

# Vertical concepts



The '[big ideas of science education](#)' were first published by Wynne Harlen and a group of experts in science education in 2010. These ideas set out key concepts that, when understood together, allow pupils to understand the world around them.

The ideas are expressed in the form of narrative descriptions that builds the understanding of key ideas from primary to secondary education. They cannot be understood in single units or lessons; we need to build concepts by attending to them in small steps within the curriculum.

Ten ideas are **ideas of science**, and span the disciplines of chemistry, biology and physics. Four are **ideas about science**, and contribute to pupils' disciplinary understanding of how scientists work today.

## Ideas of science

1. All material in the Universe is made of very small particles
2. Objects can affect each other at a distance
3. Changing the movement of an object requires a net force acting on it
4. The total amount of energy in the Universe is always the same but energy can be transformed when things change or are made to happen
5. The composition of Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate
6. The solar system is a very small part of one of millions of galaxies in the Universe
7. Organisms are organised on a cellular basis
8. Organisms require a supply of energy and materials for which they are often dependent on or in competition with other organisms
9. Genetic information is passed down from one generation of organisms to another
10. The diversity of organisms, living and extinct, is the result of evolution

Year 3: Spring 2		Biology: Plants
	Required prior knowledge	Knowledge to be explicitly taught
Substantive	<ul style="list-style-type: none"> <li>• Coniferous plants keep their leaves all year round; deciduous plants lose their leaves in winter (e.g. oak, silver birch, horse chestnut, sycamore, ash) (Y1 Aut)</li> <li>• Trees are a type of plant that have a tall stem made of wood (Y1 Aut)</li> <li>• The basic parts of a plant are leaves, flowers, roots, stem/trunk/branch (Y1 Aut)</li> <li>• Germination is the development of a plant from a seed, during germination roots and shoots emerge and grow (Y1 Aut)</li> <li>• Germination is the development of a plant from a seed. During germination roots and shoots emerge and grow</li> <li>• A seed is living. A seed is the embryonic stage of the plant life cycle. A seed consists of three parts: the seed coat, the endosperm and the embryo. To germinate, a seed needs water and a certain temperature (Y2 Aut)</li> <li>• Many plants make fruits or vegetables; some of these grow below ground (Y2 Aut)</li> <li>• Animals and plants depend on each other in their habitats (Y2 Spr)</li> <li>• Living things have adapted to their environment. This means they may not be able to survive in other habitats (Y2 Spr)</li> <li>• Soil is a mixture of particles of rock, dead plants and animals, air and water (Y2 Aut)</li> </ul>	<ul style="list-style-type: none"> <li>• Oxygen and carbon dioxide are found in the air</li> <li>• Plants need air (oxygen and carbon dioxide), water, light, nutrients from the soil, space, and a suitable temperature to grow</li> <li>• Requirements for life vary from plant to plant and they adapt to their environment</li> <li>• Roots absorb nutrients from the soil and help anchor the plant</li> <li>• The stem/trunk supports the plant and transports water up the plant. The xylem transports water and nutrients from the roots, and the phloem transports food from the leaves to the all parts of the plant</li> <li>• Leaves use sunlight, carbon dioxide from the air and water to make their own food</li> <li>• The four main stages of the plant's life cycle include germination, pollination, fertilization and seed dispersal</li> <li>• Coniferous trees transport their seeds in cones; deciduous trees use seeds and flowers/fruit</li> <li>• Pollination and fertilization usually takes place in flowers. Dispersal is important to make sure there is enough space for seeds to germinate and plants to grow</li> <li>• Seeds can be dispersed by wind (e.g. sycamore), by animals in their droppings (e.g. things that are eaten, like a raspberry), attached to animal fur (e.g. goosegrass), or seeds can be self-prepared (pea pod)</li> </ul>
Disciplinary	<ul style="list-style-type: none"> <li>• Mathematics: Measure length and height (cm/mm) (Y2); interpret and construct block diagrams (Y2)</li> <li>• ASP: Dependent, independent and control variables (Y3 Aut)</li> <li>• ASP: Make a prediction based on substantive knowledge (Y2 Spr)</li> <li>• ASP: Scientists identify factors in an investigation that should</li> </ul>	<ul style="list-style-type: none"> <li>• How knowledge will be built upon</li> <li>• The male part of the plant is called the stamen, made up of the anther and filament, and the anther produces pollen grains (Y5 Spr)</li> <li>• The female parts of the plant are the ovary (which produces the female sex cells which are contained in the ovule) and the stigma which collects pollen (Y5 Spr)</li> <li>• Sexual reproduction is two parents - usually male and female - create a new organism by mixing their genes (Y5 Spr). Asexual reproduction does not involve sex cells or fertilisation. Only one parent is needed, and the offspring are (genetically) identical to the parent and each other (Y5 Spr)</li> <li>• Potatoes develop tubers and daffodils have bulbs, which will grow to be identical copies of the plant (Y5 Spr)</li> <li>• Geography: Adaptations of some plants in rainforests (e.g. buttress roots) (Y4 Spr)</li> <li>• Geography: A symbiotic relationship is a long-term relationship between one or more species. Mutualism is where this both species in the relationship receive benefits</li> </ul>
VCS	<ul style="list-style-type: none"> <li>• 4: All living things need food to give them energy (Y2)</li> <li>• 7: Living things grow, need, water, air and food, react to their surroundings, move, get rid of their waste, reproduce (Y2)</li> <li>• 8: Most plants make their own food (Y2)</li> </ul>	<ul style="list-style-type: none"> <li>• 7: Living things - organisms - need water, air, food, a way of getting rid of water and an environment that stays within a particular temperature range</li> <li>• 8: Plants make their own food using sunlight, carbon dioxide and water</li> <li>• 7: Micro-organisms are organisms that are so small that we cannot see them with our eyes alone (Y6)</li> <li>• 8: Animals are ultimately dependent on plants for their survival (Y4)</li> </ul>

Most units attend to at least one of these big ideas. The unit overview outlines the relevant building blocks that pupils will learn in each unit, and how the idea is developed in previous and subsequent units or at KS3-4.





	1. All material in the universe is made of very small particles	2. Objects can affect each other at a distance	3. Changing the movement of an object requires a net force to be acting on it
<b>EYFS</b>	<ul style="list-style-type: none"> <li>The same substance (water) can look different when it is hot or cold (ice)</li> </ul>	<ul style="list-style-type: none"> <li>Magnets can attract or repel other magnets</li> <li>Magnets attract magnetic objects</li> </ul>	<ul style="list-style-type: none"> <li>We can push and pull objects to make them move</li> </ul>
<b>Y1</b>			
<b>Y2</b>	<ul style="list-style-type: none"> <li>All the 'stuff' encountered in everyday life, including air, water and different kinds of solid substances is called matter</li> <li>Different materials are recognisable by their properties</li> </ul>		
<b>Y3</b>		<ul style="list-style-type: none"> <li>Objects can have an affect on other objects even when they are not in contact with them. Light reaches our eyes, even though the light source may be far away</li> <li>The non-contact force of magnetism mean magnets can attract or repel other magnets</li> </ul>	<ul style="list-style-type: none"> <li>Forces can push, pull or twist objects, making them change shape or motion</li> <li>Things can only change their motion if there is a net force acting on them</li> <li>When forces acting on an object are not equal and opposite in direction, they are unbalanced and will change an object's speed, direction or shape</li> </ul>
<b>Y4</b>	<ul style="list-style-type: none"> <li>The amount of material does not change when a solid melts or a liquid evaporates</li> <li>If a material could be divided into smaller and smaller pieces it would be found to be made of pieces, particles, smaller than can be seen even with a microscope. These particles are not in a material; they are the material.</li> </ul>	<ul style="list-style-type: none"> <li>Sound comes from things that vibrate and can be detected at a distance from the source because the air or other material around is made to vibrate. Sounds are heard when the vibrations in the air reach our ears</li> </ul>	
<b>Y5</b>	<ul style="list-style-type: none"> <li>When some materials combine, they do not change permanently and can be separated again</li> <li>Materials can be changed by heating and cooling</li> </ul>	<ul style="list-style-type: none"> <li>The non-contact force of gravity makes things fall to Earth</li> <li>There is gravitational force between all objects, but it is only felt when one or more of the objects has a very large mass</li> </ul>	<ul style="list-style-type: none"> <li>An object on Earth pulls the Earth as much as the Earth pulls the object, but because the Earth's mass is much bigger, we observe the motion of the object</li> <li>The downward force of gravity on an object on the Moon is less than that on Earth because the Moon has less mass on Earth</li> </ul>
<b>Y6</b>	<ul style="list-style-type: none"> <li>When some materials are combined, they form a new material with different properties to the original materials</li> </ul>		
<b>KS3</b>	<ul style="list-style-type: none"> <li>The smallest piece of a material is called an atom. All materials, anywhere in the universe, living and non-living, are made of a very large numbers of these basic 'building blocks' of which there are about 100 different kind</li> </ul>	<ul style="list-style-type: none"> <li>There is attraction and repulsion between objects that are electrically charged</li> <li>Visible light and other forms of radiation can travel through any empty space</li> </ul>	<ul style="list-style-type: none"> <li>How quickly an object's motion is changed depends on the force acting and the object's mass. The greater the mass of the object, the longer it takes to speed it up or slow it down (inertia)</li> </ul>





	4. The total amount of energy in the Universe is always the same, but energy can be transformed when things change or are made to happen	5. The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate
EYFS	<ul style="list-style-type: none"> <li>We have to push or pull objects to make them move</li> </ul>	<ul style="list-style-type: none"> <li>We experience different types of weather in different seasons</li> </ul>
Y1	<ul style="list-style-type: none"> <li>Things around us can be made to change or happen. We can pull objects behind us or push them across the table</li> </ul>	<ul style="list-style-type: none"> <li>Plants grow in soil</li> <li>The weather can change rapidly. Different seasons have different weather patterns</li> </ul>
Y2	<ul style="list-style-type: none"> <li>All living things need food to give them energy</li> <li>The arrows in a food chain show where energy is being transferred from and to</li> </ul>	<ul style="list-style-type: none"> <li>There is air all around us on Earth</li> </ul>
Y3		<ul style="list-style-type: none"> <li>Much of the solid surface of the Earth is covered in soil, which is a mixture of pieces of rock of various sizes and the remains of organisms. Some soil also contains air, water and some nutrients.</li> <li>There are many different kinds of rock with different composition and properties.</li> <li>Beneath the Earth's solid crust is a hot layer called the mantle. The Earth's crust consists of a number of solid plates which move relative to each other, carried along by movements of the mantle. The formation of mountains, earthquakes and volcanic activity are likely to occur at these cracks (see <b>Geography Year 3 Spring: Mountains and Volcanoes and Year 4 Summer: Earthquakes</b>)</li> </ul>
Y4	<ul style="list-style-type: none"> <li>The arrows in a food web show where energy is being transferred from and to</li> <li>Things around us can be made to change or happen. We can turn on a light bulb and make it brighter or dimmer.</li> </ul>	
Y5	<ul style="list-style-type: none"> <li>Many processes and phenomena are explained in terms of energy exchanges</li> <li>Energy cannot be created or destroyed. When energy is transferred from one object to others, the total amount of energy in the universe remains the same; the amount that one object loses is the same as the other objects gain</li> </ul>	<ul style="list-style-type: none"> <li>There is less and less air further away from the Earth's surface; space is a vacuum</li> <li>Light from the Sun warms the Earth's surface and the heat is trapped by the Earth's air. This is known as the greenhouse effect (see <b>Geography, Year 5 Summer: Climate across the world</b>)</li> </ul>
Y6	<ul style="list-style-type: none"> <li>Across the world, the demand for energy increases as human populations grow and modern lifestyles require more energy, particularly electrical energy.</li> </ul>	
KS3	<ul style="list-style-type: none"> <li>Objects have energy because of their chemical composition, their movement, their temperature, their position in a gravitational or other field, or because of compression or distortion of an elastic material.</li> </ul>	<ul style="list-style-type: none"> <li>Weather is determined by conditions of the air. The temperature, pressure, direction and speed of the movement and the amount of water vapour in the air combine to create the weather.</li> <li>Radioactive decay of material inside the Earth since it was formed is its internal source of energy.</li> </ul>





	6. Our solar system is a very small part of one of millions of galaxies in our universe	7. Organisms are organised on a cellular basis	8. Organisms require a supply of energy and materials for which they are often dependent on or in competition with other organisms
EYFS			<ul style="list-style-type: none"> <li>• There is a wide variety of living things, including plants and animals</li> </ul>
Y1	<ul style="list-style-type: none"> <li>• Daytime is when the Earth is facing the Sun; nighttime is when the Earth is facing away from the Sun.</li> </ul>	<ul style="list-style-type: none"> <li>• Living things, including humans, react to their surroundings with their senses</li> </ul>	
Y2		<ul style="list-style-type: none"> <li>• Living things grow, need, water, air and food, react to their surroundings, move, get rid of their waste, reproduce</li> </ul>	<ul style="list-style-type: none"> <li>• All living things need energy for food, as well as air, water and certain temperature conditions.</li> <li>• Most plants make their own food</li> <li>• Animals need food, which comes by eating plants (herbivores) or by eating animals (carnivores), which have eaten plants or other animals.</li> <li>• Plants and animals are dependent on each other.</li> <li>• Organisms are adapted to their environment. If conditions in a habitat change, organisms may not be able to survive.</li> </ul>
Y3	<ul style="list-style-type: none"> <li>• The Moon reflects light from the Sun.</li> </ul>	<ul style="list-style-type: none"> <li>• Living things need water, air, food, a way of getting rid of water and an environment that stays within a particular temperature range.</li> </ul>	<ul style="list-style-type: none"> <li>• Plants make their own food using sunlight, carbon dioxide and water</li> </ul>
Y4			<ul style="list-style-type: none"> <li>• Animals are ultimately dependent on plants for their survival.</li> <li>• The relationships among organisms can be represented as food chains and food webs.</li> </ul>
Y5	<ul style="list-style-type: none"> <li>• Our Sun is one of many stars that make up the Universe.</li> <li>• The distances between us and the bodies in solar system is huge, and even bigger in the Universe</li> </ul>		
Y6		<ul style="list-style-type: none"> <li>• Micro-organisms are organisms that are so small that we cannot see them with our eyes alone</li> </ul>	<ul style="list-style-type: none"> <li>• In any given ecosystem there is competition among species for the energy and materials they need to live.</li> </ul>
KS3	<ul style="list-style-type: none"> <li>• The tilt of the Earth's axis gives rise to seasons.</li> <li>• The movements of galaxies suggest that the Universe is expanding from a past state called the 'big bang', towards a future that is still unclear</li> </ul>	<ul style="list-style-type: none"> <li>• All organisms are made of one or more cells, which can only be seen through a microscope</li> <li>• All the basic functions of life – growth, reproduction, extracting energy from food – are the results of what happens inside cells</li> <li>• Cells are often aggregated into tissues, tissues into organs, and organs into organ systems</li> </ul>	<ul style="list-style-type: none"> <li>• Decomposers are essential (alongside producers and consumers) for a stable ecosystem.</li> </ul>





	9. Genetic information is passed down from one generation of organisms to another	10. Diversity of organisms, living and extinct, is the result of evolution
<b>EYFS</b>	<ul style="list-style-type: none"> <li>• Young animals grow into adult animals</li> </ul>	<ul style="list-style-type: none"> <li>• There are many different kinds of plants and animals in the world today.</li> </ul>
<b>Y1</b>		
<b>Y2</b>	<ul style="list-style-type: none"> <li>• Plants and animals reproduce (have offspring)</li> </ul>	
<b>Y3</b>		<ul style="list-style-type: none"> <li>• Fossils are the preserved remains or traces of living things.</li> </ul>
<b>Y4</b>		
<b>Y5</b>	<ul style="list-style-type: none"> <li>• Organisms produce offspring of the same kind, but in many cases offspring are not identical with each other or with their parents.</li> <li>• Plants and animals, including humans, resemble their parents in many features because information is passed from one generation to the next.</li> <li>• Not all information is passed on from one generation to the other in the same way; some skills and behaviour have to be learned</li> </ul>	<ul style="list-style-type: none"> <li>• Although organisms of the same species are very similar, they vary a little from each other.</li> </ul>
<b>Y6</b>		<ul style="list-style-type: none"> <li>• There are many kinds of organisms that were once alive but are now extinct.</li> <li>• We know about extinct animals from fossils.</li> <li>• Living things are found in certain environments because they have the features that enable them to survive there. This adaptation to their environment has come about because of the small differences that occur during reproduction, resulting in some individuals being better suited to the environment than others. In the competition for materials and energy, those that are better adapted will survive and are more likely to pass on their adapted feature to their offspring.</li> </ul>
<b>KS3</b>	<ul style="list-style-type: none"> <li>• In a human body, most cells contain 23 pairs of chromosomes. These provide information that is needed to make more cells in growth and reproduction.</li> </ul>	<ul style="list-style-type: none"> <li>• The natural selection of organisms has been going since the first form of life appeared on Earth 3.5 billion years ago.</li> <li>• Multi-cellular organisms evolved around 2 billion years ago</li> </ul>





### Ideas about science

Ideas about science relate to disciplinary knowledge and working scientifically. They are best taught with explicit reference in appropriate units. Not all the ideas are relevant to every unit (for example, the idea that 'theories and models fit the facts of the time' is better considered through the topics of classification or the solar system than, for example, magnetism). The most relevant ideas are therefore explicitly referenced at an appropriate level in the unit overviews and lesson slides:

Science assumes that for every effect there is one or more causes



Scientific explanations, theories, and models are those that best fit the facts known at a particular time



The knowledge produced by science is used in some technologies to create products to serve human ends



Applications of science often have ethical, social and economic consequences

