Cambridge Assessment International Education

Syllabus

Cambridge International AS & A Level Marine Science 9693

Use this syllabus for exams in 2022, 2023 and 2024.
Exams are available in the June and November series.

Version 1

Cambridge Pathway

Why choose Cambridge International?

Cambridge International prepares school students for life, helping them develop an informed curiosity and a lasting passion for learning. We are part of the University of Cambridge.

Our Cambridge Pathway gives students a clear path for educational success from age 5 to 19. Schools can shape the curriculum around how they want students to learn – with a wide range of subjects and flexible ways to offer them. It helps students discover new abilities and a wider world, and gives them the skills they need for life, so they can achieve at school, university and work.

Our programmes and qualifications set the global standard for international education. They are created by subject experts, rooted in academic rigour and reflect the latest educational research. They provide a strong platform for students to progress from one stage to the next, and are well supported by teaching and learning resources.

We review all our syllabuses regularly, so they reflect the latest research evidence and professional teaching practice – and take account of the different national contexts in which they are taught.

We consult with teachers to help us design each syllabus around the needs of their learners. Consulting with leading universities has helped us make sure our syllabuses encourage students to master the key concepts in the subject and develop the skills necessary for success in higher education.

Our mission is to provide educational benefit through provision of international programmes and qualifications for school education and to be the world leader in this field. Together with schools, we develop Cambridge learners who are confident, responsible, reflective, innovative and engaged – equipped for success in the modern world.

Every year, nearly a million Cambridge students from 10 000 schools in 160 countries prepare for their future with the Cambridge Pathway.

‘We think the Cambridge curriculum is superb preparation for university.’

Christoph Guttentag, Dean of Undergraduate Admissions, Duke University, USA

Quality management

Cambridge International is committed to providing exceptional quality. In line with this commitment, our quality management system for the provision of international qualifications and education programmes for students aged 5 to 19 is independently certified as meeting the internationally recognised standard, ISO 9001:2015. Learn more at **www.cambridgeinternational.org/ISO9001**

Contents

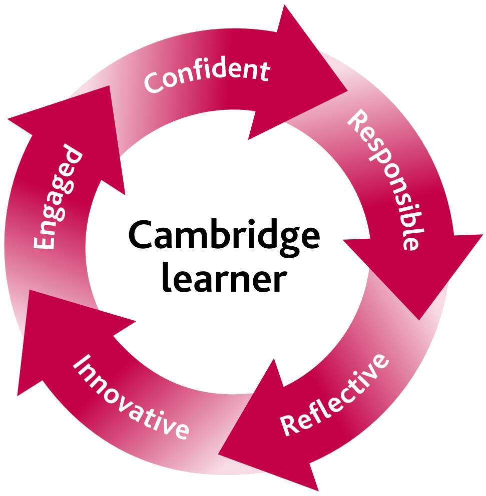
Changes to this syllabus

For information about changes to this syllabus for 2022, 2023 and 2024, go to page 55

1 Why choose this syllabus?

Key benefits

The best motivation for a student is a real passion for the subject they're learning. By offering students a variety of Cambridge International AS & A Levels, you can give them the greatest chance of finding the path of education they most want to follow. With over 50 subjects to choose from, students can select the ones they love and that they're best at, which helps motivate them throughout their studies.



Following a Cambridge International AS & A Level programme helps students develop abilities which universities value highly, including:

- a deep understanding of their subjects
- higher order thinking skills – analysis, critical thinking, problem solving
- presenting ordered and coherent arguments
- independent learning and research.

Cambridge International AS & A Level Marine Science develops a set of transferable skills including handling data, using the scientific method and applying knowledge and understanding of scientific facts and concepts to solve problems. Learners develop relevant attitudes, such as concern for accuracy and precision, objectivity, integrity, enquiry, initiative and inventiveness. They acquire the essential scientific skills required for progression to further studies or employment.

Our approach in Cambridge International AS & A Level Marine Science encourages learners to be:

confident, secure in their understanding of a wide range of facts and concepts, able to engage in informed debate with an open mind and a scientific approach and able to communicate effectively through the language of science

responsible, making decisions about how best to improve their own knowledge and understanding, working collaboratively with others, using efficient and safe scientific practices and developing an appreciation of human responsibilities towards the marine environment

reflective, developing strategies that enable them to increase their understanding, able to evaluate evidence to draw informed and appropriate conclusions and considering how the applications of science have the potential to affect the individual, the community and the environment

innovative, approaching challenges with novel approaches built on a firm foundation of scientific understanding, applying problem-solving skills to a range of theoretical and practical tasks and engaging with new tools and techniques, including information technology, to develop successful approaches

engaged, developing an enquiring mind and an interest in new ideas, keen to apply understanding of issues relating to marine science in everyday life.

'Cambridge students develop a deep understanding of subjects and independent thinking skills.'

Principal, Rockledge High School, USA

Key concepts

Key concepts are essential ideas that help students develop a deep understanding of their subject and make links between different aspects. Key concepts may open up new ways of thinking about, understanding or interpreting the important things to be learned.

Good teaching and learning will incorporate and reinforce a subject's key concepts to help students gain:

- a greater depth as well as breadth of subject knowledge
- confidence, especially in applying knowledge and skills in new situations
- the vocabulary to discuss their subject conceptually and show how different aspects link together
- a level of mastery of their subject to help them enter higher education.

The key concepts identified below, carefully introduced and developed, will help to underpin the course you will teach. You may identify additional key concepts which will also enrich teaching and learning.

The key concepts for Cambridge International AS & A Level Marine Science are:

- Observation and experiment
  The scientific process of observation and enquiry, experimentation and fieldwork are fundamental to marine science.
- The science of water
  Water is the key component of the oceans and an understanding of water at a molecular level underpins concepts such as salinity, pressure, density and the availability of key gases and nutrients, which in turn affect the distribution and abundance of living organisms.
- Forming and shaping the ocean floor and coastlines
  Dynamic interactions between the lithosphere, atmosphere and hydrosphere lead to the development of diverse marine habitats, which are subject to ongoing changes.
- Organisms in their environment
  The marine biome is the largest biome on the planet and contains many diverse habitats, within which organisms interact with the biotic and abiotic environment. The morphology, physiology and behaviour of organisms are adapted to niches within these habitats. By understanding this diversity, students will have a greater appreciation of the marine environment and the need for its conservation.
- Human influences in local and global contexts
  Human activities may have a local and global impact. The exploitation of marine resources and the disposal of waste in and around our oceans must be managed if our use of the oceans is to be sustainable for future generations.

International recognition and acceptance

Our expertise in curriculum, teaching and learning, and assessment is the basis for the recognition of our programmes and qualifications around the world. Every year thousands of students with Cambridge International AS & A Levels gain places at leading universities worldwide. They are valued by top universities around the world including those in the UK, US (including Ivy League universities), Europe, Australia, Canada and New Zealand.

UK NARIC, the national agency in the UK for the recognition and comparison of international qualifications and skills, has carried out an independent benchmarking study of Cambridge International AS & A Level and found it to be comparable to the standard of AS & A Level in the UK. This means students can be confident that their Cambridge International AS & A Level qualifications are accepted as equivalent, grade for grade, to UK AS & A Levels by leading universities worldwide.

Cambridge International AS Level Marine Science makes up the first half of the Cambridge International A Level course in marine science and provides a foundation for the study of marine science at Cambridge International A Level. Depending on local university entrance requirements, students may be able to use it to progress directly to university courses in marine science or some other subjects. It is also suitable as part of a course of general education.

Cambridge International A Level Marine Science provides a foundation for the study of marine science or related courses in higher education. Equally it is suitable as part of a course of general education.

For more information about the relationship between the Cambridge International AS Level and Cambridge International A Level see the 'Assessment overview' section of the Syllabus overview.

We recommend learners check the Cambridge recognitions database and the university websites to find the most up-to-date entry requirements for courses they wish to study.

Learn more at **www.cambridgeinternational.org/recognition**

Cambridge Assessment International Education is an education organisation and politically neutral. The content of this syllabus, examination papers and associated materials do not endorse any political view. We endeavour to treat all aspects of the exam process neutrally.

'The depth of knowledge displayed by the best A Level students makes them prime targets for America's Ivy League universities'

Yale University, USA

Supporting teachers

We provide a wide range of practical resources, detailed guidance, and innovative training and professional development so that you can give your students the best possible preparation for Cambridge International AS & A Level.

Support for Cambridge International AS & A Level

Teaching resources

- School Support Hub **www.cambridgeinternational.org/support**
- Syllabuses
- Schemes of work
- Learner guides
- Discussion forums
- Endorsed resources

Exam preparation resources

- Question papers
- Mark schemes
- Example candidate responses to understand what examiners are looking for at key grades
- Examiner reports to improve future teaching

Training

- Introductory – face-to-face or online
- Extension – face-to-face or online
- Enrichment – face-to-face or online
- Coursework – online
- Cambridge Professional Development Qualifications

Find out more at **www.cambridgeinternational.org/profdev**

Community

You can find useful information, as well as share your ideas and experiences with other teachers, on our social media channels and community forums.

Find out more at **www.cambridgeinternational.org/social-media**

'Cambridge International AS & A Levels prepare students well for university because they've learnt to go into a subject in considerable depth. There's that ability to really understand the depth and richness and the detail of a subject. It's a wonderful preparation for what they are going to face at university.'

US Higher Education Advisory Council

2 Syllabus overview

Aims

The aims describe the purposes of a course based on this syllabus.

The aims are to enable students to:

- acquire knowledge and understanding and develop practical skills, including efficient, accurate and safe scientific practices
- learn to apply the scientific method, while developing an awareness of the limitations of scientific theories and models
- develop skills in data analysis, evaluation and drawing conclusions, cultivating attitudes relevant to science such as objectivity, honesty, enquiry and inventiveness
- develop effective scientific communication skills, using appropriate terminology and scientific conventions
- understand their responsibility to others / society and to care for the environment
- enjoy science and develop an informed interest in the subject that may lead to further study.

Support for Cambridge International AS & A Level Marine Science

The School Support Hub is our secure online site for Cambridge teachers where you can find the resources you need to deliver our programmes, including schemes of work, past papers, mark schemes and examiner reports. You can also keep up to date with your subject and the global Cambridge community through our online discussion forums.

www.cambridgeinternational.org/support

Content overview

Candidates for Cambridge International AS Level Marine Science study the following topics:

1	Water	1.1 Particle theory and bonding 1.2 Solubility in water 1.3 Density and pressure
2	Earth processes	2.1 Tectonic processes 2.2 Weathering, erosion and sedimentation 2.3 Tides and ocean currents
3	Interactions in marine ecosystems	3.1 Interactions 3.2 Feeding relationships 3.3 Nutrient cycles
4	Classification and biodiversity	4.1 The classification of marine organisms 4.2 Key groups of marine organisms 4.3 Biodiversity 4.4 Populations and sampling techniques
5	Examples of marine ecosystems	5.1 The open ocean 5.2 The tropical coral reef 5.3 The rocky shore 5.4 The sandy shore 5.5 The mangrove forest

AS Level candidates also study practical skills.

Candidates for Cambridge International A Level Marine Science study the AS topics **and** the following topics:

6	Physiology of marine organisms	6.1 General cell structure 6.2 Movement of substances 6.3 Gas exchange 6.4 Osmoregulation
7	Energy	7.1 Photosynthesis 7.2 Chemosynthesis 7.3 Respiration
8	Fisheries for the future	8.1 Life cycles 8.2 Sustainable fisheries 8.3 Marine aquaculture
9	Human impacts on marine ecosystems	9.1 Ecological impacts of human activities 9.2 Global warming and its impact 9.3 Ocean acidification 9.4 Conservation of marine ecosystems

A Level candidates also study practical skills.

Assessment overview

AS Level candidates take Papers 1 and 2.

A Level candidates take Papers 1, 2, 3 and 4.

Paper 1

AS Level Theory 1 hour 45 minutes
75 marks
Structured and free-response questions
Section A: Structured questions (45 marks)
Section B: Free-response questions (30 marks)
Questions are based on the AS Level syllabus content.
Externally assessed
50% of the AS Level
25% of the A Level

Paper 2

AS Level Data-handling and investigative skills 1 hour 45 minutes
75 marks
Structured questions
Questions are based on the AS Level syllabus content.
Externally assessed
50% of the AS Level
25% of the A Level

Paper 3

A Level Theory 1 hour 45 minutes
75 marks
Structured and free-response questions
Section A: Structured questions (45 marks)
Section B: Free-response questions (30 marks)
Questions are based on the A Level syllabus content but knowledge of the AS Level syllabus content may be required.
Externally assessed
25% of the A Level

Paper 4

A Level Data-handling and investigative skills 1 hour 45 minutes
75 marks
Structured and extended response questions
Questions are based on the A Level syllabus content but knowledge of the AS Level syllabus content may be required.
Externally assessed
25% of the A Level

Information on availability is in the **Before you start** section.

There are three routes for Cambridge International AS & A Level Marine Science:

	Route	Paper 1	Paper 2	Paper 3	Paper 4
1	**AS Level only** (Candidates take all AS components in the same exam series)	✓	✓		
2	**A Level** (staged over two years) Year 1 AS Level*	✓	✓		
	Year 2 Complete the A Level			✓	✓
3	**A Level** (Candidates take all components in the same exam series)	✓	✓	✓	✓

* Candidates carry forward their AS Level result subject to the rules and time limits described in the *Cambridge Handbook*.

Candidates following an AS Level route will be eligible for grades a–e. Candidates following an A Level route are eligible for grades A*–E.

Assessment objectives

The assessment objectives (AOs) are:

AO1 Knowledge and understanding

Candidates should be able to demonstrate knowledge and understanding of:

- scientific phenomena, facts, definitions, concepts and theories
- scientific vocabulary, terminology and conventions (including symbols, quantities and units)
- scientific and technological applications, with their social, economic, ethical and environmental implications.

AO2 Handling and applying information

Candidates should be able to apply knowledge in familiar and unfamiliar contexts in words or using other forms of presentation (e.g. drawings, symbols, graphical and numerical) to:

- locate, select, organise and communicate relevant information from a variety of sources
- manipulate numerical, graphical and other data
- analyse and interpret observations and data to identify patterns, report trends and reach conclusions
- give reasoned explanations for phenomena, patterns and relationships.

AO3 Experimental skills and investigations

Candidates should be able, in familiar and unfamiliar contexts to:

- make estimates, predictions and propose hypotheses from given scenarios, information or data
- describe how to ethically and safely use techniques, apparatus and materials in an investigative context
- plan experiments and investigations
- present and display data and observations in suitable formats
- evaluate given experimental methods and the quality of data, and suggest possible improvements.

Weighting for assessment objectives

The approximate weightings allocated to each of the assessment objectives (AOs) are summarised below.

Assessment objectives as a percentage of each qualification

Assessment objective	Weighting in AS Level %	Weighting in A Level %
AO1 Knowledge and understanding	45	40
AO2 Handling and applying information	40	45
AO3 Experimental skills and investigations	15	15
Total	100	100

Assessment objectives as a percentage of each component

Assessment objective	Weighting in components %			
	Paper 1	**Paper 2**	**Paper 3**	**Paper 4**
AO1 Knowledge and understanding	67	20	53	20
AO2 Handling and applying information	33	47	47	47
AO3 Experimental skills and investigations	–	33	–	33
Total	100	100	100	100

3 Subject content

Candidates for Cambridge International AS Level study topics 1–5.

Candidates for Cambridge International A Level study all topics.

The AS Level learning outcomes are assumed knowledge for the A Level components.

Practical work and The Scientific Method is an essential part of the course and it underpins many of the topic areas. Candidates are expected to undertake all of the core practical activities included within the learning outcomes of this syllabus, as a minimum. Candidates' experience of practical activities and the skills gained will be examined through both recall of the core practicals themselves and also, through application to a new context, of the skills and knowledge gained from these.

The practical activities are indicated by the practical activity (**PA**) symbol.

Teachers should ensure that candidates are prepared for the assessment of both the theory and practical learning outcomes.

Further guidance on practical work can be found in the section on Practical work in Marine Science.

We also expect candidates to be able to use the mathematical skills and knowledge listed in the section on Mathematical requirements. Teaching the mathematical requirements listed in this syllabus should be included in the teaching of the AS and A Level Marine Science course.

This syllabus gives you the flexibility to design a course that will interest, challenge and engage your learners. Where appropriate you are responsible for selecting suitable subject contexts, resources and examples to support your learners' study. These should be appropriate for the learners' age, cultural background and learning context as well as complying with your school policies and local legal requirements.

AS Level subject content

1 Water

1.1 Particle theory and bonding

An understanding of particle theory, including the structure of atoms and ions, and how they bond together to form compounds, helps to explain the properties of water and other substances important to marine life.

Learning outcomes
Candidates should be able to:

1.1.1 explain the changes of state in water, between solid, liquid and gas, in terms of the kinetic particle theory

1.1.2 describe the structure of the atom, including the nucleus containing protons and neutrons, surrounded by electrons arranged in shells

1.1.3 understand that sea water is a mixture of different elements and compounds

1.1.4 describe (including through the use of diagrams) the covalent bonding in a water molecule, limited to the sharing of electron pairs between atoms

1.1.5 identify (including from diagrams) covalent molecules, including water, carbon dioxide, oxygen, sulfur dioxide and glucose

1.1.6 describe (including through the use of diagrams) the ionic bonding in sodium chloride, limited to the loss and gain of electrons to form ions and the subsequent attraction between positive and negative ions

1.1.7 identify (including from diagrams) ionic substances, including sodium chloride and calcium carbonate

1.1.8 state the chemical name and formula of salts found in sea water, including sodium chloride ($NaCl$), magnesium sulfate ($MgSO_4$) and calcium carbonate ($CaCO_3$)

1.1.9 explain the formation of hydrogen bonds in water

1.1.10 explain how hydrogen bonding in water affects the properties of water, limited to solvent action, density, and specific heat capacity

1.2 Solubility in water

Sea water is a solution made up of many different solutes dissolved in water. Various environmental factors affect the solubility of salts and gases in sea water. Hydrogen ion concentration is particularly important, as this affects pH.

Learning outcomes
Candidates should be able to:

1.2.1 explain the terms solute, solvent, solution and solubility

1.2.2 describe how soluble salts, such as sodium chloride, dissolve in water by the dissolution of ions

1.2.3 explain the effect of water temperature on the solubility of salts

1.2.4 define the term salinity as the concentration of dissolved salts in sea water (note that the unit for salinity used in this syllabus is parts per thousand (ppt))

1.2.5 (**PA**) investigate the effect of salinity on the freezing point of water

1.2.6 explain the effect of surface run-off, precipitation and evaporation on the salinity of sea water

1.2.7 describe the pH scale as a measure of the hydrogen ion concentration in water, including the terms acidic, neutral and alkaline
(calculations relating to hydrogen ion concentration are not required)

1.2.8 (**PA**) use litmus indicator, Universal Indicator and pH probes to measure the pH of water samples

1.2.9 state that oxygen has a low solubility in water

1.2.10 describe the effect of water temperature, water pressure (depth), atmospheric pressure and salinity on the solubility of gases in water and the implications this has for marine organisms
(knowledge of the gas laws is not expected)

1.3 Density and pressure

Density is a measure of the mass of a defined volume of water, and is affected by temperature, pressure and salinity. Density differences help to maintain temperature and salinity gradients in the oceans, which affect the distribution of organisms.

Learning outcomes
Candidates should be able to:

1.3.1 explain how water temperature, water pressure and salinity affect the density of sea water

1.3.2 recall and apply the formula: density = mass ÷ volume, with units of $kg\ m^{-3}$, kg and m^3 respectively

1.3.3 state that the density of ice is lower than sea water, causing ice to float

1.3.4 explain the importance of ice floating, limited to its action as a thermal insulator and as a habitat for marine organisms

1.3.5 describe how temperature and salinity gradients form in water columns to produce ocean layers, including the surface layer, thermocline, halocline and deep ocean, and how subsequent mixing of these layers may occur

2 Earth processes

2.1 Tectonic processes

The movement of tectonic plates is responsible for the formation of many different features of the ocean floor, including hydrothermal vents and ocean trenches, and phenomena such as earthquakes and tsunamis.

Learning outcomes
Candidates should be able to:

2.1.1 describe the structure of the Earth, limited to crust (oceanic and continental), mantle and core

2.1.2 describe and apply the theory of plate tectonics, and the evidence supporting the theory, limited to the geological matching of rock formations, distribution of fossils and living organisms, paleomagnetic stripes on the ocean floor and the jigsaw fit of the continents

2.1.3 identify and describe the three types of plate boundary as convergent, divergent and transform

2.1.4 explain how tectonic processes produce ocean trenches, mid-ocean ridges, hydrothermal vents, abyssal plains, volcanoes, earthquakes and tsunamis

2.1.5 state that the water coming from hydrothermal vents is under pressure, hot and rich in dissolved nutrients and that this forms the hydrothermal vent plume

2.1.6 understand that the effects of the hydrothermal vent plume can be detected some distance from the hydrothermal vent site

2.1.7 explain how the chimneys form at hydrothermal vents, including reference to temperature and solubility of salts

2.2 Weathering, erosion and sedimentation

Weathering of rocks results in the production of small fragments, which may be eroded (carried away) and deposited elsewhere as sediment. The balance between the rate at which sediments are eroded and deposited in the littoral zone determines the type of shore that forms.

Learning outcomes
Candidates should be able to:

2.2.1 distinguish between weathering and erosion

2.2.2 describe the three main types of weathering: chemical, physical and organic, and be able to describe an example of each type

2.2.3 describe the four main types of erosion: by ice, water, wind and gravity

2.2.4 describe sedimentation as the deposition of suspended particles

2.2.5 understand how the speed of water flow and particle size affect the removal, transport and deposition of particles

2.2.6 define the littoral zone as the intertidal region on a shoreline, between the highest and lowest spring tide marks

2.2.7 state examples of the littoral zone, including rocky shores, sandy shores, muddy shores, estuaries and deltas

2.2.8 describe how weathering, erosion and sedimentation give rise to the morphology of rocky shores, sandy shores, muddy shores, estuaries and deltas

2.3 Tides and ocean currents

Twice each day, the level of the seas and oceans rises and falls, in a pattern determined by the alignment of Earth, Moon and Sun. The magnitude of these changes in level, known as tides, is also affected by environmental factors such as winds.

Winds and temperature, along with other factors, also give rise to ocean currents. These currents ensure that the water in all the world's oceans is able to mix, via the global ocean conveyor belt.

Learning outcomes
Candidates should be able to:

2.3.1 explain how tides are produced, and how the alignment of the Earth, Moon and Sun, coastal geomorphology, wind, air pressure and size of water body affect the tidal range

2.3.2 explain the formation of spring and neap tides

2.3.3 interpret tide tables and graphs in terms of tidal height, tidal range, spring and neap tides

2.3.4 describe how wind, temperature, density, the Coriolis effect (limited to the deflection of currents clockwise in the northern hemisphere and anticlockwise in the southern hemisphere) and the shape of the sea bed produce ocean currents and upwelling

2.3.5 explain the formation of the global ocean conveyor belt and its importance in moving sea water around the Earth

2.3.6 discuss the causes and effects of El Niño and La Niña events during the El Niño Southern Oscillation (ENSO) cycle in the Pacific Ocean

3 Interactions in marine ecosystems

3.1 Interactions

Different species of organism may live in a close relationship with one another, which is known as symbiosis. Parasitism, commensalism and mutualism are types of symbiosis, differing from one another in the degree of benefit gained by each partner.

Learning outcomes
Candidates should be able to:

3.1.1 describe the meaning of parasitism, commensalism and mutualism, and understand that they are all examples of symbiotic relationships

3.1.2 describe the parasitic relationship between copepods and marine fish

3.1.3 describe the commensal relationship between manta rays and remora fish

3.1.4 describe the mutualistic relationship between boxer crabs and anemones

3.2 Feeding relationships

Producers harness an energy source – through either photosynthesis or chemosynthesis – to convert inorganic substances to organic substances, which contain energy that becomes available to consumers. The rate at which producers transfer energy into organic substances and produce biomass is measured as productivity, and this is affected by factors such as the availability of light.

Energy is lost as it passes along a food chain, and this results in a decrease in the energy content of the organisms at each trophic level.

Learning outcomes

Candidates should be able to:

3.2.1 explain the following terms in relation to feeding relationships: consumer (including primary, secondary, tertiary and quaternary), producer, herbivore, carnivore, omnivore, decomposer, predator, prey, food chain, food web, trophic level

3.2.2 represent and interpret feeding relationships in an ecosystem as food chains and food webs

3.2.3 understand that producers can be photosynthetic or chemosynthetic

3.2.4 explain that photosynthesis captures the energy of sunlight and makes some of the energy available to the food chain, and, it can be summarised by the word equation

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{light}} \text{glucose} + \text{oxygen}$$

(further details of photosynthesis and balanced chemical equations are not required at AS Level)

3.2.5 (**PA**) investigate the effect of light intensity on the rate of photosynthesis
(use of fresh water plants is acceptable)

3.2.6 understand that some of the glucose produced by photosynthesis is used to produce biomass

3.2.7 understand that some of the glucose produced by photosynthesis is used in respiration to provide usable energy and can be summarised by the word equation

$$\text{glucose} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water}$$

(further details of respiration and balanced chemical equations are not required at AS Level)

3.2.8 define productivity as the rate of production of biomass per unit area or volume, and explain how high primary productivity may influence food chains

3.2.9 calculate and explain the energy losses along food chains

3.2.10 draw, describe and interpret pyramids of energy, numbers and biomass, including those that incorporate parasites and periods of plankton bloom

3.3 Nutrient cycles

Nutrients are materials that are required by organisms for an energy supply, and for growth and maintenance of body tissues. The availability of nutrients has a large effect on productivity, and therefore on the types and numbers of organisms that live in different parts of the oceans at different times.

Learning outcomes

Candidates should be able to:

3.3.1 understand that nutrient is a generic term for substances that are required by an organism for growth, repair, energy or normal metabolism

3.3.2 understand that nutrients can include gases such CO_2, ions such as Mg^{2+}, CO_3^{2-}, PO_4^{3-} and NO_3^{-} and organic compounds such as carbohydrates, lipids and proteins

3.3.3 state the chemical elements that make up carbohydrates, lipids and proteins

3.3.4 state that large molecules are made from smaller molecules, limited to starch and cellulose from glucose, proteins from amino acids, and lipids from fatty acids and glycerol

3.3.5 understand that some nutrients supply organisms with a source of essential elements and these elements have important biological roles:

- nitrogen, which is used to make proteins and DNA
- carbon, which is used to make all organic compounds
- magnesium, which is used to make chlorophyll
- calcium, which is used to make bones, shells and coral skeletons
- phosphorus, which is used to make DNA and bones

3.3.6 understand that some nutrients are soluble and that there is a reservoir of these nutrients dissolved in the ocean which is available to producers and consumers

3.3.7 explain the processes by which the reservoir of dissolved nutrients is replenished, including upwelling, run-off, tectonic activity, dissolving of atmospheric gases, excretion and decomposition

3.3.8 understand that the reservoir of dissolved nutrients is depleted by uptake into organisms

3.3.9 understand that the nutrients taken up by organisms in food chains can be removed by harvesting

3.3.10 explain why productivity may be limited by the availability of dissolved nutrients

3.3.11 describe the carbon cycle, limited to combustion, photosynthesis, respiration, decomposition, formation of fossil fuels, formation and weathering of rocks containing carbonate

4 Classification and biodiversity

4.1 The classification of marine organisms

Organisms are classified in a hierarchical system, in which the largest group is the domain. Each type of organism belongs to a particular species, which is given a universally recognised two-word name called a binomial.

Dichotomous keys are made up of pairs of contrasting descriptions, constructed so that the sequential choice of one of each pair leads to the name of the organism.

Learning outcomes
Candidates should be able to:

4.1.1 describe the classification of species into the taxonomic hierarchy of domain, kingdom, phylum, class, order, family, genus and species

4.1.2 understand and use the binomial system of species nomenclature

4.1.3 construct and use simple dichotomous keys based on easily identifiable features

4.1.4 (**PA**) make observations and drawings from unfamiliar structures or specimens from the key groups in topic 4.2 and additionally *Cnidaria* in topic 5.2

4.2 Key groups of marine organisms

The number of phyla living in the oceans is considerably greater than on land. The adults and larvae of many different types of organism are planktonic, drifting in ocean currents. Crustaceans, echinoderms, bony fish and cartilaginous fish are some of the more obvious animals in the oceans, while macroalgae (seaweeds) and seagrasses form the basis of many food chains.

Learning outcomes
Candidates should be able to:

4.2.1 define plankton as a diverse collection of generally microscopic organisms that have limited motility and drift in water currents

4.2.2 understand that phytoplankton are producers which absorb nutrients from their environment (like all producers) and obtain their nutrition by photosynthesis; examples include microscopic algae such as diatoms and dinoflagellates

4.2.3 understand that zooplankton are consumers; examples include larvae, copepods and larger animals such as jellyfish

4.2.4 state the main features of a typical adult echinoderm, limited to pentaradial symmetry and tube feet

4.2.5 understand the ecological and economic importance of echinoderms, including the crown of thorns starfish

4.2.6 state the main features of a typical adult crustacean, including carapace, segmented abdomen, jointed legs and two pairs of antennae

4.2.7 understand the ecological and economic importance of crustaceans, including Antarctic krill

4.2.8 state the main internal and external features of a typical adult bony fish, including bony skeleton, operculum, gills, swim bladder, scales, externally visible lateral line, fins (pectoral, caudal, pelvic, anal and dorsal)

4.2.9 understand the ecological and economic importance of bony fish, including the Peruvian anchoveta

4.2.10 state the main internal and external features of a typical adult cartilaginous fish, including cartilaginous skeleton, gill slits, gills, denticles, lateral line, fins (pectoral, caudal, pelvic, anal and dorsal)

4.2 Key groups of marine organisms continued

Learning outcomes
Candidates should be able to:

4.2.11 understand the ecological and economic importance of cartilaginous fish, including the blue shark

4.2.12 understand that bony fish and cartilaginous fish are both chordates (i.e. in the Phylum *Chordata*) and that all organisms in this phylum share common features (at some point in their development), including notochord, dorsal neural tube, pharyngeal slits and post-anal tail

4.2.13 state the main features of a typical macroalga, such as kelp, including holdfast, stipe, gas bladders and blades

4.2.14 understand the ecological and economic importance of macroalgae, including kelp

4.2.15 state the main features of a typical marine plant, such as seagrass, including rhizome, roots, flowers and leaves

4.2.16 understand the ecological and economic importance of marine plants, including seagrass

4.3 Biodiversity

Biodiversity is a measure of the range of different species and ecosystems, as well as the genetic diversity within a species. High biodiversity tends to be linked to stability in ecosystems on both small and large scales.

Learning outcomes
Candidates should be able to:

4.3.1 explain that biodiversity can be considered at three different levels:
- genetic diversity (variation in the genes of a species)
- species diversity (number of species and their relative abundance)
- ecological diversity (variation in ecosystems on a regional and global level)

4.3.2 understand the importance of marine biodiversity in terms of the services it provides, including:
- maintaining stable ecosystems (for example, diversity in communities maintains complex interactions between all organisms and the physical environment)
- protection of the physical environment (for example, coral reefs protect coastlines)
- climate control (for example, phytoplankton absorb CO_2 and release O_2)
- providing food sources (for example, algae, crustaceans and fish)
- providing a source of medicines (for example, anticancer drugs such as keyhole limpet hemocyanin (KLH))

4.4 Populations and sampling techniques

Biotic and abiotic factors affect the distribution and abundance of different types of organism in the marine environment. It is important to select appropriate techniques to study distribution and abundance in particular circumstances – for example, whether sampling should be random or systematic. The data collected can be analysed to look for correlations between abundance and a particular environmental factor.

Learning outcomes

Candidates should be able to:

4.4.1 explain, using marine examples, the terms ecosystem, habitat, niche, species, population and community

4.4.2 explain the terms biotic factor (including intra- and inter-specific competition, symbioses, predation and disease) and abiotic factor (including salinity, temperature, pH, oxygen concentration, carbon dioxide concentration, light availability, turbidity, wave / tide action, nutrient availability and exposure to air) and identify those factors that affect an organism in a named marine ecosystem

4.4.3 understand the mark-release-recapture method for estimating population size of a named species

4.4.4 apply the Lincoln index and identify the limitations of this method (the equation and symbols for the Lincoln index will be provided in the question papers)

$$N = \frac{n_1 \times n_2}{m_2}$$

N = estimate of population size

n_1 = number of individuals captured in first sample

n_2 = number of individuals (both marked and unmarked) captured in second sample

m_2 = number of marked individuals recaptured in second sample

4.4.5 describe random and systematic sampling and understand their advantages and disadvantages

4.4.6 (**PA**) use suitable methods, including frame quadrats, line transects, belt transects and mark-release-recapture, to investigate the distribution and abundance of organisms in the littoral zone
(note that candidates should be taught the importance of designing an ethical and safe method)

4.4 Populations and sampling techniques continued

Learning outcomes
Candidates should be able to:

4.4.7 use Simpson's index of diversity (D) to calculate the species diversity of a habitat and interpret different values of D
(the equation and symbols for the calculation of D will be provided in the question papers)

$$D = 1 - \left(\sum \left(\frac{n}{N}\right)^2\right)$$

$\sum$ = sum of (total)

n = number of individuals of each **different** species

N = the total number of individuals of **all** the species

4.4.8 use Spearman's rank correlation (r_s) to analyse the relationships between the distribution and abundance of species and abiotic or biotic factors
(the equation and symbols for the calculation of r_s will be provided in the question papers)

$$r_s = 1 - \left(\frac{6 \times \sum D^2}{n^3 - n}\right)$$

Σ = sum of (total)

n = number of pairs of items in the sample

D = difference in rank between each pair of measurements

(candidates should understand that correlations exist between –1 (perfect negative correlation), 0 (no correlation) and +1 (perfect positive correlation), and, that a correlation does not necessarily imply a causal relationship)

5 Examples of marine ecosystems

5.1 The open ocean

Depth zones in the oceans range from the surface layers to the very deepest parts in the benthic zones. The oceans have considerable influence on global climate and on the composition of the atmosphere, with which they continually interact.

Learning outcomes
Candidates should be able to:

5.1.1 identify the world's five oceans as the Arctic, Atlantic, Pacific, Indian and Southern, and understand that these oceans are inter-connected and encircle the Earth as a World Ocean

5.1.2 identify zones found in the open ocean, limited to epipelagic, mesopelagic, bathypelagic, abyssopelagic and benthic zones, and describe these zones in terms of light penetration

5.1.3 explain the importance of oceans and their interaction with the atmosphere:
- as carbon sinks
- as sources of oxygen
- in temperature buffering
- in global climate control

5.2 The tropical coral reef

Tropical coral reefs are built by tiny coral polyps, which live in close association with photosynthetic zooxanthellae and are therefore limited in their distribution to areas where abundant light is available and temperatures are warm. The polyps themselves are consumers and require a source of small organisms that they can capture and digest.

Changes to biotic or abiotic factors in the oceans can lead to the erosion of coral reefs. Artificial structures can be provided as a substrate on which reef communities can develop.

Learning outcomes
Candidates should be able to:

5.2.1 describe the conditions required for tropical coral reef formation

5.2.2 describe and compare the four types of tropical coral reef: fringing, barrier, patch and atoll, in terms of their proximity to the coast and lagoon structure (if present)

5.2.3 describe corals as animals in the Phylum *Cnidaria* that form sessile colonies of polyps, often having a symbiotic relationship with zooxanthellae

5.2.4 understand that there are two general types of coral, hard (for example, staghorn) and soft (for example, sea fan) which are characterised by the extent of calcification and the presence of zooxanthellae

5.2.5 describe the structure of a typical coral polyp, limited to tentacle, nematocyst, mouth, stomach, calyx, theca and basal plate, and describe the functions of these structures

5.2.6 explain how corals obtain their nutrition, including the mutualistic relationship between the polyps of some corals and zooxanthellae

5.2.7 discuss the importance of coral reefs, including tourism, food source, coastal protection, medicines and biodiversity

5.2.8 discuss the causes and effects of reef erosion, including pH change, temperature change, predation, physical damage and the presence of sediment

5.2.9 discuss the use of artificial reefs

5.3 The rocky shore

Organisms living on rocky shores experience variations in temperature and salinity, availability of water and exposure to sunlight at different stages of the tidal cycle. High on the shore, these abiotic factors are the main influence on the distribution and abundance of species, but lower down the shore biotic factors such as competition and predation have the greatest influence.

Learning outcomes
Candidates should be able to:

5.3.1 identify the different zones on a typical exposed rocky shore, limited to splash zone, upper shore, middle shore and lower shore, and describe the changing abiotic factors across these zones during one tidal cycle

5.3.2 explain how biotic and abiotic factors interact to affect the distribution and abundance of organisms in the different zones on the rocky shore
(candidates should study a range of named organisms from the different zones)

5.3.3 explain, using named examples, the adaptations that organisms have to living in the different zones

5.4 The sandy shore

Organisms cannot attach securely to the unstable substrate on sandy shores. The variations in abiotic factors through the tidal cycle can be even greater than on a rocky shore, and relatively few types of organism have adaptations – such as the ability to burrow – that enable them to live there.

Learning outcomes

Candidates should be able to:

5.4.1 describe the sandy shore as an ecosystem with an unstable, shifting substrate that is porous

5.4.2 explain how the biotic and abiotic factors that affect a sandy shore lead to a relatively low biodiversity

5.4.3 (**PA**) investigate the effect of particle size on the permeability of substrates

5.4.4 explain, using named examples, the adaptations that organisms have to living on a sandy shore

5.5 The mangrove forest

Mangroves have adaptations for surviving in environments where they are partly submerged in salt water. They grow on muddy shores in tropical and subtropical regions, and have a major influence on biodiversity. They are of great value to human coastal communities, although many human activities pose serious threats to mangrove forests.

Learning outcomes

Candidates should be able to:

5.5.1 describe the mangrove forest as a tidal ecosystem featuring salt tolerant trees and other plants, together with populations of other species, all interacting in the littoral zone of some tropical and subtropical coasts

5.5.2 outline the conditions required for the formation of mangrove forest

5.5.3 explain how the red mangrove tree, *Rhizophora mangle*, is adapted to the mangrove environment, including:
- prop roots for stability in unstable substrates and supplementary oxygen uptake due to low oxygen concentrations in the substrate
- salt exclusion by the roots
- viviparous reproduction using propagules

5.5.4 explain the ecological importance of mangrove forests in terms of:
- nursery area for juveniles of many animal species
- sediment trapping which stabilises and protects the coastline and prevents sediment build up on coral reefs and seagrass beds

5.5.5 discuss the importance of mangrove forests, including tourism, food source, coastal protection, timber, fuel source and biodiversity

5.5.6 discuss the threats to mangrove forests, including temperature change, over-harvesting, storm damage and change in coastal land use

A Level subject content

Topics 6–9 contain the additional material to be studied for Papers 3 and 4.

6 Physiology of marine organisms

6.1 General cell structure

All living organisms are formed of units called cells, which have many features in common. Each cell is separated from its immediate environment by the cell surface membrane, and an understanding of the structure of this membrane enables us to understand its functions.

We use microscopes to visualise cells. The images produced can be studied and interpreted to increase understanding of cell structure.

Learning outcomes
Candidates should be able to:

6.1.1 recognise the following cell structures and outline their functions:
- cell surface membrane
- nucleus
- rough and smooth endoplasmic reticulum
- ribosomes
- Golgi body
- mitochondria
- chloroplasts
- cell wall
- large permanent vacuole

6.1.2 describe the fluid mosaic model of membrane structure, including an outline of the structure and functions of phospholipids and proteins, limited to carrier and channel proteins

6.1.3 understand the selectively permeable nature of membranes and relate this to the transport (active and passive) of substances across a membrane

6.1.4 describe and interpret photomicrographs, electron micrographs and drawings of typical animal and plant cells

6.1.5 recall and apply the formula:
magnification = image size ÷ actual size

6.1.6 (**PA**) make observations, drawings and magnification calculations from unfamiliar structures or specimens
(taken from any of the key groups in topic 4.2, topic 5.2 or the cell structures in Learning outcome 6.1.1)

6.2 Movement of substances

Diffusion and facilitated diffusion across cell membranes are passive processes. Osmosis is a particular type of diffusion involving water. Active transport however uses energy provided by the cell to move substances against their concentration gradient.

Water potential is a measure of the relative number of water molecules, and their freedom to move, in a solution. Water diffuses down a water potential gradient and can move freely through cell membranes.

Learning outcomes
Candidates should be able to:

6.2.1 describe and explain the processes of diffusion, facilitated diffusion, osmosis and active transport

6.2.2 understand the concept of water potential and explain how dissolved solutes affect the water potential of a solution or cell (knowledge of solute potential is not required)

6.2.3 (**PA**) investigate diffusion and osmosis using plant tissue and non-living materials, such as Visking tubing and agar

6.2.4 calculate surface areas and volumes of simple shapes (all formulae and relevant symbols will be provided) to illustrate the principle that surface area to volume ratio decreases with increasing size

6.2.5 (**PA**) investigate the effect of changing surface area to volume ratio on diffusion using agar blocks of different sizes

6.2.6 (**PA**) investigate the effects of immersing plant tissues in solutions of different water potentials, using the results to estimate the water potential of the tissues

6.2.7 explain the movement of water between cells and solutions with different water potentials and explain the different effects on plant and animal cells

6.3 Gas exchange

Aerobic respiration requires oxygen and produces carbon dioxide. These two gases diffuse into and out of the organism, from and to its environment. This process is called gas exchange.

Smaller marine organisms often allow the gases to diffuse across their whole body surface, but most larger organisms have specialised surfaces across which gas exchange takes place. They may also have methods of ventilating these surfaces.

Learning outcomes
Candidates should be able to:

6.3.1 understand that the raw materials and waste products of respiration must be moved to and from the surface of organisms

6.3.2 discuss how surface area to volume ratio is dependent on the size and shape of an organism, and relate this to the need for specialised gaseous exchange surfaces and transport systems in larger animals

6.3.3 describe gaseous exchange by simple diffusion, pumped ventilation and ram ventilation, in examples including coral polyps, grouper and tuna

6.3.4 relate an organism's method of gas exchange to its habitat and motility

6.4 Osmoregulation

Sea water has a similar water potential to the body fluids of most marine organisms, and therefore many species do not need to regulate their water content. Other species are osmoregulators and control the water content of their bodies.

Most marine organisms can survive within only a small range of salinity, and are termed stenohaline. Euryhaline species can live in a range of salinities. Salmon are an example of a euryhaline osmoregulator, spending part of their life cycle in the sea and part in fresh water.

Learning outcomes
Candidates should be able to:

6.4.1 explain why marine organisms may need to regulate their water content and ion content, with reference to the composition of sea water and of body fluids

6.4.2 explain the terms osmoconformer and osmoregulator with reference to marine mussels and tuna

6.4.3 explain the terms euryhaline and stenohaline with reference to salmon, marine mussels and tuna

6.4.4 outline the processes of osmoregulation in salmon

7 Energy

7.1 Photosynthesis

Photosynthesis is a two-stage process in which energy is harvested from light by pigments, and then transferred to organic compounds. These compounds can be used to synthesise biomass or to provide useful energy for life processes. Photosynthesis takes place in chloroplasts, whose structure enables these stages to take place efficiently.

If a requirement for photosynthesis is in short supply, it may act as a limiting factor, preventing the rate of photosynthesis from increasing.

Learning outcomes
Candidates should be able to:

7.1.1 understand that white light is composed of a range of colours, each with a different wavelength

7.1.2 differentiate between the terms wavelength, intensity and penetration in the context of light

7.1.3 describe the effect of wavelength on the penetration of light to different depths

7.1.4 understand that photosynthesis is the process that nearly all marine producers use to fix carbon, and it can be summarised as:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$$

7.1.5 understand that photosynthesis is a two-stage process, light-dependent and light-independent

7.1.6 explain that energy is transferred as ATP and reduced NADP from the light-dependent stage to the light-independent stage (Calvin cycle) and is used to produce organic molecules

7.1.7 describe the structures in a typical chloroplast, to include outer membrane, inner membrane, stroma, thylakoids, thylakoid membrane, thylakoid space and grana

7.1.8 state the sites of the light-dependent and the light-independent stages in the chloroplast

7.1.9 describe the role of chloroplast pigments (chlorophyll a and accessory pigments) in light absorption in the grana

7.1 Photosynthesis continued

Learning outcomes
Candidates should be able to:

7.1.10 relate the presence of accessory pigments, including xanthophylls and phycobilins, in marine producers to the penetration of different wavelengths of light

7.1.11 (**PA**) describe and use chromatography to separate and identify chloroplast pigments (reference should be made to R_f values)

7.1.12 interpret absorption spectra of chloroplast pigments and action spectra for photosynthesis

7.1.13 describe the light-dependent stage as the photoactivation of chlorophyll resulting in the photolysis of water and the transfer of energy to ATP and reduced NADP
(details of cyclic and non-cyclic photophosphorylation are not required)

7.1.14 describe the light-independent stage (Calvin cycle) as the fixation of carbon dioxide using the enzyme rubisco and the ATP and reduced NADP formed during the light-dependent stage
(details of intermediate compounds are not required)

7.1.15 describe the effect of limiting factors of photosynthesis, including light intensity, wavelength of light, carbon dioxide concentration and temperature on the rate of photosynthesis

7.1.16 (**PA**) investigate the effect of wavelength of light on the rate of photosynthesis
(use of fresh water plants is acceptable)

7.2 Chemosynthesis

Hydrothermal vents provide a habitat for a very unusual community of living organisms adapted to the unique conditions found there. As there is no light, bacteria use energy from inorganic chemicals to produce organic substances. This forms the basis of the food web. The bacteria live in symbiosis with tubeworms.

Learning outcomes
Candidates should be able to:

7.2.1 describe chemosynthesis as the fixation of carbon using the chemical energy of dissolved substances; these substances include hydrogen sulfide, methane, hydrogen and iron

7.2.2 understand that chemosynthetic bacteria at hydrothermal vents fix the energy into a form that other organisms can use, which allows the formation of a food chain

7.2.3 describe the symbiotic relationship between the giant tubeworm, *Riftia*, found at hydrothermal vents, and the chemosynthetic bacteria *Endoriftia*

7.2.4 explain that *Endoriftia* uses the energy from hydrogen sulfide to fix carbon thereby producing organic compounds such as glucose
(word and chemical equations are not required)

7.3 Respiration

Organisms require constant supplies of energy to maintain life processes. Respiration releases energy from organic nutrients in a usable form, as ATP.

Learning outcomes
Candidates should be able to:

7.3.1 understand that aerobic respiration is the process that organisms use to release the energy they require in the form of ATP when oxygen is available

7.3.2 represent aerobic respiration using word and chemical equations

glucose + oxygen → carbon dioxide + water

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

7.3.3 understand that in conditions where oxygen is limited or unavailable, most organisms also use anaerobic respiration which yields far less ATP per molecule of glucose
(word and chemical equations are not required)

8 Fisheries for the future

8.1 Life cycles

Many species of marine organisms have complex life cycles with several different stages, in which one or more stages are adapted for dispersal. Marine mammals have simpler life cycles.

The female gametes of most invertebrates, and some vertebrates such as bony fish, are fertilised outside the body of the female, but fertilisation is internal in mammals and sharks.

Learning outcomes
Candidates should be able to:

8.1.1 describe metamorphosis, larval stage, sessile and non-sessile with reference to life cycles of marine animals

8.1.2 describe the differences between simple and complex life cycles, to include marine mammals (simple) and crustaceans (complex), relating to the presence or absence of a larval stage and metamorphosis

8.1.3 outline the importance of different stages in the life cycle of sessile and non-sessile organisms

8.1.4 discuss the advantages and disadvantages of internal and external fertilisation, and subsequent investment in the care of offspring, with reference to tuna, sharks and whales

8.2 Sustainable fisheries

Modern fishing methods can harvest so many fish that there is a danger that fish populations may be reduced beyond the point at which they can recover. Sustainable exploitation can be achieved by collecting information about fish stocks, regulating fishing and rehabilitating depleted stocks.

Learning outcomes
Candidates should be able to:

8.2.1 explain the need for the sustainable exploitation of fisheries, with reference to a named marine organism

8.2.2 discuss the impact of modern fishing technology, including sonar, purse seine fishing, benthic trawling and factory ships, on populations and habitats

8.2.3 describe the principal information needed to decide how best to exploit fisheries on a sustainable basis, limited to recruitment, growth, natural mortality, fishing mortality, age of reproductive maturity, fecundity and dependency on particular habitats

8.2.4 outline the principal tools used to ensure that fisheries are exploited on a sustainable basis, including:

- restriction by season
- restriction by quotas
- restriction by licensing
- restriction of location, including refuge zones, no-take zones and marine protected areas (MPAs)
- restriction of method, including minimum mesh sizes and the compulsory use of rod-and-line
- restrictions on the size of organism that can be retained
- restriction of fishing intensity, including restrictions on the number of boats, boat and engine size, and the amount of fishing gear (for example, maximum net size, maximum number of traps)
- monitoring, including air and sea patrols, satellite tracking, inspection of catch and fishing gear
- imposition of fines, confiscation of boats and gear, imprisonment
- consumer-orientated tools, including labelling, publicity campaigns and price tariffs

8.2.5 discuss the advantages and disadvantages of the tools in 8.2.4, to include their effectiveness and impact on non-target species

8.2.6 discuss the long-term and short-term sociological and economic impacts of, restrictions on fishing and of unrestricted fishing

8.2.7 discuss the advantages and disadvantages of strategies for the rehabilitation of depleted stocks, including replanting mangroves, building artificial reefs and introducing cultivated stock to the wild

8.3 Marine aquaculture

Increasingly, marine organisms are grown in controlled systems, as an alternative to harvesting from the wild. Aquaculture systems may be intensive or extensive, and both types can have a range of positive and negative social, economic and environmental impacts that should be considered when developing an aquaculture project.

Learning outcomes

Candidates should be able to:

8.3.1 describe intensive and extensive aquaculture techniques, with reference to named marine organisms

8.3.2 outline the processes for the aquaculture of salmon, marine mussels and shrimp

8.3.3 explain the requirements for the long-term success of aquaculture projects, limited to availability of stock, availability of clean water, availability of feed, efficiency of use of feed, availability of labour, disease management, availability of location, market demand, access to market and return on investment

8.3.4 discuss the principal impacts of aquaculture, limited to habitat destruction, overexploitation of feedstocks, pollution, escape of cultured stock, introduction of (potentially) invasive species, spread of disease, competition for resources, reduction in the exploitation of native stocks, social impacts and economic impacts

9 Human impacts on marine ecosystems

9.1 Ecological impacts of human activities

Human activities, whether taking place on land or at sea, frequently affect marine ecosystems. Oil spills, run-off from terrestrial industries and agriculture, and the use and disposal of plastics, have become serious issues, with potentially very significant and widespread effects. Bioaccumulation of heavy metals and other toxins can also have considerable negative impacts.

Learning outcomes

Candidates should be able to:

9.1.1 explain the impacts on marine water quality, habitats, organisms and food webs of:

- the oil industry
- agriculture
- renewable energy installations
- sewage disposal
- refuse disposal
- desalination plants
- fishing practices (including dredging and blast fishing)

9.1.2 explain the bioaccumulation of toxins along food chains, including heavy metals in antifouling paint and mercury from the combustion of fossil fuels

9.1.3 understand that microplastics are plastic particles with a diameter of less than 5 mm and that there are two broad categories; primary microplastics and secondary microplastics

9.1.4 describe how most plastics do not biodegrade but can be broken down to form secondary microplastic fragments, through the action of UV radiation, wind action and wave action, and how temperature affects this process

9.1 Ecological impacts of human activities continued

Learning outcomes
Candidates should be able to:

9.1.5 discuss the impacts of plastics and microplastics on the marine ecosystem, including:
- uptake of microplastics by plankton
- transfer of microplastics along the food chain
- absorption of toxic compounds and their release after being taken up
- ingestion of plastics by marine organisms
- risk to humans if plastics or toxins enter the human food chain
- entanglement (for example, ghost fishing nets)

9.1.6 discuss strategies to limit the release of plastics and microplastics into the marine ecosystem

9.2 Global warming and its impact

The Earth's atmosphere naturally contains carbon dioxide, which produces the greenhouse effect, helping to maintain a temperature on Earth that is suitable for life. However, increasing quantities of carbon dioxide, resulting at least partially from human activities, are enhancing the greenhouse effect and causing global warming. Global warming is already producing a range of negative impacts on the marine environment.

Learning outcomes
Candidates should be able to:

9.2.1 describe how the natural greenhouse effect creates the Earth's ambient temperature

9.2.2 explain how the enhanced greenhouse effect leads to global warming

9.2.3 describe the evidence for global warming

9.2.4 discuss and evaluate the evidence for and against the hypothesis that human activity significantly contributes to global warming

9.2.5 describe the possible impacts of global warming on the marine environment, including sea level rise, coral bleaching, changes in the distribution of species and potential changes to the global circulation of sea water

9.3 Ocean acidification

Carbon dioxide dissolves in sea water to form a weak acid, and increasing concentrations of atmospheric carbon dioxide therefore lead to a decrease in the pH of sea water. This has damaging effects on many marine organisms, particularly those such as corals and molluscs whose skeletons and shells contain calcium carbonate.

Learning outcomes
Candidates should be able to:

9.3.1 explain the relationships between atmospheric carbon dioxide, dissolved carbon dioxide and acidity in the ocean, and understand how the oceans help to limit the increase in atmospheric carbon dioxide concentrations

9.3.2 describe how carbon dioxide reacts with water to form hydrogen ions and hydrogen carbonate ions, and, the impact this has on pH and carbonate ion availability

9.3.3 describe the impact of 9.3.2 on hard corals and shelled organisms

9.3.4 (**PA**) investigate the effect of pH on the loss of mass of empty mollusc shells

9.4 Conservation of marine ecosystems

Local, regional and global conservation efforts can go some way to reducing and even reversing harmful effects on marine ecosystems, but their implementation can sometimes be difficult and expensive.

Learning outcomes

Candidates should be able to:

9.4.1 understand the need for conservation in terms of maintaining or enhancing biodiversity

9.4.2 understand how the International Union for Conservation of Nature (IUCN) Red List can assist in prioritising decisions on local, regional and global marine conservation projects

9.4.3 explain the meaning of the terms invasive species and endangered species, as defined by the IUCN

9.4.4 understand why invasive species pose a threat to native marine species and ecosystems

9.4.5 evaluate the viability of potential conservation projects from given information

9.4.6 discuss strategies for conserving marine species, including:
- MPAs and no-take zones
- captive breeding and release programmes
- legislation both locally and globally, including CITES and IWC moratorium
- UNESCO biosphere reserves
- the role of marine zoos and aquaria
- ecotourism
- control of invasive species

9.4.7 understand that due to the scale of many marine ecosystems, international cooperation and legislation is necessary, but not always possible (for example, non-universal sign-up to IWC moratorium or CITES), and the implications of this for conservation

4 Details of the assessment

All four papers assess:

- knowledge and understanding in a context that is directly from a syllabus learning outcome
- application of knowledge and understanding of syllabus learning outcomes to an unfamiliar context
- the handling and application of information in familiar and unfamiliar contexts using different types of presentation (drawings, tables, graphs or numerical data)
- the mathematical requirements section of this syllabus, within the context of marine science (however the majority of data handling will be assessed in Paper 2 and Paper 4).

Paper 1 – AS Level Theory

Written paper, 1 hour 45 minutes, 75 marks

Candidates answer **all** questions.

Questions in Paper 1 assess a candidate's knowledge and understanding of the syllabus content for topics 1–5 (AO1) and their ability to apply this knowledge by handling and applying information in familiar and unfamiliar contexts (AO2).

There is a range of **question types**, including:

- structured, short-answer
- simple calculations*
- labelling a diagram
- data and graph interpretation
- extended, free-response.

*Candidates may be required to complete simple calculations only, such as the calculation of a percentage, or the calculation of the mean.

Question types will use a variety of **source material,** including:

- passages of text or diagrams giving information about an aspect of marine science
- tabulated data
- photographs (for example, habitats or organisms) and other image types (for example, maps)
- diagrams (for example, food webs and nutrient cycles)
- data presented in the form of graphs
- descriptions (or images) of investigations, or results from investigations, that can be used for interpretation.

The skill of using appropriate units may be assessed directly in this paper. When a candidate is specifically required to state the appropriate units, clear instructions will be provided in the question paper and the mark allocation will reflect this.

Candidates will **not** be required to plot graphs, produce biological drawings or construct tables. They may, however, be expected to interpret information in these formats and use skills outlined in the mathematical requirements section on page 40. Additional detail of this aspect of AO2 is given on pages 46 and 47.

Section A: Structured questions (45 marks)

Candidates answer a variable number of questions from a wide range of question types. The questions are divided into items. The minimum mark for any item is one and the maximum is four.

Section B: Free-response questions (30 marks)

Candidates answer a variable number of questions. The questions are divided into items. The minimum mark for any item is five and the maximum is ten. Candidates are required to write extended answers in continuous prose. It is recommended that candidates support their answers, where relevant, with facts, examples or other evidence.

Paper 2 – AS Level Data-handling and investigative skills

Written paper, 1 hour 45 minutes, 75 marks

Candidates answer **all** questions.

Questions in Paper 2 assess a candidate's knowledge and understanding of the syllabus content for topics 1–5 (AO1) and their ability to apply this knowledge by handling and applying information in familiar and unfamiliar contexts (AO2). Questions which test knowledge recall will not be asked in isolation. They will be, for example, embedded within a question as part of an explanation for data, or provide a link from one investigative context to another. They may be used to set the scene of a question but there will be much less emphasis on knowledge recall than in Paper 1 or Paper 3.

In addition to AO1 and AO2, candidates will be tested on AO3 (Experimental skills and investigations). Candidates will be assessed on their knowledge of The Scientific Method, their ability to plan and evaluate investigations, and data/observation presentation skills (drawing graphs, constructing tables and biological drawings). As well as producing a biological drawing, candidates may be asked to label and/or annotate drawings. Data interpretation (AO2) will also be assessed on this paper.

Candidates may be expected to recall any of the core practical activities (**PA**) included within the syllabus learning outcomes for topics 1–5. In addition, they may be expected to use the knowledge and skills gained from the experience of these activities and apply this to an unfamiliar context. Pages 43 to 47 break down each practical and investigative skill which could be required in this paper. It is essential that candidates are given the opportunity to develop these skills throughout their course of study.

Candidates will be assessed on their ability to use appropriate units and state answers to an appropriate number of significant figures. Marks will be allocated to these skills.

Mathematical skills such as the use of descriptive statistics (mean, median, mode and range) and lengthier calculations will be tested. Candidates may be expected to calculate and interpret Spearman's rank correlation, the Lincoln index and the Simpson's index of diversity. Detailed information on the mathematical requirements which may be tested is given on pages 40 to 42.

Questions in Paper 2 will be short and structured. Scaffolding may be included to assist candidates.

There is a range of **question types**, including:

- structured, short-answer
- data manipulation and calculations
- graph drawing, table construction and biological drawings.

Question types will use a variety of **source material**, including:

- passages of text or diagrams giving information about an aspect of marine science
- photographs (for example, habitats or organisms) and other image types (for example, maps)
- diagrams (for example, apparatus used in an investigation)
- data presented in the form of graphs or tables
- descriptions of investigations, or results from investigations, that can be used for interpretation or evaluation.

Paper 3 – A Level Theory

Written paper, 1 hour 45 minutes, 75 marks

Candidates answer **all** questions.

Questions in Paper 3 assess a candidate's knowledge and understanding of the syllabus content primarily for topics 6–9 (AO1) and their ability to apply this knowledge by handling and applying information in familiar and unfamiliar contexts (AO2). However, this paper may also assess knowledge which falls within topics 1–5 from the AS part of the course. AS Level knowledge may be directly relevant as part of a complete answer, particularly for the longer question items.

There is a range of **question types**, including:

- structured, short-answer
- simple calculations*
- labelling a diagram
- data and graph interpretation
- extended, free-response.

*Candidates may be required to complete simple calculations only, such as the calculation of a percentage, or the calculation of the mean.

Question types will use a variety of **source material**, including:

- passages of text or diagrams giving information about an aspect of marine science
- tabulated data
- photographs (for example, habitats or organisms) and other image types (for example, maps)
- diagrams (for example, life cycles)
- data presented in the form of graphs
- descriptions (or images) of investigations, or results from investigations, that can be used for interpretation.

The skill of using appropriate units may be assessed directly in this paper. When a candidate is specifically required to state the appropriate units, clear instructions will be provided in the question paper and the mark allocation will reflect this.

Candidates will **not** be required to plot graphs, produce biological drawings or construct tables. They may be expected to interpret information in these formats however and use skills outlined in the mathematical requirements section on pages 40 and 41. Additional detail of this aspect of AO2 is given on pages 46 and 47.

Section A: Structured questions (45 marks)

Candidates answer a variable number of questions from a range of question types. The questions are divided into items. The minimum mark for any item is one and the maximum is four. Knowledge of AS Level topics may be needed for a complete answer to some items.

Section B: Free-response questions (30 marks)

Candidates answer a variable number of questions. The questions are divided into items. The minimum mark for any item is five and the maximum is ten. Candidates are required to write extended answers in continuous prose. It is recommended that candidates support their answers, where relevant, with facts, examples or other evidence. At least one of the items in this section will specifically require knowledge from both the AS and A Level topics, enabling candidates to demonstrate synthesis of ideas and to make connections between AS and A Level.

Paper 4 – A Level Data-handling and investigative skills

Written paper, 1 hour 45 minutes, 75 marks

Candidates answer **all** questions.

Questions in Paper 4 assess a candidate's knowledge and understanding of the syllabus content for topics 6–9 (AO1) and their ability to apply this knowledge by handling and applying information in familiar and unfamiliar contexts (AO2). Questions which test knowledge recall will not be asked in isolation. They will be, for example, embedded within a question as part of an explanation for data, or provide a link from one investigative context to another. They may be used to set the scene of a question but there will be much less emphasis on knowledge recall than in Paper 1 or Paper 3. Paper 4 may also assess knowledge which falls within topics 1–5 from the AS part of the course. It is likely that AS Level knowledge may be directly relevant as part of a complete answer for some question items.

In addition to AO1 and AO2, candidates will be tested on AO3 (Experimental skills and investigations). Candidates will be assessed on their knowledge of The Scientific Method, their ability to plan and evaluate investigations, and data/observation presentation skills (drawing graphs, constructing tables and biological drawings). As well as producing a biological drawing, candidates may be asked to label and/or annotate drawings. Knowledge of scale and magnification will be assessed; candidates may be asked to draw to a specific magnification or add an appropriate scale line to a drawing. They may be required to calculate the magnification of a drawing or image.

Candidates may be expected to recall any of the core practical activities (**PA**) included within the syllabus learning outcomes for topics 1–9. In addition, they may be expected to use the knowledge and skills gained from the experience of these activities and apply this to an unfamiliar context. Pages 43 to 47 break down each practical and investigative skill which could be required in this paper. It is essential that candidates are given the opportunity to develop these skills throughout their course of study.

Candidates will be assessed on their ability to use appropriate units and state answers to an appropriate number of significant figures. Marks will be allocated to these skills.

Data interpretation (AO2) will also be assessed and may require calculation of and/or reference to the standard deviation, standard error or 95% confidence intervals (in addition to the descriptive statistics that can be assessed in Paper 2). Candidates may be expected to calculate and interpret Spearman's rank correlation, the Lincoln index and the Simpson's index of diversity. In addition, the calculation and interpretation of the chi-squared test may be assessed on this paper (including being able to calculate the number of degrees of freedom). Detailed information on the mathematical requirements which may be tested is given on pages 40 to 42. Candidates could be expected to demonstrate any of the skills listed at both AS and A Level (page 40) and at A Level only (page 41).

Questions in Paper 4 will be a mixture of short and more extended response items. There will be much less scaffolding than in Paper 2. In particular, candidates will be expected to write an experimental plan in an extended form, with little or no scaffolding. Candidates will however be explicitly told what aspects will be assessed in the planning activity.

There is a range of **question types**, including:

- structured, short-answer
- extended response
- data manipulation and calculations
- graph drawing, table construction and biological drawings.

Question types will use a variety of **source material**, including:

- passages of text or diagrams giving information about an aspect of marine science
- photographs (for example, habitats or organisms) and other image types (for example, maps)
- diagrams (for example, apparatus used in an investigation)
- data presented in the form of graphs or tables
- descriptions of investigations, or results from investigations, that can be used for interpretation or evaluation.

Command words

Command words and their meanings help candidates know what is expected from them in the exam. The table below includes command words used in the assessment for this syllabus. The use of the command word will relate to the subject context.

Command word	What it means
Analyse	examine in detail to show meaning, identify elements and the relationship between them
Assess	make an informed judgement
Calculate	work out from given facts, figures or information
Comment	give an informed opinion
Compare	identify / comment on similarities and/or differences
Consider	review and respond to given information
Contrast	identify / comment on differences
Define	give precise meaning
Demonstrate	show how or give an example
Describe	state the points of a topic / give characteristics and main features
Develop	take forward to a more advanced stage or build upon given information
Discuss	write about issue(s) or topic(s) in depth in a structured way
Evaluate	judge or calculate the quality, importance, amount, or value of something
Examine	investigate closely, in detail
Explain	set out purposes or reasons / make the relationships between things evident / provide why and/or how and support with relevant evidence
Give	produce an answer from a given source or recall / memory
Identify	name / select / recognise
Justify	support a case with evidence / argument
Outline	set out main points
Predict	suggest what may happen based on available information
Sketch	make a simple freehand drawing showing the key features, taking care over proportions
State	express in clear terms
Suggest	apply knowledge and understanding to situations where there are a range of valid responses in order to make proposals / put forward considerations
Summarise	select and present the main points, without detail

5 Additional information

Mathematical requirements

We expect candidates to be able to use the following mathematical skills and knowledge in the assessment. Teaching the mathematical requirements should be included in the Cambridge International AS & A Level Marine Science course.

At AS and A Level

Candidates should be able to:

- understand and use the prefixes: giga (G), mega (M), kilo (k), milli (m), micro (μ) and nano (n)
- select and use the most appropriate units for recording data and the results of calculations
- recognise and use numbers in decimal and standard form
- understand and use the symbols: $<$, $>$, $\leqslant$, $\geqslant$, /, $\propto$ and $\sum$
- make estimations of the results of calculations
- use a calculator for addition, subtraction, multiplication and division, and to calculate squares (x^2), square roots ($\sqrt{x}$), reciprocals ($\frac{1}{x}$) and means ($\bar{x}$)
- take account of significant figures in calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified
(the correct number of significant figures for calculated quantities is the same as, or one more than, the smallest number of significant figures in the data used in the calculation)
- calculate areas of triangles, rectangles and circles
- calculate perimeters of rectangles and circumferences of circles
- calculate surface areas and volumes of cuboids and cylinders
- calculate the mean, median, mode and range of a set of values
- recognise and use ratios
- calculate percentages and percentage changes
- translate information between graphical, numerical, and algebraic forms
- construct and interpret diagrammatic representations of data, including line graphs, bar charts and histograms (candidates may also be expected to interpret pie charts)
- understand when data should be presented in the form of a bar chart, histogram or line graph
- plot data on graph paper with each axis scaled appropriately
- recognise when it is appropriate to join the points on a graph with straight ruled lines and when it is appropriate to use a line (straight or curved) of best fit
- choose, by inspection, a line (straight or curved) which will serve as the line of best fit through a set of data points presented graphically
- calculate the rate of change from the gradient of a straight line on a graph
- calculate the rate of change from the gradient of a tangent to a curved line on a graph
- understand the difference between correlation and causation and that a correlation does not necessarily imply a causative relationship
- use Spearman's rank correlation (r_s) to test for correlation (formulae will be provided – see page 42)
- understand the principles of sampling as applied to biological situations and data
- use the Lincoln index to calculate an estimate of population size using mark-release-recapture data (formulae will be provided – see page 41)
- calculate and interpret the Simpson's index of diversity (D) (formulae will be provided – see page 41).

At A Level only

Candidates should be able to:

- calculate magnifications and actual sizes
- understand the importance of chance and probability when interpreting data
- understand the use of descriptive statistics to simplify data, including the mean, median, mode, range, standard deviation (*s*), standard error (S_M) and 95% confidence intervals (95% CI) (mean, median, mode and range are also expected at AS Level)
- calculate standard deviation (*s*), standard error (S_M) and 95% confidence intervals (95% CI) using given formulae (formulae will be provided – see page 41)
- use standard deviations (*s*), standard errors (S_M) or 95% confidence intervals (95% CI) to plot error bars on graphs
- calculate the results of chi-squared tests, including the number of degrees of freedom (formulae **will** be provided for the chi-squared test – see page 41 but **will not** be provided for the number of degrees of freedom – see page 42)
- use the results of chi-squared tests together with the relevant probability tables of critical values, to assess the significance of differences (tables of critical values will be provided).

Mathematical formulae

Candidates are **not** expected to remember the formulae and symbols for the mathematical formulae in the table below. When needed, candidates will be provided with this information in the question papers.

Lincoln index	$N = \frac{n_1 \times n_2}{m_2}$ Key to symbols: *N* = estimate of population size n_1 = number of individuals captured in first sample n_2 = number of individuals (both marked and unmarked) captured in second sample m_2 = number of marked individuals recaptured in second sample
Simpson's index of diversity (*D*)	$D = 1 - \left(\Sigma\left(\frac{n}{N}\right)^2\right)$ Key to symbols: Σ = sum of (total) *n* = number of individuals of each **different** species *N* = the total number of individuals of **all** the species
standard deviation (*s*)	$s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$
standard error (S_M)	$S_M = \frac{s}{\sqrt{n}}$
95% confidence interval (95% CI)	You can assume this approximation: $95\% \text{ CI} = \bar{x} \pm (2 \times S_M)$
chi-squared (χ^2) test	$\chi^2 = \Sigma\frac{(O-E)^2}{E}$

Key to symbols for s, S_M, 95% CI and χ^2 test:

s = standard deviation	Σ = sum of (total)
x = observations	$\bar{x}$ = mean
n = sample size (number of observations)	S_M = standard error
O = observed 'value'	E = expected 'value'

Spearman's rank correlation (r_s)	$r_s = 1 - \left(\frac{6 \times \sum D^2}{n^3 - n}\right)$ Key to symbols: Σ = sum of (total) *n* = number of pairs of items in the sample *D* = difference in rank between each pair of measurements
Number of degrees of freedom (v)	$v = c - 1$ Key to symbols: c = number of classes
Candidates are expected to know how to calculate the number of degrees of freedom **without being provided with the formula**.	

Notes on the use of statistics

Paper 2 and Paper 4 may include questions involving the use of descriptive statistics and the statistical tests stated in the syllabus. Candidates will **not** be expected to carry out all the steps in these calculations during an examination, but they may be given partly completed calculations to finish.

Candidates are allowed to use electronic calculators in the examination, as long as they are permitted by the Cambridge International general regulations.

Candidates are **not** expected to appreciate the difference between the population standard deviation, s_n, and the sample standard deviation, s_{n-1}.

The **chi-squared** test is used to test whether the difference between observed and expected frequencies of nominal data is significant. The chi-squared test is commonly used in the context of evaluating the results of ecological sampling. Chi-squared tests will only be expected on one row or one column of data.

Spearman's rank correlation is used to test for a correlation between two sets of data that are not distributed normally. The test should be used if:

- data points within samples are independent of each other
- ordinal data have been collected or the data that have been collected can be converted to an ordinal scale using ranking
- a scatter diagram indicates the possibility of an increasing or a decreasing relationship
- the number of paired observations is between 10 and 30 in total (the test can be used if there are more than 5)
- all individuals are selected at random from a population; each individual has an equal chance of being selected.

For Spearman's rank correlation, candidates should know that correlations exist between –1 (perfect negative correlation), 0 (no correlation) and +1 (perfect positive correlation).

Practical work in Marine Science

Introduction

Practical work is an important part of the Marine Science syllabus and should be fully integrated into the course. The subject content section of this syllabus lists several core practical activities (**PA**) that candidates should complete. These are, however, the minimum requirement for practical work. Schools are encouraged to provide as many opportunities as possible for candidates to participate in practical science. Opportunities for the practice of experimental skills should be provided throughout the course of study. The practical work that candidates do during their course should:

- provide learning opportunities enabling candidates to develop the skills they need to carry out experimental and investigative work
- reinforce the learning of the theoretical subject content of the syllabus
- instil an understanding of the interplay of experiment and theory in scientific method
- be enjoyable, contributing to the motivation of the candidates.

Assessment objective AO3 (Experimental skills and investigations) assesses candidates' understanding of practical skills in both familiar and unfamiliar contexts. It is tested in Paper 2 and Paper 4 and accounts for 15% of the marks for AS and A Level.

There are **three** main aspects within AO3:

- experimental planning and knowledge of techniques, including making estimates, predictions and hypotheses
- presentation and display of data and observations in suitable formats
- evaluation of experimental methods and quality of data.

Questions that focus on practical investigations may also incorporate elements of AO2:

- analysis of data, including statistical analysis
- making conclusions from data.

The planning aspect of practical assessment is examined in Paper 2 and Paper 4, along with data analysis, interpretation and evaluation. Candidates will not be adequately prepared for planning, data analysis, interpretation and evaluation without extensive laboratory work during their course of study, under careful supervision from teachers to ensure that experiments are conducted with due regard to safety. Throughout their course, candidates should therefore be given opportunities to make decisions about their practical work including the range and number of values of the independent variable, the number of replicates, and the provision of controls. They should also plan complete experiments to include methods of data collection and analysis. Candidates should keep records of the practical work they carry out during their course.

Both Paper 2 and Paper 4 could include questions that test any of the aspects of AO3 and AO2, but the level of demand will be appropriate to AS Level (Paper 2) and A Level (Paper 4). On Paper 2, planning exercises will have more scaffolding to guide candidates compared to Paper 4. A higher level of data analysis and evaluation will be expected on Paper 4, including the use of additional statistical tests.

1 Experimental planning including making estimates, predictions and hypotheses (AO3)

1.1 Defining the problem

Candidates should be able to:

(a) identify the dependent and independent variables in an investigation or experiment

(b) express the aim in terms of a prediction or hypothesis, and express this in words and, if appropriate, in the form of a predicted graph

(c) identify the key variables that are to be standardised
(variables expected to have a minimal effect, such as variation between test-tubes of the same type do not need to be standardised)

(d) decide on a control experiment or experiments (if appropriate)

(e) where statistical tests are used, state and refer back to an appropriate null hypothesis.

1.2 Choosing appropriate techniques*

Candidates should be able to:

(a) decide a suitable range of values to use for the independent variable at which measurements of the dependent variable are recorded

(b) decide the number of different values of the independent variable (a minimum of five) and the intervals between them

(c) decide how to change the value of the independent variable

(d) decide the number of replicates at each value

(e) decide how the dependent variable should be measured

(f) decide on an appropriate control for the experiment or investigation

(g) explain how any control experiments will be used to verify that it is the independent variable that is affecting the dependent variable and not some other factor

(h) decide which variables need to be standardised and how to standardise them

(i) assess the risks of their proposed methods

(j) describe precautions that should be taken to keep risks to a minimum

(k) understand the need for the ethical treatment of organisms

(l) construct tables for data that they might wish to record

(m) describe how the data might be used in order to reach a conclusion.

* Candidates should be familiar with the use of common school laboratory equipment, such as stopwatches, balances, measuring cylinders, syringes, water-baths and thermometers (see the practical apparatus list on pages 48 and 49). If reference to specialised equipment is required for a planning question, relevant information will be provided.

2 Presentation of data and observations (AO3)

2.1 Recording data and observations in tables and other suitable forms

Candidates should be able to:

(a) present numerical data, values or observations in a single table of results

(b) make tables of data and observations large enough so that all the entries can be comfortably fitted in the available space

(c) include in the table of results, if necessary, columns for raw data, for calculated values and for deductions

(d) use descriptive column headings including any required units (no units in the body of the table)

(e) record quantitative data to the number of decimal places that is appropriate for the measuring instrument used

(f) make drawings large and unshaded and use fine, clear, unbroken lines, showing clear outlines of structures

(g) use pencil for drawings

(h) use ruler-drawn label lines to identify structures on diagrams, without an arrowhead.

2.2 Presenting data in the form of graphs and charts

Candidates should be able to:

(a) display data as a line graph (continuous data), bar chart (discontinuous or categorical) or histogram (frequency data)

(b) draw a line graph, bar chart or histogram clearly and accurately with:
- axes labelled to match the relevant table headings, including units where appropriate
- a scale where both axes should use most or all of the grid available and allow the graph to be read easily to half a square
- all graph points plotted accurately using a sharp pencil, as a small cross or a small dot in a circle, with the intersection of the cross or centre of the dot exactly on the required point
- the plotted points of a graph connected with a clear, sharp and unbroken line, either as a line of best fit, a smooth curve or with ruled straight lines joining the points
- no extrapolation of graph lines unless this can be assumed from the data
- all bars on a bar chart or histogram plotted accurately, with clear, unbroken lines that are drawn with a sharp pencil and ruler

(c) use keys and labels on graphs where appropriate.

3 Evaluation of procedures and data (AO3)

3.1 Identifying limitations and sources of error

Candidates should be able to:

(a) make criticisms of the experimental procedure

(b) evaluate the effectiveness of standardisation of variables and thus the confidence with which conclusions might be drawn

(c) identify the main sources of error in a particular investigation

(d) identify systematic or random errors from using apparatus in an investigation, understanding that systematic errors do not affect the trend in results whereas a random error may affect the trend

(e) identify anomalous results

(f) within familiar contexts, suggest possible explanations for anomalous readings

(g) identify the extent to which provided readings have been adequately replicated, and describe the adequacy of the range of data provided

(h) evaluate the confidence with which conclusions might be made.

3.2 Suggesting improvements

Candidates should be able to:

(a) suggest improvements to a procedure that will increase the accuracy of the observations or measurements, including:

- using a more effective method to standardise relevant variables
- using a more accurate method of measuring the dependent variable
- using smaller intervals for the values of the independent variable
- collecting replicate measurements so that a mean can be calculated

(b) suggest how to extend the investigation to answer a new question, for example by investigating a different independent variable or applying the method to a new context

(c) describe clearly, in words or diagrams, improvements to the procedure or modifications to extend the investigation.

4 Analysis of data and conclusions (AO2)

4.1 Display of calculations and reasoning

Candidates should be able to:

(a) show their working in calculations, and the key steps in their reasoning

(b) calculate an answer with the correct number of significant figures using quantitative results or data provided

(c) identify and remove anomalous results before beginning calculations, e.g. when calculating means.

4.2 Description of patterns and trends

Candidates should be able to:

(a) use tables and graphs to draw attention to the key points in quantitative data, including the variability in data

(b) describe patterns and trends using the data provided in tables and graphs

(c) describe and summarise the key points of a set of observations.

4.3 Interpretation of data and observations

At both AS Level and A Level, candidates should be able to:

(a) identify and carry out the calculations necessary to be able to draw conclusions from primary and/or secondary data

(b) use descriptive statistics limited to mean, median, mode and range, to simplify data, assess their variability and determine the confidence in the validity of conclusions

(c) find an unknown value by using coordinates or intercepts with axes on a graph/calibration curve, or extrapolation where the data allow

(d) determine the gradient of a straight line graph or of a tangent to a curved line on a graph and use the values to inform the conclusion, e.g. calculation of the rate of change

(e) use Spearman's rank to test for correlation.

Note: Candidates are **not** expected to recall the equation or symbols for Spearman's rank. These will be provided in the question papers.

At A Level, candidates should also be able to:

(a) use standard deviation, standard error and/or 95% confidence intervals to assess the spread of the results and determine the level of certainty of conclusions

(b) put error bars on graphs, which may be calculated using standard error

(c) use values of standard deviation or standard error, or graphs with standard error bars, to determine whether differences in mean values are likely to be statistically significant

(d) use the chi-squared test to test whether the difference between observed and expected frequencies of nominal data is significant.

Note: Candidates are **not** expected to recall the equation or symbols for standard deviation, standard error or the chi-squared test. These will be provided in the question papers. If required, candidates **will** be expected to recall and use the formula for the number of degrees of freedom.

4.4 Making conclusions, drawing on theoretical knowledge and understanding

Candidates should be able to:

(a) draw conclusions from an investigation or from interpretations of observations, data and calculated values, providing a detailed description of the key features of the observations, data and analyses, and considering whether experimental data support a given hypothesis or not

(b) make detailed scientific explanations of the data and of their conclusions

(c) make further predictions and suggest informed and relevant further questions to investigate.

Apparatus and materials list

The following is a recommended list of basic materials and apparatus. However, the list is by no means exhaustive.

In accordance with the COSHH (Control of Substances Hazardous to Health) Regulations, operative in the UK, a hazard appraisal of the list has been completed.

The following codes have been used where relevant.

C corrosive
HH health hazard
F flammable
N hazardous to the aquatic environment
MH moderate hazard
T acutely toxic
O oxidising

Responsibility for safety matters rests with schools.

Apparatus

test-tubes, small, capacity 20–30 cm^3, including some that are heat resistant
test-tubes, large (boiling tubes), capacity 40–50 cm^3, including some that are heat resistant
test-tube holders
test-tube racks
bungs to fit small test-tubes and large test-tubes
bungs with delivery tube to fit small test-tubes and large test-tubes
specimen tubes with lids
Bunsen burners
tripod stands and gauzes
heat-proof mats
measuring cylinders
syringes (various sizes, e.g. 1 cm^3, 2 cm^3, 5 cm^3, 10 cm^3)
clear plastic tubing to fit syringe nozzles
small teat pipettes or droppers (plastic or glass)
beakers (various sizes, e.g. 100 cm^3, 250 cm^3, 400 cm^3)
conical flasks (various sizes, e.g. 100 cm^3, 250 cm^3)
thermometers, –10 °C to +110 °C
filter funnels and filter paper
Petri dishes, plastic or glass, 9 cm diameter
white tiles or other suitable surfaces on which to cut
clamp (retort) stands and bosses
dialysis (Visking) tubing, 14 mm width with a pore diameter of approximately 2.5 nm
capillary tubing
soda-glass tubing
paper towels
cotton wool
glass (stirring) rods
spatulas

black paper or black card
white paper or white card
aluminium foil
chromatography paper
water-resistant marker pens (for labelling glassware)
blunt forceps
scissors
mounted needles
cutting implements, such as single-edged razor blade / knife / scalpel
rulers with mm scale (ideally clear plastic)
mortars and pestles
suitable eye protection
microscope and lamp / inbuilt illumination – with high-power and low-power objective lenses
microscope slides and glass coverslips
hand lenses (not less than ×6, preferably ×10)
bench lamp with flexible arm
balance (0.01 g precision)
thermostatically controlled water-bath
pH probe
stop-clock or timer showing seconds

Chemicals

[C] [MH] potassium hydroxide
[C] sodium hydroxide
sodium chloride
dilute hydrochloric acid
hydrogencarbonate indicator
sodium hydrogencarbonate
[MH] limewater
distilled / deionised water
Universal Indicator paper with chart
Universal Indicator solution with chart
red and blue litmus paper
[F] [MH] [HH] thymolphthalein indicator
petroleum jelly
reagents for paper chromotography

Ecological/fieldwork equipment

apparatus for sampling, e.g. 'open' and 'grid' quadrats, point quadrats

long tape measures to make transects

apparatus for measuring abiotic factors, e.g. oxygen meter, flow meter, light meter

sweep net (muslin)

plankton net and dip net

trays for hand sorting

non-toxic paint and brushes

Secchi disc

water flow-rate meter

Specimens

(dead) fish (complete or head only)

mollusc shells, e.g. mussel, clam

aquatic plants

ideally, live specimens from the key groups listed in topic 4 for observation and drawing practice (assuming these can either be returned live to their habitat or ethically kept in a suitable aquarium)

6 What else you need to know

This section is an overview of other information you need to know about this syllabus. It will help to share the administrative information with your exams officer so they know when you will need their support. Find more information about our administrative processes at **www.cambridgeinternational.org/eoguide**

Before you start

Previous study

We recommend that learners starting this course should have completed a course in Cambridge O Level or Cambridge IGCSE™ in Biology or Marine Science or the equivalent.

Guided learning hours

We design Cambridge International AS & A Level syllabuses based on learners having about 180 guided learning hours for each Cambridge International AS Level and about 360 guided learning hours for a Cambridge International A Level. The number of hours a learner needs to achieve the qualification may vary according to local practice and their previous experience of the subject.

Availability and timetables

All Cambridge schools are allocated to one of six administrative zones. Each zone has a specific timetable.

You can view the timetable for your administrative zone at **www.cambridgeinternational.org/timetables**

You can enter candidates in the June and November exam series.

Check you are using the syllabus for the year the candidate is taking the exam.

Private candidates can enter for this syllabus.

Combining with other syllabuses

Candidates can take this syllabus alongside other Cambridge International syllabuses in a single exam series. The only exceptions are:

- syllabuses with the same title at the same level.

Group awards: Cambridge AICE

Cambridge AICE (Advanced International Certificate of Education) is a group award for Cambridge International AS & A Level. It allows schools to offer a broad and balanced curriculum by recognising the achievements of learners who pass examinations in a range of different subjects.

Learn more about Cambridge AICE at **www.cambridgeinternational.org/aice**

Making entries

Exams officers are responsible for submitting entries to Cambridge International. We encourage them to work closely with you to make sure they enter the right number of candidates for the right combination of syllabus components. Entry option codes and instructions for submitting entries are in the *Cambridge Guide to Making Entries*. Your exams officer has a copy of this guide.

Exam administration

To keep our exams secure, we produce question papers for different areas of the world, known as administrative zones. We allocate all Cambridge schools to one administrative zone determined by their location. Each zone has a specific timetable. Some of our syllabuses offer candidates different assessment options. An entry option code is used to identify the components the candidate will take relevant to the administrative zone and the available assessment options.

Support for exams officers

We know how important exams officers are to the successful running of exams. We provide them with the support they need to make your entries on time. Your exams officer will find this support, and guidance for all other phases of the Cambridge Exams Cycle, at **www.cambridgeinternational.org/eoguide**

Retakes

Candidates can retake Cambridge International AS Level and Cambridge International A Level as many times as they want to. To confirm what entry options are available for this syllabus, refer to the *Cambridge Guide to Making Entries* for the relevant series.

Candidates can carry forward the result of their Cambridge International AS Level assessment from one series to complete the Cambridge International A Level in a following series, subject to the rules and time limits described in the *Cambridge Handbook*.

Equality and inclusion

We have taken great care to avoid bias of any kind in the preparation of this syllabus and related assessment materials. In compliance with the UK Equality Act (2010) we have designed this qualification to avoid any direct and indirect discrimination.

The standard assessment arrangements may present unnecessary barriers for candidates with disabilities or learning difficulties. We can put arrangements in place for these candidates to enable them to access the assessments and receive recognition of their attainment. We do not agree access arrangements if they give candidates an unfair advantage over others or if they compromise the standards being assessed.

Candidates who cannot access the assessment of any component may be able to receive an award based on the parts of the assessment they have completed.

Information on access arrangements is in the *Cambridge Handbook* at **www.cambridgeinternational.org/eoguide**

Language

This syllabus and the related assessment materials are available in English only.

After the exam

Grading and reporting

Grades A*, A, B, C, D or E indicate the standard a candidate achieved at Cambridge International A Level, with A* being the highest grade.

Grades a, b, c, d or e indicate the standard a candidate achieved at Cambridge International AS Level, with 'a' being the highest grade.

'Ungraded' means that the candidate's performance did not meet the standard required for the lowest grade (E or e). 'Ungraded' is reported on the statement of results but not on the certificate. In specific circumstances your candidates may see one of the following letters on their statement of results:

- Q (pending)
- X (no result)
- Y (to be issued).

These letters do not appear on the certificate.

If a candidate takes a Cambridge International A Level and fails to achieve grade E or higher, a Cambridge International AS Level grade will be awarded if both of the following apply:

- the components taken for the Cambridge International A Level by the candidate in that series included all the components making up a Cambridge International AS Level
- the candidate's performance on the AS Level components was sufficient to merit the award of a Cambridge International AS Level grade.

On the statement of results and certificates, Cambridge International AS & A Levels are shown as General Certificates of Education, GCE Advanced Subsidiary Level (GCE AS Level) and GCE Advanced Level (GCE A Level).

'Cambridge International A Levels are the 'gold standard' qualification. They are based on rigorous, academic syllabuses that are accessible to students from a wide range of abilities yet have the capacity to stretch our most able.'

Director of Studies, Auckland Grammar School, New Zealand

How students, teachers and higher education can use the grades

Cambridge International A Level

Assessment at Cambridge International A Level has two purposes:

- to measure learning and achievement
  The assessment:
  - confirms achievement and performance in relation to the knowledge, understanding and skills specified in the syllabus, to the levels described in the grade descriptions.

- to show likely future success
  The outcomes:
  - help predict which students are well prepared for a particular course or career and/or which students are more likely to be successful
  - help students choose the most suitable course or career.

Cambridge International AS Level

Assessment at Cambridge International AS Level has two purposes:

- to measure learning and achievement
  The assessment:
  - confirms achievement and performance in relation to the knowledge, understanding and skills specified in the syllabus.

- to show likely future success
  The outcomes:
  - help predict which students are well prepared for a particular course or career and/or which students are more likely to be successful
  - help students choose the most suitable course or career
  - help decide whether students part way through a Cambridge International A Level course are making enough progress to continue
  - guide teaching and learning in the next stages of the Cambridge International A Level course.

Grade descriptions

Grade descriptions are provided to give an indication of the standards of achievement candidates awarded particular grades are likely to show. Weakness in one aspect of the examination may be balanced by a better performance in some other aspect.

Grade descriptions for Cambridge International A Level Marine Science will be published after the first assessment of the A Level in 2022. Find more information at **www.cambridgeinternational.org/alevel**

Changes to this syllabus for 2022, 2023 and 2024

The syllabus has been reviewed and revised for first examination in 2022.

The AS Level learning outcomes are assumed knowledge for the A Level components. From 2022, the A Level components will assume knowledge of the **revised** AS Level content. All candidates should therefore be familiar with the revised AS Level content in this syllabus.

You are strongly advised to read the whole syllabus before planning your teaching programme.

Changes to syllabus content	• The subject content section has been updated and refreshed. Some of the content areas have been removed and others have been added. • The content has been restructured into nine new topics. The learning outcomes have been rewritten making the requirements more explicit. • An introductory explanation to each of the subtopics has been added. • Practical work and The Scientific Method has become an essential part of the course underpinning many of the syllabus topics. Candidates will be expected to undertake all the core practical activities included as learning outcomes in the subject content section of this syllabus, as a minimum. Guidance on practical work has been added in the new Practical work in Marine Science section. • Overarching key concepts for Cambridge International AS & A Level Marine Science have been introduced. • The glossary of terms used in science papers has been removed from the syllabus. This has been replaced with the generic glossary of command words used in other Cambridge International syllabuses.
Changes to assessment (including changes to specimen papers)	• The syllabus aims have been updated and aligned to the syllabus aims in the Cambridge International AS & A Level Biology, Chemistry and Physics syllabuses. • The assessment objectives have been updated and regrouped into three new assessment objectives: – AO1 Knowledge and understanding – AO2 Handling and applying information – AO3 Experimental skills and investigations (the testing of AO3 is new to this syllabus, allowing a further emphasis on the teaching of investigative skills). • We have renamed the papers to reflect the changes in the assessment for each paper: – Paper 1 is now named AS Level Theory (previously AS Structured Questions) – Paper 2 is now named AS Level Data-handling and investigative skills (previously AS Data-Handling and Free-Response) – Paper 3 is now named A Level Theory (previously A2 Structured Questions) – Paper 4 is now named A Level Data-handling and investigative skills (previously A2 Data-Handling and Free-Response).

Changes to assessment (including changes to specimen papers) continued	• The weightings of the assessment objectives and across the components have been updated. • All papers are now worth 75 marks. (Papers 1 and 3 remain at 75 marks with Papers 2 and 4 increasing from 50 to 75 marks). • The weighting of the papers has changed to reflect the change in the number of marks. All four papers now have equal weighting. Papers 1 and 2 are worth 50% of the AS Level each. In the A Level, each of the four papers is weighted at 25%. • All four papers will continue to be externally assessed. • We have increased the duration of all four papers to 1 hour 45 minutes each. Paper 1 has increased by 15 minutes, Paper 2 by 30 minutes, Paper 3 by 15 minutes and Paper 4 by 30 minutes. • In line with the changes to the assessment objectives the papers will be assessed with new and restructured assessment tasks. For example, the free-response questions from Papers 2 and 4 have been moved to Papers 1 and 3. • A new section has been introduced explaining the Details of the assessment. Please see section 4 Details of the assessment. • Updated specimen papers have been published to accompany the new syllabus. These exemplify the changes to the assessment and the syllabus content.
Other changes	• A new section detailing the requirements of practical work in Cambridge International AS & A Level Marine Science has been added. This includes guidance on experimental planning, presentation of data and observations and recommended apparatus and material lists to complete the investigations. Please see the section on Practical work in Marine Science. • The list of mathematical requirements has been updated. Please see the section on mathematical requirements.

In addition to reading the syllabus, you should refer to the updated specimen papers. The specimen papers will help your students become familiar with exam requirements and command words in questions. The specimen mark schemes explain how students should answer questions to meet the assessment objectives.

Any textbooks endorsed to support the syllabus for examination from 2022 are suitable for use with this syllabus.

'While studying Cambridge IGCSE and Cambridge International A Levels, students broaden their horizons through a global perspective and develop a lasting passion for learning.'

Zhai Xiaoning, Deputy Principal, The High School Affiliated to Renmin University of China

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