VBEST NOTES

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A2 BIOLOGY

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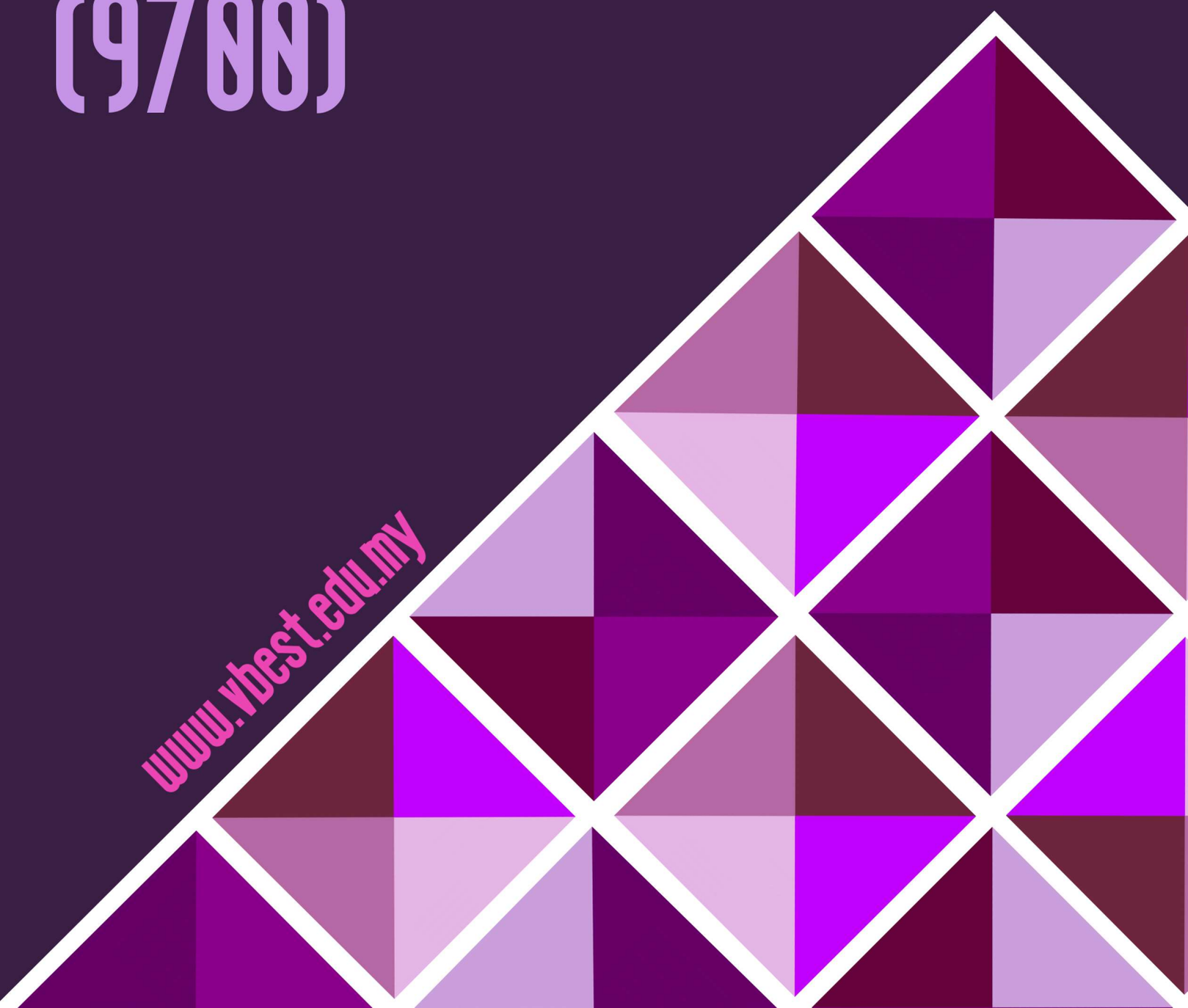

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Biology

- [ ] Energy and respiration
- [ ] Photosynthesis
- [ ] Homoeostasis
- [ ] Control and coordination
- [ ] Inherited change
- [ ] Selection and evolution
- [ ] Biodiversity, classification and conservation
- [ ] Genetic technology

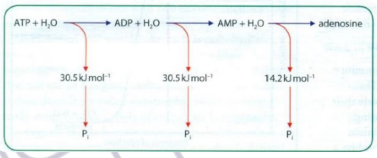
Chapter 1 : Energy and respiration

Actions that require energy :

- Anabolic with actions such as the synthesis of proteins and other large molecules
- Active transport of ions and molecules across a membrane against their concentration gradient
- Movement of the whole organism or movement of organelles in cells
- Maintenance of body temperatures
- Photosynthesis

a) ATP

ATP is an activated phosphorylated nucleotide that consist of adenosine and three phosphate groups.
It is a universal energy currency.
Energy released when ATP molecule is hydrolysed is used by the cells.
When ATP molecule is hydrolysed it becomes ADP + inorganic phosphate.



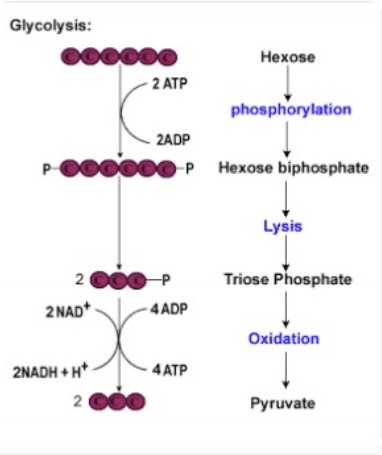
b) Respiration

During respiration, oxidation occurs.
Energy from oxidation is used to combine ADP with inorganic phosphate to make ATP.
Respiration can be anaerobic (lack oxygen) aerobic (with oxygen)
Respiration has four main stages :

- Glycolysis (occurs in the cytoplasm)
- Link reaction (occurs in the matrix)
- Keeps cycle (occurs in the matrix)
- Oxidative phosphorylation (occurs in the inner mitochondrial membrane)

—> Glycolysis (doesn't require oxygen)

- A hexose sugar is phosphorylated, using phosphate from 2 molecules of ATP, to give hexose bisphosphate.
- The hexose bisphosphate is split into 2 triose phosphate (TP) molecules.
- TP is oxidised into pyruvate by removal of hydrogen and phosphate groups by coenzyme NAD
- Phosphate groups removed are added to ADP to give ATP.
- In total there is a net gain of 2 ATPs per hexose molecule

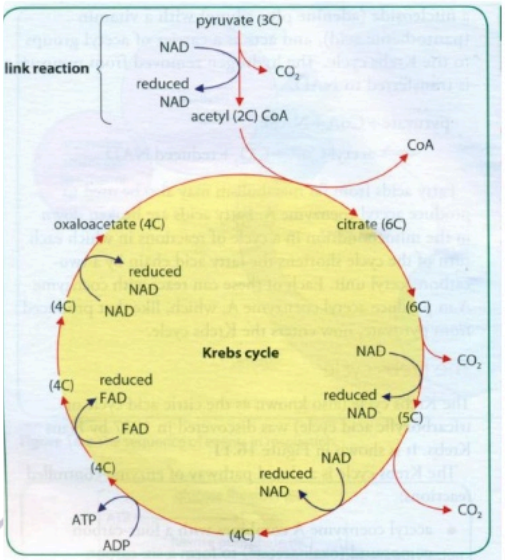


—> Link reaction

- Pyruvate enters the matrix of mitochondria.
- CO2 is removed from pyruvate then diffuses out of the mitochondria. (Decarboxylated)
- Hydrogen is removed from pyruvate and is picked up by NAD producing RNAD. (Dehydrogenated)
- The two carbon compound is then combined with coenzyme A to give acetyl-CoA.

—> Kreb's cycle (requires oxygen)

- Acetyl-CoA combines with oxaloacetate to give citric acid. (Coenzyme A is reformed and reused)
- Citric acid is then converted back to oxaloacetate through decarboxylation and dehydrogenation.
- 2 CO2 molecules and 4 pairs of hydrogen atoms are removed.
- Hydrogen atoms are picked up by 3 NAD and 1 FAD molecules becoming RNAD and RFAD.
- For each glucose molecule, the cycle turns twice.



The link reaction and the Krebs cycle.

—> Oxidative phosphorylation

- Hydrogens from RFAD and RNAD are split into protons and electrons
- Electrons are passed along ETC. As they move along the chain, they lose energy.
- Energy lost is used to actively transport protons from mitochondrial matrix to the inter-membrane space.
- Increased concentration of protons in inter-membrane space creates a gradient where protons diffuse back into the matrix to through ATPase.
- Movement of protons provide energy to combine ADP and inorganic phosphate to make ATP.
- At the end of the chain electrons and protons recombined with oxygen (oxygen is the final electron acceptor)

	ATP used	ATP made	Net gain
Glycolysis	-2	4	+2
Link Reaction	0	0	0
Krebs Cycle	0	2	+2
Oxidative Phosphorylation	0	28	+28
Total	-2	34	+32

c) Anaerobic respiration

- In the absence of oxygen, oxidative phosphorylation cannot take place as oxygen is not present to be the final electron acceptor.
- Hydrogen is used up, so RNAD cannot be recycled.
- Mitochondria runs out of NAD and FAS accept hydrogen from Krebs cycle.
- Glycolysis is the only process to continue as long as pyruvate can be removed and RNAD can be converted back to NAD
- To pathways allow recycling of RNAD : ethanol and lactate pathways

—> Ethanol pathway :

Pyruvate is decarboxylated to ethanal. Ethanal accepts hydrogen from RNAD and is reduced to ethanol. NAD can now be reused.

—> Lactate pathway :

Pyruvate acts as hydrogen acceptor and is removed by converting it to lactate.

Lactate produced in the muscles is carried through the blood to the liver to convert back to pyruvate.

This process requires oxygen so extra oxygen is required after exercise has finished.

- Extra oxygen is known as oxygen debt.
- Ethanol and lactate produced are toxic.
- These pathway are also very wasteful as there is only a net gain of two ATP molecules per glucose molecule.
- Only lactate pathway is reversible.

d) Rice adaptation

- Rice stems contain a large number of hollow aerenchyma (air spaces). This allows oxygen to penetrate through stem and move to the roots for aerobic respiration.
- Rice has shallow roots, allowing access to oxygen in waterlogged soil.
- Cells in rice plants roots have high tolerance to ethanol. This is because they have a high concentration of alcohol dehydrogenase and allowing them to break down ethanol. This allows them to respire anaerobically for longer periods.

Chapter 2 : Photosynthesis

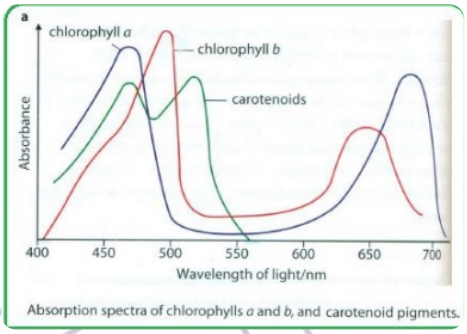
a) Photosynthetic pigments

These pigments absorb different wavelengths of light : Chlorophyll and carotenoids

—> Chlorophylls
Absorb : red and blue-violet light
Reflect green light
Gives leaves their colour

—> Carotenoids:
Absorb : blue-violet light
Reflect : orange-yellow light
Orange pigments protect chlorophyll from damage by free radicals.

- 2 types of chlorophylls : chlorophyll a and chlorophyll b
- 2 types of carotenoid: carotenes (β-carotene) and xanthophylls.
- Main pigment : chlorophyll a
- Accessory pigment : chlorophyll b



Absorption spectra of chlorophylls *a* and *b*, and carotenoid pigments.

b) Light dependent reaction

—> Non-cyclic photophosphorylation.

- Chlorophyll molecules in PSI and PSII absorb light energy.
- The energy excites electrons, raising their energy level so that they leave the chlorophyll.
- The water molecules are split into oxygen and hydrogen atoms by enzymes in PSII. (photolysis)
- Each hydrogen atom then loses its electron, to become H+.
- The electrons are picked up by the chlorophyll in PSII, to replace the electrons they lost.
- The oxygen atoms join together to form oxygen molecules, which diffuse out of the chloroplast and into the air around the leaf.
- The electrons emitted from PSII are picked up by electron carriers
- Energy lost as they move along ETC are used to make ATP by combining ADP with inorganic phosphate group. (photophosphorylation)
- At the end of the electron carrier chain, the electron is picked up by PSI, to replace the electron lost.
- The electrons from PSI are passed along a different chain of carriers to NADP.
- The NADP becomes reduced NADP by picking up H+ ion.
- ATP and NADPH are made.

—> Cyclic photophosphorylation

- Light is absorbed by only PSI.
- Electron emitted from PSI is passed along ETC then back to PSI again.
- ATP is produced as it moves along ETC
- No NADPH is produced.

c) Light independent reaction

- CO_2 diffuses into the stroma from the air spaces within the leaf. It combines with ribulose bisphosphate, RuBP. The reaction is called carbon fixation and is catalysed by enzyme rubisco.
- The products of this reaction are two molecules of glycerate 3-phosphate, GP.
- Energy from ATP and hydrogen from reduced NADP (from light dependany reactions) are then used to convert the GP into triose phosphate, TP.
- Triose phosphate is the first carbohydrate produced in photosynthesis.
- TP is used to regenerate RuBP, so that more carbon dioxide can be fixed.
- TP is also used to make glucose or whatever other organic substances the plant cell requires.

d) Limiting factors in photosynthesis

- Light intensity

This affects the rate of the light-dependent reaction and subsequently Calvin cycle.
In low light intensity, less ATP and NADPH is produced.
Without this product GP in Calvin cycle cannot be reduced, rate of photosynthesis decreases.

- Temperature

Photosynthesis process uses many enzymes. that are sensitive to temperature.
Enzymes work slower in low temperatures and may denature in extremely high temperatures.

- CO_2 concentration

CO_2 is needed for carbon fixation in Calvin cycle.
Reduced concentration of CO_2 affects rate of photosynthesis

- Availability of water

When plant has low supply of water, stomata will close to reduce water loss by transpiration.
CO_2 cannot diffuse into the leaf when stomata is closed.

d) Greenhouse

Conditions controlled in greenhouse

- Use of artificial light : Allows photosynthesis to continue even in the nighttime. Brighter lights also provide higher light intensity, increasing the rate of photosynthesis.
- Use of artificial heating : Higher temperature increases the rate of photosynthesis.
- Use of additional CO2 : Increased CO2 increases rate of photosynthesis.

*Paraffin lamps are often used as the burning of paraffin produces heat, CO2 and light

Chapter 3 : Homeostasis

Definition : Maintenance of a constant internal environment around a set point regardless of changes in the external environment.

a) Mechanisms of homoeostasis

- Receptor to detect change in parameter and send information to effector.
- Effector to cause action by reducing or increasing parameter to restore parameter to usual set point.
- Central control transfers information from receptors to effectors. (Hypothalamus)

—> Negative feedback mechanism is used to maintain a constant internal environment.
It is a regulatory mechanism in which a 'stimulus' causes an opposite 'output' in order to maintain an ideal level of whatever is being regulated.

—> Positive feedback mechanism is well original stimulus is intensify and increases the disturbance even further.

—> Thermoregulation is the regulation of internal body temperature.
Effects when temperature drops : Vasoconstriction, shivering, raising of body hair, decreased production of sweat
Effects when temperature rises : Vasodilation, lowered body hair, increased sweat production

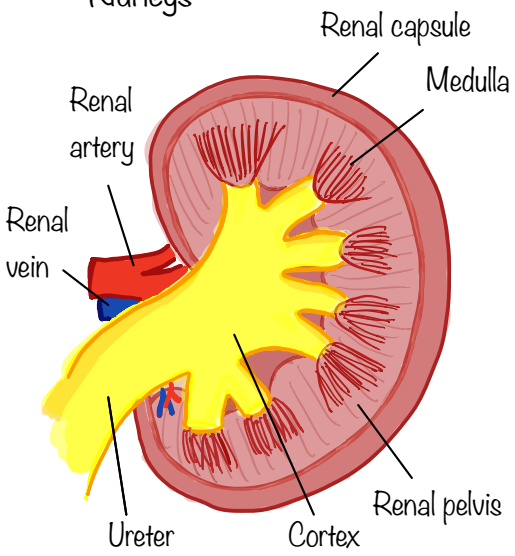
Hypothalamus releases a hormone to anterior pituitary gland when a decrease in temperature is detected. This triggers APG to release thyroid stimulating hormone (TSH). TSH stimulates the thyroid gland to release thyroxine hormone that increases metabolic rate to release heat.

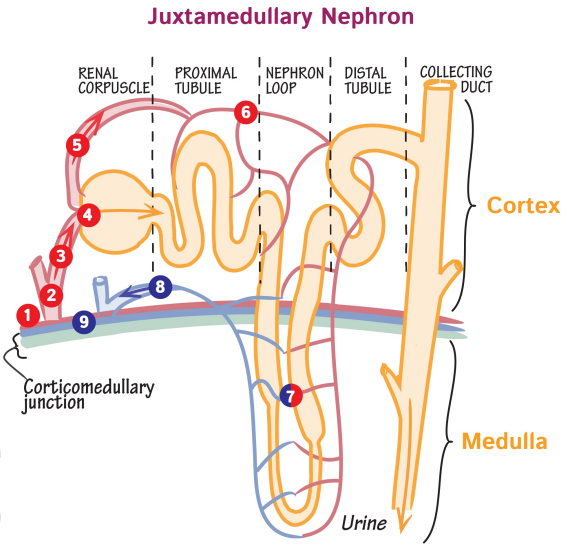
b) Excretion

—> Urea

- Breakdown of amino acid produces ammonia and organic acid. (Deamination)
- Ammonia is toxic and highly soluble.
- They are converted to urea and keto acid in the liver. Urea is less soluble and less toxic.
- CO2 + ammonia --> urea + H2O
- Urea is released from the liver into the blood and filtered out by the kidneys to produce urine.

—> Kidneys





- Blood enters the kidney through the renal artery and subsequently passes through the capillaries in the cortex of the kidneys.
- Blood flows through the glomerulus from afferent arteriole to the narrow efferent arteriole. High pressure pushes small molecules (glucose, urea, water and sodium) into the Bowman's capsule from the blood. (Ultrafiltration)
- At the proximal convoluted tubule, selective reabsorption takes place. Amino acids, glucose, vitamins are reabsorbed back through the tubules in the medulla. Sodium ions and glucose are cotransported back into the blood through a sodium-potassium pump.
- Filtrate then passes through loop of Henle, which consist of descending limb and ascending limb.
- At the descending limb, water diffuses out of the filtrate. This results in a concentrated filtrate.
- At the ascending limb, Na+ and Cl- ions are actively pumped out. This section of the limb is impermeable to water so filtrate gets more dilute.
- The substances to be excreted pass along the tubules and ureter and finally reach the bladder where they are disposed of as urine.
- The filtered blood passes out of the kidneys through the renal vein.

c) Water reabsorption

- Water potential of blood is monitored by hypothalamus controlled by hormones ADH.
- When blood is highly concentrated, impulses are sent to the pituitary gland to release more ADH.
- ADH makes the walls of the collecting ducts more permeable to water, so more water is reabsorbed back into the blood.

d) Blood glucose regulation

- α cells of the pancreas produce glucagon and β cells of the pancreas produce insulin.
- —> High glucose
- Increase in blood glucose concentration is detected by β cells. β cells release insulin to target cells hepatocytes in the liver. Insulin binds to receptors on the target cells causing adenyl cylase to convert ATP into cAMP.
- cAMP acts as a secondary messenger and activates enzyme controlled reactions stimulating the opening of glucose channels, causing more glucose to enter the cell.
- —> Low glucose
- Low blood glucose concentration is detected by α cells.
- α cells release glucagon to stimulate hepatocytes to convert glycogen into glucose.
- Glucose difuses out of hepatocytes into the blood.

e) Second messenger model of adrenaline

- Secretion of adrenaline increases heart rate, blood flow and metabolic rate.
- Adrenaline released by the adrenal glands bind to the receptors on the cell-surface membrane of the target cell.
- This activates adenyl cyclase and triggers the conversion of ATP to cAMP which acts as a secondary messenger.
- cAMP activate the enzyme protein kinase a, triggering the breakdown of glycogen into glucose for energy.

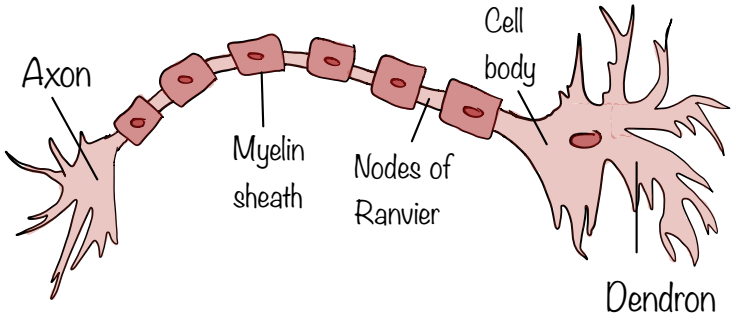
f) Homeostasis in plants

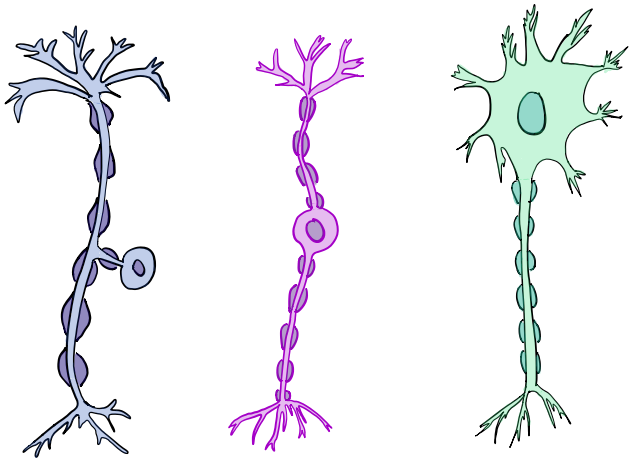
- Plants respond to changes in environmental conditions by opening and closing of its stomata
- During high light intensity and low concentration of CO_2 stomata opens.
- During low humidity, high temperatures and high concentrations of CO_2, stomata closes.
- Opening of stomata is due to expansion of guard cells.
- Water diffuses into the guard cells due to high concentration of K^+ inside the cell, causing it to expand. Stomata opens when guard cell is turgid and closes when guard cell is flaccid.
- Abscisic acid (ABA) is a stress hormone secreted in the roots of a plant as a response to stress or decrease in water potential.
- ABA triggers stomata to close to reduce transpiration and prevent water loss.

Chapter 4 : Control and coordination

a) Neurones

Motor neurone : CNS → effectors (action)
Sensory neurone : Receptor → CNS (feel)
Intermediate neurone : Sensory → motor (link)
*axon carries impulse away from cell body
*dendron towards the body





Features	Motor	Sensory
Position of cell body	Inside spinal cord	Outside spinal cord
Axon length	long	short
Dendron length	short	long
Direction of impulse	CNS to effector	Receptor to CNS
Role	Stimulate muscle contraction	Transmit info to CNS

Mylelin sheath is made out of Schwann cells that surround the axons and dendrone.
They are impermeable to Na+ and K+ which allows for faster conduction of nerve impulses.

b) Reflex arc

Impulses carried through this pathway does not go through the conscious regions of the brain.

- Strong impulse at the receptor is converted to stimulus
- The stimulus is transmitted along sensory neuron, passing through dorsal root of spinal nerve and into spinal cord.
- Impulse is then passed through the intermediate neuron to motor neuron.
- At the motor neuron, impulse is transmitted along axon to effector (muscle) and a response is generated.
- (impulses can travel to the brain, but responses occur before it reaches)

Reactions from the impulses carry through these reflex arc are instantaneous, this is important in life or death situations.

c) Transmission of nerve impulses

Resting potential - occurs when there is no stimulation

- Na+/K+ pump actively pumps out 3 Na+ out of axon and 2 K+ into axon.
- Cell-surface membrane is of the axon and also has a lot of ion channels ; more K+ than Na+
- This causes the electrical potential outside the axon to be more positive than the inside, creating a potential difference. (-70mV ; polarized)

Action potential - occurs when there is simulation

Depolarization

- When there is a stimulation above threshold potential (-55mV) , it triggers the voltage gated Na+ channels to open.
- Na diffuses into the axon, depolarising the axon (less negative) and raising its potential difference to +30mV.

When the potential difference reaches +30mV, voltage gated Na+ channels will close.

Repolarization

- Voltage gated K+ channels will open, causing K+ to exit the axon, polarizing the axon (make more negative)

Hyperpolarization

- K+ will continue to exit the axon until potential difference reaches -80mV.
- At this point voltage gated K+ channels will close.
- Na+/K+ pump will restore potential difference to that of resting potential.

Receptors are energy converters.

They convert energy in stimulus to electrical energy in action potential

A stronger stimulus will produce a higher frequency of impulses.

Action potentials don't change in size and speed.

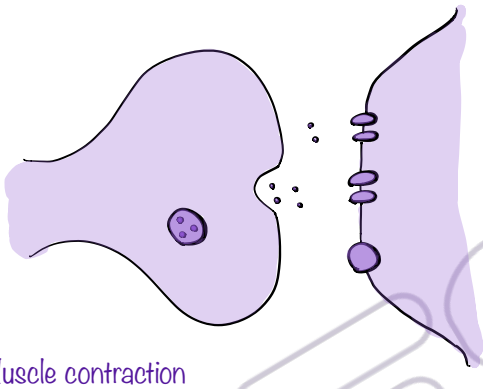
Intensity of stimulus affects frequency of action potentials and the number of neurons transmitting action potential.

d) Transmission of action potential

- Depolarisation of the first action potential will spread to the neighbouring regions of the membrane, depolarising it and initiating a second action potential.
- New action potential will only be generated head of it because the vision behind it will still be recovering from action potential and be in refractory period.

e) Mechanism of synaptic transmission

- When action potential reaches presynaptic membrane, voltage gated Ca2+ channels will open and Ca2+ will enter the synaptic knob.
- This will induce vesicles containing acetylcholine (Ach) to move towards the membrane. With vesicles will then fuse with the presynaptic membrane and release Ach into the synaptic cleft.
- Ach Will diffuse across the cleft and bind to the receptor protein channels on the postsynaptic cleft.
- This binding will cause protein channels to change shape and allow entry of Na+ into postsynaptic neuron.
- Post synaptic membrane becomes the depolarised and action potential is generated.
- Ach left in the synaptic cleft will be broken down by acetylcholinesterase into acetate and choline.



f) Muscle contraction

- Striated muscles contain many mitochondria and are aligned with many myofibrils.
- Structures of striated muscle cells include sarcolemma, sarcoplasm, sarcoplasmic reticulum and t tubule.
- Myofibrils are elongated contractile threads made out of actin and myosin.
- Muscle contraction is due to the interaction between actin and myosin.
    - Myosin head is an ATPase molecule (that hydrolyses ATP).
    - Myosin head is initially bounded to actin.
    - When ATP binds to myosin, actin is unbounded
    - When ATP hydrolysed, myosin tilts to another position and ADP + Pi released.
    - Myosin head attaches back to actin and tilt back to original position. (power stroke)
    - Process is repeated when another ATP molecule attaches.
- Troponin and tropomyosin are protein molecules associated with actin.
    - When muscle is not contracting, tropomyosin binds to actin.
    - Troponin contains active site of Ca2+.
    - When muscle is contracting calcium binds to troponin and changes its shape.
    - This induces a change in shape of tropomyosin, revealing the binding sites on actin.

g) Menstrual cycle

- Control centres are hypothalamus and anterior pituitary gland.
- Hormonal events are cycling in females.
    - At the beginning of the cycle, hypothalamus releases GNRH to the anterior pituitary gland.
    - Pituitary gland then secrets FSH into the blood.
    - FSH target the ovary to stimulate the development of primary follicle where the follicle secretes increasing amounts of estrogen as it grows. (estrogen helps thicken the endometrium.)
    - As the follicle continues to secrete high levels of estrogen, this triggers LH and FSH to be released in a surge.
    - LH target the ovaries to cause ovulation. (release of secondary oocyte)
    - This stimulates the remains of the ovarian follicle to develop into corpus luteum which secretes progesterone.
    - As the ovarian follicle is no longer present, the production of estrogen decreases.
    - Corpus luteum continues to secrete a estrogen and progesterone
    - Progesterone stimulates glandular activity and helps. to maintain uterus thickness
- If the egg is not fertilised
    - Corpus luteum needs FSH and LH survive.
    - Low progesterone and estrogen level inhibits FSH and LH.
    - Corpus luteum degenerates, and the. supply of estrogen and progesterone is cut off.
    - Lining of uterus breaks down causing menstrual cycle.
- If the egg is fertilised
    - Corpus luteum receives hormone stimulus hCG from implanted embryo.
    - hCG allows corpus luteum to continue survive without LH and FSH.
    - Estrogen and progesterone continue to be secreted.
    - Endometrial lining is maintained and pregnancy supported.
- Birth contro - Contraceptive Pills
    - Contains oestrogen and progesterone.
    - Mimics the luteal phase by inhibiting the secretion of FSH and LH.
    - No ovulation takes place.
    - It also thickens mucus at cervix to prevent entry of sperm.

- Auxin is synthesized in growing tips of roots and shoots and responsible for apical dominance.
- It stimulates the growth at apical buds by cell elongation and inhibits growth of lateral buds.
- Allows plant to grow upwards instead of going sideways to obtain source of sunlight.
- Mechanism :
    - Auxin binds to receptor on cell surface membrane.
    - This stimulates proton pumps on cell surface membrane to actively pump H+ from cytoplasm into cell wall.
    - Proteins known as expansins in cell wall are activated and they loosen bonds between cellulose microfibrils.
    - Cell wall becomes more elastic and as water molecules diffuse into cell, it expands and becomes elongated.
- Germination
    - Gibberellin (GIB) is synthesized in most parts of plants.
    - It is present in high concentrations in young leaves and seeds.
    - A seed contains an embryo which is surrounded by the endosperm. The whole seed is covered by waterproof testa.
    - When water is introduced to the seed, the embryo synthesizes GIB in response.
    - The aleurone layer synthesizes amylase in response to GIB.
    - Amylase hydrolyses starch from the endosperm into maltose, which is then converted into glucose for respiration.
- GIB synthesis is controlled by Le/le gene.
    - Le is the dominant gene that codes for functioning GIB and le is the recessive gene that codes for non functioning GIB.
    - Functional GIB stimulate stem elongation and non func GIB results in drawfism.
    - Absence of GIB
    - DELLA protein attaches to transcription factor PIF.
    - This results in PIF being unable to bind to promoter region and tanscription of growth genes turned off.
    - Presence of GIB
    - GIB binds to receptor on enzyme which results in the breakdown of DELLA protein.
    - PIF is able to bind to promoter region on DNA and both genes are turned on and expressed.

i) Electrical communication

- Plants have electrochemical gradient across cell membrane
- Action potential travels from cell to cell via plasmodesmata
- Depolarization results from outflow of chloride ions
- Repolarization results from a flow of potassium ions
- Example :
    - Venus flytrap obtaining nitrogen by digesting small animals.
    - They have leaf structures with two lobes that close together rapidly enough to capture an insect.
    - These are connected by hinge cells in the middle.
    - Glands in leaves secrete nectar and digestive enzymes.
    - Mechanism
        - Deflection of trigger hair activates Ca2+ channels at base of hair.
        - Ca2+ channel open allowing Ca to flow into cell - generating receptor potential
        - 2 trigger hair or 1 trigger hair simulated twice must occur within 35 seconds for receptor potential to be generated.
        - Action potential then spreads across leaves.
        - Further deflection by trapped insect stimulates exocytosis of vesicles that have digestive enzymes.

Chapter 5 : Inherited Change

a) Gametogenesis in mammals

- Haploid cells have one complete set of chromosomes while diploid cells have 2.
- Homologous chromosomes are a pair of chromosomes in a diploid cell that pair together to form bivalents during meiosis I.
- Meiosis is a reduction division.

Spermatogenesis

- Diploid cells in tubules of testes multiply via mitosis to form spermatogonia.
- Spermatogonia grow and mature to primary spermatocytes.
- Primary spermatocytes undergo meiosis I to produce secondary spermatocytes.
- Secondary spermatocytes undergo meiosis II to produce spermatid.
- Spermatids undergo maturation process to become spermatozoa.
- Spermatids differentiate to become spermatozoa. They form flagellum for motility in presence of many mitochondria and acrosome, that contains hydrolytic enzymes.
- Spermatogonia —> primary spermatocytes —> secondary spermatocyte —> spermatic —> spermatozoa

- Oogenesis
  - Diploid cells in ovaries multiply via mitosis to form oogonia. (starts during embryo stage)
  - Oogonia grows and matures into primary oocytes. Primary oocytes then undergo meiosis I and stop at prophase I. (Cells are still considered as primary oocytes)
  - Upon puberty, primary oocyte finally completes meiosis I and divides unequally into two haploid cells.
  - The smaller daughter is known as polar body and the larger daughter is the secondary oocyte.
  - Meiosis process stops are metaphase II.
  - During ovulation the secondary oocyte is released into the oviduct.
  - If secondary oocyte is fertilized, it completes meiosis II, but if secondary oocyte is not fertilized it will still be at metaphase 2.
  - Oogonia —> primary oocyte —> secondary oocyte/polar body

b) Gametogenesis in plants

- Anthers
  - Diploid cell divides by meiosis to form 4 haploid cells.
  - Each nucleus divide by mitosis but without cytokinesis, resulting in each cell containing 2 haploid nuclei, which are tube nucleus and generative nucleus.
  - These cells mature into pollen grains which are male gametes.
  - Extine : resistant outer wall ; Intine : thinner inner wall
- Ovules
  - Each ovule contains a diploid mother cell.
  - Cell divide by meiosis and produces four haploid cells. 3 of the haploid cells will degenerate and only one will survive.
  - Surviving haploid cell develops into an embryo sac and grows larger.
  - Embryo sac haploid nucleus divides by mitosis 3 times, forming 8 haploid nuclei.
  - One becomes female gamete.
  - Two become pollen nuclei (n) which eventually fuse to form single polar nucleus (2n).
  - Two become synergids that secrete chemical signals to guide pollen tube during fertilization.
  - Three become antipodal cells that provide nutrients to embryo sac.

d) Meiosis

- Meiosis is split into two parts, meiosis I and meiosis II.
- Meiosis I is a reduction division that results in 2 haploid daughter nuclei.
- Meiosis II is like mitosis where 4 haploid daughter nuclei is formed.
- In meiosis I
    - Prophase I
        - Centrosomes divide and move to opposite poles of nucleus and synthesize spindle fibres.
        - Homologous chromosomes pair up (synapsis), cross over (point of crossing over - chiasmata) and form bivalents.
        - Nucleus disappears and nuclear envelope breaks down.
    - Metaphase I
        - Bivalents line up at equator of the cell.
        - Spindle fibres attach to centromere of chromosomes
    - Anaphase I
        - Whole chromosomes move to opposite poles of cell, pulled by shortening spindle fibres.
    - Telophase I
        - Nuclear envelope and nucleolus reforms.
- In meiosis II
    - Nuclear envelope breaks down and nucleolus disappears in prophase II. During metaphase II, chromosomes line up separately at equator of the cell. Centromeres divide and chromosome are pulled apart during anaphase II. Lastly 4 haploid daughter cells are formed in telophase II.
- Variation occurs during meiosis when chromatids of two homologous chromosomes cross over and due to independent assortment.
- Chromosomes exchange genes with each other at loci when they cross over.
- Independent assortment is the random alignment of bivalents on the equator during metaphase I.

c) Definition

- Gene: length of DNA that codes for a particular protein/polypeptide
- Locus: position at which a particular gene is found on a particular chromosome
- Allele: particular variety of a gene
- Dominant: the allele whose effect on the phenotype of a heterozygote is identical to its effect on a homozygote
- Recessive: the allele that is only expressed when no dominant allele is present
- Codominant: alleles that both have an effect on the phenotype of a heterozygous organism

- Linkage: the presence of 2 genes on the same chromosome so that they tend to be inherited together and do not assort independently
- F1: generation of offspring produced from homozygous dominant x homozygous recessive genotype
- F2: generation of offspring produced from cross between 2 F1 organisms
- Phenotype: organisms' characteristics; resulting from an interaction between its genotype and the environment
- Genotype: alleles possessed by an organism
- Homozygous: having 2 identical alleles of a gene
- Heterozygous: having 2 different alleles of a gene

d) Genetic mutation

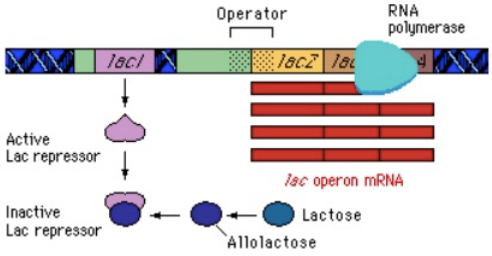
- Gene mutation: change in the structure of a DNA molecule, producing a different allele of a gene.
- Chromosome mutation: changes in the structure or number of whole chromosomes in a cell.
- Mutation could be due to environmental factors or completely random.
- Types: base substitution, base addition, base deletion
- Disease
- Sickle-cell anaemia
    - Base substitution in the gene that codes for the amino acid sequence in the β-globin.
    - Glutamic acid is replaced with valine; HbA allele becomes HbS allele
    - Haemoglobin molecule becomes less soluble, causing molecules to stick together and form long fibres inside red blood cells. RBC are pulled out of shape and become stuck in small capillaries and so cannot transport oxygen, blocking normal RBC from getting through.
- Albinism
    - It is an autosomal recessive mutation
    - Mutation in the gene for tyrosinase.
    - Tyrosinase is the enzyme that converts tyrosine into DOPA and subsequently melanin.
    - Mutation in the gene for tyrosinase, results in absence of tyrosinase or presence of inactive time tyrosinase.
    - This results in melanin partially or totally missing from the skin, hair and eyes.
- Haemophilia
    - It is a recessive sex linked mutation. (Only on the X chromosome)
    - A mutation in the gene coding for factor VIII causes blood be unable to properly clot.

- Huntington's disease
  - Dominant mutation in the gene coding for huntingtin.
  - In a normal human, there is a small number of repeats of the triplet of bases CAG
  - In a Huntington's patient, a 'stutter' is present. They have a larger number of CAG repeats.
  - This mutation causes a neurological disorder Where the patient has progressive mental deterioration
  - The more CAG stutters, the earlier the age of onset.

e) Gene control in prokaryotes

- In both prokaryotes and eukaryotes, transcription of a gene is controlled by transcription factors.
- Transcription factors are proteins that bind to a specific DNA sequence and control the formation of mRNA.
- Structural genes code for proteins required by a cell.
- Regulatory genes code for proteins that regulate the expression of other genes.
- The synthesis of repressible enzymes can be prevented by binding a repressor protein to the operator (a specific site) on the bacterium's DNA.
- The synthesis of inducible enzymes occur when its substrate is present.

- Prokaryotic lac operon
- Operon is a length of DNA making up a unit of gene expression in a bacterium.
- The lac operon consists of a length of DNA with operator and promoter regions and a cluster of 3 structural genes:
  - lacZ - coding for β-galactosidase
  - lacY - coding for permease
  - lacA - coding for transacetylase



- Close to the promoter is the regulatory gene for the lac operon.
- Lactose absent
  - Regulatory gene codes for repressor protein. Repressor binds to operator region, close to lacZ. RNA polymerase can't bind to DNA at promoter region. so transcription of the 3 structural genes doesn't occur.
- Lactose present:
  - Lactose is taken up by the bacterium. Lactose binds to repressor protein, distorts it's shape and prevents it from binding to the operator region on the DNA. The transcription no longer inhibited and mRNA is produced from 3 structural genes.
  - This makes sure that the bacterium can produce β-galactosidase, permease and transacetylase

- The role of a transcription factor is to make sure that genes are correctly expressed in the correct cell at the correct time into the correct extent.
- GIB controls seed germination in plants by stimulating the synthesis of amylase.
- DELLA protein inhibits the binding of transcription factor to gene promoter PIF.
- GIB causes the breakdown of DELLA and allows PIF to bind to its target promoter.

Chapter 6 : Selection and evolution

- Genetic variation is the variation that exists within a species. It can be continuous or discontinuous.
- Expression of features is influenced by the environment.
- Discontinuous variation :
    - Different alleles at a single gene locus have different effects on the phenotype. For example : hair colour, blood group
- Continuous variation
    - Different alleles at a single gene locus have same effects on the phenotype. Where large number of genes have a combined effect on a particular phenotypic trait. For example : height, shoe size

a) Natural selection

- Variation means some individuals in a population will have features which give them an advantage in when selection pressure arises. Selection pressures control the chances of some alleles being passed on to the next generation.
- The effects of such selection pressures on the frequency of alleles in a population is called natural selection.
- As the frequency of advantageous alleles increase, the frequency of disadvantageous alleles decrease.
- Types of selection
    - Stabilising selection: organisms are already well adapted to their environment, so there is no disruption.
    - Directional selection: an extreme phenotype is favoured over other phenotypes and this causes the allele frequency to shift over time in favour of the extreme phenotype .
    - Disruptive selection: favours both extreme traits in a population

b) Genetic drift

- Founder effect
  - A small number of individuals are separated from a large population
  - They comprise of a small sample from the original population and may experience different evolution process than parent population

c) Hardy Weinberg Principle

- Calculates the proportion of the population with a given combination of genotype.
- Equations
  - $p + q = 1$
  - $p^2 + 2pq + q^2 = 1$
- Can only be used if
  - Population is large
  - No genetic drift
  - No natural selection
  - No mutation has occurred

p : frequency of dominant allele
q : frequency of recessive allele
p^2 : chance of offspring inheriting dominant allele from both parents
q^2 : chance of offspring inherited a recessive allele from both parents
pq : chance of offspring inheriting a dominant allele from one parent and a recessive allele from another

- The importance of this principle is to predict the ratios of different genotypes and compare the predicted ratios to the population of the next generation .

d) Artificial selection

- This is the process where humans apply selection pressure on purpose to improve the features in livestock and crops plants.
- An increase of desired characteristics can be achieved by selective breeding.
  - Individuals with one or more of the desired characteristics are crossed with each other and some advantageous alleles are passed on to offsprings.
  - Over many generations, desired characteristics allele will increase in frequency and undesired characteristics allele will decrease in frequency.
- However sometimes inbreeding depression might occur.
  - This is an increase in the proportion of weaker or spring due to many generations of inbreeding.
  - They are less likely to adapt to the change of environment due to their increase homozygosity resulting in less a hybrid vigor.

e) Speciation

- A species is a group of organisms with similar physiological biochemical and behavioural features.
- They can interbreed to produce fertile offspring.
- If two groups of organisms can interbreed and produce another group of organisms but this offspring group cannot interbreed successfully, the two groups must be reproductively isolated.
- Reproductive isolation is to prevent members from different species from producing offspring.
    - Prezygotic isolation is when individuals do not recognise each other as potential mates, therefore do not respond to meeting behavior
    - Postzygotic isolation is the failure of cell division in th zygote, producing a non-viable offspring.
- Types of speciation
    - Allopatric speciation is the production of new species cause by geographical isolation
    - A barrier arises between two populations of the same species and interbreeding between the two populations is prevented.
    - Each species in new locations experience different selection pressures, resulting in different alleles being selected.
    - Overtime the original group cannot breathe with a group in the new location, thus a new species in born.
    - Sympatric speciation is the production of a new species evolved from a single ancestral species what inhabiting the same geographic region.
    - This occurs through polyploidy.
        - A polyploid is an organism that has more than two complete sets of chromosomes.
        - Autopolyploidy contains more than two sets of chromosomes from the same species. (Infertile offspring)
        - Allopolyploidy is formed when the polyploid contains two sets of chromosomes from one species or two sets of chromosomes from another closely related species. (Fertile offspring)

Chapter 7 : Biodiversity

The three domains system consist of eukarya, bacteria and archaea.
Archaea and bacteria are almost similar to prokaryote types when they have no nucleus and no membrane-bound organelles.
Archaea has DNA transcription properties and circular DNA supported by histones.

a) Three domain system

- Domain bacteria
  - Has no nucleus, may contain plasmids, has no membrane bound organelles.
  - Divides by binary fusion, not mitosis.
  - Exist as single cellls
  - Has circular DNA without histone proteins, 70s ribosomes and peptidoglycan cell wall.
- Domain archaea
  - Has no nucleus, may contain plasmids, has no membrane bound organelles.
  - Divides by binary fusion, not mitosis.
  - Exist as single cellls
  - Has circular DNA with histone proteins, 70s ribosomes and cell wall not made by peptidoglycan.
- Domain eukarya
  - Has nucleus and membrane-bound organelles
  - Divide by mitosis, reproduces asexually and sexually,
  - Has linear DNA and 80s ribosomes.
    - Kingdom Protoctista
      - Eukaryotic, mostly single celled or multicellular.
      - Eg : Animal like cells - Protozoa, Plant like cells - Algae
    - Kingdom Fungi
      - Eukaryotic, has no chlorophyll, is heterotrophic.
      - Reproduces by spores and can be unicellular or multicellular
      - Has cell wall made of out of chitin.
    - Kingdom Plantae
      - Eukaryotic, is a multicellular organism, has specialized cells.
      - Some cells have chloroplast, have large permanent vacuoles and cellllose cell wall.
    - Kingdom Animalia
      - Eukaryotic, is a multicellular organism, has specialized cells
      - Do not have chloroplast, no cell walls, has small vacuoles

- Viruses are not part of the domain system
  - They do not contain cellular features and may not be considered a living organism.
  - They are made out of protein particles, contains DNA or RNA.
  - They use host as biochemical machinery to duplicate the nucleic acid.

b) Biodiversity

- Habitat : A place that an organism lives in
- Population : Group of organisms of the same species living in the same place at the same time.
- Community : All population of all species living in a particular habitat.
- Ecosystem : Self contained, with interactions between organisms and between organisms and their environment.
- Niche : The functional role of an organism in the ecosystem.
- Biodiversity is defined by the total number of species living in the ecosystem.
- There are three levels of diversity
    - Genetic variation : total number of different alleles of all genes.
    - Ecosystem variation : some areas may have higher biodiversity than others.
    - Species diversity : species richness which is the number of different species present and species evenness which refers to the closeness in numbers of each species in an environment.
- Importance of maintaining biodiversity
    - Ecological purpose
    - Economical purpose
    - Ethical purpose
    - Genetic variation

c) Conservation

- Species are considered endangered when their numbers have become critically low and are unlikely to be maintained by normal rates of reproduction.
- Reasons why species have become endangered : Loss of habitat, spread of disease, climate change, lack of food source, poaching/hunting, agriculture.
- Methods of protecting is species
- Zoos : Can be used to bring awareness to the public and help raise funds for captive breeding programs.
- Captive breeding : Advantages of captive breeding are that sperms and oocytes can be obtained and stored in frozen form, artificial insemination and IVF can be done and health of animals can be monitored.
- Botanic gardens :Ideal growing conditions can be created, endangered species of plants can be propagated and endangered species of plants can be re-introduced into their natural habitats.
- Seed banks : Seeds can be stored as they are small, low maintenance and long living if kept carefully in controlled conditions.
- Conservation area : An area of land that has been awarded protected status where natural features, cultural heritage or biodata are safeguarded. Examples are nature reserves.

d) Controlling alien species

- An alien species is classified as an invasive species in an ecosystem and where they were previously unknown.
- Alien species may reduce the other populations of other species, alter the food chain, spread disease and increase competition for habitat and food.
- Ways to control alien species : Culling, hunting or trapping, Contraceptive measures, Biological control and Disease agent

e) Assessing species biodiversity

- Sampling methods
- Frame quadrants
  - This method is a random sampling method where organisms must be stationary, quadrant must be chosen randomly and sample must represent the whole population.
  - To investigate an area, the area is divided into a grid of equal sizes and organisms under investigation are counted in each quadrant.
  - Species frequency = $\frac{\text{Number of quadrant containing species}}{\text{Total number of cadets}} \times 100\%$
  - Species density = $\frac{\text{Total number of specific spaces in all quadrant}}{\text{Number of quadrants x Area of quadrant}}$
  - Percentage cover = $\frac{\text{Area containing species in a quadrant}}{\text{Area per quadrant}} \times 100\%$
- Line transect
  - Measures the distribution of a species in a straight line across a habitat
  - Detect the presence or absence of a species within the line.

Mark-Release-Recapture

  - Used to estimate the population size of mobile species within a habitat.
  - Animals are trapped and marked, then released back into the habitat, after a period of time, animals are recaptured.
  - Population size = $\frac{\text{Total no of organisms marked initially x Total no of organisms recaptured}}{\text{Number of marked recaptured organism}}$
- Simpson's index of diversity
- Measure of diversity often used to quantify the biodiversity of a habitat.
- Formula : n : num of individuals of a particular species, N : total num of organisms of all species

$$D = 1 - \left(\frac{\Sigma\, n(n-1)}{N(N-1)} \right)$$

- Pearsons linear correlation
- Evaluates the linear relationship between two continous variables where the data is normally distributed.
- The scatter plot is used to determine if there is a linear relationship
- +1 : positive correlation, -1 : negative correlation, 0 = no correlation
- Formula

$$r = \frac{N\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{[N\Sigma x^2 - (\Sigma x)^2][N\Sigma y^2 - (\Sigma y)^2]}}$$

ere:

N	=	number of pairs of scores
Σxy	=	sum of the products of paired scores
Σx	=	sum of x scores
Σy	=	sum of y scores
Σx^2	=	sum of squared x scores
Σy^2	=	sum of squared y scores

Spearman's rank correlation

Evaluates the non-linear relationship between two ranked variables.

Data must not be normally distributed.

Formula :

$$r_s = 1 - \frac{6\sum D^2}{n\left(n^2 - 1\right)}$$

Chapter 9 : Genetic Technology

a) Genetic engineering

- Human insulin production
- **Insulin gene is identified** (B cells have a lot of mRNA complementary to human insulin gene)
- **Extract mRNA from B cell using reverse transcriptase** to generate complementary DNA (cDNA)
- Single-stranded cDNA is then converted into a double-stranded cDNA using **DNA polymerase**
- **Double-stranded cDNA is cloned** to make multiple copies of cDNA molecules using PCR
- **Restriction enzymes are used to produce sticky ends**, which are non-coding DNA added to the ends of the cDNA.
- This allows the molecules to join up with one another.
- Plasmid are also cut with restriction enzymes
- The **cut plasmid and cloned cDNA are then mixed together** and their sticky ends with complementary base pairs will pair.
- **Recombinant DNA** is created

- The plasmid vectors are **mixed with a culture the bacteria E. coli**.
- Calcium ions are added to improve the uptake of plasmids and heat shock treatment is applied.
- Bacterial cells which take up the recombinant plasmids are said to have been transformed.
- To **identify the genetically modified bacteria**, the bacteria is grown in a nutrient that contains antibiotic.
    - Surviving bacterias are the ones that have successfully taken up the plasmid containing the antibiotic resistant gene.
- To **test if plasmids contain the inserted gene**, one of the three methods can be used
    - The second different antibiotic as marker
    - Plasmids contain and be ampicillin and tetracycline resistance genes.
    - If the insulin gene is inserted within the tetracycline resistance gene, it the disrupts the gene and results in a recombinant plasmid that is not resistant to tetracycline.
    - This can be confirmed by the replica plating.
- Fluorescent marker
    - Marker gene for a protein that fluorescent green under UV light is inserted into plasmid along with the desired gene.
    - Cells that are fluorescent green are likely to have taken up the desired gene.
- Lac Z gene
    - Insertion of insulin gene into the like lac Z region will disrupt the gene responsible to code for enzyme B-galactosidase.
    - Without the enzyme, substrate X gal cannot be broken down to form blue pigment.
    - Recombinant plasmid will not be able to produce B-galactosidase and therefore have a white appearance.
- The **transformed bacteria is then cloned** to produce genetically identical offsprings.

- Advantages of using human insulin produced by bacteria
    - It is chemically identical to human insulin and is an exact fit in human insulin receptors.

- PCR
  - A method of rapid production of large copies of a fragment of DNA.
  - Denaturation (95°C)
  - DNA is denatured
  - Annealing (65°C)
  - Take polymerase can only begin in the presence of a primer.
  - Primers are attached to the ends of the single-stranded DNA.
  - Elongation (72°C)
  - Taq polymerase is used to build new strands of DNA using exposed strand as a template.
  - It will add nucleotides after the primer sequence.
  - Taq polymerase has a very high optimum temperature and does not get destroyed during denaturation step.
- DNA gel electrophoresis
  - This is a method of separating DNA and analysing its molecular structure based on its side.
  - DNA separation is done using a gel that has spaces between the molecules to which DNA can move.
  - The gel is immersed in a buffer solution and electrodes are placed at either end of the gel.
  - DNA samples are pipetted into wells.
  - An electric current is passed through the gel and DNA molecules of different fragments will migrate to the other end of the electrode.
  - Smaller fragments will move further away from the well while larger fragments will stay closer to the well.
  - After DNA fragments have completed the migration, they are stained with ethidium bromide to the visible under UV light.
  - DNA fragments can then be compared with other DNA samples.
  - Genetic fingerprinting is used to identify individuals from each other using DNA.
    - There is a region of DNA called the variable number tandem repeats (VNTR) which are specific to each person.
    - DNA fragments from electrophoresis can be used to compare with other DMA samples. The same DNA will have the same VNTR.

- Protein gel electrophoresis
    - It is done using a gel that has spaces between the molecules.
    - Protein samples are protected into wells.
    - An electric current is passed through the gel.
    - The migration of polypeptide is based on the negative charge of the protein molecules and the size of a polypeptide strand.
    - Gel is stained using commassie blue stain.
- Microarray
    - Micro DNA chip is used to identify the presence of genes and expressed genes.
    - It is based on hybridisation between complimentary strand of single-stranded DNA.
    - mRNA extracted from two samples and reverse transcribed to produce it cDNA.
    - cDNA is amplified using PCR.
    - cDNA is labelled with fluorescent tags then denatured to produce single-stranded DNA.
    - Label cDNA is allowed to hybridise with DNA probe on microarray chip.
    - Under fluorescent detector, if labeled cDNA colour can be detected, means cDNA has hybridise with the probe, if a blue colour is seen means cDNA did not manage to hybridize.
- Bioinformatics
    - Database collection for analysis of biological data using computer software.
    - The database whole sequence of genes, amino acids and proteins.
    - This allows for comparison of a newly sequence Gino with non-genomes and the comparison between amino acid sequences.

c) Genetic technology in medicine

- Examples of other genetically modified proteins besides insulin : Factor VIII, Adenosine delaminase, antithrombin
- Advantages of using bacteria, yeast and cultures of the mammalian cells produce protein
    - Cells have simple nutritional requirements
    - Large volumes of products are produced
    - Few ethical problems as proteins are not extracted from animal sources
- Disadvantages of using bacteria to produce human proteins
    - Bacterias have different methods of protein modifications.
    - Genetic screening test samples of DNA from a group of people to identify the presence or absence of particular alleles and the risk of having or passing on a particular genetic condition.

- Types of genetic screening are carrier screening, prenatal screening, newborn screening, PGD
- If a carrier screening is done, a pedigree analysis can be performed.
- Prenatal screening is to determine the genetic make up of an unborn child.
    - Methods of prenatal screening are amniocentesis and CVS.
    - Aminiocentesis is done at a later stage in pregnancy and has less risk.
    - Testing is done from a sample obtained from the amniotic fluid.
    - CVS is done with the sample obtained from placenta.
- Pre-implantation genetic diagnosis (PGD)
    - It is done during IVF at the 8 cell stage where one cell is removed from the embryo to be analysed.
    - It is used to avoid pregnancy if baby tested positive for genetic disease.
- Adult genetic screening
    - Screening for breast cancer alleles

d) Gene therapy

- Changing the DNA of an individual in an attempt to kill a genetic disease
- Somatic gene therapy works by inserting gene into body cells. Does not affect the gamate cells
- Germline gene therapy works by changing the DNA of cells involved in a sexual reproduction and can be passed on to the next generation.
- Cystic fibrosis is an autosomal recessive disease. It is caused by a defect in the transmembrane protein.
    - A person with cystic fibrosis has abnormally thick mucus in the lungs causing difficulty in breathing and reduced gaseous exchange.
    - CFTR protein acts as a chloride channel to transport chloride ions out of the cell using active transport.
    - As Cl- accumulates outside the cell, water potential decreases and water moves out of the cell by osmosis. Due to the faulty CFTR protein, there is less water found outside the cell area, making the mucus thick and sticky.
- Gene therapy for cystic fibrosis
    - Therapy can be done by adding normal CFTR gene to the DNA of sufferers.
    - Delivery can be done using vectors by viral delivery system or lysosomes
- Viral delivery system uses adenovirus with the virulence removed.
    - They are genetically engineered to carry the normal CFTR protein and used to infect lung cells.
- Liposomes
- Normal CFTR gene is inserted into tiny balls of lipids and sprayed as an aerosol into respiratory passages.

e) Genetic technology in agriculture

- Genetically modified plants
    - Herbicide resistant oil seed rape
        - Genes that allow resistance to herbicide containing glyphosate and glufosinate are inserted into oil seed rape seed cells.
        - Hence this plants do not die when herbicide is sprayed, only weeds will die.
    - Insect resistant maize and cotton
        - To combat pest on crops, pesticides are applied but these pesticides can also harm other beneficial insects.
        - To overcome this problem is genes that code for the protein BT toxin have inserted into maize and cotton plants.
        - Therefore plants will be able to produce this protein and it will be converted into a toxin once inside the guts of the insects that have eaten the leaves.
    - Golden rice
        - Rice has vitamin A content in the aleurone layer but not in the endosperm. However the aleurone is removed during the production of white rice.
        - Gene coding for vitamin A are extracted from bacteria and maize.
        - Gene is inserted into plasmids along with promoter.
    - Plasmid is put into Agrobacterium tumefaciens.
    - Rice embryos are infected with the bacteria and they take up bacteria along with the vitamin A gene.
- Disadvantages of using GM plants
    - How to obtain GM seed in developing countries
    - High cost
    - Possible allergic reactions in humans
    - Cross pollination with wild plants may create resistant weeds
- GM Atlantic salmon
        - Can grow all year long and reduced growth duration

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