

# SYLLABUS

**Cambridge O Level  
For Centres in Mauritius  
Science for All**

**5031**

For examination in November 2017, 2018 and 2019

### Changes to syllabus for 2017, 2018 and 2019

This syllabus has been updated, but there are no significant changes.

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

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# 1. Introduction

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## 1.1 Why choose Cambridge?

Cambridge International Examinations is part of the University of Cambridge. We prepare school students for life, helping them develop an informed curiosity and a lasting passion for learning. Our international qualifications are recognised by the world's best universities and employers, giving students a wide range of options in their education and career. As a not-for-profit organisation, we devote our resources to delivering high-quality educational programmes that can unlock learners' potential.

Our programmes set the global standard for international education. They are created by subject experts, are rooted in academic rigour, and provide a strong platform for progression. Over 10 000 schools in 160 countries work with us to prepare nearly a million learners for their future with an international education from Cambridge.

### Cambridge learners

Cambridge programmes and qualifications develop not only subject knowledge but also skills. We encourage Cambridge learners to be:

- **confident** in working with information and ideas – their own and those of others
- **responsible** for themselves, responsive to and respectful of others
- **reflective** as learners, developing their ability to learn
- **innovative** and equipped for new and future challenges
- **engaged** intellectually and socially, ready to make a difference.

### Recognition

Cambridge O Level is internationally recognised by schools, universities and employers as equivalent in demand to Cambridge IGCSE<sup>®</sup> (International General Certificate of Secondary Education). There are over 700 000 entries a year in nearly 70 countries. Learn more at [www.cie.org.uk/recognition](http://www.cie.org.uk/recognition)

### Support for teachers

A wide range of materials and resources is available to support teachers and learners in Cambridge schools. Resources suit a variety of teaching methods in different international contexts. Through subject discussion forums and training, teachers can access the expert advice they need for teaching our qualifications. More details can be found in Section 2 of this syllabus and at [www.cie.org.uk/teachers](http://www.cie.org.uk/teachers)

### Support for exams officers

Exams officers can trust in reliable, efficient administration of exams entries and excellent personal support from our customer services. Learn more at [www.cie.org.uk/examsOfficers](http://www.cie.org.uk/examsOfficers)

Our systems for managing the provision of international qualifications and education programmes for learners aged 5 to 19 are certified as meeting the internationally recognised standard for quality management, ISO 9001:2008. Learn more at [www.cie.org.uk/ISO9001](http://www.cie.org.uk/ISO9001)

## 1.2 Why choose Cambridge O Level?

Cambridge O Levels have been designed for an international audience and are sensitive to the needs of different countries. These qualifications are designed for learners whose first language may not be English and this is acknowledged throughout the examination process. The Cambridge O Level syllabus also allows teaching to be placed in a localised context, making it relevant in varying regions.

Our aim is to balance knowledge, understanding and skills in our programmes and qualifications to enable students to become effective learners and to provide a solid foundation for their continuing educational journey.

Through our professional development courses and our support materials for Cambridge O Levels, we provide the tools to enable teachers to prepare learners to the best of their ability and work with us in the pursuit of excellence in education.

Cambridge O Levels are considered to be an excellent preparation for Cambridge International AS and A Levels, the Cambridge AICE (Advanced International Certificate of Education) Group Award, Cambridge Pre-U, and other education programmes, such as the US Advanced Placement program and the International Baccalaureate Diploma programme. Learn more about Cambridge O Levels at [www.cie.org.uk/cambridgesecundary2](http://www.cie.org.uk/cambridgesecundary2)

### Guided learning hours

Cambridge O Level syllabuses are designed on the assumption that learners have about 130 guided learning hours per subject over the duration of the course, but this is for guidance only. The number of hours required to gain the qualification may vary according to local curricular practice and the learners' prior experience of the subject.

## 1.3 Why choose Cambridge O Level Science for All?

Cambridge O Levels are established qualifications that keep pace with educational developments and trends. The Cambridge O Level curriculum places emphasis on broad and balanced study across a wide range of subject areas. The curriculum is structured so that students attain both practical skills and theoretical knowledge.

Cambridge O Level Science for All should be accepted by universities and employers as proof of knowledge and understanding. It meets the needs of students who are not traditional scientists, but who would like to follow a course which emphasises the development of scientific literacy, enabling them to make sense of the science they come across in everyday life. The syllabus enables candidates to:

- recognise the impact of science and technology on everyday life
- make informed decisions about issues and questions that involve science
- understand and reflect on the information included in (or omitted from) media reports and other sources of information.

## Prior learning

We recommend that candidates who are beginning this course should have previously studied a science curriculum such as that of Cambridge Lower Secondary Programme or equivalent national education frameworks. Candidates should also have adequate mathematical skills for the content contained in the syllabus.

## Progression

Cambridge O Levels are general qualifications that enable candidates to progress either directly to employment, or to proceed to further qualifications.

Candidates wishing to proceed to qualifications in the sciences at Cambridge International Advanced Level should have completed a course in another Cambridge O Level Science or one or more of the separate sciences.

## 1.4 How can I find out more?

### If you are already a Cambridge school

You can make entries for this qualification through your usual channels. If you have any questions, please contact us at **info@cie.org.uk**

### If you are not yet a Cambridge school

Learn about the benefits of becoming a Cambridge school at **www.cie.org.uk/startcambridge**. Email us at **info@cie.org.uk** to find out how your organisation can register to become a Cambridge school.

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## 2. Teacher support

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### 2.1 Support materials

We send Cambridge syllabuses, past question papers and examiner reports to cover the last examination series to all Cambridge schools.

You can also go to our public website at **[www.cie.org.uk/olevel](http://www.cie.org.uk/olevel)** to download current and future syllabuses together with specimen papers or past question papers and examiner reports from one series.

For teachers at registered Cambridge schools a range of additional support materials for specific syllabuses is available online from Teacher Support, our secure online support for Cambridge teachers. Go to **<http://teachers.cie.org.uk>** (username and password required).

### 2.2 Endorsed resources

We work with publishers providing a range of resources for our syllabuses including print and digital materials. Resources endorsed by Cambridge go through a detailed quality assurance process to ensure they provide a high level of support for teachers and learners.

We have resource lists which can be filtered to show all resources, or just those which are endorsed by Cambridge. The resource lists include further suggestions for resources to support teaching.

### 2.3 Training

We offer a range of support activities for teachers to ensure they have the relevant knowledge and skills to deliver our qualifications. See **[www.cie.org.uk/events](http://www.cie.org.uk/events)** for further information.

The University of York Science Education Group (UYSEG) and the Nuffield Curriculum Centre have produced resources specifically to support the UK version of this syllabus. The resources comprise:

- candidates' texts
- candidates' work books
- teacher guide with suggested schemes of work and candidate activity sheets (in customisable format)
- technician guide
- ICT resources (for example, animations, video clips, models and simulations)
- assessment materials
- a website for teachers and candidates (**<http://www.21stcenturyscience.org>**).

The resources are published by Oxford University Press. Further information is available from:

**<http://www.twentyfirstcenturyscience.org/index.htm>**

Telephone: +44 1536 741068

Fax: +44 1536 454579

The UYSEG/Nuffield Website for 21st Century Science can be found at:

**<http://www.21stcenturyscience.org>**

### 3. Assessment at a glance

All candidates take Papers 1, 2 and 3 and submit a Case Study. Grades A\* to E are available.

The Periodic Table will be included in Papers 1, 2, and 3.

#### Paper 1: Multiple Choice

1 hour

A multiple choice paper consisting of 40 items of the four-choice type.

**Weighting: 20% of the final total marks available.**

#### Paper 2: Written

1 hour 30 minutes

A theory paper consisting of 60 marks of short-answer and structured questions.

**Weighting: 40% of the final total marks available.**

#### Paper 3: Comprehension and Practical Procedures

1 hour 30 minutes

This paper has two sections.

##### **Section A: Comprehension (30 marks)**

Candidates answer several short and structured questions based on a number of passages.

##### **Section B: Practical procedures, data handling and analysis (30 marks)**

This section contains three structured questions covering practical aspects of the syllabus and associated data processing.

**Weighting: 20% of the final total marks available.**

#### Paper 4: Case Study

This is a school-based assessment which is internally marked and externally moderated. Candidates carry out and report on an investigation of a local issue relating to the syllabus. The report carries a maximum mark of 24.

**Weighting: 20% of the final total marks available.**



## Availability

This syllabus is examined in the November examination series.

This syllabus is not available to private candidates.

Detailed timetables are available from **[www.cie.org.uk/examsOfficers](http://www.cie.org.uk/examsOfficers)**

It is available in Mauritius only.

Cambridge O Levels are available to Centres in Administrative Zones 3, 4 and 5. Centres in Administrative Zones 1, 2 or 6 wishing to enter candidates for Cambridge O Level examinations should contact Cambridge Customer Services.

## Combining this with other syllabuses

Candidates can combine this syllabus in an examination series with any other Cambridge syllabus, except:

- syllabuses with the same title or including Twenty First Century Science in the title at the same level

Please note that Cambridge O Level, Cambridge IGCSE and Cambridge International Level 1/Level 2 Certificate syllabuses are at the same level.

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## 4. Syllabus aims and assessment objectives

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### 4.1 Syllabus aims

The aims of the Cambridge O Level Science for All syllabus are to encourage candidates to:

- acquire a systematic body of scientific knowledge, and the skills needed to apply this in new and changing situations
- acquire an understanding of scientific ideas, of how they develop, of the factors which may affect their power, and of their limitations
- consider and evaluate critically their own data and conclusions, and those obtained from other sources, using ICT where appropriate
- evaluate, in terms of their scientific knowledge and understanding and their understanding of the processes of scientific enquiry and of the nature of scientific knowledge, the benefits and drawbacks of scientific and technological developments, including those related to the environment, personal health and quality of life, and considering ethical issues where these arise
- select, organise and present information clearly and logically, using appropriate scientific terms and conventions, and ICT where appropriate
- interpret and evaluate scientific data and conclusions from a variety of sources
- use electronic (internet, CD ROMs, databases, simulations, etc.) and/or more traditional sources of information (books, magazines, leaflets, etc.) to collect data and ideas on a topic of scientific interest.

### 4.2 Assessment objectives

The Assessment Objectives (AOs) describe the intellectual and practical skills which candidates should be able to demonstrate, in the context of the prescribed content. Candidates should demonstrate communication skills, including ICT, using scientific conventions (including chemical equations) and mathematical language (including formulae).

#### AO1: Knowledge and understanding of science and how science works

Candidates should be able to:

- demonstrate knowledge and understanding of the scientific facts, concepts, techniques and terminology in the syllabus
- show understanding of how scientific evidence is collected and its relationship with scientific explanations and theories
- show understanding of how scientific knowledge and ideas change over time and how these changes are validated.

#### AO2: Application of skills, knowledge and understanding

Candidates should be able to:

- apply concepts, develop arguments or draw conclusions related to familiar and unfamiliar situations
- plan a scientific task, such as a practical procedure, testing an idea, answering a question or solving a problem
- show understanding of how decisions about science and technology are made in different situations, including contemporary situations and those raising ethical issues
- evaluate the impact of scientific developments or processes on individuals, communities or the environment.

## AO3: Practical, enquiry and data-handling skills

Candidates should be able to:

- carry out practical tasks safely and skilfully
- evaluate the methods used when collecting first-hand and secondary data
- analyse and interpret qualitative and quantitative data from different sources
- consider the validity and reliability of data in presenting and justifying conclusions.

## Specification grid

The approximate weightings allocated to each of the assessment objectives in the assessment model are summarised in the table below. All figures are in percentages.

Assessment Objective	Paper 1	Paper 2	Paper 3	Paper 4	Weighting
<b>AO1</b> Knowledge and understanding of science and how science works	10	15	2.5	2.5	30
<b>AO2</b> Application of skills, knowledge and understanding	10	15	5	5	35
<b>AO3</b> Practical, enquiry and data-handling skills	0	10	12.5	12.5	35
	20	40	20	20	100

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## 5. Syllabus content

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### 5.1 Introduction

Cambridge O Level Science for All emphasises scientific literacy – the knowledge and understanding which candidates need to engage, as informed citizens, with science-based issues. As with other courses in this suite, this qualification uses contemporary, relevant contexts of interest to candidates, which can be approached through a range of teaching and learning activities.

This syllabus aims to enhance candidates' 'scientific literacy', leading to better engagement with science. The course is designed to enable candidates to:

- recognise the impact of science and technology on everyday life
- make informed personal decisions about issues and questions that involve science
- understand and reflect on the information included in (or omitted from) media reports and other sources of information.

To achieve this, candidates must have a broad understanding of the main scientific concepts that provide a framework for making sense of the world. These are referred to as 'Science Explanations'.

But candidates also need to be able to reflect on scientific knowledge itself, the practices that have produced it, the kinds of reasoning that are used in developing a scientific argument, and the issues that arise when scientific knowledge is put to practical use. These are referred to as 'Ideas about Science'.

There is a balance between the Ideas about Science and the Science Explanations, so that 50% of the learning outcomes and the assessments that test them relate to Ideas about Science and 50% to Science Explanations.

The syllabus content is based upon these two essential elements, which were developed by the University of York Science Education Group (UYSEG) as part of a project on 'Science in the 21st Century'.

### Skills and processes

The syllabus is designed with the processes and skills that are the fabric of science as much in mind as knowledge and understanding of scientific ideas. Examination questions will test understanding of these processes and skills.

### Experimental work

Experimental work is an essential component of all science. Experimental work within science education:

- gives students first hand experience of phenomena
- enables students to acquire practical skills
- provides students with the opportunity to plan and carry out investigations into practical problems.

This can be achieved by individual or group experimental work, or by demonstrations which actively involve the students.

## Target group

The syllabus is aimed at students across a wide range of attainments, and will allow them to show success over the Cambridge O Level range of grades from A\* to E.

## Course duration and structure

While Centres will obviously make their own decisions about the length of time taken to teach this course, it is assumed that most Centres will attempt to cover it in two years.

Within that time it is assumed that Centres may wish to allocate 3 × 40 minute periods per week to science.

The curriculum content is presented as nine modules which are listed below. Each module uses contexts that make it clear and of immediate relevance and interest to candidates. The contexts relate to candidates' everyday experiences and interests, for example, issues often in the news, or to work and leisure. A module defines the required teaching and learning outcomes. Ideas about Science should have a strong influence on the teaching of each module. Each module is designed to be taught in approximately half a term, in 10% of the candidates' curriculum time.

### Module B1: You and your genes

- What are genes and how do they affect the way that organisms develop?
- Why can people look like their parents, brothers and sisters, but not be identical to them?
- How can and should genetic information be used? How can we use our knowledge of genes to prevent disease?
- What are stem cells and why could they be useful in treating some diseases?

### Module B2: Keeping healthy

- How do our bodies resist infection?
- What are vaccines and how do they work?
- What are antibiotics, and why can they become less effective? How are new drugs developed and tested?
- How can my lifestyle affect my health? What factors increase the risk of heart disease?

### Module B3: Life on Earth

- How did life on Earth begin and evolve?
- How have scientists developed explanations of evolution?
- How did humans evolve? How are our nervous systems organised?
- Why do some species become extinct, and does it matter? What is the importance of biodiversity?

**Module C1: Air quality**

- Which chemicals make up air, and which ones are pollutants? How do I make sense of data about air pollution?
- What chemical reactions produce air pollutants? What happens to pollutants in the atmosphere?
- Is air pollution harmful to me, or to my environment?
- What choices can we make personally, locally, nationally or globally to improve air quality?

**Module C2: Material choices**

- What different properties do different materials have?
- Why is crude oil important as a source of new materials such as plastics and fibres?
- Why does it help to know about the molecular structure of materials such as plastics and fibres?
- When buying a product, what else should we consider besides its cost and how well it does its job? How should we manage the wastes that arise from our use of materials?

**Module C3: Everyday chemicals**

- What chemicals are used in industries and agriculture?
- What chemicals are deliberately added to food?
- What chemicals are used at home and in medicines?
- What chemicals are used in perfumes and cosmetics?
- How do we use marine resources and ensure good water quality?

**Module P1: The Earth in the Universe**

- What do we know about the Earth and Space?
- How have the Earth's continents moved, and with what consequences?
- What is known about stars and galaxies?
- How do scientists develop explanations of the Earth and Space?

**Module P2: Radiation and life**

- What types of electromagnetic radiation are there? What happens when radiation hits an object?
- Which types of electromagnetic radiation harm living tissue and why?
- Why are some materials radioactive?
- How can ionising radiation be used and handled safely?
- What ideas do citizens and scientists have about risk?

**Module P3: Energy and sustainability**

- How can electricity be generated?
- How does electromagnetic radiation make life on Earth possible?
- What is the evidence for global warming, why might it be occurring, how serious a threat is it and are there implications for the local area?
- What risks are posed by global warming?

## Layout of module content

The content is displayed as nine modules B1, B2, B3, C1, C2, C3, P1, P2 and P3. Each module has an overview page summarising the content and providing a context, as shown below.

<b>Issues for citizens</b>	<b>Questions that science might help to answer</b>
e.g. Is it safe to use mobile phones?	e.g. Which types of radiation harm living tissues and why?
<b>Science Explanations</b>	<b>Ideas about Science</b>
e.g. SE 12 Radiation	e.g. IaS 2.5–2.7 Correlation and cause

The overview identifies:

- issues which are likely to be uppermost in the minds of citizens when considering the module topic, whatever their understanding of science
- questions about the topic that science may be able to address, which could reasonably be asked of a scientifically literate person
- those *Science Explanations* and *Ideas about Science* which are introduced or further developed in the module.

Some symbols and fonts are provided to give teachers additional information, expressed in abbreviated form, about the way in which the content is linked to other parts of the specification, and the table below summarises this information.

Abbreviation/ Font	Explanation and guidance
①	Advisory notes for teachers to clarify depth of cover required.
<b>Bold</b>	More difficult material <b>to stretch students targeting A*–C grades.</b>

## Command words used in the syllabus content

recall = be able to remember and use, from the learning that occurred during this course.

understand = be able to comprehend well enough to be able to explain how or why, from the learning that occurred during this course.

## Module B1: You and your genes – overview

The inheritance of detailed information from each generation to the next is a fundamental story in science. For each of us, inheritance also raises questions about our own development. In this module candidates learn basic concepts of inheritance: genes as units of inheritance, the interplay between genes and environment, sexual reproduction as a source of variation.

These concepts are sufficiently detailed for candidates to make sense of related ideas in other Cambridge O Level Science for All modules.

Throughout the module, candidates are introduced to genetic technologies that open up new possibilities for individuals and society. In doing so, they present significant ethical issues for citizens. Candidates explore some of the ideas people use to make ethical decisions. This enables them to engage with issues which regularly appear in the media, such as genetic testing, gene therapy and cloning research.

Issues covered in this module may be very sensitive for candidates.

Issues for citizens	Questions that science may help to answer
How do my genes affect my appearance, my body, and my health?	What are genes and how do they affect the way that living organisms develop? Why can people look like their parents, brothers or sisters, but not be identical to them?
How and why do people find out about their genes? What decisions do people make with this information?	How can and should genetic information be used?
Can we change our genes, and should this be allowed?	How can we use our knowledge of genes to prevent disease?
What is cloning, and should it be allowed?	What are stem cells and why could they be useful in treating some diseases?
Science Explanations	Ideas about Science
SE 8 The gene theory of inheritance SE 6 Cells as the basic units of living things	laS 6.4–6.7 Making decisions about science and technology

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science. For example, the use of the internet to disseminate scientific findings about public health issues.

#### Use of ICT in teaching and learning can include:

- an animated journey through a cell to illustrate the relationship between the nucleus, chromosomes, genes and DNA and a simple explanation of protein synthesis
- an interactive animation of genetic crosses
- video clips of relevant media reports.



**B1.1 What are genes and how do they affect the way that organisms develop?**

1. State that instructions for how an organism develops are found in the nucleus of its cells.
2. Explain that genes are instructions for a cell that describe how to make proteins, **which may be structural or enzymes.**
3. Describe genes as sections of very long DNA molecules that make up chromosomes in the nuclei of cells.

**B1.2 Why can people look like their parents, brothers and sisters, but not be identical to them?**

1. State that sex cells have a copy of only one chromosome from each pair.
2. Explain that the occurrence of chromosomes (and hence genes) in pairs relates to their origin from each parent's sex cells.
3. State that chromosomes in a pair carry the same genes in the same places, but that there are different forms of genes called alleles.
4. Explain that a person may have two alleles the same, or two different alleles, for any gene.
5. Interpret (through family trees or genetic diagrams) the inheritance of normal single gene characteristics with a dominant and recessive allele.
6. Explain that offspring may have some similarity to their parents because of the combination of maternal and paternal alleles in the fertilised egg.
7. Explain why different offspring from the same parents can differ from each other.
8. State that human males have sex chromosomes XY and females have sex chromosomes XX.
- 9. State that the sex of a human embryo is determined by a gene on the Y chromosome.**
- 10. Explain the link between this gene and the development of sex organs into either ovaries or testes.**

### B1.3 How can and should genetic information be used? How can we use our knowledge of genes to prevent disease?

1. State that most characteristics are determined by several genes working together, for example, height.
2. Explain that most characteristics are also affected by environmental factors, for example, lifestyle factors contributing to disease or malnutrition.
3. State that a small number of disorders are caused by alleles of a single gene, e.g. sickle cell anaemia.
4. State the symptoms of sickle cell anaemia.
5. Explain why a person with one recessive allele will not show the associated characteristic, but is a carrier and can pass the allele to their children.
6. Interpret (through family trees or genetic diagrams) the inheritance of a single gene disorder, e.g. sickle cell anaemia, including the risk of a child being a carrier.
7. Explain the implications of testing adults and fetuses for alleles which cause genetic disease, for example:
  - whether or not to have children at all
  - whether or not a pregnancy should be terminated.
8. Explain the implications of testing embryos for embryo selection (**pre-implantation genetic diagnosis**).
9. **Explain the implications of the use of genetic testing by others, (for example for genetic screening programmes, by government agencies, employers and insurance companies).**
10. Explain that gene therapy may make it possible to treat certain genetic diseases.
11. In the context of genetic testing (when provided with additional information about the reliability and risks of genetic tests) or gene therapy be able to:
  - distinguish questions which could be addressed using a scientific approach, from questions which could not
  - say clearly what the issue is
  - summarise different views that may be held
  - identify and develop arguments based on the idea that
    - the right decision is the one which leads to the best outcome for the majority of people involved
    - certain actions are never justified because they are unnatural or wrong.
12. **In the context of use of genetic testing by others**
  - **distinguish what can be done (technical feasibility), from what should be done (values)**
  - **explain why different courses of action may be taken in different social and environmental contexts.**

**B1.4 What are stem cells and why could they be useful in treating some diseases?**

1. State that bacteria, plants and some animals can reproduce asexually to form clones (with identical genes to their parent).
2. Explain that any differences between clones are likely to be due only to environmental factors.
3. Describe how clones of animals occur:
  - naturally, when cells of an embryo separate (identical twins)
  - **artificially, when the nucleus from an adult body cell is transferred to an empty, unfertilised egg cell.**
4. State that embryonic stem cells are unspecialised cells that can develop into any type of cell.
5. Describe the potential use of stem cells to treat some illnesses.
6. State that the cells of multicellular organisms become specialised during the early development of the organism.
7. In the context of cloning embryos to produce large numbers of stem cells to treat illnesses:
  - say clearly what the issue is
  - summarise different views that may be held
  - identify and develop arguments based on the ideas that
    - the right decision is the one which leads to the best outcome for the majority of people involved
    - certain actions are never justified because they are unnatural or wrong.

## Module C1: Air quality – overview

The quality of air is becoming a major world concern. In this module, candidates explore environmental and health consequences of certain air pollutants, and options for improving air quality in the future. The emphasis is on health issues arising from burning fuels, rather than global issues such as climate change, which is covered in P2, Radiation and life.

Candidates learn about the chemical relationship between the burning of fossil fuels and the production of air pollutants. This module introduces molecular elements and compounds to illustrate chemical explanations.

By analysing their own and given data on concentrations of pollutants, candidates learn about the way in which scientists use data, and also that all data has certain limitations.

Issues for citizens	Questions that science may help to answer
How do I make sense of data about air pollution?	Which chemicals make up air, and which ones are pollutants?
Where do pollutants come from?	What chemical reactions produce air pollutants?
Is air pollution harmful to me or my environment?	What happens to pollutants in the atmosphere?
How can we improve air quality?	What choices can we make personally, locally, nationally or globally to improve air quality?
Science Explanations	Ideas about Science
SE 1 Chemicals SE 2 Chemical change	laS 1 Data and their limitations laS 2.1, 2.3–2.5 Correlation and cause laS 4.2 The scientific community laS 6.3 Making decisions about science and technology

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- collecting, storing and displaying data from a large network of measuring instruments
- displaying data in a variety of charts, graphs and maps for analysis and evaluation.

### Use of ICT in teaching and learning can include:

- the internet to research local air quality data
- animation to illustrate chemical change during reactions
- simulation to model effects of local government policy decisions on air quality.

### C1.1 Which chemicals make up air, and which ones are pollutants? How do I make sense of data about air pollution?

1. Recall that the Earth is surrounded by an atmosphere made up mainly of nitrogen, oxygen and argon, plus small amounts of water vapour, carbon dioxide, and other gases.
2. Recall that the relative proportions of gases in the atmosphere are about 78% nitrogen, 21% oxygen and 1% argon.
3. State that human activity adds small amounts of carbon monoxide, nitrogen oxides and sulfur dioxide to the atmosphere and relate to local conditions.
4. State that human activity also adds extra carbon dioxide and small particles of solids (e.g. carbon) to the atmosphere and relate to local conditions.
5. Describe how some of these substances, called pollutants, are directly harmful to humans and some are harmful to the environment and so cause harm to humans indirectly. The effects of air pollution on a local ecosystem can be studied.
6. When using their own and given data relating to measured concentrations of atmospheric pollutants or the composition of the atmosphere, ideally based on local issues, be able to:
  - use data rather than opinion in justifying an explanation
  - suggest reasons why a measurement may be inaccurate
  - suggest reasons why several measurements of the same quantity may give different results
  - when asked to evaluate data, make reference to their reliability (i.e. is it repeatable?)
  - calculate the mean of a set of repeated measurements
  - from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value
  - explain why repeating measurements leads to a better estimate of the quantity
  - make a sensible suggestion about the range within which the true value of a measured quantity probably lies
  - **justify the claim that there is/is not a 'real difference' between two measurements of the same quantity**
  - identify any outliers in a set of data, and give reasons for including or discarding them.

**C1.2 What chemical reactions produce air pollutants? What happens to pollutants in the atmosphere?**

1. State that coal is mainly carbon.
2. State that petrol, diesel fuel and fuel oil are mainly compounds of hydrogen and carbon.
3. State that, when fuels burn, atoms of carbon and/or hydrogen from the fuel combine with atoms of oxygen from the air to produce carbon dioxide and/or water (hydrogen oxide).
4. State that atoms are rearranged during a chemical reaction.
5. Interpret representations of the rearrangement of atoms during a chemical reaction.
6. Explain how during the course of a chemical reaction the numbers of atoms of each element must be the same in the products as in the reactants.
7. Describe and explain how the conservation of atoms during combustion reactions has implications for air quality.
8. State that the properties of the reactants and products are different.
9. Explain how sulfur dioxide is produced if the fuel contains any sulfur.
10. Explain how burning fossil fuels, in power stations and for transport, pollutes the atmosphere with: a) carbon dioxide and sulfur dioxide, b) carbon monoxide and particulate carbon (from incomplete burning) and c) nitrogen oxides (from the reaction between atmospheric nitrogen and oxygen at the high temperatures inside engines).
11. Relate the formulas for carbon dioxide  $\text{CO}_2$ , carbon monoxide  $\text{CO}$ , sulfur dioxide  $\text{SO}_2$ , nitrogen monoxide  $\text{NO}$ , nitrogen dioxide  $\text{NO}_2$ , and water  $\text{H}_2\text{O}$ , to visual representations of their molecules.
- 12. Explain how nitrogen monoxide  $\text{NO}$ , is formed during the combustion of fuels in air, and is subsequently oxidised to nitrogen dioxide  $\text{NO}_2$  ( $\text{NO}$  and  $\text{NO}_2$  are jointly referred to as ' $\text{NO}_x$ ').**
13. Describe and explain how atmospheric pollutants cannot just disappear, they have to go somewhere:
  - Particulate carbon is deposited on surfaces, making them dirty.
  - Sulfur dioxide and nitrogen dioxide react with water and oxygen to produce acid rain.
  - Carbon dioxide is used by plants in photosynthesis.
  - Carbon dioxide dissolves in rain water and in sea water.

These to be studied with reference to local air pollutants and their effects on the local environment whenever possible.

- ① *Candidates will be expected to write word and symbol equations for the reactions involved in items 3, 9 and 10.*

### C1.3 Is air pollution harmful to me or my environment?

- When given data relating to the effect of air quality, preferably from a local context, be able to:
  - identify the absence of replication as a reason for questioning a scientific claim
  - explain why scientists regard it as important that a scientific claim can be replicated by other scientists**
  - identify the outcome and the factors that may affect it
  - suggest how an outcome might be affected when a factor is changed
  - give an example from everyday life of a correlation between a factor and an outcome
  - use the ideas of correlation and cause appropriately when discussing historical events or topical issues in science
  - explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and can give an example to illustrate this**
  - suggest factors that might increase the chance of an outcome, but not invariably lead to it
  - explain that individual cases do not provide convincing evidence for or against a correlation.

### C1.4 What choices can we make personally, locally, nationally or globally to improve air quality?

- Explain how atmospheric pollution caused by power stations which burn fossil fuels can be reduced, or an increase in pollution due to development avoided, by:
  - using less electricity
  - removing sulfur from natural gas and fuel oil
  - removing sulfur dioxide and particulates (carbon and ash) from the flue gases emitted by coal-burning power stations.
- State that the only way of producing less carbon dioxide is to burn less fossil fuels.
- Explain how atmospheric pollution caused by exhaust emissions from motor vehicles can be reduced by:
  - burning less fuel by having more efficient engines
  - using unleaded petrol
  - using low sulfur fuels
  - using catalytic converters, which convert nitrogen monoxide to nitrogen and oxygen and carbon monoxide to carbon dioxide
  - adjusting the balance between public and private transport
  - having legal limits to emissions.
- Describe and explain the measures that could be taken by individuals and the government to reduce pollution locally and how future developments can be controlled to reduce their impact on the local environment.

## Module P1: The Earth in the Universe – overview

Scientific discoveries in the Solar System and beyond continue to inspire popular culture and affect our explanation of our place in the Universe. In this module, candidates learn about the life cycle of a star and its implications for the Sun and Earth. They also explore the scale of the Universe and its past, present and future, and consider whether we are alone or if there might be life elsewhere.

Closer to home, candidates consider both long and short term changes in the Earth's crust, and how these changes impact on human life. A theme running through the module is natural disasters: earthquakes, volcanoes and asteroid impact – explaining them, predicting them and coping with or averting them.

Across the whole module, candidates encounter many examples showing relationships between data and explanations. Through these contexts they learn about the way scientists communicate and develop new explanations.

Issues for citizens	Questions that science may help to answer
Is there life elsewhere in the Universe?	What do we know about the Earth and space?
Why do mountains occur in chains, in particular places? Can we predict earthquakes, especially those that are likely to cause most damage?	How have the Earth's continents moved, and with what consequences?
Could the human race be destroyed by an asteroid colliding with the Earth? What will happen to the Earth and the Sun?	What is known about stars and galaxies?
What do we know about the Universe? Where do the elements of life come from?	How do scientists develop explanations of the Earth and space?
Science Explanations	Ideas about Science
SE 14 a, b The Earth SE 15 The Solar System SE 16 The Universe	laS 3 Developing explanations laS 4 The scientific community

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- with computer modelling of galaxies in collision
- processing data on movements of the Earth's lithosphere (to confirm the theory of plate tectonics)
- creating a 3D model of the large-scale structure of the Universe from individual galaxy observations.

### Use of ICT in teaching and learning can include:

- animations to illustrate continental drift and movement at tectonic plates margins
- the internet to research a particular geohazard.



**P1.1 What do we know about the Earth and space?**

1. State that rocks provide evidence for changes in the Earth (erosion and sedimentation, fossils, folding, radioactive dating, craters) using local examples if possible.
2. Describe how continents would be worn down to sea level, if mountains were not being continuously formed.
3. Explain how the rock processes seen today in the region can account for past changes.
4. Explain that the Earth must be older than its oldest rocks **which are about four thousand million years old**.
5. Label on a given diagram of the Earth its crust, mantle and core.
6. State that the solar system was formed over very long periods from clouds of gases and dust in space **about five thousand million years ago**.
7. Distinguish between planets, moons, the Sun, comets, asteroids and be aware of their relative sizes and motions.
8. State that fusion of hydrogen **nuclei** into **nuclei** of larger atoms is the source of the Sun's energy.
9. State that the early Universe consisted mostly of hydrogen and helium, and that all chemical elements larger than helium were made in earlier stars.
10. Discuss the probability and possible consequences of an asteroid colliding with the Earth, including the extinction of the dinosaurs.
11. In relation to the above, or when provided with relevant additional information:
  - identify statements which are data and statements which are (all or part of) an explanation
  - recognise data or observations that are accounted for by (or conflict with) an explanation
  - identify imagination and creativity in the development of explanations
  - justify accepting or rejecting a proposed explanation on the grounds of whether or not it accounts for observations
    - **and/or provides an explanation that links things previously thought to be unrelated**
    - **and/or leads to predictions that are subsequently confirmed.**
12. State that light travels at a high but finite speed of **300 000 km/s**.
13. Explain how the speed of light means distant objects are observed as younger than they are now.
14. State that a light-year is the distance travelled by light in a year.
15. Compare the relative ages of the Earth, the Sun and the Universe.
16. Compare the relative diameters of the Earth, the Sun and the Milky Way.
17. Relate uncertainty in the distance of stars and galaxies to the difficulty of observations.

### P1.2 How have the Earth's continents moved, and with what consequences?

1. State Wegener's theory of continental drift and his evidence for it (geometric fit of continents and their matching fossils, mountain chains, and rocks).
2. Explain how Wegener's theory accounted for mountain building.
3. State reasons for the rejection of Wegener's theory by geologists of his time (movement of continents not detectable, Wegener an outsider to the community of geologists, too big an idea from limited evidence, simpler explanations of the same evidence).
4. Explain how seafloor spreading is a consequence of movement of the solid mantle.
- 5. State that seafloors spread by about 10 cm a year.**
- 6. Explain how seafloor spreading produces a pattern in the magnetism recorded in ocean floors, limited to reversals of the Earth's magnetic field and solidification of molten magma at oceanic ridges.**
7. State that earthquakes, volcanoes and mountain building generally occur at the edges of tectonic plates.
- 8. Explain how the movement of tectonic plates causes earthquakes, volcanoes, mountain building and contributes to the rock cycle.**
9. Describe some actions that public authorities, especially those in the local area if appropriate, can take to reduce damage caused by geohazards.

### P1.3 What is known about stars and galaxies?

1. State that what we know about distant stars and galaxies comes only from the radiation astronomers can detect.
2. Recall that the Earth's atmosphere absorbs radiation from distant stars and galaxies except visible light and radio waves.
3. Explain how distance to stars can be measured using the relative brightness of stars or parallax (qualitative idea only).
4. Recall that light pollution and weather conditions interfere with observations of the night sky from the Earth's surface using visible light, but they do not affect radio waves.
5. State that the Sun is a star in the Milky Way galaxy.
6. State that there are thousands of millions of galaxies, each containing thousands of millions of stars, and that all of these make up the Universe.
7. State that all stars have a life cycle.
8. State that astronomers have detected planets around some nearby stars.
9. Describe how, if even a small proportion of stars have planets, many scientists think that it is likely that life exists elsewhere in the Universe.
10. State that no evidence of alien life (at present or in the past) has so far been detected.
11. State that distant galaxies are moving away from us.
- 12. Relate the distance of galaxies to the speed at which they are moving away (Hubble's law, but not redshift).**
- 13. Explain why the motions of galaxies suggests that space itself is expanding.**
14. State that the Universe began with a 'Big Bang' about 14 thousand million years ago.
15. Explain why the ultimate fate of the Universe is difficult to predict.

#### P1.4 How do scientists develop explanations of the Earth and space?

1. In relation to movements of the Earth's continents (P1.2) or what is known about stars and galaxies (P1.3), or when provided with relevant additional information, be able to:
  - identify statements which are data and statements which are (all or part of) an explanation
  - recognise data and observations that are accounted for by (or conflict with) a given explanation
  - identify imagination and creativity in the development of an explanation
  - describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists
  - recognise that new scientific claims which have not yet been evaluated by the scientific community are less reliable than well established ones.
2. In relation to movements of the Earth's continents (P1.2), or when provided with relevant additional information be able to:
  - justify accepting or rejecting a proposed explanation on the grounds of whether or not it accounts for observations
    - **and/or provides an explanation that links things previously thought to be unrelated**
    - **and/or leads to predictions that are subsequently confirmed**
  - draw valid conclusions about the implications of given data for a given explanation
  - recognise that an observation that agrees with a prediction (derived from an explanation) increases confidence in the explanation **but does not prove it is correct**
  - recognise that an observation that disagrees with a prediction (derived from an explanation) indicates that either the observation or the prediction is wrong **and that this may decrease our confidence in the explanation**
  - identify a scientific question for which there is not yet an agreed answer **and suggest a reason why**
  - identify absence of replication as a reason for questioning a scientific claim
  - suggest plausible reasons why scientists involved in a scientific event or issue disagree(d)
  - **explain why scientists regard it as important that a scientific claim can be replicated by other scientists**
  - **suggest reasons for scientists' reluctance to give up an accepted explanation when new data appear to conflict with it.**

## Module B2: Keeping healthy – overview

Keeping healthy involves maintaining a healthy lifestyle, practicing good hygiene to avoid infection, and using medication when necessary. This module illustrates these principles through prevention of infectious diseases and heart disease.

Candidates learn about the immune system, and how vaccines work. They consider the causes of heart disease, and how individuals can minimise this risk. The module explores how new drugs are developed, including the stages of testing for safety and efficiency. Candidates also learn about the increase of ‘superbugs’, and how correct use of antibiotics can help to reduce their prevalence.

In the contexts of vaccination policy and the study of clinical trials, candidates explore ideas of correlation and cause, and how peer review by the scientific community strengthens the reliability of scientific claims. They also consider particular ethical issues arising in modern medicine, for example the right of individual choice versus social policy, illustrated through vaccination policy.

Issues for citizens	Questions that science may help to answer
Why do I catch some diseases but not others?	How do our bodies resist infection?
Why are we encouraged to have vaccinations?	What are vaccines and how do they work?
Why won't the doctor give me an antibiotic when I catch a cold? What are 'superbugs'?	What are antibiotics, and why can they become less effective?
How do drug companies make sure a new drug is as safe as possible?	How are new drugs developed and tested?
How can my lifestyle affect my health?	What factors increase the risk of heart disease?
Science Explanations	Ideas about Science
SE 7c Maintenance of life SE 10 The germ theory of disease	laS 2.3–2.7 Correlation and cause laS 4.1–4.2 The scientific community laS 5.1–5.5 Risk laS 6.5–6.7 Making decisions about science and technology

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- storing and displaying magnified images from microscopes
- storing and displaying data from studies of factors which may, or may not, cause disease.

### Use of ICT in teaching and learning can include:

- animations to illustrate the immune response
- animations to illustrate development of antibiotic-resistant bacterial populations
- video clips to illustrate smallpox vaccination programmes
- video clips of interviews with patients who have heart disease
- video clips illustrating how epidemiological research is carried out and reported.

### B2.1 How do our bodies resist infection?

1. State that there are natural barriers to reduce the risk of harmful microorganisms entering the body (limited to the skin, chemicals in tears, sweat and stomach acid).
2. Explain how in suitable conditions (such as inside the body) these microorganisms can reproduce rapidly.
3. Explain how symptoms of a disease are caused by damage done to cells by the microorganisms or the poisons (toxins) they produce.
4. State that our bodies have immune systems to defend themselves against the invading microorganisms.
5. Explain how white cells can destroy microorganisms by engulfing and digesting them, or by producing antibodies.
6. State that a different antibody is needed to recognise each different type of microorganism.
7. Explain how, once the body has made the antibody to recognise a particular microorganism, it can make that antibody again very quickly, therefore protecting against that particular microorganism.

### B2.2 What are vaccines and how do they work?

1. Explain how microorganisms may enter the body and cause illness before the immune system can destroy them.
2. Explain how vaccinations provide protection from microorganisms by establishing antibodies before infection.
3. State that a vaccination contains a usually safe form of a disease-causing microorganism.
4. Explain how vaccination can never be completely safe, since individuals have varying degrees of side-effects from a vaccine.
- 5. Explain why, to prevent epidemics of infectious diseases, it is necessary to vaccinate a high percentage of a population.**
6. Describe and explain the conflict between a person's right to decide about vaccination for themselves or their children, and what is of benefit to society as a whole.
7. Explain how new vaccines against influenza have to be developed regularly because the virus changes very quickly.
- 8. Explain that it is difficult to develop an effective vaccine against the HIV virus (which causes AIDS) because the virus damages the immune system and has a high mutation rate.**
9. With respect to vaccination policy be able to:
  - say clearly what the issue is
  - summarise different views that may be held
  - **distinguish what can be done (technical feasibility) from what should be done (values)**
  - **explain why different courses of action may be taken in different social and economic contexts**
  - identify and develop arguments based on the ideas that
    - the right decision is the one which leads to the best outcome for the majority of people involved
    - certain actions are never justified because they are unnatural or wrong.

### B2.3 What are antibiotics, and why can they become less effective? How are new drugs developed and tested?

1. State that we can kill bacteria and fungi, but not viruses, using chemicals called antibiotics.
2. State that over a period of time bacteria and fungi may become resistant to antibiotics.
- 3. Explain how random changes (mutations) in the genes of these microorganisms sometimes lead to varieties which are less affected by the antibiotic.**
4. State that to reduce antibiotic resistance we should only use antibiotics when necessary and always complete the course.
5. State that new drugs are first tested for safety and effectiveness using animals and human cells grown in the laboratory.
6. State that human trials may then be carried out on:
  - healthy volunteers to test for safety
  - people with the illness to test for safety and effectiveness.
- 7. Describe and explain the use of 'blind' or 'double-blind' human trials in the testing of a new medical treatment.**
- 8. Explain why placebos are not commonly used in human trials.**

### B2.4 How can my lifestyle affect my health? What factors increase the risk of heart disease?

1. Explain why heart muscle cells need their own blood supply.
2. Explain how the structures of arteries and veins are related to their functions.
3. State the effects of excessive sugar, salt and fats in the diet.
4. Explain how fatty deposits in the blood vessels supplying the heart muscle can produce a 'heart attack'.
5. Relate lifestyle factors, including poor diet, stress, cigarette smoking and excessive alcohol intake, to the likelihood of contracting heart disease, high blood pressure and strokes.
6. Explain that heart disease is more common in countries such as USA and UK than in non-industrialised countries.
7. State that regular moderate exercise reduces the risk of developing heart disease.
8. Understand that high levels of sugar, common in some processed foods, are quickly absorbed into the blood stream, causing a rapid rise in the blood sugar level.
9. Recall that there are two types of diabetes (type 1 and type 2), and that late-onset diabetes (type 2) is more likely to arise because of poor diet.
10. Understand that obesity is one of the risk factors for type 2 diabetes.
11. Understand that inheritance may be a factor in the likelihood of developing type 2 diabetes.
12. Understand that type 1 diabetes arises when the pancreas stops producing enough of the hormone, insulin, but that type 2 diabetes develops when the body no longer responds to its own insulin or does not make enough insulin.
13. Recall that type 1 diabetes is controlled by insulin injections and that type 2 diabetes can be controlled by diet and exercise.

14. Explain the relationship of a balanced diet (especially energy intake) to age, sex and activity of an individual.
15. State the effects of malnutrition in relation to dietary balance and energy intake.
16. In the context of diet, lifestyle and health be able to:
  - give an example from everyday life of a correlation between a factor and an outcome
  - use the ideas of correlation and cause appropriately
  - **explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and give an example to illustrate this**
  - suggest factors that might increase the chance of an outcome but not invariably lead to it
  - explain that individual cases do not provide convincing evidence for or against a correlation
  - evaluate the design for a study to test whether or not a factor increases the chance of an outcome, by commenting on sample size and how well the samples are matched
  - **use data to develop an argument that a factor does/does not increase the chance of an outcome**
  - **identify the presence (or absence) of a plausible mechanism as significant for the acceptance (or rejection) of a claimed causal link**
  - describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists
  - recognise that new scientific claims which have not yet been evaluated by the scientific community are less reliable than well-established ones
  - identify absence of replication as a reason for questioning a scientific claim
  - **explain why scientists regard it as important that a scientific claim can be replicated by other scientists**
  - suggest benefits of activities that have a known risk
  - offer reasons for people's willingness (or reluctance) to accept the risk of a given activity
  - discuss personal and social choices in terms of a balance of risk and benefit
  - **discuss a given risk, taking account of both the chance of it occurring and the consequences if it did.**

## Module C2: Material choices – overview

Our way of life depends on a wide range of materials produced from natural resources. This module considers how measurements of the properties of materials can inform the choice of material for a particular purpose. By taking their own measurements, candidates explore some of the issues which arise when trying to establish accurate and meaningful data.

Key ideas in this module are illustrated through polymers. Candidates learn how the particles (e.g. molecules) that make up a material fit together and how strongly they hang on to each other, providing an explanation of the properties of materials. This provides an example of a scientific explanation which makes sense of a wide range of observations.

Through conducting a life cycle assessment, candidates learn that in selecting a product for a particular job we should assess not only its 'fitness for purpose' but also the total effects of using the materials that make up the product over its complete life cycle, from its production from raw materials to its disposal.

Issues for citizens	Questions that science may help to answer
How can we pick a suitable material for a particular product or task?	What different properties do different materials have?
	Why is crude oil important as a source of new materials such as plastics and fibres?
	Why does it help to know about the molecular structure of materials such as plastics and fibres?
When buying a product, what else should we consider besides its cost and how well it does its job?	How should we manage the wastes that arise from our use of materials?
Science Explanations	Ideas about Science
SE 3 Materials and their properties	laS 1 Data and their limitations laS 2.2 Correlation and cause laS 6.1–6.4, 6.7 Making decisions about science and technology

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science. For example, logging, storing and displaying of data in a variety of formats for analysis and evaluation.

#### Use of ICT in teaching and learning can include:

- spreadsheets to record and display measurements of the properties of materials
- video clips to illustrate main stages from extraction of oil to the production of synthetic plastic or fibre
- still images and diagrams to create presentations to show how the properties of a material depend on its molecular structure
- simulation to explore the impact of choices made during the life cycle of a product
- the internet to explore case studies of the sustainable use of materials.



## C2.1 What different properties do different materials have?

1. Interpret information about how solid materials can differ with respect to properties such as:
  - melting points
  - strength (in tension or compression)
  - stiffness
  - hardness
  - density.
2. Relate properties to the uses of materials such as ceramics, plastics, rubbers and fibres.
3. Relate the effectiveness and durability of a product to the materials used to make it.
4. Interpret information about the properties of materials such as ceramics, plastics, rubbers and fibres to assess the suitability of these materials for particular purposes.
5. With respect to data from the measurement of properties of materials be able to:
  - use data rather than opinion in justifying an explanation
  - suggest reasons why a measurement may be inaccurate
  - suggest reasons why several measurements of the same quantity may give different results
  - when asked to evaluate data, make reference to their reliability (i.e. is it repeatable?)
  - calculate the mean of a set of repeated measurements
  - from a set of repeated measurements of a quantity, use the mean as the best estimate of the true value
  - explain why repeating measurements leads to a better estimate of the quantity
  - make a sensible suggestion about the range within which the true value of a measured quantity probably lies
  - **justify the claim that there is/is not a 'real difference' between two measurements of the same quantity**
  - identify any outliers in a set of data, and give reasons for including or discarding them
  - identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive feature, or the fact that they are not as a design flaw
  - **explain why it is necessary to control all factors thought likely to affect the outcome other than the one being investigated.**

**C2.2 Why is crude oil important as a source of new materials such as plastics and fibres?**

1. State that the materials we use are chemicals or mixtures of chemicals, and state examples.
2. State that materials can be obtained or made from living things, and give examples such as cotton, paper, silk and wool.
3. State that there are synthetic materials which are alternatives to materials from living things.
4. Interpret representations of rearrangements of atoms during a chemical reaction.
5. Explain how during the course of a chemical reaction the numbers of atoms of each element must be the same in the products as in the reactants.
6. State that crude oil consists mainly of hydrocarbons which are chain molecules of varying lengths made from carbon and hydrogen atoms only.
7. State that only a small percentage of crude oil is used for chemical synthesis.
8. State that the petrochemical industry refines crude oil to produce fuels, lubricants and the raw materials for chemical synthesis.
9. Explain how some small molecules can join together to make very long molecules called polymers and that the process is called polymerisation.
10. Be able to write word, **symbol and diagrammatic representation** equations for simple addition polymerisation reactions such as the formation of poly(ethene) and PVC.
- 11. Be able to draw the structure of a monomer or repeating unit when given a diagram of the structure of a polymer.**
12. Explain how, by using polymerisation, a wide range of materials may be produced.
13. State an example of a material that has replaced an older material because of its superior properties.

**C2.3 Why does it help to know about the molecular structure of materials such as plastics and fibres?**

1. Explain how the properties of solid materials depend on how the particles from which they are made are arranged and held together.
2. Relate the strength of the forces between the particles to the amount of energy needed for them to break out of the solid structure, and to the temperature at which the solid melts.
3. Explain how modifications in polymers produce changes to their properties (see C2.1), to include modifications such as:
  - increased chain length
  - cross-linking
  - the use of plasticisers
  - **increased crystallinity.**

**C2.4 When buying a product, what else should we consider besides its cost and how well it does its job? How should we manage the wastes that arise from our use of materials?**

1. State the key features of a Life Cycle Assessment (LCA) including:
  - the main requirements for energy input
  - the environmental impact and sustainability of making the material from natural resources
  - the environmental impact of making the product from the material
  - the environmental impact of using the product
  - the environmental impact of disposing of the product by incineration, landfill or recycling and relate these to local issues.
2. **Explain how the outcomes of a Life Cycle Assessment (LCA) for a particular material will depend on which product is made from the material.**
3. When given appropriate information relating to a Life Cycle Assessment (LCA), compare and evaluate:
  - the use of different materials for the same job
  - the use of the same material for different jobs.
4. In the context of a Life Cycle Assessment, be able to:
  - distinguish questions which could be addressed using a scientific approach, from questions which could not
  - identify the groups affected and the main benefits and costs of a course of action for each group
  - explain the idea of sustainable development, and apply it to specific situations, particularly those of local relevance
  - show awareness that scientific research and applications are subject to official regulations and laws
  - **distinguish between what can be done (technical feasibility) and what should be done (values)**
  - **explain why different courses of action may be taken in different social and economic contexts.**

## Module P2: Radiation and life – overview

The possible health risks of radiation, both in nature and from technological devices, are becoming of increasing concern. In some cases, mis-explaining the term 'radiation' generates unnecessary alarm. By considering the need to protect the skin from sunlight, candidates are introduced to a general model of radiation travelling from the source to a receiver. They learn about the electromagnetic spectrum and the harmful effects of some radiation. Through an investigation of evidence concerning the possibly harmful effects of low intensity microwave radiation from devices such as mobile phones, candidates learn to evaluate reported health studies and interpret levels of risk.

The terms 'radiation' and 'radioactivity' are often interchangeable in the public mind. Because of its invisibility, radiation is commonly feared; a more objective evaluation of risks and benefits is encouraged through developing an explanation of the many practical uses of radioactive materials.

Through the use of radioactive materials in the health sector candidates learn about the nature of radioactivity, its harmful effect on living cells and how it can be handled safely. In the context of health risks associated with irradiation and/or contamination by radioactive material, they also learn about the interpretation of data on risk.

Issues for citizens	Questions that science may help to answer
What is radiation?	What types of electromagnetic radiation are there? What happens when radiation hits an object?
Is it safe to use mobile phones? Is it safe to sunbathe?	Which types of electromagnetic radiation harm living tissues and why? What ideas do citizens and scientists have about risk?
What does 'radioactive' mean?	Why are some materials radioactive?
If radiation from radioactive materials is dangerous, how can it help to cure cancer?	What are the health risks from radioactive materials? How can ionising radiation be used and handled safely?
Science Explanations	Ideas about Science
SE 12 Radiation SE 13 Radioactivity	laS 2.1, 2.3–2.7 Correlation and cause laS 5 Risk laS 6.1–6.3, 6.7 Making decisions about science and technology

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- computer climate modelling
- displaying data on stratospheric ozone concentrations as a false colour map.

### Use of ICT in teaching and learning can include:

- datalogging to show decay of protactinium
- animation to illustrate atomic structure and decay
- video clips to illustrate key ideas of risk in context of radioactive materials.

### P2.1 What types of electromagnetic radiation are there? What happens when radiation hits an object?

1. State that light is one of a family of radiations, the electromagnetic spectrum.
2. Recall how a beam of electromagnetic radiation delivers energy in 'packets' called photons.
3. List the electromagnetic radiations in order of the energy delivered by each photon – radio waves, microwaves, infra-red, visible light (red to violet), ultra-violet, X-rays, gamma rays.
4. Interpret a situation in which one object affects another some distance away in terms of the general model of electromagnetic radiation:
  - One object (a source) emits radiation.
  - The radiation travels from the source and can be reflected, transmitted or absorbed by materials on its journey.
  - Radiation may be absorbed by another object (a detector) some distance away.
5. Explain that the energy deposited by a beam of electromagnetic radiation depends on both the number of photons arriving and the energy that each photon delivers.
6. State that the intensity of electromagnetic radiation is the energy arriving at a surface each second.
7. Explain how the intensity of a beam of electromagnetic radiation decreases with distance **and be able to explain why**.
8. Explain how ionising radiation is able to break molecules into bits (called ions) **which can then take part in other chemical reactions**.
9. State that ionising radiation includes:
  - ultra-violet radiation
  - X-rays
  - gamma rays.
10. Explain how microwaves heat materials containing particles that the microwaves can vibrate.
11. Relate the heating effect of non-ionising radiation to its intensity **and duration**.
12. State an example of the way in which each of infra-red, microwaves and radio waves are used for transmitting information.

### P2.2 Which types of electromagnetic radiation harm living tissue and why?

1. State that the heating effect of absorbed radiation can damage living cells.
2. State that low intensity microwave radiation, for example from mobile phone hand sets and masts, may be a health risk, but this is disputed.
3. State that ionising radiation can damage living cells.
4. Describe examples of how exposure to different amounts of ionising radiation can affect living cells.
5. Describe how the metal cases and door screens of microwave ovens protect users from the radiation.
6. Describe how physical barriers protect people from ionising radiation, for example, sun-screens and clothing can be used to absorb most of the ultra-violet radiation from the Sun.

### P2.3 Why are some materials radioactive?

1. State that some elements emit ionising radiation all the time and are called radioactive.
2. Explain how radioactive elements are naturally found in the environment, emitting background radiation.
3. State that the behaviour of radioactive materials cannot be changed by chemical or physical processes.
4. State three types of ionising radiation (alpha, beta and gamma) emitted by radioactive materials.
5. Describe the penetration properties of each type of radiation.
6. Explain how, over time, the activity of radioactive sources decreases.
7. Explain the meaning of the term 'half-life'.
8. Recall how radioactive elements have a wide range of half-life values.

### P2.4 How can ionising radiation be used and handled safely?

1. Explain that ionising radiation can damage living cells.
2. Explain how ionising radiation is able to break molecules into bits (called ions) **which can then take part in other chemical reactions.**
3. Explain how when ionising radiation strikes living cells these may be killed or may become cancerous.
4. State how ionising radiation can be used to:
  - treat cancer
  - sterilise surgical instruments
  - sterilise food.
5. State that radiation dose (in sievert) (based on both amount and type of radiation) is a measure of the possible harm done to your body.
6. Interpret given data on risk related to radiation dose.
7. Explain how radioactive materials expose people to risk by irradiation and contamination.
8. Explain how we are irradiated and contaminated all the time and name some sources of this background radiation.
9. Relate ideas about half-life and background radiation to the time taken for a radioactive source to become safe.
10. State categories of people who are regularly exposed to risk of radiation and that their exposure is carefully monitored.

## P2.5 What ideas do citizens and scientists have about risk?

1. When provided with additional information on the health risks due to radiation, and the steps taken to limit these, be able to:
  - use the ideas of correlation and cause appropriately when discussing historical events or topical issues in science
  - identify the outcome and the factors that may affect it
  - give an example from everyday life of a correlation between a factor and an outcome
  - suggest factors that might increase the chance of an outcome, but not invariably lead to it
  - suggest how an outcome might be affected when a factor is changed
  - evaluate the design for a study to test whether or not a factor increases the chance of an outcome, by commenting on sample size and how well the samples are matched
  - explain that individual cases do not provide convincing evidence for or against a correlation
  - **explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and give an example to illustrate this**
  - **use data to develop an argument that a factor does/does not increase the chance of an outcome**
  - **identify the presence (or absence) of a plausible mechanism as significant for the acceptance (or rejection) of a claimed causal link**
2. When provided with necessary additional information about alleged health risks due to radiation be able to:
  - identify examples of risk which arise from new scientific or technological advances
  - suggest ways of reducing specific risks
  - interpret and discuss information on the size of risks, presented in different ways
  - **discuss a given risk, taking account of both the chance of it occurring and the consequences if it did**
  - explain why it is impossible for anything to be completely safe
  - suggest benefits of activities with known risk
  - offer reasons for people's willingness (or reluctance) to accept the risk of a given activity
  - discuss personal and social choices in terms of a balance of risk and benefit
  - **identify, or propose, an argument based on the 'precautionary principle'**
  - **distinguish between actual risk and perceived risk, when discussing personal and social choices**
  - **suggest reasons for given examples of differences between actual and perceived risk**
  - **explain what the ALARA (as low as reasonably achievable) principle means and how it applies to the issue in question**
  - identify the groups affected and the main benefits and costs of a course of action for each group
  - explain the idea of sustainable development, and apply it to specific situations
  - show awareness that scientific research and applications are subject to official regulations and laws
  - **distinguish what can be done (technical feasibility), from what should be done (values)**
  - **explain why different courses of action may be taken in different social and economic contexts.**

## Module B3: Life on Earth – overview

Theories for the origin of life on Earth often feature in the media and popular culture. Candidates consider different explanations for life on Earth, and its subsequent evolution. These contexts illustrate how explanations arise and become accepted, and the role of the scientific community in this process. Natural selection is introduced as the mechanism for evolution.

Evolution of multi-cellular organisms has led to complex body communication systems, both nervous and hormonal. Through the context of human evolution, candidates consider implications of data for given theories.

Living organisms are dependent on their environment and each other for survival. Biodiversity is recognised as an important natural resource, which is increasingly threatened by human activity. Candidates consider causes of extinction, and whether extinctions should be a global concern.

Issues for citizens	Questions that science may help to answer
Where did life on Earth come from?	How did life on Earth begin and evolve?
Is evolution 'just a theory'?	How have scientists developed explanations of evolution?
How do some species survive? Why do some species become extinct, and does it matter?	How did humans evolve? How are our nervous systems organised? What is the importance of biodiversity?
Science Explanations	Ideas about Science
SE 4b, c The interdependence of living things SE 7e Maintenance of life SE 9 The theory of evolution by natural selection	laS 3 Developing explanations laS 4.3–4.4 The scientific community

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- recording and displaying the results of DNA analysis
- monitoring and recording human and animal behaviour.

### Use of ICT in teaching and learning can include:

- video clips to illustrate varied ecosystems
- internet to research endangered plants or animals
- presentations to show how understanding of evolution develops as new evidence is discovered.



### B3.1 How did life on Earth begin and evolve?

1. State that the many different species of living things on Earth (and many species that are now extinct) evolved from very simple living things.
2. State that life on Earth began about 3500 million years ago.
3. Describe how evidence for evolution is provided by fossils and from analysis of similarities and differences in DNA of organisms.
4. State that the first living things developed from molecules that could copy themselves.
5. Explain how these molecules were produced by the conditions on Earth at that time, or may have come from elsewhere.
6. State that evolution happens due to natural selection.
7. Explain the process of natural selection in terms of variation, competition, increased chance of survival and reproduction, and increased number of individuals displaying certain characteristics in later generations.
8. Explain how variation is caused by both environment and genes, but only genetic variation can be passed on.
9. Explain the difference between natural selection and selective breeding.
- 10. Interpret data on changes in a species in terms of natural selection.**
- 11. State that changes can occur in genes (mutations).**
- 12. Explain how mutated genes in sex cells can be passed on to offspring and may occasionally produce new characteristics.**
- 13. Explain how the combined effect of mutations, environmental changes and natural selection can produce new species.**
14. Explain why if the conditions on Earth had, at any stage, been different from what they actually were, evolution by natural selection could have produced different results.

### B3.2 How have scientists developed explanations of evolution?

1. When provided with information about alternative views on the origin of life on Earth, or the evolutionary process, be able to:
  - identify statements which are data, and statements which are (all or part of) an explanation
  - recognise data or observations that are accounted for by (or conflict with) an explanation
  - identify imagination and creativity in the development of an explanation
  - justify accepting or rejecting a proposed explanation on the grounds that it
    - accounts for observations
    - **and/or provides an explanation that links things previously thought to be unrelated**
  - identify a scientific question for which there is not yet an agreed answer **and suggest a reason why**
  - suggest plausible reasons why scientists involved in a scientific event or issue disagree
  - **suggest reasons for scientists' reluctance to give up an accepted explanation when new data appear to conflict with it.**

**B3.3 How did humans evolve? How are our nervous systems organised?**

1. State that the evolution of multi-cellular organisms has led to nervous and hormonal communication systems.
2. State that sensor (receptor) cells detect stimuli, and effector cells produce responses to stimuli.
3. State that nervous systems are made up of nerve cells (neurones) linking receptor cells (e.g. in eyes, ears and skin) to effector cells (in muscles/glands).
4. State that in humans and other vertebrates the nervous system is coordinated by a central nervous system (spinal cord and brain).
5. Explain how nervous systems use electrical impulses for fast, short-lived responses.
6. State that hormones are chemicals which travel in the blood and bring about slower, longer-lasting responses.
7. State two examples, in humans, of each of nervous and hormonal communication.
- 8. State that nervous and hormonal communication systems are involved in maintaining a constant internal environment (homeostasis).**
9. State that the evolution of a larger brain gave some early humans a better chance of survival.
10. Explain human evolution in terms of a common ancestor, divergence of hominid species, extinction of all but one of these species.
11. When provided with additional information about human evolution, be able to:
  - draw valid conclusions about the implications of given data for a given theory, for example
    - recognises that an observation that agrees with a prediction (derived from an explanation) increases confidence in the explanation **but does not prove it is correct**
    - recognises that an observation that disagrees with a prediction (derived from an explanation) indicates that either the observation or the prediction is wrong **and that this may decrease our confidence in the explanation.**

**B3.4 Why do some species become extinct, and does it matter? What is the importance of biodiversity?**

1. Explain why living organisms are dependent on the environment and other species for their survival.
2. Describe and explain competition for resources between different species of animals or plants in the same habitat.
3. Relate changes affecting one species in a food web to the impact on other species that are part of the same food web.
4. Explain how a rapid change in the environment may cause a species to become extinct, for example, if:
  - the environmental conditions change
  - a new species that is a competitor, predator or disease organism of that species is introduced
  - another organism in its food web becomes extinct.
5. Explain how species have become extinct (or are in danger of becoming extinct) and that this is likely to be due to human activity.
6. State two examples of modern extinctions caused by direct human activity, and two caused by indirect human activity.
7. Explain why maintaining biodiversity is an important part of using the environment in a sustainable way.
8. Explain why biodiversity may be important for the future development of food crops and medicines.

## Module C3: Everyday chemicals – overview

Chemicals are used in industry, agriculture, our homes and in the products that we buy. Using these chemicals has both advantages and disadvantages.

Intensive and organic farmers use different methods to maintain soil fertility by recycling chemicals. Farmers also use a range of techniques to combat loss of crop yields by competition from weeds, or attack by pests and diseases.

There may be harmful or toxic chemicals in the food we eat. Some occur naturally. Some are deliberate additives. The added chemicals may be to preserve foods or to improve their colour, texture and flavour. These chemicals need not be harmful in small amounts. Their effects depend on how much we eat. To determine the safe levels of chemicals in food it is necessary to carry out a risk assessment. Regulators ensure that food does not contain any chemicals known to be unsafe.

Water is a vital resource that requires care in its management and use. Water requires treatment before it is fit for human consumption.

Issues for citizens	Questions that science may help to answer
What chemicals are used in industry, medicine, agriculture and our homes?	How can we make sure that the chemicals we use are safe for us and our environment?
Is organic food better for us?	What is the difference between intensive and organic farming?
What are food additives, and why are they used?	Why are chemicals deliberately added to food?
Are food additives safe to eat?	How can we make sure that our food does not contain chemicals that may be harmful to health?
How should we use water resources?	How can water resources be maintained?
Science Explanations	Ideas about Science
SE 5b, c, d The chemical cycles of life SE 7e Maintenance of life	laS 5.1–5.5 Risk laS 6.1–6.3, 6.7 Making decisions about science and technology

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science. For example, disseminating scientific findings to the public in forms which allow individuals to make decisions about the issues related to food safety.

#### Use of ICT in teaching and learning can include:

- the internet to research particular food additives
- modelling software to display small and large biological molecules
- animation to illustrate key stages in the nitrogen cycle.

### C3.1 What chemicals are used in industry and agriculture?

- Describe and explain the main processes of cane sugar production:
  - crushing and extraction of juice
  - clarification with slaked lime
  - evaporation to form a syrup
  - crystallisation
  - separation and drying of the crystals
  - refining to produce white sugar.
- Describe uses of the by-product molasses.
- Describe the impact on the environment of the sugar cane industry and explain how this impact may be reduced.
- Describe and explain how sustainability of growing and processing sugar cane can be increased by management of by-products of sugar production.
- Describe the main stages of the nitrogen cycle.**
- Explain that where crops are harvested, elements such as nitrogen, **potassium and phosphorus** are lost from the soil so that the land becomes less fertile unless these elements are replaced.
- State and explain how the availability and affordability of synthetic fertilisers has an effect on the farming methods used in different countries.
- State and explain the effects of 'slash and burn' methods of agriculture on soil fertility and local climate.
- Describe and explain different methods that can be used to protect crops against pests and diseases and reduce competition from weeds, and how some of these methods affect the environment.
- State and explain how the effect of pests and diseases and competition from weeds on crop yield and quality may depend on the availability and affordability of chemical treatments in different countries.
- Describe and explain how a conflict may occur between different ways to use land, e.g. for agriculture or industry.
- When provided with information about the methods used in industry and agriculture, be able to:
  - identify the groups affected and the main benefits and costs of a course of action for each group
  - explain the idea of sustainable development, and apply it to specific situations
  - show awareness that scientific research and applications are subject to official regulations and laws
  - distinguish between what can be done (technical feasibility) from what should be done (values)**
  - explain why different courses of action may be taken in different social and economic contexts.**

### C3.2 What chemicals are deliberately added to food?

1. State that food colours can be used to make processed food look more attractive.
2. State that flavourings enhance the taste of food.
3. Explain that artificial sweeteners help to reduce the amount of sugar in processed foods and drinks.
4. State that emulsifiers and stabilisers help to mix ingredients together that would normally separate, such as oil and water.  
① *Explaining how emulsifiers and stabilisers function is not required.*
5. Explain that preservatives help to keep food safe for longer by preventing the growth of harmful microbes.
6. Explain that antioxidants are added to foods containing fats or oils to prevent them deteriorating by reaction with oxygen in the air.
7. Explain that there are health concerns about the use of some additives.
8. Explain why food in some countries is consumed locally and is stored for only a short time before it is eaten, but in other countries may be transported over long distances and stored for a long time before being eaten.
9. Explain that chemicals used in farming such as pesticides and herbicides may remain in the products we eat.
10. Explain the steps that people can take to reduce their exposure to harmful chemicals.
11. Explain how food labelling can help consumers decide which products to buy.
12. Explain the role of local agencies in safeguarding public health and consumer interests in relation to food.
13. Explain the role of scientific advisory committees which carry out risk assessments to determine the safe levels of chemicals in food.
14. In the context of stages in the 'food chain' be able to:
  - show awareness that scientific research and applications are subject to official actions and laws
  - explain why it is impossible for anything to be completely safe
  - identify examples of risk which arise from new scientific or technological advances
  - suggest ways of reducing specific risks
  - interpret and discuss information on the size of risks, presented in different ways
  - **identify, or propose, an argument based on the precautionary principle.**

**C3.3 What chemicals are used at home and in medicines?**

1. State that the active ingredient in baking powder is sodium hydrogen carbonate.
2. Describe how sodium hydrogen carbonate decomposes on heating to release carbon dioxide.
3. Explain how sodium hydrogen carbonate can be used as a raising agent for cakes.
4. Describe how soap is made from an oil or fat and an alkali.
5. Describe how a soap molecule has a hydrophobic end and a hydrophilic end.
6. Explain how soap molecules remove greasy dirt and keep it in suspension.
7. Describe the differences between soaps and synthetic detergents.
8. Explain the advantages and disadvantages of using soaps and synthetic detergents.
9. Describe how Universal Indicator can be used to test acids and alkalis.
10. State that sulfuric acid is used in car batteries, and that vinegar contains ethanoic acid.
11. State that sodium hydroxide is used in oven cleaners and magnesium hydroxide in indigestion remedies.
12. Describe the differences between strong and weak acids and relate these to the way they are used.
13. Define a drug as an externally administered substance which modifies or affects chemical reactions in the body.
14. Define an analgesic as a drug used to reduce pain.
15. State the names of common analgesics: aspirin, paracetamol, ibuprofen.
16. Explain the advantages and disadvantages of using aspirin, paracetamol and ibuprofen.
17. Discuss issues relating to the testing of new drugs.

**C3.4 What chemicals are used in perfumes and cosmetics?**

1. State that a perfume is a solution of esters in a volatile solvent.
2. Explain how perfumes applied to the skin dry quickly but release scent over a period of time.
3. Define a cosmetic as a substance used to enhance or protect the appearance of the human body.
4. Describe lipstick as a mixture of a pigment with castor oil in a wax base.
5. Explain the purpose of each component in lipstick.
6. Describe an antiperspirant as a mixture of perfume and aluminium salts with a volatile solvent.
7. Explain the action of aluminium salts in blocking sweat pores.
8. Describe nail polish as a solution of nitrocellulose, resins and pigments in the solvent ethyl ethanoate.
9. Explain the function of each ingredient in nail polish.
10. Explain how pearlescence in nail polish can be produced by including mica in the formulation.

### C3.5 How do we use marine resources and ensure good water quality?

1. Describe how salt is obtained from sea water on an industrial scale by evaporation of water from shallow pans.
2. Describe how sand is obtained from shallow lagoons and from quarried or surface rocks on land.
3. Explain the advantage and disadvantages of obtaining sand from lagoons and from land based sources.
4. Explain the need to control the mining of sand since it is a slowly renewable resource.
5. Describe sources of fresh water, e.g. aquifers, bore-holes, reservoirs, lakes, rivers, desalinated sea water, and explain the need to conserve water.
6. Explain why water from different sources may need different treatment before domestic use.
7. Describe and explain the main stages in the purification of domestic water supplies:
  - addition of chlorine to kill bacteria
  - addition of aluminium sulfate to coagulate colloidal clay
  - sedimentation and filtration
  - use of carbon slurry to remove tastes and odours
  - use of lime slurry to adjust acidity
  - addition of sulfur dioxide to remove excess chlorine.
8. Explain the need for monitoring, including regular sampling and testing, of fresh water sources.
9. Describe sources of water pollution and their consequences.
10. Understand how waste water from domestic, industrial and tourism sources has an effect on the environment.
11. Understand how waste water is treated to reduce pollution.
12. Explain the relevance of water quality to the future of coral reefs and the maintenance of fish stocks for the continuation of the fishing industry.
13. Describe and explain the need for monitoring of the quality of sea water.
14. Describe the effects of pollution, tourism and fishing methods on the health of coral reefs.
15. Describe and explain measures taken by local government to protect marine ecosystems and preserve fish stocks.
16. In the context of our use of marine resources and the chemicals used in our homes, in medicines, perfumes and cosmetics and for water purification, be able to:
  - suggest benefits of activities that have a known risk
  - offer reasons for people's willingness (or reluctance) to accept the risk of a given activity
  - discuss personal and social choices in terms of a balance of risk and benefit
  - **discuss a given risk, taking account of both the chance of it occurring and the consequences if it did.**



## Module P3: Energy and sustainability – overview

Candidates consider different ways that electricity could be generated, with particular reference to their sustainability. These case studies illustrate that public decisions must be made by weighing up benefits against costs. Factors to consider include both technical feasibility and likely social and environmental impact, now and in the future.

The greenhouse effect and photosynthesis illustrate how radiation from the Sun is vital to life, whilst the ozone layer is shown to be natural protection from harmful radiation. Finally, candidates study evidence of global warming and its relationship to the carbon cycle. Candidates relate global warming to the effects of climate change on the local area. Possible consequences and preventative actions are explored.

Issues for citizens	Questions that science may help to answer
What energy sources do we need?	How can electricity be generated?
Are there any benefits from radiation?	How does electromagnetic radiation make life on Earth possible?
What is global warming, and what can be done to prevent or reduce it?	What is the evidence for global warming, why might it be occurring, how serious a threat is it and are there implications for the local area? What risks are posed by global warming?
Science Explanations	Ideas about Science
SE 5a The chemical cycles of life SE 11a, b, e Energy sources and uses SE 14c The Earth	laS 2.1, 2.3–2.7 Correlation and cause laS 5 Risk laS 6.1–6.3, 6.7 Making decisions about science and technology

### ICT Opportunities

This module offers opportunities for illustrating the use of ICT in science, for example:

- computer tomography used with gamma imaging
- computer climate modelling.

### Use of ICT in teaching and learning can include:

- PowerPoint slides to illustrate evidence of climate change
- video clips to illustrate infrared imaging
- animation to model the Sun's radiation and the greenhouse effect
- animation to model the effect of carbon dioxide levels on global temperature
- computer climate models.

### P3.1 How can electricity be generated?

1. Explain why electricity is called a secondary energy source.
2. Explain how electricity is convenient because it is easily transmitted over distances and can be used in many ways.
3. Label a block diagram showing the basic steps by which electricity is generated.
4. Interpret a simple Sankey diagram of electricity generation and distribution to calculate the efficiency of energy transfers.
5. Describe two examples to show that we can use renewable energy sources instead of fuels to generate electricity.
6. State that power stations which burn carbon fuels will produce carbon dioxide.
7. **Explain that burning carbon fuels can be carbon neutral (have a zero carbon footprint) if the same amount of carbon dioxide as that produced by the burning is removed from the atmosphere by some means, e.g. planting trees or sugar cane.**
8. Compare different ways to generate electricity in terms of cost, sustainability and suitability for specific locations.
9. Describe measures that can be used to reduce the use of electricity, e.g. use of solar water heating.

### P3.2 How does electromagnetic radiation make life on Earth possible?

1. State that the Earth is surrounded by an atmosphere which allows light radiated from the Sun to pass through.
2. State that this radiation:
  - provides the energy for photosynthesis
  - warms the Earth's surface.
3. State that photosynthesis removes carbon dioxide from the atmosphere and adds oxygen, and that this reverses the effect of respiration.
4. Explain how the Earth emits electromagnetic radiation that is absorbed by some gases in the atmosphere, so keeping the Earth warmer than it would otherwise be. This is called the greenhouse effect.
5. Explain how the ozone layer absorbs ultra-violet radiation, **producing reversible chemical changes in that part of the atmosphere.**
6. Explain how the ozone layer protects living organisms, especially animals, from the harmful effects of ultra-violet radiation.

**P3.3 What is the evidence for global warming, why might it be occurring, how serious a threat is it and are there implications for the local area?**

1. State that one of the greenhouse gases in the Earth's atmosphere is carbon dioxide, present in small amounts.
- 2. State that other greenhouse gases include methane, present in trace amounts, and water vapour.**
3. Interpret simple diagrams representing the carbon cycle.
4. Use the carbon cycle to explain:
  - why for thousands of years the amount of carbon dioxide in the Earth's atmosphere was approximately constant
  - how decomposers play an important part in the recycling of carbon
  - that during the past two hundred years, the amount of carbon dioxide in the atmosphere has been steadily rising
  - that the rise in atmospheric carbon dioxide is largely the result of
    - burning increased amounts of fossil fuels as an energy source
    - burning forests to clear land.
- 5. Explain how computer climate models provide evidence that human activities are causing global warming.**
6. Explain how global warming could result in:
  - climate change and how this could make it impossible to continue growing some food crops in particular regions
  - extreme weather conditions in some regions
  - rising sea levels due to melting continental ice and expansion of water in the oceans, which would cause flooding of low-lying land.

### P3.4 What risks are posed by global warming?

1. When provided with additional information on the risks due to global warming, and the steps taken to limit these, be able to:
  - use the ideas of correlation and cause appropriately when discussing historical events or topical issues in science
  - identify the outcome and the factors that may affect it
  - give an example from everyday life of a correlation between a factor and an outcome
  - suggest factors that might increase the chance of an outcome, but not invariably lead to it
  - suggest how an outcome might be affected when a factor is changed
  - evaluate the design for a study to test whether or not a factor increases the chance of an outcome, by commenting on sample size and how well the samples are matched
  - explain that individual cases do not provide convincing evidence for or against a correlation
  - **explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and give an example to illustrate this**
  - **use data to develop an argument that a factor does/does not increase the chance of an outcome**
  - **identify the presence (or absence) of a plausible mechanism as significant for the acceptance (or rejection) of a claimed causal link**
2. When provided with necessary additional information about alleged risks that may arise from global warming, be able to:
  - identify examples of risks which arise from new scientific or technological advances
  - suggest ways of reducing specific risks
  - interpret and discuss information on the size of risks, presented in different ways
  - **discuss a given risk, taking account of both the chance of it occurring and the consequences if it did**
  - explain why it is impossible for anything to be completely safe
  - suggest benefits of activities with known risk
  - offer reasons for people's willingness (or reluctance) to accept the risk of a given activity
  - discuss personal and social choices in terms of a balance of risk and benefit
  - **identify, or propose, an argument based on the 'precautionary principle'**
  - **distinguish between actual risk and perceived risk, when discussing personal and social choices**
  - **suggest reasons for given examples of differences between actual and perceived risk**
  - **explain what the ALARA (as low as reasonably achievable) principle means and how it applies to the issue in question**
  - identify the groups affected and the main benefits and costs of a course of action for each group
  - explain the idea of sustainable development, and apply it to specific situations.
  - show awareness that scientific research and applications are subject to official regulations and laws
  - **distinguish what can be done (technical feasibility), from what should be done (values)**
  - **explain why different courses of action may be taken in different social and economic contexts.**

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## 6. Assessment of Papers 3 and 4

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### 6.1 Paper 3: Comprehension and Practical Procedures (20%)

#### Section A: Comprehension (30 marks)

There will be several short and structured questions relating to a number of passages which may be adapted from scientific journals or books and which will relate to the content of the syllabus.

Questions may ask candidates to explain the meaning of terms used in the passage, analyse data in the passage, develop arguments for or against the views expressed in the passage and draw conclusions from what they have read.

#### Section B: Practical procedures, data handling and analysis (30 marks)

This section will have **three** structured questions. The questions will cover aspects of biology, chemistry and physics and will relate to the syllabus. Questions may ask candidates to:

- describe in simple terms how they would carry out practical procedures
- explain and/or comment critically on described procedures or points of practical detail
- take readings from printed diagrams including:
  - reading a scale with appropriate precision/accuracy, with consistent use of significant figures and with appropriate units
  - interpolating between scale divisions
  - taking repeat measurements to obtain an average value.
- process data as required and complete tables of data
- present data graphically, using suitable axes and scales (appropriately labelled) and plot the points accurately
- take readings from a graph by interpolation and extrapolation
- determine a gradient, intercept or intersection on a graph
- draw and report a conclusion or result clearly
- identify and/or select, with reasons, items of apparatus to be used for carrying out practical procedures
- explain, suggest and/or comment critically on precautions taken and/or possible improvements to techniques and procedures.

## 6.2 Paper 4: Case Study (20%)

The candidate presents one Case Study, a report based on detailed study of a chosen topic.

This assignment should arise naturally from work on the course. It should be a local issue or a larger scale issue that affects local people. It should be related to an aspect of science that involves an element of controversy, in terms either of the interpretation of evidence, or of the acceptability of some new development and may involve the collection of first-hand data. Topics for study should be selected by candidates in discussion with teachers, and should be seen as an extension or consolidation of studies undertaken as a normal part of the course. The work should be capable of being completed within approximately 6–8 hours over a period of time, for example, one lesson per week for half a term, with some non-contact time.

### Choosing a topic

In everyday life, citizens most often become aware of science-related issues through reports in the media: newspapers, teenage magazines, television, etc. This component of the assessment is designed to help candidates develop strategies for evaluating such information, and to increase awareness of appropriate ways of making decisions about such issues.

Ideally, the study should arise from such a media source. Suitable topics involve some degree of controversy, or disagreement, either about the interpretation of the scientific evidence, or about how individuals or society should respond. The title for a Case Study is best phrased as a question to be answered by careful balancing of evidence and opinions from a variety of sources.

Suitable topics often fall into one of three main types.

- Evaluating claims where there is uncertainty in scientific knowledge (e.g. “Is global warming entirely due to human activities?” or “Does using mobile phones lead to a risk of brain damage?”). Controversies of this type focus attention on the relationship between data and explanations in science, and on the quality of research which underlies competing claims.
- Contributing to decision making on a science-related issue (e.g. “Should a shopping street be pedestrianised to reduce air pollution?” or “Is nuclear power the way forward for our country?”). Studies in this category are more likely to involve elements of personal choice, values and beliefs, and may involve balancing of risks and benefits of any proposed action.
- Personal or social choices (e.g. “Should my child receive the triple MMR vaccine?” or “Does the school have a waste problem? If so what can be done to reduce the problem?”). Ethical and personal issues are likely to figure in such studies, but it is important to evaluate these in relation to what is known about the science which underlies the issue.

In all cases, an important factor in the choice of subject should be the availability of information giving a variety of views in forms that can be accessed by the candidate. Candidates may be provided with the initial stimulus for the study, but should be encouraged to search for a range of opinions in order to reach a balanced conclusion.

The subject need not be restricted to topics studied in the course. However, it is necessary for the candidate to apply relevant scientific knowledge and understanding to discussion of the issues raised. This is most likely to be the case if the study arises naturally during normal work on the course.

Candidates need not all study the same, or related, topics. Motivation is greatest if they are given some degree of autonomy in the choice of topic. This may be achieved by allowing choice of different issues related to a general topic (e.g. different aspects of air pollution when studying Air Quality) or by encouraging candidates to identify topics of interest and begin collecting resource materials over an extended period. At a time chosen by the Centre, candidates then complete their Case Study, and may each be working on a different topic.

## Presentation of the Case Study

The Case Study will often take the form of a 'formal' written report. However, candidates should not be discouraged from other styles of presentation, for example:

- a newspaper or magazine article
- a PowerPoint presentation
- a poster or booklet
- a teaching/learning activity such as a game
- a script for a radio programme or a play.

In all cases, sufficient detail must be included to allow evaluation in all of the performance areas. Some types of presentation would require supporting notes.

A Case Study represents a major piece of work and it is not expected that candidates will attempt more than one during the course. If a candidate has attempted more than one Case Study, then the total for the assessment should be the highest total for any one Case Study.

It is not permitted to aggregate marks from two or more different pieces of work, nor to add marks obtained from separate, limited range tasks, exercises or part-studies.

## Marking Criteria – Case Study

Marks are awarded under four headings, A, B, C and D.

Because of the risk of some studies becoming excessively long, it is important to link marks to the quality of the work done, rather than the quantity.

The four strands to be awarded credit are:

<p><b>A: Quality of selection and use of information, on a scale of 0–4 marks</b></p> <p>Here candidates should show an awareness of sources of information such as their own notes, text books, encyclopaedias, or the internet. They should consider the reliability of any sources used. All sources should be credited, and it should be clear where each piece of information has come from. Credit is given for being selective in choosing only relevant material. Direct quotations should be acknowledged.</p>
<p><b>B: Quality of understanding of the case, on a scale of 0–8 marks</b></p> <p>Candidates should describe the basic science which helps understanding of the topic, and apply it to evaluate the reliability of claims made. In many cases, they may follow a topic beyond the normal limits of the specification; credit should be awarded for understanding, whether within or beyond the specification.</p>
<p><b>C: Quality of conclusions, on a scale of 0–8 marks</b></p> <p>Different evidence, arguments or views should be compared and evaluated and used as a basis for a balanced conclusion or proposal for action.</p>
<p><b>D: Quality of presentation, on a scale of 0–4 marks</b></p> <p>Communication skills should be rewarded for effective presentation including use of different forms for presenting different types of information (e.g. pictures, tables, charts, graphs, etc.).</p>

## 6.3 Strand A: Quality of selection and use of information

Candidates will select and organise information from a variety of sources, bearing in mind both relevance to the study and the apparent reliability of the sources. It is expected that Centres will make at least a basic selection of resources available for candidates to work from. A survey of the units included in the course will identify topics which are likely to be relevant, topical and of interest to candidates. In addition to standard textbooks and library books, resources are available from industry, from environmental groups and in popular science magazines, as well as through the internet.

Candidates should be encouraged to seek out their own additional resources, but should not be completely dependent on this, and in particular, should not be dependent on home or out of school support.

Credit will be given for selection of appropriate material from the available resources, rather than indiscriminate copying. It will also be given for judgement shown in selecting from a variety of sources to give a balanced view of the topic. Good work is characterised by the ability of the candidate to adapt and re-structure information to suit the purpose of the study.

In some cases, candidates may wish to collect information about the public acceptability of an idea or perception of risk through questionnaires (administered to classmates or other groups) or to test media claims through experimental work. Whilst relevant work of these types may be credited, it should not dominate the study.

In all cases, candidates should record the sources of information they have used. The assignment can be used as an introduction to the value of crediting sources in scientific communication.

Marks are awarded on a scale of 0 to 4 by matching the work to performance descriptors.

Candidates should show awareness of the variety of sources of information relevant to science-based issues, and some understanding that the reliability of sources may vary.

This aspect of the work is linked to understanding of Ideas about Science 4: The Scientific Community.



Aspect of Performance	Strand A Mark			
	1	2	3	4
<b>a Planning the use of sources of information</b>	Very little information is given beyond that provided by the original stimulus material.	Information from a limited range of additional sources is included, although some may be irrelevant or inappropriate to the study.	Relevant information is selected from a variety of sources.	Sources of information are assessed for reliability as a basis for selection of relevant information from a wide variety of sources.
<b>b Acknowledgement of sources used</b>		Sources are identified by incomplete or inadequate references.	References to sources are clear, but limited in detail.	References to these sources are clear and fully detailed.
<b>c Linking information to specific sources</b>		Direct quotations are rarely indicated as such.	Direct quotations are generally acknowledged.	The sources of particular opinions are indicated at appropriate points in the text of the report.

## 6.4 Strand B: Quality of understanding of the case

Where possible, candidates should make reference to explanatory scientific theory to help them understand the significance of the information they are dealing with. However, controversies in science often arise in areas where there is no (Cambridge O Level Science for All level) descriptive theory to provide a basis for understanding and evaluating the issues involved. In such cases, candidates should draw on Ideas about Science, especially IaS 2 (Correlation and cause), to justify the conclusions they reach about the information they have collected.

Note that these studies should not be used to extend or assess the candidate's knowledge of basic academic theory related to the topic, but rather to encourage them to see how the science knowledge they have can be related to topical issues to help them reach valid judgements. Some candidates may wish to go beyond what they have been taught in class and, if they find and correctly apply theory which is directly relevant to the Case Study, this can help to raise their mark. However, credit should not be given to uncritical copying of large amounts of theory from texts.

Candidates should provide some background to the case study in relation to relevant scientific theory. They should also evaluate how well-founded are links between the available evidence and claims or views made on the basis of the evidence. Where little explanatory theory is available at this level, candidates should draw on Ideas about Science 2, 3 and 4 to help them evaluate the evidence they find.

This aspect of the work depends on understanding of:

- Ideas about Science 1: Data and its limitations (mainly 1.2, 1.3 and 1.4);
- Ideas about Science 2: Correlation and cause (mainly 2.1, 2.2, 2.4–2.7).

Aspect of Performance	Strand B Mark			
	2	4	6	8
<b>a Making use of science explanations</b>	Only superficial mentions of science explanations, often not correctly applied to the case.	Provides a basic outline of the main scientific ideas which are relevant to the case.	Provides a detailed review of the scientific knowledge needed to understand the issues studied.	Considers how different views described in the study can be supported by detailed scientific explanations.
<b>b Recognition and evaluation of scientific evidence</b>	Sources are uncritically quoted without distinguishing between scientific evidence and unsupported claims.	Science content and data in sources is recognised.	Claims and opinions are linked to the scientific evidence they are based on.	The quality of scientific evidence in sources is evaluated in relation to the reliability of any claims made.

## 6.5 Strand C: Quality of conclusions

The work should take account of different views or opinions which are represented in the information collected. Credit will be given for discussion of the perceived benefits and associated risks of any proposed actions, and for judgements of the acceptability of any conclusions reached.

The case studied should be such that there is scope for taking views about the acceptability of some opinion or course of action.

Work on this aspect of the Case Study will be linked to understanding of:

- Ideas about Science 1: Data and its limitations (mainly parts 1.2 and 1.4);
- Ideas about Science 5: Risk (mainly parts 5.1, 5.2, 5.4, 5.6 and 5.7);
- Ideas about Science 6: Making decisions about science and technology (mainly parts 6.3, 6.4, 6.5 and 6.6).

Aspect of Performance	Strand C Mark			
	2	4	6	8
<b>a Comparing opposing evidence and views</b>	Information is unselectively reported without taking any clear view about any course of action.	Claims for a particular idea, development or course of action are reported without critical comment.	Claims and arguments for and against are reported, but with little attempt to compare or evaluate them.	Details of opposing views are evaluated and critically compared.
<b>b Conclusions and recommendations</b>	A conclusion is stated without reference to supporting evidence.	A conclusion is based on evidence for one view only.	Some limits or objections to the conclusion are acknowledged.	Alternative conclusions are considered; showing awareness that different interpretations of evidence may be possible.

## 6.6 Strand D: Quality of presentation

Candidates should be encouraged to be creative and imaginative in their choice of method and media for communicating their findings. The report may be in a variety of forms, including formal written reports, newspaper articles, PowerPoint presentations, posters, scripts for a radio programme or play, etc. Whatever form of presentation is chosen, it should be supported by sufficient documentation to allow assessment of all four qualities. It should also be remembered that the work may need to be posted to a moderator towards the end of the course. Where electronic media are included, a paper print-out must be provided for moderation purposes.

Note that quality and fitness for purpose should be rewarded in the assessment, rather than the sheer quantity of the work.

Where written reports are given, candidates should be encouraged to structure the report clearly. An attractive cover helps to improve motivation and make the work “special”; thinking about a good structure for the contents can help candidates to organise their ideas. Use of tables of contents, and sub-headings between sections of text are valuable in this context.

Illustrations should be used where they lead to clearer communication of ideas. These may be taken from resource leaflets or ‘clip-art’ sources, or drawn by candidates; they may be pictorial or graphical. Tables, charts and graphs should be used to present and summarise data. Reports may be hand-written or word-processed.

Candidates should be encouraged to think carefully of their target audience and how to communicate their ideas clearly.

Aspect of Performance	Strand D Mark			
	1	2	3	4
<b>a Structure and organisation of the report</b>	The report has little or no structure or coherence, or follows a pattern provided by worksheets.	The report has an appropriate sequence or structure.	Information is organised for effective communication of ideas, with contents listing, page numbering, etc. as appropriate to aid location of key elements.	Considerable care has been taken to match presentation and format to present issues and conclusions clearly and effectively to a chosen audience.
<b>b Use of visual means of communication</b>	There is little or no visual material (charts, graphs, pictures, etc.) to support the text.	Visual material is merely decorative, rather than informative.	Visual material is used to convey information or illustrate concepts.	Pictures, diagrams, charts and/or tables are used appropriately and effectively to convey information or illustrate concepts.
<b>c Spelling, punctuation and grammar</b>	Spelling, punctuation and grammar are of generally poor quality, with little or no use of appropriate technical or scientific vocabulary.	Spelling, punctuation and grammar are of variable quality, with limited use of appropriate technical or scientific vocabulary.	Spelling, punctuation and grammar are generally sound, with adequate use of appropriate technical or scientific vocabulary.	The report is concise, with full and effective use of relevant scientific terminology.  Spelling, punctuation and grammar are almost faultless.

## 6.7 Regulations for internally assessed work

### Supervision and authentication of work

Cambridge expects teachers to supervise and guide candidates who are undertaking work that is internally assessed. The degree of teacher guidance will vary according to the kind of work being undertaken. It should be remembered, however, that candidates are required to reach their own judgements and conclusions.

When supervising internally assessed tasks, teachers are expected to:

- offer candidates advice about how best to approach such tasks
- exercise supervision of work in order to monitor progress and to prevent plagiarism
- ensure that the work is completed in accordance with the specification requirements and can be assessed in accordance with the specified mark descriptors and procedures.

Skills assessment should, wherever possible, be carried out under supervision. However, it is accepted that some tasks may require candidates to undertake work outside the Centre. Where this is the case, the Centre must ensure that sufficient supervised work takes place to allow the teachers concerned to authenticate each candidate's work with confidence.

Candidates will require guidance in their choice of Case Study and some of the work is likely to be carried out individually and independently without direct supervision. Teachers will need to ensure that the work presented for assessment accurately reflects each candidate's individual attainment. It is strongly recommended that a substantial proportion of the final report is written under supervision.

### Production and presentation of internally assessed work

Candidates must observe certain procedures in the production of internally assessed work.

- Any copied material must be suitably acknowledged.
- Where work is based on the use of additional secondary data, the original sources must be clearly identified.
- Each candidate's assessed work submitted for moderation should be stapled together at the top left hand corner and have a completed cover sheet as the first page.

### Annotation of candidates' work

Each piece of assessed work should be annotated to show how the marks have been awarded in relation to the mark descriptions.

The writing of comments on candidates' work provides a means of dialogue and feedback between teacher and candidate and a means of communication between teachers during internal standardisation of marking.

However, the main purpose of annotating candidates' work is to provide a means of communication between teacher and moderator, showing where marks have been awarded and why they have been awarded.

Annotations should be made at appropriate points in the margins of the script of all work submitted for moderation. The annotations should indicate where achievement for a particular skill has been recognised.

It is suggested that the minimum which is necessary is that the 'shorthand' mark descriptions (for example, Ba6) should be written at the point on the script where it is judged that the work has met the mark description.

## Moderation

All internally assessed work is marked by the teacher and internally standardised by the Centre. Marks are then submitted, after which the moderation takes place in accordance with Cambridge procedures. The purpose of moderation is to ensure that the standard of the award of marks is the same for each Centre and that each teacher has applied the standards appropriately across the range of candidates within the Centre.

The internally moderated marks for all candidates must be recorded on the Coursework Assessment Summary Form. This form, and the instructions for completing it, may be downloaded from **[www.cie.org.uk/samples](http://www.cie.org.uk/samples)**. The database will ask you for the syllabus code (i.e. 5031) and your Centre number, after which it will take you to the correct form. Follow the instructions when completing the form. It is the responsibility of the Centre to carry out effective internal standardisation to ensure that similar standards are applied by each teacher involved in the assessment.

## Minimum requirements for internally assessed work

If a candidate submits no work for this internally assessed unit, then the candidate should be indicated as being absent from that unit on the mark sheets submitted to Cambridge. If a candidate completes any work at all for an internally assessed unit, then the work should be assessed according to the criteria and mark descriptions and the appropriate mark awarded, which may be zero.

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## 7. Appendices

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### Appendix A: Grade descriptions

#### Grade C

- Candidates demonstrate a good overall knowledge and understanding of science content, how science works and of the concepts, techniques, and facts across most of the syllabus. They demonstrate knowledge of technical vocabulary and techniques, and use these appropriately. They demonstrate communication and numerical skills appropriate to most situations.
- They demonstrate an awareness of how scientific evidence is collected and are aware that scientific knowledge and theories can be changed by new evidence.
- Candidates use and apply scientific knowledge and understanding in some general situations. They use this knowledge, together with information from other sources, to help plan a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem.
- They describe how, and why, decisions about uses of science are made in some familiar contexts. They demonstrate good understanding of the benefits and risks of scientific advances, and identify ethical issues related to these.
- They carry out practical tasks safely and competently, using equipment appropriately and making relevant observations, appropriate to the task. They use appropriate methods for collecting first-hand and secondary data, interpret the data appropriately, and undertake some evaluation of their methods.
- Candidates present data in ways appropriate to the context. They draw conclusions consistent with the evidence they have collected and evaluate how strongly their evidence supports these conclusions.

#### Grade A

- Candidates demonstrate a detailed knowledge and understanding of science content and how science works, encompassing the principal concepts, techniques, and facts across all areas of the syllabus. They use technical vocabulary and techniques with fluency, clearly demonstrating communication and numerical skills appropriate to a range of situations.
- They demonstrate a good understanding of the relationships between data, evidence and scientific explanations and theories. They are aware of areas of uncertainty in scientific knowledge and explain how scientific theories can be changed by new evidence.
- Candidates use and apply their knowledge and understanding in a range of tasks and situations. They use this knowledge, together with information from other sources, effectively in planning a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem.
- Candidates describe how, and why, decisions about uses of science are made in contexts familiar to them, and apply this knowledge to unfamiliar situations. They demonstrate good understanding of the benefits and risks of scientific advances, and identify ethical issues related to these.
- They choose appropriate methods for collecting first-hand and secondary data, interpret and question data skilfully, and evaluate the methods they use. They carry out a range of practical tasks safely and skilfully, selecting and using equipment appropriately to make relevant and precise observations.
- Candidates select a method of presenting data appropriate to the task. They draw and justify conclusions consistent with the evidence they have collected and suggest improvements to the methods used that would enable them to collect more valid and reliable evidence.



## Appendix B: Mathematical requirements

During the course of study for this syllabus, many opportunities will arise for quantitative work, including appropriate calculations. The mathematical requirements which form part of the syllabus are listed below.

- add, subtract and divide whole numbers
- recognise and use expressions in decimal form
- make approximations and estimates to obtain reasonable answers
- use simple formulae expressed in words
- understand and use averages
- read, interpret, and draw simple inferences from tables and statistical diagrams
- find fractions or percentages of quantities
- construct and interpret pie-charts
- calculate with fractions, decimals, percentage or ratio
- recognise and use expressions in standard form
- solve simple equations
- substitute numbers in simple equations
- manipulate equations
- interpret and use graphs
- plot graphs from data provided, given the axes and scales
- choose by simple inspection and then draw the best smooth curve through a set of points on a graph
- select appropriate axes and scales for graph plotting
- determine the intercept of a linear graph
- understand and use inverse proportion
- calculate the gradient of a graph

## Appendix C: Physical quantities and units

It is expected that candidates will show an understanding of the physical quantities and corresponding SI units listed below and will be able to use them in quantitative work and calculations. Whenever they are required for such questions, units will be provided and, where necessary, explained.

### Fundamental Physical Quantities

<b>Physical quantity</b>	<b>Unit(s)</b>
length	metre (m); kilometre (km); centimetre (cm); millimetre (mm)
mass	kilogram (kg); gram (g); milligram (mg)
time	seconds (s); millisecond (ms) year (a); million years (Ma); billion years (Ga)
temperature	degrees Celsius (°C); Kelvin (K)
current	ampere (A); milliampere (mA)

### Derived Quantities and Units

<b>Physical quantity</b>	<b>Unit(s)</b>
area	cm <sup>2</sup> ; m <sup>2</sup>
volume	cm <sup>3</sup> ; dm <sup>3</sup> ; m <sup>3</sup> ; litre (l); millilitre (ml)
density	kg/m <sup>3</sup> ; g/cm <sup>3</sup>
force	Newton (N)
speed	m/s; km/h
energy	joule (J) ; kilojoule (kJ); megajoule (MJ)
power	watt (W); kilowatt (kW); megawatt (MW)
frequency	hertz (Hz); kilohertz (kHz)
radioactivity	becquerel (Bq)
radiation dose	sievert (Sv)

## Appendix D: Health and Safety

Responsibility for safety matters rests with Centres.

**Important note:** The list below contains resources that comply with European, and in particular UK safety legislation. However, they must not be taken to be a replacement for local regulation and recommendation. Where they exist they must be committed and adhered to.

A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of Safety in Science Education. For members, the CLEAPSS guide, Managing Risk Assessment in Science offers detailed advice.

Attention is drawn to the following UK resources:

- Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X
- Topics in Safety, 3rd edition, 2001, ASE ISBN 0 86357 316 9
- Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2
- Hazards, 1995 with 2004 updates, CLEAPSS School Science Service\*
- CLEAPSS Laboratory Handbook, 1997 with 2004 update, CLEAPSS School Science Service\*
- CLEAPSS Shorter Handbook (CLEAPSS 2000), CLEAPSS School Science Service\*
- Hazardous Chemicals, A manual for Science Education, (SSERC, 1997) ISBN 0 9531776 0 2

\* Note that CLEAPSS publications are only available to members or associates.  
([www.cleapss.org.uk/secmbfr.htm](http://www.cleapss.org.uk/secmbfr.htm))

## Appendix E: Explanations of terms used in module content

All the module content statements are expressed in terms of what the candidates know, understand or can do, and are prefixed by 'Candidates should be able to ...' which is followed by a statement containing one or more 'command' words.

This appendix, which is not intended to be exhaustive or prescriptive, provides some guidance as to the meanings of these command words.

It must be stressed that the meaning of a term depends on the context in which it is set, and consequently it is not possible to provide precise definitions of these words which can be rigidly applied in all circumstances. Nevertheless, it is hoped that this general guidance will be of use in helping to interpret both the specification content and the assessment of this content in written papers.

### Command words associated with scientific knowledge and understanding (AO1)

Candidates are expected to remember the facts, concepts, laws and principles which they have been taught. Command words in this category include Learning Outcomes beginning:

Explain      State      Recognise      Name      Draw      Test for      Appreciate      Describe

The words used on examination papers in connection with the assessment of these Learning Outcomes may include:

Describe      List      Give      Name      Draw      Write      What?      How?      What is meant by?

e.g. 'What is meant by the term 'catalyst'?'  
'Name parts A, B and C on the diagram.'

### Command words associated with interpretation, evaluation, calculation and communication (AO2)

The command words include:

Relate      Interpret      Carry out      Deduce      Explain      Evaluate  
Predict      Use      Discuss      Construct      Suggest      Calculate      Demonstrate

The use of these words involves the ability to recall the appropriate material from the specification content and to apply this knowledge and understanding to the question.

Questions in this category may include the command words listed above, together with:

Why?      Complete      Work out      How would you know that?      Suggest

e.g. 'Use the graph to calculate the concentration of the acid.'  
'Explain why it is important for these materials to be recycled.'  
'Suggest two reasons why some people are concerned about the use of these artificial flavours in foods.'

## Appendix F: Ideas about Science

In order to deal sensibly with science as we encounter it in everyday life, it is important not only to understand some of the fundamental scientific explanations of the behaviour of the natural world, but also to know something about science itself, how scientific knowledge has been obtained, how reliable it therefore is, what its limitations are, and how far we can therefore rely on it – and also about the interface between scientific knowledge and the wider society.

The kind of understanding of science that we would wish pupils to have by the end of their school science education might be summarised as follows:

The aim of science is to find explanations for the behaviour of the natural world. A good explanation may allow us to predict what will happen in other situations, and perhaps to control and influence events.

There is no single ‘method of science’ that leads automatically to scientific knowledge. Scientists do, however, have characteristic ways of working. In particular, data, from observations and measurements, is of central importance.

One kind of explanation is to identify a correlation between a factor and an outcome. This factor may then be the cause, or one of the causes, of the outcome. In complex situations, a factor may not always lead to the outcome, but increases the chance (or the risk) of it happening. Other explanations involve putting forward a theory to account for the data. Scientific theories often propose an underlying model, which may involve objects (and their behaviour) that cannot be observed directly.

Devising and testing a scientific explanation is not a simple or straightforward process. First, we can never be completely sure of the data. An observation may be incorrect. A measurement can never be completely relied upon, because of the limitations of the measuring equipment or the person using it.

Second, explanations do not automatically ‘emerge’ from the data. Thinking up an explanation is a creative step. So, it is quite possible for different people to arrive at different explanations for the same data. Personal characteristics, preferences and loyalties can also influence the decisions involved.

The scientific community has established procedures for testing and checking the findings and conclusions of individual scientists, and arriving at an agreed view. Scientists report their findings to other scientists at conferences and in special journals. Claims are not accepted until they have survived the critical scrutiny of the scientific community. In some areas of enquiry, it has proved possible to eliminate all the explanations we can think of but one – which then becomes the accepted explanation (for the time being).

Where possible, scientists choose to study simple situations in order to gain understanding. But it can then be difficult to apply this understanding to complex, real-world situations. So there can be legitimate disagreements about how to explain such situations, even when there is no disputing the basic science involved.

The application of scientific knowledge, in new technologies, materials and devices, greatly enhances our lives, but can also have unintended and undesirable side-effects. An application of science may have social, economic and political implications, and perhaps also ethical ones. Personal and social decisions require an understanding of the science involved, but also involve knowledge and values beyond science.

This is, of course, a simplified account of the nature of science, which omits many of the ideas and subtleties that a contemporary philosopher or sociologist of science might think important. It is intended as an overview of science in terms which might be accessible to 14–16 year old candidates, to provide a basic understanding upon which those who wish to may later build more sophisticated understandings. It is

important to note that the language in which it is expressed may well not be that which one would use in talking to candidates of this age.

The following pages set out in more detail the key ideas that such an understanding of science might involve, and what candidates should be able to do to demonstrate their understanding.

**Bold** font is used to identify more difficult material **to stretch students targeting A–C grades**.

## 1 Data and their limitations

Data are the starting point for scientific enquiry – and the means of testing scientific explanations. But data can never be trusted completely, scientists need ways of evaluating how useful and accurate their data are.

### Ideas about Science

- 1.1** Data are crucial to science. Explanations are sought to account for known data, and data are collected to test proposed explanations.
- 1.2** We can never be sure that a measurement tells us the true value of the quantity being measured.
- 1.3** If we make several measurements of the same quantity, the results are likely to vary. This may be because we have to measure several individual examples (e.g. the height of cress seedlings after one week), or because the quantity we are measuring is varying (e.g. amount of ozone in city air, time for a vehicle to roll down a ramp), and/or because of the limitations of the measuring equipment or of our skill in using it (e.g. repeat measurements when timing an event).
- 1.4** Usually the best estimate of the value of a quantity is the average (or mean) of several repeat measurements.
- 1.5** The spread of values in a set of repeated measurements gives a rough estimate of the range within which the true value probably lies.
- 1.6** If a measurement lies well outside the range within which the others in a set of repeats lie, or is off a graph line on which the others lie, this is a sign that it may be incorrect.

### A candidate who understands this...

- uses data rather than opinion in justifying an explanation
- can suggest reasons why a measurement may be inaccurate
- can suggest reasons why several measurements of the same quantity may give different results
- when asked to evaluate data, makes reference to its reliability (i.e. is it repeatable?)
- can calculate the mean of a set of repeated measurements
- from a set of repeated measurements of a quantity, uses the mean as the best estimate of the true value
- can explain why repeating measurements leads to a better estimate of the quantity
- can make a sensible suggestion about the range within which the true value of a measured quantity probably lies
- can justify the claim that there is/is not a 'real difference' between two measurements of the same quantity**
- can identify any outliers in a set of data, and give reasons for including or discarding them

## 2 Correlation and cause

Scientists look for patterns in data, as a means of identifying possible cause-effect links, and working towards explanations.

### Ideas about Science

- 2.1** It is often useful to think about processes in terms of factors which may affect an outcome (or input variable(s) which may affect an outcome variable).
- 2.2** To investigate the relationship between a factor and an outcome, it is important to control all the other factors which we think might affect the outcome (a so-called 'fair test').
- 2.3** If an outcome occurs when a specific factor is present, but does not when it is absent, or if an outcome variable increases (or decreases) steadily as an input variable increases, we say that there is a correlation between the two.
- 2.4** A correlation between a factor and an outcome does not necessarily mean that one causes the other; both might, for example, be caused by some other factor.
- 2.5** In some situations, a factor increases the chance (or probability) of an outcome, but does not invariably lead to it, e.g. a diet containing high levels of saturated fat increases an individual's risk of heart disease, but may not lead to it. We also call this a correlation.
- 2.6** To investigate a claim that a factor increases the chance (or probability) of an outcome, we compare samples (e.g. groups of people) that are matched on as many other factors as possible, or are chosen randomly so that other factors are equally likely in both samples. The larger the samples the more confident we can be about any conclusions drawn.
- 2.7** Even when there is evidence that a factor is correlated with an outcome, scientists are unlikely to accept that it is a cause of the outcome, unless they can think of a plausible mechanism linking the two.

### A candidate who understands this...

in a given context, can identify the outcome and the factors that may affect it

in a given context, can suggest how an outcome might be affected when a factor is changed

can identify, in a plan for an investigation of the effect of a factor on an outcome, the fact that other factors are controlled as a positive feature, or the fact that they are not, as a design flaw

### can explain why it is necessary to control all factors thought likely to affect the outcome other than the one being investigated

can give an example from everyday life of a correlation between a factor and an outcome

uses the ideas of correlation and cause appropriately when discussing historical events or topical issues in science

### can explain why a correlation between a factor and an outcome does not necessarily mean that one causes the other, and give an example to illustrate this

can suggest factors that might increase the chance of an outcome, but not invariably lead to it

can explain that individual cases do not provide convincing evidence for or against a correlation

can evaluate the design for a study to test whether or not a factor increases the chance of an outcome, by commenting on sample size and how well the samples are matched

### can use data to develop an argument that a factor does/does not increase the chance of an outcome

can identify the presence (or absence) of a plausible mechanism as significant for the acceptance (or rejection) of a claimed causal link

### 3 Developing explanations

Scientific explanations are of different types. Some are based on a proposed cause-effect link. Others show how a given event is in line with a general law, or with a general theory. Some theories involve a model, which may include objects or quantities that cannot be directly observed, which accounts for the things we can observe.

#### Ideas about Science

- 3.1** A scientific explanation is a conjecture (a hypothesis) about how data might be accounted for. It is not simply a summary of the data, but is distinct from it.
- 3.2** An explanation cannot simply be deduced from data, but has to be thought up imaginatively to account for the data.
- 3.3** A scientific explanation should account for most (ideally all) of the data already known. It may explain a wide range of observations. It should also enable predictions to be made about new situations or examples.
- 3.4** Scientific explanations are tested by comparing predictions made from them with data from observations or experiments.
- 3.5** For some questions that scientists are interested in, there is not yet an answer.

#### A candidate who understands this...

can identify statements which are data and statements which are (all or part of) an explanation

can recognise data or observations that are accounted for by, or conflict with, an explanation

can identify imagination and creativity in the development of an explanation

can justify accepting or rejecting a proposed explanation on the grounds that it:

- accounts for observations
- **and/or provides an explanation that links things previously thought to be unrelated**
- **and/or leads to predictions that are subsequently confirmed**

can draw valid conclusions about the implications of given data for a given explanation, in particular:

- recognises that an observation that agrees with a prediction (derived from an explanation) increases confidence in the explanation **but does not prove it is correct**
- recognises that an observation that disagrees with a prediction (derived from an explanation) indicates that either the observation or the prediction is wrong, **and that this may decrease our confidence in the explanation**

can identify a scientific question for which there is not yet an answer, **and suggest a reason why**



## 4 The scientific community

Findings reported by an individual scientist or group are carefully checked by the scientific community before being accepted as scientific knowledge.

### Ideas about Science

- 4.1** Scientists report their findings to other scientists through conferences and journals. Scientific findings are only accepted once they have been evaluated critically by other scientists.
- 4.2** Scientists are usually sceptical about findings that cannot be repeated by anyone else, and about unexpected findings until they have been replicated.
- 4.3** Explanations cannot simply be deduced from the available data, so two (or more) scientists may legitimately draw different conclusions about the same data. A scientist's personal background, experience or interests may influence his/her judgements (e.g. data open to several interpretations; influence of personal background and experience; interests of employers or sponsors).
- 4.4** A scientific explanation is rarely abandoned just because some data are not in line with it. An explanation usually survives until a better one is proposed (e.g. anomalous data may be incorrect; new explanation may soon run into problems; safer to stick with ideas that have served well in the past).

### A candidate who understands this...

can describe in broad outline the 'peer review' process, in which new scientific claims are evaluated by other scientists

can recognise that new scientific claims which have not yet been evaluated by the scientific community are less reliable than well-established ones

can identify absence of replication as a reason for questioning a scientific claim

### can explain why scientists regard it as important that a scientific claim can be replicated by other scientists

can suggest plausible reasons why scientists involved in a scientific event or issue disagree(d)

can suggest reasons for scientists' reluctance to give up an accepted explanation when new data appear to conflict with it

## 5 Risk

Every activity involves some risk. Assessing and comparing the risks of an activity, and relating these to the benefits we gain from it, are important in decision making.

### Ideas about Science

- 5.1** Everything we do carries a certain risk of accident or harm. Nothing is risk free. New technologies and processes based on scientific advances often introduce new risks.
- 5.2** We can sometimes assess the size of a risk by measuring its chance of occurring in a large sample, over a given period of time.
- 5.3** To make a decision about a particular risk, we need to take account both of the chance of it happening and the consequences if it did.
- 5.4** People are often willing to accept the risk associated with an activity if they enjoy or benefit from it. We are also more willing to accept the risk associated with things we choose to do than things that are imposed, or that have short-lived effects rather than long-lasting ones.
- 5.5** If you are not sure about the possible results of doing something, and if serious and irreversible harm could result from it, then it makes sense to avoid it (the 'precautionary principle').
- 5.6** Our perception of the size of a risk is often very different from the actual measured risk. We tend to over-estimate the risk of unfamiliar things (like flying as compared with cycling), and things whose effect is invisible (like ionising radiation).
- 5.7** Reducing the risk of a given hazard costs more and more, the lower we want to make the risk. As risk cannot be reduced to zero, individuals and/or governments have to decide what level of risk is acceptable.

### A candidate who understands this...

- can explain why it is impossible for anything to be completely safe
- can identify examples of risks which arise from new scientific or technological advances
- can suggest ways of reducing specific risks
- can interpret and discuss information on the size of risks, presented in different ways
- can discuss a given risk, taking account of both the chance of it occurring and the consequences if it did
- can suggest benefits of activities that have a known risk
- can offer reasons for people's willingness (or reluctance) to accept the risk of a given activity
- can discuss personal and social choices in terms of a balance of risk and benefit
- can identify, or propose, an argument based on the 'precautionary principle'
- can distinguish between actual and perceived risk, when discussing personal and social choices
- can suggest reasons for given examples of differences between actual and perceived risk
- can explain what the ALARA (as low as reasonably achievable) principle means and how it applies in a given context

## 6 Making decisions about science and technology

To make sound decisions about the applications of scientific knowledge, we have to weigh up the benefits and costs of new processes and devices. Sometimes these decisions also raise ethical issues. Society has developed ways of managing these issues, though new developments can pose new challenges to these.

### Ideas about Science

- 6.1** Science-based technology provides people with many things that they value, and which enhance the quality of life. Some applications of science can, however, have unintended and undesirable impacts on the quality of life or the environment. Benefits need to be weighed against costs.
- 6.2** Scientists may identify unintended impacts of human activity (including population growth) on the environment. They can sometimes help us to devise ways of mitigating this impact and of using natural resources in a more sustainable way.
- 6.3** In many areas of scientific work, the development and application of scientific knowledge are subject to official regulations and laws (e.g. on the use of animals in research, levels of emissions into the environment, research on human fertility and embryology).
- 6.4** Some questions, such as those involving values, cannot be addressed by scientists.
- 6.5** Some applications of science have ethical implications. As a result, people may disagree about what should be done (or permitted).
- 6.6** In discussions of ethical issues, one common argument is that the right decision is one which leads to the best outcome for the majority of people involved. Another is that certain actions are unnatural or wrong, and should not be done in any circumstances. A third is that it is unfair for a person to choose to benefit from something made possible only because others take a risk, whilst avoiding that risk themselves.
- 6.7** In assessing any proposed application of science, we must first decide if it is technically feasible. Different decisions on the same issue may be made in different social and economic contexts.

### A candidate who understands this...

- in a particular context, can identify the groups affected and the main benefits and costs of a course of action for each group
- can explain the idea of sustainable development, and apply it to specific situations
- shows awareness that scientific research and applications are subject to official regulations and law
- can distinguish questions which could be addressed using a scientific approach, from questions which could not
- where an ethical issue is involved, can:
- say clearly what this issue is
  - summarise different views that may be held
- in a particular context, can identify, and develop, arguments based on the ideas that:
- the right decision is the one which leads to the best outcome for the majority of people involved
  - certain actions are never justified because they are unnatural or wrong
- in a particular context, can distinguish what can be done (technical feasibility), from what should be done (values)**
- can explain why different courses of action may be taken in different social and economic contexts**

## Appendix G: Science Explanations

Material in *italics* denotes material that will not be the focus of assessment items but will have been understood and assessed in earlier stages of study. Material in **bold** is only intended for Higher Tier candidates.

### SE 1 Chemicals

- a** *All materials, living and non-living, are made of chemicals. There are millions of different chemicals in the world around us. They are all made up of about 90 simple chemicals called elements. Elements are made up of very tiny particles called atoms. The atoms of each element are the same as, or very similar to, each other and are different from the atoms of other elements.*
- b** *The atoms of different elements can join together (combine) to form other substances called compounds. There are many different ways that atoms of elements can join together so there is a very large number of different compounds.*
- c** In many compounds, atoms of different elements are joined up to make larger building blocks called molecules. No matter how a compound is made, or where it comes from, the types of atom in its molecules, and the number of atoms of each type in each molecule, are always the same. The atoms in each molecule of a compound can be shown in the formula for the compound; water molecules, for example, consist of two atoms of hydrogen joined to one atom of oxygen so the formula for a molecule of water is H<sub>2</sub>O.
- d** The properties of a compound are completely different from the properties of the elements from which it is made.

### SE 2 Chemical change

- a** In chemical reactions, new chemicals are produced. This happens because atoms that were there at the start (in the reactants) have been re-arranged in some way (to form the products):
- atoms that were joined together at the start may have separated
  - atoms that were separate at the start may have joined together
  - atoms that were present at the start may have separated and then joined together in different ways.
- For example, when fuels burn, atoms of carbon and/or hydrogen from the fuel combine with atoms of oxygen from the air to produce carbon dioxide and/or water (hydrogen oxide). If the fuel contains any sulfur, sulfur dioxide will also be produced.
- b** No atoms are destroyed in chemical reactions and no new atoms are created.

### SE 3 Materials and their properties

- a** All the materials that we use are chemicals or mixtures of chemicals. We obtain them, or make them, from materials that we find in the world around us, e.g. in non-living things such as the Earth's crust or in living things such as plants or animals.
- b** We use materials that have suitable properties for the jobs that we want them to do. Solid materials can differ with respect to
- their melting points
  - how strong they are (in tension and in compression)
  - how stiff they are
  - how hard they are
  - their density.

- c The properties of solid materials depend on how the particles (e.g. molecules) from which it is made are arranged and held together in the solid. For example, the stronger the forces between the molecules, the more energy they need to break out of the solid structure and the hotter the solid must be before it melts (in other words, the higher the melting point).
- d An understanding of why a material has particular properties can help us find ways of improving the properties of a material to make it even more useful.

## SE 4 The interdependence of living things

- a *All living things need materials and energy from their surroundings to stay alive. They also produce waste materials that they must get rid of into their surroundings. The Sun provides the energy that all living things need. The leaves of green plants use the energy in sunlight to make a sugar called glucose from carbon dioxide (taken from air) and water (taken by roots from the ground). This process is called photosynthesis; oxygen is the waste product. Plants use glucose and chemicals (minerals) from the soil to make all the other chemicals that they need to live and grow. Animals obtain the materials they need to live and grow by eating plants (or by eating other animals that have eaten plants). They obtain the energy they need by reacting glucose (from their food) with oxygen (from the air). This process happens in their cells and is called respiration; carbon dioxide and water are the waste products.*
- b *We can show what eats what in a particular habitat (or ecosystem) by using a food web.*
- c There is often competition between different species of animals or plants in a particular habitat for the same space or the same food source. A change which affects one species in a food web also affects other species that are part of the same food web. Ecosystems can often adjust to changes but large disruptions may change an ecosystem permanently.

## SE 5 The chemical cycles of life

- a The materials from which living things are made are used over and over again; they are recycled. For example, carbon is a vital element in all the molecules from which living things are made. The continual cycling of compounds containing carbon is called the carbon cycle.
- b Decomposers, such as certain microbes, break down the dead bodies of plants and animals. They play a very important part in the recycling of materials.  
Atoms of the element nitrogen are found in the protein molecules that are important in all living cells.  
**The continual cycling of compounds containing nitrogen is called the nitrogen cycle.**  
**Other elements that are important in living things, for example potassium and phosphorus, are also continually recycled.**
- c Farmers use the same land over and over again to grow plants and raise animals for food. This means that chemicals containing nitrogen, **potassium and phosphorus** are lost from the soil. Unless these are replaced, the land will gradually produce less and less food.
- d Water is an essential requirement for all life. The provision of clean water for human consumption is necessary for good health. Water is itself a natural resource, but also provides other resources such as fish and chemicals.

## SE 6 Cells as the basic units of living things

- a *All living things (organisms) are made from small units called cells. Cells are 'chemical factories'; the chemical reactions that must happen for living things to stay alive take place inside cells. For example, cells make protein molecules and obtain the energy needed to do this by reacting glucose with oxygen (respiration).*

- b** *Most organisms are made up of many different types of cell. Different types of cell are built in different ways (they have a different structure) so that they can do their particular job (function). We say that the cells are specialised.*

## SE 7 Maintenance of life

- a** *All living things need to maintain themselves if they are to survive. Animals, including humans, need to have a balanced mix of proteins, carbohydrates, fats, minerals, vitamins and water in their diet. Larger molecules are broken down in the human gut by chemicals called enzymes to form smaller molecules. Starch is digested into glucose, and proteins are digested into amino acids. These smaller molecules pass through the wall of the small intestine into the blood which transports them to all the cells of the body.*
- b** *In cells glucose reacts with oxygen to provide energy; this process is called respiration. Cells use some of this energy to build up amino acids into the much larger molecules of many different proteins.*
- c** *In humans and in many other animals, the heart pumps blood around the body. The lungs provide the blood with oxygen which is transported from the lungs, via the heart, to all the cells of the body (including the cells of the heart itself). Regular, but not excessive, exercise reduces the risk of developing heart disease. The risk of heart disease is increased by poor diet, stress, and such activities as cigarette smoking and high levels of alcohol consumption.*
- d** *The cells in the body produce waste materials which are toxic and so must be got rid of. The carbon dioxide that is produced from glucose and oxygen by cells when they respire is transported to the lungs where it is breathed out. Urea, produced by the breakdown of protein, is excreted from the body by the kidneys in urine. Undigested food never actually enters our bloodstream but passes through the gut and leaves as faeces.*
- e** *Organisms are more likely to survive if they can sense, in their surroundings, the things that they need (e.g. water, food or light) and what they need to avoid (e.g. harmful chemicals, extreme temperatures or predators). Multicellular organisms have sensor cells that are specialised to detect things in their surroundings and effector cells that are specialised to respond to what is detected. Multicellular animals have nervous systems, comprising nerve cells (neurones) which link sensor cells (e.g. in eyes, ears and skin) to effector cells (e.g. muscles). In humans, and other vertebrates, this linking is coordinated via a central nervous system (spinal cord and brain). Hormones are chemicals which travel in the blood and bring about slower, longer-lasting responses.*

**Nervous and hormonal communication systems are involved in maintaining a constant internal environment (homeostasis).**

## SE 8 The gene theory of inheritance

- a** *Most animals and plants reproduce by sexual reproduction. In this process a male sex cell joins with a female sex cell to form a fertilised egg. This single cell then grows by cell division and differentiation to form a new individual. Differences between individuals are caused by both genes and environment.*
- b** *Instructions for how an organism develops are found in the nucleus of its cells. The information consists of many pairs of genes which control what the organism is like, for example its shape, size, colour and many other characteristics. Each gene affects a specific characteristic. Genes are sections of very long DNA molecules that make up the chromosomes in the nuclei of cells, so each chromosome contains a large number of genes. Chromosomes occur in pairs. One chromosome from each pair came originally from each parent's sex cell. Both chromosomes in a pair carry the same genes in the same place, but genes in a pair are often slightly different versions (called alleles).*
- c** *Offspring may be similar to their parents because of this combination of maternal and paternal alleles. Different offspring from the same parents receive different combinations of the alleles of all the genes, so they can differ from each other in many ways.*
- d** *Genes are instructions for a cell that describe how to make proteins.*

- e Because all organisms use the same genetic code to carry units of information, a gene can be taken from the nucleus of one cell and placed into a different cell. This is called genetic modification. The gene may be from a different organism. This process produces cells with a new combination of genes, and the resulting organism will display new characteristics which may be useful to humans.
- f Bacteria, simple animals and most plants can reproduce without sex (asexually). A new organism just starts to grow from a small part of the older one. Each time a body cell divides, the chromosomes (and hence the genes) are copied so that each body cell contains an identical set of genes. So new individuals produced asexually have exactly the same genes in their cells as the parent (they are called clones). This means that they also have very similar characteristics. Any differences are due only to environment.
- g The cells of multicellular organisms become specialised during the early development of the organism. However, some cells in an adult plant remain unspecialised and can develop into any type of plant cell. This is why clones of plants can often be grown from small parts (cuttings) of their roots, stems or leaves.

## SE 9 The theory of evolution by natural selection

- a The first living things developed from molecules that could copy themselves. These molecules were produced in the conditions on Earth at that time. Most biologists believe that the many different species of living things that now exist, and the many more species which once existed but have died out (become extinct) all evolved from the same very simple living things that first appeared on Earth about 3500 million years ago.
- b Evolution happened, and continues to happen, mainly because of a process called natural selection. Individuals of the same species are not identical; their characteristics vary. If the environment changes, or if vital resources become scarce, individuals with certain characteristics may have a better chance of surviving long enough to reproduce. This means that there will be more individuals with these characteristics in the next generation and, if the environment stays the same, even more in the generation after that. This process is called natural selection because it produces changes like the ones deliberately produced by farmers or animal breeders when they select the animals or plants with the characteristics that they prefer for breeding the next generation. Natural selection, however, does not involve people making deliberate selections.
- c **The genes that control the way an organism develops can be changed by certain chemicals, by ionising radiation and by copying errors when chromosomes are copied. This is called mutation. Mutations can cause body cells to reproduce in an uncontrolled way (cancer). Mutated genes in sex cells may be passed on to offspring and produce new characteristics. Mutations usually have such a harmful effect that the fertilised eggs do not develop. Some mutations, though, have no effect on an individual or may even improve the chance of surviving and reproducing. When this happens, the mutated gene is passed on and becomes more common.**
- d Over a very long period of time (and many generations) new species have evolved. **The combined effects of mutations, environmental changes and natural selection can produce new species. The 3500 million years since life on Earth first evolved are believed by most biologists to have been long enough for all the living things that exist (or that have existed) to have evolved in this way.** A large change in the environment may cause a whole species to become extinct.
- e **Evolution has happened in the way that it has because of random mutation, random breeding and natural selection. If the conditions on Earth had, at any stage, been different from what they actually were, evolution by natural selection would have produced different results.**

## SE 10 The germ theory of disease

- a** *Many diseases are caused by small organisms (microbes) such as bacteria, fungi and viruses. These are present in the environment and can get inside the bodies of humans or other organisms. The body has natural barriers to reduce the likelihood of harmful microorganisms entering the body from outside. Our skin acts as a barrier, and chemicals in tears and sweat and acid in the stomach kill microorganisms.*
- b** *If they get inside a body, the microorganisms can reproduce rapidly. The reproducing microorganisms may cause damage to cells or produce poisons (toxins) which cause the symptoms of the disease. Our bodies have an immune system to defend themselves against the microorganisms that cause infections. Some of our white blood cells can surround and destroy microorganisms by digesting them. Other white blood cells produce chemicals called antibodies that help destroy microorganisms. A different antibody is needed to recognise each different type of microorganism. Once your body has made the antibody to kill a particular microorganism it can make that antibody again very quickly. This means that your body is then protected against that particular microorganism. This idea can be used to immunise people against diseases by deliberately infecting (vaccinating) them with a form of the microorganism that has been altered so that it is unable to cause disease. The body produces antibodies and, on future exposure to the natural form of the microorganism, protective antibodies will be produced quickly. **Vaccines are not so effective against influenza because there are so many different strains of the virus that causes the disease. As yet, there is no effective vaccination against AIDS, a disease caused by the virus called HIV, because the virus has a high mutation rate within the body.***
- c** *Sometimes microorganisms against which we have not been immunised get into our bodies. These can cause illness, or even death, before our immune systems can destroy them. In such cases, we can kill bacteria and fungi, but not viruses, using chemicals called antibiotics. Over a period of time, however, bacteria and fungi may become resistant to antibiotics. **Random mutations in the genes of these microorganisms sometimes lead to varieties which are less affected by the antibiotic. These have a better chance of surviving a course of antibiotic treatment, especially if the patient does not complete the course.** To prevent this happening, we should only use antibiotics when really necessary, and always complete the prescribed course.*

## SE 11 Energy sources and uses

- a** *We often need a source of energy to change things in some way or make things happen. Fuels (e.g. coal, oil, natural gas and wood) are very valuable because, when oxygen is also available, they are very concentrated sources of energy. There is, however, only a limited amount of fossil fuels (coal, oil and natural gas) in the Earth's crust so they are a non-renewable energy source. Wood, from trees, is a renewable fuel when properly managed.*
- b** *In some situations, we can use renewable energy sources that are less concentrated (for example, wind, waves, tides, dammed water or radiation from the Sun) instead of fuels.*
- c** *Moving objects have (kinetic) energy; (potential) energy can be stored in objects that are lifted up against the force of gravity and in elastic objects that have been stretched, compressed, bent or twisted; a hot object has more (thermal) energy than the same object when it is cooler.*
- d** *Energy can be transferred from one object to another in various ways:*
- *mechanically (by one object pushing or pulling another)*
  - *thermally (by conduction or convection of energy from a high temperature region to a low temperature region)*
  - *electrically (by an electric current)*
  - *by radiation.*



- e Electricity is very convenient because it can be easily transferred from where it is generated to where it is needed, and can then readily be used to produce movement (kinetic) energy, light, sound or heating as required. Electricity is, however, a secondary energy source; another (primary) energy source is needed to generate it. In most power stations this is done by using a fossil fuel to boil water and then using the steam to turn a turbine, which rotates a generator to generate electricity.

## SE 12 Radiation

- a Some processes in which one object affects another some distance away fit the following general model: radiation source → receiver

One object (a source) emits radiation (of some kind). This travels from the source and can affect another object (a receiver) some distance away. When radiation strikes an object, some may pass through it, or be reflected or absorbed. A detector of radiation is simply an absorber which produces some observable response to the radiation it has absorbed. When radiation is absorbed it ceases to exist as radiation; usually it simply heats the absorber.

- b Light is one of a family of radiations. The spectrum of visible light (red → violet) can be extended in both directions:

radio    microwave    infra-red    <sup>red</sup> light    <sup>violet</sup>    ultra-violet    X-ray    gamma

The whole family of radiations is called the electromagnetic spectrum.

- c Some types of electromagnetic radiation when absorbed do not just cause heating; X-rays, gamma rays and ultra-violet radiation can cause damage to the molecules in living cells. Radiation that can do this is called ionising radiation. **When ionising radiation strikes molecules it can make them more likely to react chemically.** Exposure to large amounts of ionising radiation can kill living cells; smaller amounts may cause changes to cells which can make them grow in an uncontrolled way, causing cancer.

## SE 13 Radioactivity

- a Some elements emit bursts of radiation all the time, even if they are broken into very small pieces, dissolved or chemically reacted to form new chemicals. Such elements, or compounds containing such elements, are called radioactive materials.

- b There are three types of radiation emitted by radioactive materials:

- alpha ( $\alpha$ ) radiation      which is easily absorbed, for example by a thin layer of paper or a few centimetres of air
- beta ( $\beta$ ) radiation        which passes fairly easily through many substances but can be absorbed by a thin sheet of any metal
- gamma ( $\gamma$ ) radiation    which passes very easily through most substances (it is penetrating) and needs a thick sheet of a dense metal such as lead, or concrete several metres thick, to absorb most of it.

- c Most types of atom never change; they are stable. But radioactive materials contain unstable atoms. The nucleus of an unstable atom can break up (decay) and when this happens it emits radiation. An atom of a different element is left behind. As time goes by, radioactive materials contain fewer and fewer unstable atoms and so become less and less radioactive and emit less and less radiation. The time it takes for a radioactive material to become half as radioactive as it was to begin with, (because half of the unstable atoms that were originally there have decayed), is called the half-life. Some radioactive materials have half-lives of billions of years; others have half-lives of a fraction of a second.

- d** All three types of radiation from radioactive materials are ionising radiations. When such radiation strikes living cells, the cells may be killed or become cancerous (i.e. grow in an uncontrolled way). Ionising radiation can be used to kill harmful cells and is used in this way to treat cancer and to sterilise surgical instruments. For each millimetre that it travels through a living cell, alpha radiation is most likely to cause damage and gamma radiation is the least likely to cause damage. The risk of cancer from radiation damage increases steadily with the amount of radiation to which a person is exposed.
- e** Radioactive materials can affect living cells in two different ways:
- the radiation from a radioactive material can reach a person (or other organism). This is irradiation
  - bits of the radioactive material can get into, or onto the person, or their clothes. This is contamination.

We are irradiated and contaminated all the time because of radioactive materials in the air, in building materials, in the soil and in our food. Medical treatments, and occupational or medical exposure to radioactive materials, increase the dose that some individuals receive. The dose received by people who are regularly exposed to radiation is carefully monitored.

## SE 14 The Earth

- a** The Earth is a sphere with a radius of about 6400 kilometres. It consists of several layers:
- on the outside, where we live, is a relatively thin crust made from solid rocks
  - below the crust, there is a thick layer of rock called the mantle which goes down about halfway to the centre of the Earth.

The rock which makes up the mantle is very hot but under pressure. It melts when the pressure is reduced. The molten rock (magma) formed in this way rises and cause volcanic eruptions.

Some changes in the Earth's surface are very slow and take place over a very long time. The mountains of the Earth's crust are gradually eroded so that the Earth's surface would be worn down to sea level if parts of the Earth's crust were not being lifted up to form new mountains.

Early in the 20th century, Wegener suggested that mountains might be formed as slowly drifting continents collided with each other. He suggested that the jigsaw fit of the east coast of South America and the west coast of Africa, together with the matching patterns of rocks and fossils, were evidence of continental drift. Most geologists at the time rejected this theory.

By the mid-20th century geologists

- knew that the mantle, even when solid, can flow very slowly
  - knew that the inside of the Earth is kept hot by the energy released when the atoms of radioactive elements inside the Earth decay
  - had discovered [mid-]oceanic ridges **and evidence that these were caused by sea-floor spreading.**
- b** The theory of plate tectonics is the unifying theory of Earth Science, explaining many rock cycle processes and changes to the Earth's surface. According to this theory, the outer rigid layer of the Earth consists of a number of separate pieces called tectonic plates. These are constantly, but extremely slowly, moving. Movement of the mantle, caused by heating from radioactive decay, contributes to the movement of the plates. At mid-ocean ridges, where plates are moving apart, molten rock (magma) rises up between the plates. In some places the plates are moving towards each other. This produces tremendous pressures that can deform rocks into mountain chains. The colliding plates may also cause earthquakes and volcanoes. An earthquake occurs when two blocks of rock, which are held together by friction, move suddenly because of the forces acting on them. Earthquakes occur where the edges of plates slide past each other, where plates collide and a more dense oceanic plate sinks beneath a less dense continental plate, and where faulting occurs near the mid-ocean ridges.

- c** The Earth is surrounded by a thin layer of atmosphere which allows light radiated from the Sun to pass through. This radiation provides the energy for plants to make glucose using carbon dioxide and water by the process of photosynthesis. Radiation from the Sun is absorbed by the Earth's surface, making it warmer. Different infra-red radiation is then emitted by the Earth and absorbed by the atmosphere so keeping the Earth warmer than it would otherwise be. This is called the greenhouse effect.
- The atmosphere also contains oxygen (a waste product of photosynthesis). This is needed by animals for respiration. **Oxygen is acted on by radiation to produce ozone in the upper atmosphere. This absorbs ultra-violet radiation, and protects living organisms, especially animals, from its harmful effects.**

## SE 15 The Solar System

- a** *The Earth is a planet that moves around the Sun. It takes one year to make a complete orbit. Other planets also move around the Sun. The Sun, the planets and other smaller bodies such as satellites (moons) of planets, asteroids and comets make up the Solar System.*
- b** The Sun is a star. It was formed, **about 5000 million years ago**, in the same way as other stars, by clouds of gas, being drawn together by the force of gravity. In stars, hydrogen **nuclei join (fuse)** and energy is released. The Sun will continue to shine for another 5000 million years. It will then become a red giant, engulfing or evaporating the Earth, and finally, a very dense black dwarf.

## SE 16 The Universe

- a** The Sun is just one of billions of stars which are clustered in a group called the Milky Way galaxy. The diameter of the galaxy is 100 000 light years. The Universe is made up of billions of galaxies, many times their own diameter apart, so it is vast.
- b** Distant galaxies are moving away from us. This means that the Universe is getting bigger (expanding). The more distant a galaxy is, the faster it is moving away. This suggests that the Universe might have begun in one place with a huge explosion (the 'big bang') about 13 700 million years ago.
- c** We do not know whether the Universe will keep on expanding forever or whether the force of gravity between the galaxies will slow them down enough to stop them moving apart so they will then start moving together again. Eventually there would then be a 'big crunch'.
- d** There are billions of galaxies, each containing billions of stars. Astronomers have detected planets around some nearby stars. If even a small proportion of stars have planets, many scientists think that it is very likely that life, and perhaps even intelligent life, exists elsewhere in the Universe.

Appendix H: The Periodic Table

Group																																																																																						
I	II	III	IV	V	VI	VII	VIII																																																																															
3 <b>Li</b> lithium 7	4 <b>Be</b> beryllium 9	1 <b>H</b> hydrogen 1	5 <b>B</b> boron 11	6 <b>C</b> carbon 12	7 <b>N</b> nitrogen 14	8 <b>O</b> oxygen 16	9 <b>F</b> fluorine 19	10 <b>Ne</b> neon 20	11 <b>Na</b> sodium 23	12 <b>Mg</b> magnesium 24	13 <b>Al</b> aluminium 27	14 <b>Si</b> silicon 28	15 <b>P</b> phosphorus 31	16 <b>S</b> sulfur 32	17 <b>Cl</b> chlorine 35.5	18 <b>Ar</b> argon 40	19 <b>K</b> potassium 39	20 <b>Ca</b> calcium 40	21 <b>Sc</b> scandium 45	22 <b>Ti</b> titanium 48	23 <b>V</b> vanadium 51	24 <b>Cr</b> chromium 52	25 <b>Mn</b> manganese 55	26 <b>Fe</b> iron 56	27 <b>Co</b> cobalt 59	28 <b>Ni</b> nickel 59	29 <b>Cu</b> copper 64	30 <b>Zn</b> zinc 65	31 <b>Ga</b> gallium 70	32 <b>Ge</b> germanium 73	33 <b>As</b> arsenic 75	34 <b>Se</b> selenium 79	35 <b>Br</b> bromine 80	36 <b>Kr</b> krypton 84	37 <b>Rb</b> rubidium 85	38 <b>Sr</b> strontium 88	39 <b>Y</b> yttrium 89	40 <b>Zr</b> zirconium 91	41 <b>Nb</b> niobium 93	42 <b>Mo</b> molybdenum 96	43 <b>Tc</b> technetium —	44 <b>Ru</b> ruthenium 101	45 <b>Rh</b> rhodium 103	46 <b>Pd</b> palladium 106	47 <b>Ag</b> silver 108	48 <b>Cd</b> cadmium 112	49 <b>In</b> indium 115	50 <b>Sn</b> tin 119	51 <b>Sb</b> antimony 122	52 <b>Te</b> tellurium 128	53 <b>I</b> iodine 127	54 <b>Xe</b> xenon 131	55 <b>Cs</b> caesium 133	56 <b>Ba</b> barium 137	57–71 lanthanoids	72 <b>Hf</b> hafnium 178	73 <b>Ta</b> tantalum 181	74 <b>W</b> tungsten 184	75 <b>Re</b> rhenium 186	76 <b>Os</b> osmium 190	77 <b>Ir</b> iridium 192	78 <b>Pt</b> platinum 195	79 <b>Au</b> gold 197	80 <b>Hg</b> mercury 201	81 <b>Tl</b> thallium 204	82 <b>Pb</b> lead 207	83 <b>Bi</b> bismuth 209	84 <b>Po</b> polonium —	85 <b>At</b> astatine —	86 <b>Rn</b> radon —	87 <b>Fr</b> francium —	88 <b>Ra</b> radium —	89–103 actinoids	104 <b>Rf</b> rutherfordium —	105 <b>Db</b> dubnium —	106 <b>Sg</b> seaborgium —	107 <b>Bh</b> bohrium —	108 <b>Hs</b> hassium —	109 <b>Mt</b> meitnerium —	110 <b>Ds</b> darmstadtium —	111 <b>Rg</b> roentgenium —	112 <b>Cn</b> copernicium —	114 <b>Fl</b> flerovium —	116 <b>Lv</b> livermorium —	—	—

**Key**  
atomic number  
atomic symbol  
name  
relative atomic mass

lanthanoids	57 <b>La</b> lanthanum 139	58 <b>Ce</b> cerium 140	59 <b>Pr</b> praseodymium 141	60 <b>Nd</b> neodymium 144	61 <b>Pm</b> promethium —	62 <b>Sm</b> samarium 150	63 <b>Eu</b> europium 152	64 <b>Gd</b> gadolinium 157	65 <b>Tb</b> terbium 159	66 <b>Dy</b> dysprosium 163	67 <b>Ho</b> holmium 165	68 <b>Er</b> erbium 167	69 <b>Tm</b> thulium 169	70 <b>Yb</b> ytterbium 173	71 <b>Lu</b> lutetium 175
actinoids	89 <b>Ac</b> actinium —	90 <b>Th</b> thorium 232	91 <b>Pa</b> protactinium 231	92 <b>U</b> uranium 238	93 <b>Np</b> neptunium —	94 <b>Pu</b> plutonium —	95 <b>Am</b> americium —	96 <b>Cm</b> curium —	97 <b>Bk</b> berkelium —	98 <b>Cf</b> californium —	99 <b>Es</b> einsteinium —	100 <b>Fm</b> fermium —	101 <b>Md</b> mendelevium —	102 <b>No</b> nobelium —	103 <b>Lr</b> lawrencium —

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## 8. Other information

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