Evolving 5-19 Biology

Recommendations and framework for **5-19 biology curricula**

Royal Society of Biology

About the **Royal Society** of **Biology**

The Royal Society of Biology is a single unified voice for biology: advising Government and influencing policy; advancing education and professional development; supporting our members, and engaging and encouraging public interest in the life sciences. The RSB represents a diverse membership of individuals, learned societies and other organisations. Individual members include practising scientists, pupils at all levels, professionals in academia, industry and education, and non-professionals with an interest in biology.

One of the priorities of the RSB is to support biology education at all levels through the stages of compulsory schooling, into further and higher education and beyond with training and professional development opportunities for the biosciences community. We recognise teachers in schools and universities with teaching awards and the Chartered Science Teacher (CSciTeach) professional register and support teachers' membership of this through our professional development programme.

We actively engage with education policy through formal consultation responses, convening special interest groups and collaboration and coordination with other scientific organisations (for example education priorities, collaborative work, and policy responses).

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Foreword

By the current and preceding RSB curriculum committee chairs

Biology is arguably the most important science of the 21st century, with issues such as climate change, emerging diseases, antibiotic resistance, food security and conservation all urgently requiring solutions. As the voice of biology, the Royal Society of Biology recognises the central importance of education in informing and preparing people for the challenges that lie ahead. The curriculum framework presented here provides a rich resource that will allow a range of stakeholders including teachers, awarding organisations and policymakers to structure and design the education that is essential as we move into this difficult future.

Over the last few years, the RSB curriculum committee has worked on the structure and detail of this curriculum framework. The complexities of the biological world and the accelerating accumulation of knowledge of it make this framework more important than at any other time. It has been designed through the contributions of a range of people from across the education landscape and the clarity and comprehensive nature of the framework is a testament to their insight, professionalism and hard work.

Given the way that biology pervades all our lives, we are particularly pleased that our approach encompasses primary to secondary, providing build and continuity along the whole biological education pipeline. Our approach captures the complexity and forward looking nature of biology while providing clear entry points appropriate for different end users. We have consulted widely throughout the development process.

Now that the framework is available, we anticipate and encourage it being used in a variety of ways; policymakers, awarding organisations and governments across the UK should use this document as a guide and liaise with the RSB on further detail during future rounds of qualification reform and curriculum review. Our framework will inform curriculum and qualification developments across all four UK nations. The curriculum framework is a definitive point of reference and starting point for exciting and necessary future initiatives across a wide range of areas within the RSB and across society.

Professor Jeremy Pritchard CSciTeach FRSB
Chair of RSB curriculum committee

Professor Libby John
Former Chair of RSB curriculum committee

Executive summary

Following previous curriculum reviews, often conducted at pace, the Royal Society of Biology (RSB) determined itself to be well prepared for future revisions of the biology curriculum for schools, enabling the Society to offer considered, evidence-based advice to policy-makers. To that end, the RSB has proactively engaged with the bioscience and education communities to develop a framework and recommendations for a future 5-19 biology curriculum.

The Society's framework has been informed by research and evidence, and with the involvement of a range of experts to set out a way of exploring biology throughout 5-19 and beyond, creating a framework that is contemporary, durable and flexible. For the first time, the RSB has a framework that demonstrates coherent progression through biology knowledge content and practical skills development between ages 5 and 19, which allows clear links to be made between areas within biology across this entire age range and that builds upon the biological ideas that pre-school children have explored and developed before starting formal education.

This framework details **three dimensions** of biology: biology as a science, core concepts of biology and biology in the world. Within these dimensions, pupils explore **23 key** themes that seek understanding of, and answers to, the **seven big questions of biology**.

DIMENSION: Practices of Biology - Biology as a science

BIG QUESTION: How do we study the biological world?

5-11 11-16 16-19

- Asking questions about the biological world
- Planning experiments and investigative work
- Carrying out experiments and investigative work
- Interpreting, analysing and evaluating data
- Developing explanations, classification systems and models
- Communicating information and engaging in evidence-based arguments

DIMENSION: Concepts of Biology - Core concepts of biology

BIG QUESTION: What are organisms and what are they made of?

5-11 11-16 16-19

- Defining life
- Tissues, organs and systems

11-16 16-19

- Cell structure and function
- Biochemistry

BIG QUESTION: How do organisms grow and reproduce?

5-11 11-16 16-19

- Reproduction, growth and development

11-16 16-19

- Inheritance and the genome

BIG QUESTION: Why are organisms so different?

5-11 11-16 16-19

- Variation, adaptation, evolution
- Classification

BIG QUESTION: How do organisms stay healthy?

5-11 11-16 16-19

- Physical and mental health
- Health and human lifestyles
- Health and infectious disease

BIG QUESTION: How do organisms live together?

5-11 11-16 16-19

- Interdependence of organisms
- Environmental interactions and processes
- Biodiversity and human impacts

DIMENSION: Applications of Biology - Biology in the world

BIG QUESTION: How do people use biological knowledge?

5-11 11-16 16-19

- Developing applications to promote human and environmental wellbeing
- Evaluating impacts of biological knowledge and its applications
- Influencing society

In this document, the RSB sets out the following **eight recommendations** to raise standards across the school biology curriculum.

1. The biology curriculum should aim to develop pupils' understanding in the three dimensions.
2. The biology curriculum should aim to develop pupils' understanding of big ideas of biology to answer big questions in biology.
3. The biology curriculum content that is set out in policy and guidance documents should enable coherent learning progression from age 5 to age 19.
4. The biology curriculum should provide pupils of all ages with ample opportunities to engage in practical and investigative work, including in the field.
5. The biology curriculum should provide pupils of all ages with ample opportunities to learn about plants and other organisms, in addition to humans and other animals.
6. The development of biology curriculum policy, guidance and content should draw upon previous curriculum development work and evidence from research, where appropriate.
7. The biology curriculum content set out in policy and guidance documents should be clear, teachable and assessable, while allowing scope for innovation in delivery.
8. The biology curriculum should be contemporary yet durable.

Sitting alongside the framework is an exemplification detailing how the content of the national curriculum for ages 5-11, 11-16 and 16-19 could be organised according to the 'big questions' of biology. The RSB's framework and recommendations have been designed to be sufficiently future-proof to reduce the need for regular updates of the curriculum, and the accompanying disruption this causes in schools.

This document **is** a framework for future biology curricula in UK schools. It is **not** a call for curriculum reform or a ready-made curriculum. The RSB intends to use this framework as a starting point for further discussions with policy makers and curriculum designers both in the lead up to, and during, future curriculum reviews and during the design of qualifications for general, technical and vocational courses. We also hope that the framework can be used more widely by teachers and school leaders, to support them in developing and justifying the biology curriculum within their schools.

SECTION ONE

01

Background & Overview

The importance of biology

Learning about biology enriches a young person's view of the world. It enhances our capacity to appreciate nature and the seemingly miraculous processes of life by encouraging us to explore and explain the structures, functions and interconnectedness of biological entities at every level of organisation, from molecules to ecosystems. It empowers us with a fuller understanding of our own bodies, other organisms and the world around us, enabling us to take better care of them and make better, informed decisions affecting them. It challenges us to re-evaluate our place and responsibilities within the amazing biodiversity of the Earth, and helps us to understand and respond to crises that threaten it, from the emergence of new diseases and antimicrobial-resistant microorganisms to the disappearance of species unable to adapt to rapid changes in their environment. Teaching and learning about biology helps to inspire the next generation to care, think, innovate and work together to protect and improve the world we live in.

The school biology curriculum

The biology curriculum in its broadest sense is everything that a young person experiences during their biology education. In the UK, as in many other countries, policy-level documents set out what pupils are expected – and entitled – to learn about biology while at school. These documents are the foundation of a biology curriculum that is realised through various mediating and assessment instruments, including lessons, textbooks and other teaching resources, specifications and examinations.

The school biology curriculum must aim to provide every young person with an experience of the explanatory power of the biological sciences, preparing them for further study, for work, and for life as scientifically literate citizens in the 21st century. Our framework seeks to ensure this through three dimensions: Practices of Biology, Concepts of Biology and Applications of Biology – we also refer to these as biology as a science, core concepts of biology and biology in the world, aiming to interweave practices, thinking and reasoning (including mathematics, laboratory and fieldwork), core concepts of biology and applications and impact of biology throughout a cohesive curriculum.

Practical skills and understanding of investigative work are vital parts of the school experience and qualifications. Biology curricula should ensure students of all ages have opportunities to investigate biological phenomena, develop investigative and analytical skills and are able to put these skills to use in laboratory and field contexts.

All life depends upon combined biological, chemical and physical processes and science disciplines work together to achieve understanding of our world and to develop new technologies. It is therefore important to ensure that biology curricula recognise the interconnectivity of scientific disciplines and must offer pupils the opportunity to use their understanding of biological concepts to contribute towards, and be enhanced by, learning from across the sciences. Developing a sound understanding of biology also relies on mathematics, and must be integrated into the structures of biology curricula throughout all stages of education.

Scope and purpose of this document

This document:

- provides an organisational framework and recommendations for the design of the school biology curriculum
- summarises the Royal Society of Biology's expectations for the biology young people should learn between the ages of 5-19, and is accompanied by detailed exemplifications of the framework for the age ranges 5-11, 11-16 and 16-19
- formalises the position of the Royal Society of Biology on approaches to designing a 5-19 biology curriculum
- is intended to be used during future curriculum reviews to inform the design and development of biology curricula for general, technical and vocational courses taken by young people
- will be of interest to:
    - *policy makers and regulatory bodies* seeking to develop or redevelop biology curriculum policy, guidance and content
    - *awarding organisations* developing biology specifications and assessments
    - *schools and their curriculum leaders* who are redeveloping their own biology curricula, particularly those concerned with making transition points at 11 and 16 more manageable for pupils and teachers, those considering the organisation and selection of topics to facilitate learning progression, and those wishing to make clearer the links between individual topics and the big ideas of biology.

This document is **not**:

- **a call for immediate curriculum reform**
  Constant policy churn and repeated curriculum reform cause disruption in schools. Although we recognise that there is room for improvement in current biology curricula in the UK, we support a period of stability. This document has been produced in preparation for future rounds of curriculum reform, whenever they should occur.
- **a ready-made curriculum**
  The recommendations and curriculum framework presented in Section 2 are intended to inform the design and development of biology curricula with improved organisation, coherence and learning progression. For the benefit of curriculum developers, Appendix 3 exemplifies how the framework could be furnished with curriculum content for ages 5-11, 11-16 and 16-19. We do not make recommendations about timetabling at each age range, the size of qualifications to be developed, teaching order or assessment. This document is not a curriculum in itself and makes no recommendations at a scheme of work or lesson plan level.

Developing our curriculum framework and recommendations

The curriculum framework, recommendations and exemplification presented in this document have been drawn up by the Curriculum Committee of the Royal Society of Biology. The committee was convened in 2014 with the aim of formalising the Society's position on the biology curriculum through a series of evidence-based and research-informed recommendations, such that we may proactively support policy makers and curriculum developers in the future. Appendix 4 details a timeline of key developments in the RSB's curriculum work as well as developments in curriculum policy and reform across the UK over 10-15 years.

The committee has received valuable input from its supporting advisory and working groups, including the Student Curriculum Committee and the Primary Working Group. Members of the committee and its supporting advisory and working groups represent a range of expertise (see Appendix 1).

The RSB, alongside the Royal Society of Chemistry and the Institute of Physics, jointly convened a Primary Curriculum Advisory Group (PCAG) to advise upon the 5-11 age-range. The PCAG fed into the curriculum framework development, taking into account their knowledge and expertise about what is known about the cognitive development of children and with a particular focus on the development of scientific understandings and skills.

The committee consults regularly with individuals representing other specialisms, including those from RSB's member organisations, and colleagues from the Royal Society of Chemistry, Institute of Physics and other learned societies across the sciences. It has also received input from RSB special interest groups (SIGs) and committees (see Appendix 2).

Evolution not revolution

The approach taken by the committee was to proceed under the mantra of "evolution not revolution". Although the organisational framework presented in Section 2 is intended to guide the design of future biology curricula, it could equally be applied to reorganise the content of existing curricula.

Appendix 3 presents an exemplification of biology curriculum content for ages 5-11, 11-16 and 16-19 organised according to the framework, with a particular focus on progression and cohesion between areas of biology. The exemplification was developed using content statements from existing national curricula in England as a starting point, followed by mapping and drawing on curricula and qualifications in Scotland, International Baccalaureate and, where appropriate, drawing on international curricula.

Next steps

Beyond publication of this document, the RSB intends to continue developing its position on the school experience of biology, including assessment, practical work and fieldwork, as well as considering how the three dimensions could be used to support the learning of biology within early-years settings. We will support teaching by signposting resources, providing a continued evidence base and disseminating best practice, as well as engaging with stakeholders, schools, teachers and pupils.

Alongside this curriculum document, the RSB will continue to work with others in the science education community to produce joint papers that will point to useful resources for teachers, evidence-based teaching order, interdisciplinary areas e.g. climate change, and other topics as appropriate.

SECTION
TWO

02

Recommendations & Framework

Recommendations

The Royal Society of Biology makes the following recommendations about the school biology curriculum:

1	**The biology curriculum should develop pupils' understanding in three dimensions:** • how biological science is done, including ways in which biological scientists work to develop scientific explanations • a body of core concepts about the structures, functions and interactions of organisms and their environments • the applications and impacts of biological science in the world.	When designing a biology curriculum it is necessary to consider the fundamental question: what should young people learn about biological science while at school? The answer is certainly more than a collection of facts. The biological sciences provide explanatory narratives that bring together observations and ideas to help explain biological phenomena[1]. Biological scientists have characteristic ways of working, thinking and reasoning that enable them to construct these explanatory narratives; the resultant body of understanding has applications and impacts for society, including benefits, risks and ethical issues. Developing pupils' understanding in these areas helps them to explain the biological world and to construct answers to questions they may have. It also prepares them to transition into further study or the workforce, and helps them to emerge from school as scientifically literate citizens able to engage critically with, and make informed decisions about, biological issues in everyday life.
2	**The biology curriculum should aim to develop pupils' understanding of big ideas in biology to answer big questions in biology.**	Prominent thinkers in science education have attempted to distil the enormous body of concepts that are explored in school biology education into a small number of '**big ideas**'[2]. These big ideas help to explain a great number of observations and phenomena in the biological world. It has been suggested[3] that the myriad concepts taught in biology lessons can be organised to form a series of **learning progressions** that build understanding of the big ideas of biology – or, perhaps, that build answers to **big questions** in biology. Previous biology curricula have been criticised for being too content heavy. A 'big ideas' organisational framework helps to provide a focus on concepts that are key to building understanding of the big ideas (or answering big questions) of biology.
3	**The biology curriculum content that is set out in policy and guidance documents should enable coherent learning progression from age 5-19.**	If the biology curriculum is defined in a series of stages or age ranges, there should be continuity between earlier and later stages. It should be possible to see how understanding of key concepts and development of key competencies is expected to progress from the start to the end of each stage, and from each age range to the next (including across transition points between school levels). To avoid overload, each concept or competency should earn its presence and age-appropriate position in the curriculum as part of a learning progression, building on prior learning and/or building a foundation for further study.

4	**The biology curriculum should provide pupils of all ages with ample opportunities to engage in practical and investigative work, including in the field.**	Biological science relies upon the collection of observations and measurements to develop scientific explanations for biological phenomena, and this is often a practical endeavour. Practical work can be used purposefully in school biology lessons to develop pupils' scientific knowledge and understanding of the biological world, their ability to use scientific equipment and follow standard practical procedures, and their understanding of scientific approaches to enquiry[4]. It may also increase pupils' engagement and motivation[5], and help to develop transferrable skills and attributes such as communication, teamwork and perseverance[6]. There is substantial research evidence suggesting that fieldwork helps pupils to develop their knowledge and skills in ways that add value to their experiences in the classroom[7].
5	**The biology curriculum should provide pupils of all ages with ample opportunities to learn about plants and other organisms, in addition to humans and other animals.**	A focus on, or preference for, learning about animals (zoocentrism) has been reported in pupils[8], teachers[9] and textbooks[10], and there is a 'leaky pipeline' of plant science undergraduates and workers[11]. As a result, there have been high-level calls for the increased inclusion of plant-related learning opportunities in all levels of the biology curriculum[12, 13] to help overcome 'plant blindness'[14] by fostering increased engagement with and knowledge of plants and other organisms.
6	**The development of biology curriculum policy, guidance and content should draw upon previous curriculum development work and evidence from research, where appropriate.**	The designers of a new biology curriculum should not start from scratch. Much work has been put into the development and revision of curricula, including for the nations of the United Kingdom, and lessons have been learnt from their implementation[15]. With some caution, inspiration may be taken from comparisons with high-performing international jurisdictions[16]. There exists a large body of published research into children's understanding of biology and the effective sequencing of ideas; accessible summaries have been provided by Project 2061 (American Association for the Advancement of Science[17]), Rosalind Driver and colleagues[18], and the Best Evidence Science Teaching project (University of York Science Education Group[19]), amongst others.
7	**The biology curriculum content set out in policy and guidance documents should be clear, teachable and assessable, while allowing scope for innovation in delivery.**	The biology curriculum should be expressed with sufficient clarity to facilitate good alignment between it and the various mediating and assessment instruments that will be created based upon it, including lessons, teaching resources, textbooks, specifications and examinations. This requires striking a balance between specifying without ambiguity what is expected to be taught and allowing sufficient scope for rich contextualisation and innovative teaching and assessment approaches.
8	**The biology curriculum should be contemporary yet durable.**	Biology is a fast-moving science, with ever increasing breadth and advancements of technologies relevant to biological sciences and interdisciplinary areas in the sciences. The biology curriculum content set out in policy and guidance documents should be up-to-date, reflecting the knowledge and practices of the contemporary biological sciences, but it should also be expressed in sufficiently future-proof terms to reduce the need for regular updates of the curriculum and the disruption this causes in schools.

These recommendations informed our development of the curriculum framework and exemplification presented in the rest of this document.

The three dimensions

There are three '**dimensions'** to our biology curriculum framework:

- **Practices of Biology (*biology as a science)*:** developing young people's understanding of characteristic ways in which biological scientists work, think and reason, including how they construct scientific explanations based on evidence.
- **Concepts of Biology (*core concepts of biology)*:** developing young people's understanding of a body of key ideas and explanations about the structures, functions and interactions of organisms and their environments, which help us to understand the living world.
- **Applications of Biology (*biology in the world)*:** developing young people's understanding of how biological knowledge can be used in real-world applications, and impacts of this on society, human wellbeing and the environment.

Understanding of all three dimensions should be developed in all age ranges. It is expected that teaching and learning about the first and third dimensions will be integrated into the second, in contexts related to the core concepts, and not taught as discrete areas.

The big questions and themes

The **big questions** of biology in our framework were inspired by the 'big ideas of science education' proposed by Wynne Harlen and colleagues[20]. Young people's understanding of each big idea must be built up gradually through appropriately-sequenced study[21]. Each **theme** in our framework is intended to comprise one or more learning progressions – sequences of ideas and key concepts that develop understanding of answers to the big questions, and that increase in depth and complexity as children progress through their biology education from age 5-19.

The power of the themes is that they represent learning progressions. Pupils' understanding within each theme is developed across several, but not necessarily all, age ranges. All of the themes introduced in the 5-11 portion of the framework continue in the 11-16 portion. Some new themes, such as cell structure and function, are introduced at 11-16. All of the themes continue into the 16-19 portion of the framework.

Why 'big questions' rather than 'big ideas'?

We want the framework to work at all stages of the biology curriculum, from age 5-19. 'Big ideas' may not be the best way to organise the curriculum in the lower levels, as a sound understanding of each big idea may not be achieved until later in the curriculum when pupils have studied a good portion of the concepts that make up the idea. The big questions in our framework are worded such that they could be asked and explored by anybody with any level of understanding of biology. It is intended that within each stage or age range of the curriculum, big questions are explored at an appropriate level for a person of that age, and can be expanded upon in later stages

Why develop a new organisational framework for the biology curriculum?

The RSB works with awarding organisations, governments, and schools as appropriate to develop curricula and qualifications. Our aim in developing the curriculum framework has been to ensure improved coherence and learning progression throughout compulsory education and post-16 and to inform future curriculum reviews and qualification reform. Our framework is intended to illustrate how the content of the biology curriculum could be organised into a series of learning progressions (our 'themes') that help to build answers to big questions of biology. It is hoped that this will help to promote understanding of how the many concepts taught in lessons link together to build understanding of big ideas of biology.

The framework and the development of general, technical and vocational courses

The framework is designed to inform the development of a broad and balanced 5-19 biology curriculum. It intended to be used during future curriculum reviews to guide the organisation and development of biology curriculum policy and guidance documents that will be the basis for general, technical and vocational courses for young people up to age 19. The RSB has already used the framework as part of discussions on the development of the new Curriculum for Wales, Scotland's Curriculum for Excellence and the new T Level programmes in England.

We expect that courses leading to general qualifications (e.g. GCSE and A level courses in England, Wales and Northern Ireland, and National, Higher and Advanced Higher courses in Scotland) will develop pupils' understanding across all seven big questions and 23 themes of the framework. The study of biology at post-16 should support students in understanding biology content and developing a range of skills during the process. Technical and vocational courses, or post-16 courses aiming to cover a narrower area of biology, may focus on particular big questions or sets of themes within this framework. Some of the skills will be specific to the study of biology whilst others will be transferable skills in a variety of contexts, supporting pupils to continue with further education in the sciences as well as support them within society and the world of work.

An exemplification of our curriculum framework

Appendices 3A, 3B and 3C present an exemplification of how our curriculum framework could be furnished with content for ages 5-11, 11-16 and 16-19 respectively, with a particular focus on progression across age-ranges.

The exemplification is intended to illustrate how new or existing curriculum content can be reorganised according to the 'big questions' framework and updated with a particular focus on learning progression across age-ranges. It is not intended to demonstrate learning progression within an age-range or suggest a teaching order.

A note about the content statements (left-hand column):

The content statements in the exemplification were not written from scratch; we used the content statements of the current National Curriculum programmes of study[22] and subject content criteria[23] for biology in England as a starting point, followed by mapping and drawing on curricula and qualifications in Scotland, International Baccalaureate and, where appropriate, drawing on international curricula. These statements were organised according to, and helped to refine, the big questions and themes of our framework.

The statements within each theme were then amended as required to ensure they were age appropriate, up-to-date, and scientifically correct, clear, and assessable. Statements that were not key parts of the learning progression in each theme were deleted to reduce the content load, and new statements were written only when completely necessary to enable coherent learning progression.

A note about the narrative accompanying the content statements (right-hand column):

It has been suggested[24] that presenting curriculum content as a series of "explanatory stories" helps to link sets of ideas and ensures that the emerging holistic understanding is not lost in the granularity of the content statements.

Thus, the content for each theme is accompanied by a narrative that summarises in prose the ideas we expect pupils to explore by the end of each age range.

Summary of expected learning at ages 5-11

The following short paragraphs encapsulate the RSB's view of the ideas that pupils should explore within each theme during their 5-11 biology education. Further detail is provided in the exemplification presented in Appendix 3A.

DIMENSION: Practices of Biology (Biology as a science)

BIG QUESTION: How do we study the biological world? — AGES 5-11

Asking questions about the biological world

The study of the biological world can be prompted by asking questions, some of which are more amenable to scientific investigation than others. Biologists try to answer questions by developing explanations based on evidence from data (observations and measurements) provided by scientific enquiries.

Planning practical experiments and investigative work

Biologists plan scientific enquiries, including practical experiments and investigative work, to collect data in a variety of settings, including in the field, in a safe, ethical and repeatable way. Scientific enquiries may aim to answer a question, or test a prediction, about a biological phenomenon.

Carrying out practical experiments and investigative work

Biologists collect data in a variety of settings, including in the field, using practical experiments and investigative work. They work safely, ethically and in an objective and repeatable way.

Analysing, interpreting and evaluating data

Before biologists can draw conclusions, the data they have collected have to be processed, interpreted, analysed and evaluated, which may be done qualitatively or quantitatively.

Developing explanations, classification systems and models

A cycle of collecting and analysing data provides evidence that enables biologists to develop and improve scientific explanations, classification systems and models. These can help to make sense of biological phenomena and answer questions about the biological world.

Communicating information and engaging in evidence-based arguments

Biologists communicate about their work with a range of audiences within and beyond the scientific community. This enables people to talk about scientific issues and make decisions about them based on evidence.

DIMENSION: Concepts of Biology (Core concepts of biology)

BIG QUESTION: What are organisms and what are they made of? AGES 5-11

Defining life

All living organisms need particular things to stay alive and they carry out characteristic processes as part of a life cycle. This separates them from things that are dead and things that have never been alive.

Cell structure and function

This theme is introduced at ages 11-14.

Tissues, organs and systems

Humans, other animals and plants are made up of parts, including tissues, organs and organ systems, with distinct functions; these parts work together to help the organism stay alive.

Biochemistry

This theme is introduced at ages 11-14.

BIG QUESTION: How do organisms grow and reproduce? AGES 5-11

Reproduction, growth and development

Reproduction is one of the characteristic life processes of living organisms, in which they produce new individuals of the same kind. Different types of living organisms have different life cycles and reproductive strategies, and change as they grow and age.

Inheritance and the genome

This theme is introduced at ages 11-14.

BIG QUESTION: Why are organisms so different? AGES 5-11

Variation, adaptation, evolution

Different habitats provide the basic needs of all living things that live there. Organisms have become adapted in different ways to survive within their environment. The characteristics of groups of living things change over generations by a process of evolution.

Classification

Organisms can be identified and classified into groups in different ways by observing their similarities and differences. Classification keys can be used to help group and identify a wide variety of organisms.

BIG QUESTION: How do organisms stay healthy? AGES 5-11

Physical and mental health

Humans and other animals have physical and mental health, which ranges from good to ill health. Both are affected positively and negatively by environment and lifestyle. In medical emergencies, knowing what to do saves lives.

Health and human lifestyles

Diet and exercise affect the mental and physical health of humans and other animals. Making positive lifestyle choices helps humans stay as healthy as possible. Some lifestyle choices, such as using drugs including nicotine and alcohol, have a negative impact on how the human body functions.

Health and infectious disease

Some diseases in humans, other animals and plants are caused by germs. Germs are so small we cannot usually see them, but they spread between living things. Preventing the spread of germs by basic hygiene and through vaccination is very important for human health and wellbeing.

BIG QUESTION: How do organisms live together? AGES 5-11

Interdependence of organisms

All living organisms need food and other nutrients to stay alive; plants can make their own food while animals (including humans) must eat other organisms. Food chains are used to represent the feeding relationships between organisms.

Environmental interactions and processes

There are a wide range of habitats which change over time and with seasonal variation. These changes affect the organisms that live there in positive and negative ways.

Biodiversity and human impacts

Human actions affect local and global habitats, and the organisms that live there, in both positive and negative ways. Some of our actions affect organisms that we depend on for food and other resources.

DIMENSION: Applications of Biology (Biology in the world)

BIG QUESTION: How do people use biological knowledge?

AGES 5-11

Developing applications to promote health and environmental wellbeing

Biological knowledge is applied to develop new products, technologies and processes intended to promote health and wellbeing, and which improve the ways in which we interact sustainably with our environment.

Evaluating impacts of biological knowledge and its applications

When considering the use of biological knowledge, we must weigh up the benefits, risks and ethical issues associated with its use, to enable evidence-based decisions to be made.

Influencing society

Biological knowledge can change the behaviour of individuals and groups of people. It enables them to make decisions based on understanding and evidence, which may affect their health and the wellbeing of other organisms and the environment. Biologists work alongside other disciplines (including physics, chemistry, history, mathematics, engineering, design and technology, geography, theology, music and the arts) to address Big Questions and real-world problems.

Summary of expected learning at ages 11-16

The following short paragraphs encapsulate the Royal Society of Biology's view of the ideas that pupils should explore within each theme during their 11-16 biology education. Further detail is provided in the exemplification presented in Appendix 3B.

DIMENSION: Practices of Biology (Biology as a science)

BIG QUESTION: How do we study the biological world? — AGES 11-16

Asking questions about the biological world

The study of the biological world can be prompted by asking questions, some of which are more amenable to scientific investigation than others. Biologists try to answer questions by developing explanations based on evidence from data (observations and measurements) provided by scientific enquiries.

Planning practical experiments and investigative work

Biologists plan scientific enquiries, including practical experiments and investigative work, to collect data in a variety of settings, including in the field, in a safe, ethical and repeatable way. Scientific enquiries may aim to answer a question, or test a hypothesis or prediction, about a biological phenomenon.

Carrying out practical experiments and investigative work

Biologists collect data in a variety of settings, including in the field, using practical experiments and investigative work. They work safely, ethically and in an objective and repeatable way.

Analysing, interpreting and evaluating data

Before biologists can make inferences and draw conclusions, the data they have collected have to be processed, interpreted, analysed and evaluated, which may be done qualitatively or quantitatively.

Developing explanations, classification systems and models

A cycle of collecting and analysing data provides evidence that enables biologists to develop and improve scientific explanations, classification systems and models. These can help to make sense of biological phenomena and answer questions about the biological world.

Communicating information and engaging in evidence-based arguments

Biologists communicate about their work with a range of audiences within and beyond the scientific community, to facilitate evidence-informed debate and decision-making.

DIMENSION: Concepts of Biology (Core concepts of biology)

BIG QUESTION: What are organisms and what are they made of? AGES 11-16

Defining life

All living organisms need particular things to stay alive and they carry out characteristic processes as part of a life cycle. Life is a property that emerges when biological structures are organised and work together in an integrated way to support the functioning of an organism.

Cell structure and function

All organisms are made up of cells. There are similarities and differences between the structures of prokaryotic and eukaryotic cells. Our understanding of cell structures and their functions has been developed using microscopy.

Tissues, organs and systems

To stay alive, cells constantly need energy and molecules for chemical reactions, and they need to get rid of waste. The structures and organisation of cells, tissues, organs and organ systems in multicellular organisms are adapted to their functions of supporting the needs of cells.

Biochemistry

Chemical reactions that make and break down substances take place all the time in living organisms. Photosynthesis and cellular respiration are important chemical processes that occur within living cells. The rate of many chemical reactions in living organisms is controlled by enzymes.

BIG QUESTION: How do organisms grow and reproduce? AGES 11-16

Reproduction, growth and development

Organisms grow by increasing the number and size of their cells. Organisms develop as their cells, tissues and organs become specialised for particular functions. Asexual reproduction leads to populations of genetically identical individuals. Sexual reproduction leads to variation in populations due to the combination of genetic material from female and male gametes.

Inheritance and the genome

Each generation of organisms inherits characteristics from the one before, which arise from genetic information stored in the DNA of the genome and are affected by the environment. Understanding the genome has important implications for healthcare, biotechnology, agriculture and classification.

BIG QUESTION: Why are organisms so different? AGES 11-16

Variation, adaptation, evolution

The characteristics of groups of organisms change and evolve over generations. Biologists explain this using ideas about variation, competition and the natural selection of individuals better adapted to survive and pass advantageous traits to subsequent generations. The diversity of organisms is the result of evolution by natural selection.

Classification

Organisms can be identified and classified into a hierarchy of groups based on their similarities and differences, which helps us make sense of the great diversity of organisms, living and extinct.

BIG QUESTION: How do organisms stay healthy? AGES 11-16

Physical and mental health

Health is not just the absence of disease. It is a measure of an individual's ability to function and cope with physical, emotional, environmental and social challenges. The physical and mental health of an individual organism results from interactions between the organism's body, behaviour, environment and other organisms. Ill health can be treated in various ways.

Health and human lifestyles

The risk of an individual developing non-communicable diseases depends on interacting factors including the information stored in their genome, their environment and aspects of their lifestyle. A number of lifestyle factors affect physical and mental health in positive and negative ways.

Health and infectious disease

Some diseases in humans, other animals and plants are infectious, caused by a variety of pathogens. Effective prevention or treatment of a communicable disease depends on identification of the disease, the pathogen causing it and how it is spread.

BIG QUESTION: How do organisms live together? AGES 11-16

Interdependence of organisms

Populations of organisms living in the same place interact to make up a community. Feeding relationships are one aspect of interdependence within ecosystems. An ecosystem is made up of a biological community and the physical environment in which the community lives and upon which it depends.

Environmental interactions and processes

A constant interplay exists between the biotic (living) and abiotic (non-living) components of ecosystems. Substances essential to life, including water and carbon, cycle through the biotic and abiotic components of ecosystems.

Biodiversity and human impacts

Biodiversity can be measured at genetic, species and ecosystem level. Human actions affect local and global ecosystems in both positive and negative ways. Biodiversity loss and sustainability affect the security of our supplies of food and other resources.

DIMENSION: Applications of Biology (Biology in the world)

BIG QUESTION: How do people use biological knowledge? AGES 11-16

Developing applications to promote health and environmental wellbeing

Biological knowledge is applied to develop new products, technologies and processes intended to promote health and wellbeing, and which improve the ways in which we interact sustainably with our environment.

Evaluating impacts of biological knowledge and its applications

When considering the use of biological knowledge, we must weigh up the benefits, risks and ethical issues associated with its use, to enable evidence-based decisions to be made.

Influencing society

Biological knowledge can change the behaviour of individuals and groups of people, including organisations and governments. It enables them to make decisions based on understanding and evidence, which may affect the wellbeing of people, other organisms and the environment. Biologists work alongside other disciplines (including physics, chemistry, history, mathematics, engineering, design and technology, geography, theology, music and the arts) to address Big Questions and real-world problems.

Summary of expected learning at ages 16-19

The following short paragraphs encapsulate the Royal Society of Biology's view of the ideas that pupils should explore within each theme during their 16-19 biology education. Further detail is provided in the exemplification presented in Appendix 3C.

DIMENSION: Practices of Biology (Biology as a science)

BIG QUESTION: How do we study the biological world? — AGES 16-19

Asking questions about the biological world

The study of the biological world can be prompted by asking questions, some of which are more amenable to scientific investigations than others. Biologists try to answer questions by developing explanations based on evidence from data (observations and measurements) provided by scientific enquiries.

Planning practical experiments and investigative work

Biologists plan scientific enquiries, including practical experiments and investigative work, to collect data in a variety of settings, including in the field, in a safe, ethical and repeatable way. Scientific enquiries may aim to answer a question, or test a hypothesis or prediction, about a biological phenomenon.

Carrying out practical experiments and investigative work

Biologists collect data in a variety of settings, including in the field, using practical experiments and investigative work. They work safely, ethically and in an objective and repeatable way.

Analysing, interpreting and evaluating data

Before biologists can make inferences and draw conclusions, the data they have collected have to be processed, interpreted, analysed and evaluated, which may be done qualitatively or quantitatively.

Developing explanations, classification systems and models

A cycle of collecting and analysing data provides evidence that enables biologists to develop and improve scientific explanations, classification systems and models. These can help to make sense of biological phenomena and answer questions about the biological world.

Communicating information and engaging in evidence-based arguments

Biologists communicate about their work with a range of audiences within and beyond the scientific community, to facilitate evidence-informed debate and decision-making.

DIMENSION: Concepts of Biology (Core concepts of biology)

BIG QUESTION: What are organisms and what are they made of? AGES 16-19

Defining life

Biologists study many levels of organisation, from molecules to ecosystems. Life is a property that emerges when the biological structures at all levels of organisation function together in an integrated way.

Cell structure and function

Prokaryotic and eukaryotic cells can be identified by the similarities and differences in their structures and ultrastructure. These differences in structure and ultrastructure are reflected in their functions.

Tissues, organs and systems

Nervous and hormonal coordination and control systems in multicellular organisms depend upon chemical and electrical changes at the cellular level. Homeostasis involves the integration of nervous and hormonal control systems to maintain a dynamic equilibrium in an organism.

Biochemistry

Cellular structures consist of different arrangements of biological molecules, including nucleic acids, carbohydrates, lipids and proteins as well as inorganic ions and water. Intracellular and extracellular reactions, including the light dependent and light independent stages of photosynthesis, and the stages of aerobic and anaerobic respiration in eukaryotic organisms, are controlled by enzymes.

BIG QUESTION: How do organisms grow and reproduce? AGES 16-19

Reproduction, growth and development

The cell cycle, including DNA replication, is tightly controlled, and mutations that result in a loss of control may lead to cancers. Genetic variation, which drives natural selection and evolution, is introduced by the independent assortment of chromosomes and crossing over during meiosis, followed by the fusing of haploid gametes.

Inheritance and the genome

Gene expression and protein synthesis are regulated by factors at transcriptional, post-transcriptional and post-translational levels that affect the proteins made, to regulate cell differentiation and function. Genome technologies enable us to sequence and alter the genomes of organisms, with applications in medicine, classification, evolutionary biology, industry and synthetic biology, although some of these applications are still controversial.

BIG QUESTION: Why are organisms so different? AGES 16-19

Variation, adaptation, evolution

Variation in living organisms, and the resulting natural selection of advantageous behavioural, physiological and anatomical adaptations, provide the basis for a scientific explanation for evolution. Explanations of evolutionary processes continue to develop as our understanding of the genome and the epigenome grows.

Classification

Historically, classification systems were based on observable features, but now a variety of technologies including genome sequencing are used to build evidence of the relationships between organisms.

BIG QUESTION: How do organisms stay healthy? AGES 16-19

Physical and mental health

Our increased understanding of the genome, stem cells and immune system is leading to a range of new therapies to support both physical and mental wellbeing. These include novel ways of producing vaccines and developing drugs to meet the challenges of responding to existing and emerging health threats.

Health and human lifestyles

Many common brain disorders, and the effects of drugs, can be explained by changes in the brain chemistry at the synapses. Many other non-communicable diseases have a global impact on human health, and a range of different strategies are being used to study and reduce their toll.

Health and infectious disease

Our increased understanding of pathogens, including their structures, infective mechanisms, mutation rate and antigen variability, together with increased understanding of passive and active immune systems, enables us to better identify and respond to infectious diseases of global significance in plants and animals.

BIG QUESTION: How do organisms live together? AGES 16-19

Interdependence of organisms

Interactions and interdependencies between organisms, including mutualism, parasitism, symbiosis, predation and herbivory, all impact on the population distribution and abundance of species within an ecosystem.

Environmental interactions and processes

There is a dynamic interaction both within and between the biotic and abiotic components of an ecosystem. Communities undergo succession, and chemical elements are cycled through the biotic and abiotic components.

Biodiversity and human impacts

Biodiversity includes genetic, species and ecosystem diversity, and both biodiversity and the factors affecting it can be measured in the field. Effective management of the conflict between the needs of the growing human population and conservation is needed to maintain biodiversity, to help ensure the sustainability of resources and food security.

DIMENSION: Applications of Biology (Biology in the world)

BIG QUESTION: How do people use biological knowledge?

AGES 16-19

Developing applications to promote health and environmental wellbeing

Biological knowledge is applied to develop new products, technologies and processes intended to promote health and wellbeing, and which improve the ways in which we interact sustainably with our environment.

Evaluating impacts of biological knowledge and its applications

When considering the use of biological knowledge, we must weigh up the benefits, risks and ethical issues associated with its use, to enable evidence-based decisions to be made.

Influencing society

Biological knowledge can change the behaviour of individuals and groups of people, including organisations and governments. It enables them to make decisions based on understanding and evidence, which may affect the wellbeing of people, other organisms and the environment. Biologists work alongside other disciplines (including physics, chemistry, history, mathematics, engineering, design and technology, geography, theology, music and the arts) to address big questions and real-world problems.

APPENDIX
ONE

01

Members of the RSB Curriculum Committee, Student Curriculum Committee and Primary Working Group

Curriculum Committee

Current members	Past members
Professor Jeremy Pritchard CSciTeach FRSB (Chair) Dr Mike Cassidy CBiol FRSB Dr Andrew Chandler-Grevatt MRSB Dr Donna Dawkins Ann Fullick CBiol FRSB Dr Dawn Hawkins Dr Carys Farrell Hughes CSciTeach MRSB Kathy Freeston MRSB Kathryn Horan Dr Neil Ingram Dr Charles Lane MRSB Dr Alistair Moore MRSB Joy Parvin Dr Claire Pike MRSB Elena Segalini-Bower MRSB Dr Natalie Vlachakis MRSB Dr Jonathan Weston MRSB Therese Osula Winthe MRSB	Professor Libby John FRSB (Chair) Professor Berry Billingsley Dr Nick Dixon Professor Stuart Ferguson Beverly Ann Goodger MRSB Dr Mark Kerrigan FRSB Dr Jennifer Koenig Professor Mariann Rand-Weaver FRSB Professor David Read Rev Professor Michael Reiss CBiol FRSB

Primary Working Group	Student Curriculum Committee
Professor Berry Billingsley Marianne Cutler FCCT FRSA Kulvinder Kaur Johal CSciTeach Dr Paula Kover FRSB Liz Lawrence CSciTeach Louise Stubberfield Joy Parvin Timothy Roberts BA Ed (QTS) MA by Research Louise Stubberfield Professor Michael Taggart BSc PhD Associate Professor Jane Turner MEd CSciTeach	Gemma Abbott BSc. Kelly Chaplin Kasha Cowles Heather Gabriela MSc Raksha Gohel MBio Harry Holmes MSci Mhairi McCann Amran Mohamed BSc MPH AFHEA Tim Weber BSc MRes Sam A. Welch MSc Dr Stephanie Zhang MBBS

The RSB would like to give special thanks to all those committee members named here involved in developing the framework, advising, refining and providing their expertise to the process and final documents. The Society sincerely appreciates the time and effort our members dedicate to the curriculum committee, its working groups and the support they continue to provide at external events and advisory groups and the ongoing work of the committee.

APPENDIX TWO

02

RSB Special Interest Groups (SIGs) and Committees

RSB SIGs and Committees

Curriculum Committee is made up of:

- assessment and curriculum development specialists;
- bioscience higher education representatives;
- education researchers;
- initial teacher training representatives;
- primary teachers;
- primary teacher specialists;
- representatives from industry;
- secondary teachers;
- secondary students;
- undergraduate students.

RSB Council

Education and Science Policy Committee (ESP)

Membership and Professional Affairs Committee (MPA)

Accreditation Committee

Biology Education Research Group (BERG)

Education Policy Advisory Group (EPAG)

Employer Advisory Group

Heads of University Biosciences (HUBS)

With thanks to The Association for Science Education, the Biochemical Society, the British Ecological Society, the British Pharmacological Society, the Gatsby Plant Science Education programme (including SAPS), the Genetics Society, the Institute of Physics, the Microbiological Society, the Royal Society, the Royal Society of Chemistry, the Salters' Institute and Wellcome for their contributions throughout the development of the 5-19 biology curriculum framework.

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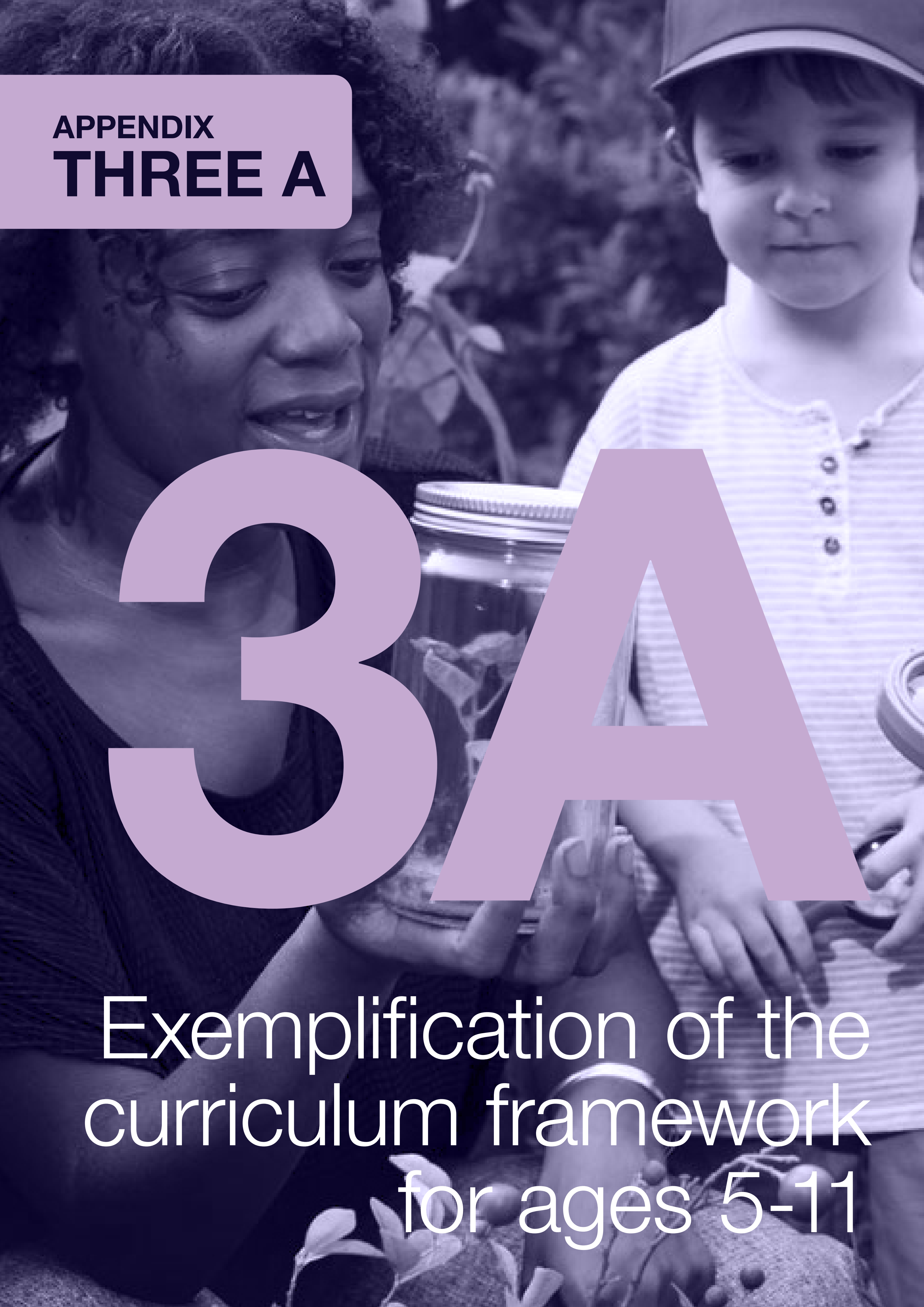


APPENDIX

THREE A

3A

Exemplification of the curriculum framework for ages 5-11

DIMENSION: Practices of Biology (Biology as a science)

BIG QUESTION: How do we study the biological world? AGES 5-11

Asking questions about the biological world

Curriculum content (5-11):

Throughout their studies, pupils should have opportunities to:

- generate their own questions and consider how they could be answered
- identify questions that could be answered using a scientific approach to collect data (observations and measurements)
- ask questions and develop lines of enquiry based on observations of the biological world, alongside prior knowledge and experience

The study of the biological world can be prompted by asking different kinds of questions. Some questions are more amenable to science than others. Biologists try to answer questions by developing explanations based on evidence from data (observations and measurements) provided by scientific enquiries. The tools that biologists have available to collect evidence determine which questions can be investigated. This means there are limits to what science can help us to explain. Answering some questions about the biological world requires us to draw upon knowledge and expertise from other disciplines across the fields of science, technology, engineering, mathematics and other subjects.

Planning practical experiments and investigative work

Curriculum content (5-11):

Throughout their studies, for different types of investigations, pupils should have opportunities to:

- select and plan appropriate scientific enquiries to help answer questions or test predictions
- generate their own testable predictions
- identify appropriate measurement to be taken, including ranges and intervals and the need for repeat measurements
- identify factors that need to be controlled, and ways in which they can be controlled
- identify and describe appropriate methods and tools (apparatus, instruments and technology) that can be used to collect data in a repeatable way
- evaluate risks associated with a data collection strategy
- compare the strengths and weaknesses of different investigative designs

Biologists plan scientific enquiries, including practical experiments and investigative work, to collect data (observations and measurements) in the classroom and in the field. The data may provide evidence that helps the biologist to answer a question or develop an explanation for a biological phenomenon.

Some types of scientific enquiry start by generating a prediction about how a change in a factor will affect the outcome. A plan is then produced to test the prediction by collecting appropriate data.

A plan for a scientific enquiry describes how to collect data in a safe, ethical way, using appropriate methods and tools (apparatus, instruments and technology). Scientific enquiries are designed and described so that they can be repeated by the experimenter and by others.

Carrying out practical experiments and investigative work

Curriculum content (5-11):

Throughout their studies, for different types of investigations, pupils should have opportunities to:

- use appropriate methods, tools (apparatus, instruments and technology), and materials to collect data in the laboratory and in the field
- work safely
- minimise harm to living organisms and disruption of ecosystems
- work with objectivity
- work carefully to avoid mistakes
- work in a repeatable way
- record data in appropriate formats

Biologists carry out scientific enquiries, including practical experiments and investigative work, to collect data (observations and measurements) in the classroom and in the field. The data may provide evidence that helps the biologist to answer a question or develop an explanation for a biological phenomenon.

When collecting data, biologists work safely to prevent accident or injury. They work to ensure that their experiments and investigations cause as little harm as possible to living organisms and to minimise disruption of ecosystems. They work carefully to avoid mistakes. They work in ways that could be repeated by themselves and by others.

Data must be recorded in a clear and organised way, for example using an appropriate diagram or table, and include units for measured values, to facilitate analysis and interpretation.

Analysing, interpreting and evaluating data

Curriculum content (5-11):

Throughout their studies, for primary and secondary data, and for different types of investigations, pupils should have opportunities to:

- use data to plot appropriate charts and graphs
- read values from charts and graphs
- convert measurements into different units (e.g. cm into mm)
- combine and use data from different sources (e.g. class sets)
- process measurements mathematically (e.g. calculating an average)
- interpret data in tables, charts and graphs to identify patterns and trends
- identify measurements that don't appear to fit a pattern or trend
- comment on the repeatability and reproducibility of data
- comment on whether data agree with a prediction
- draw conclusions from data
- suggests ways to collect better data, and identify further questions for investigation

Before biologists can draw conclusions, the data they have collected have to be processed, interpreted, analysed and evaluated.

Data can be analysed qualitatively, or quantitatively using mathematical methods. Displaying data graphically can help to show trends and patterns.

Combined data sets (e.g. pooled class data, year-on-year data, and citizen science projects) can provide additional insights.

Many factors can affect the repeatability and reproducibility of data, and these must be evaluated and taken into account when conclusions are made.

Data may agree or disagree with a prediction. In either case, we may choose to test the prediction further by carrying out additional investigations.

Developing explanations, classification systems and models

Curriculum content (5-11):

Throughout their studies, pupils should have opportunities to:

- suggest explanations for patterns and trends in primary and secondary data, including cause-effect links
- identify and classify things in the biological world based on evidence of their similarities and differences
- use scientific models to explain complicated ideas and to make predictions

Scientific explanations, classification systems and models can help us to answer questions about the biological world and make sense of it.

Biologists develop scientific explanations from evidence provided by data. Things in the biological world can be identified and classified based on evidence of their similarities and differences that can be seen with the unaided eye or with a microscope. Scientific models represent things in the real world, and may be simple or detailed. They are used to explain complicated ideas, and to make and test predictions.

Scientific explanations, classification systems and models are continually tested by collecting new data, and they may be changed over time to make sure they are the best possible fit for the available evidence.

Communicating information and engaging in evidence-based arguments

Curriculum content (5-11):

Throughout their studies, pupils should have opportunities to:

- engage with scientific information presented in a range of formats
- present scientific methods, data, ideas and implications in a range of formats, including written, oral and audio-visual, for a range of audiences
- identify and use evidence from data to support arguments and make decisions

Biologists communicate about their work with a range of audiences beyond the scientific community, including members of the public and the government. This enables people to talk about scientific issues and make decisions about them based on evidence.

DIMENSION: Concepts of Biology (Core concepts of biology)

BIG QUESTION: What are organisms and what are they made of? AGES 5-11

Defining life

Curriculum content (5-7):
- identify what humans and some other familiar animals need to stay alive (including water, food and air)
- identify what some familiar land plants need to stay alive (including water, light, air and a suitable temperature)

Curriculum content (7-11):
- all living organisms are made of substances, including water, oxygen, carbon dioxide and sugars
- recognise that there are some characteristic processes that take place in all living organisms at some point in their life cycle (including movement, growth, reproduction, nutrition, excretion and sensitivity)
- explore and compare the differences between things that are living, dead and things that have never been alive

At 5-11 pupils should be introduced to the basic requirements for life and the processes carried out by all living things in order to distinguish between things that are living, dead and never been alive.

Cell structure and function

This theme is introduced at ages 11-14.

Tissues, organs and systems

Curriculum content (5-7):
- identify and describe the basic parts of the human body and say which part of the body is associated with each sense
- describe and compare the basic structure of a variety of common animals (fish, amphibians, reptiles, birds and mammals)
- identify and describe the basic structure of a variety of common flowering plants, including trees

Curriculum content (7-11):
- identify that humans and some other animals have skeletons and muscles for support, protection and movement
- describe the simple functions of the basic parts of the digestive system in humans including the function of teeth and how to look after them
- identify and describe the functions of different parts of flowering plants: roots, stem/trunk, leaves and flowers
- explore and observe the way in which water is transported within plants
- identify, name and describe the main parts of the human circulatory system including the functions of the heart, blood vessels and blood

At 5-11, pupils should learn that the bodies of humans and other animals are made up of different parts with different functions, including senses, musculo-skeletal system, digestive system and cardiovascular system. Flowering plants are also made up of parts with different functions.

Biochemistry

This theme is introduced at ages 11-14.

BIG QUESTION: How do organisms grow and reproduce? AGES 5-11

Reproduction, growth and development

Curriculum content (5-7):

- observe that plants and animals, including humans, have offspring which grow into adults of the same kind
- explore, observe and describe how seeds and bulbs grow into mature plants

Curriculum content (7-11):

- observe that living things produce offspring of the same kind, but normally offspring vary and are not identical to their parents
- observe and describe the life cycle and reproductive strategies of a variety of flowering plants, including pollination, fruit formation and seed dispersal
- describe and compare the life cycles and reproductive strategies of mammals (including humans), amphibians, insects and birds
- describe the changes as humans grow and develop from birth to old age, including puberty

At 5-11, pupils should learn that reproduction is one of the characteristic life processes of living organisms, in which they produce new individuals of the same kind.

They should explore the life cycles and reproductive strategies of different organisms including mammals, amphibians, insects and birds, and in different groups of plants.

Flowering plants can reproduce when flowers are pollinated to form seeds.

Humans and other animals reproduce when a female individual and a male individual come together to produce offspring. The offspring of humans and other mammals grow inside the mother until they are developed enough to be born, while the offspring of amphibians, insects and birds grow inside eggs until they are developed enough to hatch.

Inheritance and the genome

This theme is introduced at ages 11-14.

BIG QUESTION: Why are organisms so different? AGES 5-11

Variation, adaptation, evolution

Curriculum content (5-7):

- describe different habitats and how they provide for the basic needs of different kinds of animals and plants
- identify that most living things live in habitats to which they are suited

Curriculum content (7-11):

- identify why animals and plants live and grow in different habitats, and how they are adapted to suit their environments in different ways
- understand that the characteristics of groups of living things change over time and that this is called evolution
- recognise that fossils provide information about living things that lived on the Earth tens of thousands to billions of years ago
- recognise that groups of organisms that are poorly adapted to their environment may become extinct

At 5-11, pupils should learn that there are many different kinds of living things in the world and that organisms live in habitats in which they are suited. Animals that are poorly adapted to their environment may die out. We can learn about such animals through the existence of fossils. The characteristics of populations changes over generations in response to changes in the environment, this process is called evolution. Characteristics are passed from parents to offspring.

Classification

Curriculum content	
Curriculum content (5-7): • identify and name a variety of common animals including invertebrates (e.g. worms and insects) and vertebrates (e.g. fish, amphibians, reptiles, birds and mammals) • identify and name a variety of common wild and garden plants, including deciduous and evergreen trees • identify and name a variety of plants and animals in their habitats, including micro-habitats (e.g. soil, tree, bush, window box, pond)	At 5-11, pupils should learn the names of common animals and plants including fish, amphibians, reptiles, birds and mammals and where they might be found. They should learn that organisms can be classified using their similarities and differences.
Curriculum content (7-11): • recognise that organisms can be grouped in a variety of ways including groups within bigger groups • explore and use classification keys to help group, identify and name a variety of organisms in their local and wider environment	

BIG QUESTION: How do organisms stay healthy? AGES 5-11

Physical and mental health

Curriculum content	
Curriculum content (5-7): • know that humans have physical health and mental health • describe ways in which animals, including humans, stay happy and well • instructions on how to respond in a medical emergency	At 5-11, pupils should learn that the physical health and the mental health of an organism can range from good to ill. A person's environment and lifestyle can affect the functions of the human body, and therefore their physical and mental health, in positive and negative ways. Medicines can be used to treat ill health, by reducing the symptoms or eliminating the cause. *these themes are explored further in *Health and human lifestyle*
Curriculum content (7-11): • know that the health of organisms can range from good to ill, including physical and mental health in humans • suggest ways in which diet, exercise and behaviour can affect physical and mental health in animals, including humans • describe the role of medicines in curing or treating ill health • instructions on how to respond when somebody collapses	

Health and human lifestyle

Curriculum content (5-7): • know that diet and exercise affect our physical and mental health • identify different types of food that animals, including humans, need to stay healthy • describe different ways in which animals, including humans, move about and why **Curriculum content (7-11):** • describe the importance of exercise for humans • describe the importance of a balanced diet for animals, including humans • recognise the impact of smoking, alcohol and other drugs on the way human bodies function	At 5-11, pupils should learn that some diseases cannot be passed from one person to another; they are caused by the person's lifestyle and behaviour and that eating too much or too little of particular foods, lack of exercise, smoking, and drinking alcohol can lead to physical and mental ill health. Changes in lifestyle and behaviour can help to prevent ill health or reduce its effects.

Health and infectious disease

Curriculum content (5-7): • explain that ill health can be caused by germs, which can be spread between living things • know that germs are very small, so they usually can't be seen • describe the importance of hygiene for human health **Curriculum content (7-11):** • recognise that there are different types of germs, including bacteria and viruses • describe how to prevent germs in food from making us ill, by refrigeration and cooking • describe the use of vaccinations to protect us from germs that cause diseases	At 5-11, pupils should learn that some diseases in humans, other animals and plants are caused by infection by germs, including some bacteria and viruses. Germs can be passed from one organism to another and that good personal hygiene can help to prevent ill health by removing germs. Proper refrigeration and cooking of food can help to prevent germs in food from making us ill. Vaccinations help the body to fight the germs that cause some diseases

BIG QUESTION: How do organisms live together? AGES 5-11

Interdependence of organisms

Curriculum content (5-7): • know that plants can make their own food but animals, including humans, obtain their food by eating plants and other animals • identify and name different sources of food • use the idea of a simple food chain in relation to their own diet and that of familiar animals • know that some animals only eat other animals, some only eat plants and some eat both	At 5-11, pupils should learn that organisms need food and other nutrients to survive. They should learn that plants can make their own food whilst animals, including humans, get their food by eating other organisms and are either herbivores, carnivores or omnivores. Pupils should be introduced to food chains as a way of representing the feeding relationships between organisms.
Curriculum content (7-11): • construct and interpret a variety of food chains of different lengths involving common plants and animals • understand the differences between producers and types of consumers, for example predators, scavengers and prey	

Environmental interactions and processes

Curriculum content (5-7): • observe biological changes across the four seasons • observe and describe weather associated with the seasons and how day length varies	At 5-11, pupils should explore the meaning of the word habitat and will learn about a range of different habitats. They should learn that animals are adapted to live in a particular habitat and that habitats change over time.
Curriculum content (7-11): • recognise that environments can change and that this affects the organisms that live there in positive and negative ways • distinguish between daily, seasonal and longer term changes in environments	

Biodiversity and human impacts

Curriculum content (5-7): • explore ways in which human actions affect local habitats, and the organisms that live there, in positive and negative ways	At 5-11, pupils should explore ways in which human actions affect a range of local and global habitats, and the organisms that live there, in both positive and negative ways. Some of our actions affect organisms that we depend on for food and other resources.
Curriculum content (7-11): • recognise that human actions affect a range of habitats, and the organisms that live there, in positive and negative ways, including habitats and organisms that we depend on	

DIMENSION: Applications of Biology (Biology in the world)

BIG QUESTION: How do people use biological knowledge? AGES 5-11

Developing applications to promote human and environmental wellbeing

Curriculum content (5-11):

Throughout their studies pupils should have opportunities to:

- learn about products, technologies and processes developed by applying biological knowledge
- consider applications of biological knowledge that make a positive difference to the lives of people and other organisms

Many things have been developed by applying biological knowledge, which improve our lives, including our health and wellbeing. Biologists also devise ways of improving the welfare of animals and plants in our care, and conserving nature.

Evaluating impacts of biological knowledge and its applications

Curriculum content (5-11):

Throughout their studies pupils should have opportunities to:

- identify risks, benefits and costs, for different groups of people and the environment, associated with applications of biological knowledge
- identify issues associated with applications of biological knowledge

All applications of biological knowledge (including products, technologies and processes) have risks, and many have benefits. To make a decision about a particular application of biological knowledge, we must take account of both the risks and benefits to different groups of people, other organisms and the environment.

Some applications of biological knowledge have ethical and moral implications. Decisions about these applications cannot be made on the basis of scientific evidence alone and will depend in part on judgements based on individual and societal values.

Influencing Society

Curriculum content (5-11):

Throughout their studies pupils should have opportunities to:

- consider ways in which biological knowledge changes people's behaviour, including the decisions they make and how they interact with other organisms and the environment

Biological knowledge can change the behaviour of individuals and groups of people. It enables them to make decisions based on understanding and evidence, which may affect their health and the wellbeing of other organisms and the environment. Biologists keep abreast of recent advances in our understanding of the biosciences and work alongside other disciplines (including physics, chemistry, history, mathematics, engineering, design and technology, geography, theology, music and the arts) to address Big Questions and real-world problems.

APPENDIX
THREE B

3B

Exemplification of the curriculum framework for ages 11-16

DIMENSION: Practices of Biology (Biology as a science)

BIG QUESTION: How do we study the biological world? AGES 11-16

Asking questions about the biological world

Curriculum content (11-16):

Throughout their studies, pupils should have opportunities to:

- generate their own questions and consider how they could be answered
- identify questions that could be answered using a scientific approach to collect data (observations and measurements)
- ask questions and develop lines of enquiry based on observations of the biological world, alongside prior knowledge and experience

The study of the biological world can be prompted by asking different kinds of questions. Some questions are more amenable to science than others. Biologists try to answer questions by developing explanations based on evidence from data (observations and measurements) provided by scientific enquiries.

The tools that biologists have available to collect evidence determine which questions can be investigated, and some questions cannot be answered until appropriate tools are developed. This means there are limits to what the sciences can help us to explore and explain. Answering some questions about the biological world requires us to draw upon knowledge and expertise from other disciplines across the fields of science, technology, engineering, mathematics and other subjects.

Planning practical experiments and investigative work

Curriculum content (11-16):

Throughout their studies, for different types of investigations, pupils should have opportunities to:

- select and plan appropriate scientific enquiries to help answer questions, test hypotheses or test predictions
- generate their own testable hypotheses and predictions
- identify independent and dependent variables
- identify appropriate measurement to be taken, including ranges, intervals and sample sizes, and the need for repeat measurements
- identify factors that need to be controlled, and ways in which they can be controlled
- identify and describe appropriate methods and tools (apparatus, instruments and technology) that can be used to collect data in a repeatable way that will maximise the accuracy and precision of measured values
- evaluate risks and ethical issues associated with a data collection strategy
- compare the strengths and weaknesses of different investigative designs

Biologists plan scientific enquiries, including practical experiments and investigative work, to collect data (observations and measurements) in the laboratory and in the field. The data may provide evidence that helps the biologist to answer a question or develop an explanation for a biological phenomenon.

Some types of scientific enquiry start by generating a hypothesis. A hypothesis can be used to make a prediction about how a change in a factor will affect the outcome. A plan is then produced to test the prediction, and the hypothesis upon which it is based, by collecting appropriate data.

A plan for a scientific enquiry describes how to collect data in a safe and ethical way, using methods and tools that will maximise the precision and accuracy of measured values. Scientific enquiries are designed and described so that they can be repeated by the experimenter and by others.

Carrying out practical experiments and investigative work

Curriculum content (11-16):

Throughout their studies, for different types of investigations, pupils should have opportunities to:

- use appropriate methods, tools (apparatus, instruments and technology), and materials to collect data in the laboratory and in the field
- work safely to minimise hazards
- work ethically, minimising harm to living organisms and disruption of ecosystems
- work with objectivity
- work to maximise the accuracy and precision of measured values
- work in a repeatable way
- record data in appropriate formats

Biologists carry out scientific enquiries, including practical experiments and investigative work, to collect data (observations and measurements) in the laboratory and in the field. The data may provide evidence that helps the biologist to answer a question or develop an explanation for a biological phenomenon.

When collecting data, biologists work safely to reduce the risk of hazards that could lead to accident or injury. They work ethically to ensure that their experiments and investigations cause as little harm as possible to living organisms and to minimise disruption of ecosystems. They work carefully to avoid mistakes, and they work with objectivity to reduce bias. They work to reduce sources of random and systematic error to increase the precision and accuracy of measured values. They work in ways that could be repeated by themselves and by others.

Data must be recorded in a clear and organised way to facilitate analysis and interpretation.

Analysing, interpreting and evaluating data

Curriculum content (11-16):

Throughout their studies, for primary and secondary data, and for different types of investigations, pupils should have opportunities to:

- translate data from one form to another, including interconverting units and graphical representation
- generate and use combined data sets
- carry out and represent mathematical processing and statistical analyses
- interpret data presented in a range of forms, including identifying patterns, trends and correlations
- identify anomalous results and outliers
- evaluate the quality of data objectively (in terms of accuracy, precision, repeatability, and reproducibility)
- identify sources of random and systematic error
- use data to evaluate predictions and the hypotheses upon which they are based
- make inferences and draw conclusions from data
- suggests ways in which the quality of data could be improved, and identify further questions for investigation

Before biologists can make inferences and draw conclusions, the data they have collected have to be processed, interpreted, analysed and evaluated.

Data can be analysed qualitatively, or quantitatively using mathematical and computational methods. Displaying data graphically can help to show trends and patterns.

Combined data sets (e.g. pooled class data, year-on-year data, and citizen science projects) can provide additional insights.

Many factors can affect the quality of data, and these must be evaluated and taken into account when inferences and conclusions are made.

Data may agree or disagree with a prediction or hypothesis. In either case, the prediction or hypothesis may be tested further by planning and carrying out additional investigations.

Developing explanations, classification systems and models

Curriculum content (11-16):

Throughout their studies, pupils should have opportunities to:

- suggest explanations for patterns, trends and correlations in primary and secondary data, including cause-effect links
- identify and classify biological entities based on evidence of their similarities and differences
- use scientific models to explain complicated ideas and to make predictions
- identify the benefits and limitations of scientific models
- learn about how scientific explanations, classification systems and models are developed and modified to account for the available evidence, using historical and contemporary examples

A cycle of collecting and analysing data provides evidence that enables biologists to develop and improve scientific explanations, classification systems and models. These can help to make sense of biological phenomena and answer questions about the biological world.

Biologists develop scientific explanations from evidence provided by data. Biological entities can be identified and classified based on evidence of their similarities and differences at the macroscopic, microscopic, molecular and genetic levels. Scientific models are used to explain complicated ideas, and to make and test predictions. The usefulness of a model is limited by how accurately it represents the real world.

Scientific explanations, classification systems and models are continually tested by collecting new data, and they may be changed over time to make sure they are the best possible fit for the available evidence.

Communicating information and engaging in evidence-based arguments

Curriculum content (11-16):

Throughout their studies, pupils should have opportunities to:

- engage with scientific information presented in a range of formats (written, numerical and graphical)
- present scientific methods, data, ideas and implications in a range of formats, including written, oral and audio-visual, for a range of audiences
- learn about ways in which biologists share data and explanations within the scientific community, including peer review, and why this is important
- learn about why biologists share data and explanations with audiences beyond the scientific community
- identify and use evidence from data to support arguments and make decisions
- evaluate information and claims related to scientific issues, from a range of sources, and decide how much confidence can be placed in them

It is important that data collected by individual biologists, and their explanations for what they have found, are shared with other scientists and checked by them. Scientists are sceptical about claims that are not based on repeatable and reproducible data.

Scientific explanations can be developed and improved using evidence and explanations from more than one scientist. Communication and debate between scientists help the scientific community to develop the best explanations for the available evidence.

Biologists communicate about their work with a range of audiences beyond the scientific community, including members of the public and the government. This enables evidence-informed debate and decision-making about scientific issues to take place.

DIMENSION: Concepts of Biology (Core concepts of biology)

BIG QUESTION: What are organisms and what are they made of? — AGES 11-16

Defining life

Curriculum content (11-14):

- all living organisms are made of cells that take in nutrients, get energy from food, get rid of waste, respond to changes in their environment, and make new cells
- in large multicellular organisms the cells are organised into tissues, organs and organ systems that work together to enable the organism to carry out life processes

Curriculum content (14-16):

- all living organisms control their internal environment, and in large multicellular organisms this depends on molecules, cells, tissues, organs and organ systems working together to achieve homeostasis
- the organisation of molecules, cells, organisms and ecosystems is adapted to allow life processes to occur

Pupils should build upon their knowledge acquired at 5-11 of the processes of living things by learning how a single cell can carry out these processes hence being the basic unit of life. They should learn how organisms can be single or multicellular and how cells can be organised together to form tissues, organs and organ systems that work together to keep the organism alive. They should learn that all living organisms control their internal environment responding to internal and external changes. In large multicellular organisms, that maintenance of a constant internal environment (homeostasis) depends on molecules, cells, tissues, organs and organ systems working together to counteract changes. It is the organisation of molecules, cells, organisms and ecosystems, adapted through natural selection, which enables life processes to occur.

Cell structure and function

Curriculum content (11-14):

- cells as the fundamental unit of living organisms, including how to observe, interpret and record cell structure using a light microscope
- the similarities and differences between plant and animal cells
- the functions of the cell wall, cell membrane, cytoplasm, nucleus, vacuole, mitochondria and chloroplasts
- the role of diffusion in the movement of materials in and between cells

Curriculum content (14-16):

- the main sub-cellular structures of eukaryotic cells (plants and animals) and prokaryotic cells and how they are related to their functions, including the nucleus/ genetic material, plasmids, mitochondria, chloroplasts, ribosomes and cell membranes
- our understanding of cell structures and their functions has been developed from observations made using light and electron microscopes
- substances move into and out of cells through diffusion, osmosis and active transport

Cell structure and function is a new concept introduced at 11-16 in which pupils should learn that in larger multicellular organisms, the arrangement of organ systems allows new characteristics and behaviours to emerge, which were not present in simpler organisms. They should learn that cells can be observed, measured, and investigated using light microscopes. These reveal similarities and differences between plant and animal cells. By 16, pupils should have learnt that living organisms can be classified into prokaryotic organisms and eukaryotic according to the structure of their cells. Eukaryotic cells are more advanced than prokaryotic cells and evolved later. They should have learnt about the differences between the structures of prokaryotic and eukaryotic cells and that these differences can be observed using electron microscopes.

Tissues, organs and systems

Curriculum content (11-14):

In complex multicellular organisms, cells are organised into tissues, tissues into organs and organs into systems.

Exchange and transport

- the structures of the human digestive system, including adaptations to function (enzymes simply as biological catalysts)
- the structures of the gas exchange system in humans, including adaptations to function
- the mechanism of breathing to move air in and out of the lungs, using a pressure model to explain the movement of gases

Coordination and control

- the structure and functions of the human skeleton, including support, protection, movement and making blood cells
- the function of muscles and examples of antagonistic muscles
- biomechanics – the interaction between skeleton and muscles, including the measurement of force exerted by different muscles

Curriculum content (14-16):

Exchange and transport

- factors such as size, surface area: volume ratio, and metabolic rate affect the requirements of organisms and this gives rise to adaptations such as specialised exchange surfaces and mass transport systems
- the adaptations of the human circulatory system to its functions
- the relationship of the circulatory system to other organ systems in the body
- the adaptations of xylem and phloem to their functions in plants
- the uptake of water and mineral ions by plants
- the processes of transpiration and translocation, including the structure and function of the stomata
- the effects of a variety of environmental factors on the rate of water uptake by a plant, including light intensity, air movement, and temperature

Coordination and control

- the adaptations of the nervous system (including sensory receptors, sensory neurones and effectors) to its functions
- the structure of a reflex arc related to its function
- the main structures of the eye, related to their functions
- common defects of the eye and how some of these problems may be overcome
- the basic structure of the brain, and functions of different regions
- the principles of hormonal coordination and control by the human endocrine system, including negative feedback
- the importance of maintaining a constant internal environment in response to internal and external control of blood sugar levels in the body by insulin and glucagon
- type 1 and type 2 diabetes and their treatments
- the control of body temperature
- the effect on cells of osmotic changes in body fluids
- the role of the kidneys and vasopressin in maintaining the water balance of the body

Pupils should build upon the ideas explored at 5-11 that the human body is made up of many parts with different functions to learn how organisms can be single or multicellular and how cells can be organised together to form tissues, organs and organ systems that work together to keep the organism alive. To stay alive, cells constantly need energy and molecules for chemical reactions, and they need to get rid of waste. The tissues and organs of the human digestive system and gas exchange system achieve this. By 16, pupils should have learnt that multicellular organisms move substances selectively into and out of their bodies at specialised exchange surfaces. The tissues and organs of the human circulatory system and plant transport system are adapted to move these substances around the organism. The tissues and organs of the human nervous system and endocrine system are adapted to respond to internal and external stimuli, and maintain homeostasis.

Biochemistry

Curriculum content (11-14):

Photosynthesis

- plants make carbohydrates in their leaves by photosynthesis
- plants take up mineral nutrients and water from the soil via their roots
- the reactants and products of photosynthesis, and a word summary of the process
- the adaptations of leaves for photosynthesis

Cellular respiration

- aerobic cellular respiration in living organisms breaks down sugars using oxygen to make energy available for life processes
- a word summary for aerobic cellular respiration

Curriculum content (14-16):

Biological molecules

- the variety of life is extensive, but all life depends on biological molecules made of carbon, hydrogen and oxygen
- biological molecules and reactions can be represented using chemical formulae
- the importance of carbohydrates, lipids and proteins and the role of sugars, amino acids, fatty acids and glycerol in the synthesis and breakdown of these molecules
- the mechanism of enzyme action including the active site, enzyme specificity and factors affecting the rate of enzyme-controlled reactions
- many biological processes require energy, which is provided by the breakdown of ATP

Photosynthesis

- a two-stage model can be used to describe the process of photosynthesis in plants and algae:
  - the first stage requires light and water
  - the second stage does not need light but uses carbon dioxide to make glucose and oxygen
- the effect of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis, and the interaction of these factors in limiting the rate of photosynthesis

Cellular respiration

- cellular respiration is a process which is continuously occurring in all living cells
- during cellular respiration ATP is made as molecules of glucose are broken down
- the process of anaerobic cellular respiration in humans and micro-organisms, including fermentation
- the differences between aerobic and anaerobic cellular respiration in terms of the reactants, the products formed and the implications for the organism

Biochemistry is a new concept introduced at 11-16. Pupils should learn that chemicals found in living organisms are involved in chemical reactions to make new products. Photosynthesis and cellular respiration are chemical processes that occur within living cells. The cells of producers make their own food using photosynthesis, a process that requires energy from light and makes carbohydrates, such as glucose. Cellular respiration breaks down chemical fuels such as glucose and makes energy available for other life processes.

By 16, pupils should have learnt that biological molecules have different shapes and structures, but all contain carbon, hydrogen and oxygen. The structure of biological molecules can be represented using chemical formulae. Chemical reactions in living cells occur because of the activities of enzymes, which are biological catalysts. Many biological processes require energy, which is provided by the breakdown of ATP, a biological molecule made during cellular respiration. Cellular respiration is therefore essential for the survival of living cells. Anaerobic cellular respiration makes less ATP than aerobic respiration but is faster, so many organisms use both forms of respiration according to their circumstances.

BIG QUESTION: How do organisms grow and reproduce? AGES 11-16

Reproduction, growth and development

Curriculum content (11-14):

Growth and development

- organisms grow by increasing the number and size of their cells
- organisms develop as their cells, tissues and organs become specialised for particular functions
- developmental changes during puberty, including the structure and function of the human female and male reproductive systems, the menstrual cycle (without details of hormones) and the development of secondary sexual characteristics

Reproduction

- sexual reproduction in humans, including fertilisation, gestation and birth
- benefits and risks of different forms of contraception
- the structure and function of reproductive systems in flowering plants
- sexual reproduction in plants, including, wind and insect pollination, fertilisation, seed and fruit formation and dispersal mechanisms
- asexual reproduction in plants, including the production of bulbs, tubers and runners

Curriculum content (14-16):

Growth and development

- the cell cycle in growth, including mitosis
- cancer as the result of changes in cells that lead to uncontrolled growth and division
- the function of stem cells in embryonic and adult animals and in meristems in plants
- stem cells mature due to the interaction of genomes and the environment
- the use of stem cells in medicine
- the importance of plant hormones in the control and coordination of plant growth and development, with reference to the role of auxins in phototropisms and gravitropisms
- the variety of effects of plant hormones, relating to auxins, gibberellins and ethene
- different ways in which humans use plant hormones to manipulate plant growth and development

Reproduction

- the role of meiotic cell division in halving the chromosome number to form gametes
- the advantages and disadvantages of asexual and sexual reproduction in a range of organisms
- the role of hormones in human reproduction, including interactions of FSH, LH, oestrogen and progesterone in the control of the menstrual cycle
- hormonal and non-hormonal methods of contraception
- the effect of female and male lifestyles on fertility and the use of hormones in modern reproductive technologies to treat infertility
- the effect of female and male lifestyles during pregnancy on the growth and development of the foetus

At 11-16, pupils should build upon prior learning of life cycles to explore the changes that occur during puberty. They should learn that new cells are created by mitosis. A zygote divides by mitosis to form an embryo.

They should learn that cancer is a non-communicable disease caused by changes to a person's DNA resulting in uncontrolled cell division.

Most cells become specialised and unspecialised cells are called stem cells.

In plants, only cells in the meristems undergo mitosis, producing unspecialised cells that can develop into any kind of plant cell. Plants are able to respond to their environment in different ways that are controlled and coordinated by plant hormones.

Building upon previous understanding from 5-11, pupils should learn more about the structures and functions of reproductive systems in humans and flowering plants. They should learn about asexual reproduction in plants, and about the role of meiosis and gametes in sexual reproduction in humans and plants.

Gametes contain half the number of chromosomes found in body cells. Fertilisation takes place when female and male gametes join, producing variation in offspring. Sexual reproduction leads to variation in populations whilst asexual reproduction leads to populations of genetically identical individuals.

Hormones play a vital role in sexual reproduction in humans, including control of the menstrual cycle.

Pupils should learn about the role, risks and benefits of hormonal and non-hormonal forms of contraception. Human fertility is affected by factors including lifestyle choices, and infertility can be treated in a variety of ways.

The lifestyle of the mother and father during pregnancy affect the health of the foetus.

Inheritance and the genome

Curriculum content (11-14):

- heredity as the process by which genetic information stored in DNA is transmitted from one generation to the next
- a simple model of the genome, including chromosomes, genes and DNA
- the development of the DNA model

Curriculum content (14-16):

- the structure of DNA
- how the genome, and its interaction with the environment, influence the development of the phenotype of an organism, including protein synthesis
- models of single gene inheritance, including dominant and recessive characteristics and homozygous and heterozygous genotypes
- most phenotypic features are affected by multiple genes
- sex determination in humans
- the development of our understanding of inheritance and the genome and human genome sequencing projects
- the importance of our increasing understanding of the human genome
- genetic variants result from mutations which are changes in the DNA; these may occur during cell division or as a result of environmental factors
- most mutations have no effect on the phenotype, however some have a negative or positive effect
- inherited mutations can affect how well adapted offspring are to their environment
- genetic technology as a process which involves modifying the genome of an organism to change its phenotype
- benefits, issues and risks of using genetic technology in modern agriculture and medicine

Inheritance and the genome is a new concept introduced at 11-16. Pupils should learn that the genome stores genetic information inherited from parents. The genome is made of DNA and is found in the chromosomes in the nucleus of cells. Growth and development of an organism depends upon its genome and interactions with the environment. A mutation is a change in the DNA during cell division and can affect the characteristics of an organism in helpful or harmful ways. Genome sequencing and genetic technologies are advancing research and have valuable applications.

BIG QUESTION: Why are organisms so different?

AGES 11-16

Variation, adaptation, evolution

Curriculum content (11-14):

- there are differences between species and between individuals of the same species
- variation between individuals within a species can be continuous or discontinuous, including measurement and graphical representation of variation
- variation can be caused by differences in the genome and the environment
- genetic variation can be inherited
- variation between species and between individuals of the same species means some organisms compete more successfully if the environment changes and are more likely to reproduce. This is natural selection, which can lead to evolution

Curriculum content (14-16):

- there is usually genetic variation within a population of a species
- evolution is a change in the inherited characteristics of a population over many generations through a process of natural selection, which may result in the formation of new species
- evolution occurs through natural selection of genetic variants that give rise to phenotypes better adapted to their environment
- evidence for evolution includes fossils, domestication of species by selective breeding, DNA analysis, and modern examples including antibiotic resistance in bacteria
- the development of the theory of evolution by natural selection and the impact of these ideas on modern biology

Building upon understanding acquired at 5-11 about adaptation and evolution, the concept of variation should be introduced at 11-16. The great diversity of organisms, living and extinct, is the result of evolution by natural selection. Variation between individual organisms of the same species is caused by differences in the genome, lifestyle choices and interactions with the environment. Only variation caused by differences in the genome can be inherited. Species, and individuals of the same species, compete for limited resources. Individuals that are better adapted are more likely to survive to reproduce and may pass on their advantageous genetic variants to their offspring and the characteristics of the species evolve over many generations. Natural selection may result in the evolution of new species. The theory of evolution by natural selection is supported by a range of evidence and underpins modern biological science.

Classification

Curriculum content (11-14):

- organisms are classified into broad groups according to common observable characteristics and based on similarities and differences
- construct a simple key that can be used to identify organisms

Curriculum content (14-16):

- organisms can be classified using a hierarchical structure of groups, including domains, kingdoms and species

At 11-16, pupils should learn that organisms can be grouped together in terms of their similarities, and separated by their differences. Keys are used to identify organisms in the lab and in the field according to their characteristics. Organisms are classified using observations at the macroscopic, cellular, and genome levels into a hierarchical structure of groups, including species, kingdoms and domains. Advances in technology have changed the ways organisms are classified.

BIG QUESTION: How do organisms stay healthy? AGES 11-16

Physical and mental health

Curriculum content (11-14):

- an organism's health is affected by interactions between its body and its environment (including other organisms)
- the physical and mental health of some animals, including humans, are also affected by their behaviour
- some factors can increase or decrease the risk of ill health
- some medicines treat the symptoms of ill health and some treat the causes

Curriculum content (14-16):

- data at local, national and global levels can help us to identify factors associated with good and ill health, and develop strategies to promote good health
- the individual and societal benefits of promoting good health, compared to treating ill health
- the process of discovery and development of potential new medicines including preclinical and clinical testing
- the emergency treatment given to a person suffering a suspected heart attack including CPR and use of a defibrillator

At 11-14, pupils should learn that the physical and mental health of an individual organism result from interactions between the organism's body, behaviour, environment and other organisms. Ill health can be caused by germs, lifestyle, environment, and information in the genome. Some factors increase or decrease the risk of ill health. By 16, pupils should have learnt that health is a measure of an individual's ability to function and cope with physical, emotional, environmental and social challenges. Individual people and government organisations have responsibility for maintaining good health within populations and studying data on factors associated with good and ill health can help us to devise strategies to promote good physical and mental health. Pupils should learn that antimicrobials used to treat some diseases are becoming less effective due to the evolution of resistant microorganisms, and their use must be carefully controlled. Discovering and developing new medicines involves studying the genomes and proteins of pathogens and host cells to identify targets for new medicines. All new medicines have to be tested before they are made widely available.

Health and human lifestyles

Curriculum content (11-14):

- content of a healthy human diet: carbohydrates, lipids (fats and oils), proteins, vitamins, minerals, dietary fibre and water, and why each is needed
- the impact of variation between individuals and lifestyles on dietary requirements
- the consequences of imbalances in the diet, including obesity, starvation and deficiency diseases
- the impact of exercise, asthma and smoking on the human gas exchange system
- the effects of recreational use of drugs (including substance misuse) on behaviour, physical and mental health, and life processes

Curriculum content (14-16):

- many human diseases are caused by the interaction of a number of biological (including genetic) and lifestyle factors, including cardiovascular diseases (atherosclerosis and hypertension), many forms of cancer, some lung and liver diseases, mental ill health and diseases influenced by nutrition, including type 2 diabetes
- effect of lifestyle factors, including exercise, diet, alcohol, smoking, acute and chronic stress, on the incidence of these diseases at local, national and global levels
- effect of kidney failure on the body and approaches to treatment including dialysis and transplant

At 11-14, pupils should learn that in order to stay in good health, humans need to eat a balanced diet and to exercise. Variation between individuals and their lifestyles affects their dietary and exercise requirements. Eating too much or too little of particular foods can increase the risk of physical and mental ill health. Exercise has short-term and long-term effects on the human body. Asthma is a disease that affects the human gas exchange system. Smoking and the recreational use of drugs have short-term and long-term effects on the human body, and can increase the risk of physical and mental ill health. By 16, pupils should have learnt that the interaction of information stored in the genome, environment and lifestyle can affect the risk of developing non-communicable diseases. Some aspects of mental ill health can be explained by changes in the central nervous system.

Health and infectious disease

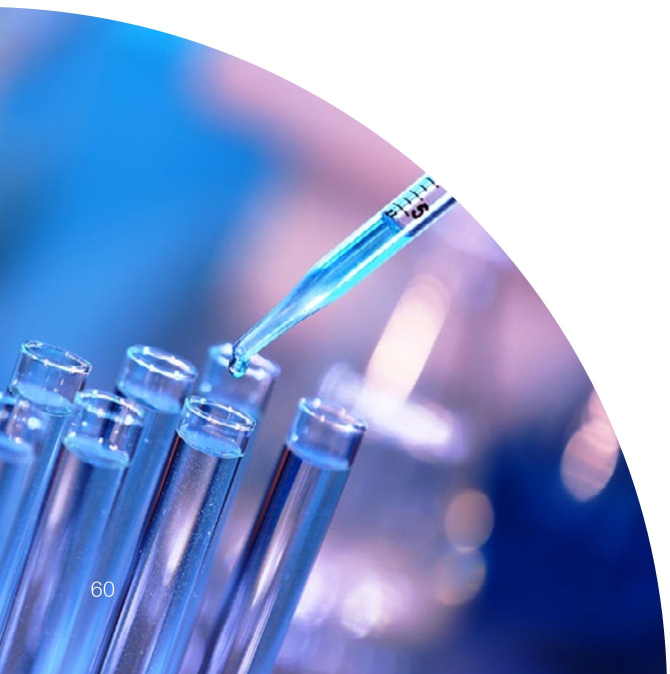
Curriculum content (11-14):

- infectious diseases in animals and plants are caused by pathogens including viruses, bacteria, protists and fungi
- how infectious diseases can be spread in animals and plants, including sexually and non-sexually transmitted diseases
- non-specific defence systems of the human body against pathogens
- physical plant defences including leaf cuticle and cell wall

Curriculum content (14-16):

- pathogens that cause diseases in animals and plants can be identified using microscopy and cultures
- the growth of bacterial colonies and factors that affect their growth
- ways in which the spread of infectious diseases may be reduced or prevented in plants and in animals
- how pathogens cause the symptoms of disease in animals and plants
- the specific defences of the human immune system, including the role of white blood cells in phagocytosis and antibody production
- how vaccines establish immunity and their use in the prevention of disease
- chemical plant defences including production of antimicrobial substances
- appropriate use of antimicrobial drugs in the treatment of disease, including the problems of antimicrobial resistance

At 11-14, pupils should learn that some diseases in humans, other animals and plants are caused by infection by pathogens which cannot usually be seen without a microscope. Humans have non-specific defences against pathogens, including physical, chemical and microbial defences. Effective hygiene, sanitation, storage and preparation of food, vaccination and contraception during sexual activity can reduce the risk of infection by pathogens. Only diseases caused by bacteria can be treated using antimicrobial substances. By 16, pupils should have learnt that the immune system of the human body includes white blood cells that help to protect us against disease by destroying pathogens. Immunity occurs when memory cells are created which make antibodies quickly upon re-infection. Vaccinations establish immunity by triggering the immune response. Protection of plants against disease caused by pathogens is important in human food security.



BIG QUESTION: How do organisms live together? — AGES 11-16

Interdependence of organisms

Curriculum content (11-14):

- different levels of organisation in an ecosystem from individual organisms to the whole ecosystem
- photosynthetic organisms are the main producers of food and therefore biomass for life on Earth
- the interdependence of plants and animals, including humans, in an ecosystem, including food webs, pollination and seed dispersal
- organisms compete for limited resources
- the importance of microorganisms in human and ruminant digestive systems, soil and decomposition

Curriculum content (14-16):

- almost all life on Earth depends on the ability of photosynthetic organisms to build organic molecules and to maintain levels of oxygen and carbon dioxide in the atmosphere
- the differences between the trophic levels within a food web
- pyramids of biomass, how biomass is lost between the different trophic levels and how this affects the number of organisms at each trophic level and has implications for human food security
- calculate the efficiency of biomass transfers between trophic levels

At 11-16, pupils should learn that an ecosystem is made up of a biological community and the physical environment in which the community lives and upon which it depends. Pupils are introduced to the term biomass and learn that all biomass originates with the producer. Pupils should be introduced to food webs as a way of showing how food chains interconnect. They should learn about the concept of interdependence within an ecosystem and of the vital importance of photosynthetic organisms. Pupils should learn about the transfer of biomass between trophic levels.

Environmental interactions and processes

Curriculum content (11-14):

- how organisms affect, and are affected by, their environment in both positive and negative ways
- changes in the environment may leave individuals within a species, and some entire species, more or less well adapted to survive and thrive

Curriculum content (14-16):

- many different materials cycle through the abiotic and biotic components of an ecosystem
- the importance of the carbon cycle and the water cycle to living organisms
- the role of microorganisms in the cycling of materials through an ecosystem
- the effect of factors such as temperature and water content on rate of decomposition in aerobic and anaerobic environments

At 11-16, pupils should learn that ecosystems are made up of biotic (living) and abiotic (non-living) components and why the carbon cycle and the water cycle are essential for life. The size of one or more populations in a community may be affected if the environmental conditions change. The abundance of organisms and different conditions within an ecosystem can be investigated scientifically.

Biodiversity and human impacts

Curriculum content (11-14):

- use basic field techniques to compare and contrast the organisms living in two distinctive habitats
- benefits of biodiversity to humans
- the impact of biodiversity loss on human food and water security

Curriculum content (14-16):

- biodiversity can be measured and valued at genetic, species and ecosystem level
- abiotic and biotic factors affect biodiversity within an ecosystem
- carry out a field investigation into the distribution and abundance of organisms in an ecosystem
- the positive and negative effects on biodiversity of human interactions within ecosystems
- the benefits and challenges of maintaining local and global biodiversity
- the impacts of climate change on the distribution of organisms
- biotechnological and agricultural solutions, including genetic technologies, to meet the needs of the growing human population

Biodiversity and human impact is a concept introduced at 11-16. Pupils should learn that conditions may not be the same in all parts of an ecosystem. The distribution and abundance of organisms, and different conditions, within an ecosystem are investigated using a variety of techniques in the field. Ecosystems provide a range of goods and services to humans. Human activities can have negative impacts on ecosystems. Populations die out and species become extinct when conditions change more quickly than they can adapt. Biodiversity loss threatens human food and water security. Humans can interact with ecosystems positively to develop sustainable systems to ensure the security of the supply of food, materials and medicines upon which we depend.

DIMENSION: Applications of Biology (Biology in the world)

BIG QUESTION: How do people use biological knowledge? AGES 11-16

Developing applications to promote human and environmental wellbeing

Curriculum content (11-16):

Throughout their studies, for a range of historical and contemporary examples, pupils should have opportunities to:

- learn about products, technologies and processes developed by applying biological knowledge
- consider applications of biological knowledge that make a positive difference to people's lives
- consider applications of biological knowledge, including conservation and sustainability, that help to reduce negative impacts of human activities

Many products, technologies and processes have been developed by applying biological knowledge. These applications provide people with many things that they value and which enhance their quality of life, including improvements to their health and wellbeing. Biologists also devise ways of reducing negative impacts of human activities, for example by improving the welfare of animals and plants in our care, conserving natural biodiversity and using ecosystem resources in a sustainable way.

Evaluating impacts of biological knowledge and its applications

Curriculum content (11-16):

Throughout their studies, for a range of historical and contemporary examples, pupils should have opportunities to:

- weigh up risks, benefits and costs, for different groups of people and the environment, associated with applications of biological knowledge
- distinguish between perceived and calculated risk
- identify ethical and moral issues associated with applications of biological knowledge
- use ideas about risk and ethics to make and justify decisions related to applications of biological knowledge

All applications of biological knowledge have risks, and many have benefits. To make a decision about a particular application of biological knowledge, we must take account of both the risks and benefits to different groups of people, other organisms and the environment. The size of a risk can be quantified, but people's perception of the size of a particular risk may differ and may not be based on scientific evidence.

Some applications of biological knowledge have ethical and moral implications. Decisions about these applications cannot be made on the basis of scientific evidence alone and will depend in part on judgements based on individual and societal values.

Influencing Society

Curriculum content (11-16):

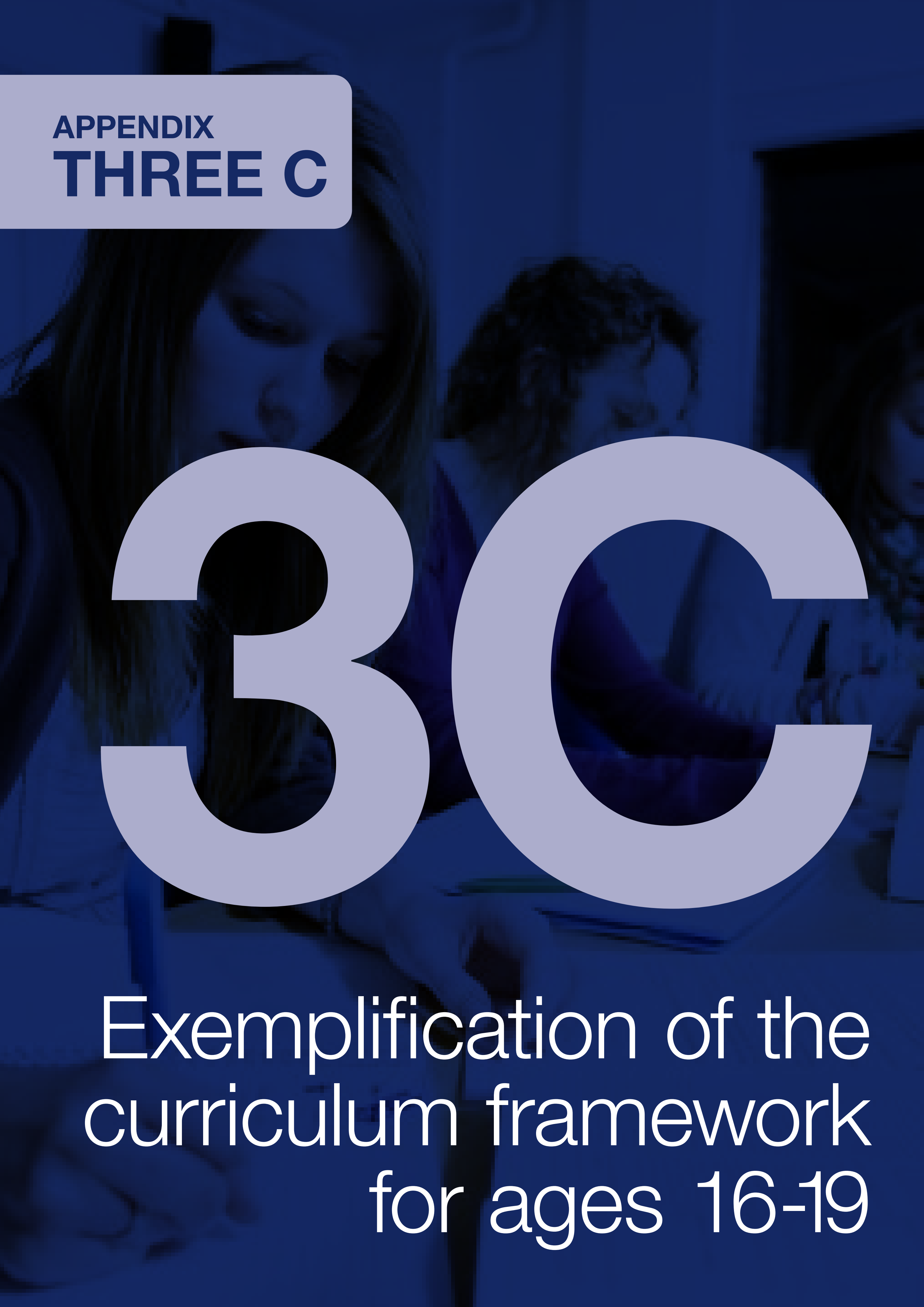
Throughout their studies, for a range of historical and contemporary examples, pupils should have opportunities to:

- consider ways in which biological knowledge changes people's behaviour, including the decisions they make and how they interact with other organisms and the environment
- consider ways in which individuals, organisations and governments are responsible for the safe and ethical use of biological knowledge and its applications

Biological knowledge, when communicated appropriately, can change the behaviour of individual people. It enables them to make decisions based on understanding and evidence, which may affect their own health and the wellbeing of other organisms and the environment.

Biologists keep abreast of recent advances in our understanding of the biosciences and work alongside other disciplines (including physics, chemistry, history, mathematics, engineering, design and technology, geography, theology, music and the arts) to address Big Questions and real-world problems.

Individuals, organisations and governments all have responsibility to use biological knowledge and its applications (including products, technologies and processes) in ways that keep people, other organisms and environments safe.



APPENDIX

THREE C

3C

Exemplification of the curriculum framework for ages 16-19

DIMENSION: Practices of Biology (Biology as a science)

BIG QUESTION: How do we study the biological world? AGES 16-19

Asking questions about the biological world

Curriculum content (16-19):

Throughout their studies, pupils should have opportunities to:

- generate their own questions and consider how they could be answered
- identify questions that could be answered using a scientific approach to collect data (observations and measurements)
- ask questions and develop lines of enquiry based on observations of the biological world, alongside prior knowledge and experience

The study of the biological world can be prompted by asking different kinds of questions. Some questions are more amenable to science than others. Biologists try to answer questions by developing explanations based on evidence from data (observations and measurements) provided by scientific enquiries.

The tools that biologists have available to collect evidence determine which questions can be investigated, and some questions cannot be answered until appropriate tools are developed. This means there are limits to what the sciences can help us to explore and explain. Answering some questions about the biological world requires us to draw upon knowledge and expertise from other disciplines across the fields of science, technology, engineering, mathematics and other subjects.

Planning practical experiments and investigative work

Curriculum content (16-19):

Throughout their studies, for different types of investigations, pupils should have opportunities to:

- select and plan appropriate scientific enquiries to help answer questions, test hypotheses or test predictions
- generate their own testable hypotheses and predictions
- identify independent and dependent variables
- identify appropriate measurement to be taken, including ranges, intervals and sample sizes, and the need for repeat measurements
- identify factors that need to be controlled, and ways in which they can be controlled
- identify and describe appropriate methods and tools (apparatus, instruments and technology) that can be used to collect data in a repeatable way that will maximise the accuracy and precision of measured values
- evaluate risks and ethical issues associated with a data collection strategy
- compare the strengths and weaknesses of different investigative designs

Biologists plan scientific enquiries, including practical experiments and investigative work, to collect data (observations and measurements) in the laboratory and in the field. The data may provide evidence that helps the biologist to answer a question or develop an explanation for a biological phenomenon.

Some types of scientific enquiry start by generating a hypothesis. A hypothesis can be used to make a prediction about how a change in a factor will affect the outcome. A plan is then produced to test the prediction, and the hypothesis upon which it is based, by collecting appropriate data.

A plan for a scientific enquiry describes how to collect data in a safe and ethical way, using methods and tools that will maximise the precision and accuracy of measured values. Scientific enquiries are designed and described so that they can be repeated by the experimenter and by others.

Carrying out practical experiments and investigative work

Curriculum content (16-19):

Throughout their studies, for different types of investigations, pupils should have opportunities to:

- use appropriate methods, tools (apparatus, instruments and technology), and materials to collect data in the laboratory and in the field
- work safely to minimise hazards
- work ethically, minimising harm to living organisms and disruption of ecosystems
- work with objectivity
- work to maximise the accuracy and precision of measured values
- work in a repeatable way
- record data in appropriate formats

Biologists carry out scientific enquiries, including practical experiments and investigative work, to collect data (observations and measurements) in the laboratory and in the field. The data may provide evidence that helps the biologist to answer a question or develop an explanation for a biological phenomenon.

When collecting data, biologists work safely to reduce the risk of hazards that could lead to accident or injury. They work ethically to ensure that their experiments and investigations cause as little harm as possible to living organisms and to minimise disruption of ecosystems. They work carefully to avoid mistakes, and they work with objectivity to reduce bias. They work to reduce sources of random and systematic error to increase the precision and accuracy of measured values. They work in ways that could be repeated by themselves and by others.

Data must be recorded in a clear and organised way to facilitate analysis and interpretation.

Analysing, interpreting and evaluating data

Curriculum content (16-19):

Throughout their studies, for primary and secondary data, and for different types of investigations, pupils should have opportunities to:

- translate data from one form to another, including interconverting units and graphical representation
- generate and use combined data sets
- carry out and represent mathematical processing and statistical analyses
- interpret data presented in a range of forms, including identifying patterns, trends and correlations
- identify anomalous results and outliers
- evaluate the quality of data objectively (in terms of accuracy, precision, repeatability, and reproducibility)
- identify sources of random and systematic error
- use data to evaluate predictions and the hypotheses upon which they are based
- make inferences and draw conclusions from data
- suggests ways in which the quality of data could be improved, and identify further questions for investigation

Before biologists can make inferences and draw conclusions, the data they have collected have to be processed, interpreted, analysed and evaluated.

Data can be analysed qualitatively, or quantitatively using mathematical and computational methods. Displaying data graphically can help to show trends and patterns.

Combined data sets (e.g. pooled class data, year-on-year data, and citizen science projects) can provide additional insights.

Many factors can affect the quality of data, and these must be evaluated and taken into account when inferences and conclusions are made.

Data may agree or disagree with a prediction or hypothesis. In either case, the prediction or hypothesis may be tested further by planning and carrying out additional investigations.

Developing explanations, classification systems and models

Curriculum content (16-19):

Throughout their studies, pupils should have opportunities to:

- suggest explanations for patterns, trends and correlations in primary and secondary data, including cause-effect links
- identify and classify biological entities based on evidence of their similarities and differences
- use scientific models to explain complicated ideas and to make predictions
- identify the benefits and limitations of scientific models
- learn about how scientific explanations, classification systems and models are developed and modified to account for the available evidence, using historical and contemporary examples

A cycle of collecting and analysing data provides evidence that enables biologists to develop and improve scientific explanations, classification systems and models. These can help to make sense of biological phenomena and answer questions about the biological world.

Biologists develop scientific explanations from evidence provided by data. Biological entities can be identified and classified based on evidence of their similarities and differences at the macroscopic, microscopic, molecular and genetic levels. Scientific models are used to explain complicated ideas, and to make and test predictions. The usefulness of a model is limited by how accurately it represents the real world.

Scientific explanations, classification systems and models are continually tested by collecting new data, and they may be changed over time to make sure they are the best possible fit for the available evidence.

Communicating information and engaging in evidence-based arguments

Curriculum content (16-19):

Throughout their studies, pupils should have opportunities to:

- engage with scientific information presented in a range of formats (written, numerical and graphical)
- present scientific methods, data, ideas and implications in a range of formats, including written, oral and audio-visual, for a range of audiences
- learn about ways in which biologists share data and explanations within the scientific community, including peer review, and why this is important
- learn about why biologists share data and explanations with audiences beyond the scientific community
- identify and use evidence from data to support arguments and make decisions
- evaluate information and claims related to scientific issues, from a range of sources, and decide how much confidence can be placed in them

It is important that data collected by individual biologists, and their explanations for what they have found, are shared with other scientists and checked by them. Scientists are sceptical about claims that are not based on repeatable and reproducible data.

Scientific explanations can be developed and improved using evidence and explanations from more than one scientist. Communication and debate between scientists help the scientific community to develop the best explanations for the available evidence.

Biologists communicate about their work with a range of audiences beyond the scientific community, including members of the public and the government. This enables evidence-informed debate and decision-making about scientific issues at the personal and societal levels.

DIMENSION: Concepts of Biology (Core concepts of biology)

BIG QUESTION: What are organisms and what are they made of? AGES 16-19

Defining life

Curriculum content (16-19):

- at each level of organisation (molecules, cells, tissues, organs, organ systems, organisms and ecosystems), new properties emerge that were not present at lower levels
- life is a property that emerges when the biological structures at all levels of organisation function together in an integrated way

At post-16, pupils should build upon knowledge of organisms to learn that life is a property that emerges when the biological structures at all of levels of organisation function together in an integrated way.

Cell structure and function

Curriculum content (16-19):

- prokaryotic and eukaryotic cells can be distinguished on the basis of their structure and ultrastructure
- the structure of the plasma membranes of prokaryotic and eukaryotic cells enables control of the movement of substances into and out of cells, by passive or active transport

At 16-19, pupils should further explore the similarities and differences between cells introduced at 11-16. They will learn that the ultrastructure of prokaryotic and eukaryotic cells shows similarities and differences and that differences in cell surface membranes, internal membranes and the presence of organelles such as the nucleus, mitochondria, chloroplasts, ribosomes, endoplasmic reticulum and Golgi apparatus can be explored along with their functions.

Tissues, organs and systems

Curriculum content (16-19):

Coordination and control

- ionic models of nerve transmission, resting potentials and action potentials
- the interplay of chemical and electrical signals in receptors and synapses
- different modes of action of hormones: some directly impact on the cell whilst others interact through a secondary messenger on the DNA
- homeostasis in terms of the integration of the parasympathetic, sympathetic nervous system and endocrine system, in the context of a dynamic equilibrium

At 16-19, pupils should learn that the complexity of coordination and control systems is related to the complexity of multicellular organisms and that a dynamic equilibrium is maintained by the interaction of the nervous and endocrine systems. They should learn that the control of body systems and behaviour by the nervous system arise from the interaction of nerve impulses in networks of nerve cells and that animal and plant hormones travel to their target organs to coordinate and control the activities of cells.

Biochemistry

Curriculum content (16-19):

Biological molecules

- many biological molecules are polymers and are based on a small number of chemical elements in living organisms nucleic acids (DNA and RNA), carbohydrates, proteins, lipids, inorganic ions and water all have important roles and functions related to the structures of the molecules and the properties of the ions
- enzymes catalyse a wide range of intracellular and extracellular reactions
- almost all enzymes are proteins with mechanisms of action and other properties determined by their tertiary structures

Photosynthesis

- A simple model of the biochemistry of photosynthesis in plants and algae includes:
- ATP and a reducing agent are synthesised in the light-dependent stage
- ATP is broken down and the reducing agent is oxidised in the conversion of carbon dioxide to sugars in the light-independent stage
- ATP synthesis is associated with the electron transfer chain in the membranes within chloroplasts

Cellular Respiration

- A simple model of the biochemistry of cellular respiration in eukaryotic organisms includes:
  - glycolysis takes place in the cytoplasm
  - the remaining steps of sugar breakdown take place in the mitochondria
- ATP synthesis is associated with the electron transfer chain in the membranes of mitochondria
- Lipids and proteins can also be used for cellular respiration

At 16-19, pupils should explore further the concept of biochemistry introduced at 11-16 to learn that the structures within cells consist of different arrangements of biological molecules. They should learn that nucleic acids, carbohydrates, proteins, lipids, inorganic ions and water all have important roles and functions related to the structures of the molecules and the properties of the ions. These determine the chemical interactions in the cytoplasm and the characteristics of the cell. Enzymes catalyse a wide range of intracellular and extracellular reactions within the cytoplasm and also within organelles. They should learn about the light dependant and light independent stages of photosynthesis and the three stages involved in cellular respiration in eukaryotic organisms.

BIG QUESTION: How do organisms grow and reproduce? AGES 16-19

Reproduction, growth and development

Curriculum content (16-19):

Growth and development

- DNA replication during mitosis
- the regulation of the cell cycle and apoptosis, and the impact of mutations leading to the loss of control of cell division and cell death

Reproduction

- the significance of meiosis in life cycles, including the production of haploid cells and genetic variation by independent assortment and crossing over

At 16-19, pupils should learn that the process of DNA replication during mitosis involves a complex sequence of events resulting in two identical sets of chromosomes in the new cells. The cell cycle is tightly controlled and many of the mutations that lead to cancer result in loss of control of the cell cycle at specific points, so cell division takes place in an uncontrolled and rapid way. They learn that apoptosis is an adaptation by which the body destroys and removes old or damaged cells. Mutations which prevent or reduce apoptosis can lead to cancers, as cells with damaged DNA are no longer removed.

Meiosis is a key process in sexual reproduction, and therefore in the life cycles of a wide range of multicellular organisms. It is the process which results in haploid gametes, so that the offspring resulting from sexual reproduction retain a normal diploid chromosome number. Meiosis also plays a vital role in introducing genetic variation, in turn driving natural selection and evolution. Genetic variation is introduced by the independent assortment of the chromosomes and the process of crossing over during the complex sequence of events during the stages of meiosis.

Inheritance and the genome

Curriculum content (16-19):

- the sequence of bases in the DNA molecule determines the structure of proteins, including enzymes
- the impact of different types of mutation, including genetic diseases
- gene expression and protein synthesis are regulated by a number of factors at transcriptional, post transcriptional and post translational levels, and this regulates cell differentiation and function
- genomics projects have sequenced the genomes of organisms ranging from microbes and plants to humans, leading to a wide range of applications a variety of genetic technologies that allow study and alteration of gene function
- genetic technologies lead to increased understanding of organism function, and facilitate the development of new industrial and medical processes, including synthetic biology

At 16-19, pupils should build upon concepts introduced at 11-16 to learn about the two-stage process of protein synthesis and that the protein produced at a ribosome is often modified within the endoplasmic reticulum and Golgi apparatus of eukaryotic cells. They should learn that genomics projects have sequenced the DNA base sequences of genomes of many organisms, providing powerful evidence for the evolutionary relationships between different groups of organisms. Understanding the impact of people's genomes on their health has the potential to revolutionise health care and understanding the impact of genetic and environmental changes on the functioning of the genome is essential for the full understanding of disease. Technologies for modifying the genome of organisms facilitate new industrial processes and products and that there is potential to create new forms of life through synthetic biology. The possible application of this technology to humans is highly controversial.

BIG QUESTION: Why are organisms so different? AGES 16-19

Variation, adaptation, evolution

Curriculum content (16-19):

- the variety of life, both past and present, is extensive, but the biochemical basis of life is similar for all living things
- variation and selection are major factors in evolution and result in the diversity of living organisms
- behavioural, physiological and anatomical adaptations of organisms can be selected for
- alternative evolutionary pathways include co-evolution
- reproductive isolation can lead to accumulation of different genetic information in populations, potentially leading to speciation
- modern explanations of evolution use genetics as a mechanism for the process of natural selection affecting population genetics and changes in population structure
- these ideas continue to develop with our increasing understanding of the genome and the epigenome

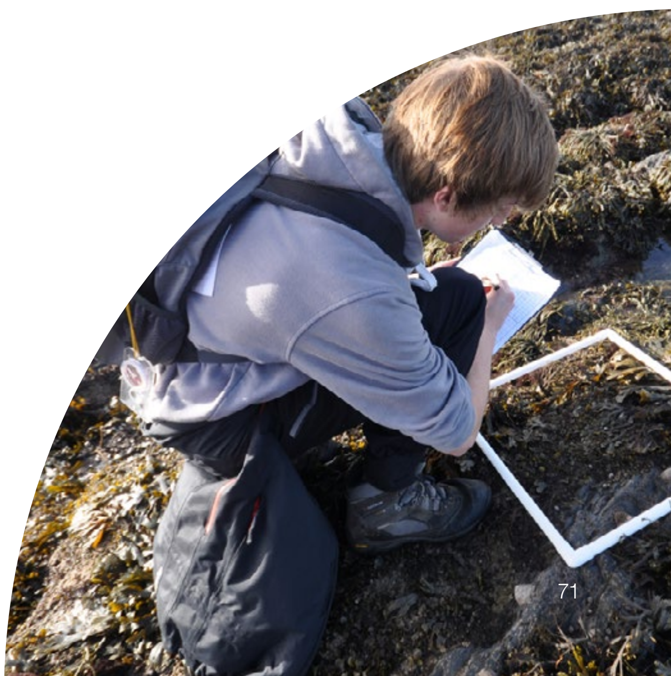
At 16-19, pupils should develop an understanding that variation is a product of sexual reproduction and that populations will increase or decrease according to environmental demands. Natural selection is a process where 'fitter' individuals are more likely to pass on their genes. Disease resistance through widespread use of antibiotics, warfarin resistance in rats and heavy metal tolerance in various plants are all examples of 'natural selection in action'. Artificial selection is the changes that occur not in the natural environment but through the intervention of humans.

Classification

Curriculum content (16-19):

- originally classification systems were based on observable features but more recent technological approaches provide a wider range of evidence to clarify relationships between organisms

Pupils should build upon concepts taught at 11-16 to learn that classification is a skilled task and requires creating groups within groups or a hierarchical system. It is important that pupils can recognise different types of living thing and provide a scientific name. Pupils should be taught to both use and construct biological keys.



BIG QUESTION: How do organisms stay healthy?

AGES 16-19

Physical and mental health

Curriculum content (16-19):

- examples of new therapies that have arisen from applications of our increasing understanding of the genome, stem cells, and the immune system, including modern approaches to drug development

At 16-19, pupils should learn about the development of novel therapeutic approaches based on genome technology, stem cells and increased understanding of the immune system. They should explore the potential advantages and limitations of these new approaches, and the challenges of developing safe and effective therapies for a range of health challenges.

Health and human lifestyle

Curriculum content (16-19):

- the impacts of brain chemistry on health and behaviour, including the effects of drugs on synapses, and disorders including Alzheimer's, Parkinson's, bipolar and depression
- current examples of non-communicable diseases of global importance in animals, including humans, and response strategies

At 16-19, pupils should apply their knowledge of nervous transmission and the role of synapses to understand the impact of brain chemistry on behaviour and health. They explore the changes in brain chemistry observed in non-communicable disorders such as Alzheimer's, Parkinson's, bipolar and depression, including the successes of different therapeutic approaches and the challenges of deploying them effectively. They should study the impacts of drugs on brain chemistry, and so on behaviour, health and well-being.

Pupils should study the global toll of current non-communicable diseases on human health. They investigate the impact of different factors including genetic predisposition and lifestyle on the incidence of different diseases, and consider the pros and cons of different response strategies.

Health and infectious disease

Curriculum content (16-19):

- microbiological, molecular and genomic techniques for the detection and identification of pathogens in the lab and in the field
- the structures and reproductive mechanisms of common viruses
- current examples of infectious diseases of global importance in plants and animals, including humans, and response strategies
- the innate and adaptive responses of the human immune system, including the roles of inflammation, phagocytes, T lymphocytes and B lymphocytes.
- the natural and artificial establishment of active and passive immunity
- continuing challenges in preventing and treating disease, including pathogen mutation rate and antigen variability, and the emergence of new infectious disease threats

At 16-19, pupils should learn more about the life cycles and infective mechanisms of pathogens, including bacteria and viruses. They investigate a range of microbiological, molecular and genomic techniques for identifying plant and animal pathogens in the lab and in the field, and consider the applications, advantages and disadvantages of each.

Pupils should study current examples of communicable diseases with a global impact on animal (including human) and plant health. They should consider reasons for the differences in impact on populations of novel and long-established infectious diseases. They should investigate the effectiveness of different response strategies in both human and plant diseases.

Pupils should study the details of the human immune response and apply this understanding to the importance of establishing active or passive immunity by natural or artificial means, including the value of herd immunity.

Pupils should learn more about the continuing challenges faced in preventing and treating infectious diseases, including human behaviours that contribute to the emergence of new infectious disease threats, the rate of pathogen mutation and antigen variability.

BIG QUESTION: How do organisms live together? — AGES 16-19

Interdependence of organisms

Curriculum content (16-19):

- different types of interactions, including mutualism, parasitism, symbiosis, predation and herbivory, all impact on population distribution and abundance

At 16-19, pupils should learn that the interdependencies between organisms lead to a wide range of different types of interactions between different trophic levels within a food web and that all of these interactions have an impact on the population distribution and abundance of both the interdependent species, and other populations in the ecosystem.

Environmental interactions and processes

Curriculum content (16-19):

- ecosystems are dynamic systems, with component communities moving from colonisation to climax in a process known as succession
- microorganisms play a key role in recycling chemical elements

At 16-19, pupils should learn that within ecosystems there is a dynamic interaction both within and between the biotic and the abiotic components. As a result of ecosystem change, the populations that make up the community within an ecosystem change from colonisation to climax in a process known as succession.

All living organisms require a supply of nutrients and create waste; life depends upon the cycling of the constituent chemical elements of these through the biotic and abiotic environmental compartments, for example via the nitrogen cycle, carbon cycle and water cycle.

Biodiversity and human impacts

Curriculum content (16-19):

- carry out a field investigation into the impact of one or more abiotic factors on the distribution and abundance of key organisms in a habitat
- effective management of the conflict between the needs of the growing human population and conservation to help maintain sustainability of resources and biodiversity
- the biological factors affecting levels of food security including increasing human population, changing diets, new pests and pathogens, environmental change, sustainability and cost of agricultural inputs

At 16-19, pupils should learn that biological diversity is a more complex topic than described from 5-16 and includes genetic and ecological diversity, and explore further how it can be measured. The environment is essential to the well-being of our species as humans depend upon food chains and food webs, as does any other species. They should learn that human impact is not necessarily negative through exploring both national and international conservation efforts.

DIMENSION: Applications of Biology (Biology in the world)

BIG QUESTION: How do people use biological knowledge?

AGES 16-19

Developing applications to promote human and environmental wellbeing

Curriculum content (16-19):

Throughout their studies, for a range of historical and contemporary examples, pupils should have opportunities to:

- learn about products, technologies and processes developed by applying biological knowledge
- consider applications of biological knowledge that make a positive difference to people's lives
- consider applications of biological knowledge, including conservation and sustainability, that help to reduce negative impacts of human activities

Many products, technologies and processes have been developed by applying biological knowledge. These applications provide people with many things that they value and which enhance their quality of life, including improvements to their health and wellbeing. Biologists also devise ways of reducing negative impacts of human activities, for example by improving the welfare of animals and plants in our care, conserving natural biodiversity and using ecosystem resources in a sustainable way.

Evaluating impacts of biological knowledge and its applications

Curriculum content (16-19):

Throughout their studies pupils should have opportunities to:

- weigh up risks, benefits and costs, for different groups of people and the environment, associated with applications of biological knowledge
- distinguish between perceived and calculated risk
- identify ethical and moral issues associated with applications of biological knowledge
- use ideas about risk and ethics to make and justify decisions related to applications of biological knowledge
- suggest why different decisions on the same issue might be appropriate in different personal, social, economic and environmental contexts

All applications of biological knowledge have risks, and many have benefits. To make a decision about a particular application of biological knowledge, we must take account of both the risks and benefits to different groups of people, other organisms and the environment. The size of a risk can be quantified, but people's perception of the size of a particular risk may differ and may not be based on scientific evidence. Some applications of biological knowledge have ethical and moral implications. Decisions about these applications cannot be made on the basis of scientific evidence alone and will depend in part on judgements based on individual and societal values.

Influencing Society

Curriculum content (16-19):

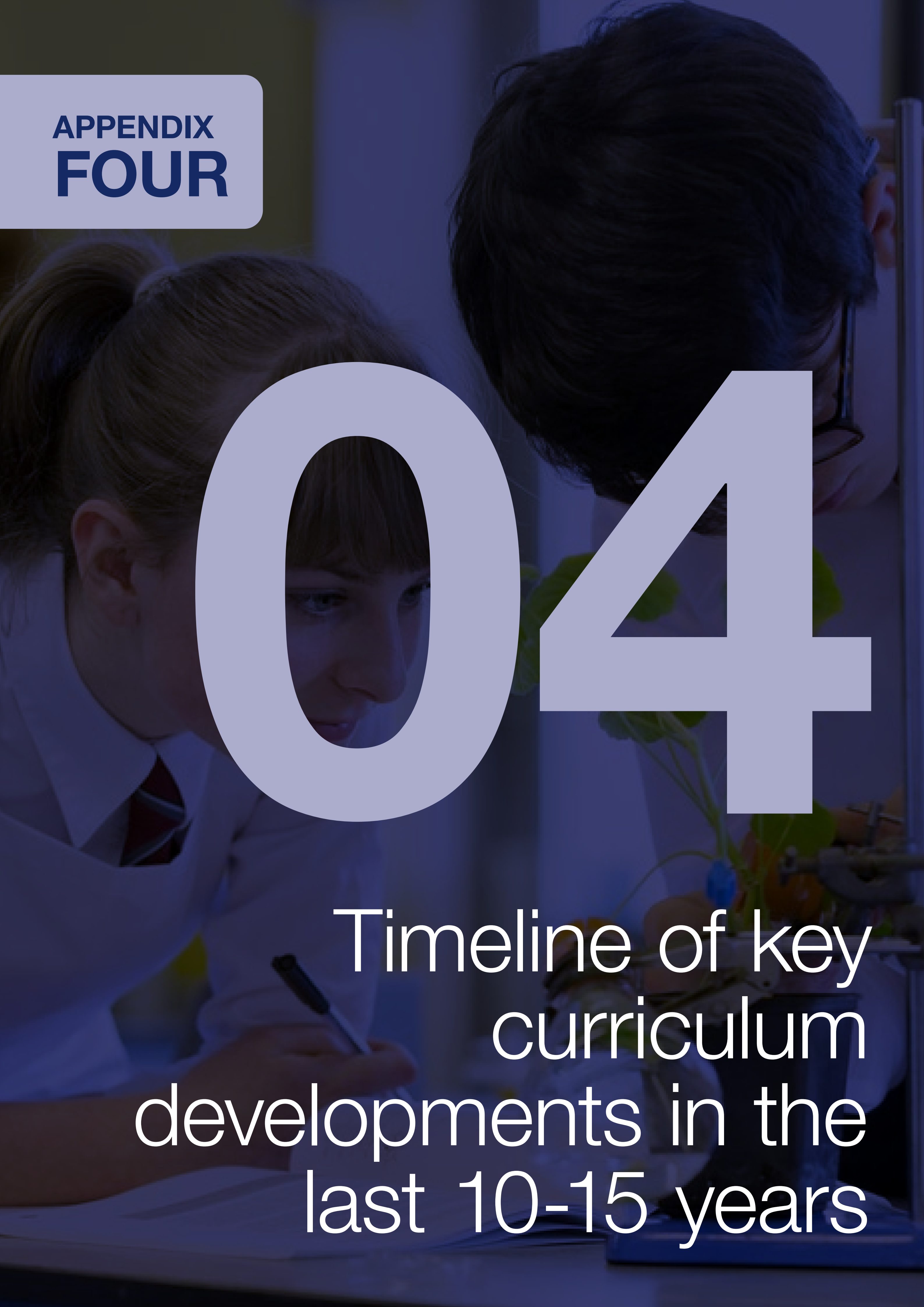
Throughout their studies pupils should have opportunities to:

- consider ways in which biological knowledge changes people's behaviour, including the decisions they make and how they interact with other organisms and the environment
- compare the responsibilities of individuals, organisations and governments for the safe and ethical use of biological knowledge and its applications

Biological knowledge, when communicated appropriately, can change the behaviour of individual people. It enables them to make decisions based on understanding and evidence, which may affect their own health and the wellbeing of other organisms and the environment.

Biologists keep abreast of recent advances in our understanding of the biosciences and work alongside other disciplines (including physics, chemistry, history, mathematics, engineering, design and technology, geography, theology, music and the arts) to address Big Questions and real-world problems.

Individuals, organisations and governments all have responsibility to use biological knowledge and its applications (including products, technologies and processes) in ways that keep people, other organisms and environments safe.



APPENDIX
FOUR

04

Timeline of key curriculum developments in the last 10-15 years

Developments in curriculum policy and RSB's work on curriculum reform across the UK

UK Curriculum Development

RSB's Curriculum Development

2010

UK Curriculum Development:

Scotland
Curriculum for excellence implemented

England
National Curriculum Review announced by Department for Education

RSB's Curriculum Development:

England
RSB advises informally on GCSE redevelopment

2011

2012

UK Curriculum Development:

Scotland
Introduction of new National 4 and 5 qualifications, replacing Standard Grades

RSB's Curriculum Development:

England
RSB consults with the biology community on content for biology National Curriculum

2013

UK Curriculum Development:

England
Department for Education draft programmes of study consultation

Scotland
First teaching of reformed Higher qualifications

2014

UK Curriculum Development

RSB's Curriculum Development

2014–2015

UK Curriculum Development

England
First teaching of reformed A levels in the sciences and introduction of Common Practical Assessment Criteria for assessing practical tasks

Wales/Northern Ireland
Wales and Northern Ireland retain pre-reform A-Levels

Wales
Design and development begins of a new curriculum

Scotland
First teaching of new Advanced Higher

RSB's Curriculum Development

RBS curriculum committee, primary working group and student working group established

2016–2017

UK Curriculum Development

England
First teaching of reformed GCSEs in the sciences

Department for Education and Department for Business, Innovation and Skills publishes Post-16 skills plan

Department for Education publishes T level action plan

RSB's Curriculum Development

Big question development and mapping of biology curriculum

2018

RSB's Curriculum Development

Development of 5-19 exemplification

UK Curriculum Development

RSB's Curriculum Development

2018

Wales
Welsh curriculum developed and draft curriculum 2022 published

RSB advised Welsh government on curriculum

2019

Development of three dimensions for 5-11, 11-16 and 16-19

2020

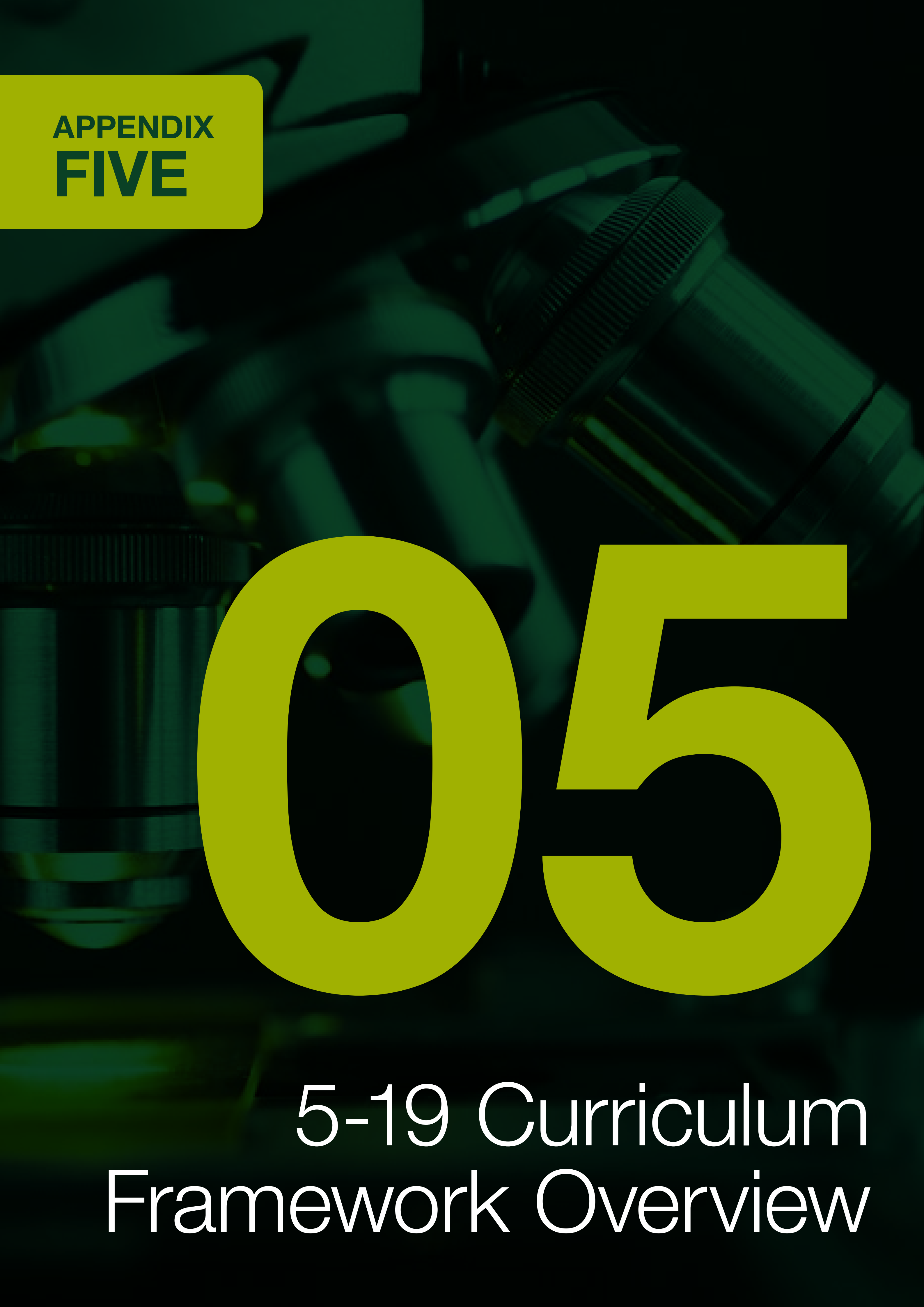
2021

RSB publishes curriculum framework

England
First teaching of T Levels

2022

2022 and Beyond
RSB will use its curriculum framework to influence UK governments, awarding organisations and support schools and will develop a suite of documents to sit alongside our framework with further detail for these stakeholders



APPENDIX
FIVE

05

5-19 Curriculum Framework Overview

Dimensions	Big questions of biology	Themes
Practices of Biology (Biology as a science)	How do we study the biological world?	Asking questions about the biological world
		Planning practical experiments and investigative work
		Carrying out practical experiments and investigative work
		Analysing, interpreting and evaluating data
		Developing explanations, classification systems and models
		Communicating information and engaging in evidence-based arguments
Concepts of Biology (Core concepts of biology)	What are organisms and what are they made of?	Defining life
		Cell structure and function
		Tissues, organs and systems
		Biochemistry
	How do organisms grow and reproduce?	Reproduction, growth and development
		Inheritance and the genome
	Why are organisms so different?	Variation, adaptation, evolution
		Classification
	How do organisms stay healthy?	Physical and mental health
		Health and human lifestyles
		Health and infectious disease
	How do organisms live together?	Interdependence of organisms
		Environmental interactions and processes
		Biodiversity and human impacts
Applications of Biology (Biology in the world)	How do people use biological knowledge?	Developing applications to promote health and environmental wellbeing
		Evaluating impacts of biological knowledge and its applications
		Influencing society

Summary of Themes

The study of the biological world can be prompted by asking questions, some of which are more amenable to scientific investigation than others. Biologists try to answer questions by developing explanations based on evidence from data, observations and measurements, provided by scientific enquiries.

Biologists plan scientific enquiries, including practical experiments and investigative work, to collect data in a variety of settings, including in the field, in a safe, ethical and repeatable way. Scientific enquiries may aim to answer a question, or test a hypothesis or prediction, about a biological phenomenon.

Biologists collect data in a variety of settings, including in the field, using practical experiments and investigative work. They work safely, ethically and in an objective and repeatable way.

Before biologists can make inferences and draw conclusions, the data they have collected have to be processed, interpreted, analysed and evaluated, which may be done qualitatively or quantitatively.

A cycle of collecting and analysing data provides evidence that enables biologists to develop and improve scientific explanations, classification systems and models. These can help to make sense of biological phenomena and answer questions about the biological world.

Biologists communicate about their work with a range of audiences within and beyond the scientific community, to facilitate evidence-informed debate and decision-making.

All living organisms need particular things to stay alive and they carry out characteristic processes as part of a life cycle. Life is a property that emerges when biological structures are organised and work together in an integrated way to support the functioning of an organism.

This theme is introduced at age 11-14. All organisms are made up of cells. There are similarities and differences between prokaryotic and eukaryotic cells. Our understanding of cell structures and their functions has been developed using microscopy.

Humans, other animals and plants are made up of parts, including tissues, organs and organ systems, adapted for distinct functions; these parts work together to help the organism stay alive.

This theme is introduced at age 11-14. Chemical reactions that make and break down substances take place all the time in living organisms. Photosynthesis and cellular respiration are important chemical processes that occur within living cells. The rate of many chemical reactions in living organisms is controlled by enzymes.

Reproduction is one of the characteristic life processes of living organisms, in which they produce new individuals of the same kind. Different types of living organisms have different life cycles and reproductive strategies, and change as they grow and age.

This theme is introduced at age 11-14. Each generation of organisms inherits characteristics from the one before, which arise from genetic information stored in the DNA of the genome and are affected by the environment. Understanding the genome has important implications for healthcare, biotechnology, agriculture and classification.

Organisms have become adapted in different ways to survive within different environments. The characteristics of groups of living things change over generations through a process of evolution by natural selection.

Organisms can be identified and classified into a hierarchy of groups based on their similarities and differences, which helps us make sense of the great diversity of organisms, living and extinct.

Humans and other animals have physical and mental health, which range from good to ill health. The physical and mental health of an individual organism results from interactions between the organism's body, behaviour, environment and other organisms. Ill health can be treated in various ways.

The risk of an individual developing non-communicable diseases depends on interacting factors including the information stored in their genome, their environment and aspects of their lifestyle. A number of lifestyle factors affect physical and mental health in positive and negative ways.

Some diseases in humans, other animals and plants are infectious, caused by a variety of pathogens. Effective prevention or treatment of a communicable disease depends on identification of the disease, the pathogen causing it and how it is spread.

Organisms living in the same place interact. All living organisms need food and other nutrients to stay alive; plants make their own food while animals, including humans, eat other organisms. Feeding relationships are one aspect of interdependence within ecosystems.

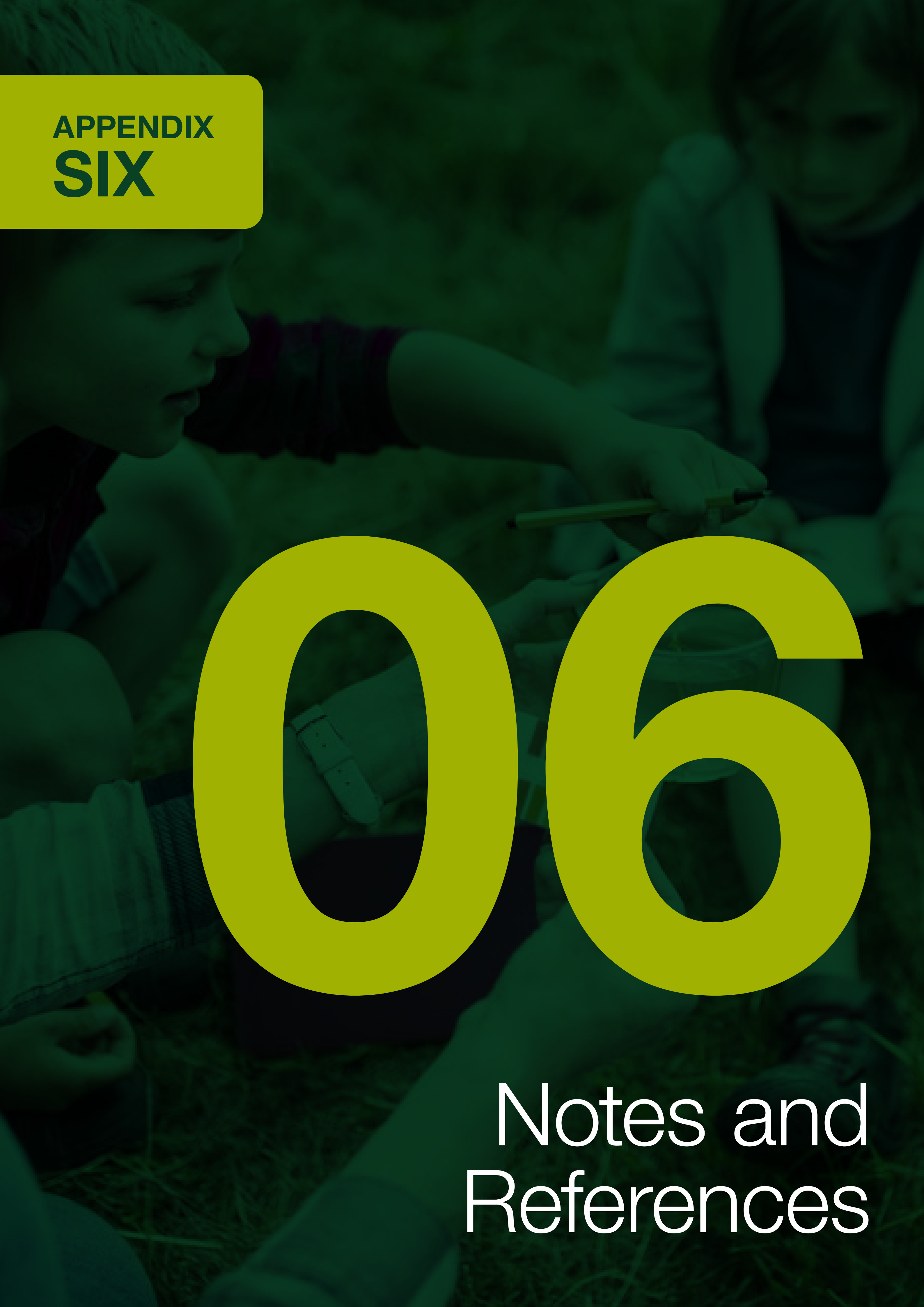
Organisms interact with the environments in which they live. These environments change over time and this affects the organisms that live there in positive and negative ways.

Human actions affect a range of local and global habitats, and the organisms that live there, in both positive and negative ways. Some of our actions affect organisms that we depend on for food and other resources.

Biological knowledge is applied to develop new products, technologies and processes intended to promote health and wellbeing, and which improve the ways in which we interact sustainably with our environment.

When considering the use of biological knowledge, we must weigh up the benefits, risks and ethical issues associated with its use, to enable evidence-based decisions to be made.

Biological knowledge can change the behaviour of individuals and groups of people, including organisations and governments. It enables them to make decisions based on understanding and evidence, which may affect the wellbeing of people, other organisms and the environment.



APPENDIX
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Notes and References

Notes

- The work of Royal Society of Biology's education policy team and information about our education-focussed SIGs and Committees can be found at www.rsb.org.uk/education.
- This curriculum framework and associated documents can be found at www.rsb.org.uk/curriculum – we intend to continue developing and adding to the suite of documents hosted on this page.
- RSB's policy library can be found at www.rsb.org.uk/policylibrary where archived formal consultation responses, reports, letters and other communications can be searched for. Our library covers a range of science and education policy areas, and includes papers from our member organisations and other partners such as the learned societies group in Scotland, Science Community Representing Education (SCORE) and joint publications with other science education organisations such as ASE, IOP, RS, RSB and RSC.

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