**IB Biology**

**Scheme of Work**

**Examination in 2009 onwards.**

**N.B. HL Topics are highlighted in bold.**

**SL = 150hrs – Theory = 110 (80 core/30 Options) + 40 Practical**

**HL = 240hrs - Theory = 180 (80 core/55AHL/45 Options) +60 Practical**

**Texts:**

A = Allott study Guide.

I = IBID Press

B = Campbell and Reece.

C = Course Companion – Allott and Mindorff

**Aims:**

Through studying any of the group 4 subjects, students should become aware of how scientists work and communicate with each other. While the “scientific method” may take on a wide variety of forms, it is the emphasis on a practical approach through experimental work that distinguishes the group 4 subjects from other disciplines and characterizes each of the subjects within group 4.

It is in this context that all the Diploma Programme experimental science courses should aim to:

1. Provide opportunities for scientific study and creativity within a global context that will stimulate and challenge students

2. Provide a body of knowledge, methods and techniques that characterize science and technology

3. Enable students to apply and use a body of knowledge, methods and techniques that characterize science and technology

4. Develop an ability to analyse, evaluate and synthesize scientific information

5. Engender an awareness of the need for, and the value of, effective collaboration and communication during scientific activities

6. Develop experimental and investigative scientific skills

7. Develop and apply the students’ information and communication technology skills in the study of science

8. Raise awareness of the moral, ethical, social, economic and environmental implications of using science and technology

9. Develop an appreciation of the possibilities and limitations associated with science and scientists

10. Encourage an understanding of the relationships between scientific disciplines and the overarching nature of the scientific method.

**Objectives:**

1. Demonstrate an understanding of:

a. scientific facts and concepts

b. scientific methods and techniques

c. scientific terminology

d. methods of presenting scientific information.

2. Apply and use:

a. scientific facts and concepts

b. scientific methods and techniques

c. scientific terminology to communicate effectively

d. appropriate methods to present scientific information.

3. Construct, analyse and evaluate:

a. hypotheses, research questions and predictions

b. scientific methods and techniques

c. scientific explanations.

4. Demonstrate the personal skills of cooperation, perseverance and responsibility appropriate for effective scientific investigation and problem solving.

5. Demonstrate the manipulative skills necessary to carry out scientific investigations with precision and safety.

**Command terms:**

Objective 1

**Define** Give the precise meaning of a word, phrase or physical quantity.

**Draw** Represent by means of pencil lines.

**Label** Add labels to a diagram.

**List** Give a sequence of names or other brief answers with no explanation.

**Measure** Find a value for a quantity.

**State** Give a specific name, value or other brief answer without explanation or calculation.

Objective 2

**Annotate** Add brief notes to a diagram or graph.

**Apply** Use an idea, equation, principle, theory or law in a new situation.

**Calculate** Find a numerical answer showing the relevant stages in the working (unless instructed not to do so).

**Describe** Give a detailed account.

**Distinguish** Give the differences between two or more different items.

**Estimate** Find an approximate value for an unknown quantity.

**Identify** Find an answer from a given number of possibilities.

**Outline** Give a brief account or summary.

Objective 3

**Analyse** Interpret data to reach conclusions.

**Comment** Give a judgment based on a given statement or result of a calculation.

**Compare** Give an account of similarities and differences between two (or more) items, referring to both (all) of them throughout.

**Construct** Represent or develop in graphical form.

**Deduce** Reach a conclusion from the information given.

**Derive** Manipulate a mathematical relationship(s) to give a new equation or relationship.

**Design** Produce a plan, simulation or model.

**Determine** Find the only possible answer.

**Discuss** Give an account including, where possible, a range of arguments for and against the relative importance of various factors, or comparisons of alternative hypotheses.

**Evaluate** Assess the implications and limitations.

**Explain** Give a detailed account of causes, reasons or mechanisms.

**Predict** Give an expected result.

**Show** Give the steps in a calculation or derivation.

**Sketch** Represent by means of a graph showing a line and labelled but unscaled axes but withimportant features (for example, intercept) clearly indicated.

**Solve** Obtain an answer using algebraic and/or numerical methods.

**Suggest** Propose a hypothesis or other possible answer.

**Order of teaching:** (Based on 32 hrs / 8 weeks available every 10 week term)

**Year 12 Year 13**

|  |  |  |  |
| --- | --- | --- | --- |
| **Term 1** | Statistical analysisCellsChemistry of Life**Nucleic Acids and Proteins (AHL+** Opt C**)** | **Term 1** | **Cellular Respiration and Photosynthesis(AHL+** Opt C**)**Human Nutrition (Opt A- SL ONLY) |
| **Term 2** | Human Health and Physiology**Human Health and Physiology (AHL)****Further Human Physiology (Option H – HL ONLY)** | **Term 2** | Physiology of Exercise (Opt B – SL ONLY)Neurophysiology and Behaviour **(Option E SL/HL) or** Evolution **(Option D SL/HL)** |
| **Term 3** | **Further Human Physiology (Option H – HL ONLY)**Genetics**Genetics (AHL)** | **Term 3** | Neurophysiology and Behaviour **(Option E SL/HL)** orEvolution **(Option D SL/HL)****Trial examinations week 8** |
| **Term 4** | **Plant Science (AHL)**Ecology and Evolution | **Term 4** | Revision programme 3 weeks.Examination leave week 4 onwards. |

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| **Statistical Analysis** |
| **Ref.** | **Statement** | **Obj.** | **Teacher’s notes** | **Pages** | **Add. Info.** |
| 1.1.1 | State that error bars are a graphical representation of the variability of data. | 1 | Error bars can be used to show either the range of the data or the standard deviation. | A – 1I - 9 |  |
| 1.1.2 | Calculate the mean and standard deviation of a set of values. | 2 | Students should specify the standard deviation (*s*), not the population standard deviation.Students will not be expected to know the formulas for calculating these statistics. They will be expected to use the standard deviation function of a graphic display or scientific calculator.**Aim 7:** Students could also be taught how to calculate standard deviation using a spreadsheet computer program. | A – 1I -10 | **Prac:** Height, palm and foot sizes of a junior class. Practise the correct graphical representation for types of data. Continuous and discontinuous data. |
| 1.1.3 | State that the term standard deviation is used to summarize the spread ofvalues around the mean, and that 68% of the values fall within one standard deviation of the mean. | 1 | For normally distributed data, about 68% of all values lie within ±1 standard deviation (*s* or σ) of the mean. This rises to about 95% for ±2 standard deviations. | A – 1C -21I -12 |  |
| 1.1.4 | Explain how the standard deviation is useful for comparing the means andthe spread of data between two or more samples. | 3 | A small standard deviation indicates that the data is clustered closely around the mean value.Conversely, a large standard deviation indicates a wider spread around the mean. | A – 1I-13 |  |
| 1.1.5 | Deduce the significance of thedifference between two sets of data using calculated values for *t* and the appropriate tables. | 3 | For the *t*-test to be applied, the data must have a normal distribution and a sample size of at least 10. The *t*-test can be used to compare two sets of data and measure the amount of overlap. Students will not be expected to calculate values of *t*. Only a two-tailed, unpaired *t*-test is expected.**Aim 7:** While students are not expected to calculate a value for the *t*-test, students could be shown how to calculate such values using a spreadsheet program or the graphic display calculator.**TOK:** The scientific community defines an objective standard by which claims about data can be made. | A – 2 |  |
| 1.1.6 | Explain that the existence of acorrelation does not establish that there is a causal relationship between two variables. | 2 | **Aim 7:** While calculations of such values are not expected, students who want to use *r* and *r*2 values in their practical work could be shown how to determine such values using a spreadsheet program. | A – 2I - 16 | Use Excel to calculate *r* and *r2*. |
| **2.1 Cell Theory** |
| 2.1.1 | Outline the cell theory. | 2 | Include the following.• Living organisms are composed of cells.• Cells are the smallest unit of life.• Cells come from pre-existing cells. | A – 3I - 17 |  |
| 2.1.2 | Discuss the evidence for the cell theory. | 3 | **TOK:** The nature of scientific theories could be introduced here: the accumulation of evidence that allows a hypothesis to become a theory; whether a theory should be abandoned when there is evidence that it does not offer a full explanation; and what evidence is needed for a theory to be adopted or rejected. | A -3I - 17 |  |
| 2.1.3 | State that unicellular organisms carry out all the functions of life. | 1 | Include metabolism, response, homeostasis, growth, reproduction and nutrition. | A -3I – 18 |  |
| 2.1.4 | Compare the relative sizes ofmolecules, cell membrane thickness, viruses, bacteria, organelles and cells, using the appropriate SI unit. | 3 | Appreciation of relative size is required, such as molecules (1 nm), thickness of membranes (10 nm), viruses (100 nm), bacteria (1 μm), organelles (up to 10 μm), and most cells (up to 100 μm). The three-dimensional nature/shape of cells should be emphasized.**TOK:** All the biological entities in the above list are beyond our ability to perceive directly. They must be observed through the use of technology such as the light microscope and the electron microscope.Is there any distinction to be drawn between knowledge claims dependent upon observations made directly with the senses and knowledge claims dependent upon observations assisted by technology? | A – 5I -18 | Discuss the contributions of Robert Hooke, Scheilden, Schwann and Virchow have made to modern cell theory. |
| 2.1.5 | Calculate the linear magnification of drawings and the actual size of specimens in images of known magnification. | 2 | Magnification could be stated (for example, ×250)or indicated by means of a scale bar, for example:1 μm **Aim 7:** The size of objects in digital images of microscope fields could be analysed using graticule baselines and image-processing software. | A – 5 | **Prac:** Electron micrographs of cells and organelles to calculate actual size and magnification |
| 2.1.6 | Explain the importance of the surface area to volume ratio as a factor limiting cell size. | 3 | Mention the concept that the rate of heat production/waste production/resourceconsumption of a cell is a function of its volume, whereas the rate of exchange of materials and energy (heat) is a function of its surface area. Simple mathematical models involving cubes and the changes in the ratio that occur as the sides increase by one unit could be compared.**Aim 7:** Data logging could be carried out to measure changes in conductivity in distilled water as salt diffuses out of salt–agar cubes of different dimensions. | A – 5C – 14I – 20 | **Prac:** Salt-agar cubes – conductivity or diffusion of pigment from beetroot cubes – colorimetry **data logging.** |
| 2.1.7 | State that multi-cellular organisms show emergent properties. | 1 | Emergent properties arise from the interaction of component parts: the whole is greater than the sum of its parts.**TOK:** The concept of emergent properties has many implications in biology, and this is an opportunity to introduce them. Life itself can be viewed as an emergent property, and the nature of life could be discussed in the light of this, including differences between living and non-living things and problems about defining death in medical decisions. | A – 3C -21I – 20 |  |
| 2.1.8 | Explain that cells in multi-cellular organisms differentiate to carry out specialized functions by expressing some of their genes but not others. | 3 |  | C -16I - 21 |  |
| 2.1.9 | State that stem cells retain the capacity to divide and have the ability to differentiate along different pathways. | 2 |  | A – 4C -17I – 22 |  |
| 2.1.10 | Outline one therapeutic use of stem cells. | 2 | This is an area of rapid development. In 2005, stem cells were used to restore the insulation tissue of neurons in laboratory rats, resulting in subsequent improvements in their mobility. Any example of the therapeutic use of stem cells in humans or other animals can be chosen.**Aim 8:** There are ethical issues involved in stem cell research, whether humans or other animals are used. Use of embryonic stem cells involves the death of early-stage embryos, but if therapeutic cloning is successfully developed the suffering of patients with a wide variety of conditions could be reduced.**Int:** Stem cell research has depended on the work of teams of scientists in many countries, who share results and so speed up the rate of progress.However, ethical concerns about the procedures have led to restrictions on research in some countries. National governments are influenced by local, cultural and religious traditions, which vary greatly, and these, therefore, have an impact on the work of scientists.**TOK:** This is an opportunity to discuss balancing the huge opportunities of therapeutic cloning against the considerable risks—for example, stem cells developing into tumours.Another issue is how the scientific community conveys information about its work to the wider community in such a way that informed decisions about research can be made. | A – 4C -18I - 22 | Essay on the pros and cons of stem cell research. How does view change in different regions of the World and how is this directed by religion and culture. |
| **2.2 Prokaryotic Cells (1hr)** |
| 2.2.1 | Draw and label a diagram of the ultrastructure of *Escherichia coli* (*E. coli*) as an example of a prokaryote. | 1 | Draw and label a diagram of theultrastructure of *Escherichia coli* (*E. coli*) as an example of a prokaryote. | A – 6C -22 | [Prokaryotic](http://www.biology.arizona.edu/cell_bio/tutorials/pev/page2.html) |
| 2.2.2 | Annotate the diagram from 2.2.1 with the functions of each named structure. | 2 |  | A – 6C -22 | N 96 H3 Q12 |
| 2.2.3 | Identify structures from 2.2.1 in electron micrographs of *E. coli*. | 2 |  | A – 6C – 22 |  |
| 2.2.4 | State that prokaryotic cells divide by binary fission. | 1 |  | A – 6C – 22 |  |
| **2.3 Eukaryotic Cells (3hrs)** |
| 2.3.1 | Draw and label a diagram of the ultrastructure of a liver cell as an example of an animal cell. | 1 | The diagram should show free ribosomes, rough endoplasmic reticulum (rER), lysosome, Golgi apparatus, mitochondrion and nucleus. The term Golgi apparatus will be used in place of Golgi body, Golgi complex or dictyosome. | A – 7 | [Eukaryotic](http://www.biology.arizona.edu/cell_bio/tutorials/pev/page3.html)[Virtual cell](http://www.ibiblio.org/virtualcell/tour/cell/cell.htm) |
| 2.3.2 | Annotate the diagram from 2.3.1 with the functions of each named structure. | 2 |  | A – 7 |  |
| 2.3.3 | Identify structures from 2.3.1 in electron micrographs of liver cells. | 2 |  | A – 7 |  |
| 2.3.4 | Compare prokaryotic and eukaryotic cells. | 3 | Differences should include:• naked DNA *versus* DNA associated with proteins• DNA in cytoplasm *versus* DNA enclosed in a nuclear envelope• no mitochondria *versus* mitochondria• 70S *versus* 80S ribosomes• eukaryotic cells have internal membranes that compartmentalize their functions. |  |  |
| 2.3.5 | State three differences between plant and animal cells. | 1 |  |  | *Cellulose cell wall, Chloroplasts, starch grains, Size, Centrioles, large vacuole.* |
| 2.3.6 | Outline two roles of extracellular components. | 2 | The plant cell wall maintains cell shape, prevents excessive water uptake, and holds the whole plant up against the force of gravity.Animal cells secrete glycoproteins that form the extracellular matrix. This functions in support, adhesion and movement. |  | Revision Q’s C - 24 |
| **2.4 Membranes**  |
| 2.4.1 | Draw and label a diagram to show the structure of membranes. | 1 | The diagram should show the phospholipid bilayer, cholesterol, glycoproteins, and integral and peripheral proteins. Use the term plasma membrane, not cell surface membrane, for the membrane surrounding the cytoplasm.Integral proteins are embedded in the phospholipid of the membrane, whereas peripheral proteins are attached to its surface. Variations in composition related to the type of membrane are not required.**Aim 7:** Data logging to measure the changes in membrane permeability using colorimeter probes can be used. |  | **Prac:** Colorimetry of beetroot cubes. How does SA affect the rate of diffusion. Data logging activity.BSR V13 No4 p36-39. |
| 2.4.2 | Explain how the hydrophobicand hydrophilic properties ofphospholipids help to maintain the structure of cell membranes. | 3 |  |  |  |
| 2.4.3 | List the functions of membrane proteins. | 1 | Include the following: hormone binding sites, immobilized enzymes, cell adhesion, cell-to-cell communication, channels for passive transport, and pumps for active transport. |  |  |
| 2.4.4 | Define *diffusion* and *osmosis*. | 1 | Diffusion is the passive movement of particles from a region of high concentration to a region of lowconcentration.Osmosis is the passive movement of water molecules, across a partially permeable membrane, from a region of lower solute concentration to a region of higher solute concentration. |  | **Prac:** Osmosis in potato tubers. Change in mass and size. |
| 2.4.5 | Explain passive transport across membranes by simple diffusion and facilitated diffusion. | 3 |  |  | **Prac:** Incipient plasmolysis in rhubarb epidermis |
| 2.4.6 | Explain the role of protein pumps and ATP in active transport across membranes. | 3 |  |  |  |
| 2.4.7 | Explain how vesicles are used to transport materials within a cell between the rough endoplasmic reticulum, Golgi apparatus and plasma membrane. | 3 |  |  |  |
| 2.4.8 | Describe how the fluidity of the membrane allows it to change shape, break and re-form during endocytosisand exocytosis. | 2 |  |  | N 96 Q2 |
| **2.5 Cell Division. (3hrs)** |
| 2.5.1 | Outline the stages in the cell cycle,including interphase (G1, S, G2), mitosis and cytokinesis. | 2 |  |  | BSR Vol 14 No4 pg 37-41  |
| 2.5.2 | State that tumours (cancers) are theresult of uncontrolled cell division and that these can occur in any organ or tissue. | 1 |  |  |  |
| 2.5.3 | State that interphase is an activeperiod in the life of a cell when many metabolic reactions occur, including protein synthesis, DNA replication and an increase in the number of mitochondria and/or chloroplasts. | 1 |  |  |  |
| 2.5.4 | Describe the events that occur in the four phases of mitosis (prophase, metaphase, anaphase and telophase). | 2 | Include supercoiling of chromosomes, attachment of spindle microtubules to centromeres, splitting of centromeres, movement of sister chromosomes toopposite poles, and breakage and re-formation of nuclear membranes.Textbooks vary in the use of the termschromosome and chromatid. In this course, the two DNA molecules formed by DNA replication are considered to be sister chromatids until the splitting of the centromere at the start of anaphase; after this, they are individual chromosomes. The term kinetochore is not expected.**Aim 7:** Students could determine mitotic index and fraction of cells in each phase of mitosis. Individual groups could paste data into a database. Pie charts could be constructed with a graphing computer program. If a graphing computer program is used in DCP for internal assessment, it should be according to the IA and ICT clarifications. |  |  |
| 2.5.5 | Explain how mitosis produces two genetically identical nuclei. | 3 |  |  |  |
| 2.5.6 | State that growth, embryonicdevelopment, tissue repair andasexual reproduction involve mitosis. | 1 |  |  |  |
| **3.1 Chemical Elements and Water** |
| 3.1.1 | State that the most frequentlyoccurring chemical elements in living things are carbon, hydrogen, oxygen and nitrogen. | 1 |  |  |  |
| 3.1.2 | State that a variety of other elements are needed by living organisms, including sulfur, calcium, phosphorus, iron and sodium. | 1 |  |  |  |
| 3.1.3 | State one role for each of theelements mentioned in 3.1.2. | 1 | Refer to the roles in plants, animals and prokaryotes. |  |  |
| 3.1.4 | Draw and label a diagram showing the structure of water molecules to show their polarity and hydrogen bond formation. | 1 |  |  |  |
| 3.1.5 | Outline the thermal, cohesive and solvent properties of water. | 2 | **Aim 7:** Data logging could be carried out to compare the thermal properties of water with those of other liquids.**TOK:** Claims about the “memory of water” have been categorized as pseudoscientific.By what criteria can a claim be judged to be pseudoscientific? |  |  |
| 3.1.6 | Explain the relationship between the properties of water and its uses in living organisms as a coolant, medium for metabolic reactions and transport medium. | 3 | Limit the properties to those outlined in 3.1.5. |  |  |
| **3.2 Carbohydrates, lipids and proteins. (2hrs)** |
| 3.2.1 | Distinguish between *organic* and *inorganic* compounds. | 2 | Compounds containing carbon that are found in living organisms (except hydrogencarbonates, carbonates and oxides of carbon) are regarded asorganic. |  |  |
| 3.2.2 | Identify amino acids, glucose, ribose and fatty acids from diagrams showing their structure. | 2 | Specific names of amino acids and fatty acids are not expected. |  |  |
| 3.2.3 | List three examples each ofmonosaccharides, disaccharides and polysaccharides. | 1 | The examples used should be:• glucose, galactose and fructose• maltose, lactose and sucrose• starch, glycogen and cellulose. |  |  |
| 3.2.4 | State one function of glucose, lactose and glycogen in animals, and of fructose, sucrose and cellulose in plants. | 1 |  |  |  |
| 3.2.5 | Outline the role of condensation and hydrolysis in the relationships between monosaccharides,disaccharides and polysaccharides; between fatty acids, glycerol and triglycerides; and between amino acids and polypeptides. | 2 | This can be dealt with using equations with words or chemical formulas. |  |  |
| 3.2.6 | State three functions of lipids. | 1 | 1 Include energy storage and thermal insulation. |  |  |
| 3.2.7 | Compare the use of carbohydratesand lipids in energy storage. | 3 |  |  |  |
| 7.5.1 | Explain the four levels of protein structure, indicating the significance of each level. | 3 | Quaternary structure may involve the binding of a prosthetic group to form a conjugated protein.**Aim 7:** Simulation exercises showing three-dimensional molecular models of proteins are available. |  |  |
| 7.5.2 | Outline the difference between fibrous and globular proteins, with reference to two examples of each protein type. | 2 |  |  |  |
| 7.5.3 | Explain the significance of polar and non-polar amino acids. | 3 | Limit this to controlling the position of proteins in membranes, creating hydrophilic channels through membranes, and the specificity of active sites in enzymes. |  |  |
| 7.5.4 | State four functions of proteins, giving a named example of each. | 1 | Membrane proteins should not be included. |  |  |
| **3.3 DNA structure** |
| 3.3.1 | Outline DNA nucleotide structure in terms of sugar (deoxyribose), base and phosphate. | 2 | Chemical formulas and the purine/pyrimidine subdivision are not required. Simple shapes can be used to represent the component parts. Only the relative positions are required. |  |  |
| 3.3.2 | State the names of the four bases in DNA. | 1 |  |  |  |
| 3.3.3 | Outline how DNA nucleotides are linked together by covalent bonds into a single strand. | 2 | Only the relative positions are required. |  |  |
| 3.3.4 | Explain how a DNA double helix is formed using complementary base pairing and hydrogen bonds. | 3 |  |  |  |
| 3.3.5 | Draw and label a simple diagram of the molecular structure of DNA. | 1 | An extension of the diagram in 3.3.3 is sufficient to show the complementary base pairs of A–T and G–C, held together by hydrogen bonds and the sugar–phosphate backbones. The number of hydrogen bonds between pairs and details of purine/pyrimidines are not required.**TOK:** The story of the elucidation of the structure of DNA illustrates that cooperation and collaboration among scientists exists alongside competition between research groups. To what extent was Watson and Crick’s “discovery” of the three-dimensional structure of DNA dependent on the use of data generated by Rosalind Franklin, which was shared without her knowledge or consent? |  |  |
| 7.1.1 | Describe the structure of DNA, including the antiparallel strands, 3’–5’ linkages and hydrogen bonding between purines and pyrimidines. | 2 | Major and minor grooves, direction of the “twist”, alternative B and Z forms, and details of the dimensions are not required. |  |  |
| 7.1.2 | Outline the structure of nucleosomes. | 2 | Limit this to the fact that a nucleosome consists of DNA wrapped around eight histone proteins and held together by another histone protein. |  |  |
| 7.1.3 | State that nucleosomes help to supercoil chromosomes and help to regulate transcription. | 1 |  |  |  |
| 7.1.4 | Distinguish between *unique or single-copy genes* and *highly repetitive sequences* in nuclear DNA. | 2 | Highly repetitive sequences (satellite DNA) constitutes 5–45% of the genome. The sequences are typically between 5 and 300 base pairs per repeat, and may be duplicated as many as 105 times per genome.**TOK:** Highly repetitive sequences were once classified as “junk DNA”, showing a degree of confidence that it had no role. This addresses the question: To what extent do the labels and categories used in the pursuit of knowledge affect the knowledge we obtain? |  |  |
| 7.1.5 | State that eukaryotic genes can contain exons and introns. | 1 |  |  |  |
| **3.4 DNA replication** |
| 3.4.1 | Explain DNA replication in terms of unwinding the double helix and separation of the strands by helicase, followed by formation of the new complementary strands by DNA polymerase. | 3 | It is not necessary to mention that there is more than one DNA polymerase. |  |  |
| 3.4.2 | Explain the significance of complementary base pairing in the conservation of the base sequence of DNA. | 3 |  |  |  |
| 3.4.3 | State that DNA replication is semi-conservative. | 1 |  |  |  |
| 7.2.1 | State that DNA replication occurs in a direction. | 1 | The 5’ end of the free DNA nucleotide is added to the 3’ end of the chain of nucleotides that is already synthesized. |  |  |
| 7.2.2 | Explain the process of DNA replication in prokaryotes, including the role of enzymes (helicase, DNA polymerase, RNA primase and DNA ligase), Okazaki fragments and deoxynucleoside triphosphates. | 3 | The explanation of Okazaki fragments in relation to the direction of DNA polymerase III action is required. DNA polymerase III adds nucleotides in the direction. DNA polymerase I excises the RNA primers and replaces them with DNA. |  |  |
| 7.2.3 | State that DNA replication is initiated at many points in eukaryotic chromosomes. | 1 |  |  |  |
| **3.5 Transcription and translation** |
| 3.5.1 | Compare the structure of RNA and DNA. | 3 | Limit this to the names of sugars, bases and the number of strands. |  |  |
| 3.5.2 | Outline DNA transcription in terms of the formation of an RNA strand complementary to the DNA strand by RNA polymerase. | 2 |  |  |  |
| 3.5.3 | Describe the genetic code in terms of codons composed of triplets of bases. | 2 |  |  |  |
| 3.5.4 | Explain the process of translation, leading to polypeptide formation. | 3 | Include the roles of messenger RNA (mRNA), transfer RNA (tRNA), codons, anticodons, ribosomes and amino acids. |  |  |
| 3.5.4 | Explain the process of translation, leading to polypeptide formation. | 3 | Include the roles of messenger RNA (mRNA), transfer RNA (tRNA), codons, anticodons, ribosomes and amino acids. |  |  |
| 7.3.1 | State that transcription is carried out in a direction. | 1 | The 5’ end of the free RNA nucleotide is added to the 3’ end of the RNA molecule that is already synthesized. |  |  |
| 7.3.2 | Distinguish between the *sense* and *antisense* strands of DNA. | 2 | The sense strand (coding strand) has the same base sequence as mRNA with uracil instead of thymine. The antisense (template) strand is transcribed. |  |  |
| 7.3.3 | Explain the process of transcription in prokaryotes, including the role of the promoter region, RNA polymerase, nucleoside triphosphates and the terminator. | 3 | The following details are not required: there is more than one type of RNA polymerase; features of the promoter region; the need for transcription protein factors for RNA polymerase binding; TATA boxes (and other repetitive sequences); and the exact sequence of the bases that act as terminators. |  |  |
| 7.3.4 | State that eukaryotic RNA needs the removal of introns to form mature mRNA. | 1 | Further details of the process of post-transcriptional modification of RNA are not required. |  |  |
| 7.4.1 | Explain that each tRNA molecule is recognized by a tRNA-activating enzyme that binds a specific amino acid to the tRNA, using ATP for energy. | 3 | Each amino acid has a specific tRNA-activating enzyme (the name aminoacyl-tRNA synthetase is not required). The shape of tRNA and CCA at the 3’ end should be included. |  |  |
| 7.4.2 | Outline the structure of ribosomes, including protein and RNA composition, large and small subunits, three tRNA binding sites and mRNA binding sites. | 2 |  |  |  |
| 7.4.3 | State that translation consists of initiation, elongation, translocation and termination. | 1 |  |  |  |
| 7.4.4 | State that translation occurs in a direction. | 1 | During translation, the ribosome moves along the mRNA towards the 3’ end. The start codon is nearer to the 5’ end. |  |  |
| 7.4.5 | Draw and label a diagram showing the structure of a peptide bond between two amino acids. | 1 |  |  |  |
| 7.4.6 | Explain the process of translation, including ribosomes, polysomes, start codons and stop codons. | 3 | Use of methionine for initiation, details of the T factor and recall of actual stop codons are not required. |  |  |
| 7.4.7 | State that free ribosomes synthesize proteins for use primarily within the cell, and that bound ribosomes synthesize proteins primarily for secretion or for lysosomes. | 1 |  |  |  |
| **3.6 Enzymes** |
| 3.6.1 | Define *enzyme* and *active site*. | 1 |  |  |  |
| 3.6.2 | Explain enzyme–substrate specificity. | 3 | The lock-and-key model can be used as a basis for the explanation. Refer to the three-dimensional structure. The induced-fit model is not expected at SL. |  |  |
| 3.6.3 | Explain the effects of temperature, pH and substrate concentration on enzyme activity. | 3 | **Aim 7:** Enzyme activity could be measured using data loggers such as pressure sensors, pH sensors or colorimeters.**Aim 8:** The effects of environmental acid rain could be discussed. |  |  |
| 3.6.4 | Define *denaturation*. | 1 | Denaturation is a structural change in a protein that results in the loss (usually permanent) of its biological properties. Refer only to heat and pH as agents. |  |  |
| 3.6.5 | Explain the use of lactase in the production of lactose-free milk. | 3 | **Aim 8:** Production of lactose-free milk is an example of an industrial process depending on biological methods (biotechnology). These methods are of huge and increasing economic importance.**Int/TOK:** Development of some techniques benefits particular human populations and not others because of the natural variation in human characteristics. Lactose intolerance is found in a high proportion of the human population (for example, in Asia) but more rarely among those of European origin. Sometimes a transfer of biotechnology is needed when techniques are developed in one part of the world that are more applicable in another. |  |  |
| 7.6.1 | State that metabolic pathways consist of chains and cycles of enzyme-catalysed reactions. | 1 |  |  |  |
| 7.6.2 | Describe the induced-fit model. | 2 | This is an extension of the lock-and-key model. Its importance in accounting for the ability of some enzymes to bind to several substrates should be mentioned.**TOK:** Scientific truths are often pragmatic. We accept them as true because they give us predictive power, that is, they work. The German scientist Emil Fischer introduced the lock-and-key model for enzymes and their substrates in 1890. It was not until 1958 that Daniel Koshland in the United States suggested that the binding of the substrate to the active site caused a conformational change, hence the induced-fit model. This is an example of one model or theory, accepted for many years, being superseded by another that offers a fuller explanation of a process. |  |  |
| 7.6.3 | Explain that enzymes lower the activation energy of the chemical reactions that they catalyse. | 3 | Only exothermic reactions should be considered. Specific energy values do not need to be recalled. |  |  |
| 7.6.4 | Explain the difference between competitive and non-competitive inhibition, with reference to one example of each. | 3 | Competitive inhibition is the situation when an inhibiting molecule that is structurally similar to the substrate molecule binds to the active site, preventing substrate binding.Limit non-competitive inhibition to an inhibitor binding to an enzyme (not to its active site) that causes a conformational change in its active site, resulting in a decrease in activity.Reversible inhibition, as compared to irreversible inhibition, is not required. |  |  |
| 7.6.5 | Explain the control of metabolic pathways by end-product inhibition, including the role of allosteric sites. | 3 |  |  |  |
| **6.1 Digestion** |
| 6.1.1 | Explain why digestion of large food molecules is essential. | 3 |  |  |  |
| 6.1.2 | Explain the need for enzymes in digestion. | 3 | The need for increasing the rate of digestion at body temperature should be emphasized. |  |  |
| 6.1.3 | State the source, substrate, products and optimum pH conditions for one amylase, one protease and one lipase. | 1 | Any human enzymes can be selected. Details of structure or mechanisms of action are not required.**Aim 7:** Data logging with pH sensors and lipase, and data logging with colorimeters and amylase can be used. |  |  |
| 6.1.4 | Draw and label a diagram of the digestive system. | 1 | The diagram should show the mouth, esophagus, stomach, small intestine, large intestine, anus, liver, pancreas and gall bladder. The diagram should clearly show the interconnections between these structures. |  |  |
| 6.1.5 | Outline the function of the stomach, small intestine and large intestine. | 2 |  |  |  |
| 6.1.6 | Distinguish between *absorption* and *assimilation*. | 2 |  |  |  |
| 6.1.7 | Explain how the structure of the villus is related to its role in absorption and transport of the products of digestion. | 3 |  |  |  |
| H.2.1 | State that digestive juices are secreted into the alimentary canal by glands, including salivary glands, gastric glands in the stomach wall, the pancreas and the wall of the small intestine. | 1 |  |  |  |
| H.2.2 | Explain the structural features of exocrine gland cells. | 3 | Include the secretory cells grouped into acini and ducts, and the ultrastructure of secretory cells as seen in the electron micrographs. |  |  |
| H.2.3 | Compare the composition of saliva, gastric juice and pancreatic juice. | 3 |  |  |  |
| H.2.4 | Outline the control of digestive juice secretion by nerves and hormones, using the example of secretion of gastric juice. | 2 | Limit this to the initial release of gastric juice under nerve stimulation after sight or smell of food, and sustained release under the influence of gastrin secreted when food is in the stomach. |  |  |
| H.2.5 | Outline the role of membrane-bound enzymes on the surface of epithelial cells in the small intestine in digestion. | 2 | Some digestive enzymes (for example, maltase) are immobilized in the exposed plasma membranes of epithelial cells in intestinal villi. |  |  |
| H.2.6 | Outline the reasons for cellulose not being digested in the alimentary canal. | 2 |  |  |  |
| H.2.7 | Explain why pepsin and trypsin are initially synthesized as inactive precursors and how they are subsequently activated. | 3 |  |  |  |
| H.2.8 | Discuss the roles of gastric acid and *Helicobacter pylori* in the development of stomach ulcers and stomach cancers. | 3 | **TOK:** This is an example of a paradigm shift, where existing ideas about the tolerance of bacteria to stomach acid were incorrect but persisted for a time despite the evidence. The story of how the Australians Robin Warren and Barry Marshall made the discovery and struggled to convince the scientific and medical community is well worth telling. |  |  |
| H.2.9 | Explain the problem of lipid digestion in a hydrophilic medium and the role of bile in overcoming this. | 3 | Lipid molecules tend to coalesce and are only accessible to lipase at the lipid–water interface. Bile molecules have a hydrophilic end and a hydrophobic end, and thus prevent lipid droplets coalescing. The maximum surface is exposed to lipases. The need for lipase to be water-soluble and to have an active site to which a hydrophobic substrate binds should be mentioned. |  |  |
| H.3.1 | Draw and label a diagram showing a transverse section of the ileum as seen under a light microscope. | 1 | Include mucosa and layers of longitudinal and circular muscle. |  |  |
| H.3.2 | Explain the structural features of an epithelial cell of a villus as seen in electron micrographs, including microvilli, mitochondria, pinocytotic vesicles and tight junctions. | 3 |  |  |  |
| H.3.3 | Explain the mechanisms used by the ileum to absorb and transport food, including facilitated diffusion, active transport and endocytosis. | 3 |  |  |  |
| H.3.4 | List the materials that are not absorbed and are egested. | 1 | Limit this to cellulose, lignin, bile pigments, bacteria and intestinal cells. |  |  |
| **6.2 The transport system** |
| 6.2.1 | Draw and label a diagram of the heart showing the four chambers, associated blood vessels, valves and the route of blood through the heart. | 1 | Care should be taken to show the relative wall thickness of the four chambers. Neither the coronary vessels nor the conductive system are required. |  |  |
| 6.2.2 | State that the coronary arteries supply heart muscle with oxygen and nutrients. | 1 |  |  |  |
| 6.2.3 | Explain the action of the heart in terms of collecting blood, pumping blood, and opening and closing of valves. | 3 | A basic understanding is required, limited to the collection of blood by the atria, which is then pumped out by the ventricles into the arteries. The direction of flow is controlled by atrio-ventricular and semilunar valves. |  |  |
| 6.2.4 | Outline the control of the heartbeat in terms of myogenic muscle contraction, the role of the pacemaker, nerves, the medulla of the brain and epinephrine (adrenaline). | 2 | Histology of the heart muscle, names of nerves or transmitter substances are not required.**Aim 7:** Simulation and data logging involving heart rate monitors, or data logging involving an EKG sensor to measure electrical signals produced during muscle contractions, can be used. |  |  |
| 6.2.5 | Explain the relationship between the structure and function of arteries, capillaries and veins. | 3 |  |  |  |
| 6.2.6 | State that blood is composed of plasma, erythrocytes, leucocytes (phagocytes and lymphocytes) and platelets. | 1 |  |  |  |
| 6.2.7 | State that the following are transported by the blood: nutrients, oxygen, carbon dioxide, hormones, antibodies, urea and heat. | 1 | No chemical details are required. |  |  |
| H.5.1 | Explain the events of the cardiac cycle, including atrial and ventricular systole and diastole, and heart sounds. | 3 | **Aim 7:** Data logging using an EKG sensor is possible. |  |  |
| H.5.2 | Analyse data showing pressure and volume changes in the left atrium, left ventricle and the aorta, during the cardiac cycle. | 3 | Recall of quantitative data is not expected. |  |  |
| H.5.3 | Outline the mechanisms that control the heartbeat, including the roles of the SA (sinoatrial) node, AV (atrioventricular) node and conducting fibres in the ventricular walls. | 2 | Bundles of His and Purkinje fibres are not required. |  |  |
| H.5.4 | Outline atherosclerosis and the causes of coronary thrombosis. | 2 |  |  |  |
| H.5.5 | Discuss factors that affect the incidence of coronary heart disease. | 3 | Risk factors include having parents who have experienced heart attacks (genetic), age, being male, smoking, obesity, eating too much saturated fat and cholesterol, and lack of exercise.**TOK:** This is an area where a huge amount of data from epidemiological studies has been obtained, but the interpretation of this data is fraught with difficulty. Rates of heart disease in different countries have often been correlated with individual factors, and a causal link has then been claimed. In other studies, data has been used selectively to try to establish statistically significant trends. The concept of risk factors could be questioned on the grounds of the complex interaction between factors. If individuals alter their lifestyles to reduce a risk factor, this may not necessarily affect their overall risk of heart disease. A distinction could also be drawn between indicators of risk, such as the levels of certain substances in the blood and factors that actually cause coronary heart disease. |  |  |
| **6.4 Gas exchange** |
| 6.4.1 | Distinguish between *ventilation*, *gas exchange* and *cell respiration*. | 2 |  |  |  |
| 6.4.2 | Explain the need for a ventilation system. | 3 | A ventilation system is needed to maintain high concentration gradients in the alveoli. |  |  |
| 6.4.3 | Describe the features of alveoli that adapt them to gas exchange. | 2 | This should include a large total surface area, a wall consisting of a single layer of flattened cells, a film of moisture and a dense network of capillaries. |  |  |
| 6.4.4 | Draw and label a diagram of the ventilation system, including trachea, lungs, bronchi, bronchioles and alveoli. | 1 | Students should draw the alveoli in an inset diagram at a higher magnification. |  |  |
| 6.4.5 | Explain the mechanism of ventilation of the lungs in terms of volume and pressure changes caused by the internal and external intercostal muscles, the diaphragm and abdominal muscles. | 3 | **Aim 7:** Data logging involving spirometers or ventilation rate monitors is possible here. |  |  |
| H.6.1 | Define *partial pressure*. | 1 |  |  |  |
| H.6.2 | Explain the oxygen dissociation curves of adult hemoglobin, fetal hemoglobin and myoglobin. | 3 |  |  |  |
| H.6.3 | Describe how carbon dioxide is carried by the blood, including the action of carbonic anhydrase, the chloride shift and buffering by plasma proteins. | 2 |  |  |  |
| H.6.4 | Explain the role of the Bohr shift in the supply of oxygen to respiring tissues. | 3 |  |  |  |
| H.6.5 | Explain how and why ventilation rate varies with exercise. | 3 | Limit this to the effects of changes in carbon dioxide concentration leading to a lowering of blood pH. This is detected by chemosensors in the aorta and carotid arteries that send impulses to the breathing centre of the brain. Nerve impulses are then sent to the diaphragm and the intercostal muscles to increase contraction or relaxation rates. |  |  |
| H.6.6 | Outline the possible causes of asthma and its effects on the gas exchange system. | 2 |  |  |  |
| H.6.7 | Explain the problem of gas exchange at high altitudes and the way the body acclimatizes. | 3 |  |  |  |
| **11.3 The kidney** |
| 11.3.1 | Define *excretion*. | 1 | Excretion is the removal from the body of the waste products of metabolic pathways. |  |  |
| 11.3.2 | Draw and label a diagram of the kidney. | 1 | Include the cortex, medulla, pelvis, ureter and renal blood vessels. |  |  |
| 11.3.3 | Annotate a diagram of a glomerulus and associated nephron to show the function of each part. | 2 |  |  |  |
| 11.3.4 | Explain the process of ultrafiltration, including blood pressure, fenestrated blood capillaries and basement membrane. | 3 |  |  |  |
| 11.3.5 | Define *osmoregulation*. | 1 | Osmoregulation is the control of the water balance of the blood, tissue or cytoplasm of a living organism.**Aim 7:** Data logging using colorimeters to measure the response of blood cells to changing salt concentrations is possible. |  |  |
| 11.3.6 | Explain the reabsorption of glucose, water and salts in the proximal convoluted tubule, including the roles of microvilli, osmosis and active transport. | 3 |  |  |  |
| 11.3.7 | Explain the roles of the loop of Henle, medulla, collecting duct and ADH (vasopressin) in maintaining the water balance of the blood. | 3 | Details of the control of ADH secretion are only required in option H (see H.1.5). |  |  |
| 11.3.8 | Explain the differences in the concentration of proteins, glucose and urea between blood plasma, glomerular filtrate and urine. | 3 |  |  |  |
| 11.3.9 | Explain the presence of glucose in the urine of untreated diabetic patients. | 3 |  |  |  |
| **H4 Functions of the liver** |
| H.4.1 | Outline the circulation of blood through liver tissue, including the hepatic artery, hepatic portal vein, sinusoids and hepatic vein. | 2 | The difference in structure between sinusoids and capillaries should also be mentioned. Reference to lobules or acini is not required. |  |  |
| H.4.2 | Explain the role of the liver in regulating levels of nutrients in the blood. | 3 |  |  |  |
| H.4.3 | Outline the role of the liver in the storage of nutrients, including carbohydrate, iron, vitamin A and vitamin D. | 2 |  |  |  |
| H.4.4 | State that the liver synthesizes plasma proteins and cholesterol. | 1 |  |  |  |
| H.4.5 | State that the liver has a role in detoxification. | 1 |  |  |  |
| H.4.6 | Describe the process of erythrocyte and hemoglobin breakdown in the liver, including phagocytosis, digestion of globin and bile pigment formation. | 2 |  |  |  |
| H.4.7 | Explain the liver damage caused by excessive alcohol consumption. | 3 |  |  |  |
| **6.3 Defence against infectious disease** |
| 6.3.1 | Define *pathogen*. | 1 | Pathogen: an organism or virus that causes a disease. |  |  |
| 6.3.2 | Explain why antibiotics are effective against bacteria but not against viruses. | 3 | Antibiotics block specific metabolic pathways found in bacteria. Viruses reproduce using the host cell’s metabolic pathways, which are not affected by antibiotics.**Aim 8:** The great benefits to people throughout the world in the control of bacterial diseases using antibiotics should be stressed. Examples of diseases that often proved fatal before the advent of antibiotics could be named. |  |  |
| 6.3.3 | Outline the role of skin and mucous membranes in defence against pathogens. | 2 | A diagram of the skin is not required. |  |  |
| 6.3.4 | Outline how phagocytic leucocytes ingest pathogens in the blood and in body tissues. | 2 | Details of the subdivisions and classifications of phagocytes are not required. |  |  |
| 6.3.5 | Distinguish between *antigens* and *antibodies*. | 2 |  |  |  |
| 6.3.6 | Explain antibody production. | 3 | Many different types of lymphocyte exist. Each type recognizes one specific antigen and responds by dividing to form a clone. This clone then secretes a specific antibody against the antigen. No other details are required. |  |  |
| 6.3.7 | Outline the effects of HIV on the immune system. | 2 | The effects of HIV should be limited to a reduction in the number of active lymphocytes and a loss of the ability to produce antibodies. |  |  |
| 6.3.8 | Discuss the cause, transmission and social implications of AIDS. | 3 | **Aim 8:** The social implications of AIDS are well known. Cases of AIDS are not evenly distributed in the world, and consideration could be given to the severe problems in southern Africa. Cultural and economic reasons for differences in the prevalence of AIDS could be considered. The moral obligation of those with the technology and the wealth to help others lacking these things could be discussed.**TOK:** The different methods of transmission of HIV each carry their own risk. The extent to which individuals in different societies can minimize or eliminate each of these risks could be considered. |  |  |
| 11.1.1 | Describe the process of blood clotting. | 2 | Limit this to the release of clotting factors from platelets and damaged cells resulting in the formation of thrombin. Thrombin catalyses the conversion of soluble fibrinogen into the fibrous protein fibrin, which captures blood cells. |  |  |
| 11.1.2 | Outline the principle of challenge and response, clonal selection and memory cells as the basis of immunity. | 2 | This is intended to be a simple introduction to the complex topic of immunity. The idea of a polyclonal response can be introduced here. |  |  |
| 11.1.3 | Define *active* and *passive* immunity. | 1 | Active immunity is immunity due to the production of antibodies by the organism itself after the body’s defence mechanisms have been stimulated by antigens.Passive immunity is immunity due to the acquisition of antibodies from another organism in which active immunity has been stimulated, including via the placenta, colostrum, or by injection of antibodies. |  |  |
| 11.1.4 | Explain antibody production. | 3 | Limit the explanation to antigen presentation by macrophages and activation of helper T-cells leading to activation of B-cells which divide to form clones of antibody-secreting plasma cells and memory cells. |  |  |
| 11.1.5 | Describe the production of monoclonal antibodies and their use in diagnosis and in treatment. | 2 | Production should be limited to the fusion of tumour and B-cells, and their subsequent proliferation and production of antibodies.Limit the uses to one example of diagnosis and one of treatment.Detection of antibodies to HIV is one example in diagnosis. Others are detection of a specific cardiac isoenzyme in suspected cases of heart attack and detection of human chorionic gonadotrophin (HCG) in pregnancy test kits. Examples of the use of these antibodies for treatment include targeting of cancer cells with drugs attached to monoclonal antibodies, emergency treatment of rabies, blood and tissue typing for transplant compatibility, and purification of industrially made interferon.**Aim 8:** Production of monoclonal antibodies is certain to be a growth area in biotechnology, with many potential applications and consequent economic opportunities. Some of the applications will be of most use in developing countries, raising the question of how they will be paid for, whether commercial companies should be expected to carry out *pro bono* research and development, or whether national governments should provide funds for it through aid budgets. Historically, the development of treatments for tropical diseases and parasites has lagged far behind those for the diseases prevalent in wealthier countries. |  |  |
| 11.1.6 | Explain the principle of vaccination. | 3 | Emphasize the role of memory cells. The primary and secondary responses can be clearly illustrated by a graph. Precise details of all the types of vaccine (attenuated virus, inactivated toxins, and so on) for specific diseases are not required. |  |  |
| 11.1.7 | Discuss the benefits and dangers of vaccination. | 3 | The benefits should include total elimination of diseases, prevention of pandemics and epidemics, decreased health-care costs and prevention of harmful side-effects of diseases. The dangers should include the possible toxic effects of mercury in vaccines, possible overload of the immune system and possible links with autism.**Aim 8:** For parents there are ethical decisions to be made, to minimize risk for one’s own child, but also to help to prevent epidemics that could affect other children.**Int:** The international dimension could be addressed here, given that some diseases have the potential to become pandemics and that the example of smallpox shows how effective international cooperation can be in combating infectious diseases.**TOK:** This is an area where it is important to estimate accurately the size of risks, using good scientific data. The use of double-blind trials for vaccines or for drug treatments could be discussed. The placebo effect could also be considered, together with the complex interplay between mind and body in feelings of illness and health. Does the patient or the doctor decide whether the patient is well or not?There are also questions about the relationship between the scientific community and the general public. How can the general public be given clear information about the benefits and risks of vaccination? What went wrong in the recent case of misplaced fears about the measles, mumps and rubella (MMR) vaccine in the UK? There are ethical questions here about who should decide vaccination policy in a country, and whether it is ethically acceptable to have a compulsory vaccination programme. |  |  |
| **4.1 Chromosomes, genes, alleles and mutations** |
| 4.1.1 | State that eukaryote chromosomes are made of DNA and proteins. | 1 | The names of the proteins (histones) are not required, nor is the structural relationship between DNA and the proteins. |  |  |
| 4.1.2 | Define *gene*, *allele* and *genome*. | 1 | Gene: a heritable factor that controls a specific characteristic. (The differences between structural genes, regulator genes and genes coding for tRNA and rRNA are not expected at SL).Allele: one specific form of a gene, differing from other alleles by one or a few bases only and occupying the same gene locus as other alleles of the gene.Genome: the whole of the genetic information of an organism. |  |  |
| 4.1.3 | Define *gene mutation*. | 1 | The terms point mutation or frameshift mutation will not be used. |  |  |
| 4.1.4 | Explain the consequence of a base substitution mutation in relation to the processes of transcription and translation, using the example of sickle-cell anemia. | 3 | GAG has mutated to GTG causing glutamic acid to be replaced by valine, and hence sickle-cell anemia.**Aim 8:** There is a variety of social issues associated with sickle-cell anemia, including the suffering due to anemia, personal feelings if one has either inherited or passed on the sickle-cell allele, questions relating to the desirability of genetic screening for the sickle-cell allele before having children, and the genetic counselling of carriers of the allele.There are also ethical issues relating to screening of fetuses and abortion of those found to have a genetic disease.**TOK:** Where a correlation is found, a causal link may or may not be present. The frequency of the sickle-cell allele is correlated with the prevalence of malaria in many parts of the world. In this case, there is a clear causal link. Other cases where there is no causal link could be described as a contrast.There has clearly been natural selection in favour of the sickle-cell allele in malarial areas, despite it causing severe anemia in the homozygous condition. Natural selection has led to particular frequencies of the sickle-cell and the normal hemoglobin alleles, to balance the twin risks of anemia and malaria. |  |  |
| **4.2 Meiosis** |
| 4.2.1 | State that meiosis is a reduction division of a diploid nucleus to form haploid nuclei. | 1 |  |  |  |
| 4.2.2 | Define *homologous chromosomes*. | 1 |  |  |  |
| 4.2.3 | Outline the process of meiosis, including pairing of homologous chromosomes and crossing over, followed by two divisions, which results in four haploid cells. | 2 | Limit crossing over to the exchange of genetic material between non-sister chromatids during prophase I. Names of the stages are required. |  |  |
| 4.2.4 | Explain that non-disjunction can lead to changes in chromosome number, illustrated by reference to Down syndrome (trisomy 21). | 3 | The characteristics of Down syndrome are not required. |  |  |
| 4.2.5 | State that, in karyotyping, chromosomes are arranged in pairs according to their size and structure. | 1 |  |  |  |
| 4.2.6 | State that karyotyping is performed using cells collected by chorionic villus sampling or amniocentesis, for pre-natal diagnosis of chromosome abnormalities. | 1 | **Aim 8:** There are ethical and social issues associated with karyotyping of unborn fetuses because this procedure allows parents to abort fetuses with a chromosome abnormality. There is also evidence that, in some parts of the world, abortion on the basis of gender is carried out.**TOK:** Various questions relating to karyotyping could be raised, including balancing the risks of side-effects (for example, miscarriage) against the possibility of identifying and aborting a fetus with an abnormality. There are questions about decision-making: who should make the decision about whether to perform karyotyping and allow a subsequent abortion—parents or health-care professionals or both groups? There are also questions about whether or not national governments should interfere with personal freedoms, and whether or not they should be able to ban procedures within the country and possibly also ban citizens travelling to foreign countries where the procedures are permitted. |  |  |
| 4.2.7 | Analyse a human karyotype to determine gender and whether non-disjunction has occurred. | 3 | Karyotyping can be done by using enlarged photographs of chromosomes.**Aim 7:** Online simulations of karyotyping activities are available. |  |  |
| 10.1.1 | Describe the behaviour of the chromosomes in the phases of meiosis. | 2 |  |  |  |
| 10.1.2 | Outline the formation of chiasmata in the process of crossing over. | 2 |  |  |  |
| 10.1.3 | Explain how meiosis results in an effectively infinite genetic variety in gametes through crossing over in prophase I and random orientation in metaphase I. | 3 |  |  |  |
| 10.1.4 | State Mendel’s law of independent assortment. | 1 | **TOK:** There are some interesting aspects of Mendel’s work, including those mentioned in 4.3.11. The law of independent assortment was soon found to have exceptions when pairs of genes are linked on a chromosome, but the law that Mendel discovered in the 19th century does operate for the majority of pairs of genes. |  |  |
| 10.1.5 | Explain the relationship between Mendel’s law of independent assortment and meiosis. | 3 |  |  |  |
| **4.3 Theoretical genetics** |
| 4.3.1 | Define *genotype*, *phenotype*, *dominant allele*, *recessive allele*, *codominant alleles*, *locus*, *homozygous*, *heterozygous*, *carrier* and *test cross*. | 1 | Genotype: the alleles of an organism.Phenotype: the characteristics of an organism.Dominant allele: an allele that has the same effect on the phenotype whether it is present in the homozygous or heterozygous state.Recessive allele: an allele that only has an effect on the phenotype when present in the homozygous state.Codominant alleles: pairs of alleles that both affect the phenotype when present in a heterozygote. (The terms incomplete and partial dominance are no longer used.)Locus: the particular position on homologous chromosomes of a gene.Homozygous: having two identical alleles of a gene.Heterozygous: having two different alleles of a gene.Carrier: an individual that has one copy of a recessive allele that causes a genetic disease in individuals that are homozygous for this allele.Test cross: testing a suspected heterozygote by crossing it with a known homozygous recessive. (The term backcross is no longer used.) |  |  |
| 4.3.2 | Determine the genotypes and phenotypes of the offspring of a monohybrid cross using a Punnett grid. | 3 | The grid should be labelled to include parental genotypes, gametes, and both offspring genotype and phenotype.**Aim 7:** Genetics simulation software is available. |  |  |
| 4.3.3 | State that some genes have more than two alleles (multiple alleles). | 1 |  |  |  |
| 4.3.4 | Describe ABO blood groups as an example of codominance and multiple alleles. | 2 |  |  |  |
| 4.3.5 | Explain how the sex chromosomes control gender by referring to the inheritance of X and Y chromosomes in humans. | 3 |  |  |  |
| 4.3.6 | State that some genes are present on the X chromosome and absent from the shorter Y chromosome in humans. | 1 |  |  |  |
| 4.3.7 | Define *sex linkage*. | 1 |  |  |  |
| 4.3.8 | Describe the inheritance of colour blindness and hemophilia as examples of sex linkage. | 2 | Both colour blindness and hemophilia are produced by a recessive sex-linked allele on the X chromosome. Xb and Xh is the notation for the alleles concerned. The corresponding dominant alleles are XB and XH. |  |  |
| 4.3.9 | State that a human female can be homozygous or heterozygous with respect to sex-linked genes. | 1 |  |  |  |
| 4.3.10 | Explain that female carriers are heterozygous for X-linked recessive alleles. | 3 |  |  |  |
| 4.3.11 | Predict the genotypic and phenotypic ratios of offspring of monohybrid crosses involving any of the above patterns of inheritance. | 3 | **Aim 8:** Statisticians are convinced that Mendel’s results are too close to exact ratios to be genuine. We shall never know how this came about, but it offers an opportunity to discuss the need for scientists to be truthful about their results, whether it is right to discard results that do not fit a theory as Louis Pasteur is known to have done, and the danger of publishing results only when they show statistically significant differences.**TOK:** Reasons for Mendel’s theories not being accepted by the scientific community for a long time could be considered. Other cases of paradigm shifts taking a long time to be accepted could be considered. Ways in which individual scientists are most likely to be able to convince the scientific community could be considered, and also the need always to consider the evidence rather than the views of individual scientists, however distinguished. |  |  |
| 4.3.12 | Deduce the genotypes and phenotypes of individuals in pedigree charts. | 3 | For dominant and recessive alleles, upper-case and lower-case letters, respectively, should be used. Letters representing alleles should be chosen with care to avoid confusion between upper and lower case.For codominance, the main letter should relate to the gene and the suffix to the allele, both upper case. For example, red and white codominant flower colours should be represented as CR and Cw, respectively. For sickle-cell anemia, HbA is normal and Hbs is sickle cell.**Aim 8:** There are many social issues in families in which there is a genetic disease, including decisions for carriers about whether to have children, personal feelings for those who have inherited or passed on alleles for the disease, and potential problems in finding partners, employment and health or life insurance. There are ethical questions about whether personal details about genes should be disclosed to insurance companies or employers. Decisions may have to be made about whether or not to have screening. These are particularly acute in the case of Huntington disease. |  |  |
| **10.2 Dihybrid crosses and gene linkage** |
| 10.2.1 | Calculate and predict the genotypic and phenotypic ratio of offspring of dihybrid crosses involving unlinked autosomal genes. | 3 |  |  |  |
| 10.2.2 | Distinguish between *autosomes* and *sex chromosomes*. | 2 |  |  |  |
| 10.2.3 | Explain how crossing over between non-sister chromatids of a homologous pair in prophase I can result in an exchange of alleles. | 3 |  |  |  |
| 10.2.4 | Define *linkage group*. | 1 |  |  |  |
| 10.2.5 | Explain an example of a cross between two linked genes. | 3 | Alleles are usually shown side by side in dihybrid crosses, for example, TtBb. In representing crosses involving linkage, it is more common to show them as vertical pairs, for exampleThis format will be used in examination papers, or students will be given sufficient information to allow them to deduce which alleles are linked. |  |  |
| 10.2.6 | Identify which of the offspring are recombinants in a dihybrid cross involving linked genes. | 2 | In a test cross ofthe recombinants will beand |  |  |
| 10.3.1 | Define *polygenic inheritance*. | 1 |  |  |  |
| 10.3.2 | Explain that polygenic inheritance can contribute to continuous variation using two examples, one of which must be human skin colour. | 3 | **Aim 8:** This is one of the most obvious opportunities to develop the theme of parity of esteem for all humans. The selective advantage of dark skin to protect against ultraviolet light and light skin to allow vitamin D production could be mentioned. The correlation between skin colour and intensity of sunlight is clear, though the selective advantages of particular skin colours can now be overcome by the use of sun-block creams and vitamin D supplements. |  |  |
| **4.4 Genetic engineering and biotechnology** |
| .4.1 | Outline the use of polymerase chain reaction (PCR) to copy and amplify minute quantities of DNA. | 2 | Details of methods are not required. |  |  |
| 4.4.2 | State that, in gel electrophoresis, fragments of DNA move in an electric field and are separated according to their size. | 1 |  |  |  |
| 4.4.3 | State that gel electrophoresis of DNA is used in DNA profiling. | 1 |  |  |  |
| 4.4.4 | Describe the application of DNA profiling to determine paternity and also in forensic investigations. | 2 | **Aim 8:** There is a variety of social implications stemming from DNA profiling, such as identity issues for a child who learns unexpectedly who his or her biological father is, self-esteem problems for someone who learns he is not a father, problems in relationships where the male partner learns that he did not father a child, but also relief for crime victims when those responsible for the crime are identified and convicted, sometimes decades later.**TOK:** A comparison could be made between blood groups and DNA profiles in their potential for determining paternity. The difficulty in assessing the chance of two individuals having the same profile could be discussed, and also the success of DNA profiling in securing convictions in some of the high-profile legal cases of recent years. |  |  |
| 4.4.5 | Analyse DNA profiles to draw conclusions about paternity or forensic investigations. | 3 | The outcomes of this analysis could include knowledge of the number of human genes, the location of specific genes, discovery of proteins and their functions, and evolutionary relationships.**Aim 7:** Online bioinformatics simulations are available.**Aim 8:** We can either emphasize the large shared content of the human genome, which is common to all of us and should give us a sense of unity, or we can emphasize the small but significant allelic differences that create the biodiversity within our species, which should be treasured. Differences in the success of human races in coping with the modern world and the threat to some small human tribes could be mentioned. It is important to stress parity of esteem of all humans, whatever their genome.**TOK:** The Human Genome Project was an international endeavour, with laboratories throughout the world collaborating. However, there were also efforts in some parts of the world to gain commercial benefits from the outcomes of the project.The data from the Human Genome Project can be viewed in different ways: it could be seen as a complete account of what makes up a human, if one takes a reductionist view of life, or, alternatively, as merely the chemical instructions that have allowed a huge range of more significant human characteristics to develop. This could lead to a discussion about the essential nature of humanity. |  |  |
| 4.4.6 | Outline three outcomes of the sequencing of the complete human genome. | 2 |  |  |  |
| 4.4.7 | State that, when genes are transferred between species, the amino acid sequence of polypeptides translated from them is unchanged because the genetic code is universal. | 1 | **Aim 8:** There is an ethical or moral question here: whether it is right to change the genetic integrity of a species by transferring genes to it from another species. The discussion could include the wider question of selective breeding of animals, and whether this is distinctively different and always acceptable. The possibility of animals suffering as a result of genetic modification could be considered. |  |  |
| 4.4.8 | Outline a basic technique used for gene transfer involving plasmids, a host cell (bacterium, yeast or other cell), restriction enzymes (endonucleases) and DNA ligase. | 2 | The use of *E. coli* in gene technology is well documented. Most of its DNA is in one circular chromosome, but it also has plasmids (smaller circles of DNA). These plasmids can be removed and cleaved by restriction enzymes at target sequences. DNA fragments from another organism can also be cleaved by the same restriction enzyme, and these pieces can be added to the open plasmid and spliced together by ligase. The recombinant plasmids formed can be inserted into new host cells and cloned. |  |  |
| 4.4.9 | State two examples of the current uses of genetically modified crops or animals. | 1 | Examples include salt tolerance in tomato plants, synthesis of beta-carotene (vitamin A precursor) in rice, herbicide resistance in crop plants and factor IX (human blood clotting) in sheep milk.**Aim 8:** The economic benefits of genetic modification to biotechnology companies that perform it could be considered. Also mention the possibility that harmful changes to local economies could result, and the danger that wealth could become more concentrated in a smaller percentage of the population if expensive but profitable new techniques are introduced. In this respect, inequalities in wealth may become greater. |  |  |
| 4.4.10 | Discuss the potential benefits and possible harmful effects of one example of genetic modification. | 3 | **Aim 8:** There are ethical questions here about how far it is acceptable for humans to change other species, as well as other ecosystems, in order to gain benefit for humans.**TOK:** This is an opportunity to discuss how we can assess whether risks are great enough to justify banning techniques and how the scientific community can inform communities generally about potential risks. Informed decisions need to be made but irrational fears should not be propagated. Consideration could be given to the paradox that careful research is needed to assess the risks, but performing this research in itself could be risky. Do protesters who destroy trials of GM crops make the world safer? |  |  |
| 4.4.11 | Define *clone*. | 1 | Clone: a group of genetically identical organisms or a group of cells derived from a single parent cell. |  |  |
| 4.4.12 | Outline a technique for cloning using differentiated animal cells. | 2 | **Aim 8:** Ethical questions about cloning should be separated into questions about reproductive cloning and therapeutic cloning. Some groups are vehemently opposed to both types. |  |  |
| 4.4.13 | Discuss the ethical issues of therapeutic cloning in humans. | 3 | Therapeutic cloning is the creation of an embryo to supply embryonic stem cells for medical use. |  |  |
| **5.1 Communities and ecosystems** |
| 5.1.1 | Define *species*, *habitat*, *population*, *community*, *ecosystem* and *ecology*. | 1 | Species: a group of organisms that can interbreed and produce fertile offspring.Habitat: the environment in which a species normally lives or the location of a living organism.Population: a group of organisms of the same species who live in the same area at the same time.Community: a group of populations living and interacting with each other in an area.Ecosystem: a community and its abiotic environment.Ecology: the study of relationships between living organisms and between organisms and their environment. |  |  |
| 5.1.2 | Distinguish between *autotroph* and *heterotroph*. | 2 | Autotroph: an organism that synthesizes its organic molecules from simple inorganic substances.Heterotroph: an organism that obtains organic molecules from other organisms. |  |  |
| 5.1.3 | Distinguish between *consumers*, *detritivores* and *saprotrophs*. | 2 | Consumer: an organism that ingests other organic matter that is living or recently killed.Detritivore: an organism that ingests non-living organic matter.Saprotroph: an organism that lives on or in non-living organic matter, secreting digestive enzymes into it and absorbing the products of digestion. |  |  |
| 5.1.4 | Describe what is meant by a food chain, giving three examples, each with at least three linkages (four organisms). | 2 | Only real examples should be used from natural ecosystems. indicates that A is being “eaten” by B (that is, the arrow indicates the direction of energy flow). Each food chain should include a producer and consumers, but not decomposers. Named organisms at either species or genus level should be used. Common species names can be used instead of binomial names. General names such as “tree” or “fish” should not be used. |  |  |
| 5.1.5 | Describe what is meant by a food web. | 2 |  |  |  |
| 5.1.6 | Define *trophic level*. | 1 |  |  |  |
| 5.1.7 | Deduce the trophic level of organisms in a food chain and a food web. | 3 | Students should be able to place an organism at the level of producer, primary consumer, secondary consumer, and so on, as the terms herbivore and carnivore are not always applicable. |  |  |
| 5.1.8 | Construct a food web containing up to 10 organisms, using appropriate information. | 3 |  |  |  |
| 5.1.9 | State that light is the initial energy source for almost all communities. | 1 | No reference to communities where food chains start with chemical energy is required. |  |  |
| 5.1.10 | Explain the energy flow in a food chain. | 3 | Energy losses between trophic levels include material not consumed or material not assimilated, and heat loss through cell respiration. |  |  |
| 5.1.11 | State that energy transformations are never 100% efficient. | 1 | Reference to the second law of thermodynamics is not expected. |  |  |
| 5.1.12 | Explain reasons for the shape of pyramids of energy. | 3 | A pyramid of energy shows the flow of energy from one trophic level to the next in a community. The units of pyramids of energy are, therefore, energy per unit area per unit time, for example, kJ m–2 yr–1. |  |  |
| 5.1.13 | Explain that energy enters and leaves ecosystems, but nutrients must be recycled. | 3 |  |  |  |
| 5.1.14 | State that saprotrophic bacteria and fungi (decomposers) recycle nutrients. | 1 |  |  |  |
| **5.2 The greenhouse effect** |
| 5.2.1 | Draw and label a diagram of the carbon cycle to show the processes involved. | 1 | The details of the carbon cycle should include the interaction of living organisms and the biosphere through the processes of photosynthesis, cell respiration, fossilization and combustion. Recall of specific quantitative data is not required.**TOK:** What difference might it make to scientific work if nature were to be regarded as a machine, for example, as a clockwork mechanism, or as an organism, that is, the Gaia hypothesis? How useful are these metaphors? |  |  |
| 5.2.2 | Analyse the changes in concentration of atmospheric carbon dioxide using historical records. | 3 | Data from the Mauna Loa, Hawaii, or Cape Grim, Tasmania, monitoring stations may be used. |  |  |
| 5.2.3 | Explain the relationship between rises in concentrations of atmospheric carbon dioxide, methane and oxides of nitrogen and the enhanced greenhouse effect. | 3 | Students should be aware that the greenhouse effect is a natural phenomenon. Reference should be made to transmission of incoming shorter-wave radiation and re-radiated longer-wave radiation. Knowledge that other gases, including methane and oxides of nitrogen, are greenhouse gases is expected. |  |  |
| 5.2.4 | Outline the precautionary principle. | 2 | The precautionary principle holds that, if the effects of a human-induced change would be very large, perhaps catastrophic, those responsible for the change must prove that it will **not do harm** before proceeding. This is the reverse of the normal situation, where those who are concerned about the change would have to prove that it will **do harm** in order to prevent such changes going ahead.**TOK:** Parallels could be drawn here between success in deterring crime by increasing the severity of the punishment or by increasing the chance of detection. If the possible consequences of rapid global warming are devastating enough, preventive measures are justified even if it is far from certain that rapid global warming will result from current human activities. |  |  |
| 5.2.5 | Evaluate the precautionary principle as a justification for strong action in response to the threats posed by the enhanced greenhouse effect. | 3 | **Aim 8:** Consider whether the economic harm of measures taken now to limit global warming could be balanced against the potentially much greater harm for future generations of taking no action now. There are also ethical questions about whether the health and wealth of future human generations should be jeopardized, and whether it is right to knowingly damage the habitat of, and possibly drive to extinction, species other than humans.The environmental angle here is that the issue of global warming is, by definition, a genuinely global one in terms of causes, consequences and remedies. Only through international cooperation will a solution be found. There is an inequality between those in the world who are contributing most to the problem and those who will be most harmed. |  |  |
| 5.2.6 | Outline the consequences of a global temperature rise on arctic ecosystems. | 2 | Effects include increased rates of decomposition of detritus previously trapped in permafrost, expansion of the range of habitats available to temperate species, loss of ice habitat, changes in distribution of prey species affecting higher trophic levels, and increased success of pest species, including pathogens. |  |  |
| **5.3 Populations** |
| 5.3.1 | Outline how population size is affected by natality, immigration, mortality and emigration. | 2 | **Aim 7:** Simulation exercises can be performed. |  |  |
| 5.3.2 | Draw and label a graph showing a sigmoid (S-shaped) population growth curve. | 1 |  |  |  |
| 5.3.3 | Explain the reasons for the exponential growth phase, the plateau phase and the transitional phase between these two phases. | 3 |  |  |  |
| 5.3.4 | List three factors that set limits to population increase. | 1 |  |  |  |
| **5.4 Evolution** |
| 5.4.1 | Define *evolution*. | 1 | Evolution is the cumulative change in the heritable characteristics of a population.If we accept not only that species can evolve, but also that new species arise by evolution from pre-existing ones, then the whole of life can be seen as unified by its common origins.Variation within our species is the result of different selection pressures operating in different parts of the world, yet this variation is not so vast to justify a construct such as race having a biological or scientific basis. |  |  |
| 5.4.2 | Outline the evidence for evolution provided by the fossil record, selective breeding of domesticated animals and homologous structures. | 2 |  |  |  |
| 5.4.3 | State that populations tend to produce more offspring than the environment can support. | 1 |  |  |  |
| 5.4.4 | Explain that the consequence of the potential overproduction of offspring is a struggle for survival. | 3 |  |  |  |
| 5.4.5 | State that the members of a species show variation. | 1 |  |  |  |
| 5.4.6 | Explain how sexual reproduction promotes variation in a species. | 3 |  |  |  |
| 5.4.7 | Explain how natural selection leads to evolution. | 3 | Greater survival and reproductive success of individuals with favourable heritable variations can lead to change in the characteristics of a population.**Aim 7:** Computer simulations can be performed. |  |  |
| 5.4.8 | Explain two examples of evolution in response to environmental change; one must be antibiotic resistance in bacteria. | 3 | Other examples could include: the changes in size and shape of the beaks of Galapagos finches; pesticide resistance, industrial melanism or heavy-metal tolerance in plants. |  |  |
| **5.5 Classification** |
| 5.5.1 | Outline the binomial system of nomenclature. | 2 | **TOK:** The adoption of a system of binomial nomenclature is largely due to Swedish botanist and physician Carolus Linnaeus (1707–1778). Linnaeus also defined four groups of humans, and the divisions were based on both physical and social traits. By 21st-century standards, his descriptions can be regarded as racist. How does the social context of scientific work affect the methods and findings of research? Is it necessary to consider the social context when evaluating ethical aspects of knowledge claims? |  |  |
| 5.5.2 | List seven levels in the hierarchy of taxa—kingdom, phylum, class, order, family, genus and species—using an example from two different kingdoms for each level. | 1 |  |  |  |
| 5.5.3 | Distinguish between the following phyla of plants, using simple external recognition features: *bryophyta, filicinophyta, coniferophyta* and *angiospermophyta*. | 2 |  |  |  |
| 5.5.4 | Distinguish between the following phyla of animals, using simple external recognition features: *porifera, cnidaria, platyhelminthes, annelida, mollusca* and *arthropoda*. | 2 |  |  |  |
| 5.5.5 | Apply and design a key for a group of up to eight organisms. | 3 | A dichotomous key should be used. |  |  |
| **6.6 Reproduction** |
| 6.6.1 | Draw and label diagrams of the adult male and female reproductive systems. | 1 | The relative positions of the organs is important. Do not include any histological details, but include the bladder and urethra. |  |  |
| 6.6.2 | Outline the role of hormones in the menstrual cycle, including FSH (follicle stimulating hormone), LH (luteinizing hormone), estrogen and progesterone. | 2 |  |  |  |
| 6.6.3 | Annotate a graph showing hormone levels in the menstrual cycle, illustrating the relationship between changes in hormone levels and ovulation, menstruation and thickening of the endometrium. | 2 |  |  |  |
| 6.6.4 | List three roles of testosterone in males. | 1 | Limit this to pre-natal development of male genitalia, development of secondary sexual characteristics and maintenance of sex drive. |  |  |
| 6.6.5 | Outline the process of *in vitro* fertilization (IVF). | 2 |  |  |  |
| 6.6.6 | Discuss the ethical issues associated with IVF. | 3 | **Aim 8:** There is great variation between human societies around the world in the views held on IVF. This is the result of cultural and religious diversity. There is little evidence to suggest that children born as a result of standard IVF protocols are different in any way from children conceived naturally. It is important that there is parity of esteem for all children, however they were conceived.**TOK:** There are potential risks in the drug treatments that the woman is given, and there are concerns about the artificial selection of sperm and the injection of them into the eggs that occurs with some IVF protocols. The natural selection of sperm with consequent elimination of unhealthy ones is bypassed, and there is evidence that there are higher rates of abnormality in the offspring as a result. |  |  |
| 11.4.1 | Annotate a light micrograph of testis tissue to show the location and function of interstitial cells (Leydig cells), germinal epithelium cells, developing spermatozoa and Sertoli cells. | 2 |  |  |  |
| 11.4.2 | Outline the processes involved in spermatogenesis within the testis, including mitosis, cell growth, the two divisions of meiosis and cell differentiation. | 2 | The names of the intermediate stages in spermatogenesis are not required. |  |  |
| 11.4.3 | State the role of LH, testosterone and FSH in spermatogenesis. | 1 |  |  |  |
| 11.4.4 | Annotate a diagram of the ovary to show the location and function of germinal epithelium, primary follicles, mature follicle and secondary oocyte. | 2 |  |  |  |
| 11.4.5 | Outline the processes involved in oogenesis within the ovary, including mitosis, cell growth, the two divisions of meiosis, the unequal division of cytoplasm and the degeneration of polar body. | 2 | The terms oogonia and primary oocyte are not required. |  |  |
| 11.4.6 | Draw and label a diagram of a mature sperm and egg. | 1 |  |  |  |
| 11.4.7 | Outline the role of the epididymis, seminal vesicle and prostate gland in the production of semen. | 2 |  |  |  |
| 11.4.8 | Compare the processes of spermatogenesis and oogenesis, including the number of gametes and the timing of the formation and release of gametes. | 3 |  |  |  |
| 11.4.9 | Describe the process of fertilization, including the acrosome reaction, penetration of the egg membrane by a sperm and the cortical reaction. | 2 |  |  |  |
| 11.4.10 | Outline the role of HCG in early pregnancy. | 2 |  |  |  |
| 11.4.11 | Outline early embryo development up to the implantation of the blastocyst. | 2 | Limit this to several mitotic divisions resulting in a hollow ball of cells called the blastocyst. |  |  |
| 11.4.12 | Explain how the structure and functions of the placenta, including its hormonal role in secretion of estrogen and progesterone, maintain pregnancy. | 3 |  |  |  |
| 11.4.13 | State that the fetus is supported and protected by the amniotic sac and amniotic fluid. | 1 | Embryonic details of the fetus and the structure of amniotic membranes are not required. |  |  |
| 11.4.14 | State that materials are exchanged between the maternal and fetal blood in the placenta. | 1 |  |  |  |
| 11.4.15 | Outline the process of birth and its hormonal control, including the changes in progesterone and oxytocin levels and positive feedback. | 2 |  |  |  |
| **11.2 Muscles and movement** |
| 11.2.1 | State the roles of bones, ligaments, muscles, tendons and nerves in human movement. | 1 |  |  |  |
| 11.2.2 | Label a diagram of the human elbow joint, including cartilage, synovial fluid, joint capsule, named bones and antagonistic muscles (biceps and triceps). | 1 |  |  |  |
| 11.2.3 | Outline the functions of the structures in the human elbow joint named in 11.2.2. | 2 |  |  |  |
| 11.2.4 | Compare the movements of the hip joint and the knee joint. | 3 | **Aim 7:** Video analysis of motion is possible here. |  |  |
| 11.2.5 | Describe the structure of striated muscle fibres, including the myofibrils with light and dark bands, mitochondria, the sarcoplasmic reticulum, nuclei and the sarcolemma. | 2 |  |  |  |
| 11.2.6 | Draw and label a diagram to show the structure of a sarcomere, including Z lines, actin filaments, myosin filaments with heads, and the resultant light and dark bands. | 1 | No other terms for parts of the sarcomere are expected. |  |  |
| 11.2.7 | Explain how skeletal muscle contracts, including the release of calcium ions from the sarcoplasmic reticulum, the formation of cross-bridges, the sliding of actin and myosin filaments, and the use of ATP to break cross-bridges and re-set myosin heads. | 3 | Details of the roles of troponin and tropomyosin are not expected.**Aim 7:** Data logging could be carried out using a grip sensor to study muscle fatigue and muscle strength. |  |  |
| 11.2.8 | Analyse electron micrographs to find the state of contraction of muscle fibres. | 3 | Muscle fibres can be fully relaxed, slightly contracted, moderately contracted and fully contracted. |  |  |
| **H1 Hormonal control** |
| H.1.1 | State that hormones are chemical messengers secreted by endocrine glands into the blood and transported to specific target cells. | 1 |  |  |  |
| H.1.2 | State that hormones can be steroids, proteins and tyrosine derivatives, with one example of each. | 1 |  |  |  |
| H.1.3 | Distinguish between the mode of action of *steroid* hormones and *protein* hormones. | 2 | Steroid hormones enter cells and interact with genes directly. Protein hormones bind to receptors in the membrane, which causes the release of a secondary messenger inside the cell. |  |  |
| H.1.4 | Outline the relationship between the hypothalamus and the pituitary gland. | 2 | Include the portal vein connecting the hypothalamus and the anterior pituitary gland, and the neurosecretory cells connecting the hypothalamus and the posterior pituitary gland. |  |  |
| H.1.5 | Explain the control of ADH (vasopressin) secretion by negative feedback. | 3 | Include neurosecretory cells in the hypothalamus, transport of ADH to the posterior pituitary gland for storage, and release under stimulus by osmoreceptors in the hypothalamus. |  |  |
| **6.5 Nerves, hormones and homeostasis** |
| 6.5.1 | State that the nervous system consists of the central nervous system (CNS) and peripheral nerves, and is composed of cells called neurons that can carry rapid electrical impulses. | 1 | No other structural or functional divisions of the nervous system are required. |  |  |
| 6.5.2 | Draw and label a diagram of the structure of a motor neuron. | 1 | Include dendrites, cell body with nucleus, axon, myelin sheath, nodes of Ranvier and motor end plates. |  |  |
| 6.5.3 | State that nerve impulses are conducted from receptors to the CNS by sensory neurons, within the CNS by relay neurons, and from the CNS to effectors by motor neurons. | 1 |  |  |  |
| 6.5.4 | Define *resting potential* and *action potential* (depolarization and repolarization). | 1 |  |  |  |
| 6.5.5 | Explain how a nerve impulse passes along a non-myelinated neuron. | 3 | Include the movement of Na+ and K+ ions to create a resting potential and an action potential. |  |  |
| 6.5.6 | Explain the principles of synaptic transmission. | 3 | Include the release, diffusion and binding of the neurotransmitter, initiation of an action potential in the post-synaptic membrane, and subsequent removal of the neurotransmitter.**Aim 7:** Data logging can be used to measure changes in conductivity in distilled water as Na+ and K+ diffuse out of salt–agar cubes or dialysing tubing. |  |  |
| 6.5.7 | State that the endocrine system consists of glands that release hormones that are transported in the blood. | 1 | The nature and action of hormones or direct comparisons between nerve and endocrine systems are not required. |  |  |
| 6.5.8 | State that homeostasis involves maintaining the internal environment between limits, including blood pH, carbon dioxide concentration, blood glucose concentration, body temperature and water balance. | 1 | The internal environment consists of blood and tissue fluid. |  |  |
| 6.5.9 | Explain that homeostasis involves monitoring levels of variables and correcting changes in levels by negative feedback mechanisms. | 3 |  |  |  |
| 6.5.10 | Explain the control of body temperature, including the transfer of heat in blood, and the roles of the hypothalamus, sweat glands, skin arterioles and shivering. | 3 | **Aim 7:** Data logging using a surface temperature sensor to investigate the warming by nasal passages could be carried out here. |  |  |
| 6.5.11 | Explain the control of blood glucose concentration, including the roles of glucagon, insulin and α and β cells in the pancreatic islets. | 3 | The effects of adrenaline are not required here. |  |  |
| 6.5.12 | Distinguish between *type I* and *type II* diabetes. | 2 | **Aim 8:** Diabetes is having an increasing effect on human societies around the world, including personal suffering due to ill health from the diabetes directly but also from side-effects such as kidney failure. There are economic consequences relating to the health-care costs of treating diabetics.**TOK:** The causes of the variation in rates of type II diabetes in different human populations could be analysed. Rates can be particularly high when individuals consume a diet very different to the traditional one of their ancestors, for example, when having migrated to a new country. There are genetic differences in our capacity to cope with high levels of refined sugar and fat in the diet. Humans also vary considerably in how prone they are to become obese. |  |  |
| **3.7 Cell respiration** |
| 3.7.1 | Define *cell respiration*. | 1 | Cell respiration is the controlled release of energy from organic compounds in cells to form ATP. |  |  |
| 3.7.2 | State that, in cell respiration, glucose in the cytoplasm is broken down by glycolysis into pyruvate, with a small yield of ATP. | 1 |  |  |  |
| 3.7.3 | Explain that, during anaerobic cell respiration, pyruvate can be converted in the cytoplasm into lactate, or ethanol and carbon dioxide, with no further yield of ATP. | 3 | Mention that ethanol and carbon dioxide are produced in yeast, whereas lactate is produced in humans.**Aim 7:** Data logging using gas sensors, oxygen, carbon dioxide or pH probes could be used. |  |  |
| 3.7.4 | Explain that, during aerobic cell respiration, pyruvate can be broken down in the mitochondrion into carbon dioxide and water with a large yield of ATP. | 3 |  |  |  |
| 8.1.1 | State that oxidation involves the loss of electrons from an element, whereas reduction involves a gain of electrons; and that oxidation frequently involves gaining oxygen or losing hydrogen, whereas reduction frequently involves losing oxygen or gaining hydrogen. | 1 |  |  |  |
| 8.1.2 | Outline the process of glycolysis, including phosphorylation, lysis, oxidation and ATP formation. | 2 | In the cytoplasm, one hexose sugar is converted into two three-carbon atom compounds (pyruvate) with a net gain of two ATP and two NADH + H+. |  |  |
| 8.1.3 | Draw and label a diagram showing the structure of a mitochondrion as seen in electron micrographs. | 1 |  |  |  |
| 8.1.4 | Explain aerobic respiration, including the link reaction, the Krebs cycle, the role of NADH + H+, the electron transport chain and the role of oxygen. | 3 | In aerobic respiration (in mitochondria in eukaryotes), each pyruvate is decarboxylated (CO2 removed). The remaining two-carbon molecule (acetyl group) reacts with reduced coenzyme A, and, at the same time, one NADH + H+ is formed. This is known as the link reaction.In the Krebs cycle, each acetyl group (CH3CO) formed in the link reaction yields two CO2. The names of the intermediate compounds in the cycle are not required. Thus it would be acceptable to note: , and so on. |  |  |
| 8.1.5 | Explain oxidative phosphorylation in terms of chemiosmosis. | 3 |  |  |  |
| 8.1.6 | Explain the relationship between the structure of the mitochondrion and its function. | 3 | Limit this to cristae forming a large surface area for the electron transport chain, the small space between inner and outer membranes for accumulation of protons, and the fluid matrix containing enzymes of the Krebs cycle. |  |  |
| **3.8 Photosynthesis** |
| 3.8.1 | State that photosynthesis involves the conversion of light energy into chemical energy. | 1 |  |  |  |
| 3.8.2 | State that light from the Sun is composed of a range of wavelengths (colours). | 1 | Reference to actual wavelengths or frequencies is not expected. |  |  |
| 3.8.3 | State that chlorophyll is the main photosynthetic pigment. | 1 |  |  |  |
| 3.8.4 | Outline the differences in absorption of red, blue and green light by chlorophyll. | 2 | Students should appreciate that pigments absorb certain colours of light. The remaining colours of light are reflected. It is not necessary to mention wavelengths or the structure responsible for the absorption.**Aim 7:** Data logging using colorimeters or light sensors could be used. |  |  |
| 3.8.5 | State that light energy is used to produce ATP, and to split water molecules (photolysis) to form oxygen and hydrogen. | 1 |  |  |  |
| 3.8.6 | State that ATP and hydrogen (derived from the photolysis of water) are used to fix carbon dioxide to make organic molecules. | 1 |  |  |  |
| 3.8.7 | Explain that the rate of photosynthesis can be measured directly by the production of oxygen or the uptake of carbon dioxide, or indirectly by an increase in biomass. | 3 | The recall of details of specific experiments to indicate that photosynthesis has occurred or to measure the rate of photosynthesis is not expected. |  |  |
| 3.8.8 | Outline the effects of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis. | 2 | The shape of the graphs is required. The concept of limiting factors is not expected.**Aim 7:** Data logging using gas sensors, oxygen, carbon dioxide or pH probes could be used. |  |  |
| 8.2.1 | Draw and label a diagram showing the structure of a chloroplast as seen in electron micrographs. | 1 |  |  |  |
| 8.2.2 | State that photosynthesis consists of light-dependent and light-independent reactions. | 1 | These should not be called “light” and “dark” reactions. |  |  |
| 8.2.3 | Explain the light-dependent reactions. | 3 | Include the photoactivation of photosystem II, photolysis of water, electron transport, cyclic and non-cyclic photophosphorylation, photoactivation of photosystem I, and reduction of NADP+. |  |  |
| 8.2.4 | Explain photophosphorylation in terms of chemiosmosis. | 3 |  |  |  |
| 8.2.5 | Explain the light-independent reactions. | 3 | Include the roles of ribulose bisphosphate (RuBP) carboxylase, reduction of glycerate 3-phosphate (GP) to triose phosphate (TP), NADPH + H+, ATP, regeneration of RuBP, and subsequent synthesis of more complex carbohydrates.**TOK:** The lollipop apparatus used to work out the biochemical details of the Calvin cycle shows considerable creativity. To what extent is the creation of an elegant protocol similar to the creation of a work of art? |  |  |
| 8.2.6 | Explain the relationship between the structure of the chloroplast and its function. | 3 | Limit this to the large surface area of thylakoids for light absorption, the small space inside thylakoids for accumulation of protons, and the fluid stroma for the enzymes of the Calvin cycle. |  |  |
| 8.2.7 | Explain the relationship between the action spectrum and the absorption spectrum of photosynthetic pigments in green plants. | 3 | A separate spectrum for each pigment (chlorophyll a, chlorophyll b, and so on) is not required. |  |  |
| 8.2.8 | Explain the concept of limiting factors in photosynthesis, with reference to light intensity, temperature and concentration of carbon dioxide. | 3 | **TOK:** This is an opportunity to discuss the need for very carefully controlled experiments. If we want to investigate the effect of one factor, all other factors that could have an influence must be controlled. In photosynthesis, the situation is relatively simple, and we can ensure that factors other than the one we are investigating are maintained at a constant and optimal level. In other areas, there are much greater problems. In the many investigations of human health, there are almost always complicating factors. For example, vegetarians have a longer life expectancy than meat eaters. We would be wrong to conclude that eating meat lowers life expectancy unless we could show that the only difference between the vegetarians and the meat eaters in our trial was the meat eating. |  |  |
| **E1 Stimulus and response** |
| E.1.1 | Define the terms *stimulus*, *response* and *reflex* in the context of animal behaviour. | 1 | A stimulus is a change in the environment (internal or external) that is detected by a receptor and elicits a response. A reflex is a rapid, unconscious response. |  |  |
| E.1.2 | Explain the role of receptors, sensory neurons, relay neurons, motor neurons, synapses and effectors in the response of animals to stimuli. | 3 | **Aim 7:** Data logging using an EKG sensor to analyse neuromuscular reflexes could be used. |  |  |
| E.1.3 | Draw and label a diagram of a reflex arc for a pain withdrawal reflex, including the spinal cord and its spinal nerves, the receptor cell, sensory neuron, relay neuron, motor neuron and effector. | 1 | Include white and grey matter, and ventral and dorsal roots. |  |  |
| E.1.4 | Explain how animal responses can be affected by natural selection, using two examples. | 3 | Use of local examples is encouraged.The bird *Sylvia atricapilla* (blackcap) breeds during the summer in Germany and, until recently, migrated to Spain or other Mediterranean areas for winter. However, studies show that 10% of blackcaps now migrate to the UK instead. To test whether this change is genetically determined or not (and, therefore, whether it could have developed by natural selection or not), eggs were collected from parents who had migrated to the UK in the previous winter and from parents who had migrated to Spain. The young were reared and the direction in which they set off, when the time for migration came, was recorded. Birds whose parents had migrated to the UK tended to fly west, wherever they had been reared, and birds whose parents had migrated to Spain tended to fly south-west. Despite not being able to follow their parents at the time of migration, all the birds tended to fly in the direction that would take them on the same migration route as their parents.This and other evidence suggests that blackcaps are genetically programmed to respond to stimuli when they migrate so that they fly in a particular direction. The increase in the numbers of blackcaps migrating to the UK for the winter may be due to warmer winters and greater survival rates in the UK.**TOK:** There are many poor examples of supposed links between animal responses and natural selection. It is easy for us to guess how the behaviour of an animal might influence its chance of survival and reproduction, but experimental evidence from carefully controlled trials is always needed to back up our intuitions. |  |  |
| **E2 Perception of stimuli** |
| E.2.1 | Outline the diversity of stimuli that can be detected by human sensory receptors, including mechanoreceptors, chemoreceptors, thermoreceptors and photoreceptors. | 2 | Details of how each receptor functions are not required.**TOK:** Other organisms can detect stimuli that humans cannot. For example, some pollinators can detect electromagnetic radiation in the non-visible range. As a consequence, they might perceive a flower as patterned when we perceive it as plain. To what extent, therefore, is what we perceive merely a construction of reality? To what extent are we dependent upon technology to “know” the biological world? |  |  |
| E.2.2 | Label a diagram of the structure of the human eye. | 1 | The diagram should include the sclera, cornea, conjunctiva, eyelid, choroid, aqueous humour, pupil, lens, iris, vitreous humour, retina, fovea, optic nerve and blind spot. |  |  |
| E.2.3 | Annotate a diagram of the retina to show the cell types and the direction in which light moves. | 2 | Include names of rod and cone cells, bipolar neurons and ganglion cells. |  |  |
| E.2.4 | Compare rod and cone cells. | 3 | Include:* use in dim light *versus* bright light
* one type sensitive to all visible wavelengths *versus* three types sensitive to red, blue and green light
* passage of impulses from a group of rod cells to a single nerve fibre in the optic nerve *versus* passage from a single cone cell to a single nerve fibre.
 |  |  |
| E.2.5 | Explain the processing of visual stimuli, including edge enhancement and contralateral processing. | 3 | Edge enhancement occurs within the retina and can be demonstrated with the Hermann grid illusion.Contralateral processing is due to the optic chiasma, where the right brain processes information from the left visual field and vice versa. This can be illustrated by the abnormal perceptions of patients with brain lesions. |  |  |
| E.2.6 | Label a diagram of the ear. | 1 | Include pinna, eardrum, bones of the middle ear, oval window, round window, semicircular canals, auditory nerve and cochlea. |  |  |
| E.2.7 | Explain how sound is perceived by the ear, including the roles of the eardrum, bones of the middle ear, oval and round windows, and the hair cells of the cochlea. | 3 | The roles of the other parts of the ear are not expected. |  |  |
| **E3 Innate and learned behaviour** |
| E.3.1 | Distinguish between *innate* and *learned* behaviour. | 2 | Innate behaviour develops independently of the environmental context, whereas learned behaviour develops as a result of experience. |  |  |
| E.3.2 | Design experiments to investigate innate behaviour in invertebrates, including either a taxis or a kinesis. | 3 | Examples include:* taxis—*Planaria* move towards food (chemotaxis) and *Euglena* move towards light (phototaxis)
* kinesis—woodlice move about less in optimum (humid) conditions and more in an unfavourable (dry) atmosphere.
 |  |  |
| E.3.3 | Analyse data from invertebrate behaviour experiments in terms of the effect on chances of survival and reproduction. | 3 |  |  |  |
| E.3.4 | Discuss how the process of learning can improve the chance of survival. | 3 |  |  |  |
| E.3.5 | Outline Pavlov’s experiments into conditioning of dogs. | 2 | The terms unconditioned stimulus, conditioned stimulus, unconditioned response and conditioned response should be included*.***TOK:** The extent to which Pavlov’s theory can be applied to different examples of learning could be considered. |  |  |
| E.3.6 | Outline the role of inheritance and learning in the development of birdsong in young birds. | 2 |  |  |  |
| **E4 Neurotransmitters and synapses** |
| E.4.1 | State that some presynaptic neurons excite postsynaptic transmission and others inhibit postsynaptic transmission. | 1 |  |  |  |
| E.4.2 | Explain how decision-making in the CNS can result from the interaction between the activities of excitatory and inhibitory presynaptic neurons at synapses. | 3 |  |  |  |
| E.4.3 | Explain how psychoactive drugs affect the brain and personality by either increasing or decreasing postsynaptic transmission. | 3 | Include ways in which synaptic transmission can be increased or decreased. Details of the organization and functioning of the entire brain, and theories of personality or explanations for personality, are not required. |  |  |
| E.4.4 | List three examples of excitatory and three examples of inhibitory psychoactive drugs. | 1 | Use the following examples.* Excitatory drugs: nicotine, cocaine and amphetamines
* Inhibitory drugs: benzodiazepines, alcohol and tetrahydrocannabinol (THC).
 |  |  |
| E.4.5 | Explain the effects of THC and cocaine in terms of their action at synapses in the brain. | 3 | Include the effects of these drugs on both mood and behaviour.**Aim 8:** The social consequences of these drugs could be considered, for the user, his or her family and the wider society. |  |  |
| E.4.6 | Discuss the causes of addiction, including genetic predisposition, social factors and dopamine secretion. | 3 |  |  |  |
| **E5 The human brain** |
| E.5.1 | Label, on a diagram of the brain, the medulla oblongata, cerebellum, hypothalamus, pituitary gland and cerebral hemispheres. | 1 |  |  |  |
| E.5.2 | Outline the functions of each of the parts of the brain listed in E.5.1. | 2 | Medulla oblongata: controls automatic and homeostatic activities, such as swallowing, digestion and vomiting, and breathing and heart activity.Cerebellum: coordinates unconscious functions, such as movement and balance.Hypothalamus: maintains homeostasis, coordinating the nervous and endocrine systems, secreting hormones of the posterior pituitary, and releasing factors regulating the anterior pituitary.Pituitary gland: the posterior lobe stores and releases hormones produced by the hypothalamus and the anterior lobe, and produces and secretes hormones regulating many body functions.Cerebral hemispheres: act as the integrating centre for high complex functions such as learning, memory and emotions. |  |  |
| E.5.3 | Explain how animal experiments, lesions and FMRI (functional magnetic resonance imaging) scanning can be used in the identification of the brain part involved in specific functions. | 3 | Include one specific example of each.**Aim 8:** There are some important ethical issues involved in animal experimentation.**TOK:** The construction of controlled FMRI experiments has proved very difficult because of the development of conditioned reflexes in experimental subjects. Investigating the human mind will always be a challenging field. |  |  |
| E.5.4 | Explain sympathetic and parasympathetic control of the heart rate, movements of the iris and flow of blood to the gut. | 3 |  |  |  |
| E.5.5 | Explain the pupil reflex. | 3 |  |  |  |
| E.5.6 | Discuss the concept of brain death and the use of the pupil reflex in testing for this. | 3 |  |  |  |
| E.5.7 | Outline how pain is perceived and how endorphins can act as painkillers. | 2 | Limit this to:* passage of impulses from pain receptors in the skin and other parts of the body to sensory areas of the cerebral cortex
* feelings of pain due to these areas of the cerebral cortex
* endorphins blocking transmission of impulses at synapses involved in pain perception.
 |  |  |
| **E6 Further studies of behaviour** |
| E.6.1 | Describe the social organization of honey bee colonies and one other non-human example. | 2 | Detailed structural differences and the life cycle of honey bees are not expected. |  |  |
| E.6.2 | Outline how natural selection may act at the level of the colony in the case of social organisms. | 2 |  |  |  |
| E.6.3 | Discuss the evolution of altruistic behaviour using two non-human examples. | 3 |  |  |  |
| E.6.4 | Outline two examples of how foraging behaviour optimizes food intake, including bluegill fish foraging for *Daphnia*. | 2 |  |  |  |
| E.6.5 | Explain how mate selection can lead to exaggerated traits. | 3 | An example of this is the peacock’s tail feathers. |  |  |
| E.6.6 | State that animals show rhythmical variations in activity. | 1 |  |  |  |
| E.6.7 | Outline two examples illustrating the adaptive value of rhythmical behaviour patterns. | 2 | Examples could include the diurnal activity variation of hamsters, coordinated spawning in corals, or seasonal reproductive behaviour in deer. |  |  |
| **9.1 Plant structure and growth** |
| 9.1.1 | Draw and label plan diagrams to show the distribution of tissues in the stem and leaf of a dicotyledonous plant. | 1 | Either sunflower, bean or another dicotyledonous plant with similar tissue distribution should be used. Note that plan diagrams show distribution of tissues (for example, xylem, phloem) and do not show individual cells. They are sometimes called “low-power” diagrams. |  |  |
| 9.1.2 | Outline three differences between the structures of dicotyledonous and monocotyledonous plants. | 2 | Teachers should emphasize three differences between monocotyledonous and dicotyledonous plants (examples include: parallel *versus* net-like venation in leaves, distribution of vascular tissue in stems, number of cotyledons, floral organs in multiples of 3 in monocotyledonous *versus* 4 or 5 in dicotyledonous, fibrous adventitious roots in monocotyledonous *versus* tap root with lateral branches in dicotyledonous). |  |  |
| 9.1.3 | Explain the relationship between the distribution of tissues in the leaf and the functions of these tissues. | 3 | This should be restricted to dicotyledonous plants. The functions should include: absorption of light, gas exchange, support, water conservation, and the transport of water and products of photosynthesis. |  |  |
| 9.1.4 | Identify modifications of roots, stems and leaves for different functions: bulbs, stem tubers, storage roots and tendrils. | 2 |  |  |  |
| 9.1.5 | State that dicotyledonous plants have apical and lateral meristems. | 1 | Apical meristems are sometimes referred to as primary meristems, and lateral meristems as cambium. Meristems generate new cells for growth of the plant. |  |  |
| 9.1.6 | Compare growth due to apical and lateral meristems in dicotyledonous plants. | 3 |  |  |  |
| 9.1.7 | Explain the role of auxin in phototropism as an example of the control of plant growth. | 3 |  |  |  |
| **9.2 Transport in angiospermophytes** |
| 9.2.1 | Outline how the root system provides a large surface area for mineral ion and water uptake by means of branching and root hairs. | 2 |  |  |  |
| 9.2.2 | List ways in which mineral ions in the soil move to the root. | 1 | There are three processes: diffusion of mineral ions, fungal hyphae (mutualism), and mass flow of water in the soil carrying ions. |  |  |
| 9.2.3 | Explain the process of mineral ion absorption from the soil into roots by active transport. | 3 |  |  |  |
| 9.2.4 | State that terrestrial plants support themselves by means of thickened cellulose, cell turgor and lignified xylem. | 1 |  |  |  |
| 9.2.5 | Define *transpiration*. | 1 | Transpiration is the loss of water vapour from the leaves and stems of plants.**Aim 7:** Data logging with pressure sensors, humidity, light or temperature probes to measure rates of transpiration can be performed. |  |  |
| 9.2.6 | Explain how water is carried by the transpiration stream, including the structure of xylem vessels, transpiration pull, cohesion, adhesion and evaporation. | 3 | Limit the structure of xylem vessels to one type of primary xylem. |  |  |
| 9.2.7 | State that guard cells can regulate transpiration by opening and closing stomata. | 1 |  |  |  |
| 9.2.8 | State that the plant hormone abscisic acid causes the closing of stomata. | 1 |  |  |  |
| 9.2.9 | Explain how the abiotic factors light, temperature, wind and humidity, affect the rate of transpiration in a typical terrestrial plant. | 3 |  |  |  |
| 9.2.10 | Outline four adaptations of xerophytes that help to reduce transpiration. | 2 | These could include: reduced leaves, rolled leaves, spines, deep roots, thickened waxy cuticle, reduced number of stomata, stomata in pits surrounded by hairs, water storage tissue, low growth form, CAM (crassulacean acid metabolism) and C4 physiology. |  |  |
| 9.2.11 | Outline the role of phloem in active translocation of sugars (sucrose) and amino acids from source (photosynthetic tissue and storage organs) to sink (fruits, seeds, roots). | 2 | No detail of the mechanism of translocation or the structure of phloem is required. |  |  |
| **9.3 Reproduction in angiospermophytes** |
| 9.3.1 | Draw and label a diagram showing the structure of a dicotyledonous animal-pollinated flower. | 1 | Limit the diagram to sepal, petal, anther, filament, stigma, style and ovary. |  |  |
| 9.3.2 | Distinguish between *pollination*, *fertilization* and *seed dispersal*. | 2 |  |  |  |
| 9.3.3 | Draw and label a diagram showing the external and internal structure of a named dicotyledonous seed. | 1 | The named seed should be non-endospermic. The structure in the diagram should be limited to testa, micropyle, embryo root, embryo shoot and cotyledons. |  |  |
| 9.3.4 | Explain the conditions needed for the germination of a typical seed. | 3 | Seeds vary in their light requirements and, therefore, this factor need not be included. |  |  |
| 9.3.5 | Outline the metabolic processes during germination of a starchy seed. | 2 | Absorption of water precedes the formation of gibberellin in the embryo’s cotyledon. This stimulates the production of amylase, which catalyses the breakdown of starch to maltose. This subsequently diffuses to the embryo for energy release and growth. No further details are expected. |  |  |
| 9.3.6 | Explain how flowering is controlled in long-day and short-day plants, including the role of phytochrome. | 3 | Limit this to the conversion of Pr (red absorbing) to Pfr (far-red absorbing) in red or white light, the gradual reversion of Pfr to Pr in darkness, and the action of Pfr as a promoter of flowering in long-day plants and an inhibitor of flowering in short-day plants. |  |  |