Genes and Genetic Engineering
Genes and Genetic Engineering

Contents

- Chromosomes, genes and DNA
- What is genetic engineering?
- Changing the genetic code
- Designer babies
- Summary activities
Passing on characteristics

What makes this baby human? What determines its gender?

In all living things, characteristics are passed on in the chromosomes that offspring inherit from their parents.

This means that all human characteristics must be something to do with chromosomes. Where are chromosomes found?
What do chromosomes look like?

Chromosomes are long strands of genetic information located in the nuclei of cells.

Chromosomes are most visible during cell division when they replicate and look like this…
Most cells of the body contain chromosomes in matching pairs. These pairs are called **homologous chromosomes**.

Where do homologous chromosomes come from?

- chromosome from female parent
- chromosome from male parent

Each pair of homologous chromosomes contains one chromosome that has been inherited from each parent.
Most human body cells contain **46 chromosomes**. How many pairs of homologous chromosomes is this?

**23 pairs of chromosomes**

You inherit **half** of your chromosomes from your mother and **half** from your father.

Other species have a different number of pairs of chromosomes; for example:

- **fruit fly = 4 pairs**
- **cat = 19 pairs**
- **maize = 10 pairs**
- **chicken = 39 pairs**

All chromosomes contain many different **genes**.
Genes are the **units of inheritance**. Organisms differ because they have different genes.

- humans have human genes
- gerbils have gerbil genes
- bananas have (yes, you’ve guessed it) banana genes!
Where are genes located?

- body
- tissues
- cells
- nucleus
- chromosomes
- genes

What is the body made of?

How and where is genetic information carried in the body?

Click on the face or use the menu to find out more.
Chromosomes and their genes are made of a molecule called **DNA**.

DNA stands for **deoxyribonucleic acid**.

Each chromosome is a very long molecule of tightly coiled DNA.

DNA molecules carry the code that controls what cells are made of and what they do.

Which part of a DNA molecule holds this information?
What is the structure of DNA?

Click on the labels to find out about the structure of DNA.
DNA and base pairs

The double helix ‘ladder’ of a DNA molecule is held together by ‘rungs’ made from pairs of chemicals called **bases**.

There are four types of bases, and they are usually identified by their initials.

- **A** = adenine
- **C** = cytosine
- **G** = guanine
- **T** = thymine

How do you think the four bases are paired?
Base pairs hold the two strands of the DNA helix together. The rules for base pairing are…

‘A’ always pairs with ‘T’

‘C’ always pairs with ‘G’

There are millions of base pairs in a DNA molecule, and they **always** follow these rules.

It is the sequence of these bases along a DNA molecule that forms the **genetic code** – it’s that simple!
Proteins are made of long chains of **amino acids**. There are 20 different types of amino acid from which to make proteins.

What happens if the amino acids are in a different order?

Different combinations of amino acids make different proteins.
How does the genetic code work?

A three-base sequence codes for each amino acid.
Making proteins

Genes don’t actually make proteins – they just contain the instructions on how to make them.

DNA stays in the nucleus but proteins are built in the cell’s cytoplasm.

Each gene contains a different sequence of bases.
If a gene changes, the cell makes a different protein.

Do cells use all of their genes, all the time?

No – different cells need different proteins at different times. An average cell makes 15,000 proteins: 2,000 in bulk and the rest in minute quantities.
<table>
<thead>
<tr>
<th>Genetic jargon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>chromosome</td>
<td>the type of molecule that genes code for</td>
</tr>
<tr>
<td>DNA</td>
<td>a section of DNA that codes for a protein</td>
</tr>
<tr>
<td>gene</td>
<td>a long, tightly-coiled molecule of DNA</td>
</tr>
<tr>
<td>bases</td>
<td>the small molecules that join to make proteins</td>
</tr>
<tr>
<td>protein</td>
<td>the chemicals in DNA that carry the genetic code</td>
</tr>
<tr>
<td>amino acid</td>
<td>the molecule that genes are made of</td>
</tr>
</tbody>
</table>
Genes and Genetic Engineering

- Chromosomes, genes and DNA
- What is genetic engineering?
- Changing the genetic code
- Designer babies
- Summary activities
Living things naturally create useful products.

**Genetic engineering** can be used to make living things produce other, more valuable, products.

For example, yeast naturally converts sugar into carbon dioxide and alcohol, and is used in baking and brewing.

Yeast can also be genetically engineered to produce vaccines for human diseases.

**Genetic engineering is about changing the DNA of a living thing to change its characteristics.**
Genetic engineering involves four main stages.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Select the product or characteristic needed</td>
<td>antigen for hepatitis B</td>
</tr>
<tr>
<td>2. Isolate genes from specialist cells</td>
<td>hepatitis B virus</td>
</tr>
<tr>
<td>3. Insert the genes into target cells</td>
<td>yeast</td>
</tr>
<tr>
<td>4. Replicate the new organism</td>
<td>yeast culture in fermenters</td>
</tr>
</tbody>
</table>

What is the product in this example? Hepatitis B vaccine.
Crops can be given extra genes for new and useful characteristics. They are genetically modified (GM).

What characteristics might be useful in crops?

- pest resistance
- frost resistance
- disease resistance
- herbicide resistance
- drought resistance
- longer shelf life
Potatoes can be genetically modified so they are toxic to pests, such as the Colorado beetle.

The gene for a powerful bacterial toxin is added to the potato plant.

If the beetle tries to eat the potato plant, it is killed by the toxin.

What benefits might this have for the environment?
Frost-resistant crops

Crops can be genetically modified so they are resistant to adverse environmental conditions.

For example, lettuces could be genetically modified to be resistant to frost.

Why are some people against the development and use of GM crops?
Rice can be genetically modified to make beta-carotene, a substance that is converted into vitamin A in the body.

The colour of the rice is an indication of how much more beta-carotene it contains.

The GM rice is called ‘Golden Rice’ and is being developed to help fight vitamin A deficiency and blindness in developing countries.
Should GM crops be allowed?

What are the advantages and disadvantages of GM crops?

**advantages**

| GM crops would need fewer chemical sprays |

**disadvantages**
Early genetic engineering

People have been doing a simple form of genetic engineering for thousands of years. This is called **selective breeding**.

Selective breeding, or **artificial selection**, is a process where people try and improve plants and animals by selecting and breeding only those that have desirable characteristics.

For example, a farmer might choose the two largest cattle in his herd and breed them together so that the offspring will be even bigger and produce more meat.
Examples of selective breeding

Many plants and animals are selectively bred to improve their characteristics. What are some examples?

- Breeding sheep to produce more wool.
- Breeding wheat to produce more grain.
- Breeding tomatoes to have more flavour.
- Breeding racing horses to become faster.
- Breeding dogs to obtain unique characteristics (e.g. bulldog, greyhound, Chihuahua).
Genes and Genetic Engineering

- Chromosomes, genes and DNA
- What is genetic engineering?
- Changing the genetic code
- Designer babies
- Summary activities
Bacteria are often genetically engineered to produce useful chemicals because their DNA is loose in the cytoplasm, making it easy to modify. They also grow and replicate quickly.

A new gene can be inserted into the plasmid and the bacteria then produce the protein for which the gene codes.
A virus cannot read its own genes but it can make a host cell copy them and make the proteins.

This virus is a **bacteriophage**. It infects bacteria by injecting its genetic material down a special tube.

Why are viruses useful in genetic engineering?
Genetically-engineered micro-organisms, such as bacteria and yeast, can easily be replicated on a large scale.

Tanks called **fermenters** or **bioreactors** are used. These enable the micro-organisms to be grown, or ‘cultured’, at optimum pH, temperature and nutrient levels.

The product can be continuously removed and purified.
How can bacteria produce human insulin?

Bacteria can be genetically engineered to produce human insulin.

Click "start" to find out how.
Genetically-engineering bacteria

What is the sequence of events in making bacteria produce a human protein?

1. The gene for the human protein is identified.
2. The modified plasmid is inserted into the bacterium.
3. The gene is inserted into the plasmid.
4. The bacteria produce the required protein.
5. The bacterium is added to a fermenter and replicates.
6. A bacterial plasmid is cut open with enzymes.
7. The gene is removed with enzymes.
Alternatives to bacteria

Genetically-engineered bacteria are unable to make proteins that are identical to those found naturally in humans, despite having human DNA.

This is because the way in which bacteria make proteins is different to the way that mammals make proteins.

A better way is to use genetically-engineered mammalian cells grown in industrial bioreactors. These produce proteins that are identical to the ones found in humans.
How can animals be genetically engineered to help humans?
Foreign DNA, including DNA from humans, can be inserted into animals. This is called transgenics.

The protein encoded by the DNA can then be produced in a specific tissue of the transgenic animal at a specific time.

This method produces higher levels of antibody, more easily and cheaply, than by using genetically-engineered bacteria or mammalian cells.

What is transgenics?
Transgenic goats

For example, the gene for a human antibody can be introduced into goats.

Additional controlling DNA is also introduced, so the human antibody is only produced in the goat’s mammary gland at a certain time.

The antibody is then expressed in the goat’s milk, where it can be purified and used to treat diseases.
Which came first?

The eggs of this transgenic chicken contain a human antibody that could one day help to treat skin cancer.

What advantages does this method of producing antibodies have?

Do you think it is right for animals to be genetically engineered to help treat human diseases?
Genes and Genetic Engineering

- Chromosomes, genes and DNA
- What is genetic engineering?
- Changing the genetic code
- Designer babies
- Summary activities
This boy got half of his genes from his mother and half from his father.

It’s completely random which ones he received. He may have his parents’ best characteristics or their worst.

Are there any characteristics you wouldn’t want your children to inherit?
Sally has breathing difficulties. Her genes gave her cystic fibrosis. She risks repeated chest infections and lung damage.

Molly could be fine, but one of her genes puts her at risk. She has a high chance of getting breast cancer. Some women with the gene choose to have their breasts removed.
Total control of a person’s genes only exists in science fiction, but it is currently possible to:

- screen embryos for genetic diseases – this is called pre-implantation genetic diagnosis (PGD)
- screen embryos for the right number of chromosomes – this is called pre-implantation genetic screening (PGS)
- screen embryos for their sex – some genetic diseases only affect boys, and in the UK, parents at risk of having a baby with a disease can choose to have a girl
- repair body cells containing faulty DNA by gene therapy.

In the future, it may be possible to replace an embryo’s faulty DNA. This is germ-line therapy and is illegal in humans.
Pre-implantation genetic diagnosis

Aborting an embryo can be very distressing, even if it would have been born with a disease. PGD removes this problem.

1. The woman’s eggs are fertilized in a ‘test tube’.

2. The embryos develop and one cell is removed from each to be tested for certain genetic diseases.

3. Up to two healthy embryos are implanted in the mother’s uterus.
Imagine your daughter has a rare genetic disease. An injection of bone marrow cells will save her but the donor must be an exact match.

Donors are hard to find. Your best hope is to make your next child a match.

You will need to produce a selection of embryos by **IVF**. The best embryo will become your next child. A few cells from its umbilical cord will save the daughter you already have.

More and more couples are asking for this treatment but should it be allowed?
Should parents be allowed to have saviour siblings?

These people have been asked if they think that parents should be allowed to choose the genetic make-up of their next child to save the life of an existing child with a serious illness.

Click on each person to find out their opinion.
What is gene therapy?

Children with faulty immune systems have been cured by adding genes to their bone marrow cells. This is called gene therapy.

1. A ‘healthy’ version of the faulty gene is cut from normal DNA and copied.

2. The gene is added to a harmless virus.

3. The virus carries the gene into the patient’s cells, where the healthy gene is released.

4. The patient’s cells can then make the correct product of the gene. The patient is then cured.
Genes and Genetic Engineering

- Chromosomes, genes and DNA
- What is genetic engineering?
- Changing the genetic code
- Designer babies
- Summary activities
Glossary

- **base** – The chemical in DNA that forms the basis of the genetic code.
- **chromosome** – A long molecule of tightly coiled DNA found in the nucleus of most cells.
- **DNA** – The molecule that contains the genetic code.
- **gene** – The part of a chromosome that codes for a protein.
- **gene therapy** – Curing a genetic disease by replacing a faulty gene with a ‘healthy’ version.
- **genetic engineering** – Altering the characteristics of an organism by changing its genetic code.
- **transgenic** – An organism that contains DNA from a different type of organism.
How quickly can you unscramble anagrams of words about genes and genetic engineering?
Do you have the general knowledge for this quiz on genes and genetic engineering?