Diploma Programme

Environmental systems and societies guide

First assessment 2026

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

Diploma Programme

Environmental systems and societies guide

First assessment 2026

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

Diploma Programme
Environmental systems and societies guide

Published February 2024

Published by the International Baccalaureate Organization, a not-for-profit educational foundation of Rue du Pré-de-la-Bichette 1, 1202 Genève, Switzerland.
Website: ibo.org

IB mission statement

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.

IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

As IB learners we strive to be:

INQUIRERS
We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life.

KNOWLEDGEABLE
We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance.

THINKERS
We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions.

COMMUNICATORS
We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups.

PRINCIPLED
We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences.

OPEN-MINDED
We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience.

CARING
We show empathy, compassion and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us.

RISK-TAKERS
We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change.

BALANCED
We understand the importance of balancing different aspects of our lives—intellectual, physical, and emotional—to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live.

REFLECTIVE
We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.

The IB learner profile represents 10 attributes valued by IB World Schools. We believe these attributes, and others like them, can help individuals and groups become responsible members of local, national and global communities.

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

Contents

Purpose of this document

This publication is intended to guide the planning, teaching and assessment of the subject in schools. Subject teachers are the primary audience, although it is expected that teachers will use the guide to inform students and parents about the subject.

This guide can be found on the subject page of the Programme Resource Centre at resources.ibo.org, a password-protected website designed to support IB teachers. It can also be purchased from the IB store at store.ibo.org.

Additional resources

Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the Programme Resource Centre. Past examination papers as well as markschemes can be purchased from the IB store.

Teachers are encouraged to check the Programme Resource Centre for additional resources created or used by other teachers. Teachers can provide details of useful resources, for example: websites, books, videos, journals or teaching ideas.

Acknowledgement

The IB wishes to thank the educators and associated schools for generously contributing time and resources to the production of this guide.

First assessment 2026

The Diploma Programme

The Diploma Programme (DP) is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

The Diploma Programme model

The course is presented as six academic areas enclosing a central core (see figure 1). It encourages the concurrent study of a broad range of academic areas. Students study two modern languages (or a modern language and a classical language), a humanities or social science subject, an experimental science, mathematics and one of the creative arts. It is this comprehensive range of subjects that makes the DP a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.

Figure 1

Diploma Programme model

Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can, instead of an arts subject, choose two subjects from another area. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IB recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers.

The core of the Diploma Programme model

All DP students participate in the three course elements that make up the core of the model.

Theory of knowledge (TOK) is a course that is fundamentally about critical thinking and inquiry into the process of knowing rather than about learning a specific body of knowledge. The TOK course examines the nature of knowledge and how we know what we claim to know. It does this by encouraging students to analyse knowledge claims and explore questions about the construction of knowledge. The task of TOK is to emphasize connections between areas of shared knowledge and link them to personal knowledge in such a way that an individual becomes more aware of their own perspectives and how they might differ from others.

In TOK, students explore the means of producing knowledge within the core theme of "knowledge and the knower" as well as within various optional themes (knowledge and technology, knowledge and politics, knowledge and language, knowledge and religion, and knowledge and indigenous societies) and areas of knowledge (the arts, natural sciences, human sciences, history and mathematics). The course also encourages students to make comparisons between different areas of knowledge and reflect on how knowledge is arrived at in the various disciplines, what the disciplines have in common, and the differences between them.

Creativity, activity, service (CAS) is at the heart of the DP. The emphasis in CAS is on helping students to develop their own identities, in accordance with the ethical principles embodied in the IB mission statement and the IB learner profile. It involves students in a range of activities alongside their academic studies throughout the DP. The three strands of CAS are creativity (arts, and other experiences that involve creative thinking), activity (physical exertion contributing to a healthy lifestyle) and service (an unpaid and voluntary exchange that has a learning benefit for the student). Possibly, more than any other component in the DP, CAS contributes to the IB's mission to create a better and more peaceful world through intercultural understanding and respect.

The extended essay (EE), including the world studies EE, offers the opportunity for IB students to investigate a topic of special interest, in the form of a 4,000-word piece of independent research. The area of research undertaken is chosen from one of the students' six DP subjects, or in the case of the interdisciplinary World Studies essay two subjects, and acquaints them with the independent research and writing skills expected at university. This leads to a major piece of formally presented, structured writing, in which ideas and findings are communicated in a reasoned and coherent manner, appropriate to the subject or subjects chosen. It is intended to promote high-level research and writing skills, intellectual discovery and creativity. An authentic learning experience, it provides students with an opportunity to engage in personal research on a topic of choice, under the guidance of a supervisor.

Approaches to learning and approaches to teaching

Approaches to learning and approaches to teaching across the DP refers to deliberate strategies, skills and attitudes which permeate the learning and teaching environment. These approaches and tools, intrinsically linked with the learner profile attributes, enhance student learning and assist student preparation for the

DP assessment and beyond. The aims of approaches to learning and approaches to teaching in the DP are to:

- empower teachers as teachers of learners as well as teachers of content
- empower teachers to create clearer strategies for facilitating learning experiences in which students are more meaningfully engaged in structured inquiry and greater critical and creative thinking
- promote both the aims of individual subjects (making them more than course aspirations) and linking previously isolated knowledge (concurrency of learning)
- encourage students to develop an explicit variety of skills that will equip them to continue to be actively engaged in learning after they leave school, and to help them not only obtain university admission through better grades but also prepare for success during tertiary education and beyond
- enhance further the coherence and relevance of the students' DP experience
- allow schools to identify the distinctive nature of a DP education, with its blend of idealism and practicality.

The five approaches to learning (developing thinking skills, social skills, communication skills, self-management skills and research skills) along with the six approaches to teaching (teaching that is inquiry-based, conceptually focused, contextualized, collaborative, differentiated and informed by assessment) encompass the key values and principles that underpin IB pedagogy.

The IB mission statement and the IB learner profile

The DP aims to develop in students the knowledge, skills and attitudes they will need to fulfil the aims of the IB, as expressed in the organization's mission statement and the learner profile. Learning and teaching in the DP represent the reality in daily practice of the organization's educational philosophy.

Academic integrity

Academic integrity in the DP is a set of values and behaviours informed by the attributes of the learner profile. In learning, teaching and assessment, academic integrity serves to promote personal integrity, engender respect for the integrity of others and their work, and ensure that all students have an equal opportunity to demonstrate the knowledge and skills they acquire during their studies.

All coursework—including work submitted for assessment—is to be authentic, based on the student's individual and original ideas with the ideas and work of others fully acknowledged. Assessment tasks that require teachers to provide guidance to students or that require students to work collaboratively must be completed in full compliance with the detailed guidelines provided by the IB for the relevant subjects.

For further information on academic integrity in the IB and the DP, please consult the IB publications *Academic integrity policy*, *Effective citing and referencing*, *Diploma Programme: From principles into practice* and the general regulations in *Diploma Programme Assessment procedures* (updated annually). Specific information regarding academic integrity as it pertains to external and internal assessment components of this DP subject can be found in this guide.

Acknowledging the ideas or work of another person

Coordinators and teachers are reminded that candidates must acknowledge all sources used in work submitted for assessment. The following is intended as a clarification of this requirement.

DP candidates submit work for assessment in a variety of media that may include audiovisual material, text, graphs, images and/or data published in print or electronic sources. If a candidate uses the work or ideas of another person, the candidate must acknowledge the source using a standard style of referencing in a consistent manner. A candidate's failure to acknowledge a source will be investigated by the IB as a potential breach of regulations that may result in a penalty imposed by the IB final award committee.

The IB does not prescribe which style(s) of referencing or in-text citation should be used by candidates; this is left to the discretion of appropriate faculty/staff in the candidate's school. The wide range of subjects, three response languages and the diversity of referencing styles make it impractical and restrictive to insist on particular styles. In practice, certain styles may prove most commonly used, but schools are free to choose a style that is appropriate for the subject concerned and the language in which candidates' work is written. Regardless of the reference style adopted by the school for a given subject, it is expected that the minimum information given includes: name of author, date of publication, title of source and page numbers as applicable.

Candidates are expected to use a standard style and use it consistently so that credit is given to all sources used, including sources that have been paraphrased or summarized. When writing text, candidates must clearly distinguish between their words and those of others by the use of quotation marks (or other method, such as indentation) followed by an appropriate citation that denotes an entry in the bibliography. If an electronic source is cited, the date of access must be indicated. Candidates are not expected to show faultless expertise in referencing, but are expected to demonstrate that all sources have been acknowledged. Candidates must be advised that audiovisual material, text, graphs, images and/or data published in print or in electronic sources that is not their own must also attribute the source. Again, an appropriate style of referencing/citation must be used.

Learning diversity and learning support requirements

Schools must ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Access and inclusion policy* and *Learning diversity and inclusion in IB programmes: Removing barriers to learning*.

The documents *Meeting student learning diversity in the classroom* and *The IB guide to inclusive education: a resource for whole school development* are available to support schools in the ongoing process of increasing access and engagement by removing barriers to learning.

Nature of environmental systems and societies

Environmental systems and societies (ESS) is a dynamic interdisciplinary subject that takes 21st-century challenges and socio-environmental real-world issues and looks at them through the lens of human societies and the interrelationships of the natural world: biosphere, atmosphere, hydrosphere and lithosphere. Students explore how these relationships change over time and space, consider the potential adaptations and mitigations that human societies and the natural world may currently be undergoing, and how these could impact the future and our place in it.

An interdisciplinary course

ESS is an interdisciplinary course that is offered at both standard level (SL) and higher level (HL). The course combines a mixture of methodologies, techniques and knowledge associated with the subject groups of individual and societies, and sciences. Due to the interdisciplinary nature of the course, students may study ESS in either subject group, or in both. If ESS is studied in both groups, students may study an additional subject from any other subject group, including those in the individuals and societies, and sciences subject groups.

Various disciplines from the sciences and social sciences come together in ESS. These include, but are not limited to, ecology, economics, chemistry, geography, design, psychology, physics, law, philosophy, anthropology and sociology. The particular knowledge, concepts, skills and approaches from these disciplines are combined to enable ESS to be studied from a unique and integrated perspective.

The course is firmly grounded in both the scientific exploration of environmental systems in terms of their structure and function, and in the exploration of cultural, economic, ethical, political and legal interactions of societies with environment and sustainability issues. Consequently, ESS requires its students to develop a diverse set of skills, knowledge and understandings.

The interdisciplinary nature of the course means students gain a holistic understanding from the various topics studied; they undertake research and investigations, and participate in philosophical, ethical and pragmatic discussions about the issues involved, from the local to the global level.

ESS has conceptual connections with the individuals and societies courses in the Middle Years Programme (MYP) and the Diploma Programme (DP). The concepts in individuals and societies of scale, power, processes and possibilities are interwoven into the three key concepts of ESS: perspectives, systems and sustainability.

Example of connections
The ESS key concepts—perspectives, systems and sustainability—connect with MYP key concepts from individuals and societies; change, global interactions, time, place and space, and systems and also the MYP key concepts in the sciences; relationships, change and systems.
Psychology, like ESS, incorporates scientific and sociocultural approaches, with ESS using this combination to explore the key concepts.
Global politics links to ESS by referring to the concepts of power, equality, sustainability and peace at a variety of scales and contexts.
The economics course aligns with the ESS concepts through its concepts of interdependence and intervention, change, sustainability and equity for fair access to resources, goods and services.
In DP sciences, the biology model of "levels" corresponds to "scales" in ESS; ESS refers to the biology ecosystems level, and extends it to include larger social and environmental scales. The biology themes of unity and diversity, form and function, interaction and interdependence, and continuity and change are all

Example of connections
integrated within the ESS course. The physics concepts of energy, forces and particles, and the chemistry concepts of structure and reactivity are also encountered across ESS topics.

An interdisciplinary approach

The interdisciplinary approach of the ESS emphasizes the importance of incorporating a variety of environmental and societal perspectives when exploring issues. It allows students to examine the complexity and scale of issues addressed in ESS.

Such an approach allows inquiry and reflection to provide explanations of phenomena and enhances the exploration of local and global issues from different and diverse perspectives. It leads to the development of skills that underpin purposeful participation and engagement.

The exploration of complex world issues is enriched and sharpened through the reductionist approach of science with a holistic view of environmental issues. It heightens consideration of bias and isolated points of view, broadens students' awareness of our interconnected world, and provides many opportunities for them to explore topics of personal interest deeply.

Key concepts as foundation topics

At the heart of the ESS course is the intention to provide students with the learning needed to understand and make decisions regarding the pressing environmental issues we face. A conceptual and interdisciplinary approach is essential to problem-solving in ESS as this allows for truly holistic thinking about environmental and societal challenges faced in the 21st century.

The foundation topic (topic 1) of ESS introduces and explores the following three key concepts.

Perspectives

The concept of perspectives provides a deeper understanding of worldviews, individual perspectives and their related value systems. A person's value systems interact in complex ways with their decision-making abilities and their actions, and these can have a real-world impact. By understanding this complexity, students can consider how to make effective progress on complex sustainability issues.

Systems

Systems theory provides a useful tool for holistic analysis, and gives insight into understanding the mechanics and purpose of human-constructed systems and the function of natural ones. Systems theory uses conceptual models that provide essential analytical tools for understanding socio-ecological systems. The models provided also allow analysis of tipping points that could lead to change, and feedback loops that could help to manage systems behaviour.

Sustainability

The concept of sustainability is central to ESS. Resource management issues are pivotal to sustainability, and students' attention is drawn to this throughout the course. Social, cultural and political issues related to sustainability are covered in the course, for example, the value and conservation of traditional ecological knowledge.

Interdisciplinary learning

Interdisciplinary learning helps students to develop a broad skill set relating to inquiry, research, and the application of technology and mathematics. This skill set stems from the scientific investigation and problem-solving approach of the experimental sciences, and the observational reasoning, critical and creative thinking, and development of argument characteristics of individuals and societies subjects. Interdisciplinary learning in ESS ensures that students acquire skills that underpin sociocultural, socio-economic and scientific methodologies. The collaborative science project presents a further opportunity for ESS students to explore ideas across disciplinary boundaries within the sciences.

Many skills are developed through interdisciplinary learning.

Students learn to:

- investigate, analyse, reflect and communicate through the inquiry cycle
- apply natural and social sciences' experimental techniques, technologies and mathematical skills to investigations and problem-solving
- collect, analyse and interpret both qualitative and quantitative data, which may include: cartographic information, field sketches, behavioural observations, population dynamics, quadrat studies, abiotic measurements, demographics, and interview and survey results
- explore current events with connections to issues, concepts, systems and models
- examine examples empathetically while exploring a range of environmental value systems and perspectives relating to global issues in a dynamic and complex set of systems and societies
- use systemic and critical thinking in the formation of research questions and the analysis and construction of methodologies
- explore both local and global contexts of environmental issues and be empowered to develop impactful solutions as internationally minded agents of change.

Investigating issues brings together knowledge from multiple disciplines, and reframes that knowledge to effectively address environmental and societal issues. Some example issues are as follows.

- Intercultural awareness helps students examine culture in context and understand the current, and future, actions of societies regarding development, consumption, injustice, environment and inequality.
- The concepts of sustainability and equity are pivotal ideas in several individuals and societies courses. For example, climate change is an overarching issue in many.
- Environmental, cultural, economic, political and social contexts are considered in the design and use of technology as are resource management, sustainable production and sustainability.

Distinction between SL and HL

Students at SL and HL study:

- a concept-based syllabus that promotes holistic thinking about strategies to address environmental issues
- a foundation topic that introduces and explores the three key concepts
- a common internal assessment
- the collaborative sciences project.

The SL course provides students with a fundamental understanding of ESS and experience of the associated skills. The HL course requires students to gain knowledge and understanding of the subject underpinned by an exploration of ethical, legal and economic issues relating to the environment (HL lenses), and provides a solid foundation for further study at university level. Both SL and HL students gain an understanding of the complexities of environmental issues, solutions and management.

The SL course has a recommended 150 teaching hours, compared to 240 hours for the HL course. This difference is reflected in the additional content studied by HL students. Some of the HL content is conceptually more demanding; the increased breadth and depth results in increased networked knowledge, requiring students to make more connections between diverse areas of the syllabus.

HL students will demonstrate critical evaluation and further explore the SL and HL common content, HL only content and HL lenses to analyse a problem at greater breadth and depth.

ESS and the core

ESS and theory of knowledge

The theory of knowledge (TOK) course plays a special role in the DP by providing opportunities for students to reflect on the nature, scope and limitations of knowledge and the process of knowing through an exploration of knowledge questions.

The areas of knowledge are specific branches of knowledge, each of which can be seen to have a distinct nature and sometimes use different methods of gaining knowledge. In TOK, students explore five compulsory areas of knowledge: history, the human sciences, the natural sciences, mathematics and the arts. Of the five optional themes, the two that fit best with ESS are: knowledge and politics, and knowledge and indigenous societies.

There is a strong connection between the TOK course and ESS that can provide useful and engaging contexts for both subjects. Teachers are encouraged to discuss knowledge questions with their students in relation to the subject material. Knowledge questions focus on the production, acquisition, sharing and application of knowledge. These should be contestable claims that use the concepts and terminology of TOK.

In TOK, there are 12 key concepts that illustrate some of the typical language of such questions, namely: evidence, certainty, truth, interpretation, power, justification, explanation, objectivity, perspective, culture, values and responsibility. Rich opportunities can be found in many aspects of the course to discuss these concepts.

Perspectives are addressed directly in both curriculums; though there are some differences in approach to understanding perspectives, worldviews and values, the courses complement each other well. In ESS, perspectives form a foundational concept and students are taught to appreciate the need for deeper understanding of our differences to resolve sustainability issues. In TOK, perspectives, as well as being one of 12 key concepts, are a key element of the knowledge framework. Many of the knowledge questions arising are therefore equally valid to both subjects and provide useful engagement and discussion material for students.

The following are example knowledge questions in relation to perspectives in ESS.

- What is the significance of key historical events to changing environmental knowledge and attitudes?
- How does knowledge that is rooted in social and cultural groups create variation in environmental perspectives in different countries or generations?
- To what extent does the way we think about, and understand, the environment change how we value it and live within it?

Ethics in TOK is an important element in the knowledge framework, and in the ESS course environmental ethics is an HL lens. Environmental decision-making often has an ethical aspect to it, and HL students should be able to provide and justify ethical arguments for action on social/environmental issues. As part of the perspectives and sustainability key concepts, all SL and HL students will consider the ethics of environmental values, a variety of moral perspectives, and intrinsic values. This includes considering the moral justification of exploiting resources or other species and, furthermore, the moral justification for considering other species as resources. Students also need to appraise sustainability claims in terms of the issues of equity and environmental justice. These could include, for example, consideration of who benefits from the action towards sustainability or the conceptualizing of sustainability as an issue of intergenerational equity.

TOK underpins and helps to unite the subjects that students encounter in the rest of their DP studies. It engages students in explicit reflection on how knowledge is arrived at in different disciplines and areas of knowledge, on what these areas have in common and the differences between them. It is intended that through this holistic approach, discussions in one area will help to enrich and deepen discussions in others. Holistic approaches and systems theory are encouraged throughout the ESS course to aid understanding.

Interdisciplinary approaches are shared by TOK and ESS, with both courses aiming to deepen understanding through making connections across disciplines and making conclusions from differing methodologies to acquire new knowledge. In ESS, holistic approaches are encouraged using systems theory to understand many aspects of the course. This ranges from small-scale ecosystem studies, to looking at local environment and society interactions, to the modelling of the entire Earth system to understand climate change. Reductionist approaches contribute more to holistic understanding than conflicting approaches, and thus are seen as an essential component for developing holistic understanding. Students can be introduced to the precautionary principle, as adopted by the United Nations (UN), to provide a framework for action for when knowledge is uncertain.

The following are example knowledge questions in relation to interdisciplinary approaches.

- Systems modelling provides a simplified version of reality, so how can modellers know which aspects of the system to include and which to ignore?
- How do we interpret the validity of different conclusions when there is conflict between the knowledge produced by two disciplines?
- To what extent is the knowledge obtained by observational natural experiments less certain than from manipulated laboratory experiments?

ESS and the extended essay

Students who choose to write an extended essay (EE) in ESS have the opportunity to explore an environmental topic of particular interest to them. Their motivation may be the result of a concern or curiosity about local or global issues that relate to the environment. As ESS is an interdisciplinary subject, the EE should focus on the interaction and integration of natural environmental systems and human societies. In this respect, a systems approach is particularly effective, and students are expected to use this approach in the analysis and interpretation of their data.

For example, the study of pure ecological principles must be explored within the context of some human interaction with the environmental system. Students may use both primary and secondary methods and sources, including the collection of data from fieldwork, laboratory experimentations, surveys and interviews, or the use of existing materials. A combination of both is highly recommended. An EE in ESS provides students with the opportunity to include insights into how different subjects complement or challenge one another when used to address the same topic or issue.

An ESS research question must allow the student to demonstrate some grasp of how both environmental systems and societies function in the relationship under study. Owing to the interdisciplinary nature of the subject, a wide spectrum of topics could be selected to study. The most successful topics reveal connections between specific or local places or phenomena and the larger global framework in which they take place.

Examples of focus and research questions

Effectiveness of vegetation reducing carbon dioxide emissions

Research question: How effective is tree planting as a means of offsetting carbon dioxide emissions of flights in Canada?

Management programmes and soil degradation

Research question: To what extent have the management programmes in the Murray-Darling river basin been successful in reducing soil degradation caused by dryland salinity?

Environmental regulations and sustainable architecture

Research question: To what extent did the Danish government regulations in sustainable architecture contribute to a reduction in Denmark’s carbon footprint between 1973 and 2020?

Beaver introduction and ecotourism

Research question: To what extent did the trial project for the introduction of *Castor fibers* (European beaver) to the Knapdale Forest in Scotland affect ecotourism and economic development in the area?

Relevance of DDT intoxication on bird population in the United States

Research question: To what extent have the *Haliaeetus leucocephalus* (bald eagle) and the *Pandion haliaetus* (ospreys) populations in the United States recovered since the ban of dichlorodiphenyltrichloroethane (DDT) usage in 1972?

TSM link: Guidance for the EE can be found in the *Environmental systems and societies teacher support material*.

ESS and creativity, activity, service

The creativity, activity, service (CAS) programme aims to inspire students to embody the IB mission statement and the learner profile through practical experiences. CAS aims to develop students who understand they are members of local and global communities with responsibilities towards each other and the environment, with clear common areas in between their CAS experiences and ESS. Students develop skills, attitudes and dispositions through a variety of individual and group experiences that provide them with opportunities to explore their interests and express their passions, personalities and perspectives. CAS complements a challenging academic programme in a holistic way, providing opportunities for self-determination, collaboration, accomplishment and enjoyment. Students are encouraged to connect their CAS experiences with their subjects, and the ESS course is rich in such possibilities for students, with clear opportunities to reinforce their learning in ESS in a more informal and experiential style.

CAS students create a portfolio of reflections to provide evidence of achievement of the CAS learning outcomes. The emphasis in CAS is on experiential and affective reflections, characterized by consideration of attitudes, feelings, values, principles, motivation and self-development.

The portfolio is built over at least 18 months and is usually based on the students' weekly experiences. These experiences arise from the three strands below, each of which can be incorporated into the ESS curriculum within local or global communities.

The three strands are:

- creativity—arts and other experiences that involve creative thinking
- activity—physical exertion contributing to a healthy lifestyle, complementing academic work elsewhere in the DP
- service—an unpaid and voluntary exchange that has a learning benefit for the student. The rights, dignity and autonomy of all those involved are respected.

Students also engage with at least one longer collaborative CAS project, a more sustained experience that they work on for a minimum of one month.

ESS and international-mindedness

The ESS course emphasizes the importance of making local to global connections to develop an understanding of sustainability issues. This has remained strong in environmental education and is also reflected in the history of the environmental movement, with its initial focus on the local leading to a realization of the significance of the global context. During the 1940s–1960s, most environmental concerns were in relation to local and national interests, agricultural sufficiency and local pollution. By the 1970s–1980s, this had moved to recognizing the need to manage regional issues, such as acid rain, and saw the start of global concerns around the ozone layer and climate change. By the 1990s, the essential global context of numerous environmental concerns had been more clearly recognized. Since the 21st century, the concept of the Anthropocene has gained growing acceptance as the term for the current epoch; essentially, there is the realization that the scale of global impact is no longer under the regulation of nature alone. In this century, the global environment is under new management: humanity.

Local context

The study of local ecosystems and environments through fieldwork is strongly recommended. Local knowledge is valuable for student studies, also in urban areas and school grounds. In some school settings, opportunities to access and gain knowledge may come from indigenous cultures. International-mindedness can include developing an understanding of communities with different worldviews, both within the school and in neighbouring communities.

Teachers can use their knowledge of local biodiversity and environments. Developing connections to build local environmental knowledge capacity can lead to long-term projects for schools and provide students with opportunities to engage in citizen science and other actions through events such as bioblitzes, nature reserve management, rural skills trusts, urban permaculture, and water and pollution monitoring. School administrations, as well as local governmental and non-governmental organizations (NGOs), may be able to help make these connections.

Global context

Global issues require global understandings of both the issues themselves and how societies may be able to tackle them. This notion is an essential premise in the course, shown clearly through studies of the planetary boundaries: for example, for defining the global problems and exploring the Sustainable Development Goals (SDGs) to provide possible solutions. There are numerous organizations working towards the resolution of global environmental problems. There are international bodies and conventions set up by the UN that seek to reach agreements between nations. There are also a number of significant NGOs working in the intergovernmental arena to influence global environmental decision-making using a variety of methods, such as consultancy, advocacy, education and protest.

Understanding the background to different perspectives through improving international-mindedness is an essential aspect of the course. In addition to understanding the local to global context, students should be exposed to a variety of local examples from across the world. At the heart of international-mindedness is the development of a deeper understanding and appreciation of different perspectives and worldviews. ESS students are encouraged to understand that competing worldviews may be a barrier to reaching agreements on environmental problems. Developing greater appreciation of cultural differences in classrooms, in local communities and through online interaction are key aspects of this approach.

Approaches to the learning and teaching of environmental systems and societies

Approaches to learning

What are approaches to learning skills and why do we teach them?

The approaches to learning framework seeks to develop in students affective, cognitive and metacognitive skills that will support their learning processes during and beyond their IB experience. The development of approaches to learning skills is closely connected with the IB learner profile attributes and, therefore, helps to advance the IB mission. The approaches to learning skills are an integral part of IB learning and teaching that should be developed across the whole programme—it is not expected that a single course should ever address all of them.

How are they organized?

The approaches to learning framework for IB programmes consists of five general skill categories: thinking skills, communication skills, social skills, research skills and self-management skills. Each of these categories covers a broad range, as shown by the examples presented in Table 1. The approaches to learning skill categories are closely linked and interrelated; therefore, individual skills may be relevant to more than one category.

How do we teach them?

Approaches to learning skills can be learned and taught, improved with practice and developed incrementally. Table 1 illustrates, through a number of examples, how environmental systems and societies (ESS) courses can support approaches to learning skill development. The examples shown in the table are not exhaustive. Teachers are encouraged to adapt them for use in their school context and collaboratively identify further examples of approaches to learning skill development.

Further information on the approaches to learning skills framework, and strategies for the development of these skills, can be found in the *Environmental systems and societies teacher support material* and the *Diploma Programme Approaches to teaching and learning website*.

Table 1: Approaches to learning skills and development

Skill category	Examples of approaches to learning skill development in the classroom
Thinking skills	• Practising holistic thinking skills and the use of a systems approach • Developing ecological literacy through seeking interconnections within and between the natural world and human society • Applying critical thinking, innovation and creativity in creating synthesis and solutions to environmental problems • Evaluating claims of attaining sustainability and the identification of barriers to attaining sustainability • Reflecting on personal perspectives and recognizing spheres of influence on action (personal, social, political, global) • Critically examining and evaluating the evidence and theory supporting competing narratives on environmental/sustainability issues • Evaluating and defending ethical positions on environmental/sustainability issues
Communication skills	• Practising active listening skills and appreciating that understanding different perspectives can allow for better communication

Skill category	Examples of approaches to learning skill development in the classroom
	• Reflecting on the needs of different target audiences for effective communication • Using terminology, symbols and communication conventions consistently and correctly • Presenting data appropriately in tables and through suitable graphical and cartographical techniques • Developing persuasive writing skills and dialectical analysis in essays • Writing effective and critically evaluated conclusions • Applying and analysing different forms of media to present a persuasive argument
Social skills	• Working collaboratively to achieve a shared solution to an issue • Assigning and accepting specific roles during group activities • Appreciating the value of diverse talents and the needs of others • Understanding that stakeholders have different perspectives—and the bridge-building needed between different stakeholders • Reflecting on the impact of personal behaviour and the resolution of conflicts or disagreements within a group • Developing the teamwork skills, ethics and inspirational leadership needed to resolve sustainability issues • Generating agreed solutions with respect to the interests of all stakeholders
Research skills	• Constructing a clear and focused research question with a genuine connection to an issue of environmental/social significance • Selecting appropriate techniques for inquiry into a research question • Evaluating the use of quantitative and qualitative observations from laboratory work and fieldwork to help answer some research questions • Recognizing the value of manipulated experimental work in determining causation in laboratory and natural experimentation • Locating and evaluating secondary information sources for accuracy, bias, credibility and relevance • Explicitly discussing the importance of academic integrity and full acknowledgement of the ideas of others • Seeking out interconnections between academic disciplines and real-world experience
Self-management skills	• Breaking down major tasks into a sequence of stages • Logically organizing and ordering a variety of information sources • Maintaining punctuality and avoiding distraction • Assessing risk in laboratory experiments or fieldwork • Taking acceptable risks and regarding setbacks as opportunities for improvement • Improving academic work through reflecting on feedback and making revisions • Developing action competence through evaluating personal or proposed actions to environmental problems

Approaches to teaching

Conceptually focused teaching in ESS

Three key concepts comprise the foundation subtopics of Topic 1: Foundation and should be taught at the start of the course.

- Perspectives (subtopic 1.1)
- Systems (subtopic 1.2)
- Sustainability (subtopic 1.3).

They are the cognitive foundations of ESS for both SL and HL students. The seven other topics (topics 2–8) cover the remaining subject material to be studied.

Concept-driven learning is an iterative process in which factual examples may change but the core understanding is universal, transferable across time and context, and is abstract. This allows students to transfer their understanding to new contexts, make generalizations, recognize patterns and make better sense of their knowledge and skills.

The guiding questions help frame each subtopic and guide inquiry. Students should be encouraged to develop conceptual understandings through the content statements. While developing specific knowledge and skills, students deepen their understanding of concepts to make generalizations that go beyond specific case studies and real-world examples.

Contextualized teaching

Context is essential in ESS as students study and make sense of the world around them and their place within it. The interdisciplinarity of ESS allows for making continual cross-curriculum links, using the key concepts, guiding questions (and HL lenses for HL students) to enhance understanding of specific content.

By connecting with the real world, contextualized learning and teaching draws on the interests and experiences of students and teachers, their cultures and perspectives. It allows students to relate to the "why" of learning, as well as the "what".

Contextualized learning and teaching has many formats, but the key elements are as follows.

- Collaboration across disciplines
- Meaningful, interactive and collaborative activities
- Authentic and relevant context of significance to students
- Interactive teaching—real-world data of current environmental issues, peer-to-peer work, student-initiated discussion
- Issue-based learning—working individually or in groups to identify and propose solutions to societal or environmental issues
- Transferable skills—applying knowledge and skills to a newly defined environmental issue

Engaging with ESS and sensitive topics

The ESS key concepts of perspectives, systems and sustainability aid student understanding and foster a desire to engage and act meaningfully on environmental issues within local and global contexts. Possible engagement opportunities are provided in each subtopic. These may be used in teaching the ESS course and are not assessed. Some may be a foundation for creativity, activity, service (CAS) activities within the Diploma Programme (DP), others may be a starting point for individual or whole-school action.

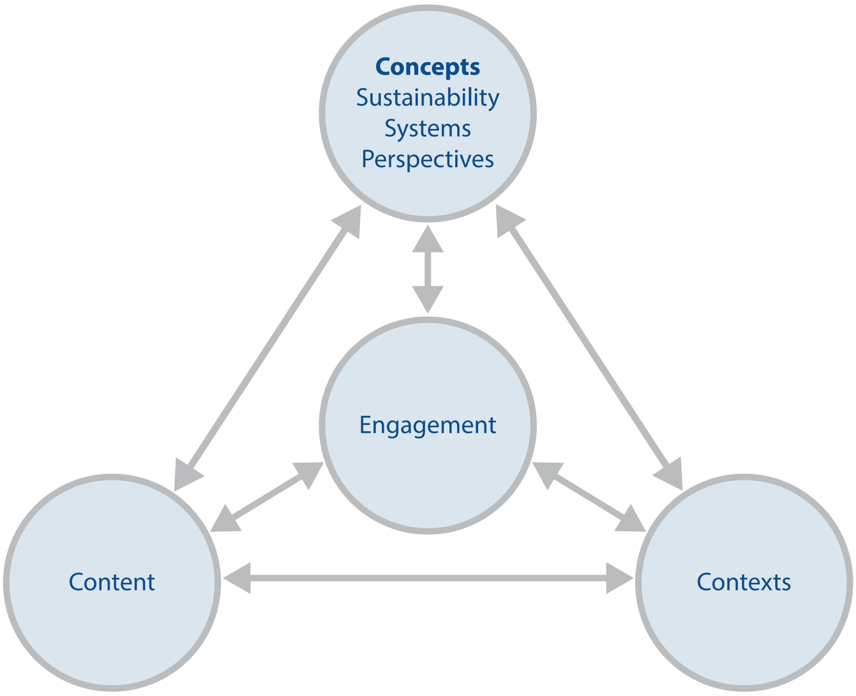
Studying this course will lead students to critically examine and develop their own perspectives on a wide range of environmental issues, including climate change, biodiversity, habitat loss, pollution and sustainable practices. By engaging with ESS, students develop their understanding of their own and humanity's environmental impact.

Students become acquainted with a diverse range of worldviews from people of different cultures and backgrounds. Appreciating diverse viewpoints on environmental issues—and the tensions arising from these—is complex and may be unsettling for students, who may feel they are not empowered to make a positive difference. For example, there is much misinformation within the media, and teachers have a responsibility to help students assess and evaluate the reliability and validity of sources and claims. These viewpoints can be critically examined, but this should be done in an atmosphere of tolerance and respect towards others.

While engagement with ESS is academic and intellectual, it is also emotional. Some students are struggling with climate anxiety, concern for biodiversity loss and the myriad issues of sustainability. They may feel anxious, helpless or overwhelmed because they are not in control. In teaching the ESS course, teachers should aim to promote resilience among their students and help them to build tools and resources to foster a sense of agency. Students should learn that individuals can take restorative action, however small it may seem.

Figure 2

Environmental systems and societies relationships (concepts–contexts–content) inspire students to engage with environmental issues



Prior learning

The ESS course requires no specific prior learning at either SL or HL. No particular background in terms of specific subjects studied for national or international qualifications is expected or required. The skills needed for the ESS course are developed within the context of the course itself.

An approach to study characterized by the IB learner profile attributes—specifically, open-minded, inquirers, thinkers and communicators—will be significant in developing holistic thinking and understanding of environmental issues.

Links to the Middle Years Programme

The alignment between Middle Years Programme (MYP) and DP courses allows for a smooth transition for students between programmes. In the MYP, students develop cognitive, procedural and social skills as well as strong conceptual understandings and problem-solving skills that support learning and teaching in the

DP and beyond. A connected, conceptual curriculum where learning is inquiry-based and contextualized are pedagogical principles that underpin the entire IB continuum.

The MYP sciences courses promote the knowledge, skills and attitudes needed to apply scientific knowledge in theoretical, experimental and authentic contexts. Similarly, the MYP individuals and societies subject group equips young people to investigate and evaluate the interactions between individuals and societies and critically engage with multiple perspectives and ways of thinking.

ESS is an interdisciplinary course that is firmly grounded in both the scientific exploration of environmental systems and the exploration of cultural, economic, ethical, political and legal interactions of societies with the environment.

Broad concepts frame MYP learning and teaching with the purpose of unifying ideas across subject areas. The MYP subject groups offer conceptual frameworks for inquiry-based learning and teaching encouraging the exploration of—and engagement with—local and global issues, phenomena and contexts.

Building on the shared IB pedagogical principles, ESS is a logical continuation of the MYP, further cultivating inquiry, conceptual understanding, international-mindedness and principled engagement.

Links to the Career-related Programme

The IB Career-related Programme (CP) incorporates the vision and educational principles of the IB into a unique programme specifically developed for students who wish to engage in career-related learning.

In the CP, students study at least two DP subjects, a core consisting of four components, as well as a career-related study, which is determined by the local context and aligned with student needs. The CP has been designed to add value to students' career-related studies. This provides the context for the choice of DP courses. ESS is a good choice for one of the DP courses. By providing insight into environmental issues and their impact on societies, it can contribute to the appreciation of concepts such as sustainability when applied to careers ranging from architecture to urban design, the food industry and international engagement. An understanding of issues such as food, water and energy security and ecological footprints is also increasingly important in all spheres of industry and commerce. ESS helps students to understand the interconnectedness of environments, economies and societies in the contemporary world. It can also contribute to a greater understanding of an individual or organization's role in responding to environmental challenges from a local to a global context, through the career opportunities and choices they make. ESS also encourages the development of strong problem-solving, critical-thinking and ethical approaches that will assist students in the global workplace.

For CP students, DP courses can be studied at SL or HL. Schools and colleges can explore opportunities to integrate CP students with DP students.

Collaborative sciences project

The collaborative sciences project is an interdisciplinary sciences project, providing a worthwhile challenge to Diploma Programme (DP) and Career-related Programme (CP) students, addressing real-world problems that can be explored through the sciences. The nature of the challenge should allow students to integrate factual, procedural and conceptual knowledge developed through the study of their disciplines.

Through the identification and research of complex issues, students can develop an understanding of how interrelated systems, mechanisms and processes impact a problem. Students will then apply their collective understanding to develop solution-focused strategies that address the issue. With a critical lens, they will evaluate and reflect on the inherent complexity of solving real-world problems.

Students will develop an understanding of the extent of global interconnectedness between national, regional and local communities, which will empower them to become active and engaged citizens of the world. While addressing local and global issues, students will appreciate that the issues of today exist across national boundaries and can only be solved through collective action and international cooperation.

The collaborative sciences project supports the development of students' approaches to learning skills, including team building, negotiation and leadership. It facilitates an appreciation of the environment, and the social and ethical implications of science and technology.

Full details of the requirements are in the *Collaborative sciences project guide*.

Aims

Environmental systems and societies aims

Environmental systems and societies (ESS) aims to empower and equip students to:

1. develop understanding of their own environmental impact, in the broader context of the impact of humanity on the Earth and its biosphere
2. develop knowledge of diverse perspectives to address issues of sustainability
3. engage and evaluate the tensions around environmental issues using critical thinking
4. develop a systems approach to provide a holistic lens for the exploration of environmental issues
5. be inspired to engage in environmental issues across local and global contexts.

Refer also to individuals and societies aims, and sciences aims.

Assessment objectives

These assessment objectives (AO) reflect how the aims of the environmental systems and societies (ESS) course will be assessed. The intention is that students, in the context of environmental systems and related issues, can fulfil the following assessment objectives.

AO1: Knowledge and understanding

Demonstrate knowledge and understanding of:

- relevant concepts, theories and perspectives
- data and data manipulation
- methods and models
- relevant case studies and real-world examples.

AO2: Application and analysis

Explain, analyse and develop:

- relevant concepts, theories and perspectives
- data and data interpretation
- methodologies and models
- clear explanations and arguments
- relevant case studies and real-world examples.

AO3: Evaluation and synthesis

Evaluate and synthesize:

- relevant concepts, theories and perspectives
- data, and use it to inform and justify conclusions
- methodologies and models, recognizing their value and limitations
- arguments and proposed solutions to environmental issues
- environmental issues within their political, economic, ethical, social and cultural contexts.

AO4: Use and application of appropriate skills

- Identify an appropriate environmental issue and research question for investigation.
- Select and demonstrate the use of appropriate methodologies and skills to carry out ethical investigations into environmental issues.

Assessment objectives in practice

Assessment objective	Which component addresses this assessment objective?	How is the assessment objective addressed?
Assessment objectives 1–3	Paper 1	Case study Both standard level (SL) and higher level (HL)
Assessment objectives 1–3	Paper 2	Section A: answer all questions Section B: SL: one essay from a choice of two HL: two essays from a choice of three
Assessment objectives 1–4	Internal assessment	Individual investigation assessed using assessment criteria
The assessment objectives will be tested in the examinations through the use of the command terms (given in the "Glossary of command terms" section of the guide).		

Syllabus outline

Syllabus component	Teaching hours	
	SL	HL
Topic 1: Foundation	**16**	
1.1 Perspectives	(3)	
1.2 Systems	(5)	
1.3 Sustainability	(8)	
Topic 2: Ecology	22	35
Topic 3: Biodiversity and conservation	13	26
Topic 4: Water	12	25
Topic 5: Land	8	15
Topic 6: Atmosphere and climate change	10	23
Topic 7: Natural resources	10	18
Topic 8: Human populations and urban systems	9	15
Higher level (HL) lenses		**17**
HL.a Environmental law		(5)
HL.b Environmental economics		(7)
HL.c Environmental ethics		(5)
Experimental programme	**50**	**50**
Practical work	(30)	(30)
Collaborative sciences project	(10)	(10)
Individual investigation	(10)	(10)
Total teaching hours	**150**	**240**

Recommended teaching time

The recommended teaching time is 150 hours to complete standard level (SL) courses and 240 hours to complete higher level (HL) courses, as stated in the general regulations (in *Diploma Programme Assessment procedures*).

The approximate number of recommended hours for teaching a topic are given for both SL and HL.

Additional hours for HL are listed separately after the core teaching hours.

Practical work

Practical work is an important aspect of the environmental systems and societies (ESS) course, whether in the laboratory, classroom or out in the field. The syllabus not only directly requires the use of field techniques, but many components can only be covered effectively through this approach. Practical work in ESS is an opportunity for students to gain and develop skills and techniques beyond the requirements of the assessment model and should be fully integrated with the teaching of the course.

In line with the *IB sciences experimentation guidelines* (see the *Environmental systems and societies teacher support material* for full details), the following guidelines exist for all practical work undertaken as part of the Diploma Programme (DP).

- No experiments involving other people will be undertaken without their written consent and their understanding of the nature of the experiment.
- No experiment will be undertaken that inflicts pain on, or causes distress to, humans or live animals.

Syllabus format

The **topics** are numbered, for example, “Topic 2: Ecology”. Refer to the “Syllabus outline” section for recommended teaching times for standard level (SL) and higher level (HL).

Guiding questions—The purpose of guiding questions is to promote inquiry. Teachers and students are encouraged to create their own guiding questions to capture the content of units of study.

The syllabus content listed under the “SL and HL” heading should be taught to both SL and HL students.

Subtopics are also numbered, for example, “2.1 Individuals, populations, communities, and ecosystems”. Each subtopic begins with a guiding question(s) that frames and guides inquiry for the learning within the subtopic. Each subtopic is divided into numbered understandings, which are, in turn, divided into a **content statement** and **notes**. Some understandings will also include reference to the application of skills.

Sections that are marked as “HL only” should be taught only to HL students.

Figure 3

Syllabus format

Understanding

0.0.0—The **content statement** indicates the content to be taught.	
Notes provide clarifications to the scope and requirements of the content statement. The notes are intended to guide teachers and students in addressing the content statement. Notes may contain information on the topic or specific instructions. Sometimes, what is not required is also given. Where terms such as “consider”, “include”, “appreciate” are used, the intention is that teachers should cover this material. It is strongly suggested that all students have a version of the guiding questions and guidance. Where the statement is self-explanatory, notes are not included.	Where **connections** can be made with other subtopics, a list of subtopics (numbers) is included next to the notes.
Application of skills includes directed activities that connect the content statement with a skill, such as interpreting data, utilizing statistics, designing or carrying out an experiment.	

Teachers and students should be familiar with the **assessment objectives** (AO) and the associated **command terms** in order to understand the depth of treatment required in teaching and in examination questions. Command terms related to cognitive demand progress from AO1 to AO3, while AO4 command terms are specific to particular skills. The command terms and their definitions are listed in alphabetical order within each assessment objective in the “Glossary of command terms” in the appendix to this guide.

Skills in the study of environmental systems and societies

The skills and techniques students must experience through the course are encompassed within the tools and inquiry process. These tools support the application and development of the inquiry process in the delivery of the environmental systems and societies (ESS) course. Guidance on how the tools can be applied in the learning and teaching of the subject is summarized in each subtopic.

Tools

- **Tool 1:** Experimental techniques
- **Tool 2:** Technology
- **Tool 3:** Mathematics
- **Tool 4:** Systems and models

Inquiry process

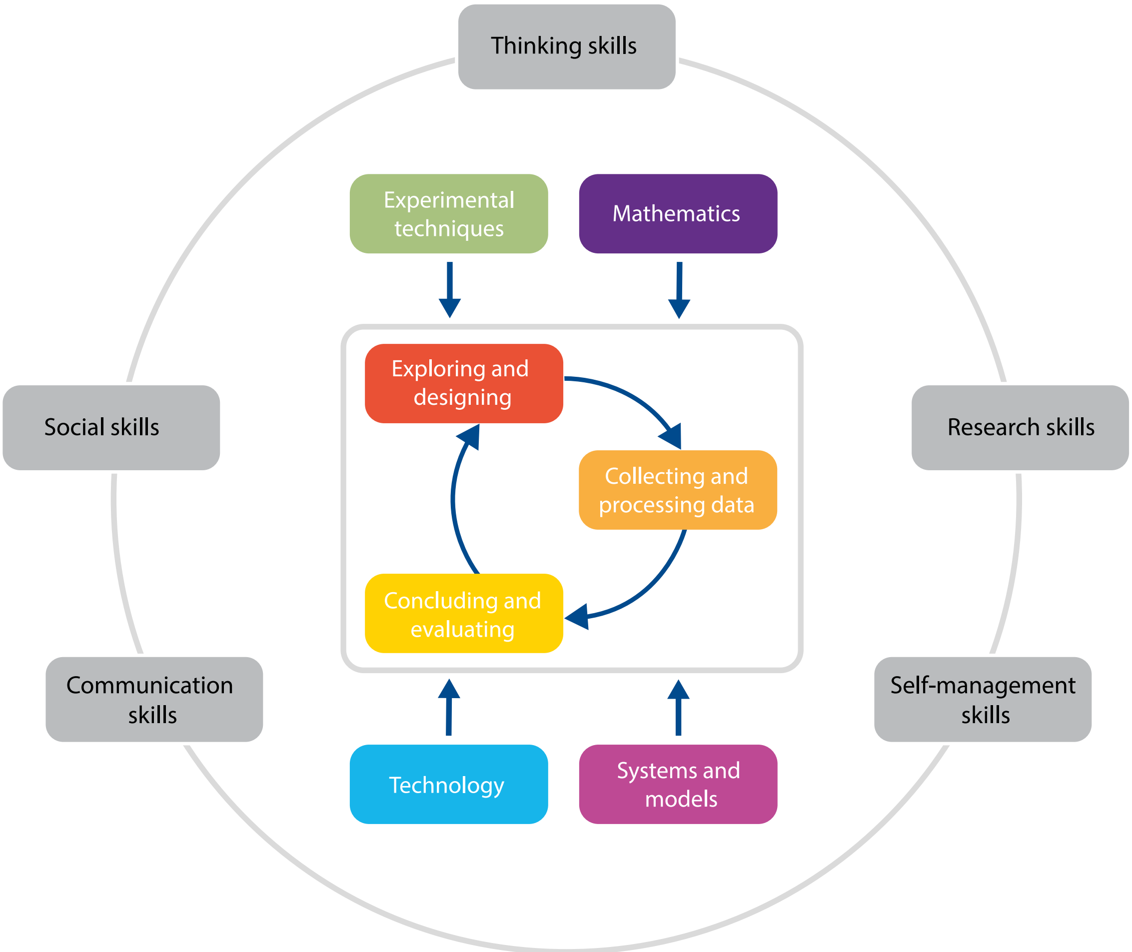
- **Inquiry 1:** Exploring and designing
- **Inquiry 2:** Collecting and processing data
- **Inquiry 3:** Concluding and evaluating

Teachers are encouraged to provide opportunities for students to encounter and practise the skills throughout the course. Rather than being taught as stand-alone topics, they should be integrated into the teaching of the syllabus when they are relevant to the syllabus topics being covered. The skills in the study of ESS can be assessed through internal and external assessment.

The approaches to learning provide the framework for the development of these skills.

Figure 4

Skills and tools for environmental systems and societies



Tools

Tool 1: Experimental techniques

Skill	Description
Laboratory work	For carrying out laboratory experiments, students should be able to: • make appropriate quantitative measurements (e.g., counts, time, mass, volume, temperature, length, pH and concentration) • select and justify appropriate techniques, sampling strategies, apparatus and materials • carry out procedures for estimating biomass (dry weight) of plant matter only • carry out procedures for measuring gross and net, primary and secondary productivity and biological oxygen demand **(HL only)** • set up and utilize appropriate laboratory equipment and materials with safety and accuracy.
Fieldwork	For carrying out fieldwork, students should understand how to:

Skill	Description
	• measure a range of abiotic factors (climatic, edaphic and aquatic) • identify flora and fauna using dichotomous keys, online databases and apps, and correctly use binomial nomenclature • use appropriate quadrat sampling for the estimation of abundance, population density, percentage cover, percentage frequency of non-motile organisms • use capture–mark–release–recapture with the Lincoln index to estimate population size of motile organisms • use transects to measure changes along an abiotic gradient • carry out sampling to collect data for calculating species diversity • carry out sampling to collect data for calculating biotic index **(HL only)**.
Questionnaires Surveys Interviews	For carrying out surveys, students should be able to: • identify and justify their choice of an appropriate target audience • construct relevant open or closed questions with multiple-choice responses/Likert scale, as appropriate • choose and justify an appropriate method and size of sample, i.e., random/ convenience/volunteer/purposive • show ethical awareness, i.e., anonymity/consent of respondents over the age of 12 • pilot/trial the survey to gain feedback for modification.
Secondary data collection	For addressing a research question with secondary data, students should be able to: • record and justify their selection of secondary sources • collect sufficient data to apply appropriate statistical tests • manipulate/process the data to address the research question or hypothesis.

Tool 2: Technology

Skill	Description
Use of digital technology	While students will not be assessed on their use of digital technology, the following resources may be valuable to their learning and investigations in this subject. • Data logging and other digital devices • Computer modelling and simulations to generate data • Spreadsheets and graph-plotting software, e.g., Excel • Collaborative platforms • Databases, e.g., Gapminder, Our World in Data, World Bank, ScienceDirect • GIS/ArcGIS and Google Maps • Ecological footprint calculator • Google Forms/Survey Monkey/social media for questionnaires/surveys • Online calculation tools for statistics, e.g., Social Science Statistics calculators

Tool 3: Mathematics

Skill	Description
General mathematical skills	For manipulating data, students should be able to: • execute basic arithmetic functions: addition, subtraction, multiplication and division • perform calculations involving averages, decimals, fractions, percentages, ratios, approximations, frequencies and reciprocals • calculate measures of central tendency: mean, median and mode • use and interpret standard notation (e.g., 3.6×10^6) • apply and use the Système International d'Unités (International System of Units—SI units) for mass, time, length and their derived units, e.g., speed, area and volume or non-SI metric units • use direct and inverse proportion • plot graphs (with suitable scales and axes) including two variables that show linear and non-linear relationships, independent variable on the x axis, dependent on the y axis • interpret graphs, including the significance of gradients, changes in gradients, intercepts and areas • interpret data presented in various forms: scatter plot, point-to-point line, line of best fit, bar chart, stacked histogram, pie chart, box and whisker plot, kite diagram • evaluate data through statistical tests and quantities (e.g., standard deviation, correlation coefficient, Spearman's rank correlation coefficient, analysis of variance (ANOVA), chi-squared test, t-test) • calculate indices from given formulae, e.g., Simpsons reciprocal index, Lincoln index • calculate natural increase rates and population doubling times from given data.

Tool 4: Systems and models

Skill	Description
Constructing and interpreting models and diagrams	For using and analysing models of systems, students should be able to: • construct a systems/flow diagram from a given set of data showing transfers, transformations and stores • construct and interpret systems diagrams representing, but not limited to, ecosystems, soil, biogeochemical cycles, urban systems • interpret models representing, but not limited to, feeding relationships, population growth and interactions, demographic transition, atmospheric changes, climate graphs, yield/fishing effort curves, circular and doughnut economies • calculate efficiency of energy transfer through a system **(HL only)** • interpret cladograms **(HL only)**.

Inquiry process

Inquiry 1: Exploring and designing

Skill	Description
Inquiring and designing	In planning and designing an inquiry, students should be able to: • identify an environmental issue and formulate a relevant, concise research question • formulate a testable hypothesis, including a null and alternative hypothesis where appropriate • identify all appropriate variables, range of values and controls • plan for collection of sufficient relevant data, repetitions and sample sizes for statistical tests.
Risk assessment and ethical considerations	In carrying out any investigation, students should be able to: • identify risks and maintain the safety and well-being of self and others • adhere to the *IB sciences experimentation guidelines* • demonstrate awareness of ethical issues and environmental impacts of investigation • demonstrate safe and environmentally responsible disposal of chemicals and other materials • assess the validity of websites used and, therefore, the reliability of information and data collected.

Inquiry 2: Collecting and processing data

Skill	Description
Recording of collected data	In collecting data from an investigation, students should: • record the collected data to an appropriate level of precision • construct tables of raw data, using descriptive titles, column and row headings with units where required • record any relevant qualitative observations made during the investigation • record any sources of secondary data.
Processing data	In processing the collected data, students should be able to: • calculate from data, including but not limited to any relevant percentages, means, indices, ratios, rates of change • construct charts and/or graphs with descriptive titles, axes labelled with units, as appropriate • construct graphs (scatter plot, point-to-point line, line/curve of best fit, bar chart, histogram, pie chart, box and whisker plot, rose diagram, kite diagram) to demonstrate relevant patterns or correlations in the data, including error bars, where appropriate • construct system diagrams, including relevant stores and flows • calculate, where appropriate, measures of dispersion, e.g., standard deviation and variance (minimum five values), interquartile range, and coefficient of determination (R^2)

Skill	Description
	• interpret values of the correlation coefficient (*r*) and identify correlations as positive or negative • select and use appropriate statistical tests (e.g., Pearson correlation coefficient, Spearman's rank correlation coefficient, t-test, ANOVA, chi-squared test).
Interpreting processed data	In interpreting processed data, students should be able to: • identify, describe and explain patterns, trends and relationships in the processed data • understand and assess accuracy, precision, validity and reliability • identify random and systematic errors, along with outliers/anomalies • identify bias in publications/media/questionnaires/surveys.

Inquiry 3: Concluding and evaluating

Skill	Description
Concluding	In drawing conclusions from investigations, students should be able to: • interpret processed data to draw and justify valid conclusions • compare the outcomes of an investigation to reliable secondary sources • relate the outcomes of an investigation to the stated research question or hypothesis • discuss the impact of the uncertainties on the conclusions.
Evaluating	In evaluating investigations carried out, students should be able to: • evaluate the methodology, including how to reduce random and systematic errors • evaluate the strengths of an investigation • evaluate the implications of methodological weaknesses, limitations and assumptions on conclusions • evaluate the reliability of sources of information • explain realistic and relevant improvements to an investigation.

Syllabus content

Topic 1: Foundation

1.1 Perspectives

Guiding questions

- How do different perspectives develop?
- How do perspectives affect the decisions we make concerning environmental issues?

SL and HL

1.1.1 A perspective is how a particular situation is viewed and understood by an individual. It is based on a mix of personal and collective assumptions, values and beliefs.
Personal perspectives give rise to a wide range of different positions on environmental and social issues. Perspectives also influence people's choices and actions.

1.1.2. Perspectives are informed and justified by sociocultural norms, scientific understandings, laws, religion, economic conditions, local and global events, and lived experience, among other factors.
A perspective is not the same as an argument. Arguments are made to support a personally held perspective or to counter a different one.

1.1.3 Values are qualities or principles that people feel have worth and importance in life.
Values affect people's priorities, judgements, perspectives and choices. They are individual but are shared with, and shaped by, others in a community.

1.1.4 The values that underpin our perspectives can be seen in our communication and actions with the wider community. The values held by organizations can be seen through advertisements, media, policies and actions.
Different values often lead to tensions between individuals and between organizations.

1.1.5 Values surveys can be used to investigate the perspectives shown by a particular social group towards environmental issues.	
The effective design of values surveys for a particular social group accommodates various perspectives towards a particular environmental issue, and assesses how these are likely to impact the issue.	HL.c
Application of skills: Design and carry out questionnaires/surveys/interviews, using online collaborative survey tools, to correlate perspectives with attitudes towards particular environmental or sustainability issues. Select a suitable statistical tool to analyse this data. Students may use and develop behaviour-time graphs to show lifestyle changes.	

1.1.6 Worldviews are the lenses shared by groups of people through which they perceive, make sense of and act within their environment. They shape people's values and perspectives through culture, philosophy, ideology, religion and politics.	
With the development of the internet and social media, one's perspective can be influenced by a far greater variety of worldviews than just that of the local community. Consequently, models that attempt to classify perspectives, though helpful, are invariably inaccurate as individuals often have a complex mix of positions.	HL.c

1.1.7 An environmental value system is a model that shows the inputs affecting our perspectives and the outputs resulting from our perspectives.
A value system has inputs (for example, information from media, education, worldviews) and outputs (for example, our judgements, positions, choices and actions).

1.1.8 Environmental perspectives (worldviews) can be classified into the broad categories of technocentric, anthropocentric and ecocentric.	
These are not exclusive categories; a variety of alternative schemes exist. There are many ways to classify our perspectives; these models are useful but imperfect, as individuals often have a complex range of positions that change over time and context. Technocentrism assumes all environmental issues can be resolved through technology. Anthropocentrism views humankind as being the central, most important element of existence, and it splits into a wide variety of views. Ecocentrism sees the natural world as having pre-eminent importance and intrinsic value.	HL.a, HL.c

1.1.9 Perspectives and the beliefs that underpin them change over time in all societies. They can be influenced by government or non-governmental organization (NGO) campaigns or through social and demographic change.	
Application of skills: Interpret behaviour-time graphs. Examples could include specific changes, such as smoking, littering, eating meat or how traditional lifestyles in indigenous cultures are being replaced by modern ones.	HL.a, HL.c

1.1.10 The development of the environmental movement has been influenced by individuals, literature, the media, major environmental disasters, international agreements, new technologies and scientific discoveries.	
Select **one** example of influence from each of the following categories. • An individual environmental activist • An author • The media—for example, Al Gore's documentary *An Inconvenient Truth* (2006), *No Impact Man* (2009), *Breaking Boundaries: The Science of Our Planet* (2021) • An environmental disaster—for example, Minamata disaster (1956), Chernobyl disaster (1986), Fukushima Daiichi nuclear disaster (2011) • International agreements—for example, Rio Earth Summit (1992) and Rio+20 (2012); 2015 and 2022 United Nations Climate Change Conferences (COP 21, COP 27) • Technological developments—for example, the Green Revolution, reduction of energy inputs and enteric fermentation, plant-based meats • Scientific discovery—for example, pesticide and biocide toxicity, species loss, habitat degradation	HL.c

Examples may also be recent, from indigenous cultures or local/global events of student interest.	

Possible engagement opportunities

- Practise debating or discussing students' own perspectives and how they might influence behaviour.
- Design appropriately persuasive materials to advocate for an environmental or social cause.

Advocate to show how personal actions can create change towards a more sustainable society.

Engage in discussing the role of politics, intergovernmental organizations (IGOs), NGOs and individuals (through social media) in solving an environmental problem. This could be through participating in a Model United Nations group (MUN).

1.2 Systems

Guiding question

- How can the systems approach be used to model environmental issues at different levels of complexity and scale?

SL and HL

1.2.1 Systems are sets of interacting or interdependent components.
System components are organized to create a functional whole.

1.2.2 A systems approach is a holistic way of visualizing a complex set of interactions, and it can be applied to ecological or societal situations.
A system has storages and flows, with flows providing inputs and outputs of energy and matter.

1.2.3 In system diagrams, storages are usually represented as rectangular boxes and flows as arrows, with the direction of each arrow indicating the direction of each flow.	
Application of skills: Create systems diagrams representing the storages and flows, inputs and outputs of systems, such as a lab-based or local natural ecosystems. The size of the boxes and the arrows may be representative of the size/magnitude of the storage or flow.	Topic 2, 4.1, 5.1, 8.2

1.2.4 Flows are processes that may be either transfers or transformations.	
Transfers involve a change in location of energy or matter; transformations involve a change in the chemical nature, a change in state or a change in energy.	2.3, 4.1, 5.1

1.2.5 Systems can be open or closed.	
An open system exchanges both energy and matter across its boundary, while a closed system exchanges only energy across its boundary. Almost all systems are open; only the global geochemical cycles approximate to closed systems. Biosphere 2 is an example of a closed system, and a local ecosystem is an example of an open system.	2.3, 4.1

1.2.6 The Earth is a single integrated system encompassing the biosphere, the hydrosphere, the cryosphere, the geosphere, the atmosphere and the anthroposphere.
James Lovelock's Gaia hypothesis is a model of the Earth as a single integrated system. The hypothesis (also known as the Gaia theory) was introduced to explain how atmospheric composition and temperatures are interrelated through feedback control mechanisms. Many variations of the Gaia theory were further developed by James Lovelock and Lynn Margulis.

1.2.7 The concept of a system can be applied at a range of scales.	
Systems are at a range of scales, including a small-scale local ecosystem, such as a bromeliad in a rainforest; a large ecosystem, such as a rainforest; and the Gaia hypothesis or atmospheric circulation as an example of a global system.	

1.2.8 Negative feedback loops occur when the output of a process inhibits or reverses the operation of the same process in such a way as to reduce change. They are stabilizing as they counteract deviation.	
Use James Lovelock and Andrew Watson's Daisyworld model to show how temperature regulation can occur due to the presence of life on a planet in contrast with a dead one. Include other examples.	2.1, 2.5, 5.3, 6.2, 7.2, 8.3
Application of skills: Use diagrams representing examples of negative feedback.	

1.2.9 As an open system, an ecosystem will normally exist in a stable equilibrium, either in a steady-state equilibrium or in one developing over time (for example, succession), and will be maintained by stabilizing negative feedback loops.	
A stable equilibrium is the condition of a system in which there is a tendency for it to return to the previous equilibrium following disturbance. A steady-state equilibrium is the condition of an open system in which flows are still occurring but inputs are constantly balanced with outputs.	2.5, 3.3

1.2.10 Positive feedback loops occur when a disturbance leads to an amplification of that disturbance, destabilizing the system and driving it away from its equilibrium.	
Positive feedback loops have amplifying roles. Positive feedback can lead to both an increase or a decrease in a system component. For example, as a population declines, the reproductive potential decreases leading to further decrease. An example of positive feedback is the reduced albedo (amount of reflection by a surface) due to melting ice caps leading to greater global warming, or an increase in population leading to increased potential for further growth. There are many other examples.	3.3, 4.4, 5.3, 6.2
Application of skills: Use diagrams representing examples of positive feedback.	

1.2.11 Positive feedback loops will tend to drive the system towards a tipping point.	
A tipping point is the minimum amount of change that will cause destabilization within a system. The system then shifts to a new equilibrium or stable state.	2.1, 2.5

1.2.12 Tipping points can exist within a system where a small alteration in one component can produce large overall changes, resulting in a shift in equilibrium.	
Tipping points result in regime shifts between alternative stable states. Use examples to support the explanation. For example, a change of nitrate/phosphate concentrations leading to eutrophication. Identify other examples of such tipping points throughout the course.	2.1, 3.3, 4.4, 6.2, 8.4

1.2.13 A model is a simplified representation of reality; it can be used to understand how a system works and to predict how it will respond to change.	
A model may take many forms, including a graph, a diagram, an equation, a simulation or words. Models are used throughout the course to represent systems and processes.	1.1

1.2.14 Simplification of a model involves approximation and, therefore, loss of accuracy.	
The simplification of a model can make it less accurate. The systems approach uses models throughout the course. For example, predictive models of climate change or projections of human population growth explain how a model may give very different results. Simplification will also affect how well a lab-based model ecosystem approximates to a natural ecosystem.	6.2, 8.1

1.2.15 Interactions between components in systems can generate emergent properties.	
Emergent properties appear as individual system components interact; the components themselves do not have these properties. For example, predator–prey oscillations and trophic cascades are examples of emergent properties where patterns of change occur that would not occur in isolated components. Include other examples.	3.3, 5.2, 5.3, 6.3, 8.3

1.2.16 The resilience of a system, ecological or social, refers to its tendency to avoid tipping points and maintain stability.	
Resilience of a system is the capacity to resist damage and recover from, or adapt efficiently to, disturbance.	3.3, 6.2, 6.3

1.2.17 Diversity and the size of storages within systems can contribute to their resilience and affect their speed of response to change (time lags).	
Consider an example of resilience (for example, the loss of resilience with the displacement of North American prairie systems with monoculture crops) showing how diversity contributes to the resilience of a system. Consider how size of storage affects the relative stability of a puddle compared to a lake.	5.2

1.2.18 Humans can affect the resilience of systems through reducing these storages and diversity.	
Use the example of loss of resilience in deforestation resulting in reduced size of storages and loss of diversity.	2.5, 5.2, 5.3

Possible engagement opportunities

- Build a bottle ecosystem, aquarium, terrarium, compost heap or other school-based ecosystem and use it to construct a systems diagram. Compare variables of the system (for example, with and without one organism or with different levels of water/nutrients).
- Use the skills of system analysis to help solve a school-wide problem.
- Advocate to peers to educate them about the importance of tipping points.

1.3 Sustainability

Guiding questions

- What is sustainability and how can it be measured?
- To what extent are challenges of sustainable development also ones of environmental justice?

SL and HL

1.3.1 Sustainability is a measure of the extent to which practices allow for the long-term viability of a system. It is generally used to refer to the responsible maintenance of socio-ecological systems such that there is no diminishment of conditions for future generations.

All activity is embedded in a system and, in general, enhancing system resilience increases sustainability.	1.2

1.3.2 Sustainability is comprised of environmental, social and economic pillars.	
The ways in which environmental, social and economic sustainability interact can be shown with diagrams. Strong sustainability models show the economy embedded in society, and both society and economy embedded in the natural environment. Weak sustainability models only show an overlap in the three pillars.	HL.b

1.3.3 Environmental sustainability is the use and management of natural resources that allows replacement of the resources, and recovery and regeneration of ecosystems.	
Sustainability in this context focuses on resource depletion, pollution and conserving biodiversity. Active regeneration of ecosystems is also considered a component of environmental sustainability. There are different timescales in the replacement of natural resources.	7.2, HL.a, HL.b

1.3.4 Social sustainability focuses on creating the structures and systems, such as health, education, equity, community, that support human well-being.	
Sustainability in this context focuses on the survival of societies and their cultures; it may include consideration of the continued use of language, belief, or spiritual practices in a society.	HL.c

1.3.5 Economic sustainability focuses on creating the economic structures and systems to support production and consumption of goods and services that will support human needs into the future.	
In terms of resource use to meet human needs, there is no economic sustainability without environmental sustainability.	HL.b

1.3.6 Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development applies the concept of sustainability to our social and economic development.	
Sustainable development is a framework that guides further development of human civilization while maintaining economic stability, social equity and ecological integrity. The Brundtland report of 1987 introduced the social and economic aspects of sustainability to sustainable development.	HL.b, HL.c

1.3.7 Unsustainable use of natural resources can lead to ecosystem collapse.	
Use an example of ecosystem collapse due to human overexploitation of the environment (for example, the impact of overfishing on Newfoundland cod fisheries).	1.2, 4.3, HL.a, HL.b

1.3.8 Common indicators of economic development, such as gross domestic product (GDP), neglect the value of natural systems and may lead to unsustainable development.	
GDP is a measure of the monetary value of final goods and services produced and sold in a given period by a country. Focusing on GDP as a measure of economic progress may cause unsustainable development. Green GDP measures environmental costs and subtracts these from GDP.	HL.b

1.3.9 Environmental justice refers to the right of all people to live in a pollution-free environment, and to have equitable access to natural resources, regardless of issues such as race, gender, socio-economic status, nationality.	
Consider one local and one global example of environmental injustice. Examples could include: Deepwater Horizon oil spill, Gulf of Mexico (2010); landfills located in low-income areas; Union Carbide gas release in Bhopal, India (1984); Maasai land rights in Kenya and Tanzania; plastic waste disposal by developed to developing countries.	1.1, 3.3, 4.2, 4.3, 5.2, 5.3, 6.3, 7.2, 8.3, HL.a, HL.c

1.3.10 Inequalities in income, race, gender and cultural identity within and between different societies lead to disparities in access to water, food and energy.	
Examples of inequality include the inability to afford an electricity supply, or the privatization of water sources.	1.1, 3.3, 4.2, 4.3, 5.2, 5.3, 6.3, 7.2, 8.3, HL.c

1.3.11 Sustainability and environmental justice can be applied at the individual to the global operating scale.	
Sustainability and environmental justice issues exist at different operating scales. Different operating scales are individual (individual decisions on how to live and work), business, community (religious, cultural, political, indigenous), city, country (policies, laws and socio-economic systems) or global (for example, the United Nations (UN) Sustainable Development Goals (SDGs)).	1.1, HL.a, HL.b, HL.c

1.3.12 Sustainability indicators include quantitative measures of biodiversity, pollution, human population, climate change, material and carbon footprints, and others. These indicators can be applied on a range of scales, from local to global.	
Consider the use of one named environmental indicator to assess sustainability.	3.3, 6.3, 8.3

1.3.13 The concept of ecological footprints can be used to measure sustainability. If these footprints are greater than the area or resources available to the population, this indicates unsustainability.	
An ecological footprint is the area of land and water required to sustainably provide all resources at the rate of consumption and absorb all generated waste at the rate of production for a specific population.	4.2, 6.3, 8.3, HL.b
Application of skills: Use footprint calculators to establish students' own ecological/carbon/water footprint. Present comparative data on footprints graphically, using a spreadsheet and graph-plotting software.	

1.3.14 The carbon footprint measures the amount of greenhouse gases (GHGs) produced, measured in carbon dioxide equivalents (in tonnes). The water footprint measures water use (in cubic metres per year).	
There are different ways of using footprints to measure sustainability. Students do not need to know details of how these are calculated.	4.2, 6.2

1.3.15 Biocapacity is the capacity of a given biologically productive area to generate an ongoing supply of renewable resources and to absorb its resulting wastes.	
Unsustainability occurs if the area's ecological footprint exceeds its biocapacity.	2.2, 2.5, 8.2, 8.3

1.3.16 Citizen science plays a role in monitoring Earth systems and whether resources are being used sustainably.	
Citizen science has a role in the larger picture of scientific research on environmental systems. The information gathered is relevant to local problems and conditions, and can be used in research on global issues, such as climate change.	2.1, 3.1, 3.2, 4.2, 6.1, 7.2, 8.4, HL.c

1.3.17 There are a range of frameworks and models that support our understanding of sustainability, each with uses and limitations.
Sustainability models, like all models, are simplified versions of reality; therefore, they have both uses and limitations.

1.3.18 The UN Sustainable Development Goals (SDGs) are a set of social and environmental goals and targets to guide action on sustainability and environmental justice.	
Consider the SDG model and the uses and limitations of the SDGs. The SDGs provide a framework for sustainable development supported by the UN and address the global challenges faced by humanity, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. Example uses and limitations include the following. Uses: Setting of a common ground for policymaking; relating to both developed and developing countries; galvanizing the international community into addressing economic and social inequality. Limitations: Goals not going far enough; goals being top down and bureaucratic; tending to ignore local contexts; lacking in supportive data.	4.2, 5.2, 7.2, 8.3, HL.a, HL.b, HL.c

1.3.19 The planetary boundaries model describes the nine processes and systems that have regulated the stability and resilience of the Earth system in the Holocene epoch. The model also identifies the limits of human disturbance to those systems, and proposes that crossing those limits increases the risk of abrupt and irreversible changes to Earth systems.	
Consider the planetary boundaries model and select which planetary boundaries appear to have been crossed and factors that have led to this. (**HL only:** Use quantitative data to discover when, and if, planetary boundaries have been crossed where appropriate in the course.) Example uses and limitations include the following. Uses: Identifies science-based limits to human disturbance of Earth systems; highlights the need to focus on more than climate change (which dominates discussion); alerts the public and policymakers about the urgent need for action to protect Earth systems. Limitations: Focuses only on ecological systems and does not consider the human dimension necessary to take action for environmental justice; the model is a work in progress—assessments of boundaries are changing as new data becomes available; the focus on global boundaries may not be a useful guide for local and country-level action.	2.3, 3.2, 4.2, 4.4, 5.3, 6.2, 6.4, 7.2, 8.4, HL.a, HL.b, HL.c

1.3.20 The doughnut economics model is a framework for creating a regenerative and distributive economy in order to meet the needs of all people within the means of the planet.	
Consider the doughnut economics model and the concepts of regenerative and distributive design. The social foundation (inner boundary of the doughnut) is based on the social SDGs. The ecological ceiling (outer boundary of the doughnut) is based on planetary boundaries science. Together, the social foundation and the ecological ceiling represent the minimum conditions for an economy that is ecologically safe and socially just—thus, the doughnut is the "safe and just space for humanity". Today, billions of people still fall short of the social foundation, while humanity has collectively overshot most of the planetary boundaries. Therefore, the goal as illustrated by this model is to move into the doughnut and create an economy that enables humanity to thrive in balance with the rest of the living world. It can only be achieved by making economies that become regenerative and distributive by design. A regenerative economy works with, and within, the cycles and limits of the living world. A distributive economy shares value and opportunity far more equitably among all stakeholders. Example uses and limitations include the following. Uses: The model includes both ecological and social elements, so it supports the concept of environmental justice; it has reached popular awareness and is being used at different scales (for example, countries, cities, neighbourhoods, businesses) to support action on sustainability. Limitations: The model is a work in progress—different groups are trying to apply the model for concrete action; it advocates broad principles of regenerative and distributive practice but does not propose specific policies.	HL.b, HL.c

1.3.21 The circular economy is a model that promotes decoupling economic activity from the consumption of finite resources. It has three principles: eliminating waste and pollution, circulating products and materials, and regenerating nature.	
The butterfly diagram from the Ellen MacArthur Foundation is a useful illustration of the circular economy. It is different to the linear economic model (take–make–waste). Example uses and limitations include the following. Uses: Regeneration of natural systems; reduction of greenhouse emissions; improvement of local food networks and support of local communities; reduction of waste by extending product life cycle; changed consumer habits. Limitations: Lack of environmental awareness by consumers and companies; lack of regulations enforcing recycling of products; some waste is not recyclable—technical limitations; lack of finance.	HL.b, HL.c

Possible engagement opportunities

- Present research on examples of environmental injustice and inequalities leading to problems of access to resources.
- Promote the doughnut economics model and/or circular economy strategies for the school community.
- Investigate the whole-school carbon footprint and produce a plan to reduce the school's carbon emissions.
- Design and plan a sustainability walk to highlight sustainable options locally.
- Use an SDG to advocate for a particular issue.

Topic 2: Ecology

2.1 Individuals, populations, communities, and ecosystems

Guiding question

- How can natural systems be modelled, and can these models be used to predict the effects of human disturbance?

SL and HL

2.1.1 The biosphere is an ecological system composed of individuals, populations, communities, ecosystems.	
A biosphere represents the parts of the Earth where life exists.	1.2

2.1.2 An individual organism is a member of a species.
According to the biological species concept, a species is a group of organisms that can interbreed and produce fertile offspring.

2.1.3 Classification of organisms allows for efficient identification and prediction of characteristics.
Classification is needed because of the immense diversity of species. The first name is the genus, the second name is the species; species in the same genus have similar traits. The genus name is given an initial capital letter. The species name is lower case; both genus and species should be either italicized or underlined.

2.1.4 Taxonomists use a variety of tools to identify an organism.
Identification in this context means determining the species of an individual organism. Tools include dichotomous keys, comparison of specimens with reference to collections by taxonomists, and deoxyribonucleic acid (DNA) surveys.
Application of skills: Know how to use dichotomous keys, applications and databases for the identification of species.

2.1.5 A population is a group of organisms of the same species living in the same area at the same time, and which are capable of interbreeding.
A population is an interbreeding unit. One species may consist of any number of populations, from one to many. The term "metapopulation" is not required.
Application of skills: Investigate a local ecosystem.

2.1.6 Factors that determine the distribution of a population can be abiotic or biotic.
Biotic refers to the living components of an ecosystem; abiotic refers to non-living physical factors that may influence organisms.

2.1.7 Temperature, sunlight, pH, salinity, dissolved oxygen and soil texture are examples of many abiotic factors that affect species distributions in ecosystems.
Abiotic factors can be quantified in order to clarify the distribution of species.
Application of skills: Use methods for measuring at least three abiotic factors in an aquatic or terrestrial ecosystem, including the use of data logging.

2.1.8 A niche describes the particular set of abiotic and biotic conditions and resources upon which an organism or a population depends.
An ecological niche is the role of a species in an ecosystem. The niche comprises all biotic and abiotic interactions that influence the growth, survival and reproduction of a population, including how food is obtained. Include some of the parameters of a niche for a named species.

2.1.9 Populations interact in ecosystems by herbivory, predation, parasitism, mutualism, disease and competition, with ecological, behavioural and evolutionary consequences.
Consider one example of each relationship and consider how the relationships influence the population dynamics of the interacting populations and the selective pressures involved.
Application of skills: Use models that demonstrate feeding relationships, such as predator–prey.

2.1.10 Carrying capacity is the maximum size of a population determined by competition for limited resources.	
Include examples of resources that may affect carrying capacity, including biotic and abiotic factors.	5.2, 8.2

2.1.11 Population size is regulated by density-dependent factors and negative feedback mechanisms.
Density-independent factors may have significant influence on population size, but it is the density-dependent factors that tend to regulate the population around the carrying capacity. In addition to competition for limited resources, include the increased risk of predation and the transfer of pathogens in dense populations. These are examples of negative feedback returning a population to equilibrium.

2.1.12 Population growth can either be exponential or limited by carrying capacity.	
If there are no limiting factors, population growth follows a J-curve (exponential growth). When density-dependent limiting factors start to operate, the curve becomes S-shaped. Consider population growth curves in terms of numbers of individuals and rates of change, and populations showing an S-curve and a "boom and bust" pattern, for example, reindeer on St Matthew Island.	5.2, 8.2

2.1.13 Limiting factors on the growth of human populations have increasingly been eliminated, resulting in consequences for sustainability of ecosystems.	
Include the effects of elimination of natural predators, technological advances, and degradation of the environment.	5.2, 8.1, 8.2

2.1.14 Carrying capacity cannot be easily assessed for human populations.	
This is because of the broad and changing ecological niche of humans. Include the idea of populations achieving equilibrium within ecosystems, but human populations being less limited due to mobility of resources. The expansion of the human niche also takes place through technological advances and changes in consumption. The rapidly changing human habitat leads to estimates of carrying capacity that are disputed and that can only be estimated for "now".	8.1, 8.2, HL.b

2.1.15 Population abundance can be estimated using random sampling, systematic sampling or transect sampling.

Consider reasons for selecting which of these procedures would be most appropriate.

2.1.16 Random quadrat sampling can be used to estimate population size for non-mobile organisms.
Percentage cover is an estimate of the area in a given frame size (quadrat) covered by the plant or animal in question. Percentage frequency is the number of occurrences divided by the number of possible occurrences. For example, if a plant occurs in 5 out of 100 squares in a grid quadrat, then the percentage frequency is 5%. Percentage cover and frequency give an estimate of abundance but not actual population size.
Application of skills: Use quadrat sampling estimates for abundance, population density, percentage cover and percentage frequency for non-mobile organisms and measures change along a transect.

2.1.17 Capture–mark–release–recapture and the Lincoln index can be used to estimate population size for mobile organisms.	
Consider use of the Lincoln index in estimating population size. Population size estimate $= \frac{(M \times N)}{R}$, where M is the number of individuals caught and marked initially, N is the total number of individuals recaptured and R is the number of marked individuals recaptured.	1.2, 1.4
Application of skills: Students should use the Lincoln index to estimate population size. Students should understand the assumptions made when using this method.	

2.1.18 A community is a collection of interacting populations within the ecosystem.
Communities comprise several populations that interact in the ecosystem. Consider the concept of community in a local ecosystem.

2.1.19 Habitat is the location in which a community, species, population or organism lives.
A description of the habitat of a species can include both geographical and physical locations, as well as the type of ecosystem required to meet all environmental conditions needed for survival. Consider the concept of habitat in a local ecosystem.

2.1.20 Ecosystems are open systems in which both energy and matter can enter and exit.	
An ecosystem is a community and the physical environment with which it interacts. Consider the concept of ecosystem in a local ecosystem.	1.2

2.1.21 Sustainability is a natural property of ecosystems.	
Inputs are balanced by outputs in a steady-state ecosystem. Consider this balance in flow diagrams of specific ecosystems. There is evidence for some ecosystems persisting for millions of years, for example, tropical rainforests.	1.3, 7.2

2.1.22 Human activity can lead to tipping points in ecosystem stability.	
Tipping points lead to the collapse of the original ecosystem and development of a new equilibrium. For example, deforestation of the Amazon rainforest reduces generation of water vapour through transpiration, and consequently reduces cooling and precipitation necessary for the maintenance of the remaining forest.	1.2

2.1.23 Keystone species have a role in the sustainability of ecosystems.	
There is a disproportionate impact on community structure of keystone species and the risk of ecosystem collapse if they are removed. Consider two examples. For example, purple sea stars controlling mussel populations on the North Pacific coast that would otherwise overwhelm the ecosystem; elephants feeding on shrubs and trees, and thus maintaining savannah grasslands.	1.2, 3.3

2.1.24 The planetary boundaries model indicates that changes to biosphere integrity have passed a critical threshold.	
There is an interrelationship between ecosystems and species diversity. Disturbance of ecosystems due to human activity has led to loss of biosphere integrity. Extinction rates provide evidence that the planetary boundary for biosphere integrity has been crossed.	1.2.14, 3.2

2.1.25 To avoid critical tipping points, loss of biosphere integrity needs to be reversed.	
Ecosystem damage and loss of species can be slowed by protecting the integrity of ecosystems. Protecting ecosystems ensures the preservation of the niche requirements essential for the ongoing survival of a species.	1.3.18, 3.3

HL only

2.1.26 There are advantages of using a method of classification that illustrates evolutionary relationships in a clade.
A clade illustrates evolutionary relationships in which all the members of a taxonomic group have evolved from a common ancestor.

2.1.27 There are difficulties in classifying organisms into the traditional hierarchy of taxa.
The traditional hierarchy of kingdom, phylum, class, order, family, genus and species does not always correspond with patterns of divergence generated by evolution.

2.1.28 The niche of a species can be defined as fundamental or realized.
The fundamental niche describes the range of conditions and resources in which a species could survive and reproduce if there were no limiting factors. The realized niche of a species is the actual mode of existence, which results from its adaptations and competition with other species. Consider the fundamental and realized niche of a named species, such as Joseph Connell's study of barnacle species, or brown and green anoles.

2.1.29 Life cycles vary between species in reproductive behaviour and lifespan.
r- and *K*-strategists are adapted by their life cycles to different environments and successional stages. *K*-strategists thrive in stable communities by producing few offspring that have a high chance of survival. *r*-strategists colonize new habitats rapidly and make opportunistic use of short-lived resources by producing many offspring with more limited provision for the individual's survival.

2.1.30 Knowledge of species' classifications, niche requirements and life cycles help us to understand the extent of human impacts upon them.	
Include examples of human impact on life cycles, such as temperature changes from climate change that affect the life cycles of plants, which in turn affect the life cycle of animals.	3.3

The life cycles of many species are synchronized with those of others and the seasons. Human impacts are contributing to climate change, which lead to a disruption in these cycles.	

Possible engagement opportunities

- Carry out an ecological investigation on natural and disturbed ecosystems using the application of skills explored in this subtopic. Secondary data can be used as a comparison.
- Raise awareness of biodiversity loss.
- Take part in citizen science projects that collect data on species distributions and abundance.

2.2 Energy and biomass in ecosystems

Guiding questions

- How can flows of energy and matter through ecosystems be modelled?
- How do human actions affect the flow energy and matter, and what is the impact on ecosystems?

SL and HL

2.2.1 Ecosystems are sustained by supplies of energy and matter.	
Ecosystems are open systems in which energy and matter are exchanged.	1.2

2.2.2 The first law of thermodynamics states that as energy flows through ecosystems, it can be transformed from one form to another but cannot be created or destroyed.	
Energy transformations occur, such as light to chemical and from chemical to heat.	1.2

2.2.3 Photosynthesis and cellular respiration transform energy and matter in ecosystems.
Transformation of energy is a change from one form to another, such as light to heat. Transformation of matter happens in chemical reactions and can be summarized using word equations.
Application of skills: Create system diagrams from a set of data of ecosystems showing transfers and transformations of energy and matter.

2.2.4 Photosynthesis is the conversion of light energy to chemical energy in the form of glucose, some of which can be stored as biomass by autotrophs.
Glucose can be converted into other carbon compounds contained within biomass. Students are not required to know the biochemical details of photosynthesis.

2.2.5 Producers form the first trophic level in a food chain.
Producers are typically plants, algae and photosynthetic bacteria that produce their own food using photosynthesis.

2.2.6 Cellular respiration releases energy from glucose by converting it into a chemical form that can easily be used in carrying out active processes within living cells.
Students are not required to know that adenosine triphosphate (ATP) is the readily usable energy currency of cells.

2.2.7 Some of the chemical energy released during cellular respiration is transformed into heat.
Heat is generated by cellular respiration because it is not 100% efficient at transferring energy from substrates, such as carbohydrates, into the chemical form of energy used in cells. Heat generated within an

individual organism cannot be transformed back into chemical energy and is ultimately lost from the body.	

2.2.8 The second law of thermodynamics states that energy transformations in ecosystems are inefficient.	
The second law of thermodynamics relates to the quality of energy, and that when energy is transformed, some must be degraded into a less useful form, such as heat. In ecosystems, the biggest losses occur during cellular respiration. The second law of thermodynamics explains why energy transfers are never 100% efficient.	1.2, 5.2

2.2.9 Consumers gain chemical energy from carbon (organic) compounds obtained from other organisms. Consumers have diverse strategies for obtaining energy-containing carbon compounds.
Include, with examples, herbivores, detritivores, predators, parasites, saprotrophs, scavengers and decomposers.

2.2.10 Because producers in ecosystems make their own carbon compounds by photosynthesis, they are at the start of food chains. Consumers obtain carbon compounds from producers or other consumers, so form the subsequent trophic levels.
In a food chain, organic matter flows from primary producers to primary consumers to secondary consumers, and so on.
Application of skills: Create a food chain from given data.

2.2.11 Carbon compounds and the energy they contain are passed from one organism to the next in a food chain. The stages in a food chain are called trophic levels.
Traditionally, decomposers are not included in food chains as they typically gain carbon compounds from a variety of sources. However, consider the role of decomposers in energy transformations in food webs.

2.2.12 There are losses of energy and organic matter as food is transferred along a food chain.
Not all the food available to a given trophic level is harvested: of what is harvested, not all is consumed; of what is consumed, not all is absorbed; of what is absorbed, not all is stored—some is lost as heat through cellular respiration. There is, therefore, never 100% transference of organic matter from one trophic level to the next.

2.2.13 Gross productivity (GP) is the total gain in biomass by an organism. Net productivity (NP) is the amount remaining after losses due to cellular respiration.	
Consider values of both GP and NP from given data. Losses due to cellular respiration are typically greater in consumers than in producers due to more energy-requiring activity. The NP of any organism or trophic level is the maximum sustainable yield that can be harvested without diminishing the availability for the future.	2.5

2.2.14 The number of trophic levels in ecosystems is limited due to energy losses.	
Energy released by cellular respiration and lost as heat by organisms is unavailable to organisms in higher trophic levels. Because of this and other energy losses, typically 10% or less of the energy flowing to a trophic level is available to the next level, limiting the length of food chains. Avoid the common misconception that organisms at higher trophic levels must eat more food to get enough energy.	4.3, 5.2

Application of skills: Work out the efficiency of transfer between trophic levels.

2.2.15 Food webs show the complexity of trophic relationships in communities.	
Arrows in food chains and food webs indicate the direction of energy flow and transfer of biomass. In a food web, species may feed at more than one trophic level.	1.2.14
Application of skills: Create a food web from given data.	

2.2.16 Biomass of a trophic level can be measured by collecting and drying samples.
Dry mass of samples is approximately equal to mass of organic matter (biomass) since water represents the majority of inorganic matter in most organisms. Energy in biomass can be measured by combustion of samples and extrapolation.

2.2.17 Ecological pyramids are used to represent relative numbers, biomass or energy of trophic levels in an ecosystem.	
Pyramids of number and biomass show the standing crop per unit area at a particular time. Pyramids of energy ("pyramids of productivity" in some texts) show the amount of energy flowing to each trophic level per unit area and per unit time (usually kJ m^{-2} $year^{-1}$). Consider pyramid diagrams and reasons for variations in their shape.	
Application of skills: Create pyramids of numbers, biomass and energy from given data. Follow experimental procedures on how to find biomass and energy from biological samples (plant material only).	1.2.14

2.2.18 Pollutants that are non-biodegradable, such as polychlorinated biphenyl (PCB), dichlorodiphenyltrichloroethane (DDT) and mercury, cause changes to ecosystems through the processes of bioaccumulation and biomagnification.	
Bioaccumulation refers to the increasing concentration of non-biodegradable pollutants in organisms or trophic levels over time (as more are absorbed). Biomagnification refers to the increasing concentration of non-biodegradable pollutants along a food chain (due to the loss of biodegradable biomass through, for example, cellular respiration).	4.4, 5.3

2.2.19 Non-biodegradable pollutants are absorbed within microplastics, which increases their transmission in the food chain.	
Include an example of pollution by microplastics and its effect on the food chain.	4.3

2.2.20 Human activities, such as burning fossil fuels, deforestation, urbanization and agriculture, have impacts on flows of energy and transfers of matter in ecosystems.	
Although burning fossil fuels may lead to increased CO_2 available for photosynthesis, the other pollutants and impacts of global warming will reduce primary productivity. Deforestation, urbanization and agriculture all lead to loss of ecosystem biomass, disruption of food webs, and the capacity for photosynthesis.	5.3, 6.2, 8.2

HL only

2.2.21 Autotrophs synthesize carbon compounds from inorganic sources of carbon and other elements. Heterotrophs obtain carbon compounds from other organisms.
All living organisms can be classified as autotrophs or heterotrophs.

2.2.22 Photoautotrophs use light as an external energy source in photosynthesis. Chemoautotrophs use exothermic inorganic chemical reactions as an external energy source in chemosynthesis.
Chemoautotrophs exist in a variety of ecosystems, especially those where there is little or no light. In such ecosystems, chemoautotrophs are the principal source of energy to sustain food webs.

2.2.23 Primary productivity is the rate of production of biomass using an external energy source and inorganic sources of carbon and other elements.
The units usually used for productivity are kg carbon m^{-2} $year^{-1}$ (kilograms of carbon per square metre of ecosystem per year). Consider protocols for determining primary productivity in ecosystems. Estimates can be based on photosynthesizing samples within a laboratory or, in the field, measuring change in biomass of samples (such as grassland) over time.

2.2.24 Secondary productivity is the gain in biomass by consumers using carbon compounds absorbed and assimilated from ingested food.
Secondary productivity is ingested food minus faecal waste. The units are the same as those for primary productivity. Faecal matter is not included as it is material that has remained undigested and unabsorbed.

2.2.25 Net primary productivity is the basis for food chains because it is the quantity of carbon compounds sustainably available to primary consumers.
Net primary production can be thought of as the plant growth that is sustainably harvestable by primary consumers in natural ecosystems or by farmers and foresters in agricultural and silvicultural systems.
Application of skills: Use laboratory and field techniques for measuring primary and secondary productivity and work out GP and NP from data.

2.2.26 Maximum sustainable yields (MSYs) are the net primary or net secondary productivity of a system.	
Consider the MSYs in natural ecosystems and in agricultural or silvicultural systems.	1.3, 4.3, 7.1.2

2.2.27 Sustainable yields are higher for lower trophic levels.	
Include the reasons for sustainability in food production being easier to achieve if humans consume organisms from lower trophic levels, especially plant-based foods.	1.3, 4.3, 5.2, HL.c

2.2.28 Ecological efficiency is the percentage of energy received by one trophic level that is passed on to the next level.	
The percentage varies between ecosystems, trophic levels and species. Work out the efficiency of the transfer of energy between trophic levels with given data. The percentage of energy transferred from one trophic level to the next is very variable, and the value of 10% is neither a fixed amount nor a true average.	5.3

2.2.29 The second law of thermodynamics shows how the entropy of a system increases as biomass passes through ecosystems.
Entropy refers to the amount of disorder within a system. Living systems are able to maintain a high degree of organization and low entropy through the net increase in entropy resulting largely from cellular respiration.

Possible engagement opportunities

- Using primary or secondary data, study the impact of pollution on an ecosystem and the effect on food chains, for example, the effect of a sewage overflow on aquatic communities. Health and safety, and ethical issues, should be considered.
- Advocate for the planetary health diet in the students' community based on the second law of thermodynamics.
- Contribute to citizen science programmes about microplastics.

2.3 Biogeochemical cycles

Guiding question

- How do human activities affect nutrient cycling, and what impact does this have on the sustainability of environmental systems?

SL and HL

2.3.1 Biogeochemical cycles ensure chemical elements continue to be available to living organisms.
Human impact on these cycles can affect the sustainability of ecosystems.

2.3.2 Biogeochemical cycles have stores, sinks and sources.	
Stores (storages) remain in equilibrium with the environment; sinks indicate net accumulation of the element; sources indicate net release of the element.	1.2

2.3.3 Organisms, crude oil and natural gas contain organic stores of carbon. Inorganic stores can be found in the atmosphere, soils and oceans.	
A store is in equilibrium when absorption is balanced by release. Residence time is the average period that a carbon atom remains in a store. Without human interference (that is, mining) the residence time in fossil fuels would be measured in hundreds of millions of years.	6.2

2.3.4 Carbon flows between stores in ecosystems by photosynthesis, feeding, defecation, cellular respiration, death and decomposition.
Consider systems diagrams of the carbon cycle and the difference between transfers and transformations in these flows.
Application of skills: Create a systems diagram of the carbon cycle.

2.3.5 Carbon sequestration is the process of capturing gaseous and atmospheric carbon dioxide and storing it in a solid or liquid form.	
Trees sequester carbon naturally by absorbing carbon dioxide and converting it into biomass. Organic matter is fossilized into coal, oil and natural gas.	6.2

2.3.6 Ecosystems can act as stores, sinks or sources of carbon.	
In an ecosystem, the difference between total inputs and outputs is the net accumulation or release of carbon. If photosynthesis exceeds cellular respiration in an ecosystem there is a net uptake of carbon dioxide, and if cellular respiration exceeds photosynthesis there is a net release of carbon dioxide. Use the example of a young forest acting as a sink, a mature forest acting as a store and a forest that is destroyed by fire or deforestation acting as a source.	1.2, 5.1, 5.3, 6.2

2.3.7 Fossil fuels are stores of carbon with unlimited residence times. They were formed when ecosystems acted as carbon sinks in past eras and become carbon sources when burned.	
Consider the concept of fossil fuels but not the detail of how and when coal, oil and natural gas were formed.	6.2

2.3.8 Agricultural systems can act as carbon stores, sources and sinks, depending on the techniques used.	
Regenerative agricultural methods, such as crop rotation, cover crops and no till, will promote the role of soil as a carbon sink whereas drainage of wetland, monoculture and heavy tillage will promote the role of soil as a carbon source. Cropping over a longer timescale (for example, timber production) and the subsequent use of harvested products will also affect these roles.	5.2, HL.b

2.3.9 Carbon dioxide is absorbed into the oceans by dissolving and is released as a gas when it comes out of a solution.	
While oceans act as a carbon sink, the human use of fossil fuels releases inorganic carbon at a faster rate than oceans can absorb it.	6.2

2.3.10 Increases in concentrations of dissolved carbon dioxide cause ocean acidification, harming marine animals.	
Small decreases in pH can interfere with calcium carbonate deposition in mollusc shells and coral skeletons.	2.1

2.3.11 Measures are required to alleviate the effects of human activities on the carbon cycle.	
Consider at last three of the measures that are required. These include low-carbon technologies, reduction in fossil-fuel burning/soil disruption/deforestation, carbon capture through reforestation and artificial sequestration.	6.3, HL.a, HL.b

HL only

2.3.12 The lithosphere contains carbon stores in fossil fuels and in rocks, such as limestone, that contain calcium carbonate.	
The residence time for carbon in these stores can be hundreds of millions of years.	6.2

2.3.13 Reef-building corals and molluscs have hard parts that contain calcium carbonate that can become fossilized in limestone.	
Limestone is the largest store of carbon in Earth systems. Not all limestone is formed by fossilization of animal remains; it can also be formed by both biological and non-biological processes. Details of these processes are not required.	6.2

2.3.14 In past geological eras, organic matter from partially decomposed plants became fossilized in coal, and partially decomposed marine organisms became fossilized in oil and natural gas held in porous rocks.	
Formation of coal, oil and gas was greatest in specific geological eras when conditions were most suitable, and it took tens of millions of years for significant stores to accumulate.	6.2

2.3.15 Methane is produced from dead organic matter in anaerobic conditions by methanogenic bacteria.

Anaerobic conditions suitable for methanogenesis occur in swamps, rice paddies and the stomachs of cattle and other ruminants.	5.2, 6.2

2.3.16 Methane has a residence time of about 10 years in the atmosphere and is eventually oxidized to carbon dioxide.	
Methane is a potent greenhouse gas.	6.1, 6.2

2.3.17 The nitrogen cycle contains organic and inorganic stores.	
Organic nitrogen stores in ecosystems consist of proteins and other nitrogenous carbon compounds in living organisms and in dead organic matter. Inorganic stores consist of nitrogen in the atmosphere, as well as ammonia and other nitrogen compounds (nitrites and nitrates) in soil and water.	1.2, 5.2
Application of skills: Create a systems diagram of the nitrogen cycle.	

2.3.18 Bacteria have essential roles in the nitrogen cycle.
Nitrogen fixation is conversion of nitrogen from the atmosphere into ammonia; nitrification is conversion of ammonia to nitrates; denitrification is conversion of nitrates to nitrogen; decomposition is the conversion of amino acids into ammonium. Conversion of ammonium and nitrites to nitrates takes place. Chemical details of reactions are not required.

2.3.19 Denitrification only happens in anaerobic conditions, such as soils that are waterlogged.	
In waterlogged, anaerobic soils, plant growth is reduced or stopped and denitrification and leaching take place. In these soils, insectivorous plants (for example, pitcher plants and sundews) can capture and digest insects and use them as a nitrogen source.	5.3

2.3.20 Plants cannot fix nitrogen so atmospheric dinitrogen is unavailable to them unless they form mutualistic associations with nitrogen-fixing bacteria.	
Include examples of plants that do form such mutualistic associations and the competitive advantage gained by such plants in ecosystems where nitrogen is a limiting factor on plant growth.	2.1, 2.5

2.3.21 Flows in the nitrogen cycle include mineral uptake by producers, photosynthesis, consumption, excretion, death, decomposition and ammonification.	
Consider systems diagrams of the nitrogen cycle and the difference between transformation (photosynthesis, decomposition and ammonification) and transfer flows.	1.2

2.3.22 Human activities such as deforestation, agriculture, aquaculture and urbanization change the nitrogen cycle.	
Include examples of the changes to the nitrogen cycle caused by these activities.	5.2, 5.3, HL.b

2.3.23 The Haber process is an industrial process that produces ammonia from nitrogen and hydrogen for use as fertilizer.	
Include the advantages and disadvantages of using the Haber process to provide fertilizer for increased crop yield.	6.2, HL.b

2.3.24 Increases in nitrates in the biosphere from human activities have led to the planetary boundary for the nitrogen cycle being crossed, making irreversible changes to Earth systems likely.	
Consider the evidence that the boundary for the biogeochemical cycles of nitrogen has been crossed and that global dependence on inorganic fertilizers for crop production is the major cause of this.	1.3, 6.2

2.3.25 Global collaboration is needed to address the uncontrolled use of nitrogen in industrial and agricultural processes and bring the nitrogen cycle back within planetary boundaries.	
Consider the measures that are needed to bring the biogeochemical cycles of nitrogen back within planetary boundaries.	HL.a, HL.b

Possible engagement opportunities

- Provide advocacy about the use of organic, instead of inorganic, fertilizers around school or community green areas.
- Explore issues of justice for local communities when the local environment is overexploited for financial gain.

2.4 Climate and biomes

Guiding questions

- How does climate determine the distribution of natural systems?
- How are changes in Earth systems affecting the distribution of biomes?

SL and HL

2.4.1 Climate describes atmospheric conditions over relatively long periods of time, whereas weather describes the conditions in the atmosphere over a short period of time.	
Weather refers to the specific conditions being experienced at a particular time or over a short period, including temperature, humidity, air pressure and wind speed. Climate is the average of these conditions over approximately 30 years.	6.1

2.4.2 A biome is a group of comparable ecosystems that have developed in similar climatic conditions, wherever they occur.
Ecosystems developed in similar conditions in different parts of the world can have many parallel features. Precipitation, temperature and insolation are major influences on the distribution of terrestrial biomes.

2.4.3 Abiotic factors are the determinants of terrestrial biome distribution.
For any given temperature and rainfall pattern, one natural ecosystem type is likely to develop. Consider a graph showing the distribution of biomes with temperature and rainfall pattern on the horizontal and vertical axes.
Application of skills: Create climate graphs showing annual precipitation/average temperature for different biomes.

2.4.4 Biomes can be categorized into groups that include freshwater, marine, forest, grassland, desert and tundra. Each of these groups has characteristic abiotic limiting factors, productivity and diversity. They may be further classed into many subcategories (for example, temperate forests, tropical rainforests and boreal forests).

Include the characteristic limiting factors, productivity and resulting biodiversity of tropical rainforests, hot deserts, tundra and at least two other biomes.

2.4.5 The tricellular model of atmospheric circulation explains the behaviour of atmospheric systems and the distribution of precipitation and temperature at different latitudes. It also explains how these factors influence the structure and relative productivity of different terrestrial biomes.	
Latitude is the angular distance from the equator (north or south of it) as measured from the centre of the Earth (usually in degrees). Give details of the tricellular model with the three distinct cells: the Hadley cell, the Ferrel cell and the polar cell. Include reasons for the distribution of biomes using the tricellular model.	1.2.14, 6.1
Application of skills: Use the tricellular model of atmospheric circulation and link it to the planetary distribution of heat and biomes.	

2.4.6 The oceans absorb solar radiation and ocean currents distribute the resulting heat around the world.	
Details of the great ocean conveyor belt and thermohaline circulation are **HL only**.	4.1, 6.1

2.4.7 Global warming is leading to changing climates and shifts in biomes.	
The general trend is of biomes moving poleward and to higher altitude.	6.2

HL only

2.4.8 There are three general patterns of climate types that are connected to biome types.
Climate types include tropical (seasonal and equatorial), temperate (maritime and continental) and polar. Include the reasons for these classifications and the type of biomes found in each one.

2.4.9 The biome predicted by any given temperature and rainfall pattern may not develop in an area because of secondary influences or human interventions.
Consider the local biome that would develop without interference from urban or agricultural development.

2.4.10 The El Niño Southern Oscillation (ENSO) cycle is the fluctuation in wind and sea surface temperatures that characterizes conditions in the tropical Pacific Ocean. The two opposite and extreme states are El Niño and La Niña, with transitional and neutral states between the extremes.	
Appreciate that the frequency and intensity of both El Niño and La Niña events are irregular and hard to predict.	6.1

2.4.11 El Niño is due to a weakening or reversal of the normal east–west (Walker) circulation, which increases surface stratification and decreases upwelling of cold, nutrient-rich water near the coast of north-western South America. La Niña is due to a strengthening of the Walker circulation and reversal of other effects of El Niño.
Consider how El Niño and La Niña events develop and also consider that the ENSO cycle affects conditions directly in the tropical Pacific Ocean and affects the climate of other regions in the tropics and subtropics indirectly. Use examples of resulting weather patterns in specific locations and the resulting changes to productivity of marine ecosystems.

2.4.12 Tropical cyclones are rapidly circulating storm systems with a low-pressure centre that originate in the tropics and are characterized by strong winds.
Tropical cyclones are classified as hurricanes or typhoons (the name depends on where the storm originates in the world) once sustained wind speeds exceed 119 km/hr.

2.4.13 Rises in ocean temperatures resulting from global warming are increasing the intensity and frequency of hurricanes and typhoons because warmer water and air have more energy.	
Include evidence for increases in hurricanes and typhoons.	6.2

Possible engagement opportunities

- Explore the effect of climate change on a local or regional biome and produce a presentation that explains the causes and effects of the shift.
- Raise awareness and fundraise for communities impacted by severe hurricanes or typhoons.

2.5 Zonation, succession and change in ecosystems

Guiding question

- How do ecological systems change over time and over space?

SL and HL

2.5.1 Zonation refers to changes in community along an environmental gradient.
Zonation occurs due to a range of factors, such as changes in elevation, latitude, tidal level, soil horizons or distance from a water source.

2.5.2 Transects can be used to measure biotic and abiotic factors along an environmental gradient in order to determine the variables that affect the distribution of species.
Consider data in tables or figures related to zonation, including kite graphs.
Application of skills: Investigate zonation along an environmental gradient using a transect sampling technique and a range of relevant abiotic measurements. Create kite diagrams to show distribution.

2.5.3 Succession is the replacement of one community by another in an area over time due to changes in biotic and abiotic variables.	
Changes occur as one community changes the environmental conditions so another community can colonize the area and replace the first through competition. This process may continue for hundreds of years; pollen records in peat provide evidence of such changes. Zonation is a spatial phenomenon; succession is a temporal phenomenon.	6.2
Application of skills: Use secondary data and a mapping database to recreate or map the changes through succession in a given area.	

2.5.4 Each seral community (sere) in a succession causes changes in environmental conditions that allow the next community to replace it through competition until a stable climax community is reached.
For example, mosses start soil formation on bare rock, allowing larger plants to colonize.

2.5.5 Primary successions happen on newly formed substratum where there is no soil or pre-existing community, such as rock newly formed by volcanism, moraines revealed by retreating glaciers, wind-blown sand or waterborne silt.
Consider an example of primary succession, which could be a well-documented example, such as Surtsey, or a local example. Use the following terms: seral communities or stages; pioneer and climax communities.

2.5.6 Secondary successions happen on bare soil where there has been a pre-existing community, such as a field where agriculture has ceased or a forest after an intense firestorm.
Consider an example of secondary succession, which could be a well-documented example, such as the Broadbalk Wilderness at Rothamsted, or a local example.

2.5.7 Energy flow, productivity, species diversity, soil depth and nutrient cycling change over time during succession.
Consider data in tables or figures related to succession and the reasons for changes in these factors.

2.5.8 An ecosystem's capacity to tolerate disturbances and maintain equilibrium depends on its diversity and resilience.	
Consider the links between ecosystem resilience, stability, succession, diversity and human activity. For example, succession increases diversity which adds to resilience and stability, though human interference can cause a reduction in these qualities.	1.2, 6.2

HL only

2.5.9 The type of community that develops in a succession is influenced by climatic factors, the properties of the local bedrock and soil, geomorphology, together with fire and weather-related events that can occur. There can also be top-down influences from primary consumers or higher trophic levels.
Include factors such as steep slopes restricting soil development, lack of drainage causing waterlogging, or underlying/parent rock causing ultra-basic or other extreme soil types to develop. Living organisms, such as wolves in Yellowstone Park or elephants in savannahs, influence the final community.

2.5.10 Patterns of net productivity (NP) and gross productivity (GP) change over time in a community undergoing succession.	
In early stages of succession, GP is low due to the unfavourable initial conditions and low density of producers. The proportion of energy lost through community cell respiration or cellular respiration is relatively low too, so NP is high—that is, the system is growing and biomass is accumulating. In later stages of succession, with an increased consumer community, GP may be high in a climax community. However, this is balanced by cell respiration or cellular respiration, so NP approaches zero.	2.2

2.5.11 *r*- and *K*-strategist species have reproductive strategies that are better adapted to pioneer and climax communities, respectively.	
r-strategist species are those that produce large numbers of offspring so they can colonize new habitats quickly and make use of short-lived resources; *K*-strategist species tend to produce a small number of offspring, which increases their survival rate and enables them to survive in long-term climax communities.	2.2

2.5.12 The concept of a climax community has been challenged, and there is uncertainty over what ecosystems would develop naturally were there no human influences.	
Consider the debate over the Vera wood-pasture hypothesis regarding the effects of primary consumers on the plant communities, or a local example. Include the concept of alternative stable states that occur due to random events.	1.2

2.5.13 Human activity can divert and change the progression of succession leading to a plagioclimax.	
Use local examples, such as the complete removal of top carnivores and grazing by domesticated livestock.	1.2

Possible engagement opportunity

- Produce an infographic or poster for the school to inform others about the fieldwork in which the students have participated.

Topic 3: Biodiversity and conservation

3.1 Biodiversity and evolution

Guiding questions

- How can diversity be explained and quantified, and why is this important?
- How does the unsustainable use of natural resources impact biodiversity?

SL and HL

3.1.1 Biodiversity is the total diversity of living systems and it exists at several levels.
The biodiversity levels are habitat diversity, species diversity and genetic diversity.

3.1.2 The components of diversity contribute to the resilience of ecological systems.	
Each component of biodiversity contributes to the resilience of living systems.	1.2, 3.3, 5.2, 5.3, 6.3, 7.2

3.1.3 Biodiversity arises from evolutionary processes.
Evolution is cumulative change in the heritable characteristics of a population or species.

3.1.4 Natural selection is the mechanism driving evolutionary change.
Natural selection operates continuously and can take place over billions of years, resulting in the biodiversity of life on Earth.

3.1.5 Evolution by natural selection involves variation, overproduction, competition for limited resources, and differences in adaptation that affect rates of survival and reproduction.
Natural selection occurs because genetic diversity gives rise to variation within a population. Individuals with variations that provide an advantage in a given environment are more likely to survive and reproduce than others. Variation is heritable; therefore, individuals with advantageous genes can pass them on to their offspring. As a result, the frequency of advantageous genes will increase over many generations.

3.1.6 Speciation is the generation of new species through evolution.
Speciation takes place when a population of a species becomes isolated and adapts in different ways to their environment. Over time, they become unable to interbreed with other populations of the original species, and thus they evolve into a new species.

3.1.7 Species diversity in communities is a product of richness and evenness.
Richness is the number of species in a community; evenness is how similar the population sizes of each species are. Consider the significance of these two variables for biodiversity.

3.1.8 Simpson's reciprocal index is used to provide a quantitative measure of species diversity, allowing different ecosystems to be compared and for change in a specific ecosystem over time to be monitored.
Consider appropriate sampling procedures for comparing diversity in areas containing the same type of organism in the same ecosystem. Calculate diversity (D) if provided with data and the formula in which N is the total number of individuals in the population and n is the number of individuals of a single species. $D = \frac{N(N-1)}{\Sigma n(n-1)}$ The value of D will be higher where there is greater richness (number of species) and evenness (similar abundance), with 1 being the lowest possible value.
Application of skills: Collect data in order to work out Simpson's reciprocal index for diversity.

3.1.9 Knowledge of global and regional biodiversity is needed for the development of effective management strategies to conserve biodiversity.	
Include how knowledge of biodiversity is gathered in the local region. This is likely to involve citizen science and the work of voluntary and government-funded agencies. The training of indigenous people and others, such as parabiologists, is also used to gather information for use in conservation management.	HL.a, HL.c

HL only

3.1.10 Mutation and sexual reproduction increase genetic diversity.
Mutation generates new variants of genes; sexual reproduction generates new combinations of genes.

3.1.11 Reproductive isolation can be achieved by geographical separation or, for populations living in the same area, by ecological or behavioural differences.	
Include two contemporary examples of speciation and their causes. (Examples such as giraffes are unsuitable as they illustrate evolutionary change rather than speciation.) Separation of bonobos and common chimpanzees is an example of speciation by geographical separation, and the apple maggot (*Rhagoletis pomonella*) is an example of behavioural separation. Consider reasons for high rates of endemism on isolated islands.	3.3

3.1.12 Biodiversity is spread unevenly across the planet, and certain areas contain a particularly large proportion of species, especially species that are rare and endangered.	
Many biodiversity hotspots are in tropical biomes.	1.1

3.1.13 Human activities have impacted the selective forces acting on species within ecosystems, resulting in evolutionary change in these species.	
Consider human activities that have affected natural selection, for example, climate change due to burning fossil fuels, hunting/poaching/harvesting, or creation of new habitats. Include the example of the tuskless elephants in Gorongosa, Mozambique or a local example.	3.2, HL.b, HL.c

3.1.14 Artificial selection reduces genetic diversity and, consequently, species resilience.	
Include the distinction between natural selection, which is not deliberate, and artificial selection, which is the deliberate act of choosing individual plants or animals for breeding. The vulnerability of artificially selected species (livestock or crops) can be used to highlight the importance of genetic diversity to preserve resilience within a population. Consider the value of genetic diversity from both economic and environmental perspectives.	4.3, 5.2, HL.b, HL.c

3.1.15 Earth history extends over a period of 4.5 billion years. Processes that occur over an extended timescale have led to the evolution of life on Earth.
Include the role of fossils in explaining the evolution of life over the geological timescale.

3.1.16 Earth history is divided up into geological epochs according to the fossil record.
The geological timescale is divided into eons, which are further classified into eras, periods and epochs. Changes in these time frames are marked by major geological and biological events. The division between one epoch and the next is marked by significant changes in fossils, indicating environmental changes causing many extinctions and the subsequent evolution of new species.

3.1.17 Mass extinctions are followed by rapid rates of speciation due to increased niche availability.	
The five mass extinctions in the past have been caused by various factors, such as tectonic plate movements, super-volcanic eruption, climatic changes, sea-level changes and meteorite impact; this is in contrast with the current anthropogenic sixth mass extinction.	2.1

3.1.18 The Anthropocene is a proposed geological epoch characterized by rapid environmental change and species extinction due to human activity.
There is debate about the existence and beginning of the Anthropocene epoch. Various start dates have been proposed for the epoch. Suitable "golden spikes" in the geological strata marking the proposed beginning include the 1610 dip in carbon dioxide caused by the arrival of Europeans in the Americas, 1950 spherical fly ash particles and the 1964 Carbon-14 markers linked to nuclear tests.

3.1.19 Human impacts are having a planetary effect, which will be detectable in the geological record.
Changes to the geological record support the argument for the Anthropocene being denoted a separate epoch from the Holocene. Consider at least four examples of evidence for the Anthropocene. • Signals from chemical pollution that are currently accumulating in geological strata, with the potential to be preserved into the far future • The mixing of native and non-native species, which will be represented in the fossil record • Deposits from nuclear testing • The modification of terrestrial and marine sedimentary systems • Minerals created solely or primarily from human activity

Possible engagement opportunities

- Investigate the origin and increase in abundance of tuskless elephants in regions undergoing civil conflict.
- Investigate the impact of inequality on knowledge of biodiversity.
- Citizen science and voluntary agencies offer opportunities for students to participate in gathering knowledge of local and regional biodiversity.
- Create a podcast exploring the epoch of the Anthropocene.

3.2 Human impact on biodiversity

Guiding question

- What causes biodiversity loss, and how are ecological and societal systems impacted?

SL and HL

3.2.1. Biological diversity is being adversely affected by both direct and indirect influences.	
Direct threats include overharvesting, poaching and the illegal pet trade. Indirect threats include habitat loss, climate change, pollution and invasive alien species.	4.4, 5.3, 6.2, 6.4, 7.2, 8.4, HL.a, HL.b, HL.c

3.2.2 Most ecosystems are subject to multiple human impacts.	
These impacts are increasing and their effects are amplified when combined. For example, when the impact of climate change has reduced resilience, other threats, such as invasive alien species, have more impact than if they were acting alone.	1.2, 6.2
Application of skills: Investigate the impact of human activity on biodiversity in an ecosystem by studying change in species diversity along a transect laid perpendicular to a site of human interference or by randomly sampling within transects before and after the human activity.	

3.2.3 Invasive alien species can reduce local biodiversity by competing for limited resources, predation and introduction of diseases or parasites.	
Consider how alien species can arrive in an ecosystem and the factors that can result in their exponential increase. Use a local example of an alien species that has become invasive and the management strategy that has been used to reduce its impact.	2.1, HL.a

3.2.4 The global conservation status of species is assessed by the International Union for Conservation of Nature (IUCN) and is published as the IUCN Red List. Status is based on number of individuals, rate of increase or decrease of the population, breeding potential, geographic range and known threats.	
Precise criteria and data are used to assign status to a species, and a sequence of conservation status ranks have been defined from least concern (LC) to extinct (EX).	HL.a

3.2.5 Assigning a global conservation status publicizes the vulnerability of species and allows governments, non-governmental agencies and individual citizens to select appropriate conservation priorities and management strategies.

Include differences between the perspectives of governments, agencies and individuals in conservation.	HL.a, HL.c

3.2.6 Investigate three different named species: a species that has become extinct due to human activity; a species that is critically endangered; and a species whose conservation status has been improved by intervention.	
For the three different named species, consider the factors that contributed to their decline and the impacts of their decline, disappearance or extinction on ecosystems and societies. Consider the conservation strategies that were employed, whether successful or not.	HL.a, HL.b, HL.c

3.2.7 The tragedy of the commons describes possible outcomes of the shared unrestricted use of a resource, with implications for sustainability and the impacts on biodiversity.	
The tragedy of the commons is a concept relating to the overexploitation of shared natural resources through human activity and the tension between individual self-interest and shared benefits of sustainable development. Include two examples where a resource is overharvested (for example, fish stocks on the Grand Banks) or where an environment is contaminated (for example plastic pollution in ocean gyres).	HL.a, HL.b, HL.c

HL only

3.2.8 Biodiversity hotspots are under threat from habitat destruction, which could lead to a significant loss of biological diversity, especially in tropical biomes.	
Consider the implications of biodiversity distribution for conservation. For example, because tropical biomes are frequently located in developing countries, this can exacerbate the challenge of effective conservation.	HL.a, HL.b, HL.c

3.2.9 Key areas that should be prioritized for biodiversity conservation have been identified on the basis of the international importance of their species and habitats.	
Key biodiversity areas (KBAs) have been used to identify sites that contribute significantly to the global persistence of biodiversity. Consider at least two areas that have been prioritized and describe their importance for global biodiversity. The sites should hold species at risk of extinction or ecosystems at risk of collapse.	HL.a

3.2.10 In KBAs, there is conflict between exploitation, sustainable development and conservation.	
Include an example of such conflict, for example, reasons for the spread of palm oil plantations in Malaysia and Indonesia and the consequences for biodiversity.	HL.b, HL.c

3.2.11 Traditional indigenous approaches to land management can be seen as more sustainable but are facing challenges of population growth, economic development, climate change and a lack of governmental support and protection.	
Threats to the notions of sustainability in traditional indigenous approaches come not only from the outside, but also from within as the society develops economically and aspires to follow the development model of the rest of the world. Consider threats to a named sustainable traditional indigenous land management practice.	5.3, 7.2, HL.a, HL.b, HL.c

3.2.12 Environmental justice must be considered when undertaking conservation efforts to address biodiversity loss.

The areas in the world expected to experience significant negative effects from the loss of biodiversity and ecosystem functions are those with large concentrations of indigenous people, whose communities may be of low income and without access to legal support. Consider one example of an indigenous or marginalized community that has been forcefully relocated from their homeland due to conservation efforts or protected habitats, which provided them with sustenance, for example, the Maasai in the Serengeti National Park.	1.1, HL.a, HL.c

3.2.13 The planetary boundary "loss of biosphere integrity" indicates that species extinctions have already crossed a critical threshold.	
Consider the claim that species extinctions caused by human impacts could lead to a tipping point in the whole Earth system.	1.3

Possible engagement opportunities

- Assess the tensions between exploitation, sustainable development and conservation in a local ecosystem or protected area.
- Raise awareness of indigenous land rights.
- Raise awareness of endangered species and volunteer in a local NGO for wildlife rehabilitation.

3.3 Conservation and regeneration

Guiding questions

- How can different strategies for conserving and regenerating natural systems be compared?
- How do worldviews affect the choices made in protecting natural systems?

SL and HL

3.3.1 Arguments for species and habitat preservation can be based on aesthetic, ecological, economic, ethical and social justifications.	
Economic arguments for preservation often involve valuation of ecotourism, of the genetic resource and commercial considerations of the natural capital. Ecological reasons may be related to the ecosystem services. Ethical arguments are very diverse and can include reference to the intrinsic or instrumental value of the species. Social arguments might highlight the importance of goods and services for the well-being of humans.	1.1, HL.b, HL.c

3.3.2 Species-based conservation tends to involve *ex situ* strategies, and habitat-based conservation tends to involve *in situ* strategies.	
Ex situ measures include botanic gardens, zoos, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and seed banks; *in situ* measures include use of national parks, reserves and sanctuaries. Consider two examples of *ex situ* measure and two examples of *in situ* measures.	HL.a, HL.b

3.3.3 Sometimes a mixed conservation approach is adopted, where both habitat and particular species are considered.	
The mixed approach usually invokes flagship and/or keystone species to justify the need to conserve intact habitats and landscapes. Consider an example of a mixed approach where the emphasis of *in situ* measures is on a particular species, for example, the Chengdu Research Base of Giant Panda Breeding.	HL.a, HL.b

3.3.4 The Convention on Biological Diversity (CBD) is a UN treaty addressing both species-based and habitat-based conservation.	
The objective of the CBD is to develop national strategies for the conservation and sustainable use of biological diversity. It further aims to identify protected marine areas outside of national jurisdictions. It also includes the Nagoya Protocol, which promotes the fair and equitable sharing of genetic resources.	HL.a, HL.b, HL.c

3.3.5 Habitat conservation strategies protect species by conservation of their natural environment. This may require protection of wild areas or active management.	
Include one example of a habitat where active management has been required and one example of the establishment of an ecosanctuary using pest-exclusion fencing. Surrounding land use for the conservation area and distance from urban centres are important factors for consideration in conservation area design.	HL.a

3.3.6 Effective conservation of biodiversity in nature reserves and national parks depends on an understanding of the biology of target species and on the effect of the size and shape of conservation areas.	
Include edge effects and the importance of wildlife corridors for connectivity. Consider an example of a UNESCO biosphere reserve with high biodiversity and species of international conservation importance, including the designation of an appropriate area for conservation, potential human impacts and management strategies. Include the concept of a pristine core, surrounded by buffer zones and outer transition zones that are sustainably managed.	2.1, HL.a

3.3.7 Natural processes in ecosystems can be regenerated by rewilding.	
Consider rewilding methods, for example, reintroduction of apex predators and other keystone species, re-establishment of connectivity of habitats over large areas, cessation of agriculture and resource harvesting, and minimization of human influences including by ecological management. Consider one example, such as Hinewai Reserve in New Zealand, any other appropriate rewilding project or a local example.	1.2, 2.1, 2.2, HL.a, HL.b, HL.c

3.3.8 Conservation and regeneration measures can be used to reverse the decline in biodiversity to ensure a safe operating space for humanity within the biodiversity planetary boundary.	
Measures can be taken to conserve and regenerate biodiversity at individual, collective, national and international levels.	1.3, HL.a

3.3.9 Environmental perspectives and value systems can impact the choice of conservation strategies selected by a society.	
The success of conservation and regeneration measures depend on incorporating a diversity of approaches, including community support, adequate funding, education and awareness, appropriate legislation, and scientific research. Consider also issues of environmental justice. More ecocentric perspectives may approach conservation for the intrinsic value of biodiversity and so focus on low-intervention *in situ* strategies; more anthropocentric/technocentric perspectives may be driven by the economic, societal value of biodiversity and thus embrace more scientific interventions involving zoos, gene banks and ecotourism.	1.1, HL.a, HL.b, HL.c

HL only

3.3.10 Success in conserving and restoring biodiversity by international, governmental and non-governmental organizations depends on their use of media, speed of response, diplomatic constraints, financial resources and political influence.	
Consider this claim with reference to named examples of the international, governmental and non-governmental organizations.	HL.a, HL.b

3.3.11 Positive feedback loops that enhance biodiversity and promote ecosystem equilibrium can be triggered by rewilding and habitat restoration efforts.	
A positive feedback loop is a necessary condition for the emergence of alternative stable states at the community scale. Consider the role of enhanced growth and biomass, reproduction and survival of species on food web interactions.	1.2

3.3.12 Rewilding projects have both benefits and limitations.	
Consider land-use issues concerning food production versus using areas for rewilding. Include the use of a rewilding project for example, Knepp Estate in England, the Affric Highlands in Scotland and the restocking of wildlife in the Gorongosa national park, Mozambique. A suitable reference for other rewilding projects can be found through the Global Rewilding Alliance website or other sources.	1.1, HL.a, HL.b, HL.c
Application of skills: Use secondary data from databases to assess the success of a rewilding project. Use questionnaires to assess the impact of ecotourism or the values that it promotes.	

3.3.13 The success of conservation or regeneration measures needs to be assessed.	
Consider claims that conservation measures have successfully protected biodiversity, and consider the impact of the measures on local communities. The success of the conservation strategy can be reviewed or evaluated at three levels. 1. Did the measures succeed in the project as planned? 2. Was the project well received by the communities impacted? 3. Was this the best way to conserve nature? Select a local or regional example or select one from: Willie Smits rainforest restoration project in Kalimantan and Sulawesi, Wangari Maathai's Kenyan Green Belt Movement, Steve Elliot and FORRU-CMU's restoration of south-east Asian forests.	HL.a, HL.c

3.3.14 Ecotourism can increase interdependence of local communities and increase biodiversity by generating income and providing funds for protecting areas, but there can also be negative societal and ecological impacts.	
Consider the use of ecotourism in a named protected area.	1.1, 1.3, HL.b, HL.c

Possible engagement opportunities

- Investigate the role of an NGO in a conservation project.
- Visit a rewilding project or protected area and raise awareness about the project.
- Volunteer in a local conservation project, for example, the removal of an invasive species or putting up bird boxes.

Topic 4: Water

4.1 Water systems

Guiding question

- How do water systems support life on Earth, and how do they interact with other systems, such as the carbon cycle?

SL and HL

4.1.1 Movements of water in the hydrosphere are driven by solar radiation and gravity.	
Heat is required for evaporation of water and is released when water condenses. Gravity causes water to drain through soil and in rivers to the sea.	1.2

4.1.2 The global hydrological cycle operates as a system with stores and flows.	
In water cycle diagrams, stores should be shown as boxes and flows as arrows.	1.2

4.1.3 The main stores in the hydrological cycle are the oceans (96.5%), glaciers and ice caps (1.7%), groundwater (1.7%), surface freshwater (0.02%), atmosphere (0.001%), organisms (0.0001%).
Percentage values are approximate so there is no need to memorize them, but students should have some idea of the relative proportions.

4.1.4 Flows in the hydrological cycle include transpiration, sublimation, evaporation, condensation, advection, precipitation, melting, freezing, surface run-off, infiltration, percolation, streamflow and groundwater flow.	
Sublimation is the transformation of ice directly to water vapour. Advection is the wind-blown movement of water vapour or condensed/frozen water droplets (clouds). Infiltration is water entering the soil. Percolation is water movement in the soil.	1.2
Application of skills: Create and use a systems diagram showing the transfers and transformations of the hydrological cycle.	

4.1.5 Human activities, such as agriculture, deforestation and urbanization, can alter these flows and stores.	
Change in land use, deforestation and urbanization often lead to reduced evapotranspiration and increased run-off, resulting in flash floods.	1.2, 5.3

4.1.6 The steady state of any water body can be demonstrated through flow diagrams of inputs and outputs.	
These can be used to calculate sustainable rates of harvesting from, for example, lakes and aquifers.	1.2

HL only

4.1.7 Water has unique physical and chemical properties that support and sustain life.
Include polarity, resulting in cohesion (attraction between water molecules due to hydrogen bonding), adhesion (attraction between water and other substances) and solvent properties. Also include

transparency, high specific heat capacity, differences in density depending on temperature and differences in gas solubility (oxygen and carbon dioxide) depending on temperature and pressure.	

4.1.8 The oceans act as a carbon sink by absorbing carbon dioxide from the atmosphere and sequestering it.	
This process has moderated increases in atmospheric carbon dioxide from the burning of fossil fuels, but a saturation point may be reached.	2.3, 6.1

4.1.9 Carbon sequestered in oceans over the short term as dissolved carbon dioxide causes ocean acidification; over the longer term, carbon is taken up into living organisms as biomass that accumulates on the seabed.	
Seabed sediments contain inorganic carbonates and carbon compounds in organic matter that is not fully decomposed. Over millions of years, these sediments can become fossil fuels.	2.3, 6.2

4.1.10 The temperature of water varies with depth, with cold water below and warmer water above. Differences in density restrict mixing between the layers, leading to persistent stratification.
The phenomenon of water being at its densest at 4°C means that colder water will float above it and a body of water freezes from the surface downwards, allowing freshwater ecosystems to survive beneath an insulating layer of ice.

4.1.11 Stratification occurs in deeper lakes, coastal areas, enclosed seas and open ocean, with a thermocline forming a transition layer between the warmer mixed layer at the surface and the cooler water below.	
Warmer surface water and cold deep water also differ in the concentrations of dissolved oxygen and mineral nutrients.	6.2

4.1.12 Global warming and salinity changes have increased the intensity of ocean stratification.	
The changes to stratification are most pronounced in the upper 200 metres of water. Temperature increases have had global effects. The melting of ice caps has reduced salinity in Antarctica.	6.2
Application of skills: Extract data from a database and analyse data on water temperatures with oxygen and salinity concentrations using an appropriate statistical test.	

4.1.13 Upwellings in oceans and freshwater bodies can bring cold, nutrient-rich waters to the surface.	
Upwelling is the mass, vertical movement of cold, nutrient-rich waters from the depths to the surface in response to displacement of wind-blown surface waters. Seasonal cycles of upwelling can occur in stratified lakes and in the upwelling associated with ENSO.	2.4, 4.3

4.1.14 Thermohaline circulation systems are driven by differences in temperature and salinity. The resulting differences in water density drives the ocean conveyor belt, which distributes heat around the world and thus affects climate.	
Rivers and melting ice caps bring low-salinity, low-density water into the North Atlantic. Wind currents from the equator, however, carry cool surface waters towards the North Atlantic that lose freshwater through evaporation and become more saline. The increased salinity and decreased temperature of these waters cause them to sink and form deep ocean currents back towards the equator, thereby creating the North Atlantic conveyor belt.	6.2

Possible engagement opportunities

- Investigate own water usage over a weekend and compare this to water use in other countries or other socio-economic groups within their own region.
- Investigate the impact of human activities on the water cycle in the local area or region, and summarize findings in promotional material for the school or college community.
- Initiate water-saving behaviours in the school community through advocacy.

4.2 Water access, use and security

Guiding questions

- What issues of water equity exist, and how can they be addressed?
- How do human populations affect the water cycle, and how does this impact water security?

SL and HL

4.2.1 Water security is having access to sufficient amounts of safe drinking water.	
Water security is a significant component of sustainable societies.	7.2

4.2.2 Social, cultural, economic and political factors all have an impact on the availability of, and equitable access to, the freshwater required for human well-being.	
Include examples of social, cultural, economic and political factors that have impacts.	1.1, HL.a, HL.b, HL.c

4.2.3 Human societies undergoing population growth or economic development must increase the supply of water or the efficiency of its utilization.	
Water is used for domestic purposes, for irrigation and raising livestock in agriculture, and for industry.	8.1, 8.2, 8.3, HL.b

4.2.4 Water supplies can be increased by constructing dams, reservoirs, rainwater catchment systems, desalination plants and enhancement of natural wetlands.	
Desalination is removal of salt and other minerals from water in order to obtain freshwater. Reverse osmosis is a method of desalination using a semi-permeable membrane.	1.3, HL.a, HL.b

4.2.5 Water scarcity refers to the limited availability of water to human societies.	
Water availability may be limited by the actual abundance of water present (physical scarcity) or by the available storage and transport systems (economic scarcity).	HL.b

4.2.6 Water conservation techniques can be applied at a domestic level.	
Include techniques such as metering, rationing, grey-water recycling, low-flush toilets, rainwater harvesting.	1.3

4.2.7 Water conservation strategies can be applied at an industrial level in food production systems.	
Include examples, such as greenhouses that use and recycle harvested rainwater, aquaponics systems that combine production of fish and vegetables, drip irrigation systems, drought-resistant crops, switching to vegetarian food production.	1.3, HL.a, HL.b, HL.c

4.2.8 Mitigation strategies exist to address water scarcity.	
Consider appropriate examples of management strategies a named country employs to address water scarcity.	1.3, HL.a, HL.b, HL.c

HL only

4.2.9 Freshwater use is a planetary boundary, with increasing demand for limited freshwater resources causing increased water stress and the risk of abrupt and irreversible changes to the hydrological system.	
Consider how the planetary boundary can be measured and possible mitigation strategies to avoid crossing the boundary.	1.3

4.2.10 Local and global governance is needed to maintain freshwater use at sustainable levels.	
Include one example of local regulations on water use, such as banning watering of gardens in droughts. Include one example of where international agreements over water sources have become necessary.	HL.a, HL.b, HL.c

4.2.11 Water footprints can serve as a measure of sustainable use by societies and can inform decision-making about water security.	
A water footprint is a measure of the use of water by individual humans or nations, or the amount needed to grow crops or livestock or manufacture textiles, steel or other products.	1.3, HL.c

4.2.12 Citizen science is playing an increasing role in monitoring and managing water resources.	
Citizen science is also called community science or crowdsourced science. Common features of citizen science are that anyone can take part. All participants use the same protocol so that high-quality data can be combined and data is open access. Consider the benefits and limitations of citizen science in ensuring sustainable water use at a local level. For example, consider whether it is possible to crowdsource accurate water-quality data.	1.3

4.2.13 "Water stress" like "water scarcity" is another measure of the limitation of water supply; it not only takes into account the scarcity of availability but also the water quality, environmental flows and accessibility.	
A region may have an ample supply and not be suffering from water scarcity, but it may be experiencing water stress because of low water quality.	1.2, 1.3

4.2.14 Water stress is defined as a clean, accessible water supply of less than 1,700 cubic metres per year per capita.	
Consider one example of a society that falls below this level and the reasons that account for this.	1.3, HL.b, HL.c

4.2.15 The causes of increasing water stress may depend on the socio-economic context.	
Include at least two different perspectives, such as the aim of increasing industrialization in an emerging economy and over-abstraction due to population pressure in a low-income country.	1.1, HL.b

4.2.16 Water stress can arise from transboundary disputes when water sources cross regional boundaries.	
Include at least one local or regional example of a transboundary dispute and references to the historical or political context for that conflict.	HL.a

4.2.17 Water stress can be addressed at an industrial level.	
Consider strategies of dams, water transfer, pipelines or tankers, estuary storage with barrages, rainmaking or cloud seeding, desalination, solar distillation, dew harvesting, water treatment plants, aquifer storage and recovery (ASR) and artificial recharge of aquifers (AR).	1.1, HL.a, HL.b
Application of skills: Use secondary data sources to investigate the causes of water stress within a given society.	

4.2.18 Industrial freshwater production has negative environmental impacts that can be minimized but not usually eliminated.	
Include the potential impacts of: concentrated brine discharges from desalination plants; noise; air pollution; impacts on aquifers (for example, saline intrusion); and combustion of fossil fuels to provide energy (for example, desalination in the United Arab Emirates (UAE)).	1.3, 7.2, HL.b, HL.c

4.2.19 Inequitable access to drinkable water and sanitation negatively impacts human health and sustainable development.	
Include an example of an equity issue relating to water and sanitation for a named marginalized group within society. Marginalized groups could include indigenous people or low-income groups. Include statistics providing evidence of inequity.	1.3, HL.c

Possible engagement opportunities

- Compare the water footprint for a variety of different food or clothing items, for example, a pair of denim jeans and a linen T-shirt, wool and polyester fleece, or an avocado and an apple.
- Engage with charities that focus on access to water, such as WaterAid.
- Advocate for reducing household water consumption.

4.3 Aquatic food production systems

Guiding questions

- How are our diets impacted by our values and perspectives?
- To what extent are aquatic food systems sustainable?

SL and HL

4.3.1 Phytoplankton and macrophytes provide energy for freshwater and marine food webs.	
Phytoplankton are a type of microscopic plankton capable of photosynthesis that are found in oceans, seas and freshwater. Macrophytes are aquatic plants that are large enough to be visible. They can be emergent from water, submerged or floating.	2.2

4.3.2 Humans consume organisms from freshwater and marine environments.	
Include one local and one global example of aquatic flora and fauna consumed by humans.	2.2

4.3.3 Demand for foods from freshwater and marine environments is increasing due to the growth in human population and changes in dietary preferences.	
Consider evidence for the increasing demand.	1.3, 8.1, HL.c

4.3.4 The increasing global demand for seafood has encouraged use of unsustainable harvesting practices and overexploitation.	
Include bottom trawling, ghost fishing and the use of poisons and explosives as destructive methods of harvesting that are unsustainable.	1.3, HL.a, HL.b, HL.c

4.3.5 Overexploitation has led to the collapse of fisheries.	
Consider details of one fishery collapse (the dramatic and lasting decrease in stocks to a point where the commercial fish can no longer recover), for example, the cod fishery on the Grand Banks of Newfoundland.	1.2, 3.2, 7.2, HL.a, HL.b, HL.c

4.3.6 The maximum sustainable yield (MSY) is the highest possible annual catch that can be sustained over time, so it should be used to set caps on fishing quotas.	
Consider the yield/fishing effort graph indicating the MSY. Typically, harvesting at the MSY requires much lower fishing rates than occurs in many fisheries.	1.3, 2.2, HL.a, HL.b

4.3.7 Climate change and ocean acidification are having impacts on ecosystems and may cause collapse of some populations in freshwater or marine ecosystems.	
Include a local or global example of an aquatic ecosystem under stress due to climate change or ocean acidification, for example, the impact of coral bleaching events on the ecosystem of the Great Barrier Reef.	1.2, 6.2, HL.b
Application of skills: Plan an experiment to investigate the impact of acidification on shelled organisms.	

4.3.8 Unsustainable exploitation of freshwater and marine ecosystems can be mitigated through policy legislation addressing the fishing industry and changes in consumer behaviour.	
Include actions at international, national, local/individual level including permits, quotas, seasons, mesh size, zones, food labelling.	1.3, HL.a, HL.b, HL.c

4.3.9 Marine protected areas (MPAs) can be used to support aquatic food chains and maintain sustainable yields.	
Include how a protected area can benefit wider areas of sea, for example, by providing shelter or spawning grounds.	1.3, HL.a

4.3.10 Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. The industry is expanding to increase food supplies and support economic development, but there are associated environmental impacts.	
Consider a specific example of aquaculture including references to negative impacts, such as loss of habitat, pollution with feed, anti-fouling agents, antibiotics and other medicines used, spread of diseases, and escapees which, in some cases, are genetically modified. Include	4.4, HL.b, HL.c

reference to at least one management technique that can reduce the effect of negative impacts.	

HL only

4.3.11 Productivity, thermal stratification, nutrient mixing and nutrient loading are interconnected in water systems.	
The highest productivity tends to occur near coastlines or in shallow seas, where upwellings and nutrient enrichment of surface waters occurs.	1.2, 2.3

4.3.12 Accurate assessment of fish stocks and monitoring of harvest rates are required for their conservation and sustainable use.	
Include at least one method of measuring a fish stock accurately and one method of monitoring harvest rates.	2.2, HL.b, HL.c

4.3.13 There are risks in harvesting fish at the maximum sustainable yield (MSY) rate and these risks need to be managed carefully.	
The MSY is only an estimated value and attempting to harvest at exactly that rate will inevitably be inaccurate. Exceeding the rate may lead to reduction in reproductive potential and positive feedback, causing rapid decline in fish stocks.	1.3, 2.2, HL.b, HL.c

4.3.14 Species that have been overexploited may recover with cooperation between governments, the fishing industry, consumers and other interest groups, including NGOs, wholesale fishery markets and local supermarkets.	
Consider the perspective of each group of stakeholders and how differences can be resolved. Measures that help to restore stocks include temporary fishing bans, limits to fishing licences, prevention of bycatch and information to help consumers choose species that are not being harvested unsustainably.	1.3, HL.a, HL.c

4.3.15 According to the UN Convention on the Law of the Sea (UNCLOS), coastal states have an exclusive economic zone stretching 370 km out to sea, within which the state's government can regulate fishing. Almost 60% of the ocean is the high seas outside these coastal zones, with limited intergovernmental regulation.	
There is an equity and justice issue when countries sell access to their fishing zones rather than managing it for local people. The UN has developed and signed an international treaty to protect the high seas.	HL.a, HL.c

4.3.16 Harvesting of seals, whales and dolphins raises ethical issues relating to the rights of animals and of indigenous groups of humans.	
Consider the hunting of a particular species from at least two contrasting perspectives, for example, the Inuit killing of narwhals or the Faroe Islanders' killing of dolphins.	1.1, 1.3, HL.c

Possible engagement opportunities

- Explore the role of MPAs in conserving ocean biodiversity, and the approaches taken by their regional or national government.
- Raise awareness of loss of access to local fishing due to international sale of fishing rights.
- Host a film show highlighting the tensions around consumption of fish.
- Raise awareness around marine certification programmes for fish consumption.

- Write emails to NGOs that highlight changes that could alleviate environmental challenges around aquaculture.

4.4 Water pollution

Guiding questions

- How does pollution affect the sustainability of environmental systems?
- How do different perspectives affect how pollution is managed?

SL and HL

4.4.1 Water pollution has multiple sources and has major impacts on marine and freshwater systems.	
Include reference to sewage, agricultural run-off, industrial effluent, urban run-off, solid waste disposal and oil spills as sources of pollution. Include a more detailed account of a specific example of water pollution, identifying the location, source of pollution, and the impacts on the environment and management strategies attempting to address it.	HL.a, HL.b, HL.c

4.4.2 Plastic debris is accumulating in marine environments. Management is needed to remove plastics from the supply chain and to clear up existing pollution.	
Include the harm that comes from oceanic plastic pollution; how plastics have come to aggregate into oceanic gyres; and how the associated microplastics that enter the food chain accumulate, magnify and transport surface toxins.	2.2, HL.a, HL.c

4.4.3 Water quality is the measurement of chemical, physical and biological characteristics of water. Water quality is variable and is often measured using a water quality index. Monitoring water quality can inform management strategies for reducing water pollution.	
Water quality in aquatic systems is assessed by monitoring dissolved oxygen, pH, temperature, turbidity, and concentrations of nitrates, phosphates, specific metals and total suspended solids. Data can be used to inform management strategies for reducing pollution.	1.3
Application of skills: Use methods for measuring key abiotic factors in aquatic systems, for example, dissolved oxygen, pH, temperature, turbidity, and concentrations of nitrates, phosphates and total suspended solids. Possible methods may include the use of oxygen and pH probes, a thermometer, a Secchi disc, nitrate/phosphate tests.	

4.4.4 Biochemical oxygen demand (BOD) is a measure of the amount of dissolved oxygen required by microorganisms to decompose organic material in water.
The usual measure is milligrams of oxygen consumed per litre of sample in five days at 20°C. BOD provides an indirect measure of the amount of organic matter within a sample.

4.4.5 Eutrophication occurs when lakes, estuaries and coastal waters receive inputs of mineral nutrients, especially nitrates and phosphates, often causing excessive growth of phytoplankton.	
Algal blooms only occur if phytoplankton growth had previously been limited by lower concentrations of phosphate and/or nitrate. Humans cause eutrophication when releasing detergents, sewage or agricultural fertilizers into water bodies.	1.2

4.4.6 Eutrophication leads to a sequence of impacts and changes to the aquatic system.

Excessive growth of phytoplankton is typically followed by their death and, therefore, high rates of decomposition, rapid consumption of dissolved oxygen leading to hypoxia or anoxia in the water, and death of aquatic life that depends on dissolved oxygen occur.	1.2
Application of skills: Create a systems model to show the impacts and changes eutrophication produces in an aquatic system. This model should include examples of positive feedback (for example, increase in nutrients>increase in death of organisms>increase in decomposition>increase in nutrients).	

4.4.7 Eutrophication can substantially impact ecosystem services.	
Eutrophication can affect services associated with fisheries, recreation, aesthetics and health.	1.1, HL.b

4.4.8 Eutrophication can be addressed at three different levels of management.	
These three levels of management are: • the reduction of human activities that produce pollutants—for example, alternatives to current fertilizers and detergents • the reduction of the release of pollution into the environment—for example, treatment of wastewater to remove nitrates and phosphates • the removal of pollutants from the environment and restoration of ecosystems—for example, removal of mud from eutrophic lakes and reintroduction of plant and fish species. These methods can also apply to other examples of pollution.	1.1, 1.3, HL.a, HL.b, HL.c

HL only

4.4.9 There is a wide range of pollutants that can be found in water.
These pollutants may include organic matter (for example, sewage), dissolved substances (for example, tributyltin, an endocrine-disrupting chemical), persistent chemicals that become biomagnified (for example, PCBs), plastics and heat energy.

4.4.10 Algal blooms may produce toxins that threaten the health of humans and other animals.	
Harmful algal blooms (HABs) contain a variety of organisms, including cyanobacteria, protists, algae and dinoflagellates. A small number of these organisms produce potentially fatal toxins. In freshwater, cyanotoxins are the most common toxins. Within the HABs that occur along coastlines, dinoflagellates produce different toxins, including a neurotoxin; these may be red in colour. Consider one example from freshwater and one from marine water.	2.1, 4.3

4.4.11 The frequency of anoxic/hypoxic waters is likely to increase due to the combined effects of global warming, freshwater stratification, sewage disposal and eutrophication.	
Hypoxic conditions can arise from a variety of causes, resulting in aquatic dead zones.	1.2, 6.2

4.4.12 Sewage is treated to allow safe release of effluent by primary, secondary and tertiary water treatment stages.	
Consider what is achieved in each of the sewage treatment stages, including both biological and chemical processes. Also consider the challenges of implementing sewage treatment equitably in all societies.	1.3

4.4.13 Some species are sensitive to pollutants or are adapted to polluted waters, so these can be used as indicator species.

Include at least one example of a tolerant and at least one example of an intolerant indicator species.	3.1, HL.a, HL.b, HL.c

4.4.14 A biotic index can provide an indirect measure of water quality based on the tolerance to pollution, relative abundance and diversity of species in the community.	
The Trent biotic index is an example of a biotic index.	3.1
Application of skills: Apply protocols for assessing biological oxygen demand and a named biotic index.	

4.4.15 Overall water quality can be assessed by calculating a water quality index (WQI).	
A WQI is a single, weighted average, consisting of the combined results of several individual water quality test parameters, representing the degree of contamination in a given water sample. Vernier's WQI is one example.	1.3

4.4.16 Drinking water quality guidelines have been set by the World Health Organization (WHO), and local governments can set statutory standards.	
Consider the role of regulations and standards in environmental impact assessments and international business agreements, for example, when a private company builds a water bottling plant in a developing country.	HL.a, HL.b

4.4.17 Action by individuals or groups of citizens can help to reduce water pollution.	
Include changes to consumption and waste disposal, peaceful citizen protest, data collection and research, formation of legal teams and lobbying of lawmakers.	1.3, HL.a, HL.c

Possible engagement opportunities

- Investigate the effects of pollution on aquatic systems in the local area or region. Health and safety, and ethical issues, should be considered.
- Produce an information film about red tides, if this is a problem in the local area.
- Engage in plastic pollution clean-ups.
- Visit a water treatment plant.

Topic 5: Land

5.1 Soil

Guiding questions

- How do soils play a role in sustaining natural systems?
- How are human activities affecting the stability of soil systems?

SL and HL

5.1.1 Soil is a dynamic system within the larger ecosystem that has its own inputs, outputs, storages and flows.	
Soils are a resource for life and they vary widely.	1.2

5.1.2 Soil is made up of inorganic and organic components, water and air.

Soil is a complex mixture of interacting components forming its own ecosystem with distinct soil organisms. Inorganic components or mineral matter (rock fragments, sand, silt and clay) come from weathering of parental rock. Organic components include living organisms and material from the decay of organisms. There are keys published online to classify soils.

5.1.3 Soils develop a stable, layered structure known as a profile made up of several horizons, produced by interactions within the system over long periods of time.	
Soil profiles have distinctive horizons that show a transition from more organic components in the upper surface to inorganic below.	2.5
Application of skills • Sample two soils from the subsoil (B horizon): one from a local garden or field, and one from a natural ecosystem. • Investigate texture, organic matter content, nitrogen, phosphorus, and potassium (NPK) concentrations, aeration, drainage and water retention. • Determine the amount of carbon in a dry soil sample by burning off the organic matter and calculating the change in mass.	

5.1.4 Soil system inputs include those from dead organic matter and inorganic minerals.	
Dead organic matter inputs may include, but not be limited to, plant litter, dead animal biomass, manure. Organic mineral inputs may include weathering, deposition or decomposition, precipitation (water with dissolved minerals), gases, air, humidity and solar energy. In managed soil systems, many inputs are anthropogenic: compost, fertilizer, agrochemicals, irrigation, salinization. Natural inputs may originate from within the ecosystem (weathering of underlying parental rock, litter from above-ground vegetation, decomposition) or be derived from other ecosystems (wind-blown and waterborne deposition, guano).	1.2, 2.5

5.1.5 Soil system outputs include losses of dead organic matter due to decomposition, losses of mineral components and loss of energy due to heat loss.	
Mineral component outputs include wind or water erosion, water and mineral absorption by plant roots, leaching of dissolved plant nutrients and water, diffusion of gases and evaporation of water. These outputs can cause the loss or modification of soil components and are different from total loss of soil by erosion; however, they can also lead to degradation of productive soil.	1.2

5.1.6 Transfers occur across soil horizons, into and out of soils.	
Include infiltration, percolation, groundwater flow, biological mixing, aeration, erosion and leaching.	1.2

5.1.7 Transformations within soils can change the components or the whole soil system.	
Include decomposition, weathering, nutrient cycling and salinization.	1.2

5.1.8 Systems flow diagrams show flows into, out of and within the soil ecosystem.	
Soil systems are essential for the water, carbon and nitrogen cycles.	1.2
Application of skills: Create a systems flow diagram representing the soil system.	

5.1.9 Soils provide the foundation of terrestrial ecosystems as a medium for plant growth (a seed bank, a store of water and almost all essential plant nutrients). Carbon is an exception; it is obtained by plants from the atmosphere.	
Soils store the key nutrients for plants: nitrogen, phosphorus and potassium.	2.3

5.1.10 Soils contribute to biodiversity by providing a habitat and a niche for many species.	
Soil communities have a large biodiversity, including microorganisms, animals and fungi (of which there are still many unknown species).	2.1

5.1.11 Soils have an important role in the recycling of elements as a part of biogeochemical cycles.	
The major input is of dead organic matter from the plants entering the soil. Leaf litter is then broken down by detritivores (for example, earthworms) into smaller fragments and decomposed by saprotrophs, such as fungi and bacteria.	2.3

5.1.12 Soil texture defines the physical make-up of the mineral soil. It depends on the relative proportions of sand, silt, clay and humus.
Soil texture can be determined using a key, a feel test or by mixing with water and separating the layers in the laboratory.

5.1.13 Soil texture affects primary productivity through the differing influences of sand, silt, clay and dead organic matter, including humus.
Humus contributes significantly to the texture of soils in which it is abundant. It is a dark brown or black substance lying beneath the leaf litter. It has a loose, crumbly texture formed by the partial decay of dead plant material. It influences mineral nutrient retention versus leaching, water retention versus drainage, and aeration versus compaction or waterlogging; these influences affect primary productivity.

5.1.14 Soils can act as carbon sinks, stores or sources, depending on the relative rates of input of dead organic matter and decomposition.	
Consider why there is little carbon stored in tropical forest soils and relatively large amounts under tundra, wetlands and temperate grasslands.	2.3, 6.2

HL only

5.1.15 Soils are classified and mapped by appearance of the whole soil profile.	
Drawing a profile diagram is a useful descriptive technique used to explain how the transfer and transformation processes work on the soil components.	2.4
Application of skills: Use soil profile diagrams to classify examples of soils that can be linked to the biomes studied, for example, brown earths to temperate deciduous forests, or oxisols to rainforests.	

5.1.16 Horizons are horizontal strata that are distinctive to the soil type. The key horizons are organic layer, mixed layer, mineral soil and parent rock (O, A, B and C horizons).
Natural soil systems have O, A, B and C horizons, but intensive agricultural systems have only B and C horizons remaining. Consider the impact of this either through looking at images or at actual examples.

5.1.17 The A horizon is the layer of soil just beneath the uppermost organic humus layer, where present. It is rich in organic matter and is also known as the mixed layer or topsoil. This is the most

valuable for plant growth but, along with the O horizon, is also the most vulnerable to erosion and degradation, with implications for sustainable management of soil.	
Topsoil has more oxygen, organic matter, microorganisms and nutrient recycling than lower soil horizons; therefore, it is where there is most root growth and other biological activity. Intensive farming removes this layer and requires the addition of fertilizers.	5.2, 5.3

5.1.18 Factors that influence soil formation include climate, organisms, geomorphology (landscape), geology (parent material) and time.	
Climate factors include contrast of temperatures from a range of biomes in tropical, temperate and polar regions. Geomorphological factors include slope, aspect and drainage. Geology and time factors include influences on weathering, erosion and deposition of materials, waterlogging and aeration. Also include the influence of calcareous and volcanic parent rock types on soil formation.	2.4

5.1.19 Differences between soils rich in sand, silt or clay include particle size and chemical properties.
Sand and silt are derived from quartz and have a low cation-exchange capacity (CEC); clays are complex silicates that have a much greater CEC that increases availability of positively charged minerals, for example, calcium, magnesium and potassium.

5.1.20 Soil properties can be determined from analysing the sand, silt and clay percentages, percentage organic matter, percentage water, infiltration, bulk density, colour and pH.
Consider data on soils, including using the soil texture triangle.

5.1.21 Carbon is released from soils as methane or carbon dioxide.	
Carbon may be released from soils through increased decomposition due to global warming, agricultural practices, drainage of wetlands or other human activity; it may lead to a tipping point. There is a tipping point where increasing temperatures lead to breakdown of methane clathrates in underlying geological structures.	2.3, 6.2

Possible engagement opportunities

- Research how local farms manage and value soil in relation to agriculture, climate change, biodiversity and overall sustainability.
- Host a documentary film festival about soil and food.
- Start an organic vegetable garden using compost bins to compost organic material.

5.2 Agriculture and food

Guiding question

- To what extent can the production of food be considered sustainable?

SL and HL

5.2.1 Land is a finite resource, and the human population continues to increase and require feeding.

About 70% of ice-free land is used for agriculture and forestry. Not all soils or land are suitable for arable crops; some land is too steep, some soils are too nutrient-poor. These are often used for livestock production.	8.1

5.2.2 Marginalized groups are more vulnerable if their needs are not taken into account in land-use decisions.	
Consider indigenous peoples and other groups that may be marginalized or have a low socio-economic status, such as members of a low caste or women farmers or people in low-income countries. Include a named example of marginalized people deprived of sufficient land rights to support their needs.	1.1, 1.3, HL.a, HL.b, HL.c

5.2.3 World agriculture produces enough food to feed eight billion people, but the food is not equitably distributed and much is wasted or lost in distribution.	
It is estimated that at least one-third of food production is wasted (post-harvest, in storage, in distribution). Include the SDG goal that aims to halve food waste.	1.3, HL.b, HL.c

5.2.4 Agriculture systems across the world vary considerably due to the different nature of the soils and climates.	
Soils in different biomes have very different potentials for crop types and productivity.	2.4, 5.1

5.2.5 Agricultural systems are varied, with different factors influencing the farmers' choices. These differences and factors have implications for economic, social and environmental sustainability.	
Agricultural systems can be classified in a number of ways. • Outputs from the farm system—arable, pastoral/livestock, mixed, monoculture or diverse. • Reasons for farming—commercial or subsistence, sedentary or nomadic. • Types of inputs required for the farm system—intensive or extensive, irrigated or rain-fed, soil-based or hydroponic, organic or inorganic.	1.3, HL.b, HL.c
Application of skills: Make a detailed study of one example of a pair of named contrasting systems.	

5.2.6 Nomadic pastoralism and slash-and-burn agriculture are traditional techniques that have sustained low-density populations in some regions of the world.	
As indigenous cultures modernize and exist in higher population densities or in fixed locations, these practices become less sustainable.	1.1, 1.3

5.2.7 The Green Revolution (also known as the Third Agricultural Revolution in the 1950s and 1960s) used breeding of high-yielding crop plants—combined with increased and improved irrigation systems, synthetic fertilizer and application of pesticides—to increase food security. It has been criticized for its sociocultural, economic and environmental consequences.	
There are both positive and negative consequences of the Green Revolution, and it did not occur in all developing nations. Improved productivity depended on fixing nitrogen into synthetic fertilizers, which makes their production fossil-fuel dependent.	1.1, 1.3, 2.3, 6.2, HL.b

5.2.8 Synthetic fertilizers are needed in many intensive systems to maintain high commercial productivity at the expense of sustainability. In sustainable agriculture, there are other methods for improving soil fertility.

These techniques include restoring natural productivity by fallowing, using organic fertilizer from farm animals or humanure, herbal mixed leys, use of mycorrhizae, continuous cover forestry and agroforestry.	2.3, 4.4

5.2.9 A variety of techniques can be used to conserve soil, with widespread environmental, economic and sociocultural benefits.	
Soil conservation techniques are very varied and can be classified in a number of ways. 1. Conservation from erosion—water and wind a. Water—terracing, contour ploughing, bunding, drainage systems, use of cover crops b. Wind—planting tree/hedge windbreaks, use of cover crops 2. Conservation of fertility with soil conditioners—lime, use of organic materials. such as compost, green manure 3. Cultivation techniques—avoid marginal land, avoid overgrazing or overcropping, strip cultivation, mixed cropping, crop rotation, reduced tillage, agroforestry, reduced use of heavy machinery Many of the techniques help conserve soil from a number of problems. For example, cover crops protect the soil from wind and water erosion, and they can also ploughed into the soil to become green compost.	HL.b, HL.c

5.2.10 Humans are omnivorous, and diets include fungi, plants, meat and fish. Diets lower in trophic levels are more sustainable.	
The yield of food per unit of land area is greater in quantity and lower in cost with crops rather than livestock. Consider to what extent plant-based diets could make agriculture more sustainable.	1.3, 2.2, HL.c

5.2.11 Current global strategies to achieve sustainable food supply include reducing demand and food waste, reducing greenhouse gas emissions from food production and increasing productivity without increasing the area of land used for agriculture.	
Examples include plant-based meat substitutes, reducing nitrogen loss to the atmosphere, low methane rice, reducing methane release by ruminants, extended shelf life for food, genetic modification to boost yields or in-field solar powered fertilizer production process.	1.3, 2.3, 3.1, 6.3, HL.a, HL.b, HL.c

5.2.12 Food security is the physical and economic availability of food, allowing all individuals to get the balanced diet they need for an active and healthy life.	
Consider the current extent of food security within differing regions of the world.	1.3, 7.2, HL.b

HL only

5.2.13 Contrasting agricultural choices will often be the result of differences in the local soils and climate.	
Consider one pair of contrasting agricultural choices from one biome. Examples include: cereal and ranching in the mollisols of steppe and prairies; soya beans and cattle ranching in the oxisols of tropical forests; ranching and irrigated crops in desert aridisol farming; or mixed arable and pasture in temperate forest brown earths.	2.4, 5.1

5.2.14 Numerous alternative farming approaches have been developed in relation to the current ecological crisis. These include approaches that promote soil regeneration, rewilding, permaculture, non-commercial cropping and zero tillage.	
Alternative approaches have been developed to address a variety of issues, including food sustainability, water quality, local economic stability, as well as restoring and conserving soils.	1.3, HL.b, HL.c

5.2.15 Regenerative farming systems and permaculture use mixed farming techniques to improve and diversify productivity. Techniques include the use of animals like pigs or chickens to clear vegetation and plough the land, or mob grazing to improve soil.	
Consider the advantages and disadvantages of these techniques. Consider how plant-based diets could be part of regenerative and permaculture farming systems.	1.3, HL.c

5.2.16 Technological improvements can lead to very high levels of productivity, as seen in the modern high-tech greenhouse and vertical farming techniques that are increasingly important for supplying food to urban areas.	
Improvements to agriculture in the 21st century can greatly improve productivity, but these are not always sustainable as they may be dependent on fossil fuels.	1.3, HL.b, HL.c

5.2.17 The sustainability of different diets varies. Supply chain efficiency, the distance food travels, the type of farming and farming techniques, and societal diet changes can all impact sustainability.	
Consider the environmental impacts of: the length of a supply chain (social, economic and physical distance); year-round food supply and the associated food miles; the cultural shifts to eating more or less meat; and the rise in veganism. For example, the planetary health diet (PHD) developed by the Eat-Lancet Commission.	1.3, HL.b, HL.c
Application of skills: Create a survey to investigate food preferences and the worldviews of various groups.	

5.2.18 Harvesting wild species from ecosystems by traditional methods may be more sustainable than land conversion and cultivation.	
Consider the claim that harvesting by traditional methods may be more sustainable. A variety of secondary forest products could be harvested, for example, Brazil nuts (*Bertholletia excelsa*), truffles (subterranean fungi), bamboo shoots, honey and insects for food. Also include the harvesting of controversial and endangered species, such as pangolins, bears or other bushmeats.	1.1, 1.3, HL.c

5.2.19 Claims that low-productivity, indigenous, traditional or alternative food systems are sustainable should be evaluated against the need to produce enough food to feed the wider global population.	
Consider the view that low-productivity subsistence systems that have little commercial value can resolve the problem of global unsustainability in food production.	1.1, 1.3, HL.b, HL.c

5.2.20 Food distribution patterns and food quality variations reflect functioning of the global food supply industry and can lead to all forms of malnutrition (diseases of undernourishment and overnourishment).	
Uneven distribution of food and variations in food quality cause health issues; care should be taken to avoid assuming biomass correlates with nutritive value—food can be low nutritive quality or highly processed. Famine is caused as much by distribution problems as crop failure.	1.1, 1.3, HL.b, HL.c

Examples include the Irish potato famine (1845–49) caused by potato blight, and East Africa famines caused by drought and conflict.	

Possible engagement opportunities

- Investigate the impacts of students' own diets.
- Engage with an organization like the World Food Programme to help support access to food by those needing support. This could include volunteering at a local soup kitchen.
- Organize a school menu aligned with the planetary health diet or meat-free Mondays.
- Learn to cook vegetarian or vegan meals, and reflect on the carbon footprints of these meals as compared to other meals.

Topic 6: Atmosphere and climate change

6.1 Introduction to the atmosphere

Guiding question

- How do atmospheric systems contribute to the stability of life on Earth?

SL and HL

6.1.1 The atmosphere forms the boundary between Earth and space. It is the outer limit of the biosphere and its composition and processes support life on Earth.	
The atmosphere includes a mixture of gases; these gases are redistributed through physical processes, such as wind.	1.2

6.1.2 Differential heating of the atmosphere creates the tricellular model of atmospheric circulation that redistributes the heat from the equator to the poles.	
This circulation disperses the heat across the planet, reducing the heat at the equator and increasing the temperature in higher latitudes.	1.2, 2.4
Application of skills: Create system diagrams to represent the atmospheric system.	

6.1.3 GHGs and aerosols in the atmosphere absorb and re-emit some of the infrared (long-wave) radiation emitted from the Earth's surface, preventing it from being radiated out into space. They include water vapour, carbon dioxide, methane and nitrous oxides (GHGs) and black carbon (aerosol).
Carbon dioxide and water vapour are the most abundant GHGs in the atmosphere, and methane also has significant warming effects. Other gases also contribute to radiative forcing. Although water vapour is a significant GHG, it is usually excluded from climate models as its abundance changes as a result of global warming; it is dynamic within the atmospheric system and is essential for life, so cannot be mitigated against.

6.1.4 The greenhouse effect keeps the Earth warmer than it otherwise would be due to the broad spectrum of the Sun's radiation reaching the Earth's surface and infrared radiation emitted by the warmed surface then being trapped and re-radiated by GHGs.	
The greenhouse effect is a natural process that keeps the Earth warm enough for life to be possible. The temperature of the Earth depends on the concentration of GHGs in the atmosphere. The term "enhanced greenhouse effect" has been used in reference to the accumulation of GHGs by human activity leading to global warming (increasing mean global	1.2

temperature). "Climate change" encompasses global warming but refers to the broader range of changes that are happening to the planet as a result.	

HL only

6.1.5 The atmosphere is a dynamic system, and the components and layers are the result of continuous physical and chemical processes.	
For physical processes, include global warming, and air movements due to temperature and pressure differences. For chemical processes, include production of ozone from oxygen.	1.2

6.1.6 Molecules in the atmosphere are pulled towards the Earth's surface by gravity. Because gravitational force is inversely proportional to distance, the atmosphere thins as altitude increases.
Include standard lapse rate (about one degree for every 100 m altitude). Quantifying volumes or pressures of gases at specific altitudes is not required.

6.1.7 Milankovitch cycles affect how much solar radiation reaches the Earth and lead to cycles in the Earth's climate over tens to hundreds of thousands of years.	
There is a relationship between the three types of Milankovitch cycles (the shape of Earth's orbit; angle of tilt; and axis of rotation) and the corresponding climate changes. Through positive feedback loops, this causes either decreasing concentrations of atmospheric carbon dioxide with cooling and glaciation or increasing carbon dioxide concentrations with warming and interglacial conditions. These cycles occur over many thousands of years but do not explain current warming.	1.2

6.1.8 Global warming is moving the Earth away from the glacial–interglacial cycle that has characterized the Quaternary period, toward new, hotter climatic conditions.	
The Quaternary period started 2.5 million years ago. Climate has changed over geological time without human influence, but current anthropogenic changes are unprecedentedly rapid and are part of the Anthropocene epoch.	3.1
Application of skills: Investigate the impact of albedo or different GHGs on the temperature of a closed system.	

6.1.9 The evolution of life on Earth changed the composition of the atmosphere, which in turn influences the evolution of life on Earth.	
The percentage composition of the pre-biotic Earth's atmosphere was very different to current composition. Photosynthesis has decreased the carbon dioxide concentration and increased the oxygen concentration, allowing stratospheric ozone to form and for the oxidation of metals, for example, the formation of iron ore. The chronology of oxygenation in the history of the Earth is not required.	3.1

Possible engagement opportunity

- Citizen science and voluntary agencies offer opportunities for students to participate in gathering knowledge of the atmosphere and the impacts of air pollution.

6.2 Climate change—causes and impacts

Guiding questions

- To what extent has climate change occurred due to anthropogenic causes?

- How do differing perspectives play a role in responding to the challenges of climate change?

SL and HL

6.2.1 Climate describes the typical conditions that result from physical processes in the atmosphere.	
The main factors impacting climate in an area are seasonal variations in temperature and precipitation.	2.4

6.2.2 Anthropogenic carbon dioxide emissions have caused concentrations of atmospheric carbon dioxide to rise significantly. The global rate of emission has accelerated, particularly since 1950.	
Increases can be traced back to the start of the Industrial Revolution in late 18th-century Europe, with the main acceleration through the 20th century with the spread of industrialization and human population increase.	1.1

6.2.3 Analysis of ice cores, tree rings and deposited sediments provide data that indicates a positive correlation between the concentration of carbon dioxide in the atmosphere and global temperatures.
Application of skills: Investigate graphs of data for the past 800,000 years and show how these variables have changed during the glacial cycles.

6.2.4 The greenhouse effect has been enhanced by anthropogenic emissions of GHGs. This has led to global warming and, therefore, climate change.	
Human activity has caused emissions into the atmosphere of large quantities of carbon dioxide, methane and nitrous oxide, and smaller quantities of other GHGs.	2.3

6.2.5 Climate change impacts ecosystems at a variety of scales, from local to global and affects the resilience of ecosystems and leads to biome shifts.	
Include alteration to individual ecosystems, such as coral bleaching and desertification as local impacts, and changes to ocean circulation and sea-level rise as global impacts. Consider a range of climate change impacts on regions where natural productivity may increase, and consider the factors that have an impact on the resilience of an ecosystem, particularly biodiversity. Use local real-world examples to emphasize the changes.	1.2, 2.2, 2.4
Application of skills: Investigate climate graphs for different global locations. Atmospheric and oceanic CO_2 levels in long-term graphs provide evidence for anthropogenic global warming and ocean acidification. Use databases to explore the impact of temperature change on a specific ecosystem, for example, coral reefs or forests.	

6.2.6 Climate change has an impact on (human) societies at a variety of scales and socio-economic conditions. This impacts the resilience of societies.	
Consider a range of climate change impacts on societies where changes to health, water supply, agriculture, infrastructure and the factors that have an impact on the resilience of a society may occur. Use local real-world examples to emphasize the changes.	1.3, 4.2, 5.2, 8.2, 8.3, HL.b

6.2.7 Systems diagrams and models can be used to represent cause and effect of climate change with feedback loops, either positive or negative, and changes in the global energy balance.

Include solar radiation variations, terrestrial albedo changes and methane gas release with their associated feedback loops.	1.3

6.2.8 Evidence suggests that the Earth has already passed the planetary boundary for climate change.	
Consider published evidence that addresses this assertion.	1.3

6.2.9 Perspectives on climate change for both individuals and societies are influenced by many factors.	
Consider different perspectives on a society's response to climate change. Include personal perspectives.	1.1, HL.c

HL only

6.2.10 Data collected over time by weather stations, observatories, radar and satellites provides opportunity for the study of climate change and land-use change. Long-term data sets include the recording of temperature and greenhouse gas (GHG) concentrations. Measurements can be both indirect (proxies) and direct. Indirect measurements include isotope measurements taken from ice cores, dendrochronology and pollen taken from peat cores.	
Both direct and indirect measurements have roles in creating climate models.	1.2

6.2.11 Global climate models manipulate inputs to climate systems to predict possible outputs or outcomes using equations to represent the processes and interactions that drive the Earth's climate. The validity of the models can be tested via a process known as hindcasting.	
There is uncertainty about the inputs (for example, the use of proxy data) and, as a result, over the outputs from the system, leading to a range of possible future outcomes. Hindcasting runs the models backwards from the present time to check the validity of the model.	1.2

6.2.12 Climate models use different scenarios to predict possible impacts of climate change.	
Consider data showing different scenarios, such as sea-level rise, local temperature and precipitation patterns.	1.2

6.2.13 Climate models show the Earth may approach a critical threshold with changes to a new equilibrium. Local systems also have thresholds or tipping points.	
Global critical thresholds may be rapid, unanticipated and potentially catastrophic. Critical thresholds are often referred to as tipping points. Consider the impact of positive feedback loops leading to tipping points and thresholds being crossed in at least one example. Examples include the melting of the Antarctic ice sheets, the slowing of the Atlantic thermohaline circulation, and the Amazon Rainforest–Cerrado transition (CAT).	1.2, 2.2, 2.4

6.2.14 Individual tipping points of the climate system may interact to create tipping cascades.	
The interactions of two or more individual tipping points make predictions of the scale and pace of climate change very uncertain. Individual tipping points can be biotic, abiotic or a combination of biotic/abiotic factors.	1.2, 2.2, 2.4

6.2.15 Countries vary in their responsibility for climate change and also in vulnerability, with the least responsible often being the most vulnerable. There are political and economic implications and issues of equity.	
Consider both current emission rates and cumulative totals since the start of the Industrial Revolution. Also consider emissions per person and per country. Include which countries are most vulnerable to negative impacts of climate change and the associated environmental changes, and the implications of this on climate justice.	1.1, 1.3, HL.a, HL.b, HL.c

Possible engagement opportunities

- Create a presentation or display for the school to raise awareness about the issue of climate change.
- Participate in climate action events.
- Join a citizen action group or youth parliament to create policies around climate change.
- Make a climate scarf—" Knit the climate stripes", developed by Professor Ed Hawkins at the University of Reading in 2018.

6.3 Climate change—mitigation and adaptation

Guiding question

- How can human societies address the causes and consequences of climate change?

SL and HL

6.3.1 To avoid the risk of catastrophic climate change, global action is required, rather than measures adopted only by certain states.	
Consider the concept of state sovereignty and the subsequent need for international cooperation through negotiation, protocols, conventions and treaties. Include an awareness of the various UN treaties and protocols addressing climate change. Include the possibility of sanctions such as cross-border carbon taxes.	1.1, 1.3, HL.a, HL.b, HL.c

6.3.2 Decarbonization of the economy means reducing or ending the use of energy sources that result in CO_2 emissions and their replacement with renewable energy sources.	
Include the concept of carbon neutrality and the varied dates that states have set for achieving this.	1.3, HL.b

6.3.3 A variety of mitigation strategies aim to address climate change.	
There are three main categories of mitigation strategies. • Reducing the process of global warming—for example, making household changes, large scale geoengineering interventions. • Reducing production of GHGs—for example, energy-efficiency measures, renewable energy, food choice changes, agriculture changes, carbon tax. • Removing CO_2 from the atmosphere—for example, through carbon sinks, rewilding, afforestation, carbon capture and storage. Consider at least two examples from each category.	1.1, 1.3, 5.2, HL.a, HL.b, HL.c

6.3.4 Adaptation strategies aim to reduce adverse effects of climate change and maximize any positive consequences.

There are two main categories of adaptation strategies. 1. Structural adaptations—examples include flood defences, desalination plants, movable infrastructure 2. Non-structural changes—examples include adapting agricultural practices (such as drought-resistant crops), vaccination for new diseases, land zoning and building code changes Consider at least two examples from each category.	1.3, HL.a, HL.b, HL.c
Application of skills: Create surveys to investigate attitudes to a proposed solution in the school or community to mitigate climate change.	

6.3.5 Individuals and societies on a range of scales are developing adaptation plans, such as National Adaptation Programmes of Action (NAPAs), and resilience and adaptation plans.	
The UN Development Programme provides a process whereby developing countries can obtain assistance to develop local priority activities to address the imminent consequences of climate change.	1.1, 1.3, HL.a, HL.b, HL.c

HL only

6.3.6 Responses to climate change may be led by governments or a range of non-governmental stakeholders. Responses may include economic measures, legislation, goal setting commitments and personal life changes.	
Economic measures include putting a price on carbon, emissions trading and the use of subsidies and tariffs. Legislation includes country-specific legislation to reduce carbon emissions. Goal setting includes mechanisms such as B Corp branding and company goals to reduce carbon emissions and change to renewable energy sources. Personal life changes may include reducing waste production, meat consumption and energy consumption Consider one example for each of these categories: economic, legislative, industry. Consider their impact.	1.1, HL.a, HL.b, HL.c
Application of skills: Investigate mitigation and adaptation policies of the regional or national government.	

6.3.7 The UN has played a key role in formulating global strategies to address climate change.	
These have largely been led by the United Nations Framework Convention on Climate Change (UNFCCC) through the Intergovernmental Panel on Climate Change (IPCC) and subsequent Conference of the Parties (COP) summits. The role of the UNFCCC is to stabilize greenhouse gas concentrations at a level that prevents interference with the climate system. Consider the outcomes of the most recent COP summit. The Kigali Amendment was used to control hydrochlorofluorocarbons (HCFCs) allowed by the Montreal Protocol, but which subsequently proved to be GHG emissions.	1.1, HL.a

6.3.8 The IPCC has proposed a range of emissions scenarios with targets to reduce the risk of catastrophic climate change.	
The IPCC has five scenarios for future GHG emissions. There is uncertainty about how emissions by countries may change, leading to the five scenarios in the IPCC model.	1.3, 2.3, HL.a
Application of skills: Investigate graphs of the IPCC scenarios and their implications.	

6.3.9 Technology is being developed and implemented to aid in the mitigation of climate change.

Socially embedded technologies include those used in smart cities, such as mobile apps or sensors that allow citizens to choose the nearest charging station or recycling centres. Industries supported by research and development centres in universities are developing new technology that is more efficient at reducing or removing carbon emissions. Consider the implementation of one technology to mitigate climate change in a named society.	1.1, 1.3, HL.b

6.3.10 There are challenges to overcome in implementing climate management and intervention strategies.	
Include the following challenges and barriers. • Lack of belief that climate change is a serious problem • Lack of financial resources or planning strategies from national governments • Lack of leadership from a range of stakeholders—for example, individuals, NGOs, political leaders, transnational companies • International inequalities—for example, economies that profit from fossil fuels and those that do not, societies in low-income and high-income countries • Differences in perspective between younger and older, coastal/low-lying and inland/upland communities	1.1, 1.3, HL.a, HL.b, HL.c

6.3.11 Geoengineering is a mitigation strategy for climate change, treating the symptom not the cause.	
Geoengineering is a deliberate and large-scale intervention in the Earth's climate system, including but not limited to measures such as space mirrors, ocean fertilization, stratospheric aerosols, cloud seeding, burning biomass with carbon capture and storage. However, it has disadvantages, such as potential high costs, uncertainty of impacts, political hesitancy, lack of convincing trials and the potential for geopolitical conflict. Consider arguments for and against the potential of geoengineering.	1.1, 1.3, HL.a, HL.b, HL.c

6.3.12 A range of stakeholders play an important role in changing perspectives on climate change.	
Consider how a range of stakeholders can influence an individual's perspectives on climate change. For example, stakeholders can include a charismatic individual, a local community group, NGOs, media and educational institutions.	1.1, HL.c

6.3.13 Perspectives on the necessity, practicality and urgency of action on climate change will vary between individuals and between societies.	
Consider differences in perspective between age groups, developed and developing societies, coastal and inland communities, and economies that profit from fossil fuels and those that do not.	1.1, 1.3, HL.b, HL.c

6.3.14 The concept of the tragedy of the commons suggests that catastrophic climate change is likely unless there is international cooperation on an unprecedented scale.	
The atmosphere is common to all, but when one nation benefits from an action that harms the atmosphere (for example, burning of fossil fuels), the costs are shared by all nations and their ecosystems. The reverse scenario is also true: the costs of restoring the atmosphere (for example, by carbon capture and storage) might be borne by a single nation, but the benefits are gained by all nations.	1.1, 1.3, HL.a, HL.b, HL.c

Possible engagement opportunities

- Create information posters for the school about personal behaviours that can be taken to mitigate climate change.
- Form a student council on climate change.
- Engage with the doughnut economics groups around the world, and implement a plan for the school.
- Create a social media channel to inform others about behaviour change to act on climate change.
- Visit a local power production site or carbon offsetting project.

6.4 Stratospheric ozone

Guiding questions

- How does the ozone layer maintain equilibrium?
- How does human activity change this equilibrium?

SL and HL

6.4.1 The Sun emits electromagnetic radiation in a range of wavelengths, from low frequency radio waves to high frequency gamma radiation.
Consider infrared/visible light/ultraviolet (UV) and the role they have in the biosphere.

6.4.2 Shorter wavelengths of radiation (namely, UV radiation) have higher frequencies and, therefore, more energy, so pose an increased danger to life.
UVA, UVB and UVC radiation damages organisms. Stratospheric ozone protects Earth by absorbing all incident UVC (which has the shortest wavelength) and most UVB rays.

6.4.3 Stratospheric ozone absorbs UV radiation from the Sun, reducing the amount that reaches the Earth's surface and, therefore, protecting living organisms from its harmful effects.
UV is damaging because it is high-energy radiation, especially the shortest wavelengths.

6.4.4 UV radiation reduces photosynthesis in phytoplankton and damages DNA by causing mutations and cancer. In humans, it causes sunburn, premature ageing of the skin and cataracts.	
Consider data related to impacts of UV radiation.	2.2

6.4.5 The relative concentration of ozone molecules has stayed constant over long periods of time due to a steady state of equilibrium between the concurrent processes of ozone formation and destruction.	
The use of chemical symbols, formulae or equations for the equilibrium of ozone is not required.	1.2, 2.2

6.4.6 Ozone-depleting substances (ODSs) destroy ozone molecules, augmenting the natural ozone breakdown process.	
When rates of ozone formation and depletion are unequal, the equilibrium will tip to increase in formation or destruction. Ozone depletion is not a cause of global warming. **HL only:** Chemical equations relating to the formation and destruction of ozone are required.	1.2

6.4.7 Ozone depletion allows increasing amounts of UVB radiation to reach the Earth's surface, which impacts ecosystems and human health.

Ozone depletion has affected the stratosphere over the whole Earth. At the poles, ozone "holes" with greater depletion appear every spring due to the effects of ODSs and seasonal atmospheric weather patterns.	2.2

6.4.8 The Montreal Protocol is an international treaty that regulates the production, trade and use of chlorofluorocarbons (CFCs) and other ODSs. It is regarded as the most successful example yet of international cooperation in management and intervention to resolve a significant environmental issue.	
Consider why the Montreal Protocol has been a success in reversing stratospheric ozone depletion and possible applications to other areas where international cooperation is necessary.	HL.a

6.4.9 Actions taken in response to the Montreal Protocol have prevented the planetary boundary for stratospheric ozone depletion being crossed.	
Consider data relating to the ozone hole over time as evidence for this conclusion.	1.3, HL.a

HL only

6.4.10 ODSs release halogens, such as chlorine and fluorine, into the stratosphere, which break down ozone.
CFCs and other ODSs have been produced and released into the atmosphere, particularly carbon compounds that break down to release highly reactive fluorine and chlorine.

6.4.11 Polar stratospheric ozone depletion occurs in the spring due to the unique chemical and atmospheric conditions in the polar stratosphere.	
Contributing chemical and atmospheric conditions include volcanic aerosols and polar stratospheric clouds, as well as the presence of "active surfaces" in the polar stratosphere upon which ozone destruction reactions can be enhanced.	1.2

6.4.12 Hydrofluorocarbons (HFCs) were developed to replace CFCs as they can be used in similar ways and cause much less ozone depletion, but they are potent GHGs. They have since been controlled by the Kigali Amendment to the Montreal Protocol.
CFCs and HFCs have been used in aerosols and as coolants in refrigerators and air conditioning systems. Unless carefully collected from redundant appliances, they leak into the atmosphere.

6.4.13 Air conditioning units are energy-intensive, contribute to GHG emissions and traditionally have contained ODSs.	
Include the development of substitute refrigerants and alternatives, such as improved building design, greening and rewilding of cities.	1.1, 6.2, 8.3, HL.b
Application of skills: Review the alternatives to air conditioning units. Use databases to collect data on the use of air conditioning units in different societies and present this data graphically, considering the reasons for the differences per capita.	

Possible engagement opportunities

- Discuss the extent to which the Montreal Protocol sets a precedent for how environmental issues can be addressed at a global scale.
- Present findings on alternatives to air conditioning to the school leadership.

- Produce information about protection against UV light during the highest-risk periods of the year.

Topic 7: Natural resources

7.1 Natural resources—uses and management

Guiding questions

- How does the renewability of natural capital have implications for its sustainable use?
- How might societies reconcile competing perspectives on natural resource use?
- To what extent can human societies use natural resources sustainably?

SL and HL

7.1.1 Natural resources are the raw materials and sources of energy used and consumed by society.
These include sunlight, air, water, land, rocks, ecosystems and living things.

7.1.2 Natural capital is the stock of natural resources available on Earth.	
Consider local examples of three types of natural capital.	1.3, HL.b, HL.c

7.1.3 Natural capital provides natural income in terms of goods and services.	
Examples of natural income goods include fish or timber. Example of natural income services include climate regulation and flood prevention.	1.1, 1.3, HL.a, HL.b, HL.c

7.1.4 The terms "natural capital" and "natural income" imply a particular perspective on nature.	
Consider the implications of regarding nature as being made up of natural capital, services and resources. This perception in itself might be associated with the contentious philosophical perspective that nature is there for human exploitation (more extreme anthropocentrism). However, it serves very effectively as a model for sustainable use of resources.	1.1, 1.2 1.3, HL.a, HL.b, HL.c

7.1.5 Ecosystems provide life-supporting ecosystem services.	
Include water replenishment, flood and erosion protection, pollution mitigation (for example, reed bed buffer zones to remove inorganic nutrients) and carbon sequestration. These ecosystem services support all living things, including humans.	1.2, 1.3, HL.a, HL.b, HL.c

7.1.6 All resources are finite. Resources can be classified as either renewable or non-renewable.	
Renewable resources can be regenerated and/or replaced as fast as they are being used, either through natural growth or reproduction (for example, food, crops or timber) or through other recurring processes (for example, freshwater or ozone). If renewable resources are used beyond their regeneration rate, their use becomes unsustainable and they become a non-renewable resource.	1.1, 1.3, HL.a, HL.b, HL.c

7.1.7 Natural capital has aesthetic, cultural, economic, environmental, health, intrinsic, social, spiritual and technological value. The value of natural capital is influenced by these factors.

Consider the distinction between each of these types of value and give an example.	1.1, HL.b, HL.c
Application of skills: Create a survey to investigate the value that members of the school community place on different ecosystem services.	

7.1.8 The value of natural capital is dynamic in that it can change over time.	
Include a variety of reasons for both increases and decreases in value, along with two named examples of change over time. Consider, for example, coal, lithium, cobalt, whale oil, cork.	1.1, 1.3, HL.b, HL.c

7.1.9 The use of natural capital needs to be managed in order to ensure sustainability.	
The long-term well-being of ecosystems and humans depends on resources not being used more rapidly than they can be regenerated, and on waste products not being released more rapidly than they can be transformed. Include examples to illustrate how ecosystems and societies could be harmed by excessive harvesting of resources and by the release of polluting waste products.	1.1, 1.2, 1.3, HL.a, HL.b, HL.c

7.1.10 Resource security depends on the ability of societies to ensure the long-term availability of sufficient natural resources to meet demand.	
Consider the extent to which resource security in two contrasting named societies has been achieved for food or water.	1.2, 1.3, 4.2, 5.2, 7.2, 8.2, 8.3, HL.b

7.1.11 The choices a society makes in using given natural resources are affected by many factors and reflect diverse perspectives.	
Factors affecting such choices may include economic, sociocultural, political, environmental, geographical, technological and historical factors. International agreements cutting GHG emissions with the aim of achieving net zero emissions changes the priority of these choices. Consider factors affecting the local choice of a named natural resource.	1.1, 1.2, HL.a, HL.b, HL.c

HL only

7.1.12 A range of different management and intervention strategies can be used to directly influence society's use of natural capital.	
Government management could include national action plans for SDGs. Government intervention could include strategies to reduce or stop the use of certain natural capital goods and services such as taxes, fines and legislation. For example, increasing the price of fossil fuels and carbon emission restrictions. Government intervention could encourage the use of certain natural capital goods and services with subsidies, legislation, publicity campaigns, research and education. For example, manufacturing concrete that stores carbon dioxide, recyclable wind turbines, biological production of ammonia replacing the Haber process. NGOs, local communities and social movements can influence society through campaigns, social media or actions, such as recycling.	HL.a, HL.b

7.1.13 The SDGs provide a framework for action by all countries in global partnership for natural resources use and management.

Consider two relevant examples pertaining to sustainable resource management. Detailed knowledge of each goal is not required.	1.1, 1.2, 1.3, HL.a, HL.b, HL.c

7.1.14 Sustainable resource management in development projects is addressed in an environmental impact assessment (EIA).	
An EIA assesses the environmental, social and economic impacts and sustainability of a development project through independent, detailed surveys, followed by audits and continued monitoring after project completion.	1.1, 1.2, 1.3, HL.a, HL.b

7.1.15 Countries and regions have different guidance on the use of EIAs.	
Baseline studies are generally used to predict and evaluate possible impacts of a project and suggest mitigation strategies to alleviate or avoid environmental harm. Consider a range of appropriate parameters that might be addressed by an EIA for a given project. Exploring a given EIA in depth is not required.	1.3, HL.a, HL.b, HL.c

7.1.16 Making EIAs public allows local citizens to have a role as stakeholders in decision-making.	
Consider the relative merits of engaging all stakeholders in decision-making for development projects.	1.1, 1.3, HL.a, HL.c

7.1.17 While a given resource may be renewable, the associated means of extracting, harvesting, transporting and processing it may be unsustainable.	
Consider one example of unsustainable extraction, harvesting, transporting and processing, for example, timber, fishing, hydropower.	1.2, 1.3, HL.b

7.1.18 Economic interests often favour short-term responses in production and consumption which undermine long-term sustainability.	
Consider one example of resources that have been depleted by excessive consumption, such as whales, fish stocks, forests.	1.2, 1.3, HL.b

7.1.19 Natural resource insecurity hinders socio-economic development and can lead to environmental degradation and geopolitical tensions and conflicts.	
Geopolitical power dynamics change if resource use changes. Oil production is centred on member countries of the Organization of the Petroleum Exporting Countries (OPEC). Most mining for minerals, such as lithium, cobalt and rare earth elements (for use in, for example, batteries and mobile phones), is in Australia, China, Chile and the Democratic Republic of the Congo (DRC). Nearly all processing of these minerals is in China. Consider one example where resource insecurity may have led to hindered development, environmental harm, geopolitical problems or conflict.	1.2, 1.3, HL.b, HL.c

7.1.20 Resource security can be brought about by reductions in demand, increases in supply or changing technologies.	
Demand can be reduced through increased efficiency of use or conservation measures. Reliance on imported resources can be reduced by technological shifts. Consider one example of increasing resource security in each of food, water and energy.	1.2, 1.3, HL.b

7.1.21 Economic globalization can increase supply, making countries increasingly interdependent, but it may reduce national resource security.	
Provide examples in different contexts, including food, water and energy.	1.2, 1.3, HL.b
Application of skills: Use secondary data sources, such as Gapminder, Our World in Data and World Bank to investigate the use of a named resource (for example, steel, concrete or inorganic fertilizer) by two different societies. Use graphs and statistical tests to show results.	

Possible engagement opportunities

- Study an example of an EIA (HL), such as the story of Nauru and resource depletion.
- Investigate and promote the ecological services provided by local or regional ecosystems, such as water provision and soil stability.
- Investigate the sustainability of local food production.
- Participate in citizen science opportunities, such as those available on Zooniverse, Project Noah or Scistarter.
- Engage with an SDG and design a project that raises awareness of the solutions available related to this SDG.
- Promote renewable energy production for the school to increase energy security.

7.2 Energy sources—uses and management

Guiding questions

- To what extent can energy consumption be equitable across the world?
- How can energy production be sustainable?

SL and HL

7.2.1 Energy sources are both renewable and non-renewable.
Renewable energy sources include wind, solar, tidal, wood, geothermal, hydropower. Non-renewable sources include nuclear and fossil fuels. Most of the energy released from these sources is converted to electricity.

7.2.2 Global energy consumption is rising with increasing population and with per capita demand.	
Globally, most energy is supplied by fossil fuels, although energy supplied from renewables is increasing. The role of fossil fuels in supporting the steel, concrete and synthetic fertilizer industries suggests dependence on them is likely to continue for some time in the future. How energy supply can meet ever-growing demand is a challenge that has to be addressed by changing energy production resources and reducing consumption. Consider the changes globally and locally, and the reasons for these changes.	1.2, 1.3, HL.b, HL.c

7.2.3 The sustainability of energy sources varies significantly.	
Consider the relative sustainability of fossil fuels, rare earth elements, nuclear, solar and one other renewable source. The use of both non-renewable and renewable energy sources have an environmental cost that includes environmental restoration. Non-renewable examples include extraction of fossil fuels, refining of crude oil, liquefaction of natural gas, mining of uranium.	1.2, 1.3, HL.b

Examples of devices for using renewable energy sources include wind turbines; solar panels; tidal barrages and their related difficulties of construction, transportation, and recycling of these products in end-of-life management.	

7.2.4 A variety of factors will affect the energy choices that a country makes.	
Consider the advantages and disadvantages of the energy sources that may influence the energy choices of two contrasting named countries. Include sustainability, economic cost, pollution, energy efficiency, availability and energy security issues.	1.1, 1.2, 1.3, HL.b, HL.c

7.2.5 Intermittent energy production from some renewable sources creates the need for energy storage systems.	
For example, wind power requires the wind to blow, and this is intermittent. Solutions to "peak-shaving" (levelling out peaks in demand) to ensure supply meets demand include batteries, pumped hydroelectricity storage (PHS), fuel cells, thermal storage. Consider one example of storage solutions.	1.2, 1.3

7.2.6 Energy conservation and energy efficiency may allow a country to be less dependent on importing a resource.	
Energy conservation is changing our behaviours to reduce consumption of energy. Examples include turning off lights, reducing use of heating or air conditioning, and travelling less by fuel-driven vehicles. It is also about increased energy-efficient technologies, such as designing housing to conserve or remove heat, low energy intelligent lighting, designing shipping with sails, or designing goods to be easily recycled (circular economy). Consider the effectiveness of two examples of energy conservation or energy efficiency.	1.2

HL only

7.2.7 Energy security for a country means access to affordable and reliable sources of energy.	
Through energy-efficiency measures, decreasing reliance on imported energy supplies and diversification, a country can improve its energy security.	1.2. 1.3, HL.b
Application of skills: Investigate graphical representations of how use of energy sources changes over time, both globally and by country. Compare these changes and their impacts. Investigate secondary data sources, such as Gapminder, Our World in Data and World Bank, to compare the types and amount of energy used by different societies. Use graphs and statistical tests to show results.	

7.2.8 The global economy mostly depends on finite reserves of fossil fuels as energy sources; these include coal, oil and natural gas.	
Consider the factors influencing timelines for final depletion of these fuels, for example, the rate of consumption, discovery of new deposits, developments in technology for extraction, increased use of renewables or nuclear power.	1.2, 1.3, HL.b

7.2.9 Nuclear power is a non-renewable, low-carbon means of electricity production.	
Most nuclear power stations obtain energy by fission reactions of uranium or plutonium. Although construction costs are high, once constructed, nuclear power stations produce low-cost, constant, low-carbon energy. Disadvantages are that mining for uranium has negative effects, thermal pollution from power stations changes water chemistry, there is a risk of	1.2, 1.3, HL.c

nuclear accidents and radioactive waste is produced. This waste is stored indefinitely in containers that shield the environment from radiation.	

7.2.10 Battery storage is required on a large scale to meet global requirements for reduction of carbon emissions, but it requires mining, transporting, processing and construction, all of which produce emissions and pollution, and cause sociopolitical tensions.
The main elements and oxides required to produce effective batteries are lithium, cobalt and rare earth elements. Their mining and processing create toxins and pollution, both on land and in the oceans, and mine tailings dam failures have occurred. Distribution of these elements is concentrated in certain countries, but demand is global, which causes unintended consequences, such as geopolitical conflicts. Consider the use of one of these elements in batteries.

Possible engagement opportunities

- Evaluate use of energy and consider whether it should be reduced individually, in the school and in the community. Consider how this reduction could occur.
- Carry out a school survey or use questionnaires to see if energy use can be reduced.
- Consider personal perspectives on using nuclear power, relating to personal environmental value systems.

7.3 Solid waste

Guiding question

- How can societies sustainably manage waste?

SL and HL

7.3.1 Use of natural resources generates waste that can be classified by source or type.
Include domestic, industrial and agricultural as sources of waste, and e-waste, food and biohazardous materials as types of waste.

7.3.2 Solid domestic waste (SDW) typically has diverse content.
Include paper, cardboard, glass, metal, plastics, organic (kitchen or garden), packaging, construction debris and clothing.

7.3.3 The volume and composition of waste varies over time and between societies due to socio-economic, political, environmental and technological factors.	
Include examples of socio-economic, political, environmental and technological factors affecting the volume and composition of waste.	1.2, 1.3, HL.a, HL.b, HL.c

7.3.4 The production, treatment and management of waste has environmental and social impacts, which may be experienced in a different location from where the waste was generated.	
Some waste is transported long distances, usually from high-income to low-income countries, and involves potential environmental injustice.	1.3

7.3.5 Ecosystems can absorb some waste, but pollution occurs when harmful substances are added to an environment at a rate faster than they are transformed into harmless substances.

Include the concepts of biodegradability and half-lives.	1.2

7.3.6 Preventative strategies for waste management are more sustainable than restorative strategies.	
Preventative strategies include altering human behaviour (for example, reduced consumption) or controlling the release of pollutants (for example, waste disposal). Restorative strategies include the clean-up and restoration of damaged systems (for example, attempts to restore oceanic garbage patches). Reduction in the consumption of goods and, therefore, production of waste is the most sustainable option.	1.1, 1.2, 1.3

7.3.7 Different waste disposal options have different advantages and disadvantages in terms of their impact on societies and ecosystems.	
Consider the relative merits and demerits of landfill, incineration, waste to energy, exporting waste, recycling and composting.	1.3

7.3.8 Sustainable options for management of SDW can be promoted in societies.	
Strategies for promoting more sustainable management include taxes, incentives, social policies, legislation, education, campaigns and improved access to disposal facilities.	1.3 HL.a, HL.b, HL.c

7.3.9 The principles of a circular economy provide a holistic perspective on sustainable waste management.	
Include an example (including the path of a resource) from manufacture through to appropriate product recovery strategies.	1.2, 1.3, HL.b

Possible engagement opportunities

- Visit the local recycling centre and learn about how waste is handled locally.
- Find out what happens to waste in your society—how much is recycled, reused, remade, goes to landfill or incineration, or is shipped to another country.
- Assess the waste management in the school, and promote ways of reducing or reusing waste.
- Raise awareness of circular economy options in the community.
- Become involved in a Repair Café or set up a Library of Things.

Topic 8: Human populations and urban systems

8.1 Human populations

Guiding questions

- How can the dynamics of human populations be measured and compared?
- To what extent can the future growth of the human population be accurately predicted?

SL and HL

8.1.1 Births and immigration are inputs to a human population.	
Crude birth rate (number of live births per 1,000 people in a population per year) and immigration rate (number of immigrants per 1,000 population per year) are the quantitative	2.1

measures of population input. The rates can be used at a variety of scales—from small urban areas, like a town, to a country to a region or to the global population.	

8.1.2 Deaths and emigration are outputs from a human population.	
Crude death rate (number of deaths per 1,000 people in a population per year) and emigration rate (number of emigrants per 1,000 population per year) are the quantitative measures of population output. The rates can be used at a variety of scales—from small urban areas, like a town, to a country to a region or to the global population.	2.1

8.1.3 Population dynamics can be quantified and analysed by calculating total fertility rate, life expectancy, doubling time and natural increase.	
Total fertility rate is the average number of births per woman of childbearing age. Life expectancy is the average number of years that a person can be expected to live, usually from birth, if demographic factors remain unchanged. Doubling time is the number of years it would take a population to double its size at its current growth rate; it can be calculated by using the rule of 70. To do this, divide 70 by the growth rate (as a percentage). Natural increase is birth rate minus death rate, expressed as a number per 1,000 or as a percentage (the birth rate minus the death rate is divided by 10).	1.2, 1.3
Application of skills: Work out natural increase rates and doubling times from given data.	

8.1.4 The global human population has followed a rapid growth curve. Models are used to predict the growth of the future global human population.	
UN projection models indicate three scenarios linked to future fertility rates. There is uncertainty about how future human fertility rates may change, leading to the three scenarios in the models.	2.1

8.1.5 Population and migration policies can be employed to directly manage growth rates of human populations.	
These may be anti-natalist or pro-natalist, thereby directly addressing birth rates, or they may address immigration and emigration. These policies may use a variety of cultural, religious, economic, social and political factors to achieve their aims. Include named examples.	1.3, HL.a, HL.b, HL.c

8.1.6 Human population growth can also be managed indirectly through economic, social, health, development and other policies that have an impact on births, deaths or migration.	
Many development policies addressing areas such as, but not limited to, gender equality, education, improvements in public health and welfare will indirectly affect births, deaths and migration. Include two named examples.	1.1, 1.2, 1.3, HL.a, HL.b, HL.c

8.1.7 The composition of human populations can be modelled and compared using age–sex pyramids.	
The pyramid is measured in absolute numbers or as a percentage of the total population. It shows the proportion of the population of either gender in each age group.	1.2.14

8.1.8 The demographic transition model (DTM) describes the changing levels of births and deaths in a human population through different stages of development over time.

There are five stages of the DTM, including death and then birth rates declining to produce an exponential increase, stabilization and possible decline in population. Consider the relationship of specific age–sex pyramids to appropriate stages.	1.2.14

HL only

8.1.9 Rapid human population growth has increased stress on the Earth's systems.	
Include current projections for the total human population over the next 50 and 100 years, and the factors that can change these projections. The increased stress on Earth's systems is related to biocapacity disparity and to the crossing of social foundation and planetary boundaries as illustrated in the doughnut economics model.	1.2, 1.3

8.1.10 Age–sex pyramids can be used to determine the dependency ratio and population momentum.	
The dependency ratio depends on the number of people in the ages defined as dependent (under 15 years and over 64 years) and economically productive (15–64 years) in a population. The dependency ratio tends to be high in populations with a very high or a very low fertility rate. Population momentum is why a population will continue to grow even if the fertility rate declines. Population momentum occurs because it is not only the number of children per woman that determines population growth, but also the number of women of reproductive age.	1.2, 1.3

8.1.11 The reasons for patterns and trends in population structure and growth can be understood using examples of two countries in different stages of the DTM.	
Consider the patterns and trends from the past (at least 30 years or more ago), the present and into the future (at least 30 years). Consider reasons—historical, cultural, religious, economic, social and political factors—for the countries selected.	1.1, 1.2, 1.3, HL.a, HL.b, HL.c

8.1.12 Environmental issues such as climate change, drought and land degradation are causing environmental migration.	
Migration as a result of climate change may be due to sudden onset events, such as flooding, droughts, forest fires and intensified storms, but it is increasingly resulting from slow onset events, such as desertification, sea-level rise and saltwater inundation. Include one example of an area where migration occurs/occurred due to an environmental issue, for example, increased migration from Tuvalu to New Zealand due to impacts of climate change on islands; repeated cyclones that have caused local devastation and emigration from Mozambique.	1.2, 1.3, 6.2, 5.3, HL.a, HL.c
Application of skills: Use secondary data from sources such as Gapminder, World Bank and Our World in Data to test a hypothesis about the relationship between a socio-economic indicator and a demographic factor using a suitable statistical tool. Use an online tool for statistics such as the Social Science Statistics calculator.	

Possible engagement opportunities

- Assess and debate issues regarding population change in the local or regional area.
- Investigate traditional migration routes that still exist, the threats to these or solutions involved in maintaining these routes.

- Volunteer in a local refugee centre.
- Engage with local NGOs supporting seasonal or indigenous communities.
- Help with the work of the United Nations High Commissioner for Refugees (UNHCR).

8.2 Urban systems and urban planning

Guiding questions

- To what extent are urban systems similar to natural ecosystems?
- How can reimagining urban systems create a more sustainable future?

SL and HL

8.2.1 Urban areas contain urban ecosystems.	
Urban ecosystems, like all ecosystems, are composed of biotic components (plants, animals and other forms of life) and abiotic components (soil, water, air, climate and topography).	1.2

8.2.2 An urban area is a built-up area with a high population density, buildings and infrastructure.	
Urban areas have a dense assemblage of buildings and people located close together for residential, cultural, productive, trade and social purposes; rural areas have relatively low population density and dispersed settlements. Cities, towns and suburbs are classified as urban areas.	5.3

8.2.3 An urban area works as a system.	
An urban system is the interconnected system of buildings, microclimate, transport, goods and services, power/energy, water/sewage supply, humans, plants and animals. In urban systems, consider waste/pollution, urban efficiency, sustainability and resilience.	1.2
Application of skills: Create a systems flow diagram representing an urban system.	

8.2.4 Urbanization is the population shift from rural to urban areas.	
Urbanization involves the process of land use becoming more built-up, industrialized and dominated by dense and continuous human settlement and infrastructures.	5.3

8.2.5 Due to rural–urban migration, a greater proportion of the human population now live in urban rather than rural systems, and this proportion is increasing.	
Include reasons (push–pull factors, forced versus voluntary) for migration from rural to urban areas and the perceived or real advantages of urban settlements. Most rural–urban migration is an internal migration. Consider the trend within a country for rural–urban migration, along with deurbanization trends.	1.2, 1.3

8.2.6 Suburbanization is due to the movement of people from dense central urban areas to lower-density peripheral areas.
Suburbanization is sometimes referred to as urban sprawl because lower-density settlements require larger areas of land.

8.2.7 The expansion of urban and suburban systems results in changes to the environment.

Include loss of agricultural land, forests or other natural ecosystems, changes to water quality, river flows and air pollution.	4.4, 5.3, 8.4

8.2.8 Urban planning helps decide on the best way to use land and buildings.	
Urban planning aims to meet the physical, domestic, environmental, commercial, industrial, financial and health needs of all stakeholders in the community.	1.2

8.2.9 Modern urban planning may involve considering the sustainability of the urban system.	
Consider factors including quality and affordable housing, integrated public transport systems, green spaces, security, education and employment, use of renewable resources, reuse and recycling of waste, energy efficiency, involvement of the community, green buildings. Include one example of sustainable urban planning, such as the Cerdà plan in Barcelona (1860), the Hausmann plan for Paris (1850s), Brasilia (1960), the controversial Forest City in Malaysia, reduction or removal of car use (Copenhagen), EV charging stations (San Francisco), water conservation (Dubai green space irrigated with grey water).	1.3, 6.3
Application of skills: Investigate maps that show the urban development of a city over time.	

8.2.10 Ecological urban planning is a more holistic approach that treats the urban system as an ecosystem, understanding the complex relationships between its biotic and abiotic components.	
Consider one example from the following list. • Urban ecology—for example, green spaces, habitats for wildlife, allotments, parks, canals, ponds • Urban farming—for example, beekeeping, horticulture, aquaculture and city farms • Biophilic design—for example, living green walls and roofs, water features, natural light • Resilience planning—for example, vertical farming in cities, building on stilts in flood-prone areas, fail-safe grids • Regenerative architecture—for example, building skins that scrub the air clean, capturing rainwater that replenishes aquifers, solar panels/wind turbines/biodigesters that export energy	1.2, 2.1, 6.3

HL only

8.2.11 Ecological urban planning will follow principles of urban compactness, mixed land use and social mix practice.	
Consider the sustainable advantages of these practices, including reduced urban sprawl, less car dependency, reduced energy consumption, better public transport, increased accessibility and social equality. Avoiding social inequality in access to green areas is a matter of environmental justice.	1.3, 5.3, 6.3, 7.1, HL.a, HL.c

8.2.12 Societies are developing systems that address urban sustainability by using models such as a circular economy or doughnut economics to promote sustainability within the urban system.	
Consider one example of the use of these models in urban development.	1.2, 1.3

8.2.13 Green architecture minimizes harmful effects of construction projects on human health and the environment, and aims to safeguard air, water and earth by choosing environmentally friendly building materials and construction practices.

Green architecture and civil engineering combines new and indigenous knowledge systems, vernacular architecture, bio-based materials and circular construction. Consider one example of green architecture, for example, bale construction, bottle and plastic construction, 3D printing houses, Arabic wind tower houses (for example, *barajeel*).	1.3, 5.3, 6.3

Possible engagement opportunities

- Investigate population change in the students' own country and discuss impacts on society and options for population management.
- Volunteer with an organization that works to support those people who may have suffered from social and environmental inequity locally.
- Students can evaluate the extent to which a local urban environment is sustainable.
- They could engage in additional activities beyond the classroom.
  - Use SDG 11—for sustainable cities and communities—to evaluate local sustainability.
  - Propose smart city functionality for your school community.

8.3 Urban air pollution

Guiding question

- How can urban air pollution be effectively managed?

SL and HL

8.3.1 Urban air pollution is caused by inputs from human activities to atmospheric systems, including nitrogen oxides (NOx), sulfur dioxide, carbon monoxide and particulate matter.	
Particulate matter is categorized according to size of particle, with PM2.5 being fine particulate matter with a diameter of 2.5 micrometres or less and PM10 being air pollution that is made of larger particulate matter with a diameter of 10 micrometres.	1.2, 6.1

8.3.2 Sources of primary pollutants are both natural and anthropogenic.	
Primary pollutants are directly active at the point of emission. Include forest fires, dust and volcanic eruptions as natural sources. Include burning for agricultural and forest clearance, burning of fossil fuels and biomass for energy production, and dust from construction/roads as anthropogenic sources.	5.3, 6.2
Application of skills: Plan an experiment to use an indicator species as a correlate for pollution in the local environment.	

8.3.3 Most common air pollutants in the urban environment are either derived directly or indirectly from combustion of fossil fuels.	
PM2.5, PM10, carbon monoxide and sulfur dioxide are primary pollutants, and tropospheric ozone is a secondary pollutant.	1.3

8.3.4 A range of different management and intervention strategies can be used to reduce urban air pollution.	
Include strategies such as, but not limited to, improved public transportation, infrastructure for cycling, growing trees, natural screens, green walls, compulsory catalytic converters, limited car use and pedestrianized town centres.	1.3, 8.3

8.3.5 NOx and sulfur dioxide react with water and oxygen in the air to produce nitric and sulfuric acid, resulting in acid rain.
Include the chemistry of acid rain formation.

8.3.6 Acid rain has impacts on ecology, humans and buildings.	
Effects are: on terrestrial habitats (leaching, toxification of the soil, direct impact on foliage); on freshwater habitats (toxicity due to aluminium solubilization, impacts on fish gills and invertebrate exoskeletons); the corrosion of marble, limestone, steel, paint and other construction materials; on breathing, from nitrate and sulfate particles (tissue damage and lung inflammation from components of PM2.5 and acid deposition).	2.2

8.3.7 Management and intervention strategies are used to reduce the impact of sulfur dioxide and NOx on ecosystems and to minimize their effects.	
As with other forms of pollution, these pollutants can be managed by altering human activity (for example, using alternative energy sources), controlling at the point of release (for example, scrubbers and catalytic converters) or restoring the damaged systems (for example, healthcare and adding limestone/fertilizer to lakes).	1.3

HL only

8.3.8 Photochemical smog is formed when sunlight acts on primary pollutants causing their chemical transformation into secondary pollutants.	
Include NOx and volatile organic compounds (VOCs) as primary pollutants that are directly emitted. Peroxyacyl nitrates (PANs) and tropospheric ozone are secondary pollutants and the main components of photochemical smog.	6.1

8.3.9 Meteorological and topographical factors can intensify processes that cause photochemical smog formation.	
Abundant insolation, reduced wind, and temperature inversion are meteorological factors. Consider how temperature inversion occurs and that this will tend to happen in locations that are surrounded by mountains or high buildings.	2.4, 6.1
Application of skills: Use graphs showing diurnal changes in urban air pollutants. Use secondary databases to study change over time in local air quality, using a statistical tool to test the significance of any change.	

8.3.10 Direct impacts of tropospheric ozone are both biological and physical.
Damage to plant cuticles and membranes, eye irritation in humans and other mammals, and respiratory illnesses are biological effects. Damage to fabrics and rubber materials are physical effects.

8.3.11 Indirect impacts of tropospheric ozone include societal costs and lost economic output.	
Impacts include those upon the healthcare systems and reduced workforces. These impacts may be differential in society, with poorer communities often carrying a larger proportion of these impacts.	1.3

Possible engagement opportunities

- Investigate and debate the causes and consequences of urban air pollution in the local environment, and strategies that could be used to reduce pollution.

- Participate in citizen science air-quality projects by installing a networked weather station in the school.
- Advocate for improved walking and cycling options for the school.

HL lenses

HL.a Environmental law

Guiding question

- How can environmental law help ensure the sustainable management of Earth systems?

HL only

HL.a.1 Laws are rules that govern human behaviour and are enforced by social or governmental authority.
Laws are made and enforced by social or governmental authority.

HL.a.2 Environmental law refers specifically to the rules about how human beings use and impact natural resources, with the aim of improving social and ecological sustainability.
An environmental law may cover management of natural resources (for example, forests, minerals, fisheries), management of pollution (for example, air, soils, water), protection of biodiversity (for example, wildlife conservation habitats), construction and development projects (for example, EIAs).

HL.a.3 Environmental laws can have an important role in addressing and supporting environmental justice, but they can be difficult to approve due to lobbying.
Environmental laws attempt to prevent overexploitation and degradation of natural resources for the short-term interests of a minority above the long-term interests of the common good. Laws can support or ensure ethical behaviour when economic systems incentivize environmental and social harm; however, it can be difficult to get environmental laws passed due to political lobbying of economically powerful stakeholders.

HL.a.4 Environmental law is built into existing legal frameworks, but its success can vary from country to country.
Environmental law requires effective enforcement of laws through strong administrative and legal institutions, general acceptance by society, as well as adequate funding to support the environmental protection measures required by law.

HL.a.5 Environmental constitutionalism refers to the introduction of environmental rights and obligations into the constitution.
Internationally, there is a growth of environmental constitutionalism as more and more cases are effectively addressed by nations' constitutions. Climate change issues are increasingly being addressed in this manner. Include an example of a national constitution successfully involved in addressing environmental issues.

HL.a.6 Environmental laws can be drafted at the local, national or international level.
Laws made at national or international levels supersede those made at local levels. International laws or bilateral agreements may be created and applied in transboundary environmental issues related to pollution and resource management. Local councils can have laws about recycling and waste disposal;

countries create environmental laws for air- and water-quality standards; international environmental agreements exist regarding fisheries and trade in endangered species. Include an example of an environmental law at each scale: local, national and international.

HL.a.7 International law provides an essential framework for addressing transboundary issues of pollution and resource management.

There are agreements addressing transboundary pollution (for example, the Association of Southeast Asian Nations (ASEAN) Agreement on Transboundary Haze Pollution) and transboundary resource management (for example, the Food and Agriculture Organization (FAO) International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing).

HL.a.8 UN conferences produce international conventions (agreements) that are legally binding, and protocols that may become legally binding, to all signatories.

International agreements and protocols can be challenging and slow to develop.

Examples of challenges include the following: the complexity of the agreements, rapidly evolving scientific knowledge, pressures on individual governments from internal stakeholders with differing interests, conflicts between countries over “differentiated responsibilities”, financing commitments of high-income countries towards low-income countries, general geopolitical conflicts, potential economic impact of agreements.

Consider the relative success of the Montreal and Kyoto Protocols and Paris Agreement along with their subsequent amendments and developments.

HL.a.9 International agreements can generate institutions or organizations to aid their implementation.

A range of conventions and organizations should be covered in the course, for example, CITES and IUCN.

HL.a.10 The application of international environmental law has been examined within international courts and tribunals.

Examples of bodies involved in the development of international environmental law include the International Court of Justice, the International Tribunal for the Law of the Sea, and the European Court of Justice. One of the difficulties faced by international judiciary bodies is how to evaluate appropriate compensation and damages for infringements of environmental law.

HL.a.11 There are an increasing number of laws granting legal personhood to natural entities in order to strengthen environmental protection.

Granting legal personhood to natural entities can result in stronger environmental protection and it is similar to the long-established granting of legal personhood to corporations. This links with indigenous knowledge systems that do not recognize the distinction between humans and nature, environmental value systems (anthropocentric and ecocentric) and to a rights-based (deontological) ethics approach.

HL.a.12 Both legal and economic strategies can play a role in maintaining sustainable use of the environment.

There are different contributions to sustainable management that can be achieved by the two strategies. There is a challenge in economics of attaching economic value to ecosystem services and their degradation, and the challenge in law of achieving agreement between stakeholders and the enforcement of compliance. The most successful outcomes may come from an integration of the two approaches, for example, laws imposing fines for illegal dumping or oil spills.

HL.b Environmental economics

Guiding questions

- How can environmental economics ensure sustainability of the Earth's systems?
- How do different perspectives impact the type of economics governments and societies run?

HL only

HL.b.1 Economics studies how humans produce, distribute and consume goods and services, both individually and collectively.
Economics focuses on supply and demand of resources and the outcomes of market interaction.

HL.b.2 Environmental economics is economics applied to the environment and environmental issues.
Technocentrics have the perspective that science and technology will enable environmental economics to work within the current economic framework. More ecocentric perspectives tend to value the more innovative approach of ecological economics.

HL.b.3 Market failure occurs when the allocation of goods and services by the free market imposes negative impacts on the environment.
For example, a factory that, in the production of goods, causes pollution that creates a net welfare loss on society at no cost to the factory.

HL.b.4 When the market fails to prevent negative impacts, the polluter-pays principle may be applied.
The polluter-pays principle means that the costs of stopping, managing and cleaning up the pollution are covered by the polluter. Environmental economics has created solutions such as quotas, fines, taxes, tradeable permits, carbon neutral certification that ensure the polluter pays to limit the burden to society.

HL.b.5 "Greenwashing" or "green sheen" is where companies use marketing to give themselves a more environmentally friendly image.
Greenwashing is a form of misinformation when companies or organizations spend time and money on marketing themselves as sustainable or environmentally friendly rather than on changing practices to become sustainable. For example, oil companies who claim to transition to clean energy.

HL.b.6 The tragedy of the commons highlights the problem where property rights are not clearly delineated and no market price is attached to a common good, resulting in overexploitation.
For example, an individual or firm can overexploit a common good despite the detriment to others. This phenomenon highlights a limitation of free market economics in addressing environmental issues. This dilemma can be circumvented, however, through alternative approaches, for example, Ostrom's shared pastures in Switzerland where the innovative strategy of the local community resolves the issue.

HL.b.7 Environmental accounting is the attempt to attach economic value to natural resources and their depletion.
Environmental (or green) accounting is problematic in achieving a consensus value for all stakeholders.

HL.b.8 In some cases, economic value can be established by use, but this is not the case for non-use values.
Non-use value may include the intrinsic value of a species, the potential for future use or the value it may have for forthcoming generations. It can be established by estimating through surveys how much people would be willing to pay for a common good, or how much compensation they would be willing to accept in return for the destruction of a common good. For example, the Exxon Valdez oil spill in 1989.

HL.b.9 Ecological economics is different from environmental economics in that it views the economy as a subsystem of Earth's larger biosphere and the social system as being a sub-component of ecology.
The ecological economist perceives the biosphere as a system with inputs of solar energy sustaining natural energy and material resources that enter the economic subsystem which, in turn, produces wastes and an overall loss of low-grade thermal energy from the biosphere. Ecological economics places emphasis on the sustainable use of natural capital, applying the precautionary principle to minimize environmental and social impacts. Ecological economics emphasizes the value of natural capital alongside physical, human and financial capital.

HL.b.10 While the economic valuation of ecosystem services is addressed by environmental economics, there is an even greater emphasis in ecological economics.
"Resource depleted" countries pay "resource rich" developing countries to not deplete their natural assets. This could occur when developing countries are at risk of using up their resources to develop economically. For example, forests are seen in ecological economics as having economic value beyond timber value. The ecological services, the aesthetic value for tourism and recreation, and the ethical value are all considered in ecological economics. Countries that have depleted some of their natural assets for economic gain in the past may pay other countries that still have natural assets, such as forests, to not remove them for economic growth. This can create tensions between countries.

HL.b.11 Economic growth is the change in the total market value of goods and services in a country over a period and is usually measured as the annual percentage change in GDP.
GDP is the monetary measure of all goods and services produced by a country in a given period of time. Per capita GDP is a more accurate assessment of living standards but does not take into account inequalities in the actual distribution of income.

HL.b.12 Economic growth is influenced by supply and demand, and may be perceived as a measure of prosperity.
This approach provides a linear economy that does not usually take into account waste, pollution and issues that lead to environmental degradation.

HL.b.13 Economic growth has impacts on environmental welfare.
Economic growth and the resulting increase in incomes can have both positive and negative effects on the environment. It may lead to higher consumption of non-renewable resources, increased pollution levels, global warming and the loss of natural habitats. And it can also provide resources to protect the environment and address environmental problems such as pollution. However, this can be a complex issue, as it raises questions about environmental justice for those who are impacted by increased consumption.

HL.b.14 Eco-economic decoupling is the notion of separating economic growth from environmental degradation.

While some countries have claimed some success in decoupling CO_2 emissions from economic growth, it seems impossible that there should ever be absolute decoupling. Indefinite growth would seem to require infinite availability of resources, though some argue that technological development can make this possible. Relative decoupling may occur, where resource degradation is at least reduced—although this still allows for some degradation.

HL.b.15 Ecological economics supports the need for degrowth, zero growth or slow growth, and advocates planned reduction in consumption and production, particularly in high-income countries.

Balancing the ecological footprint of a country with its biocapacity leads to sustainability, and this is the goal of ecological economics.

HL.b.16 Ecological economists support a slow/no/zero growth model.

There are inherent difficulties in dismantling deeply embedded economic systems and objectively measuring social and environmental well-being.

Ecological economists address the extent to which the ecological footprint of a country is sustainably balanced by its biocapacity (and remove the focus on GDP).

HL.b.17 The circular economy and doughnut economics models can be seen as applications of ecological economics for sustainability.

The effectiveness of these models in addressing the sustainable activity of a society varies. The circular economy involves product stewardship, in which the responsibility for sustainable management of a product is attributed to the manufacturer, seller and user. There are attempts to quantify the doughnut economics model for different countries and the doughnut model fundamentally attempts to address issues of inequality and injustice.

HL.c Environmental ethics

Guiding questions

- To what extent do humans have a moral responsibility towards the environment?
- How does environmental ethics influence approaches to achieving a sustainable future?

HL only

HL.c.1 Ethics is the branch of philosophy that focuses on moral principles and what behaviours are right and wrong.

Students should be exposed to a variety of ethical examples from across the world. Details of these are not required.

HL.c.2 Environmental ethics is a branch of ethical philosophy that addresses environmental issues.

This branch of ethics arose in the 1960s and 1970s when environmental issues and awareness became more prevalent. There was a concern that Western ethical traditions focused on interpersonal actions and relationships and were inadequate to address the moral status of non-human or non-living environmental entities.

HL.c.3 A variety of ethical frameworks and conflicting ethical values emerge from differing fundamental beliefs concerning the relationship between humans and nature.

If one believes the human species is of no significant difference to the rest of nature, this might lead to a more ecocentric position that all components of nature have intrinsic and equal rights, and ethical judgements can be made on that basis.

If one believes that the human species is part of nature, but has special responsibility of stewardship towards it, that may influence ethical judgements in favour of a compassionate, respectful, good steward.

If one believes that nature is quite separate and is there to serve human needs, then one may be likely to embrace a more extreme anthropocentric or technocentric worldview and simply consider what brings the greatest good to the greatest number of people.

HL.c.4 Instrumental value is the usefulness an entity has for humans.

The value may come from providing goods (for example, food and water), services (for example, decomposers processing waste) or opportunities for human development (for example, knowledge or creative inspiration).

HL.c.5 Intrinsic value is the value one may attach to something simply for what it is.

For example, non-living objects, such as landscapes, may be valued because they are wild, culturally significant or beautiful. Living organisms may be valued because, like humans, they have parts, processes and behaviours organized to accomplish survival and reproduction, so we should respect their ongoing existence and well-being.

HL.c.6 The concepts of instrumental and intrinsic value are not exclusive.

For example, whales may be considered to have intrinsic value from their aesthetic appeal; they may be considered to have instrumental value as a tourist attraction.

HL.c.7 An entity has "moral standing" if it is to be morally considered with regard to how we ought to act towards it.

To ask if something has moral standing is to ask if it should be taken into account by others or make a claim on others. Ecocentrists believe that all living things have moral standing because they have intrinsic value. Some ecocentrists would extend this argument to non-living things in nature, such as rivers, rocks, landscapes. For example, Aldo Leopold's land ethic argues that "a thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise." Likewise, one may consider the moral standing of future generations. For example, do humans alive today have obligations towards humans living in the future, irrespective of benefits to humans of today.

HL.c.8 There are three major approaches of traditional ethics: virtue ethics, consequentialist (for example, utilitarian) ethics and rights-based (deontological) ethics.

These ethical approaches contrast by focusing on the person's character (virtues), the consequences of actions or the rights of the entities involved.

HL.c.9 Virtue ethics focuses on the character of the person doing the action. It assumes that good people will do good actions and bad people will do bad actions.

It might be judged that respect, compassion and responsibility are virtuous approaches to the natural world.

HL.c.10 Consequentialist ethics is the view that the consequences of an action determine the morality of the action.

In consequentialist ethics, actions with good consequences are good actions, and actions with bad consequences are bad actions. Morally good actions are those that result in the greatest common good. The intention of the action does not affect the morality of the action; it is simply a matter of the outcome.

HL.c.11 Rights-based ethical systems focus on the actions and whether they conflict with the rights of others. There is debate about what these rights might be.
For example, if one believes that ethical rules come from a religious text and the text states that killing animals is wrong, then one might consider killing animals for food to be ethically incorrect because it conflicts with the rights of the animal.

HL.c.12 Some people hold the view that whatever is natural is correct or good. This position is contentious and is described as the "appeal to nature" fallacy.
It is debatable that all that is "natural" is a reliable ethical guide. For example, diseases are natural but not good—is it right to protect mosquitoes despite their spread of disease?

HL.c.13 Environmental movements and social justice movements have developed from separate histories but are increasingly seeking common goals of equitable and just societies.
There is a parallel issue of human superiority over nature with other types of exploitation. There are parallels with the rights of disenfranchised social groups, issues of sexism, racism and equity with future generations.

Assessment in the Diploma Programme

General

Assessment is an integral part of learning and teaching. The most important aims of assessment in the Diploma Programme (DP) are that it should support curricular goals and encourage appropriate student learning. Both external and internal assessments are used in the DP. IB examiners mark work produced for external assessment, while work produced for internal assessment is marked by teachers and externally moderated by the IB.

There are two types of assessment identified by the IB.

- **Formative assessment** informs both learning and teaching. It is concerned with providing accurate and helpful feedback to students and teachers on the kind of learning taking place and the nature of students' strengths and weaknesses in order to help develop students' understanding and capabilities. Formative assessment can also help to improve teaching quality, as it can provide information to monitor progress towards meeting the course aims and objectives.
- **Summative assessment** gives an overview of previous learning and is concerned with measuring student achievement at or towards the end of the course of study.

A comprehensive assessment policy is viewed as being integral with learning, teaching and course organization. For further information, see the IB *Programme standards and practices* document.

The approach to assessment used by the IB is criterion-related, not norm-referenced. This approach to assessment judges students' work by their performance in relation to identified levels of attainment, and not in relation to the work of other students. For further information on assessment within the DP, please refer to the publication *Assessment principles and practices—Quality assessments in a digital age*.

To support teachers in the planning, delivery and assessment of the DP courses, a variety of resources can be found on the Programme Resource Centre or purchased from the IB store (store.ibo.org). Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the Programme Resource Centre. Past examination papers as well as markschemes can be purchased from the IB store.

Methods of assessment

The IB uses several methods to assess work produced by students.

Assessment criteria

Assessment criteria are used when the assessment task is open-ended. Each criterion concentrates on a particular skill that students are expected to demonstrate. An assessment objective describes what students should be able to do, and assessment criteria describe how well they should be able to do it. Using assessment criteria allows discrimination between different answers and encourages a variety of responses. Each criterion comprises a set of hierarchically ordered level descriptors. Each level descriptor is worth one or more marks. Each criterion is applied independently using a best-fit model. The maximum marks for each criterion may differ according to the criterion's importance. The marks awarded for each criterion are added together to give the total mark for the piece of work.

Markbands

Markbands are a comprehensive statement of expected performance against which responses are judged. They represent a single holistic criterion divided into level descriptors. Each level descriptor corresponds to a range of marks to differentiate student performance. A best-fit approach is used to ascertain which particular mark to use from the possible range for each level descriptor.

Analytic markschemes

Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response.

Marking notes

For some assessment components marked using assessment criteria, marking notes are provided. Marking notes give guidance on how to apply assessment criteria to the particular requirements of a question.

Inclusive access arrangements

Inclusive access arrangements are available for candidates with access requirements. Standard assessment conditions may put candidates with assessment access requirements at a disadvantage by preventing them from demonstrating their attainment level. Inclusive access arrangements enable candidates to demonstrate their ability under assessment conditions that are as fair as possible.

The IB document *Access and inclusion policy* provides details on all the inclusive access arrangements available to candidates. The IB document *Learning diversity and inclusion in IB programmes: Removing barriers to learning* outlines the position of the IB with regard to candidates with diverse learning needs in the IB programmes. For candidates affected by adverse circumstances, the publication *Diploma Programme Assessment procedures* (updated annually), which includes the general regulations, provides details on access consideration.

Responsibilities of the school

The school is required to ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Access and inclusion policy* and *Learning diversity and inclusion in IB programmes: Removing barriers to learning*.

Assessment outline—SL

First assessment 2026

Assessment component	Weighting
External assessment (3 hours)	**75%**
Paper 1 (1 hour) Students will be provided with a range of data in a variety of forms relating to a specific, previously unseen case study. Questions will be based on the analysis and evaluation of the data in the case study. All questions are compulsory. (35 marks)	**25%**
Paper 2 (2 hours) Section A (40 marks) is made up of short-answer and data-based questions. Section B (20 marks) requires students to answer one structured essay question from a choice of two. Each question is worth 20 marks. (60 marks)	**50%**
Internal assessment (10 hours)	**25%**
This component is internally assessed by the teacher and externally moderated by the IB at the end of the course. The internal assessment consists of one task: the individual investigation. (30 marks)	

Assessment outline—HL

First assessment 2026

Assessment component	Weighting
External assessment (4.5 hours)	**80%**
Paper 1 (2 hours) Students will be provided with a range of data in a variety of forms relating to a specific, previously unseen case study. Questions will be based on the analysis and evaluation of the data in the case study. All questions are compulsory. (70 marks)	**30%**
Paper 2 (2.5 hours) Section A (40 marks) is made up of short-answer and data-based questions. Section B (40 marks) requires students to answer two structured essay questions from a choice of three. Each question is worth 20 marks. (80 marks)	**50%**
Internal assessment (10 hours)	**20%**
This component is internally assessed by the teacher and externally moderated by the IB at the end of the course. The internal assessment consists of one task: the individual investigation. (30 marks)	

External assessment

The following methods are used to assess students.

- Detailed markschemes specific to each examination paper
- Markbands

The markbands are published in this guide.

For paper 1, there is a markscheme.

For paper 2, there are markbands and a markscheme.

The markbands are related to the assessment objectives established for the environmental systems and societies (ESS) course. The markschemes are specific to each examination.

External assessment details—SL

The external assessment consists of two written papers and is worth 75% of the final assessment.

A calculator is required for both papers. Graphic display calculators (GDCs) are permitted (see the *Calculators guidance for examinations booklet* published annually on the Programme Resource Centre).

Note: Wherever possible, teachers should use, and encourage students to use, the Système International d'Unités (International System of Units—SI units).

Paper 1

Duration: 1 hour

Weighting: 25%

Marks: 35

Students will be provided with a range of data in a variety of forms relating to a specific, previously unseen case study.

Questions will be based on the analysis and evaluation of the data in the case study.

All questions are compulsory.

The questions in paper 1 test assessment objectives 1, 2 and 3.

Paper 2

Duration: 2 hours

Weighting: 50%

Marks: 60

Paper 2 consists of two sections: A and B.

- Section A (40 marks) is made up of short-answer and data-based questions.
- Section B (20 marks) requires students to answer one structured essay question from a choice of two. Each question is worth 20 marks.
- The questions in paper 2 test assessment objectives 1, 2 and 3.

External assessment markbands—SL

The final part of each essay in paper 2 section B (9 marks) will be marked using markbands. The descriptors of these markbands suggest certain features that may be offered in response. The descriptors outline the kind of elements to look for when deciding on the appropriate markband and the specific mark within that band.

The aim is to find the descriptor that conveys most accurately the level attained by the submitted work, using the best-fit model. A best-fit approach means that compensation will be made when a piece of work matches different aspects of a markband at different levels. The mark awarded will be one that most fairly reflects the balance of achievement against the markband. It is not necessary for every single aspect of a level descriptor to be met for that mark to be awarded.

It is recommended that the markbands be made available to students.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The response contains: • minimal evidence of knowledge and understanding of ESS issues or concepts • fragmented knowledge statements that are poorly linked to the context of the question • some appropriate use of ESS terminology • no examples, where required, or examples with insufficient explanation or relevance • superficial analysis that amounts to no more than a list of facts or ideas • judgements or conclusions that are vague or not supported by evidence or arguments.
4–6	The response contains: • some evidence of sound knowledge and understanding of ESS issues and concepts • knowledge statements that are effectively linked to the context of the question • largely appropriate use of ESS terminology • some use of relevant examples, where required, but with limited explanation • clear analysis that shows a degree of balance • some clear judgements or conclusions that are supported by limited evidence or arguments.
7–9	The response contains: • substantial evidence of sound knowledge and understanding of ESS issues and concepts • a wide breadth of knowledge statements that are effectively linked to each other and to the context of the question • consistent, appropriate and precise use of ESS terminology • effective use of pertinent, well-explained examples, where required, showing some originality • thorough, well-balanced, insightful analysis • explicit judgements or conclusions that are well supported by evidence or arguments and that include some critical reflection.

External assessment details—HL

Paper 1

Duration: 2 hours

Weighting: 30%

Marks: 70

Students will be provided with a range of data in a variety of forms relating to a specific, previously unseen case study.

Questions will be based on the analysis and evaluation of the data in the case study.

All questions are compulsory.

The questions in paper 1 test assessment objectives 1, 2 and 3.

Paper 2

Duration: 2.5 hours

Weighting: 50%

Marks: 80

Paper 2 consists of two sections: A and B.

- Section A (40 marks) is made up of short-answer and data-based questions.
- Section B (40 marks) requires students to answer two structured essay questions from a choice of three. Each question is worth 20 marks.
- The questions in paper 2 test assessment objectives 1, 2 and 3.

External assessment markbands—HL

The final part of each essay in paper 2 section B (9 marks) will be marked using markbands. The descriptors of these markbands suggest certain features that may be offered in response. The descriptors outline the kind of elements to look for when deciding on the appropriate markband and the specific mark within that band.

The aim is to find the descriptor that conveys most accurately the level attained by the submitted work, using the best-fit model. A best-fit approach means that compensation will be made when a piece of work matches different aspects of a markband at different levels. The mark awarded will be one that most fairly reflects the balance of achievement against the markband. It is not necessary for every single aspect of a level descriptor to be met for that mark to be awarded.

It is recommended that the markbands be made available to students.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The response contains: • minimal evidence of knowledge and understanding of ESS issues, concepts or HL lenses content • fragmented knowledge statements that are poorly linked to the context of the question • some appropriate use of ESS terminology • no examples, where required, or examples with insufficient explanation or relevance • superficial analysis that amounts to no more than a list of facts or ideas • judgements or conclusions that are vague or not supported by evidence or argument.
4–6	The response contains: • some evidence of sound knowledge and understanding of ESS issues, concepts and HL lenses content • knowledge statements that are effectively linked to the context of the question • largely appropriate use of ESS terminology

Marks	Level descriptor
	• some use of relevant examples, where required, but with limited explanation • clear analysis that shows a degree of balance • some clear judgements or conclusions that are supported by limited evidence or arguments.
7–9	The response contains: • substantial evidence of sound knowledge and understanding of ESS issues, concepts and HL lenses content • a wide breadth of knowledge statements that are effectively linked to each other and to the context of the question • consistent, appropriate and precise use of ESS terminology • effective use of pertinent, well-explained examples, where required, showing some originality • thorough, well-balanced, insightful analysis • explicit judgements or conclusions that are well supported by evidence or arguments and that include some critical reflection.

Internal assessment

Purpose of internal assessment

Internal assessment is an integral part of the course and is compulsory for both standard level (SL) and higher level (HL) students. It enables students to demonstrate the application of their skills and knowledge and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations. The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught.

The internal assessment requirements at SL and at HL are the same.

The internal assessment task involves the design, implementation and completion of an individual investigation of an environmental systems and societies (ESS) research question. The investigation is submitted as a written report.

Any investigation that is to be used for internal assessment should be specifically designed by the student to address the assessment criteria. Students must, therefore, be provided with a copy of the assessment criteria when the requirements of the investigation are explained to them.

An extended essay (EE) must not be based on the student's research question of the ESS internal assessment.

Guidance and authenticity

The individual investigation (SL and HL) submitted for internal assessment must be the student's own work. However, it is not the intention that students should decide upon a title or topic and be left to work on the internal assessment component without any further support from the teacher. The teacher should play an important role during both the planning stage and the period when the student is working on the internally assessed work. It is the responsibility of the teacher to ensure that students are familiar with:

- the requirements of the type of work to be internally assessed
- the *IB Sciences experimentation guidelines* publication
- the assessment criteria: students must understand that the work submitted for assessment must address these criteria effectively.

Teachers and students must discuss the internally assessed work. Students should be encouraged to initiate discussions with the teacher to obtain advice and information, and students must not be penalized for seeking guidance. As part of the learning process, teachers should read and give advice to students on one draft of the work. The teacher should provide oral or written advice on how the work could be improved, but not edit the draft. The next version handed to the teacher must be the final version for submission.

It is the responsibility of teachers to ensure that all students understand the basic meaning and significance of concepts that relate to academic integrity, especially authenticity and intellectual property. Teachers must ensure that all student work for assessment is prepared according to the requirements and must explain clearly to students that the internally assessed work must be entirely their own. Where collaboration between students is permitted, it must be clear to all students what the difference is between collaboration and collusion.

All work submitted to the IB for moderation or assessment must be authenticated by a teacher, and must not include any known instances of suspected or confirmed malpractice. Each student must confirm that the work is their authentic work and constitutes the final version of that work. Once a student has officially submitted the final version of the work it cannot be retracted. The requirement to confirm the authenticity of work applies to the work of all students, not just the sample work that will be submitted to the IB for the purpose of moderation. For further details refer to the IB publications *Academic integrity policy*, *Diploma Programme: From principles into practice* and the relevant general regulations (in *Diploma Programme Assessment procedures*).

Authenticity may be checked by discussion with the student on the content of the work and scrutiny of one or more of the following.

- The student's initial proposal
- The first draft of the written work
- The references cited
- The style of writing compared with work known to be that of the student
- The analysis of the work by a web-based plagiarism detection service such as www.turnitin.com

The same piece of work **cannot** be submitted to meet the requirements of both the internal assessment and the extended essay.

Group work

Collaborative work relating to the research question and developing methodology of a student's investigation is permitted. Students may support others (groups of three or less).

Students are required to develop a unique research question and methodology with unique data.

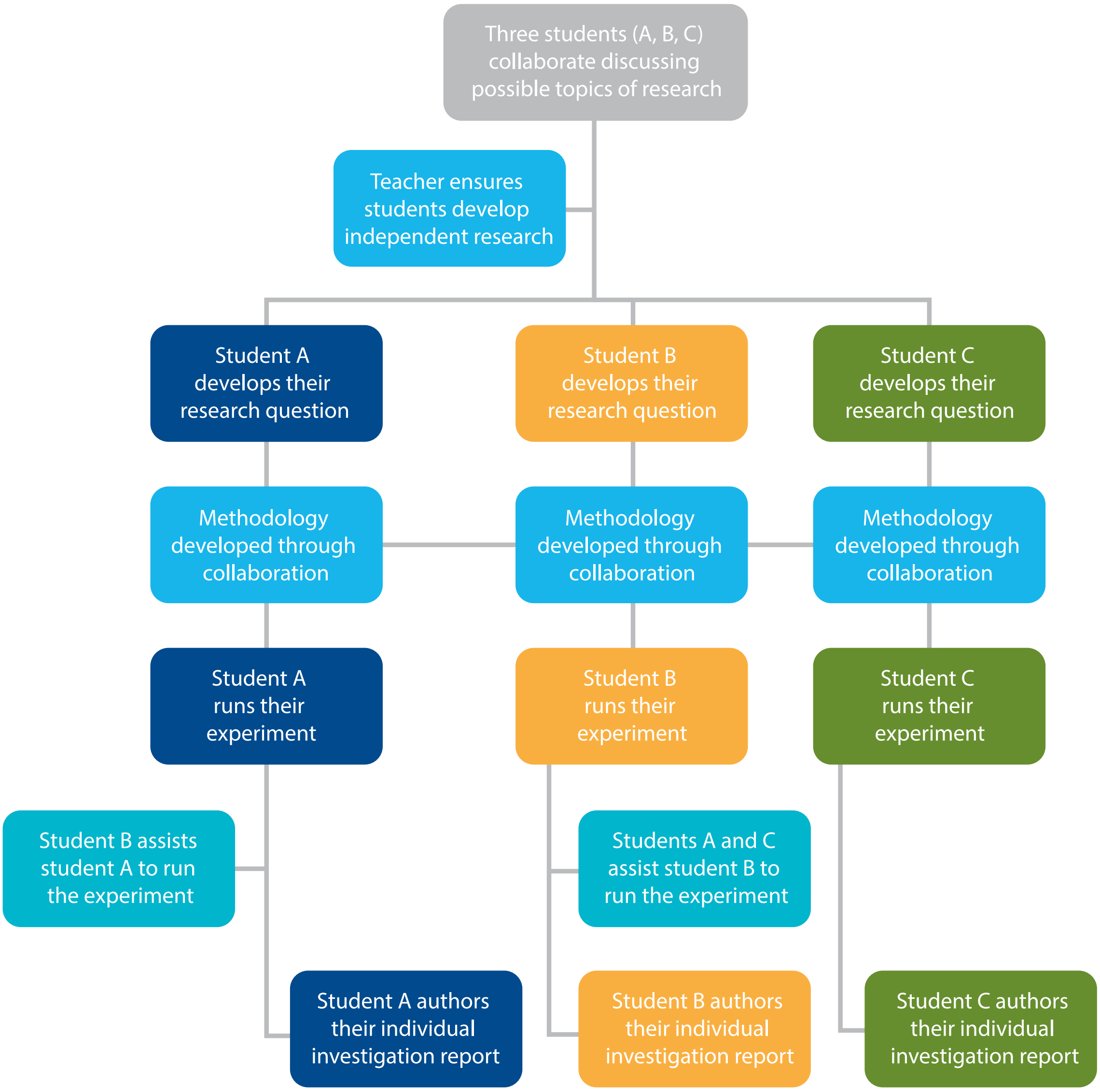
The methodology developed to answer an individual research question may be, in part, the outcome of a collaborative activity. For example, a student within a group investigates their individual research question by manipulating one of the following.

- A different independent variable from those selected by other group members
- The same independent variable with a different dependent variable from those selected by other group members
- Different data from those selected by other group members from within a larger communally acquired data set

In this context, collaborative work is permitted on the understanding that the final report presented for assessment is that of the individual student. A report by the group is not permitted. All authoring, including the description of the methodology, must be done individually.

Figure 5

A possible route through collaborative work



Class collaboration to set up a database

A school may take part in a large-scale activity collecting data to generate a database using standardized protocols. If a student decides to utilize this database in order to answer their research question, then the investigation must be treated as a database investigation. In such a case, the methodology should be focused on the way the data is filtered and sampled from the whole database in the same way as if the data was wholly acquired from an external source.

Time allocation

Internal assessment is an integral part of the ESS course, contributing 25% to the final assessment in the SL course and 20% in the HL course. The difference in weighting reflects the time allocated to teaching the knowledge, skills and understanding required to undertake the work, as well as the total time allocated to carry out the work.

The time allocation for the internal assessment activity is 10 hours. This includes time for:

- the teacher to explain to students the requirements of the internal assessment
- consultation between the teacher and each student to discuss the research question before the individual investigation is implemented
- development of an appropriate methodology and collection of data (the methodology could be undertaken as part of a group, but the report is written separately, see the "Group work" section)
- review, monitoring and support of progress.

It should be noted that during the consultation stage, the teacher provides advice to support the student but does not tell the student what to investigate or how to carry out the investigation. Before the final submission, teachers should also provide feedback to the student on one draft of the written report.

Safety requirements and recommendations

It is the responsibility of everyone involved in science education to make an ongoing commitment to safe and healthy practical work.

The working practices and protocols should be effective in safeguarding students and protecting the environment. Schools are responsible for following national or local guidelines, which differ from country to country. The *Environmental systems and societies teacher support material* provides further guidance.

Using assessment criteria for internal assessment

For internal assessment, a number of assessment criteria have been identified. Each assessment criterion has level descriptors describing specific achievement levels, together with an appropriate range of marks. The level descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Teachers must judge the internally assessed work at SL and at HL against the criteria using the level descriptors.

- The same assessment criteria are provided for SL and HL.
- The aim is to find, for each criterion, the descriptor that conveys most accurately the level attained by the student, using the best-fit model. A best-fit approach means that compensation should be made when a piece of work matches different aspects of a criterion at different levels. The mark awarded should be one that most fairly reflects the balance of achievement against the criterion. It is not necessary for every single aspect of a level descriptor to be met for that mark to be awarded.
- When assessing a student's work, teachers should read the level descriptors for each criterion until they reach a descriptor that most appropriately describes the level of the work being assessed. If a piece of work seems to fall between two descriptors, both descriptors should be read again and the one that more appropriately describes the student's work should be chosen.
- Where there are two or more marks available within a level, teachers should award the upper marks if the student's work demonstrates the qualities described to a great extent; the work may be close to achieving marks in the level above. Teachers should award the lower marks if the student's work demonstrates the qualities described to a lesser extent; the work may be close to achieving marks in the level below.
- Only whole numbers should be recorded; partial marks (fractions and decimals) are not acceptable.
- Teachers should not think in terms of a pass or fail boundary, but should concentrate on identifying the appropriate descriptor for each assessment criterion.
- The highest level descriptors do not imply faultless performance but should be achievable by a student. Teachers should not hesitate to use the extremes if they are appropriate descriptions of the work being assessed.
- A student who attains a high achievement level in relation to one criterion will not necessarily attain high achievement levels in relation to the other criteria. Similarly, a student who attains a low achievement level for one criterion will not necessarily attain low achievement levels for the other

criteria. Teachers should not assume that the overall assessment of the students will produce any particular distribution of marks.

- It is recommended that the assessment criteria be made available to students.

Internal assessment details—SL and HL

The individual investigation

SL

Duration: 10 hours

Weighting: 25%

HL

Duration: 10 hours

Weighting: 20%

Requirements

The individual investigation is an open-ended task in which the student gathers and analyses data in order to answer their own formulated research question. The requirements are the same for both SL and HL. The individual investigation covers assessment objectives 1, 2, 3 and 4.

The outcome of the individual investigation will be assessed through the form of a written report. The maximum overall word count for the report is 3,000 words.

The following are not included in the word count.

- Charts and diagrams
- Data tables
- Equations, formulae and calculations
- Citations/references (whether parenthetical, numbered, footnotes or endnotes)
- Bibliography
- Headers

The following details should be stated at the start of the report.

- Title of the investigation
- IB candidate code (alphanumeric, for example, xyz123)
- IB candidate code for all group members (if applicable)
- Number of words

There is no requirement to include a cover page or a contents page.

Internal assessment criteria—SL and HL

There are six internal assessment criteria for the ESS investigation.

A: Research question and inquiry	B: Strategy	C: Method	D: Treatment of data	E: Analysis and conclusion	F: Evaluation
4 marks	4 marks	4 marks	6 marks	6 marks	6 marks

Teachers should read the guidance on using assessment criteria shown in the section called "Using assessment criteria for internal assessment" before starting to mark. It is also essential to be acquainted with the marking of the exemplars in the *Environmental systems and societies teacher support material*. The precise meaning of the command terms used in the criteria can be found in the glossary of this subject guide.

Criterion A: Research question and inquiry

This criterion assesses the extent to which the student establishes and explores an environmental issue (either local or global) for an investigation, and develops this issue to state a relevant and focused research question. (Maximum 4 marks)

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	The report: • describes a local or global environmental topic or issue but with errors or omissions showing a limited understanding • states a research question but there is a lack of focus or it is not linked to the chosen environmental topic or issue.
3–4	The report: • explains a local or global environmental topic or issue with sufficient background research to support the research question • states a focused research question that addresses the chosen environmental topic or issue.

Clarifications for research question and inquiry
A lack of focus may lead to a research question that cannot be suitably addressed within the word limit (3,000 words). **Background research:** For example, a literature review or consideration of a theory or model. The citation of published materials must be sufficiently detailed to allow these sources to be traceable. Further guidance is available in the *Environmental systems and societies teacher support material*.

Criterion B: Strategy

This criterion assesses the extent to which students understand how tensions between perspectives can impact the environmental or societal outcomes of a strategy that addresses an issue central to the student's investigation. (Maximum 4 marks)

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	The report: • states an existing or developing strategy that addresses an environmental issue linked to the research question • describes a tension between different perspectives (economic, social, cultural, political or environmental) that results from the strategy
3–4	The report: • describes an existing or developing strategy that addresses an environmental issue linked to the research question • explains a tension between different perspectives (economic, social, cultural, political or environmental) that results from the strategy

Clarifications for strategy
The environmental issue or strategy explored can be different to the one explored in the investigation. However, the issue must have a clearly stated and credible connection to the research question. Tensions arise from potentially conflicting goals and needs of groups with different points of view. Further guidance is available in the *Environmental systems and societies teacher support material*.

Criterion C: Method

This criterion assesses the extent to which the student has developed an appropriate and repeatable method to collect data that is relevant to the research question. The data could be primary or secondary, qualitative or quantitative. (Maximum 4 marks)

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	• The report describes a method that is not repeatable. • The method does not allow for sufficient data to be collected to address the research question.
3–4	• The report describes a repeatable method. • The method does allow for the collection of sufficient data to answer the research question.

Clarifications for method
A method that is repeatable should include sufficient details to allow a third party to replicate the investigation. The description of the method should include the set-up and the student contribution, sampling or surveying techniques, and how data is collected. A descriptive, literature-based investigation that only reviews the literature cannot be considered a repeatable method. Further guidance is available in the *Environmental systems and societies teacher support material*.

Criterion D: Treatment of data

This criterion assesses the extent to which the student has effectively communicated and processed the data in ways that are relevant to the research question. The student should utilize techniques associated with the appropriate experimental or social science method of inquiry. (Maximum 6 marks)

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	• The communication of raw and processed data is not clear. • The techniques used to process the raw data lead to findings that do not address the research question. • The raw data is processed with major errors.
3–4	• The communication of raw and processed data is clear. • The techniques used to process the raw data lead to findings that do not fully address the research question. • The raw data is processed with some minor errors.
5–6	• The communication of raw and processed data is clear and detailed.

Marks	Level descriptor
	• The techniques used to process the raw data lead to findings that fully address the research question. • The raw data is processed correctly.

Clarifications for treatment of data
Minor errors (those that do not affect the conclusion) should not prevent a report from achieving full marks for the criteria/performance level. **Data** can be primary or secondary, and qualitative or quantitative. **Clear** means that the presentation or method of processing can be understood easily, including appropriate details such as the labelling of graphs and tables or the use of units, decimal places and significant figures, where appropriate. The **raw data** presented might be a sample if there is a large amount, that is, survey results or data logging; the remaining data can be included within an appendix. Further guidance is available in the *Environmental systems and societies teacher support material*.

Criterion E: Analysis and conclusion

This criterion assesses the extent to which the student has interpreted the data in ways that are relevant to the research question. The patterns in the data are highlighted and correctly interpreted to reach a valid conclusion. (Maximum 6 marks)

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	• The analysis identifies patterns or trends within the data that are relevant to the research question. • The conclusion either does not address the research question or is not supported by the analysis presented.
3–4	• The analysis describes patterns or trends within the data that are relevant to the research question, including (some) measures of bias, reliability, validity and uncertainty. • The conclusion addresses the research question and is partially supported by the analysis presented.
5–6	• The analysis explains all the patterns and trends within the data that are relevant to the research question, including measures of bias, reliability, validity and uncertainty. • The conclusion addresses the research question and is supported by the analysis presented.

Clarifications to analysis and conclusion
A **supported conclusion** should include measures of bias, reliability, validity and uncertainty. Further guidance is available in the *Environmental systems and societies teacher support material*.

Criterion F: Evaluation

This criterion assesses the extent to which the student carries out an evaluation of the investigation. (Maximum 6 marks)

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	The evaluation: • states generic methodological limitations or weaknesses that impact the conclusion • states improvements to the method that address the identified limitations or weaknesses • states generic unresolved questions that arise from the investigation.
3–4	The evaluation: • describes methodological limitations or weaknesses that impact the conclusion • describes improvements to the method that address the identified limitations or weaknesses • outlines unresolved questions that arise from the investigation.
5–6	The evaluation: • evaluates specific methodological limitations or weaknesses that impact the conclusion • evaluates improvements to the method that address limitations or weaknesses • describes unresolved questions that arise from the investigation as they impact the conclusion.

Clarifications for evaluation
A **generic** methodology is general to many methodologies and is not specifically relevant to the methodology of the investigation being evaluated. Methodological **weaknesses** relate to issues regarding the control of variables or the precision of measurements. **Limitations** could refer to how the conclusion is limited in scope by the range of the data collected, the confines of the system or the applicability of assumptions made. Further guidance is available in the *Environmental systems and societies teacher support material*.

Glossary of command terms

Command terms for environmental systems and societies

Students should be familiar with the following key terms and phrases used in examination questions, which are to be understood as described below. Although these terms will be used frequently in examination questions, other terms may be used to direct students to present an argument in a specific way.

These command terms indicate the depth of treatment required.

Assessment objective 1

Define	Give the precise meaning of a word, phrase, concept or physical quantity.
Draw	Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve.
Label	Add labels to a diagram.
List	Give a sequence of brief answers with no explanation.
Measure	Obtain a value for a quantity.
State	Give a specific name, value or other brief answer without explanation or calculation.

Assessment objective 2

Annotate	Add brief notes to a diagram or graph.
Apply	Use an idea, equation, principle, theory or law in relation to a given problem or issue.
Calculate	Obtain a numerical answer showing the relevant stages in the working.
Describe	Give a detailed account.
Distinguish	Make clear the differences between two or more concepts or items.
Estimate	Obtain an approximate value.
Identify	Provide an answer from a number of possibilities.
Interpret	Use knowledge and understanding to recognize trends and draw conclusions from given information.
Outline	Give a brief account or summary.

Assessment objective 3 and assessment objective 4

Analyse	Break down in order to bring out the essential elements or structure.
Comment	Give a judgement based on a given statement or result of a calculation.

Compare and contrast	Give an account of similarities and differences between two (or more) items or situations, referring to both (all) of them throughout.
Construct	Display information in a diagrammatic or logical form.
Deduce	Reach a conclusion from the information given.
Demonstrate	Make clear by reasoning or evidence, illustrating with examples or practical application.
Derive	Manipulate a mathematical relationship to give a new equation or relationship.
Design	Produce a plan, simulation or model.
Determine	Obtain the only possible answer.
Discuss	Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.
Evaluate	Make an appraisal by weighing up the strengths and limitations.
Examine	Consider an argument or concept in a way that uncovers the assumptions and interrelationships of the issue.
Explain	Give a detailed account including reasons or causes.
Justify	Give valid reasons or evidence to support an answer or conclusion.
Predict	Give an expected result.
Sketch	Represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.
Suggest	Propose a solution, hypothesis or other possible answer.
To what extent	Consider the merits or otherwise of an argument or concept. Opinions and conclusions should be presented clearly and supported with appropriate evidence and sound argument.

Bibliography

Adams, W. M. (2006, January 29–31). *The future of sustainability: Re-thinking environment and development in the twenty-first century* [Report of the International Union for Conservation of Nature and Natural Resources (IUCN) Renowned Thinkers Meeting]. The World Conservation Union. Gland, Switzerland.

Adams, W. M., & Jeanrenaud, S. J. (2008). *Transition to sustainability: Towards a humane and diverse world*. IUCN.

Almond, R. E. A., Grooten, M., Juffe Bignoli, D., & Petersen, T. (Eds). (2022). *Living Planet Report 2022 – Building a nature-positive society*. WWF.

Bauwens, T. (2021). Are the circular economy and economic growth compatible? A case for post-growth circularity. *Resources, Conservation & Recycling*, *175(4)*, 1–3. https://doi.org/10.1016/j.resconrec.2021.105852

Bendell, J., & Read, R. (Eds.) (2021). *Deep adaptation: Navigating the realities of climate change*. Polity.

Berners-Lee, M. (2010). *How bad are bananas?: The carbon footprint of everything*. Green Books.

Biesta, G. (2011). Transcendence, revelation, and the constructivist classroom: Or, in praise of teaching. *Philosophy of Education*, *67*, 358–365. https://doi.org/10.47925/2011.358

Bosschaert T. (2010–2019). *Symbiosis in development: Making new futures possible*. Except Sustainability Academy.

Bregman, R. (2021). *Humankind: A hopeful history*. Bloomsbury Publishing plc.

Carver, S. (2014). Making real space for nature: A continuum approach to UK conservation. *ECOS*, *35(3/4)*, 4–14.

Chiras, D. D. (2009). *Environmental science* (8th ed.). Jones and Bartlett Publishers.

Clark, S. G., & Wallace, R. L. (2015). Integration and interdisciplinarity: Concepts, frameworks, and education. *Policy Sciences*, *48*, 233–255. https://doi.org/10.1007/s11077-015-9210-4

Clay, J. (Director). (2021). *Breaking boundaries: The science of our planet* [Film]. Netflix. https://www.netflix.com/de-en/title/81336476

Common Worlds Research Collective. (2020). *Learning to become with the world: Education for future survival* [Programme and meeting document]. UNESCO. Retrieved March 27, 2023, from https://unesdoc.unesco.org/ark:/48223/pf0000374032

Cook, J. (2015). How do we stop the spread of science denial? *Education in Science*, *262*, 16.

Cooper, C. (2016). *Citizen science: How ordinary people are changing the face of discovery*. Abrams Press.

Curry, P. (2014) (revised). *Ecological ethics: An introduction* (Chapter 8: Dark green or deep (ecocentric) ethics). Retrieved March 27, 2023, from http://ruby.fgcu.edu/courses/twimberley/EnviroPhilo/currypdf.pdf

Díaz, S., Settele, J., Brondízio, E., Ngo, H. T., Guèze, M., et al. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services. Retrieved March 27, 2023, from http://www.mari-odu.org/academics/2018su_Leadership/commons/library/Summary%20for%20Policymakers%20IPBES%20Global%20Assessment.pdf

Dommerholt, E. (2021). *Towards the circular economy and beyond: Implications of an ongoing transition for the professorship Biobased Business Valorization at the Hanze University of Applied Sciences Groningen*. Hanze University of Applied Sciences Groningen. Retrieved March 27, 2023, from https://research.hanze.nl/ws/portalfiles/portal/35977420/HANZE_21_0187_Lectorale_Rede_Towards_the_Circular_Economy_and_Beyond_LR.pdf

Doughnut Economics Action Lab. (2020). *Doughnut diagrams in 25+ languages*. Doughnut Economics Action Lab. Retrieved March 27, 2023, from https://doughnuteconomics.org/tools/65

Doughnut Economics Action Lab. (2020). *Get animated! Introducing the seven ways*. Doughnut Economics Action Lab. Retrieved March 27, 2023, from https://doughnuteconomics.org/tools/2

Doughnut Economics Action Lab. (2022). *Introduction to distributive design* [Video]. YouTube. https://youtu.be/xYrdOpaMQhI

Doughnut Economics Action Lab. (2022). *Introduction to regenerative design* [Video]. YouTube. https://youtu.be/OY0meOEzifI

Doughnut Economics Action Lab. (2022). *Meet the economy* [Video]. YouTube. https://www.youtube.com/watch?v=ZLnAXNbtcZQ

Ellen MacArthur Foundation. (2011). *Explaining the circular economy and how society can rethink progress* [Video]. YouTube. https://youtu.be/zCRKvDyyHmI

Ellen MacArthur Foundation. (2019). *The butterfly diagram: Visualising the circular economy*. Ellen MacArthur Foundation. Retrieved March 27, 2023, from https://ellenmacarthurfoundation.org/circular-economy-diagram

Ellen MacArthur Foundation. (2020). *Ellen MacArthur on the basics of the circular economy* [Video]. YouTube. https://youtu.be/NBEvJwTxs4w

Ellen MacArthur Foundation. (2023). *It's time for a circular economy*. Ellen MacArthur Foundation. Retrieved March 27, 2023, fromhttps://ellenmacarthurfoundation.org/

Ellen MacArthur Foundation. (2023). *Teaching resources*. Ellen MacArthur Foundation. Retrieved March 27, 2023, from https://ellenmacarthurfoundation.org/resources/education-and-learning/teaching-resources

Elsevier Foundation. (2020). *The power of data to advance the SDGs: Mapping research for the sustainable development goals*. Elsevier and RELX Group, SDG Resource Centre.

Farahbakhsh, I., Bauch. C. T., & Anand, M. (2022). Modelling coupled human–environment complexity for the future of the biosphere: Strengths, gaps and promising directions. *Philosophical Transactions of the Royal Society B*, *377*, 1–13. https://doi.org/10.1098/rstb.2021.0382

Forum for the Future. (no date). *What is sustainability?* Forum for the Future. Retrieved April 4, 2023, https://www.forumforthefuture.org/faqs/what-is-sustainability#:~:text=Sustainable%20development%20means%20being%20able,to%20fulfil%20their%20own%20needs

Foster, J. (2005). Making sense of stewardship: Metaphorical thinking and the environment. *Environmental Education Research*, *11(1)*, 25–36. https://doi.org/10.1080/1350462042000328721

Freydont-Attie, J. (Director). (2015). *The cross of the moment* [Documentary].

Gates, B. (2022). *How to avoid a climate disaster: The solutions we have and the breakthroughs we need*. Penguin Books.

Gough, S., Scott, W., & Stables, A. (2000). Beyond O'Riordan: Balancing anthropocentrism and ecocentrism. *International Research in Geographical and Environmental Education*, *9(1)*, 36–47. https://doi.org/10.1080/10382040008667628

Harlen, W. (2011). Working towards big ideas of science education. *Education in Science*, *242*, 20.

Hickman, C., Marks, E., Pihkala, P., Clayton, S., Lewandowski, R. E., & Mayall, E. (2021). Climate anxiety in children and young people and their beliefs about government responses to climate change: A global survey. *The Lancet Planetary Health*, *5(12)*, e863–e873. https://doi.org/10.1016/s2542-5196(21)00278-3

Holmes, T., Blackmore, E., Hawkins, R., & Wakeford, T. (2011). *The common cause handbook: A guide to values and frames for campaigners, community organisers, civil servants, fundraisers, educators, social entrepreneurs, activists, funders, politicians, and everyone in between*. Public Interest Research Centre.

Howarth, S., & Slingsby, D. (2006) Biology fieldwork in school grounds: A model of good practice in teaching science. *School Science Review*, *87(320)*, 99–105. https://eprints.worc.ac.uk/id/eprint/2076

Huckle, J. (1996). Realizing sustainability in changing times. In J. Huckle & S. Sterling (Eds.), *Education for sustainability* (pp. 3–17). Earthscan.

Intergovernmental Panel on Climate Change (IPCC). (2023). *Synthesis report of the sixth assessment report: A report of the Intergovernmental Panel on Climate Change*. IPCC. Retrieved April 3, 2023, from https://www.ipcc.ch/ar6-syr/

International Baccalaureate. (2014). *MYP: From principles into practice* (7th ed.). International Baccalaureate Organization.

IPBES. (2022, July 3–9). *Report of the plenary of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on the work of its ninth session* [Programme and meeting document]. Plenary of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Bonn, Germany.

James, P. (2015). *Urban sustainability in theory and practice: Circles of sustainability*. Routledge.

Jickling, B., & Wals, A. E. J. (2008). Globalization and environmental education: Looking beyond sustainable development. *Journal of Curriculum Studies*, *40(1),* 1–21. https://doi.org/10.1080/00220270701684667

Kahn, R. (2010). *Critical pedagogy, ecoliteracy and planetary crisis: The ecopedagogy movement*. Peter Lang.

Kidron, A., & Kali, Y. (2015). Boundary breaking for interdisciplinary learning. *Research in Learning Technology*, *23*. https://doi.org/10.3402/rlt.v23.26496

Klein, N. (2014). *This changes everything: Capitalism vs. the climate*. Penguin.

Kothari, A., Salleh, A., Escobar, A., Demaria, F., & Acosta, A. (Eds.) (2019). *Pluriverse: A post-development dictionary*. Tulika Books.

Krznaric, R. (2021). *The good ancestor: How to think long term in a short-term world*. WH Allen.

Kucera, S. (Director). (2018). *Living in the future's past* [Documentary]. Rangeland Productions.

Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., et al. (2019). Climate tipping points—too risky to bet against. *Nature*, *575*, 592–595. https://doi.org/10.1038/d41586-019-03595-0

Lorimer, J., & Driessen, C. (2014). Experiments with the wild at the Oostvaardersplassen. *ECOS*, *35(3/4)*, 44–52.

Luckie, D., &. Newell, W. (2019). Pedagogy for interdisciplinary habits of mind. *Journal of Interdisciplinary Studies in Education*, *8(1)*, 6–20. https://doi.org/10.32674/jise.v8i1.584

Lynas, M. (2008). *Six degrees: Our future on a hotter planet*. Harper Perennial.

Lynas, M. (2011). *The God species: How humans really can save the planet*. Fourth Estate.

McDonald, R. I., Aronson, M. F. J., Beatley, T., Beller, E., Bazo, M., et al. (2023). Denser and greener cities: Green interventions to achieve both urban density and nature. *People and Nature*, *5(1)*, 84–102. https://doi.org/10.1002/pan3.10423

McGuire, B. (2022). *Hothouse Earth: An inhabitant's guide*. Icon Books.

Meadows, D. H. (2008). *Thinking in systems: A primer*. Earthscan.

Menken, S., & Keestra, M. (Eds). (2016). *An introduction to interdisciplinary research: Theory and practice*. Amsterdam University Press.

Moberg, F., & Simonsen, S. H. (2014). *What is resilience? An introduction to social-ecological research*. Stockholm Resilience Centre.

Monbiot, G. (2007). *Heat: How we can stop the planet burning*. Penguin.

Monbiot, G. (2013). *Feral: Searching for enchantment on the frontiers of rewilding*. Penguin Books.

Monbiot, G. (2022). *Regenesis: Feeding the world without devouring the planet*. Allen Lane.

Morton, T. (2018). *Being ecological*. Pelican Books.

Munson, B. H. (1994). Ecological misconceptions. *The Journal of Environmental Education*, *25(4)*, 30–34. https://doi.org/10.1080/00958964.1994.9941962

Odum, E. P. (1997). *Ecology: A bridge between science and society* (3rd ed.). Oxford University Press Inc.

O'Riordan, T. (1981). *Environmentalism* (2nd ed.). Pion.

Palmer, A. (2020, December). *Trying to avoid sustainababble* [Discussion notes]. Environmental systems and societies (ESS) curriculum review meeting. The Hague, the Netherlands.

Persson, L., Lundegård, I., & Wickman, P. (2011). Worry becomes hope in education for sustainable development – an action research study at a secondary school. *Utbildning & Demokrati*, *20(1)*, 123–144. https://doi.org/10.48059/uod.v20i1.946

Peterson del Mar, D. (2014). *Environmentalism* (2nd ed.). Routledge.

Polman, J. L., & Scornavacco, K. (2022). *Meanings and practices of inquiry-based teaching and learning in the International Baccalaureate*. University of Colorado Boulder and International Baccalaureate Organization.

Rahmstorf, S. (2004). The climate sceptics. *The state of Science: Weather catastrophes and climate change*, 76–83. Retrieved April 4, 2023, from http://www.pik-potsdam.de/~stefan/Publications/Other/rahmstorf_climate_sceptics_2004.pdf

Raworth, K. (2018). *A healthy economy should be designed to thrive, not grow* [Video]. TED. https://www.ted.com/talks/kate_raworth_a_healthy_economy_should_be_designed_to_thrive_not_grow?language=en

Raworth, K. (2018). *Doughnut economics: Seven ways to think like a 21st-century economist*. Random House Business.

Rea, A. W., & Munns, W. R. (2017). The value of nature: Economic, intrinsic, or both? *Integrated Environmental Assessment and Management*, *13(5)*, 953–955. https://doi.org/10.1002/ieam.1924

Reimers, F. M. (2017). *Empowering students to improve the world in sixty lessons*. CreateSpace Independent Publishing Platform.

Reimers, F. M. (Ed). (2021). *Education and climate change: The role of universities*. Springer.

Rockström, J. (2020). *10 years to transform the future of humanity—or destabilize the planet* [Video]. TED. https://www.ted.com/talks/johan_rockstrom_10_years_to_transform_the_future_of_humanity_or_destabilize_the_planet

Rockström, J., Steffen, W., Noone, K. J., Persson, Å., .Chapin, F. S. III, et al. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, *14(2)*. https://doi.org/10.5751/es-03180-140232

SDG Academy. (2023). *Professional Certificate in Foundations of Sustainable Development*. EdX. Retrieved March 27, 2023, from https://www.edx.org/professional-certificate/sdgacademyx-sustainable-development

Shepardson, D. P., Niyogi, D., Choi, S., & Charusombat, U. (2011). Students' conceptions about the greenhouse effect, global warming, and climate change. *Climatic Change*, *104*, 481–507. https://doi.org/10.1007/s10584-009-9786-9

Smil, V. (2022). *How the world really works: A scientist's guide to our past, present and future*. Penguin Books.

Spaiser, V., Ranganathan, S., Swain, R. B., & Sumpter, D. J. T. (2017). The sustainable development oxymoron: Quantifying and modelling the incompatibility of sustainable development goals. *International Journal of Sustainable Development & World Ecology*, *24(6)*, 457–470. https://doi.org/10.1080/13504509.2016.1235624

Stevenson, R. B., Brody, M., Dillon, J., & Wals, A. E. J. (2013). *International handbook of research on environmental education*. American Educational Research Association, Routledge Publishers.

Stibbe, A. (2009). *The handbook of sustainability literacy: Skills for a changing world*. GreenBooks.

Stockholm Resilience Centre. (2022). *Planetary boundaries*. Stockholm University. Retrieved March 27, 2023, from https://stockholmuniversity.app.box.com/s/5rc9wwwzv3c03ghgawcjkflno77zptd0

Stroh, D. P. (2015). *Systems thinking for social change: A practical guide to solving complex problems, avoiding unintended consequences, and achieving lasting results*. Chelsea Green Publishing.

The Institution of Environmental Sciences. (2011). Education: A journey through environmental science. *Journal of the Institution of Environmental Sciences*, *20(2)*.

Thompson, P. B., & Norris, P. E. (2021). *Sustainability: What everyone needs to know*. Oxford University Press.

Thunberg, G. (2022). *The climate book*. Allen Lane.

Tree, I. (2019). *Wilding: The return of nature to a British farm*. Picador.

Trudgill, S. T. (1990). *Barriers to a better environment: What stops us solving environmental problems?* Belhaven Press.

UNESCO & UNESCO Associated Schools. (2014). *ASPnet strategy for 2014–2021, Global network of schools addressing global challenges: Building global citizenship and promoting sustainable development* [Programme and meeting document]. UNESCO. Paris, France.

University of Leeds. (2023). *A good life for all within planetary boundaries*. University of Leeds. Retrieved March 27, 2023, from https://goodlife.leeds.ac.uk/

Wallace-Wells, D. (2019). *The uninhabitable Earth: Life after warming*. Tim Duggan Books.

Warburton, K. (2003). Deep learning and education for sustainability. *International Journal of Sustainability in Higher Education*, *4(1)*, 44–56. https://doi.org/10.1108/14676370310455332

Webster, K., & Johnson, C. (2010). *Sense and sustainability: Educating for a circular economy* (2nd ed.). TerraPreta.

Zabel, I., Duggan-Hass, D., & Ross, R. M. (2018). *The teacher-friendly guide to climate change*. Paleontological Research Institution. Retrieved March 28, 2023, from https://www.priweb.org/science-education-programs-and-resources/teacher-friendly-guide-to-climate-change#aguide

Zhou, S. L., & Smulders, S. (2021). Closing the loop in a circular economy: Saving resources or suffocating innovations? *European Economic Review*, *139*. https://doi.org/10.1016/j.euroecorev.2021.103857

Zinkunegi-Goitia, O., & Rekalde-Rodríguez, I. (2022). Employability within an education for sustainability framework: The Ocean i3 Case Study. *Education Sciences*, *12*, 277. https://doi.org/10.3390/educsci12040277