Activity 1 : Worksheet

THE HUMAN SIDE OF AI – THE ETHICAL CHALLENGE

Diversity in AI project planning

How do we decide how to use AI in the future? Who works in this field? You are going to discover the backgrounds of four AI scientists and how they plan to develop ethical AI projects.

Starter:

- What is AI?
- Where can we see AI, or AI-controlled robots, being used in real life?
- What can't AI tell us?

Task 1: AI scientist skills

Read all the profiles in Chapter 1 – Expanding AI and watch the video of Professor Maja Pantić.

Write a list of skills and experiences the scientists have and which they have in common.

- Is this the skill set you expected an AI scientist to have?
- What do you find most surprising?
- What do you imagine a job developing AI would be like?
- What skills do you think will be important for developing the next wave of AI?

Task 2: Ethics of AI

You are going to design a 'Future AI Project' inspired by one scientist's work.
You are going to work in a small group and need to be ready to present your idea to the class.
This could be in the form of a poster, a design pitch or a news-style interview.

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.

You need to:

1. Identify a community need.
2. Ask the question: What ethical issues need to be addressed?
3. Identify the skills and technologies required of your AI robots or system (e.g. temperature sensors, navigation, knowing what data needs to be gathered).
4. 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).

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 your Future AI Project?
- Read Asimov's laws of robotics in Professor Murray Shanahan's profile. Do you think these rules should apply to modern-day AI systems? Which rules would you use or amend?

Activity 2 : Worksheet

ROBOT SWARMS TO THE RESCUE – CODING

How robots working in teams can save lives

How do we use robots in disaster zones? What do they need to be able to communicate back to base and to each other? You are going to have a go at modelling this process and coming up with your own commands.

Task 1: Robot swarms

Read Razanne Abu-Aisheh's profile on page16.

- What information needs to be gathered from a disaster site where buildings have fallen down?
- Why use robot swarms to rescue those trapped in rubble?
- How do you think robot swarms are likely to communicate, and what information do they need to pass to each other?
- Why is it useful to use many simple robots in a disaster zone instead of one complex one?

Task 2: Modelling a rescue mission

1. As a class, come up with a list of useful commands to communicate the location of survivors and obstacles between the swarm and the analysts.

> **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. In a group of 4–6, choose two members to 'analyse' the data and modify the 'programmes'. Everyone else will be a robot. Each robot has a numbered sticker and team name, or colour. The robots can move, make brief communications and make simple decisions in response to codewords or signals.

3. Search time!

- Each robot moves around (walking slowly in a set area) searching for survivors. When a robot finds one, they can 'ping' (using the agreed codeword or signal) and communicate the location of the survivor to their team. The robot should then continue its search for other survivors.
- Try to avoid collisions and do not remove survivors, allow other teams to search for them.
- The analyst should record how many survivors are found, at which times, and how many obstacles were encountered in total.

4. After 5–7 minutes, pause for the robots to discuss how well they communicated the location of survivors and obstacles. At this point, you can design new code to improve communication and strategy, e.g. by assigning zones and relaying information, and changing communication methods.

5. Use this improved strategy for the second round of searches. The analysts measure how much faster or more successful their team is with the modifications.

Thinking deeper: Feeding back on your 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 : Worksheet

BITS AND QUBITS – QUANTUM COMPUTING

Where quantum physics meets computing

What happens if computers can simultaneously consider all of the possible answers to a question at once rather than having to consider them all one after the other? Welcome to the world of quantum computing.

Starter:

Read the profiles of Professor Winfried Hensinger and Dr Georgina Croft in Chapter 2 (pages 32–35, 38–41).

Task 1: Bits and qubits

For this task you need a circular coin – any size will do.

- Do a heads or tails coin toss; imagine that heads = 1 and tails = 0. This is the traditional 'bits' system in a computer, where only one thing can be true at a time.
- How would you model a qubit, which is able to be both 1 and 0 (heads and tails) simultaneously?
- Multiple qubits can calculate many outcomes at once as the computer can examine all the possibilities simultaneously. How does this affect how quickly the computer can reach a decision?

Task 2: Quantum Superposition Simulation game

In this simulation you need to imagine you are acting as either a bit or a qubit.
You need to help find the answer to a problem, first by a traditional computing method and second by a quantum computing method. You will be given a red card (representing 0/no) and a green card (representing 1/yes) and a mini whiteboard and pen.

- There will be two rounds and in each one you need to write a code or draw a route map on the board – your teacher is not allowed to peek...
- Your teacher will ask questions to try to guess the code or route. In the first round you are a normal bit and have to answer your teacher's questions by holding up yes (green) or no (red) until they have guessed the correct code or route.
- In the second round you are a qubit in 'superposition' in a quantum computer. Your teacher will now ask more detailed questions and in answer you can either spin the cards or hold them on their side to represent the quantum state. Then, you can write the answer to each question on a mini whiteboard. This shows that all possibilities have been considered so your teacher can work out the answer very quickly.
- Compare the processing speed of the different methods; the quantum computer method should be faster as many possibilities are considered simultaneously!

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 : Worksheet

CYBER 'ONION LAYER' SECURITY – DEFENCE STRATEGIES

How do layered and segmented cyber defence systems work?

Starter:

Cyber attacks can throw businesses and services into chaos. Thankfully most are usually intercepted before they cause too much damage, but how is this done?

Task 1: Layers of defence

Read the profiles of Alex Bunn and Ian Pratt (pages 36–37, 42–43).

Below are the names of the six cyber-security layers and their definitions – but they are mixed up! Draw lines, use arrows or write the correct letter next to each layer. Use the onion diagram at the bottom of the page to help you.

Cyber Security Layers	Definitions (mixed up)
1. Physical security (outermost layer)	a) Protecting the information that travels between devices or across the internet, making sure only trusted users can send or receive it.
2. Perimeter security	b) Protecting the actual buildings and computer hardware from theft, fire or damage using locks, CCTV and alarms.
3. Network and data-transfer security	c) Keeping the most valuable information and the people who use it safe – this is what all the other layers are protecting.
4. Endpoint security	d) Keeping stored information safe and private by using passwords, encryption and backups.
5. Data security	e) Protecting the devices (like laptops, tablets and phones) that connect to the network, using antivirus software and updates.
6. The core (centre)	f) Protecting the edge of the network – using firewalls and routers to stop attackers getting in from the internet.

Cyber Security Onion

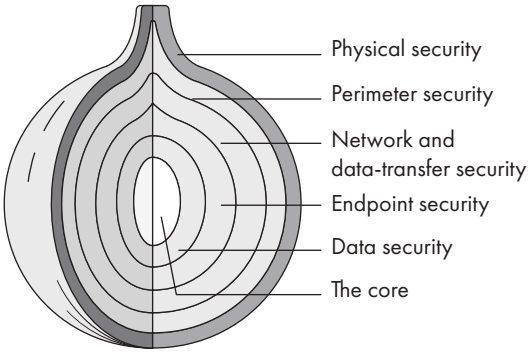


Image credit: Adam Allsuch Boardman.

- Can you come up with an analogy for each layer about how your personal data in school is protected from data breaches? For example, if the core was your paperwork, it could be kept in a filing cabinet, the key for which could be put in a safe and there might be a perimeter fence around the building.
- Which layer do you think protects people the most? Why?

Activity 4 : Worksheet continued

CYBER 'ONION LAYER' SECURITY – DEFENCE STRATEGIES

Task 2: Modelling a cyber-attack

You are going to play a hands-on 'Cyber Onion' defence game!

- Organise yourselves into groups of 6–8.
- In your group assign roles: **hackers** try to breach the security system and **defenders** protect the core data (a paper envelope labelled 'data' that has a secret message inside). You can decide what the message says.
- Defenders need to mimic the different defence layers. While they set this up the hackers can sit at a table on one side and discuss techniques to get to the envelope.
- Defenders could create physical layers around the core using desks, paper shields or tape circles – each layer represents a type of protection (passwords, antivirus software, staff training, firewalls).
- Play the game. Hackers propose a cyber-attack scenario (e.g. phishing email, malware USB). Defenders explain how each layer stops it. If they cannot think of how to stop it, that layer is breached!
- Swap roles and have a go again if time allows.

Reflect:

- Which layer was most effective?
- Why do companies need more than one?

Thinking deeper: Personal cyber security

- What data do you hold that could be at risk?
- Consider a plan to improve cyber security in your own life.

Activity 4 : Teacher sheet

TASK 1 ANSWERS

Cyber Security Layers	Definitions	Analogy
1. Physical security (outermost layer)	(b) Protecting the actual buildings and computer hardware from theft, fire or damage using locks, CCTV and alarms.	Like a school fence that keeps strangers out.
2. Perimeter security	(f) Protecting the edge of the network – using firewalls and routers to stop attackers getting in from the internet.	Like locking the staffroom door so only teachers can enter.
3. Network and data-transfer security	(a) Protecting the information that travels between devices or across the internet, making sure only trusted users can send or receive it.	Like sending a confidential message through a friend you trust, so no one else can read it.
4. Endpoint security	(e) Protecting the devices (like laptops, tablets and phones) that connect to the network, using antivirus software and updates.	Like keeping a filing cabinet key or code somewhere that students cannot access it.
5. Data security	(d) Keeping stored information safe and private by using passwords, encryption and backups.	Like keeping student records locked in a filing cabinet that only teachers can open.
6. The core (centre)	(c) Keeping the most valuable information and the people who use it safe – this is what all the other layers are protecting.	Confidential paperwork.

Activity 5 : Worksheet

DNA DATA ANALYSIS – HIDDEN CODES

How DNA data is being used to identify disease-related genes

Starter:

Read the profile of Beth Sampher (pages 52–53).

Task 1: What is DNA sequencing?

- What do the letters A, T, C and G represent in a DNA sequence?
- Work in a pair or small group 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.
- What do you think the 'UK Biobank' project may reveal in terms of DNA data gathered? What do you think we may find genes for, and how would this affect future healthcare?

Task 2: Hidden DNA codes

Some sequences in the table below contain a change or 'variant' in code (often called a gene mutation). Compare the sequences carefully and look for the following:

- Circle or highlight any differences (mutations).
- Decide whether the sample is the **Reference** or a **Variant**.

Discuss how any variants might affect a living organism.

Reference (Normal DNA Sequence)

A T G C T A G C A T G G C T

Sample Sequences

Sample	DNA Sequence	Reference or Variant?
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

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.

Activity 5 : Teacher sheet

TASK 1 ANSWERS

Decode the DNA Worksheet

This worksheet helps students visualise how small changes in DNA sequences can represent mutations.

Sample	Answer
1	Normal
2	Mutated (substitution: T replaces A at position 6)
3	Mutated (substitution: A replaces T at position 5)
4	Mutated (substitution: A replaces G at position 12)
5	Mutated (substitution: A replaces G at position 3)
6	Mutated (substitution: T replaces C at position 8)

Teaching Tips

- Encourage students to describe mutations as substitutions, insertions or deletions.
- Have students use highlighters or coloured pens to visualise differences.
- Discuss how some mutations cause diseases while others have no effect.
- Link the activity to bioinformatics careers like Beth Sampher's.

Activity 6 : Worksheet

PROCESSING HEALTH DATA – APP DESIGN

Considering the data collected by healthcare apps and how it can be used in research

Starter:

- List all the kinds of data that a smartwatch or phone might collect about you.
- Have you ever used the data gathered by your devices to change your behaviours?

Task 1: Healthcare apps

Read the profile of Arjun Panesar (pages 54–57) and watch the video.

Arjun discusses the need for different languages and formats in apps in his interview.
In a pair, discuss the ways in which apps are made more accessible and what barriers are still in place.

Task 2: Design an app

In a small group, design your own health app or device considering the following:

- What problem will your app or device solve?
- What health data will it collect, and how?
- How can you 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?

Present your ideas to the class through a poster or oral presentation. Be creative! You could consider pitching your idea as if you were at a science fair.

Thinking deeper: Future predictions

- Brainstorm how you think your data might be used in 20 years' time to support your health.
- What are you excited about and what might worry you?

Activity 7 : Worksheet

IN VITRO CELLS – GROWING THE BRAIN IN A DISH

Investigating how stem cells can be manipulated

Starter:

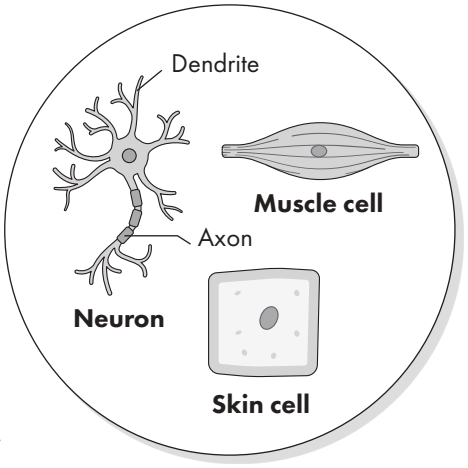
- List any disorders or diseases you know of which affect the brain.
- Why is it hard to test new medicines for these disorders or diseases?

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

Read the profile of Dr Emma Jones (pages 62–65). If possible, you can also read more from the Dana Foundation website.

Are the following truths or myths?

- Your brain is fully developed by the time you are 18...
- The brain is the fattiest organ in the body...



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. You are going to model how stem cells can be guided to become different types of cells (including brain cells) to test new treatments.

Types of cells to be modelled; **neurons** (nerve cells, mostly found in the brain, that pass signals along), **muscle cells** (which relax, contract and can grow – a process called hypertrophy) and **skin cells** (which can respond to external stimuli and contain pigments).

1. Begin by making three identical 'stem cells' from modelling clay, play dough or paper. These should be plain spheres. Place them on a sheet of paper or label them. These stem cells can become any cell if given the correct signals.
2. Choose an instruction card to read – this will give you the instructions you need to turn one of your stem cells into the cell type specified on the card (a neuron, muscle cell or skin cell).
3. Shape or decorate your model to show how it's changing according to the instructions. Write down the change on the blank paper or a label.
4. Then try following the other sets of instructions for your remaining stem cells.
5. Display the different cell models side-by-side to show the differences and notice how all the cells started the same but became specialised.

Answer the following:

- What do scientists mean by the term 'stem cell'?
- How do scientists control what kind of cell a stem cell develops into?
- Why is it helpful to grow cells in the lab instead of using animals for experiments?

Thinking deeper: Ethics of using stem cells

- 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?

Image credit: Adam Allsuch Boardman.

Neuron (nerve cell) instructions

Signal 1 – Growth factor BDNF (brain-derived neurotrophic factor)

A special brain signal tells your cells to grow long, thin branches (axons and dendrites) to pass electrical messages.

> Roll your clay to form one long tail and several thin branches.

> Label your cell 'neuron'.

Signal 2 – Electrical stimulation

Tiny electrical pulses activate your cell's membrane, helping it to connect to other nerve cells.

> Add 'connection points' (small dots or raised bumps).

> Use another colour to mark where signals enter and leave.

Signal 3 – Neurotransmitter signal (dopamine)

Your cell produces a chemical messenger to send signals across the brain.

> Add a small 'bubble' to represent a vesicle filled with neurotransmitters.

> Label this part 'signal vesicle'.

Muscle cell instructions

Signal 1 – Growth factor MyoD (myoblast determination protein)

This signal tells your cell to grow long fibres that can contract.

> Roll your clay into a long cylinder and mark faint stripes or ridges.

> Label your cell 'muscle cell'.

Signal 2 – Calcium ion activation

Calcium ions enter the cell and trigger muscle contraction.

> Add small dots around the cell surface (to represent calcium – use a different colour if possible).

> Squeeze the model slightly to show contraction.

Signal 3 – Exercise hormone (adrenaline)

Your cell strengthens and becomes more powerful when stimulated by hormones.

> Add a few extra 'fibres' to show muscle growth.

> Label the signal 'adrenaline' and label the new fibres as 'muscle growth'.

Skin cell (epithelial cell) instructions

Signal 1 – Growth factor EGF (epidermal growth factor)

Your cell flattens out and links tightly with others to make a protective layer.

> Flatten your clay into a thin tile-like shape.

> Label your cell 'skin cell'.

Signal 2 – Keratin protein activation

Your cell begins making keratin to make the skin strong and waterproof.

> Add lines or patterns on top to represent keratin layers.

> Label this 'keratin layer'.

Signal 3 – UV light exposure

Sunlight triggers pigment (melanin) production in your cell.

> Add small darker spots to represent melanin.

> Label the area 'pigment granules'.

Activity 8 : Worksheet

SEEING INSIDE THE BRAIN – THE POWER OF MRI

Analysing brain patterns to speed up diagnosis

SAFETY INFORMATION

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

Starter: Diagnosing Alzheimer's disease

How do you think MRI scans can support an Alzheimer's diagnosis?

Task 1: Using MRI scans

Magnetic resonance imaging (MRI) is a powerful tool used by medical physicists, such as Dr Hamied Haroon, to take 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.
   - Consider the risk of inaccurate diagnosis for someone experiencing mental deterioration.
   - MRI machines contain a powerful magnet – watch a demo or investigate magnetic field lines around a bar magnet for yourself. What happens to iron filings or metal paperclips near a magnet?

Task 2: Mystery boxes activity

In a small group, have a go at using magnets to test materials in mystery boxes for a reaction. You will need to have access to a relatively strong bar magnet.

- Place your magnets near the mystery boxes one by one. Notice any attraction or movement and try to work out if the item inside is magnetic. How big do you think the objects inside the boxes are?
- Record your guesses and reasoning.

Task 3: What do we use MRI images for?

- Look online or in textbooks to find out which tissues show up on an MRI scan, and why people may have an MRI scan.
- Draw an outline of a body and record your findings by labelling and annotating it with MRI scan information.

Image credit: Wikimedia Commons/Nickbyrd (CC BY-SA 4.0).

Activity 8 : Worksheet continued

SEEING INSIDE THE BRAIN – THE POWER OF MRI

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.

Work in a small group to create a short communication piece to tell NHS patients what happens in an MRI machine and why MRI is helpful. You 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?

How does an MRI machine use magnetism to create images of the brain?

MRI scanners use strong magnets to align protons in the nucleus of certain atoms in the body. Varying frequencies of radiowaves are applied and the protons absorb, then re-emit, these frequencies once the radiowaves are turned off. The energy released can be detected and used to build up an image.

Activity 9 : Worksheet

COOL CHEMISTRY – KEEPING VACCINES SAFE

Solving the problems of the cold chain

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

Starter:

Why do some vaccines need to stay cold?

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. Why do you think this is?
2. Read the profile of Dr Asel Sartbaeva (pages 80–83).
3. How could Dr Sartbaeva's development of silica-encased vaccines help countries without reliable electricity, and why this is important globally?

Task 2: Encasing Molecules experiment

You are going to model how Dr Sartbaeva's silica shell protects vaccines.

1. Working in a group, collect two sugar cubes and wrap one of them in cling film – this represents the silica-encased vaccine. Leave the other sugar cube unwrapped.
2. Set up two beakers with equal volumes of warm water in them (around 100 ml).
3. 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. 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. Observe which sugar cube dissolves faster and time how long it takes them each to fully dissolve.
6. Write down or discuss your conclusions about the experiment. Is there anything significant about the difference in the rates at which the sugar cubes dissolved?

Thinking deeper: Write a video script

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 : Worksheet

USING MOLECULAR SCISSORS – EDITING DNA

Modelling how gene editing can change DNA codes and re-write cell instructions

Starter: Spot the difference!

Try 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**
FOAL > _____ > _____ > **FARM**
POTS > _____ > _____ > **PAST**

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. 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. What health effects do you think this may have?
3. Watch the 'How CRISPR lets you edit DNA' video.
4. Write your own versions of the Starter task to mimic the CRISPR technique: a few of the letters in your chosen words will be swapped out to form new, different words with a different meaning. This is like changing part of a DNA sequence.

Task 2: Gene-editing simulation

You are now going to model how CRISPR can cut and replace a faulty base. To do this, you are going to use strips of paper to represent DNA strands with the base pair codes A, T, C, G.

Here is a 'reference' DNA sequence for red blood cell formation:

C T C G A A G A A

Write a mutated sequence on your strips of paper, replacing one or two of the letters with a different letter (A, T, C, G).

- Swap strips with a partner and then act as the researcher to find the mutation (swapped letter or letters).
- The CRISPR process is often referred to as 'using molecular scissors'; cut the mutated DNA section out of the sequence.
- Write the correct letter on a fresh piece of paper, then cut it out and glue it in place to fix the gene code. This represents the correction of the mutated gene.
- Have a go at making up other 'reference' gene sequences and write out variations for each other to try to find the changes. You can include deletions (remove a letter), mutations (change a letter) or insertions (add a letter). 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.

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.

Work in a group of 2–4 to come up with a set of 'red lines' or situations where gene editing should not be used.

- Do you think these red lines will be crossed in the future? If so, why?
- Do you think that attitudes to gene therapy will change in 50 years' time?

Activity 11 : Worksheet

FORENSIC BOTANY – PLANT DETECTIVES

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

Starter:

Imagine these trainers belong to a potential suspect from a crime scene in the local area.
What clues could the shoes hold that might prove if the owner was at the crime scene?

Task 1: Forensic botany

- Read the profile of Dr Mark Spencer (pages 98–101).
- Explain to someone you are sat with what you think 'forensic botany' means.

Task 2: Evidence match exercise

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

1. Working in a group, collect an evidence envelope and transfer the contents to a plate or tray. Using a magnifier, try to learn as much as you can from each fragment. For example, if you think it came from a pinecone, where might it have been found, and how would it have ended up on the shoe?
2. Now compare the evidence with the samples in the location trays. The aim is to decide which location matches your evidence and therefore where your suspect may have been walking.
3. Put your evidence back into the envelope and try another one if time allows.
4. Come up with a checklist of natural clues you would examine at a crime scene. You can work individually or in a small group.

Thinking deeper: Botanical reliability

Discuss how reliable this kind of evidence is, in a small group or as a class.

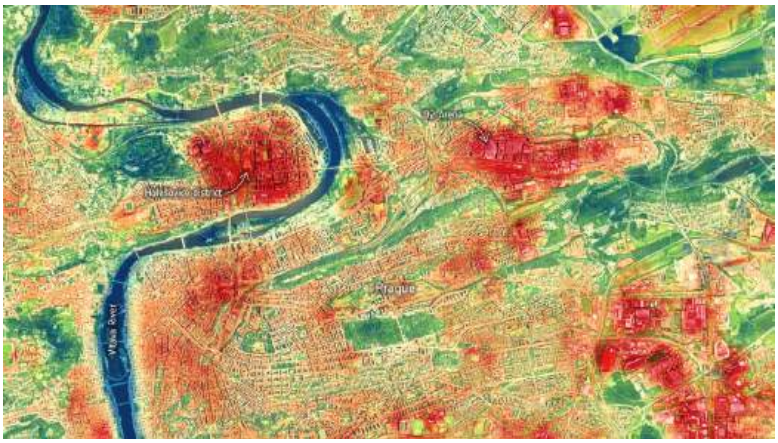
- Is it a reliable way to link a suspect to a crime scene?
- What other evidence would investigators need in order to link a suspect to a crime?

Image credit: Pixabay/alwhitbeck.

Activity 12 : Worksheet

TREES TO COOL OUR CITIES – CANOPY RESEARCH

Investigating the extent to which trees can decrease the urban heat effect



- This aerial heat map shows both parkland and built-up areas in Prague, in the Czech Republic. Identify which features increase and decrease temperature.
- Read the profile of Sophia Cunningham (pages 102–103) and watch the video on her work with Sheffield's Urban Tree Observatory.

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

You are going to conduct a 'Mini Urban Tree Survey'.

1. Go to an area outside 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.

Extra:

To allow different varieties of tree to be compared when they have a different canopy size, you can scale the data up or down according to the total canopy diameter.

- Divide all the data by the smallest canopy value to do this easily on a spreadsheet.
- Draw a graph comparing radius of shade (x-axis) vs temperature (y-axis).

Image credit: NASA/JPL-Caltech/ESA.

Activity 12 : Worksheet continued

TREES TO COOL OUR CITIES – CANOPY RESEARCH

Birch trees

Oak tree

Maple tree

Task 2: Indoor version tree analysis

1. Research online to find out more 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. Take the following 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 the three tree species shown above. Discuss which species is best for cooling purposes, and why.
3. Choose the 'best urban tree' and tell the class which species you would plant. Share the reasoning and evidence behind your choice.

Thinking deeper: Local action

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? Turn your research into action! You 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 your ideas or findings, if appropriate.

Activity 13 : Worksheet

HIDDEN CLUES – TRACKING WILDLIFE WITH eDNA

Investigating how environmental DNA can be used for conservation

Starter:

How would you go about proving that a turtle had been on a beach like this if it had already left?

Task 1: eDNA

1. Read the profile of Dr Liam Whitmore (pages 112–115).
2. Do a 'think-pair-share' – where would your DNA be detected if someone was trying to work out where you had been?
3. How could you minimise the eDNA you leave behind?

As animals are not trying to remove evidence of their presence, water samples can reveal the DNA of the species passing through that area.

Task 2: Sea detective exercise

You are going to model the process of extracting DNA from seawater.

1. Working in a small group, collect a beaker containing a 'seawater sample'. (Beakers will each contain some food colouring and a selection of insoluble 'eDNA' clues.)
2. Use the key on the board to understand what species each different 'eDNA' clue represents.
3. Filter your sample through filter paper into a conical flask or new beaker. Discard the filtrate that drips through.
4. Examine the residue in the filter paper, which you can tip out onto a fresh piece of paper or tray. Identify the species present using the key on the board.
5. If time allows, repeat steps 1–4 with new samples.

Reflect: Discuss the following questions, in a small group 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.

Image credit: Flickr/Cape Hatteras National Seashore, North Carolina (National Park Service).

Activity 14 : Worksheet

PACK POWER – HOW WILD DOGS SURVIVE TOGETHER

Learning how teamwork in African wild dog packs aids their survival

Starter: Teamwork or lone wolf?

List as many predators as you can that live and hunt as part of a pack, and a separate list of those that live and hunt alone.

Task 1: Success in a pack

1. Identify the factors that allow some predators to survive better alone, while other predators need to be part of a pack to survive. Consider:
   - The habitat
   - The type of prey – are prey animals numerous, or is prey limited?
   - The method of hunting
2. Identify how climate change may affect pack animals and lone predators differently.
3. Read the profile of Jenny Linden (pages 118–121) and watch the video on her research into the African wild dog.
4. Work in a pair to explain pack hierarchy: use the terms 'alpha pair', 'helpers' (often younger family members) and '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! Review your list of factors that allow some predators to survive better as part of a pack. Which of these factors are present in wild dogs?

Task 2: Pack hunt game

You are going to simulate an African wild dog hunt using small balls or beanbags (prey) and hula hoops (safe zones). The goal is to collect as much prey as possible in one minute.

- Pair up and decide who will be the **solo hunter** and who will be the **pack hunter**.

Round 1: Solo hunters

1. Start collecting prey when the whistle is blown.
   - Each solo hunter can collect only one piece of prey at a time – you must bring it back to your partner or desk before going to pick up another one.
   - You cannot talk or share information.
   - Prey can only be gathered from a safe zone if you can get the prey out of the zone without touching it. You could, for example, dislodge it by throwing another piece of prey at it.

2. Stop collecting when the whistle is blown again and make a note of the total prey collected.
3. How easy was it as a solo hunter to find prey on your own? Did you feel overwhelmed or tired by the individual strategy? How would you feel if you had to do this every time you needed food?

Round 2: Pack hunters

1. The pack hunters are allowed one minute to communicate and plan before the hunt starts. You might assign roles, e.g. finders to discover new food and runners to relay it back to base.
2. When the planning ends, pack hunters have one minute to hunt, starting with the blow of the whistle.
    - 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: you cannot touch prey with your hands.
3. Stop collecting when the whistle is blown again and make a note of the total prey collected.
4. Did working in a team make a difference to how many prey you managed to collect? What roles or strategies worked best? What advantages are there to a cooperative strategy? Hopefully, you'll find that teamwork = greater success.

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

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. 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 African wild dogs are not a cute and cuddly species to advocate for, you need to explain all of the potential benefits of the collars very effectively. You must also explain how the collars can be put on the dogs safely and ethically. Here are some ideas:

- 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.
- Other factors can also 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.

Activity 15 : Worksheet

PLASTIC PLANET – REDUCING MICROPLASTICS

Identifying microplastics in the environment

Starter: Hidden plastics

What do these plastics all have in common?

Task 1: Microbead ban

1. Read the profile of Professor Richard Thompson (pages 128–131).

- Discuss 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? Why?
- What are the potential impacts of microplastics on wildlife?

2. **Beach in a tray activity:**

You are going to conduct a short experiment to see how microplastics are found and separated. 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.

Reflect: 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. Watch the video 'Kids take action against ocean plastic' to see how plastic can build up in wildlife, and how we can make changes and decisions for a better future.
   - 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.

- Think about plastic items you 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.

2. Work in a pair 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

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 you encourage community action? Look up ways to make big local changes.
- Identify an area of your life where you can decrease your personal contribution to the source of microplastics. Make an action plan with a friend.

Activity 16 : Worksheet

ICE DETECTIVES – INVESTIGATING CLIMATE CHANGE

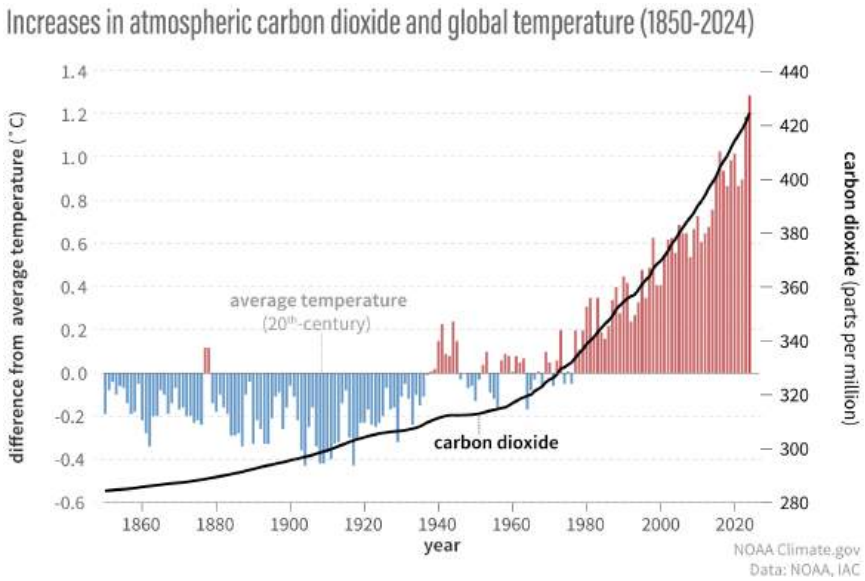
Investigating how climate science evidence can be collected

Starter: Frozen in time

Why do you think scientists would want to access the sediment deep below the surface of Antarctica?

Task 1: Secrets under the ice

1. Read the profile of Professor Tina van de Flierdt (pages 132–135) and watch the video on her Antarctic expeditions. If you can, look up the SWAIS2C website for more information.
2. What is the link between carbon dioxide levels and temperature? Look at the following graph.



3. 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?
4. Draw a diagram or a cartoon strip to show 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.
5. Gases dissolve better in cold water rather than warm water. We use this when preserving drinks; what would you do to keep a fizzy drink fizzy once it was opened and why?

Task 2: Ice core model

In this activity, you are going to model the layers of climate data trapped under (and in) Antarctic ice – sediment, for example.

1. Form a group and collect a beaker of crushed ice and a boiling tube. You also need to have access to the 'sediment'.
2. 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. Label each layer with a year on the side of the tube.
4. Try to 'drill' a core with the metal straw. Then use the stirring rod to push out the 'ice core' and observe the layers in it.

Thinking deeper: Would you go?

Would you want to go on an Antarctic mission and build your own base camp in the cold?

- What do you 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 you feel if you were doing experiments on air which is older than humanity?

Activity 17 : Worksheet

POWER IN MOTION – GENERATING ENERGY FROM EVERYDAY MOVEMENT 1/2

Research and design a different style of wind turbine

SAFETY INFORMATION

During Task 2, do not put hair or faces near the spinning blades as there is a risk of entanglement or an eye injury.

Starter:

Draw what you think a wind turbine usually looks like. Where would you find them?

Task 1: Utilising airflow

- Where can we find moving air in our daily lives (aside from off-shore or up a big hill)? Be ready to share your ideas!
- Read the profile of Anjali Devadasan (pages 146–149) and watch the 'Treeva' video. Compare the design of Treeva turbines with the turbine you drew at the start of the lesson.
- There is predictable air movement at an airport when planes take off and land, or as trains pass by a track. What, at an airport or by a railway, could Treeva turbines provide power for?

Treeva turbine

Task 2: Designing turbines

You are now going to have a go at designing and building a turbine, experimenting with the number and shape of the blades.

1. Working in a small group, decide on a blade design (straight, curved, tapered or paddle) and how many blades you will use; 3–8 is a good range. Blades should be around 7–10 centimetres long.
2. Draw your blades on card, making one of them a bold colour, then cut them out.
3. Attach the blades to the lollipop sticks.
4. Attach the lollipop sticks to the cork (or bottle cap or tack) and the pencil. Slot the pencil into the straw.
5. Use the play dough to make a base for the turbine, and trap the straw between some books. The turbine should spin freely when someone blows on it.
6. Place the turbine on the testing line in front of the hairdryer or fan.

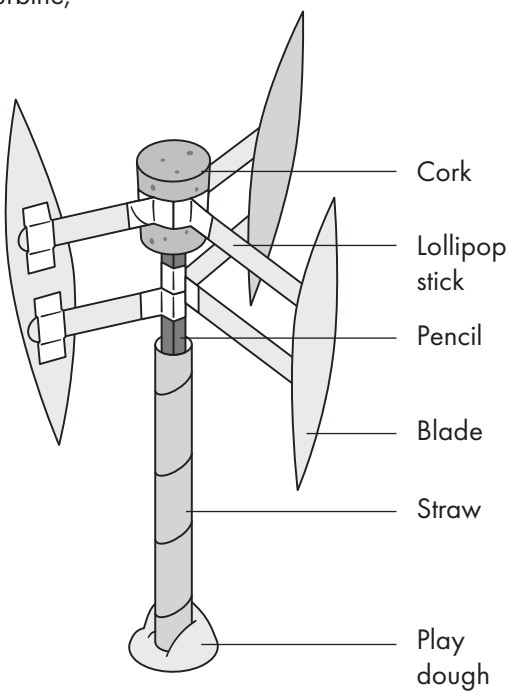


Image credits: Treeva turbine: Anjali Devadasan, Turbine illustration: Adam Allsuch Boardman.

Activity 17 : Worksheet continued

POWER IN MOTION – GENERATING ENERGY FROM EVERYDAY MOVEMENT 2/2

7. Data gathering – start the 'wind' and count how many rotations occur in 10 seconds. You may require the help of slow-motion video if your turbine is going fast! Record the result on a table like this:

Design	No. of blades	Blade shape	Number of rotations in 10s	Extra notes

8. Adjust your design, varying blade shape or number of blades. Remember to adjust only one variable at a time. Keep testing and recording results.

9. Share your most successful model with the class and compile the features of the best blade design on the board. Consider:

- Which blade design spun the fastest?
- Did more blades always improve performance?
- How might the mass of blades affect the rotation speed?

10. Write your own conclusions, e.g. ' The best turbine design was X because . . .'

Thinking deeper: Energy transfers in electricity generation

Using your knowledge of energy storage and transfer, answer the following:

- What type of energy is in the wind?
- What type of transfer occurs when a turbine blade spins?
- What energy transfers happen inside a turbine?
- What does a transformer do?

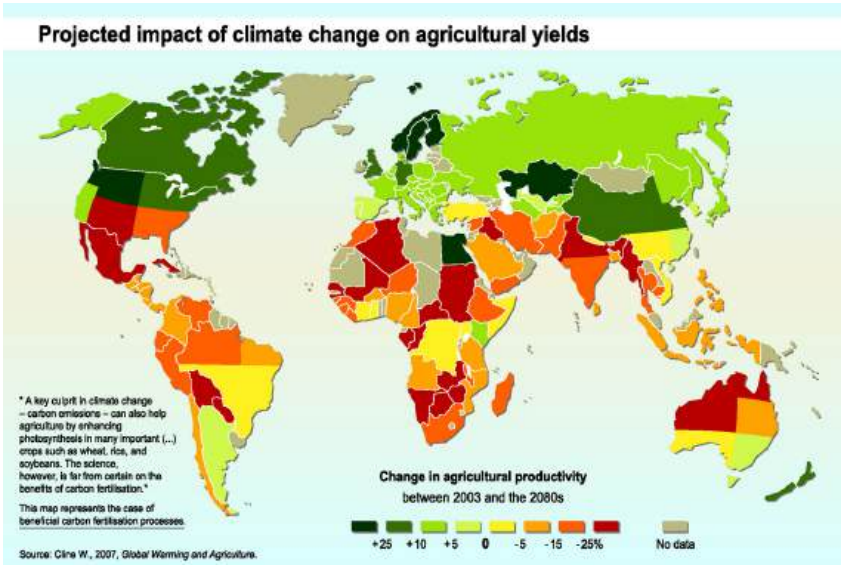
Activity 18 : Worksheet

ENGINEERING FUTURE FOOD – SELECTING TRAITS

Investigating how we plan for future food security

Starter:

The global climate is changing. On average it is getting warmer but the warming is not equally felt by all countries. A consequence of climate change is changes to weather patterns.



Look at the climate change and agriculture map above. List potential issues with crop growth that can occur because of climate change. Consider:

- Changes in rainfall volume and patterns (think about 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.

Task 1: Gaining desired genetic traits in plants

1. Read the profile of Maheen Alam (pages 166–167), explaining her research into plant immunity. 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. Think of examples of plants. Describe the plants and explain these three terms:
    - Natural selection
    - Selective breeding
    - Genetic engineering

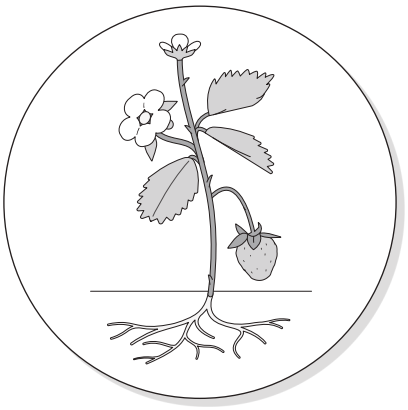
The scientists in Chapter 10 often start by observing natural selection to identify plants where there is an advantageous trait and then analysing DNA to find the DNA code section (gene) responsible.

Image credit: Wikimedia Commons/European Environment Agency (Public Domain).

Task 2: Natural selection in plants

Draw a basic plant, choosing from the following features:

- 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



Start with a tally of 10 of these sticky plants.
Now read the story and adjust your tally accordingly...

Welcome to 'sticky plant land'

In sticky plant land there are lots of different flowering plants.
However, the climate is changing quickly, and some may not survive the coming years. Each generation faces its own challenges, and some sticky plants may not survive while others will thrive. Read on and see how your plants will fare...

1. In the height of summer there are heatwaves occurring alongside a long spell of dry weather.
- Sticky plants with narrow, deep roots and narrow leaves survive well. Gain two plants for each advantageous feature your sticky plants have. Lose two plants if your sticky plants have wide leaves. Lose four plants if your sticky plants have shallow roots.

2. The offspring of the first plants are doing well in the long, hot summers but farmers are using pesticides nearby and the local bee population declines.
- Those with stripy flowers are more attractive to bees and double the seeds produced (double your number of plants for the next round if your sticky plants have stripy flowers), while those with plain flowers halve the plants that can reproduce (reduce your number of plants by half for the next round if your sticky plants have plain flowers).

3. The plants are growing well but the following year there is a new disease that affects plants with smooth stems only.
- Those plants with thorns survive and produce healthy seeds; add five plants if your sticky plants have thorns. Those with smooth stems do not produce many mature seeds; lose five plants if your sticky plants have smooth stems.

Count up your tally of plants; which features indicated a successful plant for this habitat?

Questions

1. Genetic engineering enables us to identify a gene, such as one that codes for resistance to disease or large fruits, and then transfer that gene into another plant. The advantage of this process is that multiple desired characteristics can be added to a plant relatively quickly.

a) Which other plant features from the story would be worth discovering the genetic codes for?

b) Why would it not have been as useful to simply breed together plants with the largest fruits?

2. What physical features and which resilient features would an ideal plant have for the habitat you live near? Place them in priority order and explain your choice.

Image credit: Adam Allsuch Boardman.

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 to extract DNA from a strawberry (this also works with a kiwi).

SAFETY INFORMATION

During Task 3, ensure no flames are present, as surgical spirit is flammable. Dispose of liquid quickly at the end of the experiment.

Method

1. Working in a group, take a strawberry and remove the leaves. Put the strawberry into the food bag, and seal the bag.
2. Gently squash the strawberry while it is in the sealed bag. Keep squashing for about two minutes, until there are no large pieces and only pulp left.
3. Carefully open the bag and add 5 teaspoons of water, 2 teaspoons of washing-up liquid and 1 teaspoon of salt. Then re-seal the bag, removing as much air as possible.
4. Gently squeeze the mixture together for another two minutes. Try to minimise the number of bubbles you make.
5. Pour the contents of the bag through the sieve into the beaker; you 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 the beaker – this will form two different layers. You must not touch your beaker now, as the two layers must not mix!
7. Leave the beaker for up to 10 minutes.
8. After this time, you should be able to see a white stringy material floating between the two layers.
9. Try to lift the white stringy material out with the stirrer... this is the strawberry DNA.

Thinking deeper: GM crops

Some people are uneasy about consuming GM (genetically modified) crops. Discuss this. Do you agree or disagree that it's acceptable to eat GM crops? Why?

Activity 19 : Worksheet

RESEARCH FARMS – FIELD RESEARCH

Investigating what scientific research looks like on a farm

Starter:

- Read the profile of Rebecca Lee (pages 172–173), which describes the varied work that is required in her role, and watch the video.
- Did you previously know there are research farms conducting farming experiments?
- What do you think the challenges around collecting repeatable data at a research farm would be?

Task 1: Farming-language research task

- 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.
- Produce a guide that explains some of the terms (hand-drilling, shadow-netting) for those without a farming background to use.
- Find out where your nearest agricultural college is, and which courses people interested in farming and land management can take. 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 even be something you have experience of in your own garden, or you may have already done other pH tests (such as testing water from a pond, fish-tank or swimming pool).

1. Working in a group, take a test tube or boiling tube and add water and a soil sample with the help of the spatula. Put a bung in the tube and shake it until a slurry is formed.
2. Let the contents settle for a minute, so that the solution at the top is easier to collect.
3. 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, test the pH of the solution.
5. Use the colour of the indicator to deduce and record the pH of the soil sample.

Alternative method: You can also decant the solution into two test tubes. 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

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 : Worksheet

SUSTAINABLE MATERIALS – BIODEGRADABLE PLASTICS

Modelling the breakdown of bioplastics

Task 1: What's different about bioplastics?

- Read Dr Florence Huynh's profile (pages 178–181) and watch the video about her mission to create plastic that turns into harmless wax.
- What makes plastic 'break down'? Plastics are polymers with many strong covalent carbon–carbon bonds; these do not break down easily under normal conditions – so what does break them?

Task 2: Plastic breakdown simulation

You are going to model the difference between biodegradable plastic and regular plastic.

1. In a group, fill two beakers with 100 ml of warm water.
2. Place a square of cling film (representing non-biodegradable plastic) in one beaker and a square of gelatine or rice paper (representing biodegradable plastic) in the other.
3. Use the table below to record your observations every 2 minutes over the course of 10 minutes — what changes occur and why?

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

4. Repeat the experiment and add salt or detergent to the beakers of water. Do the observations change?

Task 3: Purposeful plastic properties

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 of the item.

Thinking deeper: Class debate on biodegradable plastics

'All plastics should be made to be biodegradable' – do you agree or disagree? Debate this statement, first in a pair or small group, then as a class.

Activity 21 : Worksheet

CONCRETE SOLUTIONS – FLOOD PREVENTION

Investigate ways in which urban flooding can be reduced using 'Kiacrete'

Starter:

Why does the water not easily soak or drain away in an urban flood?

Task 1: Kiacrete

1. Read the profile of Dr Alalea Kia (pages 186–187) and watch the 'This is Kiacrete' video.

- Have a go at writing your own definition for porosity and list items you have used this week that are porous and those that are non-porous.
- Kiacrete uses plastic tubes and the principles of chemistry to create a substance that is both strong and porous. Suggest where Kiacrete could be used to reduce the risk of urban flooding.

Task 2: Measuring the permeability of materials

You are going to investigate flow rate versus porosity using a model.

1. Work in a group of 2–4 and mark 3 small paper cups with a hole in the bottom with a line about 5 cm from the bottom.
2. Fill each cup up to the line with a different material: gravel, sand and soil.
3. Using a measuring cylinder, pour 100 ml of water into the first cup and hold it above the beaker. Record how long the water takes to drain.
4. Clean out the beaker, and repeat with the other two cups.
5. Rank the materials by permeability.

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

Thinking deeper: Designer pavements

Design a 'smart draining' pavement that both drains water and collects it for re-use. How wide and how close together do you think the holes need to be?

Activity 22 : Worksheet

SEARCHING FOR THE INVISIBLE – DARK MATTER AND COSMIC MYSTERIES

How can we detect dark matter?

Starter:

What makes up a galaxy?
What holds it all together?

Task 1: Underground laboratories

- Read the profile of Kayleigh Johnson (pages 202–205), which describes her work testing materials for radioactivity at the Boulby Underground Laboratory.
- Have a go at explaining to someone sat near you what dark matter is.
- Why do the research facilities need to be underground? What other kinds of radiation are present?
- How would you feel about doing Kayleigh's 'morning commute' underground?

Task 2: Shield the detector simulation

You are going to have a go at mimicking radiation and how it can be blocked.

1. Place a coin into a 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: What materials do you think would make a good shield against different types of radiation?

Thinking deeper: Scientific communication

Write a news article explaining why building underground laboratories that contain detectors helps us to study space.