

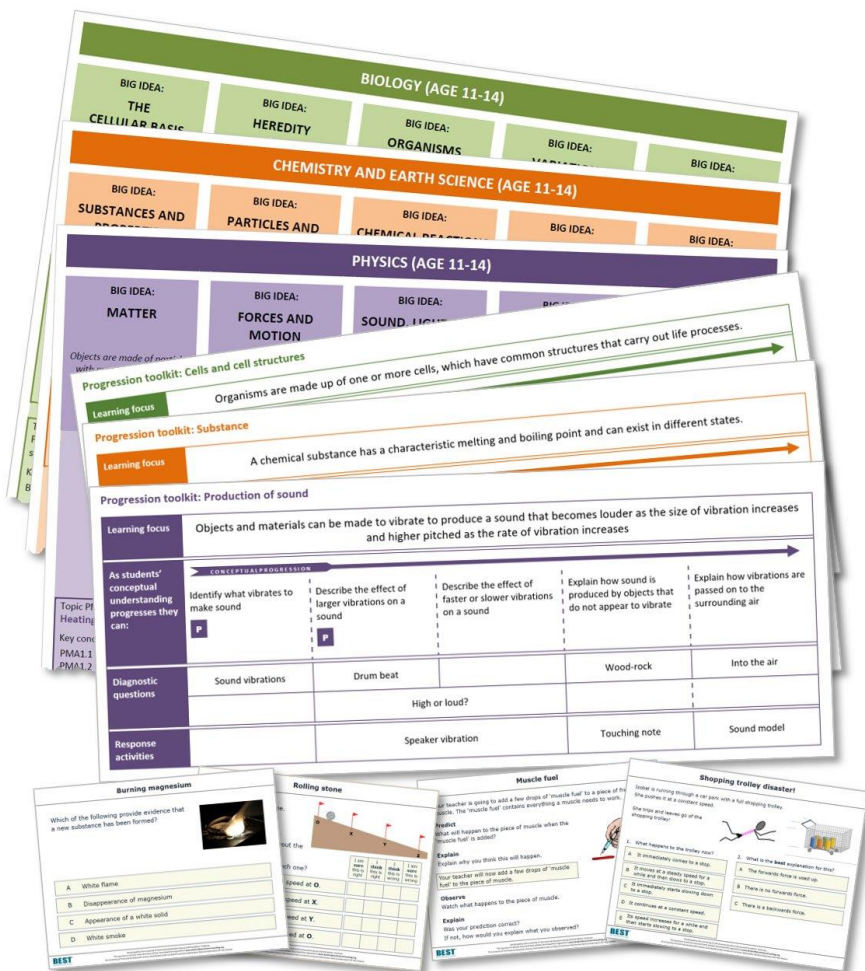
BEST™

Best Evidence Science Teaching

The best teaching
draws on the best evidence

Brief introduction
to resources

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BEST™

Best Evidence Science Teaching

Hundreds
of
resources

All based
on research
evidence

ONLINE,
OPEN-ACCESS
& FREE!

Is it a bird...?

Colour change

Compound A and compound B are added to a small glass jar. Both compounds are white.

A lid is placed on the jar. The jar is shaken. A yellow colour appears.

What do you think about each statement?

| | I am sure this is right | I think this is right | I think this is wrong | I am sure this is wrong |
|--|-------------------------|-----------------------|-----------------------|-------------------------|
| 1 A yellow substance has been released from the white powder. | | | | |
| 2 The white powder has changed colour. | | | | |
| 3 One of the white substances has changed into a yellow substance. | | | | |
| 4 A new yellow substance has been formed. | | | | |

Comparing melting

Steady force

A dynamics trolley is pulled with a steady force. It is pulled by a weight hanging over a pulley.

Predict

What do you think a distance-time graph of the trolley's movement will look like?

Explain

Why do you think the graph will look like this?

Watch the demonstration

Observe

Sketch a distance-time graph of how the trolley moves.

Explain

Were your prediction and explanation correct?

Try to improve your first explanation to explain what happens more clearly.

Progression toolkit: Substance

Learning focus

A chemical substance has a characteristic melting and boiling point and can exist in different states.

As students' conceptual understanding progresses they can:

| | CONCEPTUAL PROGRESSION | | | |
|---|---|--|--|---|
| Recognise that a substance may exist in the solid, liquid or gas state, depending upon the temperature. | Match observations of melting (or cooling) to the temperature at which they take place. | Match observations of boiling to the temperature at which they take place. | Distinguish the scientific use of the word pure from the everyday meaning. | Distinguish a pure sample of a substance from an impure sample (mixture) by recognizing that a sharp melting point is characteristic of a pure sample of a substance. |
| | | | | |
| Diagnostic questions | Possible states | Melting observations Cooling observations | Boiling observations | Pure or mixture? Melting and purity |
| Response activities | Unusual states | Comparing melting | | All that glitters... Contamination mystery |

DIAGNOSTIC
QUESTIONS

RESPONSE
ACTIVITIES

PROGRESSION
TOOLKITS

...to help teachers develop **evidence-based practices**

...to test and consolidate students' understanding of **key concepts** in science.

Evidence-informed progression

A **progression toolkit** helps you to test and consolidate understanding of a **key concept** in science.

Progression toolkit: Changing motion

A resultant force on an object can cause it to speed up or slow down, depending on the direction of the force.

| Learning focus | A resultant force on an object can cause it to speed up or slow down, depending on the direction of the force. | | | | |
|--|--|---|---|--|---|
| As students' conceptual understanding progresses they can: | CONCEPTUAL PROGRESSION | | | | |
| | Calculate the size and direction of the resultant force of two forces acting along the same straight line. P | Describe how quickly the speed of an object can be changed if acted on by resultant forces of different size. P | Describe how the speed of an object changes throughout the time that a resultant force is acting on it. | Explain how friction and other resistive forces can act to continually reduce the speed of an un-propelled object. | Explain why friction and other resistive forces make it necessary to exert a constant force to keep an object moving at a steady speed. B |
| Diagnostic questions | How much is left over? | Drag race | Skydiving Rolling stone | Shopping trolley disaster! | Supermarket dash |
| Response activities | Calculating resultant force | Steady force | | Counter force | Trolley racing |

Key:
P Prior understanding from earlier stages of learning
B Bridge to later stages of learning

A research-informed progression pathway describes what students should be able to do as their understanding of the concept develops.

Diagnose misunderstandings

Progression toolkit: Substance


| Learning focus | A chemical substance has a characteristic melting and boiling point and can exist in different states. | | | | |
|--|---|--|----------------------|----------------------|-----------------------|
| As students' conceptual understanding progresses they can: | <div>CONCEPTUAL PROGRESSION</div> <div> <div>Recognise that a substance may exist in the solid, liquid or gas state, depending upon the temperature.</div> <div>Match observations of melting (or cooling) to the temperature at which they take place.</div> <div>Match observations of boiling to the temperature at which they take place.</div> <div>Distinguish the scientific use of the word pure from the everyday meaning.</div> <div>Distinguish a pure sample of a substance from an impure sample (mixture) by recognizing that a sharp melting point is characteristic of a pure sample of a substance.</div> </div> | | | | |
| Diagnostic questions | Possible states | Melting observations Cooling observations | Boiling observations | Pure or mixture? | Melting and purity |
| Response activities | Unusual states | Comparing melting | | All that glitters... | Contamination mystery |

Diagnostic questions help you to collect:

- evidence of where your students are in their conceptual progression
- evidence of common misunderstandings and preconceptions.

They can be used formatively to decide what to do next.

Body cells



Which statement about the human body is true?

A The body contains cells.

B The body is a cell.

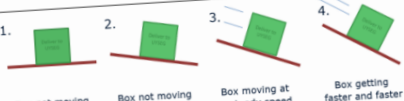
C The body is made up of cells.

D Cells are only found between the organs.

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No friction



1. Which boxes have no friction?

A They all have friction

B Box 1 has no friction

C Boxes 1 and 2 have no friction

D Boxes 3 and 4 have no friction

E Box 4 has no friction

2. Why do you think this?

A There is no force pushing sideways

B The surfaces are a little bit rough

C There is movement

D There is no movement


E There is no force to slow the movement

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Sugar solution

A teaspoon of sugar is dissolved in a glass of water making a sugar solution.



Read the statements in the table.

What is your decision for each statement?

| | I am sure this is right | I think this is right | I think this is wrong | I am sure this is wrong |
|--|-------------------------|-----------------------|-----------------------|-------------------------|
| 1 The solution includes sugar in the liquid state. | | | | |
| 2 You cannot see sugar in the solution, so it is not there. | | | | |
| 3 You could taste the sugar in the solution, if it were safe to do so. | | | | |
| 4 The sugar has reacted with the water. | | | | |

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Respond effectively

Response activities:

- encourage students to talk and think about what they're thinking (metacognition)
- facilitate purposeful practical work
- encourage meaning-making.

They help to challenge misunderstandings and overcome barriers to conceptual development.

Progression toolkit: Cells and cell structures

Organisms are made up of one or more cells, which have common structures that carry out life processes.

| Learning focus | CONCEPTUAL PROGRESSION | | | | |
|--|--|---|--|--|--|
| As students' conceptual understanding progresses they can: | Use a light microscope to make and record observations of cells from a range of tissues and organisms. | Apply the idea that organisms are made up of one or more cells. | Identify subcellular structures and their functions. | Use ideas about cell structures and their functions to explain why a cell is a living thing. | Describe the features and the limitations of the animal and plant cell models. |
| Diagnostic questions | Using a light microscope | Body cells Made of cells? | Organ or organelle? | A single cell can... | Animal cell or plant cell? |
| Response activities | What is it made of? | Cell drawings The hungry alien | Job ads: Cell structures wanted! | Match game! Substance-structure-process | What do they have in common? |

Heating a compound

A sample of a green compound is heated.

The table describes what is observed.

Some students try to explain the observations.
Who do you agree with? Why?

| Stage | Observation |
|----------------|--------------|
| Before heating | Green powder |
| During heating | No flames |
| After heating | Black powder |

Danny: The colour of the compound changed from green to black.

Amy: Heating released the black colour out of the green powder.

Kyle: The compound has broken up to form two new substances.

Sujata: The compound has combined with oxygen from the air to form a new substance.

Flames

Your teacher is going to place burning candles into two jars of air.

- One jar contains **air from the room**.
- The other jar contains **exhaled air** (air breathed out by a person).

Predict

What will happen to the candle in each jar?

Explain

Explain why you think this will happen.

Your teacher will now place the candles in the jars.

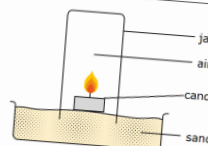
Observe

Watch what happens to the candles in the jars.

Explain

Was your prediction correct?

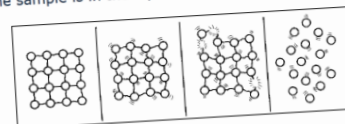
If not, how would you explain what you observed?



Particle model - melting

The diagram is from a textbook.

It shows the **particle model** of a substance in the solid state melting so that the sample is in the liquid state.



To talk about in your group

State three ways in which you think the diagram is a **good representation** of a substance melting.

State three ways in which you think the diagram is **not an accurate representation** of a substance melting.

Evidence-informed practice

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TEACHER NOTES

Biology> Big idea BCL: The cellular basis of life > Topic BCL2: From cells to organ systems > Key concept BCL2.3: The human skeleton and muscles

Diagnostic question

Moving through the digestive system

Overview

| | |
|------------------------------|---|
| Learning focus: | Bones and muscles are tissues that work together with organs in organ systems to support the life processes of cells to keep organisms alive. |
| Observable learning outcome: | Describe the presence and roles of muscles in organs and organ systems. |
| Question type: | Simple multiple choice |
| Key words: | digestive system, muscle |

What does the research say?

When children up to age 15 were asked to draw what is inside the human body, most drew organs but very few drew muscles, and when muscles were drawn they were commonly only depicted in the limbs (Reiss et al., 2002; Bartoszek, Machado and Amann-Gainotti, 2011). Driver's review of the research literature suggested that there was no evidence that school-age children recognise the involvement of muscles in the digestive, circulatory and respiratory systems (Driver et al., 1994).

Several studies have found that children from ages 4 to 10 do not appreciate that food is pushed through the digestive tract by waves of muscle contraction (peristalsis), believing instead that gravity and body movements such as walking and bending are responsible (Teixeira, 2000; Ahi, 2017).

Ways to use this question

Students should complete this question as a pencil and paper exercise, or you could use the PowerPoint presentation with an electronic voting system or mini white boards.

Differentiation

You may choose to read the question to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

Expected answers

B – Contracting muscles

How to respond - what next?

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs. Responses often work best when the activities involve paired or small group discussions, which encourage social construction of new ideas through dialogue.

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TEACHER NOTES

If students have misunderstandings about the presence and functions of muscles in organ systems such as the digestive system, the following BEST 'response activity' could be used in follow-up to this diagnostic question to develop understanding:

- Response activity: Muscles in organ systems

Acknowledgments

Developed by Alistair Moore (UYSEG).

Images: pixabay.com/Elionas2 (1463369)

References

Ahi, B. (2017). Thinking about digestive system in early childhood: a comparative study about biological knowledge. *Cogent Education*, 4(1).

Bartoszek, A. B., Machado, D. Z. and Amann-Gainotti, M. (2011). Graphic representation of organs and organ systems: psychological view and developmental patterns. *EURASIA Journal of Mathematics, Science & Technology Education*, 7(1), 41-51.

Driver, R., et al. (1994). *Making Sense of Secondary Science: Research into Children's Ideas*, London, UK: Routledge.

Reiss, M. J., et al. (2002). An international study of young peoples' drawings of what is inside themselves. *Journal of Biological Education*, 36(2), 58-64.

Teixeira, F. M. (2000). What happens to the food we eat? Children's conceptions of the structure and function of the digestive system. *International Journal of Science Education*, 22(5), 507-520.

Teacher notes summarise the **research evidence** underpinning each resource.

This provides bitesize CPD to help you develop your evidence-informed practices.

Research-informed curriculum planning

Progression toolkit: Cells and cell structures

Learning focus Organisms are made up of one or more cells, which have common structures that carry out life processes.

Progression toolkit: Substance

Learning focus A chemical substance has a characteristic melting and boiling point and can exist in different states.

Progression toolkit: Production of sound

Learning focus Objects and materials can be made to vibrate to produce a sound that becomes louder as the size of vibration increases and higher pitched as the rate of vibration increases

As students' conceptual understanding progresses they can:

| CONCEPTUAL PROGRESSION | 1 | 2 | 3 | 4 |
|--------------------------------------|---|---|--|---|
| Identify what vibrates to make sound | Describe the effect of larger vibrations on a sound | Describe the effect of faster or slower vibrations on a sound | Explain how sound is produced by objects that do not appear to vibrate | Explain how vibrations are passed on to the surrounding air |
| Diagnostic questions | Sound vibrations | Drum beat | Wood-rock | Into the air |
| Response activities | | Speaker vibration | Touching note | Sound model |

Burning magnesium

Which of the following provide evidence that a new substance has been formed?

A. White flame
B. Disappearance of magnesium
C. Appearance of a white solid
D. White smoke

Rolling stone

What happens to the speed of a stone as it rolls down a slope?

A. It increases
B. It decreases
C. It stays the same
D. It stops

Muscle fuel

What happens to the speed of a muscle when it is used?

A. It increases
B. It decreases
C. It stays the same
D. It stops

Shopping trolley disaster

What happens to the speed of a shopping trolley when it is pushed?

A. It increases
B. It decreases
C. It stays the same
D. It stops

BIOLOGY (AGE 11-14)

BIG IDEA: THE CELLULAR BASIS OF LIFE

BIG IDEA: HEREDITY

BIG IDEA: ORGANISMS

BIG IDEA: ECOSYSTEMS

BIG IDEA: BIOLOGICAL SCIENCE

CHEMISTRY AND EARTH SCIENCE (AGE 11-14)

BIG IDEA: SUBSTANCES AND PROPERTIES

BIG IDEA: PARTICLES AND ATOMS

BIG IDEA: CHEMICAL REACTIONS

BIG IDEA: EARTH AND SPACE

BIG IDEA: BIOLOGICAL SCIENCE

PHYSICS (AGE 11-14)

BIG IDEA: MATTER

Objects are made of particles with mass. Understanding particles helps us to design our world.

BIG IDEA: FORCES AND MOTION

Forces make things change. Understanding forces helps us to predict and control physical change.

BIG IDEA: SOUND, LIGHT AND WAVES

Waves radiate information. Understanding waves helps us to communicate.

BIG IDEA: ELECTRICITY AND MAGNETISM

The everyday world is largely a consequence of electrical charge. Understanding electricity and magnetism helps us develop technology to improve lives.

BIG IDEA: EARTH IN SPACE

Understanding the uniqueness of the Earth and the vastness of space gives us perspective and awe.

Topic PFM1 Forces

Key concepts:

- PFM1.1 What forces do
- PFM1.2 Describing forces
- PFM1.3 Balanced and unbalanced forces
- PFM1.4 Friction
- PFM1.5 Energy stores and transfers

Topic PSL1 Sound and light

Key concepts:

- PSL1.1 Absorption and reflection of sound and light
- PSL1.2 Characteristics of sound and light

Topic PMA1 Heating and cooling

Key concepts:

- PMA1.1 Temperature
- PMA1.2 Heating and cooling

Topic PSL2 How we see

Key concepts:

- PSL2.1 The 'passive eye' model of vision

Topic PES1 Solar system and beyond

Key concepts:

- PES1.1 Planets and the solar system
- PES1.2 Gravity
- PES1.3 The night sky, stars and galaxies

The BEST resources can be incorporated into existing schemes of learning...

...or use our research-informed maps for curriculum planning. They suggest how key concepts can be sequenced to build understanding of **big ideas** of science.

Best Evidence Science Teaching (BEST)

The resources have been developed from the best available research evidence on:

- common misunderstandings in science
- effective diagnostic questioning and formative assessment
- constructivist approaches to building understanding
- sequencing of key concepts.

The resources are developed by the [University of York Science Education Group](#).

The [Salters' Institute](#) has been proud to fully fund the BEST project since it began in 2016.

The [Institute of Physics](#) is now a co-funder of BEST, having supported the project since 2021.

We are providing **FREE** online access to the resources in collaboration with [STEM Learning](#) to support science teaching.



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