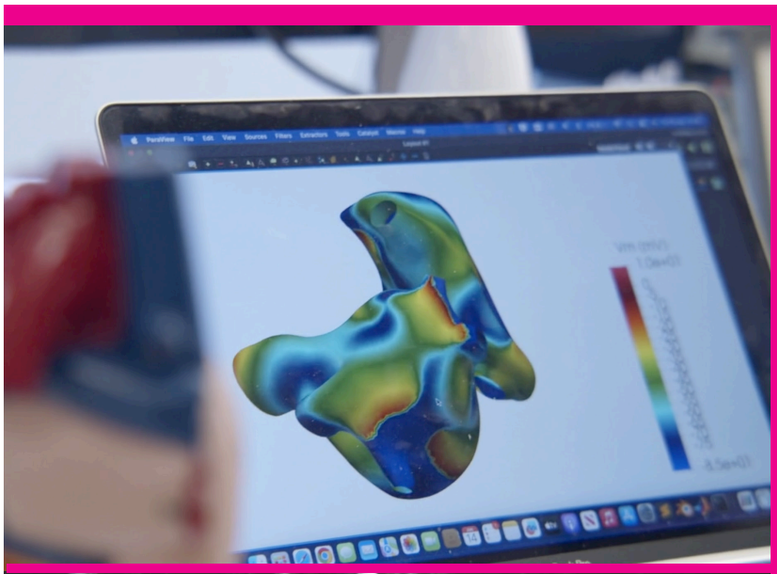

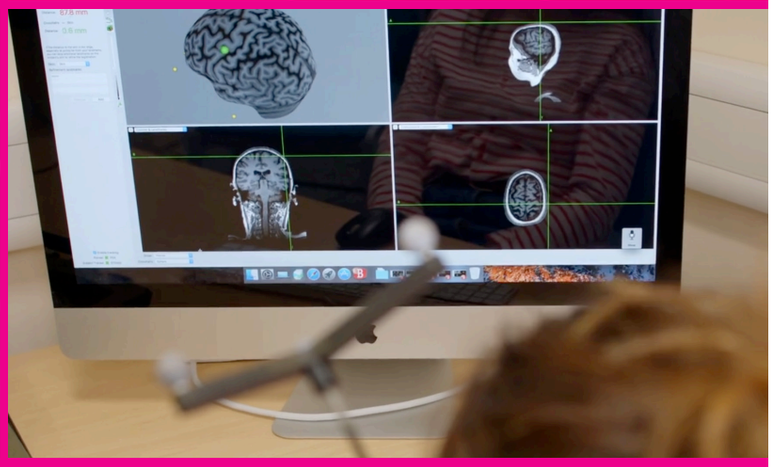

THE FUTURE OF SCIENCE LESSON PLANS

animalaid.org.uk/future-of-science-film

View, download and order our FREE science resources from our website

ANIMAL AID

RIGHTS • RESPECT • COMPASSION
FOR ALL ANIMALKIND

LESSON 1: AN INQUIRY INTO ANIMAL EXPERIMENTS

Age: Key Stage 4 or Key Stage 3

Duration: 60 to 120 minutes

Resources: An inquiry into animal experiments presentation
Polling cards (x2 per student)
Stakeholder cards

View/download film & other resources

Overview: Students take part in a mock independent inquiry on behalf of the government. They play the role of different stakeholders to investigate the scientific arguments in favour of and against animal experiments. Students will use their critical thinking, literacy and presentation skills to debate this topic respectfully.

LEARNING OBJECTIVES

The process of discovery and development of new medicines
Working scientifically: appreciating the power and limitations of science and considering ethical issues which may arise; explaining everyday and technological applications of science; evaluating associated personal, social, economic and environmental implications; and making decisions based on the evaluation of evidence and arguments

STARTER

Students discuss each statement on slide 1 and decide whether they agree or disagree. Encourage them to think about and explain their reasoning.

Introduce the two research approaches: animal models and humane research and how the two scientists would have different opinions about animal experiments.
Suggested follow-up questions:

- Why might the two scientists have different opinions? (They have different experiences, different knowledge, they may be biased)
- How does question 3 differ from 1 and 2? (It is subjective rather than objective - explain that this lesson will deal only with the objective questions)

Vote 1:

- Introduce the question of "Should we continue to fund animal experiments to find treatments for human disease?"
- Students cast their initial votes using the ballot cards or alternatively you can label three containers with 'yes', 'no' and 'not sure' and give each student a marble to place in one of the buckets.
- Count up the votes and announce the result to the class.

MAIN

Give each student a *stakeholder card* (print from slides 4 to 9 of the 'An inquiry into animal experiments' presentation).

Students sit with other students who have the same stakeholder card. They will assume the role of their stakeholder, no matter what their own personal beliefs are. Allow a few minutes for each student to read the arguments on their stakeholder card and write down any other arguments they think their stakeholder could make. If time allows, they could research on the internet (or this could be set as a homework in preparation for the lesson). Make it clear to them that they are arguing from their stakeholder's position, not their own!

They will be presented with three pieces of evidence. After each piece of evidence, give them time to discuss with their stakeholder group and the opportunity to respond.

Prompts for discussion after each piece of evidence:

- What was the most important message from the evidence we just saw?
- Was there anything in this evidence that you disagreed with?
- Was this evidence biased or unbiased?
- Was there anything in this evidence which surprised you?
- Do animal experiments cause suffering to animals?
- Are animal experiments necessary to find treatments for human diseases?

Evidence A:
The Future of Science film from Animal Aid explores the work of four scientists using humane research methods to research causes and treatments for human disease.

Evidence B:
This 4 minutes clip from *Animal Experiments: pain, production and playing god* from The Guardian features an interview with a scientist who conducts animal experiments. She lays out the arguments used to defend and justify animal experiments.

Evidence C:
UK government statistics on scientific procedures involving living animals which shows the number, severity and species of animals used.

PLENARY

Vote 2:
Students cast their votes again in light of the evidence that has been presented during the inquiry. Encourage them to discuss with a partner their reason for changing or not changing their answers.

Count up the votes and announce the outcome of the inquiry. Did anybody change their mind? Why? Why not? Is anybody more confident or less confident in their beliefs now? What might they do with what they've learned?

Direct students to www.animalaid.org.uk to learn more.

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BALLOT CARDS SHEET

Should we continue to fund animal experiments to find treatments for human disease?

Yes | Not sure | No

Should we continue to fund animal experiments to find treatments for human disease?

Yes | Not sure | No

Should we continue to fund animal experiments to find treatments for human disease?

Yes | Not sure | No

Should we continue to fund animal experiments to find treatments for human disease?

Yes | Not sure | No

Should we continue to fund animal experiments to find treatments for human disease?

Yes | Not sure | No

Should we continue to fund animal experiments to find treatments for human disease?

Yes | Not sure | No

Should we continue to fund animal experiments to find treatments for human disease?

Yes | Not sure | No

Should we continue to fund animal experiments to find treatments for human disease?

Yes | Not sure | No

STAKEHOLDER CARDS

Scientist who conducts animal research

- We need to use animals to understand the causes of and treatments for human diseases.
- Animals are used when there is a need to find out what happens in a whole living organism.
- Testing new drugs on animals means we can predict if the drug can be safely given to humans.
- Our animals are well taken care of and do not suffer more than they need to.

Scientist who conducts humane research

- Though we share some similarities with other animals, there are vast differences at the subcellular and genetic level. This means experiments on animals are poor indicators of what will happen in humans.
- Other animals don't suffer the same diseases as humans do and drugs affect them differently too.
- Using human-relevant methods such as stem cells, organ-on-a-chip and computer modelling to test new drugs will result in better, safer medicine.

A patient

- I don't like the idea of animals suffering but we need safe and effective treatments for diseases. Animal experiments are the price we must pay for this.
- Mice and rats are less intelligent than humans and we are more important than other animals.
- We've been experimenting on animals for hundreds of years and this is the reason we live longer today.

A doctor

- Many people believe we are living longer because of animal experiments but this is mostly thanks to improvements in nutrition, vaccines and antibiotics.
- Lots of time and money has been spent on animal experiments for diseases that we still have no effective treatments for, for example Alzheimer's.
- Some drugs pass trials in animals but are found to be unsafe in humans. Thalidomide was found to be "safe" when tested in mice, rats, guinea-pigs and rabbits, but caused deformities in thousands of humans. We need to find better, safer ways to test new drugs.

A politician

- A recent poll showed 72% of the British public want to see animal experiments phased out. This government supports this policy and will work towards a plan to end animal experiments within the next 50 years.
- If we end animal experiments abruptly, we could do more harm than good. We must be cautious and do things in the right way.
- Currently many of our biomedical laboratories have the equipment and staff for animal experiments. It is not easy or cheap to switch to humane methods.

Animal rights organisation

- Around 3 million animals are used in experiments every year in the UK. Tens of thousands of these are classified as causing "severe" suffering.
- The animals – mice, rats, cats, dogs, monkeys - used in experiments can feel pain and fear, just like the companion animals we share our homes with.
- Animal welfare laws do not apply to animals used in laboratories. Animal experiments are shrouded in secrecy to stop people finding out how much these animals suffer.

LESSON 2:
STEM CELLS IN MEDICINE

Age: Key Stage 4

Duration: 60 minutes

Resources: Stem cells in medicine presentation
Future of Science information sheet
Stem cell types diagram
Stem cell table
Stem cell Venn diagram

VIew/download film & other resources

Overview: This lesson builds on students' knowledge of embryonic and adult stem cells and offers an opportunity to apply this knowledge to real-life cutting-edge medical research. Can be used to extend or embed learning or as a revision exercise.

LEARNING OBJECTIVES

Describe and explain how different types of stem cells are used in medicine
Explain some of the clinical, ethical and social issues associated with stem cells

STARTER

Students suggest the connection between the four images on slide 1 of the *Stem cells in medicine* presentation. Recap details of embryonic and adult stem cells (where they are found, what they can do, what they are used for, any problems associated with their use, etc.).

The brain organoid and the mini beating heart are examples of cutting-edge medical research carried out using stem cells.

Show students *The Future of Science* film which explains these examples in more detail.

Suggested follow-up questions:
- Was there anything in this film that surprised you?
- What did you think was the most important message from the film?

MAIN

1. Using their prior knowledge along with the *Future of Science* film and *information sheet*, students add the labels to the *Stem cells diagram*.
Show correct answers on slide 5 for students to self-assess.

2. Students use their prior knowledge along with the *Future of Science film* and *information sheet*, to complete the differentiated *Stem cells table*.
Show answers on slide 9 for students to self-assess and correct.

Suggested follow-up questions:
- Name three different types of stem cells.
- Describe two ways in which stem cells are already used.
- Suggest one way that stem cells could be used in the future.
- Explain why some people are against using stem cells.

PLENARY

Print the *Venn diagram* on A3 paper for students to work in groups of 2-3 to place each statement into the correct section of the Venn diagram. Encourage them to think of their own statements to add.

Follow-up discussion points:
- Which of these do you think is the most important?
- If you had £10 billion to invest into stem cell research, how would you invest it and why?

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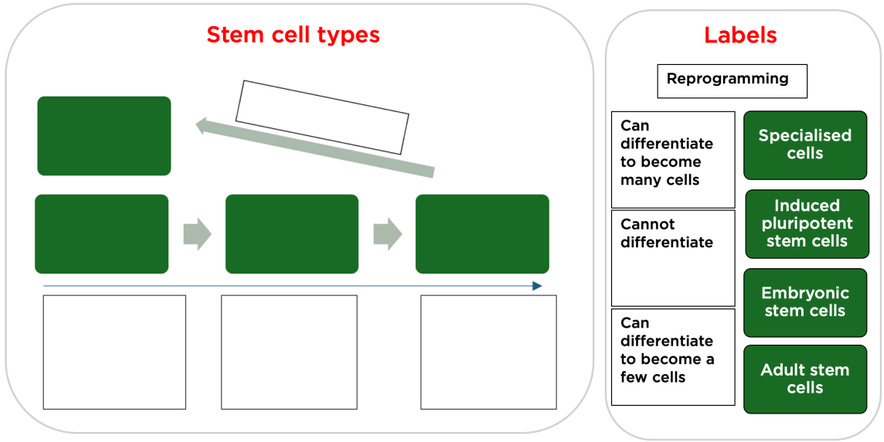
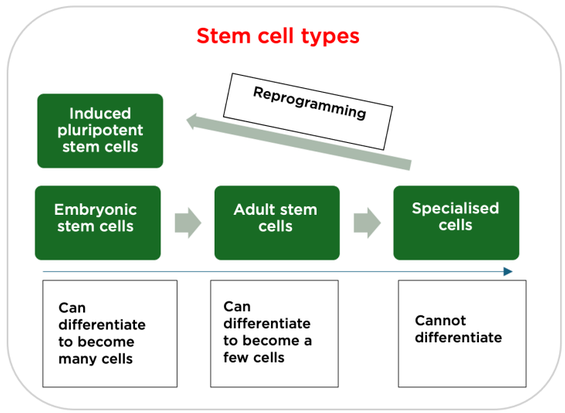
STEM CELL DIAGRAM



STEM CELL DIAGRAM ANSWERS



FUTURE OF SCIENCE INFORMATION SHEET

THE FUTURE OF SCIENCE

Many people believe that animal experiments are not only cruel but also produce results that are unreliable and misleading when applied to people. This factsheet describes some of the human-relevant research methods that are replacing animal experiments and helping to improve medicine.

More Information
www.animalaid.org.uk

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HUMAN STEM CELLS

Stem cells can divide and become many different types of cell. They have great potential for use in medicine.

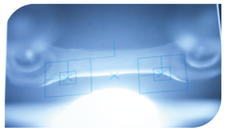
Embryonic stem cells (ESC) are pluripotent, meaning they can differentiate into any type of cell. They are already used to treat diabetes by replacing cells in the pancreas. However, some people believe it is unethical to use ESCs because the embryos are destroyed.

Adult stem cells (ASC) are less controversial, but they can only differentiate into a small number of cell types. For example cells taken from the bone marrow can only become blood cells.

Technological breakthough

In 2007, a team in Japan discovered a technique to 'reprogramme' ASCs back into their pluripotent form — similar to ESCs.

Induced Pluripotent Stem Cells (iPSCs) solve many of the problems associated with ESCs and ASCs. This is a huge breakthrough with enormous potential to improve disease research and the drug development process.



iPSCs can be grown into organoids which are simplified *in vitro* versions of organs, capable of modelling some functions of an organ in the lab.

Mini human heart organoids (pictured above) are used to research heart disease and to test the safety and efficacy of new drugs. Mini human brain organoids have been used in the study of Alzheimer's and Parkinson's disease.

It is extremely challenging to keep these mini organs alive in a laboratory environment outside a human body. Scientists are gradually refining and improving these techniques so that they can one day completely replace animal experiments.

ORGAN-ON-A-CHIP

Organs-on-a-chip are small devices which model human organs or groups of organs (called organ systems). They can be used for disease research and drug development.

These chips have tiny chambers, each containing different types of cells or tissues. A blood-like substance moves from chamber to chamber through channels, like how blood flows through capillaries in a human body. The test substance circulates around the device, modelling what happens in the organ or organ system on a microscopic scale.

Sensors in the chip detect how the different types of cells react to substances such as drugs and send the data to a computer for analysis.

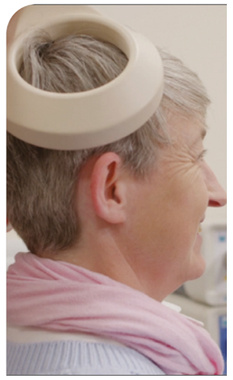
Chips that model the workings of various human organs include skin-on-a-chip, lung-on-a-chip, heart-on-a-chip, liver-on-a-chip and brain-on-a-chip. Researchers are working towards building a human-on-a-chip which is a device that mimics several key organs in the body.

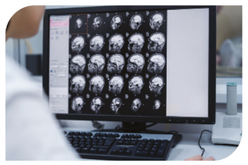
ELECTRICAL STIMULATION

All activities in the brain — our thoughts, behaviour and perceptions — are caused by electrical impulses. Electrical stimulation involves safely and reversibly activating regions of a human brain and observing the response. This can help us discover more about how the brain coordinates our behaviour, how it goes wrong and how we can treat disease.

One such technique is TMS (Transcranial Magnetic Stimulation) which sends a magnetic field into a specific part of the brain, stimulating electrical activity in that area. Stimulating different areas will result in the person responding differently. For example, stimulating the motor cortex will cause an involuntary movement in the body.

Learning what different parts of the brain do and how they communicate with each other means we can look for other parts of the brain which could potentially carry out the same function. TMS research at Durham University has trained people with damage in the visual area of their brain to look differently at the world and restore their vision. It is hoped that this technique could lead to treatments for neurodegenerative diseases.





IMAGING TECHNOLOGIES

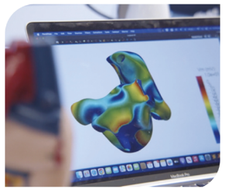
Imaging techniques such as MRI (Magnetic Resonance Imaging) use magnetic fields and radio waves to show what is happening inside the human body, particularly the brain.

COMPUTER MODELLING

In silico research involves collaboration between experts in different fields such as computer science and medicine. The result is a powerful tool which is rapidly improving our understanding of disease and provides a reliable way to test new treatments.

Human data is turned into mathematical models which can be used to create simulations of organs and organ systems. Because these models are based on human physiology, the results are more easily translatable to humans than results from experiments on animals.

One study at the University of Oxford's Department of Computer Science found that a computer model representing human heart cells predicted the safety of new drugs with greater accuracy than animal studies.



These sophisticated computer models allow us to delve into the complexity of the human body and study how variables such as sex or ethnicity might affect the diagnosis and treatment of disease. Work is also ongoing in a European project to co-ordinate the development of a 'virtual physiological human' as a single complex system.

It is hoped that one day this research will pave the way for personalised medicine in the form of an AI-generated digital twin. This is a digital representation of a person which could accurately and precisely predict a patient's health outcomes if given different treatments.

Watch the Future of Science film:

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STEM CELL TABLE CLOZE

	Embryonic	Adult	Induced pluripotent
Where do the cells come from?	Discarded _____ from IVF treatment	_____ marrow	Almost any _____ in the body
What can they do?	Can _____ into any cell in the body	They are multipotent - can differentiate into a ____ number of cells	Unipotent cells are _____ to become pluripotent
What could they be used for?	To treat _____ by replacing damaged cells in the pancreas	Bone marrow _____ for people with cancer	Disease research and _____ development
What are the problems?	Ethical issues: Embryo is _____during process	Risk of _____	Cells in a dish may not behave exactly as they do in a _____

Word bank: diabetes, drug, body, bone, cell, limited, reprogrammed, embryos, transplants, differentiate, destroyed, infection

STEM CELL TABLE CLOZE SUPPORT

	Embryonic	Adult	Induced pluripotent
Where do the cells come from?	Discarded e_____ from IVF treatment	B_____ marrow	Almost any c_____ in the body
What can they do?	Can d_____ into any cell in the body	They are multipotent - can differentiate into a l____ number of cells	Unipotent cells are r_____ to become pluripotent
What could they be used for?	To treat d_____ by replacing damaged cells in the pancreas	Bone marrow t_____ for people with cancer	Disease research and d_____ development
What are the problems?	Ethical issues: Embryo is d_____during process	Risk of i_____	Cells in a dish may not behave exactly as they do in a b_____

Word bank: diabetes, drug, body, bone, cell, limited, reprogrammed, embryos, transplants, differentiate, destroyed, infection

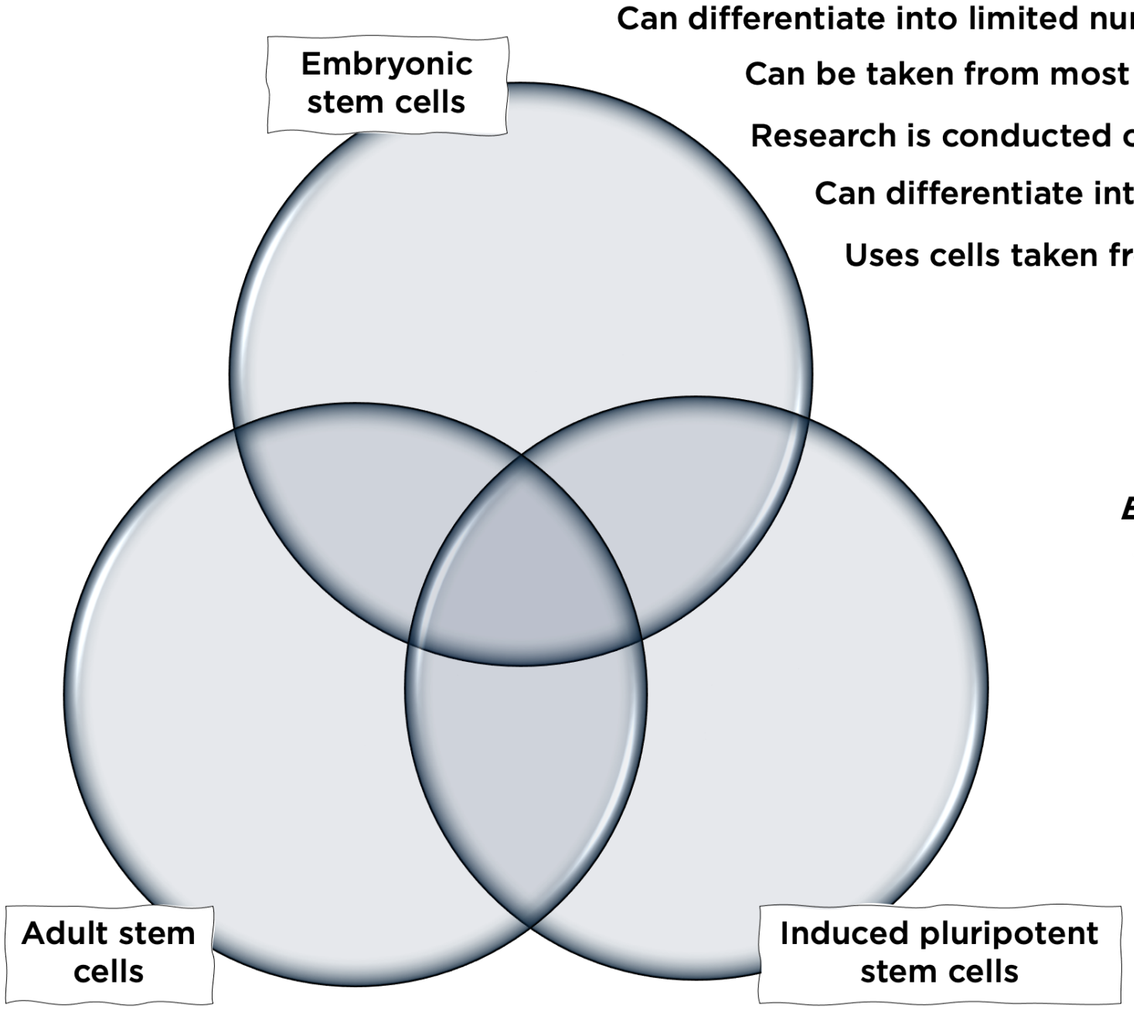
STEM CELL TABLE BLANK

	Embryonic	Adult	Induced pluripotent
Where do the cells come from?			
What can they do?			
What could they be used for?			
What are the problems?			

STEM CELL TABLE ANSWERS

	Embryonic	Adult	Induced pluripotent
Where do the cells come from?	Discarded embryos from IVF treatment	Bone marrow	Almost any cell in the body
What can they do?	Can differentiate into any cell in the body	They are multipotent - can differentiate into a limited number of cells	Unipotent cells are reprogrammed to become pluripotent
What could they be used for?	To treat diabetes by replacing damaged cells in the pancreas	Bone marrow transplants for people with cancer	Disease research and drug development
What are the problems?	Ethical issues: Embryo is destroyed during process	Risk of infection	Cells in a dish may not behave exactly as they do in a body

STEM CELL VENN DIAGRAM



Can differentiate into limited number of cell types

Can be taken from most parts of the body

Research is conducted on sentient beings

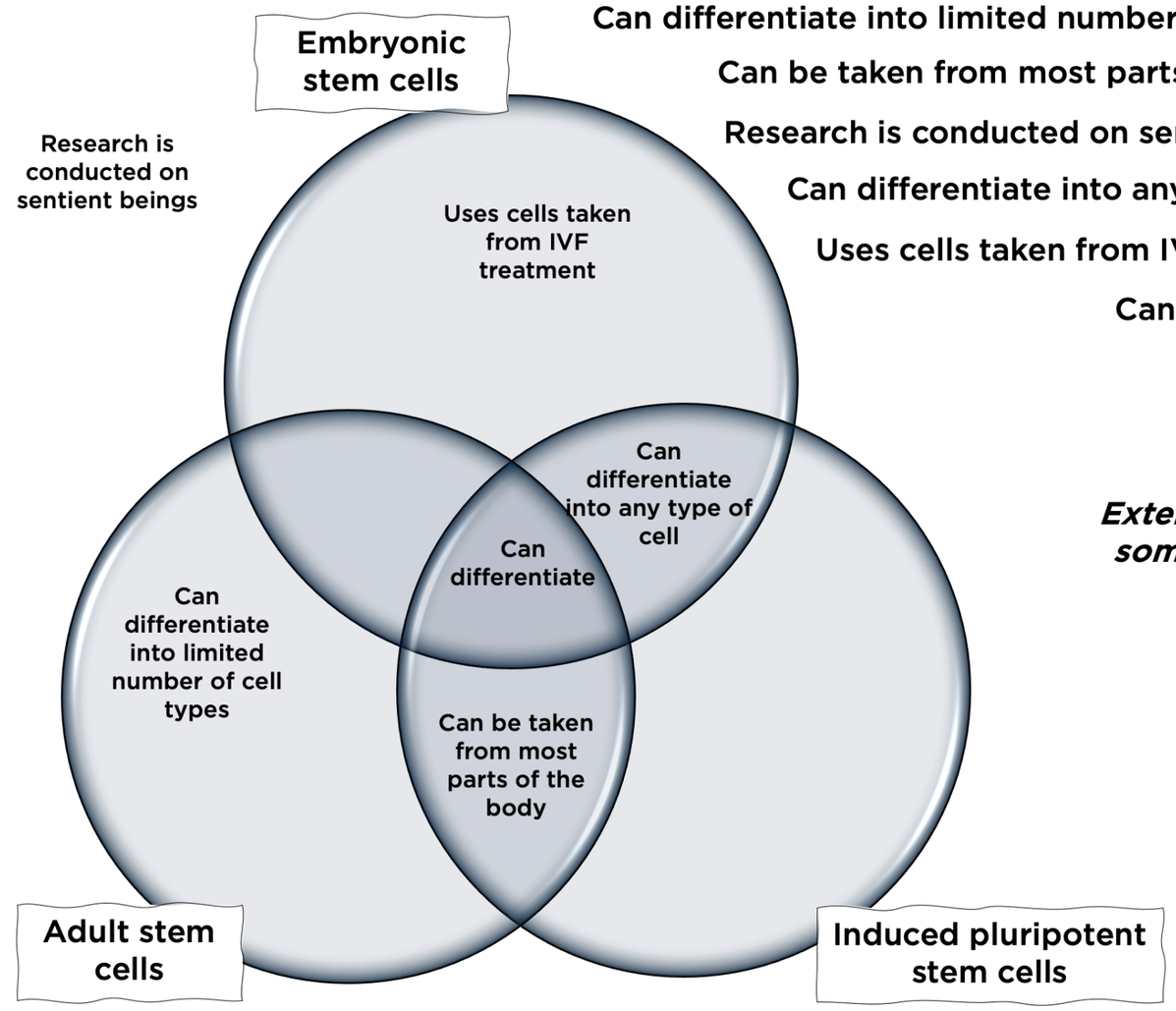
Can differentiate into any type of cell

Uses cells taken from IVF treatment

Can differentiate

Extension: add some of your own

STEM CELL VENN DIAGRAM ANSWERS



Can differentiate into limited number of cell types

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Research is conducted on sentient beings

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Uses cells taken from IVF treatment

Can differentiate

Extension: add some of your own

LESSON 3: INVESTIGATING THE BRAIN

Level: Key Stage 4

Duration: 60 minutes

Resources: Investigating the brain presentation
Areas of the brain diagram
Investigation techniques information sheets
Investigation techniques table

View/download film & other resources

Overview: This lesson introduces students to the human brain and what makes it such a challenging and fascinating area of study. They work in teams to research and report on different techniques including electrical stimulation, brain imaging and animal studies. Students evaluate the strengths and weaknesses of each method.

LEARNING OBJECTIVES

Identify some areas of the brain, and describe their function
Explain some of the difficulties of investigating brain function and treating brain damage/disease
Working scientifically: evaluate the benefits and risks of procedures carried out in the brain and nervous system

STARTER

Reveal the quotes on slide 1 of the 'Investigating the brain' presentation one-by-one and have students guess what word goes in the blanks.

Use slide 3 to show and describe the function of the cerebral cortex, hypothalamus, pituitary gland, medulla and cerebellum. Give students an *Areas of the brain diagram* for them to label and note the function.

Take suggestions as to why it is difficult to understand the brain. Discuss the fact that the brain is a complex and delicate structure which makes investigating and treating brain disorders very challenging.

MAIN

1. Show *The Future of Science* film which explores transcranial magnetic stimulation (TMS) and how it can be combined with brain imaging.

Follow-up discussion prompts:
- Was there anything in this film which surprised you?
- What are some of the problems with using animal experiments?
- How does TMS overcome these problems?

2. Display instructions on slide 6 of the *'Investigating the brain' presentation.*

Ask students to get into groups of four and label each member of their group A, B, C and D. You can then divide the classroom into four sections (A, B, C and D) and have students move to their section.

Each section will research a different procedure used to investigate the brain:
- A: Animal experiments
- B: Studying patients with brain damage
- C: Electrical stimulation
- D: Brain imaging

They will gather information from the relevant *Investigation techniques information sheet* and write notes in the *Investigation techniques table.*

Students return to their original team of four and report the information they learned for others to write in their tables. Everyone should have a completed table by the end.

Extension: through discussion and debate with their group, students can evaluate each procedure and decide which they believe to be the most effective and important to medicine.

PLENARY

Show slide 11 of the *'Investigating the brain' presentation* and ask students to decide which procedure would be most useful to answer the three questions.

Show slide 12 of the *'Investigating the brain' presentation* for think, pair, share follow-up discussion:
- If you had £10 billion to find out more about the brain, how would you invest the money?
- Explain why you would invest in some procedures, but not others. (Prompt them to discuss animal experiments and whether they feel this is a good area on which to spend time and money.)

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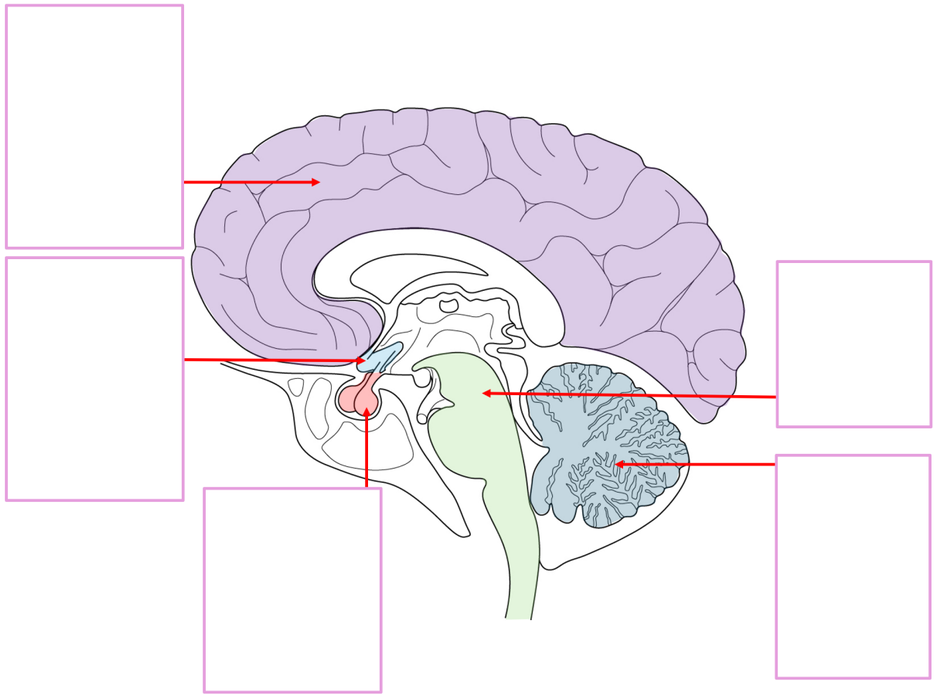
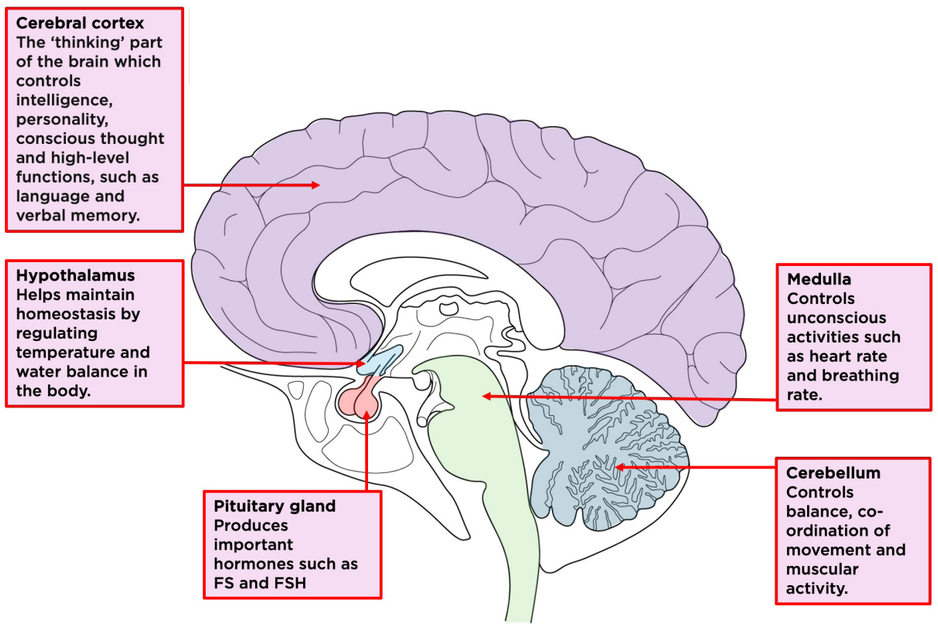
AREAS OF THE BRAIN DIAGRAM



AREAS OF THE BRAIN ANSWERS



INVESTIGATION TECHNIQUES INFORMATION SHEETS

HOW DO EXPERIMENTS ON ANIMALS HELP US UNDERSTAND THE HUMAN BRAIN?

Scientists study animals such as rats, mice, cats, dogs, sheep and monkeys to learn more about the human brain. These experiments aim to help us understand how the brain works and what happens when something goes wrong.

HOW DOES IT WORK?

In these studies, researchers damage specific parts of an animal's brain, a process called lesioning. This can involve starving the brain of oxygen or using chemicals to destroy brain cells. Afterwards, scientists observe how the damage affects the animal's behaviour, memory or movement. Once the experiments are finished, the animals are usually killed.

WHAT ARE THE BENEFITS?

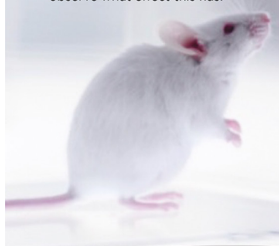
Can target specific areas of an animal brain to lesion and observe what effect this has.

WHAT ARE THE PROBLEMS?

Animal brains are very different from human brains, so the results don't always apply to people.

Animals cannot demonstrate traits that are unique to humans, such as complex language.

On top of that, there are ethical concerns. Many people believe it's wrong to harm animals for experiments, especially when it causes pain or suffering. This has led to the development of better, kinder alternatives such as electrical stimulation.



More Information
www.animalaid.org.uk

HOW DO PATIENTS WITH BRAIN DAMAGE HELP US UNDERSTAND THE BRAIN?

In 1848, Phineas Gage survived an extraordinary accident when an iron rod blasted through his skull, destroying part of his left frontal lobe. Although he lived, Gage's personality changed drastically — he became less socially aware and more impulsive. The case helped scientists discover that the left frontal lobe plays a big role in reasoning and social behaviour.

HOW DOES IT WORK?

People who suffer brain damage due to accidents or strokes can reveal the functions of different areas of the brain. We can compare the person's behaviour, memory or abilities before and after the brain damage.

Modern brain imaging technologies, such as MRI scans, allow us to pinpoint the damaged areas. By observing what happens when they don't function properly, we can determine their function.

WHAT ARE THE BENEFITS?

Studying brain injuries is valuable due to its direct relevance to humans.

If we want answers to questions about the human brain, we need to study the brains of humans and not other species.

WHAT ARE THE PROBLEMS?

One major challenge is that scientists must rely on accidents or illnesses to study brain damage. They can't plan experiments to damage specific brain areas

Additionally, this method will only give data on damaged or diseased brains, which are not typical of how healthy brains work.

More Information
www.animalaid.org.uk

HOW CAN ELECTRICAL STIMULATION HELP US UNDERSTAND THE BRAIN?

Electrical stimulation has helped us understand a great deal about how the brain controls movement, behaviour and thought. It is a valuable tool in neuroscience research.

HOW DOES IT WORK?

Electrical stimulation sends a weak electrical current or magnetic field to stimulate specific areas. This stimulation creates electrical activity in the brain, helping researchers see how different parts work. When certain areas are stimulated, they cause specific responses.

For example, if the motor area is stimulated, it might cause the person to make an involuntary movement, such as an arm twitch.

It can be combined with brain imaging techniques to target specific areas of the brain. By targeting different areas, scientists can explore the role of each part of the brain.

WHAT ARE THE BENEFITS?

It is brief, reversible and completely harmless. It can be used to study both healthy and damaged brains. Brain imaging technology helps scientists stimulate very specific areas for more accurate results.

WHAT ARE THE PROBLEMS?

The process can cause mild discomfort for the person being studied. However, it's generally well-tolerated and is a safe way to investigate brain function.

More Information
www.animalaid.org.uk

HOW CAN BRAIN IMAGING HELP US UNDERSTAND THE BRAIN?

Brain imaging has revolutionised the way we understand the brain, making it an important tool in medicine and neuroscience.

HOW DO BRAIN SCANS WORK?

MRI scans use magnetic fields and radio waves to create detailed images of the brain's structure.

CT scans use X-rays fired from different angles to build a picture of the brain.

PET scans use a small amount of radioactive material to track activity in the brain and show how it is functioning.

These methods allow doctors and researchers to study the brain without needing surgery or other invasive procedures.

WHAT ARE THE BENEFITS?

Brain imaging is non-invasive and safe for most people. It provides detailed images that can help identify problems, such as tumours or damage from strokes.

WHAT ARE THE PROBLEMS?

A minor concern with MRI scans is that the radio waves can cause slight heating if a person is exposed for too long. However, scans are carefully controlled to keep them safe.

More Information
www.animalaid.org.uk

INVESTIGATION TECHNIQUES CLOZE

Procedure	How does it work?	What are the benefits?	What are the problems?
Animal experiments	Animals have their brains _____ (lesioned). This can involve starving areas of oxygen or applying chemicals to kill brain cells. Scientists then observe how the damage affects the animal's behaviour, movement or memory. When the experiment is finished, the animals are killed.	Scientists can target _____ areas of the animal brain to see what effect this has.	Animal brains are very different to human brains, so the results do not always apply to people. Studying animals can't tell us about things that are unique to humans such as complex _____. The ethical issue of causing pain and suffering to animals.
Studying patients with brain damage	Patients with brain damage can be observed to see what changes occur in their behaviour, memory or abilities. We can use brain _____ to find out which area of the brain is damaged and observe what happens when that area does not function the way it should.	The results of these observations are _____, so they reveal things about how the human brain functions.	We rely on _____ or injuries so cannot target specific areas. We can only study atypical, damaged or diseased brains.
Electrical stimulation	Stimulation causes _____ activity in specific areas of the brain. Stimulating different areas results in different _____. For examples, if the motor area is stimulated, the patient makes an involuntary _____.	Brief, _____ and safe. Allows us to study typical or atypical brains. Using brain imaging we can stimulate specific areas of the brain.	Can cause mild discomfort during process.
Brain imaging	MRI scans use magnetic fields and radio waves to produce detailed _____ of brain. CT scans fire x-rays from different angles at the brain to build up a picture of it. PET scans: Use a small amount of radioactive material to track activity in the brain and show how it is functioning.	Can be used to diagnose or monitor brain _____. Non-invasive. Safe.	Radio waves can _____ the body if exposed for too long.

Word bank: responses, language, damaged, specific, disease, imaging, movement, accidents, image, heat, electrical, human-relevant, reversible

INVESTIGATION TECHNIQUES SUPPORT

Procedure	How does it work?	What are the benefits?	What are the problems?
Animal experiments	Animals have their brains d_____ (lesioned). This can involve starving areas of oxygen or applying chemicals to kill brain cells. Scientists then observe how the damage affects the animal's behaviour, movement or memory. When the experiment is finished, the animals are killed.	Scientists can target s_____ areas of the animal brain to see what effect this has.	Animal brains are very different to human brains, so the results do not always apply to people. Studying animals can't tell us about things that are unique to humans such as complex l_____. The ethical issue of causing pain and suffering to animals.
Studying patients with brain damage	Patients with brain damage can be observed to see what changes occur in their behaviour, memory or abilities. We can use brain i_____ to find out which area of the brain is damaged and observe what happens when that area does not function the way it should.	The results of these observations are h_____, so they reveal things about how the human brain functions.	We rely on a_____ or injuries so cannot target specific areas. We can only study atypical, damaged or diseased brains.
Electrical stimulation	Stimulation causes e_____ activity in specific areas of the brain. Stimulating different areas results in different r_____. For examples, if the motor area is stimulated, the patient makes an involuntary m_____.	Brief, r_____ and safe. Allows us to study typical or atypical brains. Using brain imaging we can stimulate specific areas of the brain.	Can cause mild discomfort during process.
Brain imaging	MRI scans use magnetic fields and radio waves to produce detailed i_____ of brain. CT scans fire x-rays from different angles at the brain to build up a picture of it. PET scans: Use a small amount of radioactive material to track activity in the brain and show how it is functioning.	Can be used to diagnose or monitor brain d_____. Non-invasive. Safe.	Radio waves can h_____ the body if exposed for too long.

Word bank: responses, language, damaged, specific, disease, imaging, movement, accidents, image, heat, electrical, human-relevant, reversible

INVESTIGATION TECHNIQUES BLANK

Procedure	How does it work?	What are the benefits?	What are the problems?
Animal experiments			
Studying patients with brain damage			
Electrical stimulation			
Brain imaging			

INVESTIGATION TECHNIQUES ANSWERS

Procedure	How does it work?	What are the benefits?	What are the problems?
Animal experiments	Animals have their brains damaged (lesioned). This can involve starving areas of oxygen or applying chemicals to kill brain cells. Scientists then observe how the damage affects the animal's behaviour, movement or memory. When the experiment is finished, the animals are killed.	Scientists can target specific areas of the animal brain to see what effect this has.	Animal brains are very different to human brains, so the results do not always apply to people. Studying animals can't tell us about things that are unique to humans such as complex language. The ethical issue of causing pain and suffering to animals
Studying patients with brain damage	Patients with brain damage can be observed to see what changes occur in their behaviour, memory or abilities. We can use brain imaging to find out which area of the brain is damaged and observe what happens when that area does not function the way it should.	The results of these observations are human-relevant, so they reveal things about how the human brain functions.	We rely on accidents or injuries so cannot target specific areas. We can only study atypical, damaged or diseased brains.
Electrical stimulation	Stimulation causes electrical activity in specific areas of the brain. Stimulating different areas results in different responses. For examples, if the motor area is stimulated, the patient makes an involuntary movement.	Brief, reversible and safe. Allows us to study typical or atypical brains. Using brain imaging we can stimulate specific areas of the brain.	Can cause mild discomfort during process.
Brain imaging	MRI scans use magnetic fields and radio waves to produce detailed image of brain. CT scans fire x-rays from different angles at the brain to build up a picture of it. PET scans: Use a small amount of radioactive material to track activity in the brain and show how it is functioning.	Can be used to diagnose or monitor brain disease. Non-invasive. Safe.	Radio waves can heat the body if exposed for too long.

LESSON 4: EVALUATING THE DRUG DEVELOPMENT PROCESS

Level: Key Stage 4

Duration: 60 minutes

Resources: Evaluating the drug development process presentation
Stages in drug development information sheet
Future of Science information sheet
Diamond nine cards

View/download film & other resources

Overview: This lesson teaches students about the drug development process within the wider context of an ever-changing, dynamic scientific process. It explores the strengths of the current process and encourages students to think critically to suggest how it could be improved in the coming decades.

LEARNING OBJECTIVES

Explain why drugs need to be tested for toxicity, efficacy and dose
Describe the steps in the drug trial process and explain the reasons each step is needed
Evaluate different methods of testing new drugs.;
The development of scientific thinking
The ways in which scientific methods and theories develop over time

STARTER

1. Show students slides 2 to 5 of the *'Evaluating the drug development process'* presentation which features some examples of the '*Lost Futures*' artworks. These images are predictions of the year 2000 drawn in the year 1900.

Discussion points:
- Did they predict anything correctly?
- What did they get wrong?
- How might science and medicine be different in another 100 years?

2. Show *Future of Science* film.

Suggested follow-up questions:
- Was there anything in this film that surprised you?
- What did you think was the most important message from the film?
- Why is it important that models, theories and equipment develop over time?

MAIN

Display slide 8 of the *'Evaluating the drug development process'* presentation. When clicked, correct answers turn green and incorrect answers disappear.

1. Students use the *Stages in drug development information sheet* to answer questions on slide 9 of the *'Evaluating the drug development process'* presentation.
Show answers on slide 10 and 11 for students to self-assess.

2. Using the *Future of Science information sheet*, Students evaluate the use of animal experiments and humane research. Display the instructions on slide 13 of the *'Evaluating the drug development process'* presentation for students to consider:
- Is the data human-relevant? i.e. Does it use human cells and data?
- Can experiments accurately predict what will happen in a human?
- Are there ethical issues?
- How well-established is it?

Show model answer on slide 14 for students to self-assess.

PLENARY

Reiterate that scientific models and technologies evolve over time and that there are many variables which influence this change. For example, social, ethical and scientific factors.

Give each pair of students a set of *Diamond nine* cards. Each card has a different fact or statistic relating to either animal experiments or humane research. Students discuss each consideration with their partner and decide how important they believe each card is, placing it in the 'diamond nine' shape accordingly.

This leads to a group discussion of whether they believe the benefits of animal experiments outweigh the problems.

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STAGES IN DRUG DEVELOPMENT INFORMATION SHEET

STAGES IN DRUG DEVELOPMENT

Before new drugs or vaccines can be approved for use in humans, they are first tested for:

SAFETY
Is the drug toxic or does it have harmful side effects?

EFFICACY
How well does the drug treat a disease or help with symptoms?

CORRECT DOSE
The amount which is high enough to be effective but low enough to be safe.

DISCOVERY	PRECLINICAL TRIALS	CLINICAL TRIALS	APPROVAL
Drugs can be extracted from plants: • Willow bark contains a chemical which is similar to aspirin. • Foxgloves contain a chemical similar to the heart drug digitalis. Today, scientists extract the active ingredient from plants and make them in a laboratory.	Drugs are tested on human stem cells and computer models. Data from these tests reveals whether the drug is effective and whether there are harmful side effects. Drugs are also tested on animals. A known amount of the substance is given to animals in controlled laboratory conditions who are monitored for side effects.	Drugs are first given to healthy volunteers to see if they are safe in humans. Drugs are then given to patients with the illness to see if they are effective. Small doses are used at first, then larger doses to find the right dose. Half the participants are given the real drug and half are given a placebo; the trial is double-blind which helps reduce bias.	The results will be reviewed and approved by an independent group who issue licences for new drugs. The drug will then be available for doctors to prescribe.

CAN WE IMPROVE PRECLINICAL TRIALS?

Millions of animals are still experimented on every year for drug development. Drugs are given to a group of animals in a laboratory, giving us data on the effects of drugs in a whole, living organism. It is believed that this reduces the risk of potential new drugs causing serious side effects in patients. Animals have been used in this way for years and many scientists and regulators understand and trust the data from these experiments.

While animal experiments give us data about a whole living organism, the results do not always translate well to humans. The genetic and cellular differences between species mean that drugs can affect humans and other animals in different ways. In fact, around 90% of drugs which appear promising in animal trials fail when they are tested on humans. Some drugs used by humans are also toxic in other animals, for example, aspirin is fatal to cats.

As our knowledge and technology advance, so too do our scientific models and methods. Many scientists believe that investing our time and money on humane research methods would lead to more reliable and safer medicine.

Humane research	Research methods which use human data instead of animals.
Animal experiment	A procedure likely to cause pain and distress to animals such as mice, rabbits or dogs.
Placebo	An inactive substance made to look like the drug, used as a control.
Double-blind trial	Neither the participants nor the researchers know who has taken the real drug and who has taken the placebo.

More Information
www.animalaid.org.uk

DIAMOND NINE CARDS

Experiments use sentient beings who feel pain and fear.

72% of the British public are against animal experiments.

Using human cells and data gives results which better predict what will happen in humans.

Differences between species mean drugs have different effects in different species.

Around 90% of drugs which pass preclinical trials on animals fail clinical trials on humans.

Animal experiments allow us to see how an entire living organism will respond to a drug.

Animal experiments have more resources (time and money) invested in them than humane research.

Using human cells and data could help lead to personalised medicine.

Many laboratories are already set up with equipment and staff trained to do animal experiments.

FUTURE OF SCIENCE INFORMATION SHEET

THE FUTURE OF SCIENCE

Many people believe that animal experiments are not only cruel but also produce results that are unreliable and misleading when applied to people. This factsheet describes some of the human-relevant research methods that are replacing animal experiments and helping to improve medicine.

More Information
www.animalaid.org.uk

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HUMAN STEM CELLS

Stem cells can divide and become many different types of cell. They have great potential for use in medicine.

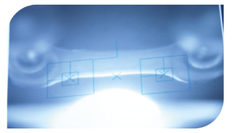
Embryonic stem cells (ESC) are pluripotent, meaning they can differentiate into any type of cell. They are already used to treat diabetes by replacing cells in the pancreas. However, some people believe it is unethical to use ESCs because the embryos are destroyed.

Adult stem cells (ASC) are less controversial, but they can only differentiate into a small number of cell types. For example cells taken from the bone marrow can only become blood cells.

Technological breakthough

In 2007, a team in Japan discovered a technique to 'reprogramme' ASCs back into their pluripotent form — similar to ESCs.

Induced Pluripotent Stem Cells (iPSCs) solve many of the problems associated with ESCs and ASCs. This is a huge breakthrough with enormous potential to improve disease research and the drug development process.



iPSCs can be grown into organoids which are simplified *in vitro* versions of organs, capable of modelling some functions of an organ in the lab.

Mini human heart organoids (pictured above) are used to research heart disease and to test the safety and efficacy of new drugs. Mini human brain organoids have been used in the study of Alzheimer's and Parkinson's disease.

It is extremely challenging to keep these mini organs alive in a laboratory environment outside a human body. Scientists are gradually refining and improving these techniques so that they can one day completely replace animal experiments.

ORGAN-ON-A-CHIP

Organs-on-a-chip are small devices which model human organs or groups of organs (called organ systems). They can be used for disease research and drug development.

These chips have tiny chambers, each containing different types of cells or tissues. A blood-like substance moves from chamber to chamber through channels, like how blood flows through capillaries in a human body. The test substance circulates around the device, modelling what happens in the organ or organ system on a microscopic scale.

Sensors in the chip detect how the different types of cells react to substances such as drugs and send the data to a computer for analysis.

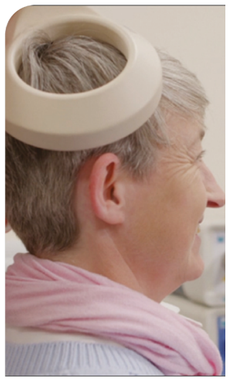
Chips that model the workings of various human organs include skin-on-a-chip, lung-on-a-chip, heart-on-a-chip, liver-on-a-chip and brain-on-a-chip. Researchers are working towards building a human-on-a-chip which is a device that mimics several key organs in the body.

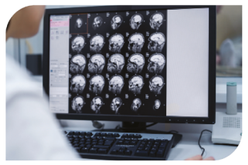
ELECTRICAL STIMULATION

All activities in the brain — our thoughts, behaviour and perceptions — are caused by electrical impulses. Electrical stimulation involves safely and reversibly activating regions of a human brain and observing the response. This can help us discover more about how the brain coordinates our behaviour, how it goes wrong and how we can treat disease.

One such technique is TMS (Transcranial Magnetic Stimulation) which sends a magnetic field into a specific part of the brain, stimulating electrical activity in that area. Stimulating different areas will result in the person responding differently. For example, stimulating the motor cortex will cause an involuntary movement in the body.

Learning what different parts of the brain do and how they communicate with each other means we can look for other parts of the brain which could potentially carry out the same function. TMS research at Durham University has trained people with damage in the visual area of their brain to look differently at the world and restore their vision. It is hoped that this technique could lead to treatments for neurodegenerative diseases.





IMAGING TECHNOLOGIES

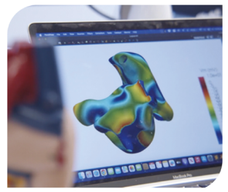
Imaging techniques such as MRI (Magnetic Resonance Imaging) use magnetic fields and radio waves to show what is happening inside the human body, particularly the brain.

COMPUTER MODELLING

In silico research involves collaboration between experts in different fields such as computer science and medicine. The result is a powerful tool which is rapidly improving our understanding of disease and provides a reliable way to test new treatments.

Human data is turned into mathematical models which can be used to create simulations of organs and organ systems. Because these models are based on human physiology, the results are more easily translatable to humans than results from experiments on animals.

One study at the University of Oxford's Department of Computer Science found that a computer model representing human heart cells predicted the safety of new drugs with greater accuracy than animal studies.



These sophisticated computer models allow us to delve into the complexity of the human body and study how variables such as sex or ethnicity might affect the diagnosis and treatment of disease. Work is also ongoing in a European project to co-ordinate the development of a 'virtual physiological human' as a single complex system.

It is hoped that one day this research will pave the way for personalised medicine in the form of an AI-generated digital twin. This is a digital representation of a person which could accurately and precisely predict a patient's health outcomes if given different treatments.

Watch the Future of Science film:

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LESSON 5:
SAFETY TESTING SUBSTANCES

Level: Key Stage 4 or Key Stage 3

Duration: 30 - 45 minutes

Resources: Safety testing substances presentation (including XCellR8 film)
pH 4, 6 and 7 in beakers labelled ‘A’, ‘B’ and ‘C’
Universal indicator strips
Safety goggles

Overview: Students will test the pH of three substances and use the data they collect to determine if the new substances are safe for human use. They will analyse their results and evaluate how reliably the data from animal experiments predicts what will happen in humans and learn about some human-relevant techniques emerging in this field.

LEARNING OBJECTIVES

The pH scale for measuring acidity/alkalinity; and indicators
The development of scientific thinking
The ways in which scientific methods and theories develop over time

STARTER

Use slides 1 and 2 to introduce the differences in human, dog and rat skin pH and how this leads to a different range of tolerated pHs for each species.

MAIN

Students carry out practical work as detailed in the *Practical instructions.*

Show students the XCellR8 film to introduce them to the world of human-relevant safety testing tecniques.

PLENARY

Think, pair, share: Do you think it is ethical to test on animals? Do you think it is good science to test on animals?

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PRACTICAL INSTRUCTIONS

During this activity you will test the pH of three potential new cosmetics and use this data to determine if they are safe for human use.

Hazards and risk minimisation:
• Solutions may cause irritation if contact with skin or eyes occurs. Take care not to touch the solutions and wear safety goggles. If contact with skin or eyes does occur, rinse with water and tell an adult.
• To minimise risk of glassware breakages and/or spillages, please leave the beakers in the centre of the table.

Method:
1. Get into groups of 2 or 3.
2. Place an indicator strip into one of the substances.
3. Hold the indicator strip next to the chart to determine the pH.
4. Make a note of the colour and pH value in the results table below.
5. Repeat for the other two substances.
6. Using the "essential background information" below the table, decide if each of these substances would be suitable for rats, dogs and humans and make a note of this in the table below.

SUBSTANCE	COLOUR OF INDICATOR	pH	SUITABLE FOR RATS?	SUITABLE FOR DOGS?	SUITABLE FOR HUMANS?
A					
B					
C					

Essential background information:
The optimal pH range for products applied to human skin is around pH4 to pH6.
Dog skin is slightly alkaline at pH 7.5 so they require their own dog shampoo within the range of pH7 to pH8.
Rat skin is close to neutral at around pH 6.5, with a suitable range of pH5 to pH7.

If you were to test these substances on dogs or rats, would the results be relevant to humans? Explain your answer.

PRACTICAL INSTRUCTIONS ANSWERS

SUBSTANCE	COLOUR OF INDICATOR	pH	SUITABLE FOR RATS?	SUITABLE FOR DOGS?	SUITABLE FOR HUMANS?
A	Orange	4	NO	NO	YES
B	Light green	6	YES	NO	YES
C	Green	7	YES	YES	NO

If you were to test these substances on dogs or rats, would the results be relevant to humans? Explain your answer.

Testing these substances on dogs or rats would not give results that are relevant to humans.
Substance A is unsuitable for rats and dogs but is suitable for humans.
The results are misleading.
Substance B is suitable for rats but not dogs. The results are contradictory and it isn't clear which results we should trust.
Substance C is suitable for dogs and rats but not humans. Again, the results are misleading.

This means that out of six tests on animals, only one is predictive of what would happen in humans. This is because there are big differences between humans and other animals at the subcellular and genetic level which mean we react differently to substances.

View, download and order our FREE science resources from our website.

animalaid.org.uk/future-of-science-film

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