THE ENDOCRINE SYSTEM

THE ENDOCRINE SYSTEM

- Comprised of a group of ductless glands that secrete hormones into the bloodstream
- Aid in the body's homeostatic control, as well as the nervous system

HORMONES

- Chemical messengers carried in the bloodstream to target cells or organs
- Each hormone has a specific purpose or function
- Secreted in tiny amounts from endocrine glands
- Work more slowly, but are longer lasting than nerve impulses

Types of Hormones

- Lipid soluble (steroid hormone)
  - Able to diffuse through cell membrane
  - Binds to receptor inside cell
  - Activates hormone-receptor complex to alter gene expression and cell metabolism
- Water soluble (protein/amine hormone)
  - Not able to diffuse through cell membrane
  - Attaches to receptor in cell membrane
  - Secondary messenger is sent to a receptor inside the cell
  - Alters gene expression or cell metabolism

Hormone Function

- Activates certain genes to produce specific enzymes or structural proteins
- Changes the shape of enzymes to turn them 'on' or 'off'
- Changes the rate of production of specific enzymes or proteins

Endocrine Glands

Pituitary Gland

- Pea sized structure located at the base of the brain
- Connected to the hypothalamus via the infundibulum
- An extension of the hypothalamus, consisting of an anterior (front) and posterior (back) lobe.
  - Anterior is a 'true endocrine gland' because it is signalled by releasing and inhibiting factors from hypothalamus, via the bloodstream, to produce and secrete its own hormones
  - Posterior is not a 'true gland' because it receives and stores oxytocin and ADH produced by the hypothalamus in its axon terminals (nerves), before releasing it when triggered by nerve impulses from the hypothalamus.
- Produces hormones that control other glands and other functions: is considered a 'master gland'
  - Secretes hormones that act on nearly all other glands
  - Exception of adrenal glands, which are controlled directly by the hypothalamus

Thyroid & Parathyroid

- Thyroid situated around the larynx
- Parathyroid behind the thyroid (four small glands)
- Complement each other – what one does the other oppose

- Thyroid controlled by the release of thyroid stimulating hormone from the pituitary, which is controlled by the hypothalamus
- Hypothyroidism
- Hyperthyroidism

Pancreas (Islets of Langerhans)

- Located below the stomach and along the duodenum
- Both an exocrine and endocrine gland
  Two types of cells:
  - Alpha cells:
    - Glucagon
  - Beta cells
    - Insulin

Adrenal Glands

- Situated on top of the kidneys
- Cortex and medulla release different hormones
- Medulla:
  - Releases hormones to prepare the body to react to threatening situations
  - Concerned with fight or flight responses, controlled through the ANS
- Cortex
  - Produces more than 20 different hormones (corticosteroids)

Pineal Gland

- Found deep inside the brain
- Approximately pea sized in children
- Decreases in size after puberty
- Regulates sleep cycles with melatonin
  - Stimulated by darkness
  - Inhibited by light
- Much of its workings are still a mystery

Thymus

- Located in the chest just above the heart and just behind the sternum
- Largest during infancy and childhood
- Begins to shrink after puberty
- Integral to immune system

The Gonads

- Include the testes and ovaries
- Produce hormones on top of sperm or ova

Other Endocrine Tissues

- Not true endocrine glands, but still secrete hormones
- Include:
  - Stomach and small intestine
  - Kidneys
  - Heart
  - Placenta

Endocrine Gland	Hormone	Target Organ	Function
Anterior Pituitary	Thyroid stimulating hormone	Thyroid	Stimulates thyroid to release thyroxine or calcitonin
	Growth Hormone	All cells, specifically muscles and bones	Growth, maintenance and repair of organs
	Adrenocorticotrophic	Adrenal cortex	Stimulates adrenal cortex to release cortisol
	Prolactin	Mammary glands	Stimulates production of milk in mammary glands
	Follicle stimulating Hormone	Testes/ovaries	Stimulates development of follicles in females, stimulates spermatogenesis in males
	Luteinising Hormone	Testes/ovaries	Triggers final maturation of follicle, ovulation, subsequent formation of oestrogen in women
Posterior Pituitary	Oxytocin	Uterus/mammary glands	Triggers uterine contractions during childbirth and lactation
	Antidiuretic hormone	Distal convoluted tubule and collecting ducts of nephrons in kidneys, and arterioles	Increases water reabsorption and raises blood pressure
Thyroid	Thyroxine	Most body cells	Basal metabolic rate
	Calcitonin	Skeleton	Decreases calcium in blood, while increasing calcium in bone
Parathyroid	Parathyroid hormone	Skeleton	Increases blood calcium levels
Pancreas (islets of Langerhans)	Insulin	Most cells	Lowers blood sugar levels
	Glucagon	Liver and fatty tissues	Increases blood sugar
Adrenal Cortex	Cortisol	Most body cells and liver	Assists body deal with stress, repair tissues, and increases blood sugar
	Aldosterone	Kidney	Increase Na^+ reabsorption, and K^+ excretion
Adrenal Medulla	Adrenaline and noradrenaline	Organs stimulated by the sympathetic NS	Flight or fight response
Pineal	Melatonin	N/A	Sleep cycles
Thymus	Thymosin	T-lymphocytes	Maturation of T-lymphocytes
Ovaries	Oestrogens	Many tissues	Development of female sex characteristics, regulates menstrual cycle
	Progesterone	Uterus and mammary glands	Maintains uterine lining during menstrual cycle and pregnancy, and prepares mammary glands for lactation
Testes	Androgens (testosterone)	Many tissues	Stimulates sperm production, growth of skeleton and muscles, and development of male sex characteristics

THE NERVOUS SYSTEM

THE NERVOUS SYSTEM

- Integrated communication network and control centre of the body
- Coordinates all voluntary and involuntary actions
- Also aids in body homeostasis

Nervous Control

- The 'message' that travels along a nerve fibre is a nerve impulse
- They occur very quickly, so the body is able to respond rapidly to any stimuli or changes in the internal or external environment
- It is an electrochemical message

Neurons

- The basic structural and functional units of the nervous system
- Can vary in size and shape
- Consist of three main parts:
  - Cell body
  - Dendrites (towards cell body)
  - Axons (away from cell body)
- Generate electrochemical impulses to transmit information
- Nerve fibres are arranged in bundles called nerves

Functional Neuron Classification:

- Interneurons
  - Connectors/association/relay neurons
  - Found in the central nervous system (CNS)
  - Link sensory and motor neurons
- Motor/Efferent Neurons
  - Carry messages away from the CNS to effectors, such as muscles or glands
- Sensory/Afferent Neurons
  - Carry messages from receptors in sensory organs, e.g. the eyes or skin, to the CNS

Structural Neuron Classification:

- Multipolar
  - One axon
  - Multiple dendrites
  - Most common type of neuron
- Bipolar
  - One axon (can have branches)
  - One dendrite (can have branches)
  - Take impulses from receptor cells to other neurons
- Unipolar
  - Only have one extension from the cell body: the axon
    - Axon terminals are found at one end
    - Dendrites are found at the other
  - Cell body is off to one side
  - Sensory neurons in the spinal cord

Dendrites

- Usually short and branched extensions of the cytoplasm
- Carry impulses towards the cell body
- Synapses connect with other neurons or receptors

Axon:

- Typically one single, long nerve fibre
- Length varies enormously, and can range from a few millimetres up to a metre or more in length
- Carry impulses away from the cell body
- Terminates at an axon terminal, or, if at a muscle fibre, a motor end plate
- Neuromuscular junctions connect with muscles
- Neuroglandular junctions connect with glands or other neurons

Schwann cells:

- Type of glial cell
  - Insulates and protects axon from damage
  - Provides neuron with nutrition
- Winds around the axon
- Speeds up movement of nerve impulses (saltatory conduction)
- Myelin sheath (inner layer)
  - White, fatty sheath surrounding the axon of some neurons
  - Neurons that have it are myelinated
  - Neurons that do not are unmyelinated
- Neurilemma (outer layer)
  - Repairs injured fibres
  - Contains the Schwann cell's nucleus and cytoplasm
- Separated by nodes of Ranvier
  - Nerve impulses jump between these nodes to increase rate of conduction

Synapses:

- The junction between branches of adjacent neurons
- Usually occur between the axon terminals of one neuron, and the dendrite or cell body of another
- The ends of axons and dendrites have synaptic end bulbs/terminals
- Messages or nerve impulses must be carried across a small gap
- The synapse between an axon and a skeletal muscle fibre is the neuromuscular junction

Nerve Impulses

- Nerve impulses are electrochemical changes that travel along a nerve fibre.
- It involves a change in electrical voltage due to changes in ion concentrations inside and outside the cell membrane

Neuron Transmission

1. At rest, the nerve cell is polarised
   - Outside of cell is positive
   - Inside is more negative
   - Resting membrane potential (RMP) is -70 mV
2. Becomes depolarised
   - When stimulated, the axon membrane becomes more permeable to sodium ions. The stimulus must be strong enough. If it is too weak, no impulse is created
   - Sodium pumps in the membrane open, causing them to rush in

    - Now the internal environment is more positive than the external environment
3. A wave of depolarisation continues along the nerve fibre – this is the nerve impulse
4. A wave of repolarisation follows directly behind the area depolarisation
    - Sodium ions rush back out
    - Hyperpolarisation occurs when too many sodium ions rush out, leaving the internal environment more negative than usual
5. Refractory period
    - No new impulse can be carried out until the voltage has been restored to RMP

Speed of Transmission

- Three conditions affecting speed of transmission:
    - Presence of myelin sheaths:
      Myelinated fibres are faster than un-myelinated fibres
    - Diameter:
      The larger the diameter, the faster the transmission
    - Length:
      The shorter the length, the faster the transmission
- Continuous Conduction
    - Non-myelinated fibres
    - The polarisation of an area of the axon/dendrite causes polarisation in the next part, at the same rate that the polarised areas are depolarised, creating a 'domino effect' that sends the electrochemical impulse along the nerve in a continuous wave
    - Max speed = 2 ms^{-1}
- Saltatory Conduction
    - Myelinated fibres
    - Polarisation occurs only in the nodes of Ranvier, where the membrane is not covered by myelin sheaths
    - The nerve impulse 'jumps' between the nodes
    - Max speed = 18-140 ms^{-1}

Synapses

- Nerve impulses are transmitted between nerve cells by neurotransmitters
- These are chemicals that are released into the synaptic cleft, the space between the two cells

Transmission across a synapse

1. A nerve impulse (action potential) moves along the membrane of the pre-synaptic neuron until it reaches the synaptic end bulb
2. Depolarisation opens channels permeable to calcium ions in the presynaptic membrane
3. The increased calcium ion concentration activates the vesicles carrying the neurotransmitter
4. Vesicles containing these neurotransmitters move towards the pre-synaptic membrane
5. These vesicles fuse with the membrane, releasing the neurotransmitter into the synaptic cleft
6. These molecules then bind to and activate receptors in the post-synaptic membrane
7. Neurotransmitters eventually break free of the receptors, and are deactivated by an enzyme
8. The deactivated neurotransmitter is then reabsorbed by the presynaptic neuron and reused

Drugs

- Many chemicals both synthetic and natural can influence nerve transmission at the synapse
- Stimulants include: caffeine, amphetamines, and nicotine
- Inhibitors include: anaesthetics, hypnotics, alcohol, and venom from some snakes and spiders
- Nerve gases (organophosphates) cause build up of acetylcholine, resulting in all muscles contracting at once and therefore loss of muscle control

CENTRAL NERVOUS SYSTEM

- Main control system
- Consists of the brain and spinal cord

Protection of the Central Nervous System

- Bone
  - Outermost layer of protection, e.g. the cranium or vertebrae
- Meningeal layers
  - Three layers of connective tissue inside the bony cavity, covering the entire CNS
  - Dura mater (outer)
    - Tough and fibrous
    - Sticks closely to the inside of the skull
    - More loosely attached to the vertebral canal to allow for movement
  - Arachnoid (middle)
    - Loose mesh of fibres
  - Pia mater (inner)
    - Much more delicate
    - Sticks closely to the surface of the brain or spinal cord
    - Contains blood blood vessels
- Cerebrospinal fluid (CSF)
  - Clear fluid containing few cells, some glucose, proteins, urea, and salts
  - Fills space between middle and inner meningeal layers
  - Circulates through cavities in the brain and through the vertebral canal
  - Acts as a shock absorber
  - Supports the brain
  - Formed from the blood plasma, and is eventually circulated back into the blood stream
  - Transports nutrients and wastes to and from the CNS

The Brain

Cerebrum

- Biggest part of the brain
- Cerebral cortex
  - The 2-4 mm thick outer layer of the cerebrum
  - Made of grey matter
  - Consists of nerve cell bodies and unmyelinated fibres
  - Consists of sensory, motor, and association areas
- Below the cortex is white matter
- Deep inside the cerebrum is grey matter called the basal ganglia
- Surface is highly convoluted
  - Increases surface area
  - Separated by shallow down folds called sulci, and ridges called gyri
  - Deep down folds or fissures (longitudinal fissures nearly separates the two hemispheres)
- Contains 70% of all neurons in the entire CNS
- Subdivided into different lobes:
  - Frontal
    - Premotor and primary motor cortex, responsible for voluntary control of muscles
    - Judgement, emotions, motivation, and memory
  - Temporal
    - Olfactory and auditory areas

        - Occipital
            - Visual areas
        - Parietal
            - Primary sensor strip and sensory association areas
        - Insula
            - Found deep inside the brain
- Tracts
    - Inside the CNS nerve bundles are called tracks
    - Tracks in the white matter between the cortex and the basal ganglia are myelinated
    - Can connect various areas of the cortex within the same hemisphere
    - Can carry impulses between the hemispheres
    - Can connect the cortex to other parts of the brain or CNS
- Hemispheres are not identical or symmetrical
    - Certain functions only occur in specific hemispheres

Functions:

- Thinking, reasoning, learning, intelligence, and sense of responsibility
- Functional areas:
- Sensory areas:
    - Receives and processes nerve impulses from receptors
    - Nearly all sensory information is processed in the cortex
- Motor areas:
    - Sends impulses to muscles, particularly voluntary movements
    - Control of skeletal muscles based in the grey matter or basal ganglia of the brain
- Association areas:
    - Concerned with intellectual and emotional processing
    - Association areas in the cortex deal with memory

The Cerebellum

- Located under the rear of the cerebrum
- Is the second largest part of the brain
- Surface is less convoluted, and folded into parallel ridges
- Outer surface is grey matter
- Inside is white matter, which branches to all parts of the cerebellum

Functions:

- Posture, balance, fine motor control/coordination, and voluntary muscle movements
    - Receives sensory information from the inner ear
        - Utricle and saccule provide information when the head is stationary
        - Semicircular canals contain fluid and provide information during movement
    - Also receives information from proprioceptors in joints, tendons, and muscles
- Functions below the conscious level
- Motor impulses do not originate here, but are 'fined tuned' in the cerebellum; without it, movements would be spasmodic and unrefined
- Stores 'muscle memory'

The Hypothalamus

- Lies in the middle of the brain
- Small
- Controls many body functions
- Mainly concerned with homeostasis

Functions:

- Autonomic nervous system
  - Regulation of heart rate
  - Blood pressure
  - Secretion of digestive juices
  - Movements of the alimentary canal
  - Dilation of pupils
- Body temperature
- Food and water intake/absorption
- Patterns of waking and sleeping
- Contraction of the urinary bladder
- Emotional responses
- Secretion of hormones and coordination of parts of the endocrine system, acting on:
  - Pituitary gland
  - Metabolism
  - Growth
  - Reproduction
  - Responses to stress

The Thalamus

- Relays/carries sensory impulses to the cerebral cortex
- Interprets some sensory impulse, such as temperature, touch, pressure, pain, etc.

The Pons Varolii

- Connects brain with spinal cord, and parts of the brain with each other
- Part of the respiratory centre, working with the medulla oblongata

The Medulla Oblongata

- Continuation of the spinal cord
- Extends from just above where the spinal cord enters the skull
- Influenced/controlled by other higher centres in the brain, particularly the hypothalamus
- Contains all the the fibres carrying nerve impulses between the brain and spinal cord

Functions:

- Cardiac centre: regulates rate and force of heartbeat
- Respiratory centre: regulates rate and depth of breathing
- Vasomotor centre: controls vasodilation/vasoconstriction
- Reflexes: swallowing, sneezing, coughing, and vomiting

The Corpus Callosum

- Area of white matter containing a large bundle of nerves, connecting the two hemispheres
- Located at the base of the longitudinal fissure
- Allow the two hemispheres to communicate with one another

The Spinal Cord

- Cylindrical structure extending from the foramen magnum to the second lumbar vertebrae
- Enclosed and protected by vertebral canal and meningeal layers
- Unlike the brain, the dura mater is not bound to the vertebral canal
  - Instead there is space for fatty and connective tissues, and blood vessels
  - Act to cushion and protect the spinal cord and allow for movement

- Made up of white and grey matter
  - White matter
    - Myelinated fibres
    - Is the outer layer, surrounding the grey matter
    - Contains ascending tracks for sensory neurons
    - And descending tracks for motor neurons
  - Grey matter
    - Nerve cell bodies and unmyelinated fibres
    - Sensory and motor synapses
    - Is the inner layer
    - Roughly an 'H' shape
    - The central canal runs through it, containing CSF

Functions:

- Carries sensory impulses to the brain
- Carries motor impulses away from the brain
- Integrates reflexes

PERIPHERAL NERVOUS SYSTEM

- Receptors, muscles, and glands connected to the central nervous system
- Nerve fibres carry information to and from the central nervous system and ganglia, and arise from the brain or spinal cord
- Ganglia are groups of nerve cell bodies outside the brain or spinal cord
- Twelve pairs of cranial nerves arise from the brain
- Fibres carrying information to the CNS are sensory fibres
- Fibres carrying impulses from the CNS are motor fibres
- Thirty one pairs of spinal nerves arise from the spinal cord
  Each is joined to the spinal cord by one of two roots:
  - Ventral Root
    - Contains axons of motor neurons
    - Cell bodies are in the grey matter of the spinal cord
  - Dorsal Root
    - Contains axons of sensory neurons
    - Cell bodies are found in the dorsal root ganglion

Sensory/Afferent Division

- Carries impulses to the CNS
- Impulses from somatic sensory neurons, nerve cells in the skin, and around muscles and joints

Motor/Efferent Division

- Carries impulses away from the CNS to effectors

Somatic Division

- Takes from the CNS to the skeletal muscles
- Uses acetylcholine
- Generally used in response to stimuli or changes in external environment

Autonomic Division

- Controls involuntary organs, glands, and muscles, such as the heart and smooth muscles
- Operates without conscious control

- » Responsible for the control of the body's internal environment
- » Regulated by groups of nerve cells in the cerebral cortex, hypothalamus, and medulla oblongata

Sympathetic Division

- » Uses adrenaline/noradrenaline
- » Moderates fight or flight response during stressful situations
- » Protects body from injury
- » Prepares body for increased activity
- » Disrupts homeostasis

Parasympathetic Division

- » Uses acetylcholine
- » Maintains body in calm or resting states
- » Maintains homeostasis

HOMEOSTASIS

DETECTING & REGULATING CHANGE

Receptors

- A receptor is a structure that is able to detect a change in the body's internal or external environment
- Receptor cells can be grouped together in sense organs
- Other receptors can simply be sensory nerve endings spread throughout parts of or even the entirety of the body

Thermoreceptors:

- Thermoreceptors are able to respond to changes in heat
- Skin thermoreceptors
  - Allow us to detect the temperature of our surroundings
  - Feeds information to either the hypothalamus or cerebrum
  - Are nerve endings that are sensitive to either hot or cold, but not both
- Hypothalamus thermoreceptors
  - Monitor internal or core body temperature
  - Detects temperature of the blood flowing through the brain
- The hypothalamus regulates body temperature using information from both sets of thermoreceptors

Osmoreceptors:

- Detects osmotic pressure, i.e. the concentration of substances dissolved in the water of blood plasma
- Receptors sensitive to osmotic pressure located in the hypothalamus
- These receptors are very sensitive and can respond to very small changes in osmotic pressure
- Stimulate the hypothalamus so the body's water content can be precisely maintained

Touch receptors:

- Touch receptors are found mainly in the skin
- Sensitive receptors:
  - Found closer to the surface of the skin
  - Sensitive to very light touches
  - Found in high concentrations in: lips, fingertips, eyelids, and external genital organs
  - Also found at the base of hair follicles
  - React/adapt quickly, so after a short time we are no longer aware of the touch
- Other receptors
  - Located deeper in the skin
  - Sensitive to pressure and vibrations

Pain receptors or Nociceptors:

- Pain receptors are stimulated by:
  - Damage to the tissues
  - Poor blood flow
  - Excessive stimulation
- Concentrated on the skin and mucous membranes
- Occur in most organs, except for the brain
- Warns us of damage to tissues so evasive actions or treatment can be enacted to minimise damage.

- Adapt very little or not at all
  - Pain continues as long as stimuli is present
  - Prolonged stimulation of receptors can make pain worse
  - Keeps the person aware that the situation still exists

Reflexes

- A reflex is a rapid autonomic response to a change in the body's internal or external environment
- Properties:
  - Stimulus – to trigger the reflex
  - Involuntary – it occurs without conscious thought
  - Rapid – only small number of neurons involved
  - Stereotyped – occurs the same way each time it happens
- Mostly coordinated by the spinal cord
  - Stimuli or impulses may not be carried all the way up to the brain, but may be passed to motor neurons in the spinal cord
  - These are spinal reflexes
  - Some involve involuntary parts of the brain
  - Impulses may be sent to the brain to make us aware of what has occurred, but only after the reflex has been initiated
  - Reflex arc:
    1. Receptors react to a change in the environment, initiating a nerve impulse in the sensory neuron
    2. Sensory neurons carry the impulse from the receptor to the CNS
    3. The impulse passes through at least one synapse, or more, as the impulse is passed to the correct motor neuron
    4. Motor neurons carry the impulse to the effector
    5. The effector (muscle or secretory cells) receives the nerve impulse and carries out the appropriate response.
- These act to protect the body from harm or injury
  - These protective reflexes are present from birth
- Include:
  - Blinking
  - Sneezing and coughing
  - Pupil dilation
  - Autonomic responses etc.
- Learned reflexes:
  - More complex reflexes and motor patterns appear during a baby's development, e.g.:
    - Sucking, chewing
    - Following movements with eyes

      ➔ These are determined genetically
  - Some motor patterns are acquired, e.g.:
    - Riding a bike
    - Catching a ball
    - Slamming the brakes while driving

      ➔ These are learned by constant repetition

THERMOREGULATION

- The regulation of body temperature
- Humans must achieve a stable, regulated internal temperature of 36.8°C
- Heat gained = heat lost

- Detected by thermoreceptors in the skin and hypothalamus
- Modulated by the thermoregulatory centre in the hypothalamus

Mechanisms of Heat Loss

Conduction

- The transfer of heat energy from a place of high energy to a place of low energy
- Occurs through contact, usually with solids, or between solids and liquids, or solids and gases.

Convection

- Radial currents spreading particles with high heat energy throughout a fluid medium
- Occurs in liquids and gases
- Hot water/air rises, cold water/air sinks

Radiation

- Movement of heat energy through a space without a medium, or without contact.

Evaporation

- When a liquid changes into a gas or vapour, e.g. sweat
- This change of state requires a latent energy for this to occur, which is drawn from its surroundings, such as the blood in the body
- This process cools the surroundings

Heat production

- Cellular respiration
  - This is derived from the energy contained in the chemical bonds of the compounds in the foods that we eat, e.g. glucose
  - Some of the energy is used to power our bodily functions, e.g. muscle contractions, active transport of substances across cell membranes, building new molecules, etc.
  - Most the energy left from this is released as heat energy
- The rate cellular respiration (breakdown of food/release of energy) occurs is the metabolic rate.
- This is affected by:
  - Exercise
    - Increased physical activity demands more energy
    - Can increase rate of cellular respiration by +40 times
    - Therefore, large quantities of heat is released
  - Stress
    - Autonomic sympathetic nervous system
    - Releases adrenaline/noradrenaline
  - Body temperature
    - For every 1°C body temp increases, metabolic rate increases by 10%

Preventing Heat Loss

- Vasoconstriction
  - Cold receptors stimulate the hypothalamus, signalling the 35FvP6fZ
  - Vasomotor centre in the medulla oblongata to constrict the smooth muscles surrounding the blood vessels in the skin
  - Reduces blood flow to the skin, decreasing transfer of heat from the core to the surface
  - The skin becomes cooler, and can become bluish or purplish in colour, reducing heat loss
- Increase in cell metabolism

    - Hypothalamus stimulates adrenal medulla via sympathetic nervous system
    - Adrenal medulla secretes adrenaline and noradrenaline
    - Adrenaline and noradrenaline triggers an increase in cell metabolism, which produces more heat to keep warm
- Movement – shivering
    - Hypothalamus sends stimuli to parts of the brain that increase muscle tone
    - Trigger oscillating, rhythmic muscle tremors called shivering
    - Increases heat production
- Increase in basal metabolic rate
    - Hypothalamus triggers pituitary to produce thyroid stimulating hormone, stimulating the thyroid to release thyroxine
    - Increased thyroxine levels raise the basal metabolic rate, producing heat
    - This response is slower but longer lasting
- Piloerection (goose bumps)
    - Erector pili muscles at the base of the hair follicles make the hairs erect, creating an insulating layer of air close to the skin
    - Very limited in its effect as modern humans are mostly hairless
- Behavioural responses
    - Wearing more clothing, hiding under a blanket
    - Sheltering oneself from the wind, etc.
    - Reducing exposed surface area, e.g. curling up

Preventing Overheating

- Vasodilation
    - Heat receptors stimulate the hypothalamus to stimulate the vasomotor centre in the medulla oblongata to dilate the smooth muscles surrounding the blood vessels in the skin
    - Increases blood flow to the skin, increasing transfer of heat from the core to the surface
    - Skin becomes hot and flushed, increasing heat loss
- Sweating
    - Usually occurs in temperatures exceeding 28°C
    - Hypothalamus detects core and/or skin temperature rising, and triggers the contraction of the muscles surrounding the glands via the sympathetic nervous system
    - Sweat is released, which evaporates and cools the skin
- Decrease in basal metabolic rate
    - Hypothalamus signals pituitary to reduce production of TSH, which reduces the thyroid's production of thyroxine
    - Decreased thyroxine levels reduce the basal metabolic rate, decreasing heat production
- Behavioural responses
    - Wearing less clothing – increasing surface area
    - Staying out of the sun – decrease heat absorption
    - Reducing physical activity – decrease cell metabolism
    - Using a fan/air conditioning – cooler environment, encourages evaporation and radiation

Tolerance limits

- Body temperature ≥42°C is dangerous
- Temperatures >45°C usually results in death
- Heat stroke
    - Occurs if the body cannot thermoregulate effectively
    - Core temperature rises too high for cells and proteins to survive and function properly
    - Fatal if brain cells are affected

- Heat exhaustion
  - Occurs when excess vasodilation and sweating occur
  - These reduce resistance to blood flow and plasma volume respectively
  - This reduces blood pressure and output of blood from the heart
  - Can cause a person to collapse, but the body temperature is relatively normal
- Hypothermia
  - Occurs when core body temperature drops below 33°C
  - The metabolic rate slows so much it cannot produce the heat that has been lost, and the temperature continues to fall
  - Death usually occurs at temperatures lower than 32°C

BODY FLUIDS

Renal Function

1. Blood enters the glomerulus under high pressure
2. Filtration: The high pressure forces water and some dissolved solutes through the thin vessel walls into glomerular capsule
3. Reabsorption: As the filtrate passes through the proximal convoluted tubule, loop of Henle, and the distal convoluted tubule, water and other useful substances are reabsorbed into the peritubular capillaries
4. Secretion: Some more materials that need to be removed from the body are secreted from the peritubular capillaries into the nephron's tubules
5. Urine: The water and dissolved solutes in the tubules are collected by the common collecting duct, before being carried to the bladder via the ureter

Fluid Regulation

- Human body is around 60% water
- There is a constant exchange of water and other materials between the different bodily fluids through cell walls and through the walls of blood vessels
- Osmotic pressure must be quickly and carefully maintained and balanced
  - Pressure detected by osmoreceptors in the hypothalamus
- Volume and composition of urine relies on:
  - Volume of water in body fluids
  - Fluid intake, and fluid lost
- Reabsorption
  - ~99% of the water filtered into the glomerular capsule is reabsorbed in the tubules
  - Reabsorption in the proximal convoluted tubule and loop of Henle is passive, or via osmosis
  - Reabsorption in the distal convoluted tubule and collecting duct is active
  - The permeability of the DCT and CD is controlled by the anti-diuretic hormone (ADH)
- Anti-diuretic Hormone
  - Produced by the hypothalamus, stored and released by the posterior pituitary gland
  - Higher ADH increases permeability, increasing water reabsorption, and decreasing urine volume while increasing urine concentration
  - Lower ADH decreases permeability, decreasing water reabsorption, and increasing urine volume while decreasing urine concentration
- Blood plasma fluid concentrations
  - Low concentrations of water in the plasma raises osmotic pressure in the blood vessels
  - This causes more water to be absorbed from the intercellular fluid, increasing intercellular fluid concentrations and its osmotic pressure

        - This then causes water to be absorbed from the intracellular fluid to the intercellular fluid, causing the cells to lose water volume and shrink
- Selective water reabsorption
    - Salt is reabsorbed under the influence of the hormone aldosterone in the ascending loop of Henle, by stimulating sodium pumps in the tubules, causing a decrease in sodium ion concentration in the filtrate and urine
    - This increases the osmotic pressure in the blood plasma
    - Reabsorption of water occurs under the influence of the anti-diuretic hormone
- Blood Pressure & Volume
    - Secretion of ADH and aldosterone can also be stimulated by decreases in blood pressure and volume
    - Detected by pressoreceptors, baroreceptors, and stretch receptors in the heart, renal, aorta, and carotid arteries
    - These do not trigger as large a response as increased osmolality
    - Can kick in in severe conditions
      e.g. loss of 15-20% of blood volume from haemorrhage results in a massive secretion of ADH to conserve blood volume

Too much or too little:

- Dehydration
    - Water loss exceeds water intake
    - Caused by sweating, vomiting, diarrhoea, not drinking enough water/fluids
    - Symptoms: extreme thirst, low blood pressure, dizziness and headaches
- Water intoxication
    - Water intake exceeds water loss
    - Body fluids becomes too diluted
    - Drop in ion or electrolyte concentration in bodily fluids
    - Symptoms: light headedness, headache, vomiting, collapse

Diuretics:

- Opposite of anti-diuretics
- Causes increased urine production/volume
- Decreases permeability of distal convoluted tubule and collecting ducts, so less water is reabsorbed into the blood plasma
- More water is lost in urine
- Includes:
    - Alcohol
    - Caffeine
    - Certain medications

BLOOD SUGAR

- Cells require a supply of glucose from the blood for all cell activities, e.g. movement, active transport, reproduction, synthesis of other molecules, reproductions, etc.
- Glucose is obtained from the food we eat; glucose concentrations rise sharply after a meal
- Homeostatic mechanisms work to keep these concentrations stable
- Excess glucose is stored for later as glycogen (long chain made up of glucose molecules) mainly in the liver and muscle cells
- The pancreas and adrenal glands secrete hormones that affect glucose concentrations in the blood

Role of the liver

- Glucose is transported from the small intestines after a meal to the liver via the Hepatic Portal Vein.
- Converts glucose into glycogen for storage
- Removes glucose for its own liver functions
- Can allow the glucose in the blood to continue circulating for the rest of the body cells can access it for energy
- Can also convert glucose into fat for long term storage
- Converts glycogen back into glucose for release into the blood

Glycogenesis

- Process of converting glucose into glycogen
- Stimulated by insulin from the pancreas
- Occurs when blood glucose is higher than normal, such as after eating
- In this form it is not useful for cells, and must be converted back
- Glycogen in muscle cells provides stored energy for muscles

Glycogenolysis

- Process of converting glycogen back into glucose
- Stimulated by glucagon from the pancreas
- Occurs when blood glucose is lower than normal, such as during exercise and between meals
- Used for short term energy storage (up to six hours)
- If more energy is needed, energy from fat stores are used

Role of the Pancreas

Islets of Langerhans:

- Alpha cells: secretes glucagon
  - Glucagon increases blood sugar levels
  - Stimulates glycogenolysis
  - Stimulates gluconeogenesis, where the liver to produce new sugars from fats and amino acids
- Beta cells: secretes insulin
  - Insulin decreases blood sugar levels
  - Accelerates the transport of glucose from the blood to the cells
  - Accelerates glycogenesis
  - Stimulates conversion of glucose into fat in adipose tissues
  - Causes an increase in protein synthesis
- Chemical detectors in the alpha and beta cells stimulate the production of either insulin or glucagon

Role of the Adrenal Glands

- Stimulated by adrenocorticotrophic hormone from anterior pituitary
- Glucocorticoids (cortisols) from the adrenal cortex
  - Regulates carbohydrate metabolism to ensure sufficient energy is provided to cells
  - Stimulates glycogenolysis
  - Mobilises fatty acids from adipose tissue
  - Increases the rate at which amino acids are removed from cells and transported to the liver for gluconeogenesis if glycogen and fat stores are low
  - Increases blood glucose levels
- Adrenaline and noradrenaline from the adrenal medulla
  - Affects the sympathetic nervous system

- Stimulates production of lactic acid from glycogen in muscles
- This lactic acid is then converted by the liver via gluconeogenesis into glucose
- This increases the blood glucose levels, and counteracts the effects of insulin

GAS CONCENTRATIONS

Cellular Respiration

- We need to continually supply our cells with oxygen and remove the carbon dioxide
- During exercise, the body needs to provide more oxygen and remove more carbon dioxide

Control of Breathing

- Breathing can be voluntary or involuntary
- Two control centres in the brain stems
  - Medulla oblongata (respiratory centre)
  - Pons (pneumotaxic centre)
- Nerve impulses from spinal nerves activate respiratory muscles:
  - Diaphragm (stimulated by the phrenic nerve)
  - Intercostal muscles (internal and external) (stimulated by the intercostal nerves)

Regulation by O_2

Oxygen concentration

- Concentration changes are detected by chemoreceptors in:
  - The walls of the aorta and carotid arteries (peripheral)
  - The medulla oblongata (central)
- Only acts as stimulus if oxygen levels are very low.
- As O_2 is consumed by the cells, the concentration in the blood falls. If concentration of O_2 falls below normal while other factors remain constant then the breathing rate may increase

Regulation by CO_2

Carbon dioxide concentration

- Concentration changes detected by chemoreceptors in the medulla oblongata (most sensitive)
- Major factor in regulating breathing rate
- Concentration of CO_2 levels is associated with concentration of hydrogen ions.

$$\mathbf{CO_2 + H_2O <-> H_2CO_3 <-> H^+ + HCO_3^-}$$

- This response takes several minutes

Regulation by H^+

Hydrogen ion concentration

- Increase in H^+ causes a decrease in pH causes an increase in breathing rate
- Changes detected by chemoreceptors in the aortic and carotid bodies
- Response is immediate

Expiration

- Stretch receptors in the walls of the lungs are stimulated during inspiration
- These send messages to the pons (pneumotaxic centre), which inhibits the respiratory centre of the medulla oblongata
- Expiration occurs, preventing the overstretching of the lungs.

Voluntary control

- Humans can voluntarily control their rate and depth of breathing
- Important for speech
- Protective device preventing irritating gas or water entering lungs
- Allows us to play instruments, blow up balloons etc.
- Control is by cerebral cortex and bypasses respiratory centre in medulla
- Build up of CO_2 will eventually overcome voluntary control and force you to breathe.

Hyperventilation

- Extremely rapid, deep breathing
- Provides more O_2 and removes more CO_2 than necessary
- May be voluntary or caused by physical pain or emotional stress
- Causes dizziness and fainting
- Usually corrects itself as breathing is not stimulated until CO_2 returns to normal
  Dangers:
  - Allows a person to hold their breath longer as the stimulus to breathe is delayed
  - It is very dangerous as the person could lose consciousness due to loss of oxygen before they feel the urge to breathe
  - Many downing deaths have been attributed to hyperventilation

Effects of Exercise:

- Increased muscle activities causes an increase in production of carbon dioxide and a greater requirement of oxygen
- Chemoreceptors in the aorta, carotid, and hypothalamus detect changes in concentrations of oxygen, carbon dioxide, and hydrogen ions in the blood plasma, and send signals to the respiratory centre in the medulla oblongata.
- The medulla oblongata sends signals through the phrenic and intercostal nerves to the diaphragm and intercostal muscles to initiate breathing, causing an increase in breathing rate, increasing the supply of oxygen and the rate of removal of carbon dioxide
- Stretch receptors in the walls of the lungs prevent overstretching of the lungs, sending signals to the pneumotaxic centre in the pons to initiate expiration.

HEART FUNCTION

- Heart rate
  - The number of time the heart beats per minute
- Stroke volume
  - The volume of blood forced from the heart with each beat
  - Factors affecting stroke volume:
    - Length of diastole
    - Venous return – return of blood to the heart. The greater the volume of the venous return, the greater the stroke volume and the stronger the strength of the contraction
    - Autonomic NS (sympathetic increases SV)
- Cardiac output
  - Amount of blood leaving the heart every minute
  - HR X SV
- Blood pressure
  - Force with which blood presses on the walls of the blood vessels.

- Arteries have higher BP than veins, because they carry blood directly away from the heart, whereas veins carry blood towards it.
- Depends on:
  - Cardiac output: high CO = high BP
  - Diameter of blood vessels: constricted BVs = high BP
  - Blood volume: high blood volume = high BP
  - Any increase in HR and force of contraction = increase in BP
  - Viscosity of the blood: high viscosity = high BP
  - Condition of the blood vessels: high resistance = high BP – e.g. arteriosclerosis (build up of plaque inside the blood vessels)
- Recorded as two numbers in mmHg
- Normal adult BP =
  120 – Systolic (pumping)
  80 – Diastolic (filling/relaxing)
- High BP = hypertension
- Low BP = hypotension

Regulation

- The heart contains specialised conductive tissue, which initiates and regulates the heartbeat
- The sinoatrial node is a cluster of specialised cardiac cells located in the wall of the right atrium – this initiates the heart beat
- The atrioventricular node, situated in the wall between the two atria near the AV valves – is the secondary pacemaker which regulates the beating of the ventricles
- The SA node is capable of initiating the heart beat on its own, but is influenced by the autonomic nervous system
- Changes in blood pressure are detected by pressoreceptors (baroreceptors) located in the aorta and carotid artery
- Messages are sent to the cardiovascular regulating centre (cardiac centre) in the medulla oblongata

Role of the Autonomic Nervous System

- Impulses are sent from the medulla oblongata to the SA node, AV node, and cardiac muscles

Sympathetic:

- Releases noradrenaline
- Increases heart rate and stroke volume
- Dominant during exercise

Parasympathetic:

- Releases acetylcholine
- Decreases heart rate and stroke volume (rate and force of contraction)
- Dominant at rest

Other factors:

- Age: fastest at birth, adult averages 70-80 bpm, slows in old age
- Sex: males slower HR than females
- Emotional state:
  - Anger, fear, anxiety, excitement increases HR
  - Depression, grief decreases heart rate
- Drugs
  - Caffeine and other stimulants

Effect of Exercise

- During exercise cardiac output can increases from 5L/min to 30 L/min
- Supplies muscles with oxygen and nutrients
- Removes wastes CO_2 and heat
- Vasodilation/vasoconstriction to direct blood to muscles and away from other organs, e.g. the digestive system.
- Wastes CO_2 and lactic acid act as vasodilators to increase blood flow to muscles
- Heat produced by cellular respiration increases blood temperature which increases heart rate
- Before exercise there is an anticipatory response brought about by the ANS and adrenaline which increases heart rate, stroke volume, and blood flow to skeletal muscles.

DISRUPTIONS TO HOMEOSTASIS

Diabetes:

- Diabetes mellitus
- Hormone disruption to blood sugar homeostasis
- Causes hyperglycaemia, or abnormally high blood glucose levels
- Diabetics either do not produce enough insulin, or their cells have abnormal resistance to the hormone
- Excess glucose is often secreted in urine/other body fluids

Type I Diabetes

- Insulin-dependent diabetes
- Begins in early childhood (juvenile diabetes)
- Caused by a fault in the immune system
- Beta cells in the Islets of Langerhans are destroyed
- Beta cells produce insulin, so when these are destroyed, the person can no longer produce insulin
- Cells are usually still receptive to the hormone, so it can be managed by providing regular injections of insulin
- No cure currently
- Even with treatment, sufferers are still at higher risk for other issues:
    - Kidney failure
    - Heart attack
    - Stroke
    - Amputations
    - Blindness
    - Nerve damage

Type II Diabetes

- Non-insulin-dependent diabetes
- Begins in adulthood, usually over the age of 45 (adult-onset diabetes)
- Caused by cells becoming non responsive to insulin
- Type II diabetics can still produce insulin
- Common in non-active/unhealthy/overweight individuals. Risk factors:
    - Lack of physical activity
    - Being overweight or obese
    - High fat, sugar, sodium, and low fibre diet
    - High blood pressure
    - High cholesterol
    - Smoking

- No cure
- Early diagnosis is important for managing it
    - Management to keep blood glucose within a normal range
    - Strict and careful diet
    - Regular exercise
    - Maintaining a healthy weight
    - Monitoring of blood glucose
    - Sometimes medications as a final measure
- Complications:
    - Kidney failure
    - Heart disease
    - Stroke
    - Eye problems
    - Nerve damage
    - Skin and foot problems, e.g. gangrene

Thyroid Problems:

- Over or under secretion of thyroid hormones
- Thyroid secretes thyroxine
- This effects nearly every tissue in the body
- Important in maintaining basal metabolic rate, and long term metabolism, such as from summer to winter
- Also important in the homeostasis of body temperature
- Triggered by thyroid stimulating hormone, secreted from the anterior pituitary, which itself is signalled by the hypothalamus
    - Over or under active thyroids are often linked with an imbalance in thyroid stimulating hormone

Hyperthyroidism (Grave's Disease)

- Excess of thyroxine
- Enlargement of the thyroid
- Causes:
    - Immune response
    - Genetic predisposition
- Symptoms:
    - Weight loss
    - Rapid heart beat
    - Increased fatigue
    - Sweating
    - Anxiety
    - Increased appetite
    - Protruding eyeballs (exophthalmia)
- Treatment:
    - Surgery to remove a part of the gland
    - Drugs to block iodine use
    - Radioactive iodine to kill thyroid cells

Hypothyroidism

- Deficiency of thyroxine
- More common that hyperthyroidism

- Causes:
  - Lack of iodine
  - Autoimmune disease (Hashimoto's disease)
  - Issues with the pituitary gland or hypothalamus, which regulate thyroid function
- Symptoms:
  - Slow heart rate
  - Unexpected weight gain
  - Fatigue
  - Intolerance to cold
  - Swelling of the face and goitre (enlarged thyroid)
- Treatment:
  - Iodine supplements
  - Thyroid stimulating hormone tablets
  - Removal of part of the enlarged gland
- Hypothyroidism in infants
  - Iodine deficiencies in a pregnant mother's diet can affect the development of the infant
  - Causes cretinism, the retardation of mental and physical growth, with impaired movement or hearing

Growth retardation or dwarfism

- Can be caused by lack of human growth hormone from the anterior pituitary gland
- Severe cases of growth retardation in children can be treated with injections of the hormone
- Used to be made by extracting the hormone from the pituitaries of deceased individuals
- Now made by genetically engineered E. coli using recombinant DNA

Behavioural Disruptions to Homeostasis

Drugs:

- Abuse of medications or use of non-medicinal drugs may disrupt homeostasis
- Drug molecules may be similar to some neurotransmitters, and bind to receptors and other cells, blocking or slowing down certain nerve transmissions

Excessive activity:

- Often linked to anorexia, bulimia, and excessive exercise
- Extreme consumption of energy with insufficient replenishment
- Causes damage to bones, cartilage, muscles, joints, etc.
- In extreme cases, if nutrition is inadequate, the body may begin to break down muscle cells for energy, causing muscle to degrade and lose mass

Eating habits and disorders:

- Inadequate levels of certain nutrients, vitamins, and minerals can lead to deficiency diseases
- Anaemia
  - Caused by inadequate iron in diet
  - Causes a deficiency in haemoglobin, the oxygen carrying protein in red blood cells
  - Slows the supply of oxygen to cells, and thus slowing cellular respiration and energy production
  - Causes fatigue, shortness of breath, and high heart rate
  - Pernicious anaemia caused by lack of vitamin B12
- Energy in = energy expended

IMMUNITY

Pathogens

- Bacteria:
  - Most bacteria are harmless
  - Some bacteria are pathogenic, and can cause diseases and illnesses
  - Reproduces by fission
  - Living organism; can reproduce on its own
  - Usually treatable with antibiotics
- Viruses:
  - Can also cause diseases and illnesses
  - Viruses have distinctive structures and sizes
  - Not a living organism; require a host
  - Contain either DNA or RNA but not both
  - Genetic material is surrounded by a protein layer
  - Genetic material is used to make new copies of itself which can infect other cells
  - Bacteriophages are viruses that multiply in bacteria
  - Not all viruses are harmful
  - Antibiotics do not work; antivirals are needed for treatment
- Fungi and parasites

Transmission of Pathogens:

- Contact
  - Direct physical contact with an infected individual
  - Indirect contact with an object an infected individual touched
- Bodily fluids
  - Blood or other body fluids coming into contact with mucous membranes (nose, mouth, throat, genitals)
  - Bodily fluids entering the bloodstream, via a needle or a break in the skin
- Droplets
  - Droplets of moisture that harbour pathogens are emitted when breathing, sneezing, coughing, or talking
  - Droplets can be breathed in by others, or ingested when droplets settle on utensils or food
- Ingestion
  - Food or drink may contain pathogens that will infect an individual when ingested
- Airborne transmission
  - Some viruses and bacteria can still remain viable even when the moisture or droplets in which they were emitted evaporates
  - These can then be inhaled and cause infection
- Vector transmission
  - The transfer of pathogens via other animals or organisms, such as insects, ticks, and mosquitoes
  - Some vectors transfer pathogens directly
  - Some transfer pathogens indirectly, such as to food or water, which is then ingested
  - Some pathogens have specific vectors, e.g. malaria is carried by mosquitos
- Zoonotic
  - Infections that can be passed from animals to humans
  - Can be caused by viruses, bacteria, parasites, and fungi

NON SPECIFIC IMMUNITY

- Work against all pathogens
- The body's first line of defence

External defences

- Skin
  - Sebum – produced by oil glands in the skin, kills some pathogenic bacteria
  - Sweat – contains salts and fatty acids that prevent the growth of some bacteria
- Mucous membranes
  - Line body cavities that open to the outside
  - Mucous inhibits entry of microorganisms
  - Line the digestive and urinary tracks
- Hairs
  - Found in the nose cavity and ears
  - Working with a layer of mucous, the hairs help to trap up to 90% of particles inhaled
- Cilia
  - Tiny hair-like projections from cells
  - Mucous membranes in the nose, trachea, and other air passages contain cilia
  - Cilia move mucous up to the throat to be coughed out or swallowed
- Acids
  - Stomach acid helps to kill microorganisms and bacteria
  - Sweat and the vagina are also slightly acidic to stop bacteria
- Lysozyme
  - An enzyme that kills bacteria
  - Found in tears, saliva, sweat, secretions from the nose, tissue fluid, earwax, etc.
- Cerumen (ear wax)
  - Protects the outer ear against infection from some bacteria
  - Is slightly acidic and contains lysozyme
- Flushing action
  - Keeps some areas relatively free of pathogens
    e.g. urine through the urethra, tears, sweat, and saliva

Protective Reflexes

- Sneezing
  - Stimulated by irritation of the walls of the nasal cavity
  - Forceful expulsion of the air expels mucous, foreign particles, and irritating gases from the nose and mouth
- Coughing
  - Caused by irritation in the lower respiratory track
  - Forces air from the lungs to expel mucous, foreign particles, and irritants from the respiratory system to the mouth
- Vomiting
  - Stimulated by over stretching of the stomach, bacterial toxins, and psychological stimuli
  - Contraction of the muscles of the abdomen and diaphragm expel the contents of the stomach
- Diarrhoea
  - Caused by irritation of the small and large intestines by bacteria, viruses, or protozoans
  - Irritation causes an increase in the contractions of walls of the intestines to move its contents containing the irritants as quickly as possible

- This means it does not stay in the intestines long enough for water to be absorbed, so faeces end up being very watery

Internal non-specific defences

Phagocytes

- Cells that can engulf and digest microorganisms and cell debris
- Leucocytes
  - White blood cells
  - Able to leave blood vessels and travel to tissues
  - Some secrete a substance to kill the bacteria before engulfing them, while some engulf and then digest them
- Macrophages
  - Large phagocytic cells
  - Some develop from leucocytes
  - Some are wandering cells that move through tissues looking for pathogens to destroy
  - Some are localised and only deal with pathogens in that area
  - Some also secrete substances to kill bacteria, or engulf and digest them

Inflammatory Response

1. Damage occurs (i.e. a sharp object penetrating the skin), introducing pathogens/bacteria into the body
2. Mast cells (cells present in most tissues) are stimulated/triggered to release histamine, heparin, and other substances into the tissue fluid.
3. Histamine increases blood flow to the area and permeability of vessels (to increase in fluid escaping from blood vessels). This results in redness, heat, and swelling.
4. Heparin prevents blood clotting in the immediate area; a clot of fluid forms instead, which slows pathogen spread.
5. Phagocytes are attracted to the area by chemicals released by mast cells from the surrounding tissue or from the increased blood flow. Phagocytes engulf and kill microorganisms and remove cell debris (phagocytosis).
6. Pain receptors are stimulated due to the changes and abnormal condition of the tissue. All the extra fluid and cells in the area stimulate the receptors.
7. Pus forms from dead cells and tissue when 'full' phagocytes die.
8. Repair of the area begins once the area as been cleared of pathogens. Mitosis creates new cells.

Signs of Inflammation

- Redness and heat
- Swelling
- Soreness/pain

Fever

- Sometimes due to a cold or influenza, an individual can have a raise in their body temperature
- This is because our body's thermostat has been reset to a higher level (hypothalamus)
- This resetting is thought to be due to substances called pyrogens, which are released by WBC's during inflammatory response and act directly on the hypothalamus (autonomic control).
- Due to reset, the body originally feels cold, resulting shivering and vasoconstriction. These mechanisms/homeostasis increase heat production, causing the body temperature to increase.

- The fever 'breaks' as the reset thermostat is at normal, however, due to the increase body temperature, one would feel hot, leading to vasodilation (flushing) and sweating, which decreases the body temperature.
- High body temperature can inhibit the growth of some bacteria and viruses, as well as increasing the rate of some chemical reactions
- However, if the body temperature exceeds 44.5°C, death occurs
- Fevers usually last between 1 and 3 days

Lymphatic System

- Main function is to collect excess fluid, but also has a role in non-specific and specific immunity.
- Made up of lymph vessels, lymph capillaries, and lymph nodes.
- Lymph nodes
  - Become swollen, usually with white blood cells, when there is an infection/illness
  - Acts as a spider web or filter, picking up bacteria, microorganisms, and other cell debris.
  - Contains a framework of lymphoid tissue, as well as macrophages and lymphocytes, which destroy foreign material by phagocytosis.

SPECIFIC RESISTANCE

- Specific defence targeted towards a particular pathogen
- Part of the immune system

Lymphocytes & Macrophages

- Both a type of white blood cell
- Both involved in both specific and non-specific defences
- Lymphocytes
  - Produced in the bone marrow
  - B cells mature in the bone marrow
    ➔ B cells create antibodies
  - T cells mature in the thymus
  - Are mobile and always in circulation in the blood plasma or lymphatic system
- Macrophages
  - Large phagocytic cell – they can engulf or consume pathogens and foreign material
  - Work to alert the immune system to foreign material and antigens in specific defence

Antigens

- A substance capable of triggering an immune response
- Triggers both antibody and cell mediated responses
- Causes the creation of antibodies
- Can be but are not necessarily living organisms or associated with living organisms
- The body produces self-antigens, which the immune system learns to recognise, and thus does not react to
- Foreign compounds that do trigger a response are non-self-antigens

Antibodies

- Specialised proteins produced to deal with specific antigens
- Immunoglobulins
- The active sites on antibodies are complementary with that on their corresponding antigens
- Form antigen-antibody complex

Antibody Mediated Response

- Antibody or humoral immune response involves the release of antibodies into the blood and lymph
- Provides resistance against extracellular pathogens before they can enter the body's cells
- First exposure to an antigen or pathogen is the primary response
    - Slow response, as it takes time to identify it and produce large amounts of the antibody
    - Leaves the immune system with a memory of the response
- Subsequent exposures are secondary responses
    - This are much more rapid due to memory cells
    - The body can produce more of the antigen at a faster rate

1. Antigen (usually extracellular) present
2. B cells are stimulated → multiply via mitosis creating clones
3. Most clones become plasma cells, which create antibodies, and the others create memory cells
4. Memory cells recognise the antigen and bring about a faster immune response subsequent to exposure
5. Antibodies attach onto antigens and create antigen-antibody complex
    - Agglutination
        - They immobilise antigens by making them stick together
        - Makes it easier for phagocytes to consume them
    - Phagocytosis
        - They coat the antigen (usually bacteria) so it is more easily consumed and destroyed by macrophages
        - They can also react with soluble substances to make them insoluble and more easily consumed by macrophages
    - Dissolves
    - Inactivate
        - Combines with toxic compounds or foreign enzymes, inhibiting their reaction with other cells or compounds
        - Leads to the breakdown of the cell or compound
    - Binds to the surface
        - Binds to viruses to prevent them from entering cells
        - Also makes it easier to be destroyed by macrophages

Cell Mediated Response

- Involves T lymphocytes (lymphoid tissues)
- Provides resistance to intracellular viruses, bacteria, fungi, and parasites
- Involved in autoimmune disease, rejection of transplants, and fighting cancer cells
- Different T cells respond to particular antigens (specific)

1. Antigen is present (intracellular)
2. Antigen is displayed on the surface of the cell, or by a macrophage, or a B-cell
3. T cells are stimulated → multiply via mitosis creating clones
4. Differentiates into:
    a. <u>Helper T cells</u>
        - Help to stimulate more T and B cells to fight the antigen
        - Secrete cytokines to attract more macrophages
    b. <u>Killer T cells</u>
        - Migrate to site of infection
        - Attach to and <u>secretes</u> a substance to destroy antigens

c. Suppressor T cells
  - Inhibits B and T cells after antigen has been eliminated

d. Memory cells
  - Recognises antigen for a more rapid response

HIV/AIDS

- Human Immunodeficiency Virus
- Infects helper T cells and macrophages
- Changes its protein coat (antigen) from one generation to the next; hard to detect and fight
- Leads to Acquired Immune Deficiency Syndrome

IMMUNITY

- Resistance to infection by invading microorganisms/pathogens
- Uses non specific and specific defences to prevent infection by pathogens or microorganisms
- Natural immunity
  - Occurs without human intervention
- Artificial immunity
  - People giving others an antibody or antigen
- Passive immunity
  - When a person is given antibodies produced by someone else.
  - Can be natural, e.g. mother to baby via the placenta
  - Can be artificial, e.g. vaccine/shot to immediately introduce antibodies
  - Is short lived; the antibodies will eventually degrade and no more are produced
- Active immunity
  - When a person is exposed to a foreign antigen and their immune system manufactures its own antibodies
  - Can also be natural, e.g. catching a disease and developing an immune response
  - Can also be artificial, e.g. receiving an injection with antigens related to a disease, and developing an immune response
  - Lasts longer, often for years, because the immune system develops a 'memory' of the antigen and its reaction to it

Vaccines

- Immunisation is programming the immune system to respond rapidly to infecting pathogens
- Can occur naturally or artificially
- Vaccination
  - The artificial introduction of antigens of pathogens to trigger an active immune response by the immune system
  - B-cells will produce antibodies, and memory cells to recognise the antigen in the future
  - Does not actually infect the person
- Attenuated vaccines
  - Contains living microorganisms of reduced virulence
  - Reduces the pathogens ability to produce symptoms
  - Virulence can be released by physical means, e.g. keeping microorganisms in an environment hotter than normal
  - Virulence can also be altered by using recombinant DNA technology, changing the DNA to render the pathogen completely harmless
- Dead microorganism
  - Not usually prolonged

- Toxoids
    - Contains filtrates of bacterial cultures containing toxins
    - Toxins are inactivated before being introduced as a vaccine
- Sub-unit vaccine
    - Uses a part or fragment of the microorganism to provoke an immune response
    - Are very effective
    - Can have side effects, e.g. damaging the immune system, or being ineffective over long periods of time
- Vaccine delivery
    - Usually via injection
    - Oral ingestion
    - Nasal spray
    - Skin patches
    - GM crops

Herd immunity

- Occurs when a large proportion of a community are immunised
- Protects those who are not/cannot be immunised
- When there is a large number of immunised individuals in a population, there is a lower chance that the pathogen will be spread

Risks

- Allergic reaction to the vaccine medium
- Cross species disease introduction
- Concern about use of certain chemicals and preservatives and their effects on the body
- Longevity of protection
- Side effects

Ethical concerns

- Treatment and use of animal and human tissue during testing and manufacture
    - e.g. Rubella vaccine uses cells from aborted human foetuses
- Animal testing
- Age appropriate
- Testing on at risk populations in developing countries
    - They may not be aware of all of the risks and potential consequences of trialling an experimental vaccine

ANTIBIOTICS

- Chemicals that can inhibit the growth of or kill microorganisms, particularly bacteria and fungi
- Must be toxic to microorganism but not the patient
- Each antibiotic has a specific action, e.g.:
    - Preventing synthesis
    - Affects bacterial ribosomes
    - Disrupts cell walls of fungi

Types of antibiotics

- Bactericidal – kills bacteria by changing the structure of the cell wall/membrane, or by disrupting the action of important enzymes
- Bacteriostatic – stops bacteria from reproducing by disrupting protein synthesis

Prescriptions:

- Broad spectrum: can act on a wide range of bacteria
- Narrow spectrum: only effective against specific types of bacteria

Antibiotic use:

- Have had a dramatic impact on human health
- Microorganisms can become resistant to the drug (natural selection)
- Worsened by incorrect prescriptions and overuse of antibiotics

Antibiotic Resistance:

- Through natural selection, bacteria gradually develop a resistance to an antibiotic
- Multiple-drug-resistant strains are resistant to most antibiotics, also called 'super-bugs'
- Total-drug-resistance

ANTIVIRALS

- Antivirals are used against viruses
- They are specific to the virus
- Do not destroy the virus, but inhibits or suppresses the life cycle
    - Blocks the entry of viral DNA/RNA into host cell
    - Interferes with reverse transcriptase enzyme needed to transcribe viral RNA to DNA
    - Prevents the release of virus from host cell
- Viruses duplicate by 'hijacking' host cells, so it is difficult to find a drug that interferes with the virus without also be toxic to the host cells

INVESTIGATING SCIENTIFICALLY

INVESTIGATING

- Variables:
  - Independent: what changes/is being changed
  - Dependent: what is being measured (units)
  - Controlled: variables that are the same between the groups
- Groups:
  - Experimental: the group(s) tested with the independent variable
  - Control: the group tested under regular conditions to compare against
  - Increases validity
- Placebo:
  - Inactive substance
  - Used on control group
  - Reduce or cancel out any psychological effects
- Blind test:
  - When the subjects do not know which one they are receiving
  - Increases reliability
- Double blind test
  - When both the subjects and the scientists do not know who is taking which
  - Increases reliability
- Sample size
- Repetition
- Bias
  - Manipulation of controlled variables to achieve desired results
- Ethics
  - Written or informed consent
  - Risks of harm; anyone participating need to know all of the risks and side effects
  - Voluntary participation
  - Confidentiality
- Studies
  - Longitudinal
    Studies performed over a long period of time.
  - Case
    In depth study of a particular person or situation.

CHAPTER 12
MUTATIONS

Terminology

- Population: a group of organisms of the same species at a particular place at a particular time.
- Gene pool: the total of all alleles in a population.
- Allele frequency: how often an allele occurs in a population

MUTATIONS

- A permanent, random change in DNA leading to new characteristics
- Mutant: an organisms that has a mutation
- Mutagen: a factor that causes mutations
    - Radiation, including X-rays, UV light, cosmic rays, and waste or fallout from nuclear events
    - Mustard gas, formaldehyde, sulphur dioxide, some antibiotics
- Most mutations are small ansd harmless
- Others that do have noticeable effects are usually disadvantageous
- Can produce advantageous traits
- They are usually recessive, meaning both parents must have the mutation/changed gene or allele for the offspring to inherit it.

Somatic & Germline Mutations

- Somatic mutations: occurs in the body cells
    - Passes on mutation to daughter cells
    - Is not passed on to offspring; the mutation dies when the individual dies
    - Can be caused by mutagens
      e.g. cancers
- Germline mutations: occurs in the reproductive cells
    - Does not usually affect the individual in whom the mutation occurs
    - The individual passes on the mutation to their offspring
      e.g. PKU

Lethal Recessive

- Most gene mutations are recessive
    - Prevents the gene from producing a protein that will able to function in the body
    - Must have both recessive alleles to have the trait
- Some recessive mutations are lethal
    - Cause death of the embryo or foetus (self-abortion), or cause early death of the child (usually before the age of 5)
    - Prevents the gene from being passed on

Gene mutation:

- Changes in a single gene
- Occur during replication of DNA before cell division
- Then passes on the mutation to other cells as it divides
- Traits produce have been either changed or destroyed

Point mutation

- Simplest type of mutation
- Involves a change in a single base pair
- Substitution – one base is swapped out for another one, but does not cause a shift

Frameshift mutation

- If a part of a base is affected, e.g. if it is deleted or another is added, is shifts the entire sequence
- Changes the composition and order of codons (groups of 3)
- This affects protein synthesis, and hence appearance, body functions, etc.
- Insertion – adding a base, causes a shift
- Deletion – removing a base, causes a shift

Chromosome mutations

- Occurs in the chromosome
- Part of the entire chromosome is affected
- Can cause loss of structure or damage to the chromosome
- Is more dangerous than gene mutations, as it affects the large number of individual genes contained in the chromosomes.
- Deletion – section has been deleted
    - Loss of a piece of chromosome due to breakage
    - Causes a lack in certain genes
    - Can be lethal
- Inversion – chromosome is flipped or switched
    - Chromosome breaks off, flips, and reattaches in reverse orientation to the same chromosome
    - Same genetic information, but the order is different
    - Can be advantageous or not depending on the genes affected
- Duplication – duplication of a section of a chromosome
    - Section of a chromosome occurs twice
    - Can be advantageous, as nothing is loss or changed
    - Not usually lethal
- Translocation – relocation of a section of a chromosome
    - Piece of chromosome breaks off and attaches to another non-homologous chromosome
    - Rearrangement of DNA
    - Can be lethal
- Non-disjunction
    - Chromosomes fail to separate during meiosis
    - Can result in either extra or a lack of chromosome in a gamete
        - Trisomy – extra chromosome
        - Monosomy – lacking one chromosome

CHAPTER 13
TECHNIQUES IN BIOTECHNOLOGY

BIOTECHNOLOGY & DNA

What is Biotechnology?

- The use of cellular processes to make products useful to humans
- Has greatly expanded the range of products and techniques to improve human life and welfare.
- This includes:
  - Treatment of disease
  - Food production
  - Clean energy
  - Increased efficiency of manufacturing processes
  - Genetic testing and gene manipulation
  - Cell replacement therapies
  - Tissue engineering

THE HUMAN GENOME PROJECT

- Human Genome Project was established in 1990
  - International research effort to map the location of all genes in all 46 chromosomes of the human genome.
  - Genome: complete set of genetic information of an organism
  - The goal of the project was achieved in 2003
  - Data is still being analysed
- Will help scientist identify the location of genes involved in diseases
  - Knowing the location of these genes allows for the use of gene replacement therapy
  - Can help to monitor gene expression for particular diseases
    e.g. monitoring of genes that turn on during different stages of cancer
- Genetic screening/profiling
  - Individuals can get information of any diseases they may be genetically predisposed to having/inheriting
  - They then can take preventative measures to reduce their risks/not pass it on to offspring.

DNA SEQUENCING

- DNA sequencing is the determination of the precise order of nucleotides in a sample of DNA.
- Can show whether a person will develop an inherited disease
- Can reveal changed alleles, as well as point mutations, and insertions and deletions.
- Examples:
  - Spastic paraplegia
  - Sickle cell anaemia
  - Cystic fibrosis
  - Some forms of cancer
- Once such diseases or mutations have been identify, people can then seek treatment
- Can also be used to identify where primers and restriction enzymes can attach

Process:

1. Required section(s) of DNA are cut using restriction enzymes
2. Heat is applied to split or denature the strands, creating two separate single strands
3. Samples of the template DNA strands are added to four separate containers
4. Primers, DNA polymerase, free nucleotide, and different modified nucleotides are added
   - » Primers are radioactive, which make the different nucleotides appear uniquely with analysis
   - » The modified nucleotides (di-deoxynucleotides/terminator nucleotides) lack a hydroxyl group (OH), which prevent the continuation of the elongation of the sequence.
   - » Are specific for each of the different nucleotides, and therefore will halt replication at the specified nucleotide.
5. This creates short sequences of DNA, which can then be analysed with gel electrophoresis

» This is an older process known as the Sanger Process
» In modern processes, the four containers are combined into one, and a fluorescent dye is added that is different for each nucleotide.

PROFILING TECHNIQUES

» DNA is unique to each individual, and thus can be used for identification
» Used in tracing ancestry and in forensic science
» Can be used to identify hereditary diseases, e.g. cystic fibrosis or Huntington's.
» These diseases can be detected at an early age, before they manifest
» People at risk of inheriting, passing on, or developing these diseases can then take preventative measures and treatments.

Gel Electrophoresis

» Technique that creates a DNA profile
» Creates a 'banded' pattern
» Machine has anode/cathode, i.e. a positively charged and a negatively charged end, through which a charge flows into the gel bed.
» Only a small fragment of DNA from a sample, cut using restriction enzymes, are used.
» STR's & VNTR's (short tandem repeats and variable number tandem repeats)
   - » These are the two different types of sequences repeated in the DNA that are completely unique between individuals.
   - » The more closely related individuals are, the more similarities there will be between the STR's and VNTR's.
   - » It are these that are isolated and analysed with gel electrophoresis
» Used to identify individuals and relationships, but not individual genes.

Steps:

» Acquire and isolate the target DNA
» Place DNA into the wells in the gel beds, usually with a coloured dye
» Apply electric current through gel bed
» DNA will move towards the positive end because DNA is negatively charged.
» Fragments will move towards the positive end at different speeds based on their size:
Small sections will move faster through the gel than larger sections of DNA.
A die is generally added so we can see the patterns forming
» A banded pattern is created, i.e. a DNA profile

POLYMERASE CHAIN REACTION

- Like a biological photocopier: it is a process that creates multiple copies of DNA from an initially small sample. Basically artificial DNA replication
- Uses:
  - Testing for diseases
  - Forensic analysis
  - Human ancestry studies ➔ amplifies DNA from fossils

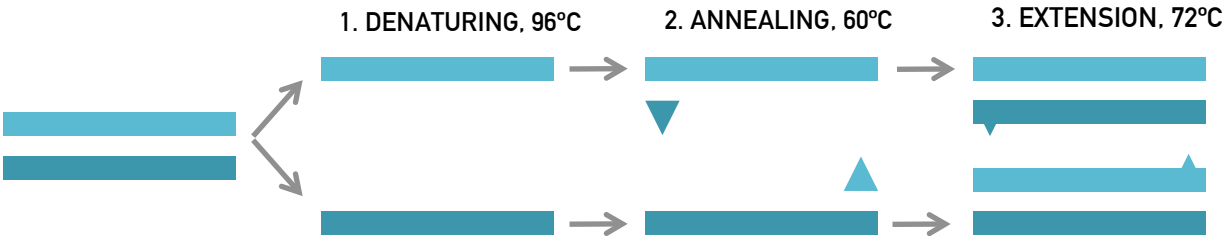
Requires:

- Thermal cycler – temperature changes during the cycle
- Polymerase enzyme that is operable at those temperatures: Taq Polymerase
- Primers – complementary to the base they are attached to
- Free nucleotides

Steps: (3 main steps)

1. Denaturing
   - Application of heat to split the two strands of DNA
   - Temperature: 96°C
2. Annealing (binding)/Hybridisation
   - Primers join on to the separated DNA strands, at opposite ends of each strand.
   - They bind onto complementary bases, which is usually only a short fragment of DNA
   - Helps the polymerase know where to start from
   - Temperature: 60°C
     Is slightly cooler than the temperature of denaturing to allow for the binding.
3. Extension/Elongation/Synthesis
   - Polymerase begins working to attach the free nucleotides to their complementary bases.
   - This creates 2 identical DNA strands based on the set AT/CG base pairing.
   - Temperature: 72°C

- Each cycle takes 3-5 minutes



RECOMBINANT DNA TECHNOLOGY

Recombinant DNA

- Used in genetic engineering.
- Made by recombining fragments of DNA from different sources, including other species.
- Used to replace faulty genes with healthy ones, or to identify mutations and hereditary diseases
- Transgenic organisms: an organism whose genome has been altered through recombinant DNA
- A genetically modified organism (GMO): an organism whose genome has been modified or altered to give it characteristics it does not normally have

Requires:

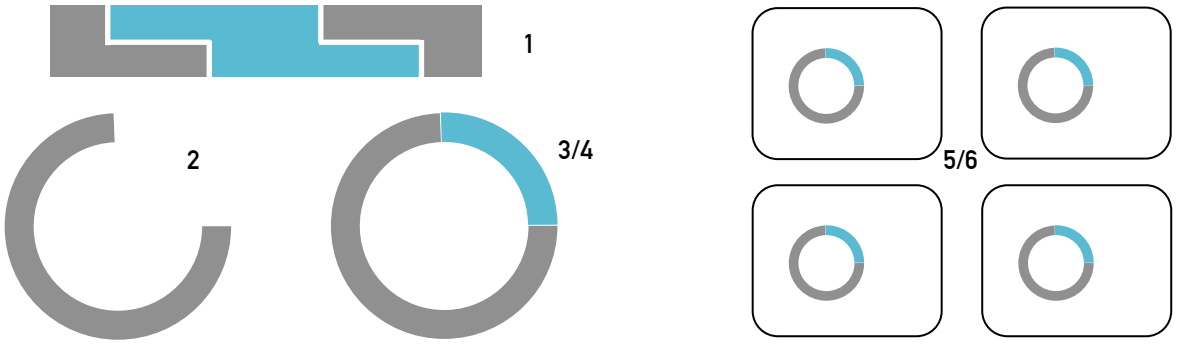
- Restriction enzymes
  - Essentially 'scissors' that cut the DNA at recognition sites

- There are hundreds of types of restriction enzymes, each of which cut different sections/sequences of DNA.
- Obtained from different bacteria
- Two types of cuts:
  - Blunt end cut – simple straight 'up and down' cut.
  - Sticky end cut – staggered cut, fits like a jigsaw.

- Ligase enzymes
  - Bind molecules together
  - They join or recombine fragments of DNA in 'ligation'
- Plasmids
  - Small, usually circular, double stranded sections of DNA found inside bacteria, yeast
  - Separate from the main chromosome
  - Self replicating
  - Used as vectors to transfer genes between organisms

Steps of RDNAT:

1. Restriction enzymes cut the specific DNA section at recognition sites that will be used. This creates sticky ends.
2. The same restriction enzymes cut the plasmid with sticky ends.
3. DNA section is inserted into plasmid.
4. DNA ligase binds the two sticky ends together, forming a recombinant plasmid.
5. Recombinant plasmid inserted back into bacteria
6. Bacteria duplicate/multiply/reproduce



Applications of Recombinant DNA Technology

- Insulin
  - Helps people who suffer from Type 1 diabetes
  - Previously obtained from pancreases of pigs and cattle, however these posed side effects as they were from another organism
  - RDNAT allowed the human gene for insulin to be inserted into bacteria
  - The bacteria became 'insulin factories', producing insulin that was safe for human use
- Human growth hormone – increased milk production in dairy cattle, increased athletic performance, decrease deterioration with aging. Has side effects for humans
  - Essential for normal growth and metabolism
  - Used for increased athletic performance
  - Used to decrease effects of aging
  - Increases milk production in dairy cattle
  - Previously obtained from the pituitaries of the deceased.
  - Now produced with modified E. coli using RDNAT

- Factor VIII
  - The lack of this leads to classic haemophilia/haemophilia A.
  - Previously obtained from donations of human plasma: this posed the risk of transmitting diseases such as HIV/AIDS
  - Now produced using recombinant DNA in mammalian cells.
- Vaccines
  - 1986 Hep. B vaccine, where Hep. B gene was inserted into the cowpox virus.
  - Influenza vaccines

GENE THERAPY

- Aims to treat or cure genetic diseases by replacing, manipulating, or supplementing faulty genes.
- Focuses on single gene disorders, e.g. cystic fibrosis, Huntington's disease muscular dystrophy, sickle cell anaemia
- Still in research stages.
- Has come about due to the success of the Human Genome Project

Cystic fibrosis

- Genetic condition caused by a recessive gene that controls the flow of salts in and out of cells
- Can lead to infections and blockages of mucous in organs such as the lungs and pancreas, which can cause irreversible and sometimes fatal damage.
- Gene can be corrected by adding normal copies of the gene (in culture)
- Modified the common cold virus by recombinant DNA technology as a vector
- Can be administered via nose drops, drizzling cells down flexible tubes into lungs, and aerosol sprays

Huntington's disease

- Genetic condition caused by a dominant gene
- Symptoms do not develop before 40 years of age
- Causes a degeneration of nerve cells, leading to loss control of limbs and dementia
- Researches have been able to modify a virus to deliver a gene to protect against the effects of the defective gene in mice and primates.
- Has not been conclusively tested on humans yet.

Genetic counselling

- Provided to couples who are at risk of having children affected by an inherited disease
- Study of family trees
- Genetic testing
- Risk of disease is determined

CELL REPLACEMENT THERAPY & TISSUE ENGINEERING

Stem Cells

- Totipotent
  - Can become any type of cell, including embryonic membranes
  - Found in the zygote/morula
- Pluripotent
  - Can become any body cell, not including embryonic cells
  - Found in the inner cell of the blastocyst (5-day old embryo)
- Multipotent
  - Are specialised and can only differentiate into specific cells
  - Found in adult cells, as well as bone marrow, umbilical cord blood, and placenta.

Applications:

- **Tissue engineering**
- **Cell replacement therapy**
- Embryonic stem cells treated with different growth factors can be made to differentiate into any type of tissue.
- Adult stem cells can be used as they are.
- It's like gene therapy but with stem cells

Tissue regeneration/Cell replacement therapy

- Growth or regrowth of cells and organs that have been damaged due to injury or disease:
  - Spinal cord injuries
  - Alzheimer's
  - Parkinson's
  - Heart disease
  - Stroke
  - Burns (spray on skin)
  - Cancer (bone marrow)
  - Diabetes
- Use of stem cells, in particular pluripotent embryonic stem cells
- These transplanted cells grow and mend the damaged tissue
- This even extends to repairing dying neurons with healthy neuronal tissue to treat Parkinson's

Tissue Engineering

- Requires disease-free stem cells of the specific tissue type
- Cells are grown over a 3-D scaffold
  - Scaffold provides support
  - Must be biodegradable
  - Produces a full, 3-D tissue
- Cell-covered scaffold implanted into patient to continue growth
- Uses:
  - Bone
  - Skin
  - Cartilage
  - Heart valves
  - Cornea
  - Adipose tissue

Genetic Probes

- A complementary (single) strand of DNA/RNA
- Labelled with radioactive isotopes or fluorescent markers.
- Finds and binds to a target sequence
- Basically a highlighter – it highlights sections of DNA that can be used for analysis and diagnosis with gel electrophoresis

ETHICAL CONCERNS OF BIOTECHNOLOGY & GENETIC ENGINEERING

Biotechnology

Advantages	Concerns
Produces products useful to humans Improves quality of life, in particular, in agriculture/ food production and medicine Can be used to find new sources of energy Allows us to detect mutations and hereditary diseases one may develop/inherit/pass on Knowing this can allow one to take preventative measures and treatment to reduce the effects, or the risk of the disease developing. Couples can decide whether they want to have a child or not if they are at risk of inheriting a hereditary diseases	Cloning – playing God Basically the plot of Gattaca – could people in the future pick and choose traits to optimise the genetics of their child? What are people allowed to do with this information Will parents of a child who could inherit/develop a fatal hereditary disease be allowed to abort? Could this information be used by companies and recruiters during the hiring process? Could it be used by insurance companies to assess your health and the cover you will need?

Stem Cells

Advantages	Concerns
Used to treat a variety of diseases and injuries, including Parkinson's. Tissue engineering would reduce the need for donated organs, which are difficult to come by, meaning people have to wait extremely long times for life saving surgeries, and still with the risk of rejection of the donated organ.	Totipotent stem cells, which are the most useful for stem cell treatments and tissue engineering, must be obtained from zygotes. This will destroy the zygote, which can be seen as unethical because it is the destruction of a life

CHAPTER 15 & 16: EVIDENCE FOR EVOLUTION

COMPARATIVE GENETICS

AMINO ACID SEQUENCING IN PROTEINS

- Proteins are made of long sequences of amino acids
- By comparing the type and sequence of amino acids in similar proteins from different species, the degree of similarity can be established.
- Indicates an evolutionary relationship and common ancestor.
- The amino acid sequence of ubiquitous proteins are analysed, e.g. cytochrome c, haemoglobin
- Ubiquitous proteins are found in all organisms and are independent of an organism's specific function or the environment in which it lives. Therefore, such proteins carry out the same functions no matter where they are found.

DNA HYBRIDISATION

- Measures degree of genetic similarity between DNA sequences
- Heat is applied to split the two strands of DNA. Then, one half is then joined with another half from another organism to create a hybrid.
- This hybrid is then heated and attempted to be separated again.
- The energy required to separate the two halves correlates with how closely related they are:
    - The more similar they are, the more firmly they will bind, and the more energy will be required to separate them.
- Provides evidence of evolutionary relationship and common ancestors.

ENDOGENOUS RETROVIRUSES (ERV)

- Endo = inside, genous = genome: i.e. viruses that gets inside the genome
- More specifically, it is **a** viral sequence that has become a part of an organism's genome.
- Retroviruses store genetic information as RNA.
- Upon entering a cell, a retrovirus copies its RNA genome into DNA through reverse transcription,
- This DNA must then become inserted into one of the host cell's chromosomes, which then allows it to be passed on through generations.
- Provides evidence of common ancestors

MITOCHONDRIAL DNA

- Small amount of DNA is stored in the mitochondria
- Mitochondrial DNA is in the from of a small circular molecule
- Is only inherited from the mother.
- There is a high rate of mutation: the amount of mutations is proportion to the amount of time passed since the common ancestor.

COMPARATIVE ANATOMY

HOMOLOGOUS STRUCTURES

- Body parts with similar structures, or similar structures amongst different species/organisms which may have different functions.
- They are evidence for a common ancestor
- Examples:
    - Pentadactyl limbs in vertebrates
    - Muscles in the limbs, etc.

VESTIGIAL STRUCTURES & ORGANS

- Structures that no longer serve any purpose, but as these remnants are not harmful they have not been eliminated completely.
    - *Some can serve some purposes, but their role and significance are greatly reduced, and are not really necessary.
- They are reduced in size to conserve energy or may eventually disappear over time.
- Provides evidence of change over time, evolutionary relationship, and common ancestry.
- Examples:
    - Coccyx – vestigial tail
    - Vestigial muscles wiggle the ears
    - Wisdom teeth
    - Nictitating membrane
    - Mail nipples
    - Hair on the body*
    - Goosebumps - erector pili muscles at the base of hairs*
    - Pyramidalis muscle (pouch)
    - Appendix*
    - Segmentation of abdominal muscles

EMBRYOLOGY

- Developmental pathway of many vertebrate embryos are similar
- Man have features not present in adults, e.g. gills, tails
- Provides evidence of evolutionary relationship and common ancestry.
- The more similarities, the more similar they are.
- Examples:
    - Gills and gill pouches
    - Tails
    - 2-chambered heart
    - Similar brain development

FOSSILS & ARTEFACTS

Definition:

A fossil is any preserved trace left by an organism.

TYPES OF FOSSILS

- Amber fossils
  - Insect embedded in tree sap.
  - Occurs when an insect lands on a plant/tree and is covered in the sap, which then hardens.
- Index fossil
  - Widely distributed fossils, which existed only for a short time period, useful for dating rocks in which they are found
- Mould
  - A hardened impression (hollow) that has been made in sediments
  - This occurs when the remains of an organism, usually bone, is gradually buried and compressed in sediments.
  - These sediments then harden around the remains.
  - Groundwater can seep through the sedimentary rock, eroding and eventually washing away the original remains, leaving a recess in the rock where the remains used to be.
- Cast
  - Occurs when a mould fossil is filled with minerals and allowed to harden into rock.
  - This is due to minerals carried in the groundwater that slowly solidifies and fills the recess.
  - The original organic material of a specimen is replaced by minerals.
- Mineralised
  - Very similar to cast fossils
  - Minerals from groundwater fills pores in the bone or shell
  - Minerals forming the bone matrix or shell are dissolved away and replaced by minerals in the groundwater.
  - Can form endocasts
- Trace Fossil
  - Remains of the organism have been fossilised.
  - Includes fossilised footprints of animals.

CONDITIONS FOR FOSSILISATION

- Sometimes soft tissues are preserved but it is mostly hard tissues such as bones that are fossilised. Therefore, for ideal conditions of fossilisation, there will still be hard body parts present.
- Rapid burial by sediments protects the remains from scavengers and mechanical damage
- Absence of decay:
  - An alkaline environment favours the preservation of hard tissues
  - An acidic environment favours the preservation of soft tissue, as long as there is no oxygen present, e.g. a bog

THE FOSSIL RECORD

- A record of all the fossils found.
- Allows us to:
  - Give evidence for evolution
  - See the increasing complexity of organisms
  - See the similarities and common ancestry of organisms, or the 'missing links'

- Disadvantages:
    - It is still incomplete, as there are always new fossils to be found.
    - Fossilisation is rare – it is a chance occurrence that requires specific conditions.
    - Fossils are often incomplete, and thus it is hard to make accurate reconstructions.
    - Fossils must actually be accessible by us.
    - Dating fossils accurately can often be difficult.

ARTEFACTS

- Man-made items left
- Include:
    - Tools
    - Pottery
    - Artwork
    - Jewellery
    - Clothing
    - Charcoal from cooking fires

DATING TECHNIQUES

RELATIVE DATING

- Determines the age of a specimen in relation to another, i.e. whether it is older or younger.

Stratigraphy

Principal of Superposition: In mostly undisturbed sedimentary rocks and layers, the younger layers are at the top, and the older layers are at the bottom.

Index fossils: fossils of organisms that existed for only a short period of time, but were wide spread. Thus they can be used in stratigraphy to approximate the age of certain layers.

- Stratigraphy is the study of sedimentary rocks, or the study of rock layers.
- Involves matching layers that correlate or are similar
- If the sequencing of layers in different areas are similar, it is likely that they are of similar age.

Disadvantages & Limitations:

- Layers can be disturbed by geological forces and/or human/animal activities.
- Fossils/artefacts can be buried deeper than its actual layer.

Fluorine Dating

- The concentration of fluorine in an object, usually bone.
- This is because of mineral replacement, as minerals in the soil gradually replace the minerals present in the bone or the fossil.
- More fluorine = older
- Less fluorine = younger

Disadvantages:

- Fluorine levels vary from place to place and time to time.
- Thus, fluorine dating can only be used to relatively date artefacts and fossils that were found in similar locations.

ABSOLUTE DATING

- Determines the actual age of a specimen in years BP (before present).
- Includes using the decay of radioisotopes, which naturally decay into more stable elements over long periods of time.

Half-life: The amount of time it takes for half of the radioisotope to decay.

Carbon-14 Dating

- This radioisotope eventually breaks down into nitrogen.
- Half-life = 5730 years.

Disadvantages & limitations:

- Must be organic
- Can only be used up to 60 000 years [sometimes up to 70 000 years].
- Needs a minimum of 3g in the sample.
    - If there is less, accelerator mass spectrometry (AMS) can be used.

Potassium-Argon Dating

- This radioisotope breaks down over time into argon and calcium.
- Half-life = 1.3 billion years
- Often used on volcanic rocks subject to extreme temperatures.

Disadvantages & limitations:

- Can only be used on rocks.
- Must be [sometimes 100 000 years] 200 000 years or older.

Dendrochronology

- Measuring the concentric growth rings of trees:
  - 1 ring = 1 year
  - The larger the ring, the more growth occurred in that year. These are called markers.

Disadvantages & limitations

- Can only be used on trees and wood.
- Growth rings can be disrupted by fire and other damage to the tree.
- Can only be used up to ~9000 years

CHAPTER 14
EVOLUTIONARY MECHANISMS

EVOLUTION

- The gradual change in the characteristics of a species over a long period of time
- This results in the species/population becoming increasingly better adapted to their environment

NATURAL SELECTION

Variation

- The differences between individuals of a population or species, caused by:
  - Random assortment
  - Crossing over
  - Random fertilisation
  - Non-disjunction
  - Mutations

Overproduction

- More individuals are produced than can or will survive to adulthood or reproductive age

Struggle for Existence

Selective pressures:

- Individuals have to contest for resources:
  - Food and water
  - Shelter
  - Mates
- Have to deal with outside forces:
  - Physical factors: weather and climate, and UV exposure
  - Disease
  - Predators

Survival of the Fittest

- Due to selective agents or pressures, the individuals who have the traits that allow them to better survive in their environment get to live, while those with non-beneficial traits either die

Allele Carryover

- Those with the beneficial traits survive to adulthood or reproductive age, and hence get to reproduce and pass on their genes to their offspring
- Individuals with non-beneficial traits may die before reaching reproductive maturity, or do not get the opportunity to mate, as they might be weak, sickly, and undesirable, and hence do not get to pass on their genes.

Change in Gene Frequency

- Now there is a higher frequency of the genes that were beneficial to the new generation's parents, which allowed them, and hence their offspring, to survive better in their environment.

SPECIATION

Variation: see above

Isolation

- The original population is divided or separated by a barrier
  - Barriers are elements that prevent gene flow or interbreeding between populations
  - This means the genetic information between the two populations are not shared.
- Two types of barriers:
  - Geographical
    Physical barriers such as mountain ranges, rivers, valleys, oceans, lakes, etc.
  - Socio-cultural
    Social barriers such as language, culture or society, religion, and even class and race.
- The environments affecting the two populations are often different

Natural Selection

- Various selective pressures act upon the now two separate populations
  - They can affect the populations differently based on geographical location, and even the populations' abilities to deal with elements in the environment through technology, etc.
- Through natural selection, only those who are best fitted to survive in the respective environments survive to pass their genes to the next generations within each population.
- This changes the gene frequencies in the populations
- This leads to the creation of subspecies over time

Subspecies

- Over time, these changes amount to the formation of a new subspecies

Speciation

- Over an even greater period of time, the differences between the populations increase
- Changes in gene frequency and genetic make-up can differ so greatly the two populations would no longer be bale to interbreed to produce fertile offspring.
- This indicates that there has been a formation of a new species.

RANDOM GENETIC DRIFT

- Any random, non-directional event that affects the gene frequency of a population, especially in small and isolated populations.

THE FOUNDER EFFECT

- The founder effect is when one small group of an original population migrate to a new isolated area, taking with them only a small portion of their alleles and gene frequency.
- This leads to a new and unique gene pool that is exclusively descended from the original individuals who migrated to the area
- This causes a decrease in genetic variation within the population due to inbreeding and can hence see a rise in recessive or non-adaptive traits.

HETEROZYGOUS ADVANTAGE

- When those carrying both forms of a gene or allele have a greater chance of surviving than those that are heterozygous for either allele.

EXPAMPLES OF EVOLUTIONARY MECHANISMS:

GENETIC DISEASES

Sickle Cell Anaemia

- Substitution gene mutation
- Affects a protein involved in the production of haemoglobin
- Causes RBC's to be misshapen, having a 'sickle' shape instead of a donut shape
    - This reduces the oxygen carrying capacity of RBC's
    - Can be fatal
- Codominant
- Is quite rare in most parts of the world, except for equatorial regions with a high prevalence of malaria, such as in Africa and South Asia
    - SCA provides a level of immunity against malaria
      Malaria virus cannot cling to the misshapen RBC's
- Heterozygous advantage:
    - BB = homozygous normal RBC's
      Healthy oxygen supply, but no immunity against malaria
      Normal areas = alive
      Malaria risk areas = dead b/c of malaria
    - SS = homozygous SCA
      Unhealthy oxygen supply, with immunity against malaria
      Normal areas = dead
      Malaria risk areas = still dead, but not b/c of malaria
    - **BS = heterozygous some normal RBC's, some SC RBC's**
      Moderately healthy oxygen supply, some immunity against malaria
      Normal areas = alive
      Malaria risk areas = alive

Tay-Sachs

- Causes build up of fatty tissues around the nervous system
- Lethal recessive
    - Usually causes death before the age of five
- Worldwide low frequency except in one part of the world:

Ashkenazi Jewish population

- Small population
- Reproductively isolated
- Live in overcrowded ghettos
    - Causes the rapid spread of diseases throughout the population:
      Tuberculosis
      ➔ Highly contagious bacterial disease that affects the lungs
- Tay-Sachs may provide some resistance against tuberculosis
    - Individuals who are heterozygous may have an advantage
      Even though the trait is not expressed (lethal recessive), they carry the trait of Tay-Sachs and therefore have an advantage
- Could have also come about from:
    - Random genetic drift
      There was randomly a higher frequency of Tay-Sachs in the population, and through inbreeding within the small population, it spread.

SOMATOTYPES

- Somatotypes, or body types, are dependent on where a population lives, in particular, the climate in which the population lives.
- Is an example of natural selection: those with the body types best suited to the environment will survive, causing a rise in the frequency of that somatotype in the population.

Endomorph

- Short, stocky
- Low surface area to volume ratio
- Helps to conserve body heat
- Usually found in populations living in extremely cold conditions, such the Eskimos, who are native to far Northern America

Ectomorph

- Tall, lanky
- High surface area to volume ratio
- Helps to get rid of and regulate body heat
- Usually found in hot equatorial regions, such as Africa

Mesomorph

- In the middle of the two mentioned above
- Adaptable to milder climates

SKIN COLOUR

- Selective agent: exposure to UV radiation
- Exposure to UV light creates melanin in the skin
- Melanin is a dark pigment, causing a 'tan', which acts as a natural sunscreen
    - Block UV radiation
    - Blocks Vitamin D absorption
- Stronger UV in equatorial areas = darker skin
- Weaker UV closer to the poles = lighter skin

Other definitions:

- Species: a group or population of similar organisms that can reproduce under natural conditions to produce fertile offspring.
- Population: a group of interbreeding individuals living in a particular place at a particular time (usually of the same species).
- Allele: alternative form of a gene
- Adaptation: any feature that makes an organism better suited to survive in its environment.
- Mutation: permanent change in the genetic material of a cell.
- Gene pool: the sum of all alleles present in a population.
- Allele/gene frequency: how often a particular allele is found in a gene pool.
    - Gene frequencies will differ for populations with different characteristics, including in different countries.

CHAPTERS 17-20: PRIMATE & HUMAN EVOLUTION

Adaptations for bipedalism

Location	Feature	Description	Advantage
Skull	Foramen magnum	Centrally placed at the base of the skull	Skull better balanced Brings centre of balance over feet
	Prognathicism	Face 'flat' or less prognathic	Skull better balanced
	Neck muscles and nuchal area	Muscles and nuchal area are smaller	Consequences of the above
Vertebral column and pelvis	Lumbar curve	S-shaped curve	Straightens spine and brings centre of balance over feet.
		Robust lumbar vertebrae	Carries the weight of the upper body
	Pelvis	Shorter and broader	To support the weight of the upper body
		Tilted to a vertical position	Brings centre of balance over feet
Legs and dat ass	Dat ass	Gluteus muscles modified	Improves stride; improves hip extension More efficient walking
		Stronger gluteal muscles	Helps to hold the body upright
	Femur	Carrying angle*	Distributes weight and brings it towards the midline of the body and over the feet.
		Enlarged head of femur and deep acetabulum (hip socket)	Greater stability to carry the weight of the upper body
	Knee joints	Strong large outer hinge/robust lateral condyle	Supports weight due to carrying angle
Feet	Calcaneus	Larger calcaneus	Improves flexion Takes the weight when you stand and when walking
	Arches	Transverse arch	Shock absorber
		Longitudinal arch	Transfers energy and weight from Achilles tendon (heel) to big toe
	Big toe	Robust and non-opposable	Carries the weight and creates thrust when walking
Muscles	Muscle tone	Muscles in a state of partial contraction	Helps to maintain posture
		Lower centre of gravity	Greater stability

Bipedalism - walking upright on two legs

Advantages	Disadvantages
Hands free to hold tools, infants, food, etc.	The spine, pelvis and acetabulum, knees, and feet are not still fully adapted for bipedal walking, as all of these anatomical parts evolved from creatures who were quadripedal, and hence problems and pain in these areas are prevalent
Greater height to increase range of view to spot predators and other elements in the environment	
Greater height gives greater reach	
Less exposure to the elements, and thus is better for thermoregulation	
More energy efficient to walk on two legs	

Apes vs. Humans

Feature	Apes	Humans
Brain	Average 400 - 500 cm^3	In modern humans average 1375 cm^3
	Cerebrum smaller with fewer convolutions	Cerebrum larger and more convoluted with larger frontal, temporal and occipital lobes.
Skull	More rugged with bony nuchal area and sagittal crests.	Smooth and rounded
	Prominent brow ridge.	Brow ridge reduced.
	Prognathic face	Flatter face tucked in beneath cranium
	Large zygomatic arches	Smaller zygomatic arches
	Large nuchal area for attachment of large neck muscles.	Nuchal area much smaller
Dentition	Dental arcade rectangular, U-shaped	Dental arcade shorter and parabolic (rounded)
	Large, protruding canine teeth	Smaller, non-protruding canines.
	Large incisor teeth	Smaller, opposed incisors
	Diastema	No diastema
	Chin not developed	Chin present in modern humans
Spine	Robust cervical vertebrae	Robust lumbar vertebrae
	No lumbar curvature	Prominent lumbar curvature
	Pelvis long and narrow	Pelvis short and broad
Pelvis	Gluteus maximus acts as abductor and swings leg to side	Gluteus maximus acts as extensor and swings leg backwards
Legs	Arms longer than legs	Arms and legs similar in length
	Shorter femur	A longer femur
	Small head to femur	Head of femur enlarged
	No carrying angle	Carrying angle present
	Wear on inner condyle of knee joint	Robust outer condyle with bony buttress preventing over-extension of knee joint
Feet	Smaller calcaneus	Calcaneus elongated and more robust
Feet	Flat-footed. Longitudinal arch only	Longitudinal and transverse arches present
	Opposable big toe set apart from other toes. (Divergence of metatarsals)	Big toe is non-opposable, in line with other toes, and more robust
Hand	Fingers long relative to thumb	Shortening of fingers increases relative length of thumb
	Limited mobility of thumb and other digits	Improved precision grip and flexibility
Skin	Body hair longer and coarser	Body hair shorter and finer

PHYSICAL EVOLUTIONARY TRENDS

Area	Feature	Trend
Skull	Cranial capacity	Volume increases
	Shape	Rounder and smoother
	Position of foramen magnum	More centrally placed
	Brow ridge	Reduction in brow ridge
	Forehead	Increase in size and inclination of forehead due to increase in skull capacity and roundness
Face	Prognathicism	Reduced prognathicism
	Zygomatic arches	Reduced zygomatic arches
Dentition and jaw	Dentition	Smaller, more regularly sized teeth
	Jaw and ramus	Smaller jaw and ramus
	Chin	No chin to chin
Spine	Shape	S-shaped instead of C-shaped
	Cervical and lumbar vertebrae	Lumbar vertebrae more robust than cervical vertebrae
Pelvis	Shape and angle	Shorter, broader, and more vertically aligned
Legs	Carrying angle	Increased carrying angle
	Height	Increased height
Skin	Body hair	Decreasing body hair
Brain	General size	Larger and more convoluted
	Frontal lobe	More convoluted; related to higher order thinking, problem solving

CULTURAL EVOLUTIONARY TRENDS

Effect of the environment on human evolution

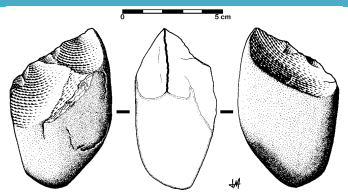
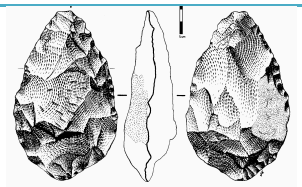
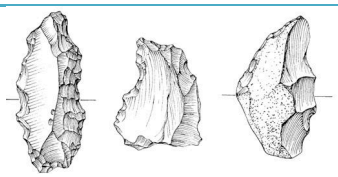
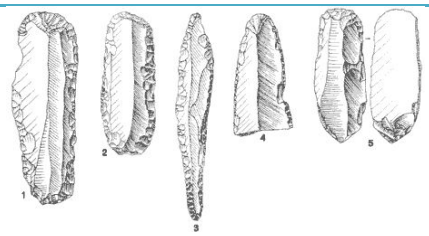
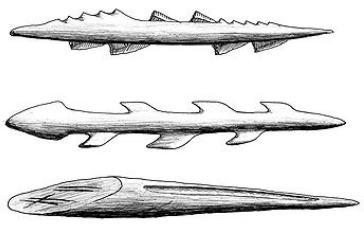
- Human ancestors used to be apes living in tropical rainforests or heavily forested areas
- Shift in climate to a cooler, drier, more arid one ➔ reduction in forested areas, turning it instead into open woodlands and savannahs.
- Less trees meant we had to adapt to walking and living primarily on the ground
- Changes in climate and environment also lead to a change in fauna, including

Australopithecines

- More distant cousins of modern humans
- Mix of humanoid and ape-like features
- Gracile
  - A afarensis, A africanus
    - Smaller, more slimly built
    - Probably more closely related to modern humans
    - Smoother, rounder skull
    - Smaller, but still present, brow ridge, and small forehead
    - Smaller jaw/ramus, zygomatic arches, and dentition
- Robustus
  - Recently renamed Panthropsus
  - A robustus, A boisei
    - Taller and more heavily built
    - Larger jaw, ramus, and zygomatic arches
    - Prominent brow ridge, and small forehead
    - Large molars contrasting with smaller incisors and canines
    - Sagittal crest

Tools:

- » Increasing complexity in tools, in terms of progressions in manufacture, materials, and applications
- » Helped with making weapons for hunting and protection from predators, and tools for building shelters and making clothing, increasing chances of survival

Hominin	Tool Culture	Description	Diagram
Australopithecines	Oldowan	Basic pebble tools Usually round, maybe with one edge Opportunistic tools	
Homo habilis		First stone tools Rounded with one worked edge	
Homo erectus	Acheulean	Flaked 'tear drop' shaped tools i.e. the hand-axe Would have helped in hunting and building shelters	
Homo neanderthalensis	Mousterian	Greater range of smaller and more detailed pressure flaked stone tools Aided in hunting and skinning animals for clothing	
Homo sapiens	Aurignacian	Rectangular stone 'blade' tools with one or two sharp edges Made by pressure flaking Could have been attached to branches with other blades to create axes for cutting	
	Solutrean	'Laurel leaf' or 'willow leaf' shaped flaked stone tools Used for cutting, or as spear or arrow heads for hunting Intricate flaking around all edges Could have been decorative	
	Magdalenian	First tools made of bone, antler and ivory Usually pointed, sometimes with serrations or barbs Incudes fish hooks, needles, and spear-heads and harpoons	

Diet

- » Nutrition helps with health, growth, and development
- » Early hominins were primarily vegetarian forages
- » H. habilis began consuming raw meat from foraging
- » H. erectus began consuming more meat from hunting, and cooking it using fire.
- » Meat has more calories, proteins, and fats
  - o Better and richer source of energy
  - o Better nutrition linked with increased brain development

Hunting

- Hunting helps with increasing food supply
- Early hominins primarily foragers and scavengers
- H. erectus first hunter-gatherer
- Hunting ability linked with meat consumption
- Hunting probably encouraged cooperation, social groups, and language

Use of Fire

- No use of fire until H. erectus
- Cooking food
    - Makes a greater variety of food more editable and palatable
- Light and heat
- Protection against predators
- Social focal point

Shelter

- Started from simple tree dwellings or home bases
- Homes improved as technology improves
- Settlements changed as social structures changed
    - Hunter gatherers would have lived in slightly larger social groups
    - Home bases would not be permanent, as they would move with the herds
    - More permanent settlements were established with agriculture

Language

- Started from no language and very basic forms of communication
- H. erectus was first to have basic languages, encouraged by their social hunter-gatherer lifestyles
- Complexity increases until modern humans
- Helps with cooperation and communication between individuals in hunting and living together in settlements and societies.

Art

- No evidence of art until H. neanderthalensis (basic cave paintings)
- H. sapiens considered the first to really have art
    - Portable art, such as sculptures
    - Mural art, like cave paintings
    - Body decorations
- Is a reflection of belief
- Form of communication to pass down knowledge, stories, and ideas through generations

Rituals and customs

- No evidence of rituals and customs until H. neanderthalensis
    - Had ceremonial burials for the dead, with decorated graves
    - Cared for the young, elderly, and disabled
- H. sapiens had increasingly complex rituals and customs
- Communication of ideas and culture through generations
- Indicative of higher order thinking

Clothing

- No clothing until H. neanderthalensis
- Provided protection from
    - Harsh elements and weather
    - Predators

Agriculture

- Neolithic Revolution/Era ~12500 years ago
- Beginning to domesticate crops and animals
    - Frist plants to be domesticated were wild grasses
    - These were bred with other domesticated species to increase yields
    - First animals to be domesticated includes sheep and goats
- Allowed modern humans to have a stable food supply, increasing populations
- They no longer had to be hunter-gatherers, and could settle in one place, establishing larger, better built settlements and communities
    - Safer for everyone, especially infants and adolescents
- They no longer had to spend all their time moving around and finding food; they could now focus on developing language, culture, and technologies.