edexcel

INTERNATIONAL GCSE

Biology (2017)

TOPIC GUIDE:

Genetic modification and cloning

Pearson Edexcel International GCSE in Science

Pearson

Introduction to the teaching of genetic modification and cloning

Specification

In the 2011 Edexcel International GCSE specification, the section covering genetic modification and cloning is set out in the following way:

Students will be assessed on their ability to:

5.12 describe the use of restriction enzymes to cut DNA at specific sites and ligase enzymes to join pieces of DNA together

5.13 describe how plasmids and viruses can act as vectors, which take up pieces of DNA, then insert this recombinant DNA into other cells

5.14 understand that large amounts of human insulin can be manufactured from genetically modified bacteria that are grown in a fermenter

5.15 evaluate the potential for using genetically modified plants to improve food production (illustrated by plants with improved resistance to pests)

5.16 understand that the term 'transgenic' means the transfer of genetic material from one species to a different species.

5.17 describe the process of micropropagation (tissue culture) in which small pieces of plants (explants) are grown in vitro using nutrient media

5.18 understand how micropropagation can be used to produce commercial quantities of identical plants (clones) with desirable characteristics

5.19 describe the stages in the production of cloned mammals involving the introduction of a diploid nucleus from a mature cell into an enucleated egg cell, illustrated by Dolly the sheep

5.20 evaluate the potential for using cloned transgenic animals, for example to produce commercial quantities of human antibodies or organs for transplantation.

In the revised 2017 Edexcel International GCSE specification, this section is set out in the following way:

Students should:

5.12 understand how restriction enzymes are used to cut DNA at specific sites and ligase enzymes are used to join pieces of DNA together

5.13 understand how plasmids and viruses can act as vectors, which take up pieces of DNA, and then insert this recombinant DNA into other cells

5.14 understand how large amounts of human insulin can be manufactured from genetically modified bacteria that are grown in a fermenter

5.15 understand how genetically modified plants can be used to improve food production

5.16 understand that the term transgenic means the transfer of genetic material from one species to a different species

5.17B describe the process of micropropagation (tissue culture) in which explants are grown in vitro

5.18B understand how micropropagation can be used to produce commercial quantities of genetically identical plants with desirable characteristics

5.19B describe the stages in the production of cloned mammals involving the introduction of a diploid nucleus from a mature cell into an enucleated egg cell, illustrated by Dolly the sheep

5.20B understand how cloned transgenic animals can be used to produce human proteins

Summary of the changes

- 5.15 has been altered from specifically expecting students to understand the reasons for producing pest resistant crops to a general idea of improved food production.
- 5.17 has been altered slightly – the wording is more general as students are still expected to understand all the steps that are taken when carrying out micropropagation.
- 5.20 has been altered to a more general understanding that cloned animals can be used to produce a range of human proteins rather than human antibodies or transplant organs. Students will still be expected to be familiar with a range of uses.
- Points 5.17 and 5.20 are specific to Biology International GCSE and not the Science (Double Award) specification – hence being in bold type and with a specification reference ending with a ‘B’.

Genetic engineering (genetic modification)

It is beyond the scope of this guidance document to provide the full details of how genetic engineering is carried out.

Key elements that students need to understand:

- There is a lot of key vocabulary in this topic that may be challenging for students with English as a second language.

> **TEACHING TIP**
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> - Producing a glossary of key terms can help students.
> - The key terms include: vector, plasmid, restriction enzyme, ligase, sticky ends, recombinant DNA and transgenic.
> - For students who find this challenging, this can be provided as a sentence sorting activity that the teacher can check. The terms should be revisited several times.

- It is important that students understand the differences between the functions of restriction enzymes and ligase, and how genes are inserted into plasmid vectors.

> **TEACHING TIP**
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> - Building craft models can help student understanding and gives a kinaesthetic approach to the subject.
> - Pipe cleaners of different colours make useful circular plasmids and pieces of DNA which can be cut with scissors (restriction enzymes) and glued together with modelling clay (ligase). If pipe cleaners are not available, different coloured string (or wool) can be used.

- Students are expected to know that genetically-engineered bacteria have been created to produce human insulin and that the bacteria are grown in fermenters (link to specification reference 5.8). Other examples, such as the production of growth hormone, can be researched by students. Although not stated on the specification, it improves understanding if students appreciate the benefits of producing insulin by using bacteria. Benefits include:
    - low price
    - lower dosage needed than using insulin from animals
    - fewer ethical objections than using insulin derived from animals
    - less risk of allergic reaction than using insulin derived from animals.

- Students are expected to understand how genetic engineering can be used to improve food production. There is no specific example stated in the specification but students should have an appreciation of some of the different possibilities as they may be used as stimulus material. It is also useful in terms of developing transferable skills if students consider advantages and disadvantages of genetically-modified crops, and some of the measures put in place to prevent their spread in the wild.

  Students could investigate one or two of the examples on the following page:

- **Pest-resistant crops.** Cotton, maize and soya make up the majority of the pest-resistant crops that are currently used. If crops are made pest-resistant, yields will increase, as less will be consumed by pests such as insects. In developing nations, where pest plagues can wipe out large numbers of crops, they could reduce the risk of food shortages. They pose a risk if they travel into the wild where they could cause the death of non-pest organisms, affecting food chains and outcompeting native plants. There may also be a risk that pests develop resistance to the pesticides.
- **Herbicide-resistant crops.** Soya beans and maize (along with other crops) have been genetically modified to be resistant to herbicides. Removing weeds is very time-consuming and labour intensive. Herbicide-resistant crops enable fields of crops to be sprayed with large quantities of herbicide to kill the weeds. The crop plants survive, have less competition and so have a higher yield (with reduced labour costs). There are reports that the intense use of herbicides is leading to resistant 'superweeds' and that there are negative effects on food chains in areas around crop fields.
- **Environmentally-resistant crops.** Crops which are resistant to drought, salt and frost are being developed. They could help provide increased food in areas which were previously unsuitable for farming, helping reduce famine in developing nations. But they could lead to loss of ecosystems for some species of plants or animals, as more land is turned over to farming.
- **Altered nutrition.** Crops with increased vitamin content, such as 'Golden rice', which has additional vitamin A, are under development. 'Golden rice' could be used to treat vitamin A deficiency, a major cause of eye disease and blindness in children in developing nations. Soya beans with 'healthier' ratios of fatty acids are also being developed.
- **Pharma crops.** Crops that produce medicine are being developed. There are crops that produce antibodies, vaccines and other therapeutic proteins. They would be a cheap source of protein drugs that are often obtained from animals. This could reduce the risk of the transfer of diseases from animals to humans, and improve animal welfare.
- **Improved crops**. Crops with a longer shelf life, higher yield and better flavour are all being considered. A range of different types of these crops are under development. They are principally to satisfy consumer demand but could also bring down food prices.

- Genetically-modified crops must undergo stringent testing before being used commercially. There must be no risk of pollen, seeds or plants escaping from the fields. They are kept in high security areas where wind pollination and insect pollination cannot occur until they are proven to pose no risk to the environment.

- Students could hold a debate about whether the use of genetically-modified crops should be allowed. Data should be given to them to help support each side in the debate. There are many websites covering both sides of the debate – care should be taken to ensure that they are reputable and provide a balanced argument, for example:
  - https://www.abpischools.org.uk/topic/genetic-engineering/1/1
  - http://www.genewatch.org/index-396405

- For students who find the topic challenging, a card-sorting exercise, with examples of genetic engineering along with statements of uses and risks, can be used.

Plant micropropagation and animal cloning

It is beyond the scope of this document to describe all the steps involved in micropropagation and animal cloning.

Key elements that students need to understand are as follows:

- All the stages in micropropagation of plants need to be considered.

> **TEACHING TIP**
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> - There is a lot of key vocabulary and students, particularly those with English as a second language, benefit from producing a glossary of terms (and relevance to micropropagation).
> - Terms include: explant, clone, sterile, nutrient agar, growth factors, humidity, photosynthesis.

- A similar glossary of terms can be used when teaching animal cloning.
  Key terms include: enucleated egg cell, diploid nucleus, electric shock, mitosis, embryo, surrogate mother, uterus.

> **TEACHING TIP**
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> - Students who find the topic of animal cloning challenging can model the transfer of a nucleus from the body cell of one sheep into the empty egg from a different sheep, and the transfer of the embryo into the uterus of a third sheep.
> - A kinaesthetic approach often helps students understand the transfer of genetic material.

- Both micropropagation and animal cloning occur as a sequence of events.

> **TEACHING TIP**
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> - Card-sorting exercises can be used.
> - Students can be given cards with each of the key stages and then sort them into the correct order.
> - This is particularly effective for students who find the topic challenging.

- Cauliflower plants can be cloned – this activity reinforces the topic on cell differentiation and stem cells. Many protocols are available, such as: http://www.saps.org.uk/secondary/teaching-resources/706-micropropagation-cloning-cauliflowers.
  If it is not possible to maintain sterile conditions to carry out cauliflower cloning, a simulation can be carried out using sterile agar blocks and any plant. Even though this may not result in the production of cloned plants, it helps student understanding to carry out a simulation of the techniques.

- The new specification does not give specific examples of uses of animal cloning. Students should investigate two or three different examples and understand that cloning is often used alongside genetic engineering. In particular, transgenic animals that are engineered to produce human proteins can then be cloned to make multiple genetically identical copies.

  Examples of animal cloning include:
  - Dolly the sheep – the first mammal to be cloned using an adult nucleus.
  - Cattle have been produced that make human antibodies that can be used to treat infections.
  - Cattle have been produced that make humanised milk. They were genetically engineered to release human proteins such as lysozyme enzyme into their milk.
  - Sheep that produce human-alpha-1-antitrypsin in their milk have been created. This protein is used to treat a lung disease called hereditary emphysema.
  - Pigs have been genetically engineered with human antigens on their cells. These animals could be used for transplant organs that would not be rejected by the human immune system.

- There are opportunities for extension with this topic.

TEACHING TIP

- Students could investigate other potential uses of cloning, such as making cryozoos to preserve cells from endangered species, making genetically-modified food organisms e.g. AquAdvantage salmon, and the cloning of pet cats and dogs.
- Students could also debate the values and risks of cloning.
- The following video could lead a discussion about whether a cloned pet would have the same behaviours and temperament as the original pet: https://www.youtube.com/watch?v=DmHYUvmiXQI
- The potential for human cloning could be investigated and linked to statement **2.6B** about the uses of stem cells in medicine.

- Ethical issues can be studied as part of this topic.

TEACHING TIP

- The effects of plant monoculture could be debated, such as the effect of Panama fungus on banana plants.
- Aspects of animal cloning, such as animal welfare issues and the low efficiency of the process can also be considered.

A note for teachers

Note that this Guide is intended to support teachers of International GCSE Biology and provides subject coverage beyond the demands of the specification.