Singapore Examinations and Assessment Board

CAMBRIDGE International Education

Singapore–Cambridge Secondary Education Certificate (2027)

G3 Biology (Syllabus K325)

CONTENTS

INTRODUCTION

The G3 Biology syllabus is designed to have less emphasis on factual materials, but a much greater emphasis on the understanding and application of scientific concepts and principles. This approach has been adopted in recognition of the need for students to develop skills that will be of long-term value in an increasingly complex and globalised world, rather than focusing on large quantities of factual material, which may have only short-term relevance.

It is envisaged that teaching and learning programmes based on this syllabus will feature a wide variety of learning experiences designed to promote acquisition of scientific expertise and understanding, and to develop values and attitudes relevant to science. Teachers are encouraged to use a combination of appropriate strategies in teaching topics in this syllabus. The assessment will be specifically intended to test skills, comprehension and insight in familiar and unfamiliar contexts.

AIMS

The aims of a course based on this syllabus should be to:

1. provide a worthwhile educational experience for all students, whether or not they go on to study science beyond this level

2. develop in students the understanding, and skills relevant to the practices of science, and enable them to

    2.1 appreciate practical applications of Biology in the real world

    2.2 deepen their interest in Biology for future learning and work

    2.3 become scientifically literate citizens who can innovate and seize opportunities in the 21st century

    2.4 understand how living organisms work to sustain life and use the disciplinary ideas in Biology to approach, analyse and solve problems in biological systems.

3. develop in students the values, ethics and attitudes relevant to science such as

    3.1 curiosity – desiring to explore the environment and question what is found

    3.2 creativity – seeking innovative and relevant ways to solve problems

    3.3 integrity – handling and communicating data and information with complete honesty

    3.4 objectivity – seeking data and information to validate observations and explanations without bias

    3.5 open-mindedness – accepting all knowledge as tentative and suspending judgement, tolerance for ambiguity, willingness to change views if the evidence is convincing

    3.6 resilience – not giving up on the pursuit of answers/solutions, willingness to take risks and embrace failure as part of the learning process

    3.7 responsibility – showing care and concern for living things and awareness of our responsibility for the quality of the environment

    3.8 healthy scepticism – questioning the observations, methods, processes and data, as well as trying to review one’s own ideas.

PRACTICES OF SCIENCE

The *Practices of Science* represent the set of established procedures and practices associated with scientific inquiry, what scientific knowledge is and how it is generated and established, and how Science is applied in society respectively. It consists of three components:

1. Demonstrating Ways of Thinking and Doing in Science (WoTD)

1.1 Posing questions and defining problems

1.2 Designing investigations

1.3 Conducting experiments and testing solutions

1.4 Analysing and interpreting data

1.5 Communicating, evaluating and defending ideas with evidence

1.6 Making informed decisions and taking responsible actions

1.7 Using and developing models

1.8 Constructing explanations and designing solutions

2. Understanding the Nature of Scientific Knowledge (NOS)

2.1 Science is an evidence-based, model-building enterprise concerned with understanding the natural world

2.2 Science assumes there are natural causes for physical phenomena and an order and consistency in natural systems

2.3 Scientific knowledge is generated using a set of established procedures and practices, and through a process of critical debate within the scientific community

2.4 Scientific knowledge is reliable and durable, yet open to change in the light of new evidence

3. Relating Science, Technology, Society and Environment (STSE)

3.1 There are risks and benefits associated with the applications of science in society. Science and its applications have the potential to bring about both benefits and harm to society

3.2 Applications of science often have ethical, social, economic and environmental implications

3.3 Applications of new scientific discoveries often inspire technological advancements while advances in technology motivate scientists to ask new questions and/or empower scientists in their inquiry (e.g. collecting more precise data or carrying out more complex data analysis)

The *Practices of Science* serve to highlight that the discipline of Science is more than the acquisition of a *body of knowledge* (e.g. scientific facts, concepts, laws, and theories); it is also a way of *thinking and doing*. In particular, it is important to appreciate that the cognitive, epistemic and social aspects of the *Practices of Science* are intricately related. For example, observation of events can lead to the generation of scientific knowledge which is, simultaneously, shaped by the beliefs of scientific knowledge. In addition, scientists develop models to construct theories, based on the assumption that there is order and consistency in natural systems. The practice of theory-making, in turn, reinforces the explanatory power of scientific knowledge. The scientific endeavour is embedded in the wider ethical, social, economic and environmental contexts.

ASSESSMENT OBJECTIVES

These describe the knowledge, skills and abilities which candidates are expected to demonstrate at the end of the course. They reflect those aspects of the aims which will be assessed.

A Knowledge with Understanding

Candidates should be able to demonstrate knowledge and understanding in relation to:

1. scientific phenomena, facts, laws, definitions, concepts, theories;

2. scientific vocabulary, terminology, conventions (including symbols, quantities and units contained in *Signs, Symbols and Systematics 16–19*, Association for Science Education, 2000 and the recommendations on terms, units and symbols in '*Biological Nomenclature* 4th Edition (2009)' published by the Institute of Biology, in conjunction with the Association for Science Education);

3. scientific instruments and apparatus, including techniques of operation and aspects of safety;

4. scientific quantities and their determination;

5. scientific and technological applications with their social, economic and environmental implications.

The subject content defines the factual knowledge that candidates may be required to recall and explain. Questions testing those objectives will often begin with one of the following words: *define*, *state*, *describe*, *explain* or *outline*. (See the *Glossary of Terms*)

B Handling Information and Solving Problems

Candidates should be able – in words or by using symbolic, graphical and numerical forms of presentation – to:

1. locate, select, organise and present information from a variety of sources;

2. translate information from one form to another;

3. manipulate numerical and other data;

4. use information to identify patterns, report trends and draw inferences;

5. present reasoned explanations for phenomena, patterns and relationships;

6. make predictions and propose hypotheses;

7. solve problems.

These assessment objectives cannot be precisely specified in the subject content because questions testing such skills may be based on information which is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, reasoned or deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: *predict*, *suggest*, *calculate* or *determine*. (See the *Glossary of Terms*)

C Experimental Skills and Investigations

Candidates should be able to:

1. follow a sequence of instructions;
2. use techniques, apparatus and materials;
3. make and record observations, measurements and estimates;
4. interpret and evaluate observations and experimental results;
5. plan investigations, select techniques, apparatus and materials;
6. evaluate methods and suggest possible improvements.

Weighting of Assessment Objectives

Theory Papers (Papers 1 and 2)

A Knowledge with Understanding, approximately 45% of the marks.

B Handling Information and Solving Problems, approximately 55% of the marks.

Practical Assessment (Paper 3)

C Experimental Skills and Investigations, 100% of the marks.

Paper 3 will assess appropriate aspects of objectives C1 to C6 in the following skill areas

- Planning (P)
- Manipulation, measurement and observation (MMO)
- Presentation of data and observations (PDO)
- Analysis, conclusions and evaluation (ACE)

The assessment of Planning (P) will have a weighting of 15%. The assessment of skill areas MMO, PDO and ACE will have a weighting of 85%.

SCHEME OF ASSESSMENT

Candidates are required to enter for Papers 1, 2 and 3.

Paper	Type of Paper	Duration	Marks	Weighting
1	Multiple Choice	1h	40	30%
2	Structured and free-response questions	1h 45 min	80	50%
3	Practical	1 hr 50 min	40	20%

Theory Papers

Paper 1 (1 h, 40 marks)

This paper will consist of 40 compulsory multiple choice items.

Paper 2 (1 h 45 min, 80 marks)

This paper will consist of two sections.

Section A will carry 70 marks and will contain a number of compulsory structured questions, with one free response question and one data-based question as the last two questions. The last two questions will carry a total of 20 marks. The data-based question requires candidates to interpret, evaluate or solve problems using a stem of information. The data-based question will carry 8–12 marks.

Section B will carry 10 marks and will consist of two free response questions. Candidates must answer only one out of these two questions.

Practical

Paper 3 (1 h 50 min, 40 marks)

This paper will comprise two to three compulsory practical questions, based mainly on Assessment Objective C.

One or more of the questions may incorporate assessment of Planning (P) and require candidates to apply and integrate knowledge and understanding from different sections of the syllabus. The assessment of PDO and ACE may include questions on data-analysis which do not require practical equipment and apparatus.

Candidates are not allowed to refer to notebooks, textbooks or any other information during the assessment.

DISCIPLINARY IDEAS OF BIOLOGY

The disciplinary ideas of Biology described below represent the overarching ideas which can be applied to explain, analyse and solve a variety of problems that seek to address the broader question of how living organisms work to sustain life. The purpose of equipping students with an understanding of these ideas is to develop in them a coherent view and conceptual framework of scientific knowledge to facilitate the application and transfer of learning. These ideas can be revisited throughout the syllabus, deepened at higher levels of learning and beyond the schooling years.

1. **The Cell** – Diverse life forms are similar in that their basic unit are cells.

2. **Structure and Function** – Structure and function of organisms from the molecular to the organ system levels are related to each other.

3. **Systems** – Biological systems interact among themselves and with the environment resulting in the flow of energy and nutrients.

4. **Energy** – To ensure survival, living organisms obtain, transform and utilise energy from the external world.

5. **Homeostasis, Co-ordination and Response** – Living organisms detect changes both from the surrounding environment and within themselves so that they are able to respond to these changes to maintain a constant internal environment needed for sustaining life.

6. **Heredity** – Genetic information is passed down from parents to offspring during reproduction to ensure the continuity of life.

7. **Evolution** – The diversity of living organisms is achieved through a process of evolution, driven by mechanisms such as natural selection.

CONTENT STRUCTURE

THEMES	Topics
I. Cells and The Chemistry of Life	1. Cell Structure and Organisation 2. Movement of Substances 3. Biological Molecules
II. The Human Body – Maintaining Life	4. Nutrition in Humans 5. Transport in Humans 6. Respiration in Humans 7. Excretion in Humans 8. Homeostasis, Co-ordination and Response in Humans 9. Infectious Diseases in Humans
III. Living Together – Plants, Animals and Ecosystems	10. Nutrition and Transport in Flowering Plants 11. Organisms and their Environment
IV. Continuity of Life	12. Molecular Genetics 13. Reproduction 14. Inheritance

SUBJECT CONTENT

SECTION I: CELLS AND THE CHEMISTRY OF LIFE

Overview

Living things are different from non-living things in their ability to grow, reproduce, move, and respond to change. Understanding what makes these characteristics of life possible requires an appreciation of the hierarchical organisation of life (from cells → tissues → organs → systems → organism) and the processes needed to sustain life at each level.

In this section, we begin by exploring life at the smallest level. Amidst the great diversity of living organisms on earth, all living organisms are fundamentally similar at the smallest level; they are all made of cells and a common set of carbon-based molecules. Physiological processes in living organisms can be explained through activities happening at the cellular level. For instance, the transport of oxygen around the body is made possible by red blood cells that bind oxygen to haemoglobin.

At the molecular level, living organisms are made of four elements carbon, hydrogen, oxygen and nitrogen. These elements make life possible as they combine to form macromolecules such as carbohydrates, proteins and fats, which are needed to sustain life by providing energy, building cellular structures, and for growth and repair.

The overarching ideas of this section are cells as the basic unit of life, correlation between structure and function and how living organisms obtain, transform and utilise energy from the external world at the cellular level to sustain life. Knowing how life works at the cellular and molecular level will provide students with a foundation to understand processes needed to sustain life at the tissue, organ and system levels, which are covered in subsequent sections of this syllabus.

1. Cell Structure and Organisation

Content

- Plant and Animal Cells
- Cell Specialisation

Learning Outcomes

Candidates should be able to:

(a) identify and state the functions of the following cell structures (including organelles) of typical plant and animal cells from diagrams, light micrographs and as seen under the light microscope using prepared slides and fresh material treated with an appropriate temporary staining technique:

- cell wall
- cell membrane
- cytoplasm
- nucleus
- cell vacuoles (large, sap-filled in plant cells, small, temporary in animal cells)
- chloroplasts

(b) identify and state the functions of the following membrane systems and organelles from diagrams and electron micrographs:

- endoplasmic reticulum
- Golgi body
- mitochondria
- ribosomes

(c) compare the structure of typical animal and plant cells

(d) explain how the structures of specialised cells are adapted to their functions (e.g. muscle cell – many mitochondria to supply more energy, root hair cell – large surface area of cell membrane for greater absorption, red blood cell – lack of nucleus allowing it to transport more oxygen)

2. Movement of Substances

Content

- Diffusion
- Osmosis
- Active Transport

Learning Outcomes

Candidates should be able to:

(a) define *diffusion* and describe its role in nutrient uptake and gaseous exchange in plants and humans

(b) define *osmosis*, investigate and describe the effects of osmosis on plant and animal tissues

(c) define *active transport* and discuss its importance as an energy-consuming process by which substances are transported against a concentration gradient, as in ion uptake by root hairs and uptake of glucose by cells in the villi

3. Biological Molecules

Content

- Carbohydrates, Fats and Proteins
- Enzymes

Learning Outcomes

Candidates should be able to:

(a) list the chemical elements which make up:

- carbohydrates
- fats
- proteins

(b) state the main roles of carbohydrates, fats and proteins in living organisms:

- carbohydrates as an immediate source of energy
- fats for insulation and long-term storage of energy
- proteins for growth and repair of cells

(c) describe and carry out tests for:

- starch (using iodine in potassium iodide solution)
- reducing sugars (using Benedict's solution)
- protein (using biuret solution)
- fats (using ethanol)

(d) state that large molecules are synthesised from smaller basic units:

- cellulose, glycogen and starch from glucose
- polypeptides and proteins from amino acids
- lipids such as fats from glycerol and fatty acids

(e) explain the mode of action of enzymes in terms of an active site, enzyme-substrate complex, lowering of activation energy and enzyme specificity using the 'lock and key' hypothesis

(f) investigate and explain the effects of temperature and pH on the rate of enzyme catalysed reactions

SECTION II: THE HUMAN BODY – MAINTAINING LIFE

Overview

Life is sustained through the integrated organisation of the whole organism. In humans, the maintenance and regulation of life processes include nutrition, transport, respiration, excretion, homeostasis and co-ordination and response.

Living systems utilise energy and macromolecules to maintain life processes such as growth, reproduction and homeostasis. Interactions also exist between living systems within organisms, which are often accompanied by the transfer of energy between matter and transfer or exchange of matter. Each system has their component parts, characterised by the division of labour. This division of labour enables an organism to function efficiently and allows for the various systems to work together as a co-ordinated whole. The co-ordinated response across systems to maintain optimal internal environments stimulated by external and internal changes forms the basis of homeostasis.

The threat of diseases disrupts the maintenance of important life processes and the functioning of human body systems. In ancient times, the concept of 'catching' a disease was unheard of, and diseases were even thought to be caused by the imbalance of 'humours' (internal fluids) within the body. However, with the invention of the microscope, we have found out that infectious diseases are often caused by pathogens, e.g. viruses and bacteria.

The overarching ideas in the study of this section are the co-ordination of the human body system as a whole and the correlation between structure and function.

4. Nutrition in Humans

Content

- Human Digestive System
- Physical and Chemical Digestion
- Absorption and Assimilation

Learning Outcomes

Candidates should be able to:

(a) describe the functions of the various parts of the digestive system: mouth, salivary glands, oesophagus, stomach, duodenum, pancreas, gall bladder, liver, ileum, colon, rectum, anus, in relation to ingestion, digestion, absorption, assimilation and egestion of food, as appropriate

(b) describe peristalsis in terms of rhythmic wave-like contractions of the muscles to mix and propel the contents of the alimentary canal

(c) describe the functions of enzymes (e.g. amylase, maltase, protease, lipase) in digestion, listing the substrates and end-products

(d) explain how the structure of a villus, including the capillaries and lacteal, is suited for its function of absorption

(e) state the function of the hepatic portal vein as the transport of blood rich in absorbed nutrients from the small intestine to the liver

(f) state the role of the liver in:

- conversion of glucose to glycogen and vice versa
- fat digestion
- metabolism of amino acids and formation of urea
- breakdown of alcohol
- breakdown of hormones

(g) outline the effects of alcohol consumption on the brain (e.g. increased reaction time, reduced self-control), the long-term effects of excessive consumption (e.g. liver disease and brain damage) and the social implications

5. Transport in Humans

Content

- Parts and Functions of the Circulatory System
- Blood
- Heart and Cardiac Cycle
- Coronary Heart Disease

Learning Outcomes

Candidates should be able to:

(a) identify the main blood vessels to and from the heart, lungs, liver and kidney

(b) relate the structures of arteries, veins and capillaries to their functions (specific names of muscle layers in arteries and veins are **not** required)

(c) describe the transfer of materials between capillaries and tissue fluid

(d) state the components of blood and their roles in transport and defence:

- red blood cells – haemoglobin for oxygen transport
- plasma – transport of blood cells, ions, soluble food substances, hormones, carbon dioxide, urea, vitamins, plasma proteins
- white blood cells – phagocytosis, antibody formation and tissue rejection
- platelets – fibrinogen to fibrin, causing clotting

(e) list the different ABO blood groups and describe all possible combinations for the donor and recipient in blood transfusions

(f) describe the structure and function of the heart in terms of muscular contraction and the working of valves

(g) outline the cardiac cycle in terms of what happens during systole and diastole (histology of the heart muscle, names of nerves and transmitter substances are **not** required)

(h) describe coronary heart disease in terms of the occlusion of coronary arteries and list the possible causes, such as unhealthy diet, sedentary lifestyle, and smoking, stating the possible preventative measures

6. Respiration in Humans

Content

- Human Gas Exchange
- Cellular Respiration

Learning Outcomes

Candidates should be able to:

(a) identify the larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries and state their functions in human gaseous exchange

(b) describe the process of breathing and the role of cilia, diaphragm, ribs and internal and external intercostal muscles

(c) explain how the structure of an alveolus is suited for its function of gaseous exchange

(d) state the major toxic components of tobacco smoke – nicotine, tar and carbon monoxide, and describe their effects on health

(e) define *aerobic respiration* in human cells as the release of energy by the breakdown of glucose in the presence of oxygen and state the equation, in words and symbols

(f) define *anaerobic respiration* in human cells as the release of energy by the breakdown of glucose in the absence of oxygen and state the word equation

(g) explain why cells respire anaerobically during vigorous exercise resulting in an oxygen debt that is removed by rapid, deep breathing after exercise

7. Excretion in Humans

Content

- Structure and Function of Kidneys
- Kidney Dialysis

Learning Outcomes

Candidates should be able to:

(a) define *excretion* and explain the importance of removing nitrogenous and other compounds from the body

(b) identify the kidneys, ureter, bladder and urethra and state their functions in excretion

(c) outline the function of the nephron with reference to ultra-filtration and selective reabsorption in the production of urine

(d) outline the mechanism of dialysis in the case of kidney failure

8. Homeostasis, Co-ordination and Response in Humans

Content

- Principles of Homeostasis
- Hormonal Control
- Nervous Control

Learning Outcomes

Candidates should be able to:

(a) define *homeostasis* as the maintenance of a constant internal environment

(b) explain the basic principles of homeostasis in terms of stimulus resulting from a change in the internal environment, a corrective mechanism and negative feedback

(c) describe the maintenance of a constant body temperature in humans in terms of the role of:

- temperature receptors in the skin detecting changes in temperature
- sweating
- shivering
- altering blood flow through blood vessels near the skin surface
- the co-ordinating role of the hypothalamus

(d) define a *hormone* as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs

(e) explain what is meant by an endocrine gland, with reference to the islets of Langerhans in the pancreas

(f) explain how blood glucose concentration is regulated by insulin and glucagon as a homeostatic mechanism

(g) describe type 2 *diabetes mellitus* in terms of a persistently higher than normal blood glucose concentration due to the body's resistance to insulin or insufficient production of insulin

(h) identify the risk factors of (e.g. unhealthy diet and sedentary lifestyle) and ways to manage type 2 *diabetes mellitus*

(i) outline the role of anti-diuretic hormone (ADH) in osmoregulation

(j) state that the nervous system – brain, spinal cord and nerves, serves to co-ordinate and regulate bodily functions

(k) outline how receptors, sensory neurones, relay neurones (located in the spinal cord or brain), motor neurones and effectors work together to produce a co-ordinated response in a reflex action as a result of a specific stimulus

(l) describe the structure of the eye as seen in front view and in horizontal section

(m) state the principal functions of component parts of the eye in producing a focused image of near and distant objects on the retina

(n) describe the pupil reflex in response to bright and dim light

9. Infectious Diseases in Humans

Content

- Organisms affecting Human Health
- Influenza and Pneumococcal Disease
- Prevention and Treatment of Infectious Diseases

Learning Outcomes

Candidates should be able to:

(a) state that infectious diseases can be spread from person to person whereas non-infectious diseases cannot and identify examples of each

(b) explain that infectious diseases are caused by pathogens such as bacteria and viruses and can be spread from person to person through body fluids, food and water

(c) state that a typical virus has a protein coat enclosing its genetic material and reproduces only in living host cells

(d) state that a typical bacteria cell has a cell wall and DNA without a nucleus; some are pathogenic and some non-pathogenic

(e) state the signs and symptoms of:

- influenza – caused by the influenza virus
- pneumococcal disease – caused by the bacteria, pneumococcus

(f) describe the transmission and methods to reduce the transmission of:

- influenza virus
- pneumococcus

(g) state that vaccines contain an agent that resembles a pathogen and prevent infectious diseases by stimulating white blood cells to quickly produce antibodies when the pathogen invades

(h) explain that antibiotics target bacteria by preventing synthesis of cellular structures but are ineffective against viruses due to structural and reproductive differences

(i) discuss how the misuse and overuse of antibiotics may accelerate the emergence of antibiotic-resistant bacteria

SECTION III: LIVING TOGETHER – PLANTS, ANIMALS AND ECOSYSTEMS

Overview

The sun is the principal source of energy for almost all living organisms on earth, without which, life will not exist as it is today. Green plants are able to capture and convert light energy to useful chemical forms through the unique process of photosynthesis. Other organisms depend on this energy captured by plants through direct or indirect feeding relationships to sustain life.

The study of ecology will further explain how all organisms are interdependent on the transfer of energy and matter in this intricate web of life. Humans are by far the singular most influential species in ensuring the conservation of the fragile ecosystem and thus, there are important lessons to be learnt from this highly interdependent relationship among organisms. In the face of global warming as one of the major challenges confronting the world now, examining how human actions can reduce the effects of global warming takes on a pressing urgency to ensure the sustainability of the environment and life on Earth.

The overarching idea of this section is the interaction between organisms in the ecosystem for the sustainability of life through the transfer of energy and matter.

10. Nutrition and Transport in Flowering Plants

Content

- Plant Structure
- Photosynthesis
- Transpiration
- Translocation

Learning Outcomes

Candidates should be able to:

(a) identify the cellular and tissue structure of a dicotyledonous leaf, as seen in transverse section using the light microscope and describe the significance of these features in terms of their functions, such as the

- distribution of chloroplasts for photosynthesis
- stomata and mesophyll cells for gaseous exchange
- vascular bundles for transport

(b) identify the positions of and explain the functions of xylem vessels and phloem (sieve tube elements and companion cells) in sections of a herbaceous dicotyledonous leaf and stem, under the light microscope

(c) explain how the structure of a root hair cell is suited for its function of water and ion uptake

(d) state that chlorophyll absorbs light energy and converts it into chemical energy for the formation of carbohydrates and their subsequent uses

(e) briefly explain why most forms of life are completely dependent on photosynthesis

(f) state the equation, in words and symbols, for photosynthesis (details of light-dependent and light-independent stages are **not** required)

(g) describe how carbon dioxide reaches mesophyll cells in a leaf

(h) investigate and discuss the effects of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis (e.g. in submerged aquatic plant)

(i) discuss light intensity, carbon dioxide concentration and temperature as limiting factors on the rate of photosynthesis

(j) define the term *transpiration* and explain that transpiration is a consequence of gaseous exchange in plants

(k) explain the movement of water between plant cells, and between them and the environment in terms of water potential (calculations on water potential are **not** required)

(l) outline the pathway by which water is transported into the roots and through the xylem vessels to the leaves by transpiration pull

(m) investigate and explain:

- the effects of variation of air movement, temperature, humidity and light intensity on transpiration rate
- how wilting occurs

(n) define the term *translocation* as the transport of food (mainly sucrose) in the phloem tissue and illustrate the process through translocation studies

11. Organisms and their Environment

Content

- Energy Flow
- Food Chains and Food Webs
- Carbon Cycle and Global Warming
- Effects of Man on the Ecosystem
- Conservation

Learning Outcomes

Candidates should be able to:

(a) describe the non-cyclical nature of energy flow

(b) describe the roles of producers, consumers and decomposers in food chains and food webs

(c) explain how energy losses occur along food chains, and discuss the efficiency of energy transfer between trophic levels

(d) describe and interpret pyramids of numbers and biomass

(e) describe how carbon is cycled within an ecosystem and outline the role of forests and oceans as carbon sinks

(f) describe how human activities, such as deforestation and use of fossil fuels, cause an increase in atmospheric carbon dioxide concentration, leading to global warming

(g) discuss how human actions can reduce the effects of global warming

(h) describe the effects of pollution caused by:

- sewage in water
- plastic wastes in the marine environment
- insecticides and their biomagnification up food chains, impacting on top carnivores

(i) discuss how the conservation of species and sustainable use of natural resources contribute to the maintenance of biodiversity and a balanced ecosystem (e.g. coral reef, tropical rainforest, mangrove)

SECTION IV: CONTINUITY OF LIFE

Overview

The many aspects of structure and function that we have examined in this syllabus can be viewed in the widest context as various adaptations aimed at ensuring reproductive success. Reproduction is vital for the survival of species across generations.

In this section, we examine the processes that contribute to the continuity of life. These processes include how genes interact to produce hereditary characteristics in the offspring and how genetic information is passed from one generation to the next.

Some important scientists who contributed to findings in this section include Gregor Mendel – who published his observations from breeding experiments on pea plants and James Watson and Francis Crick – who developed the model for deoxyribonucleic acid (DNA), a molecule that was deduced as the hereditary material that is passed down through generations. Models aid in the visualisation of science and led to the breakthrough of the discovery of the double-helix molecule – DNA.

The overarching ideas of this section are the storage of genetic information in the DNA and the passing down of genetic information through generations to ensure the continuity of life.

12. Molecular Genetics

Content

- The Structure of DNA
- From DNA to Proteins
- Genetic Engineering

Learning Outcomes

Candidates should be able to:

(a) outline the relationships among DNA, genes and chromosomes

(b) state that DNA is a double helix comprising two strands of nucleotides, each nucleotide formed of a sugar, a phosphate group and one of four different bases

(c) state the rule of complementary base pairing

(d) state that each gene:

- is a sequence of nucleotides, as part of a DNA molecule
- codes for one polypeptide
- is a unit of inheritance

(e) state that DNA is used to carry the genetic code, which is used to synthesise specific polypeptides (details of transcription and translation are **not** required)

(f) state that genes may be transferred from the cells of one organism to the cells of another to form transgenic organisms

(g) briefly explain how a gene that controls the production of human insulin can be inserted into bacterial DNA to produce human insulin in medical biotechnology

(h) discuss the possible benefits and ethical considerations of genetic engineering, in medicine and production of economically important plants and animals

13. Reproduction

Content

- Asexual Reproduction
- Cell Division
- Sexual Reproduction in Flowering Plants
- Sexual Reproduction in Humans
- Sexually Transmitted Diseases

Learning Outcomes

Candidates should be able to:

(a) define *asexual reproduction* as the process resulting in the production of genetically identical offspring from one parent

(b) state that *mitosis* is a type of cell division giving rise to genetically identical cells in which the chromosome number is maintained

(c) state the importance of mitosis in growth, repair and asexual reproduction

(d) define *sexual reproduction* as the process involving the fusion of nuclei of male and female gametes to form a zygote and the production of genetically dissimilar offspring

(e) define the terms *haploid* and *diploid*, and explain the need for a reduction division process prior to fertilisation in sexual reproduction

(f) state what is meant by *homologous pairs* of chromosomes

(g) state that *meiosis* is a type of cell division that gives rise to genetically dissimilar cells in which the chromosome number is halved due to the separation of homologous chromosomes

(h) state that meiosis is used in the formation of gametes

(i) identify, using a hand lens if necessary, the sepals, petals, stamens and carpels of insect-pollinated, dicotyledonous flowers, and examine the pollen grains under a light microscope

(j) state the functions of the sepals, petals, anthers and carpels

(k) identify, using a hand lens if necessary, the stamens and stigmas of wind-pollinated flowers, and examine the pollen grains under a light microscope

(l) outline the process of pollination and distinguish between self-pollination and cross-pollination

(m) compare, using fresh specimens, an insect-pollinated and a wind-pollinated flower and explain their differences

(n) outline the growth of the pollen tube and its entry into the ovule followed by fertilisation (production of endosperm and details of development are **not** required)

(o) identify the male reproductive system and state the functions of: testes, scrotum, sperm ducts, prostate gland, urethra and penis

(p) identify the female reproductive system and state the functions of: ovaries, oviducts, uterus, cervix and vagina

(q) outline the menstrual cycle with reference to the alternation of menstruation and ovulation, the natural variation in its length, and the fertile and infertile phases of the cycle with reference to the effects of progesterone and oestrogen only

(r) describe fertilisation and early development of the zygote simply in terms of the formation of a ball of cells which becomes implanted in the wall of the uterus

(s) state the functions of the amniotic sac and the amniotic fluid

(t) describe the function of the placenta and umbilical cord in relation to exchange of dissolved nutrients, gases and excretory products (structural details are **not** required)

(u) discuss the transmission of human immunodeficiency virus (HIV) and methods to reduce transmission

14. Inheritance

Content

- The Passage of Genetic Information from Parent to Offspring
- Monohybrid Crosses
- Variation
- Natural Selection

Learning Outcomes

Candidates should be able to:

(a) distinguish between the terms *gene* and *allele*

(b) explain the terms *dominant*, *recessive*, *codominant*, *homozygous*, *heterozygous*, *phenotype* and *genotype*

(c) predict the results of simple crosses with expected ratios of 3:1 and 1:1, using the terms homozygous, heterozygous, F_1 generation and F_2 generation

(d) explain why observed ratios often differ from expected ratios, especially when there are small numbers of progeny

(e) use genetic diagrams to solve problems involving monohybrid inheritance

(f) explain co-dominance and multiple alleles with reference to the inheritance of the ABO blood group phenotypes (A, B, AB, O) and the gene alleles (I^A, I^B and I^O)

(g) describe the determination of sex in humans – XX and XY chromosomes

(h) describe mutation as a change in the sequence of a gene such as in sickle cell anaemia, or in the chromosome number, such as the 47 chromosomes in the condition known as Down syndrome

(i) name ionising radiation (e.g. X-ray) and chemical mutagens as factors which may increase the rate of mutation

(j) distinguish between continuous and discontinuous variation and give examples of each

(k) state that variation and competition lead to differential survival of, and reproduction by, those organisms best fitted to the environment

(l) give examples of environmental factors that act as forces of natural selection

(m) explain the role of natural selection as a possible mechanism for evolution which is a gradual change in the inheritable characteristics of a population over time

SUMMARY OF KEY QUANTITIES, SYMBOLS AND UNITS

The list below is intended as a guide to the more important quantities which might be encountered in teaching and learning. This list is not exhaustive.

Quantity	Symbol	Unit
length	l	mm, cm, m
area	A	cm^2, m^2
volume	V	cm^3, dm^3, m^3
mass	m	mg, g, kg
concentration	c	g / dm^3
time	t	s, ms, min,
pH	pH	–
temperature	T	°C
energy	E	J

PRACTICAL ASSESSMENT

Scientific subjects are, by their nature, experimental. It is therefore important that an assessment of a candidate's knowledge and understanding of Science should include a component relating to practical work and experimental skills.

This assessment is provided in Paper 3 as a formal practical test and is outlined in the Scheme of Assessment.

Paper 3
This paper is designed to assess a candidate's competence in those practical skills which can realistically be assessed within the context of a formal test of limited duration.

Candidates will be assessed in the following skill areas:

(a) Planning (P)

Candidates should be able to:
- identify key variables for a given question/problem
- outline an experimental procedure to investigate the question/problem
- describe how the data should be used in order to reach a conclusion
- identify the risks of the experiment and state precautions that should be taken to keep risks to a minimum

(b) Manipulation, measurement and observation (MMO)

Candidates should be able to:
- set up apparatus correctly by following written instructions or diagrams
- use common laboratory apparatus and techniques to collect data and make observations
- describe and explain how apparatus and techniques are used correctly
- make and record accurate observations with good details and measurements to an appropriate degree of precision
- make appropriate decisions about measurements or observations

(c) Presentation of data and observations (PDO)

Candidates should be able to:
- present all information in an appropriate form
- manipulate measurements effectively for analysis
- present all quantitative data to an appropriate number of decimal places/significant figures

(d) Analysis, conclusions and evaluation (ACE)

Candidates should be able to:
- analyse and interpret data or observations appropriately in relation to the task
- draw conclusion(s) from the interpretation of experimental data or observations and underlying principles
- make predictions based on their data and conclusions
- identify significant sources of errors and explain how they affect the results
- state and explain how significant errors may be overcome or reduced, as appropriate, including how experimental procedures may be improved.

One, or more, of the questions may incorporate some assessment of skill area P, set in the context of the syllabus content, requiring candidates to apply and integrate knowledge and understanding from different sections of the syllabus. It may also require the treatment of given experimental data in drawing relevant conclusion and analysis of proposed plan.

The assessment of skill areas MMO, PDO and ACE will be set mainly in the context of the syllabus content. The assessment of PDO and ACE may also include questions on data-analysis which do not require practical equipment and apparatus.

The material used in experiments will be closely related to the subject matter of the syllabus but will not necessarily be limited to the particular types mentioned in the curriculum content.

Candidates may be asked to carry out exercises comprising:

1. simple physiological experiments, involving tests for food substances, enzyme reactions, hydrogencarbonate indicator solution, cobalt(II) chloride paper and so on

2. simple physiological experiments, involving the use of sharp instruments such as mounted needles, scalpels, knives, forceps and scissors on plant or animal materials (accurate observations of these specimens will need a hand lens of not less than ×6 magnification for each candidate)

3. manipulative skills in assembling apparatus, in using chemical reagents and in using such instruments as mounted needles, scalpels and razor blades, forceps and scissors

4. measurements using appropriate instruments (e.g. thermometer, syringe, measuring cylinder, ruler and so on) and simple arithmetical calculations

5. familiar and unfamiliar techniques to record observations and make deductions from them

6. recognition and observation of features of familiar and unfamiliar biological specimens, recording observations and making deductions about functions of whole specimens or their parts

7. clear line drawings of the specimens provided, indicating magnification and labelling familiar structures

This is not intended to be an exhaustive list. Candidates are expected to be familiar with the use of data-loggers. Assessment of Skill P may include the appropriate use of data-loggers.

When planning practical work, teachers should make sure that they do not contravene any school, education authority or government regulations which restrict the sampling, in educational establishments, of urine, saliva, blood or other bodily secretions and tissues. Candidates should also be aware of the need to take simple precautions for safety and/or accuracy.

Within the Scheme of Assessment, the practical paper constitutes 20% of the G3 Biology examination. It is therefore recommended that the schemes of work include learning opportunities that apportion a commensurate amount of time for the development and acquisition of practical skills.

Apparatus List

This list given below has been drawn up in order to give guidance to Centres concerning the apparatus that is expected to be generally available for examination purposes. The list is not intended to be exhaustive and practical examinations may require additional apparatus and materials. General laboratory glassware and items that are commonly regarded as standard equipment in a Biology laboratory (e.g. Bunsen burner, tripod and gauze, safety goggles, paper towels and so on) are not included in this list.

Unless otherwise stated, the rate of allocation is 'per candidate'.

Light microscope, with high-, medium- and low-power objective lens (2 candidates to 1)
Microscope slides and coverslips
Mounted needle
Hand lens (not less than ×6)
Half metre rule or metre rule
30 cm plastic ruler with a mm scale
Syringes (e.g. 1 cm^3, 5 cm^3, 10 cm^3)
Dropper/Pasteur pipettes
Measuring cylinders
Beakers
Petri dishes
Test-tubes (some of which should be heat-resistant)
Test-tube rack and holder
Boiling tubes
Boiling tube rack
Glass rod
Rubber bungs to fit test-tubes and boiling tubes
Knife or scalpel
Forceps
Capillary tubes
Visking tubings
Rubber tubings
Thermometer: –10° C to +110° C
Stopwatch
White tile
Filter funnel and paper
Pestle and mortar
Spatulas
Glass marker pen
Cotton wool
Black paper
Aluminium foil
Balance, single pan, direct reading, 0.01 g or better (1 per 8–12 candidates)
Retort stand and clamp
Bench lamp with 60W bulb
Distilled/deionised water in a wash bottle
Cutting mat

The apparatus and material requirements for Paper 3 will vary year on year. Centres will be notified in advance of the details of the apparatus and materials required for each practical examination.

Reagents

This list given below has been drawn up in order to give guidance to Centres concerning the standard reagents that are expected to be generally available for examination purposes. The list is not intended to be exhaustive and Centres would be notified in advance of the full list of all the reagents that are required for each practical examination.

Iodine solution, in a container with a dropping pipette
Benedict's solution, in a container with a dropping pipette
Ethanol (denatured), flammable – in a stoppered bottle with a dropping pipette
Biuret reagent, in a container with a dropping pipette
Glucose solution
Starch solution
Sodium chloride
Dilute hydrochloric acid
Hydrogencarbonate indicator
Sodium bicarbonate/sodium hydrogencarbonate
Limewater
Universal Indicator paper and chart
Litmus paper
Cobalt chloride paper
Methylene blue
Vaseline/petroleum jelly (or similar)

GLOSSARY OF TERMS USED IN BIOLOGY PAPERS

It is hoped that the glossary will prove helpful to candidates as a guide, i.e. it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

2. *Comment* is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.

3. *Compare* requires candidates to provide both similarities and differences between things or concepts.

4. *Define* (*the term(s)* …) is intended literally, only a formal statement or equivalent paraphrase being required.

5. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena.

6. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula.

7. *Discuss* requires candidates to give a critical account of the points involved in the topic.

8. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about the points of principle and about the values of quantities not otherwise included in the question.

9. *Explain* may imply reasoning or some reference to theory, depending on the context.

10. *Find* is a general term that may be variously interpreted as calculate, measure, determine, etc.

11. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should not be exceeded.

12. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or mass, using a balance.

13. *Outline* implies brevity, i.e. restricting the answer to giving essentials.

14. *Predict* or *deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted from an earlier part of the question.

15. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value.

    Sketch, when applied to diagrams, implies that a simple, freehand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.

16. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.

17. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer, or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.

18. *What is meant by* (*the term(s)* ...) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in light of the indicated mark value.

SPECIAL NOTE

Units, significant figures

Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

Calculators

An approved calculator may be used in all papers.