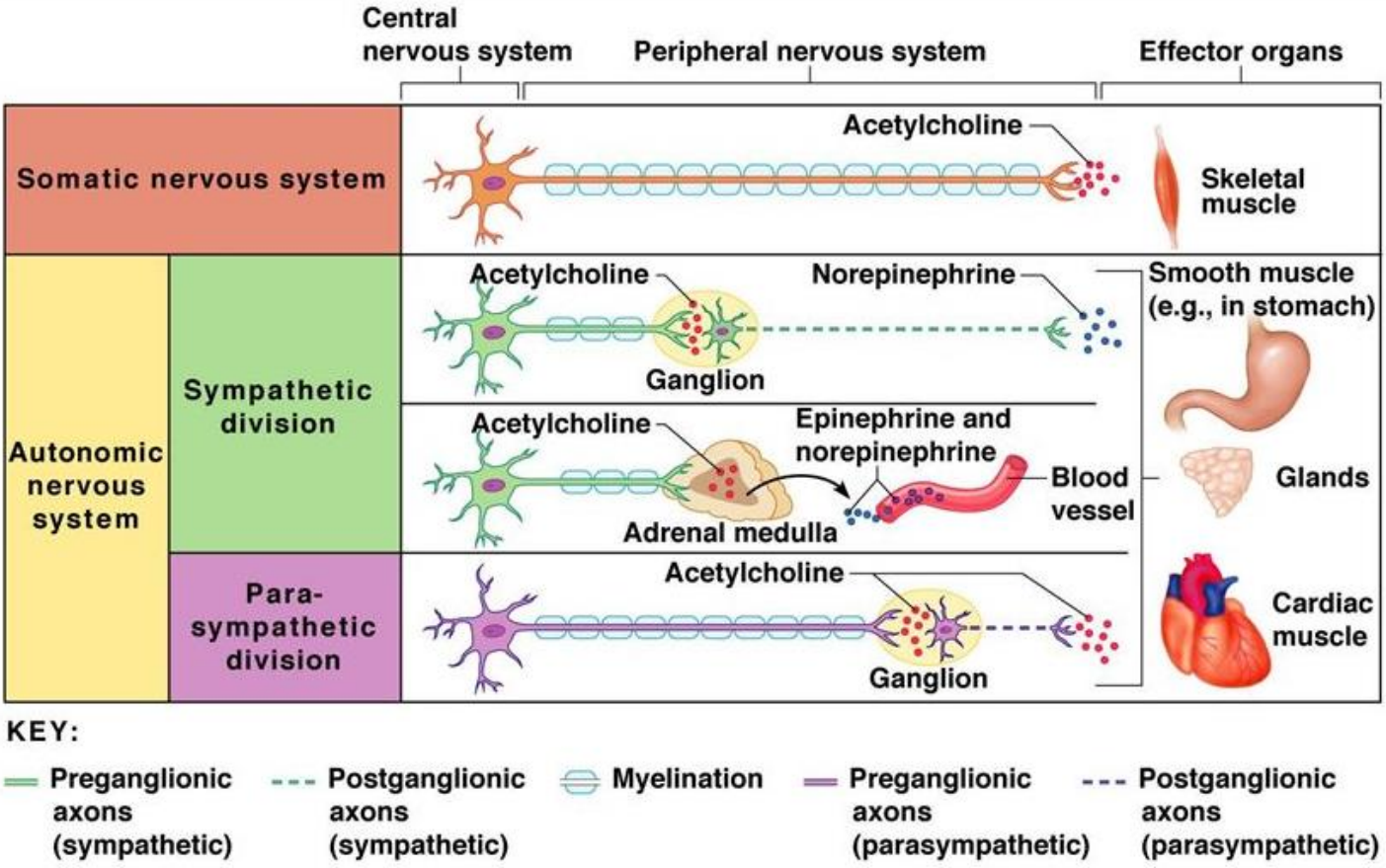
Autonomic & Somatic pathway to effector

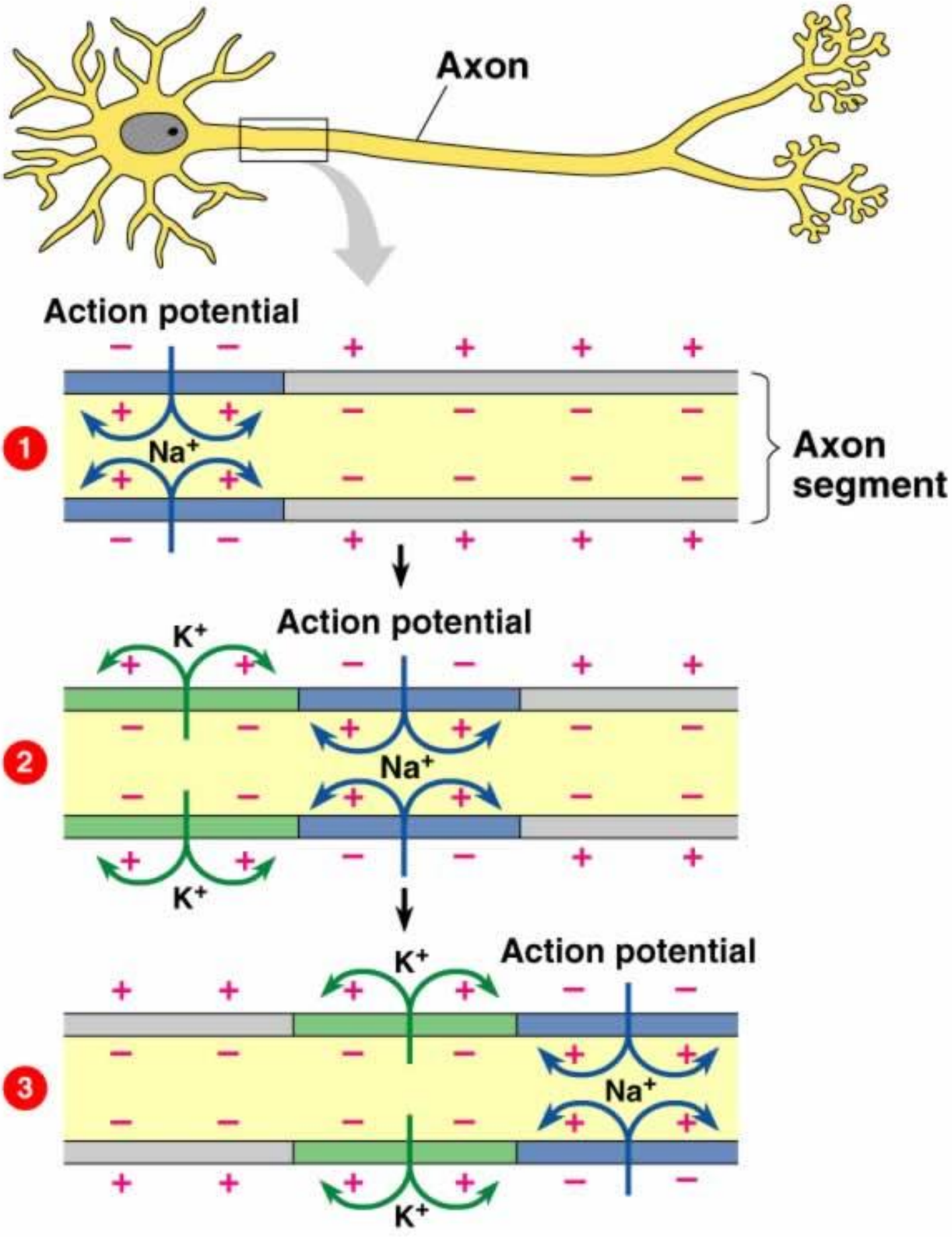


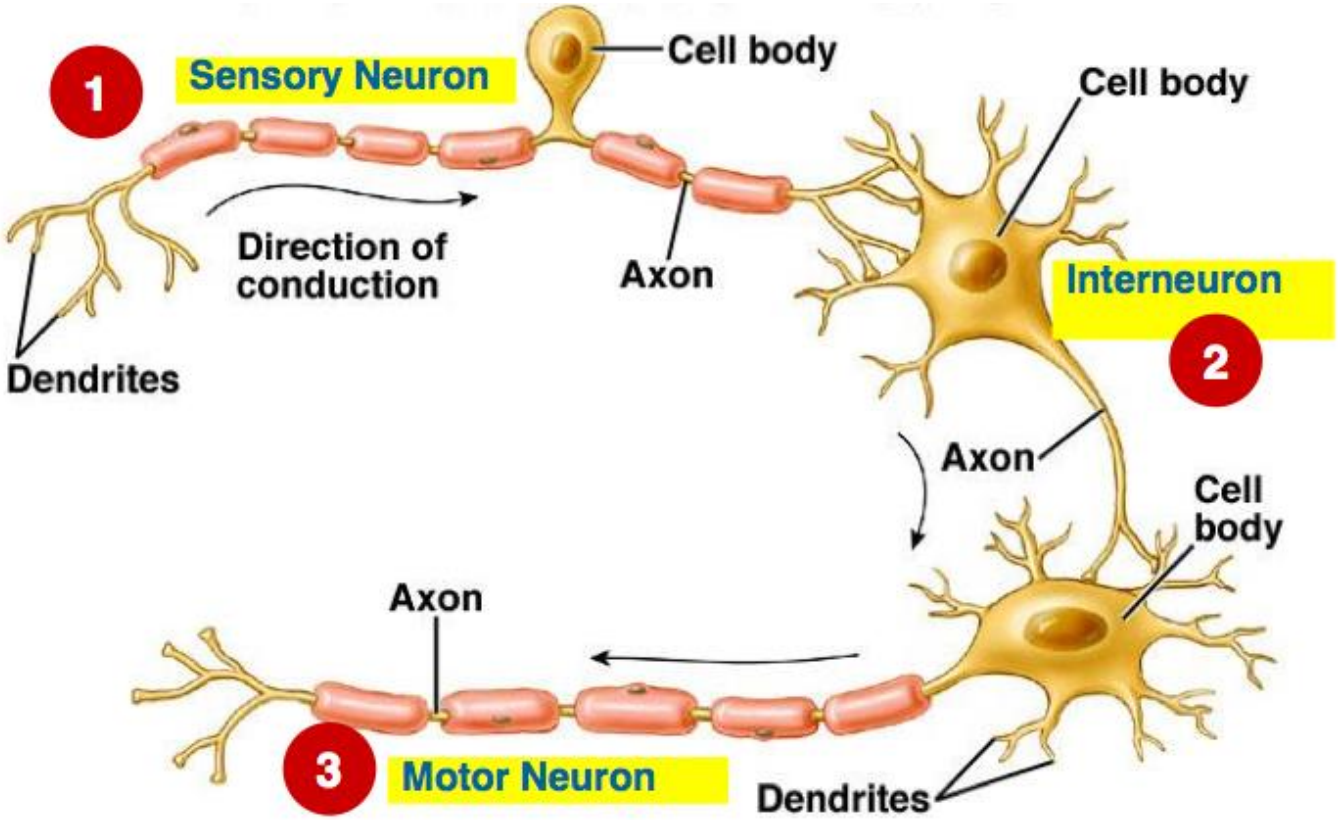




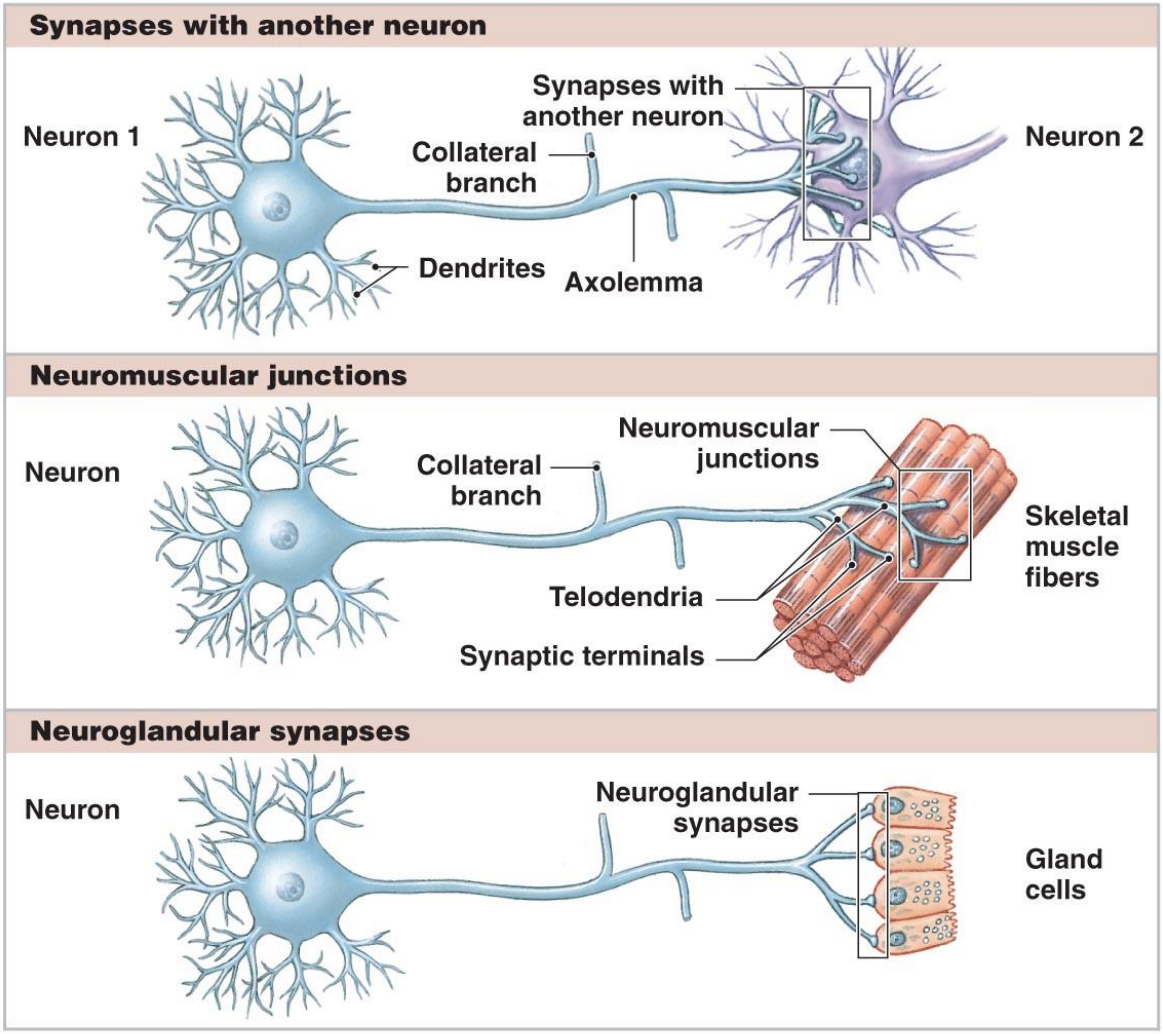
PNS: Comparison of Somatic and Autonomic Nervous Systems




Axon
Action potential
1
Na+
Axon segment
Action potential
K+
2
Na+
K+
Action potential
K+
3
Na+
K+



The types of synapses



1.5-Deterioration of the nervous system

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Alzheimer's disease

Alzheimer's disease is the most common cause of dementia among older people. Dementia is the reduction in mental ability beyond what would be expected from normal ageing.

Cause

People with Alzheimer's disease have abnormal clumps (amyloid plaques) & tangled bundles of fibres (tau tangles) in the brain.

Symptoms

Alzheimer's disease is characterised by progressive & irreversible mental deterioration. It gradually destroys memory & thinking skills, eventually leading to confusion, mood swings, aggression & general withdrawal.

Treatment

Drugs are available to manage the symptoms of the illness & slow its progress. Drugs aim at increasing acetylcholine levels, as acetylcholine is a neurotransmitter essential for processing memory & learning.

Parkinson's disease

A degenerative disorder of the brain.

Cause

Destruction of dopamine-producing cells in the basal nuclei of the cerebrum.

Symptoms

Slowed physical & mental responses, muscular tremors, stiffness of the limbs, impaired balance & coordination.

Treatment

A variety of medications which either contain or act like dopamine, block acetylcholine or prevent the breakdown of dopamine.

Cell Replacement Therapy

Obtain some embryonic/adult stem cells.

Differentiate these into neurons in vitro (in test tube).

Insert these cells into the affected area of the patient's brain.

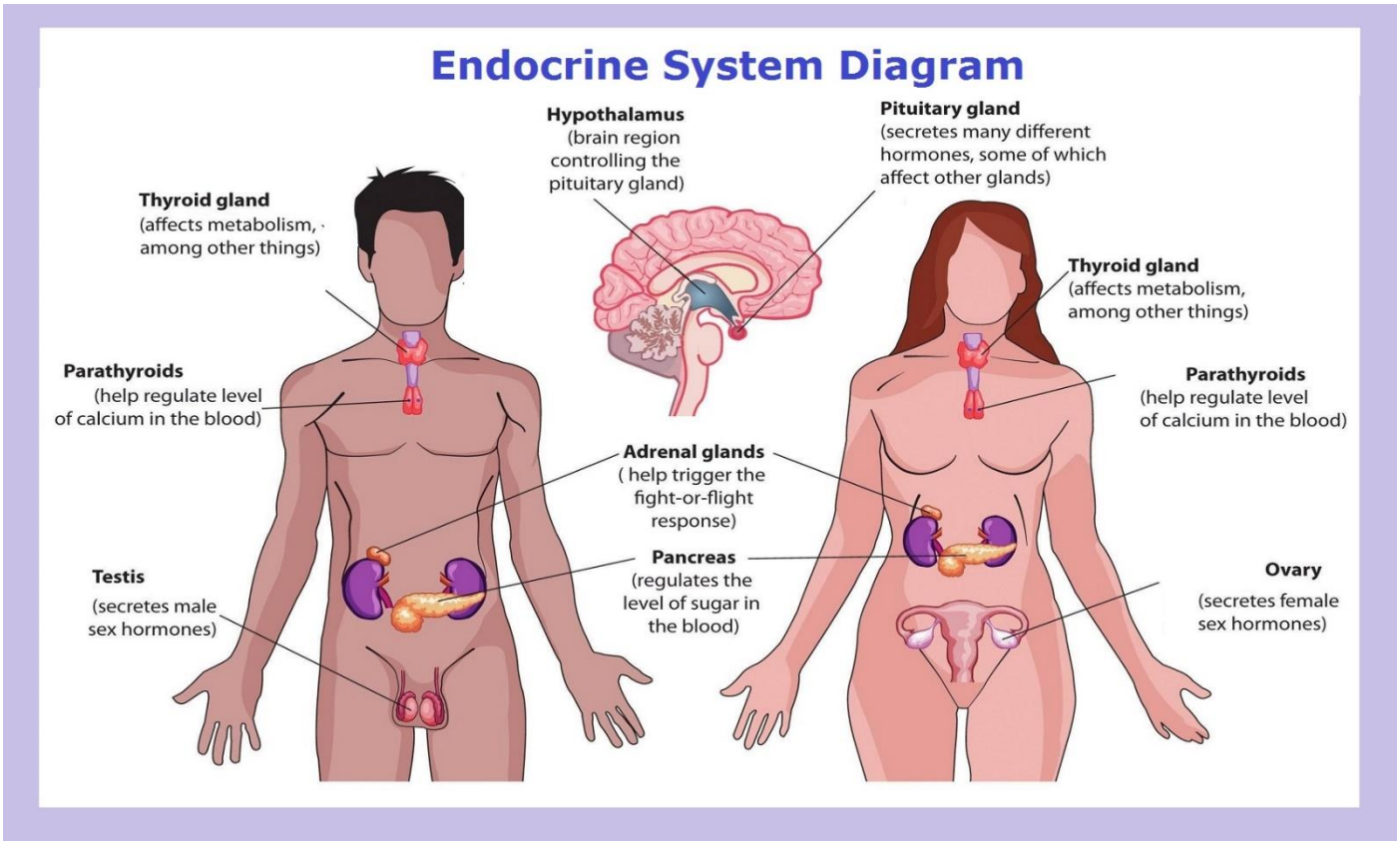
Healthy neurons initiate self-repair, replacing damaged neurons.

2-Endocrine system

Function

Regulate & maintain the various functions of the body by releasing hormones. These hormones are produced & secreted by what are known as endocrine glands. The hormones maintain a stable internal environment of the body, this is known as homeostasis.

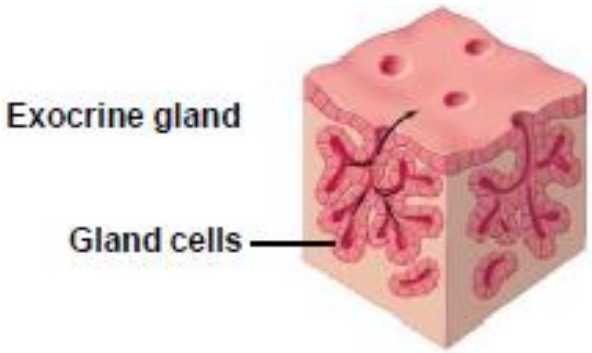
Location/Structure

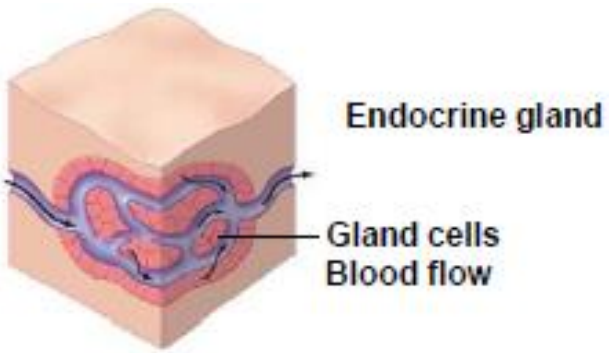


Endocrine glands

Exocrine glands – Glands that secrete into ducts that lead to the body surface or body cavity. Examples include salivary glands that secrete saliva into the mouth, bile-producing glands of the liver, prostate gland, the portion of the pancreas that secretes pancreatic fluid into the duodenum, gastric glands & sweat glands.

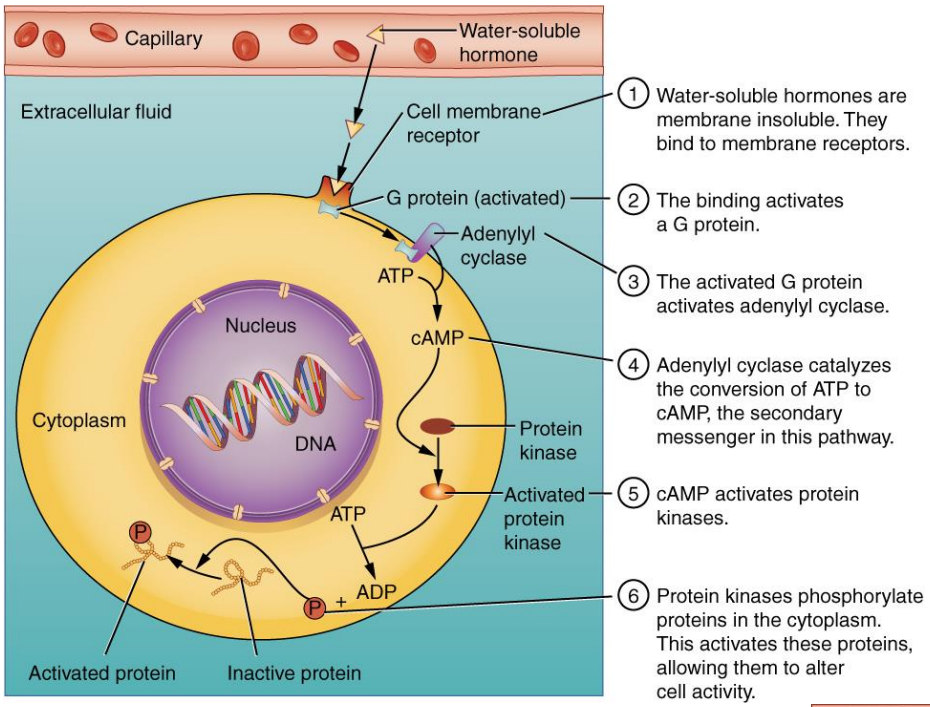
Endocrine glands – Glands that secrete hormones into the bloodstream, these glands are considered ductless. Examples are pituitary gland, pineal gland, thyroid gland, thymus gland, parathyroid, adrenal glands, pancreas, testes & ovaries.





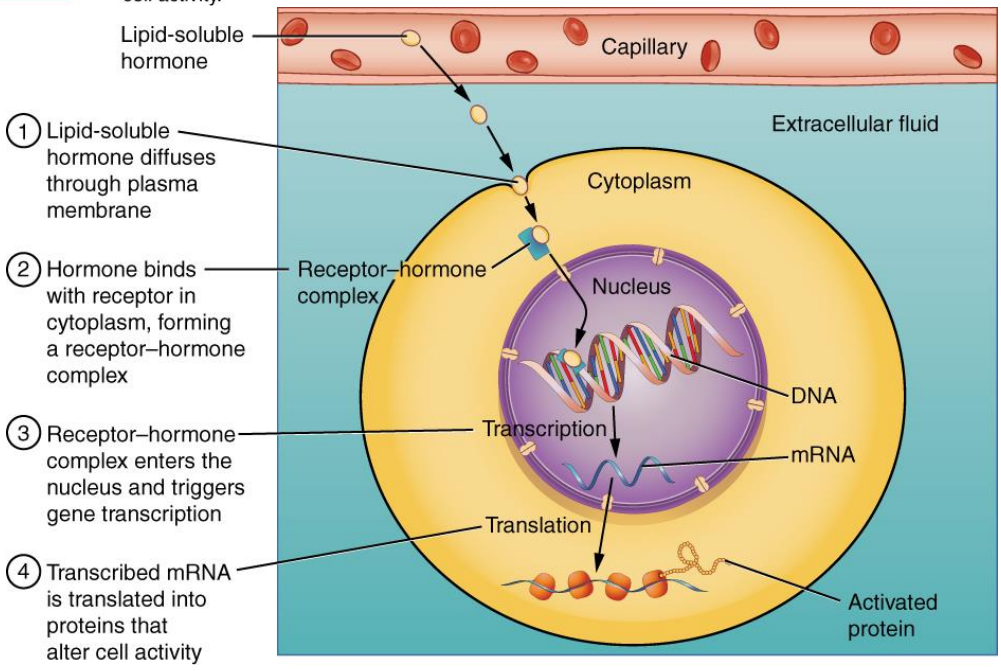
Hormones

Chemical messengers secreted by endocrine glands carried in bloodstream to target organs/cells. Hormones are mostly proteins, amines or steroids which are able to change the way in which cells function.



Proteins & Amine hormones – Made of amino acids or chains of amino acids. They travel in blood plasma as they are **water soluble**. They bind to receptor proteins on the cell membrane as they are not able to enter the phospholipid bilayer. This causes a secondary messenger substance to diffuse through the cell altering enzyme activity. Acts in seconds to minutes.

Steroids – Made of lipids. They travel through the cell membrane as they are soluble. Steroid hormones bind with receptor proteins on the nucleus, mitochondria & other organelles. Steroids are able to activate genes to produce particular enzymes or structural proteins. Change the rate of production of an enzyme or protein (transcription & translation of RNA) also inhibit or express enzymes by changing their shape or structure. Acts in hours to days.



Enzyme amplification

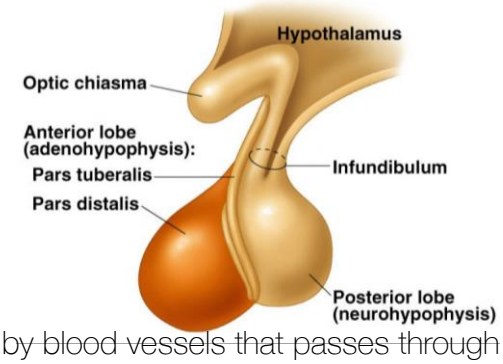
One hormone molecule can trigger the production or activation of up to a billion enzymes. The hormone causes a cascade of events, a very small stimulus can produce a very large effect.

Hormone/receptor complex

Protein receptors are hormone specific, each type of receptor will bind with only one specific molecule. Saturation, occurs when all protein receptors have been occupied by hormones, meaning an increase of hormones does not produce a greater effect or increase cell activity.

Pituitary & Hypothalamus

Hypothalamus – An endocrine gland that acts as a link between the endocrine system & nervous system. The hypothalamus is responsible for maintaining the body's internal balance, which is known as homeostasis. The hypothalamus functions by secreting inhibiting & releasing factors that affect the anterior pituitary into producing hormones. While the hypothalamus is able to secrete hormones, which are stored in the posterior pituitary gland.



Anterior pituitary gland – Linked by blood vessels that passes through the infundibulum. Produces **Thyroid Stimulating Hormone (TSH)**, **Adrenocorticotropic Hormone (ACTH)**, **Follicle Stimulating Hormone (FSH)**, **Luteinising Hormone (LH)**, **Growth Hormone** & **Prolactin**.

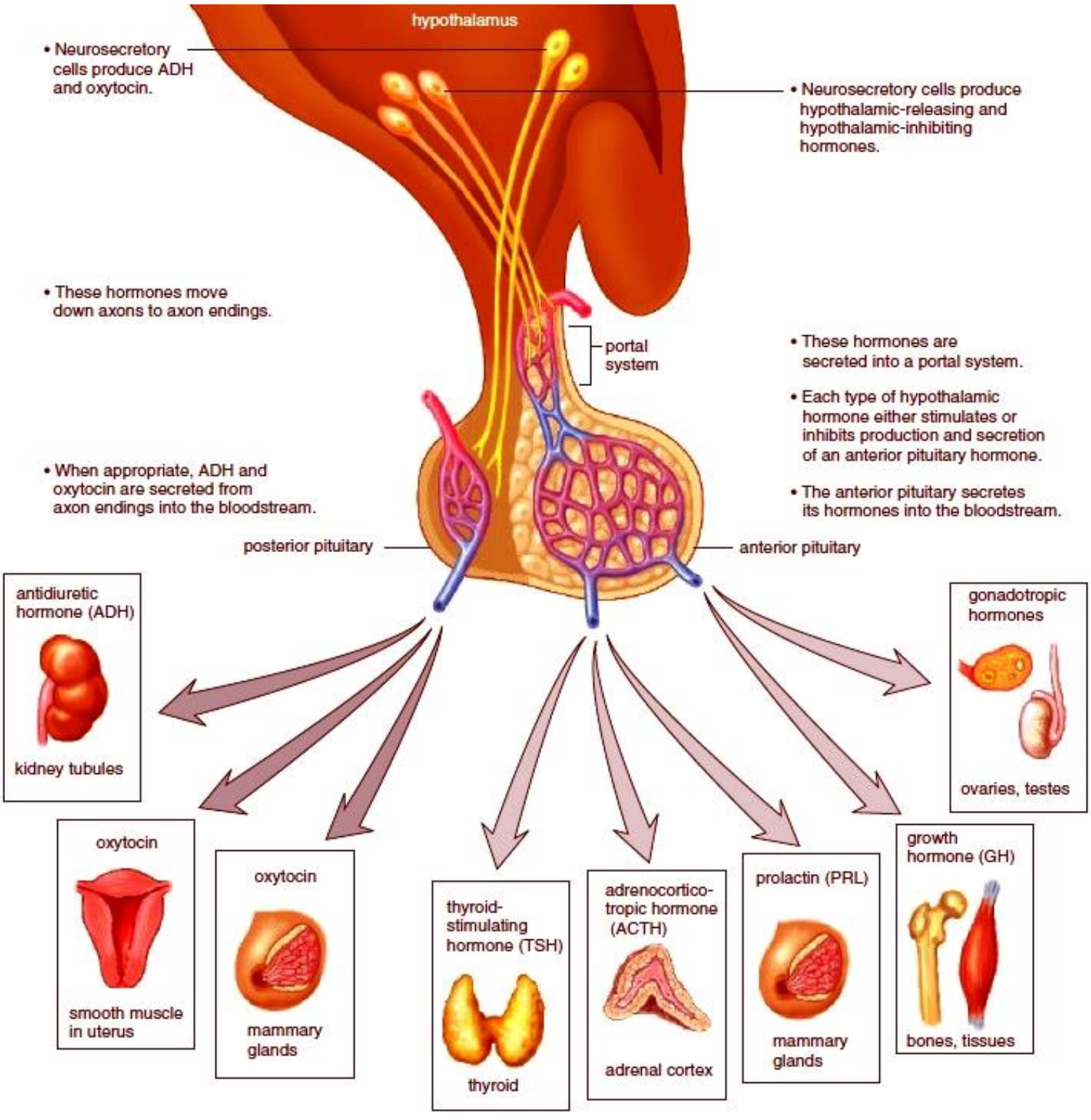
Posterior pituitary gland – Linked by neurons that passes through the infundibulum. Does not produce any hormones. Hypothalamus produces **Antidiuretic Hormone** & **Oxytocin**, which are stored in the posterior pituitary gland. These hormones are released from posterior pituitary gland upon nerve stimulation from the hypothalamus.

Anterior Pituitary Gland Hormones

Hormone Produced	Target Organ/cells	Action
Thyroid Stimulating Hormone (TSH)	Thyroid Gland	Stimulates the production of Thyroxine
Adrenocorticotropic Hormone (ACTH)	Adrenal Cortex	Stimulates the production of corticosteroids
Follicle Stimulating hormone (FSH)	Follicle of ovaries Seminiferous tubules of testes	Maturation of Follicle Production of Sperm
Luteinising Hormone (LH)	Follicle of ovaries Interstitial cells of testes	Ovulation Formation of Corpus Luteum Testosterone production
Growth Hormone	All cells (affects bone & skeletal tissue most)	Protein synthesis & growth
Prolactin	Milk producing cells in mammary glands	Initiates & Maintains milk production

Posterior Pituitary Gland Hormones

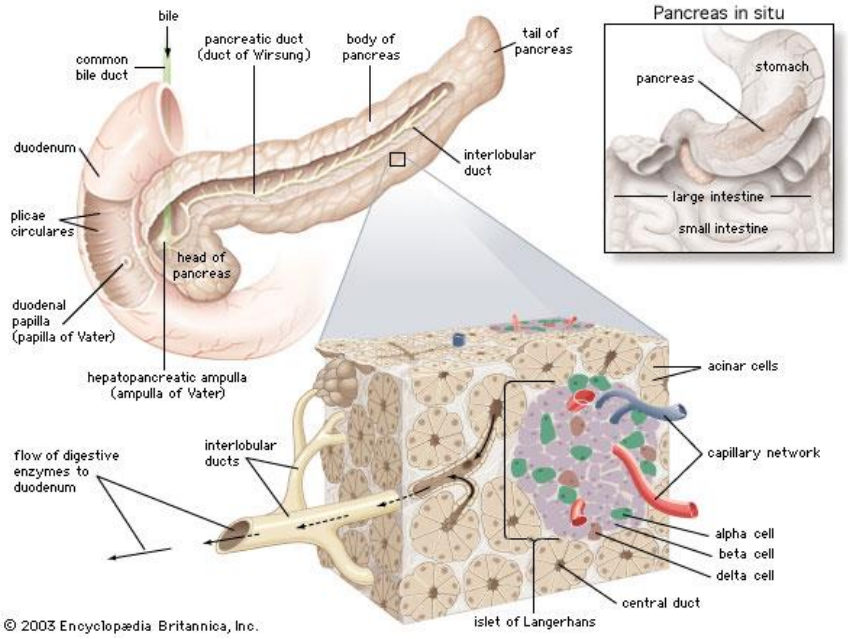
Hormone /secreted	Target organ/cells	Action
Antidiuretic hormone (ADH)	Collecting Duct & Distal Convoluted Tubule of nephrons in kidney	Increases water reabsorption from kidneys
Oxytocin	Milk producing cells in mammary glands Smooth muscles in uterus	Allows milk letdown/suckling reflex Initiates labour

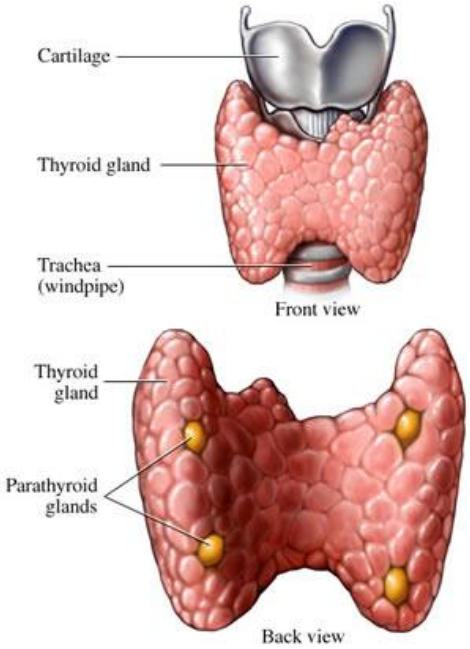

hypothalamus
• Neurosecretory cells produce ADH and oxytocin.
• Neurosecretory cells produce hypothalamic-releasing and hypothalamic-inhibiting hormones.
• These hormones move down axons to axon endings.
portal system
• These hormones are secreted into a portal system.
• Each type of hypothalamic hormone either stimulates or inhibits production and secretion of an anterior pituitary hormone.
• The anterior pituitary secretes its hormones into the bloodstream.
• When appropriate, ADH and oxytocin are secreted from axon endings into the bloodstream.
posterior pituitary
anterior pituitary
antidiuretic hormone (ADH)
kidney tubules
gonadotropic hormones
ovaries, testes
oxytocin
smooth muscle in uterus
oxytocin
mammary glands
thyroid-stimulating hormone (TSH)
thyroid
adrenocortico-tropic hormone (ACTH)
adrenal cortex
prolactin (PRL)
mammary glands
growth hormone (GH)
bones, tissues

Thyroid & Parathyroid

The thyroid gland is wrapped around the larynx. Four small parathyroid glands are embedded in the thyroid.

Gland	Principle hormones	Target organs /cells	Action
Thyroid	Thyroxine Calcitonin	Most cells Bones/osteocytes	Stimulates metabolism Calcium deposition
Parathyroid	Parathormone/Parathyroid hormone	Bones osteoclasts & small intestine	Raises blood calcium levels





Pancreas (Islets of Langerhans)

The pancreas is both an exocrine & endocrine gland. The exocrine part of the pancreas secretes digestive enzymes in the pancreatic duct. While within the pancreas, clusters of special cells called Islets of Langerhans (pancreatic islets) are responsible for the endocrine function of the pancreas.

Gland	Principle hormones	Target Organs/ Cells	Action
Islets of Langerhans *Beta-cells*	Insulin	Most	Lowers blood sugar levels, by converting glucose into glycogen & fat
Islets of Langerhans *Alpha-cells*	Glucagon	Liver & Adipose tissue (fat cells)	Raises blood sugar levels, by converting glycogen back to glucose

Adrenal Glands

The adrenal glands are located on top of the kidneys. Each adrenal gland contains an inner adrenal medulla & an outer adrenal cortex. These two parts are considered to be separate endocrine glands as they secrete different hormones.

Gland	Principle hormones	Target organs/ cells	Action
Adrenal cortex	Mineralocorticoids e.g. aldosterone	DCT, collecting duct & Loop of Henle	Increases sodium reabsorption in kidneys
	Glucocorticoids e.g. cortisol	Most	Helps body's stress response/ Increase blood glucose
	Gonadocorticoids e.g. testosterone	Many	Secondary sexual characteristics
Adrenal medulla	Adrenaline (epinephrine)	Most	Fight or flight response
	Noradrenaline (norepinephrine)		

Gonads

Gland	Principle hormones	Target organs/ Cells	Action
Testes	Testosterone	Many tissues	Stimulates sperm production, growth of skeleton & muscles, secondary sex characteristics
Ovaries	Oestrogen Progesterone	Many Endometrium & Mammary Glands	secondary sexual characteristics, development of the endometrium Maintenance of endometrium, prepares mammary glands for milk production

Nervous System/Endocrine comparison

Characteristic	Nervous System	Endocrine System
Speed of action	Rapid, milliseconds	Slow, seconds to days
Nature of message	Electrochemical	Hormonal
Transmission	Neurons	Bloodstream
Specificity	Local & specific	General & widespread
Duration of response	Brief – stops quickly when the stimulus stops	Longer lasting – may continue long after the stimulus has stopped

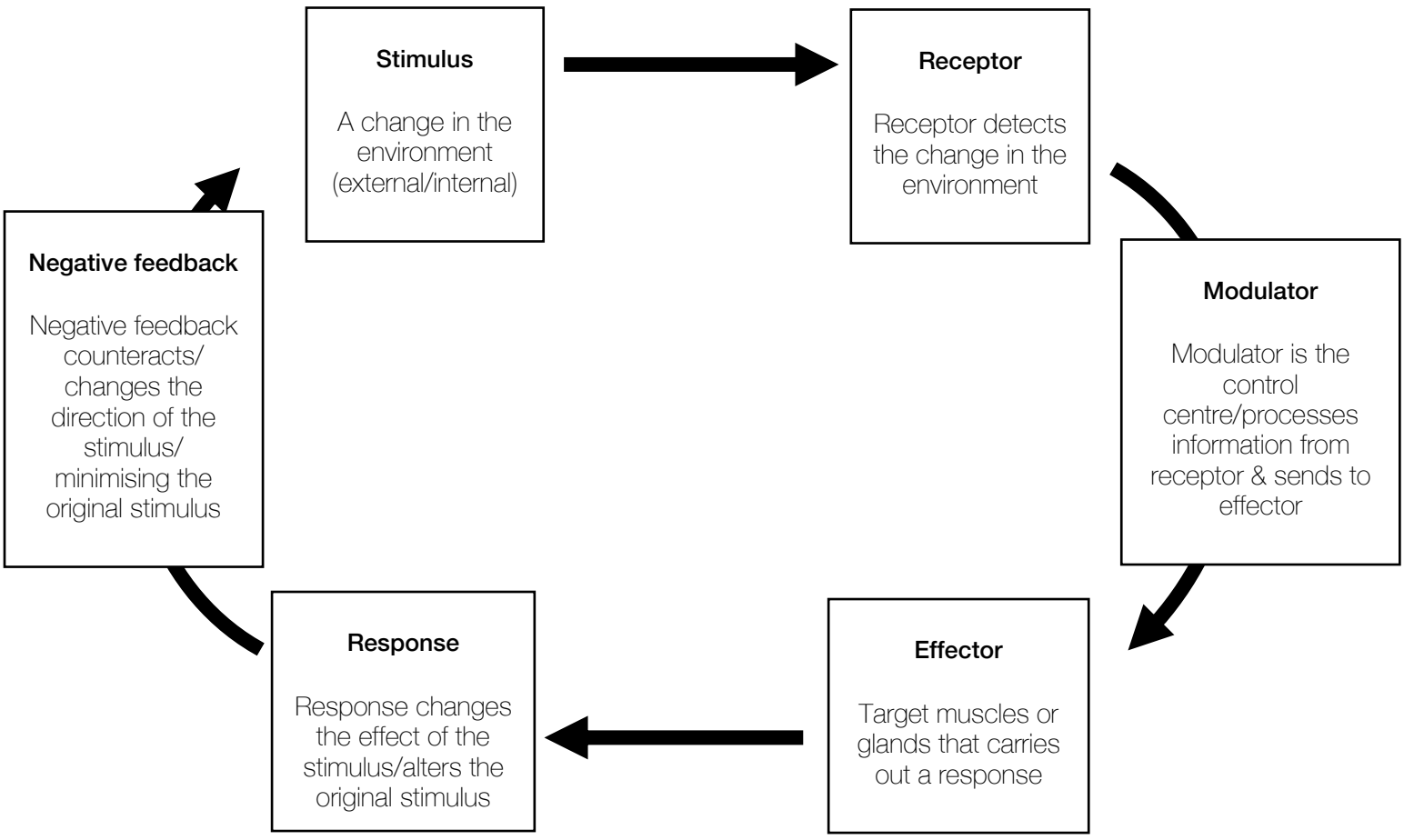
Homeostasis

Homeostasis – Maintaining the body's internal environment at a constant level. Homeostatic mechanisms regulate core body temperature, pH & concentrations of dissolved substances in the body fluids, concentration of glucose in blood, concentration of O_2 & CO_2 in the blood & other body fluids, blood pressure & concentration of metabolic wastes.

Feedback System

Homeostasis responds to stimulus through a negative feedback system. A negative feedback system works by minimizing/eliminating the stimulus. A negative feedback system or steady state control system consists of the stimulus, receptor, modulator, effector, response & feedback.

Stimulus-response-feedback model



Thermoregulation

Thermoregulation – The body's ability to regulate the core temperature. All thermoregulation mechanisms are designed to return your body to homeostasis.

Heat transfer

Conduction – The transfer of heat through direct contact with the heat source e.g. stepping on hot sand.

Convection – The transfer of heat by the circulation or movement of the heated parts of a liquid or gas.

Radiation – The transfer of heat without direct contact with the source. Warmer objects radiate heat to cooler surroundings due to the concentration gradient.

Evaporation – Evaporation is the transformation of water from its liquid state to its gaseous state (i.e. steam or water vapour)

Thermoregulation – **low** core temperature

The thermoneutral zone in humans is between 36.3℃ & 37.3℃.

When the thermoneutral zone is lower than 36.3, the hypothalamus detects this change & implements a negative feedback system to counteract this stimulus. This feedback system works by initiating responses that **increase** heat production in the body while **minimizing** heat loss.

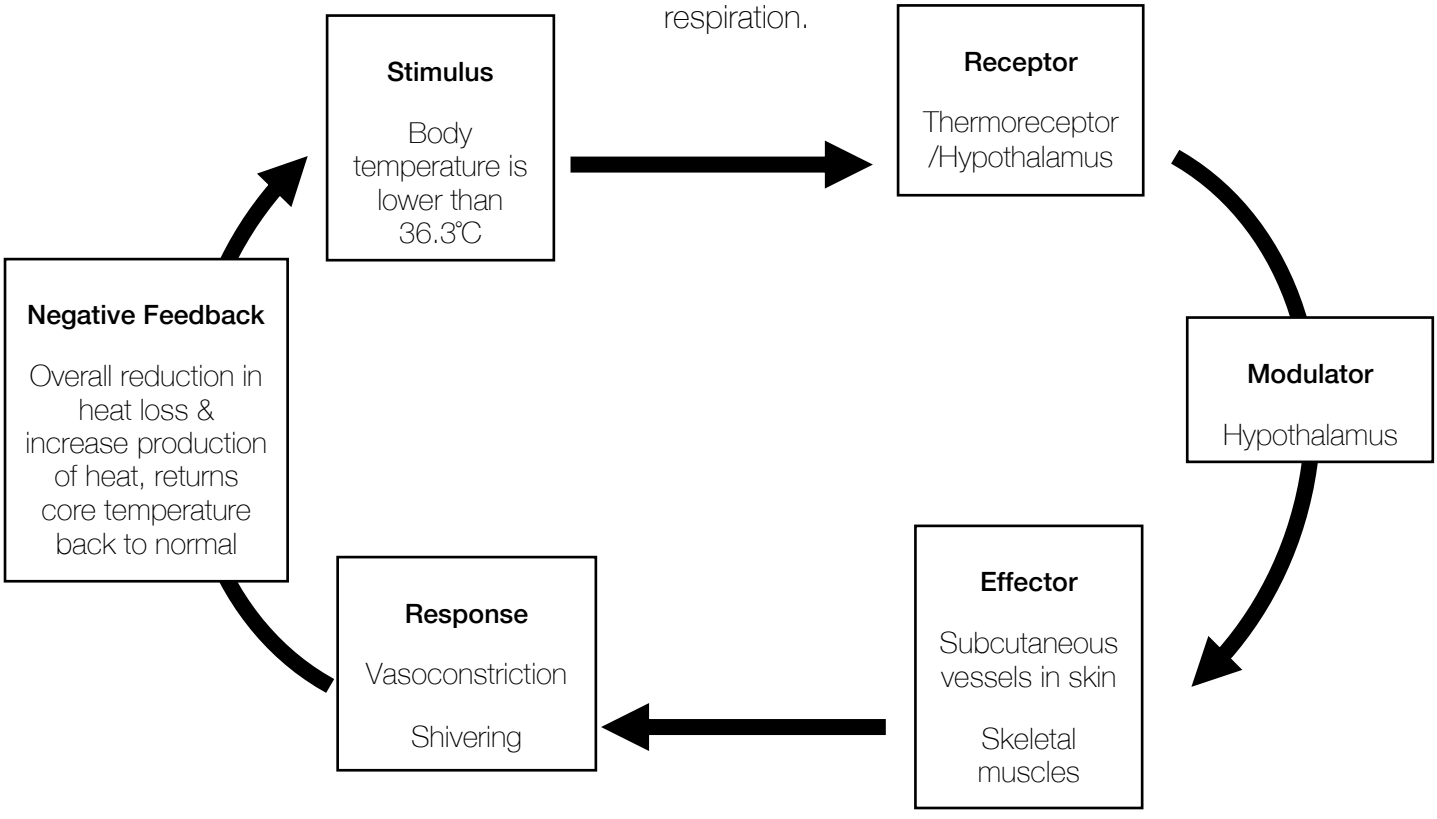
Heat Loss

Vasoconstriction – Vasoconstriction of cutaneous blood vessels in the skin occur. This allows for the minimization of the body's heat radiating into the surrounding.

Heat Production

Hormones (Long term response) – Adrenaline, noradrenaline secreted by the adrenal medulla & thyroxine secreted by the thyroid are hormones which increase the metabolic rate which allows for the increase in heat production by the body. This response is slower in having an effect.

Shivering – Muscles continuously contract & relax, allow for the formation of heat through cellular respiration.



Thermoregulation – **high** core temperature

When the thermoneutral zone is higher than 37.3, the hypothalamus detects this change & implements a negative feedback system to counteract this stimulus. This feedback system works by initiating responses that decrease heat production in the body while maximizing heat loss.

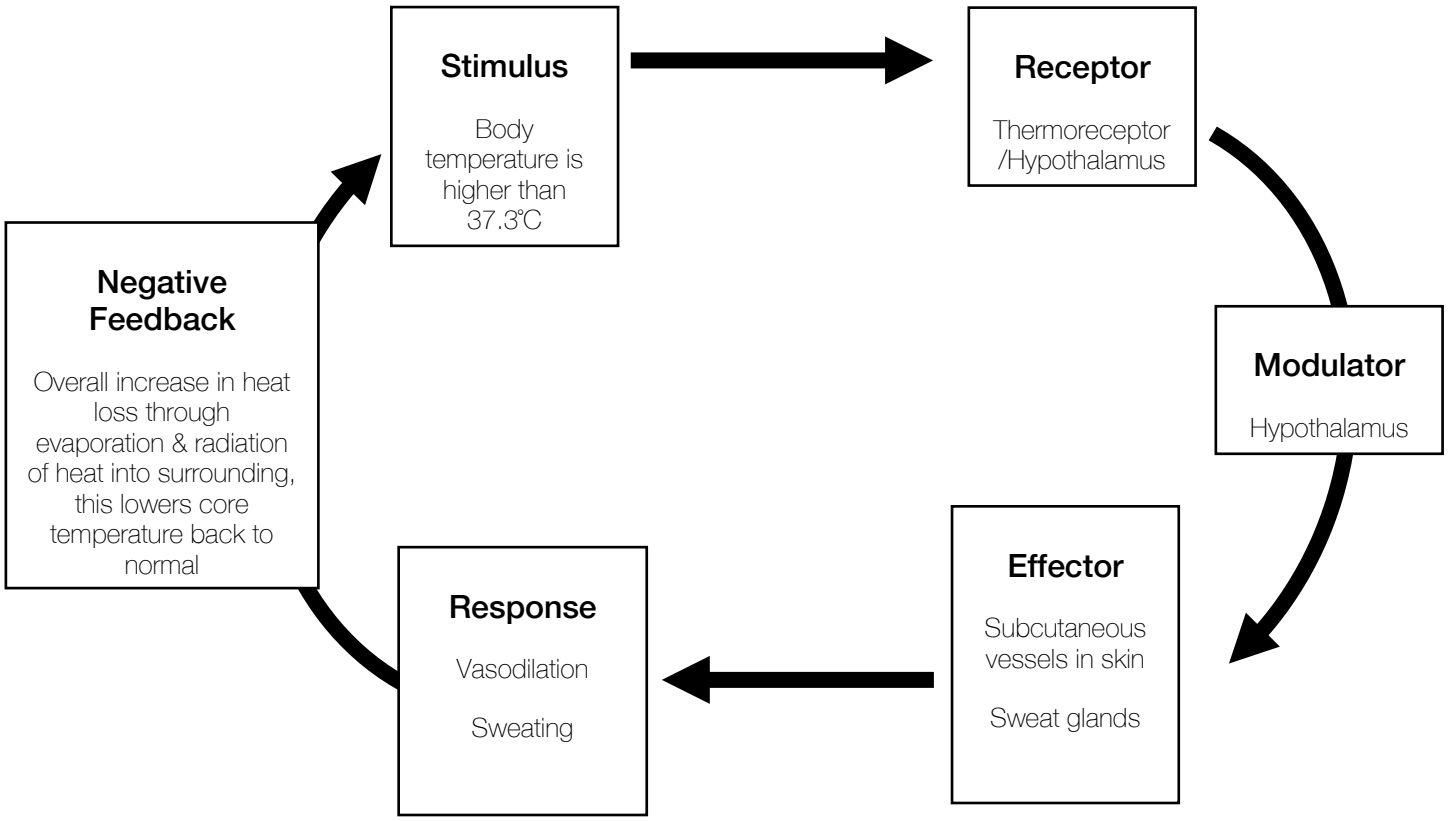
Heat Loss

Vasodilation – Vasodilation of cutaneous blood vessels in the skin occur. This allows for the maximization of the body's ability to radiate heat into the surrounding.

Sweating – Sweat glands secrete sweat, which evaporates allowing for heat loss to occur. Sweating can only happen in dry conditions, whereas in humid conditions sweat cannot evaporate.

Heat Production

Hormones (Long term response) – The secretion of thyroxine is decreased. This lowers the metabolic rate in the body, in turn lowering the core body temperature.



Behavioural Response

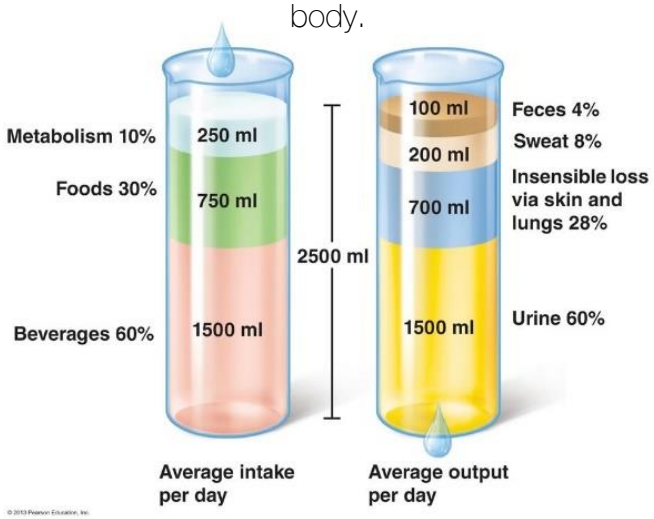
Conscious behaviour also has an effect on thermoregulation. During cold conditions a person may put on warmer clothing, shelter themselves from wind, consume warm food or increase voluntary activity. During hot conditions a person may seek shade, swim in cool water, turn on a fan/air conditioner in order to reduce body temperature.

Regulation of Body Fluid

Fluid balance is an aspect of the homeostasis of living organisms in which the amount of water in the organism needs to be controlled, such that the concentrations of electrolytes (salts in solution) in the various body fluids are kept within healthy ranges. The core principle of fluid balance is that the amount of water lost from the body must equal the amount of water taken in.

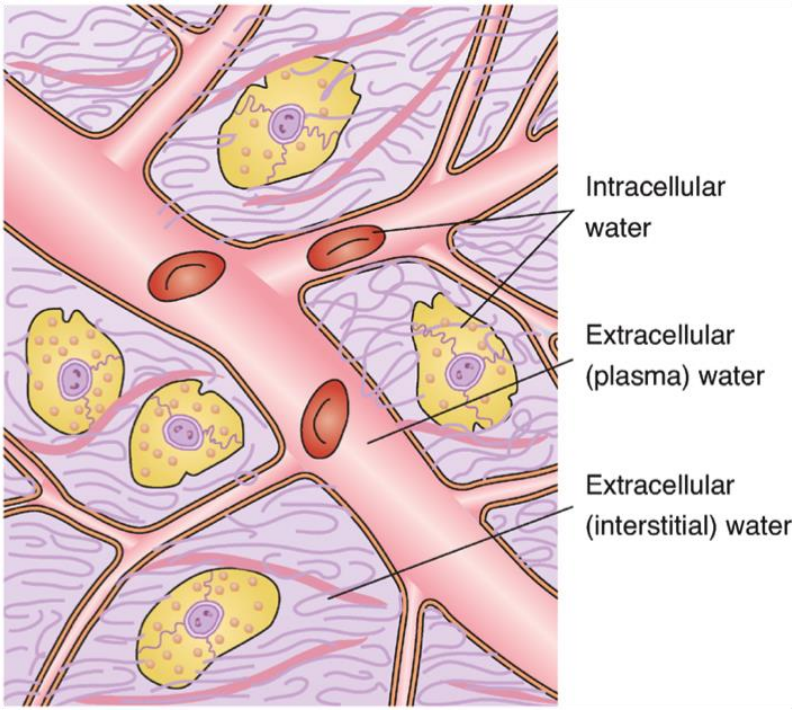
Water intake – 1200 ml is ingested from fluids, 1000 ml is ingested from food, 300 ml formed from cellular respiration, which is known as metabolic water. On total 2500 ml of water is ingested into the body.

Water output – 1200 ml of water is lost through urine, 750 ml is lost through sweating, 400 ml is lost as water vapour through the lungs & 150 ml is lost in the faeces. On total 2500 ml of water is lost out the body.



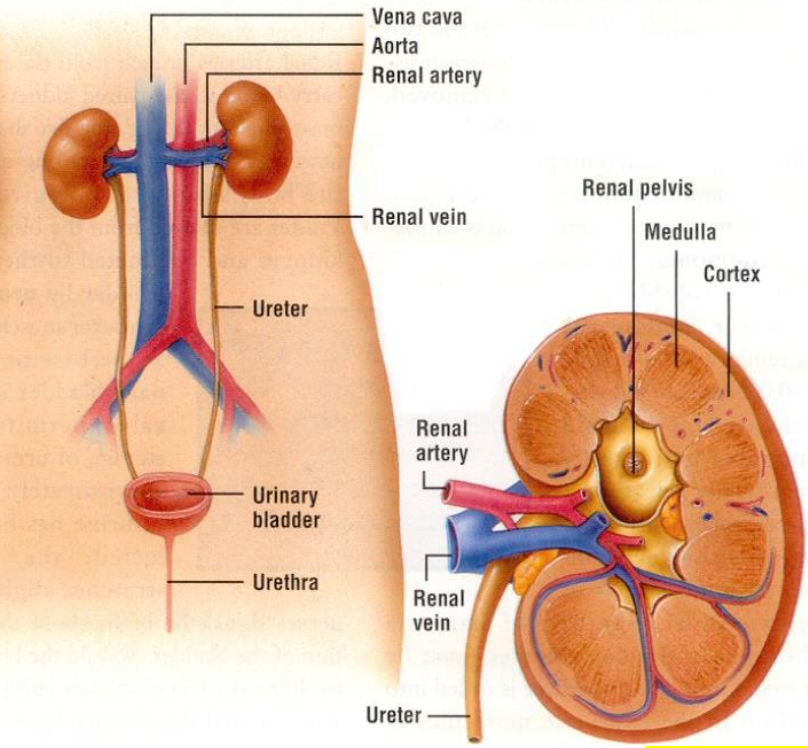
Intracellular fluid – Fluid inside the cell also known as the cytosol. 2/3 of the body's water is located.

Extracellular fluid – All fluid outside the cell or between. Extracellular fluid makes up 1/3 of the body's water. Plasma makes up ¼ of extracellular fluid. The remaining ¾ is made up of intercellular (fluid between cells). Intercellular fluid includes lymph, cerebrospinal fluid, synovial fluid, kidney filtrate & fluids in eyes & ears.



Kidneys

The kidneys function by maintaining fluid balance, salt balance & pH balance, while they are also responsible for the removal of wastes & production of urine.

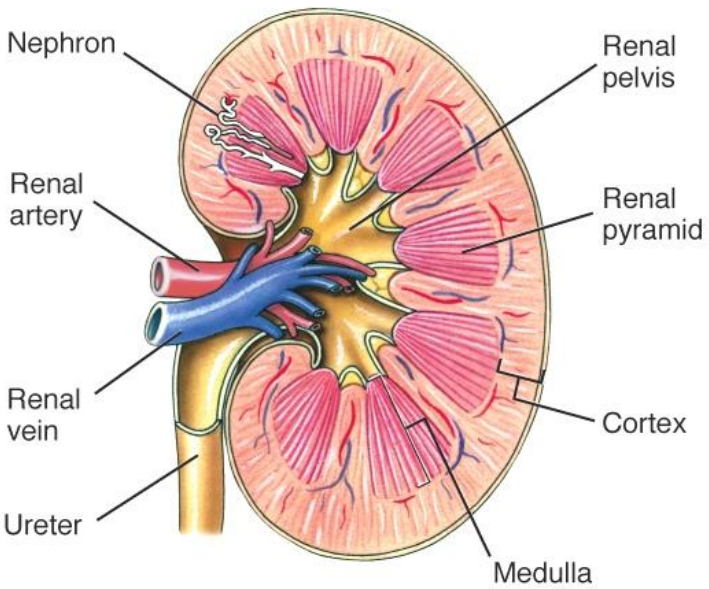


Water reabsorption

The kidneys important for homeostasis of body fluids (volume & the composition) as water loss via faeces, breathing & sweating is not linked to regulation of body fluids.

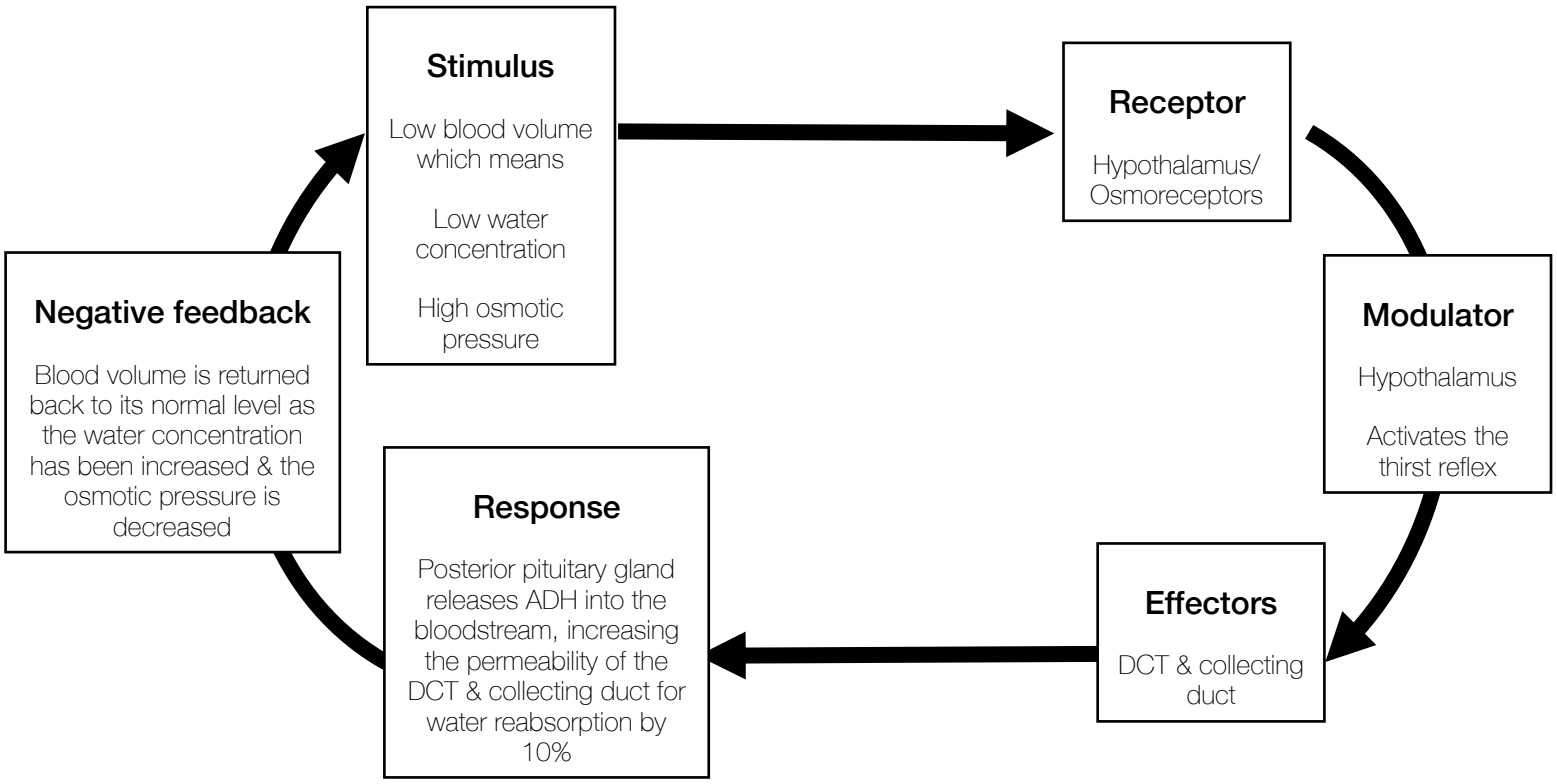
If we are dehydrated more water is reabsorbed so less urine is produced. If our tissue fluids are too dilute, less water is reabsorbed so more urine is produced

99% of water that enters the nephron is reabsorbed back into the bloodstream. 60-70 % of water reabsorption occurs in the proximal convolute tubule via osmosis (obligatory reabsorption). 20-30 % is selectively reabsorbed in the Loop of Henle, also via osmosis (obligatory reabsorption). 10% of water is reabsorbed in the DCT & Collecting Duct. This is regulated by ADH & aldosterone. (facultative reabsorption)



Fluid balance (Antidiuretic hormone) – low water concentration in blood

When there is a low water concentration in the blood & high osmotic pressure, a negative feedback system works to increase water reabsorption in the kidneys (DCT & collecting duct to be specific).



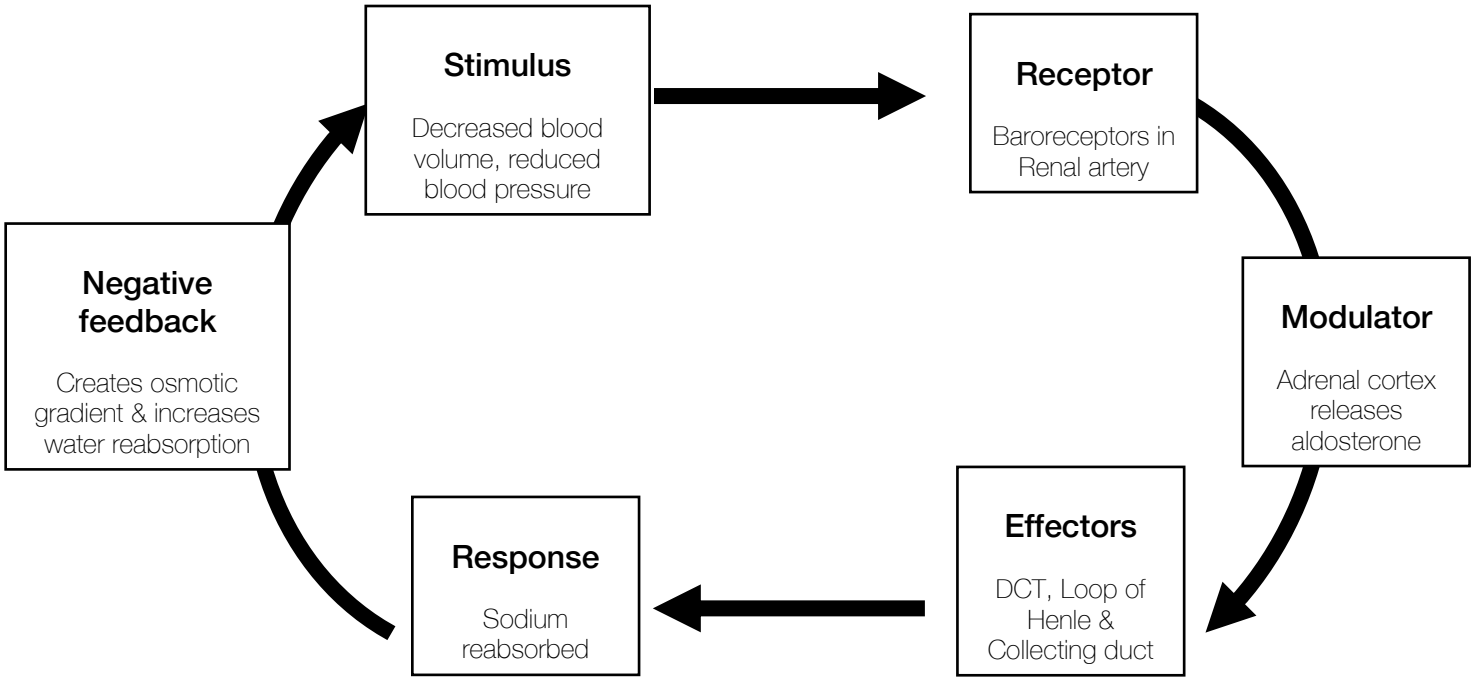
Thirst reflex – Causes a large conscious desire to drink

Stimulus: Low plasma volume → High extracellular osmotic concentration

Receptor: Osmoreceptors (hypothalamus). Stimulates the thirst reflex (person feels thirsty). Causes person to seek & drink fluid.

Salt balance (aldosterone) – low water concentration in blood

In addition to the ADH, water is also regulated by aldosterone a hormone secreted by adrenal cortex. Aldosterone increases the reabsorption of salts back into the blood. This creates a concentration gradient which in turn increases water reabsorption.



Blood glucose

Glucose is a major energy source for the body as it allows for all cell activities such as movement, reproduction, synthesis of molecules, active transport & many more. Normal glucose levels in the bloodstream are between 4.0 to 6.0 millimole/L. The pancreas & adrenal cortex is directly responsible for the regulation of glucose levels. Both glands work through negative feedback systems.

Pancreas (Islets of Langerhans)

Insulin – Hormone that lowers blood glucose, produced by beta cells.

Glucagon – Hormone that raises blood glucose, produced by alpha cells.

Glucose – Simple carbohydrate (basic carbohydrate building block), soluble.

Glycogen – Complex carbohydrate (stored in liver & muscles), insoluble.

Processes

Glycogenesis – Formation of glycogen from glucose in liver & muscles.

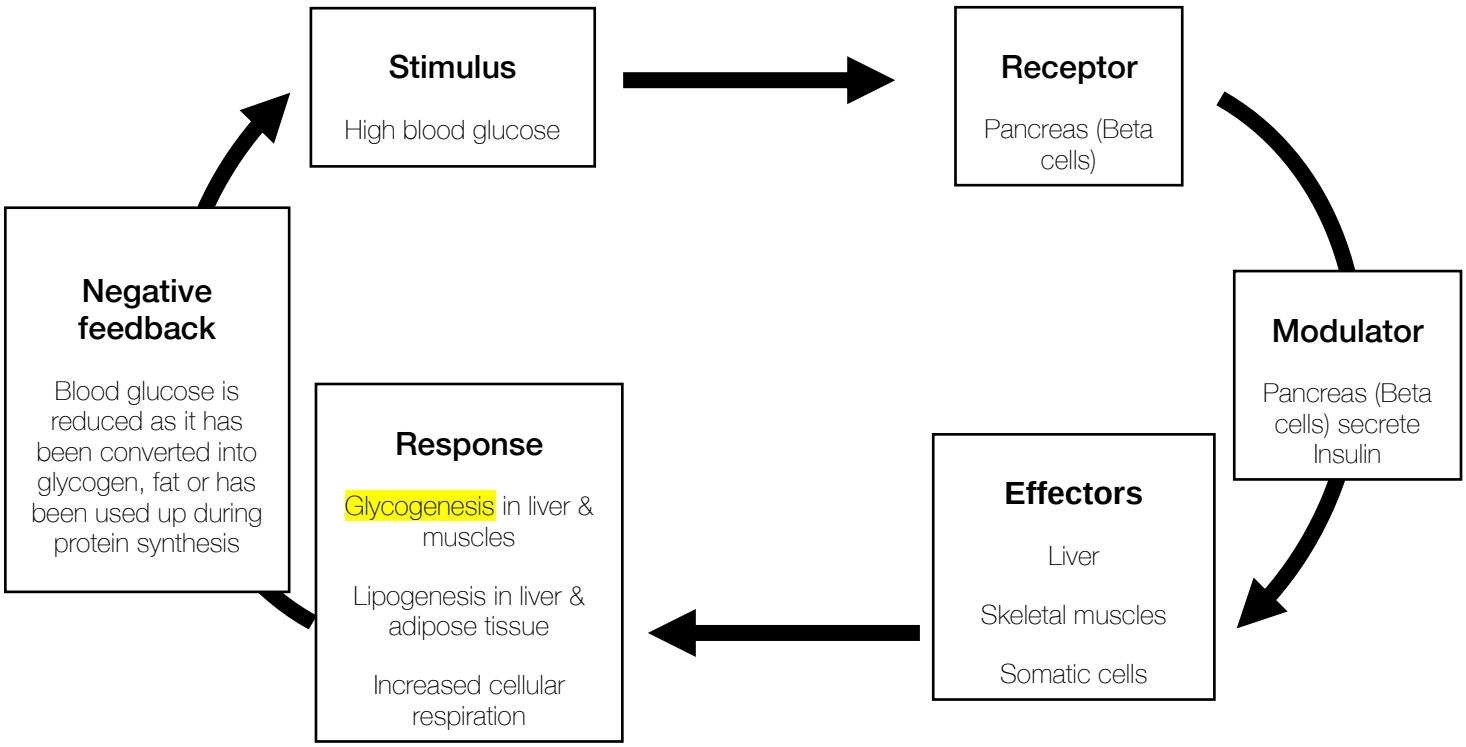
Glycogenolysis – Break down of glycogen to glucose. Takes place in the liver.

Gluconeogenesis – Formation of glucose from breakdown of lipids or protein. Takes place in the liver & adipose tissue.

Lipogenesis – Formation of fats from carbohydrate in adipose tissue.

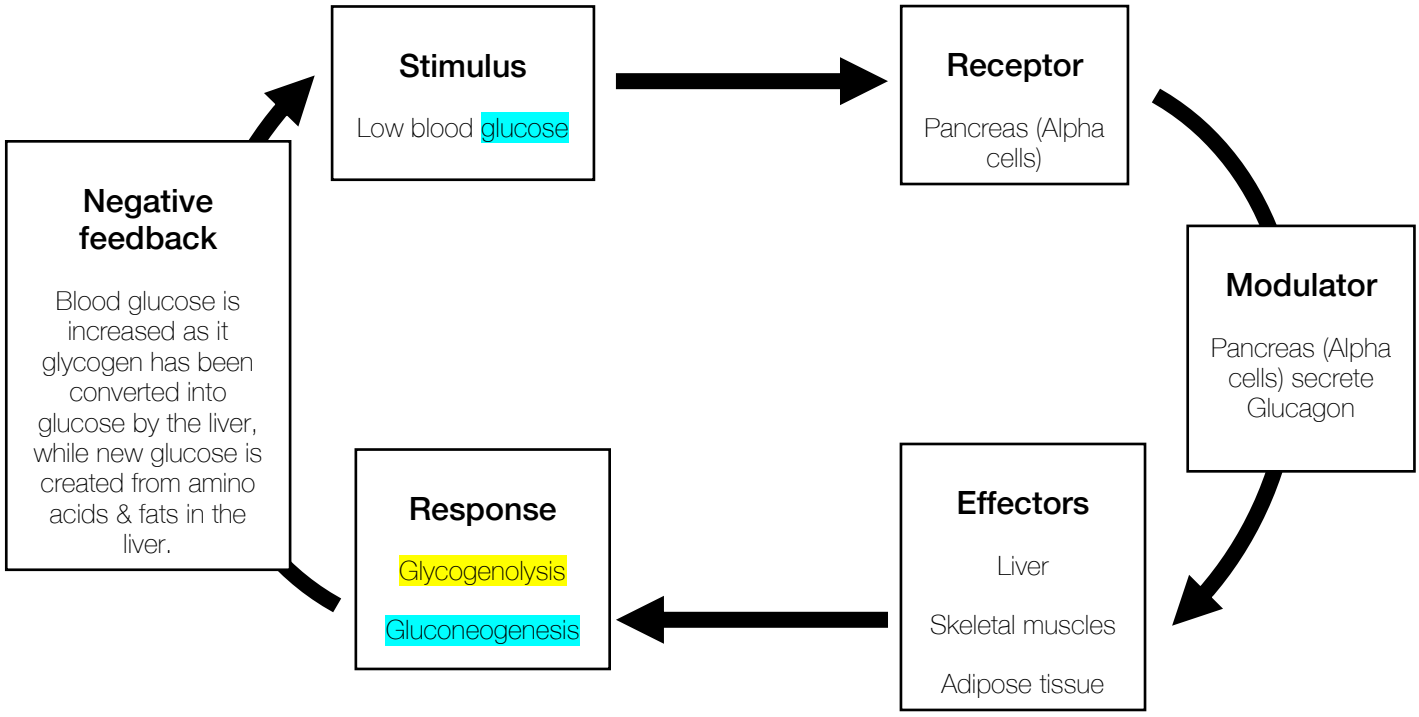
Glycaemia – Blood glucose level.

Blood glucose level – high glucose



Blood glucose

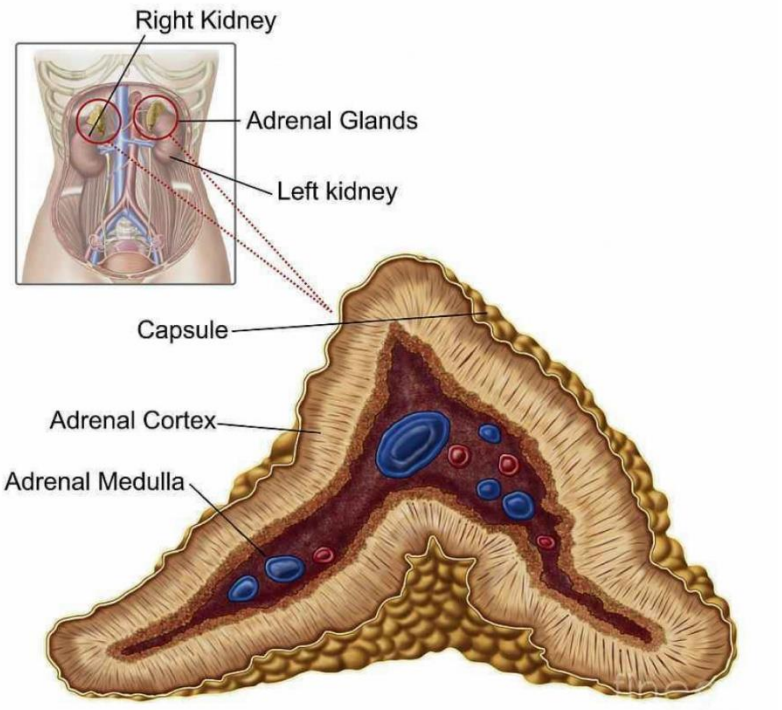
Blood glucose level – low glucose



Adrenal gland

Glucocorticoid/Cortisol - Stimulates glycogenolysis in the liver. Stimulates gluconeogenesis of amino acids in the liver. Cortisol is secreted by the Adrenal cortex, when ACTH (adrenocorticotropic hormone) is secreted by the anterior pituitary gland.

Adrenaline/Noradrenaline - Stimulates glycogenolysis in liver & skeletal muscle. Promotes conversion of lactic acid to glucose in the liver.



Gas concentrations

The regulation of gas concentrations in the body is an important homeostatic process. Oxygen, carbon dioxide & pH must be regulated in order for the body to function properly. The respiratory & circulatory systems work together in processing inhaled oxygen, exchanging it with carbon dioxide through gas exchange & exhaling it out of the body.

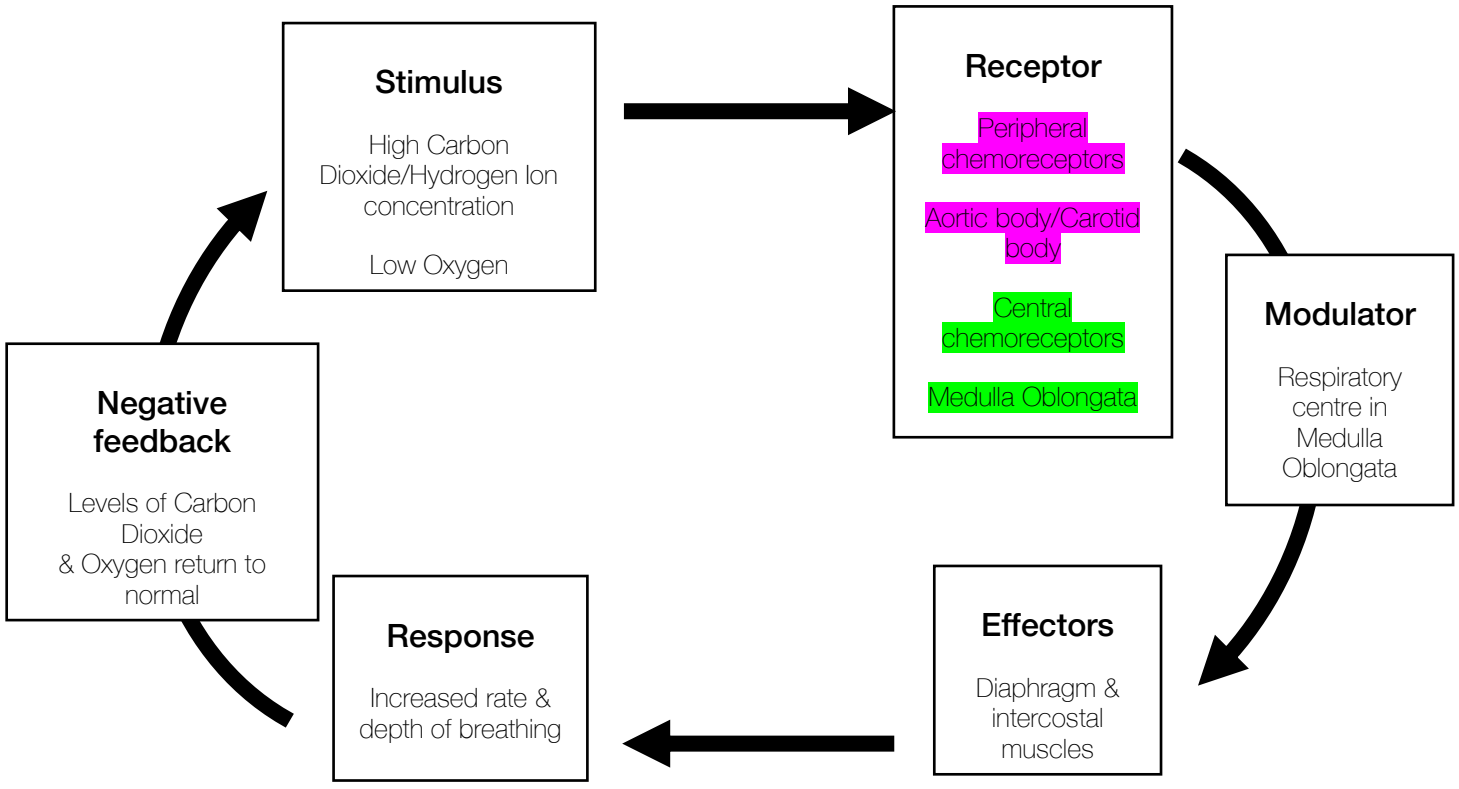
Control of breathing

Voluntary control of breathing is through the **cerebral cortex**. This allows for speech as we can stop breathing & protects us from accidently inhaling liquids or toxic gases. But due to carbon dioxide build up in the body, the respiratory centre in the medulla oblongata involuntarily causes us to breath, meaning we cannot hold our breaths forever. Involuntary control of breathing is regulated by the **medulla oblongata**. It contains the respiratory centre; two regions exist in the respiratory centre. The **inspiration centre** controls breathing in & **expiration centre** controls breathing out.

Peripheral chemoreceptors – Carotid & Aortic bodies, are sensitive to oxygen, carbon dioxide & pH concentrations in blood. Carotid & aortic bodies initially effect the breathing rate when there is a low oxygen and high pH concentration in blood, as it takes serval minutes for a response to occur from the respiratory centre.

Central chemoreceptors – Medulla Oblongata, is sensitive to a high concentration of hydrogen ions (H^+) in the cerebrospinal fluid. The Medulla is responsible for the stimulation of **phrenic nerves & intercostal nerves** which carry impulses through the spinal cord, activating contractions in the diaphragm & intercostal muscles respectively.

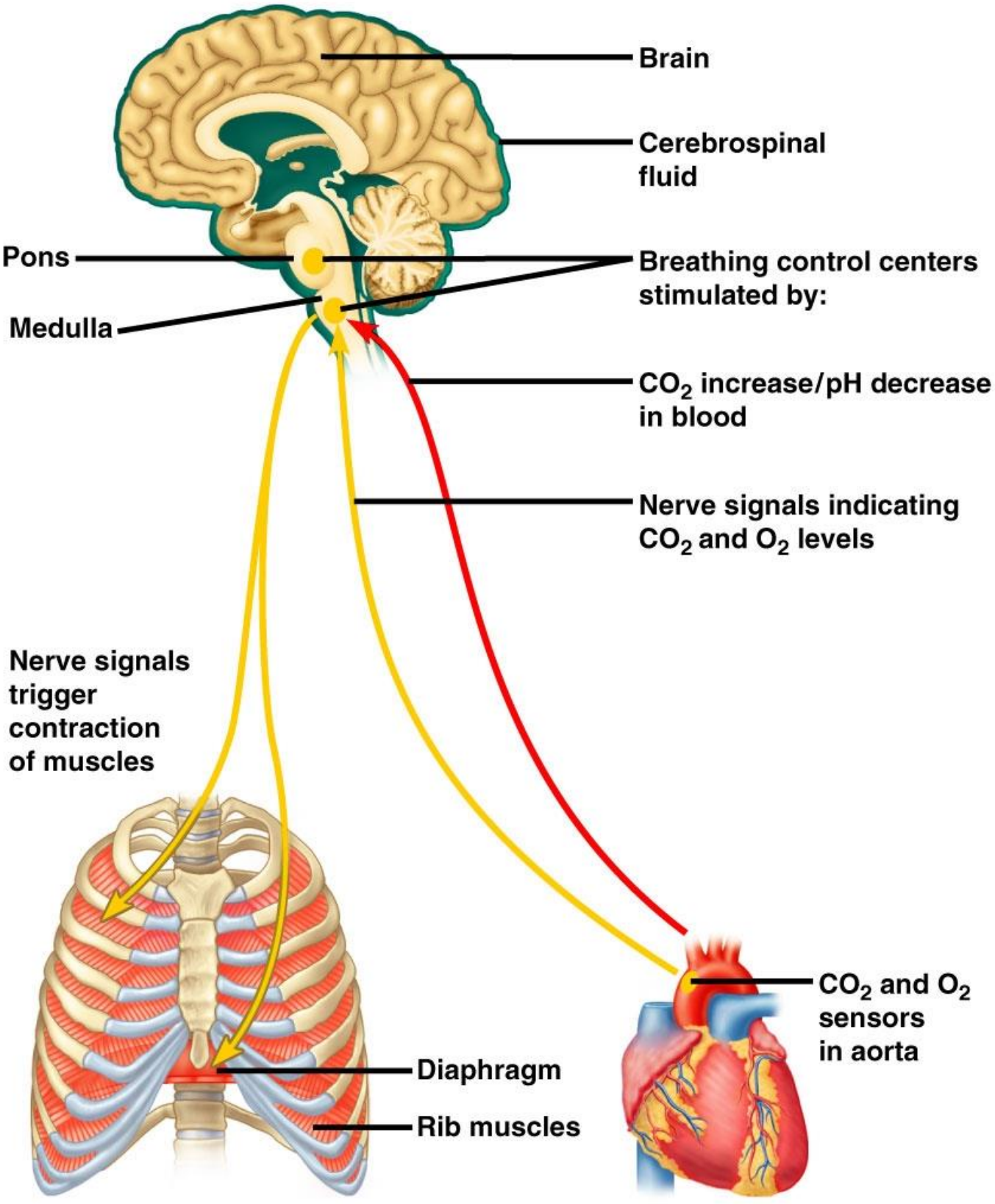
Gas concentrations – High carbon dioxide levels



Gas concentrations

A low oxygen concentration triggers carotid & aortic bodies, to alert the medulla oblongata. A high carbon dioxide concentration in blood plasma, which readily diffuses into the cerebrospinal fluid reacts with water, to produce carbonic acid (**H_2CO_3**) & hydrogen ions (**H^+**) which **decreases the pH** in the cerebrospinal fluid which is actively detected by the medulla oblongata.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^-$$



2.5-Disruption to Homeostasis - Diabetes

Type 1 Diabetes

Cause of condition – Begins in childhood & may have a genetic factor, occurs because of a fault in the patient's immune system that causes the destruction of beta cells in the Islets of Langerhans of the pancreas. It is not known what causes the auto-immune reaction.

Symptoms/effects on body – Type 1 diabetes causes serious disruptions to homeostasis. Beta cells produce insulin & because they are being destroyed, a person with type 1 diabetes does not produce insulin. Without insulin cells are resistant to the effects of insulin meaning they cannot take in glucose from the blood or stimulate the conversion of glucose into glycogen. Symptoms include excessive thirst/frequent urination/weight loss/fatigue/visual disturbances, such as blurred vision/itching skin, particularly around the genitals/nausea & vomiting. The long-term effects on the body lead to kidney failure, heart attack, stroke, amputations, blindness or nerve damage.

Medical technologies – **(Current)** Monitoring blood-sugar levels by testing blood droplets in a glucose meter. Regular injections of insulin or the use of a programmable pump that provides a continuous supply of insulin under the skin. Pancreas replacement. Yeast is now used to make insulin for the treatment of diabetes's & almost all the insulin used is biosynthetic recombinant 'human' insulin instead of animal insulin. **(Future)** Gene therapy can also be used to treat type-1 diabetes, it has undergone animal trials but not yet successful human trials. It involves differentiated cells, such as other types of pancreas cells & liver cells that can be stimulated to secrete insulin, from their own insulin genes.

Type 2 Diabetes

Cause of condition – Type 2 diabetes occurs because the bodies cells cannot respond to insulin properly (insulin resistance). Type 2 diabetes has a strong genetic & family related risk factor. It usually develops in people over the age of 45 with a genetic disposition to the condition. Type 2 diabetes is a lifestyle disease. Lifestyle factors that increase the risk of developing type 2 diabetes include lack of physical activity/being overweight or obese/high fat, sugar, salt diet/high blood pressure/high blood cholesterol/smoking

Symptoms/effects on body – Patients are able to produce insulin but their cells don't respond to it properly (insulin resistance). This means the pancreas does not produce enough insulin for the body's needs. If the insulin cannot do its job, the glucose channels do not open properly & glucose builds up in the blood instead of being taken into cells for energy. Many people don't often show symptoms until a later stage. Some symptoms include /being thirstier than usual/passing more urine/feeling tired & lethargic/slow-healing wounds/itching & skin infections/blurred vision.

Medical technologies – Treatments include management programs that aim to keep blood glucose levels within the normal range. Management includes careful diet, regular physical activity, healthy weight, monitoring blood glucose & medication that regulates blood glucose or insulin therapy.

Disruption to Homeostasis – Hypo/Hyperthyroidism

Hyperthyroidism

Cause of condition – Occurs when the thyroid gland is over-active & produces too much of the hormone thyroxine. The most common type of hyperthyroidism is known as Grave's disease. It is an enlargement of the thyroid caused by an immune system reaction. There is a genetic predisposition for the condition.

Symptoms/effects on body – Hyperthyroidism is where the thyroid gland secretes excessive amounts of thyroxine. The increased production of thyroxine over-stimulates cells & the body's processes speed up. For this reason, people experience symptoms such as rapid heartbeat/weight loss/increased appetite/fatigue/sweating/anxiety/in the case of Grave's disease, protruding eyeballs.

Medical technologies – Can be treated by drugs that block the thyroid glands use of iodine. The surgery to remove some or all of the gland. Another method is to give the patient a drink containing radioactive iodine which is taken up by the active cells in the thyroid, which are then killed. Other cells do not absorb the iodine. The radioactive iodine is then excreted in the urine

Hypothyroidism

Cause of condition – Occurs either through problems with the thyroid gland or due to problems with the pituitary gland or hypothalamus. The most common cause is an attack on the thyroid gland by the patient's immune system, this is known as Hashimoto's disease. Another cause of hypothyroidism is a severe deficiency of iodine, a deficiency of iodine in the diet can prevent the thyroid gland from making enough hormones. Another cause is surgery for cancer of the thyroid gland that involves the removal of the thyroid gland.

Symptoms/effects on body – Hypothyroidism is where the thyroid gland is under-active & does not make enough of the thyroxine hormone. The lack of thyroxine slows down bodily process & people experience the following symptoms: slow heart rate/unexplained weight gain/fatigue or a feeling of lack of energy/intolerance to cold/swelling of the face/goitre: enlarged thyroid gland.

Medical technologies – Most hypothyroid patients are treated with hormones made synthetically by a chemical process. Levothyroxine is the most commonly prescribed drug for thyroid hormone replacement. It is a synthetic form of T4. If the cause is lack of iodine it is treated by the inclusion of extra iodine in the diet.

Similarities	
Type 1	Type 2
Abnormally high blood glucose levels/hyperglycaemia High levels of glucose excreted in urine 1–2 Complications such as kidney failure/heart disease/stroke/nerve damage/eye problems	
Differences	
Type 1	Type 2
Usually begins in childhood/ born with it	Usually adult onset or occurs in people over 45
Autoimmune response causing the destruction of beta cells	Lifestyle disease caused by obesity/lack of exercise/high blood pressure/diet high in fat and salt
Inability to produce insulin	Can produce insulin
Cells are able to respond normally to insulin	Cells are not able to respond to insulin due to insulin resistance
Treatment by injections/ programmable pump for regular supply of insulin	Treatment by changing lifestyle choices/weight loss/exercise/ monitoring blood glucose levels

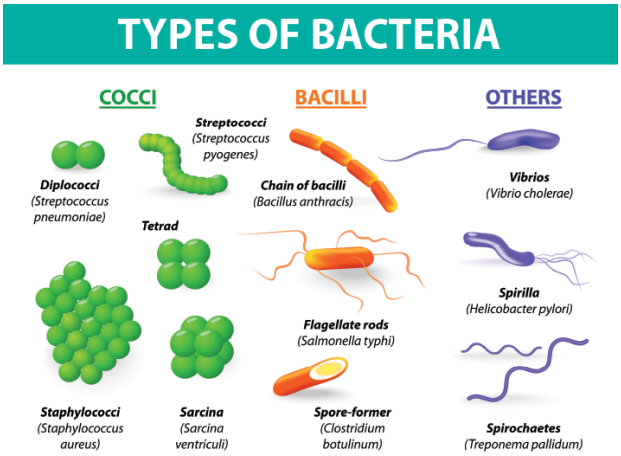
3-Defence against disease

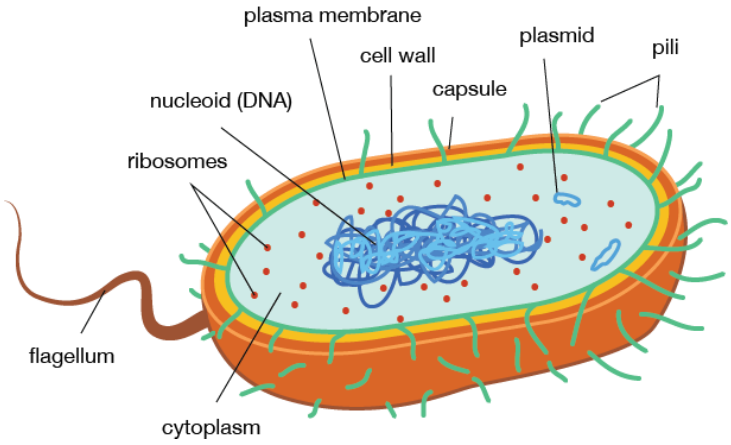
Pathogens

Pathogen – Disease causing organisms e.g. viruses, bacteria, parasites & fungi.

Pathogenic Bacteria

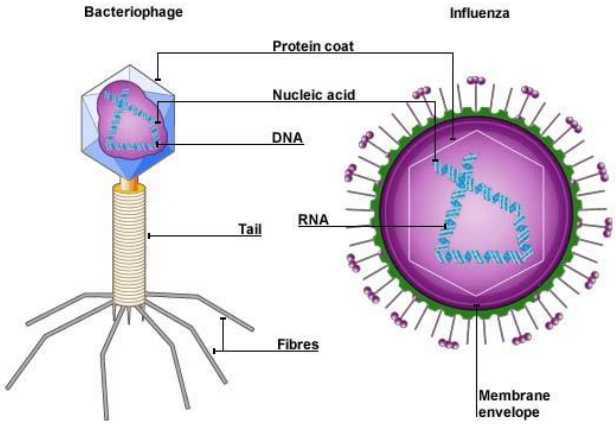
Single celled organisms, micrometres in size, which cause harm by producing toxins. Types of bacteria are classified by their cellular shape

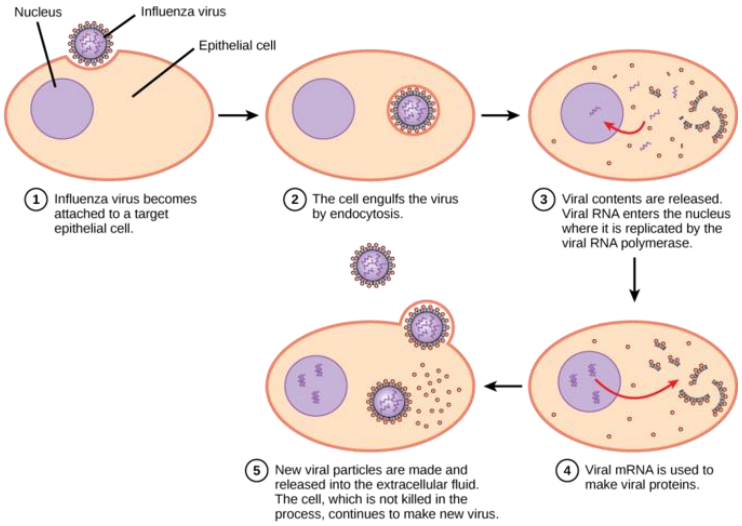




Pathogenic Virus

A small infectious agent (pathogen) which consists of RNA or DNA. Viruses lack the ability of reproducing, so they reproduce through host cells. Viruses inject their nucleic acid into the host cell which causes the host cell to produce new viruses. After the death of the cell, the virus is spread infecting other cells.





Diseases

Viruses – HIV/AIDS, influenza, measles, rabies, smallpox, chickenpox, Ebola, genital herpes & hepatitis A-G

Bacteria – Anthrax, chlamydia, cholera, gonorrhoea, pneumonia, syphilis, tuberculosis, typhoid & tetanus

Defence against disease

Transmission of pathogens

Direct/indirect – Either touching an infected person e.g. hand shake or touching an object that has been infected e.g. door knobs, switches, benches or stationery owned by the infected person.

Transfer of body fluid – Body fluids such as blood from an infected person can infect others by entering through mucous membranes.

Airborne – Pathogens surviving outside the body & remaining suspended in the air for long periods of time. Transmission occurs when pathogens are inhaled by others.

Vectors – Animals e.g. insects which carry the pathogen & spread it by directly infecting humans.

Ingestion – Pathogens maybe spread through contaminated food or water also unproperly cooked food. When it is consumed & ingested infection will occur.

Non-specific defences

Non-specific defence – The body's first line of defence which acts on all pathogens the same way.

External defences

Skin – Impervious & water proof. Lysozyme in sweat or oil in sebum is antiseptic to some bacteria. Salty environment of skin inhibits bacterial growth

Nasal cavity – Hairs in nose trap large particles. Nasal secretions contain lysozyme. Sticky mucous traps dust/spores or pathogens.

Bronchi & throat – Mucus traps microbes, cilia push mucus to the throat where it is coughed up or swallowed.

Stomach – Gastric juices are highly acidic as they contain hydrochloric acid, which kills pathogens in food consumed.

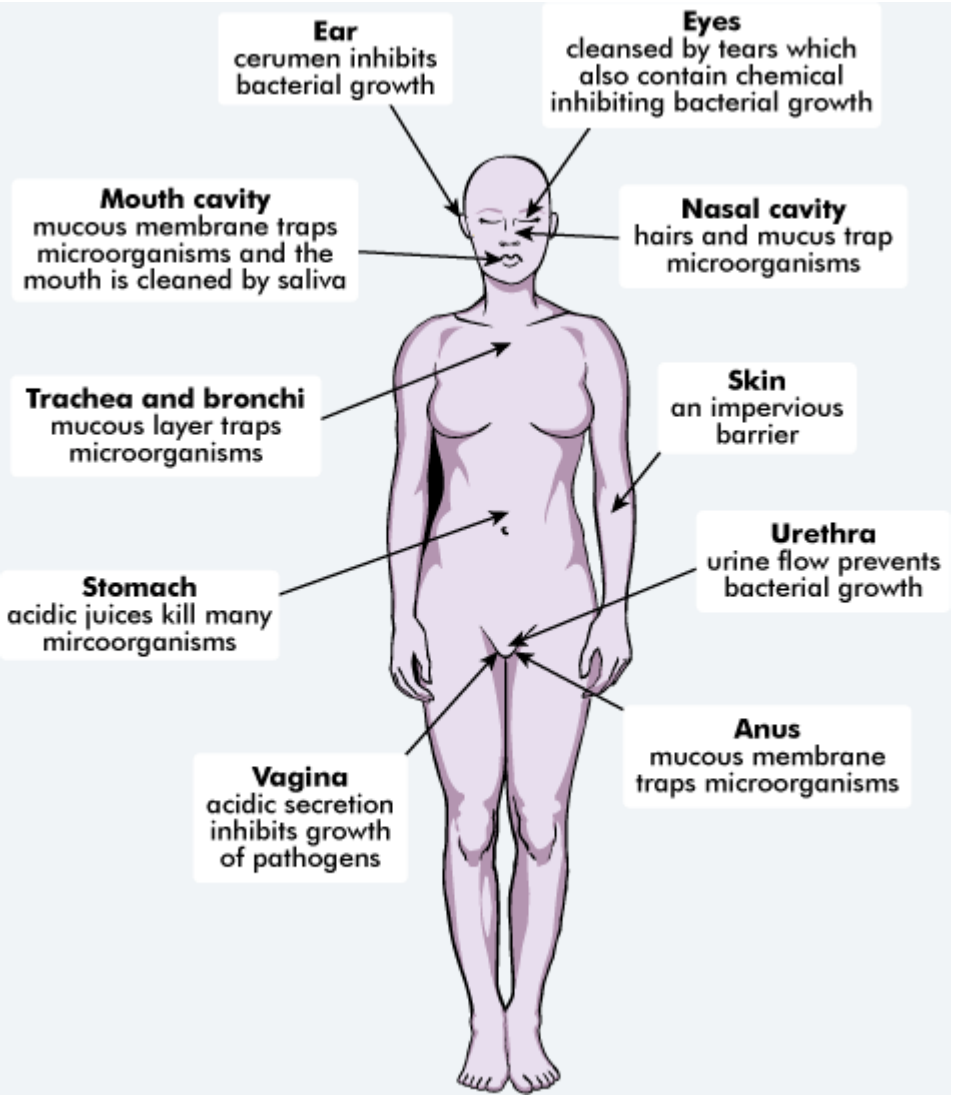
Vagina – Bacterial growth is reduced in the vagina by acid secretions.

Eyes – Tears flush eyes removing pathogens & contain lysozymes which kill bacteria.

Ears – Cerumen (ear war), covers the inside of the ear which inhibits bacterial growth.

Urethra – Urine flushes out bacteria & low pH of urine kills bacteria.

Anus – Mucous membrane traps pathogens.



Defence against disease

Protective reflexes

Four reflexes exist which protect the body from infection

Sneezing – Irritation of the nasal cavity. Causes air from the lungs to remove irritants e.g. dust particles which may contain pathogens.

Coughing – Irritation of the bronchi & trachea (lower respiratory tract). Air from lungs removes irritants by pushing it up back the throat to the mouth.

Vomiting – Abdominal muscles & the diaphragm contract to expel stomach content.

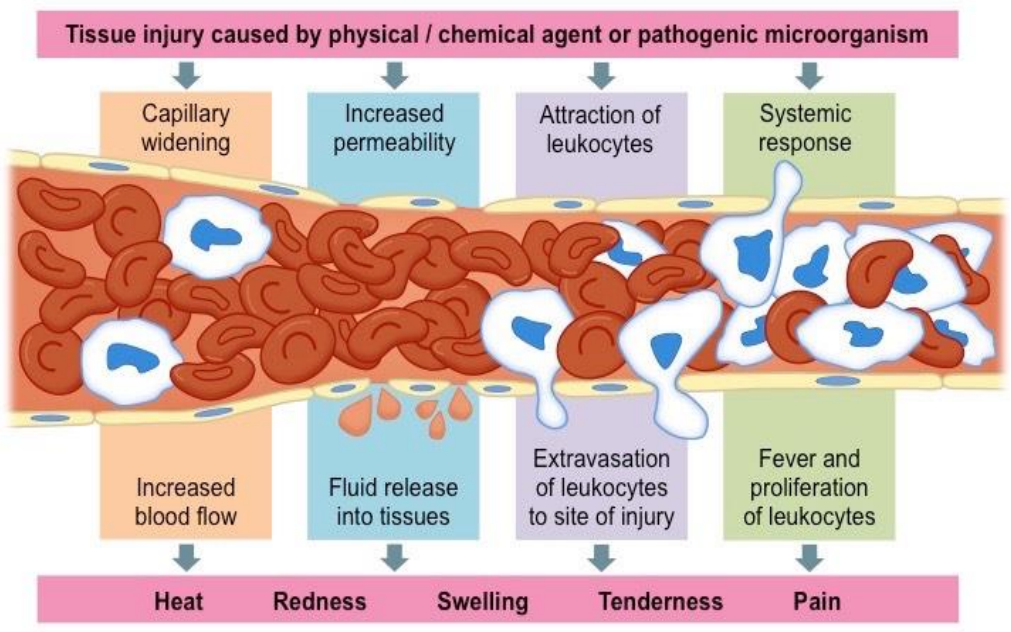
Diarrhoea – Irritation of the small & large intestines by bacteria & viruses. Contractions of the intestine walls are increased so that the irritant is expelled.

Internal Defences

Phagocytosis – White bloods cells such as macrophages either engulf or release substances that eliminate pathogens & damaged cells.

Inflammation – This is the body's non-specific **response to damaged tissue & chemical changes**. The aim is to destroy pathogens present at the site, prevent the entry of other pathogens, remove damaged tissue & cell debris & begin the repair of damaged tissue. Symptoms of inflammation are **pain**, **heat**, **redness** & **swelling**.

- **1** – Mast cells stimulate & coordinate inflammation by releasing histamine, heparin & other substances into the tissue fluid.
- **2** – Histamine increases blood flow (**redness & hot**), causes capillaries to become more permeable which lets fluid leak from blood into the damaged tissue (**swelling**).
- **3** – Heparin prevents clotting of blood; a clotting area does not form.
- **4** – Other chemicals released by mast cells attract leucocytes & macrophages which consume micro-organisms & debris.
- **5** – Chemicals & inflammation stimulate pain receptors (**pain**).
- **6** – Pus is formed from dead phagocytes & tissue fluid.
- **7** – New cells are formed by mitosis & repair of tissue occurs.



Defence against disease

Lymphatic system – Lymph capillaries collect fluid that has leaked from blood vessels. Lymph (fluid) may contain pathogens which enter lymph nodes. Macrophages ingest pathogens in the lymph nodes through phagocytosis.

Fever – A response to infection. Caused by pyrogens (fever inducing substance) which makes a change in body temperature, the hypothalamus increases the body temperature. The body works in increasing heat production & conserving it. Fevers inhibit some viruses & bacteria, increase pathogen reproduction rates (increases the speed that the disease runs its course & increase metabolic rate (to speed up tissue defences & repair).

Specific defences

Specific defence – The body's second line of defence which acts only on specific pathogens e.g. only specific antibodies respond to specific pathogens.

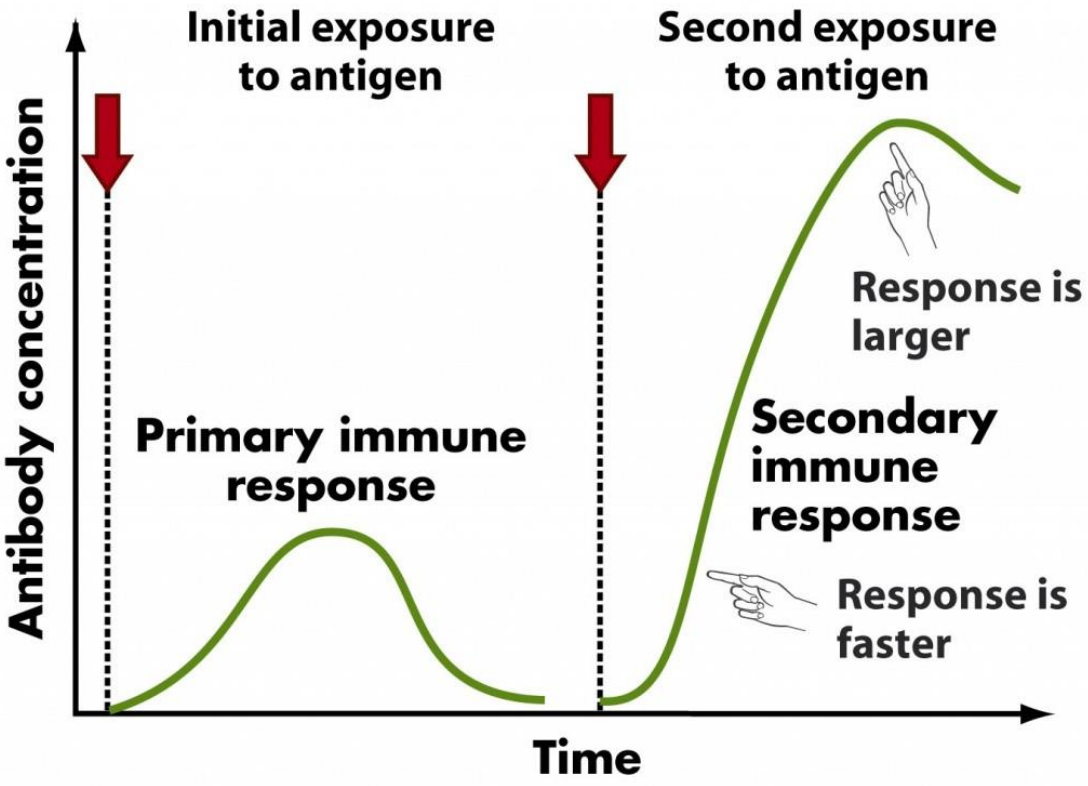
Antigens (antibody generator) – A substance capable of causing a specific immune response. Antigens may be carbohydrates, proteins, lipids or nucleic acids. Antigens may be pathogens such as viruses & bacterial cells & external substances e.g. pollen & egg white.

Antibodies – Specialised proteins produced in response to non-self antigens (antigens not recognised by your body). Antibodies are immunoglobins, they combine with antigens to form an **antigen-antibody complex**. The active site of the antigen must be complimentary to the active part of the antibody.

Lymphocytes – 20-30% white blood cells in blood are lymphocytes. Lymphocytes are produced in bone marrow & lymphoid tissue. B lymphocytes mature in bone marrow while T lymphocytes mature in the thymus. B cells (B lymphocytes) are involved in antibody-mediated immunity while T cells (T lymphocytes) are involved in cell-mediated immunity.

Primary response – First exposure to an antigen. The immune response is relatively slow as it takes time for B lymphocytes to differentiate into antibody producing plasma & memory cells.

Second response – Second exposure to the same antigen results in antibody levels rising faster, reaching higher concentrations & remaining elevated for an extended period due to the memory cells.



Defence against disease

Antibody-mediated immunity (humoral immunity)

1. Antigens in blood or lymph are recognised by B lymphocytes.
2. B lymphocytes enlarge & divide into plasma.
3. B lymphocytes that did not differentiate become memory cells.
4. Plasma secretes antibodies, which travel through blood lymph & circulatory fluid reaching the response site.
5. Antibodies combine with antigens forming an antigen-antibody complex.

Antibodies can **PLAN C**

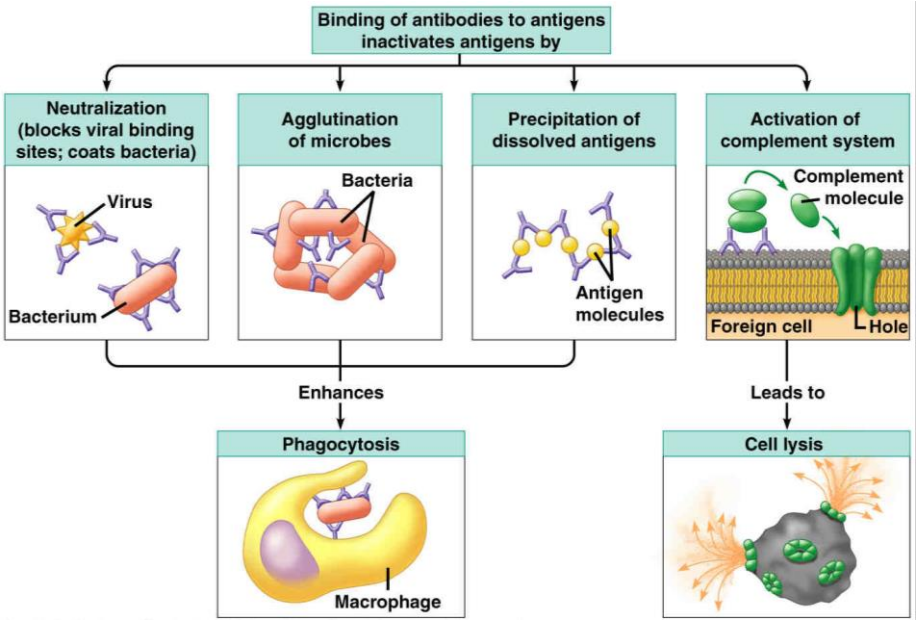
Precipitation – Bind to soluble antigens to make them insoluble, assisting in phagocytosis.

Lysis – Activates chemicals that destroy microbe cell membranes dissolving & destroying them.

Agglutination – Binds to foreign cells causing them to clump together.

Neutralise – Binds to toxins preventing them from binding to receptors. Binds to viruses preventing cell entry.

Coat – The surface of bacteria is coated, to make it easier for phagocytes to consume.



Cell-mediated immunity (cellular immunity)

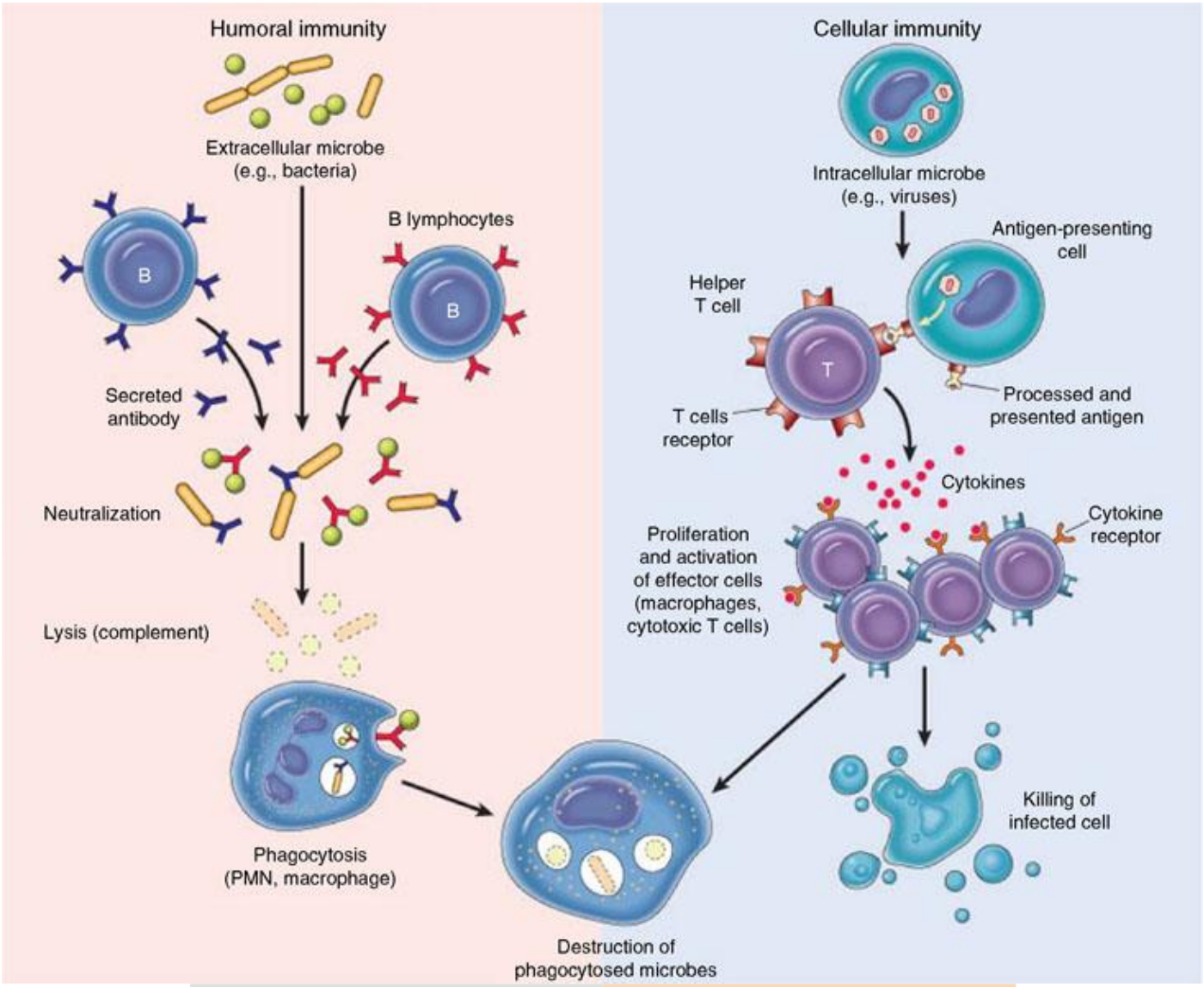
1. A macrophage or B lymphocyte presents the foreign antigen to a specific T lymphocyte in lymph nodes.
2. The T lymphocyte is activated/sensitised, which enlarges & divides into clones.
3. Some clones become memory cells in the lymphoid tissue.
4. T lymphocytes that do not become memory cells either become killer T-cells, helper T-cells & suppressor T-cells

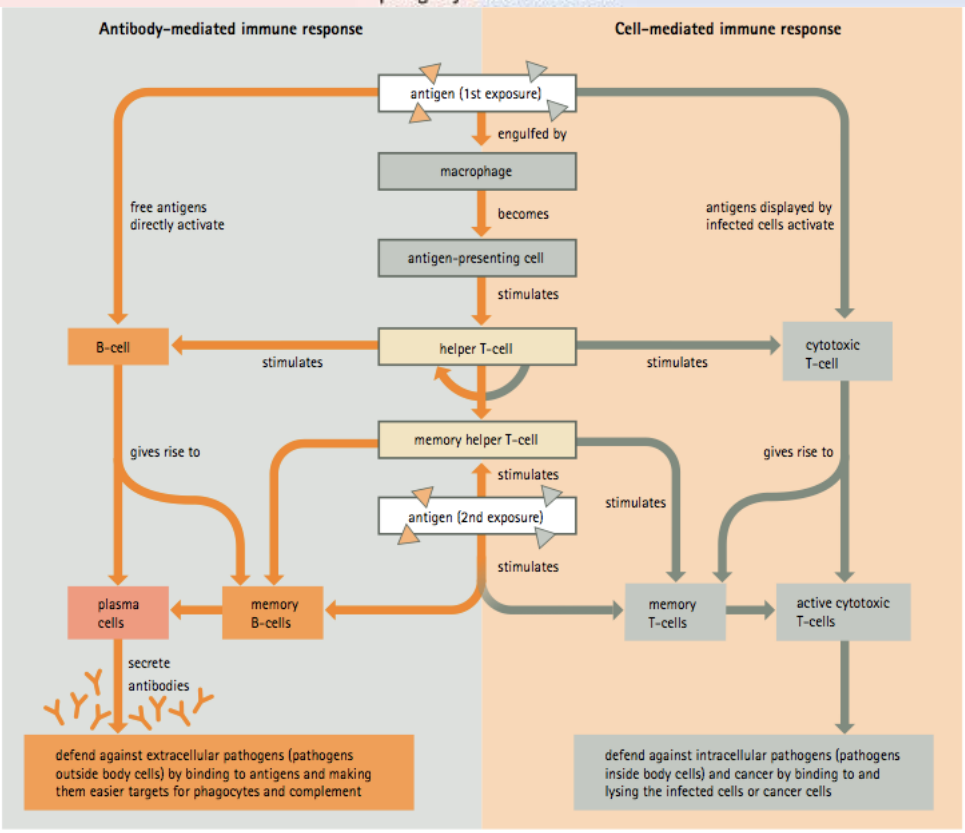
Killer T-cells – Secrete a substance that destroys the antigen.

Helper T-cells – Present in both cellular & humoral immunity, secrete cytokines that cause more T lymphocytes to become activated/sensitised, attract phagocytes to infection site & intensify phagocytosis.

Suppressor T-cells – Releases substance that inhibit T & B lymphocyte activity after infection has been dealt with or if immune response is excessive.

Defence against disease





Defence against disease

B Lymphocytes	T Lymphocytes
Humoral immunity Antibody mediated immunity	Cellular immunity Cell mediated immunity
Chemical-based system i.e. antibodies (Immunoglobins)	Cell-based system
Become plasma cells which produce & release antibodies	Produce mainly killer T-cells & helper cells
Antibodies combines with antigen to inactivate it or destroy it	Killer T-cells destroy antigen Helper cells promote macrophage phagocytosis
Effective against extracellular bacteria (some viruses)	Effective against intracellular viruses & cancer cells (some bacteria)

Immunity

Immunity – Resistance to infection caused by pathogens/micro-organisms.

Natural immunity – Normal exposure to antibodies or antigen.

Artificial immunity – A person deliberately receives an antigen or antibodies.

Passive Immunity – When a person receives antibodies, no immune response.

Active Immunity – A person produces antibodies after exposure to an antigen, immune response occurs.

	Natural immunity	**Artificial immunity**
Passive immunity Protection is immediate, but only temporary as **an immune response is not activated** meaning memory cells are not formed	Transfer of antibodies from breast milk or the placenta	Injection of antibodies into bloodstream
Active immunity Protection slow to develop but permanent as **an immune response occurs** where memory cells are formed	Production of antibodies from natural exposure of **antigens** e.g. getting infected	Production of antibodies from a vaccination containing **antigens**

Defence against disease

Vaccines

Attenuated – Weakened pathogen e.g. polio

Dead pathogen – Killed pathogen/micro-organism e.g. typhoid

Toxoid – Altered & harmless version of a toxin e.g. tetanus

Sub unit – Part of a pathogen e.g. human papilloma virus

Factors that influence participation in vaccination programs

Factors	For	Against
Social/Cultural	• Helping to create herd immunity. • Following health advice of governments & health professionals.	• Ethical or religious objection to medical intervention. • Perceived health concerns or side effects from vaccines.
Economic	• Immunisation bonus paid to participants (for parents). • No loss of health care benefits (for parents).	• Cost of vaccines not covered by the government/private health care. • Cost of administering vaccine, more than the cost of treating sick for some diseases

Antibiotics

Antibiotics – Drugs that are used to treat infections from bacterial pathogens. Antibiotics are selective, they will attack bacterial cells but not our own.

Bactericidal antibiotics – Kill bacteria by changing the structure of cell walls or disrupting enzyme action e.g. penicillin.

Bacteriostatic antibiotics – Interrupt reproduction by disrupting protein synthesis.

Anti-viral

Anti-viral – Drugs used to treat infections from viral pathogens.

Work by targeting viral specific proteins & disabling them

Work to inhibit the life cycle of the virus. Blocking enzymes to prevent the assembly of virus particles or the copying of DNA. They may also bind to a receptor on viruses preventing their exit from host cells.

3.5-DNA Technology

Polymerase chain reaction

The polymerase chain reaction (PCR) is used for creating multiple copies of a specific section of DNA from a sample. 100 billion identical strands can be produced from a single DNA segment within a few hours. Used when scientists are only able to obtain tiny fragments of DNA, e.g. at a crime scene or from fossils

Once a small amount of DNA has been extracted from a tissue sample the following steps are carried out: Denaturing/strand separation, Primer Annealing, Primer Elongation

Before this the DNA sample must be mixed with 2 **primers** (short synthetic DNA fragments), many molecules of each of the 4 nucleotides & **Taq polymerase** (heat resistant DNA polymerase)

1. Denaturing/ Strand separation

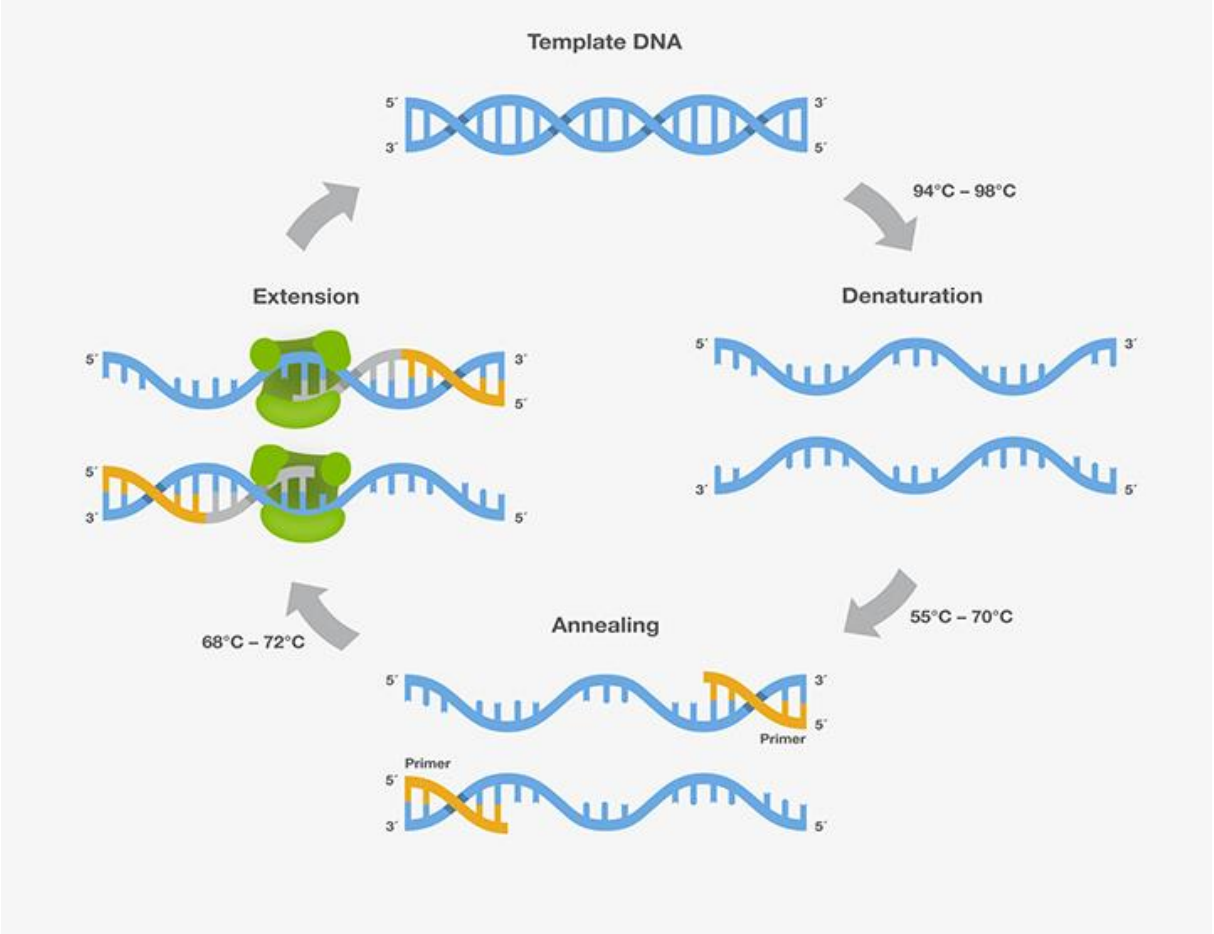
DNA is heated to 90-95° C to denature the strand. This process separates the double helix into two single separate strands.

2. Primer Annealing

The mixture is cooled to about 50°C. Primers bind to each of the complimentary base sequences on the separated DNA strands. The primers act as starting points for the replication of new DNA molecules.

3. Primer Elongation

The mixture is heated to about 72°C. Starting at the primer, the DNA polymerase reads the DNA code & builds a complementary strand of DNA. This doubles the number of strands. The 3 steps are repeated 30 times to obtain over 1 billion identical strands of DNA. Each cycle takes 3-5 minutes.



Gel Electrophoresis

A technique used to sequence DNA strands by length. This can be used in DNA profiling (DNA fingerprints), DNA sequencing & sometimes to test for genetic disorders (when the abnormal allele is a different length to the normal allele)

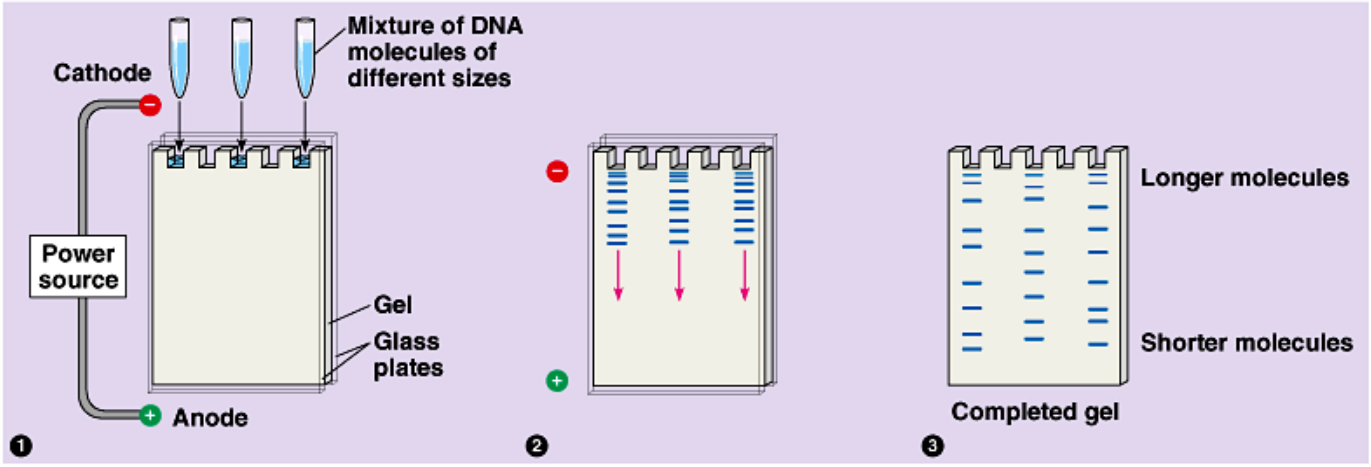
DNA/protein placed at negative end of gel bed

An electric current is passed through the gel/ voltage applied across the gel

The negatively charged DNA/protein move towards positive charge at the opposite end of the tank

The DNA/protein pieces move through the gel at different speeds/ smaller pieces move faster than large ones

Forming bands/bar code representing different segments/ sizes of DNA/protein. Sketch OK if show bands



DNA sequencing

DNA sequencing is the determination of the exact order of the base pairs in a segment of DNA.

DNA preparation

DNA segments are inserted into plasmids. Plasmids are circular units of DNA that are able to reproduce inside of host cells. The host cells are bacterium which are placed in a culture to reproduce until over a million clones are made.

Sequencing Reaction

Denaturing

Heating the DNA segment above 90°C to separate the strands

Primer Annealing (hybridisation)

Rapid cooling occurs to allow the Primer to bind to the DNA template strand

Primer Extension

DNA polymerase extends the Primer with nucleotides (dNTPs) complementary to the DNA template strands

Chain termination

ddNTPs are like normal nucleotides but are missing the 3' hydroxyl group. The ddNTP Prevents extending the DNA chain further.

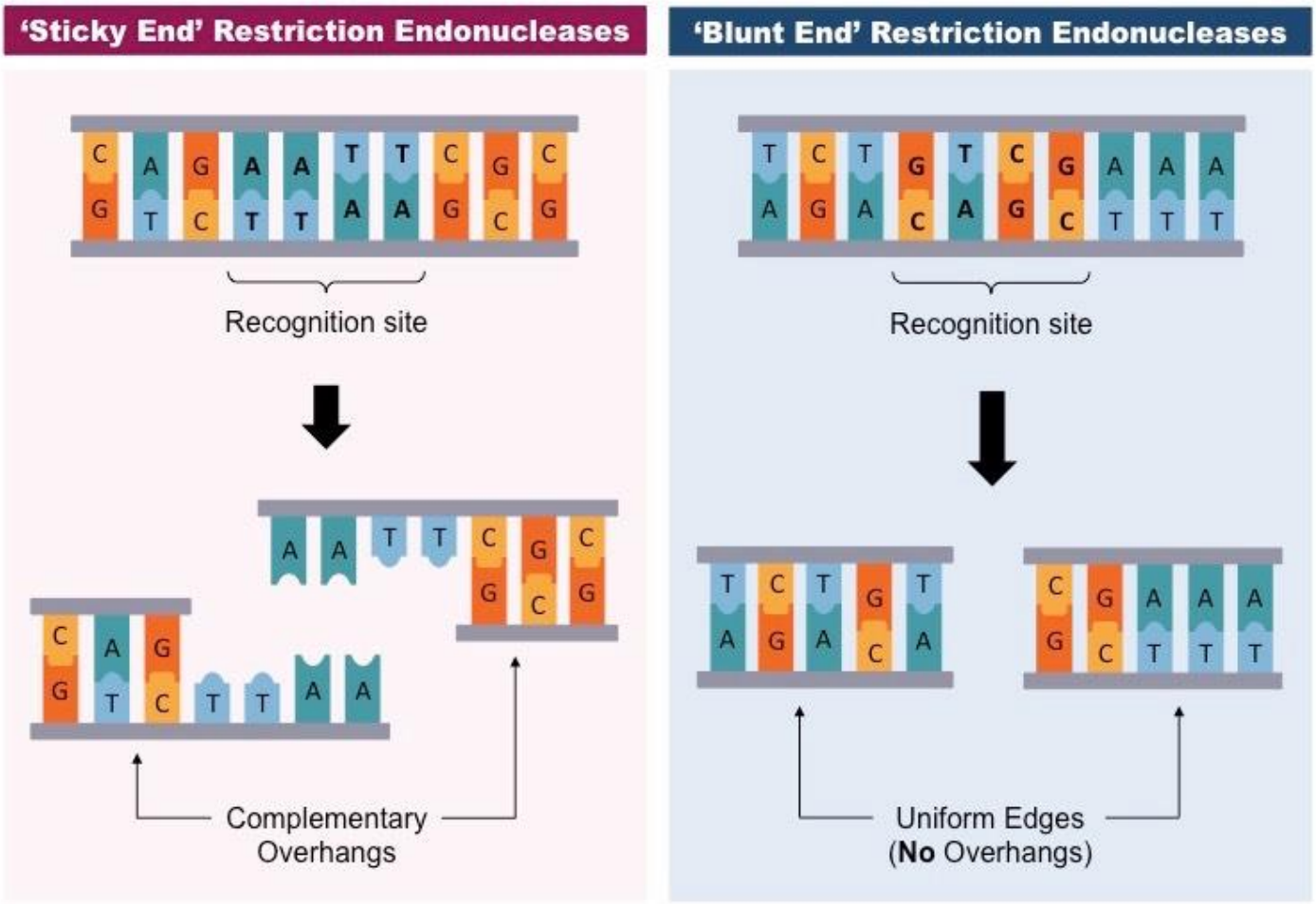
Recombinant DNA

Recombinant DNA technology is the technology used in genetic engineering. Recombinant DNA is made by recombining fragments of DNA from different organisms.

Plasmid – A small, circular, double-stranded DNA molecule, that are cut & combined with a gene.

Restriction enzyme – Enzymes that cut through the double helix of DNA. Cuts can form blunt or staggered DNA ends.

DNA ligase – Enzymes that's acts like glue, attaching the sticky ends of the plasmid to the sticky ends of the isolated gene.



Recombinant DNA – Artificial Hormones (Insulin)

1. Hormone producing gene is separated using restriction enzyme that cut producing sticky ends.
2. A plasmid from bacteria is cut using the same restriction enzyme.
3. DNA ligase is used to join complementary sticky ends of plasmid & hormone gene together.
4. The recombinant plasmid is placed into a host /bacterium/yeast cell.
5. The host/bacterium/yeast cells are placed in a culture to reproduce.
6. Host cells will produce hormone to be administered to patients.

Recombinant DNA – Gene Therapy (in vivo & ex vivo)

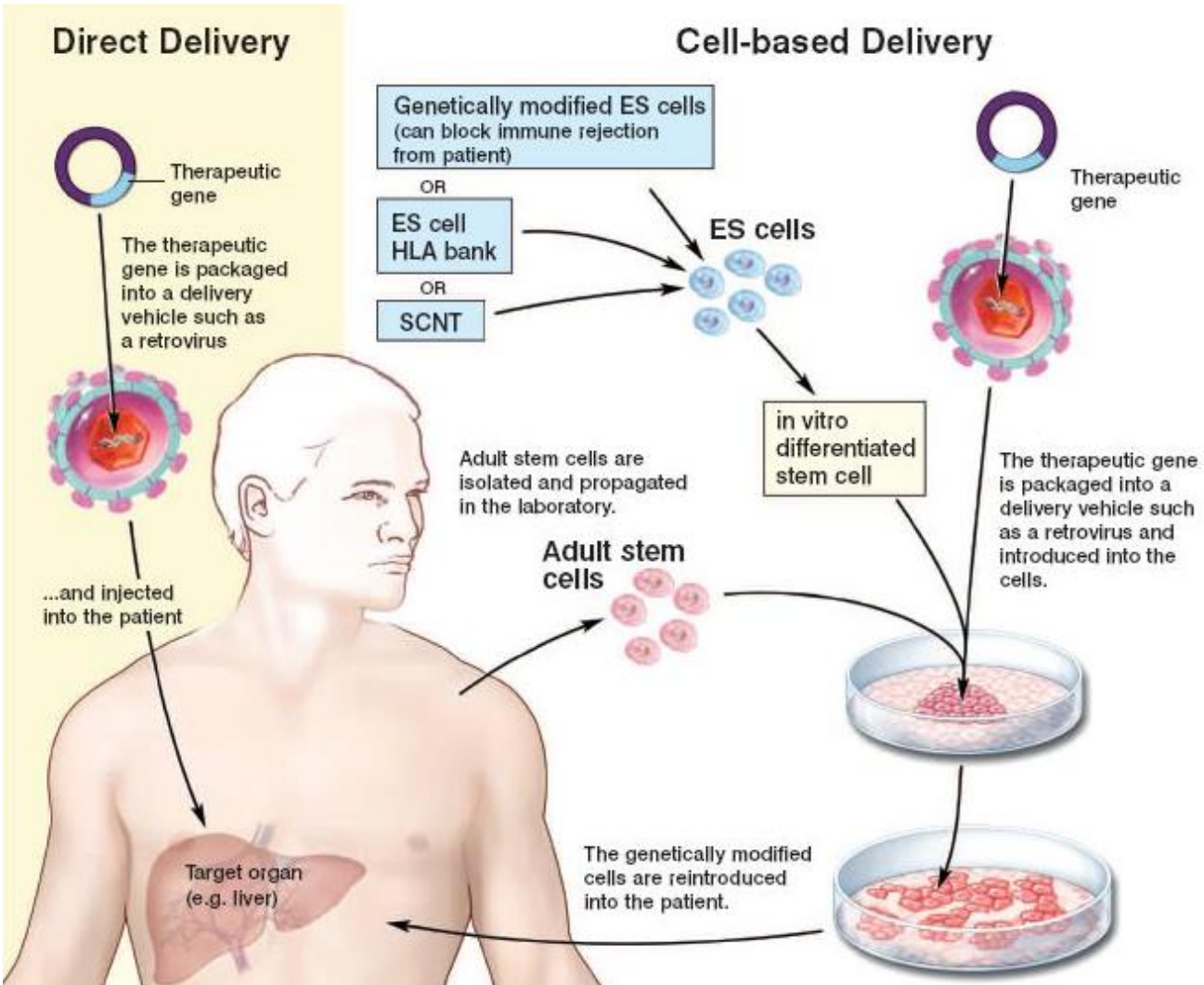
1. Obtain human gene that produces insulin.
2. Remove gene using restriction enzyme.
3. Produce many copies using PCR.
4. Select a vector to carry insulin gene possibly a deactivated virus.
5. If virus, use DNA ligase to insert insulin gene.
6. Culture many copies of the vector.
7. Inject vector with insulin gene into host tissue e.g. pancreas/liver.

(In-Vivo) Injecting vector directly into tissue/organ.

1. Vector should insert insulin gene into stem cells within the tissue
2. Cells with insulin gene should start producing insulin which will allow patient to self-regulate blood glucose levels

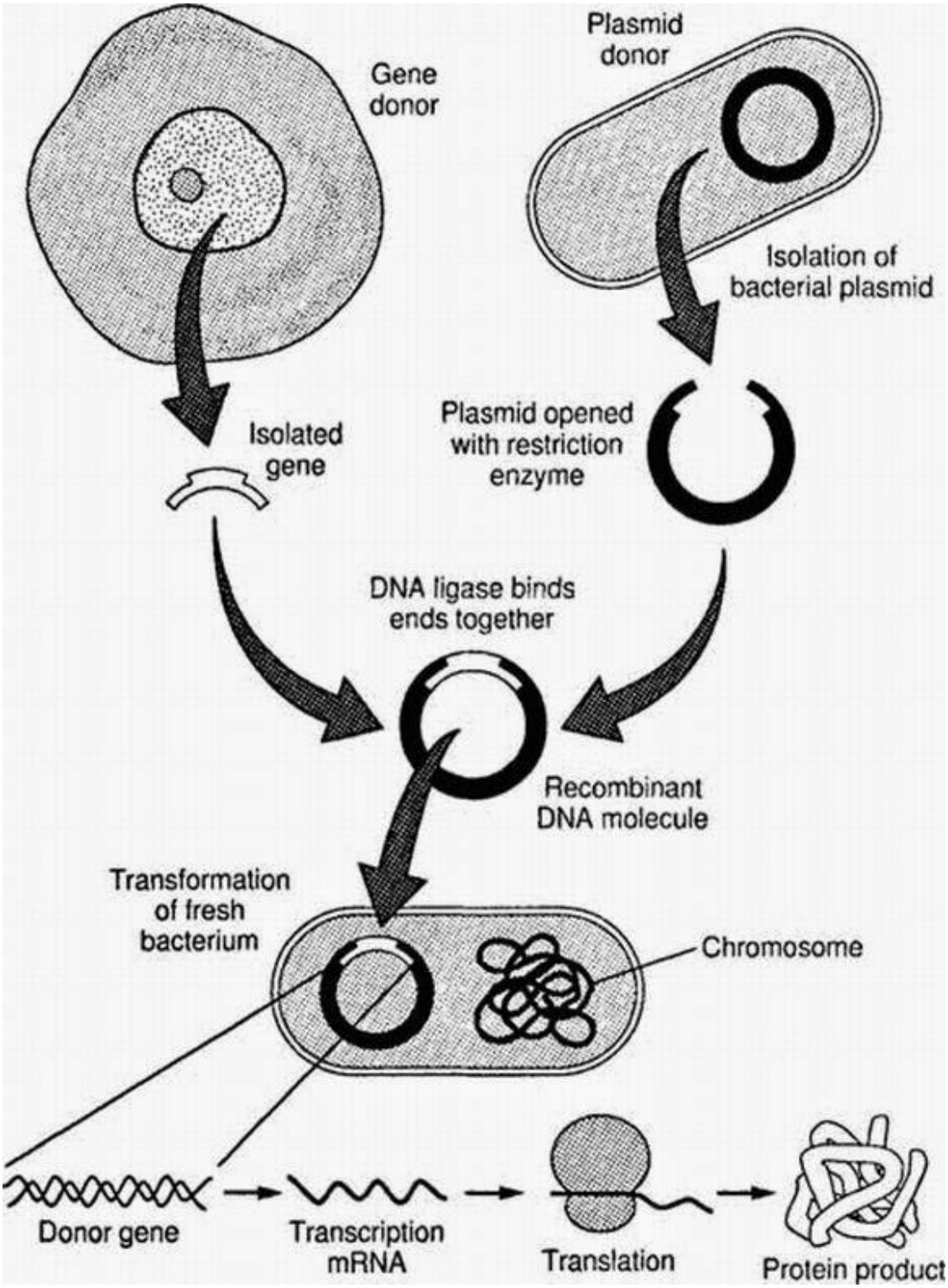
(Ex-Vivo) Injecting vector into a culture outside the body.

1. Obtain stem cells place into culture
2. Add vector to culture so that stem cells obtain insulin gene
3. Culture stem cells containing insulin gene & differentiate them into beta cells
4. Inject cultured beta cells into pancreas/liver
5. Introduced cells should start producing insulin which will allows patient to self-regulate blood glucose levels



Recombinant DNA – Vaccines

1. The gene/segment of DNA for the antigen is isolated by cutting it at a recognition site by the use of a restriction enzyme.
2. The enzyme cuts the DNA on either side of the gene to produce sticky ends.
3. A plasmid (a circular strand of DNA inside a bacterial cell) is removed from a bacterium. The plasmid is cut with the same type of restriction enzyme to also create complimentary sticky ends.
4. DNA ligase is used to join the sticky end of the isolated gene & the plasmid together.
5. The plasmid is inserted into the bacterial cell.
6. The bacteria are then cloned to produce large amounts of the gene or its product, e.g. vaccine.



4-Gene Pool

Gene pool – All the genes & their alleles that exist in a particular species or population.

Allele frequency – How often each allele of a gene occurs in a population.

Changes to a gene pools & allele frequency

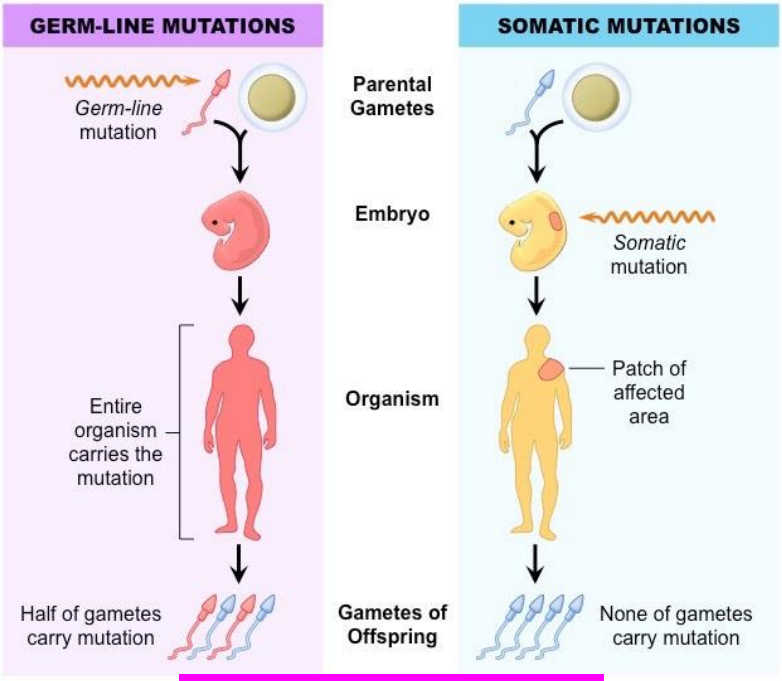
Mutations

Mutation – Permanent structural alteration in DNA. A gene mutation occurs where single genes are changed or destroyed through point mutations. Chromosomal mutations occur on all or parts of a chromosome.

Mutagens – Physical or chemical agents that increase the frequency of mutations e.g. UV light, mustard gas or formaldehyde.

Germline mutations – Occur in gamete cells. Individual is **not affected**. Mutation is passed on **to offspring**.

Somatic mutations – Occurs in somatic cells. Individual is affected. Mutation is passed on **to daughter cells**.



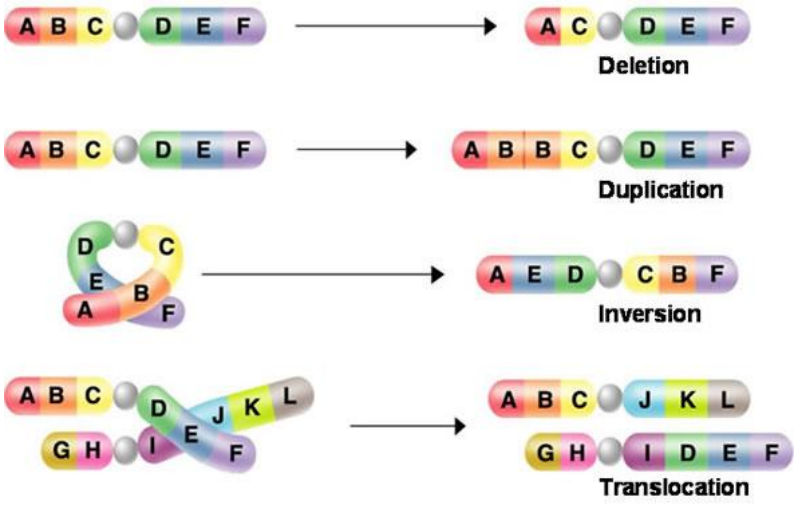
Chromosomal mutations

Deletion – Part of the chromosome is lost.

Duplication – Part of the chromosome is repeated twice.

Inversion – Part of the chromosome sequence is inverted (reverse order).

Translocation – Part of the chromosome breaks off & joins to another chromosome.



Gene Pool

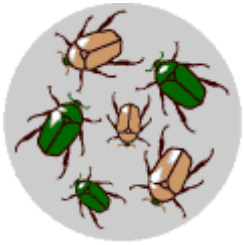
Evolution by Natural Selection

Overproduction of offspring – Most populations have more offspring each year than local resources can support leading to a struggle for resources.

Variation – Populations exhibit individual variation in their genotype & phenotype due to a large population of the species from overproduction of offspring.

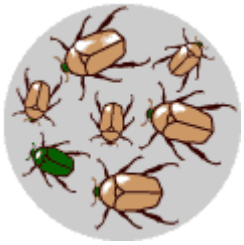
Selection – Some traits are consistently passed on from parent to offspring. But traits that are better adapted to the environment & are advantageous are determined by selection pressures.

Change in gene pool – Individuals possessing advantageous traits for the struggle for local resources will contribute more offspring to the next generation.

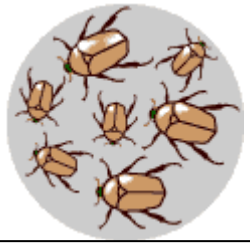


There is variation in traits. For example, some beetles are green & some are brown. Both excessively reproduce.

Selection pressures act on the population. There is a struggle for existence, green beetles tend to get eaten by birds & survive to reproduce less often than brown beetles do.



The surviving brown beetles have brown baby beetles because this trait has a survival advantage, this is known as survival of the fittest.



The brown colour allows the beetle to have more offspring, becoming more common in the population (change in gene pool).

Random genetic drift – Genetic drift is the random, non-directional variation in allele frequencies from one generation to the next. Genetic drift occurs in small populations, due to inbreeding that occurs due to limited mating possibilities. The effects of genetic drift can be amplified by differences in the number of children raised by couples, or individuals dying prematurely. Genetic drift can result in: traits being lost from small populations. unusual traits, not commonly found in the parent population, & that are often non-adaptive, becoming established.

Population bottleneck – Anything that creates a sudden drop in population size (e.g. wars, natural disasters or migration), or prevents individuals from breeding, reduces mating possibilities & can cause a genetic bottleneck.

Founder effect – Occurs when a small number of people migrate & settle in a new area. The founding population carry only a small fraction of the original population's genetic variation. As a result, they may differ both genetically & in appearance, compared with the parent population. These differences remain in the new population many generations later.

Migration – This adds to the gene pool of a populated area. When a group of people migrate into a new location they may have alleles that are not present in the population before their arrival.

Gene Pool

Barriers to gene flow

Geographical Barriers – This is where a population is separated from others due to oceans, mountain ranges, deserts or expansive ice sheets. Different environmental pressures will mean that some alleles will be more advantageous than others. After many generations, these advantageous alleles will occur in higher frequencies than in other populations.

Cultural barriers – This is when factors such as race, religion, language or socioeconomic status prevent groups within one geographical location from interbreeding. This will lead to different allele frequencies occurring within these separate sub-population. Can be founder effects or different environmental pressures e.g. employment conditions

Selection pressures – **External agents which affect an organism's ability to survive in a given environment**. Resource availability – Presence of sufficient food, habitat (shelter / territory) & mates. Environmental conditions – Temperature, weather conditions or geographical access. Biological factors – Predators & pathogens.

Speciation

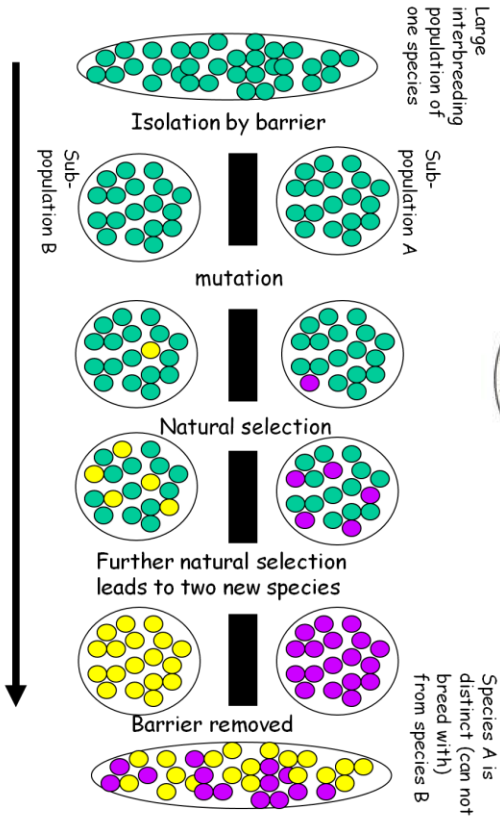
Speciation – The process that leads to the formation of a new species, through variation, isolation, selection & speciation.

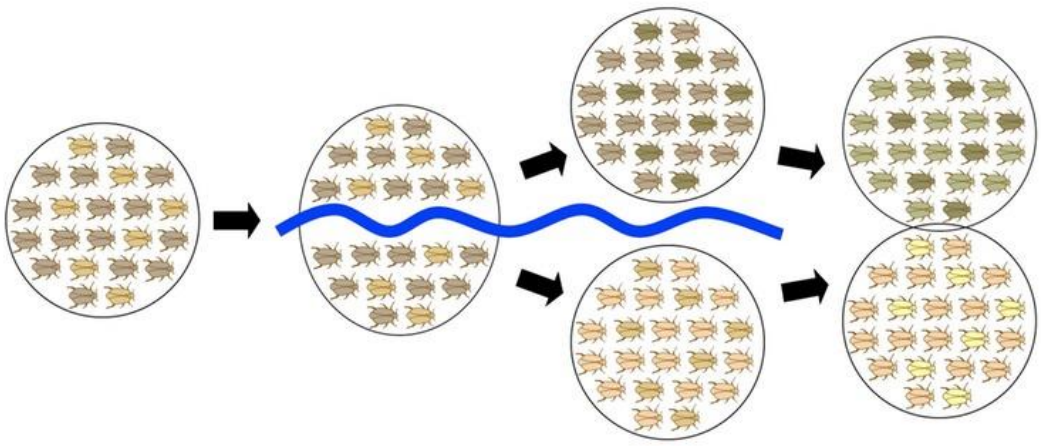
Variation – Variation exists within the population, there is a **common gene pool**.

Isolation – Separation occurs through a physical barrier e.g. island break, mountains or floods. Interbreeding can no longer occur. Separate gene pools are created.

Selection – Selection pressures, mutations, random genetic drift & founder effect act on the two-different population. Subspecies form due to **changes in the gene frequencies** in the gene pools on the two populations.

Speciation – Over a long period of time, speciation occurs if the two populations become sufficiently different (structural, behavioural, physiological or genetic) that they can no longer interbreed, or produce fertile offspring. If this occurs, the two populations are regarded as different species.





Evidence for Evolution

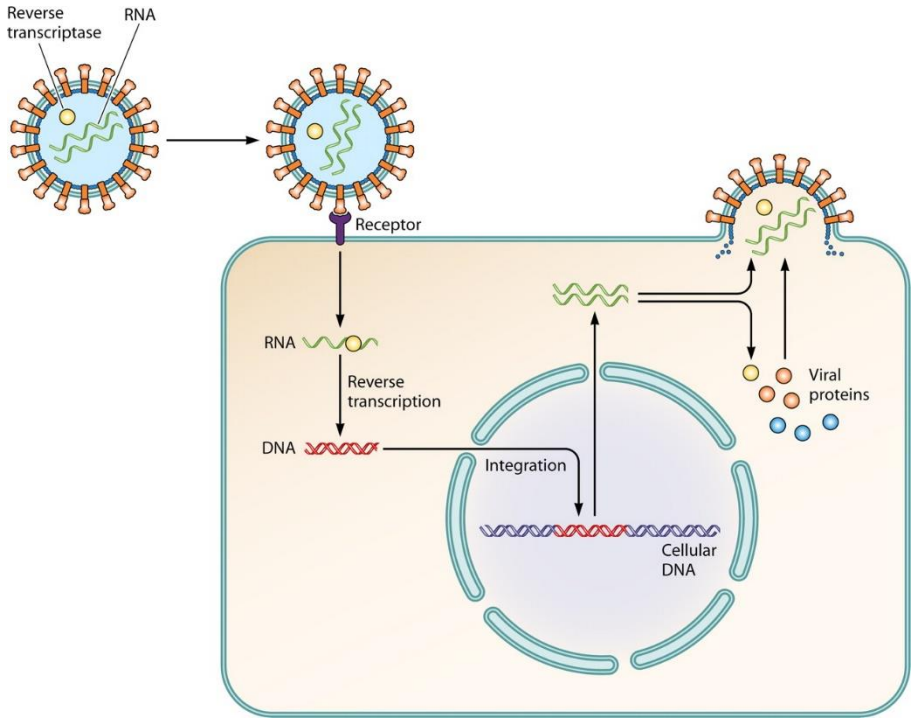
Biochemistry

DNA – Can be used as evidence, as all living organisms possess the four base pairs (adenine, guanine, cytosine & thymine), suggesting there is a common ancestor. Sequences of bases are very similar in closely related species. Sequences are less similar in more distantly related species.

Comparative genomics – Genome, the complete sequence of an organism's DNA is compared with a different species. Similarities & differences are able to be identified. Genomes containing large sections of sequences that are similar **suggests** a divergence from a more recent ancestor between species.

Mitochondrial DNA – Mitochondrial DNA is used within the same species to track the maternal ancestry & to show the closeness of two individuals. This is possible as unlike nuclear DNA, mtDNA has a high mutation rate. The original mtDNA has changed, the amount of mutations has been proportional to the time taken.

Endogenous retroviruses – ERV are viral sequences that are part of an organism's genome through, reverse transpiration of the retrovirus's RNA into DNA of gamete cells. Matching ERVs have been found between similar primate species. The more closely related the primate to humans the more ERVs they have in common, **suggesting** a recently shared ancestor.

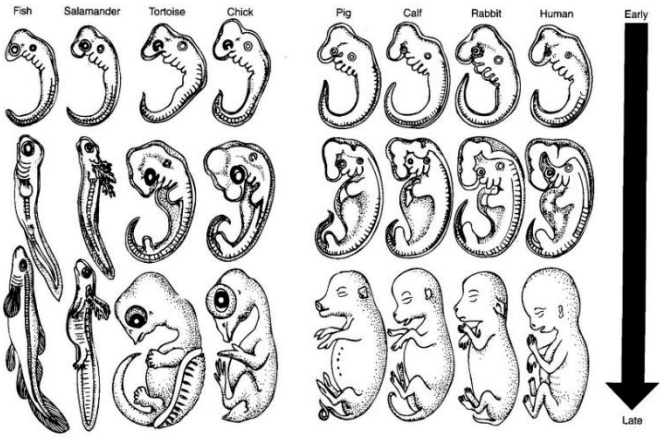


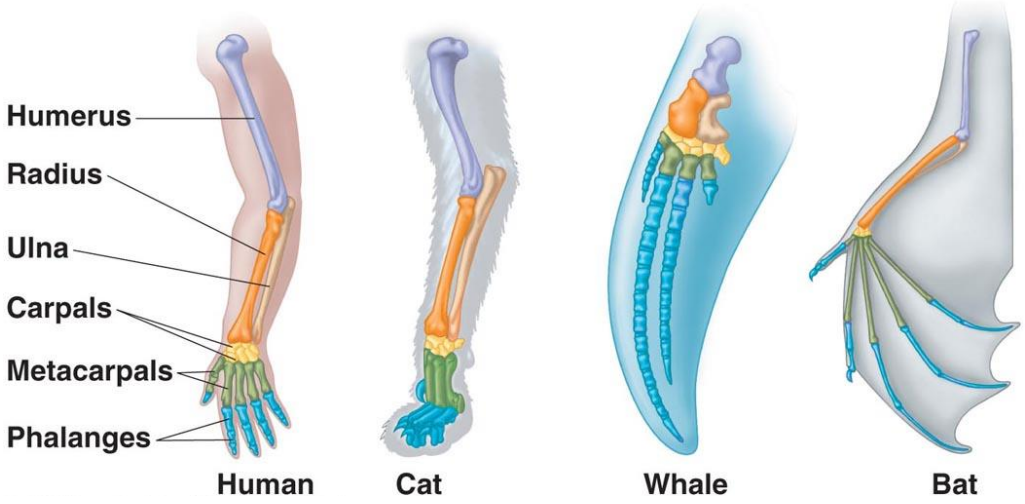
Proteins – Proteins are made out of amino acids. The sequences of these amino acids are compared between different species to look at similarities & differences. Organisms of the same species have identical amino acid sequences whereas other species have different sequences. By looking at the different number of amino acids, the time when two species shared a common ancestor can be determined. Cytochrome C, is a protein that performs basic & essential tasks that all organisms require for life e.g. cytochrome C is needed for cellular respiration. This is known as an ubiquitous protein. The amino acid sequence for cytochrome C is compared with other species against humans. The more similar the cytochrome protein sequence, **suggesting** the more recently a common ancestor is shared.

Evidence for Evolution

Anatomy

Embryology – Embryos of more closely related vertebrates show greater similarities in development than those distantly related. Embryos of reptiles, fish, birds & mammals all feature tails & gill pouches. This **suggests** that the common ancestor over time developed into different vertebrates.





Homologous structures – Similar structures that function differently among different vertebrate species. Homologous structures **suggest** that vertebrate species share a common ancestor from which the same structure adapted to different functions. Pentadactyl limbs in vertebrates are examples of homologous structures.

Vestigial organs – These are organs that no longer serve a function & have diminished in size. Vestigial organs are commonly found within vertebrate species & are used as evidence for evolution. Examples of these organs include muscles around body hair, as it no longer can properly insulate the body through piloerection, third molars, as humans no longer eat raw vegetables & meat or muscles around the ears.

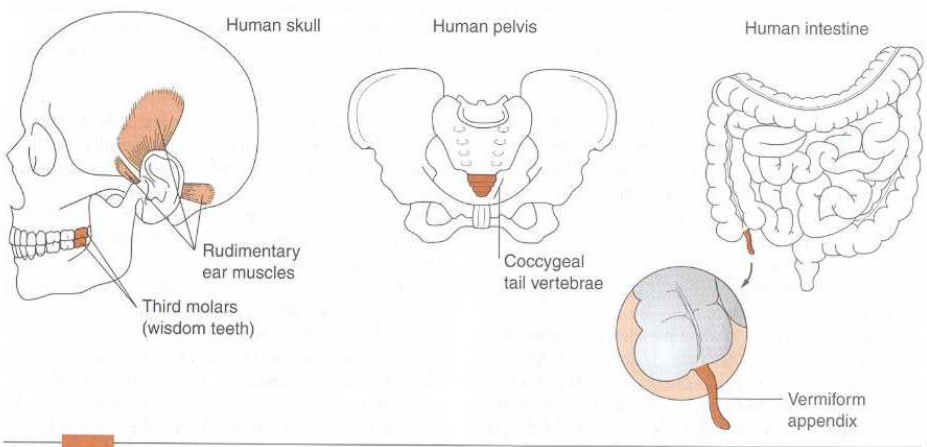


FIGURE 3–9 Some vestigial structures found in humans. (*After Romanes, modified.*)

Fossil Evidence for Evolution

Fossils – Are the preserved remains or traces of animals, plants, & other organisms that lived. Examples of fossils include footprints, parts of animals & plants.

Fossil record – A record of all fossils that have been found, the location of where they were found & the age of the fossil. This shows us how life has changed on Earth over time.

Fossilisation – The formation of fossils is a very rare occurrence, as there are specific conditions that allow for fossilisation. There as must be quick burial of the material, there must be hard body parts, there must be an absence decomposing organisms & there must be geographical stability.

Environmental conditions – Environments must lack oxygen or moisture. An alkaline environment favours the preservation of hard parts, as minerals in bones are not dissolved. An acidic environment favours the preservation of soft parts. Petrification occurs in mineral rich environments, minerals over time replace organic material in bone or wood but the structure & detail is preserved.

Fossil dating

Relative Dating – Calculating the age of a fossil through the comparison of older & younger fossils.

Stratigraphy – The study of the order & relative position of strata (sedimentary rock) & their relationship to the geological timescale. The Law of Superposition states that the lower the stratum the older it is, while stratum that is higher is younger.

Comparative stratigraphy – Strata of different locations is compared in order to estimate its age. If the sequence of sedimentary rocks in different strata is similar it is likely that they are of the same age.

Limitations of stratigraphy – The Law of Superposition cannot be always applied, as due to the Earth's shifting tectonic plates, this leads to strata being flipped upside down. While the burial of animals affects the age recorded as the fossil formed will be younger than the stratum it is found within.

Index fossils – Must be distinctive appearance, the species existed for short time span, there must be an abundance of fossils & that has a wide geographical distribution. If rocks in different locations contain the same index fossils, it is likely that both areas are of the same age.

Absolute Dating – Calculates an exact age of a fossil.

Isotope – Atoms with the same number of protons but a different number of neutrons.

Half-life – the time taken for the radioactivity of a specified isotope to fall to half its original value.

Potassium-40/Argon-40 – K-40 is a radioactive isotope found in certain rock samples. K-40 decays to Ar-40. **K-40 has a half-life of 1.251 billion years**. By determining the ratio of K-40 to Ar-40 the age of the rock/fossil sample can be calculated.

Limitations – Can only be use to date fossils older than 100 000 years. The rock being dated must be the same age as the fossil being dated. The rock sample must be **igneous containing Potassium**.

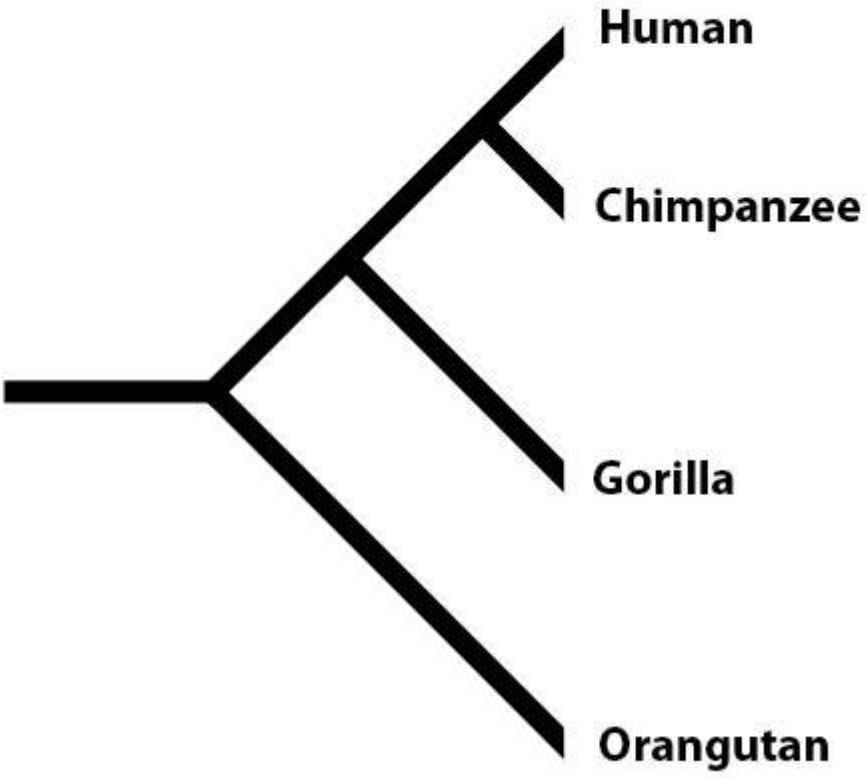
Carbon-14 – The isotope Carbon-14 occurs in 1 to 1 x 10^{12} (trillion) atoms of Carbon (usually Carbon-12). Carbon-14 decays to form nitrogen. **Carbon-14 has a half-life of 5730 years**. By measuring the amount of Carbon-14 in a fossil containing carbon the age of the sample can be calculated.

Limitations – Can only be used to date fossils to about 60 000 years. **Sample must contain Carbon (organic)**. Is only reliable if the amount of C-14 in the atmosphere has always been constant.

Limitations of the fossil record – Not all fossils have been discovered. Not all fossils are accessible. Not all species were fossilised. Fossilisation is a rare event & is unlikely. Some fossils have been destroyed by decomposers or natural disasters. Fossils are found as fragments, leading to reconstructions which may be inaccurate.

Fossil Evidence for Evolution

Phylogenetic trees – Also known as a dendrogram, they represent the evolutionary relationships between a number of organisms derived from a common ancestor. The base of the tree = ancestral organism. The branches = organisms that have arisen from it. These are constructed using comparisons of DNA, proteins or anatomy, as evidence of inheritance from a common ancestor.



From the tree above, humans & chimpanzees have the most recent shared common ancestor. While the split of a common ancestor between humans & orangutans occurred less recently.

Genetic disease

Thalassemia

Thalassemia is an inherited blood disorder characterised by less oxygen-carrying protein (haemoglobin) & fewer red blood cells in the body than normal.

Cause – Autosomal recessive inheritance, due to inbreeding within populations.

High incidence – Mediterranean coast line, particularly Greece & Italy.

Sickle cell anaemia

Sickle cell anaemia is an inherited blood disorder characterised by sickle shaped blood cells. Individuals who suffer from sickle cell disease are chronically anaemic, experience significant damage to their heart, lungs, & kidneys, & often die.

Cause – Autosomal recessive inheritance, mutated haemoglobin gene.

High incidence – Africa & India.

Sickle cell trait

Sickle cell trait is the heterozygous form of sickle cell anaemia, where sickling of red blood occurs but is not lethal.

Cause – Single sickle cell anaemia allele, co-dominant where mild sickling of blood cells only occurs under low oxygen conditions.

High incidence – Africa & India, locations in majorly Africa & India where malaria is prevalent. This is due to the fact that sickle cell trait gives a form of resistance to malaria therefore is a survival advantage, causing this form of the allele to be higher.

Tay–Sachs disease

Tay –Sachs disease causes an accumulation of a fatty substance in the nervous system, destroying nerve cells leading to death by the age of 4 or 5 years,

Cause – Autosomal recessive inheritance.

High incidence – Ashkenazi Jew population. Due to this population being initially small & isolated. While heterozygous form of Tay Sachs has an increased resistance to tuberculosis.

5-Evolution

Hominid – The group consisting of all modern & extinct Great Apes (that is, modern humans, chimpanzees, gorillas & orang-utans plus all their immediate ancestors).

Hominins – The group consisting of modern humans, extinct human species & all our immediate ancestors.

Evolution – Slow gradual change in characteristics of a species.

	Great Apes	Humans
Relative size of cerebral cortex	**1.** Smaller cranial capacity **2.** Sagittal crest **3.** Sloping forehead **4.** Posteriorly located foramen magnum **5.** Increased post-orbital constriction **6.** Thicker cranium **7.** Prominent brow ridges **8.** Less rounded cranium	**1.** Larger cranial capacity **2.** No sagittal crest **3.** Vertical forehead **4.** Anteriorly located foramen magnum **5.** Decreased post-orbital constriction **6.** Thinner cranium **7.** Reduced brow ridges **8.** Rounded cranium
Mobility of the digits	**1.** Less opposable first digit **2.** Opposable big toe **3.** Precision grip **4.** Power grip **5.** Shorter thumb relative to other digits **6.** Curved fingers	**1.** More opposable first digit **2.** Non-opposable big toe **3.** Precision grip **4.** Power grip **5.** Longer thumb relative to other digits **6.** Straight fingers
Locomotion	**1.** Quadrupedal **2.** C shaped spinal curve **3.** Less wedge shaped lumbar vertebrae **4.** Thinner lower vertebrae **5.** Longer, narrow pelvis **6.** Lesser carrying angle **7.** Longer arms than legs **8.** Longitudinal arch only **9.** Smaller heel bone	**1.** Bipedal **2.** S shaped spinal curve **3.** More wedge shaped lumbar vertebrae **4.** Thicker lower vertebrae **5.** Shorter, wider pelvis **6.** Greater carrying angle **7.** Shorter arms than legs **8.** Longitudinal/transverse **9.** Larger heel bone
Prognathism/ dentition	**1.** Sloping/prognathic face **2.** Large jaw **3.** No chin **4.** Larger molars & canines **5.** Diastema **6.** U shape dental arcade	**1.** Flatter face **2.** Small jaw **3.** Definite chin **4.** Smaller molars & canines **5.** No diastema **6.** Parabolic dental arcade

Quadrupedal adaptations

Foramen magnum – Posteriorly positioned foramen magnum under the base of the skull, pushes the centre of gravity in front of the pelvis

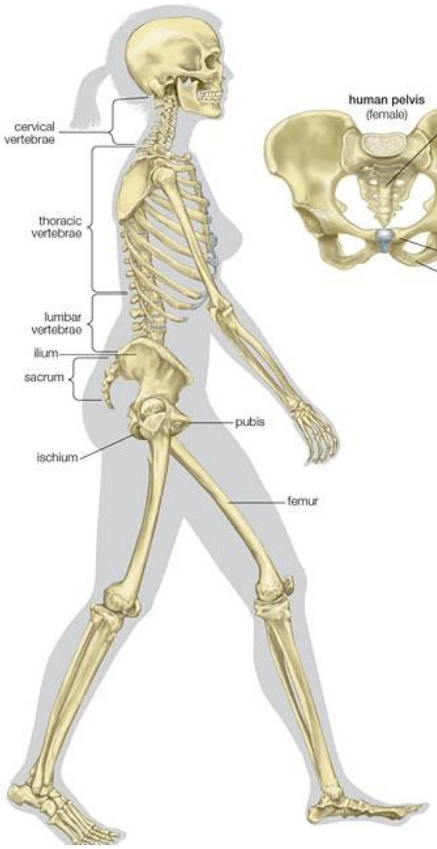
C shaped curvature of the spine – C shaped curvature of the spine projects centre of gravity forward of the pelvis/ for improved balance in the quadrupedal position.

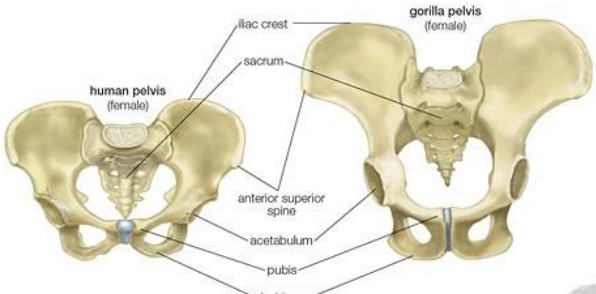
Long narrow pelvis – Allows hind limbs to move under centre of gravity which is in front of the pelvis.

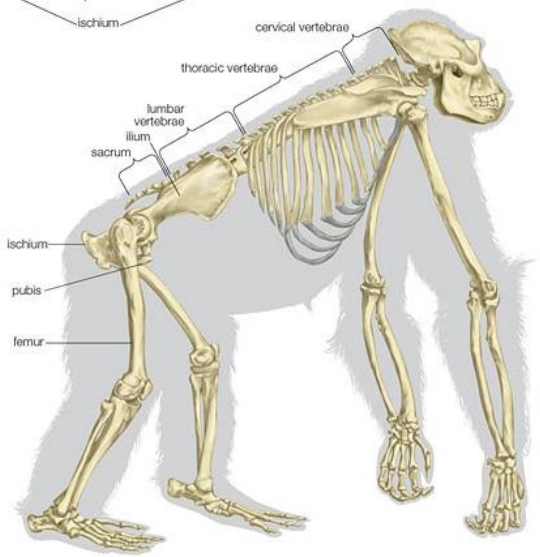
Longer arms than legs – Helps make centre of gravity in front of pelvis at chest level. Allows arms to more easily assist in support of body weight.

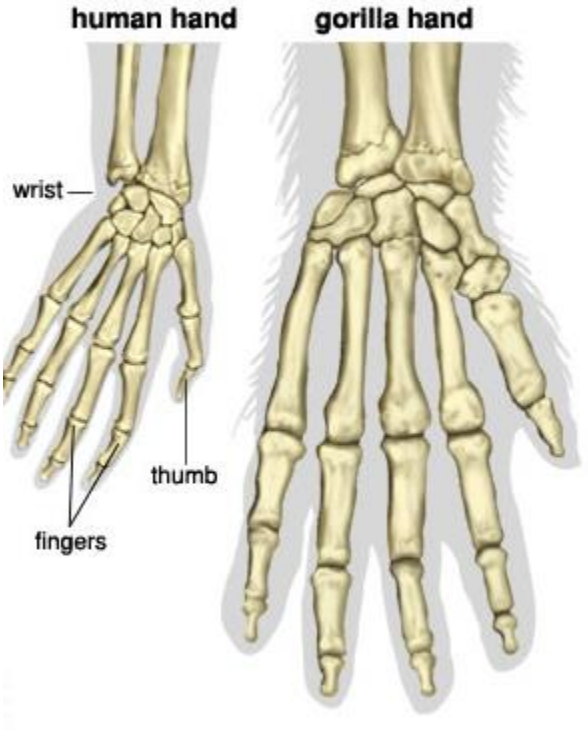
Thick robust fingers/toes/digits – Allow for weight bearing for knuckle walking.

Rib cage – Apes have a rounder, barrel shaped rib cage, which pushes the centre of gravity in front of the pelvis.



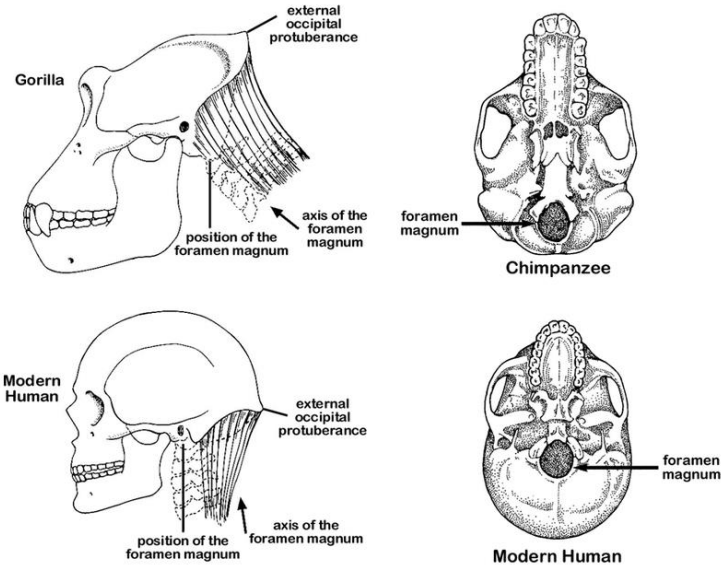




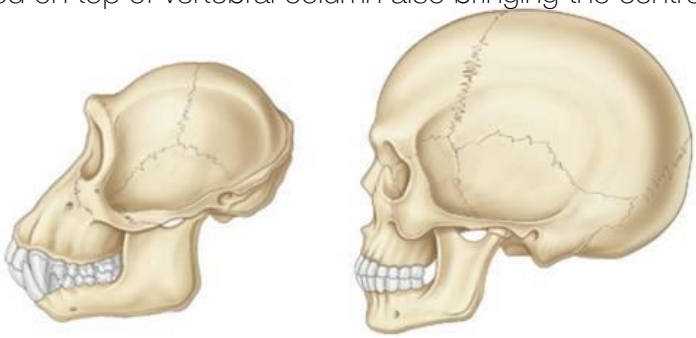


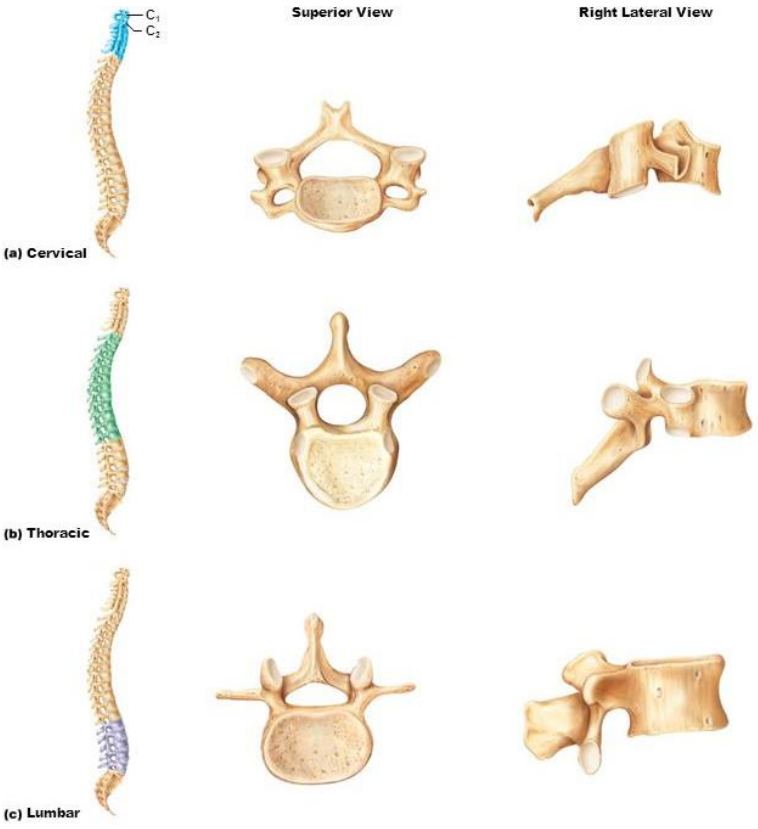
Bipedal adaptations

Foramen magnum – The foramen magnum is more anteriorly, positioned underneath the base of the skull. Allows for the skull to be better balanced on top of the vertebral column.

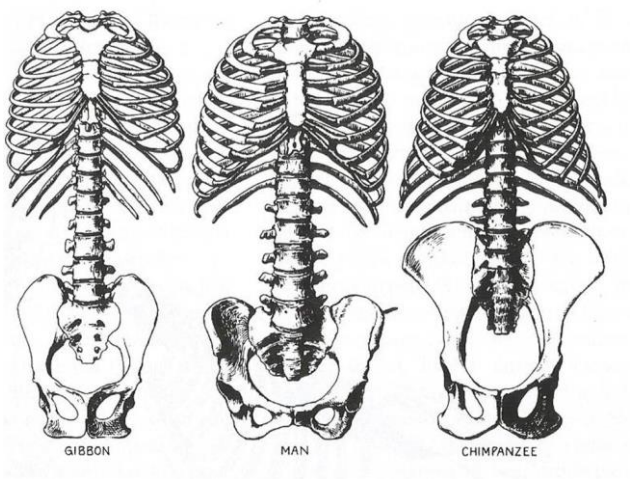


Jaw – The jaw is less prognathic meaning the jaw bone is smaller & non-protruding which allows for the skull to be better balanced on top of vertebral column also bringing the centre of balance over feet.



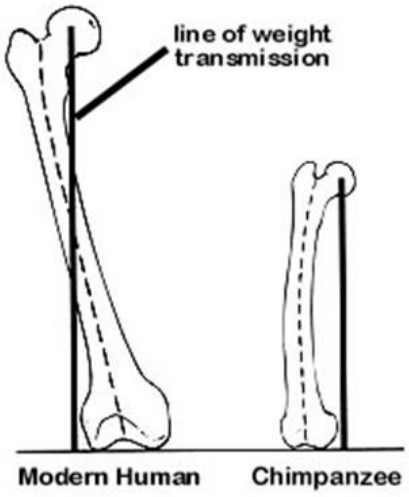


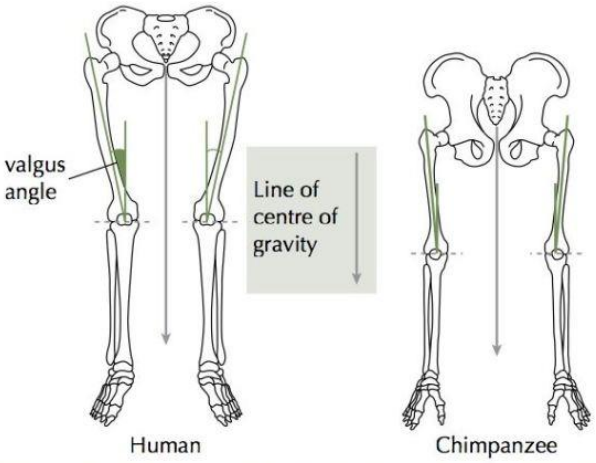
Spinal column – S shape curvature brings vertebral column directly under weight of skull. Improves balance in upright position. While the lumbar vertebrae is thick & wedge shaped from front to back supporting the upper body weight.



Bipedal adaptations

Pelvis – Bowl shape supports abdominal organs & foetus. Broad shape provides attachment for large gluteal muscles & creates wide hip sockets for femurs creating the carrying angle aligning knees to the centre of the body.



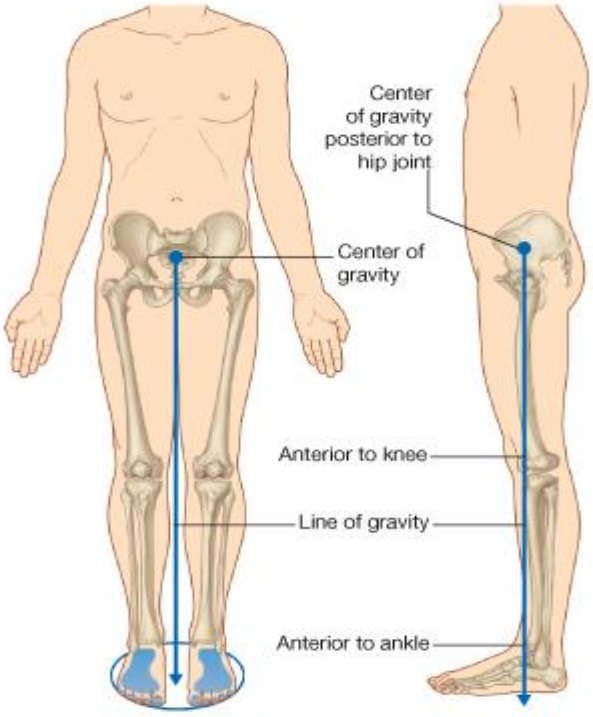


How the valgus angle of the knee joint keeps the centre of gravity close to the point above the feet.

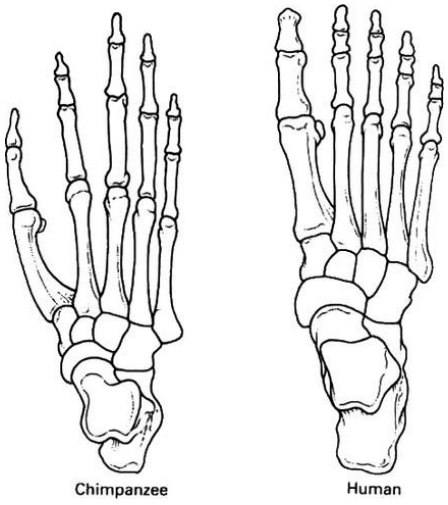
Femur – Wide hip sockets, creates carrying angle of femur. Curvature of femur towards the midline creates a carrying angle, allows knees to converge toward the central axis of body, improves stride & lowers the centre of gravity.

Knee joint – Bears weight through the lateral condyles (outer hinge), which are larger than the medial condyles & the knee is able to be straightened.

Legs – Human legs are longer than arms. The relatively long legs increase the length of the stride when walking, & also lower the centre of gravity of the body. Lowering the centre of gravity enables greater stability when moving bipedally or when standing erect.

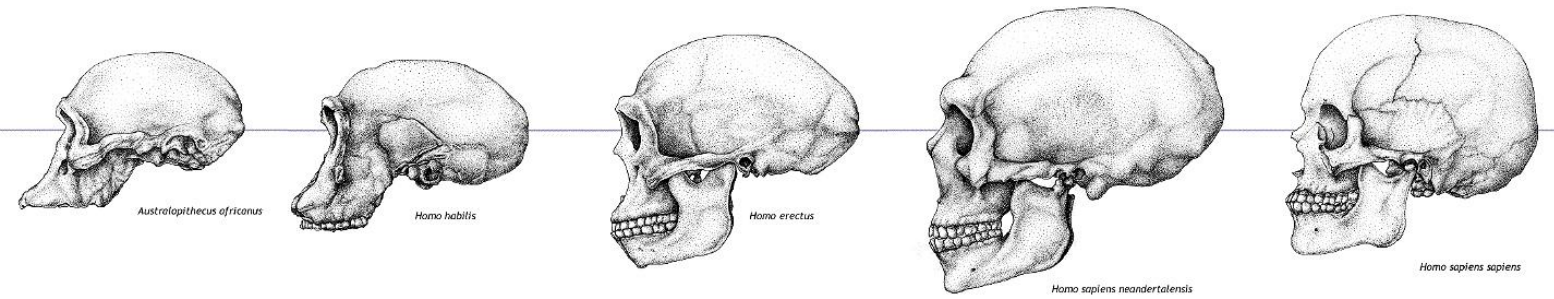


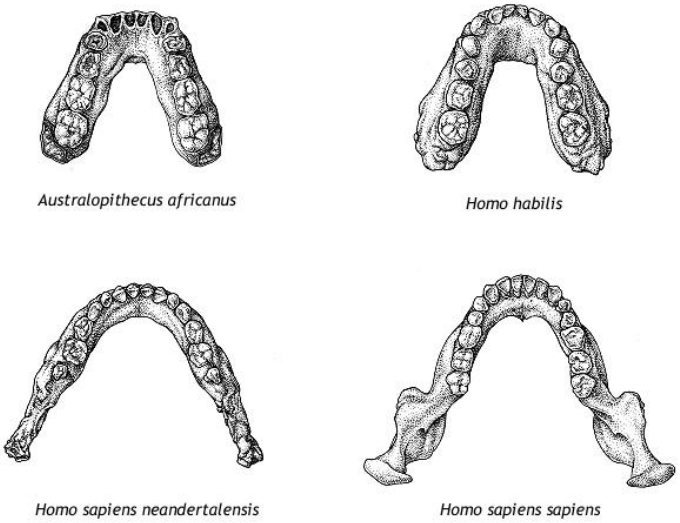
Foot – Larger calcaneus (heel), for weight bearing & aligns with big toe. Longitudinal & transverse arch, transfers energy from Achilles tendon to big toe. Robust, **non-opposable** big toe which improves stride by providing thrust.

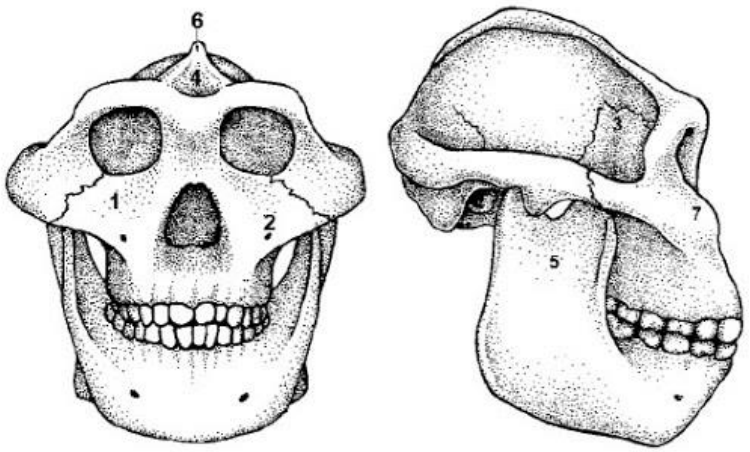


Human evolution

	Location	Time	Cranial capacity	Height
Australopithecus afarensis	East Africa	3.9 mya – 3 mya	430	105 – 150
Australopithecus africanus	South Africa	3.3 mya – 2.1 mya	450	115 – 138
Paranthropus robustus	East & South Africa	2.0 mya – 1.2 mya	590	100 – 120
Homo habilis	Eastern Africa	2.4 mya – 1.4 mya	650	100 – 135
Homo erectus	Asia & Europe	1.9 mya – 300,000	950	145 – 185
Homo neanderthalensis	Europe & Asia	400000 – 40000	1450	155 – 165
Homo sapiens	Africa, Asia & Europe	200000 – present	1350	160 – 180

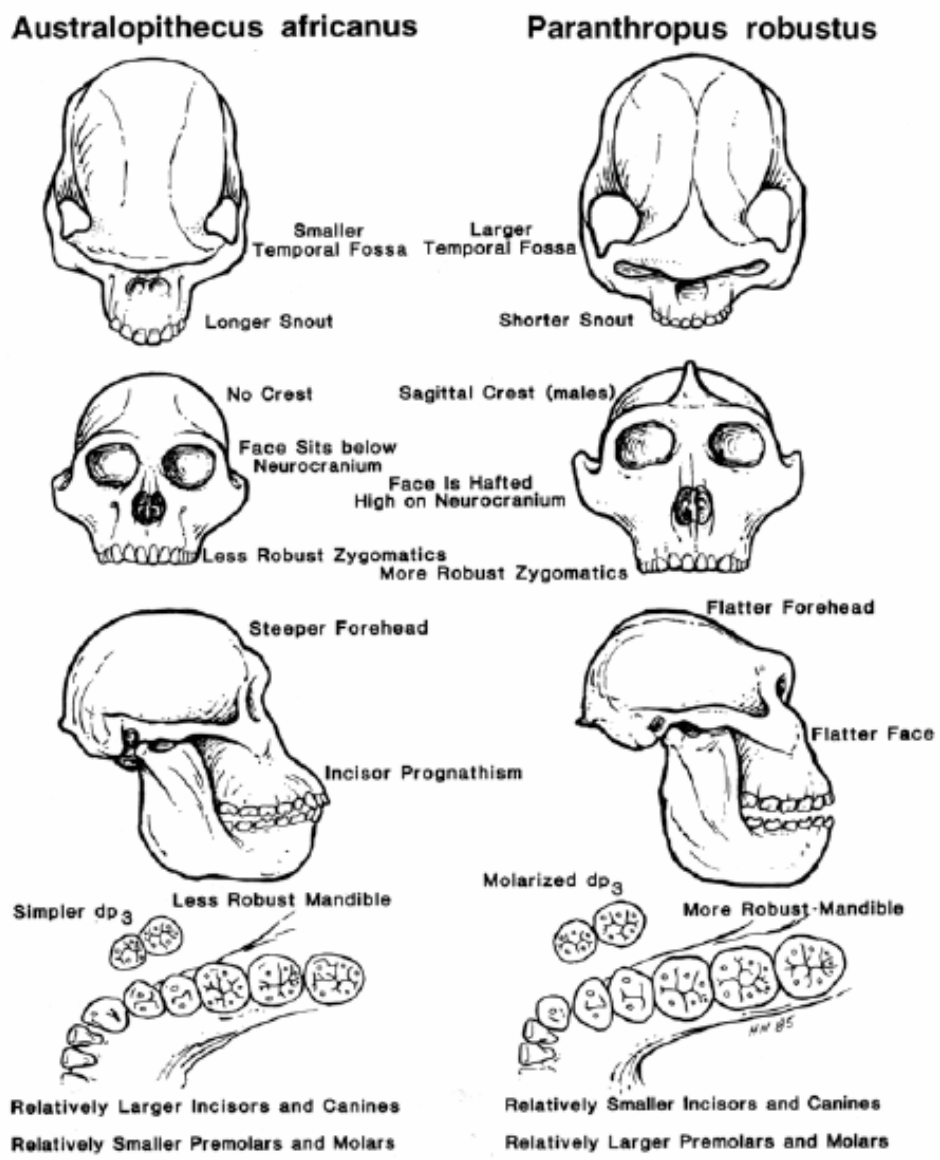


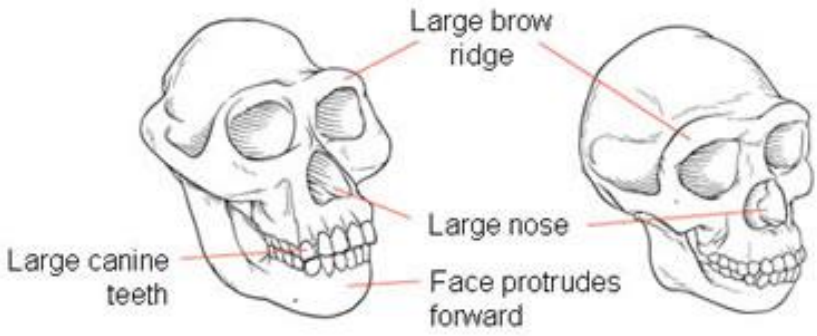


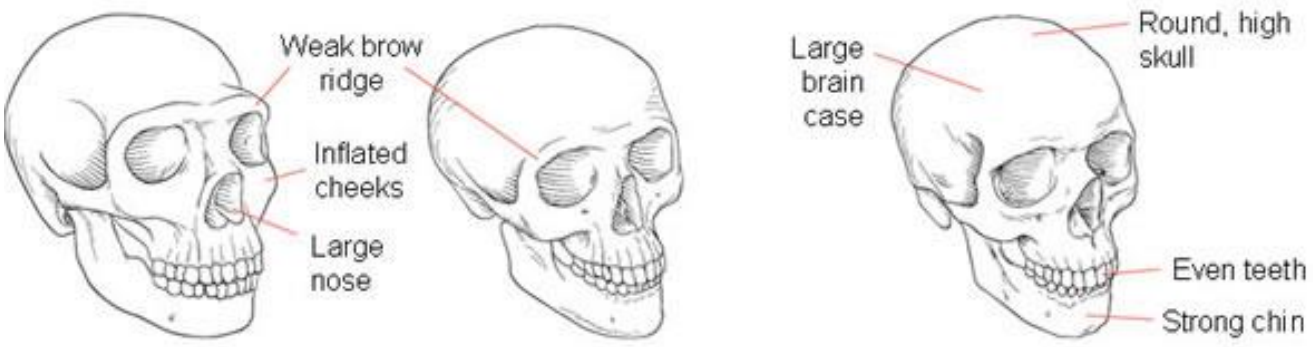


Australopithecus

(Fleagle, 1999)





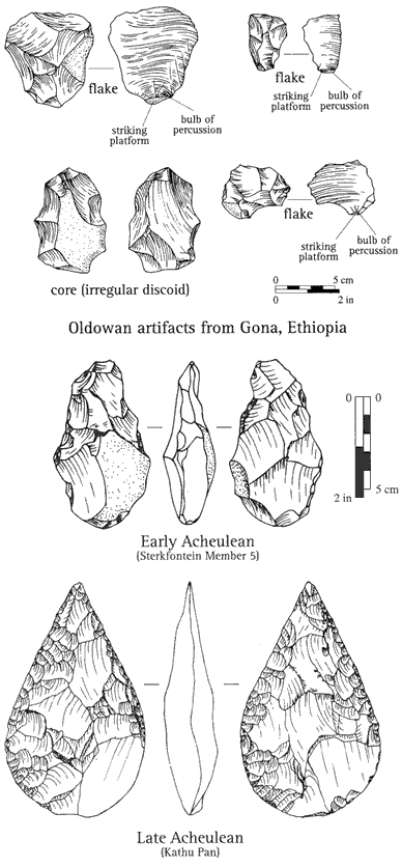


Hominin Culture

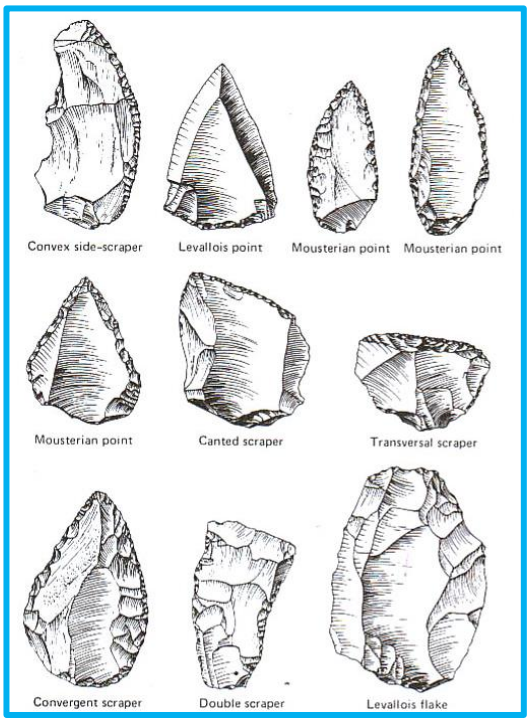
Culture – The range of learned behaviour patterns acquired by a species/population

Trends – Increase in the variety of tools made. Increase in the complexity of manufacturing process of the tool. Increase in the quality of workmanship. Increase in the range of materials used to produce tools. Increase in the number of different activities tools are used for.

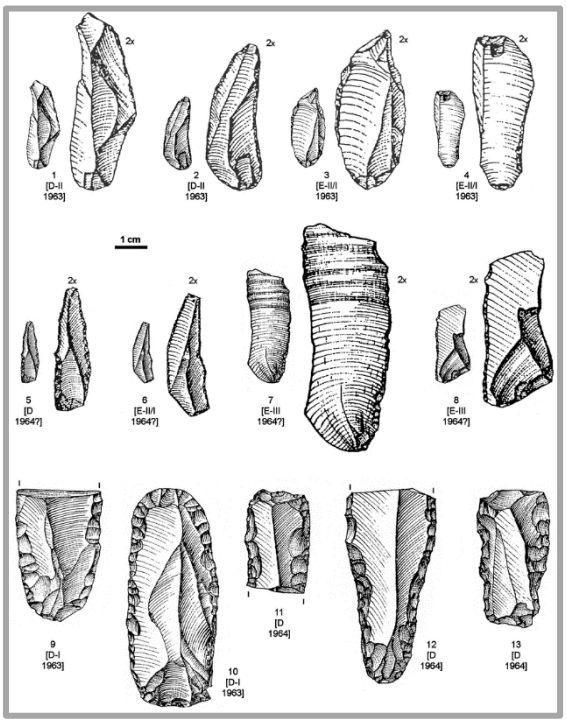
Hominin	Tool culture/time range	Material/manufacturing techniques
Homo habilis	Oldowan/ **2.6 mya – 1.7 mya**	Stone/ Percussion flaking
Homo erectus	Acheulean/ **1.76 mya – 100000**	Stone/Percussion flaking
Homo neanderthalensis	Mousterian/ **200000 – 40000**	Stone, wood & bone/ Percussion flaking & hafting
Homo sapiens	Aurignacian/ **43000 – 26000**	Stone, wood & bone/ punch flaking
Homo sapiens	Solutrean/ **22000 – 19000**	Stone, wood & bone/pressure flaking
Homo sapiens	Magdalenian/ **18000 – 12000**	Stone, wood & bone/Hafting, punching & pressure flaking

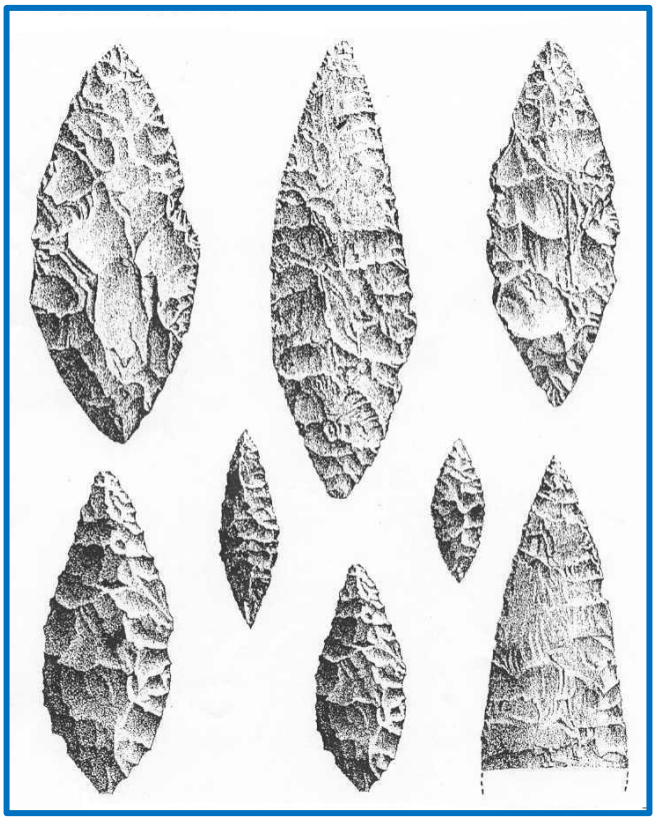


Mousterian

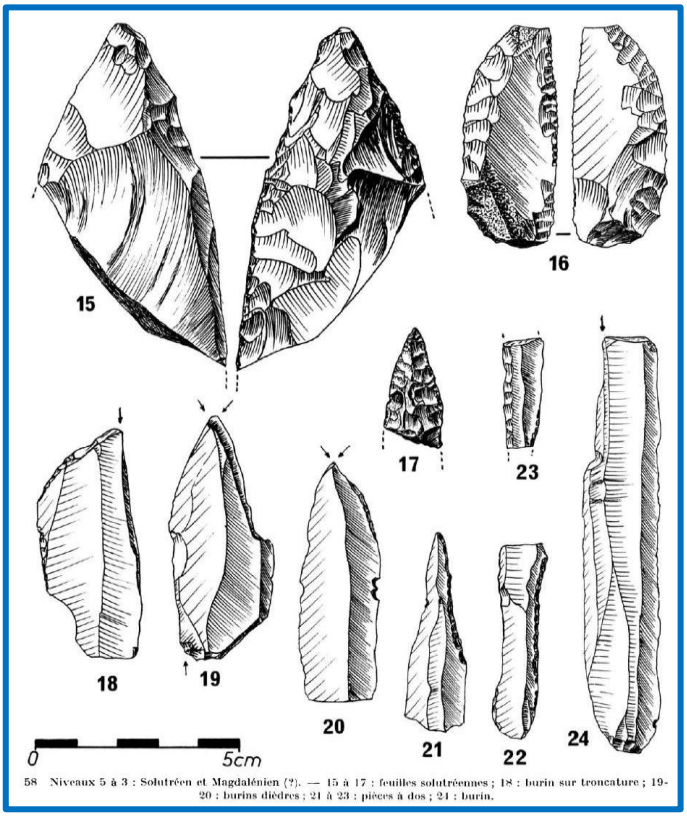


Aurignacian

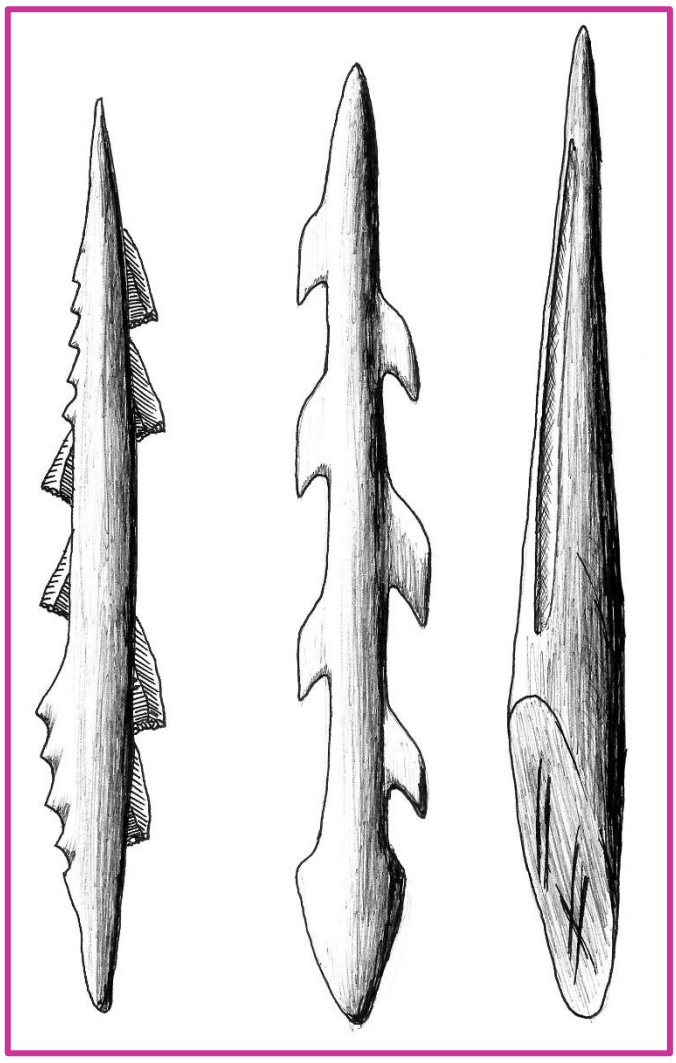




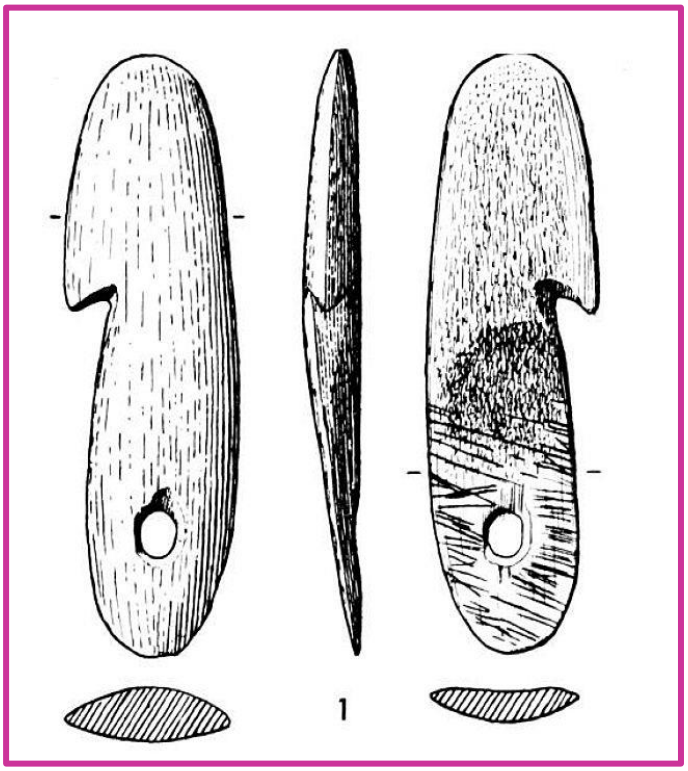
Solutrean



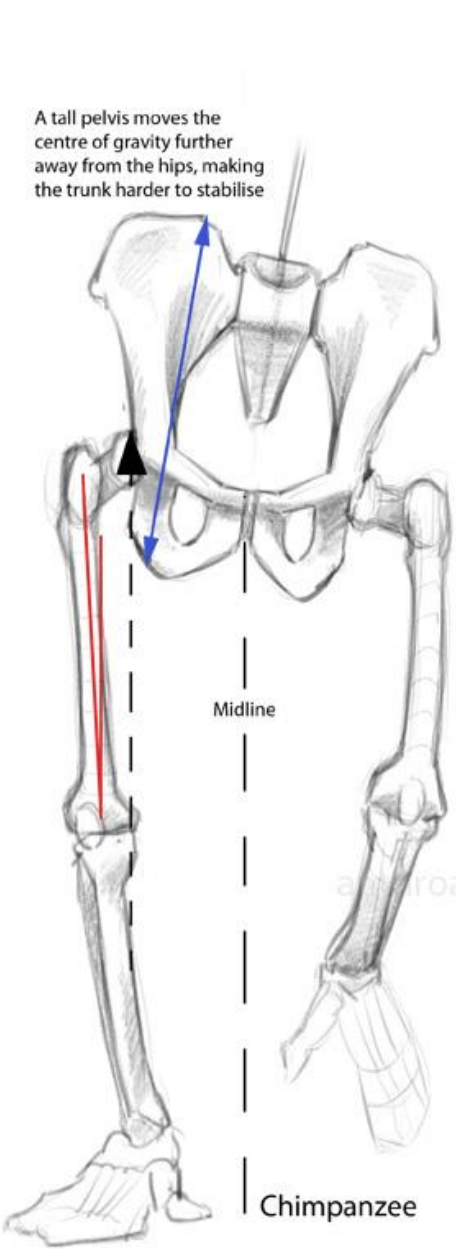
58 Niveaux 5 à 3 : Solutréen et Magdalénien (?). — 15 à 17 : feuilles solutréennes ; 18 : burin sur troncature ; 19-20 : burins dièdres ; 21 à 23 : pièces à dos ; 24 : burin.



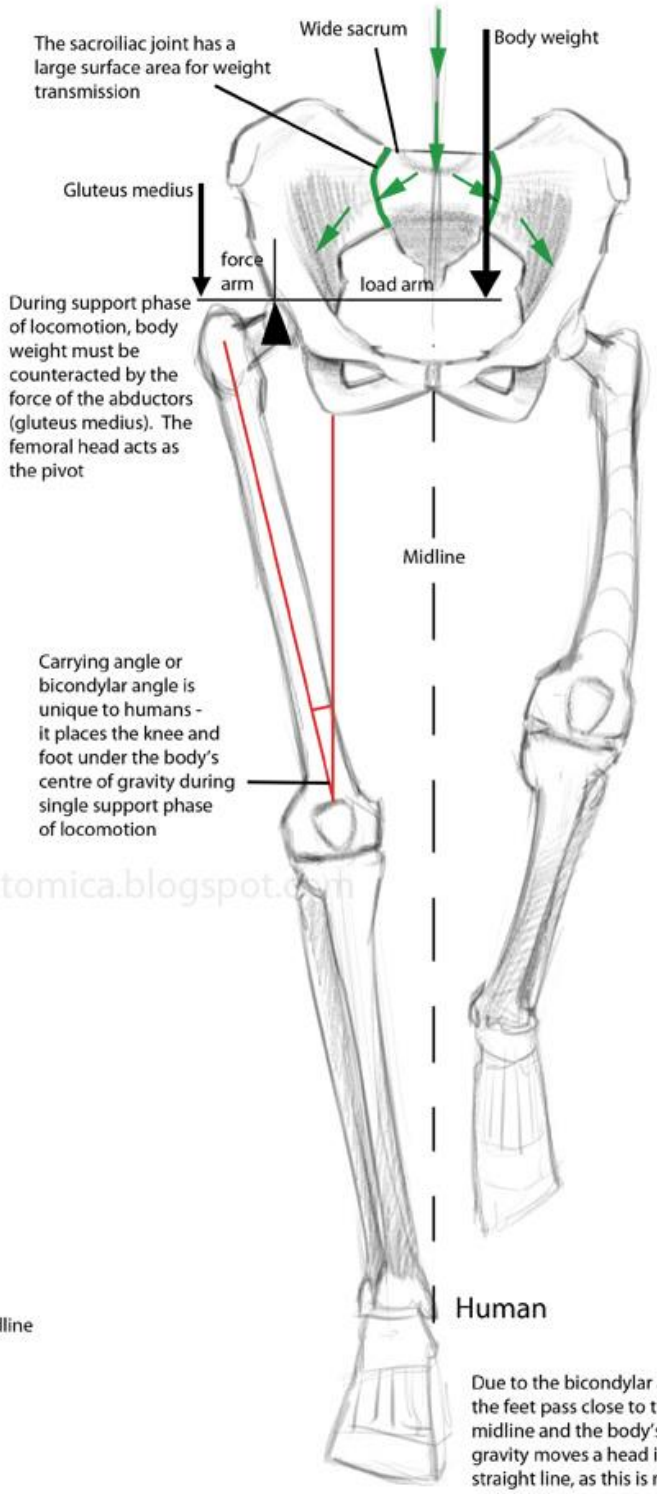
Magdalenian



Adaptations to aid bipedalism



Femurs are almost vertical beneath the hip joints, their is only a slight bicondylar angle. feet far from the midline causing a shift in the centre of gravity of each stride, this is very energy inefficient



Due to the bicondylar angle the feet pass close to the midline and the body's centre of gravity moves a head in a straight line, as this is more stabile, it is more energy efficient

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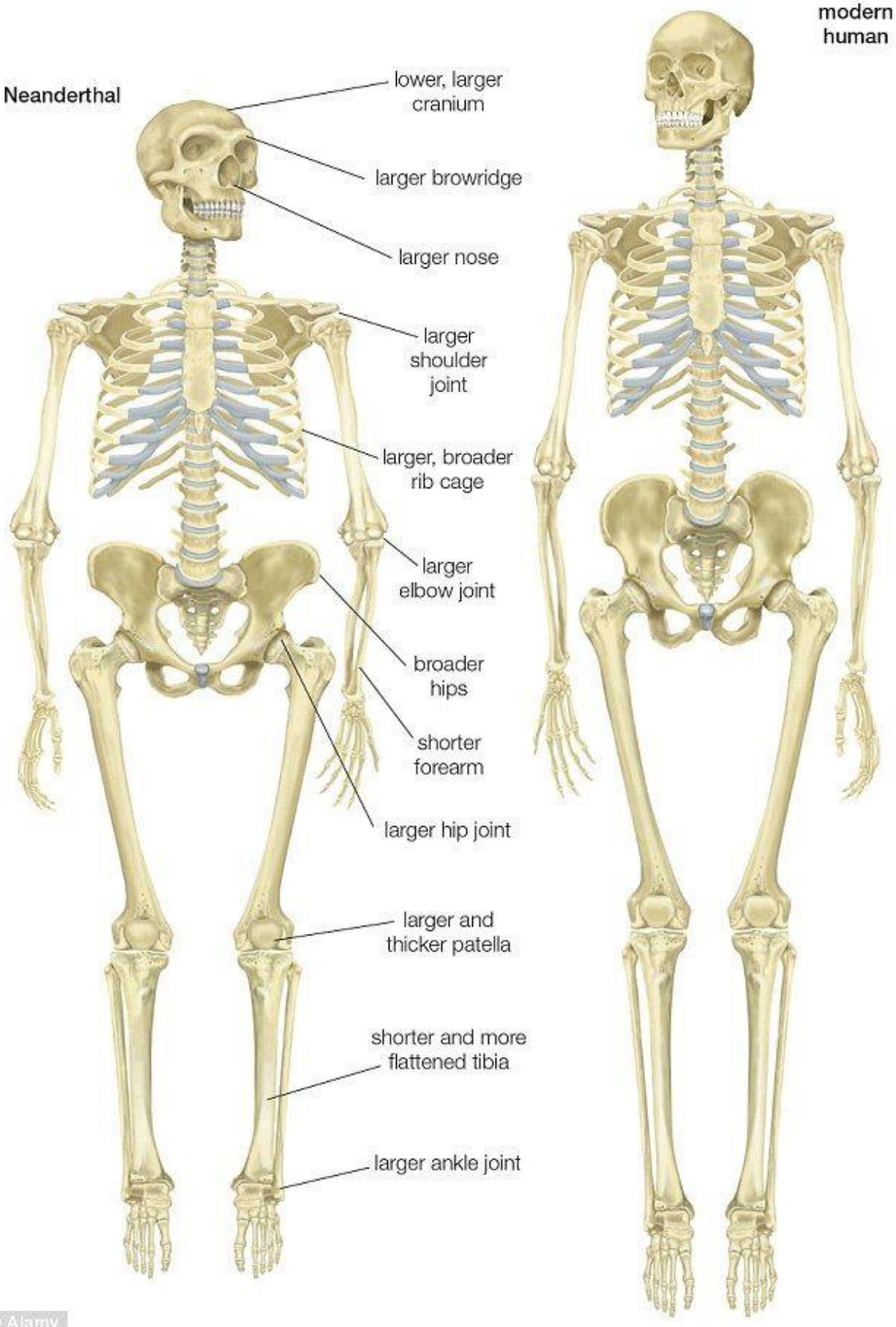
Neanderthal
modern human
lower, larger cranium
larger browridge
larger nose
larger shoulder joint
larger, broader rib cage
larger elbow joint
broader hips
shorter forearm
larger hip joint
larger and thicker patella
shorter and more flattened tibia
larger ankle joint

Australopithecus Afarensis

Skull

- Low, sloping forehead, a projecting face, & prominent brow ridges above the eyes.
- unlike most modern apes, this species did not have a deep groove lying behind its brow ridge & the spinal cord emerged from the central part of the skull base rather than from the back.

Jaws & teeth

- canine teeth were pointed & were longer than the other teeth. Canine size was intermediate between that of apes & humans.
- a gap (diastema) was often present between the canines & adjacent teeth. This ape-like feature occurred between the canines & incisors in the upper jaw, & between the canines & premolars of the lower jaw.

Pelvis

- pelvis was human-like as it was short & wide, but it lacked the refinements that enable humans to walk with a striding gait

Limbs

- Femurs (thigh bones) that slanted in toward the knee. Knees with enlarged & strengthened outer condyles. Arched feet & wide heels. Aligned non-opposable big toes. Powerful arms with long forearms. Very short thigh bones with long, curved finger & toe bones.

Australopithecus Africanus

Skull

- compared with the earlier species, *Australopithecus afarensis*, the skull showed some slightly more human-like features such as a smaller brow ridge & a slightly arched (rather than flat) forehead area.
- like all human ancestors, the spinal cord emerged from the central part of the base of the skull rather than from the back.

Jaws & teeth

- jaws & teeth were intermediate between those of humans & apes & those of earlier species, such as *Australopithecus afarensis*
  - the canine & incisor teeth had become shorter & smaller
  - a gap (diastema) between the canines & adjacent teeth was rare
  - premolar teeth & molar teeth were all quite large

Limbs

- they also indicate some ape-like features including slightly curved finger, toe bones & arms that were quite long, although not longer than their legs.

Pelvis

- was fully adapted for walking on two legs but compared with those of modern humans it was less rounded, had a narrower birth canal, & was not specialised for a striding gait.

Paranthropus Robustus

Skull

- cranial features were ape-like with a flat forehead & a prominent brow ridge above the eyes.
- the face was relatively broad with flaring cheekbones. *Paranthropus robustus* had shorter, flatter faces.
- spinal cord passed through the centre of the skull base, indicating these species walked upright.
- males had a massive bony ridge running along the top of the skull, called a sagittal crest. This acted as an anchor for their powerful jaw muscles.

Jaws & teeth

- front teeth (incisors & canines) were very small compared with the extremely large molar teeth. The molar teeth were very effective for crushing & grinding tough plant foods
- jaws were large & robust for the attachment of powerful chewing muscles

Limbs & pelvis

- legs had human-like features that indicate an ability to walk upright
- arms were long compared with the legs
- pelvis was similar to that of *Australopithecus* as it was built for walking on two legs but without the refinements for the striding gait of humans.

Homo Habilis

Skull

- brain case had become fuller & more rounded due to expansion of the brain
- beginnings of a slight forehead were appearing
- face had a small, arched brow ridge & was smaller & shorter than those of earlier ancestors
- The foramen magnum was located in the centre of the skull base, showing that this species walked on two legs
- facial projection was reduced compared with earlier species

Jaws & teeth

- teeth were arranged in a more rounded arc like those of modern humans
- teeth had become smaller & more human-like, although the incisors were still relatively large

Limbs

- features of the leg & foot bones indicate that this species walked on two legs.
- legs were relatively short, providing this species with arm & leg proportions that were relatively ape-like & similar to those of the australopithecines.
- finger bones are slightly curved & intermediate in shape between the curved finger bones of quadrupedal apes & the straight finger bones of modern humans
- finger bone proportions suggest the human-like ability to form a precision grip

Homo Erectus

Skull

- face was large with a low, sloping forehead, a massive brow ridge & a broad, flat nose
- skull was broad & long with sharp angles at the rear, unlike the curve found in modern humans
- bones of the skull were very thick & formed a small central ridge, known as a midline keel, along the top of the skull

Jaws & teeth

- jaw was large & thick without a pointed chin
- molar teeth had large roots but were decreasing toward a more modern size

Limbs

- limbs were like those of modern humans although the bones were thicker, suggesting a physically demanding lifestyle.

Homo Neanderthalensis

Skull

- distinctive skull shape that was long & low, with a rounded brain case
- back of the skull had a bulge called the occipital bun & a depression (the suprainiac fossa) for the attachment of strong neck muscles
- thick but rounded brow ridge lay under a relatively flat & receding forehead
- mid-face region showed a characteristic forward projection (this resulted in a face that looked like it had been 'pulled' forward by the nose)
- orbits (eye sockets) were large & rounded
- nose was broad & very large

Jaws & teeth

- jaws were larger & more robust than those of modern humans & had a gap called the retromolar space, behind the third molars (wisdom teeth) at the back of the jaw.
- jaw lacked the projecting bony chin that is found in Homo sapiens.
- teeth were larger than those of modern humans.

Limbs & pelvis

- limb bones were thick & had large joints which indicates they had strongly muscled arms & legs
- shin bones & forearms tended to be shorter than those of modern humans. These proportions are typical for people living in cold climates.
- pelvis was wider from side to side than in modern humans & this may have slightly affected their posture

Homo Sapiens

Skull

- modern *Homo sapiens* skulls have a short base & a high braincase. Unlike other species of *Homo*, the skull is broadest at the top. The fuller braincase also results in almost no post-orbital constriction or narrowing behind the eye sockets
- back of the skull is rounded & indicates a reduction in neck muscles
- face is reasonably small with a projecting nose bone
- brow ridge is limited & the forehead is tall
- orbits (eye sockets) are square rather than round

Jaws & teeth

- jaws are short which result in an almost vertical face
- usually no gap (retromolar space) between the last molar teeth & the jaw bone
- jaws are lightly built & have a protruding bony chin for added strength. *Homo sapiens* is the only species to have a protruding chin.
- shortened jaw has affected the arrangement of the teeth within the jaw. They are now arranged in a parabolic shape in which the side rows of teeth splay outwards rather than remain parallel as in our earliest long jawed ancestors.
- teeth are relatively small compared with earlier species. This is especially noticeable in the front incisor & canine teeth.
- front premolar teeth in the lower jaw have two equal-sized cusps (bumps on the chewing surface)

Limbs & pelvis

- limb bones are thinner & less robust than earlier human species & indicate a reduction in muscle size from earlier humans.
- legs are relatively long compared with the arms.
- finger & toe bones are straight & without the curvature typical of our earliest australopithecine ancestors.
- pelvis is narrower from side-to-side & has a deeper bowl-shape from front-to-back than previous human species.