Oxford
Smart Curriculum

Oxford Smart Curriculum for Science

OXFORD

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Curriculum intent

The Oxford Smart Curriculum draws connections between content, methods, assessment, insight and evaluation to deliver a holistic learning experience, within which the science curriculum bases knowledge, skills, strategies and competences around individual opportunity and progression. Data, insights and research are drawn from to equip teachers to deliver increasingly personalised learning for students.

The Oxford Smart Curriculum is founded on a sound corpus of pedagogical research and will generate its own evidence and impact from educators, experts, and real learning and assessment. Over time, this portfolio of evidence will in turn inform and inspire future curriculum evaluation and development.

The Oxford Smart Curriculum is developed with input from AQA, an awarding body with a mission to help every student realise their potential. Designed with an explicit egalitarian purpose at its heart to enable teachers and learners to experience the joy and wonder of learning and to reap the transformative benefits of quality education, the Oxford Smart Curriculum for Science intent is based on the six curriculum pillars below.

Curriculum pillars in Science

Coherence

Provide clear and coherent curriculum pathways

For each scientific domain, a clear and coherent progression is incorporated within the curriculum structure, and underpinned through documents such as the curriculum narratives (*see page 9*) and resources that support transition across key stages.

High expectations

Hold high expectations, aspirations, and ambitions for all learners

We have high aspirations for all learners, and support them to achieve this with the Developing, Secure, Extending (DSE) framework (*see page* 67). Expectations are clearly defined, and challenge and scaffolding are provided in curriculum resources. Differentiation is opt-in, not by task.

Assessment has a diagnostic purpose, supporting teachers and learners to identify useful next steps, which are also provided with feedback and meaningful intervention. Detailed diagnostic reporting on Kerboodle also supports teachers and learners with high achievement.

Metacognitive learning

Support engaged, self-regulated and metacognitive learning

Self-regulation of learning and metacognitive principles are integrated throughout the curriculum components and resources, and feature in every lesson. Learners are supported with scaffolded resources to develop their metacognitive learning, and teachers are supported to deliver this through targeted resources and extensive professional development (PD).

Learner identity

Promote development of learner identity and identification with each subject

Relevance of Science to learners is integrated throughout curriculum components and resources, including student-facing content on accessible Science and diverse scientists in society.

Support for teachers promoting learner identity and identification with Science is provided through PD and resources like the curriculum narratives (*see page 9*), which explore the impact and relevance to learners' lives and society, and pathways in Science, for each domain.

Responsive teaching and learning

Enable responsive teaching and learning, that continually evolves and improves

The curriculum, resources, assessment, and next steps are all based upon Oxford Smart curriculum data, which drives responsive, diagnostic, and individualised content for both learners and teachers.

Roadblocks or areas of improvement for learners and teachers will be identified through use of the curriculum; this will directly feed into iterative improvement of the curriculum and its resources, and allow further creation of targeted support in the form of resources or PD.

Awe and **wonder**

Stimulate fascination, awe and wonder in discovery of self and the world around us

This is intrinsically linked to development of learner identification with Science, and is integrated throughout student-facing curriculum resources. The curriculum narratives (*see page 9*), teacher resources, and PD also highlight meaningful areas of the curriculum to engage learners in ways specific to different points in their development. Stimulating fascination is also a key aim of the focus on thinking and working scientifically.

Curriculum at a glance

The table below gives a top-level picture of the Oxford Smart Curriculum for Science, showing the topics covered across Key Stage 3 and 4, the development of learner skills and cognition, and demonstrating how each scientific domain (represented by the curriculum narratives) progresses from Primary to the end of Year 11.

	Curriculum narrative (*see page 9*)	Year 7	Year 8	Year 9	GCSE
Biology	How organisms work	Cells Structure and function of body systems	Photosynthesis Respiration	Cells Cells to systems Photosynthesis and respiration	Cell structure and transport Organisation and body systems Organising animals and plants Photosynthesis Respiration Human nervous system Hormonal coordination
	Growth, development, and reproduction	Reproduction in plants and animals		Reproduction	Cell division Reproduction
	Health and disease		Health and lifestyle		Communicable diseases Preventing and treating disease Non-communicable diseases
	Ecosystems and environment		Ecosystem processes Adaptation		Ecosystem processes Organising an ecosystem Biodiversity
	Variation and evolution		Variation and natural selection	Variation and natural selection	Variation Evolution
	Genetics and inheritance		Inheritance		Genetics and inheritance

	Curriculum narrative (*see page 9*)	Year 7	Year 8	Year 9	GCSE
Chemistry	Substances, bonding, and structure	Particles and their behaviour Changes of state	Different materials	Particle model and state changes	Atomic structure Structure and bonding Polymers
	Elements, compounds, and organic Chemistry	Elements, atoms, and compounds	Periodic Table Metals and acids Elements and Groups	Atoms and the Periodic Table	Periodic Table Organic reactions
	Chemical reactions	Reactions and energy transfer Acids, alkalis, and pH		Chemical reactions Word equations and conservation of mass	Chemical calculations Chemical changes Energy changes Electrolysis Rates and equilibrium
	Chemical analysis		Separation techniques		Chemical analysis
	Chemistry of the Earth, and Earth's resources		Earth's atmosphere Climate change Cycles and recycling		Crude oil and fuels Earth's atmosphere Earth's resources Using our resources
Earth Sciences	Earth and environment		Rocks Structure of the Earth		Fossils and life on Earth Material cycling Human impacts on the world, and sustainability Seismic waves Earth's resources Earth's changing atmosphere
Physics	Forces and motion	Forces Balancing forces	Motion and pressure	Forces and motion	Forces in balance Forces and motion Moments and pressure
	Waves	Wave properties Sound Light		Waves, sound, and light	Wave properties Electromagnetic waves Light
	Earth in space	Solar System Earth and the Moon			Space
	Electricity and magnetism		Electricity, circuits, and magnetism	Electricity and magnetism	Electric circuits Electricity in the home Electromagnetism
	Energy		Energy Energy resources Energy and power	Energy	Energy Energy transfer by heating Energy resources
	Atomic, nuclear, and quantum Physics				Molecules and matter Radioactivity

	Curriculum narrative (*see page* 9)	Year 7	Year 8	Year 9	GCSE
Nature of Science and Science identity		Scientific attitudes Experimental skills and investigations Analysis and evaluation Measurement The scientific method, research, and use of models Science capital and Science identity: the value and relevance of Science to me			
Mathematics		Quantitative problem solving Estimations, calculations, equations Recording and interpreting data Understanding number, scale, units		Build on Y7-8 skills Simple probability	
Literacy		Vocabulary Reading and accessing academic texts Complex writing tasks Combine writing and reading Structured talk			
Metacognition and self-regulation of learning		Skills in revision, reading, note taking, scientific working, and evaluating use Focus on individual as a learner Teacher-led reflective questioning Strategy development		Exam skills Advanced task strategy development Higher-order skills	

Coherence across the curriculum, assessment, resources, and professional development

The Oxford Smart Curriculum is built on a rich and expanded definition of curriculum that incorporates content, methods, assessment, professional development, insight and evaluation. Conception of the curriculum, resources, assessment, and professional development as a whole ensures the components work together to support schools to deliver the best for their learners.

Coherence in the Oxford Smart Curriculum for Science has been implemented through:

- provision of clear disciplinary pathways, as shown in the curriculum narratives from page 9
- sequencing of concepts, knowledge, skills, and principles in common across the curriculum, resources, assessment, and professional development
- components work together to enable learners to develop and consolidate knowledge and skills, enabling them to practise and apply their learning, and draw connections
- support to diagnose learner strengths and weaknesses, the misconceptions that are being held and learning gaps, and enabling easy interventions with relevant teaching or resources
- sequencing across Science and Maths to support student understanding of Maths skills in the context of Science.

Curriculum narratives

Overview of curriculum narratives

What are curriculum narratives?

Overarching domain narratives, that provide a macro-level view of a learner's journey through the curriculum for each domain of Science. They give a broad picture of the scope and progression of learning within the curriculum, and articulate the rationale for the inclusion of content. They are divided into coherent domains within each subject area, and set Key Stage 3 learning in the context of prior content covered during Primary and to come during GCSE. For each domain the narratives also provide contextual information, as detailed below, such as wider opportunities for learners to think and work scientifically, and relevancies to their lives to develop their identity in Science.

Learning progression	Details how the domain's substantive knowledge is introduced to learners, explored, and developed, from Key Stage 1 (where appropriate) to the end of Key Stage 4.
Fundamental concept	Short summary of the core substantive knowledge for the domain, at each key stage.
Misconceptions	Some of the most common and key misconceptions learners may have about the domain's knowledge.
Thinking and working scientifically	Opportunities for students to practise thinking and working scientifically in the domain and key stage, encompassing both procedural and epistemic knowledge and competencies.
Science in everything	Gives relevancies of the domain content to learners' personal lives, to wider society, and lists some potential pathways that are related to the domain.
What do we know? How do we know? Why does it matter?	Addresses the rationale behind the knowledge in the domain, and its importance to society and our understanding of the world, demonstrating why our knowledge of Science is crucial.

How did we create them?

The domain Learning progression, content was created using Oxford Smart Curriculum data, which fully maps out all the content and its prerequisite knowledge in each domain of the curriculum from its beginnings to the end of Secondary education. This was combined with an assessment of the knowledge sequencing across our KS3 course. Finally, the full curriculum narratives with their broader contextual content were created using this information, working together with experienced and subject-expert teachers and reviewers.

How have we used them?

The curriculum narratives have helped us ensure effective and coherent sequencing of learning for each Science domain through the curriculum. This has helped align all components of the curriculum and its supporting resources, informing on all curriculum documents, assessment, student resources, and lesson planning. They have also been of crucial importance in ensuring the KS3 curriculum content seamlessly follows on from Science content covered at Primary and supports the Primary-Secondary transition, and enabled us to align with student and teacher needs at GCSE.

How can you use them?

The 'Learning progressions', 'Misconceptions', and 'What/How/Why' sections of the curriculum narratives provide broad-scale information to better equip teachers with making decisions about curriculum pathways, longer-term teaching plans, transition between key stages, and how their teaching can best suit the needs of their learners. The 'Thinking and working scientifically' sections provide suggestions for how teachers can broaden learners' procedural and epistemic knowledge in Science at all key stages, in addition to those detailed within the KS3 course and lesson resources. Crucially, the 'Science in everything' sections give suggestions for how teachers can contextualise the Science content in the curriculum to enable learners to better understand its relevance to their lives and society as a whole. Overall, the curriculum narratives should be used as a tool accompanying other Oxford Smart Curriculum for KS3 Science resources to plan how each domain of Science is approached.

How organisms work

Key Stage 1 *Plants and animals are alive and grow*

Learning progression

Students look at the main parts of plants and animals. These will most commonly have been introduced as young children discover their own bodies and the world around them.

In the earliest years this is at a macroscopic level, looking at structures they can see and touch, such as their head or a tree branch.

Students also explore how they interact with their environment through their senses.

- Sorting things into living and non-living
- Identifying common plants and animals
- Observing animals in different media

In my life: parts of my body; five senses; senses inside and out

In society: plants in our world

Pathways: doctors, nurses, farmers, florists, tree growers, garden centre nurseries, vets

- Plants are not living because living things move and non-living things do not
- All animals are furry and four-legged
- Animals are limited to those in farms and zoos
- Humans and insects are not animals
- Height is always dependent on age
- Men are always taller than women
- A person gets bigger on their birthday
- Only the skeleton is inside the human body
- Death is a reversible process

What do we know? How do we know? Why does it matter?

All living things have certain characteristics that are essential for keeping them alive and healthy, which we can see in the world around us and through comparing living things.

It is important for us to understand this so that we can survive, grow, keep healthy, and look after other animals and plants.

Key Stage 2 *Essential life processes allow plants and animals to move, reproduce, and grow*

Learning progression

Students begin to look at the major organs of plants and animals. They are introduced to the key life processes – in particular, eating, moving, growing, and reproducing – and begin to form links between particular organs and their roles in life processes. Some of the major organ systems and the circulatory system are also introduced at this point. Content is delivered via structures students can visualise or interact with, such as the skeletal system enabling movement, and through the study of body functions with which students are familiar. For example, the digestive system, presented with a focus on mechanical digestion by teeth, is delivered around the time when their own adult teeth are emerging and hence gives students a concrete basis for their developing knowledge.

- Drawing diagrams of living things or systems
- Safe and ethical handling of living things
- Labelling diagrams of organ systems

In my life: bodily functions including eating and drinking; adult teeth emerging and the heart beating; pets in the home; cooking meals in school and at home

In society: seeing animals in zoos or museums; plants and cut flowers at home or school

Pathways: sportspeople, chefs, dentists, zookeepers

- Plants die if they are not kept on a windowsill
- The bigger the plant, the healthier it must be
- Animals and plants only grow upwards
- Seeds come from a packet rather than from an adult plant
- Adult plants will grow without light if they have water
- We see from the eye outwards rather than because light gets into it
- 'A force' comes out of the eye that makes one able to see
- Food travels around the body to give you energy
- Plants only need sunlight
- All animals have skeletons

What do we know? How do we know? Why does it matter?

Every part of a plant has a job to do, keeping it alive and healthy. Plants produce their own food, which is important as food for animals; we know this through observations of our environment, and testing how organisms adapt to different conditions (such as light). Animals need the right types and amount of nutrition to stay healthy, and cannot make their own food; we can compare the things different animals eat.

Key Stage 3 *All living organisms are made of cells*

Learning progression

Cells: Students study cells and learn the fundamental concept that all living organisms are made up of cells. These building blocks of life make up all the major structures in living organisms. This topic ignites a sense of wonder as it introduces students to the new world of life at a microscopic level. Through using microscopes, students can visualise the cell components in which the key processes of photosynthesis and respiration take place – terms they may have encountered at KS2 but lack understanding of. Specialised cells are introduced, along with the movement of substances into and out of cells by the key process of diffusion.

Levels of organisation: Students learn about the levels of organisation within organisms as they study how cells group together to form tissues. The major organ systems are revisited, and knowledge is built relating to the structure and function of key organs, based on pre-existing understanding of each system's purpose. For example, when studying the respiratory system, students begin with the KS2 knowledge that lungs take in oxygen. They then discover in detail how they breathe (including through the movement of their ribs, which they can feel) as well as how the lung is adapted so that oxygen passes efficiently into the bloodstream.

Metabolic processes: Study of digestion focuses on the abstract concept of chemical digestion through enzymes. Photosynthesis and respiration are explored. These abstract concepts require knowledge of chemical reactions, and the use of representative word equations is studied. Ultimately, students begin to consider the links between different life processes in animals and plants. For example, respiration builds on students' prior knowledge of digestion, breathing, and the circulatory system to form a more holistic understanding of how an organism functions.

- Using a microscope to understand cells
- Practising drawing skills to present observations
- Investigating diffusion in fluids
- Observing photosynthesis and respiration in plants
- Discussing similarities and differences between plants and animals
- Applying skills learnt in chemistry to metabolic processes
- Using different models of organ systems to understand function

In my life: experiencing body processes; seeing garden plants and how they grow; participation in physical activity and sports; considering how we decide what we eat and drink

In society: smells diffusing across a room; people with conditions that affect organ system function, such as asthma or coeliac disease

Pathways: personal trainers, PE teachers, sportswear designers, farmers, gardeners, surgeons, physiotherapists, builders, and people that do heavy lifting

- Breathing and respiration are the same thing
- Only animals respire
- Plants only photosynthesise, and do not respire
- Plants respire only in the daylight
- Only organisms with lungs can respire
- Plants obtain water through their leaves when it rains
- All cells have a nucleus
- Any small molecule can pass through a cell membrane
- Particles actively seek isolation or more room
- Diffusion occurs quickly
- Plant mass only comes from the water and minerals from the soil
- Anaerobic respiration only takes place when there is no air
- Food enters the blood stream from the stomach
- Arteries only carry oxygenated blood; veins only carry deoxygenated blood
- Muscles contract and expand to cause motion

What do we know? How do we know? Why does it matter?

Multicellular organisms are composed of cells, which are then organised into tissues, organs, and organ systems; we know this through investigations of anatomy and function. There are many different types of cell; we can observe them using a microscope. Each cell has a different structure or feature so it can do a specific job. Specialised cells and systems are essential for all life, and allow further understanding of Earth's biology.

Key Stage 4 *Structural differences between cells enable them to perform specific functions within an organism*

Learning progression

Cells and transport: Students look again at cells and sub-cellular structures. Using electron microscopy, more structures within the cell, such as ribosomes, are studied by scientists. Plant and animal cells (eukaryotes) are compared with those of prokaryotes. Osmosis, building on knowledge of diffusion, and active transport are introduced as mechanisms for moving substances into and out of cells. Students finally move on to study how cells divide and differentiate, and consider the roles of stem cells. Micrographs help students visualise the various structures and processes.

Organ systems: Students return to key organ systems in plants and animals in greater depth, building on the understanding gained in KS2 and KS3. For example, transport systems in both animals and plants are studied, as well as the factors which affect the rate of enzyme-controlled reactions in digestion.

The main structures in the nervous and endocrine systems are introduced, and parallels drawn in their control of the body's response to stimuli. This section of work includes the study of plants' trophic responses to stimuli.

Metabolic processes: The key chemical reactions, photosynthesis and respiration, are revisited in more detail, including their representation by chemical formulae. Factors limiting the rate of photosynthesis are studied, including the application of this knowledge commercially to maximise crop yields.

Homeostasis: Finally, the principle of homeostasis is developed from an understanding of an automatic control system. Specific examples contextualise this knowledge, with students examining the control of body temperature (nervous system) and blood glucose levels (hormonal system).

- Models of systemic/metabolic processes
- Microscopy to observe, draw, and measure cells
- Researching the uses of stem cells
- Understanding the importance of metabolic processes for evolution
- Investigating osmosis in plants
- Linking enzyme activity to rates of reactions in chemistry
- Investigating changing conditions and their impact on photosynthesis
- Measuring the reactions of different organisms to stimuli
- Exploring the importance of pH in a biological context

In my life: choosing clothes to cope with being too hot or too cold; reflex reactions when touching a stimulus; visiting the GP surgery or hospital

In society: stem cell research in the news, including using stem cells to propagate crop plants; farming practices and agricultural development; impact of health conditions that affect diet, such as diabetes and food allergies; the food manufacturing industry; homeostasis during extreme activities

Pathways: medical careers, anatomists, lab workers, science teachers, chefs, food industry workers, horticulturalists, gardeners, farmers, brewers

- Enzymes are alive
- Respiration occurs only in the lungs
- The cell cycle and mitosis are the same
- Cell division and cell differentiation are the same
- Plants do not have chromosomes
- Plants only respond to light stimuli
- The optimum temperature for all animals is the same
- Temperature is the only thing we need to maintain by homeostasis
- Reflexes are conscious
- You grow out of reflexes as you get older
- Hormones affect the body faster than neurones
- Hormones affect the whole body
- Males and females have identical hormone-secreting glands
- Core body temperature is the same as skin temperature

What do we know? How do we know? Why does it matter?

Structural differences between types of cells enable them to perform specific functions within organisms, which we know through laboratory investigations and observations under a microscope at high magnifications; this differentiation means organisms can be extremely complex. For an organism to grow, cells must divide by mitosis; microscopy investigations of cell division reveal this process, which is important for growing cells in labs for research, farming, and healthcare. Knowledge of stem cells and cell specialisation has led to stem cell technologies that may have crucial medical applications.

Growth, development, and reproduction

Key Stage 1 *Plants and animals grow and change as they get older*

Learning progression

Students are aware of the concept of growth and development from a very early age, as they track their own growth, as well as key developmental milestones. Young children have a strong natural desire to discover the world in which they live.

Throughout KS1 this curiosity is nurtured and students are encouraged to look more deeply at how particular organisms grow and develop. The concept of life cycles is introduced, with many students observing first-hand the main steps in the life cycles of insects and amphibians, developing wonder and curiosity.

- Observing a life cycle, for example, butterflies or frogs
- Observing seeds growing into adult plants
- Measuring the height of plants and animals
- Investigating what seeds need to grow into plants

In my life: measuring height on a chart; meeting developmental milestones such as riding a bike or writing their name; growth of siblings

In society: animals and plants in the world around us; seasons and changes in growth; visit to an allotment, farm, or commercial nursery

Pathways: parents, farmers, health visitors, teachers

- All seeds need light to germinate
- All life cycles begin with an egg
- All life cycles begin with birth and end with death
- You grow on your birthday
- Seeds are not alive
- Roots grow into the ground to get food
- Flowers must be coloured
- All fruits are edible
- Plants receive their food from the soil
- Animals always get better at things as they get older

What do we know? How do we know? Why does it matter?

Many types of living things have life cycles taking them through a number of stages, from birth to death. During this time, they grow and change. We know this through first-hand observation and measurement or second-hand observation from watching film clips. It is important as it allows us to determine whether organisms are healthy and growing properly.

Key Stage 2 *Plants and animals produce new offspring by the process of reproduction*

Learning progression

Students look in more detail at how reproduction occurs. This introduces more abstract concepts. For example, they are encouraged to look in increasing detail at a flower; they personally observe the stamens and pollen, but also meet the more abstract concepts of pollination and fertilisation. Students develop their ideas of life cycles further, considering and, where possible, observing similarities and differences in the life cycles of types of animals. Reproduction in humans is also introduced, normally in conjunction with PSHE puberty sessions. This begins by looking at the physical and mental changes students are currently undergoing as they enter adolescence. Students discover the main structures in the male and female reproductive system alongside a simple explanation of the events of pregnancy and birth.

- Observing and drawing the structures of a flower
- Finding out about the work of people who study animal and plant lifecycles
- Drawing timelines to indicate growth and development in humans and other organisms, including both plant and animal life cycles

In my life: birth of a family member and growth of younger and older family members; body changes during puberty

In society: growth of puppies and kittens; seeing larvae or tadpoles change as they grow; change in growth of plants and trees in spring/autumn; nature documentary programmes; breeding programmes (e.g., breeding dogs, cats, hamsters, etc. as pets); plant nurseries and garden centres; farming and conservation

Pathways: school nurses, midwives, animal behaviourists, naturalists, vets, nurses, nursery or care assistants

- Flowers are for people to enjoy
- Pollen is a food source for bees
- Pollination is the same as seed dispersal
- Pollination and fertilisation are the same process
- Plants do not reproduce sexually
- All forms of reproduction are sexual
- Babies develop inside their mother's tummy (when used to mean stomach)
- All new offspring have to be born
- All fruits grow on trees
- All life cycles begin with birth and end with death

What do we know? How do we know? Why does it matter?

Plants and animals produce new offspring by the process of reproduction. This often involves cells from a male and a female parent joining together. We know this through observations of plants and animals, including people. It is important for the continuation of a species. Organisms reproducing provides resources, such as food and building materials.

Key Stage 3 *Fertilisation of gametes is required in the process of sexual reproduction*

Learning progression

Reproductive systems: Students look at the structure of both the human and plant reproductive systems in more detail. The main stages of puberty and the menstrual cycle are also introduced, along with the role hormones play in them. Students identify the role of all the key reproductive structures. In humans, they focus on gestation and birth, including how the mother's lifestyle affects the fetus through the placenta.

In plants, they focus on how flower structure is adapted for insect or wind pollination, and adaptations for seed dispersal.

Gametes: The roles of sperm and egg cells in transferring genetic information between parents and their offspring are introduced, as well as the fact that sex hormones control this process; however, at this stage students are not required to understand details of how these chemicals work or interact, for example, in the menstrual cycle.

Fertilisation: The abstract concept of fertilisation in both plants and animals is also studied in more detail, using annotated diagrams of processes they cannot see, but based on words with which they are becoming more familiar. This core concept provides the basis for understanding much of inheritance. Methods of preventing fertilisation in humans through contraception are also introduced.

- Quantitative investigation of seed dispersal mechanisms
- Dissecting flowers to observe ovules in the ovary
- Investigating germination in plants
- Research into gestation periods in other animals
- Linking prior knowledge of cells and sub-cellular structures to the concept of reproduction
- Appreciating scale of small structures
- Using specific scientific vocabulary to communicate ideas and information

In my life: physical and emotional changes during adolescence; hay fever from pollen; visits to zoos or safari parks

In society: food sustainability; importance of pollinators and effects of declining bee populations; impacts of pregnancy and ways of preventing unwanted pregnancy; different methods of contraception; breeding programmes, including for food sustainability or conservation

Pathways: supermarket food buyers, school counsellors, radiographers, GPs, obstetricians, gynaecologists, nurses, animal breeders, beekeepers, fruit growers, dieticians, lab technicians, midwives

- Pollen grains move down the pollen tube
- Bees are the only insects that pollinate flowers
- All flowers are pollinated by insects/bees
- Adolescence occurs in the teenage years and ends at either 18 or 21 years
- Periods start only in your teenage years
- All methods of contraception are 100% effective
- The mother's blood and baby's blood mix at the placenta
- Sexual reproduction always involves sexual intercourse
- The uterus is lost during menstruation
- A fetus is not alive
- You can't get pregnant the first time you have sex
- You can't get pregnant standing up
- You are most fertile when you are having a period

What do we know? How do we know? Why does it matter?

During sexual reproduction, gametes are produced. These fuse together during fertilisation, leading to the formation of offspring. In humans the fertilised egg implants in the uterus where it is supported by the mother until it develops to a stage where it is ready to be born. In plants, the fertilised ovules develop into seeds, which are dispersed away from the parent plant before germinating. We know this through observations of plants and animals, through microscopy, blood analysis, and ultrasound scans of pregnant women.

Key Stage 4 *Organisms reproduce using sexual or asexual reproduction*

Learning progression

Hormones involved in reproduction: Students look at the hormonal control of reproduction, starting with the changes in levels of testosterone and oestrogen, which trigger the onset of puberty. This concept is presented first as it looks at the effects of one hormone at a time and the physical results can be seen.

The hormonal control of the menstrual cycle is then covered as this requires students to understand the interaction of four hormones.

Manipulating fertility: Students are introduced to the use of hormones in both fertility treatments and contraception.

Asexual and sexual reproduction: Students focus on the difference between asexual and sexual reproduction in plants and animals. The advantages and disadvantages of both mechanisms are discussed.

Fertilisation is looked at in more detail by studying the production of gametes by meiosis and the random variation caused in sexual reproduction. This has strong links with the genetics and inheritance domain and requires basic understanding of chromosomes.

- Observing asexual reproduction through cloning or budding under the microscope
- Synthesising knowledge of cells, sub-cellular structures, and genetics
- Applying knowledge of hormonal control to a life process
- Appreciating that scientific understanding evolves as a result of new discoveries or technology
- Developing an understanding of the ethical considerations involved with fertility treatment

In my life: hormonal effects on the body through puberty

In society: growing plants from cuttings/tissue cultures; IVF and advances in fertility treatments; importance of contraception in family planning; applications of the management of reproductive rates, for example in food storage

Pathways: lab technicians, reproductive endocrinologists, midwives, horticulturalists, GPs, commercial growers, embryologists, fertility specialists, fertility marketing/administration/advertising, gynaecologists

- Reproduction is having babies
- Asexual reproduction is only performed by bacteria
- Women can only get pregnant at the point of sexual intercourse
- Organisms reproduce either sexually or asexually, but not both
- Males do not produce any oestrogen
- Women do not produce any testosterone
- IVF involves the use of test tubes to produce 'test-tube babies'

What do we know? How do we know? Why does it matter?

Asexual reproduction requires only one parent; there is no mixing of genetic information and so genetically-identical offspring are produced. Sexual reproduction requires two parents; when the gametes fuse, genetic information is mixed, resulting in non-identical offspring. Reproduction is controlled by hormones and can be manipulated artificially to increase fertility as well as to prevent pregnancy. This is important in family planning, and in helping couples to conceive who may otherwise be unable to start a family. The stages of sexual and asexual reproduction can be observed on a cellular level using a microscope, and by measuring hormone levels in the blood.

Health and disease

Key Stage 1 *Exercise, good hygiene, and eating the right food keeps you healthy*

Learning progression

Students learn what they need to do to keep their body healthy, in terms of regular exercise, eating the right amounts of the right foods, and maintaining good body hygiene. These are factors some students will be aware of from their home environment, but they will be reminded of their importance through good routines at school such as regular handwashing, PE lessons, and lunchbox requirements.

- Asking questions about keeping healthy
- Practising good hygiene techniques

In my life: eating healthy foods; washing; playing outside; going to playgrounds; trip to a swimming pool

In society: government campaigns (e.g., hands, face, space)

Pathways: nurses, cleaners, sports coaches, cooks

- The only healthy foods are fruits and vegetables
- You should never eat any unhealthy foods
- Dieting is needed to lose weight
- A diet is eating less food to lose weight

What do we know? How do we know? Why does it matter?

Exercising regularly, eating the right amounts of different types of food, and maintaining good personal hygiene help keep us healthy.

We know this from information given to us by healthcare professionals, who have studied the effects of food and exercise on the human body; it is important for preventing us from getting ill.

Key Stage 2 *Diet, exercise, drugs, and lifestyle affect body function and health*

Learning progression

The concept of a balanced healthy diet is introduced where students begin to look more closely at food groups, such as fruits and vegetables (specific scientific names for food groups are not required at this level), and the components of different foods such as proteins, vitamins, and carbohydrates. Students are taught the groups' roles in the body, and the proportion of the diet they should make up. An emphasis is placed on the importance of healthy eating; the need to exercise regularly, along with sleeping well, is reinforced for the development of a healthy lifestyle. The importance of teeth cleaning links lifestyle to both KS1 hygiene and work on teeth. Students also begin to look at the impact drugs can have on the body. This is presented to students in a positive manner, by looking at common medical drugs, and negatively by studying the effects of smoking and drinking alcohol (but with sensitivity).

- Researching different types of diet
- Grouping animals according to what they eat
- Researching the negative effects of some drugs
- Observing teeth and investigating the effect of teeth cleaning

In my life: cleaning teeth; choosing healthy meals/cooking at home; visits to the dentist

In society: governmental campaigns (e.g., 'Change4Life'); scientific research on links between diet, drugs, or exercise on health; sports personalities' discussions of diet and exercise routines

Pathways: dieticians, PE teachers, dentists, sportspeople, dental nurses, hygienists, cleaners, cooks

- Water is a form of food and can give you energy
- Vitamins and minerals are only found in fruits and vegetables
- All fats are bad
- Antibiotics can be used to treat colds and flu
- Colds are caught from being out in the cold
- Alcohol is not a drug
- All drugs are harmful

What do we know? How do we know? Why does it matter?

A balanced diet, regular exercise, and sleeping well help to keep us healthy. Some drugs are used to treat diseases, but others have a negative effect on health. We know this from observations and information given to us by healthcare professionals based on research about diet, exercise, and drugs, and this is important for preventing disease.

Key Stage 3 *Eating an unbalanced diet can result in obesity or deficiency diseases*

Learning progression

Diet: The concept of a healthy diet is revisited through the study of all the major food groups, looking in detail at their roles in the body and other living organisms.

A person's dietary energy requirements are calculated based on, for example, their gender, job, or age; students then discuss what happens if a person takes in too much or too little energy.

The topic concludes by linking specific health issues caused by a poor diet to their cause, such as a particular mineral deficiency or the strain placed on an organ through being obese.

Drugs: Building on knowledge from KS2, the specific effects of common recreational drugs on behaviour, health, and life processes are then explored. The impacts of misusing and the side effects of medicinal drugs are also highlighted. This requires a general understanding of many of the body's major organs and organ systems. Many of these issues will be reinforced through PSHE lessons during this time as it is important that students are aware of consequences that may occur from the decisions they make.

- Classifying foods into food groups
- Detecting the presence of food groups in a food sample
- Linking physics knowledge of the energy required for an object to do work with a person's daily energy requirements
- Researching the effects of taking specific illegal drugs
- Calculating energy content of food through burning
- Measuring reaction times

In your life: maintaining a healthy weight and lifestyle; drinking coffee; taking antibiotics or painkillers; reading food labels; doing exercise or visiting a gym

In society: obesity studies and BMI calculations; images of starvation in areas experiencing famine; drug support groups, such as Alcoholics Anonymous; drink-driving/stopping smoking adverts and campaigns

Pathways: dieticians, chefs, doctors, personal trainers, physiotherapists, psychiatrists, cardiologists, drug counsellors, social workers, pharmacists

- Caffeine is not a drug
- All recreational drugs are illegal
- Males always have a higher energy requirement than females
- Overweight people have 'big bones'
- Alcohol is not harmful
- Medicinal drugs do not have any negative medical effects
- You only put on weight if you eat a lot of fatty foods
- You can't put on weight if you only eat healthy foods

What do we know? How do we know? Why does it matter?

A balanced diet means eating food containing the right nutrients in the correct amount. The failure to do so can result in conditions such as obesity or deficiency diseases. Medicinal drugs are used to benefit health and can be used to treat disease, whereas recreational drugs are used for enjoyment. However, both can have some negative effects on health. We know this from observations and information given to us by healthcare professionals about the effects of an unbalanced diet, and this is important for preventing and treating disease.

Key Stage 4 Communicable and non-communicable diseases are major causes of ill health

Learning progression

Cardiovascular disease: After studying the structure and function of the circulatory system, students are made aware of a range of health problems linked to this system, through looking at their causes and possible treatments. This acts as an approachable introduction to more challenging content later in the unit.

Communicable diseases: Communicable diseases are studied in detail before non-communicable diseases, as students are likely to be more familiar with these. For each type of microorganism, human diseases are introduced first and then the knowledge applied to plant diseases.

Physical methods for preventing the spread of disease are examined before students move on to look at the more abstract concept of the body's defence systems.

The primary physical defences are introduced first, in both plants and animals, before the role of the human immune system is studied. Students become aware of the impact of plant diseases on food security.

Once students develop an understanding of the role of white blood cells and the immune system, the mechanism by which vaccines work is presented.

The uses of medicinal drugs are revisited using familiar drugs, such as antibiotics, before learning how new drugs are discovered, safety tested, and licensed for use.

Students are brought up to date with the latest research into treatments using monoclonal antibodies.

This concept requires detailed understanding of the very abstract concepts of antibodies and antigens taught in body defenses.

Non-communicable diseases: These are looked at from the viewpoint of risk factors to health, many of which are familiar from work covered in earlier key stages. There is a focus on cancer, which requires knowledge of the cell cycle. Other non-communicable diseases are then introduced, following the teaching of the healthy function of body organs. For example, knowledge of normal kidney function is required before students can understand how a dialysis machine functions, and a knowledge of the hormonal control of insulin before explaining diabetes.

- Using aseptic techniques to grow bacteria
- Testing the effectiveness of disinfectants and antibiotics on bacterial growth
- Research into major scientific breakthroughs in preventing and treating disease, such as those of Fleming and Semmelweis
- Categorising diseases into communicable and non-communicable
- Testing for the presence of sugars, proteins, and lipids

In my life: common infections (e.g., cold, flu); living through the SARS-CoV-2 pandemic and practising hands, face, space; lifestyle choices from coffee drinking to smoking, alcohol, and illegal recreational drugs; having vaccinations; using hand sanitiser; visiting a GP or pharmacist

In society: SARS-CoV-2 pandemic; drug trials and new drug development; lifestyle choices of family and peers around you

Pathways: epidemiologists, endocrinologists, microbiologists, vaccinators, plant scientists, market gardeners, farmers, pharmaceutical scientists, healthcare workers, medical equipment producers, medical policy workers, lab technicians, phlebotomists, GPs, pharmacists

- All bacteria are harmful
- Bacteria are not normally found inside the human body
- Mutations are not random
- Only obese adults get diabetes
- Diabetes is caused from eating too much sugary food
- Heavy smokers will all develop lung cancer
- Organs can only be donated after a person has died
- All diseases are infectious
- Diseases only affect animals

What do we know? How do we know? Why does it matter?

Health is a state of physical and mental well-being and is affected by a person's lifestyle. Diseases are either communicable or non-communicable, and both types are major causes of ill health. There are several types of immune response in both plants and animals, and these are crucial to the health of organisms. We know this from observations and information given to us by healthcare professionals, and the body of research surrounding diseases. It is important knowledge to enable the development of new treatments for diseases, and to help prevent their occurrence. Knowledge of plant diseases and deficiencies is crucial for modern farming and food production.

Ecosystems and environment

Key Stage 1

Plants and animals live in a habitat, which provides them with the things they need to survive

Learning progression

Students' natural curiosity about the world around them is nurtured, through the hands-on discovery of organisms that live in their immediate surroundings, as well as photos and videos of plants and animals living in more exotic habitats. Students look at the basic needs of plants and animals and begin to discover that organisms live in habitats that are suited to their needs. They begin to consider the interdependence between animals and plants. The abstract concept of using a diagram to represent a process is introduced through simple food chains, normally represented pictorially at this level.

- Identifying common organisms
- Discussing what organisms need to survive
- Safe and ethical handling of living things

In my life: seeing animals and plants in the garden and environment around you such as pets; visits to zoos, parks, school grounds

In society: TV nature documentaries

Pathways: caretakers, groundskeepers, conservation workers, wildlife rangers, gardeners, farmers

- Humans are not animals
- All animals are furry and four legged
- Plants do not need animals to survive
- Only animals have a habitat

What do we know? How do we know? Why does it matter?

The place where a plant or animal lives is known as its habitat, which provides it with the things it needs to survive. Within a habitat, the organisms depend on each other to survive. We know this from observing the plants and animals that are found together in the wild. It is important for us to understand this so we can look after the habitats of all plants and animals.

Key Stage 2

Animals and plants are adapted to the habitat in which they live

Learning progression

Students observe further how organisms interact with their environment and with each other. Through the use of scientific equipment they investigate habitats, introducing at a simple level the concept of taking a sample.

Students look at the main differences between predator and prey organisms. This links to their work on teeth and provides an introduction to structural adaptations. This work is further developed by students looking at the adaptations of plants and animals living in particular environments, such as the Arctic. They build on earlier work on food chains, enabling students to identify the different trophic levels within the chain. Students also begin to construct their own food chains based on supplied information or their own knowledge.

- Investigating habitats and measuring factors that affect organisms
- Using identification keys to identify unknown organisms
- Taking a sample of a habitat using equipment such as pooters

In my life: seeing invertebrates in the garden or nearby areas; taking part in conservation work, such as building bug houses, litter picking; visits to zoos, safari parks, or botanical gardens

In society: news stories about climate change and extinction; books and TV programmes about specific adaptations in different organisms

Pathways: National Trust, forestry commission, conservationists, museum curators, ecologists, farmers

- Animals choose to adapt to suit their surroundings
- Deserts are always hot
- In food chains, arrows show what an organism eats so point at that organism
- Food chains involve only predators and prey, but not plants
- Only predators can run fast
- Plants are prey organisms
- A cactus does not have leaves
- A camel's hump stores water

What do we know? How do we know? Why does it matter?

Plants and animals are adapted to the place in which they live. This increases their chance of survival. We know this through taking samples from or observing habitats, and looking at the animals and plants present. It is important to gain an appreciation of the human impact on biodiversity, and our role in preserving species adapted to specific environments.

Key Stage 3 *Organisms within an ecosystem are interdependent and those best adapted survive*

Learning progression

Food chains and webs: Food chains are revisited, introducing the concept of biomass transfer between organisms. Food chains are then interlinked to form food webs, which enable students to model feeding relationships with an ecosystem more effectively.

Earlier work on interdependence is developed further, using the example of insect pollination to illustrate this concept. Students start to predict how the effect of environmental changes on one organism can have a knock-on effect on others in the food web. The concept of bioaccumulation is also developed.

Adaptation and competition: Students are introduced to the principles of competition between organisms, with simple plant and animal examples; the work then builds on their knowledge of adaptations to generate ideas behind the concept of 'survival of the fittest'.

Predator-prey relationships: Building on their knowledge of predator and prey organisms, students consider the interdependence of organisms on a more abstract basis using data, representing the changing patterns of predator-prey relationships graphically.

- Using diagrams to model biomass transfer through living organisms
- Observing adaptations in common organisms
- Interpreting diagrammatic representations of feeding relationships
- Using graphs to model predator-prey relationships
- Research into the adaptations of less well-known animals and plants
- Using quadrats to sample the plants present in an environment
- Manipulating data collected using quadrats

In my life: visits to local conservation/environmental projects; vegetarian and vegan human diets

In society: seasonal changes in plants and animals interactions in local habitats; predator and prey organisms as pets; real world examples of bioaccumulation (e.g., mercury in fish); importance of bees in crop production; concept of food security

Pathways: conservationists, statisticians, environmental scientists, park rangers, animal technicians, vets, ecologists, animal and crop farmers, policy makers, fishing industry

- Non-farmed food products are always better for you
- A cactus does not have leaves
- Adult animals do not change their appearance
- Camouflaged animals are brown or green
- Plants cannot defend themselves against herbivores
- Food webs are interpreted as simple food chains, rather than a flow of biomass
- Organisms higher in a food web eat all organisms that are lower in the food web
- Carnivores are big and ferocious; herbivores are small and passive
- Predator and prey populations are similar in size

What do we know? How do we know? Why does it matter?

Organisms within an ecosystem are interdependent. Those best adapted to their environment are better competitors and therefore have an increased chance of survival. We know this through observations and data analysis, such as investigations of predator/prey populations. It is important to understand the interdependence of plants and insects for food security. We also need to recognise the harmful effects pollution and pesticides can have on untargeted organisms through bioaccumulation.

Key Stage 4 *Organisms within an ecosystem are affected by abiotic and biotic factors*

Learning progression

Ecosystem organisation: Students' study of ecosystems begins by looking at communities and the abiotic and biotic factors that affect them, building and deepening students' knowledge of interdependence and competition. Students confirm their models by sampling their environment.

In addition to the structural adaptations already familiar to students, the concept of adaptation is revisited by looking at behavioural and functional adaptations, including those of extremophiles.

Biomass transfer: Students revisit the transfer of biomass between organisms in food chains, assigning organisms to trophic levels, and studying in detail why the available biomass diminishes at each trophic level.

Food security: Food security is having enough food to feed a population now and in the future. Students study how food security may be affected by biological factors, including the increasing human birth rate, and environmental factors such as drought or increasing temperatures.

Together with work on biomass transfer, this forms the basis for investigating efficiency in food production, and steps to increase food security. Methods of sustainable food production are studied, including the use of biotechnology, applying students' knowledge of genetic engineering.

- Using sensors to monitor abiotic factors
- Measuring the abundance and distribution of organisms using quadrats
- Understanding and using the principle of random sampling
- Understanding bias
- Sampling an ecosystem along a transect
- Representing feeding relationships through constructing pyramids of biomass
- Calculating percentage biomass transfer in a food chain
- Appreciating ethical considerations of animal food production

In my life: changing to vegetarian and vegan products or alternatives, such as mycoprotein; considering sustainability and modern eating habits

In society: observing bird migration and animal hibernation; sustainable food production such as fishing quotas; biological pest control; intensive versus organic farming; GM crops

Pathways: dieticians, supermarket food buyers, chefs, ecologists, conservationists, environmental biologists, naturalists, wildlife photographers, microbiologists, fishing industry, policy makers, animal and crop farmers

- All human impacts on or changes to the environment are negative
- Biodiversity refers to the range of animals present in an area
- Ecosystems are simply a collection of organisms
- Ecosystems change little over time
- Biomass accumulates in an ecosystem so that a top predator has all the biomass from the organisms below it
- Vegetarian and vegan diets are healthier than eating meat
- 'Low food miles' products always have a smaller environmental impact

What do we know? How do we know? Why does it matter?

Organisms within an ecosystem are affected by both abiotic and biotic factors. Materials are transferred through ecosystems; however, biomass diminishes at each trophic level as not all biomass is passed on. We know this from observations within an ecosystem, and through collecting data about organisms and their environment, for example, population levels in polluted areas compared to conserved areas. This is important as it forms the basis for investigating efficiency in food production and steps to increase food security.

Variation and evolution

Key Stage 1 *Plants and animals can be grouped by similar features*

Learning progression

Students are encouraged to use their natural curiosity to find similarities both between groups of plants or animals, and between different species of these organisms. This early introduction to classification focuses mainly on visual characteristics such as the differences between deciduous and evergreen trees, and the five vertebrate animal groups. Students are then introduced to classification from a more abstract perspective by examining less visible characteristics such as the dietary adaptations of carnivores, herbivores and omnivores, including their teeth and their behaviour.

- Grouping plants and animals based on observations of their appearance
- Grouping animals by observation of their diet and behaviour

In my life: wildlife and plants found in the garden, school grounds, local park, or countryside; pets, farm animals and zoo animals seen in real life; visit to your own garden, countryside, park, or forest

In society: range of organisms in the natural world; nature documentaries and books

Pathways: pet shop assistants, zoo keepers, farmers, gardeners

- Humans are not animals
- Only large land mammals are animals
- All animals are furry and four-legged
- Snakes are slimy and feel cold to touch
- There are three groups of living organisms: animals, humans, and plants

What do we know? How do we know? Why does it matter?

Plants and animals are all different, and these differences can be seen in how the organism looks, or how it behaves. We know this through first-hand observations and looking at photos or videos.

This is important so that we can sort organisms into groups who share similar characteristics, to understand the world around us and what characteristics are needed to survive in different ecosystems.

Key Stage 2 *Living organisms vary; those that are better adapted survive and breed*

Learning progression

Students look more closely at an organism's structure when using classification keys. They then use these detailed observations to classify the organisms into smaller groups, such as invertebrates into insects and spiders, giving reasons for their decisions.

Students are introduced to the concept of variation by looking at similarities between themselves and their siblings or cousins. This is then applied to other species.

Building on their knowledge of fossils, students are made aware of how living things have changed over time. They are encouraged to link their understanding of adaptations and variation, ultimately building the idea that differences in offspring over time can make organisms more or less able to survive. This forms an introduction to the concept of evolution.

- Using classification keys to identify unknown organisms
- Classifying vertebrates and invertebrates
- Safe and ethical handling of living things

In my life: similarities and differences in siblings'/cousins' characteristics; visit to a museum or area containing fossils; pond dipping

In society: variety of characteristics in a litter of puppies or kittens; fossils of dinosaurs and other organisms; nature documentaries

Pathways: ecologists, conservationists, park rangers, palaeontologists, museum curators

- Animals choose to adapt to suit their surroundings
- Evolution no longer occurs
- The Earth is only several thousand years old
- All organisms on the Earth are unchanging; they have always had the characteristics we see today
- Penguins and turtles are amphibians because they are both in and out of water
- Whales, jellyfish, and starfish are all fish
- Humans are not mammals

What do we know? How do we know? Why does it matter?

Living things are classified into broad groups according to observable characteristics and based on similarities and differences. Living things have changed over time, and fossils provide evidence for this process. We know this through studying both living organisms and fossils. This is important for our understanding of how life has developed on Earth.

Key Stage 3 *Species evolve through the process of natural selection*

Learning progression

Variation: Differences within and between species are revisited when students study the genetic and environmental causes of variation within a species. The concept of breeds or varieties is discussed as a way to recognise variation within a species.

These ideas are further developed into an understanding of continuous and discontinuous variation through the measurements of common characteristics in plants and animals. The data developed are displayed graphically, helping students visualise this abstract concept.

Natural selection and evolution: Students may be introduced to the evidence-based concept that all organisms evolved from unicellular organisms. Building on students' knowledge of variation and adaptation, the process of natural selection is presented. This is often illustrated by concrete, evidence-based studies, such as the example of peppered moths, applying ideas of evolution to a timescale that students can comprehend. Changes in other species, shown using the fossil record, can then be explored. This discussion should include our understanding of evolution, natural selection, and biodiversity and how it has changed over time, including the work of Charles Darwin and Alfred Russell Wallace.

Extinction: Students discover some of the factors that can lead to extinction (a consequence of natural selection), including the impact of humans, and some of the techniques being used to prevent further extinctions. This includes discussing the benefits and drawbacks of captive breeding programmes, and their role within conservation, along with other methods to preserve biodiversity.

- Linking knowledge of the genetic causes of many characteristics to the existence of variation
- Investigating variation within a species
- Representing continuous and discontinuous variation graphically
- Research into different theories of evolution
- Appreciating the timescale over which evolution normally occurs and that this varies depending on the size and life cycle of the organisms

In my life: thinking about scientific and religious beliefs about creationism; comparing own characteristics with those of their peer group; visits to zoos and seed banks as centres of conservation of DNA; visit to a safari park or breeding centre

In society: breeding programmes of domestic pets and plants; identical twins; endangered species; application of statistical models to unfamiliar situations; citizen science biodiversity projects, such as the garden bird and butterfly counts

Pathways: conservationists, geneticists, environmental scientists, statisticians, ecologists, molecular biologists, vets, zoo keepers

- Evolution happens in individuals rather than populations over time
- Characteristics are all caused by genetics
- When organisms are no longer found in one area of the world, they have become extinct
- Species are organisms that can reproduce, for example, a donkey and a horse are the same species
- The theory of evolution encompasses how life began
- 'Survival of the fittest' relates to strength and dominance between individual organisms
- Modern humans have stopped evolving
- Evolution and natural selection are the same thing

What do we know? How do we know? Why does it matter?

Variation within a species occurs as a result of differences in genetic material and/or environmental causes. The organisms that are better adapted to the environment survive and pass on their genes. This leads to evolution through the process of natural selection. We know this through observations of living organisms and by studying fossils. This is important for understanding how organisms have changed over time and for appreciating that evolution is a continuous process.

Key Stage 4 *Organisms are now classified according to similarities in characteristics and evolutionary links*

Learning progression

Natural selection: The concept of natural selection is revisited in greater detail, looking at mutation as a cause of genetic variation. Students develop understanding that, in rare cases, genetic variation leads to physical adaptations that increase the chances of survival in a given environment, and of how this process can be harnessed for the benefit of humans through selective breeding.

Theories of evolution: The different theories of evolution that were proposed by Lamarck, Darwin, and Wallace are explored further. Students consider the evidence presented that has led to our current understanding. Students are also challenged to understand how further scientific advances, alongside Darwin's original evidence, have developed these ideas over time – reflecting the scientific method. Students also study the evolution of antibiotic-resistant bacteria as a current example of evolution, and how natural selection can result in speciation.

Classification systems: The topic of classification is revisited through a detailed look at the Linnaean classification system, and the binomial system for naming organisms. Students' knowledge is brought up to date with the current scientific understanding of classification, based on Woese's three-domain system, taking into consideration similarities in both physical characteristics and evolutionary links determined through DNA studies, biochemical analysis, and fossil evidence. This work concludes with the abstract concept of evolutionary trees; students use these to map and study evolutionary relationships between different organisms, bringing together work on genetics, morphology, and evolution.

- Research into different theories of evolution
- Interpreting evolutionary trees
- Appreciating that scientific models and theories change over time in light of new technology and developments
- Understanding the timescales for evolution
- Using knowledge of bacterial replication to explain how antibiotic-resistant bacteria can evolve in a short period of time
- Understanding the importance of collaboration and peer review in developing new theories

In my life: visits to biological research facilities or university laboratories

In society: moral perspectives on harnessing 'ideal' characteristics in a species; animal breeding – farm animals, pedigree dogs; Darwin and Wallace; MRSA and SARS-CoV-2 in the news; genome sequencing

Pathways: farmers, animal breeders, biochemists, molecular biologists, geneticists, conservationists

- Positive mutations are a response to a change; they do not occur without a stimulus
- Individual organisms develop adaptations to their environments (Lamarckism)
- Darwin gathered all of his evidence to support the theory of evolution by natural selection while in the Galapagos Islands
- Evolution only occurs slowly, or gradually
- Scientists have never observed the formation of a new species in the wild
- Individual organisms evolve to become better adapted
- Bacteria become immune to antibiotics
- Changes to an organism are always passed on to their offspring
- Genetic mutation is always a bad thing
- The fossil record preserves everything that has lived

What do we know? How do we know? Why does it matter?

Organisms are usually classified by looking at their genomes and physical characteristics. We are able to do this through observations of organisms and fossils, DNA studies, and biochemical analysis. Classification is important as it makes it easier for organisms to be studied, provides scientists with a common language, and enables us to recognise the biodiversity present in the world. Studying the process of evolution in populations is also vital for measuring how ecosystems are coping with climate change, and are particularly vital in medicine where mutations for antibiotic resistance and vaccine immunity must be caught early to develop medicine effectively.

Genetics and inheritance

Key Stage 2 *Living things produce offspring of the same kind, but these are not normally identical to their parents*

Learning progression

Students were introduced to the concept of lifecycles during KS1–2, which provides a basis for this work on inheritance, within the narrative of growth and development. From this, they should be familiar with the idea that offspring look similar to their biological parents. The concept of inheritance is introduced by looking at characteristics that have been passed onto offspring from their biological parents, such as to puppies and kittens. This may also be an opportunity to encourage students to think about shared characteristics in their own families, though consideration should be given to all including a full diversity of family compositions. This is a concrete approach looking at visual similarities between parents and their offspring, and can be reinforced by looking at the process in other, less familiar, animals.

- Identifying similarities and differences between siblings, and parents and children
- Comparing pedigree and cross-bred dogs

In my life: family members often look similar; pets and their offspring look similar; seeing plants in garden centres; visits to zoos, farms, or safari parks

In society: farmers select their best livestock to breed; gardeners do the same with plants

Pathways: animal breeders, horticulturalists, farmers, florists, vets, midwives, gardeners

- Two parents are always needed to produce offspring
- Each characteristic must be seen in one of the offspring's parents
- Twins are always identical
- New plants can only be produced from seeds
- Height is always dependent on age

What do we know? How do we know? Why does it matter?

Living organisms produce offspring of the same type. Offspring share many features of their parents, but they are not normally identical. We know this from observing reproduction in plants, and humans and other animals. This is important to animal and plant breeders, who can select parents with the best characteristics to breed.

Key Stage 3 *Characteristics are passed from one generation to the next through heritable genetic material*

Learning progression

Gametes: Through the topic of cells, sperm and egg cells are introduced and their function of transferring genetic information between parents and their offspring. Although this is a slightly abstract concept due to their size, microscope images of these cells and video footage can be used to allow students to observe gametes in action.

Inheritance: Building on work on human characteristics and variation in a species, the more abstract concept of how characteristics are inherited through DNA is introduced.

The concept of organisation of structures is also revisited by looking at how genes are sections of DNA, found on chromosomes.

DNA structure: The key role of Watson, Crick, Franklin, and Wilkins is focused on as a major breakthrough in scientific understanding. This also underlines the importance of the scientific method in advancing human understanding of the natural world.

- Using a microscope to observe cells
- Using diagrams and models to represent structures in a nucleus and the DNA molecule
- Recognising the links between genes and variation in a species
- Appreciating that scientific understanding evolves as a result of new discoveries or technologies
- Understanding the need for scientists to work together and combine expertise from more than one discipline

In my life: gametes in boys and girls during and after puberty; different offspring of the same parents look different, depending on the characteristics they inherit (unless they are identical twins)

In society: solving crimes through DNA fingerprinting; genome sequencing project; sequencing SARS-CoV-2 and developing new drugs and treatments for disease; paternity testing

Pathways: lab technicians, molecular biologists, geneticists, forensic scientists, DNA sequencers, family historians, genetic disease specialists, taxonomists, vets, gynaecologists

- Each characteristic is controlled by a single gene
- The genes for key traits are on a single chromosome
- Genes determine all of your characteristics
- Scientists have a full understanding of how genes control the structure and function of organisms
- Characteristics are always passed on from a parent to their offspring

What do we know? How do we know? Why does it matter?

Heredity is the process by which genetic information is transmitted from one generation to the next. The information is contained in DNA in the nucleus of a cell and passed on when gametes fuse to form a new organism. Sections of DNA, known as genes, code for particular characteristics. We know this from the results of experiments carried out on inheritance, the use of microscopes, and the discovery of the DNA molecule. This is important as it helps to explain how and why organisms behave as they do.

Key Stage 4 An organism's inherited alleles dictate many of its characteristics

Learning progression

Meiosis: Students study the production of gametes through meiosis. This requires students to have an understanding of cell structure and chromosomes, and how these are passed on and offspring are created through fertilisation. This results in offspring displaying some characteristics of each of their parents, depending on the chromosomes received.

Genetic crosses: Students learn the difference between dominant and recessive alleles and then carry out their own genetic crosses to predict the likelihood of characteristics being passed on. Crosses are performed in humans as well as other animal species and plants, for both known characteristics and inherited disorders. This widens students' knowledge and enables students to apply the scientific method to less familiar situations to predict an unknown outcome. Students become aware that most genes influence a number of characteristics.

DNA structure and protein synthesis: The detailed structure of DNA is explored and students are introduced to the concept of complementary base pairing. The very abstract concept of how DNA actually codes for these characteristics through the production of proteins is then presented.

Genetic manipulation: This brings students up to date with the latest advances in biology, such as cloning and in-vitro fertilisation. The use of genetic engineering (now usually called gene editing) to give organisms desired characteristics is discussed, including current research into gene therapy to treat inherited disorders. This is presented relatively superficially at this stage, in preparation for a more detailed treatment at KS5.

- Synthesising knowledge of reproduction, mitosis, and cell structure to develop an understanding of meiosis
- Performing genetic crosses to calculate the likelihood of an organism displaying a characteristic
- Interpreting family trees
- Using models to represent the structure of DNA and protein synthesis
- Developing an understanding of the ethical considerations involved with genetic screening or manipulation of an organism's genome

In my life: noticing inherited characteristics that are present/absent between different generations of a family

In society: incurable genetic diseases; parents using in-vitro fertilisation to conceive; considering the development, widespread use, and benefits of GM crops; new treatments for genetic diseases being developed, such as gene therapy for cystic fibrosis; genetically engineering organisms to produce new drugs, or crops able to withstand challenges of global warming; ethical challenges produced through cutting-edge genetic research

Pathways: genetic counsellors, radiographers, medical careers, biological laboratory staff, crop scientists, geneticists, molecular biologists, farmers, policy makers

- All GM food crops are dangerous to health
- Only genetically modified food crops contain genes
- Agriculture is 'more natural' than lab-based GM crops
- Dominant traits are always the most common traits in a population
- Only people with genetically inherited disorders have alleles that cause the disease
- All genetic mutations are bad; these mutations compromise an organism or lead to its death
- Once a mutation is discovered in a person's DNA, it can be repaired
- If a couple has a 25% risk of having a child with a genetically inherited disorder, and their firstborn has the disorder, their next three children will not have the disorder
- When a couple has a baby, their next child is more likely to be of the opposite sex
- The alleles for a displayed characteristic are only inherited from a single parent

What do we know? How do we know? Why does it matter?

Gametes are formed by the process of meiosis. When they combine during fertilisation, the offspring that develops inherits a combination of both parents' genetic material. Dominant alleles are always expressed if present. This was discovered through studying and observing inheritance in plants (Mendel) and results can be predicted using genetic crosses. The genetic information codes for proteins, which in turn determine an organism's characteristics. Genetic engineering involves taking genes from one organism and inserting them into another to produce desired characteristics or changing (editing) genes already present. This can be used to produce higher-yield plants and new medicines.

Substances, bonding, and structure

Key Stage 1 *Objects are made of materials; some materials dissolve in water to make mixtures*

Learning progression

In their exploration of materials, young learners should learn the meanings of the terms *object* and *material* and realise that the same object can be made from different materials. For example, show a metal spoon and ask what material it is made of, and can it be made of materials other than metal. Have wooden and plastic spoons at hand. Ask for the pros and cons of each material. Learners can also be introduced to a material that dissolves, such as sugar or salt, and describe what happens when you add jelly cubes to hot water and stir. Learners can consider how we use mixtures of materials with water in everyday life.

- Suggesting reasons why one material is better than another for making a particular object
- Learners add a soluble material, such as sugar, to water and observe and describe it dissolving

- A substance that dissolves disappears and no longer exists
- You can see the separate substances in a solution
- An object, such as a spoon, is always made from the same type of material

In my life: see that a single object can be made from different materials; think about examples of dissolving seen at home, or when you eat foods

In society: all the different objects we use at home and school are made from materials; dissolving different substances when cooking

Pathways: engineers, materials scientists, chefs

What do we know? How do we know? Why does it matter?

Objects can be made from different materials. We use materials mixed with water in our everyday lives, for example, diluting fruit drinks and adding sugar to hot drinks like tea and coffee.

Key Stage 2 *Matter exists in three states; changes of state are reversible*

Learning progression

Some materials can exist in three states – as solid, liquid, or gas. Some of the properties of these materials are different in the three states. Water is a suitable example, because its three states are accessible in class and its changes of state (melting, freezing, evaporating, boiling, and condensing) can all be observed. Point out that these processes are all reversible changes. There are links to geography here when we consider the changes of state with respect to the water cycle.

In the later stages of KS2, introduce the idea that all materials are made of particles that are too small to see, perhaps in the context of sugar dissolving. The use of a mixture of rice and dried beans can be used as a simple model to help to explain and visualise this abstract concept.

- Observing and recording changes of state, for example ice, wax, or butter melting, or water boiling and condensing
- Investigating factors that affect how quickly sugar dissolves, for example stirring

- Evaporation does not take place at room temperature
- All liquids are pure substances.
- Melting is the same as dissolving
- Clouds are fluffy solids

In my life: freezing or melting ice; watching steam rise from hot food or drinks; seeing condensation on the window

In society: solutions to avoid problems with condensation; understanding how changes of state and the water cycle affect the weather

Pathways: chefs, water industry workers, fuel station workers, tanker drivers

What do we know? How do we know? Why does it matter?

Through our observations and measurements of water we can describe the states of matter and changes of state. These changes of state are applied in many household and industrial contexts, including cooking, food storage, damp courses in buildings, and casting metals.

Key Stage 3 *The particle model explains the properties of a substance in its three states*

Learning progression

Applying the particle model: Learners will apply the particle model to explain the physical properties of substances in the solid, liquid, and gas states, as well as changes of state (including sublimation), gas pressure and diffusion. In each case they describe the movement, separation, and arrangement of particles. Establish the idea of 'conservation of matter' when a substance changes state.

Learners use a Bunsen burner to monitor the temperature rise as they heat a beaker of water to its boiling point and plot the results on a line graph. They observe diffusion and give everyday examples of the process. Researching melting and boiling points of some substances will require learners to use negative numbers (plotting the points on a number line can be helpful).

Properties of mixtures: Learners define a mixture as containing two or more substances, which may be elements or compounds. They realise that the substances in a mixture keep their own properties, and the amounts of the different substances in a mixture can be varied.

Learners recognise a pure substance from its sharp melting point as opposed to an impure mixture of substances that melts over a range of temperatures. At this stage, learners can make the distinction between substances (made of one type of particle) and materials (that may be made of one type of particle, or a mixture of different types of particle).

Learners can then also apply particle theory to solid substances dissolving in a liquid, and are introduced to the terms solute, solvent, solubility, and saturated solution.

Properties of some useful materials: Learners have looked at the properties and uses of a variety of materials in KS2, as well as exploring their uses. They can now revisit and develop this work by considering a variety of polymers, ceramics, and composite materials. This can be done by observing samples and carrying out research. Encourage learners to use their knowledge of the particle model to speculate about the particles, and their arrangements, in these categories of useful materials. Acknowledge all suggestions, using this activity to form an introduction to the KS4 concept of chemical structures.

- Using the Bunsen burner to heat a beaker of water or a solution safely on a tripod and gauze
- Researching the fixed points of substances
- Investigating the solubility of solids
- Using the unit 'g/100 g of water' to describe solubility
- Applying the particle model to explain changes of state, diffusion, gas pressure, dissolving, and distillation
- Observing and researching the properties and uses of ceramics, polymers, and composites
- Exploring different particle model representations

In my life: observing changes of state during cooking; freezing foods to preserve them; boiling water to make hot drinks; seeing diffusion in relation to deodorants, perfumes, and aftershaves

In society: hazards of volatile liquids, such as on garage forecourts; uses of polymers, ceramics, and composites in all aspects of life, including mugs, mobile phone cases, and vehicles

Pathways: polymer chemists, ceramic producers, perfume designers, chefs, coffee roasters, water company and safety workers, food production workers, caterers

- All particles are the same
- Particles are all perfect spheres
- The particles in a liquid are not touching their nearest neighbours
- The same mass of ice occupies a smaller volume than that mass of liquid water; water is less dense than ice at all temperatures
- Polymers are all fibres
- Boiling and evaporation have the same meaning
- A substance with a boiling point of −5 °C is a liquid at room temperature
- A boiling point of −5 °C is lower than a boiling point of −25 °C, for example
- Gases have no mass
- All the particles in a gas are travelling at the same speed
- Large, heavy particles diffuse faster than small, light particles

What do we know? How do we know? Why does it matter?

The particle model enables us to construct logical explanations of the physical changes we observe in changes of state, diffusion, gas pressure, dissolving, and distilling. Pure substances have sharp melting points, unlike mixtures, which we can experimentally measure. We can use our sense of smell, and see coloured particles, to detect diffusion; this is evidence for the existence of particles. Knowledge of the particle model helps us to understand the nature of matter.

Key Stage 4 *Atoms are made up of sub-atomic particles; the structure and bonding of a substance give the substance some of its properties*

Learning progression

Atomic structure: Start with a reminder of the particle model and introduce its limitations (forces between particles, size, and shape of particles) before discussing the history of the discovery of the atom and the tremendous breakthroughs made by hard-working scientists just over a century ago. This leads to our knowledge of sub-atomic particles (protons, neutrons, and electrons) and their arrangement in atoms, including the electronic structures of the first 20 elements. Then consider the existence of isotopes of elements, calculate an element's relative atomic mass, and discover how ions can lose or gain electrons to become positively- or negatively-charged ions.

Bonding: This deals with how particles (atoms and ions) bond to each other. Start with ionic bonding – explain transfer of electrons between atoms of metals and non-metals to form oppositely charged ions that have strong electrostatic attraction to each other. Then progress to covalent bonding – explain the sharing of electrons between non-metal atoms. Use molecular model kits to make physical representations of molecules. Finally introduce the concept of metallic bonding – explain how each metal atom donates one or more electrons into a 'sea' of delocalised electrons that binds the positive metal ions (or atoms) to each other.

Structure and properties: Students pair up each type of bonding with the structure(s) that its ions, atoms, or molecules take up in compounds or elements. Alternatively, cover the appropriate structures directly after introducing each type of bonding. The structures (giant ionic, simple molecules, giant covalent, and giant metallic) explain the physical properties of substances, for example melting and boiling points, and electrical conductivity in different states. Taking this further, discuss polymers, with their relatively large molecules determining their intermolecular forces. Introduce recent developments with the discovery of fullerenes and the advent of the use of nanotechnology to produce nanoparticles with properties that differ from the bulk material they are made from. Following up work at KS3, the properties of ceramics can now be explained with reference to their giant structures of atoms and ions. Alloys and pure metals can also be compared using a model that shows layers of uniform spheres for the pure metal and introduces differently sized spheres to show the alloy with disrupted layers that no longer slide smoothly over each other.

- Using a range of different models (physical and conceptual) to represent bonding and the various atomic/ionic structures, and discussing their good points and their limitations
- Appreciating the scale of the component particles of different types of structure
- Investigating the properties of different compounds to deduce their bonding and structure
- Appreciating the advances made by scientists in the late 19th and early 20th centuries in discovering the structure of the atom
- Researching the latest developments in nanotechnology and materials sciences

In my life: appreciating that many objects you use are made from materials that have been developed by chemists and material scientists; considering which materials are used, how they are extracted/disposed of, and how that impacts the environment

In society: choosing materials because their properties make them suitable for making an object; new materials are being developed using knowledge of bonding and structure, and they will impact on the lives of everyone in the near future, such as electric cars, and nanoparticles that can deliver drugs to specific sites in the body

Pathways: nanotechnologists, material scientists, researchers, Science editors, Science authors, Science teachers, technicians, Science presenters, engineers, electricians

- Atoms form positive ions when they gain electrons
- Atoms form negative ions when they lose electrons
- NaCl is a molecule of common salt
- A Na atom forms a more stable Na^{7-} ion
- There is one ionic bond between Na^+ and Cl^- in NaCl
- There are different kinds of electron shown in dot-and-cross diagrams
- Solid ionic compounds conduct electricity
- Electrons, protons, and neutrons are the same size
- The nucleus contains neutrons that neutralise the charge on the protons
- Molecules in a gas experience no intermolecular forces
- Metallic bonds are sticky, like glue
- Models are an exact representation of reality

What do we know? How do we know? Why does it matter?

Bonding involves atoms transferring or sharing electrons, and the structures of substances determine their properties. Mass spectrometry is one of the main methods we can use to understand the composition of different substances. Developments in nanotechnology and materials science (e.g., the discovery of graphene) mean that new and exciting applications are guaranteed to affect all our lives in the near future.

Elements, compounds, and organic Chemistry

Key Stage 1 *Everything is made of materials; different materials have different properties*

Learning progression

Young learners will be given the opportunity to observe and explore everyday materials using their senses. They are encouraged to talk about their observations, developing descriptive language, for example, by using feely bags, and start recording their findings in drawings, simple tables, and charts. Materials to explore include wood, paper, cardboard, sponge, metals, plastics, brick, and fabrics. Learners could use some of these materials to make their own artworks.

When revisited later in KS1, learners can do simple comparative tests between materials, and can group them in simple categories.

- Careful observation, such as using a hand lens
- Recording findings in drawings, simple tables, and charts
- Sharing ideas

In my life: interacting with materials you are familiar with and use at home

In society: materials you use every day of your life – consider these from waking to going back to bed

Pathways: builders, carpenters, making clothes, artists

- The word 'materials' is only used to describe fabrics
- There is no distinction between the words 'material' and 'object'
- All materials occur naturally
- A material only has one property

What do we know? How do we know? Why does it matter?

Objects are made of one or more materials. We can describe materials by their properties; we need to know about the properties of materials to decide which ones to use when making useful objects.

We can find and compare the properties of materials by making observations and measurements. We can then choose the materials that are best for particular uses.

Key Stage 2 *We can test materials and group them according to their properties*

Learning progression

Learners build on their observational study of materials in KS1 to investigate ways of grouping and classifying materials, making and explaining their decisions. The range of properties is extended from KS1 to include electrical conductivity, thermal conductivity, and magnetism, linking to physics topics, as well as considering solubility. In a sorting materials activity, start by letting groups decide their own categories, then view another group's attempt and guess their criteria, before discussing as a whole group. Their testing of materials to judge which one is best for a particular use develops into more sophisticated fair tests, where predictions are checked, standard measurements are taken, results in tables are displayed on bar charts (and, later in KS2, on line graphs), conclusions are explained, and suggestions are made on how to improve their investigations.

- Investigating materials in fair tests in which learners can start making decisions on planning and how to record findings
- Classifying materials according to their properties
- Thinking about why we test properties of materials

In my life: everyday objects are made of one or more materials with properties suitable for the object; environmental impacts of production/use/disposal when choosing materials for different uses

In society: different materials are used to suit a particular job; wood and metals used for building

Pathways: consumer testing, interior designers, engineers, product designers

- All metals are magnetic
- You can see a blurred image through an opaque material
- Repeating measurements makes a test fair
- There are no gaps between the bars on a bar chart
- There is only one correct way to group a collection of materials

What do we know? How do we know? Why does it matter?

Materials can be grouped according to their properties, and these properties make them suitable for particular uses. Testing the properties of materials (such as their strengths) can be done in a laboratory. Then, a fair test can be planned to decide which material to use to do a certain job best. Choosing the right material is vital to make sure an object will suit its role, from buildings to clothing.

Key Stage 3 *All substances are made of atoms of one or more elements, which may be joined together in compounds*

Learning progression

Elements and compounds: Students learn definitions of atoms, elements, and compounds and use molecular model kits, 3D models, and diagrams to distinguish between elements and compounds, whilst being introduced to the term 'molecule'.

They go on to find out the names and chemical symbols of common elements, as well as how to name compounds (for example oxides, sulfates, nitrates, and carbonates) and use chemical symbols to write their formulae – an international code that is used worldwide.

Students go on to test and research the physical properties of some elements and distinguish between metals and non-metals on the basis of their findings.

The Periodic Table: Following the introduction of the Periodic Table as a way of organising the elements, the positions of the metallic and non-metallic elements can be discussed using findings from the investigations into their properties. Link to physics here with testing for magnetism and electrical conductivity. Point out the 'staircase' that can form a dividing line between the metals and non-metals, showing students the few elements that have intermediate properties – so do not fall neatly into either category. Students should be introduced to the terms 'groups' (vertical columns) and 'periods' (horizontal rows) and identify elements given their group and period number in the Periodic Table.

Groups in Periodic Table: Stress that elements in the same group are similar – but not the same. Some data analysis exercises can be used to show that there are often patterns in the physical properties, as well as the chemical properties (reactions), of elements going down a group. Then introduce the metallic elements of Group 1, plotting melting point data to look for a pattern. Demonstrate the reactions of Li, Na, and K with water to ask for the pattern evident in their observations. Then consider the non-metallic elements in Group 7 and look for patterns in their properties. Group 0 elements are noted for their lack of reactivity, but boiling points of the gases can be plotted (negative numbers) to see the pattern going down the group.

- Using molecular models and drawings of molecules to explain the difference between elements and compounds
- Exploring and researching the properties of metallic and non-metallic elements
- Distinguishing and explaining the differences between the terms 'atom', 'molecule', 'element', and 'compound'
- Identifying patterns in groups of the Periodic Table from observations and data analysis

In my life: nearly 99% of your body mass is made up of compounds made from just six elements: oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus

In society: millions of substances known to humankind are all made from the hundred or so chemical elements that appear in the Periodic Table

Pathways: metallurgists, metal workers, research scientists, science teachers, science technicians, electricians, engineers, jewellery makers, jewellery traders, sculptors, medical implant/prosthetics makers, stock exchange traders (who look for trends in material prices)

- You cannot have a molecule of an element
- All molecules are examples of compounds
- Compounds cannot be broken down into their elements
- Compounds display the properties of the elements they contain
- Compounds are mixtures of elements
- All elements exist as single atoms
- Mixtures are the same as compounds
- The numbers in chemical formulae are written as superscripts; for example, the formula of water is H^2O
- Every compound has its own symbol
- The majority of chemical elements are non-metals
- The Periodic Table lists elements in order of their mass/weight/density/date of discovery
- All metals are magnetic
- Lithium is black and sodium is white
- There are no non-metallic elements that are conductors of electricity
- All the elements in Groups 3 to 0 are non-metals

What do we know? How do we know? Why does it matter?

We know about elements, compounds, atoms, and molecules from the work of chemists in the 19th century. They deduced their existence from observations of their experiments, and organised these elements in an arrangement called the Periodic Table that explains how elements behave and allows us to predict their properties. Without their work, many of the materials used in modern technological societies would not have been made.

Key Stage 4 *The patterns in the Periodic Table are explained by electronic structures; organic chemistry describes and explains the properties of compounds of carbon*

Learning progression

The Periodic Table revisited: Although the same groups students met in KS3 are revisited in KS4, knowledge of atomic structure and its relevance to the organisation of the elements is added. The historic work of Mendeleev thrust chemistry into a new era and later scientists discovered that the elements in Mendeleev's table were in fact in order of their atomic numbers. We also now know that patterns in the electronic structures of atoms are responsible for the patterns in the properties of the elements. At KS4, greater emphasis is placed on the chemical equations that describe the reactions of the elements in Groups 1 and 7. Students readily want to observe the demonstration of Group 1 metals with water, with the addition of video of rubidium and caesium.

Group 7 displacement reactions illustrate the trend in reactivity of the halogens. Knowledge of electronic structures also enables us to explain the patterns observed in reactions going down Group 1 and Group 7, as well as the lack of reactivity in Group 0.

Then the transition metals, situated in the central block of the Periodic Table, are introduced. This block contains many of the metals used in everyday life, such as iron, copper, and zinc. Students can compare the chemical properties of the transition metals with the Group 1 alkali metals. They can also carry out research into the many varied uses of transition metals and make group presentations of their findings.

Organic chemistry: Students are introduced to organic chemistry for the first time, so time must be spent familiarising them with fundamental terminology, for example, homologous series, functional group, displayed formula, hydrocarbons, and general formula. Different types of molecular model kits show different aspects of the 3D structures of organic molecules and how these relate to the displayed formula. The alkanes are the first homologous series to be introduced (these have no functional group) – the first 4 members are presented, i.e. methane, ethane, propane, and butane. These are followed by the alkenes (with the C=C functional group), alcohols (with the –OH functional group), the carboxylic acids (with the –COOH functional group), and the esters (with the –COO– functional group). Amino acids are naturally occurring compounds whose molecules contain the functional groups –COOH and $-NH_2$; the –COOH group is acidic and the $-NH_2$ group is basic. About 20 naturally occurring amino acids join together in different sequences to make protein molecules.

- Appreciating the contribution of chemists in the 19th and early 20th centuries in developing the Periodic Table, including female chemists such as Ida Noddack, who worked with colleagues to discover the element rhenium
- Explaining the trends observed in reactivity going down groups in the Periodic Table
- Researching the uses of transition metals and their compounds and presenting findings
- Relating different types of molecular models (in 3D) to the displayed formulae of organic molecules (in 2D), and evaluating these different types of models
- Calculating the M_r of compounds
- Using dot-and-cross diagrams to demonstrate electron sharing

In my life: observing everyday materials that are pure elements, compounds, or mixtures of these; considering what impact the use and disposal of these objects has on the environment and for sustainable development

In society: extraction and manufacture of everyday materials; discovery and testing of vaccines, including in the Covid-19 pandemic; choices of materials for different uses

Pathways: organic chemists, biochemists, medical researchers developing new medicines and vaccines, polymer chemists, doctors, nurses, food scientists

- The alkali metal elements are examples of alkalis
- All the halogens are gases at room temperature
- All the noble gases have 8 electrons in their outermost shell
- No compounds of the noble gases exist
- The transition metal elements are all coloured
- Only transition metal elements can act as catalysts
- Organic chemistry is environmentally friendly
- Amino acids are proteins
- All organic chemicals are toxic
- Every bond angle around a carbon atom with four covalent bonds is 90°

What do we know? How do we know? Why does it matter?

The Periodic Table arranges the elements in order of their atomic number (number of protons). Elements in the same group of the Periodic Table have the same number of electrons in their outer shell, so there are trends in the physical and chemical properties of the elements in a group. We can observe these trends by analysing data showing measurements of physical properties of elements in the same group, as well as observation of their chemical reactions to gauge trends in reactivity. Knowledge of the properties of elements and compounds is vital for manufacturers in choosing the best materials for particular purposes.

Chemical reactions

Key Stage 2 *Some changes make new substances – these changes are irreversible*

Learning progression

Observing irreversible changes: This work links into the 'reversible changes' that learners meet when covering basic changes of state, such as melting or condensing, and dissolving. The stress here is on changes that cannot be reversed once they have occurred, as new substances are made. Show a rusty iron or steel object and ask if the object looked like this when it was first made. Scrape some rust off and ask if they think that rust could be easily turned back to iron. Demonstrate burning a match and ask for observations before, during and after the change takes place. Is this reversible? Use vinegar and bicarbonate of soda, and burning paper as other examples. Challenge students to observe and explain the changes taking place when a candle burns, is blown out, and is left to cool – here both reversible and irreversible changes occur.

- Making and recording detailed observations, speculating about the changes happening
- Comparing irreversible changes to reversible changes, such as changes of state and dissolving

In my life: lighting bonfires; watching firework displays; cooking and baking

In society: firing distress flares; making useful materials; burning substances to heat things up or make vehicles move

Pathways: chefs, firefighters, firework designers

- When wax melts a new material is formed
- A flame is a material
- All solids melt when they are heated
- Smoke is a gas
- Burning is a change of state

What do we know? How do we know? Why does it matter?

Chemical reactions happen in lots of ways, and can make permanent changes to substances, such as in cooking or when burning fuels to generate electricity. We know this from closely observing reactions like combustion and oxidation. Some reactions are reversible, and we can tell the difference between these and non-reversible reactions by understanding what is happening to the substances taking part in the reactions.

Key Stage 3 In a chemical reaction, atoms are rearranged and joined together differently to make new substances

Learning progression

Understanding chemical reactions: Early in KS3, students are introduced to chemical reaction as a process in which new substances are made. Starting substances are called reactants and the substances that are made are called products. The students will perform practical tasks to illustrate the signs that indicate that a chemical reaction is occurring, and learn how to write a word equation to describe it. They will use a suitable reaction to show the conservation of mass. Then using molecular models, they will demonstrate that, when chemical reactions take place, the atoms of the reactants are rearranged and joined together differently to form the products. Following 'Elements and compounds', they will progress from word equations to using formulae in balanced symbol equations (including state symbols when students are more confident). Finally, they will encounter catalysts and discuss why they are shown on top of the arrow in a chemical equation.

Different types of chemical reaction: In all chemical reactions, energy is conserved. In some reactions, energy is transferred from the reactants to the surroundings. In other reactions, energy is transferred from the surroundings to the reaction mixture. The students will encounter different types of chemical reaction:

- Combustion can be demonstrated using any safely burning fuel or by viewing video footage of forest fires.
- Define oxidation as the addition of oxygen to a substance. Combustion reactions are examples of oxidation, as are some corrosion reactions, for example, the corrosion in air of the freshly cut surface of a piece of sodium.
- Introduce the pH scale, and the use of indicators, to measure acidity/alkalinity. Then define neutralisation as the reaction of an acid with an alkali. The reactions of acids with metals and carbonates are also introduced, with their general equations and an opportunity to prepare a salt.
- Thermal decomposition can be demonstrated by the breakdown of copper carbonate on heating.
- Displacement reactions can be introduced following work on the reactivity series. The order of reactivity of metals can be deduced from their group in the Periodic Table, and observations of the reactions of metals with air (oxygen), water, and dilute acid. Demonstrating displacement reactions between metals and metal oxides will allow students to carry out displacement reactions by adding metals to salt solutions. This leads on to the position of the non-metals hydrogen and carbon in the reactivity series and their use in obtaining metals from metal oxides in displacement reactions.

- Investigating the conservation of mass in a chemical reaction
- Using 3D molecular models to model the rearrangement of atoms in a chemical reaction
- Representing reactions by word equations, and beginning to use balanced symbol equations
- Safely preparing salts in the reactions of acids with metals, metal oxides and metal carbonates
- Deducing the order of reactivity of metals from observations
- Using the reactivity series to predict displacement reactions

In my life: measuring your metabolism; reactions between the acid and carbonate in baking powder when baking; using indigestion tablets to neutralise excess stomach acid

In society: using metals such as iron that have been extracted by displacement reactions; displacement reactions to extract useful metals from their ores; use of iron in steel for bridges, tall buildings, ships, buses, trains, and cars; adding acid/alkali to soil to make its pH suitable for particular crops; neutralising the acidic gases made in some industrial processes

Pathways: steel workers, pharmacists, cement producers, firework manufacturers, pharmacists, firefighters, bakers

- When balancing a chemical equation, the multiplier/balancing number applies only to the element it is directly on the left of
- Mass is not conserved because in a reaction that gives off a gas, the mass of the solid product remaining has less mass than the reactants before the reaction takes place
- Energy is a substance
- All acidic solutions are corrosive
- Alkaline substances are not corrosive
- Salts are all chlorides
- The reaction of a metal plus acid gives a salt plus water
- The reaction of a metal carbonate plus acid gives salt plus carbon dioxide
- All salts are soluble in water
- Metals 'fight' each other in displacement reactions
- Aluminium has many outdoor uses, so must be an unreactive metal

What do we know? How do we know? Why does it matter?

In a chemical reaction, the atoms are rearranged and joined together differently, so mass is conserved. Experiments focusing on combustion, oxidation, and reduction have helped us to understand what happens to different substances during chemical reactions. Chemical reactions enable all life on Earth, make the substances we use in society, and transfer energy. There are several types of chemical reaction, and we can represent reactions by word equations and balanced symbol equations.

Key Stage 4 Chemical reactions make new substances and transfer energy

Learning progression

Using chemical equations: Students develop their understanding of the different types of chemical reaction studied in KS3, and practise writing and interpreting chemical equations. The balancing of symbol equations, including state symbols, can be more complex, for example, in the combustion of hydrocarbon fuels. Calculations can be carried out to work out masses of reactants and products using moles or relative formula masses, applying the ratios from the balanced equation. Students learn how to carry out calculations involving a reactant present in excess, and are introduced to the term 'limiting reactant'.

Extending KS3 concepts: The reactions of the alkali metals and water are revisited and students are introduced to their reactions with halogens. The reactions of alkali metals are compared with those of transition metals. The displacement reactions of the halogen solutions and their salts are used to show the trend in reactivity going down the group. Ionic equations that only show the ions and molecules involved in a reaction could be introduced here. Electrolysis is introduced, including half equations showing the transfer of electrons, and its application in extracting aluminium. The reactions of acids are revisited and developed to include an explanation of redox reactions using half equations. Neutralisation reactions and the impact of hydrogen ion concentration on pH are explored further. Strong and weak acid reactions are introduced and compared.

Energy changes in reactions are revisited, before progressing to reaction profile diagrams, including the concept of activation energy. Energy changes are explained in terms of breaking bonds in reactants and making bonds in products, and this is applied to estimate energy changes in reactions using bond energy data. Then the different factors that affect rates of reaction are investigated and explained using collision theory. This can be followed by the introduction of reversible reactions, chemical equilibria and the application of Le Chatelier's principle, which predicts how the position of equilibrium shifts as conditions are changed.

Students are introduced to some reactions of organic compounds (alkanes, alkenes, alcohols, and carboxylic acids), including the combustion of hydrocarbons, before considering addition and condensation polymerisation.

- Carrying out reacting mass calculations from given data
- Preparing salt from a metal carbonate or oxide
- Investigating the electrolysis of solutions, energy changes and the effect of concentration on rate of reaction
- Evaluating the repeatability and reproducibility of these investigations
- Calculating the mean rate of a reaction, and the rate at a particular point in time, using data from a graph
- Drawing 2D representations to model polymerisation reactions

In my life: using chemically-activated hand warmers; using cool packs on injuries; using fuels that transfer energy to cook food or drive a car

In society: biochemical processes occur in all living things to keep them alive; role of chemical reactions in producing the materials needed in modern society, and in transferring the energy needed for many processes (e.g., by burning fuels); use of reversible reactions in industrial processes that produce useful materials

Pathways: chemical engineers, quality controllers, health and safety officers, food scientists, electroplaters, manufacturers of plastics, polymer scientists, organic chemists

- A reaction in a state of equilibrium is always a 50:50 mixture of reactants and products
- Heating up a reaction mixture at equilibrium always produces more product
- Ionic equations only show the ionic products of a chemical reaction
- A limiting reactant is the reactant in excess
- Energy is 'lost' in an exothermic reaction
- Bond breaking is exothermic
- Sulfur is one of the products formed in the electrolysis of an aqueous sulfate salt
- Nitrogen is one of the products formed in the electrolysis of an aqueous nitrate salt
- Electrons flow through the electrolyte during electrolysis
- Catalysts do not change as the catalysed reaction takes place
- The carbon atom in the –COOH group of a carboxylic acid is not counted when naming the acid

What do we know? How do we know? Why does it matter?

Chemical reactions produce new substances and involve a transfer of energy either from the reaction mixture to the surroundings or from the surroundings to the reaction mixture, as evidenced from our observations of reactions and measurements of temperature changes. Understanding what happens in chemical reactions is fundamental to all processes that occur in living things and in all chemical manufacturing processes.

Chemical analysis

Key Stage 2 *We can use filtering, sieving, evaporating, or a magnet to separate some mixtures*

Learning progression

Learners use basic methods to separate mixtures. It is a good idea to let the learners make up the mixture to be separated themselves so they appreciate that the mixture contains two (or more) different materials. Separation techniques to practice are filtration, sieving, evaporation, and using magnets. To investigate filtration, use a filter paper, folded to fit in a filter funnel held over a beaker or similar container. Add sand to water in another beaker, stir the mixture, then pour it through the filter paper. The sand (residue) is left on the filter paper. Ask learners to describe and suggest how filtration works. You can use a colander to sieve a mixture of dry sand and peas, and if you have different grades of sieve, try to separate dry sand, peas and rice grains. Demonstrate separation by evaporation by dissolving salt in water and leaving near a sunny window. Show how a magnet can separate a magnetic material from a mixture.

- Using filtration and sieving to separate mixtures
- Investigating evaporation by leaving salt solutions in different places
- Discussing why a particular technique is used to separate a mixture, as well as why we need to separate mixtures

In my life: sieving in the kitchen, such as to strain vegetables; sieving sand at sand pits

In society: separation of differently sized items, such as coffee beans, by using different grades of sieve with differently sized holes; making filter coffee and straining tea

Pathways: chefs, producers of sea salt, water supply workers, manufacturers

- Filtering dirty water with filter paper makes it fit to drink
- Filtering can be used to separate a dissolved substance from a solvent
- Liquids are not materials
- Evaporation cannot take place without heating a liquid or a solution
- The dried salt that is left after leaving salty water to evaporate is not the same material as the grains of salt dissolved in the water
- Solutions are not a mixture
- Water disappears when salt is separated from salty water
- New materials are made when solids dissolve in water
- Gases do not dissolve in water

What do we know? How do we know? Why does it matter?

Mixtures can be separated by carrying out the techniques of filtration, sieving, and evaporation, or using a magnet. The method chosen depends on the materials in the mixture. Separating mixtures is important in food and drink preparation and purifying materials, such as turning dirty water into water that is safe to drink.

Key Stage 3 *Substances can be analysed or purified using several techniques, including chromatography*

Learning progression

Separating mixtures: Students can build on work done in KS2 by revisiting the separation technique of filtration. Ask them to work out how to separate a mixture of sand and salt. This task will also involve the use of the Bunsen burner for heating when looking at evaporation to separate a solid (in this case salt) from its solution with water. Students can also observe or carry out simple distillation to collect a liquid from a solution, explaining the process using the particle model. Learners can then go on to explore the separation of coloured substances that are all soluble in the same solvent (for example inks or food colourings) using chromatography. Ask learners to speculate as to how chromatography works.

Concentration: Students can look more closely at the process of dissolving. They can make a saturated solution to see that there is a limit to the mass of solute that can dissolve in a set mass of water. This maximum amount of a solute is its solubility, as measured by its mass (g) that can dissolve in 100 g of water. As temperature increases, the solubility of most soluble solids increases, but the solubility of most soluble gases decreases. Solubility of different solutes can be plotted and interpreted from line graphs. The concentration of a solution is a measure of how much solute is dissolved in a given volume of the solution. A solution is described as concentrated if it has relatively more solute dissolved in it, and dilute if it has relatively less solute dissolved in it.

- Problem solving to determine the method to separate mixtures of different substances
- Carrying out the separation techniques of filtration, evaporation, simple distillation, chromatography, and using a magnet
- Justifying and evaluating the methods used to separate mixtures
- Carrying out investigations into the solubility of different solids
- Plotting line graphs of solubility versus temperature for different substances
- Drawing a particle diagram to illustrate what a scientist means by a 'dilute' solution as opposed to a 'concentrated' solution, and evaluating their accuracy (they are not to scale, for example)

In my life: accessing clean drinking water, which has been filtered and sterilised; appreciating that this is available on tap in the UK (but not in all parts of the world); using filters in fish tanks; adding sugar to hot drinks; observing that fizzy drinks stay fizzy for longer when kept cold

In society: sea salt is separated from seawater by evaporation and is collected from salt pans; rock salt is extracted from seams underground (formed by the evaporation of prehistoric seas); using salt on roads in winter

Pathways: chemical engineers, water treatment workers, brewers, chemical analysts, workers for the Environment Agency, chefs

- Poking a filter paper with a glass rod improves the process of filtration through a filter funnel
- Chromatography only works for the separation of coloured substances
- The larger the original spot on the base line of chromatography paper is, the clearer the result
- The substances separated by chromatography are insoluble
- All powdered solids are soluble in water
- Separation processes involve chemical reactions
- The solubility of solids decreases as you increase the temperature
- Sea salt is a single substance: sodium chloride
- A dilute solution always has fewer particles of solute in it than a concentrated solution

What do we know? How do we know? Why does it matter?

Filtration is used to separate an insoluble solid from a liquid. Evaporation is used to obtain a solute from a solution. Simple distillation is used to separate a solvent from a solution. Chromatography is used to separate mixtures of solutes in solution.

We can also use chromatography to distinguish between pure substances and mixtures, to find the number of substances in a mixture, and to identify solutes. These are all important processes used in modern industries for the production of useful substances.

Key Stage 4 We can use a range of techniques to separate mixtures, identify substances, and determine their quantities

Learning progression

Separating mixtures of substances: Students will quickly revisit their KS3 techniques for separating mixtures, such as filtration, simple distillation, evaporation, and chromatography, using different mixtures and open-ended problems to ensure progression. In KS4, these techniques are extended to include crystallisation (needed to prepare salts) and fractional distillation (applied to the separation of miscible liquids and obtaining fractions from crude oil). The explanation of chromatography is developed to include mobile and stationary phases, as well as the use of locating agents with colourless substances. Then calculations of R_f values from developed chromatograms will be used to identify unknown substances. They should understand that all these separation techniques are physical changes, since no new substances are made.

Identifying substances: Students will use the standard tests to identify common gases. They will also use flame tests and precipitation reactions with sodium hydroxide solution to identify the positive ions in unknown substances. These are complemented by the 'test-tube' tests for the negatively charged ions in the substances under investigation in order to identify the compounds.

An instrumental technique used to identify substances, flame emission spectroscopy, is briefly introduced to highlight modern analytical methods. Students will evaluate the advantages and disadvantages of this instrumental technique compared with the chemical methods.

Quantitative analysis: Chemists can work out the percentage purity of a sample by dividing (mass of the pure product) by (total mass of this product plus its impurities) × 100. (Understanding of 'amount of substance' measured in moles is not required in this calculation.) Many students find calculations involving moles difficult, so we should acknowledge this and reassure them that they will revisit the concept throughout KS4.

Students will start by revisiting relative atomic mass and formula mass, and introduce the Avogadro constant and simple calculations involving mass and moles, then concentrations of solutions, and volumes of gas. The practical technique of performing a titration can be taught as they cover neutralisation reactions in KS4. However, the calculation of unknown concentrations using titration data is best left until the final year of KS4, as it involves reacting numbers of moles, as well as manipulation of the concentration equation.

- Solving open-ended problems using a range of separation techniques
- Interpreting chromatograms and using them to calculate R_f values
- Safely carrying out and interpreting chemical tests on unknown substances
- Evaluating and comparing chemical tests and instrumental techniques used to identify unknown substances
- Carrying out a titration to investigate reacting volumes
- Calculating amounts of substance involving moles
- Considering the purposes of separation and analytical techniques, as well as calculations

In my life: using everyday products made from crude oil, including fuels and plastics; understanding the environmental issues associated with their manufacture, use, and disposal

In society: making distilled water for use in all types of lab; making medicinal drugs, which have precise amounts of different substances mixed in certain formulations; monitoring air quality and pollutants; extraction of salt from rock salt on an industrial scale; forensic identification of unknown substances or tracing criminals; using chromatography to identify and quantify substances (such as alcohol and other drugs) in blood and urine

Pathways: conservationists, pollutant controllers, forensic scientists, police officers, environmental health officers, art restorers, lab workers, industrial chemists, nurses, doctors, pharmacists, pharmaceutical company workers

- A fractionating column is hotter at the top than at the bottom
- A fraction obtained from crude oil contains a single hydrocarbon
- The Avogadro constant has no unit
- A mole of a gas contains fewer particles than a mole of a solid
- The volume of a mole of hydrogen gas is smaller than the volume of a mole of carbon dioxide gas under the same conditions
- You multiply the number of dm^3 by 100 to change the unit to cm^3

What do we know? How do we know? Why does it matter?

We know that separation techniques do not make new substances, so they are examples of physical changes. We can conduct chemical tests, and make and interpret observations, to identify unknown substances. We can also do calculations to find out about the quantity of substances in a given mass of a mixture, the concentration of a solution, or the volume of gas, and carry out titrations to find the unknown concentration of a solution. As a result, we can identify unknown compounds through separation or mass spectrometry for drugs tests, and calculate concentrations of substances for use in medicine (such as anaesthesia or prescription drugs).

Chemistry of the Earth, and Earth's resources

Key Stage 3 *Fuels transfer useful energy and metals are extracted from ores*

Learning progression

Defining fuels: Students are introduced to fuels as substances that burn in chemical reactions with oxygen, transferring useful energy by heating. The use of the fuel methane gas in the Bunsen burner in the science lab is a thrilling experience for most students as they start secondary school. Environmental concerns can be discussed as traditional fossil fuels are shown to be non-renewable and their products of combustion include carbon dioxide gas, as well as the pollutant carbon monoxide from incomplete combustion (water is the other product). The environmental theme is continued with the introduction of biofuels and the use of hydrogen as a fuel in motor vehicles.

Using fuels: The work on fuel cells can be introduced after considering adverse effects of burning traditional fossil fuels. This will be part of the solution to climate change caused by global warming, with many countries planning a switch to sales of electric cars only. Detail of the workings of fuel cells is not required at this stage but is covered in KS4. The use of catalytic converters in conventional vehicles is explained as a way to cut down the toxic exhaust pollutants carbon monoxide, the oxides of nitrogen, and unburnt carbon compounds from petrol and diesel (but does not reduce the amount of carbon dioxide released).

Metals: Students will be familiar with metals from their work on the properties and uses of materials in primary school. Now we move on to discover how we get these useful metals from the naturally occurring ores (which are also non-renewable resources from the Earth's crust). The extraction of metals is introduced by considering the least reactive metals, for example, gold, which occurs as the element itself. The more reactive metals are found in compounds in their ores. Students are introduced to displacement of a metal by carbon when heated. The terms 'reduction' and 'displacement' are given as types of reaction, together with 'oxidation' when investigating the rusting of iron.

- Using the Bunsen burner safely for heating
- Observing demonstrations of the burning of different fuels
- Researching impacts of the sources and uses of fuels
- Discussing the environmental impacts of burning fossil fuels
- Carrying out experiments to reduce metal oxides by heating with carbon
- Explaining observations of the reduction of a metal oxide by carbon in terms of reactivity
- Investigating the conditions needed for iron to rust
- Modelling to explain what happens in a displacement reaction

In my life: seeing energy sources used at home and travelling; considering how these can be replaced by 'cleaner fuels'; taking steps to improve the local and global environment; considering your carbon footprint

In society: traffic pollution and its impacts on human health and other living things; movement towards 'cleaner fuels' and the reduction in fossil fuel use; increasing support for sustainable development

Pathways: environmental scientists (e.g., monitoring pollution levels, protecting wildlife), conservationists, health and safety officers, workers in green energy industries, energy assessors, ecologists

- All fuels are in the liquid state
- Hydrogen-powered vehicles have no disadvantages
- Cars can only run on petrol or diesel
- Hydrogen (rather than water) is a product of the combustion of fossil fuels
- The production of biofuels involves no carbon dioxide released into the atmosphere
- Nitrogen gas has no reactions
- The yellow flame on a Bunsen burner is hotter than a blue flame
- The oxidation of iron decreases its mass
- Rusting is not a chemical reaction
- Air (oxygen) or water are required for iron to rust
- Displacement reactions only occur between metals and metal oxides (or between metals and metal salt solutions)

What do we know? How do we know? Why does it matter?

Combustion, reduction, oxidation, and displacement are all ways of categorising chemical reactions as evidenced by observing reactions in the lab. The reactants and products of the reactions can be shown in chemical equations. The consequences of these reactions on an industrial and domestic scale have environmental implications – and implications for sustainable development – that must be addressed now.

Key Stage 4 *Application of chemistry is essential to many modern industries*

Learning progression

Extraction of metals, yield, and atom economy: Students learn that very reactive metals (at the top of the reactivity series) are extracted using electrolysis (the breakdown of an electrolyte by electricity). They investigate the electrolysis of different aqueous solutions, and identify the products formed at the electrodes. A closer look is taken at the extraction of copper using displacement by iron or using electrolysis. There are links here to bioleaching and phytomining that appear in the 'Earth and environment' concept strand. A mathematical concept can then be introduced to calculate reaction yields, as well as the economically and environmentally important atom economy calculations that affect industrial processes. Students can discuss the factors that determine how industrial products are made.

Fuels, chemical cells, and fuel cells: The KS3 fuels topic is revisited here, with students focusing on crude oil – its formation, fractional distillation, cracking of its heavy fractions, and the useful substances obtained.

Students are introduced to simple chemical cells and can plan and carry out an investigation into the voltage measured between different pairs of metals in the same electrolyte. They compare a non-rechargeable electric cell or battery and a rechargeable electric cell. Then students learn details of the workings of hydrogen fuel cells, as well as considering their pros and cons.

Formulations and fertilisers: Students are introduced to industrially important formulations – mixtures that have been made to have specific properties so that they will be useful. They will look at examples, focusing on the manufacture of fertilisers. This will include the Haber process to make ammonia, and its subsequent conversion to a variety of different salts, called NPK fertilisers, that farmers add to soil to improve crop yield and quality.

Corrosion and alloys: Looking at corrosion, students will revisit rusting and explore the different methods of preventing rust. Students can then find out about a variety of alloys and how their properties can be manipulated to suit particular uses by altering their composition.

- Planning and carrying out investigations into factors affecting electrolysis, recording their results
- Planning and carrying out investigations into factors affecting the voltage produced by different electrical cells, consisting of pairs of different metals in an electrolyte
- Investigating and evaluating the effectiveness of different methods used to prevent rusting
- Researching uses of alloys
- Carrying out calculations of yields and atom economy
- Considering the environmental impacts of the manufacture and uses of substances and the uses of fuels
- Evaluating advantages and disadvantages of extracting metals by different methods

In my life: using formulations at home, for example, paint, medicines, tablets, and foods; using fertilisers and 'liquid plant food' in pot plants and gardens; the use of alloys in devices, home appliances, and cars

In society: fuels cells in electric vehicles; how corrosion affects metals in the environment; using fertilisers on farms to grow food crops, as well as a consideration of alternatives; electrolysis in beauty salons

Pathways: designers of perfumes, jewellers, researchers of new commercial products, producers or sellers of electric vehicles, installers of electric charging points for cars

- Metal ores are all pure compounds
- Negative ions are formed by atoms losing electrons
- Positive ions are formed by atoms gaining electrons
- Negative ions gain electrons at an electrode; positive ions lose electrons at an electrode
- Electrolysis is only involved in the extraction of highly reactive metals
- Aluminium is an unreactive metal
- A fraction from the fractional distillation of crude oil is a single, pure hydrocarbon
- A catalyst affects the position of equilibrium in a reversible reaction
- Obtaining hydrogen from water does not need any energy input
- Ammonia is in the liquid state at room temperature

What do we know? How do we know? Why does it matter?

Highly reactive metals need to be extracted by electrolysis. The electrolyte is a molten salt, not a solution of a salt of the metal, and we can predict the products at each electrode. There are many useful products originating from crude oil, obtained by fractional distillation and cracking. Formulations are designed for specific uses in industry, and factors such as the yield and atom economy must be considered to minimise damage to our environment.

Earth and environment

Key Stage 1 *There are different types of rock, which have different properties and uses*

Learning progression

As part of their study of everyday materials, young learners will observe rocks. They use a magnifying glass to look closely at the surface of two natural rocks, such as limestone and chalk, and a processed rock (e.g., polished, or cut for building), to compare observations. Use secondary sources to show some uses of the two rocks observed. Learners can extend this work to start making suggestions as to why rocks are used in making buildings, roads and statues, for example. There are links to biological observations of nature.

- Observing and comparing rocks
- Suggesting uses for different rocks

In my life: looking at the uses of rock in the local environment and their occurrence in nature

In society: thinking about the use of manufactured in bricks and concrete, and in buildings

Pathways: construction work, gardeners, landscape designers, architects, sculptors

- Brick and concrete are natural materials
- All rocks are hard
- All rocks are made out of the same material

What do we know? How do we know? Why does it matter?

We know that many rocks, but not all, are hard. They are used to make houses and other buildings that need to be strong, so it is important we understand their properties.

Key Stage 2 *Rocks can be classified into different groups; soil contains tiny pieces of rock*

Learning progression

In KS2, learners meet a wider variety of rocks. Let them group the rocks according to their own criteria and discuss the outcomes as a whole class. They use a hand lens or microscope to look closely at the surface to group rocks into those made of grains and those made of crystals. Observing rocks in the environment and/or using secondary sources, look for signs of weathering and ask for suggestions as to how this happens. This provides opportunities to look at the composition of soils, containing tiny pieces of weathered rock. Observation and investigations into different types of soil can follow, for example, to find out which type of soil drains best. Discuss rock that builds up in layers over millions of years and the fossils that can be in found in them. This topic links with geography.

- Classifying rocks and soils
- Comparing properties of rocks and soils, and their suggested uses

In my life: appreciating the different types of rocks and soils, including sand and rock on sea beds

In society: growing plants in suitable types of soil; using different rocks for a wide variety of uses

Pathways: stone masons, farmers, gardeners, palaeontologists, gardeners, agronomists

- All fossils are the preserved replicas of the original living thing
- Soil is a single material, not a mixture
- Rocks stay the same forever
- Clay is not made from weathered rock
- Chalk and talc are not rocks
- Rocks are the same type if they are the same colour

What do we know? How do we know? Why does it matter?

There are many different types of rocks that can be grouped together in different ways, and particles of broken-down rock are a major part of the mixtures we call soil. Fossilised remains and traces of living things can be found in rocks that formed in layers. These help us understand how living things have evolved over time.

Key Stage 3 *Different types of rock form in different ways; climate change is partially caused by greenhouse gases from human activities entering the atmosphere*

Learning progression

Structure of the Earth and rocks: Students are introduced to the structure of our planet, learning about the crust, mantle outer core, and inner core of the Earth. This is followed by the composition of the Earth's atmosphere. When students have studied different types of weathering, they will look at the formation of the different types of rock: sedimentary rock formed by sediments building up over millions of years and undergoing compaction and cementation; igneous rocks formed from molten magma (called lava at the surface) solidifying/freezing; and metamorphic rocks formed by the action of high temperatures and/or high pressure that change the structure of a rock. The topic finishes with a look at the rock cycle.

Carbon dioxide and the atmosphere: Starting with the carbon cycle, students learn about the importance of carbon dioxide gas in the natural processes on Earth, including its role in keeping the planet warm enough for liquid water to exist in the seas and oceans. However, as excessive amounts enter the atmosphere as a result of human activities, CO_2 contributes to enhanced global warming. As average temperatures around the world increase, there are already signs that climate change could have catastrophic impacts. Learners discuss these and what we can do – including personally, nationally, and internationally – to combat the effects of climate change.

Introduction to Earth's resources and recycling: We can preserve the Earth's resources by reducing what we buy, reusing objects where possible, and recycling materials. Recycling metals (for example, copper and aluminium) helps to conserve the remaining deposits of metal ores, reduces solid mine waste and reduces carbon dioxide emissions from the energy-intensive processes needed to mine and extract metals from their ores.

Glass, plastics, and paper are also recycled, and many things can be re-used rather than disposed of in landfill sites.

- Interpreting models of natural cycles on Earth, including the rock cycle and the carbon cycle
- Comparing the size of crystals formed when a molten substance (e.g., salicylic acid) is cooled quickly and slowly and relate this to igneous rock formation
- Discussing climate change, its causes, its implications, and ways to combat it, both individually and nationally/internationally
- Classifying rocks by close observation as sedimentary, igneous, or metamorphic

In my life: hiking, rock climbing or caving; visiting Natural History museums; noticing different types of rock in use as paving stones, roofing etc.; observing pollution from petrol and diesel vehicles; noticing different types of rock and their uses at home; reusing objects when possible and recycling materials at home and at school

In society: reducing what we buy and the energy we use; government support for solar panels and the installation of wind turbines and other energy sources with minimal carbon dioxide emissions

Pathways: environmental scientists, data analysts, recycling workers, conservationists, builders, environmental health officers, electric vehicle producers or salespeople, marine scientists, museum workers

- Slate is a sedimentary rock
- Rocks with layers are always sedimentary
- There is only one type of limestone
- Limestone is soft as it is a sedimentary rock
- Weathering is the same process as erosion
- Rocks cannot change their structure
- Lava can only flow on land
- Volcanoes are all active
- Igneous rocks are only found on volcanoes
- Igneous rocks are formed from one type of crystal
- Limestone, marble, and chalk cannot be made of mainly the same substance
- Enhanced global warming will have the same effect on weather patterns all over the world
- All types of plastic can be recycled
- Recycling is the only way of preserving the Earth's resources
- Basalt is not an igneous rock
- Rocks always take a long time to form
- All rocks were formed when the earth was formed
- Rocks cannot move from where they were formed

What do we know? How do we know? Why does it matter?

We understand the structure of the Earth and how rocks are formed, and appreciate how human activities affect natural cycles, such as the carbon cycle. Observations of the environment and human activity, through measuring emissions and the rate of climate change, makes it clear humans are contributing to climate change. We know how human resource use – particularly by people in rich countries – damages the environment and prevents sustainable development, and must identify actions to address these issues.

Key Stage 4 Chemistry

The Earth's atmosphere has changed over time; enhanced global warming is a vital issue that must be addressed immediately

Learning progression

Earth's atmosphere: After revisiting the composition of gases in the air, students learn about current ideas concerning the history of Earth's atmosphere from its origins to the present day. With limited evidence from billions of years ago, there is some uncertainty about hypotheses. However, scientists link early volcanic activity and the subsequent development of life on Earth to the composition of the atmosphere. Carbon dioxide was removed from the volcanic atmosphere by the first plants to evolve, as well as other processes, and oxygen was first produced from photosynthesis about 2.7 billion years ago.

The atmosphere and pollutants: Work on climate change is developed to explain how greenhouse gases warm the atmosphere, and how human activities are causing enhanced global warming by increasing natural levels of greenhouse gases, mainly carbon dioxide and methane. Students discover that making predictions about the rate of climate change is difficult when using a model on a global scale. They consider pollution of the atmosphere, including the sources and effects of particulates, carbon monoxide, oxides of nitrogen, and sulfur dioxide.

Natural resources and recycling: The emphasis is on the use of water, its sources, its pollution, and making water that is fit to drink. Students should investigate water samples from different sources. KS3 work on the finite sources of metal ores is extended to look at more sustainable methods of mining ores, such as phytomining and bioleaching. The sustainable practice of conducting Life Cycle Assessments on processes is dealt with. This is an ideal time to carry out/revise calculations of atom economy and yields of chemical reactions. Students then recap KS3 recycling and extend the work by considering how recycling is carried out.

- Purifying and testing water samples from different sources
- Considering the awe-inspiring vast periods of time over which the Earth's atmosphere has evolved
- Understanding that models have limitations
- Carrying out and evaluating Life Cycle Assessments, comparing two products or processes
- Carrying out calculations of atom economy and yield of some chemical reactions (atom economy can be applied to different routes to get the same product and used in LCAs)

In my life: considering issues of sustainability and environment when making purchases; appreciation that the Earth's atmosphere, land, and seas are vulnerable to damaging pollution, which must be remedied

In society: reducing what we buy and the energy we use; reusing objects when possible and recycling materials at home and at school

Pathways: meteorologists, running a recycling plant, working to promote sustainability for a local authority/government agency, industrial chemists, mining consultants, water engineers/scientists, makers of catalytic converters, developers of electric batteries, environmental campaigners

- The Earth's atmosphere has remained constant from the time of its formation
- Scientific theories are absolute truths that can never be changed
- Humans have been on Earth since its creation
- The Earth's atmosphere contains a high proportion of carbon dioxide gas
- The greenhouse effect is a new phenomenon
- Chlorine is only added to water in swimming pools
- Carbon monoxide smells like exhaust fumes from a car
- There is only one type of nitrogen oxide
- Sulfur dioxide is a liquid that causes acid rain

What do we know? How do we know? Why does it matter?

We know that not all hypotheses we have developed to explain the composition and development of gases in the Earth's atmosphere can be verified and may well be modified or even completely changed when a better hypothesis is proposed and vetted by the scientific community. Enhanced global warming, causing climate, change is a vital issue and we must act now – individually, nationally, and as a global community – to reduce greenhouse gas emissions that are contributing to this.

Key Stage 4 Physics *The atmosphere affects the Earth's temperature; seismic waves reveal the Earth's structure*

Learning progression

Atmospheric pressure: Students link what they have learned about gas pressure to a simple model of the atmosphere; atmospheric pressure at a point is a result of the weight of air above that point, which depends on height above sea level. Parallels with water pressure are useful; students can compare and contrast for a deeper understanding.

The role of the atmosphere in maintaining hospitable temperatures on Earth is vital; without it there would be extremes of temperature. Comparisons with planets without atmospheres can be enlightening.

Students use their knowledge of the electromagnetic spectrum to learn about the absorption and emission of radiation by the Earth's atmosphere, and the impact on the Earth's temperature. There are clear links to the history of the formation of the atmosphere, and how temperatures have changed. Students make links to combustion and the carbon cycle in chemistry, and to climate change, both here and on other planets, such as Venus.

Seismic waves: Students may know the internal structure of the Earth but may not have wondered 'how do we know?'

They use their knowledge of wave properties to learn about how the internal structure of the Earth can be deduced from the detection of seismic waves produced by earthquakes. There are longitudinal (P, or primary) waves and transverse (S, or secondary) waves that can be detected by seismometers at different locations on the Earth's surface. Shadow zones where seismic waves are not detected provide evidence for the size and structure of the Earth's core. This is still a model. We cannot travel inside the Earth.

- Researching how atmospheric pressure changes with height
- Investigating the effect of CO_2 levels on the absorption of radiation from a lamp
- Modelling the internal structure of the Earth and production of shadow zones with light
- Making a timeline of previous models of the internal structure of the Earth, showing how evidence led to the model being changed
- Researching how the average temperature of the Earth is measured, and the uncertainty in it
- Interpreting patterns and links between rising levels of CO_2 and rising temperatures

In my life: changes of pressure are detected by our ears when we fly in planes or climb mountains; observing how crisp packets change on planes

In society: more extreme weather events as a result of climate change; the need for pressurised cabins in aircraft; using absorption of radiation by atmospheres helps us look for life on other planets; some animals can sense seismic waves; the effects of natural disasters, and how they are predicted

Pathways: mountain climbers, pilots, aircraft designers, meteorologists, sun lotion manufacturers, seismologists, tsunami warning system operators

- Liquids rise in a drinking straw because of suction
- Fluid pressure only acts downwards
- Human activity is not responsible for climate change
- Global warming and climate change are the same thing
- The atmosphere is transparent to all radiation
- The Earth is molten except for the crust
- The Earth is completely solid
- The Earth's core is hollow
- Earthquakes are rare events
- Seismic waves involve the long-distance motion of particles
- Shadow zones for S-waves occur because S-waves don't travel through oceans
- Seismic waves travel into the core but not back to the crust
- The ground cracks open when there is an earthquake
- Air does not exert a pressure as we cannot feel it
- Air does not weigh anything
- Air particles get less dense/lighter as the height above sea level increases

What do we know? How do we know? Why does it matter?

Atmospheric pressure decreases with height, which can be demonstrated experimentally; this affects air travel and mountain climbing. The atmosphere absorbs, reflects, and re-emits radiation, which we know from experimentation with gases and modelling. We can account for previous changes to climate and predict future changes, which impacts how we live on Earth. Earthquakes produce seismic waves that can be detected by seismometers. The existence of shadow zones where some seismic waves are not detected provides evidence that some of the Earth's core is liquid.

Key Stage 4 Biology *Human interactions with ecosystems have positive and negative impacts on biodiversity and the climate*

Learning progression

Material cycling: Through studying the carbon and water cycles, students study how materials are cycled through the abiotic and biotic components of ecosystems. This requires them to combine their knowledge of processes such as evaporation (physics) and combustion (chemistry) with their biological knowledge of processes such as respiration and photosynthesis. They then focus on the importance of decomposers in returning minerals to the soil and carbon to the atmosphere, and the optimum conditions for decay.

Human interactions with ecosystems: The importance of biodiversity is explored by looking at some of the negative effects of population growth, including pollution, deforestation, and peat destruction; links with global warming are also examined. Finally, students look in detail at the steps being taken to manage waste and to maintain and increase biodiversity.

This is an important topic at both national and international levels, and so discussion of current affairs is encouraged, developing students' ability to distinguish between scientific fact and exaggeration (and how the mainstream media and social media can misuse both). Students also gain a greater understanding of many of the latest developments in maintaining biodiversity, such as through the use of gene banks.

This topic is placed towards the end of KS4 as it draws together knowledge from throughout the biology course and other scientific disciplines.

- Using sensors to monitor abiotic factors
- Synthesising knowledge of materials cycling with chemical processes
- Investigating and calculating the rate of decay
- Researching into peat bog loss
- Graphical representation of world population over time
- Evaluating the impact of environmental changes on the distribution of species in an ecosystem
- Observing eutrophication in pond weed

In my life: making and using compost; recycling; walking to school; visits to conservation projects, such as seed banks

In society: clearing of land for new buildings; increasing world population; biogas production; deforestation; carbon footprint; environmental disasters such as oil spillages; United Nations climate change conferences; government campaigns and legislation; vehicle and factory emissions

Pathways: gardeners, organic farmers, architects, waste managers, environmental biologists, naturalists, climate scientists, weather forecasters, policy makers

- Decay occurs best in damp, cold places (mouldy walls)
- Organisms only breathe out carbon dioxide
- Worms and woodlice are decomposers
- Decomposers release energy that is cycled back to plants
- Biodiversity refers to the range of animals present in an area
- All human activity has a negative effect on the environment
- Species are being lost through extinction and no new species are emerging
- The climate has always changed – so the current measured rate of global warming is natural
- Carbon dioxide levels are tiny – they can't make a big difference to global warming

What do we know? How do we know? Why does it matter?

Materials such as carbon and water constantly cycle through the abiotic and biotic parts of an ecosystem. Human interactions have both positive and negative effects on ecosystems. We know this from observation, and through collecting data about organisms and their environment (e.g., population numbers). This is important as all material in the living world must be recycled to provide building blocks for future organisms and to provide suitable habitats for them to live in, maintaining biodiversity, which is in turn is essential for the future of the human species.

Forces and motion

Key Stage 1 *Forces can change the shape of objects*

Learning progression

Forces are 'invisible', but students can see their real-world effects. Different types of forces can be applied to change the shape of objects by twisting, squashing, bending and stretching, and students begin to develop their vocabulary. These types of forces can be thought of as either 'pushing' or 'pulling' or a combination of a push and a pull.

Students explore how the same force can have a different effect on different objects; trying to squash a sponge or a brick, for example. They explore how they can use their muscles to exert forces, and see how objects can exert forces.

Observing the effect of squashing and stretching different objects

- Solid objects cannot be compressed
- Forces acting on bodies/objects are only associated with living things.
- Force is only something applied to people

In my life: sitting on beds or cushions; stretching elastic bands; using clay in art or making things; cooking or baking
In society: buildings and moving objects such as cars
Pathways: trampolinists, gymnasts

What do we know? How do we know? Why does it matter?

Forces can be exerted on objects to change their shape, which we know from direct experimentation. This is important because the forces people exert on objects should achieve the required goal, or not result in injury.

Key Stage 2 *Forces affect the motion of objects*

Learning progression

Students begin to distinguish between forces that act at a distance and forces that arise when objects are in contact, a categorization that will continue later. They investigate the phenomena of repulsion and attraction of magnets at a distance, the force of gravity acting at a distance, and the effect of contact forces such as friction and drag on the motion of machines and animals. These investigations provide a secure basis for the modelling of forces in KS3. They begin to make links between forces and motion in terms of making things move, speeding them up, or slowing them down.

Students learn how simple machines can be force multipliers, and how such machines are used in everyday life.

- Observing magnets repelling and attracting
- Watching objects falling through water
- Using levers to lift objects

In my life: floating in a swimming pool; feeling magnets repelling; feeling gravity pull you down
In society: sports such as football, cricket, netball, skateboarding, skating; simple machines in the kitchen
Pathways: athletes, swimmers, car designers, engineers, mechanics, plumbers, manufacturers

- All metals are attracted to magnets
- Larger magnets are always stronger than smaller magnets
- Magnetism is the same as the force due to gravity
- All forces need objects to be in contact to have an effect
- Friction only occurs between solid objects
- Air does not exert a force because it is too light
- Things fall naturally with no forces involved
- Barriers stop things falling
- In the absence of a force, objects slow down naturally
- If a force(s) act on an object, it must be speeding up or slowing down

What do we know? How do we know? Why does it matter?

Some forces act at a distance, while others act on objects in contact. We can observe the difference, which is important for developing a model to show how forces arise. Forces affect motion, which we can observe directly, and they apply to all objects that move.

Key Stage 3 *Forces explain motion, stability, and pressure*

Learning progression

Forces: Students move from concrete explorations of the effects of forces to abstract representations of forces, and an understanding of how contact forces arise as a result of interactions at a microscopic level. They meet the idea of a 'field', which is a fundamental concept in physics as a region where objects experience forces. They develop an understanding of the difference between weight and mass, and how to calculate weight; this is the beginning of quantifying and calculating that will continue throughout physics. The stiffness of a spring can be quantified using Hooke's Law. By exploring ideas that forces can be balanced or unbalanced, they develop a sense of vector quantities for forces that act in the same or in opposite directions.

Motion: Students learn to measure and describe motion, move on to quantifying it with calculations of speed, and then to explaining it using ideas of forces. They interact with the idea of how a graph can 'tell a story' by looking at graphs of distance against time. They develop a sense of 'rate' being related to slope, an idea that will be used across the sciences. An important principle is that differences produce change, and in the case of motion it is resultant forces, or unbalanced forces, that produce changes in speed or direction. Forces can change direction without changing speed, which further develops into the idea that quantities have magnitude and direction.

Pressure and moments: Students make links between macroscopic phenomena, such as gas pressure, and the motion of particles on a microscopic scale, using ideas about forces. They distinguish between force and pressure and make calculations and carry out experiments that develop ideas about the inverse link with area. Many mathematical skills are developed, including the importance of units. Students investigate the effect of forces on extended objects, with the practical importance of turning forces, centre of mass, and the stability of objects in everyday life.

- Take photos of everyday objects and model forces by putting labelled arrows on the them
- Apply knowledge of the particle model from chemistry to the origin of contact forces
- Investigate different types of forces using everyday objects
- Use a newton meter to measure forces
- Calculating weight for given masses, such as weight on different planets
- Sketch distance-time graphs for different journeys
- Try simple experiments in gas pressure using a balloon
- Investigate the stability of a bottle of water as you empty it

In my life: lifting or carrying objects; sensing water pressure in your ears when underwater; using simple machines to make jobs easier

In society: car or bicycle journeys when moving steadily, accelerating, and braking; aircraft journeys and the effects of pressure in the cabin; space travel, getting to the Moon and Mars; stability of high-sided vehicles

Pathways: athletes, personal trainers, sports equipment designers, physiotherapists, pilots, aircraft engineers, astronauts, builders, architects, acrobats, divers

- Only animate objects can exert a force, so if an object is at rest on a table, there are no forces acting on it
- Friction only occurs between solid objects and when an object is moving
- Gravity stops acting when the object hits the ground
- Earth's magnetism and/or spin creates gravity
- There is more gravity the higher up you go because things dropped from higher up suffer greater damage when they hit the floor
- Mass and weight mean the same thing, are equal at all times, and have the same unit
- Gravity only affects heavy things
- Astronauts are 'weightless' in an orbiting spacecraft because there is no gravity
- Gravity only works one way – the Earth attracts the Moon, but the Moon does not attract the Earth
- If there is no air there is no gravity
- Pressure and force mean the same thing
- Pressure arises from moving liquids or gases
- Moving fluids cause higher pressures
- Pressure in liquids and gases can be stronger in one direction than another
- Objects float in water because they're lighter than water or contain air, and sink because they are heavier
- Heavier objects always fall faster than lighter objects

What do we know? How do we know? Why does it matter?

Contact and non-contact forces produce resultant forces that can act to change the motion of objects; we know this by observing motion and can represent forces as arrows. This enables us to predict and explain all motion or situations where motion does not change. Weight and mass are different, which we know from their definitions, and effects. This enables us to accurately describe the world.

Microscopic collisions produce gas pressure and moments produce a turning effect, which we know from modelling gas particles in motion, and observations. This is important for human interactions with gases and forces on extended objects.

Key Stage 4 *Forces and their effects can be quantified*

Learning progression

Representing forces: Students learn to consider equilibrium and non-equilibrium situations using free-body diagrams. They use arrows to represent and model forces, and develop an understanding of vectors and scalars; the arrows are not forces. Forces can be resolved into components; forces in two mutually perpendicular directions that are independent. They link forces on free-body diagrams with forces arising from interactions as described by Newton's Third Law, and learn that two forces of equal magnitude in opposite directions on an object is not an example of Newton's Third Law. They learn about the concept of a 'system' in physics; external resultant forces do not act on closed systems.

Forces and matter: Students develop their understanding of the effect of forces on materials by testing strips of different materials and metal springs, plotting graphs, and quantifying the spring constant. Forces exerted on or by solids can be modelled by treating bonds between atoms as springs. Graphs of force and extension describe the behaviour of materials. Pressure in fluids can be quantified. Students make links between pressure in a fluid, depth and density, and use these ideas to explain upthrust. Phenomena such as gas pressure can be explained by the force due to changing momentum of particles when they collide with surfaces. The action of pivots, levers and gears can be explained using the rotational effects of forces.

Forces and motion: Students use ideas of vectors and scalars to categorise quantities such as speed and velocity, and work out the effect of adding them. This enables them to explain the shapes of displacement-time and velocity-time graphs, for example, for skydivers. Students learn more about gradients; what acceleration from a velocity-time graph is, and that area under a graph can be meaningful; the area under a v-t graph is the distance travelled. Students should learn about acceleration due to gravity, g, and the effect of air resistance on a falling object. Students should establish $a = F/m$ through experimentation, and example calculations. They should also link $a = F/m$ to $g = W/m$; the definition of gravitational field strength.

Momentum is an important concept that links force and time of collision. There is a crucial link between the conservation of momentum and Newton's Third Law. There is argument for teaching Newton's Laws in reverse order. Newton's Third Law explains how forces arise, the Second Law describes the link between force, change in momentum and time, and the First Law describes what happens when there is no resultant force.

- Explain the effect of raising a ramp on an object placed on it
- Investigate the effects of mass and force on acceleration
- Investigate stopping distance
- Research the safety features of cars and link them to time and change in momentum
- Research forces in extreme situations: rocket propulsion, ISS
- Practice calculating acceleration from velocity-time graphs
- Use remote sensors or light gates to make measurements of motion
- Discuss uncertainties in the context of precise time, such as in sports events

In my life: most people learn to drive, ideas about stopping distance are tested, drivers make decisions that affect their reaction time; if you dive liquid and gas pressure are important

In society: cars have stopping distances, and human and physical conditions affect them; bungees and other activities rely on knowledge of elastic properties of materials; safety features on cars are designed to increase the time of collisions; airplanes take off and land safely; astronauts go to and live on the ISS

Pathways: computer games designers, designers of prosthetics, bridge designers, aerospace engineers, racing car drivers/ engineers/designers

- Only equal masses can be balanced on a seesaw
- Earth's magnetism and/or spin create gravity
- A rigid solid cannot be compressed or stretched
- Forces only cause changes in speed, not direction
- Speed-time and velocity-time graphs are the same
- Opening a parachute during freefall makes the skydiver go upwards
- When dropped in a vacuum, heavier objects will reach the ground first
- If an object is stationary there are no forces acting on it
- If an object is moving there must be a force acting on it
- Acceleration can only occur in the same direction as an object is moving
- Force is a property of an object; an object has force and when the force 'runs out', it stops moving
- Rocket propulsion is due to exhaust gases pushing on something behind the rocket
- When a force makes an object travel on a circular path the object must get faster (the force must cause a change in speed, not just direction)
- Falling objects stay at the same speed as they fall
- If a force acts on an object it will inevitably move
- The weight of an object resting on a surface and the normal reaction of the surface are an interaction pair
- Cornering objects are forced outwards by a force called centrifugal force

What do we know? How do we know? Why does it matter?

The effect of forces can be quantified using free-body diagrams and Newton's Laws, which we know from modelling and laboratory investigations. This means that motion can be predicted and explained quantitatively. The application of the concept of momentum, also known from investigation, enables fluid phenomena to be explained and the safe use of machines for the transportation of people.

The behaviour of many materials can be modelled using the idea that the bonds between atoms behave like springs. Spring behaviour can be investigated experimentally, and this enables us to manufacture and use them widely.

Waves

Key Stage 2 *Humans detect light and sound*

Learning progression

Light: Students learn that some objects emit light, and we see objects because light from them reaches our eyes. This happens directly or because light is reflected. They begin to investigate the way light interacts with materials; opaque materials can produce shadows; some materials are transparent or translucent. They develop a vocabulary through direct exploration using their eyes as detectors. Light travels in straight lines.

Sound: Students link the vibration of objects to the production of sound and make observations about the materials that sound can travel through. They link the nature of the vibration to the pitch and loudness of the sound that they detect. These explorations link to learning about the five senses in biology.

- Investigate how shadows form
- Make different sounds using instruments and observe the source of the sound

In my life: being in an orchestra/choir; observing objects that reflect light; hearing music and speech

In society: translucent materials in bathrooms; eclipses; shadows; animals making sounds

Pathways: musicians, builders, makeup artists

- Shiny objects give out light
- We see things when light travels from our eyes
- We see things when light shines on them (but does not need to be reflected from them)
- All shadows are black
- Sounds can be produced without any materials
- Megaphones produce sound
- Pitch is related to how hard you hit something
- Pitch is the same as loudness

What do we know? How do we know? Why does it matter?

Light and different types of sound are emitted by sources and detected by eyes and ears. We can make direct observations of this. We use both light and sound to communicate. Light and sound both interact with matter, which we can observe. The use of materials is linked to how they interact with light and sound.

Key Stage 3 *Wave behaviour explains many light and sound phenomena*

Learning progression

Wave properties: Students learn the types of waves, and how waves are described. Direct observations of waves on springs and in water help to develop an understanding that will apply to waves that cannot be seen; sound and light at KS3, electromagnetic and seismic waves at KS4. Understanding how waves are produced enables them to be categorized by type: longitudinal and transverse. This is an important introduction to modelling; light can be modelled using waves, rays, or, later, photons.

The model of a wave is an example of an abstract idea that can be applied widely to predict and explain phenomena. Students learn the overarching principle that waves transfer energy or information.

Sound: Students build on their concrete explorations of sound at KS2 by applying a wave model to predict and explain a range of observations; echoes, how sounds of different loudness and pitch are produced, the range of human hearing, ultrasound and infrasound. They use knowledge of the particle model in chemistry to explain the speed of sound in different materials, and why sound doesn't travel through a vacuum. They use knowledge of cells in biology to explain how sound waves are detected by the ear, and why humans do not sense all sounds. They learn many uses of sound and ultrasound; echo sounding and imaging. The concept of a 'journey' from a source to a 'detector' is a useful general principle for both light and sound, as is the production of electrical signals.

Light: Light can be modelled as rays or waves. The wave nature of light is less obvious to students than that of sound. Mirrors produce images. Refraction is explained using the wave model, as is dispersion. Students learn about spectra; humans detect a small range of frequencies of both light and sound. Light is part of a wider electromagnetic spectrum where waves can be useful, but also damaging. Understanding our perception of colour requires knowledge of frequencies of light and specialized cells in the retina. The ray model better explains the formation of images in mirrors, by refraction, and in lenses. The fact that scientists use different models in the same domain is a powerful message.

- Model different types of wave using slinky springs
- Produce echoes
- Investigate the sound absorbing properties of materials
- Research how traffic noise can be reduced
- Measure the speed of sound in air
- Model sound travelling at different speeds in solids, liquids, and gases using people or objects as particles
- Discuss the similarities and differences between light and sound
- Compare the eye and the ear as detectors
- Observe reflection, refraction, and dispersion in everyday situations
- Investigate reflection in mirrors and the law of reflection
- Research auditory ranges of humans and animals

In my life: viewing optical illusions; loud noises affecting your hearing; seeing colours

In society: music events, concerts; use of echolocation; submarines; detecting schools of fish and the seabed; ultrasound scanning of a fetus, and using ultrasound to diagnose disease; optical illusions in theme parks; high-pitched sounds as deterrents

Pathways: opticians, doctors, nurses, physiotherapists, sonographers, musicians, studio engineers, artists, fashion designers

- Amplitude is measured from the bottom of a wave to the top
- Sound waves transfer air
- As the wave travels, the material travels with it
- Sound is carried by individual molecules
- Sound waves are transverse
- Sound can travel in space (films show this)
- Sound travels fastest in air because it is thinner
- Sound and light travel at the same speed
- Light travels in wavy lines
- Light takes no time to travel
- Light needs air to travel
- Light from a bulb only extends outward a certain distance and then stops
- Light always passes straight through transparent material without changing direction
- When objects are seen, light comes out of the eye and travels to the object
- Light is reflected by shiny surfaces, but not reflected at all from other surfaces
- When light passes through a prism or a filter, colour is added to the light
- All objects that you can see give out their own light
- The rules for mixing coloured lights are the same as the rules for mixing coloured paints

What do we know? How do we know? Why does it matter?

Light and sound both behave like waves, which we know because we observe superposition. This means we can explain a wide range of phenomena involving light and sound using the wave model, and manipulate materials that help us use light and sound.

Waves have properties such as wavelength, frequency, and amplitude, which we can measure directly or indirectly. We can make links between the behaviour of sources of sound and sound wave properties to make music or reduce noise.

Key Stage 4 Waves of the electromagnetic spectrum have similarities and differences we can use

Learning progression

Waves: Students learn to make and use measurements of wave properties using water waves and sound waves. They link frequency and wavelength to wave speed, and learn about amplitude and time period.

Light: Lenses bring very distant or very small objects into view, and they correct vision problems. Students investigate the refraction of light, including total internal reflection and the law of refraction. They apply their knowledge of refraction and lenses to learning how the nature of images in lenses can be predicted and explained and how lenses correct short and long sightedness. Lens behaviour can be explained using the wave or ray model of light. Ray diagrams enable students to predict the position, magnification, and nature of images in lenses and to show how total internal reflection occurs. They also explain its use in optical fibres.

Electromagnetic waves: Our eyes only detect visible light, which can give students the impression that visible light is different or special. By investigating the dispersion of white light by a prism, they learn to consider light as one of similar types of waves in the electromagnetic spectrum. Students learn that all electromagnetic waves consist of oscillating electric and magnetic fields that travel at the same speed in a vacuum. They learn the identity and the broad similarities and differences of the different parts of the electromagnetic spectrum. Some electromagnetic waves are produced by the transition of electrons within atoms, but radio waves are produced by oscillating electrons and gamma rays by transitions within the nucleus.

Waves interact differently with matter, including body cells, depending on their energy. Energy is related to frequency, and hence wavelength. Longer wavelength waves have a heating effect; shorter wavelength waves ionize atoms which can cause mutations in genetic material. Gamma radiation, being both a wave in the electromagnetic spectrum and one type of ionizing radiation emitted from unstable nucleus, is better dealt with in the nuclear physics domain. Uses of electromagnetic waves depend on their interactions with matter, for example radio waves for communications, microwaves for cooking, and X-rays for imaging. The distinction between seeing and imaging is important. All objects emit and absorb infrared radiation dependent upon their temperature. An object that does so perfectly is a black body. We can produce images using all the waves of the electromagnetic spectrum. This is widely used in astronomy, and gives us a view of the universe that we would not otherwise have.

- Observe objects through lenses and use ray diagrams to explain images
- Make a simple telescope
- Research the types of telescopes used in astronomy
- Investigate the type of radiation given off by objects at different temperatures
- Research the use of electromagnetic waves to produce images of the human body
- Link absorption of electromagnetic radiation to what happens in photosynthesis in biology
- Link production of electromagnetic waves to energy levels of electrons in chemistry
- Investigate uses of waves for transmission and exploration

In my life: your eyes detect visible light; visiting the dentist or hospital, infrared for physiotherapy; using microwave ovens, regular ovens, television, radios, mobile phones, Wi-Fi, and sun lamps

In society: electromagnetic waves such as X-rays or gamma rays are used in medical imaging; ultraviolet radiation can damage our bodies and tan our skin; lenses can be used to adjust our eyesight, in microscopes, and in telescopes; astronomical images of stars and galaxies; insects and animals detect infrared and ultraviolet, so 'see' differently to us; satellites bringing communication to all parts of the world

Pathways: doctors, nurses, opticians, radiologists, sonographers, oncologists, television and radio engineers, broadcasters, artists, astronomers

- An object gives off a 'potential image', which travels through space; the image may be turned upside down by the lens
- Blocking part of the lens surface blocks the corresponding part of the image
- The purpose of the screen is to capture the image so that it can be seen; without a screen, there is no image
- An image can be seen on the screen regardless of where the screen is placed relative to a lens; to see a larger image on the screen, the screen should be moved further back
- An image is always formed at the focal point of a lens
- The size of an image depends on the size (diameter) of the lens used to form the image
- Gamma rays, X-rays, ultraviolet light, visible light, infrared light, microwaves, and radio waves are all very different entities
- All radiation is dangerous and should be blocked
- When a wave moves, particles move along with the wave from the point of transmission to the point of reception
- Colour is a property of an object, and colour is not affected by the eye-brain system or other receiving systems
- All images are like photographs
- Waves 'carry' colours

What do we know? How do we know? Why does it matter?

We know from laboratory investigation that lenses produce images, and these are used in a wide variety of optical instruments. Visible light is just one of the waves of the electromagnetic spectrum, all of which have different properties but are fundamentally the same; we know this from laboratory observations and theories of electromagnetism. We use the whole spectrum for imaging, communication, cooking, and in medicine, and we know how the risk of injury from the waves can be reduced.

Earth in space

Key Stage 1 *Weather and day length change during the year*

Learning progression

Students build an understanding of the place of the Earth in the Universe by first making observations that will later be explained by the motion of the Earth around the Sun. They learn that there are seasons in the UK, that the average daytime temperature is higher in the summer than in the winter, and that day length is longer in the summer than winter. The idea of finding patterns, then developing ideas or models that explain observations, is a powerful and enduring understanding in science. Astronomy is an observational science.

Keep a diary of observations over a year or a season

In my life: choosing what clothes you wear in different seasons; seeing that trees change over the seasons; using a calendar; snow in winter; Summer holidays
In society: seasonal festivals; bird migration
Pathways: weather forecasters, clothing manufacturers

- We get winter because there are more clouds in winter which stop the heat from the sun reaching Earth
- Seasons are caused by the Earth being nearer to or further from the Sun

What do we know? How do we know? Why does it matter?

The length of the day and average temperature changes in a largely predictable pattern, which we know from direct measurements. This enables us to predict and respond to conditions in our everyday lives and gives us a basis to develop explicatory models.

Key Stage 2 *We build models of the Universe using observations of celestial objects*

Learning progression

Students turn their attention to objects outside the Earth's atmosphere, known as celestial bodies. They begin to develop an understanding of the structure of the Universe: moons orbit planets, planets orbit stars, solar systems consist of planets orbiting a star, and all these celestial bodies are roughly spherical. They learn that stars are seen because they emit light, but other objects, such as the planets of our Solar System, are seen because they reflect light. The power of science to bring into view objects we cannot see with the naked eye becomes apparent; students learn how the telescope changed our view of the structure of the Solar System. For the first time they meet an explanation that does match their direct observation; the spinning Earth explains day and night and the apparent movement of the Sun and stars, but to them nothing is moving.

- Use shadows to investigate the Sun's movement
- Make models of the planets of the Solar System

In my life: you cannot feel the Earth spinning, but you know that it does by watching objects in the night sky
In society: moon landings; exploration of Mars; space probes imaging planets and moons; history of interpretations of the night sky
Pathways: astronomers, telescope makers

- The moon gives out its own light
- Only the Earth has a moon
- All planets have moons
- Pluto is a planet
- The Sun is not a star
- There are other stars in our Solar System
- The Earth is the centre of the Solar System
- The Earth is stationary, and the Sun is moving
- The Sun orbits the Earth, and this causes day and night
- The Moon does not orbit the Earth
- The Moon, Sun, and Earth are all the same size
- Day and night happen because the Sun goes up and down in the sky

What do we know? How do we know? Why does it matter?

There are objects outside the Earth's atmosphere such as moons, planets, and stars which we can observe with the naked eye or with telescopes. This enables us to build up an accurate model of our place in the Universe. A model of a spinning Earth explains day and night and the apparent motion of the Sun and stars in the sky. The technological advancements made in exploring the Universe can affect our everyday lives.

Key Stage 3 *What we see in the Universe is explained by models that are continually refined*

Learning progression

Earth, Sun and the Moon: At KS3 students develop models involving the spinning and orbiting of the Moon about the Earth and the Earth about the Sun to explain the phases of the Moon, eclipses, seasonal changes on different parts of the Earth, and the tides. Tidal locking means we see one half of the Moon.

Modelling of the Earth/Sun/Moon system is important. The role of force due to gravity is threefold; gravity keeps objects in their orbits, pulls dust and gas in space together to form solar systems, including ours, and is responsible for the concept of weight on Earth, planets, and moons.

Our Solar System: Students learn about the objects within our Solar System in more detail and they learn about the scale of the Solar System in terms of the distance between the Sun and Earth.

They study the nature of the planets and their moons and they learn that the outer planets are giant balls of hot gas whereas the inner planets are solid. They learn that satellites can be natural or artificial, and the latter have a wide range of uses. Geostationary satellites stay in the same place over the Earth's surface; the International Space Station does not. Comets, asteroids, and meteors add to the list of celestial bodies in our solar system.

Beyond our Solar System: Students learn about structures beyond the Solar System: the Oort Cloud and Kuiper Belt and dwarf planets, including Pluto. They learn about our galaxy, and that there are billions of galaxies each containing billions of stars, all formed in a similar way.

Astronomers know there are thousands (but probably billions) of planets orbiting other stars in our galaxy as well as in other galaxies; we are probably not alone. Our place in the Universe is not special and this is a profound insight that astronomy has given us. In addition, huge distances are measured in light-time; looking at the night sky is looking back in time. Modelling is central to our understanding of the Universe; physical modelling helps to communicate the sense of scale, but no one has seen our galaxy from the 'outside'. More sophisticated telescopes, like the Hubble Space Telescope, help us to develop and refine our models, a process that has happened over time and will continue into the future.

- Make models of the Solar System that show distances to the Sun and/or magnitude of the planets
- Research the satellites in orbit around the Earth and their uses
- Make an animation of the formation of the Solar System and Earth
- Use a lamp, globe, and ball to model eclipses and phases of the Moon
- Model the orbits of satellites, and explain the limitations of the model
- Graph differences between the planets of the Solar System
- Research exoplanets and where they are
- Contrast space and terrestrial telescopes

In my life: observing the stars; safely watching solar and lunar eclipses

In society: searching for life on other planets (the Hubble Space telescope); putting rovers on planets like Mars; putting satellites into orbit or sending them to other planets; the Voyager space probe has left the Solar System

Pathways: astronomer, satellite designers, astronauts, GPS device manufacturers, ecologists, artists

- The Solar System is the same as our galaxy
- Mercury is the hottest planet because it is closest to the Sun
- The Earth is the largest object in the Solar System
- The Solar System only includes the Sun, planets, and our Moon
- The Moon can only be seen at night
- Phases are due to the shadow of the Earth on the Moon or clouds blocking the Moon
- The Moon orbits the Earth once each day
- There is a side of the Moon that is always dark
- The Sun is the only star that has planets
- There is no gravity in space or on the Moon
- Planets cannot be seen without a telescope
- Planets appear in the same place every night
- A light year is a measure of time
- It is hotter in the summer because the Earth is closer to the Sun
- The position of stars and planets affects humans on Earth
- Everything we see in the night sky is a star

What do we know? How do we know? Why does it matter?

We live on a planet that is part of a solar system, which is one of many in a galaxy; itself one of many in the Universe. We have built up this model from observations of the night sky, and it means we understand our place in the Universe. The Earth spins on a tilted axis, orbits the Sun, and has a moon in orbit around it, which is a model we have developed from observations. It explains many phenomena including tides, eclipses, and phases. The advancements in the technology used to build our knowledge of this can affect our everyday lives. Gravity is responsible for keeping objects in orbit and for the formation of objects, which we know from mathematical modelling, and means we can predict astronomical events.

Key Stage 4 *The Universe is expanding, stars will die, and there are other planets like Earth*

Learning progression

Stars: Our understanding of the life-cycle of stars is an example of how observations can be used to develop an explicatory model. Students learn that stars form when gravity pulls together gas and dust, and shine when the conditions for nuclear fusion are met. Chemical elements as heavy as iron are formed in this process. Stars continue to shine until their nuclear fuel is exhausted; what happens next in their life-cycle depends on their mass. Students apply ideas about gases and gravity to the death of stars, and use knowledge of the speed of light to define black holes. That heavy elements are made in supernovae suggests our solar system formed long ago from the remnants of a supernova. This makes gold far more valuable than diamonds, which can be made on Earth.

Observing the Universe: Stars emit electromagnetic radiation, some of which is reflected by their planets and moons. Telescopes observe a small fraction of the sky. Students learn that observations used to be only possible with visible light, but now telescopes sensitive to all electromagnetic waves are used; the atmosphere absorbs some frequencies, so those telescopes are in space. The light from stars forms line spectra that tell us elements that are in the stars; light reflected from or transmitted through the atmosphere of exoplanets (planets in other solar systems) give evidence of oxygen or water. The orbits of exoplanets tell us whether they are in the habitable zone. Gravity produces stable orbits and acts perpendicularly to velocity, and velocity changes with radius.

The expanding Universe: Students learn that observations of light from galaxies show that light is red-shifted. Distant galaxies are moving apart, evidence that space is expanding, which supports the Big Bang Theory that the Universe began about 14 billion years ago. Our Solar System is much younger. Observations of galaxies suggest that 'dark matter' is speeding up the rotation of galaxies, and 'dark energy' is speeding up the expansion of the Universe. Students learn that we do not know what most of the Universe is made of; the nature of dark matter and dark energy eludes us. There is still much to learn about the universe.

- Make observations of stars in the night sky and use their colour to work out where they are in their life-cycle
- Use diffraction gratings to observe light emitted by different light sources
- Research the telescopes that are in space and compare the wavelengths they detect with those on Earth
- Make a model of the expanding Universe with elastic/a balloon
- Research how estimates of the age of the Universe have changed
- Make an animation of the life-cycles of low and high mass stars
- Research the candidates for dark energy and dark matter

In my life: tuning your radio or TV to white noise, as 10% of what you hear is the 'echo of the Big Bang'; watching rockets lift off from the Earth

In society: images from the Hubble Space Telescope show star nurseries where stars are born, and remnants of supernovae; satellites are in orbit; some rovers have gone to Mars or to explore the Solar System

Pathways: astronomers, SETI scientists, digital image processors, rocket builders, NASA engineers

- There is only one planet like Earth
- Space is totally empty
- The Sun is on fire
- Our Sun is the biggest star in the Universe
- Stars never die, they shine forever
- All stars are the same size
- A black hole is like a vacuum
- The Solar System formed during the Big Bang, along with the rest of the Universe
- There is a space outside the Universe into which the Universe is expanding
- The Universe is a few thousand years old
- Water is only found on Earth
- The Solar System and galaxies are very 'crowded'
- All stars are the same size, so the brightness of a star depends only on its distance from earth

What do we know? How do we know? Why does it matter?

The life-cycle of a star depends on its mass and can be deduced from modelling it as a gas that experiences gravity and in which nuclear fusion occurs. This enables us to explain what we see, and predict what will happen to our Sun. The spectra of light from stars contains absorption lines, like a bar code that tell us which elements are present, and can be used to determine the motion of the source. We know this from observation, and it provides evidence for candidates for extra-terrestrial life, and for the expansion of the Universe. The Big Bang happened about 14 billion years ago; observations of receding galaxies tell us this, but the speed of expansion is increasing because of dark energy.

Electricity and magnetism

Key Stage 2 *Magnets attract and repel, cells make circuit components work*

Learning progression

Students experiment (play) with magnets and simple circuits, making observations to be explained with models later. Investigations at this level should allow for introducing vocabulary like: poles, attract, repel, circuit, cell, lamp, buzzer, switch, complete circuit, conductor, insulator, and magnetic. Students can investigate which materials are magnetic and which conduct. They will see a pattern; all metals conduct, but not all metals are magnetic. They can make simple circuits and observe the effect of adding cells, buzzers, lamps, and switches. The level of abstraction extends only to the introduction of circuit symbols to draw circuit diagrams. Students will use the word 'electricity' to describe what is 'flowing' in the wires. Clarification of what is happening in the wires follows in the next Key Stage. There are clear links to forces, and it is useful to make those links explicit as we later introduce 'fields'.

- Use magnets to find magnetic materials
- Research what wires are made of in the International Space Station

In my life: toys can use magnets and circuits; lifting up paperclips and finding they 'stick'; making words with magnetic letters on the fridge

In society: batteries in electronic devices; electrical devices working all around us

Pathways: electricians, builders, appliance manufacturers

- All metals are attracted to magnets
- All silver-coloured items are attracted to magnets
- Larger magnets are always stronger than smaller magnets
- Magnetic poles are always at the end of the magnet
- Only metals conduct electricity

What do we know? How do we know? Why does it matter?

Magnets have north and south poles, like poles repel and unlike poles attract, which we know from experimenting with magnets, and this enables us to make compasses. Some materials conduct electricity and are used to make circuit components like lamps, used in circuits with cells. We use a wide range of electrical devices that contain cells.

Key Stage 3 *Models of electricity and fields explain phenomena in circuits and magnets*

Learning progression

Electrostatics: Students learn that electrostatic phenomena can be explained by considering the transfer of electrons, usually by friction, because electrons have (negative) charge. They learn this before formally studying the structure of atoms; the concept of charge as a property of a material, like mass, should be explored with a little history. Flow of charge per second as a current is a key point. In any situation there is a current when charge flows. Conductors and insulators exist on a spectrum, not as a binary choice, this is shown by an insulating air gap in a switch and air conducting when lightning strikes. There is a force on any charge in an electric field.

Current electricity: Students cannot see electrons moving in wires, but they can investigate simple circuits and model them; rope loops and water circuits are examples.

A model helps students learn the difference between current and potential difference (p.d.); charge per second and energy per charge/setting up a field. The concept of resistance also emerges from models and can be related to definitions of conductors and insulators. A model of a metal shows why metals resist charge flowing. Students learn that current is the dependent variable and use p.d. and resistance to calculate it. Circuits that fulfil particular functions are possible using series and parallel circuits.

Magnetism and electromagnetism: Students will have met gravitational, electric, and magnetic fields by the end of this topic, and learned that a field is a region where there is a force on an object (a mass, charge, or magnetic material). A field is an abstract concept, represented by physical lines (which are not the field).

Compasses indicate the Earth's magnetic field, the poles of which are not where geographic poles are, and show the shape of the field around magnets, Fields are stronger near poles; we draw denser field lines there. Compasses also show a magnetic field around current carrying wires and electromagnets; our lives have been changed immeasurably by devices with motors. Using lots of coils, a core of magnetic material, and a large current can make very strong electromagnets; the field around a coil has the same shape as a bar magnet. Students learn that combining fields can produce a force on a wire that is used to make electric motors.

- Research how a Van de Graaf generator works
- Investigate conductors and insulators
- Make simple circuits with lamps, switches, batteries and buzzers
- Practice using ammeters and voltmeters in series and parallel circuits
- Make an animation showing how an object can be charged positively and negatively
- Use the rope model to explain the effect of more cells and more lamps in a series circuit
- Use a model to explain the difference between series and parallel circuits
- Investigate the strength of an electromagnet
- Make a simple motor

In my life: getting a static shock when touching something metal because you are charged by friction; clothes crackle when you take them off

In society: damaging or fatal lightening; balloons stick to walls; bending water; Earth's magnetic field; scrapyards moving cars with magnets; there are over 50 electric motors in most houses

Pathways: scrapyard employees, Maglev train designers, painters of aircraft, engineers, electrical manufacturers, doctors, farmers, paramedics, nurses, electricians

What do we know? How do we know? Why does it matter?

Subatomic particles are charged positively or negatively, which we can show by deflecting these particles in electric or magnetic fields. We explain electrostatic phenomena by considering the transfer of electrons. Electrons move through metal wires because of a potential difference across the wire that sets up an electric field. We deduce this from models of atoms and indirect measurements, and we can design useful circuits. There is a magnetic field around a magnet, the Earth, and current-carrying wires, which we can detect by their effect on magnetic materials, and use for navigation and to make motors and other electromagnetic devices.

- Objects become positively charged because they have gained protons/electrons have been destroyed
- All the electrons in an electrical circuit are initially contained in the battery or other source of the electricity
- Potential difference is the same as current
- Potential difference flows through components
- A larger battery will always make a motor run faster or a bulb glow brighter
- Current flows from a battery to a light bulb, but not from the light bulb to the battery
- A battery gives out a certain current but if the circuit has lots of resistance that current will get smaller as it flows round the circuit
- Wires are hollow like a water hose and electrons move inside the hollow space
- Pure water is a good conductor of electricity
- Electrons which are lost by an object disappear
- Current flows out of both terminals of a battery or power-pack (the 'clashing' current model)
- Current is used up in a circuit
- The magnetic pole of the Earth in the northern hemisphere is a north pole, and the pole in the southern hemisphere is a south pole
- Larger magnets are stronger than smaller magnets
- Earth's magnetism and/or spin create gravity
- The magnetic and geographic poles of the Earth are located at the same place
- Magnetic poles are charged
- Voltmeters are connected in series

Key Stage 4 *Electric circuits and electromagnetic devices have made our world cleaner and easier*

Learning progression

Electrostatics: Students use the law of force to explain charging by induction and they learn that tiny sparks can have dramatic consequences in the wrong environment. They learn more about electric fields, how they are represented, and how strength varies with distance from a charge. They see an analogy with gravitational fields; there are forces between two charged objects. Charge is a quantity in coulombs, like mass is in kilograms.

Current electricity: With an understanding of current, p.d., and resistance students can investigate series and parallel circuits and learn the behaviours and uses of diodes, resistors, variable resistors, thermistors, and LDRs. Some are ohmic, some are not. They can use these components as sensors. The 'internet of things' relies on converting physical phenomena to a potential difference. Students learn about mains electricity; it is alternating, high p.d., and reaches homes via the National Grid. Fuses, circuit breakers, and double insulation protect appliances and/or us. Compare current, p.d., and resistance in series and parallel circuits. We pay for a generator to turn and produce a p.d. so a current can transfer energy electrically over a certain time; units are kWh, which use power and time. We are also paying for the infrastructure of the National Grid, as well as fuels, power stations, and power lines. As learned in 'Energy', electrical power is not a substance that you buy. The definitions of current and p.d. explain how to calculate electrical power. Students learn how transformers enable power to be transmitted at high p.d./low current, reducing heating losses. The law of conservation of energy explains this trade-off between less energy being dissipated but higher potential difference, which is more dangerous.

Electromagnetism: Magnetic field strength, or magnetic flux density, is a vector measured in teslas. These definitions need explanation. Magnetic materials placed in a magnetic field become induced magnets. Students learn about the link between electricity and magnetism: motion + magnetic field produces an induced p.d. (and current in a circuit), current + magnetic field produces motion. This is the overview of generators and motors that applies to microphones and loudspeakers. In the motor effect, the motion of current carrying wires in fields can be predicted and quantified. In the generator effect, it is the relative motion of a coil and magnet that induces a p.d. Generators can be designed to produce direct or alternating current. Historically, a decision had to be taken about which type to use; we use alternators so that we can use transformers.

- Draw Venn diagrams that show the similarities and differences between gravitational, magnetic and electrostatic fields
- Design circuits to measure the environment (e.g., temperature)
- Investigate the output of a wind generator
- Research the structure of the National Grid
- Compare the structure of dynamos and alternators
- Practice calculations of the cost of electricity used in household devices
- List features that mains electricity uses and design features that reduce risk of injury

In my life: avoiding flying kites near power lines; avoiding substations (transformers) that are part of the National Grid

In society: mains electricity in the house can cause us injury if misused; birds perch on wires at a high potential difference without getting a shock; hospitals monitor the status of patients remotely using sensors; alarm systems are linked to sensors; electric cars do not emit polluting gases, but the ways of generating the electricity may do; very strong electromagnets are used in MRI machines

Pathways: musicians, concert hall designers, National Grid engineers, electricians, 'Smart' house designers, electric car designers, intensive care nurses, doctors, gardeners

- The electrostatic force between two charged objects is not affected by the distance between them
- A charged object can only affect other charged objects
- Gravitational forces are stronger than electrostatic forces
- Mains sockets have current inside them waiting to get out (hence child socket covers to stop it 'leaking out')
- All wires are insulated
- Birds can perch on bare wires without being hurt because birds have insulated feet
- Electricity is produced in the wall socket
- Magnetic field lines are really there – a magnetic field really is a pattern of lines

What do we know? How do we know? Why does it matter?

Electric circuits containing components whose resistance changes with the environment can be used to sense and control, which we know from direct measurements, and this enables us to monitor the status of patients, houses, and machinery. Generators use the relative motion of magnets and wires to induce a potential difference. We can demonstrate electromagnetic induction experimentally and use electrical devices in our homes via the National Grid as a result. There is a force on a current-carrying wire in a magnetic field, which we can demonstrate and use in electric motors, and explain with the addition of magnetic fields.

Energy

Key Stage 2 *Temperature describes how hot a material is*

Learning progression

Students inhabit a world that changes temperature, and now they can quantify that using thermometers to measure the temperature of objects. This is an opportunity to contrast the senses in the human body with measuring instruments; skin is better at detecting differences in temperatures than absolute values of temperature. This is also an opportunity to discuss units; at one time there were over 35 different units of temperature, but now we use degrees Celsius in science (and later will use Kelvin).

Contrast the temperature of bowls of water using skin and thermometers

In my life: feeling hot or cold; hot food cools down; shower and bath temperature

In society: in hot countries you can cook eggs on the pavement; thermostats keep houses a comfortable temperature

Pathways: clothes designers, plumbers, meteorologists

- All liquids boil at 100 °C and freeze at 0 °C
- Some objects are naturally warmer than others
- Hot and cold are different entities rather than being opposite ends of a continuum
- Boiling point is the maximum temperature and freezing point the minimum temperature of a substance

What do we know? How do we know? Why does it matter?

Temperature can be measured with a thermometer and tells you how hot a material is, which can be quantified using a unit of temperature (e.g., Celsius) and then measured experimentally. Temperature is an important concept throughout Science as many processes, such as chemical reactions, depend on it, and the human body cannot survive extremes of temperature.

Key Stage 3 Energy is an accounting system that can be modelled

Learning progression

Energy as a concept: Energy is a fundamental concept because it is simply a quantity that can be calculated. At KS3 these calculations are not appropriate, and instead modelling is required to communicate that energy is just a number, and that the numbers add up. Energy shows us what is possible, not why things happen. A useful analogy is that energy is like money. Students can get a feel for 1 joule by lifting an apple 1m. Students use the particle model to distinguish between temperature as the average energy per particle, and the 'total energy' (or internal energy), which depends on the amount of material. Temperature, by contrast, does not. Energy conservation is one of the most important principles in science. 'Heat' as a substance is an idea with historic origins that can be explored.

Energy stores and transfers: Modelling of energy should introduce the idea of stores; these are systems (one object or a group of objects) where energy can be calculated. This definition clarifies (to teachers) why light, sound, heating, and electric current are not stores but methods of transferring energy between stores. We can show students that we calculate energy transferred using the power and time taken. Important energy stores are kinetic, gravitational potential, elastic potential, thermal, chemical, and nuclear. It is also important that students know that processes transfer energy concurrently, not consecutively. An energy analysis involves considering two points in time, or snapshots, that enable you to identify which stores are depleted, and which augmented, and by what processes. Energy is transferred through heating by conduction, convection, or radiation; radiation is 'infrared', which is emitted and absorbed by all objects, but more by dark, matte surfaces and less by light, reflective surfaces.

Energy resources, work and power: Explaining why we need to 'save energy' when energy is conserved needs explaining with the concept of dissipation. Some processes are efficient and transfer less energy to stores that are not useful, or dissipate less energy. Insulation and lubrication reduce dissipation. Power stations use fuels to produce a potential difference; we save the *fuel*, not energy, by turning off lights. A generator contains a magnet and a coil. Energy stores should not be confused with energy resources or fuels. Many energy resources are limited. Power is the rate of transfer of energy, and we are charged for 'units' that involve power and time. Machines can make jobs easier, but obey the law of conservation of energy; work out = work in, so you can have a bigger force, but it will act over a smaller distance.

- Model processes like using a microwave oven using beakers and coloured water, or counters
- Investigate materials to find the best insulator
- Research different energy resources in terms of how long they will last
- Find out how the energy efficiency of household devices are calculated
- Make a wind generator
- Practice calculations of work, power and cost of electricity
- Do an energy analysis of simple toys
- Find processes that appear to contravene the law of conservation of energy, or perpetual motion machines and explain how they work
- Study electricity bills
- Compare the energy value of different foods

In my life: feeling hotter when you wear darker clothing on a hot day

In society: being encouraged to turn off appliances to 'save energy' (but really fuels); microwaving popcorn takes less time on a higher power setting; houses changing to renewable energy resources such as solar panels; wind farms are renewable energy resources; oil is used for plastics, but we are running out of it

Pathways: fabric manufacturers, architects, kitchenware designers, climate researchers, mountaineers, energy company workers, oil prospectors, oil rig workers

- Energy is a thing or object that is tangible
- Energy can be changed completely from one store to another (no energy losses)
- 'Heat' is a substance which can flow from place to place
- An object at rest has no energy
- Energy and force are interchangeable terms
- Energy gets used up/energy can be made
- Devices use up energy
- Energy is confined to some particular origin, such as food, electric companies
- 'Heat' rises (as opposed to hot substances rising)
- Thermal conductors and insulators are opposites, not part of a continuum
- Hot objects can cool down without something else around them getting hot
- Energy is only transferred upwards by heating
- Cold can be transferred
- Energy is truly lost in many energy transfers
- When you heat a substance, particles get hotter
- Energy is fuel
- Work is synonymous with labour or a job, and not to do with forces
- Power and energy are the same thing
- Heat and temperature are the same thing

What do we know? How do we know? Why does it matter?

Energy is conserved, which is a principle that can be demonstrated practically, such as a pendulum swinging back and forth. If energy appears to be 'lost' we look for a reason; a pendulum eventually slows down because of air resistance or heat losses. Energy is transferred by heat, light, sound, when doing work electrically, or by forces, which we can demonstrate experimentally. Efficient transfers save fuels for use elsewhere. Energy resources for producing electricity or heating are limited and should be conserved. We can quantify the available non-renewable resources and develop renewable resources so that the world continues to be supplied with electricity.

Key Stage 4 Calculating energy is useful and necessary for many analyses and industries

Learning progression

Energy and matter: At KS4 energy stored and transferred can be quantified; a closed system has no energy transfer in or out. Heating can increase the kinetic energy of particles; this relates to specific heat capacity, or an increase in the potential energy, which relates to specific latent heat. In both cases internal energy increases. The way that energy is stored in a system changes when you heat it; how objects feel, however, depends on conductivity. This is an everyday experience that is counter-intuitive. Temperature is related to the average energy of particles. The gradient of temperature-time graphs is related to specific heat capacity for heating at a constant rate. The gradient is horizontal for a change of state. Students investigate the effect of heating materials on changes of state and temperature.

Students learn the thermodynamic principle that the internal energy of a gas can be increased by heating or working. This, and calculations of efficiency, pave the way for learning about heat engines later. Efficiency increases as dissipation decreases. The link between work and energy should be brought out here. The relationship between energy, power, and time is seen when heating materials, including relevant equations.

Energy stores: Students can now put numbers to the stores they learned at KS3: energy in a kinetic, gravitational potential, elastic potential, and thermal store can be calculated, and the numbers can be used to deduce quantities such as velocity. They see that energy can also be stored electrostatically or magnetically. Students can see work being done in a range of situations, and notice that all examples involve a force moving through a (parallel) displacement, resulting in a transfer of energy.

Energy resources: At this level students can investigate the full range of energy resources used for transportation (oil), heating and cooking, and generating electricity (other resources). There are social, moral, political and economic considerations surrounding the use of different energy resources, which differ across the world. Climate change is a unifying concern for all countries.

- List cooking processes that involve specific latent heat/specific heat capacity
- Measure the specific latent heat of water with a kettle of known power
- Research materials used in extreme conditions; at the poles, in space
- Tabulate the pros and cons of the use of different energy resources for generating electricity
- Use g.p.e. and k.e. to calculate speed for different theme park rides
- Use the g.p.e. of objects on a ramp to quantify work done by friction
- Investigate the power output of a solar cell
- Investigate thermal conductivity

In your life: feeling chocolate and butter melt in your mouth; sweating to cool down; some liquids feel cold to the skin; feeling temperature differences between different materials such as plastic and metal

In society: entertainment such as rollercoasters, snowboarding, and even cheese rolling all use energy and energy transfers; trains that run on magnetic levitation are more efficient because there is less friction; climate change affects sea level and food production

Pathways: dry ice makers, engine manufacturers, heating engineers, power shower makers, plumbers, chefs, athletes, theme park designers, space probe and satellite manufacturers

- Heating boiling water more vigorously will make its temperature rise above 100 °C
- Boiling point is the maximum temperature a substance can reach
- The bubbles in boiling water contain air/oxygen or nothing
- Some objects are naturally warmer than others
- There are energy types that are distinct from each other
- The only type of potential energy is gravitational
- Gravitational potential energy depends only on the height of an object
- Doubling the speed of a moving object doubles the kinetic energy
- All renewable energy resources are good, and all non-renewable energy resources are bad
- All power stations produce smoke
- Wind generators are very loud

What do we know? How do we know? Why does it matter?

We can calculate the energy associated with stores and transfers, which we can deduce from principles of forces and fields. This enables us to make decisions about processes that use fuels or food. Transferring energy to and from matter happens all the time in our everyday lives, and can happen efficiently or inefficiently, which we know from measuring the useful output energy and comparing it with the total input energy. This has financial and environmental consequences. Our supply of some of the fuels we use is limited, and using them affects the planet. We know from the direct measurement of current CO_2 levels, and the indirect measurement of historic CO_2 levels, that climate change and fuel use are issues we will need to deal with in the future.

Atomic, nuclear, and quantum physics

Key Stage 4 *Atomic and nuclear structure explains radiation*

Learning progression

Emission and absorption of electromagnetic radiation: Students build on knowledge of electromagnetic waves, and how they are produced. They link the concept of energy levels of electrons in atoms in chemistry to the production of spectra (both absorption and emission). The evidence from the spectra of stars informs our knowledge of the matter in the Universe and the search for extra-terrestrial life. The concept of energy levels provides a mechanism for understanding the production of gamma rays by the nucleus when studying radioactivity.

Radioactivity: The history of radioactivity illustrates the transition from observations of macroscopic phenomena to understanding at a microscopic level; in this case the behaviour of radioactive materials is explained by changes to nuclei. The model of the atom has developed due to experimental evidence.

Students learn that radioactive materials emit alpha α and beta β particles, and gamma γ rays that interact differently with matter, but all originate from the nucleus of an unstable atom. The nature of $\alpha\beta\gamma$ radiation is brought out in decay equations. The identification of beta particles as electrons produced and instantly emitted by the nucleus provides evidence that nucleons are not fundamental particles. The search for 'fundamental building blocks of matter' has driven much of physics for over 100 years. Half-lives of radioactive materials vary enormously, and individual nuclear decays cannot be predicted. The link between probability and randomness is important, with parallels in many other phenomena from modelling the spread of a virus to weather forecasting.

Decay, uses, dangers, and risks: Students learn that radiation takes different forms, and can have many uses, but some can be damaging. Uses of $\alpha\beta\gamma$ radiation reflect their different properties, for example, alpha in smoke detectors and gamma in finding pipes leaking underground. Students learn the importance of balancing risk with the benefit from uses of radiation such as radiotherapy; an overarching principle in applying science. Background radiation poses little risk, and contamination and irradiation are different and can pose a greater risk. There are moral issues with the use of fission, but it may provide energy resources that contribute less to climate change. The attempts to produce nuclear fusion reactions will have significant societal consequences in the future, like nuclear fission has had in the past and present.

- Plotting graphs of activity vs. time, and using graphs to work out half-life
- Modelling radioactive decay with dice or M&Ms
- Make physical models of the changing model of the atom
- Make a scale model of the atom showing the relative diameter of the nucleus and atom
- Compare the ways of working of scientists who discovered the electron/nucleus with those who discovered quarks/Higgs boson
- Research methods of detecting exoplanets/exobiology
- Research progress of fusion reactors
- Do a risk/benefit analysis of uses of radioactive isotopes

In my life: using lasers for scanning bar codes and storage devices; eating irradiated food, and breathing in radioactive material harmlessly; light reaching your eyes coming from radiation

In society: using radiation therapy to treat cancer; radiation in scans such as MRIs and CT scanning; nuclear medicine used for diagnosis and treatment of illnesses; nuclear power stations, nuclear accidents, nuclear waste or leaks around the world; fusion in the Sun and stars make them shine; astronomy in the news; exoplanets

Pathways: archaeologists, gamma astronomers, plumbers, nuclear pharmacists, food scientists, radiologists, GPs, dentists, engineers, forensic scientists

- All radiation is harmful
- Nuclei disappear when they decay
- Radiation makes things radioactive
- Radioactivity first appeared during World War II
- Once a material is radioactive it is radioactive forever
- Half-life is half the time for the radioactivity to disappear
- Radiation causes cancer, so it cannot be used to cure cancer
- Beta particles come from electron shells and not from the nucleus
- Atoms cannot be changed from one element to another
- Irradiation makes things radioactive
- You get most of your background radiation from nuclear power stations
- Fission and fusion are the same; fission is more powerful than fusion
- Nuclear power stations are always dangerous
- Radiotherapy and chemotherapy have the same effects on the body
- You always get contaminated by radiation

What do we know? How do we know? Why does it matter?

We understand the structure of the atom and nucleus from direct experimentation (e.g., alpha scattering) and modelling, which enables us to explain how electromagnetic radiation is produced, and why some nuclei are unstable. Unstable nuclei decay and emit radiation as discovered by experimentation, which is used in nuclear power stations and weapons; nuclear material has a wide range of uses. Radiation can have a detrimental effect on human tissue, which we know by irradiating cells and studying the results, and evidence from nuclear explosions. Knowledge of the risks of injury protects people working with radioactive material, but has enabled radiation to be used in food treatment and used in medical diagnosis and treatment.

The *Activate* KS3 curriculum

Course structure and resources

Course structure

The Oxford Smart Curriculum for Science is a fully comprehensive and responsive curriculum designed for learners and their teachers from age 11–16. As part of Oxford Smart Science, the *Activate* course provides a complete Key Stage 3 curriculum, with extensive support for learners of all attainments, and experienced and non-specialist teachers alike. Curriculum resources are available as print and e-books that are fully integrated with digital content hosted on Kerboodle. The curriculum also fully integrates formative paper-based assessment, automated summative assessment with personalised next steps, detailed teacher reporting and intervention content, and extensive teacher personal development.

The KS3 course provides for a 2, 2.5, and 3-year KS3 through adaptable resources. All core Science content (aligned with the UK National Curriculum) is covered by the end of Year 8 in the curriculum to facilitate a range of approaches to Year 9. Core curriculum content in Years 7 and 8 is split up into separate Biology, Chemistry, and Physics topics, which cover all of the knowledge needed for the content, provide opportunities for consolidating learning through retrieval and further questioning, and focus on developing maths and working scientifically skills. Each topic also supports learners in taking charge of their own learning through metacognitive practices, and demonstrates diverse perspectives and pathways within Science. The assessment model of the course is based around the Developing, Secure, Extending framework (*see page 67*), which aims to bring all learners to at least the secure level for each topic before progressing.

Activate's Year 9 focuses on revisiting core concepts in KS3 to consolidate learning, and to prepare for the GCSE transition. The course provides two approaches to Year 9:

1. Refresh, Apply, Extend: learners recap key knowledge from Years 7 and 8, then apply this to unfamiliar contexts and real-world scenarios, and finally extend their knowledge by stretching up to studying this core knowledge in a GCSE setting.
2. A project-based approach to develop knowledge with skills, written by experts in incorporating project work into Science curricula.

Schools will have both Year 9 approaches available to them, and so can choose the right path for their school, cohorts, or individual classes.

The total KS3 curriculum is separated into two major pathways, either of which are compatible with 2 and 3-year KS3 courses and can be chosen by individual schools to best suit their cohorts:

1. *Activate* 123, corresponding to Years 7, 8, and 9; Biology, Chemistry, and Physics are all taught in each year.
2. *Activate* BCP; Biology, Chemistry, and Physics are grouped together rather than divided into Years 7–9.

Course resources

For learners:

- A student book for each year (or subject), with all the required knowledge for each topic, plenty of practice questions, retrieval questions, lots of opportunities to develop maths, literacy, and working scientifically skills, and support for self-regulated learning.
- Student books also contain profiles of a diverse range of scientists, and information on the relevance of Science topics to everyday life.
- Interesting, challenging, and supportive resources on Kerboodle to accompany lessons and to do outside of class for each topic.
- Post-assessment automated and personalised next steps on Kerboodle, which support learners in improving and consolidating their knowledge and skills, and challenge them with appropriate extension activities. Next steps are also available on Kerboodle for learners to repeat at any time.
- Automated retrieval question bank, targeting the forgetting curve, for learners to refresh their knowledge at any time.
- Resources on the relevance and importance of Science to themselves and society, and diverse pathways related to Science, to demonstrate that Science is useful and accessible to everyone and engage learners with scientific careers.

For teachers:

- A comprehensive suite of teaching resources for each year (or subject) as part of the teacher handbooks and on Kerboodle. These include one full lesson plan for each topic, which fully align with the student book content, and integrate development of metacognitive learning, and maths, literacy, and working scientifically skills.
  The teacher handbooks also contain targeted assessment intervention lessons, and support preparation for each area of content.
- Each lesson plan is fully accompanied on Kerboodle by its required resources, including student and teacher versions of worksheets, and additional support for learners.

- Online professional development modules, covering areas including curriculum implementation, self-regulation of learning and metacognition, responsive teaching and learning, and scientific identity.
- Detailed reporting on Kerboodle at the cohort, class, and individual level, which displays progress through each curriculum topic, assessment information, top misconceptions displayed by learners, and suggested next steps and interventions.
- Automated assessment and next steps for learners on Kerboodle save teacher time. Next steps are diagnostic and personalised so teachers can see learner progress and needed support; these are also fully assignable by teachers.

Introduction to DSE framework

The KS3 *Activate* course is structured around the learning objectives and Developing, Secure, Extending learning outcomes. Learning objectives are the knowledge learners will cover in that topic.

Learning outcomes are the extent to which learners aim to cover that knowledge. These should be used as guidance of how deeply a learning objective is covered and how its knowledge can be applied by a learner.

The learning outcomes take into account age-related expectations, level of cognitive demand, prior learning, familiarity of content and contexts, and component/composite knowledge. Each learning objective is differentiated into **Developing**, **Secure**, and **Extending** (DSE) outcomes:

- Developing learning outcomes: learners at this stage are working towards secure knowledge and understanding, but need more support to achieve this.
- Secure learning outcomes: learners at this stage have a secure knowledge and understanding; this is the aspiration for all learners to achieve, prior to moving on to the next topic.
- Extending learning outcomes: learners at this stage are working beyond age-related expectation, and their knowledge and understanding can be stretched and challenged.

The learning objectives and outcomes have been used to create all of the teaching and learning resources within *Activate*, including the student and teacher books, lesson content, and assessment. They show what knowledge should be covered when and to what extent in the curriculum, and reflect sequencing of topics. Therefore, they are of key importance for curriculum planning, diagnostic assessment of learners and their needs, intervention, and determining support needed for learners.

Complete learning objectives and outcomes are given for Years 7 and 8 on pages 83–125.

Year 9 overview

The *Activate* curriculum's Year 9 provides a more flexible route, catering for the different needs of schools following a 2.5- or 3-year KS3. All schools will have covered all of the required content from the UK National Curriculum by the end of Year 8. Schools following a 2-year KS3 will skip Year 9 of *Activate*, proceeding directly onto a GCSE course. While catering for different learners, *Activate* Year 9 will move all students towards GCSE by preparing them for the skills and knowledge they need for success.

The course provides two approaches to Year 9:

1. Refresh, Apply, Extend – available as a blended resource with student and teacher book, and associated Kerboodle content. Learners recap key knowledge, apply this to unfamiliar contexts and real-world scenarios, and extend their knowledge by stretching up to a GCSE setting. This is a highly adaptable route, with high levels of flexibility to alter teaching focus depending on needs of cohorts.
2. A project-based approach – available as a suite of Kerboodle resources. Series of cross-subject practical projects, to do sequentially throughout early Year 9, or interspersed with Approach 1. This will focus on consolidating key concepts from Years 7 and 8 through strongly developing epistemic and procedural knowledge and skills, engendering ownership of learning, and strengthening Science identity in learners.

It is also possible to mix-and-match between the two approaches within a cohort, or even class. For example, choosing Approach 1 for Year 9 Biology, but Approach 2 for Chemistry and Physics.

Approach 1

As for Years 7 and 8, the Year 9 content is arranged into Biology, Chemistry, and Physics chapters in the student and teacher books. Each chapter is divided into Refresh, Apply, and Extend sections, and each chapter focuses on a core concept within Science. The longer Apply section allows learners to apply learned knowledge to new unfamiliar (AO2 and AO3) contexts, with different question types and practicals, and consideration of real-world applications. The Extend section gives learners the opportunity to extend their knowledge by studying the same concept in a GCSE setting, providing more challenge and a slightly different focus. The time an individual, class, or cohort spends on each section (Refresh, Apply, Extend), and the pace of progression, can be adapted depending on their needs.

The core concepts each chapter will cover are those from KS3 that underpin many scientific domains, recur throughout Secondary Science, and are essential for GCSE.

Biology core concepts	Chemistry core concepts	Physics core concepts
Plant and animal cells	Materials	Types and pairs of forces, and force diagrams
Specialised cells	The particle model	Motion
Diffusion and osmosis	State changes	Stretching and Hooke's Law
Cells to systems	Atoms and elements	Forces at a distance
Photosynthesis	The Periodic Table	Mass and weight
Aerobic respiration	Compounds	Unbalanced forces
Fertilisation and implantation	Word equations	Wave properties
Variation and natural selection	Conservation of mass	Seeing light
		Static electricity and change
		Circuits and current
		Energy conservation, transfer, and dissipation
		Speed

DSE learning objectives and outcomes for Approach 1 of Year 9 are to follow.

Approach 2

An alternative option for Year 9 takes the form of extended practical projects hosted on Kerboodle. The practicals incorporate some of the core concepts in Approach 1, and also draws on many cross-domain links within Science. The project work from Approach 2 can be easily interspersed with content from Approach 1, for example, using the Recap and Apply sections of Approach 1 to consolidate concept knowledge before applying it within a relevant project from Approach 2. This is supported by teaching resources and professional development on implementing effective practical and project work.

Practical project plans for Approach 2 are to come at a later date.

Skills progression within the curriculum

Maths

Mathematical skills are fundamental to success within scientific disciplines, and as such, learners' development of these crucial skills is emphasised within all curriculum materials. In particular, application of skills and knowledge learnt within the Maths curriculum to scientific contexts can be a sticking point for learners, and we aim to support learners with this throughout *Activate* and within all resources. Maths skills are incorporated into all relevant lesson and student book content, and further supported by targeted resources on Kerboodle.

The maths skills included and developed over the course of *Activate* have been identified as being important to success in Science and to progressing onto KS4, in line with the UK National Curriculum. The progression of these skills has been carefully planned to accompany the scientific content, and so that it is age-appropriate. Thorough comparison to the *White Rose Maths* learning progression has ensured that all skills are appropriately sequenced to support effective development, and that curriculum coherence with learners' Maths curricula is strengthened, supporting them in applying their mathematical knowledge to Science. Particular skills within the *Activate* course benefit from greater focused teaching and practice time, where a notable mismatch with Maths curricula has been identified.

The table below shows the Maths skills developed within each year of *Activate*, at the general level of attainment expected for secure-level students finishing each year.

Maths skill	Secure Year 7	Secure Year 8	Secure Year 9
Quantitative problem solving	Use given strategies for solving single-step problems	Use given strategies for solving simple multi-step problems Identify the mathematical aspects in scientific contexts, and use mathematical solutions for scientific problems	Independently solve more complex multi-step calculations or problems Independently use a range of mathematical approaches to solve scientific problems
Understand when and how to use estimation		Make numerical estimates from samples, and trends in graphical or tabular data Use rounding and standard units to estimate simple outcomes	Make mental estimates by rounding to one significant figure

Maths skill	Secure Year 7	Secure Year 8	Secure Year 9
Carry out calculations involving +, – , ×, ÷ (without a calculator) Independently use a range of mathematical approaches to solve scientific problems	Perform straightforward calculations using addition, subtraction, multiplication, and division using positive and negative integers, and decimals Perform simple mental calculations	Use the order of operations in straightforward calculations Perform straightforward mental calculations using addition, subtraction, multiplication, and division using integers	Use the order of operations in complex calculations Perform more complex mental calculations
Record and interpret data in suitable results tables	Record data using standard units Design a simple results table; record data; identify trends in tabulated data; draw simple conclusions from tabulated data Identify outliers in a set of repeat results	Record data from secondary sources in a constructed results table; draw conclusions Construct a results table for grouped data; record grouped data; draw conclusions Record data to a given degree of accuracy Identify and remove outliers from a data set	Record data to a given number of significant figures Draw detailed conclusions from tabulated data
Plot, draw, and interpret data graphically or visually	Define categoric and continuous data Plot a simple bar chart using given axes Plot a simple line graph using given axes, line of best fits Plot a pie chart using given segment angles Interpret data from simple bar charts, line graph, and pie charts Identify trends from bar charts, line graphs, and pie charts Draw conclusions from graphical data Represent physical phenomena using mathematical constructs	Choose the most appropriate graph or chart to plot data Plot pie charts, histograms, grouped bar charts, and line graphs with multiple lines Extract data from bar and line charts to perform simple calculations Draw inferences from separate and linked graphical data Identify correlation between data sets	Plot compound bar charts Add a line of best fit to a scatter graph to identify the type of correlation Use data from graphs to support conclusions Extract data from mathematical constructs to perform simple calculations
Calculate areas and volumes of simple shapes		Calculate the areas of simple shapes	Use formulae to calculate circumferences, areas, and volumes of 2D and 3D shapes when solving problems

Maths skill	Secure Year 7	Secure Year 8	Secure Year 9
Understand number size, scales, and the quantitative relationship between units	Use standard units for common quantities Convert measurements of time, and SI units with familiar prefixes Measure familiar quantities using a scale; use scales with negative numbers; order integers including decimals Use a protractor to measure angles and construct diagrams	Accurately measure quantities using a scale Convert SI units to carry out calculations using standard units Use compound units	Derive units from multi-step equations Estimate unknown angles using knowledge of angular relationships
Use of fractions, percentages, and ratios	Calculate percentages of amounts Represent results using fractions Solve simple problems using direct proportion Recognise simple ratios, and solve simple ratio problems	Calculate percentage change Solve complex problems using ratios	Use fractions or percentages to solve problems involving proportional changes Understand and use the equivalences between fractions, decimals, and percentages Perform calculations using ratios
Calculate range and average of a set of data	Calculate means	Calculate mean, mode, and range Identify and remove outliers before calculating means	Identify the most appropriate type of average for data and understand their limitations
Substitute numerical values into simple equations using appropriate units	Substitute values into an equation using standard units	Rearrange an equation containing three variables	Substitute values into an equation represented algebraically
Calculate using indices	Recognise simple indices	Perform calculations using simple indices	
Understand the idea of probability			Relate probability to the notion of risk
Calculator skills	Perform straightforward calculations with positive and negative integers, and decimals	Use the order of operations in calculations Perform calculations using simple indices	Use a calculator to perform multi-step calculations with brackets

Nature of Science and Science identity

Scientific working, an understanding of the nature of Science, and how Science relates to learners and their identities is at the heart of the Oxford Smart Curriculum and *Activate* course. This includes not just procedural knowledge required within the Science curriculum (the use of instruments and experimental techniques), but also epistemic competencies; ways of thinking, observing, analysing, and learning about Science. The procedural (working scientifically) skills required for success in KS3 Science, aligning with the UK National Curriculum, have been sequenced to ensure effective development for learners and to accompany the course's scientific knowledge. Epistemic competencies have been similarly defined and sequenced, to ensure constructive progression and development of learners as scientists that fully engage with the world around them and Science as a way of thinking.

The table below shows the Nature of Science skills developed within each year of *Activate*, at the general level of attainment expected for secure-level students finishing each year.

Nature of Science skill	Secure Year 7	Secure Year 8	Secure Year 9
Scientific attitudes	Recognise familiar examples of being objective using accuracy, precision, repeatability, and reproducibility (APRR)	Use an objective approach by applying APRR to familiar situations	Use an objective approach by applying APRR to familiar and unfamiliar situations
	Describe simply how a familiar scientific method or theory changed over time Describe simply how scientists publish results and use peer review	Explain how a number of familiar scientific methods or theories have changed over time Describe familiar examples of how scientists publish results and use peer review	Explain in detail how and why scientific methods or theories have changed over time Explain how and why scientists publish results and use peer review, giving specific examples
	Under guidance, follow a risk assessment to safely carry out an experiment	Follow a risk assessment to safely carry out an experiment	Write and carry out a risk assessment to safely perform an experiment
Experimental skills and investigations	Use prior knowledge to ask simple scientific questions	Use prior knowledge to ask scientific questions and suggest how to investigate them	Use prior knowledge to ask a range of scientific questions and suggest how to investigate them
	Use prior knowledge to ask simple scientific questions	Predict/hypothesise using a scientific theory or explanation	In a range of situations, predict/hypothesise using a scientific theory or explanation
	With support, plan a simple investigation to test a prediction, and identify an independent, dependent, and control variable	Plan familiar investigations to test predictions, deciding on relevant independent, dependent, and control variables	Plan unfamiliar investigations to test predictions, identifying the relevant independent, dependent, and control variables
	Use suitable techniques, apparatus, and materials for familiar experiments/fieldwork	Select suitable techniques, apparatus, and materials for familiar experiments/fieldwork	Apply suitable techniques, apparatus, and materials for unfamiliar experiments/ fieldwork

Nature of Science skill	Secure Year 7	Secure Year 8	Secure Year 9
Experimental skills and investigations	Make and record observations from an investigation	Make accurate observations and systematically record several observations from a range of investigations	Make accurate observations and systematically record a range of observations from a range of unfamiliar investigations
	Use suitable sampling techniques for simple investigations	In planning and carrying out investigations, select a suitable sampling method	In planning and carrying out investigations, select and justify any sampling methods used
Analysis and evaluation	Identify simple quantitative relationships between variables State a conclusion based on the evidence	Identify quantitative relationships between variables to inform conclusions	Process data, including multi-step calculations and compound measures, to identify complex relationships between variables and justify conclusions
	Identify scientific evidence used in explanations	Present explanations consistent with scientific evidence; relate the data to the hypothesis	Present explanations consistent with scientific evidence, assessing the strength of the evidence; relate the data to the hypothesis
	Identify a source of random error and systematic error in familiar experiments	Identify a source of random error and systematic error in familiar experiments, and suggest how to account for this	Identify a source of random error and systematic error in unfamiliar experiments, and explain the impact on data collected
	Suggest an improvement to a method of an investigation	Describe a specific improvement to a method of an investigation	Describe in detail specific improvements to a method of an investigation and justify the choice
Measurement	Use appropriate SI units and chemical names	Use familiar appropriate SI units and chemical names	Accurately use a wide range of appropriate SI units and chemical names in unfamiliar situations
	With support, carry out simple mathematical analyses	Select suitable mathematical analyses Explain how data has undergone specific mathematical or statistical analysis	Choose suitable mathematical analysis methods and justify the choice

Nature of Science skill	Secure Year 7	Secure Year 8	Secure Year 9
The scientific method, research, and use of models	Use models and analogies as a way of understanding things that are very small, large, processes, or abstract	Understand that models and analogies have limitations and their usefulness depends on how accurately they describe the real world	Select or design a suitable model or analogy for a particular concept, evaluating its suitability and limitations
	Carry out guided research into a particular topic or to find the answer to a defined question	Select suitable resources and an approach to research a particular topic	Research a topic independently and select an appropriate method for recording and presenting findings
	Take part in teacher-led discussions, using own knowledge	Take part in peer-to-peer discussion with little teacher intervention	Lead and guide discussions with peers
	Understand what is meant by scientific questions and the process by which we answer them	Select appropriate scientific questions and methods of finding answers to particular problems	Propose scientific questions and suggest ways and methods of finding the answers, along with the potential limitations
Science capital and Science identity: the value and relevance of Science to me	Learn how and why Science knowledge and skills are useful in my daily and future life, including personal health, the Science of everyday tasks and interactions, and Science skills in jobs beyond STEM	Learn about the relevance and value of science knowledge and skills for me and my community	Learn about the relevance of Science for my society, in a broader context
	Understand the everyday relevance of Science skills such as making observations, recording data, carrying out calculations, interpreting data, and drawing conclusions	Explore why my community might care about making observations of the natural world	How we can use Science for action: Citizen Science and activism through Science
	Explore everyday examples of why you might need to convert units and people who do this in their jobs, and people that represent data visually	Understand the importance of more complex calculations involving compound units in everyday life, and what data is relevant to me and my community	Understand, interpret, and use big data
	Appreciate that Science is not just for 'scientists' who wear white coats and work in labs; Science knowledge and skills are everywhere in daily life	Appreciate that Science is not just for scientists; seeing the link between scientific processes and real-life applications Jobs and activities that need to know about scientific theories, phenomena, and their application	

Nature of Science skill	Secure Year 7	Secure Year 8	Secure Year 9
Science capital and Science identity: the value and relevance of Science to me	Seeing scientists like me: valuing and recognising diverse scientists, and that a great variety of careers use Science and Maths	Seeing scientists like me nationally and globally, and understanding that Science is often a collaborative process between regions and nations	

Literacy and the Word Gap

Effective use of vocabulary, reading and writing skills, and scientific communication are all integral to long-term success in Science. Practice of literacy skills is therefore embedded throughout the *Activate* course components, following a progression designed around the EEF's *Improving Secondary Science* recommendations. Literacy skills are developed through the lesson activities, targeted guidance and activities in the student books, and additional Kerboodle resources. Literacy is also emphasised throughout the *Activate* course specifically to target recommendations within the *OUP Bridging the Word Gap report*, which highlighted literacy as a major target area for improvement in the transition to Secondary.

The table below shows the literacy skills developed within each year of *Activate*, at the general level of attainment expected for secure-level students finishing each year.

Literacy competencies		Secure Year 7	Secure Year 8	Secure Year 9
Provide targeted vocabulary instruction	Understand the constituent parts of appropriate scientific vocabulary, in order to understand their meaning	With support and explanation, describe the constituent parts of scientific vocabulary, and use a glossary	Use root words to break down complex vocabulary, and link scientific vocabulary to commonly confused words in everyday speech to practise specific use of vocabulary; understand simple command words in questions	Use knowledge of root words and vocabulary to decode new scientific vocabulary; understand command words used in examination-style questions
	Understand key scientific vocabulary, and use technical terminology and scientific vocabulary accurately and precisely	Understand and be able to read and use a limited range of relevant scientific keywords when provided; use standard English for complex situations	Confidently use key scientific vocabulary to suit the situation; use standard English in formal situations	Use a broader range of scientific and general vocabulary fluently; use precise standard English where required

Literacy competencies		Secure Year 7	Secure Year 8	Secure Year 9
Develop pupils' ability to read and access academic texts	Read and comprehend appropriate scientific texts, including reports, articles, works of fiction, etc.	With support, read simple, short scientific texts about taught topics; read textbook independently	Read a greater variety of short scientific texts related to taught topics, including on historical developments in science	Read and comprehend a variety of scientific texts with fluency and accuracy, including science in a broader context (e.g. the news)
	Make inferences and describe relationships in scientific texts	Show understanding of significant ideas in texts, and, with support, use inference and deduction	Show understanding of a range of scientific texts, and the ability to select essential points and use inference and deduction where appropriate	Show understanding of the different ways information is conveyed in a broad range of scientific texts

Literacy competencies		Secure Year 7	Secure Year 8	Secure Year 9
Break down complex writing tasks	Write descriptions and explanations for scientific phenomena and observations, and provide appropriate responses to written questions	With support and scaffolding, break down complex writing tasks to provide short scientific explanations for simple phenomena	With support, provide scientific explanations for a range of phenomena and observations; understand the use of command words in written questions	Write answers to extended response questions and multipart questions with little scaffolding and in response to command words
	Write scientific reports on phenomena, observations, and practicals carried out	With support and scaffolding, write simple scientific reports, including conclusions, relationships, and explanations	Practice planning for more complex scientific reports, including plans, keywords, concept maps, and 'but, so, and' techniques	Write complete scientific reports using conventional structures, including aims, methods, etc.
	Use appropriate writing styles and forms of writing (letter, article, argumentative etc.) to suit purpose	With scaffolding and support, use some of the main features of different forms of writing to convey clear information	Use a range of forms and formal style where appropriate to clearly convey meaning, including presenting arguments and opinions, and discussing ethical issues	Use a large range of forms of writing to engage the audience in fluent communication of scientific ideas, including objective presentation of ethical issues and arguments
	Appropriate organisation of ideas and information in written work	Present information through clear writing with sentences that are logically ordered	Present information in clear and well-developed paragraphs and sentences, and use other forms of presenting information appropriately (e.g. lists, tables)	Present ideas in well-developed and linked paragraphs, with punctuation that aids clarity, and address various viewpoints where appropriate
	Use correct and appropriate spelling, punctuation, grammar, and sentence structure	Use simple punctuation correctly, including full stops and capital letters; spelling and grammar is usually accurate	Use proper spelling for complex vocabulary, and more sophisticated punctuation	Use a range of grammatical features accurately and effectively, and correct spelling of complex vocabulary

Literacy competencies		Secure Year 7	Secure Year 8	Secure Year 9
Combine writing instruction with reading	Write summaries and questions based on content read from a variety of scientific texts	With support, write short summaries of scientific texts about taught topics	Write recall and descriptive questions based on texts read; use connectives, compare and contrast, refer to the text, and collate information from different sources	Write recall, describe, and explain comprehension questions based on a variety of scientific texts; identify and use key information referred to in texts to support viewpoints; synthesise and compare information from a variety of sources, and evaluate information used
	Understand and interpret scientific diagrams, and write what diagrams show in prose	Read simple labelled diagrams, and explain what they show in prose	Describe and explain scientific techniques using diagrams of apparatus; translate information from models (e.g. of cycles) into prose, and vice versa	Interpret data and graphs to write analyses of scientific phenomena; identify links between diagrams and written information

Literacy competencies		Secure Year 7	Secure Year 8	Secure Year 9
Provide opportunities for structured talk	Understand and interpret scientific diagrams, and write what diagrams show in prose	Read simple labelled diagrams, and explain what they show in prose	Describe and explain scientific techniques using diagrams of apparatus; translate information from models (e.g. of cycles) into prose, and vice versa	Interpret data and graphs to write analyses of scientific phenomena; identify links between diagrams and written information
	Correctly pronounce complex multisyllabic words, and use these in scientific discussion	With support, practice correctly pronouncing complex multisyllabic words	Correctly pronounce multisyllabic scientific words for a range of topics	Correctly pronounce multisyllabic scientific words for a range of topics, and use these unprompted in discussion
	Give clear and rational verbal descriptions of scientific phenomena, using appropriate vocabulary	With guidance, present clear verbal descriptions of simple phenomena and observations	Verbally explain the meaning of simple word/symbol equations; explain more complex observations	Give well-structured and ordered verbal explanations for scientific phenomena and observations
	Explain thought processes and lines of reasoning to others in a clear and precise manner	Clearly communicate and justify simple scientific ideas, using scientific language and illustrations	Structure verbal presentations on scientific topics so they are clearly communicated and effective at explaining scientific ideas to an audience	With support, form and deliver a verbal debate on a known science topic
	Distinguish between fact and opinion when discussing scientific topics	Identify scientific evidence used to support or refute ideas in discussion	Identify when opinion is used in place of fact, and the circumstances surrounding when these can be/should be used	Recognise the challenges regarding fact versus opinion, and the use of vocabulary, when discussing scientific phenomena; recognise potential biases in scientific accounts
	Ask relevant questions about scientific observations and phenomena in discussion	Ask pertinent questions about simple scientific phenomena and observations, demonstrating understanding of key points	Make contributions to discussions and observations of scientific phenomena, including asking questions that are responsive and develop ideas	Make significant contributions to discussions, evaluating others' ideas and showing understanding and sensitivity to different viewpoints

Literacy competencies		Secure Year 7	Secure Year 8	Secure Year 9
	Communicate ideas and information to a wide variety of audiences and situations	Adapt verbal information to the needs of the listener, varying vocabulary and the amount of detail given	Talk confidently in a wide range of contexts including some formal, and structure communication for required purposes	Confidently match the information and structure of communication to differing contexts, including some unfamiliar contexts, and develop discussions purposefully

Metacognition and self-regulation

Understanding of how an individual learns and self-regulation of that learning are key to develop in effective Science learners. The EEF notes that incorporating metacognition and self-regulation approaches in teaching and learning lead to high levels of positive impact on learner progress.

This ownership of learning is developed in a number of ways, integrated throughout the *Activate* course:

- Incorporation of the plan-monitor-evaluate cycle within relevant activities and resources, so that learners become familiar with planning the steps they will take within an activity or to solve a problem, monitoring their progress, and evaluating what they have learned.
- Direct teaching and practice of a range of metacognitive strategies throughout the lesson content and student resources, as appropriate for the scientific topic at hand, followed by use of metacognitive strategies outside of class to review and reflect.
- Consistent teacher-led modelling of thinking and problem-solving skills, to demonstrate how an expert employs strategies like the plan-monitor-evaluate cycle.
- Fostering metacognitive talk in the classroom at appropriate opportunities.
- Dedicated support within teaching materials and targeted PD resources for teachers in incorporating the above.

The table below gives an indication of the progression of the above over the *Activate* course, at the secure-level for each year.

Metacognition and self-regulation	Secure Year 7	Secure Year 8	Secure Year 9
General metacognitive skills and strategies in Science	Use structured templates and teacher guidance to practise using metacognition strategies	Take increased responsibility for choosing own strategies and use less scaffolding	Confidently make independent choices of strategies to best support own learning
	How to be a Secondary scientist: explicit instruction of strategies and techniques, including revision, reading, note taking, and basic working scientifically; how to ask scientific questions	How to approach specific Science skills (e.g, calculations, balancing equations) Develop independence in choosing the strategies that best support their own learning	Independently use strategies and techniques to support and enhance own learning and use them autonomously, automatically integrating them into work
Reflective questioning	Reflective questions focus on learners as students of Science; what do they want a Year 7 scientist to look like, what skills do they need to have	Reflective questions focused on what specific skills/protocols learners should learn and how they are going to do this through the year	Reflective questions focused on strengths and weaknesses relating to specific knowledge and skills as learners transition from KS3 to KS4
Planning	Think about the goal of learning (set by teacher) and consider how to approach tasks; this includes understanding the goal, activating relevant prior knowledge about the task, and guided selection of appropriate strategies and allocation of effort	Think about the goal of learning and decide how to approach tasks; choose own strategies and determine how best to allocate time	
Monitoring	Assess and monitor progress being made, including self-testing and self-questioning	Assess and monitor progress and identify gaps or difficult areas; select strategies to support in rectifying these identified areas	Be aware of own weaknesses and work preemptively to negate these using suitable available strategies
Evaluating	Reflect on the effectiveness of a plan and its implementation	Reflect on a plan and suggest ways to improve and extend it	Continuously use evaluation to appraise and improve their work and plans

Activate DSE learning outcomes

Year 7

Biology	Topic	Learning objective	Learning outcomes: Developing	Learning outcomes: Secure	Learning outcomes: Extending
	1.1 Observing cells	Define what a cell is	List some facts about cells	Describe what a cell is	Describe what a cell is, using examples
		Describe how to use a microscope to observe very small objects	Identify the parts of a microscope	Describe how to use a microscope to observe very small objects	Explain how to get a focused image when using a microscope
		Calculate the total magnification used to observe an object	Give the eyepiece lens and objective lens magnification	Calculate the total magnification used to observe an object using a scaffolded approach	Calculate the total magnification used to observe an object using an equation
	1.2 Plant and animal cells	Describe the function of each part of a cell	Identify the function of each part of a cell	Describe the function of each part of a cell	Compare the functions of each part of plant and animal cells
		Compare the parts of plant and animal cells	Label the parts of plant and animal cells	Compare the parts of plant and animal cells	Explain the differences between plant and animal cells
		Use a microscope to view plant and animal cells	Use a microscope to view pre-prepared slides of plant and animal cells	Use a microscope to view student-prepared slides of plant and animal cells	Explain why stains are used when viewing plant and animal cells through a microscope
	1.3 Specialised cells	Describe the function of specialised cells	Identify the function of specialised cells	Describe the function of specialised cells	Suggest the function of an unfamiliar specialised cell
		Describe the adaptations of specialised animal cells	Identify the main adaptations of specialised animal cells	Describe the adaptations of specialised animal cells	Explain how the adaptations of a specialised animal cell enable it to perform its function
		Describe the adaptations of specialised plant cells	Identify the main adaptations of specialised plant cells	Describe the adaptations of specialised plant cells	Explain how the adaptations of a specialised plant cell enable it to perform its function

Biology

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
1.4 Movement of substances	Name some substances that move into and out of cells	Identify some substances that are needed by cells	Name some substances that move into and out of cells	Explain why substances move into, or out of, a cell
	Describe the process of diffusion	Describe simply the particles in liquids and gases	Describe the process of diffusion	Explain the process of diffusion using the particle model
	Describe examples of diffusion	Give some examples of diffusion	Describe examples of diffusion	Explain why diffusion occurs in plant and animal cells
1.5 Unicellular organisms	Define what a unicellular organism is	Name some unicellular organisms	Define what a unicellular organism is	Identify examples of unicellular organisms based on their description
	Describe the features of an amoeba	Identify the main features of an amoeba	Describe the features of an amoeba	Compare the features present in an amoeba with those in an animal cell
	Describe the features of a Euglena	Identify the main features of a Euglena	Describe the features of a Euglena	Justify why a Euglena could be classified as a plant or an animal cell
2.1 Levels of organisation	Define the terms tissue, organ, and organ system	Name some examples of tissues, organs, and organ systems	Define the terms tissue, organ, and organ system	Describe examples of tissues, organs, and organs systems in animals and plants
	Describe the hierarchy of organisation in a multicellular organism	Order the terms cell, tissue, organ, and organ system from smallest to largest	Describe the hierarchy of organisation in a multicellular organism	Use examples to illustrate the hierarchy of organisation in a multicellular organism
2.2 Gas exchange	Define the process of gas exchange	Name some of the gases humans breathe in and out	Define the process of gas exchange	Explain the importance of gas exchange
	Describe how parts of the gas exchange system are adapted to their function	Label the main parts of the human gas exchange system	Describe how parts of the gas exchange system are adapted to their function	Explain the structural adaptations of the parts of the gas exchange system
	Compare the composition of inhaled and exhaled air	State the meaning of inhalation and exhalation	Compare the composition of inhaled and exhaled air	Explain the differences in composition of inhaled and exhaled air

Biology

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
2.3 Breathing	Describe the changes that occur when a person inhales and exhales	Give some examples of changes that occur when a person inhales and exhales	Describe the changes that occur when a person inhales and exhales	Explain the changes that occur when a person inhales and exhales
	Describe how a bell jar can be used to model breathing	Identify which parts of the gas exchange system are represented in the bell jar model	Describe how a bell jar can be used to model breathing	Evaluate the bell jar as a model of breathing
	Describe a method used to estimate lung volume	State the meaning of the term lung volume	Describe a method used to estimate lung volume	Evaluate the method used to estimate lung volume
2.4 Skeleton	Label the main bones in the human skeleton	Name some bones in the human skeleton	Label the main bones in the human skeleton	Compare the functions of different human bones
	Describe the structure of a bone	State what a bone is	Describe the structure of a bone	Explain the structural adaptations of a bone
	Describe the functions of the skeletal system	Give some of the functions of the skeletal system	Describe the functions of the skeletal system	Explain the functions of the skeletal system
2.5 Movement – joints	Describe the role of joints in movement	State what is meant by a joint	Describe the role of joints in movement	Use examples to describe the movements that different types of joint allow
	Describe the structure of a joint	Label the parts of a joint	Describe the structure of a joint	Explain the functions of the different parts of a joint
	Describe how to measure the force exerted by different muscles	Use a newtonmeter to accurately measure a force	Describe how to measure the force exerted by different muscles	Evaluate the methods used to measure force exerted by muscles
2.6 Movement – muscles	Describe the function of the major muscle groups	Give the role of muscles in the human body	Describe the function of the major muscle groups	Suggest the function of an unfamiliar muscle from a diagram
	Describe how muscles cause movement in the body	Give the function of muscle tissue	Describe how muscles cause movement in the body	Explain how muscles cause movement in the body
	Describe how antagonistic muscles control movement at a joint	State some features of antagonistic muscles	Describe how antagonistic muscles control movement at a joint	Use examples to explain how antagonistic muscles control movement at a joint

Biology	Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
	3.1 Adolescence	Describe the difference between adolescence and puberty	Identify the meanings of the terms puberty and adolescence	Describe the differences between adolescence and puberty	Compare similarities and differences between adolescence and puberty
		Compare the physical changes in females and males during puberty	Give some changes that take place in females and males during puberty	Compare the physical changes in females and males during puberty	Explain the changes in females and males during puberty
		Describe the role of sex hormones during puberty	State the meaning of the term hormone	Describe the role of sex hormones during puberty	Compare the role of sex hormones in males and females
	3.2 Reproductive systems	Describe the function of the female and male reproductive systems	Name the sex cells produced by the female and male reproductive systems	Describe the function of the female and male reproductive systems	Compare the function of the female and male reproductive systems
		Label the main structures in the female and male reproductive systems	Name some parts of the female and male reproductive systems	Label the main structures in the female and male reproductive systems	Label the main structures in the female and male reproductive systems in front and side cross-sections
		Describe the function of the main structures in the female and male reproductive systems	Identify a function of the female and male reproductive systems	Describe the function of the main structures in the female and male reproductive systems	Compare the functions of the main structures in the female and male reproductive systems
	3.3 Fertilisation and implantation	Describe the process of fertilisation	State what is meant by the term gamete	Describe the process of fertilisation	Explain what happens during fertilisation
		Describe what happens during sexual intercourse	Describe the purpose of sexual intercourse	Describe what happens during sexual intercourse	Explain how sexual intercourse can lead to reproduction
		Describe the main steps which must take place for implantation to occur	State what is meant by the term implantation	Describe the main steps that must take place for implantation to occur	Suggest why sexual intercourse does not always lead to implantation

Oxford
Smart Curriculum

Biology	Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
	3.4 Development of a fetus	Describe what is meant by the term gestation	Describe what is meant by pregnancy	Describe what is meant by the term gestation	Suggest reasons for differences in gestational length between organisms
		Describe the function of the placenta, umbilical cord, and fluid sac	Label the main structures involved in pregnancy	Describe the function of the placenta, umbilical cord, and fluid sac	Explain how substances are exchanged between mother and fetus
		Describe the main stages in the process of birth	Name the structures a baby passes through during birth	Describe the main stages in the process of birth	Explain the main stages in the process of birth
	3.5 The menstrual cycle	Describe what happens during a period	Give the function of the uterus lining	Describe what happens during a period	Explain why females have periods
		Describe the main stages in the menstrual cycle	State what is meant by the term ovulation	Describe the main stages in the menstrual cycle	Label a diagram to describe the stages of the menstrual cycle
		Describe some different methods of contraception	State what is meant by the term contraception	Describe some different methods of contraception	Evaluate the use of condoms and the contraceptive pill as methods of contraception
	3.6 Flowers and pollination	Describe the function of the main structures in a flower	Label the main structures in a flower	Describe the function of the main structures in a flower	Identify similarities in function between the male and female parts of a flower
		Describe the process of pollination	Describe the function of the anther and stigma	Describe the process of pollination	Explain the differences between self-pollination and cross-pollination
		Compare the structure of wind-pollinated and insect-pollinated plants	Name some features of wind-pollinated and insect-pollinated plants	Compare the structure of wind-pollinated and insect-pollinated plants	Explain the structural adaptations of wind-pollinated and insect-pollinated plants

			Learning outcomes		
	Topic	Learning objective	Developing	Secure	Extending
Biology	**3.7 Fertilisation and germination**	Describe the process of fertilisation in plants	State what is meant by the term fertilisation	Describe the process of fertilisation in plants	Compare the process of fertilisation in plants and animals
		Describe how seeds and fruits are formed	Identify the parts of a flower which will develop into the fruit and the seeds	Describe how fruits and seeds are formed	Suggest a reproductive advantage of producing sweet-tasting fruits
		Describe the main steps in germination	Name the conditions a seed needs for germination	Describe the main steps in germination	Explain how to maximise the rate of germination in seeds
	3.8 Seed dispersal	Describe the advantages of seed dispersal	State what is meant by the term seed dispersal	Describe the advantages of seed dispersal	Suggest some disadvantages of seed dispersal
		Explain how seeds are adapted for their method of dispersal	Name the main methods of seed dispersal	Explain how seeds are adapted for their method of dispersal	Suggest and justify the mechanism of dispersal for a given seed
		Describe a method to investigate seed dispersal	Identify the independent, dependent, and a control variables in a seed dispersal investigation	Describe a method to investigate seed dispersal	Explain the steps taken to produce valid data in a seed dispersal investigation
Chemistry	**1.1 The particle model**	Use the particle model to explain why different materials have different properties	State what materials are made up of	Use the particle model to explain why different materials have different properties	Compare one property of two different materials, and use the particle model to explain the difference
		State the four factors in the particle model that determine the properties of a substance	Identify the factors in the particle model that determine the properties of a substance	State the factors in the particle model that determine the properties of a substance	Suggest why the properties of two different given substances differ

Chemistry			Learning outcomes		
	Topic	Learning objective	Developing	Secure	Extending
	1.2 The three states of matter	Compare the properties of a substance in its three states	Identify the properties of a substance in its three states	Compare the properties of a substance in its three states	Compare the properties of an unfamiliar substance in its three states
		Describe the arrangement, separation, and movement of particles in the three states of matter	Identify the arrangement, separation, and movement of particles in the three states of matter	Describe the arrangement, separation, and movement of particles in the three states of matter	Compare the arrangement, separation, and movement of particles in the three states of matter
		Use the particle model to explain the properties of a substance in its three states	Using the particle model, identify explanations of the properties of a substance in its three states	Use the particle model to explain the properties of a substance in its three states	Use the particle model to explain the differences and similarities in the properties of a substance in its three states
	1.3 Density	State the meanings of mass, volume, and density	Identify the meanings of mass, volume, and density	State the meanings of mass, volume, and density	Compare the concepts of mass, volume, and density
		Use the particle model to explain why the same substance has different densities in its three states	Identify the factor in the particle model that affects the density of a substance in its three states	Use the particle model to explain why the same substance has different densities in each of its three states	Compare the densities of a substance in each of its three states, and explain the difference using the particle model
		Use the particle model to explain why, in the solid state, different substances have different densities	Identify the factor in the particle model that causes different substances in the solid state to have different densities	Use the particle model to explain why, in the solid state, different substances have different densities	Using the particle model, explain the difference in density, from data, of two different solids

Chemistry

		Learning outcomes		
Topic	**Learning objective**	**Developing**	**Secure**	**Extending**
1.4 Melting and freezing	Describe how the arrangement, separation, and movement of the particles change when a substance melts or freezes	Identify differences in the arrangement and movement of the particles in the solid and liquid states	Describe how the arrangement, separation, and movement of the particles change when a substance melts or freezes	Use the particle model to explain melting and freezing
	State the factor in the particle model that explains why different substances have different melting points	Identify the factor in the particle model that explains why different substances have different melting points	State the factor in the particle model that explains why different substances have different melting points	Use the particle model to explain why some substances have higher melting points than others
	Give the melting point of a substance from its cooling curve	Describe a temperature-time graph for a substance as it melts or freezes	Estimate the melting point of a substance from its temperature-time graph	Compare temperature-time graphs, and hence melting points, for different substances
1.5 Boiling	Describe how the arrangement, separation, and movement of the particles change when a substance boils	Identify the factor in the particle model that explains why different substances have different boiling points	Describe how the arrangement, separation, and movement of the particles change when a substance boils	Use the particle model to explain boiling
	Predict the state of a substance at a given temperature from its melting and boiling points, where both are above 0°C	Identify melting and boiling points on a given temperature scale	Predict the state of a substance at a given temperature from its melting and boiling points, where both are above 0°C	Predict the state of a substance at a given temperature from its melting and boiling points, where boiling and melting points could be any temperature
	Give the boiling point of a substance from its temperature-time graph	Describe a temperature-time graph for a substance as it boils	Give the boiling point of a substance from its temperature-time graph	Compare temperature-time graphs, and boiling points, for different substances

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
1.6 More changes of state	Compare evaporating, condensing, and subliming in terms of the before and after states	Identify the before and after states of evaporation, condensation, and sublimation	Compare evaporating, condensing, and subliming in terms of their before and after states	Compare evaporating, condensing, and subliming in unfamiliar situations
	Describe how the arrangement, separation, and movement of the particles changes when a substance evaporates, condenses, and sublimes	Identify differences in the arrangement and movement of the particles when a substance evaporates, condenses, and sublimes	Describe how the arrangement, separation, and movement of the particles change when a substance evaporates, condenses, and sublimes	Use the particle model to compare subliming to evaporating
	Use the particle model to compare evaporation and boiling	Describe the arrangement, separation, and movement of the particles during evaporation and boiling	Compare the changes in the arrangement, separation, and movement of the particles in evaporation and boiling	Use the particle model to compare evaporation and boiling
1.7 Diffusion	Use the particle model to explain diffusion	Give examples of situations where diffusion occurs	Describe how the separation and speed of movement of the particles change when a substance diffuses	Suggest and justify whether diffusion can occur in unfamiliar situations
	Use the particle model to explain how temperature, particle size, and state affect how quickly diffusion happens	Identify the factors that affect how quickly diffusion occurs	Use the particle model to explain how temperature, particle size, and state affect how quickly diffusion happens	Use the particle model to compare how quickly diffusion will occur in unfamiliar situations
	Explain the observations in an experiment that demonstrates diffusion	Describe the observations you might make in a specified experiment demonstrating diffusion	Use the particle model to explain the observations in an experiment that demonstrates diffusion	Evaluate the particle model in explaining observations in an experiment that demonstrates diffusion

Chemistry

Topic	Learning objective	Learning outcomes		
		Developing	**Secure**	**Extending**
2.1 Elements	Write the definition for the term element and list some examples of elements	Identify the meaning of the term element, and examples of elements	State the meaning of the term element and list some examples of elements	Justify whether a substance is an element based on its description
	Explain what is shown in the Periodic Table	Identify what is shown in the Periodic Table	Describe what is shown in the Periodic Table	Identify element(s) that have similar properties to a given element
	Use the Periodic Table to give the chemical symbols of elements	Identify the chemical symbols of elements	Use the Periodic Table to give the chemical symbol of any element, given its name	Use the Periodic Table to give the name of any element, given its chemical symbol
2.2 Atoms	Write definitions for the terms atom and element	Identify the meaning of the terms atom and element	State the meanings of the terms atom and element	Compare the concepts atom and element, giving examples
2.3 Compounds	State the meaning of the term compound	Identify the meaning of the term compound	State the meaning of the term compound	State the meaning of the term compound, giving examples
	Explain whether a molecule diagram shows an element or a compound	Identify molecule diagrams that show an element, or a simple compound	Explain whether a molecule diagram shows an element or a compound	Compare and justify molecule diagrams of elements or compounds
	Explain why a compound has different properties to its constituent elements	Identify the reason why a compound has different properties to its constituent elements	Explain why a compound has different properties to its constituent elements	Explain why a compound has different properties to its constituent elements, with examples

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
2.4 Chemical formulae	Name a two-element compound, given its particle diagram or the relative numbers of atoms of the elements in it	Identify a two-element compound, given its particle diagram or the relative numbers of atoms of the elements in it	Name a familiar two-element compound, given its particle diagram or the relative numbers of atoms of the elements in it	Name an unfamiliar two-element compound, given its particle diagram or the relative numbers of atoms of the elements in it
	Give the chemical formula of a compound, given the relative numbers of atoms of the elements in it	Identify the chemical formula of a compound, given the relative numbers of atoms of the elements in it	Determine the chemical formula of a familiar compound, given the relative numbers of atoms of the elements in it	Determine the chemical formula of an unfamiliar compound, given the relative numbers of atoms of the elements in it
	Give the chemical formula of a compound, given a labelled molecule diagram	Identify the chemical formula of a compound, given a labelled molecule diagram	Determine the chemical formula of a familiar compound, given a labelled molecule diagram	Determine the chemical formula of an unfamiliar compound, given a labelled molecule diagram
3.1 Chemical reactions	Write the definition for the term chemical reaction	Identify the meaning of the term chemical reaction	State the meaning of the term chemical reaction	State the meaning of the term chemical reaction, and give an example
	Explain how chemical reactions are useful	Identify useful and non-useful chemical reactions	Explain how chemical reactions are useful	Suggest disadvantages for some useful chemical reactions
	Compare chemical reactions to physical changes	Describe one difference between chemical reactions and physical changes	Compare chemical reactions to physical changes	Justify why changes are either physical or chemical

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
3.2 Word equations	Identify reactants and products in word equations	Identify the meanings of the terms reactants and products of chemical reactions	Identify reactants and products in word equations	Describe the difference between reactants and products
	Write word equations for chemical reactions, given the reactants and products	Identify word equations for chemical reactions, given the reactants and products	Write word equations for chemical reactions, given the reactants and products	Write word equations for chemical reactions, given either the reactants or products
	Given a particle diagram for a chemical reaction involving molecules, explain how the atoms are rearranged and joined together differently	Given a particle diagram for a chemical reaction involving molecules, describe how the atoms are joined together in the reactants and products	Given a particle diagram for a familiar chemical reaction involving molecules, explain how the atoms are rearranged and joined together differently	Given a particle diagram for an unfamiliar chemical reaction involving molecules, explain how the atoms are rearranged and joined together differently
3.3 Oxidation	Write the definitions for combustion and oxidation reactions	Identify the definitions for combustion and oxidation	Define combustion reaction and oxidation reaction	Compare combustion and oxidation reactions
	Write word equations for oxidation reactions, given the reactants and products	Identify word equations for familiar oxidation reactions, given the reactants and products	Write word equations for familiar oxidation reactions, given the reactants and products	Write word equations for unfamiliar oxidation reactions, given the reactants and products
	Use a pattern to predict the products of oxidation reactions	Name the products of combustion of familiar metals	Predict the names of the products of combustion of fuels	Predict the products of oxidation reactions of metals and fuels

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Learning outcomes: Secure	Learning outcomes: Extending
3.4 Decomposition reactions	Define the term decomposition reaction	Identify the meaning of decomposition reaction	Define the term decomposition reaction	Describe a familiar decomposition reaction
	Given word equations, choose those that show decomposition reactions and justify your choice	Identify word equations for familiar decomposition reactions, given the reactants and products	Write word equations for familiar decomposition reactions, given the reactants and products	Write word equations for unfamiliar decomposition reactions, given the reactants and products
	From data presented on a bar chart, identify the substance that starts to decompose first	From data presented in a bar chart, give the time taken for each substance to decompose	From data presented in a bar chart, identify the substance that starts to decompose first	From data presented in a bar chart, compare the decomposition times for different substances
3.5 Ratios and application to chemical equations	Show information using ratios	Identify the number of atoms of each element in a compound	Show information using ratios	Show information using ratios in unfamiliar compounds
	Simplify ratios in chemical formulae and equations	Identify simplified ratios in chemical formulae and equations	Simplify ratios in chemical formulae and equations	Simplify ratios in unfamiliar chemical formulae and equations
	Use ratios to calculate values in chemical formulae and equations	Identify ratios in chemical formulae and equations	Use ratios to calculate values in chemical formulae and equations	Use ratios to calculate values in unfamiliar chemical formulae and equations
3.6 Conservation of mass	Explain why mass is conserved in chemical reactions	Give the total mass of products formed in a chemical reaction, when given the total mass of reactants	Explain why the total mass of reactants is equal to the total mass of products in a chemical reaction	Explain why the mass of a reaction decreases if a gas is given off as a product
	Calculate masses of reactants and products in chemical reactions	Identify the missing mass of a reactant or product in a chemical reaction, given all other masses	Calculate the mass of one reactant or product in a chemical reaction, given the masses of all other reactants and products	Calculate the mass of gas given off in a chemical reaction, when given all other masses
	Describe how chemical reactions are represented by balanced formula equations	Identify what a balanced formula equation shows	Describe what a balanced formula equation shows	Balance simple chemical equations

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
3.7 Exothermic and endothermic	Describe the energy changes in exothermic and endothermic changes	Identify the energy changes in exothermic and endothermic changes	Describe the energy changes in exothermic and endothermic changes	Compare the energy changes in endothermic and exothermic reactions
	Predict whether a given change is exothermic or endothermic	Describe the energy changes in endothermic and exothermic changes	Predict whether a given change is exothermic or endothermic	Suggest examples of familiar and unfamiliar situations where exothermic and endothermic changes are occurring
	Identify exothermic and endothermic changes from temperature data	Describe the temperature change in endothermic and exothermic changes in solution	Identify endothermic and exothermic changes from temperature data	Compare the temperature change in exothermic and endothermic changes in solution
4.1 Acids and alkalis	Describe the hazards linked to using laboratory acids and alkalis and how to control the risks from hazards	Identify how to control the risks from hazards that are linked to using laboratory acids and alkalis	Describe the hazards linked to using laboratory acids and alkalis and how to control the risks from hazards	Write a risk assessment (identify hazards and describe how to control the risks) for a given experiment using familiar reagents
	Use the particle model to describe differences between concentrated and dilute solutions	Identify the difference between concentrated and dilute solutions, in terms of particles	Describe the difference between concentrated and dilute solutions, in terms of particles	Given labelled particle diagrams, identify the diagram which shows the more concentrated solution, and justify your choice
4.2 Indicators and pH	Identify acids, alkalis, and neutral solutions on the pH scale	Identify the range on the pH scale that determines if a solution is acidic, neutral, or alkaline	Identify acids, alkalis, and neutral solutions on the pH scale	Compare acidity or alkalinity of familiar and unfamiliar substances, given their pH
	Given the colour change on adding indicator, determine whether a solution is acidic or alkaline	State the colour change of litmus in acidic and alkaline solutions	Given the colour change on adding indicator, determine whether a solution is acidic or alkaline	Given either an acidic or an alkaline solution, predict the colour change on adding indicator
	Use universal indicator to measure the pH of solutions	Give the correct order of statements describing how to use universal indicator to determine the pH of a solution	Use universal indicator to measure the pH of a solution	Describe how to use universal indicator data, to order substances in increasing acidity

Chemistry

		Learning outcomes		
Topic	**Learning objective**	**Developing**	**Secure**	**Extending**
4.3 Neutralisation	Write the definitions for the terms base and alkali	Identify the meanings of the terms base and alkali	State the meanings of the terms base and alkali	Compare bases and alkaline substances
	Describe how pH changes in neutralisation reactions	Describe the pH range for acidic, neutral, and alkaline solutions	Describe how pH changes in neutralisation reactions	Predict how the pH will change in unfamiliar neutralisation reactions
	Explain how neutralisation reactions are useful	Identify examples of useful neutralisation reactions	Give examples to show how neutralisation reactions are useful	Explain how neutralisation reactions can be used, with examples
4.4 Making salts	Write the definition for the term salt	Identify the meaning of the term salt	State the meaning of the term salt	State the meaning of the term salt and give examples
	Predict the salts that form when acids react with metals or bases	Identify the name of a salt formed when an acid reacts with a metal or base	Predict the salt that forms when a familiar acid reacts with a metal or base	Suggest an acid/ base needed to produce a given sulphate, chloride, or nitrate salt
	Describe how to make a salt from an acid and a metal or insoluble base	Give the correct order of statements describing how to make a given salt from a specified acid and a specified metal or insoluble base	Describe how to make a given salt from a specified acid and a specified metal or insoluble base	Describe how to make a given salt, including naming the acid and base/ metal required

Physics

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
1.1 Introduction to forces	Identify everyday forces, explain how they arise, and use force arrows	Label force arrows for familiar forces	Use force arrows to explain how forces arise	Explain how the forces on an object can change
	Compare everyday contact and non-contact forces	Identify contact and non-contact forces	Compare everyday contact and non-contact forces	Explain differences between contact and non-contact forces
	Describe how to measure forces and give the unit of force	Identify a newtonmeter and state the unit of force	Describe how to measure forces and give the unit of force	Explain the readings of a newtonmeter in unfamiliar situations
1.2 Squashing and stretching	Describe how forces deform objects	Identify scenarios in which force deform objects	Describe how forces deform objects	Explain why forces will deform an object
	Explain how solid surfaces provide a support force	State situations in which a solid surface applies a support force	Explain how solid surfaces provide a support force	Apply the term reaction force to a range of unfamiliar scenarios
	Use Hooke's law	Describe Hooke's Law	Apply Hooke's Law to a familiar situation	Apply Hooke's law to an unfamiliar situation
1.3 Drag forces and friction	Describe the effect of drag forces and friction	Identify situations where forces slow an object	Describe the effect of drag forces and friction	Explain why there is greater resistance in a solid than a gas
	Explain how drag forces and friction arise	Identify objects which have large or low values of friction	Explain how drag forces and friction arise	Use ideas about particles to compare the friction and drag caused by different states of matter
	Describe how drag forces and friction can be reduced	Identify streamlined and non-streamlined shapes and objects	Describe how drag forces and friction can be reduced	Use the particle model to explain the effect of streamlining

Physics

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
1.4 Forces at a distance	Describe the effects of fields	Describe the effect of the Earth's gravitational field	Describe the effect of gravitational, magnetic, and electric fields	Compare different types of fields
	Describe the difference between weight and mass	Identify features of weight and mass	Describe the difference between weight and mass	Explain why weight is a force and mass is not
	Calculate weight	State the equation for weight	Calculate weight using W = mg for the Earth, planets, and the Moon	Change the subject of the weight equation to calculate mass or gravitational field strength on a different planet
1.5 Balanced and unbalanced forces	Describe the difference between balanced and unbalanced forces	Identify scenarios in which forces are balanced or unbalanced	Describe the difference between balanced and unbalanced forces	Explain the effect of balanced and unbalanced forces in unfamiliar situations
	Explain why an object is in equilibrium	Identify situations in which objects are in equilibrium	Explain why an object is in equilibrium	Explain how the position of equilibrium can be changed
	Explain the changing motion of objects	Identify the forces acting on an object that has changing motion	Explain the motion of familiar objects in terms of balanced and unbalanced forces	Explain why the speed or direction of objects can change
2.1 Waves	Describe the different types of wave and their features	Identify the key features of a wave	Describe the different types of wave and their features	Compare the features of a longitudinal and transverse wave
	Describe what happens when water waves hit a barrier	Identify the features of a water wave	Describe what happens when water waves hit a barrier	Explain unfamiliar situations in which waves can hit a barrier
	Describe what happens when waves superimpose	Compare different waves	Describe what happens when waves superimpose	Explain how noise cancelling technology works
2.2 Sound, vibrations, and energy transfer	Describe how sound is produced and travels	State how sound is caused	Describe how sound is produced and travels	Explain how sound is caused in unfamiliar situations
	Use the particle model to explain why the speed of sound is different in different materials	Using the particle model, identify how sounds travels in different states of matter	Use the particle model to explain why the speed of sound is different in different materials	Use the particle model to form a link between type of a substance and wave speed

Physics

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
2.3 Loudness and pitch	Describe the link between loudness and amplitude	Identify wave diagrams of loud and quiet sounds	Describe the link between loudness and amplitude	Explain why amplitude decreases with distance from the source of the sound
	Describe the link between frequency and pitch	Identify wave diagrams of high and low pitch sounds	Describe the link between frequency and pitch	Interpret soundwaves from unfamiliar situations
2.4 Detecting sound	Describe how the ear works	Identify different parts of the ear	Describe how the ear works	Explain the journey of sound through the ear
	State the range of human hearing and describe how it differs from the range of hearing in animals	Describe how the range of hearing is different in animals and humans	Compare the range of human hearing with different animals	Explain why the range of hearing decreases with age
	Describe how a simple microphone works	Label a diagram of a microphone	Describe how a simple microphone works	Compare and contrast the mechanisms of a microphone and ear
2.5 Ultrasound and echoes	Explain how echoes are used to find distance	Describe how to use an echo to calculate distance	Explain how echoes are used to find distance	Calculate distance using an echo
	Compare sound and ultrasound	Describe what ultrasound is	Compare sound and ultrasound	Deduce what infrasound is and compare this to ultrasound
	Describe uses of ultrasound to make images and find distances	List uses of ultrasound	Describe uses of ultrasound to make images and find distances	Calculate distance of objects using information about ultrasound
3.1 Light	Describe the journey light takes	Describe differences between luminous and non-luminous objects	Describe how light is emitted, travels, and is detected or absorbed	Explain the journey of light from an emitter to a receiver
	Describe what happens when light interacts with matter	Identify opaque, translucent, and transparent materials	Describe how light interacts with matter	Compare the amount of light passing through different objects
	Describe how the speed of light is used to define distance	Describe what a light year is	State the meaning of the term light-time	Calculate relative distances using light years

Physics	Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
	3.2 Reflection	Describe how light is reflected	Describe the features of a light ray diagram	Describe how light is reflected and the law of reflection	Apply the law of reflection to unfamiliar scenarios
		Explain how images are formed in a plane mirror	Label a ray diagram to measure the angle of reflection and refraction	Use the law of reflection to explain how images are formed in a plane mirror	Apply the law of reflection to form a virtual image
		Describe the difference between specular reflection and diffuse scattering	Identify specular and diffuse reflection	Describe what happens when light is reflected by smooth and rough surfaces	Explain why an image is not formed from all types of surfaces
	3.3 Refraction	Describe what happens when light is refracted	Identify the angle of incidence and angle of refraction	Describe what happens when light is refracted	Explain why light refracts
		Explain what happens when light is refracted	Identify more and less dense materials due to the changing direction of a light ray	Explain why light is refracted in terms of the speed of light in different media	Predict the effect of density of a material on the refraction of light
		Describe how a convex lens affects light	Describe the structure of a convex lens	Draw a ray diagram for light rays moving through a convex lens	Explain the size of images formed from convex lenses
	3.4 The camera and the eye	Describe how the eye works	Label a diagram of the eye	Describe how the eye works to produce an image that is sent to the brain	Suggest how the lens changes when looking at objects different distances away
		Compare a simple camera with the eye	Identify the structures within a camera	Compare a simple camera with the eye	Compare how images are formed with the eye and a camera

Physics

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
3.5 Colour	Describe and explain what happens when light passes through a prism	Describe what white light is made up of	Describe and explain how a prism produces a spectrum of white light	Explain how white light can be separated into a spectrum in unfamiliar situations
	Describe how primary colours add to make secondary colours	State the primary colours	Describe how the three pairs of primary colours of light add to make the three secondary colours of light, and one tertiary colour	Compare why some objects appear white or black
	Explain the effect of filters and coloured materials on light	Identify the colour of light when passed through a filter	Explain the effect of filters and coloured materials on light in terms of selective absorption	Explain why coloured objects appear different colours when viewed through a colour filter
4.1 The night sky	Describe the objects that you can see in the night sky	List familiar objects in the night sky	Describe the objects that you can see in the night sky with the naked eye and with a telescope	Explain why some objects in the Solar System cannot be seen with the naked eye
	Describe the structure of the Universe	List objects in the Universe in size order	Describe the structure of the Universe	Compare objects in the Universe in terms of size and characteristics
4.2 The Solar System	Compare the planets of the Solar System	Name the planets in the Solar System	Compare the planets of the Solar System	Explain trends and patterns in the Solar System
	Describe how the Solar System formed	List the stages by which the Solar System formed	Describe how the Solar System formed	Explain stages in the formation of the Solar System
4.3 The Earth	Explain the apparent motion of objects in the sky	Describe relative motion	Explain the apparent motion of the Sun and other objects in the sky	Compare the motion of the Sun with the motion of the planets
	Describe and explain seasonal changes	Recognise features of the Earth which cause seasons	Describe and explain seasonal changes in the UK	Compare and explain the seasonal changes in the UK and Australia
	Describe seasonal changes in different places on Earth	Describe how different locations on Earth have different seasons at the same time	Describe seasonal changes in different locations on Earth	Explain how the tilt of the Earth affects seasons

	Topic	Learning objective	Learning outcomes		
			Developing	Secure	Extending
Physics	**4.4 The Moon**	Describe the phases of the Moon	Describe the Moon's orbit of the Earth	Describe the phases of the Moon and timescale over which they are observed	Explain how the position of the Moon affects the Moon's phases
		Explain why you see phases of the Moon	Identify the phases of the Moon	Explain the phases of the Moon	Explain the appearance of phases of unfamiliar objects in the Solar System
		Explain why eclipses happen	Describe the conditions needed for an eclipse	Explain why we see lunar and solar eclipses	Compare and contrast Lunar and solar eclipses

Year 8

Biology

		Learning outcomes		
Topic	**Learning objective**	**Developing**	**Secure**	**Extending**
1.1 Food groups	Describe what is meant by a balanced diet	Name some foods that are considered healthy or unhealthy	Describe what is meant by a balanced diet	Explain why eating a balanced diet is important for health
	Name the seven components of a balanced diet, giving examples	Name some components of a balanced diet	Name the seven components of a balanced diet, giving examples	Suggest a balanced diet for one day
	Describe the role of each component of a balanced diet	Identify the function of some components of a balanced diet	Describe the role of each component of a balanced diet	Explain the role of each component of a balanced diet
1.2 Food tests	Name the chemicals used to test foods for starch, lipids, sugar, and protein	Identify some of the chemicals used for food tests	Name the chemicals used to test foods for starch, lipids, sugar, and protein	Determine which chemical(s) would produce a positive test result for a named food sample
	State the positive result for each food test	Identify the positive result for each food test	State the positive result for each food test	Identify the nutrients present in a food based on the outcome of the four food tests
	Describe how to test foods for starch, lipids, sugar, and protein	State what is meant by a food test	Describe how to test foods for starch, lipids, sugar, and protein	Explain some safety precautions to be taken for the four food tests
1.3 Unhealthy diet	Describe some health issues caused by an unhealthy diet	List some health problems associated with an unhealthy diet	Describe some health issues caused by an unhealthy diet	Explain some health issues caused by an unhealthy diet
	State what is meant by a vitamin or mineral deficiency	Name some examples of vitamins and minerals needed in a human diet	Describe what is meant by a vitamin or mineral deficiency	Describe examples of specific vitamin or mineral deficiencies
	Compare the energy requirements of different people	Name some factors which affect a person's daily energy requirements	Compare the energy requirements of different people	Estimate and justify the energy requirements for different occupations
1.4 Digestive system	Describe the process of digestion	State what is meant by digestion	Describe the process of digestion	Explain the importance of digestion
	Describe the function of the main structures in the digestive system	Label the main structures in the digestive system	Describe the function of the main structures in the digestive system	Explain the structural adaptations of the main structures in the digestive system

Biology

		Learning outcomes		
Topic	**Learning objective**	**Developing**	**Secure**	**Extending**
1.5 Bacteria and enzymes in digestion	Describe the role of bacteria in digestion	List some facts about bacteria	Describe the role of bacteria in digestion	Explain the importance of bacteria in digestion
	Define what is meant by an enzyme	Identify the role of an enzyme in digestion	Define what is meant by an enzyme	Explain the role of enzymes in digestion
	Describe the role of enzymes in carbohydrate, protein, and lipid digestion	Identify the enzymes used to digest carbohydrates, proteins, and lipids	Describe the role of enzymes in carbohydrate, protein, and lipid digestion	Explain how bile supports the digestion of lipids
1.6 Drugs	Define what is meant by a drug	Name some drugs	Define what is meant by a drug	Describe some effects of drugs on the human body
	Describe the difference between recreational and medicinal drugs	List some medicinal and recreational drugs	Describe the difference between recreational and medicinal drugs	Compare the health benefits and drawbacks of some common drugs
	Describe what happens during drug addiction	State what is meant by an addiction	Describe what happens during drug addiction	Suggest some behavioural or societal impacts of drug addiction
1.7 Alcohol	Describe some effects of alcohol on the body	Name the drug present in alcohol	Describe some effects of alcohol on the body	Explain why a person should not drive after drinking alcohol
	Describe some health problems caused by alcohol consumption	Name some health problems associated with alcohol consumption	Describe some health problems caused by alcohol consumption	Explain some health problems caused by alcohol consumption
	Describe some effects of alcohol consumption on conception and pregnancy	Identify some problems associated with alcohol consumption on conception and pregnancy	Describe some effects of alcohol consumption on conception and pregnancy	Explain some effects of alcohol consumption on conception and pregnancy
1.8 Smoking	Describe the effects of the components of tobacco smoke on the body	List some of the components of tobacco smoke	Describe the effects of the components of tobacco smoke on the body	Explain the effects of the components of tobacco smoke on the body
	Describe some health problems caused by smoking	List some diseases linked to smoking	Describe some health problems caused by smoking	Explain some health problems caused by smoking
	Describe some effects of smoking on pregnancy	Identify some problems associated with smoking during pregnancy	Describe some effects of smoking on pregnancy	Explain how smoking during pregnancy can cause serious illness in a fetus or miscarriage

Biology	Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
	2.1 Photosynthesis	Describe the process of photosynthesis	Describe the difference between a producer and a consumer	Describe the process of photosynthesis	Explain the importance of photosynthesis to all organisms on Earth
		State the word equation for photosynthesis	Identify the substances a plant uses for photosynthesis and the substances it makes	State the word equation for photosynthesis	Explain why plants require light to photosynthesise
		Describe how to test a leaf for the presence of starch	State the chemical test used to show the presence of starch	Describe how to test a leaf for the presence of starch	Predict the outcome of a starch test on a variegated leaf
	2.2 Leaves	Describe the main adaptations of a leaf	List some features of a leaf	Describe the main adaptations of a leaf	Explain the main adaptations of a leaf
		Describe the role of stomata	State what stomata are	Describe the role of stomata	Explain how stomata allow gas exchange in a leaf
		Describe how water is transported through a plant	Name the organs through which water passes within a plant	Describe how water is transported through a plant	Explain how plants obtain the reactants for photosynthesis
	2.3 Plant minerals	Describe how a plant uses minerals for healthy growth	List some minerals required by plants	Describe how a plant uses nitrates, phosphates, and magnesium	Explain how minerals enable healthy growth in a plant
		Explain why farmers use fertilisers	List some ways farmers can add minerals to soil	Explain why farmers use fertilisers	Explain why using fertilisers enable land to be used for crop growth year after year
		Describe the symptoms of plant mineral deficiencies	List some symptoms of unhealthy plants	Describe the symptoms of plant mineral deficiencies	Suggest and justify a mineral deficiency based on a plant's appearance

Biology

		Learning outcomes		
Topic	**Learning objective**	**Developing**	**Secure**	**Extending**
2.4 Aerobic respiration	Describe the process of aerobic respiration	Name the chemical reaction where energy is transferred to cells	Describe the process of aerobic respiration	Explain why respiration is performed by all living organisms
	State the word equation for aerobic respiration	Identify the substances used for aerobic respiration and the substances produced	State the word equation for aerobic respiration	Compare the processes of aerobic respiration and photosynthesis
	Describe how the reactants and products of respiration are transported to and from cells	Identify the substances that move into and out of cells during respiration	Describe how the reactants and products of respiration are transported to and from cells	Explain how the reactants and products of respiration are transported to and from cells
2.5 Anaerobic respiration	Compare the processes of aerobic and anaerobic respiration	State what is meant by anaerobic respiration	Compare the processes of aerobic and anaerobic respiration	Explain why the body normally respires aerobically
	State the word equation for the process of anaerobic respiration	Identify the substances used for anaerobic respiration and the substances produced	State the word equation for the process of anaerobic respiration in animals	Explain what is meant by the term oxygen debt
	State the word equation for fermentation	Name some food products made using fermentation	State the word equation for fermentation	Explain how the fermentation reaction is used to manufacture some food products
3.1 Food chains and webs	Use relevant information to construct a food chain	State what is meant by a food chain	Use relevant information to construct a food chain	Explain why the Sun is the ultimate source of energy in food chains
	Describe the feeding relationships between organisms in a food chain	Identify the producer and consumer in a food chain	Describe the feeding relationships between organisms within a food chain	Explain why food chains rarely have more than four links
	Describe the feeding relationships between organisms within a food web	State what is meant by a food web	Describe the feeding relationships between organisms within a food web	Explain why food webs describe feeding relationships more realistically than food chains

Biology

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
3.2 Disruption to food chains and webs	Describe what is meant by the interdependence of organisms	Name some ways in which organisms depend on each other to survive	Describe what is meant by the interdependence of organisms	Use specific examples to explain why organisms are interdependent on each other
	Suggest and justify how a population change of one organism affects the population of another within a food web	List the food chains within a food web	Suggest and justify how a population change of one organism affects the population of another within a food web	Suggest and explain the effect of a population change of one organism on a range of other organisms within a food web
	Describe how toxic materials can accumulate in a food chain	Describe how the number of organisms changes moving through a food chain	Describe how toxic materials can accumulate in food chains	Explain how bioaccumulation can lead to human health problems
3.3 Ecosystems	Define the terms habitat, community, and ecosystem	Give an example of a habitat and the plants and animals that live there	Define the terms habitat, community, and ecosystem	Describe the levels of organisation within a named ecosystem
	Describe how different organisms coexist within an ecosystem	Name some organisms that coexist within a familiar ecosystem	Describe how different organisms coexist within an ecosystem	Explain why different organisms within an ecosystem have different niches
3.4 Competition	Explain the resources that plants and animals compete for	Give some resources which plants and animals compete for	Explain the resources that plants and animals compete for	Compare the resources that plants and animals compete for
	Describe the interaction between predator and prey populations	State what is meant by predator and prey organisms	Describe the interaction between predator and prey populations	Explain the interaction between predator and prey populations
3.5 Adapting to change	Describe how organisms are adapted to their environment	Identify some adaptations of organisms that help them to survive	Describe how organisms are adapted to their environment	Explain how organisms are adapted to their environment
	Describe how organisms adapt to environmental changes	Describe some seasonal changes that take place throughout the year	Describe how organisms adapt to environmental changes	Use examples to explain how organisms adapt to environmental changes

Biology

Topic	Learning objective	Learning outcomes		
		Developing	**Secure**	**Extending**
4.1 Variation	Define the term variation	Give some ways that organisms of the same species differ from each other	Describe what is meant by the term variation	Suggest why identical twins look very similar, but are not exactly the same
	Use examples to describe the difference between inherited and environmental variation	Name some human characteristics that are inherited and some that are affected by the environment	Use examples to describe the difference between inherited and environmental variation	Explain why many characteristics are affected by both the environment and inheritance
4.2 Continuous and discontinuous variation	Use examples to describe the difference between continuous and discontinuous variation	State what is meant by continuous and discontinuous data	Use examples to describe the difference between continuous and discontinuous variation	Explain why some numerically measured characteristics show discontinuous variation
	Choose and justify the most appropriate graph to display examples of variation data	Name the types of graph used to display continuous and discontinuous data	Choose and justify the most appropriate graph to display examples of variation data	Explain why variation in characteristics caused only as a result of inheritance are usually plotted on a bar chart
4.3 Inheritance	Define the terms DNA, chromosome, and gene	State where genetic material is found within a cell	Define the terms DNA, chromosome, and gene	Describe the relationship between DNA, chromosomes, and genes
	Describe how characteristics are inherited	Describe the role of sperm and egg cells in fertilisation	Describe how characteristics are inherited	Explain why siblings appear similar, but are not the same
	Describe how scientists worked together to develop the DNA model	Identify some of the scientists involved in the development of the DNA model	Describe how scientists worked together to develop the DNA model	Explain the importance of collaborative working in scientific research
4.4 Natural selection	Describe the role of the fossil record as evidence for evolution	State what is meant by the term evolution	Describe the role of the fossil record as evidence for evolution	Suggest why some species that once lived are not present in the fossil record
	Describe the process of natural selection	Describe what is meant by an adaptation	Describe the process of natural selection	Use a named species to illustrate the process of natural selection
	Describe how new species evolve through the process of natural selection	Define what is meant by a species	Describe how new species evolve through the process of natural selection	Explain why environmental change can lead to the evolution of new species

Biology	Topic	Learning objective	Learning outcomes		
			Developing	**Secure**	**Extending**
	4.5 Extinction	Describe some factors that may lead to extinction	State what is meant by the terms endangered and extinct	Describe some factors that may lead to extinction	Explain how changes to a species' environment can lead to extinction
		Describe how gene banks can be used to prevent the extinction of a species	State what is meant by biodiversity	Describe how gene banks can be used to prevent the extinction of a species	Justify the importance of gene banks in maintaining biodiversity

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
1.1 Elements and the Periodic Table	Describe the properties of three elements	Identify the properties of three elements	Describe the properties of three elements	Compare the properties of three elements
	Explain how the uses of three elements are determined by their properties	Identify the uses of three elements	Explain how the uses of three elements are determined by their properties	Justify how the properties of an unfamiliar element make it suitable for its use
1.2 Metals and non-metals 1	Explain how elements are classified as metals and non-metals	Identify non-metals and metals on the Periodic Table	Use the Periodic Table to determine whether a given element is a metal or non-metal	Suggest why it is useful to be able to determine which elements are metals and non-metals using the Periodic Table
	Write the meaning of the term physical properties	Identify the meaning of the term physical properties	Write the meaning of the term physical properties	Write the meaning of the term physical properties, giving some examples
	Use patterns to classify an element as a metal or non-metal	From data presented in tables or bar charts, describe patterns in the properties of elements in Groups or Periods	Describe the physical properties of typical metal and non-metal elements	Compare the physical properties of typical metal and non-metal elements
1.3 Metals and non-metals 2	Write the meaning of the term chemical properties	Identify the meaning of the term chemical properties	Write the meaning of the term chemical properties	Explain the difference between physical and chemical properties, giving examples
	Describe the chemical properties of metals and non-metals	Identify the chemical properties of metals and non-metals	Describe the chemical properties of metals and non-metals	Compare the products of the chemical reaction between a metal and oxygen, and a non-metal and oxygen

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
1.4 Groups and Periods	Use patterns to predict the properties of elements	State the name of the columns and rows in the Periodic Table	Determine the Group and Period number of an element in the Periodic Table	Compare two given elements' positions in the Periodic Table
	From data presented in tables or bar charts, describe patterns in the properties of elements in Groups or Periods	Identify patterns in properties of elements in Groups or Periods	From data presented in tables or bar charts, describe patterns in the properties of elements in Groups or Periods	From data presented in tables or bar charts, compare patterns in the properties of elements in Groups or Periods
	Compare patterns in properties in the Groups and Periods of the Periodic Table	Using data, describe a pattern in the properties of elements in a Group or Period	Using data, predict the properties of another element in a Group or Period	Using data, justify errors in predictions of the properties of another element in a Group or Period
1.5 The elements of Group 1	Interpret data to describe patterns in properties of the Group 1 elements	Identify the physical properties of the Group 1 elements	Describe the physical properties of the Group 1 elements	Compare the physical properties of Group 1 elements with those of a typical metal
	Using data from tables or bar charts, describe patterns in the melting and boiling points of the Group 1 elements	Using data from a bar chart, identify the pattern in the melting and boiling points of the Group 1 elements	Using data from tables or bar charts, describe patterns in the melting and boiling points of the Group 1 elements	From data presented in tables, describe patterns in the melting and boiling points of the Group 1 elements
	Use patterns to predict reactions of Group 1 elements	Describe the pattern in reactions of the Group 1 elements with water	Use the pattern in the reactions of the Group 1 elements with water to predict the reaction of another Group 1 element with water	Use the pattern in the reactions of the Group 1 elements with water to predict the reaction of another Group 1 element with water, and justify the answer

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
1.6 The elements of Group 7	Use patterns to predict properties of Group 7 elements	Identify the colours and states of the Group 7 elements at room temperature	Describe the physical properties, including colours and states at room temperature, of the Group 7 elements	Compare the physical properties of the Group 7 elements
	Using data from bar charts, describe patterns in the melting and boiling points of the Group 7 elements	Using data from a bar chart, identify the pattern in the melting and boiling points of the Group 7 elements	Using data from bar charts, describe patterns in the melting and boiling points of the Group 7 elements	From data presented in tables, describe patterns in the melting and boiling points of the Group 7 elements
	Use patterns to predict reactions of Group 7 elements	Describe the pattern in reactions of the Group 7 elements with iron	Use the pattern in the reactions of the Group 7 elements with iron to predict the reaction of another Group 7 element with iron	Compare the reactions of chlorine and iodine with iron
1.7 The elements of Group 0	Describe the physical and chemical properties of the Group 0 elements	Identify the physical properties of the Group 0 elements	Describe the physical properties of the Group 0 elements	Compare the physical properties of the Group 0 elements with those of the Group 7 elements
	From data presented in bar charts, describe patterns in the melting and boiling points of the Group 0 elements	From data presented in bar charts, identify patterns in the melting and boiling points of the Group 0 elements	From data presented in bar charts, describe patterns in the melting and boiling points of the Group 0 elements	From data presented in tables, describe patterns in the melting and boiling points of the Group 0 elements
	Use patterns to predict properties of Group 0 elements	Describe the properties of the Group 0 elements	Explain how the properties of the Group 0 elements make them suitable for their uses	Evaluate the how the properties of Group 0 make them suitable for unfamiliar uses

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
2.1 Mixtures	Describe the particle arrangements in mixtures	Identify the meaning of the term mixture	Write the meaning of the term mixture	Write the meaning of the term mixture and give some examples
	Compare mixtures and compounds	Write the meanings of the terms mixture and compound	Compare mixtures and compounds	Compare unfamiliar mixtures and compounds
	Explain how to identify pure substances	Identify the melting point of a substance on a temperature-time graph	Use a temperature-time graph for a melting substance to determine whether or not it is pure	Use temperature-time graphs to compare the purity of two different substances
2.2 Solutions	Describe solutions using key words	Identify the meanings of the terms solution, solute, solvent, and dissolve	Write the meanings of the terms solution, solute, solvent, and dissolve	Explain the relationship between the terms solute, solvent, solution, and dissolve
	Use the particle model to explain dissolving	Describe dissolving	Use the particle model to explain dissolving	Use the particle model to explain dissolving in an unfamiliar situation
	Use the particle model to explain dissolving	Determine the total mass of solvent and solute present	Predict the mass of a solution made from given masses of solute and solvent	Predict the missing mass of a solute or solvent, given the masses of a solution and either the solute or solvent
2.3 Solubility	Explain what a saturated solution is	Describe how to make a saturated solution	Write the meaning of the term solubility	Use data to compare the solubility of two different substances
	Plot a solubility-temperature graph from data in a table	Describe what a solubility-temperature graph shows	Plot a solubility-temperature graph from data in a table	Using data given in a table, plot the solubility-temperature graphs for two different substances and compare them
	Describe how solubility changes with temperature for a named substance	From data given in a table, identify the temperature at which a solute is most soluble	Describe how solubility changes with temperature for a named substance, given data in a table or line graph	Using data given in a table or line graph, compare how the solubility of two different substances change with temperature

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
2.4 Filtration	Explain how filtration works	Identify the types of mixtures that can be separated by filtration	Name the types of mixtures that can be separated by filtration	Name the types of mixtures that can be separated by filtration and give some examples
	Explain how filtration works	Describe how to use filtration to separate a soluble substance from an insoluble one	Explain how filtration works	Suggest advantages and disadvantages of filtration as a separation technique
	Explain some uses of filtration	Identify some uses of filtration	Explain some uses of filtration	Evaluate the use of filtration as a separation technique in given situations
2.5 Evaporation and distillation	Use the particle model to explain how evaporation works	Describe how to use evaporation to separate the solute from a solution	Use the particle model to explain how evaporation works	Use the particle model to explain how evaporation works in unfamiliar situations
	Describe how to use distillation to separate mixtures	Label the equipment and set up in a distillation experiment	Describe how to use distillation to separate the solvent from a solution	Use the particle model to explain how distillation works
	Determine whether to use evaporation or distillation to separate a named substance from a solution	Describe the uses of evaporation and distillation	Determine whether to use evaporation or distillation to separate a named substance from a solution	Justify whether to use evaporation or distillation to separate a named unfamiliar substance from a solution
2.6 Chromatography	Describe how to use chromatography to separate the substances in a mixture	Label the equipment in a chromatography experiment	Describe how to use chromatography to separate the substances in a mixture	Use the particle model to explain how chromatography separates mixtures
	Analyse chromatograms to identify substances in mixtures	Use evidence from chromatography to determine how many different substances are contained in a mixture	Use evidence from chromatography to identify unknown substances in mixtures	Suggest advantages and disadvantages of using chromatography to identify unknown substances in mixtures

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
3.1 Metals and acids	Compare the reactions of different metals with dilute acids	Identify the pattern in the products of the reaction of metal with an acid	Use a pattern to predict the products of the reaction of a metal with an acid	Predict the products of the reaction of a metal with an acid
	Write a word equation for the reaction of a metal with an acid, given the names of the reactants and products	Identify the word equation for the reaction of a metal with an acid, given the names of the reactants and products	Write a word equation for the reaction of a metal with an acid, given the names of the reactants and products	Write a word equation for the reaction of a metal with an acid
3.2 Metals and oxygen	Compare the reactions of different metals with oxygen	Identify the pattern in the products of the reaction of a metal with oxygen	Use a pattern to predict the products of the reaction of a metal with oxygen	Predict the products of the reaction of a metal with oxygen
	Write a word equation for the reaction of a metal with oxygen, given the names of the reactants and products	Identify the word equation for the reaction of a metal with an acid, given the names of the reactants and products	Write a word equation for the reaction of a metal with oxygen, given the names of the reactants and products	Write a word equation for the reaction of a metal with oxygen
	Compare the patterns in the reactivity of metals with acids and with oxygen	Describe how gold and magnesium react with acids and oxygen	Compare the patterns in the reactivity of metals with acids and with oxygen	Predict how a metal will react with oxygen, given information about how it reacts with acids
3.3 The reactivity series	Compare the reactions of metals with water	Identify the pattern in the reactions of metals with water	Use a pattern to predict the products of the reaction of a metal with water	Predict the products of the reaction of a metal with water
	Write a word equation for the reaction of a metal with water, given the names of the reactants and products	Identify the word equation for the reaction of a metal with water, given the names of the reactants and products	Write a word equation for the reaction of a metal with water, given the names of the reactants and products	Write the word equation for the reaction of a metal with water
	Use the reactivity series to predict reactions	Write the meaning of the term reactivity series	Use the reactivity series to predict how vigorously metals react with acids, oxygen, and water	Using reactivity data given, predict where a metal sits in the reactivity series

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
3.4 Obtaining metals	Use the reactivity series to decide which metals can be extracted from their ores by heating with carbon	Identify the two steps needed to extract a metal from its ore	Describe the two steps needed to extract a metal from its ore	Describe the two steps needed to extract a metal from its ore, and explain why this is necessary
	State which metals in the reactivity series can be extracted by heating their oxides with carbon	Identify which metals in the reactivity series can be extracted by heating their oxides with carbon	State which metals in the reactivity series can be extracted by heating their oxides with carbon	Use the reactivity series to predict and justify whether a given metal can be extracted from its oxide by heating with carbon
	Calculate the mass of metals in ores	Identify the mass of metal in an ore	Calculate the mass of metal in an ore	Calculate the percentage of metal in an ore
3.5 Ceramics	Describe properties of ceramics	Identify properties of ceramics	Describe properties of ceramics	Explain properties of ceramics
	Explain why the properties of ceramics make them suitable for their uses	State some properties of ceramics	Explain how the properties of ceramics make them suitable for their uses	Evaluate the properties of ceramics for an unfamiliar use
3.6 Polymers	Explain why properties of polymers make them suitable for their uses	Describe the properties of some polymers	Explain why the properties of polymers make them suitable for their uses	Compare the uses of two polymers
3.7 Composites	Describe properties of composites	Describe properties of some composites	Explain properties of some composites	Use information given to suggest advantages and disadvantages of the properties of composites
	Explain why composite properties make them suitable for their uses	Identify the properties of components of composite materials	Explain why the properties of composites make them suitable for their uses	Evaluate the properties of composites for an unfamiliar use
4.1 The Earth and its atmosphere	Compare the layers of the Earth	Name the layers of the Earth	Compare the layers of the Earth	Compare the physical properties of the layers of the Earth
	Describe the composition of the atmosphere	Identify the four main gases which comprise the Earth's atmosphere	Describe the composition of the Earth's atmosphere	Compare the quantities of the four main gases in the Earth's atmosphere

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
4.2 Sedimentary rocks	Explain two properties of sedimentary rocks	State two properties of typical sedimentary rocks	Explain two properties of sedimentary rocks	Suggest and justify the properties of unfamiliar sedimentary rocks
	Describe the four stages in the formation of sedimentary rock	Give the four stages in the formation of sedimentary rock	Describe the four stages in the formation of sedimentary rock	Compare the processes of weathering and transport
	Explain how the properties of sedimentary rocks make them suitable for their uses	State a use of sedimentary rocks	Explain how the properties of sedimentary rocks make them suitable for their uses	Suggest disadvantages of using sedimentary rocks for making statues, and justify the answer
4.3 Igneous rocks	Describe how igneous rocks form	Identify how igneous rocks form	Describe how igneous rocks form	Explain why some igneous rocks have small crystals and others have big crystals
	Explain the properties of igneous rocks	Describe two properties of typical igneous rocks	Explain the properties of igneous rocks	Explain the properties of unfamiliar igneous rocks
	Explain how the properties of igneous rocks make them suitable for their uses	State some uses of igneous rocks	Explain how the properties of igneous rocks make them suitable for their uses	Compare the advantages and disadvantages of using igneous rocks and sedimentary rocks for building materials
4.4 Metamorphic rocks	Describe how metamorphic rocks form	Identify how metamorphic rocks form	Describe how metamorphic rocks form	Compare how metamorphic and igneous rocks form
	Explain the properties of metamorphic rocks	State the properties of metamorphic rocks	Explain the properties of metamorphic rocks	Suggest and justify the properties of unfamiliar metamorphic rocks
	Explain how how the properties of metamorphic rocks make them suitable for their uses	State some uses of metamorphic rocks	Explain how how the properties of metamorphic rocks make them suitable for their uses	Compare the advantages and disadvantages of using igneous rocks and metamorphic rocks for roof tiles

Chemistry

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
4.5 The rock cycle	Use the rock cycle to describe how the materials in rocks are recycled	Label the types of rock and the processes in the rock cycle	Use the rock cycle to describe how the materials in rocks are recycled	Use the rock cycle to explain in detail how the materials in rocks are recycled
	Explain how uplift provides evidence for the rock cycle	Describe the process of uplift	Explain how uplift provides evidence for the rock cycle	Apply understanding of uplift to explain unfamiliar rock formations
4.6 The carbon cycle	Use the carbon cycle to identify stores of carbon	Name some carbon stores	Describe the processes by which carbon moves from one store to another	Compare the processes by which carbon moves from one store to another
	Explain the relative stability in the concentration of carbon dioxide in the carbon cycle over part of Earth's history	Name two processes that add carbon dioxide to the atmosphere, and two that remove it from the atmosphere	Explain the relative stability in the concentration of carbon dioxide in the carbon cycle over part of Earth's history	Compare the processes causing the relative stability in the concentration of carbon dioxide in the carbon cycle over part of Earth's history
4.7 Climate change	Describe the greenhouse effect	Label a diagram of the greenhouse effect	Describe the greenhouse effect	Evaluate the advantages and disadvantages of carbon dioxide existing in the atmosphere
	Explain why global warming happens	Identify the meaning of the term global warming	Explain why global warming happens	Suggest some methods for reducing global warming and explain how they might work
	Describe some impacts of global warming	Identify some impacts of global warming	Describe some impacts of global warming	Explain some impacts of global warming
4.8 Recycling	Write the meaning of the term recycling	Identify the meaning of the term recycling	Write the meaning of the term recycling	Write the meaning of the term recycling and give some examples
	Describe how aluminium is recycled	Identify the stages in recycling aluminium	Describe how aluminium is recycled	Use data to compare the process of recycling aluminium with the process of recycling another metal
	Describe some advantages and disadvantages of recycling	Identify some advantages and disadvantages of recycling	Describe some advantages and disadvantages of recycling	Evaluate the advantages and disadvantages of recycling

Physics

Topic	Learning objective	Learning outcomes		
		Developing	Secure	Extending
1.5 Changing the subject of simple equations	Change the subject of an equation	Substitute values into a given equation	Change the subject of an equation	Apply knowledge of unit conversion to suit a given equation
	Apply changing the subject to the equation for resistance	State the equation to calculate current	Calculate current using simple values of potential difference and resistance	Change the subject of the current equation to calculate resistance or potential difference
1.6 Series and parallel circuits	Describe the difference between series and parallel circuits	Identify series and parallel circuits	Describe the difference between a series and a parallel circuit	Evaluate why some circuits are better suited to be parallel or series
	Describe how current varies in series and parallel circuits	Identify where to place ammeters in a series circuit	Describe how current varies in series and parallel circuits	Calculate current values in unfamiliar circuits
	Describe how potential difference varies in series and parallel circuits	Identify where to place voltmeters in a series circuit	Describe how potential difference varies in series and parallel circuits	Calculate potential difference values in unfamiliar circuits
1.7 Magnets and magnetic fields	Describe how to investigate and represent the shape of a magnetic field	State one way to observe magnetic fields	Describe how to investigate and represent the shape of a magnetic field	Plan an investigation to observe how magnetic fields interact
	Define the term magnetic field	Identify a region where a magnetic field is present	State what is meant by the term magnetic field	Compare and contrast electric, magnetic, and gravitational fields
	Describe the Earth's magnetic field	Identify the North and South poles of the Earth	Describe the Earth's magnetic field	Explain how a compass works
1.8 Electromagnets	Describe how to make an electromagnet	List the equipment needed to make an electromagnet	Describe how to make an electromagnet	Explain how to test the strength of an electromagnet
	Describe the magnetic field around a current-carrying wire	Identify the magnetic field around a wire	Describe the magnetic field around a current-carrying wire	Compare the magnetic field of a current-carrying wire and a permanent bar magnet
	Describe how to change the strength of an electromagnet	Identify factors that affect the strength of an electromagnet	Describe the factors that affect the strength of an electromagnet	Explain why, by looking at diagrams, certain electromagnets have different field strengths

Physics

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
1.9 Using electromagnets	Describe some uses of electromagnets	State uses of electromagnets	Describe the uses of electromagnets	Explain why the properties of electromagnets make them suitable for different uses
	Compare permanent magnets and electromagnets	Identify examples of permanent magnets and electromagnets	Describe the difference between a permanent magnet and an electromagnet	Evaluate the use of permanent magnets and electromagnets for different purposes
	Describe how a simple motor works	Identify simple motors in everyday life	Describe how a simple motor works in terms of magnetic fields	Explain how different factors can affect the strength of a motor
2.1 Food and fuels	Compare the energy values of foods and fuels	Identify foods with high and low energy values	Compare the energy values of food and fuels	Predict energy values based on different proportions of food groups
	Compare the energy in foods and fuels with the energy needed for different activities	Identify different situations or activities which need greater intakes of energy	Compare the energy requirements of different activities	Explain the diets of different groups of people, relating this to their energy needs
2.2 Energy resources	Describe how fossil fuels are formed	State three fossil fuels	Describe how fossil fuels are formed	Compare the differences between fossil fuels
	Describe the difference between a renewable and a non-renewable energy resource	Identify renewable and non-renewable energy resources	Describe the difference between a renewable and non-renewable energy resource	Compare the long-term use of renewable and non-renewable energy resources
	Describe how electricity is generated with renewable and non-renewable resources	Label the parts of a power station	Describe how electricity is generated with renewable and non-renewable resources	Evaluate the suitability of different energy resources for different locations
2.3 Energy adds up	Describe energy stores before and after a change	State a range of everyday energy stores	Describe the energy stores involved in everyday transfers	Describe energy stores in unfamiliar energy transfers
	Describe what brings about changes in energy stores	State ways in which energy can be transferred between stores	Describe the ways of transferring energy between stores	Explain how energy is transferred in unfamiliar scenarios
	Use the conservation of energy in energy analyses	Describe ways energy can be dissipated	Use the law of conservation of energy in an energy analysis	Apply the law of conservation of energy to an unfamiliar scenario

Physics

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
2.4 Energy and temperature	State the difference between energy and temperature	State the units of temperature and energy	Describe the difference between energy and temperature in terms of the particles in a substance	Explain the difference between energy and temperature
	Describe what happens when you heat up solids, liquids, and gases	State factors that can affect the temperature increase of a substance	Describe the factors that affect the change in temperature of a substance	Calculate the energy required to increase the temperature of different substances
	Explain what is meant by equilibrium	Identify scenarios in which equilibrium has been reached	Explain what is meant by equilibrium in terms of energy and temperature	Explain factors which could alter the position of equilibrium
2.5 Energy transfer – particles	Describe how energy is transferred by particles during conduction	Identify scenarios in which conduction occurs	Describe how energy is transferred by particles during conduction	Explain, using the particle model, why conduction occurs at different rates in different substances
	Describe how energy is transferred by particles during convection	Identify scenarios in which convection occurs	Describe how energy is transferred by particles during convection	Explain how convection occurs in unfamiliar scenarios
	Explain how an insulator can reduce energy transfer	State everyday examples of conductors and insulators	Explain the constructions of some insulators	Compare conductors and insulators using the particle model
2.6 Energy transfer – radiation	Describe what is meant by the term radiation	State the difference between temperature and radiation	Describe what is meant by radiation in the context of energy transfer from objects at a certain temperature	Explain the difference between radiation and temperature
	Compare energy transfer by conduction, convection, and radiation	Identify everyday examples of conduction, convection, and radiation	Compare energy transfer by conduction, convection, and radiation	Justify the energy transfer in unfamiliar scenarios
	Give the waves of the electromagnetic spectrum	Identify waves that are part of the electromagnetic spectrum	State the waves of the electromagnetic spectrum	Explain how the properties of different waves relate to their uses

Physics

Topic	Learning objective	Learning outcomes: Developing	Secure	Extending
2.7 Work, energy, and machines	Describe what is meant by the term work	Identify the meaning of the term work	State the meaning of the term work	Explain why no work is done when an object moves in a circle
	Calculate work done	State factors that will affect work done	Calculate work done in familiar situations	Change the subject of the work done equation to calculate force or distance
	Apply the conservation of energy to simple machines	Describe a simple machine	Explain in terms of conservation of energy how machines make jobs easier	Explain examples of force multipliers
2.8 Energy and power	Describe the difference between energy and power	Describe similarities between energy transferred and work done	State what is meant by the term power	Explain how power can vary in unfamiliar situations
	Calculate power and energy	Identify the units of work done, energy transferred, and power	Calculate power and energy in familiar situations given values of energy/work and time, or power and time	Change the subject of the power equation to calculate work done and time
	Calculate the cost of using domestic appliances	State the link between kilowatts and kilowatt hours	Calculate energy used in kilowatt hours and its cost in familiar situations, given values of power and time	Change the subject of the kilowatt hour equation to calculate time, power, or cost
3.1 Speed	Calculate speed	Identify the correct units for speed, distance, and time	Calculate average speed in familiar situations	Change the subject of the speed equation to calculate distance and time
	Describe the difference between average and instantaneous speed	Identify examples of instantaneous and average speed	Describe the difference between average and instantaneous speed	Compare the average and instantaneous speeds on different sections of the same journey
	Describe relative motion	Identify situations in which relative motion is seen	Describe examples of relative motion	Compare relative motion of objects in an unfamiliar situation

Physics

Topic	Learning objective	Learning outcomes		
		Developing	Secure	Extending
3.2 Motion graphs	Interpret distance-time graphs	Label a distance-time graph with descriptions of an object's motion	Describe motion using a distance-time graph	Explain why a distance-time graph matches a specific journey
	Calculate speed using a distance-time graph	Identify areas of different speeds from a distance-time graph	Use data from a distance-time graph to calculate average speed	Calculate areas of instantaneous speed on a distance-time graph
3.3 Pressure in gases	Describe the factors that affect gas pressure	Identify factors that affect gas pressure	Describe how volume and temperature affect gas pressure	Explain how changing particular factors affects gas pressure
	Describe what is meant by atmospheric pressure	Define atmospheric pressure	Describe what is meant by atmospheric pressure	Compare the atmospheric pressure of different planets
	Describe how atmospheric pressure changes with height	Identify altitudes and different locations at which atmospheric pressure will be higher or lower	Describe how atmospheric pressure changes with height	Explain why changing altitude affects atmospheric pressure using the particle model
3.4 Pressure in liquids	Explain how liquids exert a pressure in all directions	Describe how particles cause pressure	Explain why liquids exert a pressure in all directions	Apply knowledge of liquid pressure to unfamiliar situations
	Describe how liquid pressure changes with depth	State areas in which liquid pressure is greater	Describe how liquid pressure varies with depth	Explain why liquid pressure changes with depth using the particle model
	Explain floating and sinking in terms of pressure	Identify objects that will float or sink	Explain why some everyday objects float and some sink	Compare floating and sinking in unfamiliar liquids
3.5 Pressure on solids	Describe what is meant by pressure on a surface	Identify situations in which pressure is acting on a solid	State the meaning of the term pressure, and the direction that it acts in	Explain why pressure acts in a certain direction using knowledge of forces
	Calculate pressure	Identify the units of pressure, force, and area	Calculate pressure on solid surfaces in everyday situations	Change the subject of the pressure equation to calculate force or area
	Apply ideas of pressure to different situations	Identify situations in which pressure is higher or lower	Describe situations where high and low pressures are useful	Describe the effect of pressure in unfamiliar situations

Physics	Topic	Learning objective	Learning outcomes: Developing	Learning outcomes: Secure	Learning outcomes: Extending
	3.6 Turning forces	Describe what is meant by a moment	Identify scenarios in which there will be the turning effect of a force	Describe situations where a force can produce a turning effect or moment	Explain turning effects of forces in unfamiliar situations
		Calculate the moment of a force	State the units of moment, distance from pivot, and force	Calculate the moment of a force in familiar situations	Change the subject of the moment equation to calculate force or distance from pivot
		Apply the law of moments	Identify situations in which moments are balanced or unbalanced	Apply the law of moments to everyday situations involving balance	Apply the law of moments to unfamiliar situations

