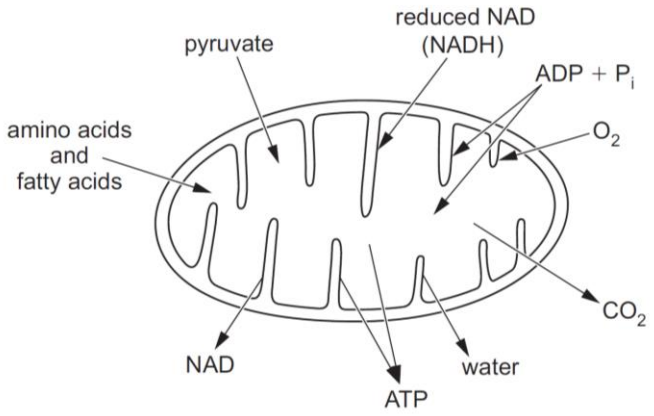
Quality of written communication:

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.

SUMMER 2014

8 Mitochondria are the organelles most associated with ATP production in the cell. The diagram below represents a mitochondrion and identifies substances that typically enter and leave the organelle as it carries out its function.



(a) Using the information provided, give an account of how the substances labelled in the diagram are used or produced in a mitochondrion during the production of ATP. [12]

(b) Analysis of the mitochondria in a cell, using the electron microscope, provides an insight into the metabolic activity of that cell. Explain how appropriate microscopic analysis of mitochondria, in terms of their number and structure, can provide information about cellular metabolic activity. [4]

8 (a) Any twelve from

- pyruvate (from glycolysis) enters the link reaction
- becomes decarboxylated (and combines with coenzyme A) to form acetyl CoA
- which enters Krebs cycle
- CO_2 also produced by Krebs cycle
- reduced NAD (from glycolysis) enters electron transport chain
- provides hydrogen
- (oxidised) NAD returns to cytoplasm for glycolysis
- ADP and P_i provide raw materials for ATP production
- ATP produced by Krebs cycle by substrate (linked) phosphorylation
- in the mitochondrial matrix (either the link reaction or Krebs cycle)
- in electron transport chain by oxidative phosphorylation
- on inner mitochondrial membrane/cristae
- oxygen is final electron acceptor in electron transport chain
- water is produced as a waste product
- fatty acids enter respiratory pathway at acetyl CoA
- amino acids enter at pyruvate/acetyl CoA/Krebs stages [12]

(b) Any four from

- TEM can provide detail of mitochondrion ultrastructure
- positive correlation between number of mitochondria in cell and metabolic activity
- positive correlation between size of mitochondria and metabolic activity
- positive correlation between length of inner mitochondrial membrane/ degree of infolding of cristae and metabolic activity
- as electron transport system/oxidative phosphorylation takes place on inner mitochondrial membrane [4]

8 Gene technology is opening up many medical and commercial opportunities through the production of transgenic organisms and in gene therapy.

(a) Describe the processes of obtaining desired genes and their subsequent transfer into the cells of organisms. [8]

8 (a) Any eight from (maximum five in each section)

Obtaining desired gene

- identifying desired gene by using a DNA probe
- use of restriction endonucleases to cut out gene
- by cutting DNA at specific base combinations/recognition sequences
- reverse transcriptase (used to obtain donor DNA)
- by manufacturing DNA from mRNA (produced by desired gene)
- DNA polymerase used to make double stranded DNA
- use of gene machine to produce small gene/synthetic DNA

Gene transfer

- incorporation of donor genes into a vector such as bacterial plasmids/ bacteriophages
- reference to sticky ends/use of same restriction enzyme in plasmid as in donor DNA
- role of DNA ligase in annealing donor DNA into vector DNA
- description of method to aid uptake into recipient cells (e.g. heat shock)
- identification of host cells that have taken up gene by the use of marker genes/gene probes/replica plating
- microinjection of DNA into animal cells
- use of 'DNA pellets' to insert donor genes into plant cells
- use of T_i plasmid/*Agrobacterium* to introduce gene into plant cells
- difference between transgenic organisms and (somatic) gene therapy (e.g. gene therapy only targeting specific cells)
- use of aerosols/liposomes/adenovirus in gene therapy [8]

(b) Eight from

Benefits (maximum five)

- production of useful medical substances (e.g. insulin, interferon, blood-clotting factors, vaccines etc)
- explanation of benefit, e.g. insulin previously only from dead animals in abbatoirs/restriction on availability/high demand
- genes introduced to improve productivity in animals (e.g. milk yield/ quality, meat production/quality)
- explanation of benefit, e.g. improved profits, less wastage
- genes introduced in plants to improve yield/commercial value (e.g. improving crop yield, prolong 'shelf-life', increase protein content, improve texture, disease resistance, pesticide resistance etc)
- explanation of benefit, e.g. improved profits, less wastage **[allow once only]**
- introduction of functional gene to restore normal metabolism (in gene therapy)
- explanation of benefit, e.g. better quality of life, longer life, treatment of named disease, e.g. cystic fibrosis
- benefit of gene transfer in 'knockin' technology described

PTO…

Potential problems (maximum five)

- named potential problem associated with GEMs, e.g. new strains of disease-causing microbes
- reference to cost of/need for containment mechanisms associated with GEMs/example of safety precautions employed, e.g. 'suicide' genes, containment mechanisms
- named potential problem associated with GM crops, e.g. development of 'super weeds', hybridisation with native crops, allergies
- limitation of gene therapy explained, e.g. only affects cells that aerosol/liposome makes contact with/short lived as new cells produced/not passed on to next generation
- potential risks of gene therapy explained, e.g. disruptive effect on host DNA/use of virus associated with allergic reaction/cancer/leukaemia
- awareness that gene transfer raises ethical issues/is controversial
- awareness that problems are mainly with public perception and not the science involved
- example of legislation required to manage risks (e.g. special laboratories when working with GMOs) [8]

June 2012

8 There are similarities and differences in the way ATP is synthesised in respiration and photosynthesis.

(a) Give an account of the synthesis of ATP in both respiration and photosynthesis. [11]

(b) Discuss the similarities and differences between the two processes. [5]

8 (a) Eleven points (a maximum of seven in either section)

Respiration

- in glycolysis, 4 ATP are produced directly/there is a net yield of 2 ATP
- in the Krebs cycle, 1 ATP is produced directly/in substrate phosphorylation
- dehydrogenation in glycolysis/Krebs cycle
- results in the production of NADH and $FADH_2$/reduced NAD^+ and FAD
- which carry the hydrogens to the ETC
- where they pass down a series of carriers at progressively lower energy levels
- the hydrogens subsequently split into H^+ ions (protons) and electrons
- the electrons pass along the cytochromes
- (at certain stages sufficient) energy is released to create an ATP molecule
- NADH yields 3 ATPs while $FADH_2$ only yields 2 ATPs

Photosynthesis

- in the light-dependent stage of photosynthesis light energy is trapped by photosystems/pigments
- the light energy causes excitation/raises energy level of electrons
- energy is funnelled to the reaction centre (of a photosystem) by resonance
- electrons are emitted from chlorophyll a/primary pigment
- and picked up by an electron acceptor
- electrons are passed down an ETC/cytochrome chain
- resulting in synthesis of ATP [11]

(b) Five points (a maximum of three in either section)

Similarities

- both processes involve an ETC (containing cytochromes)/use of electrons
- which are arranged in sequence in a (intracellular) membrane/carriers at progressively lower energy levels
- carriers are successively oxidised and reduced/involve REDOX reactions
- phosphorylation is associated with electron transfer

Differences

- membranes are thylakoids (in chloroplasts) for photosynthesis and the cristae (of mitochondria) for respiration *[both needed]*
- in respiration the starting point is the delivery of hydrogen atoms to the ETC/chemical energy of glucose
- so that ATP production is described as oxidative phosphorylation
- in photosynthesis the starting point involves light energy
- hence ATP production is described as photophosphorylation
- different hydrogen carriers used/NADP in photophosphorylation, while NAD and FAD in respiration
- terminal electron acceptors different/terminal acceptor is O_2 in respiration, $NADP^+$ in photosynthesis [5]

8 The kingdom Plantae contains the mosses (division Bryophyta), the ferns (division Tracheophyta: subdivision Pteridophyta) and the flowering plants (division Tracheophyta: subdivision Spermatophyta).

(a) Give an account of the life cycle of flowering plants. [10]

(b) Discuss how mosses, ferns and flowering plants are differently adapted for life on land. [6]

8 (a) Any ten from

- in flowering plants the (diploid) sporophyte is the dominant stage/leafy plant
- the gametophyte is reduced to a short stage within the flower
- microspores are produced in the anther/develop into pollen grains
- by meiosis
- the pollen grain is the male gametophyte
- pollination by wind or insect (both required)
- pollen grains germinate on a (receptive) stigma
- the (pollen grain) nucleus divides by mitosis to produce the generative nucleus and the tube nucleus
- the (generative) nucleus divides again (by mitosis) to create two male gametes
- cell in the ovule (megasporangium) divides to produce the embryosac (megaspore)
- by meiosis (allow only once)
- the embryosac is the female gametophyte
- the embryosac undergoes (three) mitotic divisions that results in an egg nucleus and two polar nuclei (as well as five other 'redundant' nuclei which degenerate)
- double fertilisation
- one male nucleus (gamete) fertilises the egg (nucleus)
- the second male nucleus joins with the two polar nuclei to make a (triploid) endosperm [10]

(b) Any six from

- mosses have rhizoids (instead of true roots) that do not penetrate deeply into the soil
- fern gametophytes have rhizoids
- and are thus confined to moist places/ions and water absorbed directly into leaves
- in ferns/flowering plants the leaves have a waterproof cuticle
- can control opening and closing of their stomata
- possess well developed roots which can absorb water from (deeper in) the soil
- possess a (well developed) vascular system
- in mosses/ferns water is needed for the motile sperm cells to swim to the egg cells
- which means they are dependent on moist places for reproduction
- in flowering plants the male gametes are enclosed in a (waterproof) pollen grain/tube
- which can travel in air to the female egg cell, thus making them more independent of water [6]

June 2010

9 **(a)** Write an account of the role of nucleic acids in the synthesis of proteins. [10]

(b) Knowledge of the role of nucleic acids has been exploited to provide new sources of medically important proteins and new crops from genetically modified organisms.

Discuss the safety precautions currently employed to overcome potential hazards of using genetically modified organisms and some of the ethical issues regarding the benefits and risks of gene technology. [6]

9 (a) Ten points

DNA:

- DNA sequence of bases represents the genetic code
- a sequence of three nucleotides (bases) codes for one amino acid
- DNA is a degenerative code as some amino acids are coded for by more than one triplet of DNA nucleotides/is an non-overlapping code

Ribosomal RNA:

- synthesized at the nucleolus/associates with protein to form a ribosome

Transcription and translation:

- a gene is a short section of DNA
- DNA unzips (by breaking the H-bonds between the bases)
- one strand acts as a template
- ribonucleotides enter opposite their complementary bases
- with U opposite A and A-T, C-G
- condensation between sugars and phosphates is catalysed by RNA polymerase
- the mRNA now detaches and leaves the nucleus via a nuclear pore/ travels to the ER where a ribosome attaches to it
- in the cytoplasm tRNA picks up specific amino acids
- an anticodon for each amino acid
- the anticodon on the tRNA is attracted to the complementary codon on the mRNA
- the ribosome holds two adjacent tRNAs together until a peptide bond/ condensation occurs between the adjacent amino acids
- the ribosome then moves along the mRNA to assist the joining of subsequent amino acids in turn (until a stop codon is reached)
- the chain of amino acids represents the primary structure of the protein
- removal of non-coding sections (introns)/edited mRNA is produced [10]

(b) Six points (three from each section)

Safety preparations taken when using genetically modified organism:

- use strains of GEM which grow more slowly than normal wild type intestinal bacteria and thus would be out-competed by the latter
- use strains of GM with a minimum temperature tolerance above human body temperature so that they will not multiply in the human body
- use strains of GM which contain 'suicide genes' these are activated outside certain pH or temperature limits
- use of containment mechanisms for example highly efficient air filters/ regular monitoring of the atmosphere within purpose-built laboratories
- legislation, where work on potentially dangerous GM's is restricted to purpose-built laboratories/is carried out by highly trained staff

PTO…

Ethical issues [arguments both for and against developments of GEM organisms]:

- improving life expectancy of patients requiring drug treatment/more successful drug treatment (e.g. human insulin)
- the possibility of cures for genetic traits using gene therapy (trials with cystic fibrosis etc)
- diagnosis (development of 'chips'), prevention and the management of inherited diseases caused by defective genes (5000 single gene disorders
- the difficulties of using prenatal information – 'designer babies'
- carrier testing for cystic fibrosis, Tay-Sachs etc
- pharmacogenomics, 'the right drug for the right patient', could avoid adverse side-effects and save valuable health care resources
- prevention of communicable diseases by DNA analysis of the pathogen and vectors (manipulation of mosquito DNA so that parasites which cause malaria and Leishmaniasis/dengue fever cannot survive in the mosquito)
- identification of markers for bowel cancer, Alzheimer disease pathways to allow drug treatment at an early stage of the disease development
- financing genomic research and drug development may limit the use of resources for other forms of treatment
- detailed knowledge of the genetic basis of sickle cell disease has lead to little health benefit
- gene disruption may trigger cancer
- genetic research has lead to the storing of large amounts of information about individuals DNA, 'who owns the DNA'. Access to confidential information could produce a 'genetic sub-class' of individuals excluded from employment, insurance etc.
- population screening should be for preventive treatment and not just information
- genetic risk profiling for complex diseases is not sufficiently predictive (disposition to bowel cancer, breast cancer)
- cost-effective food production through improved disease resistance in plants/reduction in the use of pesticides
- in animals successfully transformation and expression of the desired gene is frequently low
- 'faulty' alleles remain in the gene pool and may be passed on
- recombinant DNA may be taken in by 'non-target' organisms, e.g. weeds may take up a gene for herbicide resistance/spread of antibiotic resistance in non-target organisms (gut bacteria can take up genes from ingested food products)/the danger of GM plants cross-breeding with wild species
- unfair competition between sponsored GM crops and less productive plants available to farmers/limitations placed on third world countries unable to pay for GM crops [6]

8 Give an account of the biochemistry of photosynthesis and use this to explain how certain environmental factors limit its rate. [13]

8 **Thirteen points (with at least four for limiting factors).**

Biochemistry of photosynthesis:

Light harvesting:
- light is absorbed by chlorophyll and other pigments (within the photosystems)
- the different pigments absorb light in different parts of the spectrum/increase the range of wavelengths utilised/increase the efficiency of energy utilisation
- mostly red and blue light absorbed/green light reflected
- causing the excitation of electrons within the pigments (whereby their energy level is raised)
- excitation passes (resonates) through the pigments until it reaches the primary pigment/energy is funnelled towards the reaction centre (of the photosystem)
- within individual photosystems the primary pigment emits an electron to an electron acceptor

Light-dependent phase:
- from photosystem II (PSII) the electrons (after being accepted by plastoquinone) pass through a series of electron carriers/cytochromes
- this is coupled to the production of ATP (photophosphorylation)
- electrons from photosystem I (PSI) pass to NADP(H^+) (after being accepted by ferredoxin) to form NADPH
- electrons "lost" from PSI are replaced from photosystem II (PSII)/via the ETC
- reference to the dissociation of water (to hydrogen and hydroxyl ions)/ hydrogen ions combine with NADP to form $NADPH^+$
- electrons "lost" from PSII are replaced from hydroxyl ions/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

Limiting factors:
- light limits photosynthesis since without it no ATP or NADPH is produced
- for the GP to TP step
- carbon dioxide is a limiting factor since without it RuBP has nothing to fix
- so no GP is synthesised
- temperature is a limiting factor since it affects the action of enzymes
- within the Calvin cycle [13]

7 Give an account of how evolutionary change may take place in populations, and how this could lead to speciation. [13]

7 **Thirteen points (with at least five from each section).**

Evolutionary change in populations:

- populations are genetically variable/genetic variation is the basis for evolutionary change
- in competition for resources with other members of the population
- 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
- where a non-modal form, not previously favoured, is now selected for
- this can be due to an environmental change
- the form being selected for survives more frequently to reproduce
- 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

Specification:

- in the theory of allopatric speciation
- populations become geographically isolated
- environment conditions differ in the geographically isolated areas
- selection pressures in the two areas differ (favouring different variants within the populations)
- resulting in divergence of the two populations' gene pools
- 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
- or other secondary isolating mechanism (such as behavioural isolation)
- 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 2010

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4 Write an account of "the uses of ATP in living organisms".

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

4 Thirteen points

General:
- ATP provides energy
- during its hydrolysis
- catalysed by ATPase
- to ADP and inorganic phosphate
- only a small proportion of energy released by breakdown of ATP is utilised

Synthetic reactions:
- ATP is used in the synthesis of macromolecules
- in protein synthesis
- for peptide bonding between amino acids
- in the synthesis of starch (glucose is phosphorylated before bonding)
- in the synthesis of lipids
- in the synthesis of nucleic acids
- in the synthesis of creatine phosphate

Resynthesis of biochemicals:
- ATP provides energy for the resynthesis of biochemicals
- resynthesis of acetylcholine in synaptic knobs
- resynthesis of rhodopsin in rods

Glycolysis:
- ATP is used in the initial steps of glycolysis
- glucose is phosphorylated
- to fructose bisphosphate
- 2 ATP are used per glucose

Photosynthesis:
- ATP (from the light stage) is used in the Calvin cycle
- substrate is glycerate phosphate
- to triose phosphate/glyceraldehyde phosphate
- and in the phosphorylation of RuP to RuBP

Membrane pumps:
- ATP provides energy for active transport
- energy used by membrane protein
- to alter its shape
- allows solutes to be moved against a concentration gradient
- example of ATP usage in active transport

Cytosis (bulk transport):
- ATP is required during exocytosis/endocytosis
- for the formation of vesicles
- for the movement of vesicles to/from the cell membrane
- for the assembly/disassembly of the microfilaments/microtubules (of the cytoskeleton)