IMPERIAL

ASSOCIATION FOR SCIENCE EDUCATION

SCIENTISTS MAKING A DIFFERENCE

TEACHERS' GUIDE

What on Earth!

Welcome to the *Scientists Making a Difference* Teachers' Guide

How to use this guide

This Teachers' Guide is designed to accompany the *Scientists Making a Difference* book of interviews with a wide variety of STEM professionals. There are activities which can be woven into the KS3 and KS4 curriculum for Biology, Chemistry, Physics, Computer Science and Geography, as well as in careers lessons as part of PSHCE. Each activity has curriculum links and an icon suggesting where it most easily lines up with the current curriculum in England.

All 22 activities have corresponding student worksheets, and they are designed to fit a 45-minute lesson slot. There are extra activities at the end of the guide. These vary in length from quick careers links (which can be tied into pre-existing lessons) to standalone lesson-length tasks, and extended research or homework opportunities. Some activities require specialist science equipment and expertise, but many do not, and are therefore suitable for use in careers lessons regardless of the specialism of the teacher delivering the material.

Some of the topics covered here will involve the discussion of ethically sensitive areas, such as cell ethics, sedation of animals, genetic editing and AI decisions impacting human life. How (and if) certain parts of an activity are suitable for a class is worth considering in advance. In particular, discussing rules for respectful debate would be a good starting point if these are not already in place. Many analogies are used to simplify complex topics. For KS4 students in particular, this can be used as an opportunity to discuss the advantages and disadvantages of using models in scientific explanations.

Students do not need individual copies of *Scientists Making a Difference* to complete these activities. Teachers may:

- Summarise or read aloud key excerpts from the relevant profile or spread.
- Project selected pages using a visualiser or screen.
- Use the accompanying video to introduce the scientist and their work.
- Work in small groups, sharing one book per group for focused tasks.
- Deliver concept-based activities independently, using the worksheet and teacher explanation where appropriate.

This guide and all worksheets are available online for printing.
They can be accessed by following this QR code.

Foreword

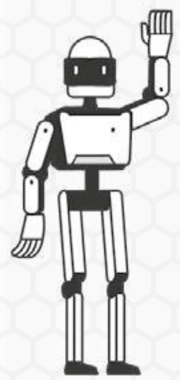
As science teachers know, many students feel that science is distant from their own lives and identities. Having researched in schools for many years, I am also extremely used to young people telling me that science is 'interesting – but not for me'! So, as the President of the Association for Science Education (ASE), I was delighted to be asked to introduce this fantastic new Teachers' Guide to accompany *Scientists Making a Difference*, the engaging and innovative new book developed through a collaboration between What on Earth!, Imperial College London and the Gatsby Charitable Foundation.

Written for secondary schools, the book draws on interviews with a diverse range of scientists – from technicians to professors – bringing to life the human side of science careers and showcasing the myriad ways in which real contemporary scientists are making a difference to our lives. The chapters, which each focus on a different area of science, introduce scientists whose work spans the rich breadth of science. Through colourful visuals and engaging, highly readable bitesize sections, the book introduces readers to the work, lives and careers of scientists working on topical, big issues such as: designing AI that can protect against deepfakes; developing vaccines and medicines of the future; tackling climate change and creating ways to live more sustainably; ensuring that everyone will have enough food; inventing self-destructing plastic and new sorts of concrete that can help prevent flooding; studying space plasma and searching for life beyond our solar system – to name but a few!

This guide and the accompanying activity worksheets provide teachers with all they need to get the most out of the book, and help bring out the joy, interest and wonder of science for all students. Whether your students are super keen on science, averagely interested in it, agnostic or feel alienated by it, this book and its highly practical resources can help you to foster and deepen their curiosity about science and their sense of connection with it. And, hopefully, it will lead to more young people feeling that science really is 'for me', whatever they want to do in life.

Professor Louise Archer
President of the Association for Science Education (ASE) and
Karl Mannheim Professor of Sociology of Education at UCL

ASSOCIATION FOR SCIENCE EDUCATION



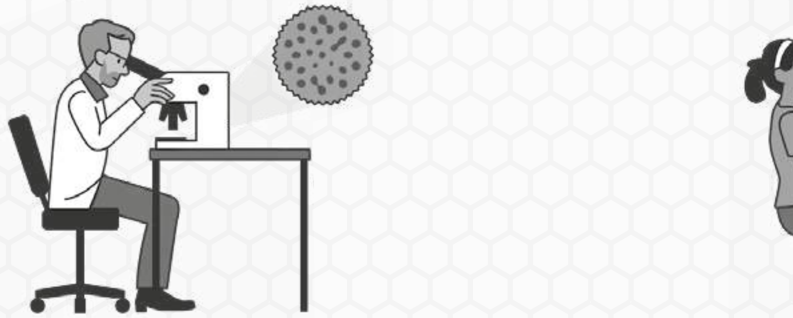
About the author

Jennifer Marchant is an experienced classroom science teacher, having spent many years as a Director of Science and STEM. Having written for Save My Exams, Educake, TeachFirst and ASE, she now balances part-time teaching with creative and communication-based educational projects, such as reviewing Lego education kits, delivering trainee teacher workshops and promoting STEM careers! Jennifer has written two books, *Stardust: The Chemistry of the Universe and You*, for KS2 students, and *The Habit of Critical Thinking*, and looks forward to writing more in the future. She is a big fan of linking classroom learning to real-world careers and applications.

About the ASE

The Association for Science Education (ASE) is a membership organisation that has supported all those in science education from pre-school to higher education for more than 100 years. Its members include teachers, technicians, teacher educators, researchers and others working in science education in the UK and internationally. ASE plays a key role in promoting high-quality teaching and learning in schools and colleges.

Working with science professional bodies, industry and business, ASE provides a UK-wide network that brings together individuals and organisations to share ideas, tackle challenges in science teaching, develop resources and support high-quality, career-long professional development. ASE is a Registered Charity with a Royal Charter, owned by its members and independent of government, and provides an authoritative voice for science-education professionals, helping to shape and strengthen science education in the UK and beyond.



Contents

KEY

Biology
Chemistry
Physics
Computer Science
Geography
Careers/PSHCE

More advanced tasks (more suitable for KS4 than KS3) are shown with a '**+**'.
Tasks that may benefit from a specialist delivering the content are labelled **SP**.

This section includes a variety of shorter tasks, project work and activities with a STEM career focus. They are suitable for Science lessons, Geography lessons, and Careers and PSHCE sessions. These flexible tasks are designed to fit into existing curriculum lessons by providing a STEM careers link without the need for additional lesson time. They may alternatively be used in STEM clubs.

Activity 1:
THE HUMAN SIDE OF AI – THE ETHICAL CHALLENGE

CURRICULUM LINKS
Computer Science – Machine learning and the ethics surrounding generative AI.
PSHCE – Understanding diversity, inclusivity and ethics in technology roles.

RESOURCES
- Activity 1 worksheet
- Video of Professor Maja Pantić (page 27)
- AI ethics: www.youtube.com/watch?v=6yDr7CWLJ8c
- Five things you really need to know about AI (BBC): www.youtube.com/watch?v=-J3YJxNnzDc

EQUIPMENT
- Large sheet of paper or whiteboard
- Optional: Timer, sticky notes (or mini whiteboards) and pens

INTENDED LEARNING OUTCOME
Investigate and present a potential future AI project, taking into account diversity, inclusivity and ethical considerations.

Activity
Students read profiles about scientists who work in AI, learning about their backgrounds and professional specialisms. They then design their own Future AI Project.

Starter: Before reading the profiles of the scientists, ask students to answer the following questions on their sticky notes or mini whiteboards:
- What is AI?
- Where can we see AI, or AI-controlled robots, being used in real life?
- What can't AI tell us?

Collect 3–4 of the most popular responses, plus any interesting ones, as examples to write on the board. You can come back to these ideas later to see what students would add, or see if any of their ideas have been challenged.

Task 1: AI scientist skills
Read all the profiles in Chapter 1 – Expanding AI. Watch the video of Professor Maja Pantić.
1. Ask students to write a list of the scientists' skills and experiences. Which ones do they have in common? List these on the board if some groups are struggling.

2. Do a quick 'think-pair-share' on the following:
   a) Is this the skill set they expected an AI scientist to have?
   b) What do they find most surprising?
   c) What do they imagine a job developing AI would be like?
   d) What skills do they think will be important for developing the next wave of AI?

Task 2: Ethics of AI
Razanne Abu-Aisheh notes that the technology she works on is often very Western-centric, and she is 'passionate about inclusivity and working with communities to determine what technology they need, desire and value'.
1. Show students the 'AI ethics' video clip.
   Challenge students to work in groups of 4–6 to design a 'Future AI Project' inspired by one scientist's work. They should identify the key skills and ethical issues that would be involved. Each group presents their idea to the class in the form of a poster, a design pitch or a news-style interview, depending on how confident and creative the class is.
   - Examples of real-world applications for AI include: using AI robots as part of migrant protection, using AI to analyse data that helps predict and prevent natural disasters and humanitarian crises, and using AI for data collection and analysis that is both less biased and more representative.
2. Students will now:
   - Identify a community need.
   - Ask the question: What ethical issues need to be addressed?
   - Identify the skills and technologies required of their AI robots or system (e.g. temperature sensors, navigation, knowing what data needs to be gathered).
   - Identify what challenges remain (e.g. human trust in the system, if the AI can work autonomously or needs human oversight, if it can cope with a changing environment).
3. Ask students to present their ideas to the group after about 15 minutes of work.

Thinking deeper: Should robots ever make life-or-death decisions?
- How can a robot decide if it's possible to save someone or not? Who would be monitoring the development of the robots in the Future AI Project? Use the Artificially Intelligent spread from Chapter 1to support students.

Initially the rules governing AI systems and robots were based on a fictional set of rules called the laws of robotics. These were invented by the science-fiction writer Isaac Asimov in his book *I, Robot*. Asimov's three laws of robotics are:
1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given to it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

*There is also a Zeroth Law: A robot must not harm humanity.

Ask students if they think these rules should apply to modern-day AI systems. Which rules would they use or amend if they had the choice?
(Quotation taken from *I, Robot* by Isaac Asimov, 2018 edition, published by Harper Voyager, UK.)

Activity 2 :

ROBOT SWARMS TO THE RESCUE – CODING

CURRICULUM LINKS

Computer Science – Understanding how algorithms and data drive digital systems.
Working scientifically – Planning and carrying out practical investigations; interpreting evidence and feedback.
PSHCE – Teamwork skills.

RESOURCES

- Activity 2 worksheet
- How ants communicate: www.bbc.co.uk/programmes/p016xzpv
- How do ants communicate with each other?: www.pestworldforkids.org/pest-info/bug-articles-by-type/how-do-ants-communicate-with-each-other
- Robots to the rescue in post-disaster recovery: www.euronews.com/embed/362448
- Robot swarms save lives: the future of rescue: www.dailymotion.com/video/x9mu2cm

EQUIPMENT

- 10–15 small, numbered paper shapes or plastic tokens to hide around the classroom. These are the 'survivors' of an emergency situation
- Tac or tape for hiding the tokens well!
- Coloured stickers to label student robots (each team to have a different colour)
- Timers or stopwatches (one per team)
- Whiteboard or chart paper for recording data
- Optional: Cones, trays, boxes or tape to mark obstacles and walls blocking the robots. Ideally these will have a secret note attached to say if they are a hazard or obstacle. It could be a gas leak, a fire, a sheer drop . . . be creative!

INTENDED LEARNING OUTCOME

Use practical data to refine a list of robot-swarm communications that would be useful in a search-and-rescue situation.

Activity

Students work as a team to develop a series of commands for modelling robot swarm activity.

Before the lesson: Hide the 'survivors' around the room – ideally using tac or tape to stick them under desks and out of obvious sight.

Starter: What is a swarm?

- Briefly discuss how swarm animals communicate (ants, bees, birds). You can use a section from one of the videos or articles listed above to help students understand how swarm insects communicate, or just discuss what students already know. The methods are scent (pheromones), touch, taste, body language and trophallaxis (sharing food).

Task 1: Robot swarms

1. Read Razanne Abu-Aisheh's profile on page16. You may want to show the 'Rescue robots' video first. You can also discuss what information needs to be gathered from a disaster site where buildings have fallen down.
2. Show students the video on robotic swarms, highlighting the potential for robot swarms to rescue those trapped in rubble.
3. Ask students how robot swarms might communicate, and what information they may need to share.
4. Ask students why it is useful to use many simple robots instead of one complex one.

Task 2: Modelling a rescue mission

Students will model a robotic-swarm rescue mission in groups of 4–6.

1. Ask students to come up with a list of commands, made up of verbal codewords and non-verbal signals, that robots can use to communicate the location of survivors. They should also communicate to indicate any obstacles.

Code example (Arduino style):
IF no obstacle ahead **>** move forward **>** choose a codeword
IF see survivor **>** stop and signal **>** choose a codeword
IF find an obstacle **>** move in another direction **>** choose a codeword

2. Assign roles within the groups: each team needs two analysts and everyone else is a robot. Each robot has a numbered sticker and team name, or colour, for ease of communication. Explain to the students that the robots can move, make brief communications and make simple decisions in response to codewords or signals.
3. Begin the 'swarm-search' simulation. Each robot searches for survivors, walking slowly in a set area. When they find a survivor, they need to use their agreed codeword to communicate the location of the survivor with the rest of their team, and carry on searching for other survivors. Communication means that the same survivor should not be found by multiple robots from the same team. The analysts should record how many survivors are found, at which times, and how many obstacles were encountered in total.
4. After 5–7 minutes, pause and ask robots to discuss how well they communicated the location of survivors and obstacles – this simulates data exchange and swarm learning. The analysts make a note of how many survivors have been found. At this point, they can design new code to improve communication. They can also improve strategy, e.g. by assigning zones and relaying information, and changing communication methods.
5. Run a second round with the improved strategy. If the class find this task easy, you can introduce the idea of a sensor failure – they have to give up communicating by hand or give up voice commands, for example. See how they adapt, and explain that back-up communication is useful!
6. The analysts measure how much faster or more successful their team is with the modifications as they try to find the rest of the survivors and avoid the obstacles.
7. Record results on the board: how many survivors were found in round 1 compared to round 2? What rules or communication helped most?

Thinking deeper: Ask each group to give brief feedback on their experience:

- What decisions did the swarm make as a group?
- How did communication affect success – which were the most and least useful codes?

Activity 3 :
BITS AND QUBITS – QUANTUM COMPUTING

CURRICULUM LINKS
Computer Science – Computer architecture and organisation; Boolean logic.
Physics – Using models to describe particles and atomic behaviour.
Working scientifically – Developing explanations using abstract ideas.

RESOURCES
- Activity 3 worksheet
- Video of Professor Winfried Hensinger (page 35)
- What is quantum computing? www.bbc.co.uk/news/av/technology-43587875
- Making quantum computers modular: www.youtube.com/watch?v=PX4gDPkHYJc

EQUIPMENT
- Coins (they have to be round, so they can be spun)
- Red and green cards for students to hold up
- Screen or whiteboard
- Simple number padlock (or a made-up four-digit passcode/password). Alternatively, draw a simple map on the board for students to navigate
- Mini whiteboards and pens (one for each student)

INTENDED LEARNING OUTCOME
Model decision-making in quantum systems. Describe the concepts of bits and qubits.

Activity
Modelling and discussing the effect of using qubits in decision making.

Starter: Read the profiles of Professor Winfried Hensinger and Dr Georgina Croft in Chapter 2 (pages 32–35, 38–41). Watch the video of Professor Hensinger, and also show the 'What is quantum computing?' video.

Quick quiz: Ask students to do a True or False quiz, where they answer with thumbs up or down.
- Quantum bits can be both 1 and 0 at the same time. *(**True** – this is called superposition.)*
- Quantum computers are powered by classic silicon chips like the ones in normal laptops. *(**False** – they use ions or atoms that are trapped and controlled in special lab systems.)*
- Quantum computing could help design new medicines much faster than today's methods can. *(**True** – it could take years instead of decades to design new drugs.)*
- Like AI, quantum computers raise new ethical questions, such as who gets access to the technology and what it is used to do. *(**True** – fair use and ethical sourcing are already issues.)*

Task 1: Bits and qubits
1. Give each student a coin.
2. Ask students to do a heads or tails coin-toss; tell them to imagine that heads = 1, tails = 0. This is the traditional 'bits' system in a computer, where only one thing can be true at a time.
3. Ask the students how they would model a qubit, which is able to be both 1 and 0 (heads and tails) simultaneously. Some may come up with the idea that spinning is like superposition, where both things can be true. Ask the students to spin their coins! Explain that while spinning coins is only a little harder than tossing them, it is *significantly* harder to build a quantum computer than a regular computer!
4. Discuss how multiple qubits can calculate many outcomes at once, and that this leads to a faster decision or process.

Task 2: Quantum Superposition Simulation game
Explain the Quantum Superposition Simulation game, as follows:
- Each student is a qubit. Give half the class red cards (representing 0/no) and half green cards (representing 1/yes).
- In each round, the students will try to solve a problem, e.g. finding the code to open a lock or the route on a map. They write answers on the screen or board behind the teacher, who should not be looking!

In the first round, the students act like normal bits in a regular computer. They solve a problem by holding up yes (green) or no (red) to questions.
1. Ask a student to write down a code or draw a route map on the board, so you can't see it.
2. Ask yes/no questions like 'Is the first digit 3?' or 'Do we turn left?'
3. Continue until the whole code or route has been discovered. The process should feel slow!

In the second round, the students behave like qubits in a quantum computer. They spin the cards (superposition) or hold them on their sides (uncertain state). This represents the computer considering both possibilities at once, so the output is much faster. Each student also needs a mini whiteboard and pen.
1. Ask a student to write down a code or draw a map on the board, so you can't see it. Make sure it is of a similar length and difficulty to the one in the first round.
2. This time, phrase your questions in a new way, e.g. 'What is the first number in the code?' or 'Which way do we go?'
3. Students spin or turn their cards to represent a quantum computer testing many possibilities at once. They then reveal the answer on their mini whiteboards.
4. Continue until the whole code or route has been discovered. It should be faster than in the first round.

Reflect: Ask the students to compare the different methods, then show the 'Making quantum computers modular' video. Explain that Rolls Royce are interested in quantum computers to speed up engine design, and other big companies are also invested in developing quantum computing. This shows students that the potential of quantum computing is being taken seriously by STEM companies.

Thinking deeper: Solving tricky problems
- What other design problems could quantum computers help with?
- How could quantum computers change medicine or climate science?

Activity 4 :

CYBER 'ONION LAYER' SECURITY – DEFENCE STRATEGIES

CURRICULUM LINKS

Computer Science – Protecting data and understanding digital security.
Working scientifically – Evaluating risks and designing secure systems.
PSHCE – Online safety.

RESOURCES

- Activity 4 worksheet
- The five biggest cyber-attacks in history: www.youtube.com/watch?v=3S-8FRKme_Y
- Cyber-attack causes delays at three European airports: www.youtube.com/watch?v=-thSQ6ca8oQ
- IT Security – layers like an onion: www.youtube.com/shorts/NGZYN7FLISc?si=L_FPXgOtyO0tuPCM
- What is a cyber-attack? Types of attacks and recent examples: www.youtube.com/watch?v=NR4zzn5VUfI

EQUIPMENT

- Whiteboard
- Paper envelopes – label each one 'data'
- Spare paper, blank envelopes, sticky tape, paperclips, scissors

INTENDED LEARNING OUTCOME

Work collaboratively to demonstrate layered protection (the onion model) and identify common types of cyber-threat (phishing, malware, password theft).

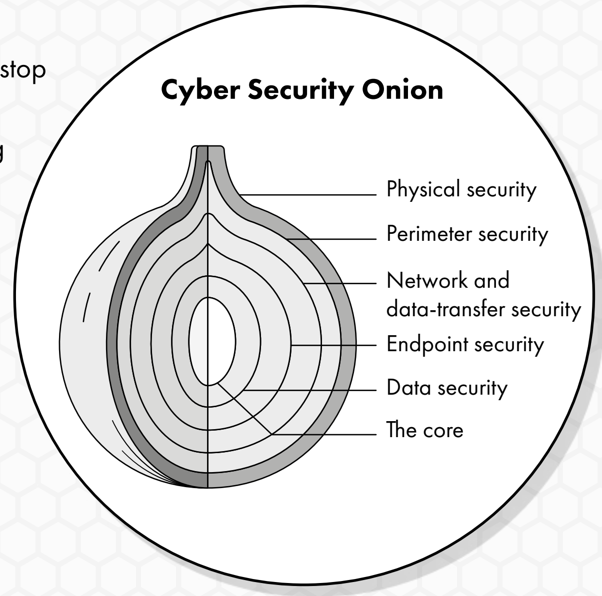
Activity

Students research layered cyber-security measures and model their own.

Starter: Cyber-crime headlines
Find a recent (age-appropriate) headline about hacks or data breaches. Ask students what they think happened and what went wrong. There are some example videos in the resources section above.

Task 1: Layers of defence

1. Read the profiles of Alex Bunn and Ian Pratt (pages 36–37, 42–43).
2. Discuss the different security methods used by Ian (sectional systems) and Alex (onion layer systems). This activity will focus on the onion analogy – multiple layers of security are needed to protect data.
3. Show the 'IT Security – layers like an onion' video. Draw the onion diagram on the board and use the worksheet to explore different layers:
   - Physical security (locks, alarms, CCTV, ID cards and computers)
   - Perimeter security (firewalls and routers help stop attackers getting into a system)
   - Network and data-transfer security (checking who's sending and receiving data; using encryption)
   - Endpoint security (antivirus software; keeping software updated on devices)
   - Data security (passwords, backups, and using encryption to keep information private)
   - The core –the confidential or valuable data that needs protecting!



Task 2: Modelling a cyber-attack
To embed the idea of the different layers, now get the students to play a hands-on Cyber Onion defence game!

1. Ask students to form groups of 6–8.
2. Students assign roles within each group: **hackers** try to breach the security system and **defenders** protect the core data.
3. Show the 'What is a cyber-attack? Types of attacks and recent examples' video so the team who are hackers know the types of attack they can try to mimic.
4. Ask the defenders to mimic different defence layers around a core, which is made of an envelope that contains written data (students can decide what the data is). They could create physical layers around the core using desks, paper shields or tape circles – each layer should represent a type of digital protection (passwords, antivirus, staff training, firewalls).
5. Meanwhile, the hackers sit at a table to one side and discuss strategies for getting to the envelope.
6. Hackers propose a cyber-attack scenario (e.g. phishing email, malware USB). Defenders explain how each layer stops the attack. If they cannot think of how to stop it, that layer is breached!
7. Swap roles and go again if there is time.

Reflect: Which layer was most effective? Why do companies need more than one? Refer to Ian Pratt's segmented approach: he can isolate any infected areas of a system to stop the problem spreading.

Thinking deeper: Personal cyber security
Encourage students to decide on a plan to improve cyber security in their own lives. What data do they hold that could be at risk?

Activity 5 :

DNA DATA ANALYSIS – HIDDEN CODES

CURRICULUM LINKS

Biology – How DNA determines characteristics and mutations; the effects of diet on health and disease.

Working scientifically – Interpreting patterns and analysing data.

RESOURCES

- Activity 5 worksheet
- Sanger Institute – Darwin Tree of Life project: www.youtube.com/watch?v=aK1Ek39z4sA
- UK Biobank releases whole genome sequencing data for 500,000 participants: www.youtube.com/watch?v=twgPXAPlHqY
- What is meant by DNA sequencing?: www.youtube.com/watch?v=Q3aihKKxzFw
- How does a DNA sequencing machine work?: www.youtube.com/watch?v=rA8MUR4pqNE

EQUIPMENT

- Highlighters or coloured pens

INTENDED LEARNING OUTCOME

Describe how data analysis can be used to identify code differences and support healthcare.

Activity

Students simulate how DNA data reveals patterns in diseases.

Starter: Read the profile of Beth Sampher (pages 52–53) and show the 'Sanger Institute – Darwin Tree of Life project' clip. Ask students:

- What is the function (or role) of DNA? *(DNA contains unique biological instructions and codes for the formation of proteins.)*
- Where it is found? *(The nucleus of a cell.)*

They can either tell a partner or write it in one sentence.

Task 1: What is DNA sequencing?

1. Show a short clip or image of a DNA sequence (A, T, C, G). Ask students what these letters represent. Keep to a basic description: they are a code for forming proteins, which make up cells.
2. Show the 'What is meant by DNA sequencing?' video or the 'How does a DNA sequencing machine work' video.
3. Ask students to work in pairs or small groups to list situations where DNA sequencing is used (or could be used in the future) to improve quality of life for people with specific variations in their genetic codes. Remember that genetic variation is important in all species, and that many variations do not change the output of the code. They should use information from Beth's profile and from the videos.

4. Show the students the 'UK Biobank' video. Ask them to predict what the project may reveal in terms of DNA data. What do they think we may find genes for, and how would this affect future healthcare?

Task 2: Hidden DNA codes

Students will process DNA sequence strips to show how bioinformaticians identify disease-causing genes.

1. Give students paper 'DNA sequences' (strings of A, T, C, G). Some sequences contain a change or 'variant' in code (often called a gene mutation). You can print out the Activity 5 worksheet for this task and distribute to the students.

Reference – Normal DNA Sequence: A T G C T A G C A T G G C T

Sample	DNA Sequence	Variant or Reference?	
1	A T G C T A G C A T G G C T	Reference	Variant
2	A T G C T T G C A T G G C T	Reference	Variant
3	A T G C A A G C A T G G C T	Reference	Variant
4	A T G C T A G C A T G A C T	Reference	Variant
5	A T A C T A G C A T G G C T	Reference	Variant
6	A T G C T A G T A T G G C T	Reference	Variant

2. Students work in pairs to highlight where variants occur.
3. Ask students to 'classify' each sample as either a reference or a variant.
4. Ask students to discuss the following:
   - How many variants did you find in total?
   - Do any samples have the same variations to their codes?
   - If a variation in the code changes the instruction for making a protein, what might happen?

Thinking deeper: Do you want to know your future from your DNA?

- Discuss the ethics of data collection and why some people may not want the results of DNA analysis.
- Remind students of the rules for respectful debate, and that all of us have varying DNA codes. Each individual is free to view the variations in their DNA however they want to.
- Students may need prompts, e.g. asking if they think there would be an impact on relationships, the cost of insurance, and access to work or accommodation.

Activity 6 :
PROCESSING HEALTH DATA – APP DESIGN

CURRICULUM LINKS
Working scientifically – Interpreting patterns and analysing data.
PSHCE – Health and wellbeing; social equality.

RESOURCES
- Activity 6 worksheet
- Video of Arjun Panesar (page 57)
- How technology can monitor and improve our health: www.bbc.co.uk/reel/video/p0kk7542/how-technology-can-monitor-and-improve-our-health
- How artificial intelligence may be the future of type-2 diabetes care: www.youtube.com/watch?v=kydr1bzuKlI

EQUIPMENT
- Whiteboard
- Optional: Paper or mini whiteboards and pens

INTENDED LEARNING OUTCOME
Evaluate how data is gathered and used by healthcare apps, then use this to design an app to help improve health outcomes.

Activity
Design an app to support healthcare research.

Starter: Create a quick brainstorm on the board: ask students to list all the kinds of data that a smartwatch or phone might collect about them (e.g. steps, heart rate, sleep). Ask students if any of their devices gather data that could be used to alter their behaviour.

Task 1: Healthcare apps
1. Introduce the idea of using data to support medical advances by reading the profile of Arjun Panesar (pages 54–57) and watch the video.
2. Show the 'How technology can monitor and improve our health' clip to get students thinking about the ways data can be used to improve health outcomes.
3. Arjun discusses the need for apps to have different languages and formats in his interview. Ask students to form pairs and discuss the ways that apps can be made more accessible. What barriers are still in place? Encourage discussion of cultural and social barriers.

Task 2: Design an app
1. In small groups, students design their own healthcare app (or device). They should consider these questions:
   - What problem will the app or device solve?
   - What health data will it collect, and how?
   - How can they make sure that the data will be accurate? What potential problems would lead to inaccurate data?
   - What advice might it offer users – how much analysis would users need to do themselves?
   - How would the app or device keep a user's data secure?
   - Could the app or device be made accessible for everyone? How?

2. Each group presents their idea through a poster or oral presentation. Encourage students to be creative, and perhaps pitch their idea as if they're at a science fair!

Thinking deeper: Future predictions
Ask students to brainstorm how their own data might be used in 20 years' time to support their health. What are they excited about and what might worry them?

Activity 7 :

IN VITRO CELLS – GROWING THE BRAIN IN A DISH

CURRICULUM LINKS

Biology – Understanding that organisms are made of cells; microscopic cell structures; assessing ways to treat and prevent disease.
Working scientifically – Evaluating risks, ethical issues and data reliability.

RESOURCES

- Activity 7 worksheet
- 'Brain Awareness Week: Exciting activities for kids': dana.org/brain-awareness-week-kid-events/
- 'Neuroscience for all students': dana.org/article/neuroscience-for-all-students/
- *'What is a stem cell?'* download: www.stem.org.uk/resources/elibrary/resource/32629/all-about-stem-cells

EQUIPMENT

- 'Truth or Myth' flashcards from dana.org/resources/truth-or-myth-flash-cards-color/
- Labels (or paper) and pens
- Play dough (or plasticine) for each student, plus trays or sheets to work on
- For the papercraft version: extra paper, tape or glue and scissors
- Mini whiteboards and pens

INTENDED LEARNING OUTCOME

Model how scientists grow and reprogramme stem cells, and evaluate the advantages and limitations of using *in vitro* models.

Activity

Investigating how stem cells can be manipulated to improve the way new medicines are tested.

Starter: Ask students if they know the names of any disorders or diseases which affect the brain. Why is it hard to test new medicines for these disorders or diseases?

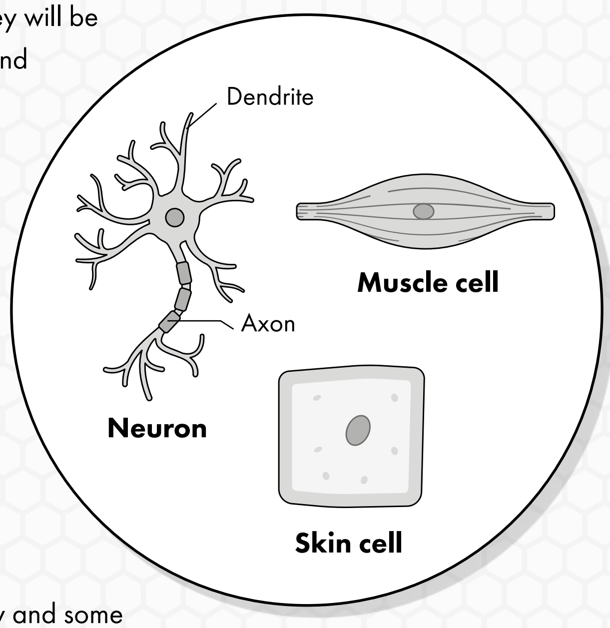
Task 1: How much do you know about your brain?

1. Read the profile of Dr Emma Jones (pages 62–65).
2. Ask students to play the 'Truth or Myth' flashcard game from the Dana Foundation, as an introduction to the brain and some commonly held myths. Examples:
   - Your brain is fully developed by the time you are 18. *(**Myth** – it takes until at least your mid-twenties.)*
   - The brain is the fattiest organ in the body. *(**True** – 60 per cent of the non-water part is fat.)*

Task 2: *In vitro* modelling

Scientists increasingly test new medicines *in vitro*, which means using cells outside the human body (e.g. in dishes or test tubes) for the earlier stages of drug development.

1. Tell the students they are going to model how stem cells can be guided to become different types of cells (including brain cells) to test new treatments. The easiest way to make the models is to use play dough, but it is possible to do a papercraft version.
2. Introduce students to the three types of cells they will be modelling. **Neurons** are nerve cells, mostly found in the brain, that pass signals along. **Muscle cells** relax and contract; they can also grow via a process called hypertrophy. **Skin cells** can respond to external stimuli; they contain pigments.



3. Give each student (or pair of students) some play dough or paper.
   a) Ask students to begin to make three identical spheres (or paper circles). These are stem cells. Put them on a piece of fresh paper, or give the students blank labels. Explain that a stem cell is a non-specialised animal cell found in embryos, bone marrow and some other tissues.
   b) Ask students to read an instruction card from the worksheet and follow the 'signals' for the formation of a specific type of cell (neuron, muscle cell or skin cell).
   c) Students then shape or decorate their model to show how it's changing, e.g. adding branches for neurons or stripes for muscle cells. Ask them to write down the change on the blank paper or a label. They do the same with the other instruction cards.
   d) Display the different cell models side-by-side to show the differences and notice how all the cells started the same but became specialised.
4. Ask students to answer these questions on mini whiteboards:
   - What do scientists mean by the term 'stem cell'? *(An undifferentiated cell that can continuously divide – a process called mitosis – and can develop into a variety of specialised cells.)*
   - How do scientists control what kind of cell a stem cell develops into? *(They expose the cells to chemical signals like the ones naturally emitted by the body.)*
   - Why is it helpful to grow cells in the lab instead of using animals for experiments? *(We get more valid outcomes using human cells. There are ethical concerns around the use of animals.)*

Thinking deeper: Ethics of using stem cells

What are the ethical questions that scientists must think about when they work with human cells? Make a list of ethical 'rules' with the students. Here are some starter ideas for a discussion:

- Who owns the cells once they are in the lab? Who profits from their use?
- Will the benefits of the research on these cells be available to everyone, or only the wealthy?
- Is there a risk that cells could be misused to enhance natural human characteristics?

Activity 8 :

SEEING INSIDE THE BRAIN – THE POWER OF MRI

CURRICULUM LINKS

Biology – Understanding brain structure and function.
Physics – Exploring magnetic fields and their effects.
Working scientifically – Using models to explain scientific ideas.

RESOURCES

- Activity 8 worksheet
- Video of Dr Hamied Haroon (page 69)
- UK Biobank brain scan: What to expect: www.youtube.com/watch?v=75TI__9IeDs
- MRI explained: How does it work?: www.youtube.com/watch?v=HUUvBICd6QI
- How does an MRI machine work? (more advanced): www.youtube.com/watch?v=nFkBhUYynUw

EQUIPMENT

- Paper clips, iron filings or plotting compass
- 'Mystery boxes' and relatively strong bar magnets (one per group). You can make the boxes out of tissue boxes with the opening covered by paper – put a mixture of magnetic and non-magentic items inside, e.g. iron nail, pencil, scissors, rubber

INTENDED LEARNING OUTCOME

Explore the uses of Magnetic Resonance Imaging (MRI), with a focus on Alzheimer's disease.

SAFETY INFORMATION

In Tasks 1 and 2, keep magnets away from any medical devices, credit cards or electronics.

Activity

Learn how MRI is used to diagnose brain changes, and use magnets to demonstrate how MRI works.

Before the lesson: Prepare the 'mystery boxes' in advance (see above).

Starter: Diagnosing Alzheimer's disease
Show the video on how Biobank brain scans are used to help improve the diagnosis of Alzheimer's and other brain conditions. MRI scans are expensive but crucial for making accurate diagnoses, and for building a collection of scans that can be used in future research.

Task 1: Using MRI scans
MRI is a powerful tool that medical physicists like Dr Hamied Haroon can use to create detailed pictures of the brain and other parts of the body.

1. Read pages 66–69 to find out more about Dr Haroon's career, and watch the video.
2. Ask students to consider the risk of inaccurate diagnosis for someone experiencing mental deterioration.

3. Demonstrate the magnetic field around a bar magnet. If using metal paperclips or iron filings (if safe – read CLEAPSS risk assessment), they will spread out in a fan from each end of the magnet. Show students that you can make a paperclip spin by moving the magnet and therefore the magnetic field. A plotting compass will clearly show the change in magnetic field direction and strength.
4. For KS4 upwards, explain that the nuclei of certain isotopes of atoms (notably H^1 and C^{13}) can also align with a magnetic field. Specific radio frequencies can 'flip' the nuclei to align against the field.
5. Explain that the H^1 atoms in water (H_2O) are therefore also spin active and detectable – and humans contain a lot of water!
6. Show one of the videos on how an MRI machine works.

Task 2: Mystery boxes activity
Ask students to have a go at using magnetic fields themselves!

1. Students work in small groups. Give each group access to a relatively strong bar magnet.
2. Students hold their magnets to the boxes to deduce if the item is magnetic. Most items are not magnetic, just like most nuclei are not spin-active and so are not sensitive to a magnetic field.
3. Students assess the size of the hidden object from how it has responded to the magnet, and record what they think it is.
4. Compare the guesses as a class and reveal the contents of each box.

Reflect: Here is a list of questions to ask during Task 2:

- What happens to iron filings when they're near a magnet? *(They line up along magnetic field lines.)*
- Why is MRI safer than X-rays for studying the brain? *(MRI uses radio waves, which are safer than the ionising radiation used in X-ray scans.)*
- What can MRI scans teach doctors about conditions like dementia? *(Brain tissue changes differ for different types of dementia.)*

Task 3: What do we use MRI images for?
Show students a whole-body MRI image, and draw an outline of a body.

- Ask students to look online or in textbooks to find out which tissues show up on MRI scans, and why people may have an MRI scan. Students can draw an outline of a body and record their findings by labelling and annotating it with MRI scan information.

Thinking deeper: Communication-challenge task
Communicating well with patients is a key part of clinical care. For example, MRI machines use the same technology as NMR (nuclear magnetic resonance) machines used in analytical chemistry. However, the term NMR cannot be used in a healthcare setting because patients would likely be concerned about the term 'nuclear', so instead the name MRI is used.

Working in small groups, students create a short communication piece to tell NHS patients what happens in an MRI machine and why MRI is helpful. They can make a leaflet, poster, presentation or a short social-media-style interview. Points to consider are:

- Who is the target audience?
- How can you explain MRI to them?
- How might they benefit from a scan?
- What concerns might they have?

Activity 9 :

COOL CHEMISTRY – KEEPING VACCINES SAFE

CURRICULUM LINKS

Biology – Vaccine usage.
Chemistry – Rate of reaction and temperature.
Working scientifically – Using models to represent abstract ideas.

RESOURCES

- Activity 9 worksheet
- What is a cold chain?: www.youtube.com/watch?v=6raX4ptZqsc
- 'Can redistribution of vaccine improve global welfare? Lessons from COVID-19': www.researchgate.net/publication/378591534_Can_redistribution_of_vaccine_improve global_welfare_Lessons_from_COVID-19

EQUIPMENT

For each group:

- 2 sugar cubes
- Cling film
- Warm water
- Thermometer
- 100 ml measuring cylinder
- 2 beakers (100 ml or 250 ml)
- Timer or stopwatch

INTENDED LEARNING OUTCOME

Describe how chemistry and materials science work together in the production of a silica material that means vaccines can be encased in a shell and don't need to be refrigerated.

Activity

Understanding how the use of materials science helps to maintain the 'cold chain' and reduce vaccine wastage.

Starter: The cold chain

Show the 'What is a cold chain?' video. Ask students why some vaccines need to stay cold. Explain that a cold chain is a temperature-controlled supply chain.

Task 1: Cold-chain challenges

1. The highest global rates of vaccine wastage (vaccines spoiling before they are used) are across Central and South American, African, Middle Eastern and Indonesian countries. Ask students why they think this is. Prompts could include geography, infrastructure and weather.

2. Read the profile of Dr Asel Sartbaeva (pages 80–83). Explain the significance of a non-encased vaccine spoiling quickly when warmed, and an encased vaccine lasting for up to three years even when temperature varies.
3. Ask students how Dr Sartbaeva's development of silica-encased vaccines could help countries without reliable electricity, and why this is important globally.

Task 2: The Encasing Molecules experiment

Students model how Dr Sartbaeva's silica shell protects vaccines. Explain to the students that the speed at which the sugar cubes dissolve represents the speed of vaccine spoilage in the heat.

1. Divide students into groups. Each group collects two sugar cubes and wraps one of them in cling film – this represents the silica-encased vaccine. They leave the other sugar cube unwrapped.
2. Students now set up two beakers with equal volumes of warm water in them (around 100 ml).
3. They need to check the temperature of the water in each beaker at the start and make a note of it. Ideally the temperature in both beakers will be the same or very similar.
4. Students place the wrapped sugar cube in one beaker and the unwrapped cube in the other beaker, at the same time as starting the timer.
5. Students observe which sugar cube dissolves faster and time how long it takes them both to fully dissolve. The wrapped sugar cube should dissolve much more slowly than the unwrapped one.
6. Ask students to write down or discuss their conclusions about the experiment. They can do this in groups or as a class. Ask them if the difference in the rate at which the sugar cubes dissolved was significant.

Quick quiz: Students answer true or flase with thumbs up or down, or fill out the answers on the Activity 9 worksheet.

- Silica is toxic. *(False)*
- Vaccines always need refrigeration. *(False)*
- Materials science can improve medicinal outcomes. *(True)*

Thinking deeper: Write a video script

Ask students to draw a storyboard and write the script (keep it brief!) for an online video that explains how a silica-encased vaccine works and why it is safe to use.

Activity 10 :
USING MOLECULAR SCISSORS – EDITING DNA

CURRICULUM LINKS
Biology – Understanding DNA, mutations and genetic diseases. Exploring how technology helps treat genetic disorders.
Working scientifically – Modelling and interpreting data in a biological context.

RESOURCES
- Activity 10 worksheet
- Video of Toluwani Alade (page 89)
- How CRISPR lets you edit DNA: www.youtube.com/watch?v=6tw_JVz_IEc
- CRISPR: Gene editing and beyond: www.youtube.com/watch?v=4YKFw2KZA5o
- The ethics of CRISPR and the perfect human: www.youtube.com/watch?v=8Xkpu72AF_k
- How gene editing is helping fight disease: www.youtube.com/watch?v=bfqLD7iTR0U

EQUIPMENT
- Whiteboard
- Strips of paper with **C T C G A A G A A** on them
- Extra paper
- Scissors and glue/tape

INTENDED LEARNING OUTCOME
Use a model to demonstrate how gene editing can repair mutations in different types of cells. Analyse the potential uses of this technology.

Activity
Students model the way that gene editing can change DNA codes and rewrite cell instructions.

Starter: Spot the difference!
Write two words on the board, with plenty of space between them. Challenge students to get from the first word to the last word by changing only one letter at a time.

Example: DEAR > BEAR > BEAT > BEST
BEND > ______ > ______ > **TANK** (BAND, BANK)
FOAL > ______ > ______ > **FARM** (FOAM, FORM)
POTS > ______ > ______ > **PAST** (PATS, PASS)

Explain to students that this is similar to the way DNA behaves, because switching even one 'letter' (nucleotide or base) in a DNA sequence can change the meaning of the instruction. Making small spelling mistakes may not affect how a word is read (temperature vs. temprature), but certain changes give the word a completely different meaning (fine vs. fire).

Task 1: What is CRISPR?
1. Read the profile of Toluwani Alade (pages 86–89) and watch the video about his work on fixing DNA mutations through gene editing.
2. Highlight his sickle cell example from the interview. Explain that sickle cells cannot transport oxygen around as red blood cells are meant to do, and this can have significant health consequences or even be fatal for people with sickle cell anaemia.
3. Show the 'How CRISPR lets you edit DNA' video.
4. Ask students to write their own versions of the Starter task to mimic the CRISPR technique: a few of the letters in their chosen words will be swapped out to form new, different words with a different meaning. Reiterate that this is like changing part of a DNA sequence.

Task 2: Gene-editing simulation
Explain to students that they are now going to model how CRISPR can cut and replace a faulty base. To do this, they will use strips of paper to represent DNA strands with the base pair codes A, T, C, G.
1. Write the 'reference' DNA sequence for red blood cell formation on the board:
   C T C G A A G A A
   a) Ask students to write a mutated sequence on their strips of paper, replacing one or two of the letters with a different letter (A, T, C, G).
   b) Students swap strips with each other. They now take on the role of a researcher whose task is to find the mutation (i.e. the swapped letter or letters).
   c) The CRISPR process is often referred to as 'using molecular scissors'. Students cut the mutated DNA section out of the sequence.
   d) They write the correct letter on a fresh piece of paper, then cut it out and glue it in place to fix the gene code.

2. Students make up other 'reference' gene sequences and write out variations for each other to try to find the changes. Students can include deletions (remove a letter), mutations (change a letter) or insertions (add a letter). They can then swap with one another to try to spot what has changed compared to the 'reference'.

Thinking deeper: The ethical implications of gene editing
The ethical implications of gene editing are significant. Gene therapy offers benefits around healthcare and life expectancy, but it also raises ethical and moral concerns. Show 'The ethics of CRISPR and the perfect human' video.

Variation in all species, including humans, is natural and important for diversity. Deciding where we should draw the line with gene editing is the subject of much debate. For example, in the UK, it is illegal to use germline gene editing to create a baby.

Ask students to work in groups of 2–4 to come up with a set of 'red lines' or situations where gene editing should not be used.
- Do they think these red lines will be crossed in the future? If so, why?
- Do they think that attitudes to gene therapy will change in 50 years' time?

Note: If this activity is used with KS5 students then a more detailed explanation of CRISPR is needed. Explain that the cell's own repair pathways are utilised, and the process is therefore error-prone.

Activity 11 :

FORENSIC BOTANY – PLANT DETECTIVES

CURRICULUM LINKS

Biology – Growth and decay.
Working scientifically – Using evidence and observations to support conclusions.

RESOURCES

- Activity 11 worksheet
- Forensic botany – examining plants to solve murders: www.youtube.com/watch?v=YHKWCM5HaQU (There is a brief reference to cocaine in this video.)
- Working as a forensic botanist (Interview with Mark Spencer): www.youtube.com/watch?v=lhBmRDqkz4g

EQUIPMENT

- Image of a muddy shoe with leaves stuck to it
- 3–4 location trays, each covered with a different soil or plant sample (e.g. grass, moss, leaf litter). These represent the different locations where a crime may have been committed
- 'Evidence' envelopes. Each envelope contains some small fragments from one of the trays and represents fragments that have been collected from a 'suspect's' shoe
- Magnifiers (magnifying glasses or hand-held microscopes)
- Empty plates or trays for examining the evidence

INTENDED LEARNING OUTCOME

Discover and investigate the ways that botanical data is used at crime scenes.

Activity

Conduct a practical to show how plant materials like seeds, pollen or leaves can link a suspect to a crime scene.

Starter: Show the image of a muddy shoe with leaves stuck to it. Tell students that there has been a crime in the local area and this shoe belongs to a potential suspect. Ask the class what clues the shoe might offer if they want to determine whether the owner was at the crime scene.

- Analysis of soil, leaves, flowers and seeds can all be isolated and identified from the clothing of a suspect.

Task 1: Forensic botany

1. Read the profile of Dr Mark Spencer (pages 98–101).
2. Ask students to summarise to each other what 'forensic botany' means.
3. Ask some students to share their definitions – either in small groups or as a class.
4. Show students one of the videos from the resources: forensic botany or the interview with Mark Spencer.

Task 2: Evidence match exercise

Explain to students that they are going to act as forensic botanists whose task is to match evidence found on a suspect's shoe to a location.

1. Divide students into groups. Each group collects an evidence envelope and transfers the contents to a plate or tray. Using a magnifier, they try to learn as much as they can from each fragment. For example, if they think it came from a pinecone, where might it have been found, and how would it have ended up on the shoe?
2. Students now compare the evidence with the samples in the location trays. The aim is to decide which location matches their evidence and therefore where their suspect may have been walking.
3. Students put their evidence back into the envelope; they can try another one if time allows.
4. Ask students to come up with a checklist of natural clues they would examine at a crime scene. They can work individually or in small groups.

Thinking deeper: Botanical reliability

Encourage students to discuss how reliable this kind of evidence is, working in small groups or as a class. Ideas for prompts are:

- Is it a reliable way to link a suspect to a crime scene?
- What other evidence would investigators need in order to link a suspect to a crime?

Activity 12 :

TREES TO COOL OUR CITIES – CANOPY RESEARCH

CURRICULUM LINKS

Biology and Geography – Ecosystems and human impact.
Physics – How shade affects temperature.
Working scientifically – Collecting, analysing and presenting data.

RESOURCES

- Activity 12 worksheet
- Video of Sophia Cunningham (page 103)
- 'The simple ways cities can adapt to heatwaves': www.bbc.co.uk/future/article/20230706-the-simple-ways-cities-can-adapt-to-heatwaves
- How trees help cool cities – exploring the heat island effect with a thermal camera: www.youtube.com/shorts/WFEQRDQmHVg
- The heat island effect explained (more detailed): www.youtube.com/watch?v=sWzfly3wVAs

EQUIPMENT

- Image of an urban heat map that includes big parks (see the BBC article for an example)
- Tape measure
- String
- Paper, labels and pens
- Thermometers or temperature sensors
- Laptops, tablets or computers with internet access
- Optional: calculators, graph paper and pencils
- Paper and pens for recording results (clipboards optional)

INTENDED LEARNING OUTCOME

Discover through data collection how trees can decrease the urban heat effect.

Activity

Analyse data to identify which tree species to plant in urban areas, and explain why this approach helps to control the local climate.

Starter: The urban heat effect

Show an aerial heat map showing both parkland and built-up areas, such as the urban heat map of Prague in the BBC article. Ask students to identify which features increase and decrease temperature. *(**Increase** – densely packed buildings. **Decrease** – trees, open spaces, water.)*

Read the profile of Sophia Cunningham (pages 102–103) and watch the video on her work with Sheffield's Urban Tree Observatory. Show students the two 'urban heat effect' videos.

Task 1: Mini tree survey (summer sunshine required!)

1. Take students to an outdoor area with trees on a warm, sunny day.
2. Choose a tree. Write down the species first. Now measure the circumference of the trunk, and make a note of this information too.
3. Hold or tie a piece of string around the tree trunk, leaving a long end loose. Holding the string taut, use labels to mark 50-centimetre intervals from the trunk to the edge of the shade cast by the tree's canopy.
4. Measure the temperature at the different distances from the trunk. Remember to leave enough time for the readings to stabilise.
5. Take an additional temperature reading in the sunshine, away from the shade of the canopy.
6. Repeat for different trees.
7. Compile the results according to species and spread of the tree. Students can use a spreadsheet with filters if there is access to ICT.
8. You can scale the data you have collected using a spreadsheet on the board. If you divide all the data by the smallest canopy radius, students can compare different varieties of tree regardless of canopy size.
9. If appropriate, ask students to plot a graph of shade (x-axis) against temperature (y-axis) using the scaled data.

Task 2: Indoor version tree analysis

1. Ask students to do online research about different species of tree, and the key features of each one. The aim is to find out which species would be best to plant in an urban area with the goal of reducing both air temperature and ground temperature. Students should take into account:
   - Density of the canopy
   - Resistance to heat and drought
   - Rate of growth (trees are likely to be planted when they're relatively small and young)
   - Resistance to disease
2. Compare photos and data of three tree species (e.g. birch, oak, maple). Discuss which species is best for cooling purposes, and why.
3. Choose the 'best urban tree'! Ask students to tell the class which species they would plant, and to share the reasoning and evidence behind their choice.

Thinking deeper: Local action

Ask students to think about a local area and identify if any more trees could be planted there. Is there a local group that could take this suggestion further? Encourage students to turn their research into action. They might do this by:

- Writing to the school council with a suggestion for planting more trees.
- Searching online to find out if there are grants available for planting trees in schools or public spaces.
- Writing an email to the local council with their ideas or findings, if appropriate.

Activity 13 :

HIDDEN CLUES – TRACKING WILDLIFE WITH eDNA

CURRICULUM LINKS

Biology – How organisms interact with their environment, understanding inheritance and the use of DNA in research.

Working scientifically – Collecting, analysing and interpreting evidence from models.

RESOURCES

- Activity 13 worksheet
- University of Florida researchers are the first to collect animal DNA from beach sand: www.youtube.com/watch?v=q7mp1wxLoyA
- eDNA: How scientists see hidden animals (6 min): www.youtube.com/watch?v=N8m8SLQZX0Q

EQUIPMENT

- Photograph of a sea turtle leaving a beach
- Water mixed with blue or green food colouring (or blackcurrent squash!)
- 'eDNA clues' made from tiny non-plastic items that will biodegrade but not dissolve: biodegradable glitter, pieces of coloured card, flaxseeds, sunflower seeds, etc.

For each group:

- At least two glass beakers (100 ml or 250 ml) or paper cups
- Funnel and filter paper (if available) or coffee filter
- Optional: blank paper or tray

INTENDED LEARNING OUTCOME

Investigate how environmental DNA can be used in conservation work.

Activity

Modelling the way that scientists extract and analyse eDNA from water samples, and learning how the data is used.

Before the lesson: Make up beakers containing 'seawater samples' in advance, by filling them with coloured water and 'eDNA clues'. Each group will need their own beaker, and each beaker should contain a slightly different mixture of eDNA clues for the students to investigate. (Make up extra samples if you think there will be time to run through the exercise twice.)

Starter: Show the photo of a sea turtle leaving a beach. Ask students how they would go about proving that a turtle had been on a beach like this. They may mention tracks, faeces, nests or eggs.

Ask them to consider eDNA. Is it possible for eDNA to disappear from a location? Can eDNA that has come from elsewhere create a 'false positive' that may mislead researchers? Ocean currents, contamination and degradation are all factors.

Task 1: eDNA

1. Read the profile of Dr Liam Whitmore (pages 112–115) and watch the two videos on eDNA.
2. Recap what DNA is and how it can be left in the environment as eDNA from skin, saliva, bodily fluids and waste. Ask students to do a 'think-pair-share' – where would their DNA be detected if someone was trying to work out where they had been?
3. Ask students to think about how they could minimise the eDNA they leave behind.

Task 2: Sea detective exercise

Water samples can reveal the DNA of whatever species passed through the water. Explain to students that they will model the process of extracting DNA from seawater.

1. Ask students to work in small groups. Each group collects a beaker containing a 'seawater sample'.
2. Provide students with a key on the board to say what species each different eDNA clue represents. For example: blue card = moon jellyfish, sunflower seed = green turtle, flaxseed = harbour porpoise, etc.
3. Ask students to filter their sample – they funnel it through filter paper into a conical flask or new beaker. Students can discard the filtrate that dripped through.
4. Students now examine the residue in the filter paper, which they can tip out onto a fresh piece of paper or tray. They should identify the species present using the key on the board.
5. If time allows, ask students to repeat steps 1–4 with new samples.

Reflect: Ask students to discuss the following questions, in small groups or as a class:

- How might eDNA data help conservation scientists?
- What factors might affect the accuracy of results? Why might the presence of eDNA in a given location be misleading, for example?
- Which species and situations do you think this type of monitoring would be useful for?

Thinking deeper: eDNA breakdown

Using the information in Dr Liam Whitmore's profile, make a list of factors which can cause eDNA to break down, and work out how to mitigate these problems.

Activity 14 :
PACK POWER – HOW WILD DOGS SURVIVE TOGETHER

CURRICULUM LINKS

Biology – Relationships between predators and prey; how animals adapt to survive in different environments.
Working scientifically – Using data and models to explain biological behaviour.
PSHCE – teamwork skills.

RESOURCES

- Activity 14 worksheet
- Jenny Linden video (page 121)
- The power of the pack! Wild dogs' AMAZING relay hunting strategy: www.youtube.com/watch?v=h4SlAc2U1A4
- A seriously feisty family of mongooses face-off with a pack of wild dogs: www.youtube.com/watch?v=PD3L3cQVc9s

EQUIPMENT

- Large open space – a sports hall, playground or cleared classroom area
- Cones or tape to mark the boundary
- 20–40 small beanbags or balls to represent 'prey'. Ball-pit balls are ideal
- 3–4 hula hoops
- Timer or stopwatch
- Whistle (or bell) to start and end each round
- Paper and pens for recording results (clipboards optional)

INTENDED LEARNING OUTCOME

Model how teamwork among wild dogs supports their survival.

Activity

Students model the way that teamwork increases survival chances for wild dogs, and find out how conservation scientists track pack animals.

Before the lesson: Set up the Pack Hunt game in advance.

- Use cones or tape to define a clear boundary for the game.
- Position the hula hoops on the floor.
- Scatter the 'prey' randomly around the space; place a few inside each hula hoop.

Starter: Teamwork or lone wolf?
Ask students to list as many predators as they can that hunt and live as a pack. Ask them to make a separate list of animals that hunt and live alone.

Task 1: Success in a pack

1. Students should have a good list of ideas for both types of predator, so the next challenge is for them to identify the factors that allow some predators to survive better alone, while other predators need to be part of a pack to survive. They should consider:
   - The habitat
   - The type of prey – are prey animals numerous, or is prey limited?
   - The method of hunting
2. Challenge students to identify how climate change may affect pack animals and lone predators differently. Suggestions could include the fact that a scarcity of water or food could hit a pack harder, as they need enough for the whole pack rather than just for one animal.
3. Read through the profile of Jenny Linden (pages 118–121) and watch the video on her research into the African wild dog.
4. Ask students to explain pack hierarchy in pairs. The hierarchy is: alpha pair, helpers (often younger family members), pups. This is a common structure in pack animals, where there is usually a dominant pair, or a dominant male or female.
5. One of the key behaviours of African wild dogs is their ability to work as a team; they care for their young together, hunt as a team and share food. They are not the largest or most powerful predators individually, but they are incredibly tenacious! Show one of the videos on African wild dogs so students can see how they work together. The second video shows a family of mongooses also working as an effective team – mongooses are the other animal Jenny Linden has studied.
6. Ask students to review the lists of factors they made in favour of predators hunting in packs. Which of these factors are present in wild dogs?

Task 2: Pack hunt game
This is best done outside or in a large hall if possible! Students will simulate a wild-dog hunt using small balls or beanbags to represent their prey. The goal is to collect as much prey as possible in one minute.

First, students pair up and decide who will be the **solo hunter** and who will be the **pack hunter**.

Round 1: Solo hunters

1. Start the timer and blow the whistle to start.
   - Each solo hunter can collect only one piece of prey at a time – they must bring it back to their partner or desk before going to pick up another one.
   - They cannot talk or share information.
   - Prey can only be gathered from a safe zone if students can get the prey out of the zone without touching it. They could, for example, dislodge it by throwing another piece of prey at it.
2. After one minute, blow the whistle again and make a note of the total prey collected.
3. Ask the solo hunters how easy it was it to find prey on their own. Did anyone feel overwhelmed or tired by the **individual strategy**? How would they feel if they had to do this every time they needed food?

Continued on the next page.

Activity 14 :
PACK POWER continued

Round 2: Pack hunters

1. The pack hunters are allowed one minute to communicate and plan before the hunt starts. They might assign roles, e.g. finders to discover new food and runners to relay it back to base.
2. When the planning ends, give the group one minute to hunt.
   - Pack hunters can pass prey between teammates to speed up the return to base; this simulates a pack sharing food.
   - The same rule as before applies to safe zones: hunters cannot touch prey with their hands.
3. After one minute, record how many pieces of prey were collected this time.
4. Ask the pack hunters how teamwork made a difference to their results. What roles or strategies worked best? What advantages are there to a **cooperative strategy**? Hopefully, they'll find that teamwork = greater success.

Swap roles and repeat Rounds 1 and 2, if there is time.

Optional Round 3: Heat challenge

- To simulate the increasingly hot weather conditions that African wild dogs face, the students run Round 2 again, but reduce the number of hunters by half – some 'dogs' will be resting in shade.
- The whole pack still needs food, so hunters must work even more cooperatively to achieve a score that's comparable to before.

Reflect: Ask students what other challenges could arise from extended periods of unusual weather patterns, and how they might affect a pack.

Thinking deeper: Tracking collars

Even though the unique markings on every wild dog mean that individuals can be tracked by observation, putting tracking collars on them still improves conservation outcomes. Challenge students to come up with a persuasive pitch, either as a presentation or a letter, to convince a wildlife charity to fund the placement of collars on African wild dogs. As wild dogs are not a cute and cuddly species to advocate for, the students will need to explain all of the potential benefits of the collars very effectively. They must also explain how the collars can be put on the dogs safely and ethically. Here are some ideas for what to say:

- Collars can improve the chance of rescuing an animal that's been trapped in a snare.
- As wild dogs travel as a pack, placing a collar on just one animal allows researchers to track the movement of many.
- It's not just about movement. Other factors can be tracked, such as the skin temperature of the animals.
- Tracking collars reduce the amount of time that researchers spend in trying to locate animals – and time is money!
- Using lightweight collars causes minimal interference with the animals.

Template: results table

	Number of prey collected (per person)												Total collected
Person													
When hunting solo													
When hunting in a pack													

	Number of prey collected (per person)												Total collected
Person													
When hunting solo													
When hunting in a pack													

Activity 15 :
PLASTIC PLANET – REDUCING MICROPLASTICS

CURRICULUM LINKS
Biology – Food webs.
Chemistry – Structure of polymers; life-cycle assessments.
Geography – Human–environment interactions; waste management.
PSHCE – Responsibility for environmental issues and sustainability.

RESOURCES
- Activity 15 worksheet
- 'Microplastics: What they are and how you can reduce them': www.nhm.ac.uk/discover/what-are-microplastics.html
- The godfather of microplastics (Interview with Professor Richard Thompson): www.youtube.com/watch?v=HqYB5uE9xE0
- Kids take action against ocean plastic: www.youtube.com/watch?v=hKFV9IquMXA
- How we can keep plastics out of our ocean: www.youtube.com/watch?v=HQTUWK7CM-Y

EQUIPMENT
- Images of everyday items that produce microplastics, e.g. a face scrub, artificial fleece fabric, tyres

For each student:
- Water, sand, biodegradable glitter and tiny coloured plastic beads (or rice), mixed together in a beaker (or paper cup)
- Sieve
- Funnel and filter paper (if available) or coffee filter
- A spare beaker (or paper cup)

INTENDED LEARNING OUTCOME
Identify sources of microplastics in the environment and methods of removing them.

Activity
Investigate methods for reducing plastic pollution from microplastics, then come up with personal and local solutions.

Starter: Hidden plastics
Show students the images of items that produce microplastics. Ask them what they all have in common. The detailed answer is that all these items break down easily or shed fibres that produce microplastics (i.e. plastics less then 5 millimetres in diameter) that get into our ecosystem.

Task 1: Microbead ban

1. Read the profile of Professor Richard Thompson (pages 128–131). Watch the video showing an interview with him. Ask students to discuss the following:
- The discovery of microbeads, and the impact of banning them in 2018.
- Why do you think a tub of face scrub containing more than 3 million tiny plastic particles hadn't been considered an issue before then?
- If you were sold a product containing microbeads today, would you consider that to be an issue?
- What are the potential impacts of microplastics on wildlife? *(Consider food chains.)*

2. Beach in a tray activity: Students conduct a short experiment to see how microplastics are found and separated. Ask them to follow these steps:
a) Take a beaker containing a water-sand-plastic sample.
b) Use a sieve to filter out the larger particles.
c) Funnel the sample through a filter to remove the sand and glitter.
d) Evaluate the results – discuss the difficulty level for removing different sizes of microplastic. *(Smaller is harder.)*

Reflect: Encourage students to identify and discuss two key issues:
- How to remove existing plastic from the environment before it breaks down further.
- How to prevent new plastic from entering the environment as waste.

Task 2: Take action
1. Show the video 'Kids take action against ocean plastic' to show how plastic can build up in wildlife, and how we can make changes and decisions for a better future.
2. Ask students to consider the lifetime of plastic products; most of the plastic cutlery and styrofoam packaging that's ever been used is still present in the world, and it will remain here for hundreds of years. Ask them about plastic items they have used but not recycled; some of these items will have gone to incineration and some will have gone to landfill. Much of the plastic we use will outlive us, our children and grandchildren.
3. Ask students to work in pairs or small groups to consider alternatives for the following common causes of microplastic pollution:
   - Fleece, nylon and polyester clothing which sheds fibres when washed.
   - Single-use plastic food packaging, particularly non-recyclable packaging.
   - Vehicle-tyre abrasion on roads.
   - Discarded fishing gear and nylon ropes.

Thinking deeper: Making change
Students make a mind map of ideas to show where changes can be made by individuals or schools, or at a national level. Here are some themes to get you started:
- Is there something your school could look at doing to prevent plastic waste?
- How can students encourage community action? Look up ways to make big local changes.
- Challenge students to identify an area of their lives where they can decrease their personal contribution to the source of microplastics. Ask them to make an action plan with a friend.

Activity 16 :

ICE DETECTIVES – INVESTIGATING CLIMATE CHANGE

CURRICULUM LINKS

Biology – The impact of human activity on the environment.
Chemistry – Climate change and greenhouse gases.
Working scientifically – Interpreting data and using evidence to support explanations.

RESOURCES

- Activity 16 worksheet
- Video of Professor Tina van de Flierdt (page 135)
- What do Antarctic ice cores tell us about climate change?: www.youtube.com/watch?v=VjTsj-fi-p0
- World's oldest Antarctic ice being melted to find out more about climate: www.youtube.com/watch?v=oi_-zYfLZTo
- 'Increases in atmospheric carbon dioxide and global temperature (1850–2024)': www.climate.gov/media/16969
- SWAIS2C project: www.swais2c.aq/

EQUIPMENT

- Images of Antarctica and ice drilling
- A fizzy drink to show students – real or an image
- 'Sediment' made from e.g. biodegradable glitter, rice or small paper dots (holepunch bits work well)
- Metal straw (can be demo only)

For each group:

- Boiling tube and 250 ml beaker
- Crushed ice
- Small spatula
- Pen or pencil for marking glass tubes

INTENDED LEARNING OUTCOME

Investigate how climate science evidence can be collected.

Activity

Students model how scientists use evidence from drilling ice cores to understand the past and predict the future of climate change.

Starter: Frozen in time

Show the images of Antarctica and scientists drilling ice there. Ask students why they think scientists would want to access the sediment deep below the surface of Antarctica.

Task 1: Secrets under the ice

1. Show the 'What do Antarctic ice cores tell us about climate change?' video, followed by the 'World's oldest Antarctic ice being melted to find out more about climate' video.
2. Read the profile of Professor Tina van de Flierdt (pages 132–135) and watch the video on her Antarctic expeditions. The SWAIS2C website has educational resources that can be used to extend students' knowledge about the size of Antarctica and the process of drilling.
3. Ask students if they know what the link between carbon dioxide levels and temperature is. Show them the 'Increases in atmospheric carbon dioxide and global temperature (1850–2024)' graph, which indicates that as carbon dioxide levels increase, so does global temperature.
4. Ask students to debate which factor causes which: does having a greater amount of CO_2 in the atmosphere increase global temperature, or does increasing the temperature raise CO_2 levels?
5. Recap the greenhouse effect: CO_2 absorbs certain frequencies of infrared radiation and re-emits them in all directions. This leads to increased warming of the Earth. A certain level of greenhouse effect is necessary to maintain a stable temperature on Earth, but too much leads to global warming.
6. Show students the fizzy drink. Ask why you would keep an open drink in the fridge. *(To keep it fizzy for longer.)* Explain that gases like CO_2 dissolve better in cold water – as the water warms up, more dissolved CO_2 gets released. This is also true for oxygen, which explains why colder waters are more oxygen-rich. Looking at ancient ice cores can give us clues about atmospheric changes over time, and this helps us predict what the climate might do in the future.

Task 2: Ice core model

In this activity, students will model the layers of climate data trapped under (and in) Antarctic ice – sediment, for example.

1. Students form groups and collect a beaker of crushed ice and a boiling tube. Everyone also needs to have access to the 'sediment'.
2. Ask students to place the boiling tube in the beaker for stability and fill the boiling tube with crushed ice. Add a layer of ice at a time, with a bit of sediment between each layer.
3. They now label each layer with a year on the side of the tube.
4. Students can try to 'drill' a core with the metal straw. If they can remove the 'ice core' intact, they'll be able to observe the layers in it.

Thinking deeper: Would you go?

Ask students if they would want to go on an Antarctic mission and build their own base camp in the cold!

- What do they think the challenges of working onsite doing the ice core drilling would be?
- Why is it important to send scientists to remote locations?
- How would they feel if they were doing experiments on air which is older than humanity?

Activity 17 :

POWER IN MOTION – GENERATING ENERGY FROM EVERYDAY MOVEMENT

CURRICULUM LINKS

Physics – Energy stores, transfers and efficiency; forces and motion.
Working scientifically – Designing and evaluating energy systems.

RESOURCES

- Activity 17 worksheet
- Treeva: www.youtube.com/watch?v=ajd6IC9BHbI
- How does a wind turbine work?: www.youtube.com/watch?v=DIlJJwsFl3w
- How do wind turbines work?: www.youtube.com/watch?v=xy9nj94xvKA

EQUIPMENT

- Whiteboard

For each group:

- Desk fan or hairdryer with a cool setting
- A4 coloured card
- Ruler, protractor, scissors, glue and tape to make blades
- A cork (or plastic bottle cap or sticky tack) to attach the blades to the shaft
- A pencil (or wooden skewer) to be the rotor shaft
- A straw that the shaft will fit inside
- Lollipop sticks
- Play dough (or plasticine) and large books to help the turbine stand up
- Timer or stopwatch (and potentially a way to film turbines in slow motion)
- Optional: small motor, wires with crocodile clips and a bulb

INTENDED LEARNING OUTCOME

Design and test a small turbine model in the style of Treeva turbines.

SAFETY INFORMATION

During Task 2, do not allow students to get their hair or faces near the spinning blades.

Activity

Students research and design a new style of wind turbine.

Starter: Ask students to draw what they think a wind turbine usually looks like. Most will draw something like a windmill! Ask where you would usually find wind turbines.

Task 1: Utilising airflow

1. Ask students to do a 'think-pair-share' about where we can find air currents in our daily lives.
2. Read the profile of Anjali Devadasan (pages 146–149) and show the 'Treeva' video. Ask students to compare the design of Treeva turbines with the turbines they drew at the start of the lesson.
3. Ask students what Treeva turbines could provide power for at an airport or by a railway.

Task 2: Designing turbines

Students will design and build a turbine, experimenting with the number and shape of the blades.

1. Divide the class into small groups, and set up each group with a test station. This includes a fan or hairdryer to represent the wind, and a 'test line' about 50 centimetres away from it.
2. Students decide on a blade design (straight, curved, tapered or paddle) and how many blades they will use; 3–8 is a good range. Encourage blades of around 7–10 centimetres long.
3. Students draw their blades on card, making one of them a bold colour, then cut them out.
4. The students attach the blades to the cork (or bottle cap or tack) using glue or tape.
5. They then attach the cork to the lollipop sticks and pencil. They slot the pencil into the straw.
6. The turbine should spin freely when someone blows on it. Place the turbine on the testing line in front of the hairdryer or fan.
7. Use the play dough to make a base for the turbine, and trap the straw between some books.
8. Data gathering – start the 'wind' and count how many rotations occur in 10 seconds. Students may require the help of slow-motion video if their turbines are are going fast! Students record the result on a table like this.

Design	No. of blades	Blade shape	Number of rotations in 10 s	Extra notes
e.g. A	3	Curved		

9. They then adjust their design, varying blade shape or number of blades. Remind them to adjust only one variable at a time. Keep testing and recording results.
10. Discuss the importance of 'test-record-adjust-test again' in experiments in STEM subjects.
11. Class data comparison – groups share their most successful model. They compile the features of the best blade design on the board.
    - Which blade design spun the fastest? *(Curved blades tend to catch the air better.)*
    - Did more blades always improve performance? *(Not always!)*
    - How might the mass of blades affect the rotation speed? *(Heavier blades lead to slower spinning.*
12. Ask students to write their own conclusions, e.g. ' The best turbine design was X because . . .'

Thinking deeper: Energy transfers in electricity generation

Ask students to recap energy storage and transfer, using a video if needed. You can ask them questions such as:

- What type of energy is in the wind? *(Kinetic)*
- What type of transfer occurs when a turbine blade spins? *(Kinetic in air to kinetic of blade)*
- What energy transfers happen inside a turbine? *(Kinetic spinning of the blades to kinetic energy rotating the shaft to electrical energy in the generator where magnets spin past wire coils and generate a current in the wires.)*
- What does a transformer do? *(Increases or decreases the potential difference or voltage.)*

Activity 18 :

ENGINEERING FUTURE FOOD – SELECTING TRAITS

CURRICULUM LINKS

Biology – Genes (inheritance and variation); plant reproduction; biotechnology.
Geography – Food security and sustainable farming.

RESOURCES

- Activity 18 worksheet
- Global crop damage: www.youtube.com/watch?v=Nxf3bxVjZTQ
- 'Strawberry DNA': www.imperial.ac.uk/be-inspired/schools-outreach/secondary-schools/stem-in-action/the-human-body/strawberry-dna--activity/
- 'Global temperature – Earth indicator' (animation): science.nasa.gov/earth/explore/earth-indicators/global-temperature/

EQUIPMENT

- Paper and pens

For each group:

- A strawberry
- A sealable sandwich bag
- Water (5 teaspoons)
- Washing-up liquid (2 teaspoons)
- Salt (1 teaspoon)
- 10 ml of surgical spirit (70% ethanol solution)
- Sieve
- Beaker
- Stirrer

INTENDED LEARNING OUTCOME

Identify different ways of altering the genome of plants grown, using practical tasks and models.

SAFETY INFORMATION

Ensure no flames are present during Task 3, as surgical spirit is flammable. Dispose of the liquid quickly at the end of the experiment. Also, ensure that none of the students have an allergy to strawberries before starting Task 3.

Activity

Students carry out a classroom simulation to compare selective breeding and natural selection among plants. They extract DNA from a plant.

Starter: Show the 'Global temperature – Earth indicator' animation. Students have a copy of the climate change and agriculture map on the worksheet. Ask students to list potential issues with crop growth that can occur because of climate change. Ask them to consider the effects of:

- Changes in rainfall volume and patterns (mention droughts and rainy seasons).
- Changes in both mean temperatures and also more extreme temperatures.
- The increased frequency of extreme weather events, such as hurricanes and typhoons.

Encourage specific examples, such as:

- Paddy fields need to be wet.
- Grain crops need rains to stop by harvest time.
- Early snowfall when trees still have their leaves on can break branches.
- The timing of frosts can significantly alter fruit harvests.

Ask if any students grow plants at home – what effect has the weather over the past year had?

Task 1: Gaining desired genetic traits in plants

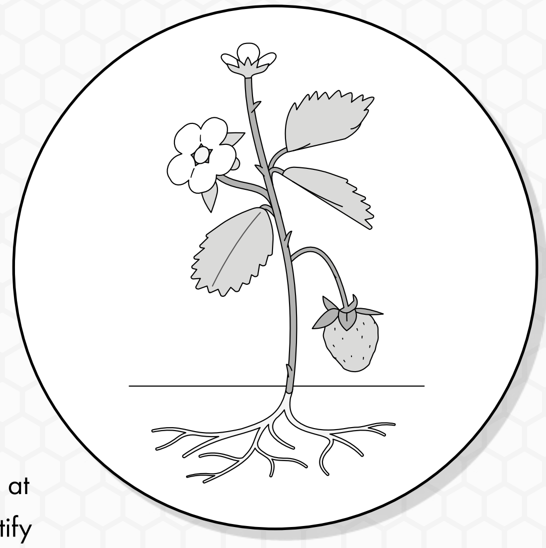
1. Read the profile of Maheen Alam (pages 166–167). Crop scientists often observe how plants react to changes in their environment in order to identify which plants survive and thrive and are the best to produce seeds. The scientists then identify the desirable traits for that habitat, isolating the DNA sequence of the desired gene, and breed plants with these traits for the next generation through selective breeding or genetic engineering.
2. Ask students to think of examples of plants. Describe the plants and explain these three terms:
   - Natural selection. *(Animals or plants with a trait that gives them a survival advantage in a particular habitat will be more likely to breed and pass on their genes. The next generation is more likely to have the advantageous traits.)*
   - Selective breeding. *(Humans select a desired trait and breed animals or plants with that trait. Humans then breed from the offspring with the desired trait and continue breeding with the offspring until the trait is embedded in that population.)*
   - Genetic engineering *(Humans isolate a desired gene and then manipulate code in the DNA of an animal or plant to contain that gene and alter the trait, without the need to wait for generations of breeding and the uncertainty of inheritance.)*

Task 2: Natural selection in plants

Model natural selection in plants to find the advantageous genes – ask students to do a paper-based activity using the activity sheet (similar to 'sticky dogs').

Continued on the next page.

1. Students draw a flowering plant on their piece of paper. They need to choose:
   - Narrow and deep or wide and shallow root systems
   - Narrow leaves or wide leaves
   - Stripy flowers or plain flowers
   - Thorns or no thorns
   - Fewer, larger fruit or many smaller fruit
2. Students read through the 'story' on the worksheet of how the habitat changes, or the story is read aloud step-by-step.
3. The students now need to work out if their plant has advantageous features and can multiply. They alter the number of plants they have on a tally chart, starting with 10 and removing or adding plants as stated in the story.
4. Students can compare the most successful plant features at the end. Which plants would researchers look at to identify genes that they wanted to replicate?



Task 3: Extracting strawberry DNA

The next step for the scientists is to analyse the DNA – but they have to extract it first! Follow the steps in the 'Strawberry DNA' resource for extracting DNA from a strawberry (which also works with a kiwi). Explain that DNA is easy to collect but hard to decode!

1. Divide students into groups. Each group takes a strawberry and removes the leaves. They put the strawberry into the food bag, and seal the bag.
2. Someone in the group gently squashes the strawberry while it is in the sealed bag. They keep squashing for about two minutes, until there are no large pieces and only pulp left.
3. They carefully open the bag and add 5 teaspoons of water, 2 teaspoons of washing-up liquid and 1 teaspoon of salt. They re-seal the bag, removing as much air as possible.
4. They gently squeeze the mixture together for another two minutes. Ask the students to try to minimise the number of bubbles they make.
5. The students pour the contents of the bag through the sieve into their beaker; they can use a spoon to press the strained bits of strawberry against the sieve, forcing even more of the solution into the beaker.
6. Very carefully, pour 10 ml of surgical spirit down the side of each beaker – this will form two different layers. Tell students they must not touch their beakers now, as the two layers must not mix!
7. Leave the beakers for up to 10 minutes.

8. When the groups return to their beakers, can they see a white stringy material floating between the two layers?
9. Students try to lift the white stringy material out with their stirrers . . . this is the strawberry DNA!

Thinking deeper: GM crops

- Some people are uneasy about consuming GM (genetically modified) crops. Ask students to discuss this. Do they agree or disagree that it's acceptable to eat GM crops? Why?

Activity 19 :

RESEARCH FARMS – FIELD RESEARCH

CURRICULUM LINKS

Biology – Conditions for optimal plant growth.
Chemistry – pH testing.
Working scientifically – Using evidence and observations to support conclusions.

RESOURCES

- Activity 19 worksheet
- 'Introducing RITS nominee and Field Technician, Rebecca Lee' (John Innes Centre website): www.jic.ac.uk/blog/introducing-rits-nominee-and-field-technician-rebecca-lee/
- 'Soil: understanding pH and testing soil' (RHS website): www.rhs.org.uk/soil-composts-mulches/ph-and-testing-soil

EQUIPMENT

For each group:

- Soil and small spatulas
- 2 boiling tube or tests tubes with bungs
- Plastic pipette (optional)
- Universal indicator solution/paper

For the alternative method:

- 1 extra boiling tube or test tube for each group
- Bicarbonate of soda
- Vinegar
- Universal indicator not needed

INTENDED LEARNING OUTCOME

Identify what research is needed on a farm and how soil pH can be tested.

Activity

Students explore the work done on a research farm, and use pH testing to analyse soil samples.

Starter: Read the profile of Rebecca Lee (pages 172–173), which describes the varied work that is required in her role. Ask students if they knew there were 'research' farms conducting experiments. What do they think the challenges around collecting repeatable data at a research farm would be?

Task 1: Farming-language research task

1. Using information from the John Innes Centre website, find out which abiotic stress factors can affect crops, and what can be done to mitigate them.
2. Ask students to produce a guide that explains some of the terms (hand-drilling, shadow-netting) for those without a farming background to use.
3. Ask students to find out where their nearest agricultural college is, and which courses people interested in farming and land management can take. Remind students that although farming is often a family business, it is open to everyone as a career, as are the research roles such as Rebecca's.

Task 2: Testing soil pH

Testing soil pH is a vital part of a healthy farming practice. It may be something students have experience of in their own gardens, or they may have already done other pH tests (such as testing water from a pond, fish-tank or swimming pool). In this practical, they will test the pH of soil.

1. Divide the class into groups. Each group takes a test tube or boiling tube. They add water and a soil sample with the help of the spatula, then put a bung in the tube and shake it until a slurry is formed.
2. They let the contents settle for a minute, so that the solution at the top is easier to collect.
3. Students extract some of the liquid using a plastic pipette, or by carefully decanting into a clean test tube.
4. Using indicator solution or indicator paper, the students test the pH of the solution.
5. Students use the colour of the indicator to deduce and record the pH of the soil sample.

Alternative method: Students decant the solution into two test tubes. They add bicarbonate of soda to one and vinegar to the other.

- If the soil solution fizzes on the addition of bicarbonate of soda, the soil sample is acidic.
- If the soil solution fizzes on the addition of vinegar, the soil sample is alkaline.

Thinking deeper: pH sensitivity

Ask students to research plants that are particularly pH sensitive, and what happens if the pH of the soil is not in the tolerance range for these plants. What methods can farmers use to correct soil pH if they want to optimise conditions for a particular crop?

Activity 20 :

SUSTAINABLE MATERIALS – BIODEGRADABLE PLASTICS

CURRICULUM LINKS

Chemistry – Polymers; chemical reactions; rates of decomposition.
Geography and PSHCE – Sustainability; waste management; global impact.

RESOURCES

- Activity 20 worksheet
- Video of Dr Florence Huynh (page 181)
- Truly biodegradable plastic: www.youtube.com/watch?v=m8aEoD29nTM
- Polymateria website: www.polymateria.com/

EQUIPMENT

- Single-use plastics to show students, e.g. bottle, food wrapper, straw
- Molymods or paperclips

For each group:

- 2 beakers (250 ml)
- Warm water
- Cling film, cut into a square
- Gelatin sheet or rice paper, cut into a square the same size as the cling film
- Thermometers or temperature probes
- Optional: salt or detergent

INTENDED LEARNING OUTCOME

Evaluate advantages and trade-offs of biodegradable plastics compared to traditional plastics.

Activity

Modelling the breakdown of bioplastics.

Starter: Plastic everywhere!
Show the students some common single-use plastics. Ask what will happen to them after they're thrown away.

Task 1: What's different about bioplastics?

1. Read Dr Florence Huynh's profile (pages 178–181) and watch the video about her mission to create plastic that turns into harmless wax.
2. Explore what makes plastic 'break down'. Explain that conventional plastic bonds are strong carbon chains.
3. Quickly model carbon chains using molymods or paperclips.
4. Show the 'Truly biodegradable plastic' video. Discuss biodegradable plastics, encouraging students to identify the fact that they include additives which react with oxygen, light and microbes.

Task 2: Plastic breakdown simulation
Students will model the difference between biodegradable plastic and regular plastic.

1. Divide students into groups. Each group fills two beakers with 100 ml of warm water.
2. Students place their square of cling film (representing non-biodegradable plastic) in one beaker and the square of gelatine or rice paper (representing biodegradable plastic) in the other.
3. Over the course of 10 minutes, they record their observations of any changes seen in their 'plastics' as well as the temperature of the water, which will be dropping, using the table on the worksheet. Ask students to consider what changes occur and why. Remind them that both of the original materials used are polymers. There is an opportunity to discuss natural versus synthetic polymers here, too.
4. You can repeat the experiment with the addition of salt or detergent. Do the observations change? Students can investigate the effect of temperature on the rate of degradation by repeating with different water temperatures.
5. Discuss the longevity of non-biodegradable plastics when you analyse the results of the simulation. What are the advantages and disadvantages?

Time (min)	Temperature of water (°C)	Observations	
		Non-biodegradable plastic square	Biodegradable plastic square
0			
2			
4			
6			
8			
10			

Task 3: Purposeful plastic properties
Alongside the practical, or afterwards, ask students to pick a specific item (or task) that a plastic could be designed for. For example, it might be a tray, a bag or a rope. Make a list of the properties the plastic would need to have. Consider:

- What properties must a plastic have, in order to be both useful and biodegradable?
- The different qualities needed for e.g. food wrappers, drink bottles or storage boxes.
- The features needed to suit the expected lifetime; link to life-cycle assessments (KS4 Chemistry).

Thinking deeper: Class debate on biodegradable plastics
Pose the statement: 'All plastics should be made to be biodegradable'. Ask students to debate this statement, first in pairs or small groups, then as a class. Useful prompts might be:

- Are there situations where biodegradable plastics are not desirable? What can be done to remove the risk of plastic entering the environment in these cases?
- Would you pay more for a product if it was made of biodegradable plastic?
- What biodegradable alternatives are there for food packaging in particular?

Activity 21 :

CONCRETE SOLUTIONS – FLOOD PREVENTION

CURRICULUM LINKS

Biology – Water cycle; impact of flooding on ecosystems.
Physics / Chemistry – Particle size, density, porosity and permeability.
Working scientifically – Collecting, analysing and presenting data.

RESOURCES

- Activity 21 worksheet
- This is Kiacrete: www.youtube.com/shorts/J5uOsCyA0fM

EQUIPMENT

- Photo of an urban flood
- Sponge
- Plastic block
- Bowl of water

For each group:

- 3 small paper cups, each with a hole in the bottom
- Marker pen and ruler
- Gravel, sand and soil
- Water and 100 ml measuring cylinder
- 250 ml beaker
- Timer or stopwatch
- Paper and pen

INTENDED LEARNING OUTCOME

Describe how Kiacrete reduces urban flooding and how permeability experiments can be used to measure flow rate.

Activity

Students investigate the relationship between pore size and drainage rate in different materials.

Starter: Show the photo of an urban flood, and ask students why the water cannot soak or drain away. Ask them to identify materials that are not porous, and drainage systems that have a limited capacity when flow rate is high.

Task 1: Kiacrete

1. Read through the profile of Dr Alalea Kia (pages 186–187). Show the 'This is Kiacrete' video.
2. Ask students to write their own definition of 'porosity'. Get them to make a list of porous items they have used this week, then a list of non-porous items.
3. Explain how pores act like tiny pipes to drain water. To demonstrate this, show how a sponge can soak up water from a bowl whereas a plastic block cannot soak up water from a bowl.
4. Discuss how Kiacrete uses plastic tubes and the principles of chemistry to create a substance that is both strong and porous. Ask students to propose where Kiacrete could be used, e.g. the school car park, city streets or fields. Get the class to vote for the most useful suggestion.

Task 2: Measuring the permeability of materials

Students will investigate flow rate versus porosity using a model.

1. Ask students to work in small groups of 2–4. They mark each cup with a line about 5 cm from the bottom. Students fill each cup up to the line with a different material: gravel, sand and soil.
2. Using the measuring cylinder, they pour 100 ml of water into the first cup and hold it above the beaker. They record how long the water takes to drain.
3. The students clean out the beaker, and repeat with the other two cups.
4. Students rank the materials by permeability.

Extension: Ask students to plot a graph using their results: either drainage time against estimated particle size (scatter graph) or drainage time against type of material (bar chart). Now ask students to try mixing two different materials and running the simulation again. Can the drainage time be predicted?

Thinking deeper: Designer pavements

Ask students to design a 'smart draining' pavement that both drains water and collects it for re-use. How wide and how close together do they think the holes need to be? There is the opportunity to explore some higher-level maths by asking students to calculate drainage rate, as this involves calculating the volume of cylinders, etc.

Activity 22 :

SEARCHING FOR THE INVISIBLE – DARK MATTER AND COSMIC MYSTERIES

CURRICULUM LINKS

Chemistry – Elements and isotopes.
Physics – The particle model; radiation and detection methods.

RESOURCES

- Activity 22 worksheet
- Bitesize Boulby – Ep. 3, Dark Matter: www.youtube.com/watch?v=o9mEffuNsXY
- Nuclear radiation explained: www.youtube.com/watch?v=dvhqzQ-K7K8
- 'Avoiding cosmic rays: Monaco's underground laboratory': www.iaea.org/newscenter/multimedia/videos/avoiding-cosmic-rays-monacos-underground-laboratory
- Classroom aid – cosmic rays (more advanced): www.youtube.com/watch?v=PIGEGURrNU4
- 'Guide to our galaxy' (animation): www.esa.int/ESA_Multimedia/Videos/2013/11/Guide_to_our_Galaxy

EQUIPMENT

For each group (or for the demonstration):

- Coin
- Tray or box
- Ping-pong balls (or scrunched up paper balls)
- Different 'shielding' materials for covering the tray or box: card, foil, fabric, sponge, plastic lid

INTENDED LEARNING OUTCOME

Identify how different types of radiation require the use of different materials to protect scientific equipment, through a simulation to model shielding.

Activity

Discovering how dark matter can be detected and why it needs to be done underground.

Starter: The hidden universe
Show the 'Guide to our galaxy' animation, and ask students to tell you what holds a galaxy together. You will probably get an answer about gravity.

Task 1: Underground laboratories

1. Read the profile of Kayleigh Johnson (pages 202–205), which describes her work testing materials for radioactivity at the Boulby Underground Laboratory. Show students the 'Bitesize Boulby – Ep. 3, Dark Matter' video.
2. Ask students to describe to each other what dark matter is. Remind the class that dark matter doesn't emit or absorb light, but it does have gravitational effects. Scientists look for dark matter using highly sensitive detectors, which are built deep underground.
3. Ask students to explain to each other why the facilities are underground. *(To block out background radiation.)* Show the three videos on nuclear radiation and cosmic rays.
4. Ask students to discuss how they feel about Kayleigh's 'morning commute'!

Task 2: Shield the detector simulation
Students mimic radiation and how it can be blocked, a key part in dark matter detection. This can also be done as a demonstration.

1. Students form groups. Each group places their coin in the tray or box. The coin represents a radiation detector, and the container represents a science lab.
2. Drop ping-pong balls from a fixed distance of 60–100 cm above the coin; these simulate cosmic rays. Count how many balls hit the coin.
3. Repeat the experiment with a layer of shielding material over the tray or box. Try all the different materials.
4. Identify which material protects the detector best: which one leads to fewest balls hitting the coin?

Reflect: Recap nuclear and cosmic radiation. Ask students to identify materials that would make a good shield against each type of radiation in experiments:

- Alpha = paper or skin
- Beta = thin aluminium layer
- Gamma = thick lead or concrete or rock
- Cosmic radiation = lead, iron or concrete (plus a magnetic field, which deflects the most)
  Students may focus on nuclear radiation from the KS4 curriculum, so remind them of the cosmic radiation from the profile too.

Thinking deeper: Scientific communication
Ask students to write a news article explaining why building underground laboratories that contain detectors helps us to study space.

Extra Activities

TIP FOR TEACHERS

These activities can be adapted for use as extension tasks within the curriculum, and also to weave some STEM-careers links into enrichment-week projects, STEM club challenges and PSHCE and careers sessions. Most of the activities require minimal materials – they encourage creative and critical thinking across Science, Computer Science, Geography, and Design and Technology.

Activities for Science lessons

A. The story of discovery

Ask students to look at the Timeline of Science wallchart and pick one breakthrough (e.g. the discovery of DNA, CRISPR or the first exoplanet). Using online or printed sources, they should create a mini fact file that includes:

- Who made the discovery?
- What problem were they trying to solve?
- How has this knowledge changed the modern world?

B. Breakthrough chain

- Explore pivotal scientific discoveries, referring to the Vaccines spread on pages 94–95.
- Now look at the Timeline of Science. Choose two or three discoveries from different centuries.
- Students try to connect the breakthroughs in a 'chain of impact', showing how one discovery enabled the next, e.g. Pasteur's germ theory > Rosalind Franklin's DNA imaging > COVID vaccine.

C. Unsung heroes of science

- In small groups, students research one lesser-known scientist from the book (e.g Kayleigh Johnson, page 202) and create a case for why they deserve to appear on the Timeline of Science.
- Ask students to think about what important research might be possible in the future thanks to all the smaller, lesser-known projects going on now.

D. Supercomputers and data storage – what is the environmental cost of AI?

- Ask students to read the Supercomputers spread (pages 44–45) and the Data Storage spread (pages 58–59). Show this video about AI and the environment: www.youtube.com/watch?v=aT89CmDxh5Q
- List the benefits of AI and the negative impact it has on the environment. Can students think of potential solutions to the negative impact?
- Read this article on small-scale projects combatting the power-usage issue: www.bbc.co.uk/news/articles/c0rpy7envr5o. Ask students if they think that this is the future – or do they have some other solutions?

E. Neurodiversity – Professor Eleanor Dommett

- Read the profile of Professor Eleanor Dommett (pages 72–75). The term 'neurodiversity' is a bit like the term 'biodiversity'; it is used to describe natural variation, in this case in brain chemistry. More is now understood about ADHD in particular, thanks to MRI scans identifying differences in brain activity, and broader social research, which for a long while was limited to young boys only.
- Watch one of these videos about ADHD to show how MRI scans can detect differences in brain development, and how an ADHD brain responds to dopamine: www.youtube.com/watch?v=Jjf-yHLaXtU (no narration) or www.youtube.com/watch?v=-8J0-TUCxv8.
- Ask students to discuss what their first impressions of ADHD are, and what they did not realise about the brain chemistry of the condition.
- Ask students to identify which parts of a daily routine could be challenging for someone with ADHD, and what could be done to support them.

F. Space weather – Dr Julia Stawarz

- Watch a short video on solar storms or auroras, such as this one: www.youtube.com/watch?v=HJfy8acFaOg or this one: plus.nasa.gov/video/space-place-in-a-snap-what-is-an-aurora/
- Ask students to read the profile of Dr Julia Stawarz (pages 198–201), which describes how plasma can be studied by analysing space weather.
- Ask students to use online or written sources to produce a one-page 'space weather alert' explaining what plasma is, what a solar storm is, how solar storms affect satellites and how the work of scientists like Dr Julia Stawarz helps protect our technology.

G. Bacterial resistance – Dr Luke Allsopp

- Read the profile of Dr Luke Allsopp (pages 92–93). Draw a cartoon strip to show the different stages of an immune response in the body.
- Why might someone with cystic fibrosis be more vulnerable to a bacterial respiratory infection?
- Ask students to design a poster, write a jingle or create a short video on why completing a whole course of antibiotics is essential.

H. The tree-kangaroo conservationist – Annabel Walker

- Read the profile of Annabel Walker (pages 116–117).
- Ask students to choose a zoo animal and create a species survival plan for it, outlining how research into hormones or diet could improve breeding success. They should include a small 'zoo map' showing what part of the zoo this species would live in, what their enclosure might look like and the jobs a keeper may need to do. What other research might help the species thrive?

I. Cleaner mining – Dr Eric Wasson Burns

- Read the profile of Dr Eric Wasson Burns (pages 150–151), where he discusses the metals used in batteries and how they are usually extracted. Ask students to research one of these metals, and create a flow chart that goes from ore being found to pure metal being extracted.
- Identify the parts of the process that Thunderstone could cut out. *(Digging quarries; having a large site of high-grade ore; negative environmental impact of moving tonnes of rocks for processing.)*
- Discuss the potential advantages and disadvantages of this new extraction method. *(Reduces environmental impact on the surface; needs to be monitored to ensure the long-term stability of the ground above the extraction site.)*

Continued on the next page.

J. Sustainable battery technology – Dr Ivana Hasa

- Read the profile of Dr Ivana Hasa (pages 156–157), which describes alternative chemicals for batteries that have a lower environmental impact. Ask students to research alkali-metal reactions, and identify the advantages and disadvantages of using sodium instead of lithium in batteries.
- Ask students to list situations when it would be beneficial to store excess energy from a 'green source'. Liken the process to charging up a mobile phone at home so that it can be used later, when you're out and about with no power supply. This may also be an opportunity to ask students if they have a storage battery in their home already.
- For KS4 Chemistry students, this case study offers a good way to revise topics such as Group 1 metals, the extraction of metals and electrolysis.

K. Protecting pollinators – Dr Richard Gill

- Read the profile of Dr Richard Gill (pages 168–171) and watch his video to learn about the effects of pesticides and climate on bees.
- Ask students to create a presentation for school or business leaders about the impact human activity has on bee populations. Include:
  – What the role of pollinators is in plant reproduction and food production.
  – How pesticides impact bee behaviour.
  – How temperature affects the way that bees react to pesticides.
  – Practical actions that support pollinators.

L. New vaccines – Dr Sagida Bibi

- Read the profile of Dr Sagida Bibi (pages 84–85), which describes how vaccines are usually developed.
- Ask students to make a flow chart of the usual stages in drug development. Identify points on the flow chart where the COVID vaccine research group could accelerate the process.
- Ask students to analyse the impact that accelerating the development of the COVID vaccine had on society. Do they think that vaccination programmes for any future pandemics would be approached in the same way? Why?
- Dr Bibi faced several potential barriers to her academic career. What could have made her give up on her dream, and how do you think she kept going? Ask students to consider potential barriers between them and their ideal career, and how they could overcome these barriers.

M. Kew the plant zoo – Charlie Foster

- Read the profile of Charlie Foster (pages 104–107) and watch the video about his role at Kew Gardens and the Millenium Seed Bank.
- Watch this video about conservation at Kew Gardens: www.youtube.com/watch?v=OvWur69eVbE and identify the ways in which Kew is acting as a wildlife-conservation park for plants.
- Students can look up the plants mentioned in Charlie's profile (e.g. vanilla orchid) to find out more about their origins, their uses and the conditions needed for growth.
- Ask students to find examples of plants that have been used to develop medicines. Familiar examples include willow bark (salicylic acid, aspirin) and yew (taxol).

N. Double strength – Thomas Warr

- Read the profile of Thomas Warr (pages 188–191) and watch his video. Ask students to list the composites that are mentioned. What is each one made of? Students can research where the composites are used, and why they are better for that job than the two separate materials.
- You can add a practical element by tasking students with making reinforced concrete!
  – The instructions and risk assessment can be found on the Royal Society of Chemistry website: edu.rsc.org/resources/making-concrete/2022.article
  – Using a set of small cardboard moulds, make three types of bar; mortar (3 parts sand: 1 part cement, plus water), concrete (as mortar, but add small gravel) and reinforced concrete (as concrete but add unwound paperclips embedded in the wet mix). These are great examples of composites.
  – Leave overnight to harden. These can then be tested for strength by loading them with hanging masses and compared.
  – A faster (and less messy) version of this experiment can be done using sticky tape, with unwound paperclips sandwiched between layers of tape.

SAFETY INFORMATION

There is a dust inhalation risk from the cement powder – open windows and have only a small opening to the bag.

O. Brain training – Ryan Cini

- Read the profile of Ryan Cini (pages 70–71), which describes areas of the brain that are being investigated as part of the effort to prevent and cure common neuron diseases.
- With the help of digital or print resources, students label a diagram of the brain to show the regions that are responsible for movement, short-term memory, long-term memory and emotion.
- Students then match up examples of real-life scenarios (listening to music, feeling afraid) with the corresponding zones on their diagram.
- Ryan works in a lab where animal experiments are conducted, and his job involves animal training. Students can look up the UK's animal welfare standards, and then debate how, when and even if animals should be used in clinical trials. Ask them to consider the broader consequences of each side of the argument.

P. Astrochemistry in action – Josh Oakley

- Read the profile of Josh Oakley (pages 196–197). Look up this feature about Josh and his career: www.technicians.org.uk/stories/josh-oakley/
- Students can discuss the idea that different elements can have their own colour signature (think flame tests and fireworks).
- Ask them why it is important to know the composition of other planets and comets.
- If it's an option, conduct some flame tests and examine the emission spectra with spectroscopes. Try testing compounds containing lithium, calcium and sodium.
- Students might research how emission spectra are used to identify the composition of stars, because we cannot get samples! You could also ask them to explain the difference between *emission* of light (stars) and *reflection* of light (planets, the Moon).

Continued on the next page.

Q. Protecting our animals – conservation

Read the Conservation spread on pages 124–125. Ask students to create a biodiversity campaign poster for a threatened species. Include:

- A sketch or image of the animal.
- Key threats and conservation strategies.
- A targeted 'call to action' for the public.

R. Save the rainforests – healthy forests

- Ask students to read the Healthy Forests spread on pages 108–109.
- Students can work in pairs or small groups to write a podcast interview about why we need to try to use products that are 'Rainforest Alliance' safe, and which products we can reduce the use of to support the conservation of rainforests.

S. Climate-change challenge – Dr Scott Hosking

- Read the Our Changing Climate spread on pages 142–143 and the profile of Dr Scott Hosking (pages 48–51). Ask students to note all of the ways that climate data is gathered and analysed.
- Turn the information into a piece of journalism that highlights the variety of evidence about climate change that is being collected today. Students can pick any medium they like:
  - – TikTok script
  - – Newspaper article
  - – Script for an online debate
  - – Poster for bus stops

T. Designing for space – life-support systems

- Students design a Mars base module, using ideas from Generating Clean Energy (pages 144–145), Investigating the Universe (pages 194–195) and Designing New Materials (pages 176–177).
- They must include the supply of air, water, food and energy, and explain how waste is recycled.
- Encourage students to make connections between the recycling of water, food and air in a space station with how these can be recycled in everyday life to support the circular economy.

U. Futuristic power – artificial photosynthesis

Use the Artificial Photosynthesis spread (pages 158–159) to design a futuristic house, a workplace or a transport hub using some of the principles covered. What are the advantages of including artificial plant power to supplement other energy sources? What are the limitations?

V. Green energy goals – Kate Osborn

- Read the profile of Kate Osborn (pages 152–155) and watch her video.
- Ask students to consider whether they think fusion technology is worth investing in.
- Watch these two videos about the company First Light Fusion: www.youtube.com/watch?v=5rGK2DFRUOk and: www.youtube.com/watch?v=tvaB1o11O90.
- Ask students to vote again – were they persuaded or put off?
- Ask students to work in small groups and imagine a world where fusion power for the masses is a reality. What would change in the daily lives of most people, and what would stay the same? What opportunities would fusion power bring? Ask students to do one of the following:
  - – Make a mind map of the possibilities.
  - – Write a news article from 50 years' time describing the 'new normal'.
  - – Make a presentation of a fictional interview with someone who has lived through the changes.

Activities for Geography lessons

W. Earthquake domino effects – Dr Ekbal Hussain

- Read the profile of Dr Ekbal Hussain (pages 136–137) and identify some of the problems that can be triggered by an earthquake, such as landslides, tsunamis, flooding and power failures.
- Ask students to discuss how satellite mapping could help with early identification of such risks.
- There is the option of linking to KS4 Geography – can students identify which risks are greatest for different types of plate boundary and various global locations?
- Ask students to find a few case studies of recent earthquakes. If there was any warning, how far in advance was it? What measurements would allow scientists to give warnings further in advance?

X. Regenerative farming – sustainable food production

- With reference to the Regenerative Farming spread on pages 174–175, ask students to design a farm that embeds as many different regenerative techniques as possible. They can focus on an arable, livestock or mixed farm.
- Ask students to explain how each feature in their design supports sustainability.

Activities for careers and PSHCE sessions

I. STEM pathways debate

- Ask students to consider the range of routes into scientific jobs. As a starting point, broad headings might be: T-levels, PhDs, apprenticeships and other industry-led routes. Ask them to look for scientist profiles that match the different routes; you can choose specific chapters for them to search.
- Ask students to create a flow chart showing the path that each of these scientists took. Discuss the pros and cons of different paths. Did they find any profiles that challenged their assumptions about what qualifications are needed for a particular role?
- Older students might discuss their own preferences for post-16 and post-18 study routes.

II. My STEM hero

- Each student picks the profile of a scientist whose insterests, specialisms or background they relate to (e.g. conservation, quantum computing, medical research). They then produce a poster, make a video, write an article or draft a mock interview script that shows:
  - – What inspired the scientist.
  - – How their work helps people or the planet.
  - – One key skill they use daily.
  - – One surprising fact about them.

Continued on the next page.

Extra Activities

III. Create a 'scientist of the future' role

- Ask students to think of a science career that might be required in the future, grounded in their reading of the book. It may be a job that doesn't exist yet, or it may be an extension of a role that's described in the book.
- Show students examples of job adverts on LinkedIn or other social media. Ask them to write a short description of their 'scientist of the future' role in this style. They can present it orally or in writing – as if they're advertising for recruits.

IV. Follow your dreams

- Students start by identifying scientists who do a job that's linked to an interest they've had since they were young. Perhaps they've followed a direct route to their current role, or maybe they've returned to their early interest after trying other things out.
- Ask students to identify their strongest interests. Ask them to make a mind map of all of the possible jobs that could develop their core interests and convictions.

V. Clean energy

- Look at the scientists in the chapter Generating Clean Energy (pages 146–157). Which profiles would each student use as inspiration for launching a new clean-energy start-up? Encourage them to be creative about the size and location of the power source (like the turbines that are situated by railway tracks on pages 147–149).
- Students design a poster for their start-up. They should include a slogan, a diagram of their technology, and a short pitch on how it will reduce carbon emissions and why this is important.

VI. Career highlights

- Every scientist profile in the book features their 'career highlights'. Ask students which highlights appeal to them and which do not.
- Get students to make a 'what to look for' guide they can use when they are searching for a course or career themselves, so they know which outcomes they value most.

VII. Citizen science – contributing to real research

- Discuss the value of citizen science. Help students explore projects like Zooniverse, Galaxy Zoo and iNaturalist, where you can participate in research and contribute to global data sets. Encourage students to sign up, so they can try collecting and categorising data.

VIII. Designer materials

- Read the Metamaterials spread on pages 192–193. Ask students to come up with their own futuristic material – what are its properties?
- Show these videos of materials science at NASA: www.youtube.com/watch?v=c0EXAuWkMqA and at Rolls Royce: www.youtube.com/watch?v=sJqOV81XOCA.
- Ask students to research what materials science is about, which training pathways are available (apprenticeships, university) and what course requirements are. Ask them to make a poster of their findings.

IX. Materials science – Dr Jonathan Bean

- Ask students to read Dr Jonathan Bean's profile (pages 182–185). Ask students to research his company, Matnex, using their website: www.matnex.ai/
- Show this video on materials science: www.youtube.com/watch?v=JZ9BkoLWdlg
- Ask students which local companies may need materials scientists, or may have specific materials designed for them.
- Explore career routes into materials science with the students, from internships to degrees.

X. The Goldilocks zone – Dr Chris Pearson

- Read the profile of Dr Chris Pearson (pages 206–209) and the Searching for Exoplanets spread on pages 210–211. Ask students to find out what the Goldilocks zone is, and why it is relevant to the search for life outside the Earth.
- Get students to compile a fact file about all the different jobs surrounding the hunt for planets, e.g. astronomers, astrophysicists, telescope operators, software engineers, instrumentation engineers and materials scientists. Remind them that telescopes can be either ground-based or space-based.

XI. Useful waste at Biogen – John Jukes

- Show this video about Biogen: www.youtube.com/watch?v=mgociafM8H4) and read the profile of John Jukes (pages 138–141).
- Ask students to discuss how they dispose of food waste at home, at school, and when they're out and about. Is there a way for their waste to be collected and used by a company like Biogen?
- Ask students to identify reasons why the collection of food waste can be tricky. Show them this video identifying some potential solutions: www.youtube.com/watch?v=ZRujRAZFq48 and ask them to add to or modify their ideas afterwards.

XII. Supporting role – Declan Jones

- Read the profile of Declan Jones (pages 122–123).
- Watch this video on veterinary nursing: www.youtube.com/watch?v=BZz9DnO5YfM and ask students to identify when the veterinary nurse is working alone, and when they are supporting the vet's work.
- Ask students to research a range of different specialisms that vets and veterinary nurses can have – which ones do they find most interesting and why? What advantages and disadvantages do they think there could be in a job working with animals?

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