SCIENCE COMMUNITY REPRESENTING EDUCATION

Draft National Curriculum for science

A SCORE response to the Department for Education's consultation on the revised draft science curriculum for Key Stages 1–2, proposed draft Key Stage 3 science programme of study and request for comment on the published Key Stage 4 programme of study for science

16 April 2013

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Introduction

1. SCORE is a partnership of organisations, which aims to improve science education in schools and colleges in England by supporting the development and implementation of effective education policy. The partnership is chaired by Professor Julia Buckingham and comprises the Association for Science Education, the Institute of Physics, the Royal Society, the Royal Society of Chemistry and the Society of Biology.

Summary

2. SCORE supports the aims of the National Curriculum Review, but is concerned that the focus on increasing rigour primarily through the addition of content has led to a curriculum that will not achieve these aims. Rigour can be achieved through the in-depth understanding of a smaller amount of content, rather than a superficial understanding of a larger amount.
3. The National Curriculum should take as its starting point the learning outcomes that students should achieve by the end of each Key Stage, with content included if it facilitates these outcomes.
4. The way in which the Review has been carried out, with a range of stakeholders asked to comment on already defined content compiled by a number of drafters, has resulted in a curriculum that lacks the coherence within and across subjects that SCORE would like to see. It is particularly difficult to see the progression of ideas that is crucial to an understanding of the sciences.
5. SCORE is pleased to see the prominence of Working Scientifically throughout the curriculum, though further work is needed to ensure these sections are valuable as they could be.
6. SCORE has some concerns about the implementation of the new curriculum, particularly alongside the other reforms to GCSEs and A-levels being introduced at the same time.

Structure and aims

7. The National Curriculum Review was launched: to increase rigour, raise standards and improve coherence in the school curriculum; to ensure children acquire a core of essential knowledge in key subject disciplines; and to allow teachers greater freedom to use their professionalism and expertise. SCORE has always supported these aims.
8. During the process, it has become apparent that the first aim (increased rigour and raised standards) was seen as the most important and it was to be achieved by building the curriculum around statements of content, incorporating more of them and moving some content previously introduced at higher Key Stages down to lower Key Stages. Throughout the development, SCORE has expressed concerns about this approach. Increased rigour does not necessarily follow from increased content (see

para 18) and raising educational standards cannot be equated with increasing the level of the content (para 19).

9. It is not clear how the proposed curriculum provides more freedom for teachers to use their professionalism in science. There remain inconsistencies (in language and approach) across the curriculum and topics are not coherently developed between the science disciplines or with other subjects. These issues are more obvious in the secondary curriculum, which seems to be at an earlier stage of development.
10. The majority of the statements of content are correct and appear at the appropriate place in the curriculum. In primary, in particular, most of the content will look familiar to teachers (with some exceptions, which are noted below).
11. Additionally, we support the view of the Expert Panel that the National Curriculum in the sciences should develop a deep understanding of some big ideas in biology, chemistry and physics and we support recent statements that students should develop mastery of a core of knowledge and the ability to reason scientifically.
12. Although subject-based ideas are developed in the topic structure, there is little evidence of the development of thematic big ideas through the key stages; and this is a missed opportunity.
13. The draft of the curriculum published in February represents a useful working document and basis for discussion but requires further review. The secondary curriculum in particular needs further revision work to improve consistency, coherence and coverage.
14. The notes and guidance column in Key Stages 1 and 2 is useful, and should be extended to Key Stage 3, to help ensure consistency between the primary and secondary curricula, and to support teachers, particularly those who are non-specialists. Notes and guidance need a consistent and recognisable structure to improve usability, and as non-statutory content should not contain advice on how to teach. The statutory content also needs to be self-explanatory without the notes and guidance.
15. It would be useful to include a glossary of technical terms appropriate to each Key Stage to ensure consistency; the book on ‘The Language of Measurement’ produced by the Association for Science Education would be a good starting point.

Content

16. It is not clear that there is any rationale behind the inclusion or omission of content. There are examples of content that appear for their own sake rather than being part of a development of ideas – big or otherwise.
17. SCORE continues to argue that there should be clear principles for choosing the content that is included in the National Curriculum. For example:

    - Content should only be included if it is rich, earns its place and encourages a deep understanding of core ideas from the sciences. This is in line with the views of the Expert Panel.
    - The intended learning outcomes – what it is that students should know and be able to do by the end of the period of study – should be made clear and content should only be included if it builds towards those learning outcomes.

- Content should not be introduced for its own sake: it should be demonstrably important at the point that it is introduced. If it could be covered later – when it is more likely to be understood and it can be taught more efficiently – then that is better than covering it earlier in a superficial way.

18. We acknowledge that if content should only be introduced when it is appropriate for the developmental stage of the students, the outcome may be a curriculum that is not evenly balanced between the three sciences at every key stage. However, this is preferable to attempting to achieve an impression of balance at the expense of the inclusion of content at the educationally appropriate point.
19. Therefore, we are pleased to note that there are examples of delaying the introduction of some complicated ideas in physics in primary school until students need them and are ready to address them. Although the content is weighted towards biology, this will give teachers the opportunity to develop attitudes and practices – such as observation, discussion and an interest in the natural world - that will be useful across all science subjects. The contexts will allow teachers to build deep foundations in rewarding situations for this age group.
20. There is a large amount of variation in the way the content for the three science subjects has been presented, presumably as a result of them having different authors, which compounds the impression of a lack of consistency between the three sciences.
21. However, these remain drafts. As such they need to be tested against the views of the teaching profession; and they need to be audited for the amount of content and how their content contributes to the development of ideas through the Key Stages (see paras 18 to 22).
22. The curriculum contains a lot of content statements. As far as SCORE is aware, no audit has taken place to determine the teaching time needed to cover all the required content across all subjects (for example, how long are teachers expected to spend on composition of the Earth and atmosphere and circular motion). This would be a valuable activity, since it would help to ensure both the appropriate volume of content, and make it easier to demonstrate balance between the subjects in the higher key stages. However, the intention of such an activity would not be to prescribe how subjects should be taught, and should be carried out with an awareness of the fact that the National Curriculum is not intended to specify the complete school curriculum.
23. Such an analysis is likely to show that the curriculum has become overloaded. If that is the case, then there are a number of implications:

    - it puts pressure on teaching time: teachers will have to cover more material in the same time, thereby reducing the opportunities for their students to develop a deep and lasting understanding; knowledge will be held superficially and temporarily
    - teachers will be tempted to present students with a set of accepted and arcane facts that have to be learnt without seeing their interconnections or appreciating their origins or implications;
    - time pressures will mean less time for effective practical work to support students' deep and lasting understanding.

24. We are concerned that some content has been brought down from higher Key Stages. This is intended, presumably, to contribute to a raising of standards. However, it is not the content but the quality of teaching and the nature of the assessment that will ensure standards are raised and maintained (see para 44). It is risky and probably counter-productive to introduce content at too high a level too soon. It will

    - widen the gap between what is taught and what is learnt; content will be 'delivered' and treated trivially;
    - students will be drilled to deal with more complicated ideas without understanding their meaning or how to use them;
    - mean that many of the large proportion of non-specialist teachers will struggle to teach more challenging content.

    For example, Year 5 students are asked to "understand how some materials will dissolve in liquid to form a solution", but will not by that stage have been introduced to the idea of particles, which will prevent a proper understanding of the topic.

25. We wish to express a significant concern that instead of discovering the intellectual beauty of the sciences as ways of understanding the world, students will be given both an inauthentic experience of them as being large bases of unconnected facts. This is likely to have a negative impact on the uptake of the sciences post-16 and will inevitably make it unlikely for the Government 'to create a culture where people feel science, engineering and technology are relevant to them'.[1]

26. Like the Expert Panel, we would prefer to see a curriculum that encourages a deep understanding of a core of big ideas – both thematic and subject-based - rather than one that leads to a trivial grasp of a multitude of, occasionally advanced, ideas. Rigour could then come through the teaching and assessment of these ideas.

27. There should be an additional audit of the way that ideas are developed through the Key Stages and across the disciplines. It is important that the sequencing of material in all subjects should be designed with coherence and progression in mind, so that students encounter related topics in the most appropriate order, in a consistent manner and in a way that builds on ideas from across the subjects. For instance, although catalysts are introduced within the biology Key Stage 3 curriculum, they are not covered within the chemistry curriculum until Key Stage 4.

28. Links between the sciences and with other subjects is of particular concern. There are many areas of science which are not exclusive to one discipline (such as the atomic theory of matter) and it is important that these are taught in a coordinated way. Understanding of many phenomena draws on a broad range of disciplines, and teachers need to be aware of this in their lessons. The notes and guidance could incorporate such cross-disciplinary advice.

29. It is therefore also important that the content of the science curriculum is structured with proper consideration being given to areas of overlapping content, in particular

[1] See https://www.gov.uk/government/policies/engaging-the-public-in-science-and-engineering--3/supporting-pages/raising-public-awareness-of-science-engineering-and-technology, accessed 9 April 2013.

with respect to the mathematics, computing, design and technology, and geography programmes of study. The sequencing of material in all subjects should be designed with this coherence in mind, so that students encounter related topics in the most appropriate order.

30. The introduction of a new curriculum should be an opportunity to ensure that content, particularly for the science subjects, is kept up to date (through regular review) and reflects not only the current wide-ranging contexts and often interdisciplinary nature of scientific endeavour, but also the needs of pupils in the twenty-first century. This should be addressed in a variety of ways:
    - The biographies included in the notes and guidance should reflect a wider variety and span of scientific achievement than is currently the case.
    - The notes and guidance should include more contemporary contexts to reflect the impact that science has on everyday lives.
    - Both the notes and guidance and the curriculum itself should acknowledge current challenges that will be addressed using science; this could include (but not exclusively) health, climate change and energy supply.
31. The curriculum contains only a limited amount of Earth science. The statements that do appear seem random and haphazard - they do not form a coherent body of knowledge, and aspects of the Earth science curriculum appear to have been cherry picked without proper consideration for whether they fit with the topic area they have been introduced with. For example, rocks are introduced in Key Stage 2 science, but in Key Stage 3 geography. SCORE has previously mapped the Earth science curriculum across overlapping subjects, and is happy to provide this mapping to the Department for Education.
32. There is also no consideration of Space as a topic in Key Stage 3, nor personal hygiene and adolescence; these omissions should be rectified.
33. It would be preferable if the content of the curriculum were presented over a whole Key Stage or in phases rather than year by year. This would make it more adaptable for schools that work with mixed age classes.
34. Each science requires a paragraph at the beginning of its programme of study that sets out the nature of that subject, what it is that we want students to appreciate about that subject, and why that subject is of value to them and to society. This will provide teachers with an overview that will help direct their teaching when addressing the detailed content knowledge.

Working scientifically

35. SCORE is pleased to see the working scientifically sections of the programme of study in a prominent place, , with different types of enquiry made explicit.
36. Through working scientifically, students should reach an understanding of what distinguishes scientific endeavour from other forms of knowledge. This should include an understanding of what makes scientific evidence robust, as well as the ethical considerations needed when undertaking scientific research.
37. The ‘using and applying mathematics’ section needs to be given greater prominence within each Key Stage, contextualised in terms of each science discipline and appropriately sequenced with, for instance, the content of the mathematics and

computing curricula, for instance with respect to the use of semi-real or real data, and the introduction of algebraic curves, which should occur in Key Stage 4.

38. The ‘nature, processes and methods of science’ section for Key Stages 1 and 2 is not very clear; we are particularly unclear what is meant by ‘statistical cycle’. This is not a phrase that will be known to science teachers.

39. The language used in the working scientifically section needs to be accurate and consistent. Words such as ‘reliability’ are used incorrectly, and could usefully be included in the glossary of terms (see para 10).

40. Further guidance and exemplification of context is needed within ‘Working scientifically’, for example what is meant by ‘taught to evaluate risks’? (Key Stage 3). Clarification should be provided to determine if there is risk during practical experiments (stools under tables etc.) or risk more widely, which might be more appropriate for Key Stage 4.

41.

42. The section headed Measurement is misnamed as it contains no statements about making measurements. This is a lost opportunity to specify the range and accuracy of measurements expected of pupils at this Key Stage (Key Stage 3).

43. The section headed ‘Scientific attitudes’ is misnamed. It does not describe accurately the content included within it (Key Stage 3).

44. The lack of specificity and exemplification in the Measurement section makes it very difficult for teachers to plan progression across Key Stages, and will lead to a lack of consistency between schools and between science disciplines.

Progression

45. More explicit consideration is required with respect to:

    a. progression from EYFS to Key Stage 1 (the expectations of the former are actually greater than those of the latter);

    b. progression within specific topics (eg in Year 1, students are expected to be taught to ‘identify and describe the basic structure of a variety of common flowering plants’ but not to describe their functions until Year 3; it would be better to introduce aspects of function earlier and develop these later);

    c. progression across the Key Stages (in particular, the transition from Key Stage 2 to Key Stage 3 being affected by the overly detailed and prescriptive nature of Key Stage 2 and the lack of clarity regarding the detail in which material in Key Stage 3 should be covered.

46. SCORE agrees that it is essential that the curriculum is designed to allow students to progress through the Key Stages, building on knowledge and understanding. However, it is difficult to determine how progression will work, particularly for the Key Stage 4 curriculum, given the ongoing uncertainties surrounding A-level design. This reflects the different processes being used to decide content at different stages of the education system.

Notes and guidance

47. In our response to the draft primary curriculum published in August 2012, SCORE advised the inclusion of 'boundary statements' to make clear when learning would be addressed later in the programme of study. Although these have been partially added, we would like to see them included more consistently throughout the document.

48. In the primary curriculum, each section has a useful introduction that sets out the way that children will approach their learning of science. Broadly, in key stage 1, they will experience phenomena, in lower key stage 2 they will start to look for and recognise patterns and in upper key stage 2 they will start to seek and give explanations. However, we feel that this progression could be made even clearer by stating these principles in the introduction to the science section. Additionally, the guidance notes could be used to highlight the opportunities for progression through the key stages.

Learning outcomes and assessment

49. SCORE would like to see clear learning outcomes that outline what students should know, understand and be able to do by the end of each Key Stage.

50. In this response, we have acknowledged the aims of achieving more rigour and raising standards. Throughout, we have challenged the assumption that these aims are best addressed by increasing the amount and raising the level of content. Throughout the process, we have maintained that the way to improve rigour and maintain standards is to improve the quality of assessments and the assessment system. It is possible to pose deep and challenging questions about the most basic principles, for example Newton's laws. It is also possible to set trivial and superficial questions about, for example, circular motion. As has been stated, SCORE would prefer to see the amount and level of the content statements being reduced and the quality of assessments being improved to ensure that students are challenged by the depth of their understanding rather than the surface area of their knowledge.

51. If designed appropriately, assessment can work as a lever to ensure that students have an authentic experience of the sciences in school; SCORE is encouraged that the sample testing regime for Key Stage 2 may include measures to assess practical work in the classroom, and it is hoped that this will encourage schools to undertake more, and more effective, practical work.

Implementation

52. The introduction of additional content will have a significant impact on teachers, particularly teachers who are not subject specialists. For example, the energy section of the physics curriculum will present a challenge, as will the inclusion of evolution in the primary curriculum. It is important that sufficient support mechanisms are put in place to ensure that teachers are ready to teach the curriculum in September 2014.

53. SCORE would like to see central coordination of the support and advice for teachers; we are aware that the National College for Teaching and Leadership is doing some work in coordinating changes to ITE, but we would advise that their remit is widened to include providing advice and support to the profession more widely.

54. SCORE's research on the resourcing of practical work[2] suggests that there are large numbers of schools that will struggle if specific items of equipment are required in the

[2] This research will be published on SCORE's website on 2 May 2013 at www.score-education.org

curriculum. As we have said in previous consultation responses, if specific equipment is referred to in the programmes of study, provision needs to be made to ensure schools are able to access this equipment. For example, 65% of primary schools report shortage of data loggers (which are mentioned in the statutory content), around 25% of primary schools reported shortages of working buzzers and motors, which are required for the year 6 programme of study, and around 35% of primary schools reported shortages of magnets.

55. The proposed phased introduction of the new curriculum is immensely complicated, and will put enormous pressure on schools, particularly given the proposed changes to GCSEs and A-levels taking place at the same time. For example,

    - There will be students who go through the new Key Stage 4 in 2014 and 2015 but take GCSE exams based on the previous criteria.
    - There will be cohorts of students who could start new GCSE courses in 2015 and 2016 who have followed (at least in part) the old Key Stage 3. Their grounding will be different from those who start GCSE courses in 2017 (who will have had three full years of the new Key Stage 3).
    - New A-levels will be introduced in 2015. These specifications will have to accommodate (over their lifetime) four different types of student: those who have been through existing GCSEs and the existing National Curriculum; those who have been through existing GCSEs and the new National Curriculum; and those who come through the revised GCSEs, as well as those in schools which do not follow the National Curriculum The fact that new A-levels are being developed in parallel with new GCSEs will make

Process for moving forward

56. SCORE continues to have grave concerns about the process by which the curriculum has been drafted, and these concerns have been expressed a number of times.
57. We would like to see audits of the curricular statements to:

    - Identify the amount of time available for each area of content
    - Ensure that ideas are introduced with all the necessary scaffolding, and that ideas are not introduced if they do not lead anywhere
    - Demonstrate how thematic ideas are developed through the content statements.
    - To revisit and develop the aim of achieving a deep understanding of a core of essential knowledge, built on the ‘big ideas’ in each of the sciences
    - Ensure there are clear learning outcomes for each statement, that can be assessed effectively

58. We are concerned that this statutory consultation will be the first and only chance for any changes to be made to the draft documents for Key Stage 3 (and 4). It is likely that there will be many comments and some of them will conflict with each other. Therefore, the next drafts cannot be the final ones. Any changes might introduce new problems. Time needs to be set aside for enough iterations to allow for thoughtful and meaningful comment by appropriate experts to be refined, collated and checked.

59. Further work is needed on the making the language consistent across the drafts published in February. It is vital that this is carried out by someone with subject knowledge, to avoid further errors being introduced.
60. SCORE would be pleased to comment on further drafts of the National Curriculum before distribution to schools.
61. We note that the Key Stage 4 programme of study is provided for information. It is not clear when, or indeed whether, this will be the subject of a consultation but SCORE would welcome the opportunity to comment.

Appendix to accompany SCORE's response to the draft National Curriculum for science

Response from Society of Biology, Royal Society of Chemistry and Institute of Physics

16 April 2013

The appendices that follow have been compiled by individual SCORE organisations, with contributions from their members and committees. There may therefore be contradictions between them.

Primary biology content showing topic progression

Plants

Statutory requirements	Notes and guidance (non-statutory)
Year 1 Pupils should be taught to: • identify and name a variety of common wild and garden plants, including trees, and those classified as deciduous and evergreen • identify and describe the basic structure of a variety of common flowering plants, including roots, stem/trunk, leaves and flowers.	***Year 1*** Pupils should use the local environment throughout the year to study plants growing in their habitats. Where possible, they should observe the growth of plants, including vegetables, that they have planted. They should become familiar with common names of plants, examples of deciduous and evergreen trees, and plant structures (trees: roots, trunk, branches, leaves, fruits; garden and wild plants: bulbs, roots, stem, leaves, flowers, petals, fruits, and seeds). Pupils might work scientifically by: observing closely, perhaps using magnifying glasses, and comparing and contrasting familiar plants; describing how they were able to identify and group them, and drawing diagrams showing the parts of different plants and trees. Pupils might keep records of how plants have changed over time, for example the leaves falling off trees and buds opening; and compare and contrast how different plants change.
Year 2 Pupils should be taught to: • observe and describe how seeds and bulbs grow into mature plants • find out and describe how plants need water, light and a suitable temperature to grow and stay healthy.	***Year 2*** Pupils should use the local environment throughout the year to observe how plants grow. Pupils should be introduced to the requirements of plants for survival and growth, as well as the process of growth and reproduction in plants. Note: Seeds and bulbs need water to grow but do not need light; seeds and bulbs have a store of food inside them. Pupils might work scientifically by: observing and recording, with some accuracy,

	the growth of a variety of plants as they change over time from a seed or bulb, or observing similar plants at different stages of growth; setting up a comparative test to show that plants need light and water to stay healthy.
Year 3 Pupils should be taught to: • identify and describe the functions of different parts of flowering plants: roots, stem, leaves and flowers • explore the requirements of plants for life and growth (air, light, water, nutrients from soil, and room to grow) and how they vary from plant to plant • investigate the way in which water is transported within plants • explore the role of flowers in the life cycle of flowering plants, including pollination, seed formation and seed dispersal.	***Year 3*** Pupils should be introduced to the relationship between structure and function: the idea that every part has a job to do. This teaching should focus on the role of the roots and stem in nutrition and support, leaves for nutrition and flowers for reproduction. Note: Pupils can be introduced to the idea that plants can make their own food, but at this stage they do not need to understand how this happens. Pupils might work scientifically by: comparing the effect of different factors on plant growth, for example the amount of light, the amount of fertiliser; discovering how seeds are formed by observing the different stages of plant life cycles over a period of time; looking for patterns in the structure of seeds that relate to how they are dispersed. They might observe how water is transported in plants, for example by putting cut, white carnations into coloured water and observing how water travels up the stem to the flowers.

Animals, including humans

Statutory requirements	**Notes and guidance (non-statutory)**
Year 1 Pupils should be taught to: • identify and name a variety of common animals that are birds, fish, amphibians, reptiles, mammals and invertebrates • identify and name a variety of common animals that are carnivores, herbivores and omnivores • describe and compare the structure of a variety of common animals (birds, fish, amphibians, reptiles, mammals and invertebrates, and including pets)	***Year 1*** Pupils should use the local environment throughout the year to study animals in their habitat. They should understand how to take care of animals taken from their local environment and the need to return them safely after study. Pupils should become familiar with the common names of a variety of birds, fish, amphibians, reptiles, mammals and invertebrates, including pets. Pupils should have plenty of opportunities to learn the names of the main body parts (including head, neck, arms, elbows, legs, knees, fingers, toes, face, ears, eyes, hair, mouth, teeth) through games, actions, songs and rhymes.

• identify, name, draw and label the basic parts of the human body and say which part of the body is associated with each sense.	Pupils might work scientifically by: using their observations to compare and contrast animals at first hand or through videos and photographs, describing how they identify and group animals; grouping animals according to what the animals eat, and using their senses to compare different textures, sounds and smells. If expanded/clarified, this could present opportunities for pupils to engage
Year 2 Pupils should be taught to: • notice that animals, including humans, have offspring which grow into adults • find out about and describe the basic needs of animals, including humans, for survival (water, food and air) • describe the importance for humans of exercise, eating the right amounts of different types of food, and hygiene.	***Year 2*** Pupils should be introduced to the basic needs of animals for survival, as well as the importance of exercise and nutrition for humans. They should also be introduced to the process of reproduction and growth in animals. The focus at this stage should be on helping pupils to recognise growth; they should not be expected to understand how reproduction occurs. The following examples might be used: egg, chick, chicken; egg, caterpillar, pupa, adult butterfly; spawn, tadpole, adult frog; lamb, sheep. Growing into adults can include reference to baby, toddler, child, teenager, adult. Pupils might work scientifically by: observing, through video or first-hand observation and measurement, how different animals, including humans, grow; asking questions about what things animals need for survival and what humans need to stay healthy; and suggesting ways to find answers to their questions.
Year 3 Pupils should be taught to: • identify that animals, including humans, need the right types and amount of nutrition, and that they cannot make their own food; they get nutrition from what they eat • describe the ways in which nutrients and water are transported within animals, including humans • identify that humans and some animals have skeletons and muscles for support, protection and movement.	***Year 3*** Pupils should continue to learn about the importance of nutrition (including a balanced diet) and should be introduced to the main body parts associated with the skeleton and muscles, finding out how different parts of the body have particular functions. Pupils might work scientifically by: identifying and grouping animals with and without skeletons and observing and comparing their movement; exploring ideas about what would happen if humans did not have skeletons. They might compare and contrast the diets of different animals (including their pets) and decide ways of grouping them according to what they eat. They might research different food groups and how they keep us healthy and design meals based on what they find out.

Year 4 Pupils should be taught to: • describe the simple functions of the basic parts of the digestive system in humans • identify the different types of teeth in humans and their simple functions.	***Year 4*** Pupils should be introduced to the main body parts associated with the digestive system, such as mouth, tongue, teeth, oesophagus, stomach and intestines and their functions. Pupils might work scientifically by: comparing the teeth of carnivores and herbivores, and suggesting reasons for differences; finding out what damages teeth and how to look after them. They might draw and discuss their ideas about the digestive system and compare them with models or images.
Year 5 Pupils should be taught to: • identify and name the main parts of the human circulatory system, and explain the functions of the heart, blood vessels and blood (including the pulse and clotting).	***Year 5*** Pupils should build on their learning from Years 3 and 4 about the main body parts and internal organs (in the skeletal, muscular and digestive systems) to explore how the circulatory system enables the body to function. Pupils should find out how ideas about the circulatory system have changed through studying the work of scientists in the past, such as William Harvey, who described the circulatory system in the seventeenth century, and Galen, the Roman physician of the second century. Pupils might work scientifically by: discussing and drawing what they think the circulatory system looks like and comparing this with images from other sources; discussing, drawing or creating models of how the main organs of the body fit together and function; comparing the effect of different types of activity on pulse rate and breathing rate. They might find out about the effects of things that can damage the body's systems.

All living things

Statutory requirements	Notes and guidance (non-statutory)
Year 2 Pupils should be taught to: • explore and compare the differences between things that are living, dead, and things that have never been alive.	***Year 2*** Pupils should be introduced to the idea that all living things have certain characteristics that are essential for keeping them alive and healthy. They should become familiar with the life processes that are common to all living things. Pupils might work scientifically by: sorting and classifying things according to whether they are living, dead or were never alive, and recording their findings using charts. They should describe how they knew where to place things, exploring questions such as: 'Is a flame alive? Is a deciduous tree dead in winter?' and talk about ways of answering their questions.
Year 4 Pupils should be taught to: • identify and name a variety of living things (plants and animals) in the local and wider environment, using classification keys to assign them to groups • give reasons for classifying plants and animals based on specific characteristics • recognise that environments can change and that this can sometimes pose dangers to certain living things.	***Year 4*** Pupils should use the local environment throughout the year to identify and study plants and animals in their habitat; and record how the habitat changes throughout the year. Pupils should classify animals into the major groups such as: vertebrates (animals with backbones) into fish, amphibians, reptiles, birds and mammals; invertebrates into snails and slugs, worms, spiders and insects. Pupils should explore examples of human impact (both positive and negative) on environments such as the effect of population and development, mowing, fertilisers or deforestation. Note: Plants are more difficult to classify, but can be grouped into categories such as flowering plants (including grasses), and non-flowering plants (such as ferns and mosses). Pupils might find out about the significance of the work of scientists such as Carl Linnaeus, a pioneer of classification. Pupils might work scientifically by: exploring local small invertebrates and using guides or keys to identify them; making a guide to local living things; posing and

	answering questions based on their observations of animals and what they have found out about other animals that they have researched.
Year 5 Pupils should be taught to: • describe the life cycles common to a variety of animals, including humans (birth, growth, development, reproduction, death), and to a variety of plants (germination, growth, development, reproduction and death).	***Year 5*** Pupils should study their local environment throughout the year and observe life-cycle changes in a variety of living things, for example plants in the vegetable garden or flower border, and animals in the wild. They should find out about the work of naturalists and animal behaviourists such as David Attenborough and Jane Goodall. Pupils might work scientifically by: observing and comparing the life cycles of plants and animals in their local environment with other plants and animals around the world (the rainforest, in the oceans, deserts and in prehistoric times), asking pertinent questions and suggesting reasons for similarities and differences.
Year 6 Pupils should be taught to: • describe the classification of living things into broad groups according to common observable characteristics and based on similarities and differences, including plants, animals and micro-organisms • describe reproduction in some plants and animals • describe the changes as humans develop from birth to old age • recognise the impact of diet, exercise, drugs and lifestyle on the way their bodies function.	***Year 6*** Pupils should build on their learning about the classification of all living things in Year 4 by looking at the classification system in more detail. They should be introduced to the term 'kingdom' and learn that most scientists classify things into 'five kingdoms' (bacteria, protists, animals, plants and fungi). Through direct observations where possible, they should classify animals into vertebrates (reptiles, fish, amphibians, birds and mammals) and invertebrates. They should find out about different types of reproduction, including sexual and asexual reproduction in plants, and sexual reproduction in animals. Pupils should build on what they have learnt in previous years about how the various body systems function. Pupils should learn how to keep their bodies healthy and how their bodies might be damaged – including how some drugs and other substances can be harmful to the human body. Pupils might work scientifically by: devising keys to identify some animals and plants in the immediate environment. Pupils might try to grow plants from different parts of the parent plant, for example seeds, stem and root cuttings,

	tubers, bulbs. They might observe changes in an animal over a period of time (for example, by hatching and rearing chicks); comparing how different animals reproduce and grow; and exploring the work of scientists and scientific research (including historical sources, e.g. the work of John Boyd Orr) about the relationship between diet, exercise, drugs, lifestyle and health. They might collect data by interviewing health professionals and create guidance for younger children about how bodies work and how to keep them healthy.

Habitats

Statutory requirements	**Notes and guidance (non-statutory)**
Year 2 Pupils should be taught to: • recognise that most living things live in habitats to which they are suited and describe how different habitats provide for the basic needs of different kinds of animals and plants, and how they depend on each other • identify and name a variety of plants and animals in their habitats, including micro-habitats	***Year 2*** Pupils should be introduced to the terms 'habitat' (a natural environment or home of a variety of plants and animals) and 'micro-habitat' (a very small habitat, for example for woodlice under stones, logs or leaf litter). They should use the local environment to identify and study a variety of plants and animals within their habitat and observe how living things depend on each other, for example plants serving as a source of food and shelter for animals. Pupils should compare animals in familiar habitats with animals found in less familiar habitats, for example, on the seashore, in woodland, in the ocean, in the rainforest. Pupils might work scientifically by: constructing a simple food chain that includes humans (e.g. grass, cow, human); describing the conditions in different habitats and micro-habitats (under log, on stony path, under bushes); finding out how the conditions affect the number and type(s) of plants and animals that live there.
Year 4 • describe how animals obtain their food from plants and other animals, using the idea of a simple food chain, and identify and name different sources of food.	***Year 4*** Add relevant non-statutory guidance

Evolution and inheritance

Statutory requirements	Notes and guidance (non-statutory)
Year 4 Pupils should be taught to: • identify how plants and animals, including humans, resemble their parents in many features • recognise that living things have changed over time and that fossils provide information about living things that inhabited the Earth millions of years ago • identify how animals and plants are suited to and adapt to their environment in different ways.	***Year 4*** Pupils should be introduced to the idea that characteristics are passed from parents to their offspring, for instance by exploring the family trees and family resemblances of historical personalities such as the Tudors or the Hapsburgs. Note: At this stage, pupils are not expected to understand how genes and chromosomes work. Building on the topic on rocks in Year 3, pupils should be reintroduced to fossils and find out, for example by studying dinosaurs, how things living on the Earth have changed over time. Pupils might find out about the work of palaeontologists such as Mary Anning. Pupils might work scientifically by identifying, comparing and recording similarities and differences among themselves and other animals and looking for patterns; observing and raising questions about local animals and how they are adapted to their environment; finding out about how some other animals and plants, beyond their own locality, are adapted to their environments.
Year 6 Pupils should be taught to: • recognise that living things produce offspring of the same kind, but normally offspring vary and are not identical to their parents • describe how adaptation leads to evolution	***Year 6*** Building on what they have learnt about evolution and inheritance in Year 4, pupils should look in more detail at how living things evolve. They should be introduced to the idea that variation in offspring over time can make animals more or less able to survive in particular environments and lead to evolutionary change. Pupils might find out about Charles Darwin's work on evolution.

• recognise how and why the human skeleton has changed over time, since we separated from other primates.	Pupils might work scientifically by: comparing how some living things are adapted to survive in extreme conditions, for example cacti, penguins and camels. They might analyse the advantages and disadvantages of specific adaptations, such as being on two feet rather than four, having a long or a short beak, having gills or lungs, tendrils on climbing plants, brightly coloured and scented flowers.

KS3 Biology

Structure and function of living organisms
Pupils should be taught about:

Cells and organisation

- cells as the fundamental unit of living organisms, including how to observe, interpret and record cell structure using a light microscope
- the functions of the cell wall, cell membrane, cytoplasm, nucleus, vacuole, mitochondria and chloroplasts
- the similarities and differences between plant and animal cells
- the role of diffusion in the movement of materials in and between cells
- the structural adaptations of a range of unicellular organisms
- the hierarchical organisation of multicellular organisms: from cells to tissues to organs to systems to organisms

The skeletal and muscular systems

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

Nutrition and digestion

- content in a healthy human diet: carbohydrates, fats, proteins, vitamins, minerals, dietary fibre and water, and why each is needed
- simple food tests for starch, simple (reducing) sugars, protein, fat
- calculations of energy requirements in a healthy daily diet
- the consequences of imbalances in the diet, including obesity, starvation and deficiency diseases

- the tissues and organs of the digestive system, including adaptations to function and how the digestive system digests food (enzymes simply as biological catalysts)
- the importance of bacteria in the digestive system
- healthy plants gain mineral nutrients from soil via their roots
-

The gas exchange system

- the structure and functions of the gas exchange system in a range of animals, including adaptations to function
- The role of leaf stomata in gas exchange in plants
- the mechanism of breathing to move air in and out of the lungs, using a pressure model to explain the movement of gases, including simple measurements of lung volume
- the impact of exercise, asthma and smoking on the gas exchange system.

Reproduction

- reproduction in humans (as an example of a mammal), including the structure and function of the male and female reproductive systems, menstrual cycle (without details of hormones), gametes, fertilisation, gestation and birth, to include the effect of maternal lifestyle on the foetus through the placenta
- reproduction in plants, including flower structure, wind and insect pollination, fertilisation, seed and fruit formation and dispersal, including quantitative investigation of some dispersal mechanisms

Health

- The importance of medicines in the treatment of disease and the effects of drugs (including substance misuse) on behaviour, health and life processes such as conception, growth and development.

Energy flow and material cycles

Pupils should be taught about:

Photosynthesis

- the dependence of almost all life on Earth on the transfer of solar energy to plants and algae in photosynthesis

- the adaptations shown in leaves which enable plants to photosynthesise more effectively the reactants and products of photosynthesis, and the word equation for photosynthesis

Cellular respiration

- aerobic and anaerobic respiration in living organisms, including the breakdown of organic molecules to enable all the other chemical processes necessary for life
- the word equation for aerobic respiration
- the process of anaerobic respiration in humans and micro-organisms, including fermentation, and the word equation for anaerobic respiration
- the differences between aerobic and anaerobic respiration, in terms of the products and amount of energy released.

Interactions and interdependencies

Pupils should be taught about:

Relationships in an ecosystem

- the interdependence of organisms in an ecosystem, including food webs and insect pollinated crops
- how organisms affect, and are affected by, their environment, including the accumulation of toxic materials
- the role of variation in enabling living things with similar requirements to survive in the same ecosystem
- the importance of plant reproduction through insect pollination in human food security

Genetics and evolution

Pupils should be taught about:

Inheritance, chromosomes, DNA and genes

- heredity as the process by which genetic information is transmitted from one generation to the next
- a simple model of the role of chromosomes, genes and DNA in heredity, and the part played by Watson, Crick, Wilkins and Franklin in the development of the DNA model
- the variation between individuals of different species

- the variation between individuals within a species being continuous or discontinuous, to include measurement and graphical representation of variation
- the variation between species and between individuals of the same species leading to competition for limited resources, which can drive natural selection
- changes in the environment that leave some species, and individuals within a species, less well adapted to compete successfully and reproduce, which might lead to extinction
- the importance of biodiversity and the use of gene banks to preserve hereditary material before a species becomes extinct.

Comments from the RSC on the chemistry content of the draft Science National Curriculum for Science at KS1-3 and the draft programme of study for KS4

Programme of study (statutory requirements	Notes and guidance (non-statutory)	Comments
Year 1: Everyday materials Pupils should be taught to: • distinguish between an object and the material from which it is made • identify and name a variety of everyday materials, including wood, plastic, glass, metal, water, and rock • describe the simple physical properties of a variety of everyday materials • compare and group together a variety of everyday materials on the basis of their simple physical properties • find out how the shapes of solid objects made from some materials can be changed by squashing, bending, twisting and stretching.	**Everyday materials** Pupils should explore, name and discuss everyday materials so that they become familiar with the names of materials and properties such as: hard/soft; stretchy/stiff; shiny/dull; rough/smooth; bendy/not bendy; waterproof/not waterproof; absorbent/not absorbent. Pupils should explore and experiment with a wide variety of materials, not only those listed in the programme of study, but including for example: brick, paper, fabrics, elastic, foil. Pupils might find out about people who have developed useful new materials; for example, Dunlop, Macintosh or McAdam.	In the notes and guidance section, the properties of materials area all properties associated with solid materials. This is not necessarily a problem but there should also be some emphasis on the idea that material is another name for ‘stuff’ and therefore makes up everything that we can see, hear, taste, smell and touch. Although we are not discussing solid, liquid and gas, it is important that children know that “air” for example is a material that can be used to make bouncy castles soft, or sponges squeezy. as one of the The fourth bullet point is perhaps more to do with forces than materials? Some reference to this could be made in the notes and guidance, something along the line of ‘pupils can also work scientifically

	Pupils might work scientifically by: performing simple tests to explore questions such as: 'What is the best material for an umbrella? ... for lining a dog basket? ... for curtains? ... for a bookshelf? ... for a gymnast's leotard?'	by describing changes to materials when they are squashed, bent, twisted and stretched and by identifying what made the changes happen' As part of the SCORE response to the informal discussions with stakeholders on the draft National Curriculum programme of study, in August, we suggested the inclusion of biographies relating to more modern materials, for example; lycra – Shivers; goretex – Gore; liquid crystals – Gray, Kevlar – Kwolek . Another biography, which students could relate to is of William Harbutt who invented plasticine.
Year 2: Uses of everyday materials Pupils should be taught to: • identify and compare the uses of a variety of everyday materials, including wood, metal, plastic, glass, brick/rock, and paper/cardboard.	**Uses of everyday materials** Pupils should identify and discuss the uses of different everyday materials so that they become familiar with how some materials are used for more than one thing (metal can be used for coins, cans, cars and table legs; wood can be used for matches, floors, and telegraph poles) or different materials are used for the same thing (spoons can be made from plastic, wood, metal, but not glass;	We suggest including some solids like sand and flour, and some liquids into the list of everyday materials to identify and compare In August we suggested inserting 'normally' in front of 'paper' in the notes and guidance section 'tables can be made from plastic, wood, metal, but not paper'. The word 'normally' could also be inserted in front of 'glass' in reference to spoons. It would be good to have an example of an unusual and creative use for everyday materials such as a desk tidy made from a recycled telephone directory or handbags made from bottle tops.

	tables can be made from plastic, wood, metal, but not paper). Pupils might work scientifically by: comparing the uses of everyday materials in and around the school with materials found in other places (at home, the journey to school, on visits, and in stories, rhymes and songs); observing closely, identifying and classifying the uses of different materials, and recording their observations. Pupils should be encouraged to think about unusual and creative uses for everyday materials.	This seems very similar to Year 1. It is also repeated in Year 5
Year 3: Rocks Pupils should be taught to: • compare and group together different kinds of rocks on the basis of their simple physical properties • relate the simple physical properties of some rocks to their formation (igneous or sedimentary) • describe in simple terms how fossils are formed when things that have lived are trapped within sedimentary rock.	**Rocks** Linked with work in geography, pupils should explore different kinds of rocks and soils, including those in the local environment. **Note:** Pupils are not expected to be taught about the formation of metamorphic rocks, such as marble and slate. Pupils might work scientifically by: observing rocks, including those used in buildings and gravestones, and exploring how and why they might have changed over time; using a hand lens or microscope to help them to identify and classify rocks according to whether they have grains or crystals, and whether they	The Earth Science content needs to be more clearly developed to show coherence between science and geography and demonstrate clear progression across the key stages. There also needs to be clearer link to what has gone before, linking what students have learnt about properties of solid materials It seems odd that sedimentary and igneous rocks appear here but are never mentioned again and that metamorphic rocks aren't mentioned at all in the whole framework document. We are concerned that at Year 3 students may not entirely grasp some of the concepts of rocks – in particular igneous rocks, if they are not studying states of matter until the following year. For

	have fossils in them. Pupils might research and discuss the different kinds of living things whose fossils are found in sedimentary rock and explore how fossils are formed.	example – relating the simple physical properties of igneous rocks to their **formation** requires an understanding that you have “Liquid rock” underground that freezes into “Solid rock” on or near to the surface. It is a big ask for a child to grasp this idea if they have not been taught about changes of state between for example water and ice, or what we mean by temperature. Without this understanding we do not believe that many children could relate property to formation. Or by “formation” do we actually mean “structure”. Much easier to see the links between the structure of a rock made of crystals being hard, and one made of layers and grains being easier to break into layers or crumble. Would suggest a rethink of the terms “formation” to “structure” here. The term ‘crystal’ could also be problematic, as it doesn’t appear anywhere else in KS1 to 3. Classifying rocks by their ‘simple physical properties’ is not so simple. Which physical properties of rocks are pupils expected to observe? It also seems odd that to make no reference to the appearance of rocks as a means of classifying them in the programme of study. In the notes and guidance reference is made to exploring different kinds of soils, although there is no mention of soils in the programme of study so it isn’t clear what about soils students should be exploring.

Year 4: States of matter Pupils should be taught to: • compare and group materials together, according to whether they are solids, liquids or gases • observe that some materials change state when they are heated or cooled, and measure the temperature at which this happens in degrees Celsius (°C), building on their teaching in mathematics • identify the part played by evaporation and condensation in the water cycle and associate the rate of evaporation with temperature.	**States of matter** Pupils should explore a variety of everyday materials and develop simple descriptions of the states of matter (solids can be held in your hands; liquids form a pool not a pile; gases escape from an unsealed container). Pupils should observe water as a solid, a liquid and a gas and should note the changes to water when it is heated or cooled. **Note:** Teachers should avoid using materials where heating is associated with chemical change, for example, through baking or burning. Pupils might work scientifically by: grouping and classifying a variety of different materials; exploring the effect of temperature on substances such as chocolate, butter, cream (for example, to make food such as biscuits and ice-cream for a party). They might observe and record evaporation over a period of time, such as a puddle in the playground or washing on a line, and investigate the effect of temperature on washing drying or snowmen melting.	It might be useful to give some examples in the notes and guidance of materials that change state when heated or cooled, which could feasibly be used by teachers or students in a typical primary school. In the notes and guidance it would be useful to point out some of the issues associated with taking temperature measurements of water as it changes state, such as the fact that due to impurities the boiling point of tap water is unlikely to be exactly 100 °C Sates of matter descriptions in notes and guidance should be altered as they might be misleading - a thick liquid like honey could he held in your hands.
Year 5: Properties of everyday materials and reversible change Pupils should be taught to:	**Properties of everyday materials and reversible change** Pupils should build a more systematic understanding of materials by exploring and comparing the properties of a broad	Bullet point 1: could also include transparency in the list of comparative and fair tests The distinction between melting and dissolving is

• compare and group together everyday materials based on evidence from comparative and fair tests, including their hardness, solubility, conductivity (electrical and thermal), and response to magnets • understand how some materials will dissolve in liquid to form a solution, and describe how to recover a substance from a solution • use knowledge of solids, liquids and gases to decide how mixtures might be separated, including through filtering, sieving and evaporating • give reasons, based on evidence from comparative and fair tests, for the particular uses of everyday materials, including metals, wood and plastic • demonstrate that dissolving, mixing and changes of state are reversible changes.	range of materials and relating these to what they learnt about magnetism in Year 3 and about electricity in Year 4. They should experiment with reversible changes, including melting, dissolving, evaporating, filtering and sieving. **Note:** Pupils are not required to make quantitative measurements about conductivity and insulation at this stage. It is sufficient for them to observe that some conductors will produce a brighter bulb in a circuit than others and that some materials will feel hotter than others when a heat source is placed against them. Pupils might work scientifically by: investigating questions such as 'Which materials would be the most effective for making a warm jacket, or for wrapping ice cream to stop it melting?' They might compare materials in order to make a switch in a circuit.	far from obvious at this stage. This should be discussed in the guidance. Second bullet point, suggest changing the word 'how' with 'that' in order to make the demand more appropriate to this age group and avoids the need for key stage 2 students to be taught about the particulate nature of matter. Dissolving for example needs expressing in terms of a material that does not disappear (we can still taste salty or sugary water) but instead is broken into smaller and smaller pieces until those pieces can fit between the particles of the liquid. The phrase 'comparative and fair tests' comes up only here and one other place. If it is important to develop this idea, it should appear more. Even the phrase 'fair test' comes up only three times in content topics. And twice is in the materials section. Not all practical activities will require fair tests, some will simply involve observing phenomena, but if it is an important idea, we need to see how it is developed through the key stages. There is quite a lot of repetition in the materials sections, the first bullet point in this section is not very different to what appears in Year 1 and the fourth, is a repeat of Year2.
Year 6: Changes that form new materials	**Changes that form new materials** Building on their work in Year 5 about changes that are easily reversible, pupils should explore changes that are difficult	Suggest changing 'new materials' to 'new substances' The use of the distinction between reversible and

Pupils should be taught to: • explain that some changes result in the formation of new materials, and that this kind of change is not usually reversible, including changes associated with burning, oxidisation, and the action of acid on bicarbonate of soda.	to reverse, such as burning, rusting (oxidisation) and reactions, for example vinegar with bicarbonate of soda. They should find out about how chemists create new materials, for example Spencer Silver, who invented the glue for sticky notes or Ruth Benerito, who invented wrinkle-free cotton. **Note:** Safety guidelines should be followed when burning materials. Pupils might work scientifically by: observing and comparing the changes that take place, for example when burning different materials or baking bread or cakes. They might research and discuss how chemical changes have an impact on our lives, for example cooking, and discuss the creative use of new materials such as polymers, super-sticky and super-thin materials.	non-reversible changes to distinguish physical and chemical changes is neither a necessary nor helpful preparation for introducing reversible reactions and chemical equilibria at KS4. Even at KS3, pupils meet reversible changes such as the effect of heat on copper sulfate crystals. Chemical change is a change of substance. In the absence of the concept 'substance' one is left groping around for proxies to introduce the idea of chemical change as a type of change. Close examination of any of these 'proxies', such as the criterion of 'non-reversibility' shows that they do not work well. There are plenty of non-reversible physical changes as well as a very large number of reversible chemical changes. Change 'oxidisation' to 'oxidation'

Chemistry Through the content across all three disciplines, pupils should be taught about:	**Comments on the draft**
Pure and impure substances • mixtures, including dissolving • techniques for separating mixtures: chromatography, filtering, evaporation and distillation • the identification of pure substances	Andrew Hunt has informed our responses here and has provided an alternative version of the chemistry content in the KS3 National Curriculum which the RSC broadly supports. His comments are informed by discussions that have taken place as part of the York Science project over the last two years and they are also informed by research at Leeds, Durham and York Universities and elsewhere. The concept of a substance is central to understanding chemistry. Students do not develop the concept naturally; it is an abstract idea that needs to be learned. Students cannot progress successfully with chemistry in KS3 and into KS4 unless they have grasped the chemist's notion of a substance. The first section needs to be about 'substances' more explicitly – even though the idea is covered by the third bullet point here. Filtering separates substances that are mixed on a different scale to the other methods of separation. The KS3 curriculum should aim to develop a sense of scale to include at least: particles (meaning atoms and molecules), microscopic particles that are grains, specks and droplets, and macroscopic lumps of stuff.

The particulate nature of matter • the properties of the different states of matter (solid, liquid and gas) in terms of particle kinetics, including gas pressure and diffusion • changes of state in terms of particle kinetics and energy changes	It would be good to make explicit that this is about a particle 'model' to explain states of matter and changes of state.
Atoms, elements and compounds • the nature of atoms, elements and compounds • chemical symbols and formulae for elements and compounds • conservation of mass in chemical and physical change	The first bullet point seems a bit vague What is the 'nature of atoms'? A simple model of the atom is to be introduced atKS4, so presumably atomic structure in terms of fundamental particles is not intended here. A Dalton model for atoms is all that is needed at KS3 for chemistry. Emphasis on the distinction between the notions of physical change and chemical change should be avoided. The distinction is a hindrance to clear thinking as students progress through Key stages 3 and 4. Many chemical changes are reversible and so the traditional distinction between physical and chemical changes based on the irreversibility of chemical changes is particularly unhelpful. The distinction is particularly misleading once students learn more about changes at the molecular level. Dissolving, for example, is regarded as a physical change in introductory courses but is explained in terms of changes to bonding between molecules (or molecules and ions) at a later stage.

Chemical reactions • chemical reactions as the rearrangement of atoms • representing chemical reactions using formulae and using equations, including state symbols • combustion, thermal decomposition, oxidation and displacement reactions	Include 'acids, alkali and neutralisation' and 'energetics sections in with this one We would suggest that at KS3 students could start learning how to balance simple equations,
Energetics • exothermic and endothermic chemical reactions (qualitative)	Should not be separate – should be in 'Chemical reactions' section
Acids, alkalis and neutralisation • defining acids, bases and alkalis in terms of neutralisation reactions • the pH scale for measuring acidity/alkalinity; and indicators • reactions of acids with bases and metals to produce a salt, plus water	Recommend putting this within chemical reactions section. . We recommend not introducing the term 'base' in KS3. First bullet point: Is the traditional pre-16 definition of a base intended? acid + base $\rightarrow$ salt + water. The traditional definition refers to the whole chemical substance as being an acid or a base. In this approach, soluble bases are defined as alkalis. This makes the position of carbonates ambiguous. Carbonates are not bases according to the traditional definition because they also produce carbon dioxide when they react with acids. However solutions of soluble carbonates are alkaline and insoluble carbonates do neutralize acids.

	In the draft programme of study for KS4 we have the Arrhenius definition for acids and alkalis in terms of the hydrogen and hydroxide ions formed when they dissolve in water. Post-16, in advanced courses, the Brønsted-Lowry theory is adopted where it is particular species that are acids or bases. So it is the hydroxide ion, the carbonate ion and the ammonia molecule that are bases. It seems unsatisfactory to introduce different definitions of the term base in each of three key stages. Not convinced that the term base is needed at KS3. If a special term is needed at all, it is better to use the term 'antacid' to cover the metal oxides, hydroxides and carbonates that neutralize acids (as on indigestion packets). Mistake in third bullet point as acid + metal → salt + hydrogen, not water

The Periodic Table • the Periodic Table: periods and groups; metals and non-metals • how patterns in reactions can be explained and predicted with reference to the Periodic Table • the varying physical and chemical properties of different elements • the chemical properties of metals and non-metals and metal and non-metal oxides with respect to acidity	Recommend including how Mendeleev came up with periodic table here rather than in KS4 – for reasons detailed below First bullet point: Presumably the idea that atoms are placed in order of atomic mass in the Periodic Table is needed here. If so, it would make sense to include the Mendeleev story here – rather than in the KS4 programme of study. The teaching needs to explain why chemists came up with the periodic table. Second bullet point: What type of 'explanation' for the patterns in reactions is expected? You can't explain many of the trends of the PT without actually understanding atomic structure ad

	electron configurations. Fourth bullet point: We unclear about what this point means? - Should it say the physical properties of metals and non-metals and relate them to their uses? - It would be better to split this into two statements to make clear that 'with respect to acidity' only refers to oxides.
Materials • the order of metals and carbon in the reactivity series • the use of carbon in obtaining metals from metal oxides • ceramics, polymers and composites	First bullet point: Is this restricted to the reactivity of the elements with oxygen? Presumably so since it is to include carbon. A reactivity series of metals with water and acids cannot include carbon in the same way. Third bullet point: What is expected here? The properties and uses of materials have been explored at KS2 so what is to be added at this stage? This appears to be a topic about making materials given that it includes the extraction of metals. Is the coverage of ceramics, polymers and composites meant to focus on how they are made? This does not seem appropriate for polymers given that the properties of hydrocarbons and polymerization reactions are KS4 topics. If this is to build on chemical ideas introduced at KS3 there would need to be some treatment of molecular and giant structures to explain the properties of these materials – but this would be much better done in terms of the theories of structure and bonding introduced at KS4. Explaining the properties of composites, if that is expected, is likely to depend more on ideas in physics than in chemistry at this level. At this level the nature and properties of composites is likely to

	concentrate on the microscale rather than the atomic/molecular scale whereas explanations of the properties of metals and polymers are more likely to be at the atomic/molecular scale. Despite the significance of the grain structure of metals, teaching about metal properties at KSs 3 & 4 generally ignores the importance of microstructure.

Earth science • the composition of the Earth and the atmosphere • changes to the Earth's atmosphere since its formation • the production of carbon dioxide by human activity and the impact on climate • the efficacy of recycling.	We notice that the Earth science content in key stage 3 chemistry has been considerable reduced. Key stage 3 would be a good time to cover the rock cycle including the formation of igneous and metamorphic rocks. We note however that consideration of the geography curriculum will be important to avoid significant overlap. An alternative way of presenting the Earth science content would be to include a separate section about 'Earth and space' alongside biology, chemistry and physics. – In general, the Earth science section needs much clearer linking to chemistry First bullet point: This seems a very narrow point that could just be covered by getting students to learn the percentage abundances of elements in the crust and the atmosphere. How much detail about the structure of the Earth is intended? Is this meant to cover the composition of all the main parts of the Earth – inner and outer cores, mantle and crust? Is this intended to cover

	the composition of different kinds of rocks and minerals? The extent of detail required determines the extent to which this is more of an earth science topic than it first seems to be. Second bullet point: This could be taught well in terms mainly of 'how we know' rather than 'what we know'. This would involve teaching about a lot of the serious ideas in earth science that are used to explain the Earth's history but this would be to expand this bullet point in ways that seem to go well beyond what KS3 chemistry teachers might expect. Clarification is needed: this is either relatively trivial or a major area of study depending on how the statement is interpreted. Third bullet point: How does the expected treatment required here differ from the coverage of carbon dioxide as a greenhouse gas included in the draft KS4 curriculum? Fourth bullet point: This really does not belong here. If this belongs anywhere it is in the section about materials. What is intended by the term 'efficacy'? This would have serious scientific value if developed to cover the notion of the life-cycle of material products and the comparison between products across their life-cycle in terms of the use of materials, energy and water resources and the overall environmental impact.

Comments on the draft programme of study for key stage 4

- Inconsistency on the contents page, chemistry doesn't have sub-heading but biology and physics do
- Chemistry content covers only three pages in the document whereas physics and biology span over five six respectively (the same applies in key stage 3 where the chemistry content takes up about half the space of either biology of physics). This may be accounted for by differences in styles of the authors, with the chemists going into less detail, but we're worried that the impression that chemistry can be taught in fewer hours.

Forces and Motion

Key Stage 1

Year 2 programme of study (statutory requirements)	Notes and guidance (non-statutory)
Movement Pupils should be taught to: • Notice and describe how things are moving, using simple comparisons such as faster and slower • Compare how different things move	Movement Pupils should observe carefully some things moving. Pupils should discuss, describe and compare the movement of a variety of objects and, where appropriate, themselves, through actions such as walking and running sliding, rolling, falling, flying,. They can explore the movements through games, songs and rhymes, including work in physical education. Pupils might work scientifically by: asking questions about the movement of objects such as parachutes, toy cars and balloon rockets; comparing them, by measuring how far they go; ordering their findings and recording their observations and measurements, for example by constructing tables and charts, and drawing on their results to answer their questions.
Year 3 programme of study (statutory requirements)	**Notes and guidance (non-statutory)**

Forces and Magnets Pupils should be taught to: • Notice that some forces need contact between two objects and some forces act at a distance • Observe how magnets attract or repel each other and attract some materials and not others • Compare and group together a variety of everyday materials on the basis of whether they are attracted to a magnet, and identify some magnetic materials	Forces and Magnets Pupils should observe that magnetic forces can act without direct contact, unlike most forces, where direct contact is necessary (for example, opening a door, pushing a swing). **Note:** Pupils do not need to be introduced to 'like' and 'unlike' magnetic poles until Year 5. Pupils might work scientifically by: investigating the strengths of different magnets and finding a fair way to compare them; sorting materials into those that are magnetic and those that are not.

Key Stage 2

Year 6 programme of study (statutory requirements)	**Notes and guidance (non-statutory)**
Forces Pupils should be taught to: • Explain that unsupported objects fall towards the Earth because of the force of gravity acting between the Earth and the falling object • Identify the effect of drag forces(such as air resistance, water resistance) and friction • Describe , in terms of drag forces and frictionwhy moving objects that are not driven tend to slow down •	Forces Pupils should explore falling objects and the effects of air resistance. They should experience forces that make things begin to move, get faster or slow down. Pupils should explore the effects of friction on movement and find out how it slows or stops moving objects, for example by observing the effects of a brake on a bicycle wheel. They should explore the effects of air resistance by observing how different objects such as parachutes and sycamore seeds fall. Pupils might find out how scientists such as Galileo and Isaac Newton helped to develop the theory of gravitation. Pupils might work scientifically by: designing and making a variety of parachutes and carrying out fair tests to determine which designs are the most effective. They might explore resistance in water by making and testing boats of different shapes.

Key Stage 3

Motion and Forces

Pupils should be taught about:

Describing Motion

- Speed and the quantitative relationship between average speed, distance and time (speed = distance/ time)

- The representation of a journey on a distance-time graph
- Relative motion: trains and cars passing one another;

Forces

- Forces as pushes or pulls, arising from the interaction between two objects
- Moment as the turning effect of a force
- Forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction between surfaces, with pushing things out of the way, resistance to motion of air and water
- Forces measured in newtons, measurements of stretch or compression as force is changed
- Hooke's Law applies in special cases
- Work done and energy changes on deformation
- Gravity forces acting at a distance on Earth and in space
- Using force arrows to denote forces; drawing forces onto a diagram; adding forces along one dimension; net force and balanced forces.

Pressure in fluids (or pressure in liquids and gases)

- Atmospheric pressure, decreases with increase of height as weight of air above decreases with height
- Pressure in liquids, increasing with depth; upthrust effects, floating and sinking
- Pressure measured by ratio of force over area – acting in all directions

Balanced forces

- Opposing forces and equilibrium: weight held by stretched spring or supported on a compressed surface

Forces and Motion

- Forces being needed to cause objects to stop or start moving, or to change their speed or direction of motion
- Change of velocity (?) depending on direction of force and its size

Key Stage 4

Motion and forces

Pupils should be taught about:

Motion

- velocity as speed in a given direction
- acceleration = change in velocity ÷ time; distance/time and velocity/time graphs and their interpretation
- estimating sizes of everyday velocities and accelerations
- relative velocity, relative velocity in head-on collision

Motion and forces

- movement without forces; skating and sliding in low friction; difficulty of starting or

stopping

- constant velocity if no net force: Newton's First Law
- acceleration caused by unbalanced force; the effect of a force depending on the object being moved; acceleration = force/mass; Newton's Second Law
- mass as the ratio of force to acceleration (inertia);
- direction of change and direction of resultant force; force as a vector

Collisions and momentum

- Forces between objects arise from interactions between the two objects; the interaction can be considered as a pair of forces (A acting on B and B acting on A); Newton's third law
- defining momentum as mass x velocity; speeds before and after objects collide: conservation of momentum (in explosion or collision)
- force as rate of change of momentum: Newton's Second (?) Law.

Earth and Space

Key Stage 1

Year 1 programme of study (statutory requirements)	**Notes and guidance (non-statutory)**
Seasonal changes Pupils should be taught to: • Observe the apparent movement of the Sun during the day • Observe changes across the four seasons • Observe and describe local weather	Seasonal Changes Pupils should observe and talk about the weather, the seasons and how the Sun seems to move during the day. Pupils might work scientifically by: observing and recording the apparent movement of the Sun during the day, for example in a sequence

associated with the seasons and how the day length varies	of photographs or moving Teddy so he stays in the sunshine; making tables and charts about the weather and displays of what happens in the world around them, including day length, as the seasons change.

Key Stage 2

Year 5 programme of study (statutory requirements)	**Notes and guidance (non-statutory)**
Earth and Space Pupils should be taught to: • Describe the Sun, Earth and moon, as approximately spherical bodies • Use the idea of the Earth's rotation to explain day and night and the apparent movement of the Sun across the sky • Describe the movement of the Earth relative to the Sun • Describe the movement of the Moon relative to the Earth • Describe the relative sizes of the Sun, Earth and Moon; •	Earth and Space Pupils should be introduced to a model of the Sun and Earth that allows the explanation of day and night. Pupils should learn that the Sun is a star at the centre of our solar system and that it has eight planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune (Pluto was reclassified as a 'dwarf planet' in 2006). They should understand that a moon is a celestial body that orbits a planet (Earth has one moon; Jupiter has four large moons and numerous smaller ones). **Note:** Pupils should be warned that it is not safe to look directly at the Sun, even when wearing dark glasses. Pupils could find out about the way that ideas about the solar system have developed by studying the work of scientists such as Ptolemy, Alhazen and Copernicus, understanding. Pupils might work scientifically by: comparing the time of day at different places on the Earth through internet links and direct communication; creating simple models of theSun, Earth, Moon system; constructing simple shadow clocks and sundials, calibrated to show midday and the start and end of the school day; working out how places such as Stonehenge were used as astronomical clocks.

Key Stage 3.

The Moon and its phases
The seasons and the Earth's tilt; day length at different times of the year in different hemispheres.
Solar and lunar exlipses;
Weight = mass x gravitational field strength; on Earth g=10 N/kg; it is different on other planets
Distinguishing between mass and weight;
The solar system; planets and their properties; linking their properties to their position in the solare system.

Our Sun as a star; other stars in our galaxy (the Milky Way); our galaxy has billions of stars; other galaxies; there are billions of galaxies in the Universe; scales in the Universe – powers of ten

Key Stage 4.

Pupils should be taught about:

Mass, weight and gravity

- gravitational pull of the earth, depends on distance from earth
- weight as derived from gravitational mass, related to inertial mass, and to strength of gravity field
- force F= Gm1m2/r2 ; experienced as m1g on earth's surface with g as measure of the field strength
- weight on moon and planets
- gravity field between Sun and planets holds solar system together

Orbital motion

- motion in a circle, acceleration towards centre
- gravity force may produce just the right inward acceleration to maintain stability of orbit for an object moving at the right speed at the right height height, if too fast - escape, if too slow - fall in
- stable orbital speeds decrease with increasing distance
- satellites and geo-stationery orbits
- elliptical orbits of planets

History of the universe

- fusion as Sun's energy source, dissipated by radiation, limited life of sun
- solar system, our galaxy, other stars and galaxies, range of distances
- red shift as expansion increases observed wavelengths (qualitative only); all expansion motion relative
- evidence of 'big bang'
- why origins and causes, and future of, expansion raise unanswered questions.

Electricity and Magnetism

Key Stage 2

Year 4 programme of study (statutory requirements)	Notes and guidance (non-statutory)
Electricity Pupils should be taught to: • Identify common appliances that run on electricity • Construct a simple series electrical circuit • Identify whether or not a lamp will light in a simple series circuit based on whether or not the lamp is part of a complete loop with a battery • Recognise that a switch opens and closes a circuit and associate this with whether or not a lamp lights in a simple series circuit • Recognise some common conductors and insulators, and associate metals with being good conductors	Electricity Pupils should construct simple series circuits, trying different components, such as bulbs, buzzers and motors, and including switches, and use their circuits to create simple devices. Pupils should draw the circuit as a pictorial representation, not necessarily using conventional circuit symbols at this stage; these will be introduced in Year 6. **Note:** Pupils might use the terms current and voltage, but these should not be introduced or defined formally at this stage. Pupils should be taught about precautions for working safely with electricity. Pupils might work scientifically by: observing patterns, for example that bulbs get brighter if more cells are added, that metals tend to be conductors of electricity, and that some materials can and some cannot be used to connect across a gap in a circuit.

Year 5 programme of study (statutory requirements)	Notes and guidance (non-statutory)
Magnetism Pupils should be taught to: • Describe magnets as having two poles: a north and a south • Predict whether two magnets will attract or repel each other, depending on which poles are facing	Magnetism Pupils should be made aware that they are being introduced to a predictive rule – based on magnetic poles - for the way magnets behave. Teachers can discuss the scientific approach of making observations and developing rules that predict behaviour. They should explore the behaviour and everyday uses of different magnets (for example, bar, ring, button and horseshoe) and find out about how the Earth acts as a magnet. Pupils might work scientifically by: looking for patterns in the way that magnets behave in relation to each other and what might affect this, such as the strength of the magnet or which pole faces another; identifying how these properties make magnets useful in everyday items and suggesting creative uses for different magnets. They might explore what happens if magnets are hung from threads or floated on water and relate this to the development and use of compasses for navigation.

Year 6 programme of study (statutory requirements)	Notes and guidance (non-statutory)
Electricity Pupils should be taught to: • Identify and name the basic parts of a simple electrical circuit, including cells, wires, bulbs, switches and buzzers • Associate the brightness of a lamp with the number and voltage of the cells used in the circuit • Compare and give reasons for variations in how components function, including the brightness of bulbs, the loudness of buzzers and the on/off position of switches	Electricity Building on their work in Year 4, pupils should construct simple series circuits, trying different components, such as switches, bulbs, buzzers and motors. They should learn how to represent a simple circuit in a diagram using recognised symbols. **Note:** Pupils are expected to learn only about series circuits, not parallel circuits. Pupils should be taught to take the necessary precautions for working safely with electricity. Pupils might work scientifically by: systematically identifying the effect of changing one component at a time in a circuit; designing and making a set of traffic lights, a burglar alarm or some other useful circuit.

Key Stage 3
Electricity and electromagnetism Pupils should be taught about:

Current electricity

- Electric current, measured in amperes,
- series and parallel circuits and the domestic ring main
- Current as a flow of charge
- Potential difference, measured in volts, battery and bulb rating; resistance, measured in ohms, as the ratio of potential difference (p.d.) to current
- Differences in resistance between conducting and insulating components

Static electricity

- Separation of positive or negative charges when objects are rubbed together: transfer of electrons, forces between charged objects
- The idea of electric field, forces acting across the space between objects not in contact

Magnetism

- Magnetic poles, attraction and repulsion
- Magnetic fields by plotting with compass, representation by field lines
- Earth's magnetism, compass and navigation
- The magnetic effect of a current, electromagnets, D.C. motors

Key Stage 4

Electricity and electromagnetism

Pupils should be taught about:

Electric circuits

- calculations of current and potential difference: for series circuits (same currents, resistances add); for parallel circuits (same potential differences, reciprocals of resistance, i.e. conductances add)
- symbolic representations of circuits
- V=IxR
- power transferred = VxI and I^2xR

Direct current (DC) and alternating current (AC)

- domestic mains: the ring circuit; potential difference and frequency; fuses, live, neutral and earth; safety
- the national grid and energy transfer from power stations to industry and homes
- high voltage transmission and efficiency

Energy and electricity

- heating effects of currents: power and energy calculations of energy transfers – from batteries, dynamos, mains – to heated materials, to work by electric motors

Static electricity and electric fields

- attraction and repulsion between unlike and like charges
- electric field forces acting over a distance, and increasing with decreased distance
- sparks between charged bodies; lightning

Magnetism and electromagnetism

- magnetic effects: action at a distance; magnetic fields
- ferromagnets; induced magnetism in some materials
- electromagnetic induction effect of changing fields; AC generators and transformers

Sensors and sources

- laboratory and commercial uses of a range of electronic sensors: e.g. position and motion, light and temperature, sound and vibration, force and stress
- oscillating currents as generators of electromagnetic waves; transmitting and detecting aerials; radio direction finders; radar.

Light

Key Stage 2

Year 3 programme of study (statutory requirements)	Notes and guidance (non-statutory)
Light Pupils should be taught to: • Observe and name a variety of sources of light, including electric lights, flames and the Sun, explaining that we see things because light travels from them to our eyes • Notice that light is reflected from surfaces and this is how we see non-luminous objects • Associate shadows with a light source being blocked by something; find patterns that determine the size of shadows • Observe that different surfaces reflect light in different ways	Light Pupils should explore materials to help them t between the meaning of transparent, translu observe shadows being formed in everyday c outside or shine torches indoors. If possible and with appropriate safety measu completely blackened room to realise that, in really cannot see anything. An almost dark ro **Note:** Pupils should be warned that it is not sa even when wearing dark glasses. Pupils might work scientifically by: looking for shadows when the light source moves or the and the object changes; investigating the suit purposes, such as blackout curtains; explorin the dark.

Year 6 programme of study (statutory requirements)	Notes and guidance (non-statutory)
Light Pupils should be taught to: • Understand that light appears to travel in straight lines • Understand that objects are seen because they give out or reflect light onto the eye • Use the idea that light travels in straight lines to explain why shadows have the same shape as the	Light Pupils should explore the way that light behav reflection and refraction. They should talk abo predictions. They should experience a range of light such as rainbows, colours on soap bu water and white light being split by prisms. Pupils might work scientifically by: deciding w cars; designing and making a periscope and u

	objects that cast them, and to predict the size of shadows when the position of the light source changes	to travel in straight lines to explain how it work relationship between light sources, objects an puppets.

Sound and Waves

Year 4 programme of study (statutory requirements)	Notes and guidance (non-statutory)
Sound Pupils should be taught to: • Observe and name a variety of sources of sound, noticing that we hear with our ears • Identify how sounds are made, associating some of them with something vibrating • Recognise that sounds get fainter as the distance from the sound source increases	Sound Linked with work in music, pupils should explore various ways of making sounds, for example using a range of musical instruments to make louder and softer, and higher and lower sounds. Pupils might work scientifically by: exploring how the pitch and volume of sounds can be changed in a variety of ways, and finding patterns in the data (for example, blowing across the top of bottles, changing the length and thickness of elastic bands). They

• Find patterns between the pitch of a sound and features of the object that produced it • Find patterns between the volume of a sound and the strength of the vibrations that produced it	might make ear muffs from a variety of different materials to

Key Stage 3

Waves

Pupils should be taught about:

Observed Waves

- Waves on a slinky as undulations which travel through a medium with transverse or longitudinal motion; these waves can be reflected, and add or cancel – superposition

Sound Waves

- Frequencies of oscillation, including sound,, measured in hertz (Hz); echoes, reflection and absorption of sound
- Sound needs a medium to travel through
- The speed of sound in air, solids, water
- Reflection of waves; echoes of sound
- Sound produced by vibrations of objects, in loud speakers, detected by their effects on microphone diaphragm and the ear drum; sound waves are longitudinal
- Auditory range(s) of humans and animals

Energy and Waves

- Waves carrying energy for cleaning and physiotherapy by ultra-sound; for carrying energy and information for conversion to electrical signals by microphone
-

Light Waves

- Light waves travelling through a vacuum; speed of light
- The transmission of light through materials; absorption, diffuse scattering and specular reflection at a surface
- The refraction of light at boudnaries; real and apparent depth; action of convex lens in focusing (qualitative) and the human eye
- Pinhole camera to form an image without and with a lens (?)
- Light transferring energy, leading to chemical and electrical effects; photo-sensitive material in the retina and in cameras
- Colour and the dispersion of light by a prism, white light and prisms (qualitative only);differential colour effects in absorption and diffuse reflection

Key Stage 4

Waves and oscillations

Pupils should be taught about:

Wave properties

- general properties of all waves, including reflection, refraction and diffraction

- speed: frequency x wavelength

Definitions of frequency, wavelength, amplitude, displacement

Waves in matter

- the range of frequencies of sound, below and above the audible; sound travelling at different speeds through different substances leading to refraction; sound waves in rocks and water, and reflections detecting subterranean structures;
- ultrasound for medical diagnosis
- resonance effects and feedback
- Earthquake detection and evidence for the structure of the Erath

Electromagnetic spectrum

- light is part of a larger spectrum of waves – the electromagnetic spectrum.
- the range of frequencies of light in visible parts of the electromagnetic spectrum: higher frequencies: gamma rays, X-rays, ultra-violet; lower frequencies: infra-red, microwaves, radio waves
- uses and dangers?
- the Earth's radiation budget;
  - the Sun and the Earth as (black body) radiators;
  - reflection, scattering, dispersion of sunlight by the atmosphere and Earth's surface;
  - absorption and emission by ozone, greenhouse gases and surface
  - the water cycle and latent heat

Waves as carriers

- waves carrying energy: e.g. radiation from Sun, infra-red radiation, ocean waves, seismic waves
- the uses of electromagnetic waves to carry information, by variations in amplitude and/or frequency; digital sampling of analogue information.

Materials and Matter

Key Stage 1

Year 1 Programme of Study (statutory requirement)	Notes and guidance (non-statutory)
Everyday Materials: Pupils should be taught to: • Distinguish between an object and the material from which it is made • Identify and name a variety of everyday solid materials, including wood, plastic, glass, metal, , and rock • Describe the simple physical properties of a variety of everyday materials • Compare and group together a variety of everyday solid materials on the basis of their simple physical properties • Find out how the shapes of solid objects made from some materials can be changed by squashing, bending, twisting and stretching	Everyday Materials Pupils should explore, name and discuss everyday materials so that they become familiar with the names of materials and properties such as: hard/soft; stretchy/stiff; shiny/dull; rough/smooth; bendy/not bendy; waterproof/not waterproof; absorbent/not absorbent. Pupils should explore and experiment with a wide variety of materials, not only those listed in the programme of study, but including for example: brick, paper, fabrics, elastic, foil. Pupils might find out about people who have developed useful new materials; for example, Dunlop, Macintosh or McAdam. Pupils might work scientifically by: performing simple tests to explore questions such as: 'What is the best material for an umbrella? ... for lining a dog basket? ... for curtains? ... for a bookshelf? ... for a gymnast's leotard?'

Year 2 Programme of Study (statutory requirement)	Notes and guidance (non-statutory)
Uses of everyday materials Pupils should be taught to: • Identify and compare the uses of a variety of everyday materials, including wood, metal, plastic, glass, brick/rock, and paper/cardboard	Uses of everyday materials Pupils should identify and discuss the uses of different everyday materials so that they become familiar with how some materials are used for more than one thing (metal can be used for coins, cans, cars and table legs; wood can be used for matches, floors, and telegraph poles) or different materials are used for the same thing (spoons can be made from plastic, wood, metal, but not glass; tables can be made from plastic, wood, metal, but not paper). Pupils might work scientifically by: comparing the uses of everyday materials in

	and around the school with materials found in other places (at home, the journey to school, on visits, and in stories, rhymes and songs); observing closely, identifying and classifying the uses of different materials, and recording their observations. Pupils should be encouraged to think about unusual and creative uses for everyday materials.

Key Stage 2

Year 3 Programme of Study (statutory requirement)	**Notes and guidance (non-statutory)**
Rocks Pupils should be taught to: • Compare and group together different kinds of rocks on the basis of their simple physical properties • Relate the simple physical properties of some rocks to their formation (igneous or sedimentary) • Describe in simple terms how fossils are formed when things that have lived are trapped within sedimentary rock	Rocks Linked with work in geography, pupils should explore different kinds of rocks and soils, including those in the local environment. **Note:** Pupils are not expected to be taught about the formation of metamorphic rocks, such as marble and slate. Pupils might work scientifically by: observing rocks, including those used in buildings and gravestones, and exploring how and why they might have changed over time; using a hand lens or microscope to help them to identify and classify types of rock according to whether they have grains or crystals, and whether they have fossils in them. Pupils might research and discuss the different kinds of living things whose fossils are found in sedimentary rock and explore how fossils are formed.

Year 4 programme of study (statutory requirements)	**Notes and guidance (non-statutory)**
States of Matter Pupils should be taught to: • Compare and group materials together, according to whether they are solids, liquids or gases at room temperature • Observe that some materials change state when they are heated or cooled, and measure the temperature at which this happens in degrees Celsius (°C), building on their teaching in mathematics • Identify the part played by evaporation and condensation in	States of Matter Pupils should explore a variety of everyday materials and develop simple descriptions of the states of matter (solids can be held in your hands; liquids form a pool not a pile; gases escape from an unsealed container). Pupils should observe water as a solid, a liquid and a gas and should note the changes to water when it is heated or cooled. **Note:** Teachers should avoid using materials where heating is associated with chemical change, for example, through baking or burning. Pupils might work scientifically by: grouping

the water cycle and associate the rate of evaporation with temperature	and classifying a variety of different materials; exploring the effect of temperature on substances such as chocolate, butter, cream (for example, to make food such as biscuits and ice-cream for a party). They might observe and record evaporation over a period of time, such as a puddle in the playground or washing on a line, and investigate the effect of temperature on washing drying or snowmen melting.

Year 5 programme of study (statutory requirements)	**Notes and guidance (non-statutory)**
Properties of everyday materials and reversible change Pupils should be taught to: • Compare and group together everyday materials based on the evidence from comparative and fair tests, including their hardness, solubility, conductivity (electrical and thermal), and response to magnets • Understand that some materials will dissolve in liquid to form a solution • Use knowledge of solids, liquids and gases to decide how mixtures might be separated, including through filtering, sieving and evaporating • Give reasons, based on evidence from comparative and fair tests, for the particular uses of everyday materials, including metals, woods and plastic • Demonstrate that dissolving, mixing and changes of state are reversible changes	Properties of everyday materials and reversible change Pupils should build a more systematic understanding of materials by exploring and comparing the properties of a broad range of materials and relating these to what they learnt about magnetism in Year 3 and about electricity in Year 4. They should experiment with reversible changes, including melting, dissolving, evaporating, filtering and sieving. **Note:** Pupils are not required to make quantitative measurements about conductivity and insulation at this stage. It is sufficient for them to observe that some conductors will produce a brighter bulb in a circuit than others and that some materials will feel hotter than others when a heat source is placed against them. Pupils might work scientifically by: investigating questions such as 'Which materials would be the most effective for making a warm jacket, or for wrapping ice cream to stop it melting?' They might compare materials in order to make a switch in a circuit.

Key Stage 3
Matter Pupils should be taught about: Density of solids and liquids??? Physical changes

- Conservation of matter and of mass, and reversibility, in melting, freezing, evaporation, sublimation, condensation, dissolving
- Similarities and differences between solids, liquids and gases
- Brownian motion in gases
- Diffusion in liquids and gases driven by difference in concentration
- The difference between chemical and physical changes

Particle model

- The differences in arrangements, in motion and in closeness of particles explaining changes of state, shape and density
- Atoms and molecules as particles
- The anomaly of ice-water transition in terms of unique structure change

Energy in matter

- Changes with temperature in motion and spacing of particles
- Internal energy stored in materials

Key Stage 4

Matter

Pupils should be taught about:

Pressure

- pressure in gases and particle movement; pressure as a scalar quantity, acting in all directions in fluids
- the kinetic model of gases; changes in pressure, temperature and volume related by pV=RT

Changes in solids

- changes of shape in solids: tensing, compressing and bending
- stress as a vector: the force per unit area in such changes
- shear stress and friction
- energy stored changes as distortion changes
- elastic and inelastic changes
- the internal structure of the Earth; changes of pressure and temperature with depth

Changes in atoms

- ionisation in static electricity; also by matter absorbing radiation
- other changes from absorption and emission associated with specific frequencies; links to nuclear model; emissions of ionising radiations, X-rays and gamma rays at higher frequencies of the electromagnetic spectrum
- emissions of particles and radiations (?); beta and alpha particles
- half-lives
- isotopes; binding energy
- nuclear fission as energy source (fusion?)

Applications of radiation with matter

- radiations for forming images of internal structures in matter, including for diagnosis in medicine and for therapy
- the hazards for biological tissue of contamination and irradiation.

Energy

Key Stage 3

Energy

Pupils should be taught about:

Changes and transfers

- examples of processes that lead to change, through
  - forces lifting an object, dropping an object, winding or releasing a spring, stretching or releasing an elastic band, changing motion);
  - with electricity (connecting a lamp to a battery, switching on an oven);
  - with matter (burning a fuel in oxygen, metabolising food);
  - heating (and cooling) by contact with an object at a different temperature or by radiation from a hotter object
- levers and gears reduced force compensated for by increased distance (you don't get something for nothing)
- the conserved quantity is called energy; the fact that it is conserved will be useful for doing calculations;

Auditing Change

- Prepare for calculations through a qualitative treatment of changes in the energy associated with:
  - elastic deformation,
  - moving and/or vibrating objects,
  - objects that have been lifted in a gravitational field
  - increased temperature (the movement of particles)
  - chemical changes involving fuels

Energy and Fuel

- amounts of energy from different foods (from labels)
- fuel, fuel sources and heating
- calculations comparing ratings of appliances in watts (W) and
- rates of change measured in W.

-
- work = force x distance;
- You can raise the temperature of a body by heating it or by doing work on it

Key Stage 4

Energy

Pupils should be taught about:

Changes and differences

- differences of some kind as conditions for change: e.g. in height, electrical potential, temperature, pressure, concentration, forces
- how change driven by a difference tends to reduce that difference: weights fall to the ground, pressure differences are reduced, batteries run down, objects come to the same temperature, pressures equalise, forces might come into balance.

Changes as energy transfer

- Calculations of the energy associated with a system due to its:
  - elastic deformation,
  - movement,
  - position in a gravitational field
  - increased temperature or change of state (the movement or arrangement of particles)
  - chemical composition

- Calculations involving changes in the way that energy is associated with parts of a system such as:
  - a falling object hitting the ground,
  - movements in other types of field,
  - accelerating objects with a constant force,
  - objects being stretched, compressed or released
  - raising the temperature of a body by heating it or doing work on it
  - changing the state of a material by heating it (or doing work on it)
  - using an electrical appliance to raise the temperature or change the state of, for example, water
  - fuels burning when reacting with oxygen

- calculations of processes that cause change:
    - work done
    - electrical work done (charge x potential difference);
    - heating (changes internal energy:mass x temperature rise x specific heat)

- power as rate of transfer

Conservation and dissipation

- changes producing no net loss of energy: energy is conserved but dissipation raises temperature and is unavoidable and cannot be reversed
- measures of efficiency
- reducing unwanted energy transfers: e.g. through lubrication, thermal insulation
- national and global fuel resources, renewable energy sources.