A2 Module 5 essays – Part 2 of 2

Quality of written communication:

2 marks:	The candidate expresses ideas clearly and fluently through well-linked sentences, which present relationships and not merely list features. Points are generally relevant and well-structured. There are few errors of grammar, punctuation and spelling.

Old June 2008

8 Give an account of anaerobic respiration as a metabolic pathway, and of its role and consequences in exercising muscle. [13]

8 Thirteen points, with a maximum of eight points in either section.

The metabolic pathway of anaerobic respiration:

- the metabolic pathway mostly involves glycolysis
- use of ATP to phosphorylate glucose
- to fructose bisphosphate
- which splits into two triose phosphate molecules
- triose phosphate is oxidised by NAD^+
- to glycerate bisphosphate
- with the release of NADH ($+H^+$)
- glycerate bisphosphate converted to pyruvate
- this is an exergonic reaction/this step provides the energy for the synthesis of ATP
- there is a net production of 2 ATP from the breakdown of one glucose molecule
- pyruvate is reduced by NADH
- to NAD^+ to allow glycolysis to continue
- lactate is produced

The role and consequences of anaerobic respiration:

- anaerobic respiration is not limited by the availability of oxygen (since the regeneration of NAD^+ allows glycolysis to continue)
- essentially a small amount of ATP is produced at a rapid rate
- representing extra ATP production over and above that generated aerobically
- this is important in strenuous exercise (such as sprinting)
- this is short-lived however
- since the lactate produced is toxic
- following the burst of strenuous activity lactate is removed
- most lactate (five sixths) is converted back to glucose
- an energy requiring process with ATP generated aerobically
- the higher rate of aerobic respiration after the exercise is known as the oxygen debt
- some of the lactate (one sixth) is used as substrate for aerobic respiration [13]

Old June 2007 **(NO LONGER ON THE SPECIFICATION)**

8 Give an account of micropropagation (plant tissue culture), explaining:

(a) the techniques involved, including the selection of the tissues to be propagated, the maintenance of sterile conditions, the nutrients used in the culture medium and the use of plant growth regulators; [7]

(b) the advantages and problems associated with producing plants by tissue culture. [6]

8 (a) Seven points

- parent plant with a desired trait is selected
- selection of explant containing meristematic tissue/totipotent tissue
- excised plant tissue is surface sterilised using hypochlorite solution
- to remove surface bacteria and fungi
- procedures carried out in a laminar flow cabinet (providing stream of finely filtered, spore-free air and so ensuring that potentially contaminating spores on the operators' clothing or hands are carried out of the cabinet)/aseptic technique
- explant transferred to culture medium
- this culture medium is composed of sterile agar jelly
- which contains a source of carbohydrate/sucrose/a range of mineral ions/ vitamins/a source of nitrogen/amino acids
- addition of growth regulators such auxin and cytokinins stimulates cell division/callus formation
- higher cytokinin levels induce shoot development
- higher auxin concentrations induce root formation
- tissues are cultured under controlled environmental conditions
- callus is sub-divided to produce new plantlets (every four to eight weeks)
- plantlets are hardened off/grown on in a fogging greenhouse [7]

(b) Six points (with at least two from each section)

Advantages:

- production of a very large number of plants/from a small initial amount of tissue/cost-effective plant production
- plant diseases can be avoided/disease-free plants can be produced
- plants can be produced at any time of the year
- clone produced with the desired, selected trait
- production of exotic plants such as orchids which are hard to produce in large numbers from seed/cuttings
- micropropagation can be linked with genetic engineering (production of many new plants from a genetically modified cell)
- hybridisation potential by fusing cell protoplasts
- allows maintenance of rare varieties
- allows rapid production of a new variety

Problems:

- mutant plants are likely to be produced (due to large number of cell divisions involved)
- there is a requirement for sterile/aseptic conditions to be maintained/need for special growth rooms
- specialist training is required for staff involved in micropropagation
- plants produced are susceptible to infection (since they are identical)/all plants produced are clones and a disease can potentially wipe out the entire population
- only applicable to high value plants [6]

8 Give an account of trends which have evolved within the plant kingdom as revealed by a comparison of the following aspects in the life cycles of **mosses, ferns** and **flowering plants**.

- dependence on water for fertilisation
- spore production and the outcome of spore production [13]

8 Thirteen points (with at least five from each section)

Dependence on water for fertilisation:

- mosses are dependent on water droplets (rain) to splash the sperm from the antheridial cups into the archegonial cups
- and are dependent on water in which flagellated sperm swim
- towards egg within the archegonium/down the neck of the archegonium towards the egg at its base
- in ferns flagellated sperm swim in a film of water
- on the underside of the prothallus towards the archegonia
- in flowering plants fertilisation is independent of water
- since generative nucleus/male gametes are contained within pollen grains/ pollen tubes
- in which they are protected from desiccation (by a tough outer wall)
- pollen grains are carried by wind or insects during transfer to the stigma
- on the stigma pollen tubes grow to carry the male gametes towards the egg-containing ovules
- eggs are enclosed within ovules (embryosac)/ovules are enclosed within the ovary
- overall there is a trend towards a lack of dependence on water for successful fertilisation
- and thereby adaptation towards a more terrestrial existence

Spore production and the outcome of spore production:

- in all plants spores are produced by meiosis
- in mosses spores are produced in individual capsules
- in ferns spores are produced within sporangia clustered in sori/protected by an indusium
- individual fern leaves have numerous sori (many sori on each pinna and many pinnae on each leaf) and so produce vast numbers of spores
- in mosses the spore develops into a protonema (and thereafter into a leafy plant)
- in ferns the spore develops into a prothallus/gametophyte
- flowering plants are heterosporous
- microspores (pollen grains) are produced within the anthers/pollen sacs
- a microspore (pollen grain) gives rise to the male gametophyte
- within which the male gametes are produced
- megaspores (embryosacs) are produced within ovules
- embryosac represents the female gametophyte
- giving rise (after a few mitotic divisions) to the female gamete (egg) [13]

Old June 2004

8 (a) Give an account of how food is obtained and digested in each of the following animal phyla.

- Cnidaria
- Platyhelminthes
- Annelida [9]

(b) Describe **four** trends in the evolution of the above animal phyla. [4]

8 (a) Nine points (three from each phylum)

Cnidaria:
- live prey paralysed by stinging cells (nematocysts) and captured food is conveyed to the mouth by tentacles
- gut cavity is a simple sac/non-digestible material is voided via the mouth
- initial digestion is extracellular
- initial products of digestion are absorbed by endocytosis
- final digestion is intracellular

Platyhelminthes:
- planarians are detritivores/carnivores
- food is ingested by the eversion of a muscular pharynx
- gut cavity is blind-ending and branched (and highly folded)
- initial digestion is extracellular, but it is completed intracellularly
- branching of gut facilitates the distribution of the products of digestion to body cells (no circulatory system)

Annelida:
- act as detritivores
- the gut is a canal with both a mouth and an anus
- the one-way nature of the canal allows specialisation along the gut/ example of specialisation, e.g. a crop for the storage of food
- digestion is extracellular only
- nutrients are absorbed into and distributed by a well developed circulatory system

[9]

(b) Any four points
- evolution from radial symmetry to bilateral symmetry
- from diploblastic condition to triploblastic
- evolution of the coelomate condition
- the development of a one-way gut/and so regional specialisation
- development towards extracellular-only digestion
- adaptation for getting nutrients to all body cells/development of a circulatory system for the distribution of absorbed nutrients
- development of metameric segmentation [4]

Old January 2003

9 Give an account of the biochemistry of photosynthesis including in your account an explanation of the following.

- how a chloroplast is structurally adapted for photosynthesis
- light-dependent phase
- light-independent phase (Calvin cycle) [13]

9 **Any thirteen points**

Chloroplast structure:

- the chloroplast has an internal membrane system or lamellae/organised into sac-like thylakoids/which are stacked into grana and joined by inter-granal lamellae
- the light-dependent phase takes place on the lamellae (since the chlorophyll is located there)
- large surface area of lamellae within granal structures increases the amount of chlorophyll accommodated
- chloroplasts may orientate so that lamellae face the sun resulting in full illumination of chlorophyll
- the light-independent phase/Calvin cycle takes place in the stroma (chloroplast matrix)
- since it contains the enzymes of the light-independent phase/Calvin cycle
- starch produced within the chloroplast may appear as starch grains

Light-dependent phase:

- light is absorbed by chlorophyll and other pigments/mostly red and blue light absorbed
- light causes the excitation of electrons within the pigments whereby their energy level is raised
- within individual photosystems (conglomerates of pigments) electrons are emitted from a primary pigment/accepted by an electron acceptor
- electrons from photosystem I (PSI) pass to $NADP^+(+H^+)$ (after being accepted by ferredoxin) to form NADPH
- to form NADPH
- electrons "lost" from PSI are replaced from photosystem II (PSII)
- from PSII the electrons (after being accepted by plastoquinone) pass through a series of electron carriers (at progressively lower energy levels)
- this is coupled to the production of ATP (photophosphorylation)
- hydrogen ions (from the dissociation of water) combine with $NADP^+$ to form $NADPH^+ (+H^+)$
- electrons "lost" from PSII are replaced from hydroxyl ions/water
- resulting in the release of oxygen

Light-independent phase (Calvin cycle):

- carbon dioxide is fixed by ribulose bisphosphate
- to form two molecules of glycerate phosphate
- which is reduced by NADPH to triose phosphate
- involving consumption of ATP
- $\frac{5}{6}$ of the triose phosphate is regenerated to ribulose bisphosphate
- the remaining $\frac{1}{6}$ is converted to C_6 sugars and other compounds [13]

Old June 2003

9 Give an account of the biochemistry of respiration. The account should include an explanation of the following.

- glycolysis
- Krebs cycle
- oxidative phosphorylation (respiratory chain)
- precise location of the above processes in a cell

[13]

9 **Any thirteen points**

Glycolysis:

1 • use of ATP to phosphorylate glucose
2 • to fructose bisphosphate
3 • which splits into two triose phosphate molecules
4 • triose phosphate is oxidised by NAD^+
5 • to glycerate bisphosphate
6 • with the release of NADH ($+H^+$)
7 • this NADH must be reoxidised to NAD^+ to allow glycolysis to continue/ NAD^+ must be recycled to allow glycolysis to continue
8 • glycerate bisphosphate is converted to pyruvate
9 • pyruvate represents end of glycolysis
10 • this is an exergonic reaction/this step provides the energy for the synthesis of ATP
11 • there is a net production of 2 ATP from the breakdown of one glucose molecule
12 • glycolysis is common to both aerobic and anaerobic pathways
13 • if O_2 present pyruvate passes into mitochondrion

Krebs cycle:

14 • where pyruvate is converted to acetyl-CoA
15 • producing CO_2 and NADH ($+H^+$)
16 • the acetyl group combines with a C_4 acid
17 • to produce a C_6 acid
18 • the C_6 acid undergoes a series of reactions through other organic acids
19 • some of which involve decarboxylation (CO_2 produced)
20 • and dehydrogenation (hydrogen released)
21 • producing NADH or, in one case, $FADH_2$
22 • NADH and $FADH_2$ deliver hydrogens to respiratory chain
23 • an ATP is produced (exergonically) directly in one step
24 • the C_4 acid is regenerated

Oxidative phosphorylation (respiratory chain):

25 • from the initial hydrogen carrier, hydrogen is passed to flavoprotein
26 • and then to co-enzyme Q
27 • thereafter, only electrons are carried through the cytochromes
28 • a series of redox reactions
29 • these carriers are at progressively lower energy levels
30 • at certain points in the chain sufficient energy is available for ATP to be produced
31 • three from NADH, and two from $FADH_2$
32 • protons and electrons recombine
33 • oxygen is the ultimate hydrogen/electron acceptor
34 • producing water

Sites of biochemical activity:

35 • glycolysis takes place in the cytoplasm
36 • Krebs cycle takes place in the mitochondrial matrix
37 • the respiratory chain takes place on the inner membrane of the mitochondria/ cristae

[13]

Old June 2003

8 Give an account of genetic variation, evolutionary change and speciation. The account should include an explanation of the following.

- The source and maintenance of genetic variation
- The role of natural selection in evolutionary change
- The role of isolating mechanisms in the evolution of species [13]

8 Thirteen points, at least three points from each section

The source and maintenance of genetic variation:

- genetic variation will result from the process of meiosis (when gametes are produced in animals)/meiosis will produce a variety of haploid cells
- this is due to the independent assortment of homologous chromosomes
- when the partner of one homologous pair will separate with either partner of any other homologous pair
- due to the random alignment of homologous chromosomes during metaphase I
- genetically either allele of a genetic locus will segregate with either allele of another locus (provided the loci are on different chromosomes, i.e. they are not linked)
- also during meiosis chiasmata will occur
- between the chromatids of homologous pairs
- during prophase I
- genetically alleles which were previously linked may be separated (and alleles which were previously not linked may be brought together)
- cross-fertilisation of haploid cells (gametes) will further generate genetic variation
- since alleles from different parents will be combined together
- gene mutation is the source of new alleles in any population
- and results from the spontaneous change of the base sequence in DNA
- polyploidy is a form of chromosome mutation
- resulting from the non-disjunction of a complete set of chromosomes

The role of natural selection in evolutionary change:

- natural selection acts on the variation in a population
- of the different forms of natural selection it is directional selection which brings about evolutionary change
- in this a non-modal form, not previously favoured, is selected for
- this can be due to an environmental change
- the form being selected for survives more frequently to reproduce
- in competition for resources with other members of the population
- and so passes more of its genes to future generations
- in this way the frequency of alleles will change over time
- and the population remain adapted to its environment
- it is the change in allele frequency which constitutes evolutionary change
- in different environments the same species will often have different variants

The role of isolating mechanisms in the evolution of species:

- in the theory of allopatric speciation populations are geographically isolated
- for long enough to accumulate sufficiently different allele frequencies to behave as different species
- different species are genetically isolated/cannot generally interbreed
- this isolation is maintained by some reproductive isolating mechanism
- polyploidy has resulted in the formation of new species in plants
- where a previously sterile hybrid
- has fertility restored with chromosome doubling
- since meiosis can resume/viable gametes can be formed [13]

Old June 2003

5 Write an account of "the role of proteins in living organisms".

Your account should show understanding of at least **three** topics which you have studied. [13]

5 Three points from any three of the following plus any other four points

General:
- proteins are made according to instructions encoded by the cell's DNA
- they are chains of amino acids (primary structure) which adopt a helical shape (secondary structure)
- they can be either fibrous or globular in nature
- globular proteins have a precise three dimensional shape
- due to bonds between (non-adjacent) amino acids which hold folds in the chain
- the precise shape of globular proteins allows them to interact specifically with other molecules

Enzymes:
- enzymes are globular proteins which catalyse metabolic reactions
- they reduce the activation energy for the reaction
- the substrate combines with a small part of the enzyme called the active site
- the enzyme's active site has regions which form chemical bonds to hold the substrate in place
- in anabolic reactions this can lead to the substrate molecules being orientated in such a way as to facilitate their reaction (and so reducing activation energy)
- the active site may be induced as the substrate collides with it (induced-fit hypothesis)
- in catabolic reactions a conformational change in the shape of the enzyme may put a "strain" on the substrate so facilitating the breaking of bonds (so reducing the activation energy)

Respiratory pigments:
- haemoglobin carries (and releases) oxygen
- it has a quaternary structure being composed of four polypeptide chains (two α-chains and two β-chains)
- it is also a conjugated protein since each polypeptide complexes with an iron-containing haem prosthetic group
- if the partial pressure of oxygen is high (as in the lungs) haemoglobin saturates with oxygen/oxyhaemoglobin is produced
- if the partial pressure of oxygen is low (as in muscle tissue) oxyhaemoglobin dissociates to release oxygen
- further oxygen will be released if the CO_2 concentration is high/pH is low/ temperature is high (the Bohr effect)
- myoglobin is a similar molecule (though smaller) which carries oxygen
- it is found in red muscle and only releases oxygen when the partial pressure of oxygen in the tissue is very low (as during strenuous exercise)

Membrane proteins:
- many enzymes are bound to membranes (within the endoplasmic reticulum, mitochondria, chloroplasts and Golgi apparatus)
- some cell-surface membrane proteins have hydrophilic channels through which some ions and molecules can move
- some membrane proteins act as carriers in active transport or facilitated diffusion
- such carriers have specific receptor sites for the attachment of particular ions or molecules (which do not dissolve in lipid)
- a conformational change in the shape of the carrier results in that molecule being deposited on the other side of the membrane
- other membrane proteins may act as specific receptors for hormones (such as insulin) or for neurotransmitters (such as acetylcholine)

- or have carbohydrate attached (glycocalyx) on the outer face of the cell-surface membrane and are important in cell recognition and interactions between cells

Immunoglobulins:
- both B-cells and T-cells have protein receptors on their surface membranes which combine with a specific antigen
- in response the B-cells divide to form plasma cells which produce specific globular proteins called immunoglobulins
- which are secreted into the blood as antibodies (humoral immunity)
- immunoglobulins (antibodies) have a specific region which attaches to the antigen forming an antibody-antigen complex (resulting in the removal of the antigen)
- T-cells have surface receptors (similar to immunoglobulins) to which antigens attach leading to their removal (cellular immunity)

Actin and myosin in muscle cells:
- myosin (thick) filaments in muscle cells are composed of myosin proteins molecules with a fibrous "rod" and a globular "head"
- actin (thin) filaments in muscle cells are helical strands of the globular protein actin (which twist round each other)
- when stimulated (release of calcium ions) the myosin head is able to bond chemically with a specific attachment site on an actin molecule
- an actomyosin cross-bridge is formed
- the myosin heads rotate and change their angle (conformational change in structure)
- this pulls the actin filaments over the myosin filaments and disengages (dependent on ATP hydrolysis)
- the myosin head repeats its attachment and as it rotates again further pulls on the actin filament (towards the centre of the sarcomere) – the muscle cell contracts

Other fibrous proteins:
- collagen is a fibrous protein and is a main constituent of tendons and ligaments/ tunica externa of arteries and veins/sclera of the eye/serosa of the gut
- keratin is a fibrous protein which occurs in nails, hair and the outer layer of the skin
- elastin is a fibrous protein which gives elasticity to ligaments and arteries

Other conjugated proteins:
- chlorophyll is a conjugated protein with a magnesium-containing porphyrin prosthetic group
- chlorophyll absorbs light, the energy causing the excitation of electrons
- cytochromes are conjugated iron-containing proteins
- they are involved in the transfer of electrons (coupled with phosphorylation) in respiration or photosynthesis

Other cellular proteins:
- tubulin is a globular protein which join to form microtubules
- which form part of the cytoskeleton
- and the spindle fibres

Other blood proteins:
- prothrombin is a plasma protein which during the process leading to clotting is converted to thrombin (by thromboplastin released when platelets break down)
- fibrinogen is converted to fibrin, a fibrous protein which forms the network of fibres constituting a clot
- any other appropriate and equivalent point [13]

5 Write an account of "the influence of light in living organisms".

Old June 2002

Your account should show understanding of, at least, three topics which you have studied. [13]

5 **Three points from any three of the following plus any other four points**

Producers:

- sunlight represents the energy source of producers/green plants convert solar energy into chemical energy during photosynthesis
- the efficiency of energy transfer is very low (approximately 1 to 2%)
- of the solar energy falling on a leaf much (approximately 50%) is of unsuitable wavelength (e.g. green)
- some solar energy is also not available as it is transmitted or reflected
- the energy incorporated into glucose molecules represents the gross primary production
- since energy is released during respiration the amount available for the production of new tissues is reduced and is known as the net primary production/producers represent the energy source of all consumers

Plant physiology:

- plant leaves have a large surface area/leaf arrangement/ "follow" the sun for maximum light absorption
- tightly packed cells in the palisade mesophyll allow maximum light absorption
- mesophyll cells contain many chloroplosts
- chloroplasts possess an elaborate system of lamellae on which light-absorbing pigments are located
- light-absorbing pigments include different types of chlorophyll, xanthophyll and carotene (which together contribute to the action spectrum)
- sun leaves are thick while shade leaves are thin
- stomata open during the day and close at night

Photosynthesis:

- light is absorbed by pigment systems containing chlorophyll and results in the emission of electrons
- electrons pass through a carrier system during which ATP is produced (photosynthetic phosphorylation)
- photosystem II regains electrons from water resulting in the formation of oxygen
- light is absorbed by two photosystems and from the photoactivation of PSI electrons are absorbed by $NADP^+$ to form NADPH
- the net products of the light-dependent reactions are NADPH and ATP which are used in the formation of triose phosphate (carbohydrate)
- photosynthesis involves carbon fixation whereby ribulose bisphosphate is joined with carbon dioxide to form glycerate phosphate (phosphoglyceric acid)

Photoperiodic control of flowering:

- the photoperiod (the relative proportions of daylight and darkness during each day) is measured by the phytochrome system present in leaves/the photoperiodic response ensures that the plant flowers at an appropriate time of the year
- there are two forms of phytochrome, P_{660} (P_R) and P_{730} (P_{FR}), with P_{730} acting as the active form physiologically
- P_{660} is converted to P_{730} during daylight, while P_{730} is converted to P_{660} during darkness
- plants actually measure the length of continuous darkness (when the amount of P_{730} declines)
- in long day plants (short night, high amount of P_{730}) P_{730} stimulates flowering
- in short day plants (long night, low amount of P_{730}) P_{730} inhibits flowering and so its removal allows flowering to take place

Phototropism:

- phototropism involves the plant hormone auxin which is produced by the apical tissue
- unidirectional light (light from one direction) causes illumination gradients which are detected by a photoreceptor pigment (possibly a flavine)
- this results in the lateral movement of auxins from the illuminated to the shaded side (it is not known how this lateral movement happens, but it is known that light neither inactivates nor destroys auxins)
- elongation of cells in a shoot is stimulated by relatively high concentrations of auxins
- by increasing the elasticity of the cell walls (so that under turgor they stretch more when vacuolated)
- increased growth on the dark side of the shoot causes it to bend towards the light/ growth towards light ensures leaves receive maximum sunlight

Photoreception in the retina:

- perception of light allows the recognition of features in the environment
- the retina contains two types of light sensitive cell, rods and cones
- in rods the photosensitive pigment is rhodopsin which, when it absorbs light, breaks down into its constituent parts (opsin and retinine, to trans-form)
- this results in a generator potential in the rod and (if this reaches a sufficient level) this in turn results in an impulse in the receptor neurone (of the optic nerve) leading to the brain
- cones work in a similar way except that the pigment is iodopsin which requires a greater amount of light to break down (partly explaining why cones are less sensitive than rods)
- there are three different types of cone (each with its unique form of iodopsin), each mainly sensitive to one of the three primary colours of light (red, green or blue)
- through the arrangement of bipolar cells, rods show retinal convergence and so have increased sensitivity/cones synapse individually with bipolar neurones and show greater visual acuity

Control and accommodation of light entering the eye:

- the size of the pupil is controlled (by the iris) to prevent the light-sensitive cells being overstimulated or damaged (in bright light)/not being stimulated at all (in dim light)
- the iris has muscles arranged in two layers – circular muscles and radial muscles – which are antagonistic in their action (that is, when one set contracts the other relaxes)
- in bright light, contraction of the circular muscles (and relaxation of the radial muscles) causes the pupil to become smaller/in dim light, contraction of the radial muscles (and relaxation of the circular muscles) causes the pupil to become larger
- for a far object, tension in the wall of the eyeball (and relaxation of the ciliary muscle) causes the lens to be pulled thinner and so it is less converging
- for a near object, the ciliary muscle contracts causing the tension in the suspensory ligaments to be lessened
- as a result of its elasticity, the lens becomes fatter and so more converging (as required for a near object)

Ultraviolet radiation:

- UV light may act as a mutagen causing changes in the DNA genetic code
- it is therefore important in generating new alleles within a population/as a source of genetic variation
- the amount of UV light reaching the Earth's surface has increased with the depletion of the ozone layer
- the ozone layer is broken down by certain gases including CFCs and methane
- the increased amount of UV light has been associated with increased incidence of skin cancer/cataracts
- UV light, while not visible to mammals, is perceived by some insects
- UV light is absorbed by the skin (inducing tanning) where it importantly stimulates the production of vitamin D

Infrared radiation:

- the Earth's atmosphere is relatively transparent to visible light but traps a large part of the outgoing infrared radiation
- this is important in warming the Earth and the organisms on it
- thus organisms may be metabolically active
- increase in greenhouse gases (e.g. CO_2) leads to global warming and climate change (through a greater retention of infrared radiation)

Other relevant area(s):

- equivalent point(s) [13]