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 insufficient time for the drafters to properly consult stakeholders on the content and, in some cases, stakeholders only being able to comment once content had already been defined, 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 as valuable as they could be.
6. SCORE has 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 more 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 less 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 2013 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. However, 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, and content that is included can give students the opportunity to develop attitudes, practices and knowledge that will be useful across all science subjects.
19. Particular attention should be given to ensuring that important transitions (particularly from EYFS to Key Stage 1 and from Key Stage 2 to Key Stage 3) are carefully managed with respect to the consistency and order in which content is introduced and developed across the sciences for effective progression.
20. There is a large degree 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.
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. 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. SCORE has a significant concern that instead of discovering the intellectual beauty of the sciences as ways of understanding the world, students will be given an inauthentic experience of them as being collections 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 big 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 with respect to the mathematics, computing, design and technology, history and geography programmes of study. The sequencing of material in all subjects should be

[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.

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 do not represent core Earth science, as would be recognised by most Earth scientists. 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, and metamorphic rocks are not explicitly mentioned, even though they are some of the most common rocks that students might be familiar with, for example slate and marble. 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. For humans puberty must be included in Year 5. This is a crucial developmental phase in the human life cycle. If it is not included at that point then there will continue to be schools in which this topic is not properly taught and students who are not prepared at an age-appropriate time for the changes happening to their own bodies. Year 6 is too late.
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, whilst also subject to challenge and change as new technologies and ideas emerge, as well as the ethical considerations needed when undertaking scientific research. In addition, students should gain the technical and investigative skills needed in order to engage in scientific enquiries.

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), as could terms such as 'risk' and 'hazard'.
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. 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).
42. 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.
43. The section headed 'Scientific attitudes' is misnamed. It does not describe accurately the content included within it (Key Stage 3).

Progression

44. 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.

45. 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

46. 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.

47. 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

48. 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. These should be framed to define the learning required, but sufficiently flexible to allow teachers the space to teach.

49. 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.

50. 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

51. 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.

52. 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.

53. 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 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 appear in the lower Key Stage 2 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.

54. 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 also add to the burdens for schools.

Process for moving forward

55. 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.

56. 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

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

- 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

57. 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.
58. 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.
59. SCORE would be pleased to comment on further drafts of the National Curriculum before distribution to schools.
60. 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 the Society of Biology, the Royal Society of Chemistry and the 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 ~~garden plants, wild plants and~~ 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 ~~flowers~~ plants, including~~and~~ vegetables, that they have planted. They should become familiar with common names of ~~flowers~~plants, examples of deciduous and evergreen trees, and plant structures (trees: ~~trunk,~~ roots, trunk, branches, leaves, fruits; garden and wild plants: bulbs, ~~flower, petals, stem, leaves,~~ roots, stem, leaves, flowers, petals, fruits, ~~bulb~~ 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.

Comment [GG1]: Plants are not revisited as a specific topic until Year 7 (although they do feature as examples in the other biology topics), yet animals/ humans continues through every Year but Year 6. There is a risk that children will forget plant work as before they reach secondary school. Plants should be given a similar status to animals, and both tackled at a similar level of difficulty at each age. For example, in Years 4 and 5, consider including more detail of plant structures, which could then be related to function. More emphasis could be placed on pupils observing plants - their distribution and types - in their natural habitats in early primary.

Comment [GG2]: Leave it up to teachers to determine which plants are common in their locality

Comment [GG3]: Consider adding a basic introduction to function alongside structure

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 ~~(including seeds, bulbs, fruit and vegetables, deciduous and evergreen bushes and trees)~~. Pupils should be introduced to the requirements of plants for survival and ~~and survival~~, as well as the process of growth and reproduction ~~and growth~~ 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.

Comment [GG4]: It would be useful to define the level of accuracy more clearly

Comment [GG5]: Needs more definition

	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.

Comment [GG6]: Assume this means plant life cycles, the current wording is not clear.

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) • identify, name, draw and label the basic parts of the human body and say which part of the body is associated with each sense. • Recognise that darkness is the absence of light.	***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. 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 ~~them~~animals; for example, grouping animals according to

Comment [GG7]: Leave it up to teachers to decide the common animals in their locality

Comment [GG8]: The guidelines should not comment on *how* teachers should teach

Comment [GG9]: Expand – this is an opportunity for pupils to use their senses to engage with animals first-hand. E.g. a child's observation of a rabbit or chick is that it looks fluffy and soft in photographs, whereas as a child who has held either will know that they have scratchy feet and can make and record appropriate observations which are more than merely visual.

	what ~~they~~ the animals eat.~~, and using their senses to compare different textures, sounds and smells.~~ Pupils should use their senses to compare and describe different textures, smells and sounds and should recognise that we cannot see when there is no light.
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	***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 ~~skeletal~~ skeleton and ~~muscular system~~muscles, finding out how different parts of the body have ~~special~~ particular functions. Pupils might work scientifically by: identifying and grouping animals with and

Comment [GG10]: The pupils'

Comment [GG11]: Clarify what pupils are expected to compare the 'textures, sounds and smells' of. Animals? If expanded/clarified, this could present opportunities for pupils to engage with animals first-hand. E.g. a child's observation of a rabbit or chick is that it looks fluffy and soft in photographs, whereas as a child who has held either will know that they have scratchy feet and can make and record appropriate observations which are more than merely visual.

Comment [GG13]: This is muddled – growth and reproduction are two different processes. So although there may be a major focus on growth at Year 2, and not on *how* reproduction occurs, there must also be some focus on the fact that reproduction *does* occur (otherwise the statement on offspring is partially redundant).

Comment [GG12]: Needs more definition

• identify that humans and some animals have skeletons and muscles for support, protection and movement.	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 ~~special~~ 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

Comment [GG14]: Ok – although, technically, without internal skeletons' is more correct

Comment [GG15]: More clarity required regarding 'simple' vs complex, as interpretations may vary (e.g. simple functions, or describe simply'). However, this should not end up as an extended list.

Comment [GG16]: The wording in the statutory information is fine, but the non-statutory guidelines make it much more complicated (asking pertinent questions and suggesting reasons for similarities and differences) – the latter is advanced for Year 5.

Comment [GG17]: This goes substantially beyond the content in the statutory column

	rate and breathing rate. They might find out about the effects of things that ~~might~~ can damage the body's systems. ~~They might compare the organ systems of the human body with the organ systems of a variety of animals, asking pertinent questions and suggesting reasons for similarities and differences.~~

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 ~~are constantly changing~~can change and that this can sometimes	***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

Comment [GG18]: This goes substantially beyond the content in the statutory column

Comment [GG19]: This is too advanced for primary

Comment [GG21]: Pupils need to develop a better biological understanding of 'living', 'once-living' and 'never-living'. Living things should not just be defined by a set of characteristics (e.g. MRS GREN, where the absence of any one characteristic implies they're not living e.g. a car doesn't reproduce, so can't be deemed living) since not all living things (as individuals) reproduce (i.e. a worker bee, a Downs syndrome person, a mule) – and yet they're clearly alive! A more sophisticated understanding could be based on the idea that all living things 'self-maintain' – they're 'doing things to keep themselves alive'.

Comment [GG20]: This is a difficult concept for Year 2 (especially if the above comment is taken into account). Suggest it could be moved to Year 3.

Comment [GG23]: Classification into broad groups does not match with using the five Kingdoms introduced at Year 6 (although five kingdoms is better tackled at secondary – see related comment below).

Comment [GG22]: More care needs to be taken over the wording here to ensure that the expectation of knowledge/understanding is not too advanced for Year 4 (or indeed primary). E.g. a fly could be classified as an insect and a spider as not an insect based on the number of legs. A cod can be classified as a fish because it has fins and gills. This can be understood AT Year 4, more advanced explanations cannot. Consider moving this to Year 5.

pose dangers to ~~specific habitats~~certain living things.	environments such as the effect of population and development, ~~litter~~ mowing, fertilisers or deforestation. Note: Plants are more difficult to classify, but can be grouped into categories such as ~~trees, grasses,~~ flowering plants (including grasses)~~s~~, 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; ~~raising~~ 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~~local environment~~. 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, ~~under~~ in the oceans, deserts ~~areas~~ and in prehistoric times), asking pertinent questions and suggesting reasons for similarities and differences.
Year 6	***Year 6***

Comment [GG24]: For humans puberty must be included here. This is a crucial developmental phase in the human life cycle. If it is not listed here then there will continue to be schools in which this is not properly taught and children who are not prepared at an age-appropriate time for the changes happening to their own bodies. Year 6 is too late.

Pupils should be taught to: • ~~explain~~ 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 ~~the life process of~~ 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.	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 ~~classification systems and~~ keys to identify some animals and plants in the immediate environment. Pupils might try to grow ~~new~~ 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.

Comment [GG26]: Leave until secondary (it is currently tackled well alongside the three domain model of classification in the draft KS4 that has been published for information).

Comment [GG25]: Greater specificity needed to ensure that SRE (sex and relationship education) is appropriately covered for this age group in all schools, and to make it clear what progression is expected from Year 5 (where the life cycle is mentioned in more detail).

Comment [GG27]: A more well-known example would be useful – e.g. James Lind and scurvy. Or a less well-known, but highly influential, example such as John Boyd Orr whose research has a direct link to our current understanding of diet and health and has a powerful link to more recent history and the experiences of people who are alive now who can talk to children about it. (ie WWI rations and poor diets pre 1930's). This would also provide teachers with a welcome opportunity to visit more recent history.

Comment [GG28]: Puberty needs to be explicitly mentioned somewhere in this section.

Habitats

Statutory requirements	Notes and guidance (non-statutory)
Year 2 Pupils should be taught to: • ~~identify~~ 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 • ~~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 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

Comment [GG30]: Move some of this to Year 4 (see comment below). Food chains needs to appear in KS2.

Comment [GG29]: Move to Year 4 (and re-introduce the topic of 'Habitats' at this age group)

Comment [GG31]: Moved from Year 3

Comment [GG32]: This should explicitly build on/make links to the classification and identification of living things, as covered elsewhere in biology at primary.

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, ~~adapt~~ are adapted to their environments.

Comment [GG35]: The family resemblance isn't always that clear. A more straightforward example could be different breeds (and cross-breeds) of dogs

Comment [GG36]: This does not fit with the history curriculum. The Hapburgs don't feature at all, and the Tudors are appear in KS2, but may not be introduced until Year 5 or 6.

Comment [GG37]: This should be obvious. This is advanced material

Comment [GG33]: This should be omitted/rephrased as it is advanced for Year 4

Comment [GG34]: Consider moving this to Year 5

Year 5 • identify how animals and plants are suited to and adapt to their environment in different ways.	
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 • recognise how and why the human skeleton has changed over time, since we separated from other primates.	***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. 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

Comment [GG38]: This should be omitted/rephrased as it is advanced for Year 4

Comment [GG39]: The language used needs to be more explicit, especially for non-science specialist teachers e.g. *identify how animals and plants are suited to and adapt to their environment* is too ambiguous – it could run the risk of teachers going way beyond what is needed or being too simplistic.

Comment [GG40]: Introduce the concept of competition? This could then link to the topic on habitats.

Comment [GG44]: Note: Populations evolve; not individuals.

Comment [GG45]: And plants

Comment [GG41]: This doesn't show much progression from Year 4

Comment [GG42]: Natural selection? This statement is misleading. This is a big concept and needs more thought regarding teh wording/how it is introduced.

Comment [GG43]: This is a difficult example at Year 6. Suggest using an alternative example.

Comment [GG46]: Mosses might facilitate investigations for less well resourced schools

Comment [GG47]: 'Pupils should able to draw on the following knowledge in a range of contexts:' (i.e. focus on learning outcomes)

- the role of diffusion in the movement of materials in and between cells
- the structural adaptations of a range of unicellular organisms~~e of Amoeba and Euglena~~
- 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

~~Human~~ 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 ~~breathing (~~gas exchange~~)~~ system

- the structure and functions of the gas exchange system in ~~humans,~~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 ~~breathing~~ gas exchange system.

Comment [GG48]: This could be interpreted by teachers as they now must teach the muscles of the body. Suggest rewording to clarify.

Comment [GG49]: These are important practicals but a small and very specific part of the curriculum. No other practicals have been specified prior to this (so why this one?). The other points in this section are more important.

Comment [GG50]: This statement about plant nutrition belongs alongside human nutrition (previously under photosynthesis). Minerals are important to both and, although you can grow plants without soil, at KS3 it is fair and important to make mention of soil as important for plant health. The process of uptake is not important, but the understanding that plants need mineral nutrients (nitrogen, potassium, phosphorous) from soil (and of course carbon, oxygen and hydrogen from air and water) is.

Comment [GG51]: This has been moved from photosynthesis because relating the function of stomata (rather than merely their presence) to photosynthesis is rather complex at KS3. The broader role of stomata in gas exchange (carbon dioxide, oxygen and water vapour) is more analogous to breathing systems. All students would need to know is that they are pores on leaves, they are called stomata and they open and close to allow gases in and out. KS3 students could do stomatal peels and get experience looking down a microscope.

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 effects of drugs (including as medicines as well as substance misuse) on behaviour, health and life processes such as conception, growth and development.~~ 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~~ Material cycles and energy

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 ~~and chemosynthesis~~
- ~~the relationship between the structures and functions of leaves, including chloroplasts and stomata~~ the adaptations shown in leaves which enable plants to photosynthesise ~~better~~more effectively
- the reactants ~~in,~~ and products of~~,~~ photosynthesis, and the word equation for photosynthesis

- ~~mineral nutrition in plants, to explain the role of nitrates~~ in plant nutrition
- ~~chemosynthesis in bacteria and other organisms~~

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

Comment [GG52]: Moved from genetics and evolution as this describes the structure and function of another organ system.

Comment [GG53]: Wording (i.e. use of 'energy') needs more thought – it is sunlight that drives photosynthesis.

Comment [GG54]: This is unduly complex for KS3 (it is complicated enough for KS4). It's interesting as an 'exception' and its important for deep sea communities, but it doesn't merit the same attention as photosynthesis. This is complicated for GCSE students let alone KS3 ones.

Comment [GG55]: Could include chloroplasts, but also thin epidermis and surface area: volume from which simple calculations could be done.

Comment [GG56]: This statement has moved to 'nutrition'

- 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 ~~and the accumulation of toxic materials~~
- how organisms affect, and are affected by, their environment, including the accumulation of toxic materials
- ~~niches and~~ the role of variation in enabling ~~closely related~~ 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:

~~***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~~
- ~~the importance of plant reproduction through insect pollination in human food security~~

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, ~~including~~ and the part played by Watson, Crick, Wilkins and Franklin in the development of the DNA model
- the variation between individuals of different species

Comment [GG57]: Wording (i.e. use of 'energy') needs more thought as energy is not a substance that can be released.

Comment [GG58]: Moved to 'Interactions and interdependencies'

Comment [GG59]: This describes an interdependence between organisms and therefore is more appropriately placed in this section.

Comment [GG60]: Moved to 'Structure and function'

Comment [GG61]: Moved to 'Interactions and interdependencies'

- 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 ~~adaptation~~ 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.

KS4 Biology

Please note: we have not commented specifically on the draft Key Stage 4 Biology Programme of Study as part of this response, since feedback on KS4 was not requested as part of the formal consultation. However, we have taken the content of the Key Stage 4 drafts into careful consideration when developing our feedback on the biology content of the drafts for Key Stages 1-3 – paying particular attention to the progression ideas and the avoidance of repetition of content that does not build on prior learning.

We plan to submit a full response on the draft Key Stage 4 Programme of Study once this is made available for formal consultation. And reiterate that this will need to be made available alongside the redrafted Programmes of Study for Key Stages 1-3.

Comment [GG62]: Should natural selection be introduced at KS3 or KS4? In the current curriculum it sits in KS4.

1 Primary chemistry content showing topic progression – comments from the Royal Society of Chemistry

Programme of study (statutory requirements	Notes and guidance (non-statutory)	Comments from RSC
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. 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?'	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. 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 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; 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	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. This section seems very similar to Year 1. It is also repeated in Year 5

	encouraged to think about unusual and creative uses for everyday materials.	
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 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.	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 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. Formation of sedimentary rocks could remain in this section. 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	**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	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.

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.	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.	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 States 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: • 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,	**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	Bullet point 1: could also include transparency in the list of comparative and fair tests The distinction between melting and dissolving is 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

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.	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.	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 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	**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 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	Suggest changing 'new materials' to 'new substances' The use of the distinction between reversible and 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

of soda.	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.	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'

Key Stage 3 Chemistry – Comments from the Royal Society of Chemistry

Chemistry	Comments from RSC
Pure and impure substances • mixtures, including dissolving • techniques for separating mixtures: chromatography, filtering, evaporation and distillation • the identification of pure substances	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.

Alternative draft Science National Curriculum for Chemistry at KS3
One alternative approach to organising the material that provides coherence between the learning areas has been produced by Dr Andrew Hunt. We append it here as an exemplar that can aid redrafting

Suggestion from Andrew Hunt

This alternative version sticks closely to the draft published for consultation while aiming to making the key teaching points more explicit and to clarify potential ambiguities.

The attempt to use the same set of sub-headings in all key stages is misguided and is not adopted here. The section on Earth Science has been omitted and some of its content has been incorporated elsewhere. There is a strong case for a whole section about 'Earth science and astronomy' alongside the biology, chemistry and physics in this KS3 curriculum.

Chemistry	**Notes**
Substances and states of matter • substances as kinds of matter that can be identified by their properties. • changes of state in terms of particle kinetics and energy changes • the properties of the different states of matter (solid, liquid and gas) in terms of particle kinetics, including gas pressure. • the arrangements of atoms in substances that may be in small groups called molecules or bonded to many other atoms in giant lattices. • the classification of substances as elements and compounds • the use of models, chemical symbols and formulae to represent elements and compounds.	The importance of the concept of a substance needs to be explicit. The concept of a substance should not be introduced until KS3 because students need an atomic/molecular particle model to make sense of it. The distinction between molecules and giant structures in needed to make sense of properties of matter at KS3. So also is the notion that there are strong bonds between atoms in molecules and giant structures but only weak forces between molecules. The nature of the bonding and the distinctions between the different kinds of strong bonding should be left to KS4. Note that diffusion belongs in the study of mixtures – see below. The use of chemical models should be explicit.

Changing substances • chemical reactions as the formation of new substances with a total mass of the products that is the same as the total mass of the reactants. • chemical reactions as the rearrangement of atoms • representing chemical reactions using models, formulae and equations, including state symbols	The use of molecular models to represent equations is as important as using symbols at Key Stage 3 and should be mentioned. This section is important to establish the idea of a chemical reaction before getting into details about different kinds of chemical change (see below). Research has shown that many students fail to grasp the key ideas in this section during KS3.
Mixtures of substances • mixing on an atomic/molecular scale as in dissolving and diffusion • limits to solubility and the effects of temperature on solubility • mixing that involves the dispersion of specks, grains or droplets of one substance in another substance (for example pastes, gels, emulsions, foams, mists and smoke). • natural mixtures including rocks, the sea and the atmosphere • techniques for separating mixtures: chromatography, filtering, evaporation and distillation.	Note that the methods of separation listed in the original draft (and retained here) imply understanding of the different scales of mixing made explicit in this version. So many everyday products are made by carefully mixing selected ingredients that this aspect of chemistry should be given more prominence.
Types of chemical reactions • acids and their reactions with metals, metals oxides, hydroxides and carbonates • the pH scale for measuring acidity/alkalinity; and indicators • combustion, thermal decomposition, oxidation and reduction • the displacement reactions of metals and the reactivity series for metals • exothermic and endothermic chemical reactions (qualitative)	The focus for acids should be on the patterns in their reactions and not on formal definitions at this level. It is best to avoid a definition of ‘base’ at this level. Displacement reactions best restricted to metal reactions at this stage. The idea of a reactivity series for metals fits better here.

The Periodic Table • the origins of the Periodic Table and the principles underpinning the Mendeleev Periodic Table • the varying physical and chemical properties of metallic and non-metallic elements • the chemical properties of metal and non-metal oxides with respect to alkalinity and acidity • the use of the Periodic Table to predict patterns in reactions.	The first bullet point in this draft indicates that the treatment here is in terms of relative atomic mass and not electron configuration. It also shows that the distinction between groups and periods is expected. The story of Mendeleev's periodic table can fit well here leaving the modern periodic table, in terms of atomic/proton number, left to KS4.
Materials • the raw materials and energy resources needed to extract metals from oxide ores with carbon • the raw materials and energy resources needed to manufacture glass and clay ceramics. • the microstructure of metals, ceramics and glasses related to their properties and uses • the properties and uses of composite materials • the benefits of recycling.	Chemistry teaching at KSs 3 & 4 generally omits to point out the importance of microstructure in determining the properties of materials. If the polycrystalline nature of metals and ceramics is covered at KS3, this can lead nicely to the treatment of atomic structure and bonding at KS4. A focus on the microscale can be related to the work on cells, on a comparable scale, in biology. The study of the manufacture, structure and properties of polymers is better left to KS4.

Key stage 4 - Brief comments from the Royal Society of Chemistry on the draft programme of study

- 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 ~~closely~~ 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, ~~walking and running~~. 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.

Comment [CT63]: E.g. a train – don't want to get too close!

Comment [CT64]: !! even themselves!! Not a big worry.

Key Stage 2

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	Forces and Magnets Pupils should observe that magnetic forces can ~~be transmitted~~act without direct contact, unlike most forces, where direct contact is necessary (for example, opening a door, pushing a swing). **Note:** ~~Pupils~~ Although some pupils will notice the pattern between the

Comment [CT65]: Also gravity.

Comment [CT66]: Teachers will need more support on what is meant by a contact force.

• 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.	poles, this can be explored but pupils do not need to be formally 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.
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, that act between moving surfaces • Describe , in terms of drag forces and friction, why moving objects that are not driven tend to slow down Understand that force and motion can be transferred through mechanical devices such as gears, pulleys, levers and springs	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 should explore the effects of levers, pulleys and simple machines on movement. 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. They might design and make a simple lever and explore its effects.

Comment [CT70]: Better to be 'could'. These are difficult to run with classes of 30 pupils. Might consider, e.g. dropping plasticene shapes through water. Easier to set up.

Comment [CT71]: Better if parachutes do not appear in KS1/2 more than once – it would be more appropriate to mention again under KS4 motion and forces, when it is a really useful context – also with motion graphs

Comment [CT72]: This has now gone from the PoS.

Comment [CT67]: Drag forces could easily move to key stage 3 where they could be covered better. NOTE: they have not done the particle model of matter at this point. So it is hard to properly understand drag forces.

Comment [CT73]: Paper cones work so much better, especially for this age group

Comment [CT68]: Doesn't really go anywhere and it isn't clear what they would do.

Comment [CT74]: No longer in POS.

Comment [CT69]: There used to be a statement about distance = speed x time. It seems like a useful, quantitative idea to introduce here; the physics version is that distance accumulates over time.

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 cares passing one another; ~~the movement of the sun, moon and Earth~~

Forces

- Forces as pushes or pulls, arising from the interaction between two objects
- Moment as the turning effect of a force~~: torque and rotational effects~~
- 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 ~~as a~~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 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

Comment [CT75]: It would be useful to have something on contact and non-contact forces. Building on Year 3.

Comment [CT76]: Seems high level. And probably not needed.

Comment [CT77]: Doesn't have to be limited to springs; other materials as well.

Comment [CT78]: Within Hooke's law is the idea of proportionality. Are we sure that this has been developed sufficiently at this stage? Or is being developed coherently through the key stage and across the sciences. Have they done it in Maths?

Comment [CT79]: Presumably qualitative. Also, is it really a part of the KS3 energy discussion.

Comment [CT80]:

Comment [CT81]: The term 'pressure forces' is a little odd.

Comment [CT82]: This is fine. However, in Key Stage 4, the same ratio is used to calculate stress. The distinction between them is the way in which they act (in all directions or as a vector). We wonder if this distinction (between pressure and stress) should be made clearer. Many people would use the word pressure to describe stress.

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, ~~net~~ 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
- ~~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); ~~Newton's Second Law~~
- 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 ~~Third~~ Second (?) Law.

Comment [CT83]: Would it be better to introduce displacement as a vector and talk about velocity as the rate of change of displacement?

Comment [CT84]: Net velocity is a new idea whereas relative velocity has been discussed.

Comment [CT85]: Why is skating mentioned specifically?

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	Magnetism Pupils should be made aware that they are being introduced to a predictive ~~model~~ 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

Comment [CT86]: Well they can be used but there won't be a big current and the component won't come on. Suggest rewording.

Comment [CT87]: This is a useful statement. However, it looks quite lonely because there is no coherent thread for working scientifically.

• Predict whether two magnets will attract or repel each other, depending on which poles are facing	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 ~~or the volume of a buzzer~~ 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.

Comment [CT88]: Very specific examples here.

Comment [CT89]: Could reintroduce something on how magnets are made/unmade.

Comment [CT90]: Do we need to provide help and guidance on the Earth's magnetic poles.

Comment [CT91]: Worth checking: but buzzers don't necessarily get louder.

Key Stage 3

Electricity and electromagnetism

Pupils should be taught about:

Current electricity

- Electric current, measured in amperes, ~~in circuits,~~
- 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 ~~measured in ohms~~
- 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

Comment [CT92]: Do we want to introduce the idea that currents add up at the point where branches meet?

Comment [CT93]: Suggest leaving out at KS3. It is repeated at KS4 and is more appropriate there.

Comment [CT94]: Needs underpinning: positive and negative charges in materials are normally balanced. Model of atom?

Comment [CT95]: Are the ideas of fields and field lines going to be meaningful at this age? Might be better to talk about magnetic effects;

Comment [CT96]: This is a repeat of KS2. Needs to be developed somehow (or left out of KS2).

Comment [CT97]: Principles only; although students should certainly have the opportunity to build a motor, they shouldn't have to learn the detailed construction. Only the principles.

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 ~~and~~
- 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 ~~un~~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

Comment [CT98]: I=V/R is nicer somehow.

Comment [CT99]: What about circuit breakers (RCCCBs and RCDs)?

Comment [CT100]: Should we mention the kWh here?

Comment [CT101]: Swap to make it respective.

- 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.

Comment [CT102]: Rotating magnet and rotating coil; again, it is the principles rather than the detailed construction and operation that matters.

Comment [CT103]: Commercial uses might just end up being stuff to learn (something best avoided)

Comment [CT104]: This is the first time that the word stress has been used. See comments in the forces topics about stress and pressure. They need to be used consistently.

Comment [CT105]: Oscillating charges might be better – e.g. warm bodies radiation of infra red

Comment [CT106]: In fact this whole statement feels too advanced for KS4. And isn't really necessary.

Light

Key Stage 2

Year 3 programme of study (statutory requirements)	**Notes and guidance (non-statutory)**
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 • Know that darkness is the absence of light. • 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	Pupils should explore materials to help them to understand the differences between the meaning of transparent, translucent and opaque. They should observe shadows being formed in everyday contexts, such as when they play outside or shine torches indoors. If possible and with appropriate safety measures, they might go into a completely blackened room to realise that, in the absence of any light, you really cannot see anything. An almost dark room will not work. **Note:** Pupils should be warned that it is not safe to look directly at the Sun, even when wearing dark glasses. Pupils might work scientifically by: looking for patterns in what happens to shadows when the light source moves or the distance between the light source and the object changes; investigating the suitability of materials for different purposes, such as blackout curtains; exploring whether shiny things shine in the dark.
Year 6 programme of study (statutory requirements)	**Notes and guidance (non-statutory)**
Pupils should be taught to: • Understand that light appears to travel in straight lines • ~~Use the idea that light travels in straight lines to explain that~~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 objects that cast	Pupils should explore the way that light behaves, including light sources, reflection and refraction. They should talk about what happens and make predictions. They should experience a range of examples of interesting aspects of light such as rainbows, colours on soap bubbles, objects looking bent in water and white light being split by prisms. Pupils might work scientifically by: deciding where to place rear-view mirrors on cars; designing and making a periscope and using the idea that light appears to

Comment [CT107]: Observe and notice might need definitions or explaining.

Comment [CT108]: This statement needs to be somewhere. It may be that it goes into the senses at Key Stage 1 – which would be better.

Comment [CT109]: Somewhere in the guidance, we need to refer to the source -> journey -> receiver model of a wave and light. This goes for waves as well.

Comment [CT110]: Refraction cannot really be done in a meaningful way at this stage.

them, and to predict the size of shadows when the position of the light source changes	travel in straight lines to explain how it works. They might investigate the relationship between light sources, objects and shadows by using shadow puppets.

Comment [CT111]: Need a point source of light.

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 • 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	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 might make ear muffs from a variety of different materials to

Comment [CT112]: Could be worded better. All sounds are produced by a vibration. So we don't want to suggest that only some of them are.

Comment [CT114]: Seems to be some text missing.

Comment [CT113]: Would loudness be better here?

Key Stage 3
Waves

Pupils should be taught about:

Observed Waves

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

Sound Waves

- Frequencies of ~~sound waves~~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

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

Light Waves

- ~~The similarities and differences between light and waves in matter~~
- Light waves travelling through a vacuum; speed of light

Comment [CT115]: Waves on a slinky might be better – many schools do not have ripple tanks; so putting this in the statutory NC will be tough.

Comment [CT116]: It seems very specific to have this in the statutory part of the curriculum.

Comment [CT117]: This is high level for KS3. Better in KS4 or omitted altogether..

Comment [CT118]: Or maybe noise and ear damage as example)

- The transmission of light through materials; absorption, diffuse scattering and specular reflection at a surface
- The refraction of light at boundaries; real and apparent depth;~~,~~ action~~ng~~ 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 ~~different frequencies~~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 ~~superposition~~ diffraction
- speed: frequency x wavelength

Definitions of frequency, wavelength, amplitude, displacement

~~Sound~~ 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; ~~earthquake detection~~
- ultrasound for medical diagnosis
- resonance effects and feedback
- Earthquake detection and evidence for the structure of the Earth

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;

Comment [CT119]: Unusual to see this word.

Comment [CT120]: Is this rods and cones? How will students understand their operation at this level?

Comment [CT121]: Isn't this in KS3?

Comment [CT122]: This is fine; but some things include applications and others don't. It needs to be consistent.

Comment [CT123]: and scanning (or is that diagnosis?)

Comment [CT124]: Not sure what these are. But they could be omitted. Especially feedback.

Comment [CT125]: This might go here. But it needs to be a part of a coherent development of ideas in Earth Science.

Comment [CT126]: Could include LEDs (through efficient lighting context) and lasers. To try to bring in some more modern physics.

Comment [CT127]: This would be a good place to put something about the Earth's radiation budget, the Sun and Earth as (black body) radiators; absorption and emission of EM waves – including IR. Absorption by the atmosphere, ozone and greenhouse gases. But this does need to be a part of a coherent development of these ideas and ideas about climate.

- the Sun and the Earth as (approximate 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.

Comment [CT128]: These ideas should be covered somewhere. They might form part of a coherent section on Earth science or they can come in here.

Comment [CT129]: This could be covered somewhere else, but it is part of the story about the Earth's radiation budget.

Comment [CT130]: Is this going to be developed at all to discuss S and P waves and what they tell us about the structure of the Earth?

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 associated with the seasons and how the day length varies	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 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.

Comment [CT132]: This is very twee. And what if they want to use a doll or other figure.

Comment [CT131]:

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	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,

Comment [CT135]: Refer back to year 1 – that the Sun appears to move across the sky but we can explain this with a model of the Earth rotating on its axis.

Comment [CT133]: BTW, can we please be consistent with capitals for Sun, Earth, the Moon.

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 ~~in the solar system~~ • Describe the movement of the Moon relative to the Earth • Describe the relative sizes of the Sun, Earth and Moon; • ~~Describe the Sun, Earth and moon, as approximately spherical bodies~~ • ~~Use the idea of the Earth's rotation to explain day and night~~	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 ~~should~~ 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 ~~how the geocentric model of the solar system gave way to the heliocentric model~~. 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 the ~~solar system~~ Sun, 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 eclipses;
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 solar system.
Our Sun as a star; other stars in our galaxy (the Milky Way); our galaxy has billions of planets and 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

Comment [CT136]: This is at odds with what is in the PoS. The solar system would be better in Key Stage 3. It might be that pupils will ask about the planets (in which case, teachers would want to talk about them. However, the Key Stage 2 content is better being confined to the Sun, Earth and Moon.

Comment [CT134]: Changed sequence.

Comment [CT137]: Could also be KS3.

Comment [CT138]: If they are not studying the solar system, they can explore the change in ideas from the Sun going around the Earth to the Earth rotating on its axis (so that the Sun appears to go round it) and the Earth going around the Sun.

Comment [CT139]: It's not clear why Alhazen is specifically included; Erastothenes and the measurement of the size of the Earth might be a better illustration of early science, and Aristarchus was a very early proponent of the heliocentric solar system (who used correct reasoning but imprecise data to estimate the relative distances of Moon and Sun). Alhazen was important historically, but in some respects his main contribution was to try to "improve" the Ptolemaic system. T ...

Comment [CT140]: Getting pupils to look at sundials in a systematic and experimental way introduces several concepts including accurate observation and measurement, and geometry of angles, ...

Comment [CT141]: Wow. How would they work this out? Plus, we think that there are competing interpretations of its **use**. Although it may function as a ...

Comment [CT142]: Currently, there is no Earth and Space at Key Stage 3. There ought to be. We have put in some suggested areas of study.

- 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~~ Sun and planets holds solar system together

Orbital motion

- motion in a circle, acceleration towards centre
- gravity force may produce ~~enough~~ 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
- ~~slower~~ 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.

Comment [CT143]: Can go in key stage 3; without specific reference to inertial mass

Comment [CT144]: This is advanced (more like AS level); at this level restrict to force gets weaker with distance. Or possibly refer to inverse square law. But no need to do whole equation.

Comment [CT145]: Missing space between g and 'as'.

Comment [CT146]: Move this to key stage 3.

Comment [CT147]: This phrase is fine but sounds a bit odd??

Comment [CT148]: Freefall and apparent weightlessness in a falling lift – related to apparent weightlessness in orbit in next section. There's a nice physics story in this.

Comment [CT149]: Or say "stable orbital motion occurs for an object orbiting at a particular height at a particular orbital speed"

Comment [CT150]: GPS and its low orbit satellites.

Comment [CT151]: Currently fusion is not in the radioactivity topic. It should be if it is being used here.

Energy

The section on energy has been discussed at some length and we propose some statements as an alternative to the ones that were in the draft. It is likely that these will need further discussion with the teaching community. During our discussions, it became apparent that

- it is impossible (and not desirable) to use a set of statements to provide helpful ways of discussing energy in schools. It would be helpful, therefore, to address this separately through an accompanying commentary;
- ideas about energy pervade many areas of physics and the other sciences; it is important that statements referring to energy are consistent across the science subjects;
- many important ideas relating to energy and systems – including ideas about difference, change and dissipation – cannot be developed satisfactorily in a stand-alone topic; they need to be addressed and developed coherently as they arise in other topics over the years. Again, a commentary would be helpful.

Key Stage 3

Pupils should be taught about:

Using fuels in the domestic context

- comparing energy values of different foods (from labels) (kJ)
- relating this to amounts of energy needed to do various things
- fuels and energy resources;
- domestic fuel bills, fuel use and costs;
- comparing power ratings of appliances in watts (W, kW);
- comparing amounts of energy transferred (J, kJ, kW hour).

Changes in systems

- energy as a quantity that can be quantified and calculated; the total energy has the same value before and after a change;
- how to look at the starting condition and the final condition of a system and describe increases and decreases in the amount of energy associated with its movement, its temperature, its position in a field, its elastic distortion and its chemical composition;

- using physical processes and mechanisms, rather than energy, to explain the intermediate steps that bring about those changes.

Simple machines

- levers and gears as examples of simple machines that transfer energy by doing work;
- simple machines allow us to exert a bigger force but at the expense of having it move less (and vice versa); you can increase force or displacement but not their product;
- work = force x displacement (measured in joules).

Transfer of energy because of a temperature difference

- heating: that when there is a temperature difference between two objects, the hotter one will transfer energy to the cooler one;
- reaching equilibrium: that the transfer of energy will tend to reduce the temperature difference until they are at the same temperature;
- maintaining a temperature difference for longer by putting an insulator between the hotter body and the cooler one; this reduces the rate at which energy is transferred;
- ways of maintaining a temperature difference by transferring energy to the hotter body at the same rate as it is heating the colder one.

Key Stage 4

Pupils should be taught about:

Doing calculations of energy changes

- the ways that the energy of a system can be changed:
  - doing work by forces (force x displacement);
  - doing electrical work (charge x potential difference);
  - heating (mass x temperature rise x specific thermal capacity).

- calculating the amount of energy associated with:
  - a moving body ($^1/_2mv^2$),
  - a stretched spring ($^1/_2kx^2$),
  - raising an object (mg□h).

- calculating changes in the way that energy is stored in some systems before and after a change; for example:
  - an object falling, or sliding down a slope,
  - an object is projected upwards, or up a slope,
  - a moving object hits an obstacle,
  - accelerating an object with a constant force,
  - bringing water to boiling point in an electric kettle,
  - slowing a vehicle.

Conservation and dissipation

- the conservation of energy: changes in a system produce no net reduction in the total energy it associated with the system;
- dissipation: that energy is dissipated and dissipation is unavoidable;
- reducing unwanted energy transfers: e.g. through lubrication, thermal insulation and U values;
- power as rate of transfer of energy;
- Efficiency, measures of efficiency and calculating efficiency.

Energy resources

- quantifying national and global energy resources;
- renewable and non-renewable energy resources;
- patterns and trends in the use of energy resources.

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, ~~water~~, 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,	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

Comment [CT152]: In general, this all feels quite repetitive. They are doing something on materials in 5 of the six years of primary school.

Comment [CT155]: These are all properties of solids. Which reinforces the point above.

Comment [CT153]: Solids, liquids and gases are done in year 4. So a bit odd to have water here.

Comment [CT156]: Doesn't seem very interesting. Or useful?

Comment [CT157]: This isn't very clear. What is it that they are expected to do?

Comment [CT154]: It is a little odd to have this statement here. They haven't done anything on forces yet. Should this be a part of forces. Or left until later?

brick/rock, and paper/cardboard	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 rocks 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	States of Matter

Comment [CT158]: This seems a bit lonely and very similar to year 1.
It is also repeated in Year 5.
Is there any reason for it being here?

Comment [CT159]: This sentence slightly contradicts the one at the end about innovative uses. For example, glass spoons – which I think do exist.

Comment [CT160]: Such as glass spoons!

Comment [CT165]: This section seems to come from nowhere and doesn't really lead anywhere. The Earth Science content needs to be much more clearly developed across the key stages. The rock types, volcanoes and other ideas are mentioned in passing and not developed at all.

Comment [CT166]: Good. But when do they do that?

Comment [CT167]: Rocks or types of rock.

Comment [CT161]: Odd that the word volcano appears only once in the whole framework document. In key stage 2 geography.

Comment [CT162]: Rocks are mentioned here. But never again in the science programme of study. They come up in Key Stage 3 geography. ...

Comment [CT163]: The progression of ideas in Earth Science really needs to be sorted out. This feels quite earl ...

Comment [CT168]: This seems very advanced. More like key stage 3 or 4 chemistry. We note that the word ...

Comment [CT164]: There is a real risk that this will end up being worksheets at this age.

Comment [CT169]: Sedimentary rock is mentioned here in passing.

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 the water cycle and associate the rate of evaporation with temperature	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.

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 ~~how~~ that some materials will dissolve in liquid to form a solution	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

Comment [CT171]: So can liquids. The distinction is probably that solids hold their shape.

Comment [CT172]: Not necessarily. Depends on the density of the gas and which way up the container is.

Comment [CT173]: Can relate this to weather patterns: rain, ice, snow, evaporation. Without the details of the water cycle (which would end up being a diagram that they have to learn. Better that they observe the phenomena.

Comment [CT174]: Doesn't this contradict the statement above about avoiding baking because it is a chemical change?

Comment [CT170]: This has come out of nowhere. And seems advanced for year 4.

Comment [CT175]: Not much different from what is in Year 1.

Comment [CT176]: Apart from the wording, this still seems very advanced for year 4.

• 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	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.

Comment [CT177]: Not sure how you can do fair tests for this. What is a fair test comparison between steel and plastic?

Comment [CT178]: 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. Again, if it is an important idea, we need to see how it is developed through the key stages.

Comment [CT179]: Repeats year 2.

Key Stage 3

Matter

Pupils should be taught about:
Density of solids and liquids???

Physical changes

- Conservation of ~~material~~ 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

Comment [CT180]: A lot of this content is (or could be) covered elsewhere – much of it is repeated in chemistry. So this section could easily be taken out.

Comment [CT181]: There are some very nice statements here – especially the diffusion one. But they would be more appropriate in key stage 4 and in chemistry.

Comment [CT182]: NB. This is the only mention of density in the whole document. At the moment, the basic idea and formula for density is not covered anywhere.

Comment [CT183]: Much of this section is repeated in chemistry. It needs to be clear what aspects are covered in each discipline. Currently, it looks strange to have the same content with different wording.

Comment [CT184]: This is interesting but difficult – it requires hydrogen bonding, I think.. Could (or should) be non-statutory.

Comment [CT185]: This could move to the energy topic.

Comment [CT186]: This statement needs to be preserved in the chemistry version. Plus, there should be something on conduction and radiation at some point.

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: ~~stretching~~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 ~~electrons~~radiations (?); beta and alpha particles
- half-lives
- isotopes; binding energy
- nuclear fission as energy source (fusion?)

Comment [CT187]: It is good to see this but it needs to be spelled out more so that there is a clear distinction between pressure and stress.

Comment [CT188]: There is a lot of content in this single statement. The concern would be that it is taught without practical work – to cover the ground. It could probably be cut back to considering only P proportional to T and P inversely proportional to V. Better to do this (with practicals) and understand the idea of proportionality than to have to learn the gas equation to do calculations.

Comment [CT189]: To go with compressing

Comment [CT190]: Not sure what 'in such changes' means. It would be ...

Comment [CT191]: We are not sure what this is or whether it is necessary.

Comment [CT192]: Would normally say 'plastic' in this context?

Comment [CT193]: Earth Science needs to be dealt with in a more coherent way between the science ...

Comment [CT194]: Interactions with alpha, beta and gamma radiation.

Comment [CT195]: Can these be spelled out more?

Comment [CT196]: This seems very specific. But we're not sure what it is after.

Comment [CT197]: Electrons are particles;

Comment [CT198]: Something about the nature and properties of the ionising radiations alpha, beta and gamma.

Comment [CT199]: Fusion is needed for the Space topic (powering the Sun and stars).

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.

Comment [CT200]: This is a context – a nice one – but it looks a bit out of place.