SUMMARY OF BIOLOGY A LEVEL

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Content

Energy and Respiration

12.1 Energy

ATP is the universal energy currency as it provides the immediate source of energy for Cellular processes.

a) outline the need for energy in living organisms, as illustrated by anabolic reactions, such as DNA replication and protein synthesis, active transport, movement and the maintenance of body temperature

b) describe the features of ATP that make it suitable as the universal energy currency
   i. The phosphate group in ATP molecules can be easily hydrolyzed and energy is released during hydrolysis.
   ii. The ATP molecule is small and water soluble, so it can move around the cell.
   iii. The turnover rate of ATP is very high.
   iv. The energy packet is small and easily accessible thus ATP is able to act as immediate energy donor.
   v. ATP is the link between energy releasing and energy consuming reactions

c) explain that ATP is synthesised in substrate-linked reactions in glycolysis and in the Krebs cycle
   Four ATP molecules are produced during glycolysis of each glucose.
   Two ATP molecules are produced in Krebs cycle

d) outline the roles of the coenzymes NAD, FAD and coenzyme A in respiration
   i. Coenzymes are organic molecules serving as cofactor in an enzyme, binding only temporarily to the enzyme molecule. They usually act as handle by which enzyme attach.
   ii. Both NAD and FAD acts as hydrogen receptor in glycolysis, link reaction and Krebs cycle and as hydrogen donor in oxidative phosphorylation.
   iii. Coenzyme A acts as acetyl group carrier. It binds an acetyl group from pyruvate in link reaction and take it to Krebs cycle by binding it to oxaloacetate.

e) explain that the synthesis of ATP is associated with the electron transport chain on the membranes of mitochondria and chloroplasts (see 12.2g)
   i. Due to the activity of electron transport chain (ETC), the proton concentration of intermembrane space is much higher than that of matrix in mitochondrion.
   ii. The only way for those protons to diffuse back to mitochondrion matrix is through ATP synthase. When electrons pass through ATP synthase, they drive the enzyme to form ATP molecules from ADP and phosphate.

f) explain the relative energy values of carbohydrate, lipid and protein as respiratory substrates and explain why lipids are particularly energy-rich

a) carbohydrate and protein have similar energy density (energy produced when substrate of unit mass is oxidized) while energy density of lipids doubles that of carbohydrate and protein.

b) Because lipid is more reduced than carbohydrate. It makes more reduced NAD and ATP per molecule. Thus, more aerobic respiration takes place when fat is used as substrate. In addition, fat is only broken down in aerobic respiration.

g) define the term respiratory quotient (RQ) and determine RQs from equations for respiration

Respiratory quotient is the product produced when the volume of carbon dioxide is divided by the volume of oxygen it consumes.

If carbohydrate is used as substrate, RQ of aerobic respiration is 1 while that of anaerobic respiration is ∞.

If lip or protein is used as substrate, RQ will be smaller than 1.

h) carry out investigations, using simple respirometers, to determine the RQ of germinating seeds or small invertebrates (e.g. blowfly larvae)

in respirometers, volume of consumed oxygen is monitored by the decreased volume of air while volume of carbon dioxide produced is monitored by the mass increase of alkali solution

12.2 Respiration

Respiration is the process whereby energy from complex organic molecules is transferred to ATP

a) **list the four stages in aerobic respiration (glycolysis, link reaction, Krebs cycle and oxidative phosphorylation) and state where each occurs in eukaryotic cells**

For each glucose

Stages	Location	Substrate	Product	ATP	NADH	$FADH_2$
Glycolysis	cytoplasm	Glucose	Pyruvate	2	2	0
Link reaction	Mitochondrion matrix	Pyruvate	Acetyl group CO_2	0	2	0
Krebs cycle	Mitochondrion matrix	Acetyl group Oxaloacetate	CO_2	2	6	2
Oxidative phosphorylation	Inner membrane of Mitochondrion	NADH $FADH_2$	H_2O NAD FAD	26-30		
				30-34		

b) **outline glycolysis as phosphorylation of glucose and the subsequent splitting of fructose 1,6-bisphosphate (6C) into two triose phosphate molecules, which are then further oxidised to pyruvate with a small yield of ATP and reduced NAD**

i. glucose is first phosphorylated with consumption of one ATP molecules so as to make it easier to react.
ii. The product will be further phosphorylated with consumption of the second ATP
iii. Then fructose biphosphate is formed and broken into two triose products
iv. Hydrogen is removed from each triose product by NAD and reduced NAD is formed.
v. Pyruvate is the final product of glycolysis, with net two ATP molecules and two reduced NAD formed.

c) **explain that, when oxygen is available, pyruvate is converted into acetyl (2C) coenzyme A in the link reaction**

i. Pyruvate move into the matrix of mitochondrion
ii. pyruvate is decarboxylated, dehydrogenated and combined with coenzyme A (CoA) to give acetyl coenzyme A.
iii. carbon dioxide and reduced NAD is produced

d) outline the Krebs cycle, explaining that oxaloacetate (a 4C compound) acts as an acceptor of the 2C fragment from acetyl coenzyme A to form citrate (a 6C compound), which is reconverted to oxaloacetate in a series of small steps
   i. Krebs cycle takes place in the matrix of mitochondrion
   ii. Oxaloacetate (4C) accepts an acetyl group from acetyl coenzyme A to form citrate (6C)
   iii. Citrate become decarboxylated with a carbon dioxide being released
   iv. The decarboxylated product is dehydrogenated with reduced NAD and reduced FAD.
   v. Substrate level phosphorylation also takes place with ATP molecules being produced.
   vi. Lots intermediate compounds are involved in the cycle and oxaloacetate is regenerated at the end of the cycle.
   vii. All the reactions in the cycle are catalyzed by enzymes
e) explain that reactions in the Krebs cycle involve decarboxylation and dehydrogenation and the reduction of NAD and FAD
f) outline the process of oxidative phosphorylation including the role of oxygen as the final electron acceptor (no details of the carriers are required)
g) explain that during oxidative phosphorylation:
   i. energetic electrons release energy as they pass through the electron transport system
   ii. the released energy is used to transfer protons across the inner mitochondrial membrane
      - Electron transport chain located at the inner membrane of mitochondrion.
      - Reduced NAD and reduced FAD are passed to ETC and gets their hydrogen released. The hydrogen splits into electron and proton.
      - Electron pass along carriers and energy it released pump proton into intermembrane space.
      - Oxygen acts as the final acceptor of protons and electrons. Water is formed at last.
   iii. protons return to the mitochondrial matrix by facilitated diffusion through ATP synthase providing energy for ATP synthesis (details of ATP synthase are not required)
      - Due to the activity of electron transport chain (ETC), the proton concentration of intermembrane space is much higher than that of matrix in mitochondrion.
      - The only way for those protons to diffuse back to mitochondrion matrix is through ATP synthase. When electrons pass through ATP synthase, they drive the enzyme to form ATP molecules from ADP and phosphate.
h) carry out investigations to determine the effect of factors such as temperature and substrate concentration on the rate of respiration of yeast using a redox indicator (e.g. DCPIP or methylene blue)

i) describe the relationship between structure and function of the mitochondrion using diagrams and electron micrographs

each mitochondrion has double membrane

i. inner membrane
   - oxidative phosphorylation takes place at inner membrane
   - the inner membrane is folded to increase surface area
   - all the carriers of electron transport chain and ATP synthase located at inner membrane

ii. intermembrane space
   - protons are pumped into intermembrane space by carriers in ETC, thus it has high proton concentration
   - proton gradient between intermembrane space and matrix enable diffusion of proton through ATP synthase which drives the reaction ADP + Pi -> ATP

iii. matrix
   - matrix contains enzyme for link reaction and Krebs cycle

iv. outer membrane
   - outer membrane is more permeable than inner membrane with presence of carriers for pyruvate and reduced NAD

Some organisms and some tissues are able to respire in both aerobic and anaerobic conditions. When yeast and plants respire under anaerobic conditions, they produce ethanol and carbon dioxide as end-products; mammalian muscle tissue produces lactate when oxygen is in short supply.

j) distinguish between respiration in aerobic and anaerobic conditions in mammalian tissue and in yeast cells, contrasting the relative energy released by each (a detailed account of the total yield of ATP from the aerobic respiration of glucose is not required)

only glycolysis occurs

pyruvate cannot enter mitochondrion thus it become hydrogen acceptor itself

i. in mammalian cells
   - pyruvate is hydrogenated by reduced NAD, producing lactate by lactate dehydrogenase

ii. in yeast cells
   - decarboxylation takes place and pyruvate is converted to ethanal
   - ethanal accept hydrogen from reduced NAD, producing ethanol by ethanol dehydrogenase
   - two steps are involved and the reaction is irreversible

NAD is released from its reduced form and 4 ATP is produced

This allows glycolysis to continue

k) explain the production of a small yield of ATP from respiration in anaerobic conditions in yeast and in mammalian muscle tissue, including the concept of oxygen debt

post-excise uptake of extra oxygen is paying back oxygen deficit

this is oxygen debt and those oxygens are used to:
- conversion of lactate to glycogen in the liver
- reoxygenation of haemoglobin in the blood

l) explain how rice is adapted to grow with its roots submerged in water in terms of tolerance to ethanol from respiration in anaerobic conditions and the presence of aerenchyma

i. It has aerenchyma in stem and roots. This help oxygen to diffuse to roots which is usually shallow. The air film is also trapped on underwater leaves, this also release the pressure of oxygen deficiency in the plants.

ii. When plants are submerged, their internode grow faster, so as the allow their leaves held above water and air can diffuse into plants via stomata. The growth rate is adjusted by gibberellin.

iii. Anaerobic respiration takes place under water and rice has high tolerance of ethanol. There is plenty ethanol dehydrogenase to convert ethanol to unharmful products.

m) carry out investigations, using simple respirometers, to measure the effect of temperature on the respiration rate of germinating seeds or small invertebrates

Photosynthesis

13.1 Photosynthesis as an energy transfer process

Light energy absorbed by chloroplast pigments in the light dependent stage of photosynthesis is used to drive reactions of the light independent stage that produce complex organic compounds.

a) explain that energy transferred as ATP and reduced NADP from the light dependent stage is used during the light independent stage (Calvin cycle) of photosynthesis to produce complex organic molecules

b) state the sites of the light dependent and the light independent stages in the chloroplast
Light dependent reaction takes place at the thylakoid membrane of chloroplast
Light independent reaction takes place at the stroma of chloroplast

c) describe the role of chloroplast pigments (chlorophyll a, chlorophyll b, carotene and xanthophyll) in light absorption inthe grana
   i. Chlorophyll a is primary pigments. It is the center of photosystem. It converts light energy into chemical energy by absorbing photons to excite its electrons.
   ii. Chlorophyll b, carotene and xanthophyll are accessory pigments. They are regular arranged in the light system. They harvest light energy at the wavelength that primary pigment does not absorb and pass on it to primary pigments.

d) interpret absorption and action spectra of chloroplast pigments
   i. absorption spectrum shows absorbance of different wavelength
   ii. action spectrum shows rate of photosynthesis at different wavelength
   action spectrum usually shows similar shape with absorption spectrum. Because the light energy absorbed by pigment is used in photosynthesis. Greater rate of photosynthesis at the wavelength absorb most.

Chromatography is used to identify chloroplast pigments and was also used to identify the intermediates in the Calvin cycle

e) use chromatography to separate and identify chloroplast pigments and carry out an investigation to compare the chloroplast pigments in different plants (reference should be made to Rf values in identification)
   i. both paper and thin layer chromatography can be applied to separate chloroplast pigments
   ii. place spot of extract pigments on pencil mark. Dry and repeat to concentrate the spot
   iii. dip paper in solvent
   iv. measure the distance travelled by solvent front and pigments. Calculated R_f value and compare it with known R_f value.
   v. $R_f = \frac{distance\ traveled\ by\ pigment}{distance\ traveled\ by\ solvent\ front}$

f) describe the light dependent stage as the photoactivation of chlorophyll resulting in the photolysis of water and the transfer of energy to ATP and reduced NADP (cyclic and non-

cyclic photophosphorylation should be described in outline only)

i. photons of different wavelength are absorbed by different pigments (both primary and accessory). The harvested light energy is passed to primary pigment and electrons in the pigment are exited.
ii. Photolysis takes place in photosystem II. Under the action of specialized enzyme, water is split into protons, electrons and oxygen. Those electrons fill the electron cavity of primary pigments.
iii. When electrons are passed through ETC proteins, protons are pumped into thylakoid space. In photosystem I, electrons are activated again.
iv. In non-cyclic photophosphorylation, electrons and protons are then accepted by NADP and form reduced NADP
v. In cyclic photophosphorylation, electrons are passed back to previous electron carrier with ATP being formed.

g) outline the three main stages of the Calvin cycle:
    i. fixation by rubisco of carbon dioxide by combination with ribulose bisphosphate (RuBP), a 5C compound, to yield two molecules of GP (PGA), a 3C compound
        - fixation of carbon dioxide is carried out by enzyme rubisco
        - it catalyses the reaction between RuBP(5C) and carbon dioxide
        - they form an unstable intermediate which immediately turns into two GP (Glycerate Phosphate, 3C)
    ii. the reduction of GP to triose phosphate (TP) involving ATP and reduced NADP
    iii. the regeneration of ribulose bisphosphate (RuBP) using ATP

h) describe, in outline, the conversion of Calvin cycle intermediates to carbohydrates, lipids and amino acids and their uses in the plant cell

13.2 Investigation of limiting factors

Environmental factors influence the rate of photosynthesis. Investigating these shows how they can be managed in protected environments used in crop production.

a) explain the term limiting factor in relation to photosynthesis

Limiting factor is the factor that is lowest among several factors. Thus, the rate of reaction depends on it.

b) explain the effects of changes in light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis

i. light intensity

stronger light intensity, more photons being absorbed and more light dependent reaction takes place. Therefore, more photolysis and more reduced NADP and ATP being produced.

ii. carbon dioxide

higher concentration of carbon dioxide, more carbon dioxide can be fixed by rubisco. Thus, more triose will be produced

iii. temperature

at higher temperature, both substrate and enzyme have higher kinetic energy. Thus, higher collision frequency and higher chance to overcome activation energy.

when temperature become too high, the shape of active site changes making it hard for the combination of substrate. Reaction rate decreases

c) explain how an understanding of limiting factors is used to increase crop yields in protected environments, such as glasshouses

Sensors are used to monitor the light intensity, the humidity of the atmosphere and the concentration of carbon dioxide around the plants. All of these factors are managed by a computer to maximise the yield of the crop.

d) carry out an investigation to determine the effect of light intensity or light wavelength on the rate of photosynthesis using a redox indicator (e.g. DCPIP) and a suspension of chloroplasts (the Hill reaction)

i. Dichlorophenolindophenol (DCPIP) is blue in oxidized form and colorless in reduced form.

ii. It can be put in chloroplast suspension with NADP being deprived. Thus, DCPIP will be reduced instead of NADP and the color change shows the degree of light dependent reaction.

iii. More light dependent reactions take place, more DCPIP would be reduced and paler the solution would become.

e) carry out investigations on the effects of light intensity, carbon dioxide and temperature on the rate of photosynthesis using whole plants, e.g. aquatic plants such as *Elodea* and *Cabomba*

13.3 Adaptations for photosynthesis

All the stages of photosynthesis occur in the chloroplast. Some tropical crops have C4 metabolism and adaptations to maximise carbon dioxide fixation.

a) describe the relationship between structure and function in the chloroplast using diagrams and electron micrographs
   i. a chloroplast is surrounded by two phospholipid membranes
   ii. it has an internal ground substance called the stroma which is the site of Calvin cycle. The stroma contains enzymes such as rubisco and also sugars, lipids and starch.
   iii. A chloroplast has an internal membrane system of fluid-filled sacs called thylakoid which can be stacked to form grana. Grana membranes hold photosynthetic pigments so that the light-dependent stage of photosynthesis can take place.
   iv. The stroma contains circular DNA which codes for some of the chloroplast proteins made by its own small ribosome

b) explain how the anatomy and physiology of the leaves of C4 plants, such as maize or sorghum, are adapted for high rates of carbon fixation at high temperatures in terms of:
   i. the spatial separation of initial carbon fixation from the light dependent stage (biochemical details of the C4 pathway are required in outline only)
      - In mesophyll cells, carbon dioxide is first bind with phosphoenolpyruvate (PEP) to form oxaloacetate by PEP carboxylase.
      - Oxaloacetate is then converted to malate which then moves to bundle sheath cells.
      - RuBP is carboxylated by the carbon dioxide released from malate.
   ii. the high optimum temperatures of the enzymes involved
      The optimum temperature of PEP carboxylase is higher than conventional enzyme.

Homeostasis

14.1 Homeostasis in mammals

Homeostasis in mammals requires complex systems to maintain internal conditions near constant.

a) discuss the importance of homeostasis in mammals and explain the principles of homeostasis in terms of internal and external stimuli, receptors, central control, co-ordination systems and effectors (muscles and glands)

Homeostasis is the maintaining of constant internal environment which mainly refers to blood and tissue fluid. Homeostasis makes sure that the organism is functioning at its optimal condition. Three features of tissue fluid that influence cell activities are:

i. temperature
   at low temperatures, metabolic reactions slow down
   at high temperatures, proteins are denatured and cannot function

ii. water potential
   water potential decreases, water may move out of cells preventing metabolic reactions
   water potential increases, water may enter the cell causing it to swell and maybe burst

iii. concentration of glucose glucose is the fuel for respiration
   low glucose concentration slow down respiration, depriving the cell of an energy source
   high glucose concentration cause water to move out of the cell disturbing the metabolism of the cell

b) define the term negative feedback and explain how it is involved in homeostatic mechanism

i. When receptors detect the changes in factor away from its set point.
ii. Hormone will be released and acts on target organ
iii. Effector performs corrective action which bring factor back to its set

c) outline the roles of the nervous system and endocrine system in coordinating homeostatic mechanisms, including thermoregulation, osmoregulation and the control of blood glucose concentration

thermal regulation

i. When hypothalamus is informed of temperature increase that detected by thermoreceptor in skin, it will send impulses to:
   - Vasodilation: arterioles dilate to encourage heat loss from blood to skin.
   - Sweating: evaporation of sweat takes heat way from body

ii. When hypothalamus is informed of temperature decrease that detected by thermoreceptor in skin, it will send impulses to:
   - Vasoconstriction: arterioles in skin gets narrower, so less blood flow through skin capillaries, preventing heat loss from blood
   - Shivering: muscle contraction releases thermal energy
   - Adrenaline Secretion: Increase rate of respiration, thus more heat is released
   - Raising body hairs: increase insulation of skin

Osmoregulation

i. Water potential of the blood is constantly monitored by osmoreceptor in the hypothalamus.
ii. Osmoreceptor shrink when less water in blood and this stimulate neurosecretory cells in hypothalamus to produce Antidiuretic Hormone (ADH).
iii. ADH is released by posterior pituitary and transport in blood.
iv. The cells of the collecting duct are the target cells for ADH. This hormone acts on the cell surface membranes of the collecting ducts cells, making them more permeable to water than usual.
v. When ADH binds to the receptors on the cell surface membrane of collecting duct, aquaporins will be added to membrane.
vi. Aquaporin is water permeable channel thus more water moves out to interstitial fluid by osmosis.
vii. Concentrated urine is produced and water potential of blood will be increased.

Control of Blood Sugar

i. When rise in blood glucose concentration is detected by β cells
   - β cells in islets of Langerhans of pancreas will release insulin into blood.
   - Insulin binds to receptors in cell surface membrane in liver or muscle.
   - The liver (muscle) cells increase uptake of glucose via allowing their membrane become more permeable to glucose.
   - The liver (muscle) cells reduce their cellular glucose concentration by respiration or conversion of glucose into glycogen.
   - Blood glucose concentration falls.

ii. When decrease in blood glucose concentration is detected by α cells
   - α cells in islets of Langerhans of pancreas will release glucagon into blood.
   - Glucagon acts as cell signaling molecule, binding to receptor on cell surface membrane of liver cell.

- Receptor changes its shape and activates G-protein. Activated G-protein activates adenylyl cyclase which give rise to the formation of cAMP.
- cAMP act as second messenger activate kinase protein. Activated kinase protein activates phosphorylase which leads to the hydrolysis of glycogen.
- This system is called enzyme cascade and signal is amplified in this way. Glycogen hydrolyzed into glucose which is then released into blood, increasing blood glucose concentration.

The kidneys remove wastes from the blood and are the effectors for controlling the water potential of the blood.

d) describe the deamination of amino acids and outline the formation of urea in the urea cycle (biochemical details of the urea cycle are not required)
   i. When more protein than needed is taken, they will be hydrolyzed into amino acids, which cannot be stored.
   ii. They are deaminated in liver, so that the rest of them can be respired or converted to glucose or fat.
   iii. Ammonia bind with carbon dioxide to form urea, which is then taken by nephron and excreted.

e) describe the gross structure of the kidney and the detailed structure of the nephron with its associated blood vessels using photomicrographs and electron micrographs
   i. Kidney
      The whole kidney is covered by a fairly tough capsule, beneath which lies the cortex.
      The central area is made up of the medulla.
      Where the ureter joins, there is an area called the pelvis.
   ii. Nephron
      1. Bowman's capture
         cup-shaped structure surrounded by a tight network of capillaries called a glomerulus
      2. Proximal convoluted tubule
         the twisted tube that out of Bowman's capsule
      3. Henle tube
         a long hairpin loop in the medulla
      4. Distal convoluted tubule
         the twisted tube that out of Henle tube
      5. Collecting duct
         tubule that leads down through the medulla and into the pelvis of the kidney

f) describe how the processes of ultrafiltration and selective reabsorption are involved with the formation of urine in the nephron

i. Ultrafiltration
    1. Ultrafiltration takes place at Bowman's capture.
    2. Because the lumen of afferent arteriole is much larger than efferent arteriole, the hydrostatic pressure is high in Bowman's capture.
    3. Plasma pass through gaps between endothelia cells of capillaries.
    4. Basement membrane act filter. Proteins have molar mass larger than 6800 cannot pass through
    5. Podocytes qualified filtrate which then passes into renal capture.

ii. Selective reabsorption
    1. In proximal convoluted tubule, all the glucose is reabsorbed into blood.
    2. Sodium ion is pumped out of cell into tissue.
    3. Sodium ion concentration decreases inside of cells.
    4. Sodium ion enters tubule cells from lumen by facilitated diffusion, this is secondary active transport.
    5. Sodium ion brings glucose with it. This is co-transport.
    6. Facilitated diffusion of glucose out of cells into tissue fluid.

g) describe the roles of the hypothalamus, posterior pituitary gland, ADH and collecting ducts in osmoregulation

i. ADH secretion
    1. Water potential of the blood is constantly monitored by osmoreceptor in the hypothalamus.
    2. Osmoreceptor shrink when less water in blood and this stimulate neurosecretory cells in hypothalamus to produce Antidiuretic Hormone (ADH).
    3. Once ADH is synthesized, it is transported down the axons of the neurons to their tips, terminating in the posterior pituitary gland.
    4. ADH is released by posterior pituitary and transport in blood.

ii. ADH action
    1. The cells of the collecting duct are the target cells for ADH.
    2. This hormone acts on the cell surface membranes of the collecting ducts cells, making them more permeable to water than usual.
    3. When ADH binds to the receptors on the cell surface membrane of collecting duct, aquaporins will be added to membrane.
    4. Aquaporin is water permeable channel thus more water moves out to interstitial fluid by osmosis.
    5. Concentrated urine is produced and water potential of blood will be increased.

h) explain how the blood glucose concentration is regulated by negative feedback control mechanisms, with reference to insulin and glucagon
   i. when blood glucose increase is detected
      1. β cells of pancreases release insulin into blood
      2. insulin binds to the receptor on the surface of liver or muscle cell
      3. this encourages liver or muscle cell take glucose into cell
   ii. when blood glucose decrease is detected
      1. α cells of pancreases release glucagon into blood
      2. glucagon binds to the receptor on the surface of liver or muscle cell
      3. this encourages liver or muscle cell release glucose into cell

i) outline the role of cyclic AMP as a second messenger with reference to the stimulation of liver cells by adrenaline and glucagon

j) describe the three main stages of cell signaling in the control of blood glucose by adrenaline as follows:
   i. hormone-receptor interaction at the cell surface (see 4.1c)
      1. when increase of blood glucose is detected by α cells
      2. α cells in islets of Langerhans of pancreas will release glucagon into blood.
      3. Glucagon acts as cell signaling molecule, binding to receptor on cell surface membrane of liver cell.
   ii. formation of cyclic AMP which binds to kinase proteins
      1. Receptor changes its shape and activates G-protein. Activated G-protein activates adenylyl cyclase which give rise to the formation of cAMP.
      2. cAMP act as second messenger activate kinase protein.
   iii. an enzyme cascade involving activation of enzymes by phosphorylation to amplify the signal
      1. Activated kinase protein activates phosphorylase which leads to the hydrolysis of glycogen.
      2. This system is called enzyme cascade and signal is amplified in this way. Glycogen hydrolyzed into glucose which is then released into blood, increasing blood glucose concentration.

k) explain the principles of operation of dip sticks containing glucose oxidase and peroxidase enzymes, and biosensors that can be used for quantitative measurements of glucose in blood and urine

i. Dip stick
    1. Urine glucose can be measured by dip sticks.
    2. Stick has pad containing immobilized enzyme that oxidize glucose (peroxidase)
    3. When stick is dipped in urine, glucose reacts to give hydrogen peroxide.
    4. Hydrogen peroxide reacts with colorless substance (chromogen) in the pad to give color change.
    5. Compare the result with color chart. The darker the color, higher urine glucose concentration.
    6. This method is highly specific. It only detects glucose.

ii. Biosensor
    1. The value of blood glucose concentration can be measured by biosensor.
    2. Pad contains glucose oxidase which is an enzyme that react with glucose in blood.
    3. Oxygen is produced in this reaction and electric current is generated and detected by electrode.
    4. The conductance can be transformed into concentration of blood glucose
    5. Biosensor is able to give the numerical value of blood glucose. Thus, biosensor is more precise than dip stick.

l) explain how urine analysis is used in diagnosis with reference to glucose, protein and ketones

14.2 Homeostasis in plants

Stomatal aperture is regulated in response to the requirements for uptake of carbon dioxide for photosynthesis and conserving water.

a) explain that stomata have daily rhythms of opening and closing and also respond to changes in environmental conditions to allow diffusion of carbon dioxide and regulate water loss by transpiration
   i. Opening during the day maintains:
      inward diffusion of carbon dioxide
      outward diffusion of oxygen
      outward diffusion of water vapor in transpiration
   ii. The closure of stomata at night when photosynthesis cannot occur reduces rates of transpiration and conserves water.

b) describe the structure and function of guard cells and explain the mechanism by which they open and close stomata
   i. proton pumps are found at the cell surface membranes of guard cells.
   ii. When stomata try to open during daytime. Those pumps pump protons out.
   iii. The inside of the cell become more negative than the outside
   iv. This opens potassium ion channel and potassium ion move into cell via facilitated diffusion
   v. Chloride ions enter the cell, bringing down the water potential of cell
   vi. Water moves into cell by osmosis through aquaporins
   vii. Volume of guard cells increase and they become turgid
   viii. Due to the unequal thickness of cell wall, stomata open

c) describe the role of abscisic acid in the closure of stomata during times of water stress (the role of calcium ions as a second messenger should be emphasised)
   i. In conditions of water stress, the hormone abscisic acid (ABA) is produced in plants to stimulate stomatal closure.
   ii. Abscisic acid binds to receptors on cell surface membrane.
   iii. This inhibits proton pumps from pumping H^+ out of cell.
   iv. The acidic cytoplasm stimulates Ca^{2+} influx.
   v. Ca^{2+} acts as second messenger encouraging K^+ efflux.
   vi. Water potential of the cell increases and water moves out of cell by osmosis.
   vii. Volume of guard cells decreases and they become flaccid. This is a very fast response.

Control and Coordination

15.1 Control and co-ordination in mammals

The nervous system provides fast communication between receptors and effectors. Transmission between neurones takes place at synapses

a) compare the nervous and endocrine systems as communication systems that co-ordinate responses to changes in the internal and external environment (see 14.1a and 14.1b)

DIFFERENCE	NERVOUS SYSTEM	ENDOCRINE
Communication	Action potential	Hormone
Name of Communication	Electrical & Chemical	Chemical
Mode of Transmission	Neurone	Blood
Response Destination	Muscle & Gland	Target organs & Tissue
Transmission Speed	Faster	Slower
Effect	Specific	Can be wide spread
Duration	Temporary	Permanent
Receptor	On cell surface membrane	On cell surface membrane within cell

b) describe the structure of a sensory neurone and a motor neurone

i. sensory neurone
- In cell body
  - Nuclear
  - Many mitochondria
  - Many Rough Endoplasmic Reticulum
- Conductance
  - Long dendron — conducts nerve impulses from a synapse to the cell body
  - Short axon — conducts nerve impulses from the cell body to its synaptic knobs
  - Schwann cells — insulation
  - Nodes of Ranvier — conducting point
- Synaptic knobs — the swollen terminal ends of axons

ii. motor neurone
- In cell body
  - Nucleus
  - Many mitochondria
- Conductance
  - Dendrites lead to cell body
  - Long axon
  - Myelin made by Schwann cells
  - Node of Ranvier
- Synaptic knob at end furthest from cell body

c) outline the roles of sensory receptor cells in detecting stimuli and stimulating the transmission of nerve impulses in sensory neurones (a suitable example is the chemoreceptor cell found in human taste buds)

In human taste bud, there are numerous chemoreceptor cell that is able to transfer chemical stimuli into electrical signal, acting as a transducer.

i. Sodium ion diffuses into cell via microvilli, depolarizing cell membrane
ii. The potential change of the receptor membrane stimulates opening of calcium ion channel
iii. Entrance of calcium ion causes movement of vesicles containing neurotransmitter
iv. The neurotransmitter releases by exocytosis stimulate action potential in sensory nerve

d) describe the functions of sensory, relay and motor neurones in a reflex arc. The endocrine system is a slower system that controls long-term changes. Fertility may be controlled by use of hormones.

sensory neurones	transmit impulses from receptors to the CNS
relay neurones	transmit impulses from sensory neurones to motor neurones
motor neurones	transmit impulses from the CNS to effectors.

e) describe and explain the transmission of an action potential in a myelinated neurone and its initiation from a resting potential (the importance of sodium and potassium ions in impulse transmission should be emphasised)

i. transmission of action potential
    1. When action potential arrives, sodium ion channel opens. Sodium ion flow in and the membrane become depolarized.
    2. Then, the sodium ion channel closes and the potassium ion channel opens. Potassium ion flow out and the membrane become polarized.
ii. myelinated neurone
    1. myelin insulates ion movement
    2. action potential only occurs at the nodes of Ranvier
    3. saltatory conduction jump from node to node
iii. back to resting potential
    1. The resting potential is produced and maintained by the sodium–potassium pumps in the cell surface membrane.
    2. They constantly move sodium ions, Na^+, out of the axon, and potassium ions, K^+, into the axon. The sodium–potassium pumps are membrane proteins that use energy from the hydrolysis of ATP to move both of these ions against their concentration gradients.
    3. Three sodium ions are removed from the axon for every two potassium ions brought in

f) explain the importance of the myelin sheath (saltatory conduction) in determining the speed of nerve impulses and the refractory period in determining their frequency

i. Myelin sheath speeds up the transport of nerve impulses because depolarization only takes place at the nodes of Ranvier and action potential jumps from node to node.

ii. Myelin sheath also shortens the refractory period, because only the membrane at nodes is depolarised and need to be repolarized.

g) describe the structure of a cholinergic synapse and explain how it functions, including the role of calcium ions

i. presynaptic membrane

Action potential arrives at the presynaptic membrane

Stimulate the opening of voltage-gated channels for calcium ions.

Calcium ion diffuse into cytoplasm

Causing vesicles containing acetylcholine to move towards presynaptic membrane and fuse with it

ii. synaptic cleft

Acetylcholine is released and diffuse across synaptic cleft

iii. postsynaptic membrane

Acetylcholine bind with receptor at the postsynaptic membrane

Sodium channel at the postsynaptic membrane open

Sodium ion diffuse into postsynaptic membrane and depolarize it

h) outline the roles of synapses in the nervous system in allowing transmission in one direction and in allowing connections between one neurone and many others (summation, facilitation and inhibitory synapses are not required)

i) describe the roles of neuromuscular junctions, transverse system tubules and sarcoplasmic reticulum in stimulating contraction in striated muscle

i. neuromuscular junction

1. in presynaptic membrane, when action potential arrives, the depolarization opens calcium ion channel in presynaptic membrane
2. calcium ion enters presynaptic knob
3. vesicles containing neurotransmitter fuse with presynaptic membrane
4. neurotransmitter is released and diffuse across synaptic cleft
5. it binds to receptor on sarcolemma
6. sodium ion channel in sarcolemma opens and sodium ions enters

ii. transverse system tubules

1. due to the entrance of sodium ion, sarcolemma is depolarized
2. the action potential spread along sarcolemma and transverse system of tubules is depolarized

iii. sarcoplasmic reticulum

1. the depolarization opens calcium ion channel at sarcoplasmic reticulum
2. calcium ions diffuse out of sarcoplasmic reticulum and bind with troponin
3. this initiate muscle contraction

j) describe the ultrastructure of striated muscle with particular reference to sarcomere structure

Components	Thick filament only	Thin filament only	Both
H	Yes		
I		Yes	
A	Yes		Yes

i. thick filament is composed of myosin
   1. myosin is fibrous protein with globular head
   2. many myosin molecules all lie together to form thick filament of 15 nm in diameter
   3. M line provides attachment for myosin

ii. thin filament is composed of actin
   1. actins are globular proteins; they combine to form a chain
   2. actin chains twisted with fibrous protein, tropomyosin to form thin filament
   3. troponin binds to thin filament and tropomyosin covers the binding site for myosin head
   4. Z line provides attachment for actin

k) explain the sliding filament model of muscular contraction including the roles of troponin, tropomyosin, calcium ions and ATP

i. the shape of troponin changes when calcium ions bind to it
ii. Tropomyosin moves exposing the binding sites on actin
iii. Myosin head hydrolyzes ATP to form ADP and Pi
iv. Myosin head bind with actin when the binding site is exposed, forming cross bridge
v. myosin head to tilt
vi. ADP and Pi detach from myosin head and new ATP binds
vii. Myosin head detach from actin and returns to previous position
viii. Actin is moved and muscle contraction takes place

The endocrine system is a slower system that controls long-term changes. Fertility may be controlled by use of hormones.

l) explain the roles of the hormones FSH, LH, oestrogen and progesterone in controlling changes in the ovary and uterus during the human menstrual cycle

i. FSH and LH are released by anterior pituitary to stimulate the development of follicles in ovary
ii. Follicle cells then produce oestrogen and the concentration of oestrogen rises for first 12 days
iii. The concentration rise of oestrogen causes endometrium to thicken
iv. Around day 14, there will be a surge in concentration of LH and this result in ovulation
v. Corpus luteum develops, producing progesterone which further thicken the endometrium of uterus
vi. If no fertilization takes place, the secretion of FSH and LH will be inhibited and corpus luteum degenerates
vii. The concentration of progesterone falls and the endometrium breaks down; menstruation occurs

m) outline the biological basis of contraceptive pills containing oestrogen and/or progesterone

i. The contraceptive pills containing oestrogen and progesterone suppress ovulation by inhibiting secretion of FSH from anterior pituitary gland.
ii. This stops follicle formation as well as ovulation.
iii. For contraceptive pills that containing only progesterone, they allow ovulation to take place but stimulates the secretion of cervical mucus which prevent the entrance of sperms.
iv. For contraceptive pills that containing synthetic progesterone-like hormone, they prevent the implantation of fertilized egg.

15.2 Control and co-ordination in plants

Plant co-ordination systems can involve rapid responses as in the case of the Venus fly trap, as well as complex interactions between plant growth regulators, such as auxin and gibberellin. Plants respond quite differently to different concentrations of plant growth regulators.

a) describe the rapid response of the Venus fly trap to stimulation of hairs on the lobes of modified leaves and explain how the closure of the trap is achieve
   i. Action potential spreads over leaf to hinge cell
   ii. Proton is then pumped out of cells and cell walls become loosen
   iii. Calcium pectate dissolves in middle lamella
   iv. Calcium ion enter cell and water follow by osmosis
   v. Cell expand and change from convex to concave
   vi. Trap shuts with 0.3 second.
b) explain the role of auxin in elongation growth by stimulating proton pumping to acidify cell walls
   i. Auxin stimulate proton pumps and protons are pumped into cell wall by active transport
   ii. pH of cell wall decreases, activating pH dependent enzyme.
   iii. Bonds between cellulose microfibrils is broken and cell wall loosens
   iv. Water enters cell and cell wall expands
c) describe the role of gibberellin in the germination of wheat or barley
   i. Gibberellin moves from embryo to aleurone layer
   ii. Gene is switched on to make mRNA for amylase.
   iii. Amylase is produced, hydrolyzing starch into maltose
   iv. Maltose is oxidized in respiration and ATP is produced and used for cell division in embryo.
d) explain the role of gibberellin in stem elongation including the role of the dominant allele, Le, that codes for a functioning enzyme in the gibberellin synthesis pathway, and the recessive allele, le, that codes for a non-functional enzyme
   i. Gibberellin is controlled by gen Le. Dominant allele gives functional enzyme which converts inactive to active gibberellin.
   ii. Without GA, transcription factor attached to DELLA protein.
   iii. GA binds to receptor complex, destroying DELLA protein.
   iv. Transcription factor binds to DNA and gene is transcribed.
   v. Active gibberellin stimulates cell division and cell elongation in the stem, so causing the plant to grow tall.
   vi. Like auxin, it also increases internode length and loosens cell wall, so as to allow entrance of water and elongation of cells.

Inherited change

16.1 Passage of information from parent to offspring

Diploid organisms contain pairs of homologous chromosomes. The behavior of maternal and paternal chromosomes during meiosis generates much variation amongst individuals of the next generation.

a) **explain what is meant by homologous pairs of chromosomes**
   i. *Homologous chromosomes*
      a pair of chromosomes in a diploid cell that have the same structure, with the same genes at the same loci, and that pair together to form a bivalent during meiosis.

b) **explain the meanings of the terms haploid and diploid and the need for a reduction division (meiosis) prior to fertilisation in sexual reproduction**
   i. *Haploid*
      cell which contains only one set of chromosomes
   ii. *Diploid*
      cells contain two sets of chromosomes
   iii. *Reduction division is needed*
      so as to maintain the number of chromosomes in diploid cell unchanged through generations

c) **outline the role of meiosis in gametogenesis in humans and in the formation of pollen grains and embryo sacs in flowering plants**
   i. *spermatogenesis in man*
      spermatogonia (2n) reproduce itself by mitosis and develop into primary spermatocyte (2n). Being through the first division of meiosis, primary spermatocyte forms two haploid, secondary spermatocyte(n) which produce spermatids(n) when second division of meiosis takes place. Spermatids (n) then mature into spermatozoa(n).
   ii. *Oogenesis in woman*
      oogonia (2n) reproduce itself by mitosis and develop into primary oocyte (2n). Primary oocyte then produce two haploid secondary oocyte and a polar body (a nuclear). Secondary oocyte complete the second division of meiosis only when it is fertilized.
   iii. *Formation of pollen grains*
      inside the anthers, diploid pollen mother cell divide by meiosis to form four haploid cells. The nuclei of each of these haploid cells then divide by mitosis, but the cell itself does not divide, resulting in cells that each contain two haploid nuclei. These cells mature into pollen grains
   iv. *Formation of embryo sacs*
      Inside each ovule, a large, diploid, spore mother cell develops. This cell divides by meiosis to produce four haploid cells. All but one of these degenerates, and the one surviving haploid cell develops into an embryo sac

d) **describe, with the aid of photomicrographs and diagrams, the behaviour of chromosomes in plant and animal cells during meiosis, and the associated behaviour of the nuclear envelope,**

cell surface membrane and the spindle (names of the main stages are expected, but not the sub-divisions of prophase)

i. in meiosis I

Chromosomes condenses and homologous chromosomes pair form bivalents.
Chromatids in bivalent for chiasma and crossing over takes place.
Nuclear envelope disappear.
Spindle fibres attach to centromeres and bivalents line up on equator. The assortment (of homologous pairs) is independent.
Chromosomes move to two ends of cell.
Nuclear envelope reforms and cytokinesis takes place.

ii. in meiosis II

chromosomes line up on equator that at right angles to first equator
centromeres divide and chromatids separate
A chromatids move to (opposite) poles to form a haploid.
Nuclear envelope reforms and cytokinesis takes place.

e) explain how crossing over and random assortment of homologous chromosomes during meiosis and random fusion of gametes at fertilisation lead to genetic variation including the expression of rare, recessive alleles

i. in prophase 1, crossing over between non-sister chromatids of homologous chromosomes allows exchange of genetic material. Linkage groups were thus broken.
ii. during metaphase 1, random assortment of homologous chromosomes create new combination of alleles
iii. at metaphase 2 independent assortment of sister chromatids also create new combination of alleles
iv. possible chromosome mutation create new alleles while random mating and random fusion allows new combination of genes.

16.2 The roles of genes in determining the phenotype

Patterns of inheritance are explained by using genetic diagrams. The results of genetic crosses are analysed statistically using the chisquared test. Studies of human genetic conditions have revealed the links between genes, enzymes and the phenotype.

a) **explain the terms gene, locus, allele, dominant, recessive, codominant, linkage, test cross, F1 and F2, phenotype, genotype, homozygous and heterozygous**

i. *Gene*
length of DNA that codes for a particular protein or polypeptide.

ii. *Allele*
variation of gene.

iii. *Locus*
position of gene

iv. *Dominant*
allele always express itself

v. *Recessive*
more than one allele only express itself when homozygous

vi. *Codominant*
more than one allele express themselves

vii. *Linkage*
Linkage is the presence of two genes on the same chromosome, so that they tend to be inherited together and do not assort independently

viii. *Test cross*
genetic cross in which an organism showing a characteristic caused by a dominant allele is crossed with an organism that is homozygous recessive

ix. *F1 and F2*
F1 generation is the offspring resulting from a cross between an organism with a homozygous dominant genotype , and one with a homozygous recessive genotypes. F2 generation is the offspring resulting from a cross between two F1 (heterozygous) organisms.

x. *Phenotype*
characteristics of an organism

xi. *Genotype*
allele possessed by an organism

xii. *Homozygous*
two identical alleles of a gene

xiii. *Heterozygous*
having two different alleles of a gene

b) **use genetic diagrams to solve problems involving monohybrid and dihybrid crosses, including those involving autosomal linkage, sex linkage, codominance, multiple alleles and gene interactions**

c) use genetic diagrams to solve problems involving test crosses

parental phenotype

parental genotype

gametes

offspring genotype and phenotype

d) use the chi-squared test to test the significance of differences between observed and expected results (the formula for the chi-squared test will be provided)

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Chi-squared test is used to find out if the observed value follows the pattern we expected. If the chi-square we obtained is smaller than probability 0.05, the we say that there is no significant difference between observed and expected value. 95% probability that the difference is due to chance.

e) explain that gene mutation occurs by substitution, deletion and insertion of base pairs in DNA and outline how such mutations may affect the phenotype

mutation gives different sequence of nucleotides, thus polypeptides with different sequence of amino acids will be produced thus gives different shape of protein.

f) outline the effects of mutant alleles on the phenotype in the following human conditions: albinism, sickle cell anaemia, haemophilia and Huntington's disease

i. *albinism*

failure to synthesis melanin (a pigment)

ii. *anaemia*

abnormal shape of hemoglobin. Make them tend to stick with each other and fail to transport oxygen

iii. *haemophilia*

failure to synthesis a protein needed for blood clotting

iv. *Huntington's* disease

HD is a neurological disorder resulting in involuntary movements (chorea) and their brain cells are dead. It is caused by a mutation on autosomal chromosomes and the culpable allele is dominant.

Normal recessive allele has 10-35 CAD repeats. People with HD have a larger number CAG repeats. The onset age of HD varies and is usually after 28. People with higher CAG repeats have earlier onset age. People with extremely large CAG repeat may develop disease in their babyhood.

The excessive CAG repeats give huntingtin protein extra length of polyglutamine tail, causing a misfolded protein.

g) explain the relationship between genes, enzymes and phenotype with respect to the gene for tyrosinase that is involved with the production of melanin

The normal TYR gene would produce an enzyme called tyrosinase.

Tyrosinase is a transmembrane protein in melanocyte and involves in conversion of DOPA to melanin, a pigment.

Mutant allele is recessive and tyrosinase will not be produced in homozygous recessive people.

People with albinism will have very pale skin color

16.3 Gene control

Some genes are transcribed all the time to produce constitutive proteins; others are only 'switched on' when their protein products are required.

a) distinguish between structural and regulatory genes and between repressible and inducible enzymes

structural gene and regulatory gene

structural gene is the gene that code structural protein/ enzyme/ rRNA, such as:

1. transporter protein which is responsible for transportation of substance between cells
2. receptor protein which is responsible for recognizing signal molecules
3. insulin which is responsible for bringing down blood sugar

regulatory gene is the gene controls gene expression, including:

1. gene codes for transcription factor or DNA-binding protein
2. gene allows the binding of promoter, operator
3. gene stops or allows, binding of RNA polymerase
4. repressor (such as A lac repressor/ DELLA repressor) and inducer

b) explain genetic control of protein production in a prokaryote using the *lac* operon

promoter	operator	lacZ	lacY	lacZ
Allow the binding of RNA polymerase	Allow the binding of repressor	β-galactosidase gene	β-permease	β-galactoside transacetylase gene

β-galactosidase is the enzyme responsible for the hydrolysis of lactose.

β-permease allows lactose to enter cell

In the absence of lactose, lac repressor protein binds to operator. β-galactosidase will not be able to synthesized, because its RNA polymerase cannot bind to operator.

In the presence of lactose, lactose binds to lac repressor, distorting its shape and preventing it from binding to DNA at the operator site. RNA binds to promotor site and transcription takes place.

c) explain the function of transcription factors in gene expression in eukaryotes

i. General transcription factors are necessary for transcription to occur. promoter allows the binding of RNA polymerase, so as to activate gene expression
ii. Other factors activate appropriate genes in sequence, controlling, when, where and how much, the gene is, expressed
iii. A transcription factor is responsible for the determination of sex in mammals
iv. Transcription factors allow responses to environmental stimuli.

d) explain how gibberellin activates genes by causing the breakdown of DELLA protein repressors, which normally inhibit factors that promote transcription

Gibberellin controls seed germination by stimulating the synthesis of amylase.

A DELLA protein inhibits the binding of a transcription factor, such as PIF, to a gene promoter

Gibberellin breaks down the DELLA protein, allowing PIF to bind to promoter.

Transcription of the gene can then take place, resulting in an increase in amylase production.

Selection and evolution

17.1 Variation

The variation that exists within a species is categorised as continuous and discontinuous. The environment has considerable influence on the expression of features that show continuous (or quantitative) variation.

a) describe the differences between continuous and discontinuous variation and explain the genetic basis of continuous (many, additive genes control a characteristic) and discontinuous variation (one or few genes control a characteristic) (examples from 16.2f may be used to illustrate discontinuous variation; height and mass may be used as examples of continuous variation)

i. continuous variation

there is a range of phenotypes such as heights and the traits usually fit normal distribution. The variation may cause by genes or environment. The continuous variation are usually polygenic and different genes or alleles have an additive effect; environment factors such as nutrients, light intensity, temperature, water availability, soil pH and mineral availability.

ii. discontinuous variation

qualitative differences fall into clearly distinguishable categories, with no intermediates. different alleles at a single gene locus have large effects on the phenotype. different genes have quite different effects on the phenotype

b) explain, with examples, how the environment may affect the phenotype of plants and animals

Environmental effects may allow the full genetic potential height to be reached or may stunt it in some way. Plants or animals with the same genotype may show difference in the same property (such as height) due to the different water, light and nutrient they got.

c) use the *t*-test to compare the variation of two different populations (see Mathematical requirements)

$$t = \frac{|\overline{x_1} - \overline{x_2}|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$\overline{x_1}$ and $\overline{x_2}$ are the means of sample 1 and 2

s_1 and s_2 are the standard deviations of sample 1 and sample 2

n_1 and n_2 are the number of individuals measurement in sample 1 and sample 2

d) explain why genetic variation is important in selection

Variation caused by gene can pass to the next generation while that caused by environment cannot. Thus, genetic variation provides raw material for selection to act on.

17.2 Natural and artificial selection

Populations of organisms have the potential to produce large numbers of offspring, yet their numbers remain fairly constant year after year.

a) **explain that natural selection occurs as populations have the capacity to produce many offspring that compete for resources; in the 'struggle for existence' only the individuals that are best adapted survive to breed and pass on their alleles to the next generation**

As a population of increases, various environmental factors come into play to keep down the numbers.

i. Biotic factor – caused by other living organisms:
   1. predation by other animals
   2. competition for food
   3. infection by pathogens

ii. Abiotic factor- they may be caused by non-living components of the environment:
   1. water supply
   2. nutrient levels in the soil.

In the 'struggle for existence' only the individuals that are best adapted survive to breed and pass on their alleles to the next generation

b) **explain, with examples, how environmental factors can act as stabilising, disruptive and directional forces of natural selection**

i. in stabilizing selection

Environment stays constant. Several factors may act as acts as a selective agent. organisms best adapted to these conditions survive while extreme phenotypes (usually caused by mutation) are selected against narrow range of genetic variation is thus maintained

ii. in directional selection

Environment changes. The changed factor acts as selective agent. some individuals (in population) are better adapted and they are more likely to survive

iii. disruptive selection

populations develop in different places where factors act as selective agent behave very differently

c) **explain how selection, the founder effect and genetic drift may affect allele frequencies in populations**

i. genetic drift

a change in allele frequency that occurs by chance, because only some of the organisms of each generation reproduce.

comparing with natural selection, genetic drift happened by chance and it shows no trends in result.

ii. founder effect

Further genetic drift in the small population will alter the allele frequencies and evolution of this population may take a different direction from that of the larger parent population. This process, is called the founder effect

d) use the Hardy–Weinberg principle to calculate allele, genotype and phenotype frequencies in populations and explain situations when this principle does not apply

When a particular phenotypic trait is controlled by two alleles of a single gene: A/a

p is the proportion of allele A while q is the proportion of allele a.

Phenotype	A		a
Genotype	AA	Aa	aa
Proportion	q^2	$2pq$	q^2
	$p + q = 1$ $p^2 + 2pq + q^2 = 1$		

These Hardy–Weinberg calculations do not apply when the population is small or when there is:

signifcant selective pressure against one of the genotypes

migration of individuals carrying alleles into, or out of, the population

non-random mating

Humans use selective breeding (artificial selection) to improve features in ornamental plants, crop plants, domesticated animals and livestock.

e) describe how selective breeding (artificial selection) has been used to improve the milk yield of dairy cattle

Desired features include docility, fast growth rates and high milk yields.

Individuals showing these desired features are chosen for breeding.

After many generations, frequency of allele for desired features increased.

This is directional selection

f) outline the following examples of crop improvement by selective breeding:

i. the introduction of disease resistance to varieties of wheat and rice

expose crops to virus that causes disease. Select individuals that are unaffected. breed them together and repeat for several generations ;

ii. incorporation of mutant alleles for gibberellin synthesis into dwarf varieties so increasing yield by having a greater proportion of energy put into grain

gibberellin synthesis is controlled by allele Le, which is dominant, while mutant allele le is recessive causing dwarfism

Le gives functional enzyme which converts inactive gibberellin to active

iii. inbreeding and hybridisation to produce vigorous, uniform varieties of maize

Desirable characteristic includes more kernels, big kernels, high yield, fast-growing, cold-tolerant and dwarfism caused by mutant allels.

Plants shown desirable features crossed repeatedly in every generation. Collect pollens in male tassels and apply them to female silks.

Cross two homozygous parents from two purebred lines

That gives more, vigorous, uniform, plants.

17.3 Evolution

Isolating mechanisms can lead to the accumulation of different genetic information in populations, potentially leading to new species. Over prolonged periods of time, some species have remained virtually unchanged, others have changed significantly and many have become extinct.

a) state the general theory of evolution that organisms have changed over time

Individuals varied in their phenotypes and phenotypic variation are caused by genetic variation or mutation. selection pressure changes as environment changes. The chance of some individuals surviving increases because they are better adapted. Survivors breed, passing on alleles to offspring changed allele frequency in population

b) discuss the molecular evidence that reveals similarities between closely related organisms with reference to mitochondrial DNA and protein sequence data

for many proteins, small changes in the amino acid sequence leave the overall structure and the function of the protein unaltered. When the amino acid sequence of a particular protein is compared in different species, the number of differences gives a measure of how closely related the species are.

c) explain how speciation may occur as a result of geographical separation (allopatric speciation), and ecological and behavioural separation (sympatric speciation)

i. allopatric speciation (geographical separation)

It takes place when a population of a species separated with other populations by geographic barrier, preventing interbreeding with other populations. Its allele frequency may change significantly due to the very different selection pressure in the new environment. Over time, the isolated population became so different from the other populations that the two populations could no longer interbreed. A new species had evolved

ii. sympatric speciation (behavioural and ecological separation)

Population in one species behaves very differently due to mutation. They do not interbreed with other populations of that species. Over time this population cannot interbreed with other populations and reproductive isolation takes place. A new species had evolved

d) explain the role of pre-zygotic and post-zygotic isolating mechanisms in the evolution of new species

i. Prezygotic (before a zygote is formed) isolating mechanisms include:
   1. individuals have no willing to mate
   2. physically unable to mate
   3. inability of a male gamete to fuse with a female gamete

ii. Postzygotic isolating mechanisms include:
   1. failure of cell division in the zygote
   2. non-viable offspring or viable, but sterile offspring

both pre-zygotic and post -zygotic isolation help stabilize the existing and new species

e) explain why organisms become extinct, with reference to climate change, competition, habitat loss and killing by humans

i. direct human effect (e.g. hunting / fishing / collection / skins)
ii. habitat destruction
iii. climate change and increase in pollution
iv. increase, in disease or new disease
v. lack of food for animals or loss of pollinators
vi. increased predation
vii. competition from alien species

Biodiversity, Classification and Conservation

18.1 Biodiversity

Biodiversity is much more than a list of all the species in a particular area.

a) define the terms species, ecosystem and niche

i. species

a group of organisms can interbreed to produce fertile offspring

ii. ecosystem

area that is self-contained and functional. It is the place where interactions of biotic (competition and predation) and abiotic (light, water and nutrient) components takes place.

iii. niche

the role of an organism in an ecosystem

b) explain that biodiversity is considered at three different levels:

i. variation in ecosystems or habitats

different habitats and different niches have different climate, rainfall, temperature, soils. Thus, provide different selection pressure.

When area of habitats decreases or fragments:

1. individuals in population would have less choice of mates, resulting in inbreeding and inbreeding depression afterwards. Population then suffers decrease in genetic variation.
2. Fragmentation of habitats may also result in possible difficulties in finding enough food.
3. small areas are more vulnerable to damage than larger ones and more easily exposed to danger outside area

ii. the number of species and their relative abundance

large difference in ecosystems and habitats allows large variety of species

when the size of population decreases, genetic diversity decreases, increasing chance of two harmful recessive alleles coming together (inbreeding depression). Hence there will be a decrease in hybrid vigor and species would become less likely to survive, because less likely to adapt to change in environmental conditions

iii. genetic variation within each species

variety in habitats allows survival of species with different traits, thus produce large genetic variation

c) explain the importance of random sampling in determining the biodiversity of an area

to avoid bias

d) use suitable methods, such as frame quadrats, line transects, belt transects and mark-release-recapture, to assess the distribution and abundance of organisms in a local area

i. quadrats
random sampling by using random number generator for coordinates
using quadrats to sample and measure the percentage cover of specific species

ii. line transects

iii. belt transects

iv. mark-release-recapture
set a trap with bait (live mammal or chocolate) in it
mark the trapped animals by painting or clipping fur
after half a year, set trap again
calculate the population size

$$\frac{number\ caught\ time\ 1 \times number\ captured\ time 2}{number\ of\ marked\ individuals\ recaptured\ time\ 2}$$

publish reports online
calculating numbers per unit area by computer modelling

e) use Spearman's rank correlation and Pearson's linear correlation to analyse the relationships between the distribution and abundance of species and abiotic or biotic factors

Spearman's Rank correlation $\mathrm{r_s} = 1 - (\frac{6 \times \sum D^2}{n^3 - n^2})$

$\mathrm{r_s}$ is Spearman's rank coefficient
$\sum D^2$ is the sum of the differences between the ranks of the two samples
n is the number of samples
Null hypothesis is that the two species are not correlated. If the r_s we calculated is bigger than the critical value at the 0.05 probability, indicating that the chance for null hypothesis is less than 0.05. Null hypothesis is then rejected and there is significant correlation between the two species.

Pearson's linear correlation $\mathrm{r} = \frac{\sum xy - n\bar{x}\bar{y}}{ns_x s_y}$

r is the correlation coefficient
x and y are the numbers of individuals in each species in each quadrat
n is the number of quadrats used in calculation
$\bar{x}$ and $\bar{y}$ are the mean numbers of each species
$\mathrm{s_x}$ and $\mathrm{s_y}$ are the standard deviation for the numbers of each species
r=+1 suggests total positive correlation
r=-1 suggests total negative correlation
r=0 suggests no correlation

f) use Simpson's Index of Diversity (D) to calculate the biodiversity of a habitat, using the formula $\mathbf{D = 1 - (\sum \left(\frac{n}{N}\right)^2)}$and state the significance of different values of *D*

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

n is the number of specific species in the sample
N is total number of organisms in the sample
Sites with larger D shows greater diversity

18.2 Classification

Organisms studied locally may be used to show how hierarchical classification systems are organised.

a) describe the classification of species into the taxonomic hierarchy of domain, kingdom, phylum, class, order, family, genus and species

i. genus

organisms in the same genus show similar appearance and behavior, they usually share a same word in their Latin name such *Canthon ebenus* and *Canthon pilularius*

ii. species

organism with the same morphology and behavior features and are able to breed to produce fertile offspring

b) outline the characteristic features of the three domains Archaea, Bacteria and Eukarya

i. Archaea

ii. Bacteria

iii. Eukarya

Cells have a nucleus and membrane-bound organelles (mitochondria/ER/golgi)
ribosomes are, large/22nm/ 80
DNA is linear and histones present
cytoskeleton/ microtubules/ undulipodia/ cilia ;

c) outline the characteristic features of the kingdoms Protoctista, Fungi, Plantae and Animalia

i. animalia

eukaryotic cells with energy stored in glycogen
centrosomes and cell skeleton such as cilia, flagella and microvilli present
no cell wall or large central vacuole

ii. plantae

eukaryotic cells with chloroplasts, large vacuole, walls made of cellulose
multicellular with differentiated cells
most of them have vascular tissue (xylem and phloem)
most are not motile and motile gametes only in mosses and ferns
autotrophic nutrition by photosynthesis

d) explain why viruses are not included in the three-domain classification and outline how they are classified, limited to type of nucleic acid (RNA or DNA) and whether these are single stranded or double stranded

i. viruses have none of the features we traditionally used for classification. They do not have either cellular structure or metabolism

ii. its classification based on the type of nucleic acid (RNA or DNA) and number of strands.

18.3 Conservation

Maintaining biodiversity is important for many reasons. Actions to maintain biodiversity must be taken at local, national and global levels. It is important to conserve ecosystems as well as individual species.

a) **discuss the threats to the biodiversity of aquatic and terrestrial ecosystems (see 18.1b)**

when there is a decrease of large carnivores

1. increase in population of herbivores and decrease in number of plants due to overgrazing. Lack of food causes increased competition and numbers decline of herbivore
2. damage of habitat, such as erosion may take place
3. reduction in biodiversity and disruption to food web

b) **discuss the reasons for the need to maintain biodiversity**

i. maintain food chains
ii. maintain stability in ecosystems
iii. maintain, genetic diversity
iv. conserve resources for humans (e.g. biofuel/ food/medicine/wood)
v. aesthetic reasons (eco)tourism;
vi. maintain, nutrient cycle, soil structure, climate stability;

c) **discuss methods of protecting endangered species, including the roles of zoos, botanic gardens, conserved areas (national parks and marine parks), 'frozen zoos and seed banks**

i. zoo and botanic garden
    1. captive breeding program
    2. research animals to find about their behavioral and habitat requirements.
    3. give them health care and adequate food
    4. assist their reproduction
    5. release them to the wild
ii. conserved areas
    1. build national parks or rangers patrol parks, protecting its habitat
    2. in which human access restricted, providing protection from predators or hunter
    3. controlled agriculture and controlled industry;
    4. visitor centers, so as to provide relative education to public
iii. seed bank

    advantage of conserving in seed banks

    1. seeds are small and easier to store
    2. seeds can be stored for a long time
    3. little maintenance required
    4. less prone to, disease or being eaten
    5. seeds can be stored anywhere in the world

    seed stored in a seed bank is germinated every few years

    1. to check that seeds are still, viable
    2. to to produce new plants from which fresh seeds can be collected
    3. to find conditions for breaking seed dormancy

d) discuss methods of assisted reproduction, including IVF, embryo transfer and surrogacy, used in the conservation of endangered mammals

i. IVF (in vitro fertilization)
Oocytes are collected by inserting a needle into the ovaries and withdrawing some mature follicles. The oocytes are then mixed with semen.

ii. Embryo Transfer
The resulting zygotes divide to form embryos and then placed into the mother

iii. Surrogacy
if embryo transferred to other females of the same or different species, they are called surrogate mother
.

e) discuss the use of culling and contraceptive methods to prevent overpopulation of protected and non-protected species

i. Culling is often used to reduce numbers

ii. Chemical contraceptives are available
1. Sedate male wild mammals and cutting their sperm ducts (vasectomy)
2. vaccine is used disable eggs of female

f) use examples to explain the reasons for controlling alien species

i. may compete with other species for food and habitat

ii. may be predators of other species

iii. may spread disease to other species

iv. may reduce population sizes or cause extinction of other species

v. may spread, disease to humans or bite humans

g) discuss the roles of non-governmental organisations, such as the World Wide Fund for Nature (WWF) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), in local and global conservation

i. banning hunting as well as sale of protected animals or their products

h) outline how degraded habitats may be restored with reference to local or regional examples

This can be done on a small scale when a farmer decides to plant trees on land that is no longer needed for food production or has become degraded by overuse

Genetic Technology

19.1 Principles of genetic technology

Genetic engineering involves the manipulation of naturally occurring processes and enzymes. Genome sequencing gives information about the location of genes and provides evidence for the evolutionary links between organisms.

1. define the term recombinant DNA
   Recombinant DNA is DNA made by joining pieces from two or more different sources.
2. explain that genetic engineering is the deliberate manipulation of genetic material to modify specific characteristics of an organism and that this may involve transferring a gene into an organism so that the gene is expressed
3. **explain that genes to be transferred into an organism may be:**
   i. **extracted from the DNA of a donor organism**
   ii. **synthesised from the mRNA of a donor organism**
   iii. **synthesised chemically from nucleotides**
4. **explain the roles of restriction endonucleases, DNA ligase, plasmids, DNA polymerase and reverse transcriptase in the transfer of a gene into an organism**
5. **explain why a promoter may have to be transferred into an organism as well as the desired gene**
6. **explain how gene expression may be confirmed by the use of marker genes coding for fluorescent products**
7. **explain that gene editing is a form of genetic engineering involving the insertion, deletion or replacement of DNA at specific sites in the genome**
8. describe the principles of the polymerase chain reaction (PCR) to clone and amplify DNA (the role of *Taq* polymerase should be emphasised)
   PCR is used to amplify DNA of the samples, so enough copies of samples can be used to analyze.
   i. DNA samples were heated to 95℃ initially, so as to separate the two strands by breaking hydrogen bonds between bases. Bases were then exposed producing template strands for complementary copying
   ii. Primer were added afterwards. DNA polymerase only attaches to double-stranded DNA. The addition of primers can reduce re-annealing of separated strands. Primer binds to DNA by complementary base pairing. The sequence is carefully designed , making it attaches close to the specific section of DNA.
   iii. *Taq* polymerase is added to synthesises complementary DNA strands. *Taq* polymerase is heat stable (works at high temperature). *Taq* polymerase does not need to be added again for each cycle, thus process is, more efficient than normal DNA polymerase.

9. describe and explain how gel electrophoresis is used to analyse proteins and nucleic acids, and to distinguish between the alleles of a gene (limited to the separation of polypeptides and the separation of DNA fragments cut with restriction endonucleases)

   Different DNA and protein can be separated because:

   i. net (overall) charge
      1. negatively charged molecules move towards the anode (+) and positively charged molecules move towards the cathode (–)
      2. highly charged molecules move faster than those with less overall charge
   ii. size
      1. smaller molecules move through the gel faster than larger molecules
   iii. composition of the gel – common gels are polyacrylamide for proteins and agarose for DNA; the size of the 'pores' within the gel determines the speed with which proteins and fragments of DNA move

   Variable number tandem repeats (VNTRs) is a region of DNA that is known to vary between different people is chosen. Restriction endonucleases is used to cut regions among VNTRs into pieces. Different VNTRs produce different fragments which behave differently in electrophoresis.

10. describe the properties of plasmids that allow them to be used in gene cloning
    i. Plasmids are small circles of DNA.
    ii. It contain genes for enzymes to enable DNA transfer to host cells
    iii. It also has restriction sites that allow restriction endonucleases to work on
    iv. It has its own origin of replication and is able to multiply independently
    v. Some plasmids also have marker genes allowing people to find out successfully transformed cells
11. explain why promoters and other control sequences may have to be transferred as well as the desired gene

    Regulatory gene is also transferred so that transcription factors and RNA polymerase can bind to it, switching on the expression of gene in interest
12. explain the use of genes for fluorescent or easily stained substances as markers in gene technology

    It can be used to distinguish transformed bacteria from those fail to be transformed.
13. explain the roles of restriction endonucleases, reverse transcriptase and ligases in genetic engineering
    i. restriction endonucleases

       enzyme that cuts DNA or plasmids, producing sticky ends. This enzyme is derived from bacteria which is initially used to destroys viral DNA
    ii. reverse transcriptase

       enzyme that produces cDNA from mRNA
    iii. ligase

       enzyme that joins gaps in the sugar-phosphate backbone of DNA
    iv. DNA polymerase

       enzyme that produces double stranded DNA from single stranded DNA or cDNA ;

14. **explain, in outline, how microarrays are used in the analysis of genomes and in detecting mRNA in studies of gene expression**

Genome is all the genetic material in a person's cell.

i. Probes are short lengths of ssDNA which is complementary to the alleles being tested for. Many copies of one type of probe placed in each cell of the microarray.

ii. Target alleles are made single-stranded and labelled with fluorescent 'tags'.

iii. Target alleles bind with probes. Unbound target alleles were then washed off. UV light is used to detect presence of the hybridised probes.

19.2 Genetic technology applied to medicine

a) define the term bioinformatics

Databases or computer programs used to analyze biological information sequences

b) outline the role of bioinformatics following the sequencing of genomes, such as those of humans and parasites, e.g. *Plasmodium* (details of methods of DNA sequencing are not required)

Sequencing the genome of plasmodium can help us to

1. identify the location of genes.
2. Predict the primary structure and 3D structure of proteins
3. identify the functions of proteins from its 3D structure and find drugs that block activity or expression of protein or denature the protein

c) explain the advantages of producing human proteins by recombinant DNA techniques (reference should be made to some suitable examples, such as insulin, factor VIII for the treatment of haemophilia and adenosine deaminase for treating severe combined immunodeficiency (SCID))

i. insulin treatment for diabetes
   1. protein produced by rDNA techniques is identical to that produced by body, thus they have the same activity and no immune response
   2. insulin produced by rDNA is uncontaminated, so there is no risk of disease
   3. compared with the traditional costly extraction from animals, it is much more efficient
   4. it has no need to kill large number of animal for their insulin, so as not to contradict with religious or for ethical reasons believing

ii. factor VIII treatment for haemophilia

iii. deaminase treatment for SCID (severe combined immunodeficiency)

d) outline the advantages of screening for genetic conditions (reference may be made to tests for specific genes such as those for breast cancer, *BRCA1* and *BRCA2*, and genes for haemophilia, sickle cell anaemia, Huntington's disease and cystic fibrosis)

Advantage

If present, enables lifestyle change, early treatment , regular check-ups

If not present removes worry

Preventative treatment may be cheaper than treating disease itself

Disadvantage

If present may cause worry

If present person may not develop cancer

Test is expensive

May have implications for life insurance

May decide to not have children

i. breast cancer

people with BRCA1 or BRCA2 gene have much higher chance to get breast cancer

ii. haemophilia

genetic screening could reduce the number of cases of haemophilia. First we identify females who are carriers and they can choose not to have children. If she want to have children, a pre-implantation genetic diagnosis can be carried out. She can choose abortion if embryo has allele and select unaffected IVF embryo to implant.

iii. sickle cell anaemia

iv. Huntington's disease

The advantage of gene screening

People can choose whether to have children.

They can prepare for the future

If the result is negative, it removes anxiety

The disadvantage of gene screening

If the result is positive, no treatment possible and anxiety may thus raise.

If the result is positive, patient maybe social discriminated

Even if positive, they may still not develop disease

v. Cystic fibrosis

Mechanism

People with cystic fibrosis have no functional channels for Cl^- ions, thus Cl^- ions cannot move out. Less water leaves cell and mucus on cell surface membrane stays thick

Symptoms of cystic fibrosis involves:

mucus cannot be moved effectively by cilia, causing reduced gaseous exchange in lungs, difficulty in breathing and more infections due to the bacteria trapped in mucus.

lungs are scarred. sperm ducts and pancreatic duct are blocked in patients

e) outline how genetic diseases can be treated with gene therapy and discuss the challenges in choosing appropriate vectors, such as viruses, liposomes and naked DNA (reference may be made to SCID, inherited eye diseases and cystic fibrosis)

Gene therapy is the therapy to treat disease caused by faulty recessive allele, such as SCID and cystic fibrosis, by delivering the other allele into target cells of individuals. Functional protein could be produced, restoring cellular functions. Gene therapy is used to reduce the symptoms of the disorder and increase the quality of life.

If virus is used as vector, treatment is needed to make sure that it does not spread or activate immune response.

i. SCID
ii. Inherited eye diseases
iii. Cystic fibrosis
iv. Huntington's disease

Huntington's disease cannot be treated with gene therapy, because gene therapy only used to treat recessive allele disorders. But Huntington's allele is dominant, so the abnormal protein will still be expressed even when, normal allele is present. Dominant allele cannot be removed, thus it still affects tissues in many parts of the body.

f) discuss the social and ethical considerations of using gene testing and gene therapy in medicine (reference should be made to genetic conditions for which treatments exist and where none exist, also to IVF, embryo biopsy and preselection and to therapeutic abortions)

i. IVF

ii. Embryo biopsy

removing a cell from an embryo for testing

iii. Preselection

Advantage

Less chance of Huntington allele being passed on ,

People with the faulty allele who otherwise would not have children

Ethical concern

Embryos might be destroyed in the process.

It is wrong for parents to be the designer of their embryos

It contradict with beliefs

iv. Therapeutic abortions

g) outline the use of PCR and DNA testing in forensic medicine and criminal investigations

19.3 Genetically modified organisms in agriculture

The ability to manipulate genes has many potential benefits in agriculture, but the implications of releasing genetically modified organisms (GMOs) into the environment are subject to much public debate in some countries.

a) explain the significance of genetic engineering in improving the quality and yield of crop plants and livestock in solving the demand for food in the world, e.g. Bt maize, vitamin A enhanced rice (Golden rice™) and GM salmon

i. Bt maize
   1. Bt toxins were originally produced by soil bacterium *B. thuringiensis*. Different strains of *B thuringiensis* produced slightly different toxins which are toxic to different insects.
   2. Bt maize have been genetically modified to produce proteins which specifically to kill the larvae of butterflies and moths, including the insects that eat it but harmless to other animals.
   3. Crops thus can produce their own insecticide, increasing its yield without using insecticide.

ii. Golden rice (vitamin A enhanced rice)
   1. Vitamin A are found in aleurone layer of rice seeds. White rice does not contain vitamin A.
   2. Genes coding for vitamin A production extracted from bacteria and maize.
   3. Vitamin A gene as well as promoters are inserted into plasmids which is used as a vector.
   4. Plasmids put into bacterium, *Agrobacterium tumefaciens*, and mixed with rice embryos. Some embryos take up bacteria and vitamin A gene.
   5. They grow into adult plants, producing seeds with vitamin A in endosperm
   6. Golden rice are used to overcome vitamin A deficiency in rice-consuming populations

iii. GM salmon
   1. A growth-hormone regulating gene from a Pacifc Chinook salmon and a promoter from another species of fish, an ocean pout, were injected into a fertilised egg of an Atlantic salmon.
   2. By producing growth hormone throughout the year, the salmon are able to grow all year, instead of just in spring and summer. As a result, fish reach market size in about eighteen months, compared with the three years needed by an unmodified fish.

b) outline the way in which the production of crops such as maize, cotton, tobacco and oil seed rape may be increased by using varieties that are genetically modified for herbicide resistance and insect resistance

Manual weeding is expensive. If herbicide resistant variety is produced, herbicide can be applied to kill weeds or pests, without hurting crops. It reduces competition between crops and weeds and increase yield

c) discuss the ethical and social implications of using genetically modified organisms (GMOs) in food production

Most objections are raised against the growth of herbicide-resistant or insect-resistant crops. The concerns about these genetically modified crops are as follows:

i. The modified crop plants may become agricultural weeds or invade natural habitats.
ii. The introduced genes may be transferred by pollen to wild relatives whose hybrid offspring may become more invasive.
iii. The introduced genes may be transferred by pollen to unmodified plants growing on a farm with organic certification.
iv. The modified plants may be a direct hazard to humans, domestic animals or other beneficial animals, by being toxic or producing allergies.
v. Genetically modified seeds are expensive, as is herbicide, and their cost may remove any advantage of growing a resistant crop.