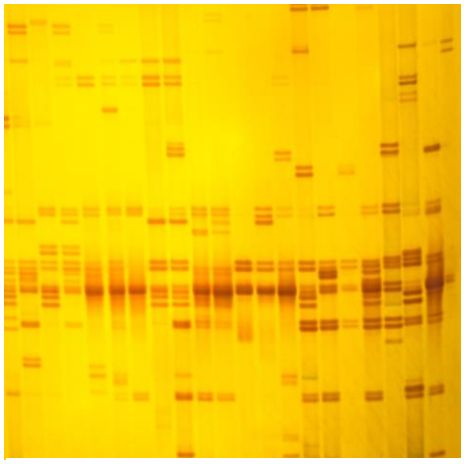
# Genetic Technologies

This resource was developed by teachers within the Royal Society Schools Network



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## Curriculum key words

Food security  Genetic engineering

## Curriculum links

- AQA Trilogy/Biology 4.6.2.4
- AQA Trilogy/Biology 4.7.5.4
- AQA Synergy 4.3.3.8
- AQA Synergy 4.4.4.6
- OCR Gateway B6.2b
- OCR Gateway B6.2d
- OCR Gateway B6.3q
- OCR 21st Century B1.3
- OCR 21st Century IaS4
- Edexcel Combined/Biology 4.10
- Edexcel Combined/Biology 4.11(HT)
- Edexcel Combined/Biology 4.12B
- Edexcel Combined/Biology 4.14

## Equipment needed

- Access to Royal Society web pages
- Post-it notes

## Resources

- Gene Technology Timeline Sorting Cards (see appendix)

## KS4

**Lesson time:** 1 hour

## Introduction

What can genetic technologies be used for?

What should genetic technologies be used for?

These are questions that students are required to be able to discuss in topics on genetic engineering and food production in the GCSE Science and Biology specifications of all exam boards. This lesson plan suggests ways to address these questions using online and downloadable resources produced by The Royal Society.

An important misconception to address in this lesson is that students can struggle to appreciate the physical relationships between the nucleus, genetic material, the genome, chromosomes and genes.

Examples of generic exam-style questions on the topic are also given, together with answers, for use as homework or revision tasks.

In the main activity section, a number of suggested options are given for using the resources so that teachers can pick a suitable number of activities for the time available and choose activities covering aspects of the topic appropriate to their own exam board specification.

## Learning objectives (adaptable):

This lesson is adaptable to the level of prior learning your students have.

- Identify uses of genetic technology.
- Evaluate the benefits and risks of gene editing.

# Genetic Technologies

## Starter activity: what do we know about gene editing

**(Approximately 5 - 10 minutes)**

This starter activity has two options, depending on your lesson capacity and style.

**Option 1**

Ask students to write down on a post-it note a question they would like to ask a scientist about genetic modification.

Stick the questions on the board trying to group them into categories such as 'knowledge'; 'ethical'; 'risks'; 'benefits' etc.

Collect and keep the questions for review after the tasks have been completed.

**Option 2**

Explain that modern genetic technologies would not be possible without all the previous discoveries.

Use the gene technology timeline card sort activity (see appendix) to construct a timeline of key historical events in the scientific development of gene technology.

## Activity A: how do we use gene editing?

**(Approximately 10 - 15 minutes)**

Watch a short animation What is gene editing? (4:22 mins). This animation introduces the basics of gene editing.

With the whole class, either note down or discuss the following questions:

- What is the definition of gene (or genetic) technologies?
    - Answer: Genetic technologies can be anything to do with understanding, making or adapting genetic material.
- What could genetic technologies be used for?

    Answers:

    - Improvements to human health e.g. leukaemia
    - Fixing the gene mutations that predispose to cancer
    - Enable new therapies for HIV
    - Edit the genes that cause hereditary disease
    - Make crops more nutritious, able to resist disease or grow in difficult conditions
    - Make animals more disease resistant

- Prevent mosquitoes from carrying malaria (already being done in Brazil by Oxbiotica based in Oxford)
- (genome editing enables faster, easier, cheaper and more precise changes to DNA)

- What are some ways in which genetic technologies could be misused?

  Answers:

  - Designer babies – choosing eye/hair colour (or gender)
  - Genetic modification of embryos would be passed on to descendants
  - Designer pets
  - More virulent srains of diseases (for weapons)

**Next, choose one of the options below that is most suitable for your lesson (Approximately 15 – 20 minutes)**

## Option 1:

**How would you use genetic technologies?**

Give small teams of students a case study (there are nine options to download from the Royal Society's website) and ask them to make a 1 minute 'Dragon's Den' pitch for their idea to the class which must include:

- Its purpose
- What its benefits would be
- What risks it might have

(Extension – for higher ability/more advanced classes they could come up with their own use of a genetic technology and research it)

## Option 2:

**Answering questions about GM crops and food**

Watch the short video What is Genetic Modification? (2:06 mins).

As the students to produce a summary of one question posed by the public. This can be done individually, in groups, as flipped learning or homework.

You might wish to point your students towards some additional support documentation. Use the Royal Society document GM Plants – Questions and Answers (to select questions relevant to GCSE specifications use pages 8, 12, 17, 22, 23, 25, 26, 27, 28, 33, 34, 37)

## Option3:

**Genetic technologies and human health – a flipped lesson or online research exercise**

Ask students to access and explore the Royal Society infographic Genetic technologies and humn health. They should answer all the interactive quizzes and watch the embedded videos

As the students to make notes on the information the infographic presents, answering the following, specific questions:

- What are the different types of genetic technology discussed in this infographic?
- What can each one be used for?
- What are the arguments in favour of and against each one?
- What are the alternatives to these genetic technology techniques?
- Why do most people think that these genetic technologies need to be controlled or regulated?
- Who do most people think should regulate these genetic technologies?

Ask the students to make their own, one page infographic summarising the answers to the above questions.

## Plenary:

**(Approximately 5 - 10 minutes)**

Use the Royal Society Jargon Buster document to quiz pupils on the correct meanings of relevant vocabulary.

Refer back to the starter questions and ask students which ones they can now answer.

## Generic, exam-style questions for assessment of learning

Please be aware that these are exemplar questions adapted from typical exam past papers and have not been standardised or approved by any exam board.

**Q.1. Rice is an important crop for human consumption. Modern rice has been developed by selective breeding of varieties that were originally wild. Compare and contrast the use of selective breeding and genetic engineering to produce modern varieties of rice.**

**(6 marks)**

Answers – indicative content:

- Both selective breeding and genetic engineering change the characteristics of the altered rice
- Both selective breeding and genetic engineering produce useful characteristics in the altered rice
- Selective breeding takes longer to produce the desired effect as the process has to be repeated many times (to enhance the desired characteristic)/genetic engineering only needs to be performed once (to produce a modified plant)
- Offspring of selectively bred plants may not show the desired enhancement/change (but those of genetically modified plants will)
- Genetically engineered plants/seeds will be more expensive to purchase
- Genetic engineering takes place in specialized labs/factories (with expensive equipment and highly skilled/educated/trained personnel)
- There may be objections from consumers to genetically engineered plants

(Please see generic exam board guidance on awarding of marks for this style of question)

**Q.2. Diabetes is a condition in which the human body is unable to regulate glucose levels. Glucose is usually controlled by the hormone insulin, produced in the pancreas. If a person's body cannot produce enough insulin or if the body's cells develop a resistance to it, the person will develop diabetes. People with diabetes may need to inject insulin into their bodies to control their glucose levels.**

**Until the 1920's there was no medical treatment for diabetes and sufferers often died but then medical researchers developed a technique to extract insulin from the pancreas of slaughtered beef cattle. In 1978 scientists developed a method to genetically modify the E.coli bacteria to produce insulin and this first went on commercial sale in 1982.**

**Discuss the advantages of producing insulin by genetic engineering and outline the concerns some people may have about this technique.**

(6 marks)

Answers – indicative content:

Advantages:

- Genetic engineering does not involve animals being slaughtered
- Some people may have religious or ethical objections to the use of (certain) animal products
- The quality of the insulin produced can be more closely controlled (as it does not rely on natural processes/variations)
- Genetic engineering allows (larger) quantities of insulin to be produced more quickly (as bacteria reproduce more quickly than large animals)
- Insulin can be produced more cheaply by genetic engineering (as it does not rely on the cost of breeding and raising large animals)

Concerns:

- Some people have objections to the genetic modification of organisms (for ethical or religious reasons)

- Insulin supplies and prices could be controlled by a few companies in the richer nations with access to genetic engineering technology

(Please see generic exam board guidance on awarding of marks for this style of question)

## Additional resources for teachers, background knowledge and extension work

Transcript of an address by the President of the Royal Society on Gene Technology to the American Association for the Advancement of Science.

Reports on the Royal Society's Gene Technologies public dialogue workshops and introductory workshop videos.

Information on international discussions of Gene Technologies including International Summits on Human Genome Editing and the Sackler Forum on Synthetic Biology.

## Resource: gene technology timeline card sort activity

Below are 39 cards, detailing historical events in the scientific development of gene technologies. Each card has a bold heading and a small amount of information to explain it. Some carry dates which can help when ordering the cards.

Cut out all the cards (one set per group) and shuffle.

These cards can be sorted into the correct chronological order (an interactive timeline solution is available to check against https://royalsociety.org/topics-policy/projects/genetic-technologies/what-are-genetic-technologies/). Alternatively, you could ask students to arrange them in order of most important (diamond 9s activity) and discuss their reasoning. This activity can promote discussion of the vocabulary, the techniques and ideas described. Note: the cards are currently in the correct order.

This is totally adaptable. Use it as a starter, plenary, revision activity. This can be done as a whole class activity, in groups or by individuals depending on factors such as the ability of the group.

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# UNDERSTANDING NATURAL SELECTION

After the famous second voyage of HMS Beagle, Charles Darwin wrote *On the Origin of Species*, which is the basis of our modern understanding of evolution.

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# DISCOVERING THE NATURE OF HERITABILITY

Gregor Mendel, an Austrian monk, carried out extensive experiments on peas, 'crossing' wrinkly and smooth peas. He was able to predict the appearance of the next generation of peas, and established basic principles of heredity.

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# X-RAY RADIATION IS FOUND TO INDUCE HERITABLE MUTATIONS

Hermann Muller generated mutations in fruit flies by means of X-ray radiation.

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# UV RADIATION IS FOUND TO INDUCE HERITABLE MUTATIONS

Lewis Stadler generated mutations using UV radiation on maize.

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# THE IMPORTANCE OF DNA FOR INHERITING CHARACTERISTICS (1)

By experimenting on bacteria, Avery, McLeod and McCarty provided the first clear suggestion that DNA, not protein, carries genetic information.

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# CHEMICALS ARE FOUND TO INDUCE HERITABLE MUTATIONS

Charlotte Auerbach and John Robson generated mutations in fruit flies using mustard gas.

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# THE IMPORTANCE OF DNA FOR INHERITING CHARACTERISTICS (2)

Hershey and Chase proved that it is the DNA in a phage (a type of virus that infects bacteria) that carries genetic information.

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# DISCOVERY OF THE STRUCTURE OF DNA

Jim Watson and Francis Crick used data collected by Rosalind Franklin and Raymond Gosling to discover the structure of DNA.

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# THE BIOLOGICAL AND TOXIN WEAPONS CONVENTION

Under the convention, signatories cannot, for example, produce DNA sequences that might be harmful, or use genetic technologies to create biological weapons.

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# FIRST GENETICALLY ENGINEERED ORGANISM

Considered ‘the birth of biotechnology’, Herbert Boyer and Stanley Cohen developed a method of removing genes from the DNA of one organism and putting them into the DNA of another.

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# FIRST GENETICALLY ENGINEERED ANIMAL

Frederick Sanger developed a new method of DNA sequencing (working out the precise order of DNA base pairs) and sequenced a whole genome for the first time: that of a virus called Φ-X174 that infects bacteria.

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# DEVELOPMENT OF IN VITRO FERTILISATION (IVF) IN HUMANS

Birth of Louise Brown, the first IVF baby, after work by Patrick Steptoe and Robert Edwards.

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# FIRST "TRANSGENIC" ANIMALS

Jon Gordon and Frank Ruddle published the first paper describing direct injection of DNA into the nucleus of fertilised mouse eggs and the birth of several mice that had incorporated the foreign DNA (the "transgene") into all their cells.

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# FIRST GENETICALLY ENGINEERED PHARMACEUTICAL

Genentech – the world's first biotechnology company - received approval to sell its genetically engineered pharmaceutical Humulin for human use as a medication for diabetes.

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# UK ANIMALS (SCIENTIFIC PROCEDURES) ACT 1986

The UK Animals Act details the criteria that must be met in order for scientists to modify genes in protected animals (all living animals with a backbone and all cephalopods such as octopus and squid).

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# FIRST PRECISE GENETIC ALTERATIONS MADE BY "GENE TARGETING" IN MICE

Oliver Smithies, Mario Capecchi, and Martin Evans shared the 2007 Nobel Prize in Medicine for their work developing 'knockout' mice – mice in which specific genes have been disabled.

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# ENVIRONMENTAL PROTECTION ACT 1990

The Environmental Protection Act defines genetically modified organisms (GMOs) in UK law for the first time.

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# HUMAN FERTILISATION AND EMBRYOLOGY ACT 1990

The Human Fertilisation and Embryology Act sets out the rules and guidelines for any research – including genome editing research – involving human embryos and germ cells (cells that produce sperm or eggs).

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# FIRST GENETICALLY MODIFIED CROP FOR HUMAN CONSUMPTION

The first genetically modified crop was approved for sale in the US: the Flavr Savr tomato. It lasted longer on the shelf, but no one really liked the taste.

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# FIRST HERBICIDE RESISTANT CROP

The US agribusiness Monsanto began selling seeds of its first herbicide resistant crop, the Roundup Ready soybean. These seeds are altered to produce plants that are resistant to a key ingredient of many herbicides: glyphosate. They are still sold today.

# FIRST CLONE PRODUCED FROM AN ADULT ANIMAL

Dolly the sheep was the first animal to be cloned by taking the nucleus from an adult cell, transferring this into an egg from which the nucleus had been removed, and implanting this egg into a surrogate mother.

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# ÁRPÁD PUSZTAI RAISES QUESTIONS OVER THE SAFETY OF GM FOOD

Árpád Pusztai, a scientist working at the Rowett Institute in Scotland, conducted an experiment feeding GM potatoes to rats and comparing their development with rats fed on non-GM potatoes (the control group). Controversy ensued.

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# CARTAGENA PROTOCOL ON BIOSAFETY

The Cartagena Protocol on Biosafety to the Convention on Biological Diversity regulates the spread, handling and transfer of GMOs across national borders and includes regulations designed to minimise possible negative impacts of genetic technologies on biodiversity.

# THE GENETICALLY MODIFIED ORGANISMS (DELIBERATE RELEASE) REGULATIONS 2002

These regulations set out the procedure for scrutinising and approving applications for the release of GMOs from controlled settings to uncontrolled settings.

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# FIRST USE OF ZINC-FINGER NUCLEASES TO EDIT A GENOME

Scientists at the University of Utah pioneered a new technique of genome editing that used zinc-finger nucleases (ZFNs). They used their technique to cut out target sections of DNA from fruit flies.

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# FIRST TIME THE HUMAN GENOME IS SEQUENCED

The Human Genome Project, begun in 1990, was completed, having sequenced 99% of the 3.2 billion letters (A, C, G, T) that in a specific order carry the instructions to make us distinct from other species as well as from each other.

# REGULATION 1829/2003/EC

It describes the current procedure for evaluating and authorising GM foods.

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# THE HUMAN TISSUE ACT 2004

The Human Tissue Act regulates all research and clinical practices in the UK that involve human bodies.

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# THE HUMAN TISSUE (QUALITY AND SAFETY FOR HUMAN APPLICATION) REGULATIONS 2007

These regulations set the standards that must be met by any tissues or cells – including those that have been genome edited – that will be used to treat patients.

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# FIRST USE OF GENETIC ENGINEERING TO TARGET CARRIERS OF DISEASE

A British company, Oxitec, ran its first big field trial in Brazil that aimed to use genetic engineering to help limit the spread of the dengue fever disease.

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# THE NAGOYA PROTOCOL

The Nagoya Protocol obliges signatories to make sure genetic resources benefit both their providers and their users. For example, some plants have genetic properties that make them useful in medicines and can only be found in certain places. Under the Nagoya Protocol, some of the benefit to companies making medicines from these plants must be shared with the people of the place from which the plants came.

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# FIRST USE OF TALENS TO EDIT A HUMAN GENOME

Transcription activator-like effector nucleases (TALENs) are used to make small deletions and edits within human genes.

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# FIRST USE OF CRISPR-CAS9 TO EDIT A MAMMALIAN GENOME

CRISPR is a molecular system based on RNA that guides a protein called Cas9 to a specific target sequence of DNA. Cas9 then cuts the DNA at that site. This is an efficient way to make a change in a gene. Alternatively, if new DNA (a DNA template) is introduced at the same time, it can replace the DNA sequence that was previously there.

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# THE GENETICALLY MODIFIED ORGANISMS (CONTAINED USE) REGULATIONS 2014

These regulate the genetic modification of organisms in controlled settings, to ensure protection for humans and the environment.

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# FIRST LIFE SAVED BY GENOME EDITING

Layla, a patient at Great Ormond Street Hospital was cured of acute lymphoblastic leukaemia. This was made possible by being able to genetically edit donor T-Cells (a type of immune cell) using TALENs.

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# GENOME EDITING OF HUMAN EMBRYOS

The CRISPR-Cas9 system was recently used to remove a genetic predisposition to heart disease in human embryos.

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# FIRST GENETICALLY ENGINEERED ANIMAL FOR HUMAN CONSUMPTION

AquaBounty Technologies' genetically engineered salmon went on sale to customers in Canada.

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# QUESTIONS RAISED ABOUT WHETHER CRISPR LEADS TO UNINTENDED CHANGES IN THE GENOME

Editing genomes using CRISPR leads to changes in the genome at places other than the target gene, referred to as off-target effects. Researchers published a paper suggesting that CRISPR causes many more off-target effects than had previously been identified.

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# THE FUTURE - FIRST SYNTHETIC COMPLEX ORGANISM

The Synthetic Yeast Genome Project is currently in the process of building a yeast genome by shuffling around genes within artificial chromosomes. Whilst yeast might not sound very complex, it has the same specialised structures (organelles), and a nucleus to contain its DNA as human cells and all other plants, animals and fungi do. Previously, such work had only been carried out using simpler organisms like bacteria.