Course content

Candidates develop skills of scientific inquiry, and analytical thinking, along with knowledge and understanding. These skills, knowledge and understanding of biology are developed through a variety of approaches and in the context of each of the three main areas of the course. Candidates undertake practical activities in the classroom/local environment. Candidates research issues and communicate information related to their findings, which develops skills of scientific literacy.

The course content includes the following areas of biology:

Cell biology
The key areas covered are: cell structure; transport across cell membranes; DNA and the production of proteins; proteins; genetic engineering; respiration.

Biology: multicellular organisms
The key areas covered are: producing new cells; control and communication; reproduction; variation and inheritance; transport systems — plants; transport systems — animals; absorption of materials.

Biology: life on Earth
The key areas covered are: ecosystems; distribution of organisms; photosynthesis; energy in ecosystems; food production; evolution of species.

Skills, knowledge and understanding

Skills, knowledge and understanding for the course

The following provides a broad overview of the subject skills, knowledge and understanding developed in the course:

- demonstrating knowledge and understanding of biology by making statements, describing information, providing explanations and integrating knowledge
- applying knowledge of biology to new situations, interpreting information and solving problems
- planning, designing and safely carrying out experimental/fieldwork investigations to test given hypotheses or to illustrate particular effects
- selecting information from a variety of sources
- presenting information appropriately in a variety of forms
- processing information (using calculations and units, where appropriate)
- making predictions and generalisations based on evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- suggesting improvements to experimental/fieldwork investigations
- communicating findings/information

Skills, knowledge and understanding for the course assessment

The following provides details of skills, knowledge and understanding sampled in the course assessment.

The course support notes provide further detail on the depth of knowledge required for each key area of the course.

Note: The key areas of the course and apparatus and techniques noted below **and** the depth of knowledge required for each key area noted in the course support notes **can be assessed in the question paper.**

Cell biology
1 Cell structure a Cell ultrastructure and functions — cell wall, mitochondrion, chloroplast, cell membrane, cytoplasm, vacuole, nucleus, ribosome and plasmid using examples from typical plant, animal, fungal and bacterial cells. b Cell wall is made of cellulose in plant cells but of different materials in fungal and bacterial cells.
2 Transport across cell membranes a The cell membrane consists of phospholipids and proteins and is selectively permeable. b Passive transport occurs down a concentration gradient and does not require energy. Examples of passive transport are diffusion and osmosis. c Diffusion is the movement of molecules down a concentration gradient from a higher to a lower concentration. d Osmosis is the movement of water molecules from a higher water concentration to a lower water concentration through a selectively permeable membrane. e Animal cells can burst or shrink and plant cells can become turgid or plasmolysed. Relationship between different concentrations of solutions and their effect on cells. f Active transport requires energy for membrane proteins to move molecules and ions against the concentration gradient.
3 DNA and the production of proteins a Structure of DNA: double-stranded helix held by complementary base pairs. DNA carries the genetic information for making proteins. The four bases: adenine, cytosine, guanine and thymine (A, C, G and T) make up the genetic code. A is always paired with T and C is always paired with G. The base sequence determines amino acid sequence in proteins. A gene is a section of DNA which codes for a protein. b Messenger RNA (mRNA) is a molecule which carries a complementary copy of the genetic code from the DNA, in the nucleus, to a ribosome, where the protein is assembled from amino acids.

Cell biology

4 Proteins

a The variety of protein shapes and functions arises from the sequence of amino acids. Proteins have many functions such as structural, enzymes, hormones, antibodies and receptors.

b Enzymes function as biological catalysts and are made by all living cells. They speed up cellular reactions and are unchanged in the process. The shape of the active site of an enzyme molecule is complementary to its specific substrate(s). Enzyme action results in product(s). Enzymes can be involved in degradation and synthesis reactions. Examples should relate enzymes to their specific substrate(s) and product(s).

c Each enzyme is most active in its optimum conditions. Enzymes and other proteins can be affected by temperature and pH. Enzymes can be denatured, resulting in a change in their shape which will affect the rate of reaction.

5 Genetic engineering

Genetic information can be transferred from one cell to another by genetic engineering. Stages of genetic engineering: identify section of DNA that contains required gene from source chromosome; extract required gene; extract plasmid from bacterial cell; insert required gene into bacterial plasmid; insert plasmid into host bacterial cell to produce a genetically modified (GM) organism.
Use of enzymes in this process.

6 Respiration

a The chemical energy stored in glucose must be released by all cells through a series of enzyme-controlled reactions called respiration.

b The energy released from the breakdown of glucose is used to generate ATP. The energy transferred by ATP can be used for cellular activities such as muscle cell contraction, cell division, protein synthesis and transmission of nerve impulses.

c Glucose is broken down to two molecules of pyruvate, releasing enough energy to yield two molecules of ATP. Further breakdown depends upon the presence/absence of oxygen. If oxygen is present, aerobic respiration takes place, and each pyruvate is broken down to carbon dioxide and water, releasing enough energy to yield a large number of ATP molecules.
In the absence of oxygen, the fermentation pathway takes place. In animal cells, the pyruvate molecules are converted to lactate and in plant and yeast cells they are converted to carbon dioxide and ethanol.
The breakdown of each glucose molecule via the fermentation pathway yields only the initial two molecules of ATP.

d Respiration begins in the cytoplasm. The process of fermentation is completed in the cytoplasm whereas aerobic respiration is completed in the mitochondria.

Biology: multicellular organisms

1 Producing new cells

a Sequence of events of mitosis. Understanding of the terms chromatids, equator and spindle fibres.

b Mitosis provides new cells for growth, repair of damaged tissues and replacement of dead or damaged cells. It also maintains the diploid chromosome complement.

c Stem cells in animals are unspecialised cells which can divide in order to self-renew. They have the potential to become different types of cell. Stem cells are involved in growth and repair.

d Specialisation of cells leads to the formation of a variety of cells, tissues and organs. Groups of organs which work together form systems.
A hierarchy exists: cells → tissues → organs → systems.

2 Control and communication

a **Nervous control**

i Nervous system consists of central nervous system (CNS) and other nerves. CNS consists of brain and spinal cord. Structure and function of parts of the brain — cerebrum, cerebellum and medulla. Neurons are of three types: sensory, inter and motor. Receptors detect sensory input/stimuli. Electrical impulses carry messages along neurons. Chemicals transfer these messages between neurons, at synapses.

ii Structure and function of reflex arc.

b **Hormonal control**

i Endocrine glands release hormones into the bloodstream. Hormones are chemical messengers. A target tissue has cells with complementary receptor proteins for specific hormones, so only that tissue will be affected by these hormones.

ii Blood glucose regulation. The roles of insulin, glucagon, glycogen, pancreas and liver.

3 Reproduction

a Cells are diploid, except gametes, which are haploid.

b The types of gametes, the organs that produce them and where these are located in plants and animals. The basic structure of sperm and egg cells.

c Fertilisation is the fusion of the nuclei of the two haploid gametes to produce a diploid zygote, which divides to form an embryo.

Biology: multicellular organisms
4 Variation and inheritance a Comparison of discrete variation (single gene inheritance) and continuous variation (polygenic inheritance). b Understanding of genetic terms: gene; allele; phenotype; genotype; dominant; recessive; homozygous; heterozygous and P, F_1 and F_2. c Monohybrid crosses from parental generation through to F_2 generation. d Reasons why predicted phenotype ratios among offspring are not always achieved.
5 Transport systems — plants a Plant organs are roots, stems and leaves. Leaf structure diagram showing upper epidermis, palisade mesophyll, spongy mesophyll, vein (consisting of xylem and phloem), lower epidermis, guard cells and stomata. b Parts of the plant involved in water transport. Water and minerals enter the plant through the root hairs and are transported in dead xylem vessels. Structure of xylem vessels. c The process of transpiration and how the rate of transpiration is affected by wind speed, humidity, temperature and surface area. d Sugar is transported up and down the plant in living phloem. Structure of phloem tissue.
6 Transport systems — animals a In mammals the blood contains plasma, red blood cells and white blood cells. It transports nutrients, oxygen and carbon dioxide. b Red blood cells are specialised by being biconcave in shape, having no nucleus and containing haemoglobin. This allows them to transport oxygen efficiently in the form of oxyhaemoglobin. c White blood cells are part of the immune system and are involved in destroying pathogens. There are two main types of cells involved. Phagocytes carry out phagocytosis by engulfing pathogens. Some lymphocytes produce antibodies which destroy pathogens. Each antibody is specific to a particular pathogen. d Pathway of oxygenated and deoxygenated blood through heart, lungs and body. Diagram of heart to show the right and left atria, ventricles, location of four valves, location of associated blood vessels (aorta, vena cava, pulmonary artery, pulmonary vein and coronary arteries). Function of each of these parts. e Arteries have thick, muscular walls, a narrow central channel and carry blood under high pressure away from the heart. Veins have thinner walls, a wider channel and carry blood under low pressure back towards the heart. Veins contain valves to prevent backflow of blood. Capillaries are thin walled and have a large surface area, forming networks at tissues and organs to allow efficient exchange of materials.

Biology: multicellular organisms

7 Absorption of materials

a Oxygen and nutrients from food must be absorbed into the bloodstream to be delivered to cells for respiration. Waste materials, such as carbon dioxide, must be removed from cells into the bloodstream.

b Tissues contain capillary networks to allow the exchange of materials at cellular level.

c Surfaces involved in the absorption of materials have certain features in common: large surface area, thin walls, extensive blood supply. These increase the efficiency of absorption.

d Lungs are gas exchange organs. They consist of a large number of alveoli providing a large surface area. Oxygen and carbon dioxide are absorbed through the thin alveolar walls to or from the many blood capillaries.

e Nutrients from food are absorbed into the villi in the small intestine. The large number of thin walled villi provides a large surface area. Each villus contains a network of capillaries to absorb glucose and amino acids and a lacteal to absorb fatty acids and glycerol.

Biology: life on Earth

1 Ecosystems

a Definitions of ecological terms: species, biodiversity, population, producer, consumer, herbivore, carnivore, omnivore, predator, prey, food chain, food web.
b An ecosystem consists of all the organisms (the community) living in a particular habitat and the non-living components with which the organisms interact. Interactions of organisms in food webs.
c A niche is the role that an organism plays within a community. It relates to the resources it requires in its ecosystem, such as light and nutrient availability and its interactions with other organisms in the community. It involves competition and predation and the conditions it can tolerate such as temperature.
d Competition in ecosystems occurs when resources are in short supply. Interspecific competition occurs amongst individuals of different species for one or a few of the resources they require. Intraspecific competition occurs amongst individuals of the same species and is for all resources required. Intraspecific competition is therefore more intense than interspecific competition.

2 Distribution of organisms

a Competition for resources, disease, food availability, grazing and predation are biotic factors. Light intensity, moisture, pH and temperature are abiotic factors.
b Measuring abiotic factors such as light intensity, soil moisture, pH and temperature. Possible sources of error and how to minimise them.
c Sampling of plants and animals using quadrats and pitfall traps. Evaluation of limitations and sources of error in their use.
d Using and constructing paired-statement keys to identify organisms.
e The effect of biotic and abiotic factors on biodiversity and the distribution of organisms.
f Indicator species are species that by their presence or absence indicate environmental quality/levels of pollution.

3 Photosynthesis

a Photosynthesis is a two-stage process:
  i Light reactions: the light energy from the sun is trapped by chlorophyll in the chloroplasts and is converted into chemical energy which is used to generate ATP. Water is split to produce hydrogen and oxygen. Oxygen diffuses from the cell.
  ii Carbon fixation: a series of enzyme-controlled reactions, which use hydrogen and ATP (produced by the light reactions) with carbon dioxide to produce sugar.
b The chemical energy in sugar is available for respiration or the sugar can be converted into other substances, such as starch (storage) and cellulose (structural).
c Limiting factors: carbon dioxide concentration, light intensity and temperature and their impact on photosynthesis and plant growth.
  Analysis of limiting factors graphs.

Biology: life on Earth
4 Energy in ecosystems a In transfers from one level to the next in a food chain, the majority of the energy is lost as heat, movement or undigested materials. Only a very small quantity is used for growth and is therefore available at the next level in a food chain. b Definitions and comparisons of pyramids of numbers and energy.
5 Food production a Increasing human population requires an increased food yield. This can involve the use of fertilisers and pesticides. Fertilisers provide chemicals such as nitrates which increase crop yield. Plants and animals which reduce crop yield can be killed by pesticides. b Nitrates dissolved in soil water are absorbed into plants. Nitrates are used to produce amino acids which are synthesised into plant proteins. Animals consume plants or other animals to obtain amino acids for protein synthesis. Fertilisers can be added to soil to increase the nitrate content of the soil. c Fertilisers can leach into fresh water, adding extra, unwanted nitrates. This will increase algal populations which can cause algal blooms. Algal blooms reduce light levels, killing aquatic plants. These dead plants, as well as dead algae, become food for bacteria which increase greatly in number. The bacteria use up large quantities of oxygen, reducing the oxygen availability for other organisms. Genetically modified (GM) crops can be used to reduce the use of fertilisers. d Pesticides sprayed onto crops can accumulate in the bodies of organisms over time. As they are passed along food chains, toxicity increases and can reach lethal levels. The use of biological control and genetically modified (GM) crops as alternatives to the use of pesticides.
6 Evolution of species a A mutation is a random change to genetic material. Mutations may be neutral, confer an advantage or a disadvantage to survival. Mutations are spontaneous and are the only source of new alleles. Environmental factors, such as radiation and some chemicals, can increase the rate of mutation. b New alleles produced by mutation can result in plants and animals becoming better adapted to their environment. Variation within a population makes it possible for a population to evolve over time in response to changing environmental conditions. c Species produce more offspring than the environment can sustain. Natural selection or survival of the fittest occurs when there are selection pressures. The best adapted individuals in a population survive to reproduce, passing on the favourable alleles that confer the selective advantage. These alleles increase in frequency within the population. d Speciation occurs after part of a population becomes isolated by an isolation barrier, which can be geographical, ecological or behavioural. Different mutations occur in each sub-population. Natural selection selects for different mutations in each group, due to different selection pressures. Each sub-population evolves until they become so genetically different that they are two different species.

Apparatus and techniques

In addition to the key areas, candidates must have knowledge of the following pieces of apparatus and have opportunities to become familiar with the following techniques.

Apparatus

- beaker
- balance
- measuring cylinder
- dropper/pipette
- test tube/boiling tube
- thermometer
- funnel
- syringe
- timer/stopwatch
- microscope
- petri dish
- quadrat
- pitfall trap
- light/moisture meter
- water bath

Techniques

- measuring enzyme activity
- using a respirometer
- measuring transpiration using a potometer
- measuring abiotic factors
- measuring the distribution of a species
- using a transect line
- measuring the rate of photosynthesis

The course support notes provide a list of suggested learning activities. Choosing from the activities suggested in the course support notes, or carrying out any other appropriate activities, allows candidates to become familiar with the apparatus and techniques listed above. Where it is not possible to carry out a particular technique other resources could be utilised.

Skills, knowledge and understanding included in the course are appropriate to the SCQF level of the course. The SCQF level descriptors give further information on characteristics and expected performance at each SCQF level (www.scqf.org.uk).