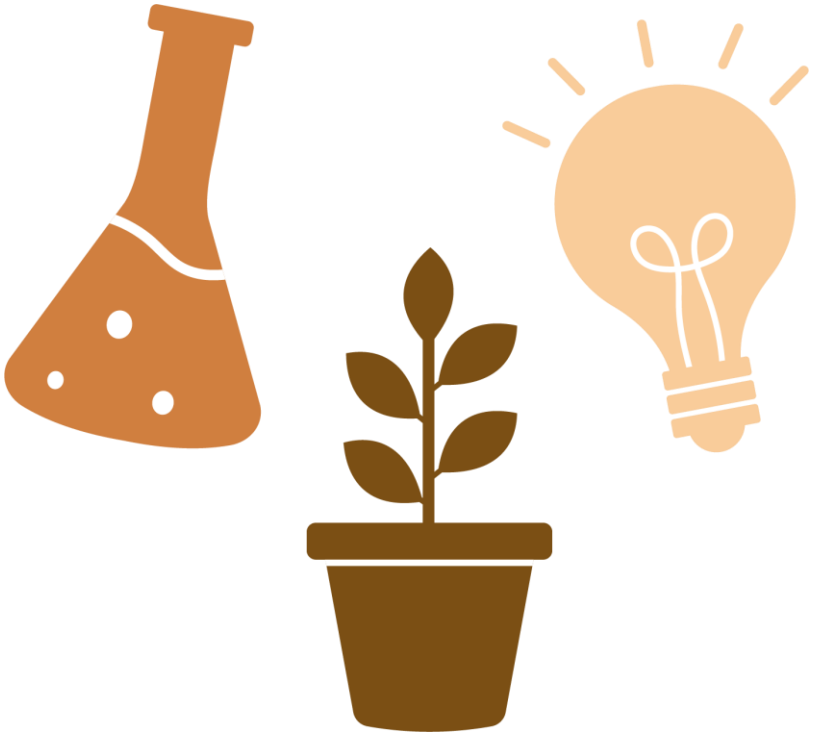
United Curriculum
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Secondary Science

Specification

Last updated 21/10/2026



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Introduction

The first iteration of the United Curriculum was developed over a decade ago in a small set of subjects at KS3. It began as a set of core concepts – co-created by subject advisers, teachers and other experts – that should be taught to all students in all United Learning schools. While it has developed over the years to include adaptable lesson resources and schemes of work, the heart of the United Curriculum is still the core concepts – the common curriculum intent – that all United Learning schools are expected to teach to its students.

Why Have a Common KS3 Curriculum?

- **Entitlement**. Our most important purpose is to teach young people things they would not learn outside school, which free them to think and act more powerfully in their lives. United Learning's common curriculum ensures that all students – no matter what classroom or school they are in – are taught at least this knowledge.
- **Scaling impacts**. Schools can share best practice more easily and the support of subject advisers can be leveraged more effectively when schools teach a common curriculum.
- **Collective expertise**. The United Curriculum harnesses United Learning's collective expertise and has invested more time in curriculum design than any one school could do alone.
- **Effective assessment**. A common curriculum allows for common, standardised assessments that are taken by thousands of students. These provide teachers with information about what their students do and do not know to inform their practice and enable reliable benchmarking across schools.

Why Has the United Curriculum for Science Been Updated for 2024-25 and Beyond?

No curriculum is ever done; all curricula should be iterated to reflect new evidence and research, as well as emerging scientific issues. The content in the United Curriculum for Secondary Science has been updated for 2024-25 (and beyond) for these reasons, as well as to ensure:

- The sequencing of the curriculum – particularly within substantive and disciplinary themes – reflects the evidence available.
- Links between subjects are more meaningful, systematic and explicit. For example, students revisit and build on knowledge about fossil fuels and climate change from geography (and vice versa) and apply knowledge from mathematics more systematically.
- The 'amount' of content reflects the model curriculum timetable, i.e. a minimum of 13% of teaching time at KS3 (or, at least four 50-minute lessons per week).

Structuring the United Curriculum for Science

The specification includes:

1. The knowledge to be taught by the end of each year.
2. How this knowledge should be used.

Knowledge to Be Taught

As described in Ofsted's Research Review (2021), knowledge in science generally falls into one of four types:

	Substantive The body of work of a subject.	**Disciplinary** How this body of work is produced.
Conceptual[1] Knowledge that can be articulated (*knowing that…*).	**1. Substantive Conceptual** For example, 'Liquids expand when they are heated (such as the liquid inside a thermometer).'	**2. Disciplinary Conceptual** For example, 'All measuring instruments, such as a thermometer, have a built-in degree of uncertainty.'
Procedural[2] Knowledge of a process (*knowing how to…*).	**3. Substantive Procedural** For example, 'Draw a particle diagram for a liquid.'	**4. Disciplinary Procedural** For example, 'Use a thermometer to measure the temperature of a solution.'

These four types of knowledge are organised across coherent, scientific **themes**. Organising the curriculum into these themes helps students to structure their knowledge into coherent conceptual frameworks. This is beneficial; students will remember new information better if they are able to locate it within an existing conceptual framework, integrate it with new knowledge, and make appropriate connections.

The themes in the United Curriculum for Secondary Science are below. Each theme contains elements of conceptual and procedural knowledge.

[1] Conceptual knowledge is sometimes known as 'declarative' knowledge.
[2] Procedural knowledge is sometimes known as 'non-declarative' knowledge.

		Themes
Substantive Knowledge	**Biology**	B1 - Cells and Life
		B2 - Inheritance and Reproduction
		B3 - Variation and Evolution
		B4 - Ecological Relationships
		B5 - Health
	Chemistry	C1 - Particles
		C2 - Substances
		C3 - Chemical Reactions
		C4 - Physical Earth
		C5 - Earth Science
	Physics	P1 - Motion and Forces
		P2 - Waves
		P3 - Matter
		P4 - Electricity and Magnetism
		P5 - Space Physics
Disciplinary Knowledge		WSAT - Scientific Attitudes and Ways of Thinking
		WSEF - Enquiry and Fieldwork
		WSAN - Analytical and Evaluative Approaches
		WSAI - Applications of Science and its Implications
		WSME - Protocols for Measurement

Note that Ecological Relationships and Physical Earth also appear as themes in the United Curriculum for Secondary Geography. There is also significant overlap between Geography's 'Weather and Climate' theme and the scientific 'Earth Science'.

How Knowledge Should Be Used

Scientists do not just need to know a list of facts or be able to complete a set of procedures; they need to apply their knowledge to familiar and unfamiliar contexts and draw upon knowledge from different themes.

In addition to teaching the detailed substantive and disciplinary knowledge set out in the sections below, schools should also ensure that students are taught how to use, and have the opportunity to practise using, this knowledge in these main ways:

U1. Demonstrate knowledge

U2. Apply knowledge

U3. Evaluate

U4. Make thematic links (synoptic)

Appropriate expectations for Year 7 are set out in 'How Knowledge Should Be Used' (below).

Using This Document

This specification sets out the knowledge that should be taught by the end of Year 7, 8 and 9 in 2026/27. It could be considered in a similar way to an exam specification.

At a minimum, schools should review the detailed knowledge below and ensure their curriculum aligns with these expectations. Where there are gaps in their current curriculum, schools should make necessary adjustments and additions to ensure all students have the opportunity to learn the content set out.

The knowledge in the specification is deliberately organised and sequenced in themes, rather than units. Schools are not obliged or expected to teach the themes as discrete units of work and, as long as the knowledge and use of knowledge are taught in a sensible order by the end of the year, schools can choose how long to spend on each area, and the order in which to teach it.

Schools may choose to teach the knowledge at a faster pace than set out in the specification (i.e. they could choose to teach all the knowledge for Year 7 before the end of Year 7).

We expect that many schools will opt to make use of the optional, centrally-provided resources – including the schemes of work and lesson resources – to support them in meeting the requirements set out in this specification.

United Curriculum for Science At a Glance

The highlighted topics reflect new additions to the curriculum. They have been included to support students' development of strong conceptual frameworks through carefully sequenced progression, enabling students to engage more confidently with complex subject content.

Year 7

Biology

B1. Cells and Life	• Life processes of organisms • Cells, tissues, organs and systems • Features of plant and animal cells • Unicellular organisms • Gas exchange system in humans • Digestive system in humans • Circulatory system in humans • Musculoskeletal system in humans
B2. Inheritance and Reproduction	• Heredity and the genome • Growth and development • Sexual reproduction • Sexual reproduction in humans • Sexual reproduction in plants • Asexual reproduction
B3. Variation and Evolution	• Types of variation

Chemistry

C1. Particles	• Particle model of matter • State changes • Gas pressure • Atoms • Elements, compounds, and mixtures • Chemical symbols and formulae • Representing atom rearrangement
C2. Substances	• Pure substances and mixtures

	• Solutions • Separating mixtures • Composite materials • Properties of metals and non-metals • Ceramics • Polymers
C3. Chemical Reactions	• Chemical change • Reactants and products • Categorising reactions

Physics

P1. Motion and Forces	• Describing forces and their effects • Modelling forces • Resultant force and its effects • Deforming objects • Describing friction • Energy stores • Energy transfers • Energy analysis
P2. Waves	• Observing sound • Observing light • General principles of radiation • Sound as radiation • Energy transfer by sound • Light as radiation • Coloured light • Refraction of light • Hearing • Seeing

Year 8

Biology

B1. Cells and Life	• Plants as organisms • Photosynthesis • Changing understanding of photosynthesis • Leaf structure and adaptations • Root structure and adaptations • Transport in plants • The rate of photosynthesis • Plants and the atmosphere • Plants as producers • Biological molecules • Digestion and enzymes • Absorption and transport of nutrients • Factors affecting enzymes • Making digestion efficient
B3. Variation and Evolution	• Classification • Competition and adaptation • Natural selection, evolution and extinction
B4. Ecological Relationships	• Interdependence • Bioaccumulation • Material cycles
B5. Health	• Diet • Energy in food

Chemistry

C2. Substances	• Acids, bases and alkalis • Indicators and pH scale
C3. Chemical Reactions	• Acids and metals • Neutralisation • Metal oxides and non-metal oxides

C4. Physical Earth	• Composition and structure of the Earth • Igneous rock formation • Weathering and erosion • Sedimentary rock formation • Metamorphic rock formation and the rock cycle • Fossils • Fossil fuels
C5. Earth Science	• Earth's atmosphere • The greenhouse effect, global warming and climate change • Acid rain

Physics

P1. Motion and Forces	• Speed • Distance-time graphs • Relative motion • Acceleration • Motion in fluids • Weight • Work • Turning forces • Support forces • Simple machines
P3. Matter	• Temperature • Changing energy in the thermal store • Thermal conduction • Energy stores of a material • Pressure and density • Convection and its causes • Thermal transfer by radiation • Real world contexts
P4. Electricity and Magnetism	• Simple circuits • Electrical charge • Electric current • Work done by charged particles

	• Electricity at home
P5. Space Physics	• The Solar System • Day and night • Years and seasons • The universe

Year 9

Biology

B1. Cells and Life	• Cellular respiration • Aerobic respiration • Anaerobic respiration • Cell structure • Transport in cells • Cell division • Culturing microorganisms
B4. Ecological Relationships	• Ecosystems and biodiversity • Populations in ecosystems
B5. Health	• Health and wellbeing • Exercise • Pathogens and disease • Health, lifestyle and ageing

Chemistry

C1. Particles	• Atomic structure • Atomic structure and isotopes • Chemical equations
C2. Substances	• Elements, compounds and mixtures • The periodic table • Development of the periodic table • Element properties • Transition elements
C3. Chemical Reactions	• Group trends • Explaining group trends • Reactivity of metals • Rate of reaction

Physics

P2. Waves	• Wave characteristics • Transverse waves • Speed of waves • Longitudinal waves • Energy transfer by waves • Electromagnetic waves • Wave properties • Electricity from waves
P3. Matter	• The particle model of matter • Internal energy • Floating • Investigating density • Pressure and fluids • Pressure and gases
P4. Electricity and Magnetism	• Magnetic fields • Electromagnetism • Motors and generators • Static electricity • Electric current • Voltage • Resistance

Detailed Knowledge for Year 7

Substantive Knowledge to Be Taught in Year 7

The below outlines the detailed knowledge that should be taught by the end of Year 7, grouped by theme and topic.

Items marked with a * are a statutory requirement of Key Stage 2. In some cases, this is prerequisite knowledge for Key Stage 3 (for example, knowledge of materials as solids, liquids or gases at room temperature at Key Stage 2 is a prerequisite for the particle model in Key Stage 3). In other cases, the Key Stage 2 content has been included to ensure students have the opportunity to revisit it in Key Stage 3 before seeing it again in Key Stage 4 (for example, the circulatory system).

Biology

7.B1 Cells and Life

7.B1.01 Life processes of organisms	1. Everything in the world can be categorised as either alive, used to be alive (dead) or has never been alive.* 2. Living things and things that used to be alive (dead) are called organisms. 3. All living organisms carry out a common set of processes: movement, reproduction, sensitivity, growth, respiration (use of glucose and oxygen to provide energy for their processes), excretion and nutrition. Common processes occur at one or more stages of an organism's life cycle but may not be present at every stage. Living organisms may not show the processes of life in an obvious way or all the time (e.g. a seed). 4. Movement is only a sign of life when the organism moves itself, and the movement is for a purpose, allowing an organism to respond to, interact with or navigate its environment. 5. Students should be able to use a microscope to observe biological specimens, including selecting magnification, identifying key components, and producing clear, labelled scientific drawings.
7.B1.02 Cells, tissues, organs and organ systems	1. Cells are the building blocks of living organisms. 2. Organisms can be made of one cell (unicellular) or many cells (multicellular).

	3. Cells carry out all the processes of life. 4. Cells can have unique shapes and structures adapted for their functions. Specialised cells have additional features to suit their specific roles. 5. Cells are organised hierarchically into tissues, organs and organ systems; tissues consist of groups of similar cells, organs are composed of different tissues, and organ systems comprise multiple organs working together. Interactions between these levels support the functioning of the organism.
7.B1.03 Features of plant and animal cells	1. Animal cells and plant cells have common parts (organelles) such as the cell membrane (which controls substance entry and exit), nucleus (which contains the organism's genome, which controls the cell's activities), mitochondria (involved in respiration and energy release), and cytoplasm (where the chemical reactions of a cell take place). 2. Plant cells have additional parts like the cell wall (provides structural strength), vacuole (stores cell sap), and chloroplasts (involved in photosynthesis, producing glucose).
7.B1.04 Needs of organisms	1. Animals, including humans, require oxygen, water, nutrients, and suitable temperature for cell functioning and vital life processes. 2. Plants need oxygen, carbon dioxide, light, water, minerals from soil, and space for growth and survival. 3. Energy is required for cell processes. Respiration is the process that takes place in cells that releases energy. Respiration requires oxygen and glucose. Its waste products are carbon dioxide and water. 4. Substances enter and leave cells by diffusion; oxygen enters cells and carbon dioxide leaves cells by diffusion, (the random movement of particles from high to low concentration). 5. Selectively permeable membranes, like cell membranes, control substance movement. 6. Factors affecting diffusion across membranes include temperature, surface area and particle concentration.

7.B1.05 Unicellular organisms	1. Unicellular organisms are single-celled, such as yeast, amoeba, and bacteria. They are living and carry out the seven life processes using their organelles, they can be helpful and harmful. 2. Unicellular organisms have adaptations. For example, bacterial cells have loose genomes in the cytoplasm and some bacterial cells have flagella for movement. 3. Unicellular organisms can be useful or harmful; yeast is used in baking to make dough rise and to produce alcohol, and bacteria are used in food production and digestion, although some cause disease in humans and plants. 4. Multicellular organisms are larger and more complex than unicellular organisms; as a result, diffusion alone is insufficient for exchange of substances, and organ systems are required to transport substances to and from cells to keep them alive.
7.B1.06 Gas exchange system in humans	1. The gas exchange system, also known as the respiratory system, facilitates the exchange of oxygen and carbon dioxide within the environment. 2. Organs involved in the respiratory system include the nose, trachea, bronchi (which have cartilage and epithelial tissue), bronchioles, lungs, alveoli, intercostal muscles, diaphragm, and ribs. 3. Oxygen moves from the alveoli into cells and then into blood capillaries, while carbon dioxide moves in the opposite direction via diffusion. Alveoli are adapted for efficient diffusion, due to thin walls, large surface area, and good blood supply. 4. Breathing involves changes in pressure and volume inside the chest, facilitated by the movement of intercostal muscles and diaphragm, which causes the movement of the ribcage. 5. The air we breathe in is a mixture of gases, including oxygen and carbon dioxide. The air we breathe out has less oxygen and more carbon dioxide than the air we breathe in. 6. Vital capacity is the maximum volume of air exhaled after inhaling fully and can be used to estimate lung volume.

7.B1.07 Digestive system in humans	1. The digestive system breaks down food* into smaller particles for absorption into the blood via diffusion. Note, the National Curriculum for Key Stage 2 requires students to have been taught to 'describe the simple functions of the basic parts of the digestive system in humans.' 2. Organs involved in the digestive system include the mouth, oesophagus, stomach, small intestine, large intestine, rectum, and anus. 3. The mouth performs both mechanical digestion (chewing) and chemical digestion (saliva). 4. The oesophagus connects the mouth to the stomach and uses peristalsis to push food down. 5. The stomach performs both mechanical digestion (muscular tissue contracts) and chemical digestion (glandular tissue producing chemical substances). Note, students are not expected to know that 'digestive substances' include enzymes or hydrochloric acid in Year 7. This will come later, once they have been taught the concepts of acids and enzymes. 6. Water is reabsorbed in the large intestine, leading to the formation of faeces. Faeces are stored in the rectum and eliminated through the anus. 7. Chemical digestion and absorption of digested nutrients into the blood takes place in the small intestine, which has many villi, providing a large surface area to increase the rate of diffusion. Villi in the small intestine are one cell thick, reducing diffusion distance. Villi have a rich blood supply to maintain a concentration gradient for efficient diffusion.
7.B1.08 Circulatory system in humans	1. The human circulatory system consists of the heart, blood, and blood vessels.* Note, the National Curriculum for Key Stage 2 requires students to have been taught to 'identify and name the main parts of the human circulatory system, and describe the functions of the heart, blood vessels and blood.' 2. The heart has four chambers: two atria and two ventricles. Valves ensure proper blood flow through the heart. The septum separates the right and left sides of the heart.

	3. The heart pumps blood in a double circulatory system, in which blood passes through the heart twice; the left side pumps oxygenated blood to the body and the right side pumps deoxygenated blood to the lungs. 4. The circulatory system includes arteries, capillaries and veins, which transport blood to and from the heart and around the body. Arteries carry (mostly oxygenated) blood away from the heart under high pressure and have thick, muscular and elastic walls with a small lumen. Veins carry (mostly deoxygenated) blood to the heart under low pressure and have thin walls, a large lumen and valves to prevent backflow. Arteries branch into capillaries, which are one cell thick, have a very small lumen and allow exchange of substances (water, oxygen, glucose, carbon dioxide) between blood and cells. 5. Blood is a transport fluid containing plasma, platelets, and red and white blood cells. Plasma is a yellow (straw-coloured) fluid mainly composed of water, transporting carbon dioxide, digested food, and hormones. Platelets are responsible for blood clotting, forming plugs to aid in wound healing. Red blood cells transport oxygen and have a biconcave disc shape, no nucleus, and contain haemoglobin. White blood cells defend against disease, are larger than red blood cells, and have a nucleus.
7.B1.09 Musculoskeletal system in humans	Note, the National Curriculum for Key Stage 2 requires students to have been taught to 'identify that humans and some other animals have skeletons and muscles for support, protection and movement.' 1. The skeleton supports the body, protects organs, allows movement,* and produces blood cells. 2. Bones are living tissues that grow and change; they are strong and rigid for support, resistant to forces, lightweight to allow movement, and contain bone marrow that produces blood cells. Examples of bones in the human body include the cranium (skull), ribcage, vertebrae (spine), humerus, ulna, radius, pelvis, femur, tibia and fibula. 3. Joints connect bones and facilitate movement. Ligaments connect bones in joints. Synovial fluid lubricates joints and prevents friction.

4. Muscles are made of muscular tissue and contract and pull on bones for movement. Tendons connect muscles to bones. Cartilage reduces bone friction and absorbs forces.
5. Different joint types allow various movements (hinge, ball-and-socket, pivot, fixed).
6. Aging can lead to joint wear, inflammation, and arthritis. Arthritis causes joint pain, and affects fluid and cartilage.
7. Antagonistic muscle pairs work together (biceps/triceps, quadriceps/hamstrings).
8. Muscle strength varies based on muscle size, age, sex, training, nutrition and injury.

7.B2 Inheritance and Reproduction

7.B2.01 Heredity and the genome

1. Reproduction, which is one of the common processes of living organisms, is the process of making new living organisms known as offspring an happens at some point in an organism's life cycle. When organisms reproduce, they produce offspring of the same kind.
2. The genome is the complete set of genetic information in an organism, organised into chromosomes; chromosomes are structures made of DNA, and genes are specific sections of DNA that provide instructions for cell processes and determine inherited traits. DNA is a natural polymer consisting of two strands that form a double helix structure.
3. Offspring inherit half of their genome from each parent.
4. Some inherited characteristics are determined by a single gene, while most are influenced by multiple genes.
5. The hierarchy of genetic material, from smallest to largest, is gene, DNA, chromosome, genome.
6. Only characteristics determined by genes in the genome can be inherited, for example eye colour and flower colour.
7. Humans have 23 pairs of chromosomes (46 in total), located in the nucleus; one chromosome from each pair is inherited from each parent. Bacteria have a single chromosome, located in the cytoplasm.

7.B2.02 Growth and development	1. When multicellular organisms grow, new cells are made from existing cells. Growth refers to an increase in the number of cells and differs to 'getting bigger' (an increase in size). Organisms grow by cell enlargement and cell division. During cell division, the genetic material is copied and two genetically identical cells are produced. As organisms develop, their tissues, organs and organ systems specialise to carry out specific functions. Note, students are not expected to know the stages of mitosis or the cell cycle in detail. 2. The human life cycle includes stages such as fertilisation, gestation, and growth from embryo to senior. Adolescence is a period of emotional and physical changes known as puberty, caused by hormones. Puberty affects both males and females, with some changes specific to each sex. Both males and females experience changes such as underarm and pubic hair growth, increased body odour, emotional changes, and a faster growth rate. Males also go through voice deepening, enlargement of the testes and penis, sperm cell production, shoulder widening, and facial and chest hair growth. Females develop breasts, start ovulating and having menstrual cycles, and experience hip widening. 3. Organisms, including animals and flowering plants, have different life cycles and offspring development.* 4. Development involves changes in form and function as an organism matures. It creates specialised cells and tissues, aids proper growth, builds structures, facilitates adaptation and reproduction. 5. The development of multicellular organisms is influenced by the genome and environmental factors.
7.B2.03 Sexual reproduction	1. Male and female gametes, specialised sex cells, transfer genetic information from one generation to the next. Each gamete contains half of the parent's genome (23 chromosomes). 2. During fertilisation in the oviduct, the nuclei of the male and female gametes fuse to form a zygote with a full genome (46 chromosomes). The zygote becomes an embryo after it has divided to produce more cells and grow; the embryo is moved along the oviduct by cilia.

7.B2.04 Sexual reproduction in humans	1. The male reproductive system produces and releases sperm and the female reproductive system produces and releases eggs. In the female, one of the ovaries releases an egg every 28 days. This is called ovulation. 2. Students should be able to describe the structure and function of the male and female reproductive systems, how they work together to produce offspring, and the adaptations of the male and female gametes. 3. The menstrual cycle is a sequence in which the uterine lining builds up, a mature egg is released (ovulation) and, if not fertilised, the lining breaks down and is lost from the body (menstruation). 4. If an egg is fertilised, it can implant itself in the prepared uterus lining. The female is pregnant and gestation begins. A human embryo is considered a foetus at the end of the 8th week of pregnancy. 5. The foetus requires protection inside the mother's uterus. The amniotic sac protects the baby and the amniotic fluid cushions the foetus. 6. The foetus is connected to the mother via the placenta and umbilical cord which allows for nutrients and oxygen to be delivered to the foetus and waste to be removed. Inside the placenta, the mother's blood and the foetus' blood flow very close to each other but do not mix. Alcohol, chemicals from cigarettes and drugs can cross the placenta and affect the baby. 7. During birth, the cervix opens and the uterus wall contracts to push the baby out through the vagina. A foetus is considered a baby when it is born.
7.B2.05 Sexual reproduction in plants	1. Plants reproduce sexually with male (pollen) and female (egg/ovum) gametes. The plant's life cycle involves germination, pollination, fertilisation, and seed dispersal. 2. Flowers contain both male (stamen) and female (carpel) parts. The stamen consists of the anther (produces pollen) and filament (supports the anther). The carpel has the stigma (collects pollen), style (connects stigma to ovary), and ovary (contains ovules). Petals attract insects.

	3. Pollination transfers pollen for fertilisation, either within the same plant (self-pollination) or between different plants (cross-pollination); pollination can occur by wind or by pollinators such as insects, birds and other animals. 4. A pollen tube grows from pollen to the ovary, where fertilisation occurs. Fertilised eggs/ova, in the ovules, become seeds and the ovary develops into fruit. Seeds have a coat, food store (endosperm), and embryo. 5. Seed dispersal methods include wind, animals, water, or explosion (self-propulsion), adapting to specific seeds. 6. Germination requires water, suitable temperature, and oxygen, causing the seed coat to split and roots/shoots to emerge. 7. Plants need water, light, and proper temperature for growth.
7.B2.06 Asexual reproduction	Note, the National Curriculum for Key Stage 2 requires students to have been taught to 'describe the life process of reproduction in some plants and animals.' The non-statutory guidance says, 'pupils should find out about different types of reproduction, including sexual and asexual reproduction in plants, and sexual reproduction in animals.' 1. Asexual reproduction involves only one parent and produces genetically identical offspring. 2. Asexual reproduction ensures offspring have advantageous traits for their environment, whilst sexual reproduction introduces genetic variation, increasing adaptability to environmental changes. 3. Some plants reproduce asexually. 4. Bacteria reproduce asexually, creating identical copies.

7.B3.01 Types of Variation

1. A species is a group of organisms that can reproduce to produce fertile offspring; organisms of different species cannot produce fertile offspring.
2. Variation within a species is important for survival and adaptation.
3. Variation can be genetic, environmental, or a combination of both. Genetic variation comes from the random combination of inherited genomes. Environmental variation is influenced by lifestyle choices and surroundings. Most variations result from a complex interplay of genetics, environment, and lifestyle factors. Only genetic variation caused by differences in the genome can be inherited.
4. Variation within a species can be categorised as discontinuous or continuous. Discontinuous variation involves distinct categories without numerical measurements and tends to be determined by a single gene or a few genes. Continuous variation involves a range of numerical measurements and tends to be determined by many genes and environmental factors.

7.C1.01 Particle model of matter

1. Matter is the 'stuff' that everything in the world is made of. Matter consists of tiny particles in motion that are represented as small, hard spheres in the particle model.
2. The particle model allows us to describe the way in which the particles are arranged and move and can explain the basic solid, liquid and gas states.
3. Matter can exist in three states: the solid state, the liquid state and the gas state.*
4. Matter made of tiny grains (such as sand) behaves rather like a liquid, but the individual grains are solid.
5. The particles of matter in its different states are arranged differently; they also move differently.
6. All matter has particles that are always moving.
7. Matter in a solid state has particles which are in an ordered arrangement, all touching and which vibrate in fixed positions; matter in a liquid state has particles which are in a random arrangement, all touching and can slide over one another; matter in a gas state has particles that are in a random arrangement, not touching and moving quickly in random directions.
8. Students should be able to draw particle diagrams for the three states of matter.
9. Attractive forces exist between particles, with varying strengths: strong in solids, weak in liquids, and very weak in gases.
10. Students should be able to describe the properties of solids, liquids, and gases and use the particle model to explain how the arrangement and forces between particles give rise to these properties.
11. The particle model explains how particle arrangement, movement, and forces change with heating, cooling, and state changes.
12. The particle model can explain diffusion and the dissolving of a substance to form a clear solution, including effects of temperature and state.

7.C1.02 **State changes**	1. Most types of matter can change from one state to another when they are heated or cooled.* 2. A change of state is a type of physical change* because there are no new products and it is reversible. 3. The amount of energy the particles have changes, which affects the arrangement and movement of the particles. 4. State changes include melting, boiling, condensation, and freezing.* 5. Hotter matter has higher particle energy and faster movement. 6. Temperature remains constant during a change of state. 7. Melting and boiling points are fixed temperatures for state changes; each substance has its own values; water has a melting point of 0°C and a boiling point of 100°C. The stronger the attractive force between the particles in a type of matter, the higher the melting and boiling points. 8. Melting and boiling points can be used for substance identification. 9. Students should be able to predict the state of matter of a specific substance given its melting and boiling points and its temperature. 10. The temperature at which matter changes state is determined by the strength of the forces of attraction between its particles. This means that the energy needed to overcome these forces varies for different types of matter. 11. Molten is the scientific term for matter that normally exists in a solid state at room temperature but has changed to a liquid state on heating. 12. Boiling and evaporation differ in terms of the temperature they take place at and where in a liquid they occur. Boiling produces bubbles whereas evaporation does not.
7.C1.03 **Gas pressure**	1. Matter in its gas state exerts pressure on the inner walls of its container, because of collisions between the particles and the walls. 2. The particles exert a force on the area of the inner surface, called gas pressure.

	3. Gas pressure can be changed by adding particles to the container and/or changing the temperature. If temperature has increased, its particles move more quickly; they collide with the walls with greater frequency and force, increasing gas pressure.
7.C1.04 Atoms	1. All matter in the universe – living and non-living – is made of small particles called atoms.
7.C1.05 Elements, compounds, and mixtures	1. Elements are substances made of one type of atom. Each element is made of its own type of atom and can be found on the periodic table. Some elements can exist as single atoms. Most elements exist as molecules, where atoms of the element join together, or structures. 2. Compounds are substances made of more than one type of atom that are chemically joined together. Compounds exist as molecules or structures. Note, refer to the 'Chemical Reactions' theme regarding the formation of a new substance. 3. The elements have different physical properties including electrical conductivity; melting and boiling points; thermal conductivity; being malleable; hard/soft; and magnetism. 4. The elements can be split into two types – metals and non-metals; they have different physical properties. Note, refer to the 'Metals and non-metals' topic within the 'Substances' theme regarding the properties of each. 5. The arrangement and collective behaviour of the atoms of a compound are different to that of the atoms in the individual elements, so the properties of the compound are different to the properties of the elements that make it. 6. There are forces between particles in molecules and structures. The strength of these forces affects the melting and boiling points of the substance. 7. Mixtures are two or more substances that are mixed but not chemically joined together. 8. Students should be able to identify elements, compounds and mixtures from particle diagrams, the relative number of atoms/ elements, and the formula of elements and compounds.

	9. Students should be able to name compounds.
7.C1.06 Chemical symbols and formulae	1. Each element's atom is represented with its own chemical symbol. Chemical symbols are usually made from one or two letters. 2. The chemical formula for a substance, such as H_2O or O_2, shows how many of each type of atom are in every molecule of that substance. 3. Students should be able to write chemical formulae for compounds.
7.C1.07 Representing atom rearrangement	1. The particle model of matter can be represented by a particle diagram. Circles are drawn together or joined to represent single atoms or molecules. Circles are drawn in different colours or sizes to represent different atoms. 2. The rearrangement of atoms during a chemical reaction can be represented using various models with products and reactants, including a particle diagram; word equation; and symbol equation. 3. State symbols are used in symbol equations to show what state each substance is in: solid (s), liquid (l), gas (g) or aqueous solution (aq). 4. Students should be able to write word equations for chemical reactions, e.g. oxidation, and draw particle diagrams to represent the rearrangement of atoms.

7.C2 Substances

7.C2.01 Pure substances and mixtures	1. Substances can be described as pure or impure (mixtures). 2. Students should be able to identify pure substances or mixtures from particle drawings. 3. Pure substances have a fixed and specific melting and boiling point, whereas mixtures do not. This can be used to identify if a substance is a mixture.
7.C2.02 Solutions	1. If a solute is added to a solvent, it dissolves, forming a solution.*

	2. A solution is an example of a mixture. Substances may be soluble or insoluble in a solvent.* 3. When water is the solvent, the solution formed is aqueous. 4. Solutions are all clear and are either colourless or coloured. 5. Stirring can speed up dissolving but is not required for dissolving to take place. 6. In general, when the temperature of the solvent is increased, the solubility of the solid increases. 7. Solutes have different solubilities in different solvents. 8. There is a limit to the mass of solute that can be dissolved in a given volume of solvent; the solution is saturated when the limit is reached, and no more solute can dissolve. 9. Mass is conserved when a solute is dissolved in a solvent.
7.C2.03 Separating mixtures	1. Any mixture can be easily separated into its component parts due to the different physical properties of those mixed substances. Depending on the properties, mixtures can be separated using physical methods such as using magnets*, a sieve*, filtration*, evaporation* and crystallisation, distillation and chromatography. 2. Students should be able to: • describe, explain and give examples of the specified processes of separation • suggest suitable separation and purification techniques for mixtures when given appropriate information. • interpret chromatograms
7.C2.04 Composite materials	1. Composite materials are made from two or more different types of material. 2. The materials chosen for composites have unique qualities that, when combined, create a more useful material. Each material in a composite retains its original properties, and their properties complement one another. For example, reinforced concrete, breathable fabrics, and fiberglass are composite materials.

	3. The behaviour of composites is influenced by the composition of the constituent materials. 4. The properties of composites make them suitable for specific applications.
7.C2.05 Properties of metals and non-metals	Note, the National Curriculum for Key Stage 2 requires students to have been taught about the properties (including 'hardness, solubility, transparency, electrical conductivity, thermal conductivity, and response to magnets') of everyday materials (including 'metals, wood and plastic'), and link their properties with the materials' uses. 1. Metals have different physical properties to non-metals.* 2. Most metals are shiny, hard, strong, malleable, ductile, sonorous, have high melting and boiling points and are good conductors of heat and electricity.* Some metals are magnetic. 3. Most non-metals are metals are dull, soft, brittle, not malleable, lacking in ductility and sonorousness, not magnetic, have low melting and boiling points and are poor conductors of electricity and heat.
7.C2.06 Ceramics	1. A ceramic is a non-metallic material that is formed by heating and cooling a soft substance like clay, which transforms it into a hard material. 2. Properties of ceramics include being hard, solid at room temperature, strong yet brittle, poor electrical conductors, non-reactive with water, and resistant to chemicals. They have high melting points.
7.C2.07 Polymers	1. Polymers are long, chain-like molecules made of identical repeating units called monomers. The joining of monomers to form polymers is called polymerisation. 2. Natural polymers occur naturally and are found in plants and animals. Synthetic polymers are man-made materials created by chemically linking monomers. 3. Polymers have common properties like electrical insulation, malleability, durability, the ability to be moulded into shape, existing as solid matter at room temperature, and being chemically unreactive.

	4. Polymer properties depend on the monomer and chain length; different monomers produce polymers with different properties, longer chains have higher melting points and greater strength, and these properties determine their suitability for different uses. 5. Plastics and polymers have both benefits and environmental/health issues. Many polymers take hundreds of years to degrade, accumulating in landfills and oceans. Improper disposal and littering of polymer products cause widespread pollution. 6. Polymers can be disposed of by reuse, recycling, incineration or landfill, each with advantages and disadvantages. 7. Globally, measures are being taken to address polymer-related environmental issues (e.g. Beat Plastics campaign and plastic bag charge). Locally, materials can be used more sustainably through reducing, reusing and recycling.

7.C3 Chemical Reactions

7.C3.01 Chemical Change	1. Matter can be observed to change, by either a physical change or a chemical change. 2. A physical change is where the substance changes its properties, but it does not become a different substance. It does not produce a new substance and the changes are easily reversed. Most physical changes are reversible (e.g. water to ice).* 3. A chemical change is a change where a new substance is formed. Chemical changes are also known as chemical reactions. Most chemical changes are irreversible (e.g. cook an egg). 4. Observable evidence of a chemical reaction includes if: gas bubbles appear; a new solid appears (precipitate); it changes colour; or changes temperature. Other evidence for chemical reactions taking place include light or sound being produced.
7.C3.02 Reactants and products	1. The materials present before a chemical reaction are called reactants. During the reaction, the atoms of the reactants rearrange to form a completely new substance(s) called the product(s).

	2. Mass stays the same during chemical reactions because no atoms are created or destroyed in a reaction, they are just rearranged. This is called the conservation of mass. 3. In some reactions, the product(s) appear to have a greater mass than the reactants. This is often; due to oxygen from the surroundings reacting with the initial substance(s). 4. In some reactions, the product(s) appear to have a smaller mass than the initial substance(s); a gas is given off and lost from the system. 5. All chemical reactions involve energy transfer. The total amount of energy before the reaction is the same as the total amount of energy after the reaction: energy conservation.
7.C3.03 Categorising reactions	1. An oxidation reaction is when a substance reacts with oxygen to produce an oxide. 2. A thermal decomposition reaction is when compound(s) split apart to form new substances. 3. A combustion reaction is when a fuel is heated and reacts with oxygen to produce carbon dioxide and water. Combustion is an irreversible chemical reaction and an example of an oxidation reaction. 4. In an endothermic reaction, energy is transferred from the surroundings to the chemical store of energy of the reactants. The thermal store of energy in the surroundings decreases, causing a temperature decrease. Thermal decomposition is an endothermic reaction. 5. In an exothermic reaction, energy is transferred to the surroundings from the chemical store of energy of the reactants. The thermal store of energy in the surroundings increases, causing a temperature increase.

7.P1.01 Describing forces and their effects	1. When an object is pushed or pulled, a force is acting on it. It is a quantity that has a direction and size, and can act for different durations. 2. When two objects interact, a force acts on each object (an interaction pair); they are equal in size and have opposite direction. 3. Forces can be contact or non-contact.* Contact forces include air resistance*, friction*, water resistance*, lift, normal contact force, thrust, and upthrust. Non-contact forces include gravity* and magnetic* forces. 4. A special case of gravity force is 'weight', the force felt by an object because of a large body near it.* 5. Students should be able to identify forces arising in given situations. 6. A force can cause a change in the movement of an object (speed or direction). It is more difficult to change the movement of heavier, faster objects. 7. A force can cause a change in the shape of an object. 8. Sometimes when a force acts, there is no observable change.
7.P1.02 Modelling forces	1. Forces can be represented using arrows. The length of the arrow represents the size of the force, and the direction of the arrow represents the direction in which the force is acting. 2. A free-body force diagram is a simplified model to show only the forces acting on a single object. 3. Students should be able to draw and label simple free-body force diagrams, sometimes to scale.
7.P1.03 Resultant force and its effects	1. When multiple forces act on an object, their effects are combined as if a single force is acting; this is called the resultant force. 2. Students should be able to qualitatively describe the resultant force, using a free-body force diagram (zero or non-zero and its direction).

	3. Students should be able to calculate the resultant force for two forces acting along the same line of action. 4. A non-zero resultant force occurs when unbalanced forces act and may change an object's motion or shape. 5. A zero resultant force occurs when balanced forces act and the object's motion will remain constant. 6. No motion does not mean no force is acting. No change in motion probably indicates there are forces acting which are balanced.
7.P1.04 Deforming objects	1. When two opposing forces act on a stationary object, it can be deformed: stretched or squashed. 2. When two opposing push forces are applied at the same time, an object may contract (shorten): compression. When two opposing pull forces are applied at the same time; the object may extend (lengthen): tension. 3. The extent of extension or compression can be found by an object's change in length during deformation. 4. Tension and compression can occur in all objects at a microscopic level; an object exerts a force on a surface causing it to compress. The surface exerts a force back on the object known as a normal contact force.
7.P1.05 Describing friction	1. Frictional forces act to resist motion. Friction is a frictional force (so are air resistance and water resistance). Friction acts when an object is sliding over a surface (or is about to slide). 2. Friction is a force that is generated due to an interaction between an object and a surface it is in physical contact with: sliding over it, or if a force is applied to make it slide. 3. The outcome of a friction force acting on an object may be a nuisance, or it may be useful. 4. Friction force can be reduced by using a lubricant between the object and surface; with a lubricant in between the object and surface, the uneven parts do not catch on each other or interlock.
7.P1.06 Energy stores	1. For something to happen, an energy store of some sort is needed.

	2. A system is an object or a group of objects; objects can be living or non-living, moving or stationary. 3. When a system changes in some way, energy is transferred between different energy stores; the energy itself remains the same throughout and is not used up or created. 4. Energy stores include the chemical store of energy, kinetic store of energy, elastic store of energy, gravitational store of energy, and thermal store of energy. Note, students are not expected to learn about electromagnetic, vibration or nuclear stores of energy in Year 7.
7.P1.07 Energy transfers	1. Energy is always conserved in an event. 2. A system normally includes its surroundings. Energy tends to be transferred to the surroundings, becoming more spread out (dissipated). This is almost always to the thermal store of the surroundings, whether desirable or not. 3. There are various ways energy can be transferred, described as energy pathways: mechanically, electrically, by heating, by radiation and by chemical reaction. 4. Sometimes an object does not store energy, but changes the way the energy is transferred e.g. energy is transferred to a light bulb electrically, and from it by radiation. 5. Students should be able to use diagrams that represent energy transfer events including box and arrow diagrams (of energy stores and pathways) and interpret Sankey diagrams without values (conservation of energy).
7.P1.08 Energy Analysis	1. To carry out an energy analysis, it is useful to follow a process of observation (an everyday description of the event), explanation (mechanisms and processes) and energy analysis (comparison of the amount of energy in energy stores at the start and end point). 2. Students should be able to carry out simple energy analysis.

7.P2.01 Observing sound	1. Sound is made when matter vibrates*, caused by a force being exerted on it, producing vibrations in the particles surrounding it. 2. Sound travels from the source in all directions and gets quieter as the distance from the sound source increases.* 3. Sound can be described in terms of loudness (dB) related to the size of the vibrations*: amplitude. The size of vibration of the source depends on the size of the force exerted on it. This affects the amount of energy transferred to its kinetic store of energy. 4. Sound can be described in terms of pitch, related to the properties of the source, such as the length of tube or tightness of string*: frequency (Hz). The frequency is related to the number of vibrations per second. 5. Sound can travel through matter in any state. It does not travel in a vacuum. Sound travels fastest through matter in its solid state, and slowest through matter in its gas state.
7.P2.02 Observing light	1. Luminous objects emit light in straight lines in all directions*. Objects can be illuminated by light which is reflected. 2. Light can travel in a vacuum. 3. Light passes through transparent matter, but not opaque matter, causing a shadow to form. Shadows are good evidence that light travels in straight lines from a source.* 4. The size and shape of shadows behind an opaque object can be explained using ray diagrams; a light ray is a model to show the direction light is travelling from a source.* 5. Light fills an enclosed space; darkness is the absence of light.* 6. Light travels faster than sound.
7.P2.03 General principles of radiation	1. Radiation is a model to explain how matter can affect other matter at a distance, by the movement of particles from a source to a detector, or by the transfer of energy from a source to a detector without transferring matter itself. 2. Light and sound are examples of radiation by waves.

	3. Radiation is emitted from a source in all directions. As the radiation travels away, it is spread out over a larger area, which is one reason for it getting weaker over a distance and occurs for both sound and light. 4. When radiation 'strikes' matter it may be transmitted through it, absorbed by it, reflected or scattered by it. 5. The further it is transmitted, the more likely it is to have been absorbed by the medium through which it is travelling. This is one reason for it getting weaker over a distance. If it is fully absorbed by matter, the radiation stops and there is a 'shadow' region behind it. 6. If radiation is absorbed by matter, the energy in the energy stores of the matter will increase depending on the type of radiation and the type of matter itself, e.g. light and a leaf cell: chemical store. 7. Radiation can be absorbed by a detector (for examples of sound or light). 8. Radiation is reflected at surfaces, in the opposite direction to which it 'struck'.
7.P2.04 Sound as radiation	1. Sound travels through matter from a source, causing vibrations in the particles of the matter. This occurs more easily in solids and cannot occur in a vacuum. 2. As the sound vibrations travel forward, the particles they travel through do not. 3. Particles of the matter absorb some energy as the sound is transmitted through it. Soft materials are better absorbers so can be used for soundproofing and noise reduction. 4. Normally, some sound is reflected at a surface. Harder materials reflect better than softer materials. 5. Echoes form when sound occurs in spaces with lots of large, flat surfaces. Echoes can be used to measure distances (sonar). Some animals use echoes to locate objects. 6. Sound vibrations are scattered when they hit rough surfaces; the vibrations bounce back in different directions.

7.P2.05 Energy transfer by sound	1. As sound is transmitted through a medium, energy is transferred from the store of energy of one particle to the store of energy of the next particle, by a mechanical pathway. 2. Energy is transferred from the kinetic store of energy of the source's particles, to the store of energy of the particles surrounding the source. 3. Normally there is some absorption, causing an increase of energy in the thermal store of energy of the matter (heating pathway). The vibrations get smaller, resulting in a quieter sound (lower amplitude). 4. Often there is some scattering when sound 'strikes' a medium; the energy transferred by the vibrations bounces back from the surface of the medium in different directions.
7.P2.06 Light as radiation	1. Light does not need particles for its transmission; it can travel through a vacuum. 2. As light 'strikes' a surface, energy is transferred there by the radiation pathway. Opaque, translucent and transparent materials transmit, absorb, reflect or scatter different amounts of energy from the beam of light. 3. Light gets dimmer farther from a light source because it is spread over an ever-increasing area and less of the light reaches our eyes; some materials' particles absorb more of the energy as light passes through it. 4. Light incident on materials always produces some reflection. Scattering occurs at rough surfaces; specular reflection occurs at a smooth surface. 5. The law of reflection helps us decide how to position mirrors so that we can see images. 6. Students should be able to demonstrate reflection using ray diagrams to explain images in mirrors.
7.P2.07 Coloured light	1. White light, emitted from most light sources, is a mixture of coloured light of the visible spectrum (red, orange, yellow, green, blue, indigo, violet). A glass prism splits a beam of light into a spectrum.

	2. Opaque objects of different colours absorb and reflect different, specific coloured light. 3. The 'three primary colours' model explains how humans see coloured light: the human eye has three types of colour sensor cells which detect the primary colours, red, blue, and green. 4. Combining different primary colour light beams produces different effects on our sensor cells and we see different colours. Adding coloured lights together results in a brighter light. 5. Coloured filters transmit the colour of light that they are and absorb the other colours of the spectrum.
7.P2.08 Refraction of light	1. Refraction is the change in direction of a wave as it interacts with a 'surface', because of a change in its speed. All waves can be refracted. 2. Light can be refracted when it travels between transparent matter (e.g. from air to glass). Light is transmitted well through glass; it travels more slowly in the glass than it does in air. On crossing the boundary between air and glass at an angle (not along the normal), the light ray changes direction. 3. Students should be able to draw refracted ray diagrams to show the change in direction on slowing or speeding up.
7.P2.09 Hearing	1. Sound travels from the source to the ear.* Within the ear, sound causes the ear drum and other parts to vibrate, which causes the sensation of hearing. 2. The ear can be damaged and can lead to hearing loss or other hearing-related problems. People living with hearing loss or deafness may use sign language, speech reading, hearing dogs, subtitles, or hearing technologies. 3. Different animals hear different sounds: pitch and range.
7.P2.10 Seeing	1. The 'passive eye' model of vision describes how we see: objects emit or reflect light into the eye. Objects would be invisible if they did not reflect light.* 2. The eye is made of many parts, which enable light from an object to fall on cells in the retina, causing the sensation of seeing. 3. Vision can be modelled with a pinhole camera.

4. Students should be able to use ray diagrams to explain the eye, and the pinhole camera.
5. The eye needs to adjust to focus clearly on near and far objects. It does this by changing the lens shape to alter the amount of refraction.
6. Many problems with our vision are caused by parts of the eye that are the not the right shape or size, or that have become cloudy. Many of these problems can be corrected through surgery or prescription glasses.
7. Long-sightedness is caused by the lens not refracting enough and short-sightedness is caused by the lens refracting too much.
8. People living with sight loss or blindness may use long canes or guide dogs when outside, talking books or Braille, and different devices in the home.
9. Light from the Sun can be dangerous and there are ways to protect our eyes and skin.*

Disciplinary Knowledge to Be Taught in Year 7

A glossary of key terms can be found in Appendix A.

Scientific Attitudes and Ways of Thinking

7.WSAT 1 Seeking Objectivity

7.WSAT 1.01 Scientific thinkers and objectivity	1. Scientific thinkers make observations about the 'natural world' and ask questions about their observations. Sometimes they propose a hypothesis in response to a question. They seek to collect high-quality data. 2. Students should be able to describe the ways scientific thinkers seek to be objective.
7.WSAT 1.02 High-quality data	1. Data is information collected during observation or measurement. Measurement results are quantitative data. Observation results can be quantitative or qualitative data. 2. Students should be able to classify data terminology including data, qualitative data and quantitative data. 3. The quality of measurement results can be judged against expectations: repeatability, reproducibility, appropriate range, systematic intervals, and appropriate and high resolution. 4. Students should be able to identify the above expectations for high-quality data.
7.WSAT 1.03 Measurement error	1. Measurement error can arise from the methods and equipment used. 2. One type of measurement error is systematic error. Sometimes a systematic error may be a zero error. 3. It may be possible to reduce or remove a systematic error if it can be identified, understood and corrected or removed. 4. One type of measurement error is random error. Random error cannot be reduced or corrected for, but its impact can be reduced by making more measurements and reporting the mean average. 5. Students should be able to identify possible causes of measurement error and describe ways to reduce it or its effects.

7.WSAT 2.01 Developing scientific methods	1. Scientific thinkers use their questions to devise a line of enquiry and develop a systematic enquiry, sometimes proposing a hypothesis, sometimes planning to manipulate variables. 2. Students should be able to describe ways that scientific thinkers develop scientific enquiries. 3. Scientific methods can be categorised into those that change variables and those that do not. They might: • test a hypothesis and change variables; • test a hypothesis and not change variables; • experiment by changing variables without testing a hypothesis; • observe phenomena without changing variables without testing a hypothesis; 4. Students should be able to identify the type of scientific method using the categorisation above.
7.WSAT 2.02 Changing methods	1. The scientific method selected is based on the research question and the available means to collect data to answer it. 2. The range of scientific methods has developed over history; this is partly due to improved technology to support the collection of high-quality data. 3. Examples of how technology has increased the ability to choose a scientific method include: microscopes, electronic and digital instruments, data logging, filming, and materials science. 4. The range of scientific methods has developed over history partly due to an increase in the body of scientific knowledge e.g. available concepts/models etc. 5. New hypotheses can emerge from data collected across scientific methods. 6. Students should be able to sequence examples of scientific methods and identify how each may have added to the body of scientific knowledge, given guidance.

7.WSAT 3 Using a variety of models

7.WSAT 3.01 Describing models	1. A model represents reality but only to an extent; it is not a literal representation of reality. 2. Models attempt to make clear the things we cannot make sense of and/or describe things that are too small to see, like atoms or cells. They can make clear things which are much bigger, like the solar system or make sense of things that change very fast or very slowly. 3. A scientific model may be descriptive and may include diagrams, mathematical (or symbolic), or may be representational (before and after, change, flow of materials). 4. Students should be able to give examples of some scientific models including: particulate model of matter, force diagrams, energy stores and pathways model and bell jar model. 5. Students should be able to describe what a specific model is representing and how it helps us understand the concept.

7.WSAT 4 The importance of peer review

7.WSAT 4.01 Scientific thinking and peer review	1. The process of peer review is used to assure scientific research (and its claims) is of high quality; the peers of scientists are other scientists, often working in the same area of research (field). 2. Students should be able to name the process by which scientific research is quality assured.
7.WSAT 4.02 Judging the quality of conclusions	1. The quality of scientific research can be judged on the quality of conclusions. 2. Conclusions are drawn from collected data in an enquiry; they are considered to be of high quality if the data they refer to is of high quality e.g. the data is repeatable and reproducible etc. 3. Students should be able to identify how scientific claims can be judged for their quality.

Enquiry

7.WSEF 1 Planning for valid methods

7.WSEF 1.01 Developing scientific methods	1. Scientific methods are planned for repeatability, to have a range of data collection that is large enough to identify any trends, to select apparatus and techniques that are likely to generate high-quality data, to have systematic intervals, so that the resolution of measuring instruments is small, and to reduce likelihood of systematic error. 2. Students should be able to identify how methods have been planned to collect high-quality data (as above).
7.WSEF 1.02 Hypotheses and variables	1. When a hypothesis is to be tested, a prediction is made; the planned data collection allows confirmation the prediction was correct or not. 2. When variables are to be managed, the independent variable, dependent variable, and control variables are identified. 3. When it is possible to manage variables, the method should be a fair test. 4. When not possible to manage variables, the method is planned so there is consistency in the way parameters are observed or measured. 5. Students should be able to make a prediction to answer an enquiry question / test a hypothesis. 6. Students should be able to identify the category of variable and if it has been managed in a fair test.

7.WSEF 2 Common techniques and apparatus

7.WSEF 2.01 Equipment	1. Apparatus is drawn in reports diagrammatically; the diagram used for each piece of equipment (and how it is shown together in a process). 2. Students should be able to draw scientific apparatus diagrams. 3. The use of the following equipment and how they are used skilfully: beakers, boiling tubes, Bunsen burner, clamp stand boss and clamp, condenser, conical flask, connecting wires, cover slip, crucible, evaporating basin, filter funnel, filter paper, gauze, heat resistant mat, masses on hook, microscope, microscope slide,

	mineral wool, pipe-clay triangle, power supply, raybox and comb, safety glasses, spatula, splint, , stirring rod, test tubes (Pyrex), test tube holder, tongs, tripod and watch glass. 4. Students should be able to identify equipment listed and skilfully use them (except a condenser).
7.WSEF 2.02 Measuring instruments	1. The use of the following measuring instruments and how they are used skilfully: force meter, measuring cylinders, metre rule*, pipette, stopclock, thermometer* and top pan balance. 2. Students should be able to identify measuring instruments listed and select the most appropriate instrument for the measurement.
7.WSEF 2.03 Techniques	1. The way the following techniques are generally carried out: (paper) chromatography, crystallisation, distillation using a condenser, filtering, heating liquids with a Bunsen burner, heating small amounts of substances with a Bunsen burner and microscopy. 2. Students should be able to carry out the techniques listed, with guidance (except the condenser).

7.WSEF 3 Planning for safe practical science

7.WSEF 3.01 General principles	1. The likelihood of harm/damage by working in a school laboratory can be minimised by employing control measures. 2. Normal laboratory rules state the general expectations for safe behaviour during practical science. 3. All practical science entails risk from hazards including the following: broken glassware, spillages, electricity, hot objects, naked flame, chemicals, some chemical products, sharp objects, gas, movement around the room, use of certain equipment, biohazards, radioactive substances, waste products etc. 4. Students should be able to identify the main hazards in practical science enquiries. 5. To reduce risk of harm to an acceptable level, 'control measures' are put in place.

	6. Students should be able to identify the main control measures appropriate to a method. 7. Students should be able to follow the laboratory rules consistently. Note, students are not expected to write their own risk assessments.
7.WSEF 3.02 Managing specific hazards	1. The risks associated with using heating apparatus are burns, fire, damage to eyes, and damage to equipment. 2. The likelihood of harm/damage by using heating apparatus (a Bunsen burner) can be minimised by employing control measures.

7.WSEF 4 Making valid observations

7.WSEF 4.01 Measuring	1. The process of measuring entails finding the value of quantities, using measuring instruments or counting. 2. Many measuring instruments are marked off with a scale: lines at equal increments, labelled with numbers and units. 3. Students should be able to use a scale and make skilful measurements for a variety of quantities: length/distance, time, mass, temperature, volume/capacity, and force.
7.WSEF 4.02 Observation without measurement	1. Observation without measurement may produce high-quality data; it can be in the form of descriptions, images, if a behaviour has been demonstrated etc. 2. Observation to collect qualitative data often requires skill in the technique. 3. Students should be able to describe observations including comparative judgements e.g. vigour of reaction.
7.WSEF 4.03 Reflecting on collected data	1. Collected data can be primary data or secondary data. 2. Measuring instruments have different resolutions which can affect the quality of collected data. 3. An estimate for expected results can be identified from secondary data.

	4. Students should be able to identify primary and secondary data, record the resolution of any measuring instrument and assess if an observation is within expected estimated values, with guidance.

7.WSEF 5 Evaluating methods

7.WSEF 5.01 Measuring	1. Using apparatus and techniques will produce different levels of measurement error. 2. Students should be able to compare the data collected using different apparatus e.g. types of thermometer. 3. Students should be able to identify the qualities of the apparatus that can lead to the collection of higher-quality data.

Analytical and Evaluative Approaches

7.WSAN 1 Presenting, analysing, interpreting data; developing explanations; evaluating data

7.WSAN 1.01 Recording data	1. Recorded data is often presented in tables. Data tables present information systematically. 2. Students should be able to record data systematically in tables including headings describing measured quantities and their units. 3. Tables can be used to support the processing of raw data; an additional column is added to include calculations of values in preceding columns. 4. Students should be able to use a table to record processed data e.g. mean average. Note, the mean is taught in the United Curriculum for Secondary Mathematics in Year 7, half term 3. 5. Any anomalies are identified in the table. 6. Students should be able to identify anomalies in a table of data.
7.WSAN 1.02 Data, charts and graphs	1. Qualitative observations cannot always be tabulated; they may be recorded in accurate, labelled drawings e.g. biological specimens.

	2. Variables can be classified by their data type: quantitative data includes discrete and continuous data, and qualitative data includes categoric data. 3. Students should be able to identify if a variable is continuous, categoric or discrete. 4. Recorded data is often visually displayed: • in a pie chart • in a bar chart • in a line graph 5. Students should be able to plot bar charts. Note, students are not expected to draw scatter graphs and lines of best fit.
7.WSAN 1.03 Processing data	1. Raw data may need to be processed which may involve calculation. 2. A calculation may relate measured values to another quantity e.g. use a formula, find the mean, find the range. 3. The impact of random error can be reduced by taking multiple measurements, ignoring anomalies (and calculating a mean). 4. Students should be able to calculate the mean for a set of data. 5. Students should be able to identify the range for a set of data.
7.WSAN 1.04 Tables, charts, and qualitative observations	1. Values can be read from a table of data, pie chart, bar chart or line graph. 2. Students should be able to interpret data tables, pie charts, bar charts and line graphs. Note, students are not expected to interpret scatter graphs or lines of best fit. 3. Information can be extracted from scientific drawings e.g. features can be counted and the size of features (may be relative size) can be identified. 4. Students should be able to interpret drawings, with guidance.
7.WSAN 1.05	1. Scientific enquiries include a conclusion. At Year 7, the conclusion:

Basic conclusions	a) describes the patterns/trends or relationship between the quantities being measured or explored, and the data that led to it; b) explains the findings, using scientific knowledge e.g. a scientific model; c) relates the findings to a scientific model/explanation; d) states the extent to which the prediction (if there was one) is correct; e) only comments on the data collected, without over-generalising. 2. Students should be able to make a conclusion including the points listed above (excluding (d) until 7.06 and (e) until 7.07).

Applications of Science and its Implications

7.WSAI 1 Developing scientific knowledge through technology

7.WSAI 1.01 Examples of technological applications to science	1. Technological advances have enabled scientific researchers to increase the body of scientific knowledge over time by: • developing their methods; • using more uniform devices e.g. lenses; • using measuring instruments rather than making subjective observations e.g. digital thermometer; • making measurements of quantities that were either too small, too large, too distant or too difficult to resolve before; • automating calculations using computers, which are less prone to mistakes and quicker; • communicating, sharing and collaborating more effectively and sharing knowledge more widely and quickly; • using digital technology (photos, film) to record and review data.

	2. Students should be able to give examples of how the development of technology has increased the body of scientific knowledge.

7.WSAI 2 Developing technology through science

7.WSAI 2.01 Examples of scientific knowledge applications to industry	1. Scientific advances have enabled STEM workers to further technology and industry by developing: • new tools and machines, making mass production possible; • new materials; • developing new medicines or medical techniques e.g. using echoes; • new products, made more efficiently; • capacity to provide clean water to more people. 2. Students should be able to give examples of technological developments due to an increased body of scientific knowledge.

7.WSAI 3 Ethical, social, economic, and political implications

7.WSAI 3.01 Increasing human population	1. Scientific and technological improvements have led to many changes, which then have knock-on effects: • raw materials including competition effects and the drive towards solutions; • space (housing, agriculture, waste disposal); • use of polymers. 2. Students should be able to give examples and describe some effects of an increased human population using the above points.

7.WSME 1 Units

7.WSME 1.01 Base quantities	1. Scientific thinkers always use units to compare quantities and measurements. 2. There are agreed base quantities, which have base units: • length or distance – the metre (m); other units used for length and distance are centimetres (cm), millimetres (mm) for small measurements and kilometres (km) • time – the second (s), other units of time are the minute (min) and the hour (h) • temperature – the degree kelvin (K); a common unit of temperature is the degree Celsius (°C) • mass – the kilogram (kg), other units used for mass are the gram (g). 3. Students should be able to identify these base quantities, state their base unit and other commonly used units.
7.WSME 1.02 Derived quantities	1. Other quantities derive from the base quantities, some units having special names: • frequency – the hertz (Hz) • force – the newton (N). 2. There are several quantities which are derived from useful ratios: • level or intensity of sound / loudness (volume) – the decibel (dB). 3. Students should be able to identify the standard unit for the quantities listed above.
7.WSME 1.03 Writing and using units	1. Values are written as a quantity multiplied by a unit; there are protocols for writing units: • a space is left between the numerical value and the unit symbol e.g. 25 kg; • all unit names are written in small letters (e.g. newton) apart from Celsius; the unit symbol is capitalised e.g. N.

	2. Students should be able to correctly write values which have units, in words and symbols.

WSME 2 Notation and conventions

7.WSME 2.01 Standard prefixes	1. Scientific thinkers use unit prefixes in notation to keep very large and very small numbers on a 'human scale'. 2. The international system (S.I.) uses a range of unit prefixes which differ by the factor of 1 000. • 'kilo-' is a unit prefix, symbol k, used as a multiplying factor of 1 000 (note, mass is an exception to this rule). • 'milli-' is a unit prefix, symbol m, used as a multiplying factor of 0.001. 3. Students should be able to identify these prefixes and what they mean e.g. the number of millimetres in a metre. Note, students are not expected to convert values in Year 7.
7.WSME 2.02 Non-standard prefixes	1. There are a few other non-standard but commonly used unit prefixes. • 'centi-' is a common unit prefix, symbol c, used as a multiplying factor of 0.01; centi- is only likely to be met as the centimetre. 2. Students should be able to identify the prefix and what it means.

7.WSME 3 Symbols and formulae

7.WSME 3.01 Quantities and substances	1. Chemical symbols in science can represent an element. Chemical formulae in science can represent a compound.
7.WSME 3.02 Formulae (equations)	1. Scientific thinkers determine and solve equations: • total magnification = eyepiece x objective 2. Calculations are assessed for if the value looks reasonable. 3. Students should be able to use the formula: 'total magnification = eyepiece x objective'.

Detailed Knowledge for Year 8

Substantive Knowledge to Be Taught in Year 8

The below outlines the detailed knowledge that should be taught by the end of Year 8, grouped by theme and topic.

These statements build on content from earlier years, with prior knowledge assumed and therefore not restated. Teachers should ensure that any required prior learning is secure and revisit it where necessary.

Biology

8.B1 Cells and Life

8.B1.01 Plants as organisms	1. Plants have four main organs: the flower (reproductive organ), leaf (photosynthesis), stem (connects the other organs and transports key substances), and roots (anchor the plant in the soil and absorb water and minerals). 2. The leaf is composed of several specialised tissues: mesophyll (photosynthesis), epidermal tissue (protective outer layer), xylem tissue (transports water and dissolved minerals), phloem tissue (transports dissolved sugars).
8.B1.02 Photosynthesis	1. Photosynthesis is a series of chemical reactions that occur in chloroplasts. Light (e.g. the Sun or artificial sources) transfers energy to the plant, allowing it to produce food in the form of glucose. 2. Chlorophyll, the green pigment found in chloroplasts, absorbs light, which transfers energy to the plant to drive photosynthesis. This process mainly occurs in palisade cells, which contain many chloroplasts. 3. The reactants of photosynthesis are carbon dioxide and water. Light is not a reactant but transfers energy to the plant for photosynthesis. The products are glucose and oxygen (released as a by-product). The word summary is: carbon dioxide + water → glucose + oxygen. 4. Photosynthesis is an endothermic process that requires energy to be transferred from its surroundings. 5. Glucose is used in respiration to release energy for life processes. Some glucose is converted into cellulose to build new

	cell walls during growth. Excess glucose is stored as starch, which is broken down when needed for energy, growth, or repair. 6. Iodine is used to test for the presence of starch (in a leaf). If starch is present, iodine turns from orange-brown to blue-black.
8.B1.03 Changing understanding of photosynthesis	1. Historically, it was believed that plants gained mass by consuming soil through their roots. 2. Jan Baptist Van Helmont discovered that a plant's mass came from water, not by absorbing soil mass, as previously believed. 3. Modern science has shown that most of plant's mass comes from carbon dioxide.
8.B1.04 Leaf structure and adaptations	1. Leaves are broad to provide a large surface area for light absorption and thin to allow light to penetrate and gases to diffuse efficiently. The upper surface contains more chloroplasts, making it more effective at capturing sunlight. Veins, containing xylem and phloem tissue, transport substances around the plant. 2. The upper epidermis is transparent, allowing light to reach palisade cells. A waxy cuticle covers the upper surface to reduce water loss. 3. The palisade mesophyll, which contains column-shaped cells packed with chloroplasts, is the main site of photosynthesis. 4. The spongy mesophyll has air spaces to facilitate gas exchange between the stomata and palisade cells. 5. The lower epidermis contains stomata (pores located mainly on underside of leaves). Stomata enable carbon dioxide to enter the leaf and oxygen to exit. Two guard cells control the opening and closing in each stoma to regulate gas exchange and water loss.
8.B1.05 Root structure and adaptations	1. Root hair cells are adapted for the absorption of water and minerals, with a long extension to increase surface area. They contain many mitochondria to provide energy for active transport. They have no chloroplasts. 2. Water is essential for photosynthesis. It maintains the structural integrity of the plant and enables chemical reactions by acting as a solvent in which reactants and products are dissolved.

	3. Minerals are vital for healthy plant growth: nitrates for healthy growth, phosphates for healthy roots, potassium for healthy leave and flowers and magnesium for producing chlorophyll. 4. Water is absorbed through osmosis, moving from an area of high water concentration in the soil to an area of lower concentration in root hair cells. 5. Minerals dissolved in water are absorbed by active transport as they are in lower concentrations in soil than in root hair cells. Active transport requires energy from respiration. Therefore, root hair cells contain many mitochondria.
8.B1.06 Transport in plants	1. Xylem transports water and dissolved minerals up the stem, from roots to leaves. Phloem transports dissolved sugars. Sugars are transported up or down the stem, depending on where sugars are needed. 2. Xylem vessels are made of dead cells with no internal contents, forming long, hollow tubes for efficient water transport. Their cell walls are thick and strengthened with lignin, preventing collapse and providing structural support. Lignin makes the xylem cell walls impermeable. 3. Phloem vessels are made of living cells with few internal structures to allow space for sugar transport. The end walls have pores called sieve plates to allow movement between cells. Phloem vessel cells are supported by companion cells, containing mitochondria to supply energy for transporting dissolved sugars. 4. Transpiration is the process of water loss from plant leaves. Water evaporates from cells inside the leaf, diffuses through air spaces in the spongy mesophyll, and exits through the stomata. This water loss pulls up more water from the roots, forming a continuous transpiration stream. This is crucial for supplying water for photosynthesis, transporting dissolved minerals, and cooling the leaf in warm weather. 5. The rate of transpiration is increased by factors that increase the rate of evaporation: higher temperatures; lower humidity; increased wind. It also increases with greater light intensity, as this enhances photosynthesis and causes the stomata to open.

8.B1.07 Rate of photosynthesis	1. The rate of photosynthesis is influenced by light intensity, chlorophyll, water, temperature, and carbon dioxide. Increasing these factors increases the rate of photosynthesis, while insufficient levels can slow or limit the process.
8.B1.08 Plants and the atmosphere	1. Today, the atmosphere contains about 0.04% carbon dioxide and 21% oxygen. Early Earth's atmosphere was mostly carbon dioxide and very little oxygen. 2. As the Earth cooled, oceans formed and absorbed the carbon dioxide. Photosynthesising algae and plants evolved, causing carbon dioxide to drop and oxygen to rise. Some of the oxygen was absorbed by the oceans and rocks on the seabed. 3. Plants impact the atmosphere by absorbing carbon dioxide and releasing oxygen, maintaining low carbon dioxide levels and high oxygen levels necessary for most life on Earth. Deforestation reduces the number of plants, increasing carbon dioxide levels.
8.B1.09 Plants as producers	1. Plants are producers that make their own food through photosynthesis. Plants provide food for humans and other animals, forming the basis of food chains. 2. Foods that contain starch can be identified using iodine. 3. Insect pollination is essential for crop growth and food production. A significant portion of our food relies on pollinators. The decline in bee populations threatens food security.
8.B1.10 Biological molecules	1. There are two types of carbohydrates: starch and sugar. Starch is a complex carbohydrate and is insoluble. Sugars, e.g. glucose, are simple carbohydrates and are soluble. 2. Complex carbohydrates are polymers made up of many sugar monomers. Simple carbohydrates are single sugar molecules. 3. Proteins are polymers made up of amino acid monomers. Proteins are insoluble. Amino acids are soluble. There are around 20 different types of amino acid. Different proteins are made of different combinations of amino acids. 4. A lipid molecule is made of one molecule of glycerol and three fatty acid chains. Lipids and fatty acids are insoluble, glycerol is soluble.

	5. Chemical reagents are used to test for protein, lipids, and carbohydrates (i.e. starch and sugar): biuret reagent for protein; ethanol and water for lipids; iodine for starch; Benedict's for sugars.
8.B1.11 Digestion and enzymes	1. Most food consists of large, insoluble molecules (lipids, proteins, and complex carbohydrates) too big to pass into the blood through the selectively permeable membrane in the small intestine walls. Digestion breaks down large molecules into smaller, soluble ones that can diffuse into the blood. 2. Mechanical digestion involves physical actions, e.g. chewing by teeth; churning by muscle contractions in the stomach. 3. Chemical digestion uses enzymes (biological catalysts) released in the mouth (saliva), the stomach and small intestine. Enzymes speed up reactions without being used up. They can be used repeatedly. 4. The enzyme attaches to the large molecule it is breaking down, breaking bonds between smaller molecules making up the large molecules. The enzyme then attaches to another large molecule and repeats the process. 5. Enzymes are specific to a given molecule: carbohydrases break down complex carbohydrates into sugars; proteases break down proteins into amino acids; lipases break down lipids into glycerol and fatty acids. 6. The liver produces bile and stores it in the gallbladder before being released into the small intestine. Bile emulsifies lipids. Emulsification is the breaking down of large droplets into smaller droplets, which increases surface area for lipase enzymes. 7. The pancreas releases all three types of enzymes into the small intestine to aid in digestion.
8.B1.12 Absorption and transport of nutrients	1. Nutrients provide energy, used for building and repairing tissues and supporting growth and development. They are transported in blood to cells and tissues, and used for cellular processes (e.g. making proteins and respiration). 2. Ineffective nutrient transport, leads to potential deficiencies and various health issues.

	3. Nutrients are absorbed into the bloodstream from the small intestine. Blood delivers nutrients to cells and removes waste products. As nutrient-rich blood circulates, it is continuously replenished with new blood.
8.B1.13 Factors affecting enzymes	1. The optimal temperature and pH is when enzymes work at their fastest rate. Different enzymes have different optimal temperatures and pH, e.g. human body temperature is 37°C, the average temperature at which the enzymes in the body work fastest. 2. As temperature increases, enzyme activity increases. At temperatures above the optimal temperature enzyme activity slows down. 3. Enzyme activity will increase as pH approaches the optimal pH and decreases as the pH moves away (in either direction). 4. If temperature becomes too high, or pH too extreme in either direction, enzyme activity permanently stops. The shape of the enzyme's active site changes (denaturing), preventing it from binding to the food molecule. This is irreversible, and denatured enzymes will not work by lowering the temperature or changing the pH.
8.B1.14 Making digestion efficient	1. Bile and hydrochloric acid increase the efficiency of enzymes. 2. Hydrochloric acid provides an acidic environment for the enzymes in the stomach to work. It creates a very acidic environment in the stomach, and these acidic conditions kill disease-causing microorganisms (pathogens). Bile is alkaline, which neutralises stomach acid, ensuring the alkalinity necessary for enzyme activity in the small intestine. 3. Bacteria help with digestion by releasing enzymes to break down food that cannot be digested by human enzymes. They protect from pathogens and produce essential vitamins.

8.B3 Variation and Evolution

8.B3.01 Classification	1. Classification is the sorting of items into groups based on shared characteristics; taxonomy is the scientific practice of classifying organisms.

	2. Organisms can be classified based on observable physical features (e.g. types of vertebrates), and microscopic characteristics such as cell structure (e.g. animal, plant, bacteria fungi). 3. Carl Linnaeus developed the modern classification system: kingdom, phylum, class, order, family, genus, and species. Species is the smallest group, with most shared characteristics. 4. Classification helps scientists identify and name organisms accurately, track species for conservation, predict characteristics, understand relationships between organisms, and study how species have evolved over time.
8.B3.02 Competition and adaptation	1. Animals compete for essential resources for survival and reproduction (e.g. food, water, shelter, mates). 2. Plants compete for resources, supporting their growth and reproduction (e.g. sunlight, water, minerals, space, pollinators, seed dispersers). 3. Interspecific competition occurs between individuals of different species. Intraspecific competition occurs within individuals of the same species. 4. Adaptations are characteristics that help an organism survive, compete for resources and reproduce in its environment. These can be classified into three types: behavioural, structural, and functional.
8.B3.03 Natural selection, evolution and extinction	1. Evolution is the process of change in the characteristics of species over many generations. It is supported by extensive evidence (e.g. fossils). 1. Within a species, individuals show genetic variation, meaning they have different characteristics. Some characteristics may give individuals an advantage in competition, making them better adapted. They are more likely to survive, reproduce and pass on their advantageous genes to their offspring. This process is called natural selection. 2. Natural selection is the scientific theory that explains how evolution occurs. The steps of natural selection are summarised as: variation, advantage, competition, survival, reproduction, inheritance.

	3. Extinction is the complete loss of all members of a species when a species cannot adapt to changes in its environment (e.g. habitat loss, new predators, new diseases, or new competitors). Species at risk of extinction are classified as endangered. 4. Human activities accelerate extinction by altering habitats and increasing competition. Rapid climate change disrupts food sources and living conditions.

8.B4 Ecological Relationships

8.B4.01 Inter-dependence	1. Habitat is the place where an organism lives. 2. Population is the number of organisms of the same species living in an area. 3. Community is the different populations interacting in the same area. 4. Ecosystem is a community of living organisms and their non-living surroundings (e.g. soil, rocks, water, and air). 5. Biomass is the dried mass of living material in organisms. Biomass is transferred between populations through feeding relationships. 6. Food chain diagrams show the flow of energy (biomass) from producers to consumers. Trophic levels indicate an organism's position in the food chain. Energy loss occurs at each level as thermal energy released during respiration, through movement, or in undigested materials. 7. Populations change due to births, deaths and migration. It is influenced by predation, diseases, seasonal variations, natural disasters, and human activities like deforestation and pollution. Habitat destruction and diseases impacts populations, while conservation restores and supports population growth. 8. Interdependence is the reliance of organisms within ecosystems on each other for survival. Changes in one population affect other populations in the same community, impacting food chains and the ecosystem. 9. Predators and prey are an example of interdependence. Increases in predator population lead to decreases in prey, which then reduces predator population due to lack of food. There is a

	lag between population peaks and troughs, helping maintain a stable community where average population sizes of all species remain relatively constant. 10. Food webs provide a more realistic model of complex feeding relationships, with arrows indicating energy transfer through interconnected food chains. 11. Changes (including human activities, e.g. overfishing) in the population of a species within a food web can impact the populations of other organisms.
8.B4.02 Bio-accumulation	1. Fertilisers provide minerals and chemicals to help plants grow, allowing farmers to increase food production. 2. Fertilisers can spread into the environment, causing soil depletion and water pollution. 3. Pesticides (e.g. herbicides and insecticides) help control pests but can kill beneficial insects, pollinators, and non-target plants. 4. Bioaccumulation occurs when toxic substances, such as pesticides, build up in organisms over time. These substances can pass through the food chain, becoming more concentrated at each trophic level.
8.B4.03 Material cycles	1. Decay is the breakdown of dead organisms and waste from living organisms (organic matter). 2. Decomposers carry out decay for their nutrition, including bacteria, fungi, and detritivores (e.g. earthworms, maggots, insects, woodlice and millipedes). 3. Decay recycles nutrients back into the soil for plant growth, sustains food chains, returns carbon to the atmosphere for photosynthesis, cleans the environment by breaking down dead organisms and waste. Decay breaks down soft tissues in fossil formation and leaves behind hard parts which are fossilised over time. 4. The rate of decay increases in warm, moist, and oxygen-rich environments. 5. Compost bins convert vegetable waste into nutrient-rich compost by speeding up decay. They are designed to create ideal conditions for decay.

6. The carbon cycle continuously moves carbon between the atmosphere, living organisms, and the Earth. It provides carbon for growth, energy, and molecule formation, regulates climate by controlling carbon dioxide levels and contributing to fossil fuel formation.
7. Carbon dioxide enters the atmosphere through respiration (plants, animals, and decomposers) as well as through the combustion of fossil fuels. It is removed during photosynthesis. Carbon is passed through food chains as animals consume other organisms, and returns to the atmosphere when they respire.
8. In low-oxygen, decomposition slows, and carbon can become stored as fossil fuels. Human activities (e.g. fossil fuel combustion) increases atmospheric carbon dioxide.

8.B5 Health

8.B5.01 Diet

1. A balanced diet provides the right amounts of all the different nutrients:
    - Carbohydrates (simple and complex) - provides energy for the body; simple carbohydrates are found in sweet foods, sugars and fruits and release energy quickly; complex carbohydrates are found as starch in foods like bread, rice, pasta and potatoes and release energy more slowly.
    - Lipid (fats and oils) - provides energy, help insulate the body, and help to build cell membranes; found in foods like butter, cheese, oils, nuts and seeds.
    - Protein - needed for growth and repair of cells and tissues, helping the body make new cells and fix damaged ones; found in foods such as meat, fish, eggs, milk and beans.
    - Vitamins - needed in small amounts for cell and body processes and for general health; found naturally in many foods like fruits and vegetables; found in many foods, especially fruits and vegetables.
    - Minerals - needed in small amounts to make red blood cells, bones and teeth; examples include iron and calcium; found in many foods, especially fruits and vegetables.

	• Fibre - adds bulk to food and helps it move through the digestive system to prevent constipation; found in foods such as fruit, vegetables and whole grains. • Water - needed for chemical reactions in cells and for maintaining the water levels in the blood; mainly obtained by drinking water. 2. Food labels contain information about the mass of each nutrient found in foods and indicate the amount of energy in the food. Energy is often given as a value in kilojoules (kJ) or kilocalories (kcal). 3. Nutritional value of a meal is calculated by summing the mass of each nutrient. 4. To maintain body mass, energy intake must equal energy use; excess intake leads to weight gain, insufficient intake leads to weight loss. 5. Energy needs vary by age, sex, muscle-to-fat ratio, exercise, external conditions, pregnancy, and genetics. 6. Time to burn calories depends on the activity's energy expenditure rate. 7. Deficiency diseases result from lack of specific nutrients, e.g., anaemia, scurvy, rickets. 8. Imbalances in energy and nutrient intake can cause starvation, obesity, and heart disease. Fatty deposits in arteries that supply the heart become more likely when a person regularly eats more energy than their body uses. These fatty deposits can narrow the arteries, reducing blood flow to the heart, which can cause a heart attack. 9. BMI indicates healthy body mass; high BMI can mean overweight or muscular; BMI alone does not determine health. Body mass index (kg/m^2) = body mass (kg) ÷ $(height)^2$ (m^2)
8.B5.02 Energy in food	1. Different foods store different amounts of energy, measured by burning food to heat water and calculating temperature change. A larger temperature rise indicates more energy in the food. 2. Energy is released from food by respiration. Glucose is oxidised inside cells using oxygen, releasing energy. Carbon dioxide and

water are waste products. Respiration is described using the word summary: glucose + oxygen → carbon dioxide + water.

3. Energy released from respiration is used to maintain core body temperature, power muscle contraction, and for making new molecules and new cells for growth and repair.
4. There are strengths and limitations of models for respiration.

8.C2.01 Acids, bases, and alkalis	1. Acids are a family of chemicals that react in similar ways. Edible acids are found in food and drink, but not all acids are edible. Bases are a family of chemicals that react in similar ways. An alkali is a soluble base and forms an alkaline solution. All alkalis are bases, but not all bases are alkalis. Many household cleaning products are alkalis 2. Some acids and alkalis are corrosive and cause chemical burns. A hazard symbol warns that the substance is corrosive. Acids often taste sour, whilst bases (including alkalis) taste bitter. Alkalis (bases dissolved in water) can feel slippery or soapy. Acids and alkalis should not be tasted in the laboratory. 3. Hazard symbols provide information to keep someone safe while using that material. Chemical hazard symbols explain how a substance might be dangerous. 4. There are symbols, risks and control measures for the following common hazards: moderate health hazard, serious health hazard, toxic, corrosive, flammable, oxidising, harmful to the environment.
8.C2.02 Indicators and pH scale	1. Aqueous solutions can be acidic, alkaline or neutral. A neutral solution is neither acid nor alkali. Pure water is neutral. 2. An indicator changes colour when added to an acid or an alkali. Indicators determine whether a solution is acidic, alkaline, or neutral. 3. Many flowers, fruits and vegetables contain chemicals called pigments that change colour in acids or alkalis. These can be extracted and made into a solution that acts as an indicator. 4. Different chemical indicators have advantages and disadvantages. Red and blue litmus are examples of simple indicators. Simple indicators do not tell you the pH, only if it is acid or alkali. 5. Universal indicator can tell you the pH of a solution. The pH scale is used to classify solutions as acidic, alkaline or neutral. The pH scale ranges from 0 to 14. We can use the pH scale to tell us how acidic or alkaline an aqueous solution is.

	6. Neutral solutions are exactly pH 7. Acidic solutions have a pH less than 7. The closer to pH 0, the more acidic a solution is. Alkaline solutions have pH more than 7. The closer to pH 14, the more alkaline a solution is.

8.C3 Chemical Reactions

8.C3.01 Acids and metals	1. Acids react with most metals. When an acid reacts with a metal, a salt and hydrogen gas are produced. This is represented by the general equation: metal + acid → salt + hydrogen. 2. The particular salt produced in reactions between a metal and acid derives from a combination of the metal and acid used. Nitric acid will produce a nitrate salt. Sulfuric acid produces a sulfate salt. Hydrochloric acid produces a chloride salt. 3. When an acid reacts with a metal, bubbles of hydrogen gas can be observed. The presence of hydrogen can be tested for using a lit splint; a squeaky pop sound indicates the presence of hydrogen. The metal gets smaller as it reacts with the acid. The reaction is usually exothermic, indicated by an increase in temperature.
8.C3.02 Neutralisation	1. The pH of a solution can be changed by adding an acid or base. Adding an acid to water will decrease the pH from 7. Adding a base to water will increase the pH from 7. 2. When bases are added to acids, the pH increases, becoming less acidic and more neutral. When acids are added to bases, the pH decreases, becoming less alkaline and more neutral. 3. A neutralisation reaction is when acids and bases are reacted together to produce a neutral solution of a salt and water. This happens when all of the acid has reacted with all of the base. This is represented by the general equation: acid + base → salt + water (or acid + alkali → salt + water). 4. Indigestion is caused by excess hydrochloric acid in the stomach. The acid moves into the oesophagus causing irritation and a burning sensation. Indigestion remedies, called antacids, are bases that alleviate symptoms by reacting with stomach acid and neutralising it.

8.C3.03 Metal oxides and non-metal oxides	1. Metals and non-metals can react with oxygen to make compounds called oxides. 2. Metal oxides are usually solids at room temperature. Metal oxides act as bases and can react with acids to neutralise them: acid + metal oxide → salt + water. Most metal oxides are insoluble in water, but some react with water to form an alkali (base + water → alkali). 3. Non-metal oxides are often gases at room temperature. Most non-metal oxides are soluble in water and react to form acidic solutions.

8.C4 Physical Earth

8.C4.01 Composition and structure of the Earth	1. The Earth has a layered structure composed of the crust, the mantle, the inner and the outer core. Each varies in composition, thickness, and temperature. 2. The crust includes continental crust, oceanic crust and is divided into large solid tectonic plates (including the upper mantle beneath). These plates move and interact at plate boundaries, causing geological activity. 3. Coastlines of continents were observed to fit together like a jigsaw puzzle. Alfred Wegener proposed the theory of continental drift, suggesting the continents were once connected in a single land mass called Pangea, which later broke apart. Wegener supported his theory with evidence such as matching coastlines, similar rock formations, and identical plant and animal fossils found on different continents. His theory eventually gained acceptance and further study lead to the development of the theory of plate tectonics. 4. Convection currents are one of the processes explaining how the tectonic plates move, which causes the continents to move over time.
8.C4.02 Igneous rock formation	1. Igneous rocks form when molten rock cools and crystallises, resulting in interlocking crystals. They are hard, strong, chemically unreactive, and impermeable. The mineral composition of the rock affects its properties, including colour.

	2. Crystal size depends on the rate at which molten rock cools; faster cooling results in smaller crystals. 3. Extrusive igneous rocks are formed from molten rock that erupts onto the surface as lava and cools quickly. 4. Intrusive igneous rocks are formed by molten rock that cools slowly deep underground.
8.C4.03 Weathering and erosion	1. Weathering is the slow breakdown of rocks while they are in place; it does not move rock pieces to another location. 2. Rocks can be weathered biologically (e.g. tree roots growing or animals burrowing), chemically (e.g. rainwater chemicals reacting with minerals), or physically (e.g. freezing water or temperature changes). 3. Freeze-thaw is a physical weathering occurring when water collects in cracks or pores, and freezes. As water freezes, it expands, increasing its volume, which forces cracks to widen. Repeated freeze-thaw cycles weaken and eventually break the rock. This process requires many cycles over a long period. 4. Erosion is the movement and carrying away of rock fragments, often weakened by weathering, by wind, rain, water, ice, or gravity. While erosion can break rock fragments further, it is distinct from weathering.
8.C4.04 Sedimentary rock formation	1. Sediments are tiny pieces of rock, soil, and other natural material that settle at the bottom of water and on the surface of Earth's crust. 2. The formation of sedimentary rock involves weathering (breaking rocks into sediments), transportation (moving sediments by erosion), deposition (sediments settling), sedimentation (layers building up), compaction (layers compressing over millions of years), and cementation (minerals hardening and sticking sediments together). 3. Strata are horizontal layers of sedimentary rock formed in chronological order, providing clues about past organisms and environments.

	4. Sedimentary rocks are made up of separate grains, are often soft, can be easily scratched and crushed, are permeable and are generally chemically reactive.
8.C4.05 Metamorphic rock formation and the rock cycle	1. Metamorphic rocks form deep within the Earth's crust due to high temperature and pressure, causing chemical changes in minerals. Over millions of years, sedimentary and igneous rocks transform into metamorphic rocks, often near tectonic plate boundaries. 2. Metamorphic rocks are hard, chemically unreactive, colourful, and impermeable, with unclear crystals due to compression. 3. The rock cycle involves recycling of rocks through weathering, erosion, sedimentation, compaction, cementation, and melting, during which rocks can change into different types.
8.C4.06 Fossils	1. A fossil is the preserved remains or trace of a dead organism from millions of years ago, primarily found in sedimentary rocks. High temperatures and pressure destroy fossils; they are not found in metamorphic or igneous rocks. 2. There are three main types of fossils: trace fossils (imprints or evidence of activities like footprints or burrows), body fossils (actual remains like bones or shells), and mineralised fossils (hard parts replaced by minerals). 3. Fossilisation occurs when a dead organism is buried under sediment, with soft parts decaying and hard parts remaining. Sediment layers build up, compact, and form sedimentary rock. Mineral-rich water soaks into the remains, becoming rock through mineralisation. This fills pores with minerals or replaces hard parts with mineral crystals, creating moulds or casts. 4. The fossil record shows how organisms and environments have changed over time. It is incomplete as few organisms fossilise, and geological activities can destroy fossils. Younger rocks are at the top, with simpler organism fossils in older rocks and more complex ones in newer rocks.

8.C4.07
Fossil fuels

1. Fossil fuels, including coal, crude oil, and natural gas, are carbon-rich natural resources formed over millions of years from remains of dead organisms.
2. Coal, a combustible sedimentary rock, forms from dead plants in swamps under high pressure and temperature.
3. Crude oil and natural gas originate from ancient plankton, transformed within sedimentary rock and collected below impermeable layers.
4. These fossil fuels store chemical energy and are primary energy sources for electricity generation, transportation, industrial processes, and heating. They are non-renewable; they cannot be replenished at the rate they are consumed.
5. Coal is mined through surface and underground mining, while crude oil and natural gas are extracted by drilling wells. Processed coal is used for electricity, steel production, and heating. Crude oil is refined into products like petrol and diesel, used in transportation and industry. Natural gas is used for home heating and cooking, electricity generation, and various industrial applications.
6. The extraction of fossil fuels has significant benefits, e.g. producing useful products, providing electricity to meet energy demands of a growing population, improved transport and creating employment.
7. Increased mining and extraction have negative implications, e.g. increase in atmospheric carbon dioxide, noise, air and water pollution, waste disposal challenges, loss of habitats, shortages of raw materials and the disproportionate negative impact on poorer countries, which face greater environmental and social consequences.

8.C5.01 Earth's atmosphere	1. The atmosphere is a thin layer of gas extending above the Earth's surface. It consists of nitrogen, oxygen, carbon dioxide, argon, and other gases including water vapour. 2. The atmosphere provides essential elements for respiration, protects against harmful light rays, and maintains a stable climate. It plays a role in industrial and agricultural processes. 3. Earth's early atmosphere contained large amounts of carbon dioxide, nitrogen, water vapour, ammonia, and methane, resembling the atmospheres of Mars and Venus. Over billions of years, its composition changed, with ammonia disappearing and quantities of other gases altering dramatically. 4. The modern atmosphere has seen a significant rise in carbon dioxide levels due to human activities (e.g. fossil fuel combustion).
8.C5.02 The greenhouse effect, global warming and climate change	1. Earth's atmosphere contains greenhouse gases (e.g. carbon dioxide, methane, and water vapour), which keep Earth warmer than it would be without them. The natural greenhouse effect warms the Earth to habitable temperatures. 2. The enhanced greenhouse effect refers to unnatural warming due to increased levels of greenhouse gases. Human activities (e.g. burning fossil fuels) have increased the concentration of these gases, increasing global temperatures. The rise in average global temperatures (global warming) contributes to climate change. 3. Climate change leads to social, economic, and environmental impacts. Socially, it affects communities, health, and living conditions. Economically, it changes jobs, industries, and incomes. Environmentally, it impacts animals, habitats, ecosystems, and food chains.
8.C5.03 Acid rain	1. Some human activities (e.g. factories, power stations, burning fossil fuels) release polluting gases leading to acid rain. Sulfur dioxide (SO_2) and nitrogen oxides (known as NO_x) are pollutants caused by burning fossil fuels. Catalytic converters in vehicles reduce acid rain by reducing emissions of nitrogen oxides (NOx).

2. All rain is weakly acidic due to dissolved carbon dioxide. Atmospheric pollutants may cause rain to become strongly acidic (pH <5.5). Sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react with water vapour, oxygen, and other chemicals to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3).
3. Pollutants can be carried a long distance from their source, by wind and weather patterns, far from where acid rain falls.
4. Acid rain damages buildings, statues, and metal structures by reacting with metals and rocks (e.g. limestone). It leaches minerals from the soil, reducing fertility, and harms the waxy layer on tree leaves, hindering mineral absorption and killing the trees. Acid rain also makes rivers and lakes too acidic for some aquatic life to survive.

Physics

8.P1 Motion and Forces

8.P1.01 Speed	1. The motion of an object is affected by forces acting on it and described by the distance travelled or the speed. 2. A faster object will travel a greater distance in a given time interval, and have a higher average speed. 3. Speed is a measure of distance travelled in a given time. 4. Students should be able to apply the formula: speed = distance travelled / time taken. 5. Moving objects have a steady (uniform) speed or one that changes. Instantaneous speed is speed at a specific instant in time.
8.P1.02 Distance-time graphs	1. An object's motion can be visualised and interpreted using a distance-time (*d*-*t*) graph, to determine the: distance travelled by an object in a given time; time taken to travel a given distance; average speed for a given journey. 2. In a distance-time graph a horizontal line indicates no change in distance over time; straight diagonal line indicates a moving object at a steady speed; steeper line indicates a faster steady speed; curve indicates a changing speed.
8.P1.03 Relative motion	1. The speed of an object depends on the frame of reference in which it is measured (e.g. speed of a car relative to the ground). 2. Relative motion is the motion of an object viewed from another frame of reference (e.g. speed of a car relative to another car travelling in the opposite direction). 3. Relative speed can be calculated by combining the speeds.
8.P1.04 Acceleration	1. Acceleration is caused by a non-zero resultant force on an object. It is the process of changing speed (or direction) over a time interval. 2. A resultant force on an object acting in the same direction as its motion causes acceleration in that direction (gets faster).

	3. A resultant force on an object acting in the opposite direction to its motion causes acceleration in that direction (gets slower, deceleration). 4. Acceleration depends on mass, and the size and direction of resultant force. 5. Larger masses need a greater force to change their speed by the same amount in a given interval of time. 6. The greater the resultant force, the greater the change in speed in a given interval of time. 7. If the resultant force is in the same direction as the motion, speed increases; if in the opposite direction, speed decreases.
8.P1.05 Motion in fluids	1. Drag force, frictional force on moving in a fluid, occurs due to a moving object pushing particles out of the way as it moves; it acts in the opposite direction to the motion of the object. 2. Drag force can be decreased with lower speed; smaller surface area 'facing' the motion; more streamlined shape; reduced viscosity/density. 3. During motion through a fluid, energy is transferred to thermal store of the object and fluid, by the mechanical pathway. 4. Drag forces can be useful or a nuisance. 5. The driving force may change during an object's motion in a fluid; if force drops to zero, it eventually slows down and stops. 6. Objects 'falling' in a fluid (e.g. air) experience drag force. 7. Falling suggests one object is moving towards another object due to gravity forces between them. 8. An object falling faster experiences a larger contact force when it hits the ground. To reduce damage to the object, it is useful to use a parachute to decrease speed. 9. When a parachute opens, surface area in contact with air increases, increasing drag force. This creates a resultant force opposite to motion, causing acceleration in opposite direction, which slows the object down.
8.P1.06 Weight	1. The weight of an object depends on its mass and gravitational constant of large object to which it is attracted.

	2. Students should be able to apply the formula: weight = mass x gravitational field strength. 3. Near the Earth's surface, the weight of 1 kg is approximately 10 N; the Earth's gravitational field strength, *g*, is 9.8 N/kg. 4. Objects with a greater mass experience a greater gravity force. 5. Objects falling in a vacuum under a gravity force experience same acceleration regardless of mass, because although the gravity force acting on a larger mass may be greater, it requires a greater force in proportion, to change its speed.
8.P1.07 Work	1. When energy is transferred to an object's stores, work is done on it. 2. Work can be done on an object when energy is transferred to it by the mechanical pathway, electrical pathway or heating pathway (or radiation pathway). 3. Mechanical work is done when a force is exerted to move an object. 4. The work done on an object increases when a greater force is applied and when the distance over which the force is applied is greater. 5. Students should be able to apply the formula: work done = force x distance moved. 6. Efficiency describes the extent to which a useful energy transfer has taken place. 7. Students should be able to apply the efficiency formulae.
8.P1.08 Turning forces	1. Any rigid object that is pivoted at a fixed point can turn under the action of a force acting at any other point on the object. 2. If an object rotates under the action of a force, it is known as the turning effect of the force. 3. The turning effect can be calculated by finding the moment of the force, the moment of a force is greater if a greater force is applied; a force is applied at a greater perpendicular distance from the pivot. 4. Students should be able to apply the formula: moment = force x distance from pivot.

	5. Multiple moments of a force can act on an object. The moment of a force causing an object to turn clockwise is the clockwise moment, and to turn anticlockwise is the anticlockwise moment. The overall turning effect is the sum of all moments (taking into account if they are clockwise or anticlockwise). 6. Objects that can turn but are in balance have zero overall moment of a force (i.e. a total clockwise moment equal to the total anticlockwise moment).
8.P1.09 Support forces	1. Objects supporting another object in static equilibrium experience distortion, causing an interaction force pair to arise: the normal contact force. 2. Distortion is increased when the object has greater mass (for the same area). 3. Distortion causes particles to have greater forces between them because they are under compression or tension forces. 4. Distortion increases when the applied force acting on a supporting object increases, therefore more work is done to it and more energy is stored by the object. 5. Supporting objects returning to original shape and size when an applied force is removed are made from elastic materials. 6. Supporting objects have a maximum energy that can be stored by their structure. 7. If the force applied is too large, the material can no longer behave elastically; it passes the elastic limit. Any supporting object with a force beyond the elastic limit will break. They break when the structure can no longer absorb energy into its stores. 8. Hooke's Law states that the change in length of an object (extension/compression) is proportional to the force applied to it within the elastic limit. 9. Students should be able to apply the formula: force applied to a spring = spring constant x extension. 10. Pressure relates the force applied to an object and the area over which the force is applied. 11. Students should be able to apply the formula: pressure = force /area.

	12. Higher pressure causes greater distortion, and greater normal contact forces arise between object and surface. 13. Pressure is transmitted through solids and liquids because particles in those states are 'touching'.
8.P1.10 Simple machines	1. Simple machines change force needed to move a load by changing distance over which force acts. 2. Simple machines change direction of forces needed to move an object making it easier to apply them. 3. Simple machines include levers, pulleys and gears. 4. Levers have a pivot (fulcrum), load and applied force. They work by application of the turning effect. 5. Hydraulic machines can act to multiply force or distance of an applied force. 6. Energy is always conserved, including in the use of simple machines. 7. Simple machines all transfer energy by the mechanical pathway; they do mechanical work on objects. 8. No machine is perfectly efficient.

8.P3 Matter

8.P3.01 Temperature	1. The temperature of matter is a measure of how hot it is. 2. Temperature is a physical measure of the average energy of particles due to their motion. 3. Particles in hotter matter (on average) have more energy than in colder matter; they vibrate more, and in liquids and gases they move faster.
8.P3.02 Changing energy in the thermal energy store	1. When particles of matter are caused to vibrate or move more, energy in thermal store of matter increases. 2. Energy is constantly transferred between thermal stores of objects in contact. 3. When two objects with different temperatures are in contact, there is a spontaneous net flow of energy transferred from the hotter to the colder region.

4. With no overall flow of energy to or from an object, temperature is constant. With a net flow, temperature changes.
5. Rate of energy transfer between objects in contact depends on their temperatures, surface in contact, and materials between them.
6. Energy is transferred between objects of different temperatures in contact by the heating pathway.
7. Energy can be transferred to an object's thermal store by mechanical, electrical, chemical reaction or radiation pathways.
8. During heating, more energy is supplied to an object than dissipates from it to its surroundings: there is a net flow of energy. Cooling occurs when there is a net flow of energy from an object's thermal store.
9. A heating/cooling graph shows the temperature increase of a material/substance over time.
10. The sloped lines in a heating/cooling graph represent one state of matter and a change in temperature.
11. When mixing liquids with different temperatures, the resulting mixture has a temperature between the two initial values. If both have the same temperature, the temperature is unchanged.
12. A steady temperature is reached when the net flow of energy into an object's thermal store is equal to the net flow of energy out of its store.
13. Objects left in contact in a closed system will eventually all reach the same temperature (thermal equilibrium).
14. An object's temperature can be kept steady even if different to its surroundings.
15. Objects experiencing constant exothermic chemical reactions lose energy from their thermal store to the surroundings, and need a continued supply of energy to their thermal store.
16. When friction forces act between surfaces, energy is transferred from the kinetic store to the thermal store by a mechanical pathway.
17. Rubbing increases energy in the thermal stores of both objects in contact.
18. When light falls on an object, energy in its thermal store increases due to absorbing energy by the radiation pathway.

	19. Hotter objects transfer energy at a distance to cooler objects by the radiation pathway (infrared radiation). 20. The rate of energy transfer to and from objects by the radiation pathway depends on surface area and colour: matt, dark surfaces transfer energy at a higher rate than shiny, light surfaces.
8.P3.03 Thermal conduction	1. Thermal conduction transfers energy between thermal stores of objects. Energy transfers from a source to particles, which means they vibrate more and cause energy to transfer to neighbouring particles. 2. Thermal conduction is a result of spontaneous transfer of energy from a region where there is a higher temperature to a region where there is a lower temperature. 3. Thermal conduction occurs between objects in their solid state, or in matter where different regions are at different temperatures. 4. Thermal conductors transfer energy quickly when heated; energy is easily passed from particle to particle. 5. Metals are good thermal conductors; they have high thermal conductivity, they efficiently transfer energy between particles. 6. Non-metals are poor thermal conductors. 7. Thermal insulators are poor thermal conductors that block energy transfer to/from thermal stores (e.g. trapped air, plastic, wood). 8. Thermal conductors feel cold when touched; they transfer energy away from our bodies easily. Thermal insulators often feel warm, because they do not. 9. Ceramics and polymers (plastics) are poor thermal conductors and act as good thermal insulators. 10. The thermal conductivity properties of composites vary depending on composition. Properties are a combined effect of different materials, including ceramics, polymers, and metals.
8.P3.04 Energy stores of a material	1. When attractive forces between particles are weakened (i.e. during a change of state), energy is stored in the material. 2. The total energy of the object includes both energy in its thermal store and energy stored due to 'separation' between particles of the material.

	3. When an object is heated, increases in temperature depend on energy supplied, its mass and material. 4. Objects with greater mass (same material, same temperature) have more particles (with same average energy), so total energy is greater. 5. Some materials require a greater amount of energy supplied to their thermal store than others for the same temperature change and mass. 6. When temperature changes, no change of state takes place. 7. Forces of attraction between particles are strongest in solids, and weakest in gases. 8. Energy stored in a material due to 'separation' between particles is lowest in solids and highest in gases. 9. During changes of state, energy transferred to materials 'separates' the particles without increasing temperature. 10. On heating/cooling graphs, horizontal lines represent changes of state and constant temperature.
8.P3.05 Pressure and density	1. Matter expands when heated; contracts as it cools. 2. During thermal expansion, particles stay same size, but take up more space. Solids: changes in space are due to increased particle vibration; liquids and gases: due to increased movement. 3. Thermal expansion and contraction can be useful (e.g. a liquid thermometer) or a nuisance. 4. In changes of state, amount of space matter takes up changes. 5. Pressure on an object is due to a force exerted on its surface. 6. Low pressure is caused by a small force or a force dispersed over a large surface area; high pressure is caused by a large force or a force concentrated on a small surface area. 7. Materials/objects experience pressure due to: weight pushing down on their lower surface, or weight of materials/objects above them, pushing on other surfaces. 8. Fluids experience pressure from forces between particles as they collide with each other, and in a container, between particles and inside walls of the container. 9. Pressure can affect density by changing space matter takes up.

	10. Density is a physical property of matter describing 'heaviness for its size'. 11. Students should be able to apply the formula density = mass /volume. 12. Gasses tend to be less dense than liquids, and liquids less dense than solids, of the same substance. 13. Hotter materials tend to be less dense, because their particles take up more space. 14. If temperature of an uncontained gas increases, the space it takes up increases and density decreases.
8.P3.06 Convection	1. Convection is when energy transfers between thermal stores of regions in a fluid with temperature differences between them. 2. As temperature of one region of a fluid increases, particles move more, taking up more space. The fluid expands, and becomes less dense than regions around it. 3. Less dense regions of a fluid rise, relative to more dense regions. 4. As less dense regions of a fluid rise, there is a net flow of energy transferred from one place to another. 5. Convection currents are the movement of fluids because of temperature differences.
8.P3.07 Thermal transfer by radiation	1. Thermal radiation is a type of thermal transfer. 2. Thermal radiation occurs because a type of light 'lights up' the space around objects. 3. Infra-red light is emitted from all objects, and is most intense from hotter objects. 4. Infra-red light is detected by infra-red thermometers, infra-red cameras and skin. 5. Objects can absorb infra-red radiation without contact. 6. All objects absorb infra-red radiation. 7. The net transfer of energy to or from an object depends on its temperature relative to the surroundings. 8. When an object absorbs energy by the radiation pathway, its particles increase in energy, increasing the object's internal energy.

	9. The rate of transfer of energy by infra-red radiation depends on the object's temperature, its surface area, surface colour and texture. 10. Dark, matt surfaces increase the rate of transfer of energy by infra-red radiation. 11. The greater an object's surface area, the higher the rate of transfer by infra-red radiation.
8.P3.08 Real-world contexts	1. Building design considers heating and cooling effects on matter. Buildings are designed to maintain steady temperatures, independent of surrounding temperature. When surroundings are cooler than inside, the net flow of energy transfers to thermal store of surroundings, and vice versa. 2. The greater the temperature difference between surroundings and inside, the higher the rate at which energy is transferred. 3. Increased transfer to surroundings requires greater use of fuel to heat building. 4. Building features to reduce energy transfer by conduction, convection and radiation pathway, include cavity wall insulation, loft insulation, double glazing and draught excluders. 5. Designing efficient devices and buildings reduces fuel use and costs. 6. The greenhouse effect is an example of thermal equilibrium to maintain a medium, steady average global temperature. 7. Weather systems are driven by temperature differences of different surfaces of the Earth. For example, air above hot surfaces causes air to expand and reduce in density. Lower density air has lower weight than higher density air (of the same volume). Lower density air exerts less force on Earth's surfaces for every square metre and is known as a low-pressure system. Air rises in low-pressure systems. Note, students are taught about the typical weather events caused in high- and low-pressure systems in Year 8 Geography.

8.P4 Electricity and Magnetism

8P4.01 Simple circuits	1. A simple electrical circuit consists of a conducting loop, a single device, connected to two terminals of a power source, with connecting wires.

	2. An electrical circuit always includes a battery (of cells) or a power supply. 3. Components of electrical circuits link the conducting loop (connecting wires and switches) or transfer energy for a purpose (e.g. batteries, bulbs, buzzers and motors). Most have two contact points. 4. A simple electrical circuit connecting a battery and bulb will light up immediately. 5. Switches can be placed anywhere in a conducting loop to control if the circuit is 'on' or 'off'. 6. A cell contain chemical substances which react when the terminals are connected. There is a positive and negative terminal. 7. The battery has a chemical energy store. When in a circuit, it transfers energy to the circuit by the electrical pathway, until its reactants are used up. 8. Cells added together by putting one terminal of a cell in contact with opposite terminal of another is a battery. 9. When size of the battery is increased: bulb is brighter; or buzzer is louder. 10. A series circuit is one whose components make up a single conducting loop.
8P4.02 **Electrical charge**	1. Electrical charge is a physical property of matter; some matter can exert a force on other matter at a distance. 2. Objects attracted/repelled by this non-contact force (electrostatic force) are 'charged'. 3. Matter with freely moving charged particles can conduct electricity. 4. Materials in the solid state that are electrical conductors, are made up mostly of particles that are fixed in position resulting in it having the physical properties of a solid. They also have available some charged particles that are free to move throughout the material. 5. If an object is charged, it exerts an electrostatic force on other charged objects.

	6. Charged objects are described as positively or negatively charged. Uncharged objects are described as neutral. 7. Some particles are charged objects, some of which can move freely in matter. 8. Objects with the same charge repel. Objects with a different charge attract. 9. Metals have many charged particles available to move freely; all have the same type of charge. 10. The positive terminal of a power source is positively charged, and the negative terminal is negatively charged. 11. Because power sources have terminals that are differently charged, they exert an electrostatic force on other charged objects. 12. One scientific model to explain how circuits work is the electric circuit model: charged particles originate in the circuit all around the loop; forced to move in one direction by the power source, they keep moving as long as power source has energy in its store. 13. Charge is conserved in the circuit: number of charged particles removed from circuit is same as those added. 14. The size of charge on a freely moving charged particle is tiny. The common unit for an amount of charge passing through a material is the coulomb (C) which is the size of charge of many charged particles added together; treated as one amount.
8P4.03 **Electric current**	1. Current is the rate at which freely moving charged particles are pushed around a circuit (i.e. amount of charge passing a given point each second). 2. Current cannot be used up in a circuit. 3. Current is the same size at any point in a series circuit. 4. Increasing supply voltage increases the current. 5. Ammeters are placed in series. 6. Ammeters are designed so that energy transferred to them by charged particles drifting through them is almost nothing.

	7. Current is represented by an arrow on circuit diagrams and flows from positive to negative. 8. Students should be able to apply the formula I = Q /t.
8P4.04 **Work done by charged particles**	1. Cells (in a battery) and power supplies have a 'voltage'. 2. A higher voltage exerts a larger force on charged particles. 3. Charged particles experiencing a larger resultant force move at a higher rate; the size of the current is greater. 4. If current through a component is larger, more energy is transferred each second, and more work is done by the charged particles. 5. Increasing current, increases the brightness of a bulb or speed of a motor. 6. Adding components to a series circuit causes current to decrease. 7. As more 'load' components are added in series, the average speed of charged particles decreases almost immediately. 8. Every component in a circuit transfers energy. 9. With more components in a series circuit, more energy is required to push free charged particles with the same force. 10. As free charged particles move through a component they transfer energy by the electrical pathway: a. Energy is transferred to bulbs by the electrical pathway, and away by the radiation pathway. b. Energy is transferred to motors by the electrical pathway, and away by the mechanical pathway. 11. Increased force on the charged particles increases energy available to transfer to the component. 12. Charged particles transfer energy by the electrical pathway to parts of a circuit, increasing the temperature of the components. 13. The voltage across a component is a measure of the energy transferred by charged particles to the component. 14. Electrical devices are designed to work with a specific voltage. If the voltage is less than the device is specified for, the effect

	is weaker. If larger it may damage it; its temperature increases and may melt or start a fire. 15. A voltmeter is connected between two points of the circuit, to measure the electrical 'push' on the current needed to transfer energy to the component. 16. Increasing the number of components in a series circuit decreases voltage across each component (for a given voltage of power supply). 17. Increasing the voltage of power supply increases the voltage across each component (for a given set of components in a series circuit). 18. The sum of voltage across every component in the series circuit equals voltage of power supply. 19. Voltage is not always shared equally across components. 20. The chemical store of the battery decreases when the circuit is working. 21. The thermal store of the surroundings increases when the circuit is working. 22. Power is the rate at which energy is transferred by an object. 23. Students should be able to apply the formula P = E I t.
P4.05 **Electricity at home**	1. Domestic appliances require an electrical source to power them. 2. Domestic appliances vary in how much energy is transferred in a given time. 3. Appliances designed to transfer energy at a higher rate, complete work faster, with a greater force and/or over a longer distance in a given time interval. 4. An electric appliance that transfers more energy in a given time than another is more powerful. 5. Some electric appliances are designed to be more powerful; they require a larger current or transfer more energy per coulomb. 6. Domestic electric appliances whose function is to transfer energy by heating need more power than other devices.

7. The power required by a domestic electric appliance is found on the appliance rating plate attached to it.
8. Electrical appliances that work for longer transfer more energy than ones working for shorter periods (if power is the same).
9. People need sources of energy for: heating, food storage or preparation, lighting, entertainment and communication appliances, and cleanliness and care appliances.
10. Electrical power is a secondary source; it is not available as a raw resource; energy from primary sources is used to generate electricity.
11. Domestic users of electricity pay companies for their supply.
12. Electricity companies charge domestic users for energy transferred by the household in a period of time (number of kWh), and charge an additional fee (standing charge).
13. Students should be able to apply the formula: energy transferred = power rating x time.
14. There are negative effects of using primary energy sources including, global warming, air pollution, space taken up by energy industry and transmission of electrical current, mining for rare materials.
15. There are some negative effects of using electrical appliances including risks associated with disposal and the risk of fire.
16. Some appliances are more efficient than others.
17. Efficient appliances stay cooler. There may be little mechanical work (rubbing); if they transmit light they do not get hot; or if their function is to heat something, energy does not dissipate to the external surroundings.
18. Efficient appliances transfer a larger proportion of energy supplied to them usefully, and a smaller proportion of energy is dissipated to the surroundings.
19. When selecting an appliance for a given use, domestic users use information about its function (e.g. bulb brightness), the power rating, the efficiency, the costs (initial and usage), how long it lasts, and measures of its sustainability.

8.P5.01 The Solar System	1. Our solar system includes the Sun, eight planets and many dwarf planets (which orbit the Sun), and their moons. 2. The Earth appears locally flat because it is very big but is spherical, as are all planets. 3. All planets have mass. There is a gravity force between them and objects approaching their surface (‘*g*’ is different for each planet). All objects have weight acting towards centre of the planet (downwards). The weight of an object varies depending on the planet. 4. The Sun is a star. It is much bigger than the Earth but looks small because it is far away. 5. The Moon is a rocky sphere; has no atmosphere; is non-luminous; part of its surface is always illuminated by the Sun’s light (though visibility of the lit-up surface from Earth changes as the Moon orbits); is smaller than Earth; has less mass the Earth; is a natural satellite of the Earth (with 28 day orbit). 6. Most other planets have moons orbiting them.
8.P5.02 Day and night	1. During the day, the Sun’s position in the sky changes in an arc; its highest position is at midday. The Sun’s apparent movement across the sky is due to the Earth's rotation. 2. The Sun emits visible light seen with the naked eye and through optical telescopes and cameras. 3. Solar radiation illuminates the half of the Earth facing the Sun; this is daytime. The Earth's surface facing away from the Sun is not illuminated (in shadow); this is nighttime. 4. The Earth rotates anticlockwise every 24 hours (a day), about an axis. Different parts of Earth's surface are exposed to the Sun's radiation throughout a day. A day is the time taken for a planet to rotate once. 5. The Sun rises in the east, travels in an arc across the sky, and sets in the west. At noon, it appears in the south viewed from the northern hemisphere, and in the north when viewed from southern hemisphere, directly overhead the observer.

8.P5.03 Years and seasons	1. Earth orbits the Sun every 365.25 days (a year) due to a gravity force on Earth by the Sun; there is a resultant force acting on the Earth towards the Sun. 2. The Earth has seasons due to the Earth rotating on a tilted axis, which is constant in space. 3. During summer time for a given hemisphere (vice versa for winter time), Earth is tilted towards the Sun and during one rotation, more of it is exposed to more light than opposite hemisphere (long days of more than 12 hours, and shorter nights). 4. Solar radiation in summer is incident on the Earth's surface for longer periods of time in each rotation. At any given time of day, the Sun is higher than in winter (it moves through a greater arc); solar radiation is incident on the surface at a more acute angle, so is more intense, and transfers more energy each second (is hotter). 5. When the Earth is not tilted towards or away from the Sun, all parts of the Earth receive equal periods of daytime and nighttime (the two equinoxes). 6. Different planets take different times to orbit the Sun (their year); the gravity force between a planet and the Sun depends on distance between them and is smaller as distance increases. They have a longer path and travel slower.
8.P5.04 The universe	1. The Solar System is only a tiny part of the Universe. 2. Stars are huge balls of hot gas and are luminous so can be seen in the night sky even though they are very far away. 3. Stars move across night sky because the Earth rotates. Because they are far away, they appear fixed in space relative to the Earth. 4. A collection of stars is a galaxy. Our galaxy is called the Milky Way and contains hundreds of billions of stars. The Universe contains billions of galaxies. 5. The Universe has changed. Stars start out as clouds of dust and eventually become cold, dense masses. The Big Bang theory suggests the Universe began as a very small, extremely hot and dense region. It expanded, forming collections of matter under gravity forces. The distance between galaxies is increasing.

Disciplinary Knowledge to Be Taught in Year 8

A glossary of key terms can be found in Appendix A.

Scientific Attitudes and Ways of Thinking

8.WSAT 1 Seeking Objectivity

8.WSAT 1.01 Scientific thinkers and objectivity	1. Scientific thinkers seek evidence to support their explanations. 2. Students should be able to identify procedures that are likely to be valid (i.e. produce evidence).
8.WSAT 1.02 High-quality data	1. Data is valid if it is accurate, repeatable and reproducible. 2. Students should be able to describe the extent to which data is valid.
8.WSAT 1.03 Measurement error	3. During measurement there is always some uncertainty or doubt about the result obtained. 4. Measurement error may be a systematic error; if identified, it may be possible to reduce or remove a systematic error, by considering the environment, methods of observation or instruments used. 5. Measurement error may be random error. Sometimes a random error may be a parallax error if the scale is viewed from a random angle each time; it can be a systematic error if the scale is viewed from the same 'wrong' view each time. 6. Precise measurements have very little spread about the mean value; precision indicates only the extent of random error. 7. Students should be able to decide whether measurement results are precise.

8.WSAT 2 Development of methods and theories over time

8.WSAT 2.01 Developing scientific methods	1. There are a range of types of scientific method; they can be broadly categorised as to whether they test a hypothesis and if they manipulate variables.

8.WSAT 2.02 Changing methods	1. After data collection, scientific thinkers propose a scientific theory; it is based on a body of facts and is repeatedly confirmed by observation and experiment. 2. Students should be able to describe an example of how scientific theory has developed over time, e.g. our changing understanding of photosynthesis and transitioning from geocentric to heliocentric models in astronomy.

8.WSAT 3 Using a variety of models

8.WSAT 3.01 Describing models	1. A model is not a literal representation of reality; scientific thinkers decide which features of reality to 'show or hide'. 2. Students should be able to give examples of some scientific models. 3. Students should be able to describe what a specific model is representing and how it helps us understand the concept.
8.WSAT 3.02 Models, limitations and strengths	1. Scientific thinkers seek to understand the limitations and strengths of models they use to explain a concept. Some models are yet tentative and may likely change in the future; all models are limited in their ability to explain all aspects of reality. 2. Models empower scientific thinkers to conceptualise without necessarily being able to observe mechanisms directly. 3. Established models enable scientific thinkers to make accurate predictions without having to test them.

8.WSAT 4 The importance of peer review

8.WSAT 4.01 Scientific thinking and peer review	1. Research that has not been peer-reviewed is considered to be less trustworthy. 2. Scientific thinkers present evidence to their peers to support an opinion and explain their reasoning. 3. New scientific claims (results or explanations) that are to be published must be reviewed by other expert scientists. 4. Research often impacts peoples' everyday lives and, if not founded on evidence, could have negative consequences. 5. Students should be able to state the importance of peer review.
8.WSAT 4.02 Judging the quality of conclusions	1. The validity of scientific research can be judged on the validity of conclusions and the evaluation of the research. Note, students are not expected to write an 'evaluation', but to be able to comment on the quality of methods, data and conclusions. 2. Claims are more likely to be valid if: • the enquiry is systematic and methods have been selected for validity; • conclusions are drawn from all collected data and the data is valid; • data is analysed and interpreted using an agreed set of principles, e.g. clarity of processing, use of charts; • conclusions are explained using known facts, mechanisms or models; • evaluations have explained limitations to methods, data and conclusions. 3. Students should be able to identify how scientific claims can be judged for their validity.

Enquiry

8.WSEF 1 Planning for valid methods

8.WSEF 1.01 Developing scientific methods	1. Scientists develop a line of enquiry and clarify research questions the investigation seeks to answer. 2. Students should be able to develop a line of enquiry and identify a research question to investigate. 3. Scientists identify the data needed to investigate the research question (what is to be observed). 4. Scientists plan to collect valid data (accurate, repeatable and reproducible). 5. Scientists select a scientific method based on the research question and the available means to collect data to answer it. 6. Collected data is more likely to be valid if: 7. the apparatus and techniques selected are known to produce precise and accurate data; researchers must understand how to carry out the method with skill and to reduce the likelihood of measurement errors; 8. repeatability is planned for; 9. observation is over an appropriate range with systematic intervals. 10. Scientists may run a trial experiment to finalise a method. 1. Students should be able to plan aspects of a method (including apparatus, techniques and the data to be collected) to answer a research question.Scientists select the category of scientific method most appropriate to investigate a line of enquiry, considering available data, knowledge, technology, cost and time.
8.WSEF 1.02 Hypotheses and variables	1. When planning to test a hypothesis, a prediction can be made and the data to collect planned for, so that if the prediction is supported, so will the hypothesis. 2. When no hypothesis is to be tested, the systematic collection of observational data is planned for, but it is not known which data may lead to new knowledge.

	3. When planning to change a variable to observe its effect on another variable, and there is the means to do so, other variables are controlled. 4. If there are no means to manipulate variables, observations of a variety of variables may be systematically collected, ideally over time. 5. Students should be able to identify the category of scientific method most appropriate to investigate a line of enquiry. 6. Students should be able to make a hypothesis/ prediction to explain a research question. 7. Students should be able to state whether the data supports them. 8. Students should be able to appropriately plan to manage and manipulate variables where possible. 9. Students should be able to plan how to make systematic observations without changing a variable if it is not possible to do so.

8.WSEF 2 Common techniques and apparatus

8.WSEF 2.01 Equipment	1. The use of the equipment listed for Year 7 plus: beaker; spotting tile; water bath; electrical circuit components (to include power supply, connecting leads, switches, lamps, crocodile clips, resistors, motors). 2. Students should be able to identify equipment listed and skilfully use them. 3. Students should be able to set up simple series circuits.
8.WSEF 2.02 Measuring instruments	1. The use of the measuring instruments listed for Year 7 plus: ammeter, voltmeter, pH indicator scales. 2. Students should be able to identify measuring instruments listed and select the most appropriate instrument for the measurement.
8.WSEF 2.03 Techniques	1. The techniques listed for Year 7 plus: measuring temperature using a liquid thermometer; testing with indicators.

	2. Students should be able to carry out the techniques listed above.

8.WSEF 3 Planning for safe practical science

8.WSEF 3.01 General principles	1. It is the responsibility of every individual in an environment to take reasonable care for the health and safety of themselves and others. 2. To reduce risk of harm to an acceptable level an experiment may be redesigned. 3. There is a consensus of control measures for commonplace apparatus and techniques, some are specified in law. 4. Emergency procedures are in place if an accident due to fires, breakages, spills, burns, and ingestion, breathing in or contact with eyes or skin of hazardous substances. 5. Students should be able to use guidance to identify hazards and carry out an appropriate risk assessment. 6. Students should know relevant emergency procedures in the case of an accident.
8.WSEF 3.02 Managing specific hazards	1. Substances which are hazardous are labelled with a hazard symbol on the container including: moderate health hazard, serious health hazard, toxic, corrosive, flammable, oxidising and harmful to the environment. 2. Students should be able to identify hazards and their associated risks and control measures for heating liquids and chemical substances, with guidance. 3. Students should be able to identify the hazard symbols. 4. Scientists look up the likely risks for specific substances when designing the method, and related control measures suggested by safety services e.g., CLEAPSS. 5. The risks associated with using heating apparatus are burns, fire, damage to eyes, and damage to equipment. 6. The risks associated with using biological matter include potential allergic reactions or harm from the ingestion of contaminated food.

7. The risks associated with using chemicals may include harm from ingestion, breathing in or contact with eyes or skin of hazardous substances, or fire and its related potential harm.
8. Students should be able to describe risks associated with hazards listed.
9. Students should be able to describe control measures to reduce levels of risk as listed.

8.WSEF 4 Making valid observations

8.WSEF 4.01 Measuring

1. Digital measuring instruments are not marked off with a scale.
2. Scientists use measurement techniques to reduce the likelihood of measurement errors.
3. Students should be able to use appropriate techniques to make skilful measurements for quantities listed for Year 7, plus: electric current and voltage and pH.
4. Datalogging is a process by which sensors measure the physical properties of a system; they send signals to a computer (through an interface); the computer controls the data that is recorded e.g., the time intervals and the logging period.
5. Datalogging equipment is often used to collect data because it can measure:
    - over long periods of time without stopping;
    - over very short intervals;
    - very small or large quantities;
    - accurately (consistent and not subjective);
    - precisely (high resolution);
    - remotely.
6. Students should be able to collect data by manipulating and controlling/measuring variables/parameters.
7. Students should be able to identify the likelihood of systematic error and account for it.

8.WSEF 4.03 Reflecting on collected data	1. Collected data can be described, for example: qualitative or quantitative, primary or secondary, and the extent to which it is valid based on its accuracy, repeatability and reproducibility and its precision and resolution. 2. An observation can be biassed either by an instrument or a person; scientists seek to check any assumptions or pre-conceptions. 3. Students should be able to assess if collected data is within expected boundaries. 4. Students should be able to estimate the potential bias of a measuring instrument, e.g. how far the measured value is from the true value, using resolution or secondary data. 5. Students should be able to identify possible observer bias.

8.WSEF 5 Evaluating methods

8.WSEF 5.02 Evaluating methods	1. Scientists evaluate methods to produce valid data, including the selection of apparatus and techniques which produce different levels of measurement error. 2. Students should be able to select the most appropriate apparatus to collect data and explain why it is likely to result in more valid data collection. 3. Students should be able to carry out techniques with regard to validity and explain how the technique results in more valid data collection.
8.WSEF 5.03 Evaluating data analysis and interpretation	1. Scientists evaluate their analysis and interpretation of data by following agreed scientific principles: • The process of reducing the impact of random error by averaging. • Demonstrating mathematical processing undertaken clearly. • Selection of appropriate units and number of significant figures from processing. • Selection of appropriate charts, and their range.

	• Judge the extent to which patterns in data reflect the conclusion. 2. Students should adhere to agreed principles for analysis and interpretation of data as above.

Analytical and Evaluative Approaches

8.WSAN 1 Presenting, analysing, interpreting data; developing explanations; evaluating data

8.WSAN 1.01 Recording data	1. Recorded data is often presented systematically in tables, including: • all measurements and repeated measurements with anomalies identified; • data about IV, DV and CV, and any processed information, with IV in the left-hand column and the DV (or its processed values in the most right-hand column ('time' as a dependent variable is an exception and normally is in the first column; • rows that increase systematically, e.g. by appropriate levels; • quantitative data recorded precisely (significant figures appropriate to the measurement) and consistently. 2. Students should be able to prepare tables in advance of an experiment. 3. Students should be able to record all data clearly and systematically.
8.WSAN 1.02 Data, charts and graphs	1. Recorded (and processed data) is often displayed in charts and graphs for further analysis and interpretation. 2. Identifying the most appropriate chart or graph depends on the type of data and the line of enquiry: • bar charts – for frequency counts (or percentages) and for levels of categoric or discrete value. Some comparative enquiries use compound bar charts. (Note - histograms are not referred to at KS3.)

	• line graphs – for continuous data compared to other quantitative data, e.g. distance run each day; through data points or for comparing two sets of continuous data, commonly with a line drawn to approximate a trend. Note – here, line graphs means graphs with a line of best fit, not point to point. The line is used as a tool to 'average' data and assess the precision of collected data. 3. Students should be able to plot line graphs, identifying anomalies.
8.WSAN 1.03 Processing data	1. Raw data in tables may need to be processed by, • finding averages and ranges; • using a formula, e.g. density, speed; • finding frequency. 2. Processed data in tables is normally rounded; commonly a mean average is rounded to the same number of significant figures as the measurement result and solutions of formulae are rounded to the same number of significant figures as the 'worst' measurement result. 3. Removing anomalies and finding the mean average of a data set is a process used to reduce the impact of random error. 4. Students should be able to identify appropriate mathematical processes to use with data. 5. Students should be able to process data to include the above points.
8.WSAN 1.04 Tables, charts and qualitative observations	1. Values can be read from a pie chart, compound bar chart, or line graph. 2. Students should be able to interpret pie charts, compound bar charts and line graphs. 3. Qualitative observations cannot always be tabulated. 4. Students should be able to make accurate qualitative observations e.g., biological specimens and celestial observations.

8.WSAN 1.05 Basic conclusions	1. Scientific enquiries include a conclusion as set out for Year 7, plus: the conclusion describes any simple quantitative relationship if there is one. 2. Students should be able to make a conclusion, where appropriate.
8.WSAN 1.06 Interpreting data	1. Scientists always bring their knowledge, skills and experience to interpret data, by reading values off tables and charts, drawing lines of best fit (where appropriate), identifying patterns and any parameters and limitations of those patterns, extracting information from scientific drawings or carrying out quantitative energy analysis. 2. If the dependent variable changes in proportion to the independent variable, the factor they both change by is the same. 3. Students should be able interpret data, as listed above. 4. The rate of something happening may change over time (shown by a curve on a line graph against time). Rate, a derived quantity, is the speed at which something is changing or happening. 5. Interpreted data that is ready for peer review includes that of all collected and processed data.
8.WSAN 1.07 Evaluating findings	1. Scientists evaluate the validity of their conclusions based on the quality of their methods and data. 2. Scientists are aware their findings can be subjective, so the work is scrutinized through peer review. 3. The validity of the data is evaluated in relation to: • variables have been controlled appropriately; • the resolution of instruments is small enough to give a perceptible change in the reading; • the range of measurements is large enough to reveal trends, and has enough and systematic intervals to observe any changes in measured values; • the levels of repeatability; • its reproducibility;

	• the number of anomalies is low or there is a small spread of data from the line of best fit; • the confidence in any identified patterns. 4. Students should be able to comment on the validity of conclusions based on the list above.

8.WSAN 2 Managing uncertainty

8.WSAN 2.01 Random error	1. No researcher is completely certain of a measurement, it is assumed there is a possibility of measurement error, including random error. 2. Random errors are caused by, • the level of skill of the experimenter; • the limitations of the method, e.g. the ability to control the environment. 3. The likelihood of random errors can be reduced by, • the same experimenter completing each measurement; • using the same apparatus; • using the same technique. 4. The impact of random error can be reduced by, • identifying likely anomalies in tabulated data; • finding the mean average of each data set (ignoring any anomaly); • using graphs to approximate trends in data.
8.WSAN 2.02 Systematic error	1. No researcher is completely certain of a measurement, it is assumed there is a possibility of measurement error, including systematic error. 2. Systematic errors are caused by, • poor technique in the use of measuring instruments; • the resolution of measuring instruments; • the variation of certain measuring instruments accuracy.

8.WSAN 3 Implications and Extensions of Enquiries

8.WSAN 3.01 Possible implications of enquiries	1. Scientists understand that further lines of enquiry can emerge from their findings. 2. Students should be able to suggest: • other questions, or a different hypothesis; or • a different method or extension to datasets related to limitations in their data.

Applications of Science and its Implications

8.WSAI 1 Developing scientific knowledge through technology

8.WSAI 1.01 Examples of technological applications to science	1. As technology advances, scientific researchers apply it to solve methodological and technical problems that have limited enquiries in the past. 2. Technological applications increase the body of knowledge over time (as listed for Year 7), and also they: • use automated recording of measurements: over long periods of time, making multiple measurements in the same way, over very short intervals (which are all causes of random errors for human observers); • use recording devices which can be enlarged, viewed repeatedly, slowed (allowing for slower, more accurate measurements); • allow for remote measurements, where it would otherwise not be possible to make observation. (8.10 space?) 3. Students should be able to give examples of how the development of technology has increased the body of scientific knowledge.

8.WSAI 2 Developing technology through science

8.WSAI 2.01 Examples of scientific knowledge	1. STEM workers design solutions to problems using scientific advances to develop: • agricultural methods;

applications to industry	• industrial methods; • new transport methods. 2. STEM workers generally use physical, mathematical or computational models to test the effect of changes to materials or design and modify them. They consider how to optimise a solution within defined constraints such as cost. 3. Students should be able to give examples of technological developments due to an increased body of scientific knowledge.

8.WSAI 3 Ethical, social, economic, and political implications

8.WSAI 3.02 Global impact of scientific research	1. Scientific research is funded by various sources. 2. Applications of science have both positive and negative implications. The negative impact on poorer countries is often the greatest. 3. The implications for the application of science include, for example, demand for space; improved transport; increased mining; waste disposal; fertilisers and pesticides; shortages of raw materials; new raw materials required for modern solutions; working conditions; cost of solutions; global warming and climate change; energy demands. 4. Students should be able to describe the societal and environmental implications of scientific applications.

Protocols for Measurement

8.WSME 1 Units

8.WSME 1.01 Base quantities	1. There are agreed base quantities, which have base units for Year 7, and also: • electric current is the ampere (A); • voltage is the volt (V); • temperature is the kelvin (K). 2. Students should be able to identify these base quantities, state their base unit and other commonly-used units.

8.WSME 1.02 Derived quantities

1. Some quantities derive from the base quantities, normally expressed as products of powers of the base units as listed for Year 7, with some units having special names, and also:
    - Area – square metre (m^2); other common units are square centimetre (cm^2) for small areas.
    - Volume – cubic metre (m^3); other common units are cubic centimetre (cm^3), litre (l) and millilitre (ml). One cubic centimetre is equivalent to one millilitre and they represent the same volume.
    - Rate – per second (/s), a derived quantity: the speed at which something is changing or happening.
    - Energy (work done) – joule (J); its derived unit is the newton metre (Nm).
    - Power – watt (W); its derived unit is the joule per second (J/s).
    - Speed – metres per second (m/s); other common units are kilometre per hour (km/h) and miles per hour (mph).
    - Gravitational field strength – newton per kilogram (N/kg).
    - Spring constant – newton per kilogram (N/kg).
    - Moment – newton metre (Nm).
    - Density – kilogram per cubic metre (kg/m^3); other common units are the gramme per cubic centimetre (g/cm^3) or the gramme per millilitre (g/ml), which are equivalent and represent the same density.
    - Electric charge – coulomb (C); its derived unit is the amp second (As).
    - Voltage (voltage) – volt (V); its derived unit is the joule per coulomb (J/C).
    - Electric resistance – ohm (Ω); its derived unit is the volt per amp (V/A).
    - Electrical energy consumption or production – kilowatt-hour (kWh), and it is commonly used for calculating electricity bills.

- Mass – milligram (mg) is a unit used to measure small masses.
- Temperature – kelvin (K); a common unit is degree Celsius (°C) derived from the kelvin.
- Distance travelled through space in one year by light - light-year (ly); a convenient unit to measure distances in space.

2. Students should be able to identify the standard unit and other commonly used units for the quantities listed above.

8.WSME 2 Notation and conventions

8.WSME 2.01 Standard prefixes

1. The international system (S.I.) uses a range of unit prefixes which differ by the factor of 1 000, as listed for Year 7.
2. It is easier to compare the size of values when they have the same unit prefix.
3. To convert a quantity to a different unit, the prefix is a multiplying factor:
    - a prefix of kilo- multiplies the base unit by 1000;
    - a prefix of centi- divides the base unit by 100;
    - a prefix of milli- divides base unit by 1000.
4. Students should be able to identify these prefixes and what they mean, e.g. the number of millimetres in a metre.
5. Students should be able to use and convert between 'milli-', 'kilo-', 'centi-' and the base unit.

8.WSME 3 Symbols and formulae

8.WSME 3.01 Quantities and substances

1. Scientific thinkers use symbols to represent quantities, relationships, concepts and processes, used as shorthand to communicate clearly between scientists.
2. Scientific symbols may represent physical quantities, or chemical substances.
3. By convention, symbols representing physical quantities are shown in italics.

	4. Symbols representing physical quantities list can be found in Appendix C. Note, students are not expected to learn them but teachers should use them when modelling equations.
8.WSME 3.02 Formulae (equations)	1. A formula is an equation representing real-world variables, either using words or symbols. They can arise from experimental data and show a relationship between physical quantities. 2. Students should be able to use and rearrange the formulae listed in Appendix B. 3. Calculations are assessed for if the value looks reasonable.

Detailed Knowledge for Year 9

Substantive Knowledge to Be Taught in Year 9

The below outlines the detailed knowledge that should be taught by the end of Year 9, grouped by theme and topic.

These statements build on content from earlier years, with prior knowledge assumed and therefore not restated. Teachers should ensure that any required prior learning is secure and revisit it where necessary.

Items that are highlighted are new additions, which are new to the curriculum entirely. They have been added to the curriculum to ensure pupils have the opportunity to build strong, conceptual frameworks in smaller steps, which will prepare them for Year 9 and beyond.

Biology

9.B1 Cells and Life

9.B1.01 Cellular respiration	1. Cellular respiration is a series of chemical reactions in cells that break down glucose (an organic molecule) to transfer energy for life processes. It is exothermic because energy is transferred to the surroundings. All living organisms carry out cellular respiration. 2. Cellular respiration is distinct from breathing. 3. Organisms use biomass as fuel for respiration to make energy available for life processes. Biomass is transferred through feeding relationships.
9.B1.02 Aerobic respiration	1. Aerobic respiration requires oxygen: glucose + oxygen → carbon dioxide + water 2. Aerobic respiration occurs inside cells. In plant, animal and fungal cells, this mainly takes place in the mitochondria. Cells with higher energy demands (e.g. muscle cells) contain more mitochondria. Organisms without mitochondria (e.g. bacteria) carry out aerobic respiration in the cytoplasm. 3. Plants carry out both photosynthesis and aerobic respiration. Aerobic respiration uses glucose produced in photosynthesis as a fuel and transfers energy for life processes. Photosynthesis requires light, whereas respiration occurs continuously (day and

	night). In the light, both processes occur; in the dark, only respiration occurs.
9.B1.03 Anaerobic respiration	1. Anaerobic respiration occurs without oxygen when supply cannot meet demand e.g. intense exercise. Anaerobic respiration takes place in the cytoplasm. In animals, it involves the incomplete breakdown of glucose, producing lactic acid: glucose → lactic acid 3. Lactic acid build-up causes muscle cramps, fatigue and a burning sensation. It is transported to the liver and broken down. 4. Both aerobic and anaerobic respiration use glucose and transfer energy. Aerobic respiration requires oxygen and transfers more energy, more slowly and for a longer duration. Anaerobic respiration does not require oxygen and transfers less energy, more quickly and for shorter periods. 5. Plants and microorganisms can also respire anaerobically when oxygen is unavailable. In plants and many microorganisms (e.g. yeast), this produces ethanol and carbon dioxide: glucose → ethanol + carbon dioxide 6. Anaerobic respiration in microorganisms is called fermentation. Fermentation is used to produce carbon dioxide and ethanol, which is useful e.g. bread making and alcoholic drinks.
9.B1.04 Cell structure	1. Animal and plant cells are eukaryotic: they contain a nucleus and membrane-bound organelles. 2. Bacterial cells are prokaryotic: smaller, lack a nucleus, DNA is circular and found free in cytoplasm, may contain plasmids (small rings of DNA). 3. Ribosomes are the site of protein synthesis. The cell wall is made from cellulose. Permanent vacuole maintains turgor pressure. 4. All cells contain cytoplasm, cell membrane and ribosomes; only eukaryotes contain a nucleus. 5. Eukaryotic cells are larger (10–100 µm) compared to prokaryotic cells (~0.2–2 µm). 6. Typical cell sizes: animal cells ≈10–30 µm; plant cells can be larger; bacterial cells ≈1–5 µm.

	7. Comparison of sizes: bacterial cells are 1–2 orders of magnitude smaller than plant and animal cells; some organelles (e.g. mitochondria) are similar in size to bacteria. 8. Students should be able to carry out calculations using the formula: $magnification = \frac{size\ of\ image}{size\ of\ real\ object}$ 9. Students should be able to prepare a slides for both plant (onion) and animal (cheek) cells and use a microscope to observe them. 10. Cell differentiation is the process by which unspecialised (stem) cells develop into specialised cells with specific roles. In animals, most differentiation occurs early in development in the embryo. 11. Specialisation is important because multicellular organisms require different cells to perform different functions efficiently. 12. Sperm cells have many mitochondria to provide energy for movement, a streamlined shape for swimming, and enzymes in the head to penetrate the egg. 13. Nerve cells (neurones) are long and branched to connect with other cells; contain many mitochondria for energy and ribosomes for protein (neurotransmitter) production. 14. Muscle cells contain filaments of protein that slide over each other to cause muscle contraction. They contain many mitochondria to provide energy for muscle contraction.
9.B1.05 Transport in cells	1. Some of the substances transported in and out of cells by diffusion are oxygen and carbon dioxide in gas exchange, and of the waste product urea from cells into the blood plasma for excretion in the kidney. 2. A concentration gradient is the difference in concentration between two areas; diffusion continues until equilibrium is reached. 3. A steeper concentration gradient increases diffusion rate; higher temperature increases kinetic energy and particle movement; larger surface area increases rate by allowing more particles to cross. 4. A single-celled organism has a relatively large surface area to volume ratio. This allows sufficient transport of molecules into and out of the cell to meet the needs of the organism.

5. At equilibrium, particles continue to move randomly but there is no net movement.
6. Surface area to volume ratio (SA:V) compares the surface area of an organism to its volume; it is calculated as surface area ÷ volume or expressed as a ratio.
7. As size increases, volume increases faster than surface area, so larger organisms have a smaller surface area to volume ratio.
8. Small organisms have a large surface area to volume ratio, so diffusion alone is sufficient to supply materials and remove waste.
9. Large multicellular organisms have a small surface area to volume ratio and long diffusion distances, so diffusion alone is not sufficient. They require specialised exchange surfaces and transport systems (circulatory systems) to move substances efficiently.
10. Exchange surfaces are adapted for efficient diffusion by having a large surface area, thin membranes (short diffusion distance), moist surfaces, and a good blood supply to maintain a concentration gradient. Examples of this are alveoli, villi/microvilli, lamellae in fish gills.
11. Osmosis is the net movement of water molecules from a region of high-water concentration (dilute solution) to a region of low water concentration (concentrated solution) across a partially permeable membrane.
12. A partially permeable membrane allows small water molecules to pass through but prevents larger solute molecules.
13. Osmosis occurs in all living cells and is essential for maintaining cell function and water balance. Examples of osmosis are water uptake by root hair cells, maintenance of turgor pressure in plant cells, and changes in animal cells in different solutions.
14. In plant cells, water entering the cell causes the vacuole to swell, pushing the cytoplasm against the cell wall, making the cell turgid and supporting the plant.
15. In plant cells placed in a concentrated (hypertonic) solution, water leaves the cell by osmosis, causing the cytoplasm and vacuole to shrink; the cell becomes flaccid and may undergo plasmolysis.

	16. In a dilute solution, cells gain water and swell; in a concentrated solution, cells lose water and shrink. In animal cells, osmosis can cause cells to swell and burst (lysis) in dilute solutions or shrink (crenate) in concentrated solutions. 17. Active transport is the movement of substances from a region of low concentration to a region of high concentration, using carrier proteins to move the substances across the membrane. 18. Active transport requires energy from respiration, unlike diffusion and osmosis which are passive. 19. In plant root hair cells, mineral ions (e.g. nitrates, phosphates) are absorbed against a concentration gradient using active transport. 20. In the small intestine (villi), glucose is absorbed into the blood by active transport.
9.B1.06 **Cell division**	1. Genes are sections of DNA that code for specific proteins: gene → DNA → chromosome → nucleus → cell. 2. The cell cycle is a series of stages that cells go through as they grow and divide. 3. Stage 1 (interphase): the cell grows, increases sub-cellular structures (e.g. mitochondria and ribosomes), and DNA replicates to form two copies of each chromosome. During DNA replication, each chromosome is copied so that identical genetic information can be passed to daughter cells. 4. Stage 2 (mitosis): chromosomes are lined up, pulled apart to opposite ends of the cell, and the nucleus divides. 5. Stage 3 (cytokinesis): the cytoplasm and cell membrane divide to form two genetically identical daughter cells. 6. Most of the cell cycle is spent in Stage 1 (growth and DNA replication), with less time spent in mitosis. 7. Mitosis produces two identical cells with the same number of chromosomes as the original cell. It is important for growth, repair and replacement of cells in multicellular organisms. In plants, mitosis occurs in meristems such as root and shoot tips. 8. Stem cells are unspecialised cells that can differentiate to become specialised cells with specific functions.

	9. Plant stem cells are found in meristems (e.g. root and shoot tips) and can differentiate into any type of plant cell. 10. Embryonic stem cells are found in early embryos and can differentiate into any type of cell. Adult stem cells are found in tissues such as bone marrow and can only differentiate into a limited range of cell types. 11. Stem cells in embryos enable development into different tissues; in adults they replace damaged or worn-out cells; in plants they enable growth. 12. Stem cells can be used to treat diseases and injuries, such as paralysis and diabetes by replacing damaged cells (therapeutic uses). 13. Embryonic stem cells are useful because they divide rapidly into any type of cell, but their use destroys embryos, raising ethical concerns. 14. Adult stem cells are less controversial as donors can give consent, but they are less versatile as they form fewer cell types. 15. Therapeutic cloning involves creating an embryo using the patient's DNA so stem cells are genetically identical, reducing the risk of rejection. 16. Process of therapeutic cloning: remove nucleus from donor egg cell; insert nucleus from patient's body cell; stimulate division to form an embryo; use resulting stem cells. 17. Advantages of therapeutic cloning: reduced immune rejection, production of matching cells. Disadvantages: ethical concerns, risk of infection, use of embryos. 18. Plant cloning occurs naturally and artificially using cuttings; plants grown are genetically identical to the parent. Uses of plant cloning include producing large numbers of identical crops with desirable features and conserving rare species.
9.B1.07 Culturing microorganisms	1. Bacteria multiply by simple cell division (binary fission), e.g. every 20 minutes with enough nutrients and a suitable temperature. 2. Bacteria can be grown in a nutrient broth solution or as colonies on an agar gel plate. Students should be able to describe how to prepare an uncontaminated culture using aseptic technique.

3. To reduce contamination, petri dishes and culture media must be sterilised before use, inoculating loops are sterilised by passing them through a flame. The lid of the Petri dish is secured with adhesive tape (to reduce contamination form air but allow oxygen in) and stored upside down (to reduce condensation). In school laboratories, cultures are incubated at a maximum temperature of 25°C to reduce harmful bacteria growth rates.
4. The effectiveness of antiseptics or antibiotics is tested by measuring the zone of inhibition on an agar plate, which is the area where bacteria have not grown; a larger zone shows greater effectiveness at preventing bacterial growth.
5. Students should be able to calculate cross-sectional areas of colonies or clear areas around colonies using πr^2.
6. A clear zone around a disc soaked in antiseptic indicates that the bacteria have been killed or inhibited.

9.B4 Ecological Relationships

9.B4.01 Ecosystems and biodiversity

1. Ecosystems contain biotic and abiotic components.
2. Biotic components are the living parts of an ecosystem, including animals, plants and microorganisms. Abiotic components are the non-living parts of an ecosystem, including light, temperature, water, air, soil and minerals.
3. Abiotic conditions affect the survival, reproduction and distribution of organisms.
4. Different ecosystems are characterised by different abiotic conditions, which may also vary within an ecosystem and create different habitats.
5. Organisms are adapted to the abiotic conditions in their habitat.
6. Organisms both depend on their environment and change it.
7. Organisms change their environment by taking in and releasing substances, altering physical conditions and cycling materials through decomposition.
8. Biodiversity is the range of different species living in an ecosystem.

9. Biodiversity includes species diversity, ecosystem diversity and genetic diversity within populations.
10. Genetic diversity is the variation in genes within a species. The range of genes present in a species is called the gene pool.
11. A larger gene pool increases variation within a species and increases the chance of survival if conditions change.
12. Small populations have smaller gene pools and lower genetic diversity, increasing the risk of extinction.
13. Higher biodiversity usually increases ecosystem stability.
14. Biodiversity is important because organisms in ecosystems are interdependent and because ecosystems provide ecosystem services.
15. Ecosystem services include provisioning, supporting, regulating and cultural services.
16. Humans depend on biodiversity for food, pollination, medicines and oxygen production.
17. Human activities can reduce biodiversity through habitat destruction, pollution, climate change, overhunting and overfishing, and by reducing genetic diversity.
18. Conservation is the protection of biodiversity and the environment. It includes habitat protection, habitat restoration, breeding programmes, legal protection of species and land, gene banks and sustainable use of resources.
19. Gene banks store hereditary material, including seeds, DNA, eggs, sperm, embryos and plant tissue, to help conserve genetic diversity.
20. Biodiversity can be protected through the sustainable use of resources, in which resources are used at a rate and in a way that does not reduce their availability for future generations.
21. Environmental conditions in ecosystems can change over time and can affect the distribution and abundance of species.
22. Distribution is the area or range in which a species is found. Abundance is the number of individuals of a species in a particular area.

	23. The main abiotic changes affecting distribution and abundance include temperature, water availability and the composition of atmospheric gases. 24. Environmental change may be seasonal, geographic or caused by human activity. 25. Environmental change affects species by altering how suitable a habitat is for survival and reproduction. 26. Environmental change can affect species directly or indirectly, by altering food supply, habitat, pollinators, prey or competitors, and can reduce biodiversity. 27. Species differ in their tolerance of environmental change.
9.B4.02 Populations in ecosystems	1. A pyramid of number shows the number of organisms present at each trophic level in a food chain. 2. Pyramids of number do not take organism size into account and may be inverted when one large producer supports many smaller consumers. 3. A pyramid of biomass shows the biomass present at each trophic level in a food chain. The biomass of a population can be estimated from the number of individuals and the average mass of individuals. 4. Sampling is used to estimate population size, abundance, distribution and biodiversity when it is not practical to count every organism in a habitat. 5. Samples should be representative of the habitat being studied. Random sampling reduces bias and makes this more likely. 6. Different sampling methods are used for different organisms and habitats, including quadrats, transects, pooters, pitfall traps and nets. 7. Quadrats can be used to estimate the abundance of a species, the number of species present, and the percentage cover of a species. 8. Population size can be estimated from the mean number of organisms per quadrat and the total area of the habitat. 9. Many crop plants depend on insect pollination, especially fruits, vegetables and nuts.

10. Changes in insect pollinator populations can affect crop production, biodiversity, ecosystem services and food security.
11. Pollinator populations can decline because of habitat loss, reduced flowering plant diversity, pesticide use, climate change, disease and competition from invasive species.
12. Pollinators can be protected by increasing flowering plants, reducing pesticide use, protecting habitats and providing nesting sites.

9.B5 Health

9.B5.01 Health and wellbeing

1. Health includes physical and mental health.
2. Physical health refers to the condition of the body and how well body structures and processes function. Mental health refers to emotional, psychological and social well-being.
3. Health is not only the absence of disease. It exists on a continuum from good health to ill health and must be considered in relation to the individual.
4. Physical and mental health can affect one another and can be negatively affected by illness, injury, long-term health conditions, lifestyle, stress, isolation and trauma.
5. Lifestyle choices, including diet, physical activity and behaviour, can increase or decrease the risk of ill health. Research evidence can identify patterns linking lifestyle and health and can inform health advice.
6. A symptom is an unusual change in appearance, body function or behaviour that may indicate ill health. Symptoms do not always indicate disease because some changes are temporary, harmless or age-related.
7. A disease is a persistent change or deviation from normal appearance, function or behaviour. Disease can have different causes, including pathogens, lifestyle, environmental factors and information in the genome, and does not always produce obvious symptoms.
8. Pathogens are microorganisms that cause disease.

9.B5.02 Exercise	1. During exercise, muscles require more energy, so muscle cells respire at a faster rate and require an increased supply of oxygen and glucose. 2. During exercise, breathing rate, breathing depth and heart rate increase. 3. Increased breathing rate and breathing depth increase ventilation, so gas exchange can occur more rapidly in the lungs. 4. Increased heart rate increases blood flow to the muscles, delivering oxygen and glucose and removing carbon dioxide. 5. These are short-term physiological responses to exercise and will return towards resting levels after exercise stops.
9.B5.03 Pathogens and disease	1. Diseases can be classified as communicable or non-communicable. 2. Communicable diseases are caused by pathogens and can be transmitted from one organism to another. 3. Non-communicable diseases are not caused by pathogens and cannot be transmitted from person to person. 4. Bacteria can cause disease by reproducing rapidly in the body and by releasing toxins that damage tissues. Viruses can cause disease by reproducing inside living cells and damaging tissues. 5. Communicable diseases can be spread by contaminated food or water, airborne droplets, direct or indirect contact, and vectors. The most effective method of reducing transmission depends on the route by which the pathogen spreads. 6. The body has non-specific defences that protect against many different pathogens. These include the skin, blood clotting, mucus, stomach acid, antimicrobial secretions, and microorganisms that normally live on and in the body. 7. White blood cells protect the body against disease. Some white blood cells defend the body by phagocytosis, in which a pathogen is engulfed and digested. 8. Plant diseases can be communicable when they are caused by pathogens and can spread from one plant to another. Plant pathogens include viruses, bacteria, fungi and protists.

	9. Tobacco mosaic virus is a viral plant disease that reduces chlorophyll content and photosynthetic efficiency. It spreads by direct contact and by contaminated hands or equipment. 10. Crown gall disease is a bacterial plant disease that disrupts vascular tissue and reduces transport through the plant. It can spread through contaminated soil and contaminated tools. 11. Plant defences against pathogens include the waxy cuticle, cellulose cell walls, bark and antimicrobial substances. Plants also defend against pests, which can damage plants and spread pathogens. 12. Plant disease can reduce plant growth and crop yield.
9.B5.04 Health, lifestyle and ageing	1. Asthma is a non-infectious disease that affects the gas exchange system. 2. During an asthma attack, the bronchi narrow and swell, reducing airflow to and from the alveoli. Reduced airflow makes gas exchange less efficient and can cause wheezing, coughing, breathlessness and chest tightness. 3. Smoking introduces harmful substances including tar, carbon monoxide and nicotine into the body. 4. Tar damages cilia and alveoli, reducing the efficiency of gas exchange. 5. Carbon monoxide reduces the amount of oxygen carried by the blood. 6. Nicotine is an addictive drug that increases heart rate and blood pressure. 7. Smoking increases the risk of bronchitis, emphysema, heart disease and cancer. 8. A drug is a substance that has a physiological effect when it enters the body. Some drugs are medicinal and some are recreational. 9. Recreational drugs may be legal or illegal and act as depressants or stimulants. 10. Depressants slow nervous system signalling and can slow reaction time. Stimulants speed nervous system signalling and can increase alertness and reduce reaction time.

11. Alcohol is a depressant. Long-term misuse of alcohol can damage the liver and increase the risk of disease.
12. Caffeine is a stimulant. Excessive caffeine intake can cause addiction, increased heart rate, insomnia and withdrawal symptoms.
13. Substance misuse is the harmful or addictive use of legal or illegal drugs. Substance misuse can damage behaviour, health and life processes.
14. Ageing is a normal part of the human life cycle.
15. Common changes with age include greying or thinning hair, wrinkling skin, reduced muscle strength and flexibility, stiffer joints, slower reaction time, and deterioration in sight and hearing.
16. Ageing can affect the reproductive system. Fertility decreases with age.
17. In males, fertility can decrease with age as sperm production decreases.
18. In females, reproductive ageing includes perimenopause and menopause. During perimenopause, menstrual cycles become irregular and other symptoms often begin. Menopause is when menstruation stops completely.
19. Lifestyle and environmental factors can increase the risk of age-related ill health.
20. Regular physical activity, a healthy diet, not smoking, limiting alcohol intake and protecting the skin from excessive sun exposure can reduce the risk of age-related ill health.

9.C1.01 Atomic structure	1. An atom is made of smaller particles called protons, neutrons and electrons. The nucleus is at the centre of the atom and contains protons and neutrons, while electrons are arranged in shells around the nucleus. The nucleus is very small compared with the whole atom and most of the atom is empty space. 2. The atomic number is the number of protons in the nucleus of an atom and is unique to each element. The mass number is the total number of protons and neutrons in the nucleus of a single atom. 3. In atoms, the number of electrons equals the number of protons. 4. Electron configuration is the arrangement of electrons in shells. For the first 20 elements, shells fill 2, then 8, then 8, with inner shells filling before outer shells. The electron configuration can be written as numbers showing the electrons in each shell, for example 2.7 or 2.8.2.
9.C1.02 Atomic structure and isotopes	1. Atoms are very small, having a radius of about 0.1 nm (1×10^{-10} m). The radius of a nucleus is less than 1/10 000 of that of the atom (about 1×10^{-14} m). 2. Protons have a relative charge of +1 and a relative mass of 1. 3. Neutrons have no charge (0) and a relative mass of 1. 4. Electrons have a relative charge of -1 and negligible mass. 5. The periodic table can be used to find atomic number and relative atomic mass of elements. 6. Atomic models have changed over time as new evidence has improved scientific understanding. 7. Early atomic models suggested that atoms were solid spheres (Dalton model). 8. The plum pudding model proposed that the atom was a sphere of positive charge with electrons embedded within it. 9. The plum pudding model was developed by J.J. Thomson after the discovery of the electron.

10. Rutherford designed the alpha particle scattering experiment to test the plum pudding model, where positive alpha particles were directed at thin gold foil.
11. Most alpha particles passed straight through the foil, indicating atoms are mostly empty space; some were deflected, showing that positive charge is concentrated in a small area; a very small number were reflected, suggesting a dense nucleus.
12. To explain these observations, Rutherford proposed the nuclear model: a small, dense, positively charged nucleus at the centre of the atom.
13. In the nuclear model, electrons orbit the nucleus.
14. The nuclear model replaced the plum pudding model due to experimental evidence.
15. Bohr improved the model by suggesting electrons orbit the nucleus in fixed energy levels (shells).
16. Electrons can move between energy levels by absorbing or emitting energy.
17. The discovery of the neutron (by Chadwick) provided evidence for the existence of neutral particles in the nucleus.
18. The modern model of the atom includes a nucleus containing protons and neutrons, with electrons in shells and was developed through collaboration and refinement by different scientists.
19. Isotopes are atoms of the same element that have the same atomic number (number of protons) but a different mass number (due to a different number of neutrons).
20. Isotopes have the same chemical properties because they have the same electron configuration.
21. Isotopes can have different physical properties (e.g. mass, stability). Some isotopes are unstable and radioactive; others are stable.
22. Relative atomic mass (RAM or Ar) is the weighted mean mass of an atom of an element compared to 1/12 of the mass of carbon-12.
23. The relative atomic mass takes into account both the mass and the abundance (the percentage of that isotope in a naturally occurring sample) of each isotope.

	24. Relative atomic mass is calculated using: isotope mass × abundance (summed for all isotopes) ÷ total abundance. 25. Relative atomic mass values on the periodic table are not usually whole numbers due to isotopes. 26. Chemical properties of elements are determined by their electron arrangement.
9.C1.03 Chemical equations	1. Symbol equations represent chemical reactions using formulae for reactants and products. 2. Symbol equations must be balanced to show that atoms (and mass) are conserved in reactions. 3. A balanced symbol equation has the same number of each type of atom on both sides of the equation. 4. Balanced symbol equations show the ratios of reactants and products. 5. Chemical formulae use subscripts to show the number of atoms of each element in a substance. 6. Coefficients show the number of units of each substance in a reaction and apply to the whole formula. 7. When balancing equations, only coefficients are changed; subscripts must not be changed.

9.C2 Substances

9.C2.01 Elements, compounds and mixtures	1. Elements are found in the periodic table. 2. Compounds of two elements end in '-ide'. Compounds with three elements including oxygen often end in '-ate'. 3. Mixtures can contain elements, compounds, or both. These components of a mixture retain their own properties. 4. State symbols can be used to determine whether a substance is soluble (aq) or insoluble (s). 5. Separation techniques, including filtration, evaporation, crystallisation, distillation and chromatography, are used to separate and purify substances from mixtures based on differences in physical properties.

	6. Students should be able to: • carry out, describe, explain and give examples of these techniques • select appropriate methods for given mixtures • identify the key equipment used 7. Chromatography can show if a substance is pure (one spot) or a mixture (multiple spots). Each spot represents a different substance in the mixture. 8. A chromatogram is the result produced from chromatography. Students should be able to interpret chromatograms. 9. Substances can be identified by comparing their positions with known substances. 10. The solvent front marks the furthest point reached by the solvent from the baseline and is used as a reference point to calculate Rf values: $\text{Rf value} = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent front}}$ 11. Substances with the same Rf value under the same conditions are likely to be the same.
9.C2.02 The periodic table	1. Elements were originally arranged in lists as new elements were discovered. 2. Mendeleev arranged elements into a table based on similar properties and atomic weight, placing elements with similar properties in the same groups. 3. Atomic weight was used as a guide, but properties were prioritised over strict order. 4. Mendeleev left gaps for undiscovered elements and predicted their properties from surrounding patterns. 5. Later discoveries that matched these predictions supported the periodic table as a scientific model. 6. The modern periodic table is arranged in order of increasing atomic number. 7. A group is a vertical column; a period is a horizontal row.

	8. Elements in the same group show similar patterns in properties. 9. The number of occupied shells determines the period of an element. 10. The group number (for groups 1–7) corresponds to the number of outer shell electrons. Group 0 elements have full outer shells. 11. Elements in the same group have the same number of electrons in their outer shell. 12. Across a period, atomic number increases and electron arrangement changes.
9.C2.03 Development of the periodic table	1. Early attempts to classify elements included grouping by properties and atomic mass. 2. In early periodic tables, elements were sometimes placed in the wrong order to keep similar properties together. 3. The discovery of protons led to the development of the modern periodic table based on atomic number. 4. Knowledge of isotopes made it possible to explain why the order based on atomic weights was not always correct. 5. Groups include alkali metals (Group 1), halogens (Group 7) and noble gases (Group 0).
9.C2.04 Element properties	1. Elements have both physical and chemical properties, which can be used to describe and classify them. 2. Examples of physical properties include melting point, boiling point, state and conductivity; chemical properties include reactivity and flammability. 3. Elements can be classified as metals, non-metals and metalloids using their properties. 4. Most elements are metals. Metals are found to the left and towards the bottom of the periodic table. Non-metals are found towards the right and top of the periodic table 5. Metalloids show a mixture of properties of metals and non-metals.

	6. Patterns in physical properties occur both down groups and across periods. 7. Down a group, physical properties such as density and melting point often change gradually; across a period, physical properties can show more complex patterns. 8. Trends in physical properties can be used to predict the properties of unfamiliar elements or missing values in data. Predictions should be consistent with the overall pattern in the data.
9.C2.05 Transition elements	1. Transition metals are in the centre of the periodic table. 2. They are typical metals and conduct heat and electricity. 3. Transition metals are less reactive than Group 1 metals. 4. They have higher melting points and densities than alkali metals. 5. Transition metals can form ions with different charges. 6. Their compounds are often coloured. 7. Many transition metals and their compounds act as catalysts. Examples include iron in the Haber process and nickel in hydrogenation. 8. Transition metals are strong and hard (compared to Group 1) and malleable, making them useful in construction.

9.C3 Chemical Reactions

9.C3.01 Group trends	1. Trends in the properties of elements can be identified down a group. 2. Group 1 elements are known as the alkali metals. 3. In Group 1, reactivity increases down the group. 4. Group 1 metals react with water to form metal hydroxides and hydrogen. 5. Group 7 elements are non-metals known as the halogens and exist as diatomic molecules.

	6. In Group 7, reactivity decreases down the group. 7. Group 7 elements react with metals to form salts (metal halides). 8. Group 0 elements are called the noble gases. 9. Group 0 elements are very unreactive monatomic gases. 10. The properties of Group 0 elements make them useful in applications such as lighting and balloons. 11. Trends down groups can be used to predict the properties of elements.
9.C3.02 Explaining group trends	1. Elements react to achieve a full outer electron shell, which is a more stable electronic configuration. 2. Chemical reactions involve the transfer or sharing of electrons between atoms. 3. Metals react by losing electrons to form positive ions (cations). 4. Non-metals react by gaining electrons to form negative ions (anions). 5. Ionic bonding occurs when electrons are transferred from a metal to a non-metal. 6. The loss or gain of electrons results in oppositely charged ions which are attracted to each other. 7. The number of electrons lost or gained depends on the number needed to achieve a full outer shell. 8. Group number indicates how many electrons are in the outer shell for main group elements. 9. Group 0 elements (noble gases) have full outer shells and are very unreactive. 10. The stability of noble gases explains why other elements react to achieve similar configurations. 11. Reactivity of elements is linked to how easily they gain or lose electrons. 12. Metals become more reactive down a group (Group 1) because outer electrons are further from the nucleus and easier to lose. 13. Non-metals become less reactive down a group (Group 7) because it is harder to gain electrons.

14. When atoms form ions, their electron configuration becomes similar to a noble gas.
15. The formation of ions is driven by electrostatic attraction between charged particles.
16. Group 0 elements have eight electrons in their outer shell, except for helium, which has only two electrons.
17. Group 0 elements have low boiling points and are gases at room temperature.
18. Boiling points of noble gases increase with increasing relative atomic mass (going down the group).
19. Group 1 metals form +1 ions by losing one electron in chemical reactions because they have one electron in their outer shell.
20. Alkali metals are soft and can be cut with a knife.
21. They have relatively low densities compared to other metals.
22. Alkali metals have low melting and boiling points compared to other metals. The melting and boiling points decrease down the group.
23. Reactivity of Group 1 metals increases with increasing number of electrons shells (down the group), because as the outer electron gets further from the nucleus, it is more easily lost because the force of attraction with the nucleus is weaker. The outer electron is also more shielded from the nucleus, reducing attraction.
24. The general reaction with water produces an alkaline solution (pH above 7).
25. Alkali metals react with oxygen to form metal oxides.
26. Alkali metals react with chlorine to form metal chlorides.
27. Reactions with oxygen and chlorine become more vigorous down the group. Lithium reacts relatively slowly, while potassium reacts quickly and vigorously. Potassium may ignite with a lilac flame when reacting with water.
28. Alkali metals must be stored in oil to prevent reaction with air or moisture.
29. Group 7 elements are called the halogens. Halogens are non-metals and exist as diatomic molecules.

	30. They have 7 electrons in their outer shell. They gain one electron to form 1− ions in chemical reactions. 31. Reactivity of halogens increases with decreasing number of electrons shells (up the group), because an electron is more easily gained as the outer electron shell gets closer to the nucleus because the force of attraction with the nucleus is stronger. The outer electron is also shielded less from the nucleus up the group, increasing attraction. 32. Melting and boiling points increase down the group. 33. Physical states change down the group: chlorine is a gas, bromine is a liquid, iodine is a solid. Colours become darker down the group. 34. Halogens react with metals to form ionic compounds called metal halides.
9.C3.03 Reactivity of metals	1. Metals can be arranged in a reactivity series from most reactive to least reactive. 2. Reactivity describes how readily a metal reacts with other substances. 3. More reactive metals react more readily and more vigorously than less reactive metals. 4. The relative reactivity of metals can be determined by comparing their reactions with oxygen, water and acids. 5. Metals higher in the reactivity series react more strongly than metals lower in the series. 6. The reactivity series can be used to predict how metals will behave in chemical reactions. 7. A displacement reaction occurs when a more reactive element displaces a less reactive element from a compound. 8. In the context of metals, a more reactive metal displaces a less reactive metal from its compound. 9. Displacement reactions involving metals commonly occur in aqueous solutions of metal salts. 10. A less reactive metal will not displace a more reactive metal from its compound.

	11. The reactivity series can be used to predict whether a displacement reaction will occur. 12. Displacement reactions provide evidence for the relative reactivity of metals. 13. Most metals are not found in nature as pure elements because they have reacted to form compounds. 14. Many metals are found as oxides in ores. 15. An ore is a naturally occurring rock that contains enough metal or metal compound to make extraction worthwhile. 16. Very unreactive metals can be found as elements in nature, whereas more reactive metals are usually found as compounds. 17. The position of a metal in the reactivity series helps determine whether it is found pure or as an ore. 18. Extraction is the process of obtaining a metal from its ore. 19. Many extraction processes involve removing oxygen from a metal oxide. 20. Reduction is the removal of oxygen from a compound. Oxidation is the addition of oxygen. 21. Carbon is included in the reactivity series as a reference point for extraction methods. 22. Carbon can be used to extract metals that are less reactive than carbon. 23. In these reactions, carbon removes oxygen from the metal oxide and forms carbon dioxide. 24. The metal oxide is reduced and the carbon is oxidised.
9.C3.04 **Rate of reaction**	1. The rate of reaction is the speed of a chemical reaction. 2. Rate can be described by how quickly a reactant is used up or how quickly a product is formed. 3. Rate measurements compare a change with time. 4. Chemical reactions occur when reactant particles collide. 5. Only successful collisions lead to reaction. 6. A successful collision is one in which new products are formed.

7. Successful collisions require particles to collide with sufficient energy.
8. Activation energy is the minimum energy required for particles to react.
9. If particles collide with less than the activation energy, they do not react.
10. The rate of reaction depends on the frequency of successful collisions between reactant particles.
11. Increasing collision frequency increases the rate of reaction.
12. Increasing the energy of colliding particles increases the number of successful collisions.
13. Rates of reaction can be measured by timing how long a reaction takes to finish.
14. Rates of reaction can be measured by how quickly a reactant is used up or a product is formed.
15. In reactions that produce a gas, rate can be measured by the volume of gas produced in a given time.
16. In reactions where gas escapes from an open system, rate can be measured by the change in mass over time.
17. In reactions that form a precipitate or become cloudy, rate can be measured by the time taken for a marked cross to disappear.
18. The method used to measure rate depends on the observable change taking place during the reaction.
19. A graph of product formed against time can show how the rate of reaction changes during a reaction.
20. The rate of reaction is usually greatest at the start of a reaction.
21. As the reaction progresses, the rate decreases.
22. The rate decreases because reactants are converted into products, so the concentration of reactant particles falls.
23. As the concentration of reactant particles decreases, collisions become less frequent.
24. The reaction stops when one or more reactants are used up.
25. A catalyst increases the rate of reaction without being used up overall.

26. A catalyst increases rate by lowering the activation energy of a reaction.
27. Lower activation energy means that more collisions have enough energy to be successful.
28. A catalyst increases the rate of product formation but does not increase the final yield from a given amount of reactants.
29. Catalysts are used in industry to increase rate and reduce energy use and cost.

9.P2 Waves

9.P2.01 Wave characteristics	1. Energy is transferred from a source to the surroundings by the process of radiation. Waves are a type of radiation; they transfer energy without transferring particles. 2. All waves cause vibrations. They can be described in terms of their amplitude, wavelength, frequency and period. The period of a wave is the time taken for one complete wave to pass a point, or for one complete vibration to take place. 3. Wave diagrams may show some or all the characteristics of waves. 4. Students should be able to identify the characteristics of a wave from a wave diagram. 5. Students should be able to use the formula, period=1/frequency. 6. A mechanical wave is a disturbance that moves through a medium, transferring energy by the vibration of particles, but not the particles themselves. Examples include, sound, ripples on water, waves through the ground (seismic waves), waves on a string. After a disturbance has passed through a medium, the particles gradually return to their resting positions.
9.P2.02 Transverse waves	1. Mechanical waves may be transverse. Ripples on water surfaces and waves on ropes are described as transverse waves. Light waves are also transverse. 2. As transverse waves travel particles/parts of an object vibrate at right angles to the direction the wave travels in. 3. Vibrating water particles (or short sections of rope) cause adjacent particles to vibrate in the same way, which is how a wave transfers energy as it moves forward. 4. Transverse waves can be shown on wave diagrams that record the size of vibration over time (distance-time graph); the distance moved by matter from rest at a moment in time (displacement-distance graph).

9.P2.03 Speed of waves	1. The wave speed is the speed at which the energy is transferred (or the wave moves) through the medium. 2. All waves obey the wave formula. Students should be able to apply the wave formula, wave speed = frequency × wavelength. 3. Making accurate measurements of waves in the 'field' can be difficult as they are constantly moving and quickly. A ripple tank can be used to observe waves on the surface of water in a laboratory setting. 4. Students should be able to describe a ripple tank investigation to find the speed of waves on the surface of water. 5. The speed of waves varies greatly. The fastest wave is light transmitted through a vacuum (3 000 000 m/s).
9.P2.04 Longitudinal waves	1. Mechanical waves can transfer energy by regions of low and high pressure moving through matter. Examples include audible sound or ultrasound, some seismic waves. 2. When particles vibrate in a direction that causes them to momentarily get closer to another region, they transfer some energy to those particles; they continue to vibrate until they have passed on all energy from the source and return to rest. 3. Particles in a region close to each other, are at high pressure (compression). Particles in a region that are far from each other, are at low pressure (rarefaction). 4. Waves caused by pressure are longitudinal waves. 5. Longitudinal waves cause particles to vibrate backwards and forwards along the direction in which the wave travels. 6. Longitudinal waves can be shown on wave diagrams that record the size of vibration over time (distance-time graph), e.g. on an oscilloscope or seismogram; the distance moved by matter from rest at a moment in time (displacement-distance graph). 7. Students should be able to use wave graphs to compare wave characteristics. 8. The differences in behaviour of a mechanical wave as it travels can be used to detect or explore objects hidden from direct observation, e.g. medical or industrial imaging, SONAR, Earth's structure. Pressure waves can cause high frequency vibrations of

	other objects, used in cleaning or to vibrate and gently heat muscle tissue in physiotherapy.
9.P2.05 Energy transfer by waves	1. The higher the frequency of a wave, the more quickly energy is transferred by the wave. 2. Energy transfers more quickly if each ripple or vibration is larger (has a bigger amplitude). 3. When waves interact with matter, energy is absorbed by particles and their energy stores increase. Depending on the wave type, particles may increase their vibration or electromagnetic store; bulk materials may increase their vibration, chemical or thermal stores. 4. When waves from two similar sources overlap, they add to produce a larger disturbance at some places (or times) and cancel each other out at other places (or times). This is superposition.
9.P2.06 Electromagnetic waves	1. Waves that do not require a medium to travel are electromagnetic waves. Examples include visible and infra-red light. 2. Electromagnetic waves can be detected by specific detectors placed in the surroundings. Unlike mechanical waves, electromagnetic waves can travel through a vacuum. They travel at the 'speed of light' in a vacuum. They are always transverse. 3. Electromagnetic waves form a continuous spectrum. Waves with different ranges of frequencies (and wavelengths) are categorised into different groups of the electromagnetic spectrum, in order of frequency (or wavelength). 4. The main groupings, in order of lowest to highest frequency (highest to lowest wavelength): radio, microwave, infra-red, visible (red to violet), ultra-violet, X-rays and gamma-rays. 5. Different sources emit electromagnetic waves with a different range of frequencies (and wavelengths). 6. Each grouping has a set of distinct characteristics that allow it to be detected and used in a particular way. Our eyes can detect visible light, but the rest are invisible to us without technology. Energy transferred by electromagnetic waves to a receiver can be

	useful, e.g. microphone; from a device to produce a wave can be useful, e.g. loudspeaker. 7. Different substances may absorb, transmit, refract, or reflect electromagnetic waves in ways that vary with wavelength. 8. The higher the frequency of an electromagnetic wave, the more energy it has and the more dangerous it can be to humans.
9.P2.07 **Wave properties**	1. The same type of wave can behave differently depending on the medium, or at interfaces; its velocity, absorption and reflection can all vary. 2. The ray model can be used for many types of waves to show the direction of travel, especially for transmission, reflection and refraction. 3. Waves are often transmitted through specific matter; a material that is opaque to one wave may be transparent to another. Neither frequency nor amplitude change the speed of a wave; it only depends on the medium through which the wave is travelling. 4. Unwanted transmission happens when waves pass through something and cause problems. 5. Refraction is transmission with a change in direction (and speed). 6. Refraction is useful for focussing and forming images, but it can distort images and reduce accuracy in measurements and signals. 7. The energy transferred by waves can be absorbed by matter; depends on the type of wave and matter. 8. Students should be able to describe an investigation to compare absorption of infra-red by surfaces. 9. When a wave interacts with a clear boundary, it reflects (scatters), obeying the law of reflection. The amount of reflection depends on the wave type, the surface, and the materials. 10. Reflection of waves is used to see things, detect objects, measure distances, and explore places we cannot see directly. It can be unwanted.

9.P2.08 Electricity from waves	1. Waves can be used to power renewable resources to generate electricity, e.g. solar radiation. 2. The Sun emits all types of electromagnetic radiation (solar radiation), but mainly visible light, infra-red, and some ultraviolet. Earth's atmosphere absorbs most ultraviolet, X-rays and gamma radiation. 3. Solar cells can use visible, infra-red and ultraviolet light to generate electricity by transferring energy to electrically charged particles to move as a current; visible light is the most efficient. 4. Solar chimneys use mainly infra-red light to heat air and turn turbines. Turbines generate electricity when they move. Solar mirrors work in a similar way, heating water, its steam turning turbines.

9.P3 Matter

9.P3.01 The particle model of matter	1. Density is a physical property of matter, a measure of the mass of a cubic metre (or cubic centimetre) of a material; it relates to the mass of its constituent particles and their spacing. 2. The mass of a material is conserved as it changes state (in a closed system), the number of constituent particles is constant. 3. Materials in their solid state are more dense than in their liquid state, and have least density as a gas; particles in solids are closely packed and fixed in position, so have most particles per unit volume; in liquids, though still closely packed, the moving particles take up slightly more space for the same mass; a gas has fast-moving particles which take up the greatest volume for the same mass. 4. During heating, a material expands due the particles taking up more space with their increased motion. 5. Ice-water is less dense than liquid water, an anomaly. When ice melts, its volume as a liquid is less than its volume as a solid. As water increases temperature, the liquid water continues to contract—up to 4 °C—then it begins to expand continuously. 6. Students should be able to find the volume of a regular solid by measuring height, length and breadth.

	7. Evidence that particles in fluids randomly move around includes diffusion and Brownian motion. 8. The rate of diffusion increases with temperature; the particles have more energy in their stores, so collide more and spread out into the substance more quickly. 9. There are different ways scientific models describe energy for a material whose temperature is increasing: particles increase vibration or kinetic stores, or particles have more kinetic energy. During a change of state, temperature remains constant and particle separation changes. On heating: particles increase electromagnetic stores, or particles have more potential energy.
9.P3.02 Internal energy	1. Internal energy is the total energy stored in the particles of a system (kinetic energy + potential energy of particles). 2. Kinetic energy is the energy of moving particles; faster particles have more kinetic energy. 3. Potential energy is the energy stored due to the positions of particles relative to each other; particles further apart have more potential energy. 4. Forces of attraction between particles mean energy is required to separate them (increasing potential energy). 5. Temperature is a measure of the average kinetic energy of particles. 6. When energy is transferred to a system, the internal energy increases. 7. There are two possible results of increasing internal energy: temperature increases (increase in kinetic energy); change of state (increase in potential energy). 8. During heating, only one of these occurs at a time (not both simultaneously). 9. During a temperature increase: kinetic energy increases; particle speed increases (or vibration increases in solids); temperature rises. 10. During a change of state: temperature remains constant; potential energy increases; energy is used to overcome forces of

attraction between particles; particles move further apart and change arrangement.

11. Heating curves (temperature vs time graphs) show: sloped sections where temperature increases (kinetic energy increasing); flat sections where temperature is constant (change of state, potential energy increasing).
12. Internal energy increases continuously during heating, even when temperature is constant.
13. Specific heat capacity (c) is the energy required to raise the temperature of 1 kg of a substance by 1°C.The equation linking energy, mass, specific heat capacity and temperature change is:
$$change\ in\ thermal\ energy = mass \times specific\ heat\ capacity \times temperature\ change$$
14. A larger mass requires more energy to change temperature by the same amount.
15. Substances with higher specific heat capacity require more energy to heat up.
16. For the same energy input, substances with lower specific heat capacity increase in temperature more.
17. State changes are physical changes (not chemical) and are reversible; mass is conserved because number of particles remains constant.
18. Specific latent heat is the energy required to change the state of 1 kg of a substance with no temperature change. The equation linking energy, mass, specific heat capacity and temperature change is:
$$energy\ for\ a\ change\ of\ state = mass \times specific\ latent\ heat$$
19. Specific latent heat of fusion relates to melting (solid → liquid) and freezing (liquid → solid).
20. Specific latent heat of vaporisation relates to boiling (liquid → gas) and condensation (gas → liquid).
21. Different substances have different specific latent heats because the strength of intermolecular forces between particles differs.
22. Specific latent heat of vaporisation is greater than that of fusion because more energy is required to fully separate particles into a gas.

	23. The same amount of energy is required for a change of state in reverse (e.g. melting vs freezing) due to conservation of energy.
9.P3.03 Floating	1. Upthrust is a force that acts upwards on an object, caused by a fluid. This can happen when it is immersed or when it floats. It depends on the volume of fluid displaced by the object. 2. When the object's weight is equal in size to the upthrust on it, the resultant force is zero-value. This happens when the density of both object and fluid are equal, or on the surface where the upthrust has decreased because a smaller volume of fluid is displaced. 3. Some objects can float in a fluid, even if made from dense materials. Their shape means they displace a greater volume of fluid for the same mass, increasing the size of the upthrust, e.g. if it is boat-shaped. 4. The apparent weight of an object is lower when it is immersed in a liquid. 5. Substances with lower density than water (≈1 g/cm³) float; higher density substances sink. 6. Students should be able to find the volume of a regular solid by using a displacement can (Eureka). The volume of water displaced equals the volume of the object. 7. Students should be able to compare calculated values for regular solids.
9.P3.04 Investigating density	1. Students should be able to find the volume of an irregular solid by using a displacement can (Eureka). The volume of water displaced equals the volume of the object. 2. Students should be able to find the volume of a liquid using a measuring cylinder. 3. Students should be able to compare calculated values for density for liquids and irregular solids.
9.P3.05 Pressure and Fluids	1. Pressure in fluids is caused by particles colliding with the walls of their container exerting forces at right angles to the surface. 2. In fluids, pressure acts equally in all directions.

	3. The pressure at the surface of a fluid can be calculated using the formula: $$pressure = \frac{force\ normal\ to\ a\ surface}{area\ of\ that\ surface}$$ 4. Pressure in a fluid increases with depth because there is a greater weight of fluid pushing down on it, so a greater force is transmitted through the lower region. 5. An object placed in a fluid experiences a greater pressure on its lower surface. The force from below is larger than the force due to pressure from above; the resultant force caused by the pressure difference is the upthrust. The size of the upthrust is equal to the weight of the displaced fluid. 6. The atmosphere decreases density with increasing altitude. 7. When air particles collide with a surface, they cause atmospheric pressure. If the surface is higher up, the number of air particles (and so the weight of air) above a surface decreases. Fewer particles colliding, and transmitting less force, results in less pressure. Changes to the air can affect the atmospheric pressure, e.g. humidity. 8. In a contained gas, its pressure, temperature and volume are all directly related to each other. 9. Some natural processes depend on pressure differences, e.g. breathing and blood circulation. Pressure changes can be disadvantageous, e.g. temperature to boil water or breathing problems at altitude. 10. Some machines and containers use pressure to carry out a function, e.g. hydraulic machines. Work can be done on a fluid, e.g. pumping up tyres, or by a fluid, e.g. wind turbines. 11. Some machines and containers use pressure to carry out a function, e.g. hydraulic machines. Work can be done on a fluid, e.g. pumping up tyres, or by a fluid, e.g. wind turbines.
9.P3.06 Pressure and gases	1. In a flexible container (e.g. balloon), increasing pressure can cause volume to increase. 2. In a fixed volume container, increasing temperature always leads to increased pressure.

3. When a gas is compressed, the volume decreases and particles are closer together. Decreasing volume means particles have less space to move. This results in more frequent collisions with the container walls, increasing the total force on the walls, increasing pressure. Therefore, when volume decreases, pressure increases (if temperature is constant).
4. Boyle's Law states that for a fixed mass of gas at constant temperature, pressure is inversely proportional to volume.
5. Boyle's Law can be written as $p \propto 1/V$. The relationship can also be expressed as: $pressure \times volume = constant$
6. The relationship between pressure and temperature (measured in Kelvin) for a fixed mass of gas at constant volume is directly proportional.
7. Conversion between scales: K = °C + 273; °C = K – 273
8. Absolute zero (0 K or −273 °C) is the theoretical temperature at which particle motion stops and pressure would be zero.
9. In a rigid container (fixed volume), increasing pressure must come from increasing temperature or number of particles.
10. Compressing a gas can increase its temperature. Examples include a bicycle pump or inflating a tyre becoming warm.
11. When a gas is compressed, work is done (mechanically) on the gas. This transfers energy to the gas, increasing its internal energy. Internal energy increases mainly through an increase in kinetic energy of particles. As kinetic energy increases, particle speed (hence temperature) increases.

9.P4 Electricity and Magnetism

9.P4.01 Magnetic fields

1. A magnet exerts a force on some types of material; can attract magnetic materials: iron (and steel, nickel and cobalt); are generally made of iron (or steel) and are permanent.
2. The interaction between a magnet and magnetic materials is non-contact and the magnetic forces act at a distance. This happens even with an air gap and through other materials, e.g. paper or paint.
3. If a magnet is in contact with a magnetic object, the object acts as an extension to the magnet; it is a temporary magnet.

	4. Magnetic forces act between two magnets. Depending on which parts of the magnets are interacting, the effect may cause the magnets to attract or repel. 5. The force exerted by a bar magnet is strongest at its ends, called poles. There are two types of magnetic pole, north-seeking (N) and south-seeking (S), one at each end. When two like poles interact, they repel. Two unlike poles attract. Forces near the sides of a magnet are weak and have little effect on other objects. 6. To test if a magnetic material is a magnet, it will attract to a magnet when one end is brought close and repel when reversed. 7. The magnetic force decreases when the distance between the magnetic objects increases. 8. The region around any magnet in which another magnet experiences a force, is called the magnetic field. 9. The strength of a magnetic field can be represented by field lines (a scientific model). They show the direction of the force on a tiny N pole placed anywhere in the field. 10. Field lines can be plotted using a small bar magnet that can turn (a compass). The direction of a magnetic field is shown with an arrow pointing from a N-pole to a S-pole. At points where the force is greatest, the field lines are closer. Field lines form a complete loop. 11. When a bar magnet is free to rotate, the magnetic force on it caused by Earth causes it to turn and its N pole points roughly northwards. The Earth behaves like a large bar magnet, with its poles near geographic north and south. This property allows magnets to be used for navigation, a compass.
9.P4.02 Electromagnetism	1. When electricity flows through a conductor, there is a magnetic field around it; a wire carrying an electric current exerts a force on magnetic materials around it. The magnetic field is represented by circular field lines, and it does not have poles. This effect is electromagnetism: electricity producing magnetism. 2. The direction of the field changes if the direction of the current (flow of charge) changes. The strength of the field increases if the current increases.

	3. When the wire is wrapped into a long coil, the field becomes stronger at its ends; it now has poles. 4. If a piece of iron is placed through the centre of the coil (a solenoid), it becomes a temporary magnet aligned with the field; the strength of the magnetic field is increased by a large amount. The iron core behaves like a bar magnet while the current flows through the coil around it. The coil-core is called an electromagnet. 5. An electromagnet can be made stronger if the number of turns (of the coil) is increased; the electric current (or voltage) is increased. The iron core(s) immediately 'demagnetises' when the current stops flowing. 6. When an electromagnet circuit is switched on, current flows through the wire, the core becomes a temporary magnet and it interacts with a magnetic material or magnet to carry out a job. When switched off, it stops being a magnet and the force on magnet or material is removed. 7. Permanent magnets are always 'on' which can limit their usefulness. Electromagnets can be switched on and off, meaning their effect on magnets and magnetic materials near them can be controlled. They are much stronger than permanent magnets. 8. Properties of electromagnets extend the range of uses of magnetism, e.g. cranes in scrapyards, Maglock doors.
	9. The electromagnetic energy store is greater when like poles are close together and when unlike poles are far apart. 10. When an electromagnet is switched on, energy is transferred to its electromagnetic store by the electrical pathway. It also gets hotter and energy is transferred to its thermal store of energy.
9.P4.03 Motors and Generators	1. When a magnet is brought near a current-carrying wire, there is an interaction between their magnetic fields. A force acts on the current-carrying wire; called the motor effect. 2. If the wire is a square coil and placed so that two sides are parallel with the magnet's field lines, the forces exerted on each side are in opposite directions and the coil turns. This is how a d.c. motor works.

	3. A moving magnet near a conductor can generate an electric current: electricity is generated. This effect is used in power stations and most renewable energy resources, where movement of turbines generates a current.
9.P4.04 Static Electricity	1. Rubbing electrical insulators with a cloth, charges them. They can then exert an electrostatic force on nearby objects. This is static electricity. 2. A scientific model can be used to explain the charging of objects. All materials are made up of neutral atoms. Their electrons are negatively charged and the fixed nucleus is positively charged. The electrons in atoms can be more easily moved. During rubbing, some electrons are moved from one object to the other. An object that loses electrons becomes positively charged and one that gains electrons becomes negatively charged. 3. A charged object placed near a neutral object exerts an electrostatic force on electrons near the surface, causing an attractive force on the neutral object. 4. If a charged object touches another object, the electrons can be redistributed, and charge is shared between the objects. If shared with a large object, the charge becomes so spread out, the effect is no longer noticeable. If connected to Earth, an object can discharge (lose its charge). 5. A charged object may suddenly discharge as electrons move rapidly to or from it. If the movement is across an air gap, it can cause a spark. Examples include sparks when taking off a jumper or getting out of a car, and lightning. 6. Electrons can move around freely throughout metals and some other materials. These are called (electrical) conductors.
9.P4.06 Electric Current	1. All parts of a circuit have free electrons. The charges all move together (like a continuous rope). Electrons are repelled from the negative terminal of the battery and attracted towards the positive terminal. Electricity is the net flow of charged particles in one direction. When a circuit is switched on, there is an electric current everywhere in it instantly.

	2. Parallel circuits, have more than one complete conducting loop, connected to the same supply voltage. One branch is independent of another but may have parts in common near the supply. 3. Along any single branch, the size of the current is the same. At a junction, the sum of the currents arriving is equal to the sum of the currents leaving. 4. Increasing the supply voltage increases the current in every branch. Increasing the resistance of a branch decreases the current in that branch (but has no effect on the current in the other branches).
9.P4.07 Voltage	1. The battery (or power supply) is the cause of the current in an electric circuit. 2. The voltage of a battery is a measure of its 'strength' (ability to electrically push). Its size depends on the chemicals used to make the battery. It is equal to the sum of the voltage across each of its component cells, depending on direction. 3. Voltage is the difference in voltage between two points of a circuit and is a measure of energy transferred by the component. 4. A very high voltage can make electrons move through insulators, e.g. across an air gap and it creates a spark. T 5. he voltage of mains electricity is higher than a battery and can push a significant current through a human body, and is hazardous.
9.P4.08 Resistance	1. The size of the electric current in a simple circuit depends on the voltage of the supply and the resistance of the circuit. 2. The greater the electrical push on the charge through a component, the greater the current. 3. For many components the relationship is directly proportional and obeys Ohm's Law. 4. Students should be able to apply the formula, voltage=current ×resistance. The resistance of an object is measured in ohms (Ω).

5. The resistance of a component is related to how easy it is for electrons to move through it. Some materials have less resistance than others. Some other metals, and some non-metallic substances, are also conductors but have a higher resistance.
6. Increasing the resistance of any component decreases the current.
7. When electrons pass through a material, some energy is always transferred to its thermal store: the heating effect of current.
8. Non-metallic substances, such as plastics and ceramics, offer extremely high resistance to the movement of electrons: electrical insulators.
9. The resistance of a circuit is related to the total resistance of all its component parts. The greater the resistance of the circuit, the smaller the current.
10. To find the resistance of a component, the current through it and the voltage are measured. Resistance is then calculated using the formula $resistance = voltage/current$

Disciplinary Knowledge to Be Taught in Year 9

A glossary of key terms can be found in Appendix A.

Scientific Attitudes and Ways of Thinking

9.WSAT 1 Seeking Objectivity

9.WSAT 1.01 Scientific thinkers and objectivity	1. A valid conclusion is supported by valid data, obtained from an appropriate experimental design and based on sound reasoning. 2. Scientific thinkers understand no method or data is ideal; they assess the limitations by identifying sources of error, assessing levels of uncertainty. 3. Actual uncertainty for measurements can be expressed in terms of the spread of values obtained, by resolution of the measuring instrument or a consensus value for a technique. 4. Uncertainty of qualitative data can be assessed by verifying it against other datasets or findings.
9.WSAT 1.02 High-quality data	1. Data is more valid if it is precise.
9.WSAT 1.03 Measurement error	1. Scientific researchers know that all measurement has uncertainty related to it. 2. Systematic error (bias) is less likely if: • measuring instruments are calibrated effectively. • common method and equipment errors are identified and minimised, including checking for zero errors. 3. Systematic errors may be suspected if: • an experiment is repeated with a different method and produces different results. • all measurements are consistently higher or lower than expected. 4. Systematic errors cannot be dealt with by simple repeats; if a systematic error is suspected, the data collection should be repeated using a different technique or a different set of equipment, and the results compared.

9.WSAT 2 Development of methods and theories over time

9.WSAT 2.01 Developing scientific methods	1. Students should be able to select the type of scientific method using the categorisation outlined in Y7 (see 7.WSAT 2.01 Developing scientific methods).
9.WSAT 2.02 Changing methods	1. Scientific methods develop as: • new explanations are theorised • when patterns in data reveal a correlation between factors • a correlation may be used to then propose a hypothesis • new apparatus or techniques are developed.
9.WSAT 2.03 Changing theories	1. Research can lead to a scientific law and describe a principle of the natural world, true for all circumstances covered by the wording of that law. 2. Research can lead to a scientific theory and explain the reasons a phenomenon occurs based on extensive evidence and testing. 3. A scientific theory may be modified considering new evidence, or it may be discredited if growing evidence refutes it.

9.WSAT 3 Using a variety of models

9.WSAT 3.01 Describing models	1. Scientific models show some aspects of reality and hide others, and they may represent some aspects of reality poorly. 2. Scientific models explain specific observations which may relate to a theory but do not explain all aspects of it.
9.WSAT 3.02 Models, limitations and strengths	1. Students should be able to describe what a specific model is representing and how it helps us understand the concept and the parameters within which it works.

9.WSAT 4 The importance of peer review

9.WSAT 4.01 Scientific thinking and peer review	1. Published research: • adds to the body of scientific knowledge, can be confirmed by others or modified and often becomes mainstream knowledge. • can suggest new ideas for further research or explanation.
9.WSAT 4.02 Judging the quality of conclusions	1. Expert peers evaluate: • method limitations, including sample size, methodology, and potential bias affecting objectivity. • source limitations, considering peer review, sample size, methodology, data quality, and potential bias. • data limitations by considering validity, scope, precision, and agreement with secondary evidence. 2. Students should be able to critique and evaluate the evidence for a claim.

9.WSAT 5 Evaluating risk in practical science and the wider context

9.WSAT 5.01 Risk assessment	1. Scientific thinkers: • assess risk by considering both the likelihood and severity of harm • identify and minimise risks in their enquiries and consider the wider impacts of their work • use evidence to carry out risk–benefit analysis when making decisions about actions • recognise that perceived risk may differ from actual risk and that this can influence decisions and behaviour. • identify and minimise risks in their enquiries and consider the wider impacts of their work. • evaluate evidence and expert advice when making informed decisions about risk. • recognise that scientific evidence may have limitations and that some areas may be uncertain or under-researched.

	2. Different opinions may exist, but decisions and conclusions about risk should be justified using scientific evidence rather than personal belief.
9.WSAT 4.02 Judging the quality of conclusions	1. Expert peers evaluate: • method limitations, including sample size, methodology, and potential bias affecting objectivity. • source limitations, considering peer review, sample size, methodology, data quality, and potential bias. • data limitations by considering validity, scope, precision, and agreement with secondary evidence. 2. Students should be able to critique and evaluate the evidence for a claim.

Enquiry

9.WSEF 1 Planning for valid methods

9.WSEF 1.01 Developing scientific methods	1. Scientific researchers plan a valid method to answer an enquiry question; they select apparatus, technique, and procedure, which includes an appropriate range of measurements and intervals between them; they know the likely associated measurement errors and how to reduce them or their impact; they ensure they have the necessary skill level to carry out any techniques; they carry out an appropriate risk assessment. 2. Scientific researchers may plan to use a sampling technique when it is not possible to collect all data, because there would be too much; they ensure data is representative of the whole dataset.
9.WSEF 1.02 Hypotheses and variables	1. Scientific researchers plan to look for patterns in data to explore if there is a correlation between factors, as a correlation may be used to propose a new hypothesis. 2. Scientific researchers plan methods which find out if the outcome of a test matches a prediction, so the factor can be accepted as being a cause that explains the observation.

9.WSEF 2 Common techniques and apparatus

9.WSEF 2.01 Equipment	1. The use of the equipment listed for Year 7&8 plus: conical flask, resistors, magnets, Eureka can, ecology fieldwork apparatus. 2. Students should be able to select appropriate equipment and skilfully use it. 3. Students should be able to set up parallel circuits. (9.06)
8.WSEF 2.02 Measuring instruments	1. The use of the measuring instruments listed for Year 7&8 plus: 2. Students select the most appropriate instrument for the measurement. 3. Calibration is the process of adjusting or determining the accuracy and precision of a measurement instrument or system by comparing it to known standards or reference points. 4. Scientific researchers check instruments are calibrated prior to experimenting. 5. Students should be able to explain the process of a simple calibration, e.g. force-meter, thermometer. 6. Measuring instruments with digital displays have divisions which are equal to the smallest measurement possible 7. There are different thermometers that can be used for different measurements depending on the materials.
9.WSEF 2.03 Techniques	1. The techniques listed for Year 7 and 8 plus: finding volume of regular and irregular solids and liquids, sampling organisms, measuring rate of chemical reaction, observing wave behaviour in a ripple tank. 2. Students should be able to carry out the techniques listed above.

9.WSEF 3 Planning for safe practical science

9.WSEF 3.02 Managing specific hazards	1. Students should be able to identify hazards, risks, and control measures associated with fieldwork, including environmental hazards, organisms and use of fieldwork equipment. 2. Students should be able to identify hazards, risks, and control measures associated with electrical investigations, including the

	use of power supplies, conductive materials, electrostatic equipment, and electromagnets.

9.WSEF 4 Making valid observations

9.WSEF 4.01 Measuring	1. Scientific methods that use measuring instruments follow agreed techniques to produce objective data. 2. A researcher identifies that a technique has a certain amount of uncertainty associated with it when carried out skilfully. 3. Students should be able to collect valid measurements and be able to suggest actual uncertainty associated with apparatus or technique.

9.WSEF 5 Evaluating methods

9.WSEF 5.02 Evaluating methods	1. Scientific researchers evaluate throughout the enquiry, including during planning, data collection, analysis, and interpretation. 2. Following evaluation, improvements are suggested to increase confidence in the outcome. 3. Students should be able to evaluate a method that has been carried out.
9.WSEF 5.03 Evaluating data analysis and interpretation	1. Students should be able to evaluate from tables and charts the extent to which analysis and interpretations are valid.

Analytical and Evaluative Approaches

9.WSAN 1 Presenting, analysing, interpreting data; developing explanations; evaluating data

9.WSAN 1.01 Recording data	1. All data is clearly and systematically recorded in tables where possible, including uncertainty values and processed data (calculations). 2. Students should be able to record data systematically in tables, where possible.
9.WSAN 1.02	1. Identifying the most appropriate chart or graph depends on the type of data and the line of enquiry:

Data, charts and graphs	• scatter graph - used to display the relationship between two continuous variables. Suitable axes scales should use sensible intervals (e.g. multiples of 2, 5, or 10) and make effective use of the available space. • sketch graph - represents the overall relationship between two variables, showing the correct shape of the trend without plotting individual data points. Axes should be labelled but do not need to be scaled. 2. Students should be able to draw a scatter graph, including a line of best fit where appropriate. 3. Students should be able to draw a sketch graph.
9.WSAN 1.03 Processing data	1. Students should be able to extrapolate to estimate values outside the measured range. 2. Students should be able to interpolate to estimate values between two known values.
9.WSAN 1.04 Tables, charts and qualitative observations	1. A straight-line graph indicates a directly proportional relationship between variables.
9.WSAN 1.05 Basic conclusions	1. A valid conclusion is supported by appropriate data, obtained from a suitable method, and based on logical reasoning. 2. Conclusions should relate to the original hypothesis (where available), stating the extent to which it is supported or refuted. 3. Students should be able to: • draw conclusions supported by data; • explain findings using scientific knowledge or models; • relate conclusions to the original hypothesis.
9.WSAN 1.06 Interpreting data	1. A straight-line graph through the origin indicates a directly proportional relationship between variables. 2. In a directly proportional relationship, as one variable doubles, the other also doubles.

	3. A correlation describes a relationship between variables, but it does not necessarily imply causation, as relationships may be influenced by other factors. 4. Apparent correlations may occur by chance; repeatable data increases confidence that a relationship is not random. 5. A causal relationship occurs when a change in one variable directly causes a change in another. 6. A curved line of best fit indicates that the relationship between variables changes across the range of data. 7. When completing an energy analysis, scientific thinkers describe: • the initial observation • the transfer or transformation of energy • the change in energy stores between initial and final states 8. When explaining past phenomena, the best explanation is the one that best fits the available evidence and is consistent with established scientific knowledge and principles.
9.WSAN 1.07 Evaluating findings	1. Data and methods are evaluated for validity (see 9.WSEF 5.02) to determine the level of confidence in conclusions. 2. Interpretation of the data and conclusions are evaluated for validity, including suggesting further work to improve confidence in the findings.

9.WSAN 2 Managing uncertainty

9.WSAN 2.01 Random error	1. Scientific researchers estimate the extent of errors and uncertainty to interpret data. 2. Uncertainty can be estimated from the spread of values in a data set, for example by calculating half the range: (max – min) / 2. 3. Random errors are often the main contributor to uncertainty, causing variation between repeated measurements. 4. Students should be able to calculate uncertainty from the spread of data and use this to evaluate the reliability of results.

9.WSAN 2.02 Systematic error	1. The actual uncertainty of using an instrument is normally a measurement of its resolution or an estimate of a random error if that is greater. 2. Some instruments lead to high uncertainty even when systematic error is low, e.g. high variation of ammeter readings with an unstable load. 3. The estimation of uncertainty can vary depending on expertise, with more precise judgements made through careful consideration of instrument resolution and measurement technique. 4. When a systematic error (constant bias) is identified, researchers evaluate whether it can be corrected using a calculation or whether the data should be rejected. 5. Students should be able to identify the actual uncertainty of measurements when using specific instruments.

9.WSAN 3 Implications and Extensions of Enquiries

9.WSAN 3.01 Possible implications of enquiries	1. Further lines of enquiry are proposed by analysing patterns, trends, and anomalous data, leading to new hypotheses and identifying areas requiring further investigation. 2. Further research questions can be devised based on the possible impact of findings. 3. Scientific conclusions often have an impact in the real-world, which demand further line of enquiry.

Applications of Science and its Implications

9.WSAI 1 Developing scientific knowledge through technology

9.WSAI 1.01 Examples of technological applications to science	1. Advances in technology have increased the use of gene banks to store and preserve hereditary material for future use. 2. Students should be able to give examples of how the development of technology has increased the body of scientific knowledge.

9.WSAI 2 Developing technology through science

9.WSAI 2.01 Examples of scientific knowledge applications to industry	1. STEM workers carry out life-cycle assessments to estimate long-term impacts of a product. 2. Scientific advances have enabled STEM workers to develop new energy sources. 3. Students should be able to give examples of technological developments due to an increased body of scientific knowledge.

9.WSAI 3 Ethical, social, economic, and political implications

9.WSAI 3.02 Global impact of scientific research	1. Students should be able to show that science and technology has the ability to identify problems and solutions arising from human activities, but may not always have the power to resolve them due to political, social, ethical or economic considerations.

Protocols for Measurement

9.WSME 1 Units

9.WSME 1.02 Derived quantities	1. Some quantities derive from the base quantities, normally expressed as products of powers of the base units as listed for Year 7 and Year 8, with some units having special names, and also: • Electrical resistance – ohm (Ω); its derived unit is the volt per amp (V/A). • Pressure – pascal (Pa); its derived unit is the newton per square metre (N/m²). 2. Students should be able to identify the standard unit and other commonly used units for the quantities listed above.

9.WSME 2 Notation and conventions

9.WSME 2.01 Standard prefixes	1. The international system (S.I.) uses a range of unit prefixes which differ by the factor of 1 000, as listed for Year 7 and year 8. 2. To convert a quantity to a different unit, the prefix is a multiplying factor:

	• a prefix of micro- (μ) divides the base unit by 1 000 000 • a prefix of mega- (M) multiplies the base unit by 1 000 000 3. Students should be able to use and convert between 'micro-' and 'mega-' and the base unit.

9.WSME 3 Symbols and formulae

9.WSME 3.01 Quantities and substances	1. Symbols representing physical quantities list can be found in Appendix C. Note, students are not expected to learn them but teachers should use them when modelling equations.
9.WSME 3.02 Formulae (equations)	1. Students should be able to use and rearrange the formulae listed in Appendix B.

How Knowledge Should Be Used

Use of Knowledge (U)	Typical Command Words	Examples
U1 **Demonstrate knowledge**	Describe, Explain, Draw, Identify, Label, State, Define, Give	Label the diagram of a cell. Draw particle diagrams to represent the three states of matter. Describe evidence of a chemical reaction. State what is meant by 'conservation of mass'.
U2 **Apply knowledge**	Calculate, Compare, Describe Explain, Estimate, Use, Determine, Suggest	Explain why sexual reproduction leads to genetic variation. Explain why temperature affects solubility. Determine the resultant force in [scenario].
U3 **Analyse and Evaluate**	Evaluate, Justify, Suggest, Predict	Predict how the resultant force will affect the motion of the object. Evaluate the technique used to measure the change in speed. Suggest why it is important to lower the cover slip slowly and gently.
U4 **Make thematic links (synoptic)**	(Various)	Describe the energy transfers involved in a combustion reaction. Use the words 'energy store' and 'energy transfer' in your answer.

Summative Assessments

What Will the Assessments Look Like?

Summative assessments will assess a sample of the content in this specification. What is assessed may vary from year to year.

Papers will include a variety of questions intended to assess students' knowledge, and their ability to use their knowledge in the ways set out in the specification. They will usually include some multiple choice or other objective questions, some short answer questions, and some extended response questions. Students may be asked to bring together knowledge from different sections of the specification to show their holistic understanding of the content.

End-of-Year

The end-of-year assessment for Science comprises separate papers for Biology, Chemistry and Physics. New, unseen papers will be provided annually.

Each paper is designed to last one hour or less, to enable them to be sat during normal lesson time.

The end-of-year assessments are intended to be taken in June, with question papers and mark schemes made available in May. Teachers will be able to input marks into Smartgrade to obtain cohort-benchmarked results for summative use and, where available, topic and question-level analysis for formative use.

Mid-Year

An additional mid-year assessment provides formative feedback and helps track students' progress through the curriculum. This will assess a sample of the content intended to be taught in the first term. The mid-year assessment for Science comprises one paper. New, unseen papers will be provided annually.

The paper is designed to last one hour or less, to enable it to be sat during normal lesson time.

The mid-year assessments are intended to be taken in January, also with analysis available through Smartgrade.

What Will Be Assessed in Each Summative Assessment?

End-of-Year 7 Assessment

This specification outlines the content that should be taught in Year 7. Because the end-of-year summative assessment takes place before the end of the school year, not all content taught in Year 7 can be summatively assessed in Year 7.

The substantive content in B2 Inheritance and Reproduction and B3 Variation and Evolution should be taught in Year 7, in the last half term of the year, but it will **not** appear in an assessment until Year 8.

Mid-Year 7 Assessment

This assessment may assess content from the first term:

Biology

- B1.01 Life processes of organisms
- B1.02 Cells, tissues, organs and organ systems
- B1.03 Features of plant and animal cells
- B1.04 Needs of organisms

Chemistry

- C1.01 Particle model of matter
- C1.02 State changes
- C1.03 Gas pressure
- C2.01 Pure substances and mixtures
- C2.02 Solutions
- C2.03 Separating mixtures

Physics

- P1.01 Describing forces and their effects
- P1.02 Modelling forces
- P1.03 Resultant force and its effects
- P1.04 Deforming objects
- P1.05 Describing friction
- P1.06 Energy stores
- P1.07 Energy transfers

- P1.08 Energy analysis

Working Scientifically skills

- 7.WSAT 1 Seeking objectivity
- 7.WSAT 2 Development of methods and theories over time
- 7.WSAT 3 Using a variety of models
- 7.WSAT 4 The importance of peer review
- 7.WSEF 1 Planning for valid methods
- 7.WSEF 2 Common techniques and apparatus
- 7.WSEF 3 Planning for safe practical science
- 7.WSEF 4 Making valid observations
- 7.WSEF 5 Evaluating methods
- 7.WSAN 1 Presenting, analysing, interpreting data; developing explanations; evaluating data
- 7.WSAI 1 Developing scientific knowledge through technology
- 7.WSAI 2 Developing technology through science
- 7.WSAI 3 Ethical, social, economic, and political implications
- 7.WSME 1 Units
- 7.WSME 2 Notation and conventions
- 7.WSME 3 Symbols and formulae

Uses of Knowledge

- U1 Demonstrate knowledge
- U2 Apply knowledge in familiar and unfamiliar contexts

End-of-Year 8 Assessment

This specification outlines the content that should be taught in Year 8. Because the end-of-year summative assessment takes place before the end of the school year, not all content taught in Year 8 can be summatively assessed in Year 8.

The substantive content in the below topics should be taught in Year 8, but it will **not** appear in an assessment until Year 9.

- 8.B5.01 Diet
- 8.B5.02 Energy in Food

- 8.B1.10 Biological molecules
- 8.B1.11 Digestion and enzymes
- 8.B1.12 Absorption and transport of nutrients
- 8.B1.13 Factors affecting enzymes
- 8.B1.14 Making digestion efficient
- 8.P5.01 The Solar System
- 8.P5.02 Day and night
- 8.P5.03 Years and seasons
- 8.P5.04 The universe

The end of Year 8 assessment is cumulative, meaning that all content taught in Year 7 and 8 – excluding that listed above – can be assessed.

Mid-Year 8 Assessment

As well as material taught in the first term of Year 8, this assessment may also include any Year 7 content. **This includes 7.B2 Inheritance and Reproduction and 7.B3 Variation and Evolution**, which are not covered in the End of Year 7 assessment. The assessable Year 8 content is below.

Biology

- 8.B1.01 Plants as organisms
- 8.B1.02 Photosynthesis
- 8.B1.03 The changing understanding of photosynthesis
- 8.B1.04 Leaf structure and adaptations
- 8.B1.05 Root structure and adaptations
- 8.B1.06 Transport in plants (points 1–3)

Chemistry

- 8.C4.01 Composition and structure of the Earth
- 8.C4.02 Igneous rock formation
- 8.C4.03 Weathering and erosion
- 8.C4.04 Sedimentary rock formation
- 8.C4.05 Metamorphic rock formation and the rock cycle
- 8.C4.06 Fossils
- 8.C4.07 Fossil fuels

- 8.C5.01 Earth's atmosphere

  8.C5.02 The greenhouse effect, global warming and climate change

Physics

- 8.P1.01 Speed
- 8.P1.02 Distance-time graphs
- 8.P1.03 Relative motion
- 8.P1.04 Acceleration
- 8.P1.05 Motion in fluids
- 8.P3.01 Temperature
- 8.P3.02 Changing energy in the thermal store
- 8.P3.03 Thermal conduction
- 8.P3.04 Energy stores of a material
- 8.P3.05 Pressure and density
- 8.P3.06 Convection
- 8.P3.07 Thermal transfer by radiation
- 8.P3.08 Real world contexts

Working Scientifically skills

- 8.WSAT 1 Seeking objectivity
- 8.WSAT 2 Development of methods and theories over time
- 8.WSAT 3 Using a variety of models
- 8.WSAT 4 The importance of peer review
- 8.WSEF 1 Planning for valid methods
- 8.WSEF 2 Common techniques and apparatus
- 8.WSEF 3 Planning for safe practical science
- 8.WSEF 4 Making valid observations
- 8.WSEF 5 Evaluating methods
- 8.WSAN 1 Presenting, analysing, interpreting data; developing explanations; evaluating data
- 8.WSAN 2 Managing uncertainty

- 8.WSAN 3 Implications and Extensions of Enquiries
- 8.WSAI 1 Developing scientific knowledge through technology
- 8.WSAI 2 Developing technology through science
- 8.WSAI 3 Ethical, social, economic, and political implications
- 8.WSME 1 Units
- 8.WSME 2 Notation and conventions
- 8.WSME 3 Symbols and formulae

Uses of Knowledge

- U1 Demonstrate knowledge
- U2 Apply knowledge in familiar and unfamiliar contexts
- U3 Analyse and Evaluate
- U4 Make thematic links (synoptic)

End-of-Year 9 Assessment

This specification outlines the content that should be taught in Year 9. Because the end-of-year summative assessment takes place before the end of the school year, not all content taught in Year 8 can be summatively assessed in Year 9.

The substantive content in the below topics should be taught in Year 9, but it will **not** appear in the Year 9 assessment.

- 9.B1.06 Cell Division
- 9.B1.07 Culturing Microorganisms
- 9.C2.01 Elements, Compounds and Mixtures
- 9.C1.02 Atomic Structure and Isotopes
- 9.C2.03 Development of the Periodic Table
- 9.C3.02 Explaining Group Trends
- 9.C2.05 Transition Elements

The end of Year 9 assessment is cumulative, meaning that all content taught in Year 7, 8 and 9 – excluding that listed above – can be assessed.

Mid-Year 9 Assessment

As well as material taught in the first term of Year 9, this assessment may also include any Year 7 or 8 content. **This includes 8.B1.10 to 8.B1.14, 8.B5.01, 8.B5.02, and 8.P5.01 to 8.P5.04**, which are not covered in the End of Year 8 assessment. The assessable Year 9 content is below.

Biology

- 9.B1.01 Cellular respiration
- 9.B1.02 Aerobic respiration
- 9.B1.03 Anaerobic respiration

Chemistry

- 9.C1.01 Atomic structure
- 9.C2.02 The periodic table
- 9.C2.04 Element properties
- 9.C3.01 Group trends
- 9.C1.03 Chemical equations

Physics

- 9.P4.01 Magnetic fields
- 9.P4.02 Electromagnetism
- 9.P4.03 Motors and Generators
- 9.P2.01 Wave characteristics
- 9.P2.02 Transverse waves
- 9.P2.03 Speed of waves
- 9.P2.04 Longitudinal waves
- 9.P2.05 Energy transfer by waves
- 9.P2.06 Electromagnetic waves
- 9.P2.07 Wave properties
- 9.P2.08 Electricity from waves

Working Scientifically skills

- 9.WSAT 1 Seeking objectivity
- 9.WSAT 2 Development of methods and theories over time
- 9.WSAT 3 Using a variety of models
- 9.WSAT 4 The importance of peer review
- 9.WSAT 5 Evaluating risk in practical science and the wider context
- 9.WSEF 1 Planning for valid methods
- 9.WSEF 2 Common techniques and apparatus
- 9.WSEF 3 Planning for safe practical science
- 9.WSEF 4 Making valid observations
- 9.WSEF 5 Evaluating methods
- 9.WSAN 1 Presenting, analysing, interpreting data; developing explanations; evaluating data
- 9.WSAN 2 Managing uncertainty
- 9.WSAN.3 Implications and Extensions of Enquiries
- 9.WSAI 1 Developing scientific knowledge through technology

- 9.WSAI 2 Developing technology through science
- 9.WSAI 3 Ethical, social, economic, and political implications
- 9.WSME 1 Units
- 9.WSME 2 Notation and conventions
- 9.WSME 3 Symbols and formulae

Uses of Knowledge

- U1 Demonstrate knowledge
- U2 Apply knowledge in familiar and unfamiliar contexts
- U3 Analyse and Evaluate
- U4 Make thematic links (synoptic)

Version History

Year	Version	Date	Description of Changes
For 2024/25	1.0	10 June 2024	Initial release
For 2024/25	1.1	25 November 2024	Addition of WS skills and Uses of Knowledge to Mid-Year Assessments. Minor amendments to statements in detailed content to be taught.
For 2025/26	2.0	06 June 2025	Addition of Year 8 topics and detailed content to be taught. Addition of Year 8 assessment information. Addition of Year 8 key words in the glossary (Appendix A). Addition of Appendix B: Formulae (for reference) Addition of Appendix C: Quantities, units and their symbols (for reference). Removal of highlighting in Year 7 topics and detailed content. Minor amendments to the Year 7 statements in the detailed content to be taught and glossary.
For 2025/26	2.1	15 August 2025	Minor amendments to the Year 8 statements in the detailed content to be taught. Addition of Working Scientifically specification points to Mid-Year 8 Assessment. Addition of 8.C5.02 to Mid-Year 8 Chemistry Assessment. Addition of 8.B5.01, 8.B5.02, & 8.B1.10 to list of non-assessed content in End-of-Year 8 Assessment.

			Updates to assessable content.
For 2026/27	3.0	15 July 2026	Addition of substantive statement to Y7 C1.01 relating to properties of solids, liquids and gases. Addition of substantive statements to Y8 B5.01 relating to food labels, a balanced diet and the seven nutrients. Minor amendments to the Year 7 statements in the detailed content to be taught. Addition of Year 9 topics and detailed content to be taught. Addition of Year 9 assessment information. Addition of key words in the glossary for KS3 (Appendix A). Addition to Appendix B: Formulae (for reference) Removal of highlighting in Year 8 topics and detailed content. Minor amendments to the Year 8 statements in the detailed content to be taught.

Appendix A: Glossary of Key Terms in Working Scientifically

Term	Meaning
accurate	The closeness of a measurement to the true or agreed value.
analogy	A similarity between two things that can be used as a comparison.
anomaly	A value in a set of results which does not fit the pattern.
apparatus	The equipment, instruments, tools, or devices used in science.
average (mean)	A term for the arithmetic mean, found by dividing the sum of the values by the number of values.
calibration	The process of setting up a measuring instrument so it matches a known reference point.
causal relationship	Occurs when a change in one variable causes a change in another.
conclusion	A summary and explanation of what has been found during an investigation.
control measure	A safety precaution that is put in place to reduce the likelihood of harm.
correlation	A relationship between two variables.
data	Information collected during observation or measurement.
data (qualitative data)	Data that is non-numerical e.g. a description.
data (quantitative data)	Data that is numerical.
data (raw data)	Data collected directly from experiments or surveys.
data (primary data)	Data that is collected first-hand by the researcher.
data (secondary data)	Data collected by other researchers doing other experiments.
enquiry	The process of asking questions about something and investigating it.
enquiry (line of enquiry)	The selection of specific research questions that take the investigation in a particular direction.

enquiry (systematic enquiry)	An organised, logical approach to answer research questions. A systematic enquiry entails the use of a scientific method.
evidence	Data which has been shown to be valid.
fieldwork	Data collection and observation conducted in the natural or outdoor environment.
fair test	An investigation in which only the independent variable has been allowed to affect the dependent variable.
hazard	An object or situation that may be harmful to people, property or the environment.
hypothesis	A statement about a research question that suggests the expected result of the investigation.
interpret	To look for patterns and trends in data.
interval	The difference between measured values.
life-cycle assessments	The process of looking at the environmental impact of a product over its whole life.
line graph	Chart that uses data points and a line of best fit to show trends and patterns in data.
measurement	The act of measuring, using a measuring instrument.
measurement error	The difference between the measured value and the true value of the quantity being measured.
measurement error (random error)	A measurement error that arises unpredictably from the experimental environment and cannot be controlled.
measurement error (systematic error)	Experimental ‘mistakes’ that affect the expected outcome or results.
measurement error (parallax error)	Misreading of a measurement due to the observer's eye being misaligned with the scale.
measurement error (zero error)	A systematic error that can arise when a measuring device shows a value other than zero even when there is nothing being measured.
measurement result	A value attributed to the quantity being measured, reported at the end of the measurement process.

natural world	The real world.
observation	The act of noticing facts about things happening or existing in the world
peer review	When researchers submit work for peer feedback to ensure research quality and trustworthiness
precise	Measurements where there is very little spread about the mean value(s).
prediction	A statement that proposes an anticipated outcome if the hypothesis is correct.
quantity	Any property that can be given a size by counting or measuring.
range	The minimum and maximum values of the variables (or results).
rate	The speed at which something is changing or happening.
repeatability	A measure of the closeness of experimental results by the same person using the same method
reproducibility	A measure of the closeness of experimental results by different people or using different methods
resolution	The ability for an instrument to measure the smallest amount of change. The higher the resolution, the smaller the measurements it can handle.
risk	The likelihood anyone will come to harm if a planned action is carried out, and to what extent
sampling	The process of collecting a smaller group of data or observations to represent a larger population.
scatter graph	A graph used to display the relationship between two continuous variables.
scientific law	A description of a pattern from repeated observations
scientific method	The application of an objective approach to collect high-quality data and use the data to explain observations.
scientific model	A representation of reality which can be used to explain observations.
scientific theory	A suggested explanation for an observation. It is based on many facts and is confirmed through repeated observations.



sketch graph	A graph that represents the overall relationship between two variables, showing the correct shape of the trend without plotting individual data points.
true value	The value that would be obtained in an ideal measurement (considered unknowable but can be estimated or a consensus view).
uncertainty (measurement)	Estimate of the amount by which a measured value may differ from the true value.
uncertainty (conclusions)	Not being completely sure whether a scientific claim or conclusion is correct
unit	A standard used to compare measurements.
validity (method)	An investigative procedure that is suitable to answer the question being asked and results in valid data that is precise, accurate, repeatable and reproducible.
validity (conclusions)	A conclusion supported by valid data, obtained from an appropriate experimental design and based on sound reasoning.
value	An expression of the size of a quantity; may be a number or a number and a unit.
variable	A quantity or characteristic that can change.
variable (categoric)	A variable that is a label, such as plant names or types of materials.
variable (continuous)	A variable that has a value which can be assigned a magnitude through counting or measurement.
variable (control)	A variable that alongside the independent variable, might influence the outcome of the enquiry and thus must be maintained at a constant level or monitored closely.
variable (dependent)	The variable that is measured or observed in an investigation.
variable (discrete)	A variable that can only have single number values.
variable (independent)	The variable that is changed in an investigation.

Appendix B: Formulae (Equations)

Students will need to be able to use, but are not expected to learn, the following formulae (equations) when given.

work done = force x distance moved	$W = F\,s$
$\text{power} = \frac{\text{energy transferred}}{\text{time}}$	$P = \frac{E}{t}$
$\text{power} = \frac{\text{work done}}{\text{time}}$	$P = \frac{W}{t}$
weight = mass x gravitational field strength (g)	$W = m\,g$
$\text{pressure} = \frac{\text{force}}{\text{area}}$	$p = \frac{F}{A}$
force applied to a spring = spring constant × extension	$F = k\,e$
$\text{speed} = \frac{\text{distance travelled}}{\text{time}}$	$v = \frac{s}{t}$
$\text{efficiency} = \frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$	
$\text{efficiency} = \frac{\text{useful output power}}{\text{total input power}}$	
turning effect = force x distance from pivot	$M = F\,d$
$\text{current} = \frac{\text{charge flow}}{\text{time}}$	$I = \frac{Q}{t}$
$\text{density} = \frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$
energy transferred = power rating x time	
wavespeed = frequency × wavelength	$v = f\,\lambda$
$\text{resistance} = \frac{\text{voltage}}{\text{current}}$	$R = \frac{V}{I}$

$period = \frac{1}{frequency}$	$T = \frac{1}{f}$
$pressure \times volume = constant$	$p\,V = constant$
$energy\ for\ a\ change\ of\ state = mass \times specific\ latent\ heat$	$E = m\,L$
$change\ in\ thermal\ energy = mass \times specific\ heat\ capacity \times temperature\ change$	

Appendix C: Quantities, Units and Their Symbols

Students are not expected to learn symbols, but teachers may choose to introduce them and use them in formulae.

Quantity	Symbol for quantity	Common unit(s)	Symbol for unit(s)
work done and energy transferred	*W*	joule	J
force	*F*	newton	N
distance	*s*	metre	m
power	*P*	watt	W
time	*t*	second	s
weight	*W*	newton	N
mass	*m*	kilogram	kg
gravitational field strength	*g*	newton per kilogram	N/kg
pressure	*p*	pascal	Pa
length /distance	*l, x, r*	centimetre	cm
area	*A*	square centimetre	cm^2
spring constant	*k*	newton per metre	N/m
extension	*e*	centimetre	cm
speed	*v*	metre per second	m/s
turning effect	*M*	newton metre	Nm
charge flow	*Q*	coulomb	C
current	*I*	ampere (amp)	A
voltage	*V*	volt	V
density	ρ	gramme per cubic centimetre	g/cm^3
volume	*V*	cubic centimetre	cm^3
temperature	*T*	degree Celsius	°C
resistance	*R*	ohm	Ω

frequency	*f*	hertz	Hz
period	*T*	seconds	s