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VCE Biology ¾

CRISPR Cas9 & Bioethics [0.7]

Workshop

Section A: Recap

Active Recall: What is the purpose of CRISPR-Cas9 in bacteria?

Active Recall: What is the purpose of CRISPR-Cas9 in gene editing?

Active Recall: Name and define the 5 "concepts" of bioethics in the study design.

Active Recall: Name and define the 3 "approaches" to bioethics in the study design.

Section B: Multiple Choice Questions (19 Marks)

Question 1 (1 mark)

CRISPR-Cas9 differs from traditional restriction enzymes, such as EcoRII:

A. It creates both sticky and blunt ends.

B. It does not have a set recognition site.

C. The recognition site is palindromic.

D. It can cut any type of nucleic acid.

Question 2 (1 mark)

What is the role of CRISPR-Cas9 in prokaryotes?

A. It repairs damaged DNA within the cell.

B. It acts as an adaptive immune defence by targeting viral DNA.

C. It enhances the efficiency of protein synthesis in bacteria.

D. It integrates plasmid DNA into the bacterial genome.

Question 3 (1 mark)

Which of the following best describes how CRISPR-Cas9 is used to create a "gene knockout"?

A. A gene is silenced by introducing a mutation into its promoter region.

B. A gene is completely removed from the genome by Cas9 cutting it at multiple locations.

C. Cas9 cuts the DNA at a specific site, leading to errors during repair, which inactivate the gene.

D. Cas9 binds to the PAM sequence and blocks transcription of the gene.

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Question 4 (1 mark)

Why is the PAM sequence essential in CRISPR-Cas9 gene editing?

A. It stabilises the sgRNA-Cas9 complex.

B. It serves as a recognition site for the Cas9 protein to bind and cut the DNA.

C. It is part of the sgRNA sequence that guides Cas9 to the target site.

D. It allows the insertion of foreign DNA into the genome.

Question 5 (1 mark)

Which of the following represents an ethical concern in the use of CRISPR-Cas9 technology?

A. The potential to accidentally modify off-target genes.

B. The lack of scalability in CRISPR-Cas9 applications.

C. The inability to design sgRNA for human genomes.

D. The reduction of the PAM sequence's efficiency during editing.

Question 6 (1 mark)

A scientist is trying to use CRISPR-Cas9 to target a specific gene in eukaryotic cells. Despite designing a guide RNA complementary to the gene, the experiment fails repeatedly. Which of the following is the most likely explanation, and how should the scientist proceed?

A. The guide RNA is defective; the scientist should use a random RNA sequence to improve binding.

B. The PAM sequence near the target DNA is missing; the scientist should redesign the target sequence to include an adjacent PAM.

C. The Cas9 enzyme is ineffective in eukaryotic cells; the scientist should use an alternative editing tool.

D. The DNA repair mechanisms are too efficient; the scientists should inhibit repair pathways entirely.

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Question 7 (1 mark)

CRISPR-Cas9 technology has been used to improve the efficiency of photosynthesis in crop plants. There are two main methods that successfully change the genome of a plant.

- Method 1 aims to disable an undesired gene in a plant, which may lead to a commercial advantage.
- Method 2 aims to insert a gene into a plant without disrupting other genes.

Which one of the following assumptions could be made about methods 1 and 2?

A. Method 1 is easier than method 2 as it only involves cutting DNA, whereas method 2 involves both cutting and pasting DNA.

B. Method 2 is faster to complete than method 1.

C. Method 1 is easier than method 2 as it involves cutting RNA, which has only one nucleic acid strand, whereas method 2 involves cutting DNA, which has two nucleic acid strands.

D. Methods 1 and 2 are equally viable for future use, but CRISPR-Cas9 technology will never be widely implemented due to the ethical concept of non-maleficence.

Question 8 (1 mark)

A major concern with the CRISPR-Cas9 system is the possibility of off-target mutations which can lead to unintended genetic alterations. Which of the following strategies could be employed to minimise off-target effects in CRISPR-Cas9 applications?

A. Increasing the length of the guide RNA (gRNA) for higher specificity.

B. Using a CRISPR-Cas9 system with a high-fidelity variant of the Cas9 enzyme.

C. Applying whole-genome sequencing to identify potential off-target sites before the procedure.

D. All of the above.

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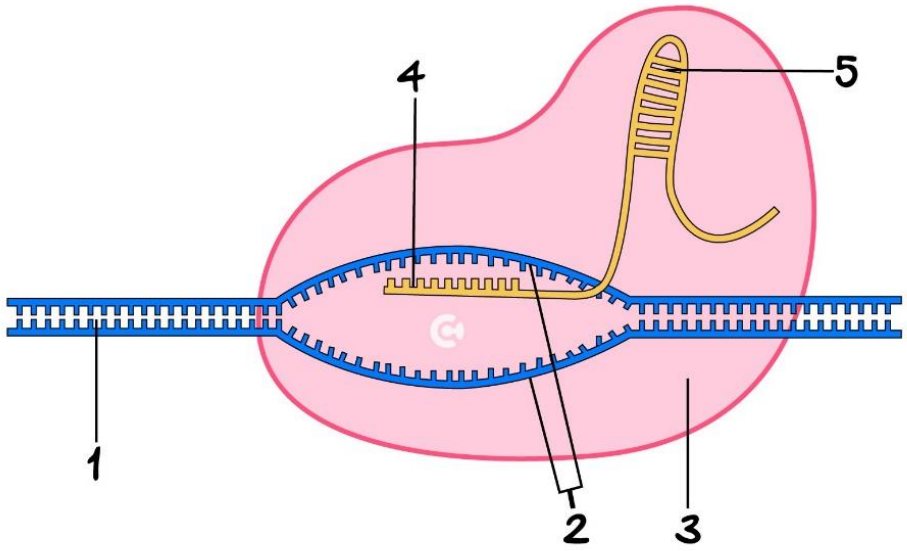
Question 9 (1 mark)

The diagram below shows the CRISPR-Cas9 complex. This is a new technology that could be superior to other gene editing technologies.



What do the components labelled **1-5** in the diagram above represent?

	1	2	3	4	5
A.	DNA	RNA	Cas9	Cutting Sites	RNA Spacer
B.	RNA	Cas9	Cutting Sites	RNA Spacer	Scaffold RNA
C.	RNA	Cutting Sites	Cas9	Scaffold RNA	RNA Spacer
D.	DNA	Cutting Sites	Cas9	RNA Spacer	Scaffold RNA

Question 10 (1 mark)

Once a specific section of DNA has been cleaved:

A. New genes can be added between the cut sections of the DNA.

B. New genes can be added to the guide RNA.

C. Another enzyme in the cytosol will join the fragments back together.

D. The CRISPR-Cas9 complex is removed from the cell.

Question 11 (1 mark)

The concept of risk minimisation and maximisation of benefit best describes which ethical principle?

A. Integrity

B. Justice

C. Respect

D. Beneficence

Question 12 (1 mark)

As the number and severity of droughts increase in Australia, scientists are developing methods to produce transgenic plants that will have an increased survival rate. Identify which one of the transgenic plants below would have an increased chance of surviving in this changing environment.

A. Rice with an introduced gene for increasing water efficiency.

B. Cotton with an introduced gene coding for herbicide resistance.

C. Squash with an introduced gene coding for mosaic virus resistance.

D. Bread wheat that was selected for its ability to grow in dry regions.

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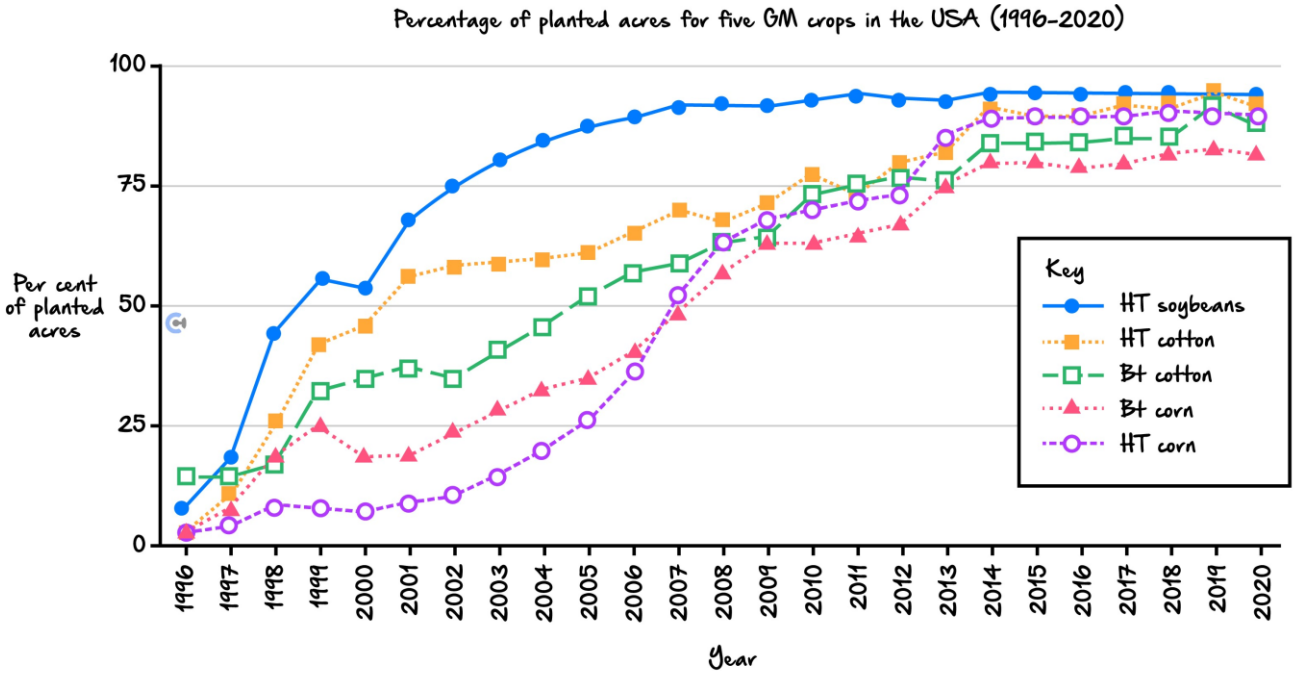
Question 13 (1 mark)

The extent to which GM crops were planted in the United States of America (USA) between 1996 and 2020 was investigated. The percentage of planted acres of GM crops out of the total planted acres of crops for five different types of crops- HT soybeans, HT cotton, Bt cotton, Bt corn and HT corn - is presented in the graph below. 'HT' indicates herbicide-tolerant varieties and 'Bt' indicates insect-resistant varieties.



Source: adapted from USDA, Economic Research Service using data from the 2002 ERS report 'Adoptaion of Bioengineeered Crops' (AER-810) for the years 1996-1999 and National Agricultural Statistics Service, (annual) June Agricultural Survey for the years 2000-2020, <www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx>

From the graph above, it can be concluded that:

A. In 1996, the percentage of planted acres of HT cotton crops was greater than 10 per cent.

B. In 2007, the percentage of planted acres of Bt corn crops was greater than the percentage of planted acres of HT corn crops.

C. In 2013, the percentage of planted acres of Bt cotton crops and the percentage of planted acres of Bt corn crops were similar.

D. In 2020, the percentage of planted acres of HT soybean crops was the lowest that it had been for the duration of the investigation.

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Question 14 (1 mark)

Browning in apples is caused by the enzyme polyphenol oxidase (PPO). The gene that codes for PPO production is activated by stress, such as by bumping or cutting an apple. A strain of apples has been produced in which the PPO gene has been silenced, which prevents the apples from going brown.

It would be reasonable to state that these apples are:

A. The result of selective breeding.

B. Genetically modified and transgenic.

C. Genetically modified but not transgenic.

D. Transgenic but not genetically modified.

Question 15 (1 mark)

Genetically modified organisms (GMOs) that are easier to produce through farming are becoming more available around the world.

Examples of such farmed organisms include:

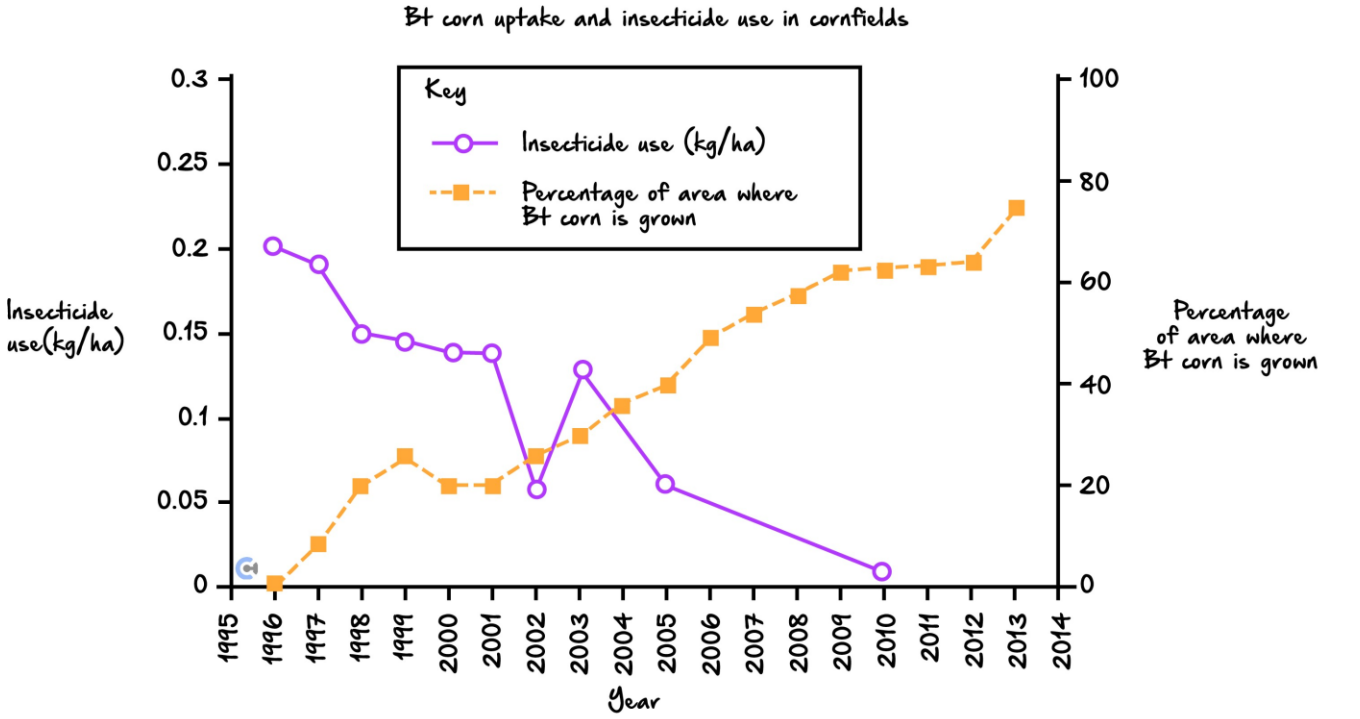
- Genetically modified corn that has an added bacterial gene, rendering the corn poisonous to some insects.
- Genetically modified potatoes that have an added RNA silencing molecule, preventing the potatoes from browning and bruising.
- Genetically modified salmon with an added growth gene from a salmon and promotor sequence from an ocean trout, increasing the salmon's growth rate.

Which row of the table shows the advantages of each GMO for farmers?

	Genetically Modified Corn	Genetically Modified Potatoes	Genetically Modified Salmon
A.	Antibiotic Resistance	Increased Size	Greater Productivity
B.	Insect Resistance	Less Food Waste	Salmon Lives Longer
C.	Lower Pesticide Use	Less Food Waste	Greater Productivity
D.	Lower Pesticide Use	Reduced Antibiotic Use	Reduced Viral Infections

Question 16 (1 mark)

Bt corn expresses a protein that acts as an insecticide.



Source: 'Smarter Pest Control', special section, Science, vol.341, 16 August 2013, p.731

Based on your knowledge and the data in the graph above, what is the benefit of using Bt corn?

A. More insecticide is used with Bt corn crops.

B. Bt corn is cheaper to produce than non-Bt corn.

C. Negative impacts on ecosystems could be reduced.

D. Fewer farmers are predicted to plant Bt corn in the future.

Question 17 (1 mark)

Which of the following best reflects the principle of beneficence in the use of CRISPR-Cas9?

A. Ensuring the benefits of CRISPR-Cas9 applications outweigh potential risks to patients.

B. Informing patients of all possible risks associated with CRISPR-Cas9 treatment.

C. Ensuring that CRISPR-Cas9 is not used for non-therapeutic purposes.

D. Preventing all possible risks associated with the use of CRISPR-Cas9.

Question 18 (1 mark)

Why is germline editing using CRISPR-Cas9 considered controversial?

A. It cannot be effectively used for therapeutic purposes.

B. Changes in the germline affect only the individual being treated.

C. It introduces changes that can be passed on to future generations, raising ethical concerns.

D. It is less effective compared to somatic gene editing techniques.

Question 19 (1 mark)

Which of the following scenarios best aligns with the ethical principle of justice in CRISPR-Cas9 applications?

A. Providing equal access to CRISPR-Cas9 treatments regardless of socioeconomic status.

B. Ensuring that only individuals with life-threatening conditions receive CRISPR-Cas9 treatment.

C. Allowing researchers to prioritise the treatment of rare diseases over common disorders.

D. Limiting CRISPR-Cas9 applications to non-human organisms to prevent human ethical dilemmas.

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Section C: Short Answer Questions (101 Marks)

Question 20 (11 marks)

What is CRISPR, the gene editing technology that won the Chemistry Nobel prize?

CRISPR technology is adapted from a system that is naturally present in bacteria and other unicellular organisms known as archaea.

This natural system gives bacteria a form of acquired immunity. It protects them from foreign genetic elements (such as invading viruses) and lets them 'remember' these in case they reappear.

In 1987, Japanese molecular biologist Yoshizumi Ishino and his colleagues were the first to notice, in *E. coli* bacteria, unusual clusters of repeated DNA sequences interrupted by short sequences. Spanish molecular biologist Francisco Mojica and colleagues later showed similar structures were present in other organisms and proposed to call them CRISPR: Clustered Regularly Interspaced Short Palindromic Repeats. In 2005, Mojica and other groups reported the short sequences (or 'spacers') interrupting the repeats were derived from other DNA belonging to viruses.
…
Evolutionary biologists...eventually proposed CRISPR and the associated Cas9 genes were acting as the immune mechanism.
…
The CRISPR-associated genes, Cas9, encode a protein that 'cuts' DNA. This is the active part of the defence against viruses, as it destroys the invading DNA.

In 2012, [Emmanuelle] Charpentier and [Jennifer] Doudna showed the spacers acted as markers that guided where Cas9 would make a cut in the DNA. They also showed an artificial Cas9 system could be programmed to target any DNA sequence in a lab setting.

This was a ground-breaking discovery that opened the door for CRISPR's wider applications in research.
…
Humans have altered the genomes of species for thousands of years. Initially, this was through approaches such as selective breeding.

However, genetic engineering - the direct manipulation of DNA by humans outside of breeding and mutations - has only existed since the 1970s.

CRISPR-based systems fundamentally changed this field, as they allow for genomes to be edited in living organisms cheaply, with ease and with extreme precision.

CRISPR…has great potential in food production. It can be used to improve crop quality, yield, disease resistance and herbicide resistance. Used on livestock, it can lead to better disease resistance, increased animal welfare and improved productive traits - that is, animals producing more meat, milk or high-quality wool.

A number of challenges to the technology remain, however. Some are technical, such as the risk of off-target modifications.

Source: Excerpt taken from D. Perrin, Queensland University of Technology, 'What is CRISPR, the gene editing technology that won the Chemistry Nobel prize?" The Conversation, 8 October 2020, <https://theconversation.com/what-is-crispr-the-gene-editing-technology-that-won-the-chemistry-nobel-prize-147695>

a. Identify t**wo** ways in which the CRISPR-Cas9 system is similar to the human immune system. (2 marks)

b. Explain how the CRISPR-Cas9 system carries out immunity functions in bacteria. (3 marks)

c. The use of CRISPR-Cas9 may result in off-target modifications. What is an off-target modification? (1 mark)

d. Why would an off-target modification be a matter of concern to scientists? (1 mark)

e. Identify **one** way in which crop yields can be improved by using CRISPR-based systems. (1 mark)

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f. Identify **one** way in which crop yields can be improved by using CRISPR-based systems. (1 mark)

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g. The article states that CRISPR-based systems fundamentally changed the field of genetic engineering because they allow for genomes to be edited in living organisms cheaply, with ease and with extreme precision.

Explain how CRISPR-based systems can be used with ease and extreme precision. (2 marks)

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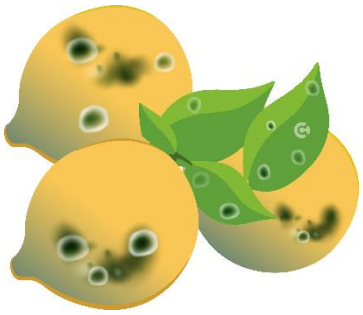
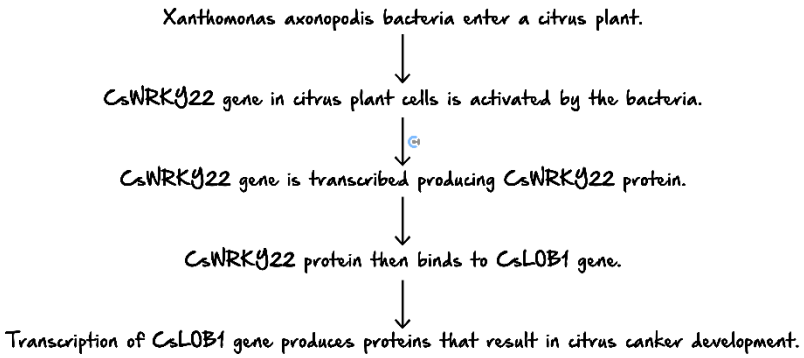
Question 21 (4 marks)

Citrus canker is a disease that affects citrus plants such as lime and orange trees, reducing fruit yield and quality by causing the development of dark spots on the fruit and leaves. It is caused by several different bacteria species, including *Xanthomonas axonopodis*. There have been several outbreaks in Australia.



Scientists have recently tried to use CRISPR-Cas9 technology to inactivate genes involved in the citrus canker pathway. This pathway for citrus canker disease is summarised below:



Using the information in the flow chart above, explain how CRISPR-Cas9 technology could be used to produce citrus-canker-resistant plants.

Question 22 (6 marks)

A fungal disease called Fusarium wilt affects tomato plants, leading to wilting and eventual plant death. It is caused by the fungal pathogen *Fusarium oxysporum*, which infects the plant's vascular system. Recent research has explored the use of CRISPR-Cas9 technology to target specific genes in the tomato plant that are exploited by the fungus.

The process for Fusarium wilt progression in tomatoes is summarised below:

1. *Fusarium oxysporum* enters the plant through the roots.
2. The fungal presence activates the *FoWRKY44* gene in tomato plant cells.
3. The *FoWRKY44* gene is transcribed to produce the *FoWRKY44* protein.
4. The *FoWRKY44* protein binds to the promoter of the *FoLOB1* gene, initiating its transcription.
5. Proteins produced by the *FoLOB1* gene weaken the plant's immune response, allowing the fungus to spread.

a. Using the information in the flow chart above, explain how CRISPR-Cas9 technology could be used to produce tomato plants resistant to Fusarium wilt. (4 marks)

b. Some of the tomato plants have shown a reduced ability to grow quickly in the aftermath of the editing. Propose a reason why this might be the case, explaining your reasoning. (2 marks)

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Question 23 (8 marks)

Phosphorus deficiency is a global agricultural problem that affects crop yields, particularly in maize plants. Scientists have used CRISPR-Cas9 to edit maize genomes by knocking out a gene called *PHO2*. This gene encodes a protein that reduces phosphorus uptake by degrading phosphate transporters in the roots. Knocking out *PHO2* increases phosphorus absorption and boosts plant growth.

The CRISPR-Cas9 complex was used to knock out the *PHO2* gene in maize plants, producing genome-edited (GE) maize plants with enhanced phosphorus uptake.

a. Explain why maize plants edited using CRISPR-Cas9 to knock out the *PHO2* gene may be advantageous over transgenic methods for phosphorus efficiency. (2 marks)

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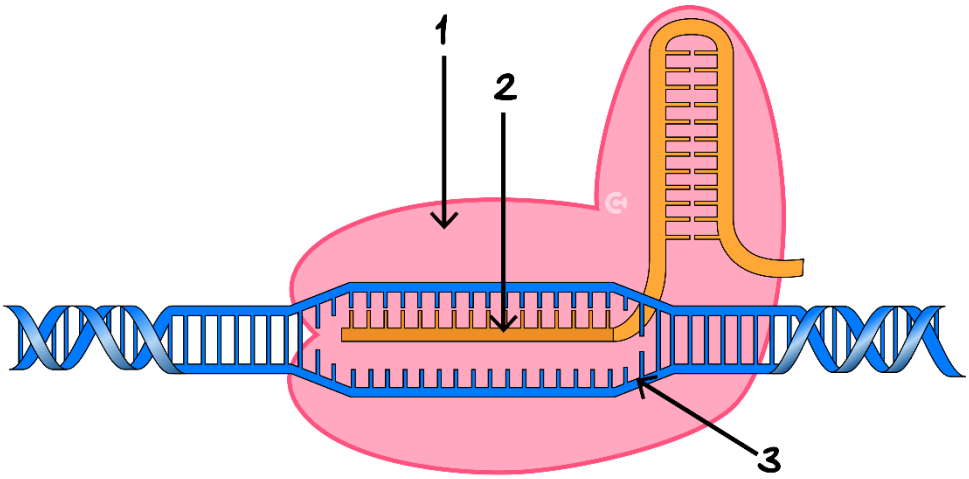
b. Phosphorus availability in soils is often limited due to its fixation in forms that are not bioavailable to plants. *PHO2* encodes a protein that degrades phosphate transporters, reducing phosphorus uptake. CRISPR-Cas9 was used to knock out *PHO2*, leading to improved root phosphorus absorption.

Refer to the diagram of the CRISPR-Cas9 complex below.



i. Which arrow, 1, 2, or 3, correctly points to the DNA strand being cut by Cas9? (1 mark)

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ii. Describe how Cas9 cuts the DNA at the targeted location and what role the sgRNA plays in this process. (2 marks)

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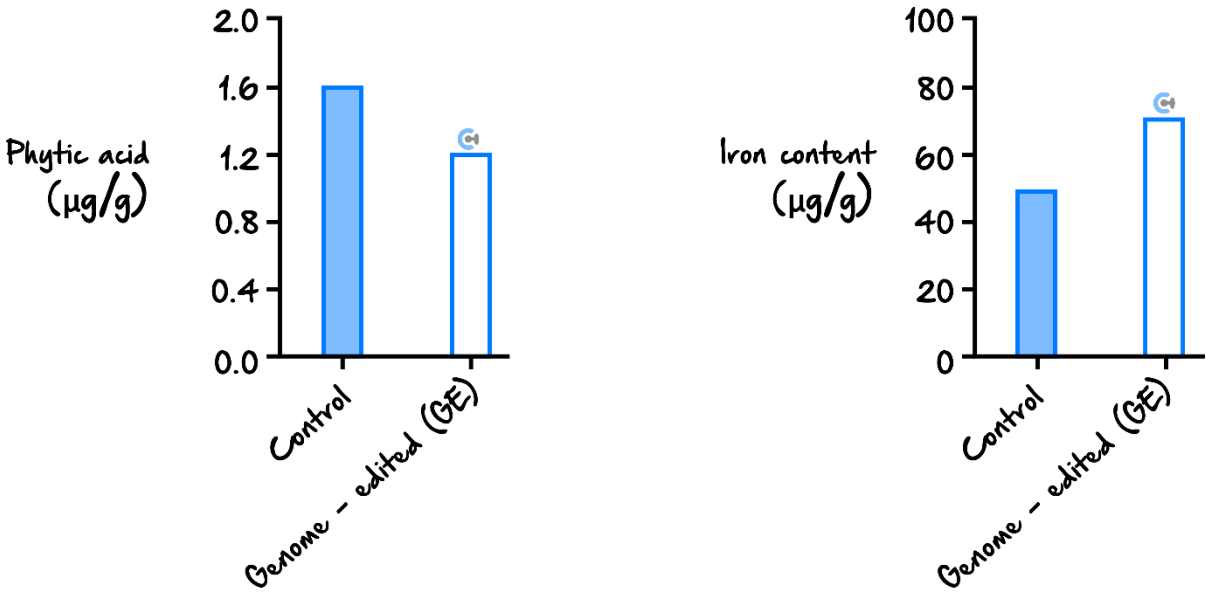
c. A controlled experiment was undertaken to determine the effectiveness of using the CRISPR-Cas9 complex to knock out the *PHO2* gene in maize plants. In the experiment, maize plants were grown under identical conditions, and phosphorus uptake and plant height were measured. The results are displayed in the graphs below.



i. Using the data from the graph above, compare the levels of phosphorus uptake and plant height in the control and GE maize plants. (2 marks)

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ii. Apart from experimental errors, give one reason why GE maize plants may not show a 100% increase in phosphorus uptake. (1 mark)

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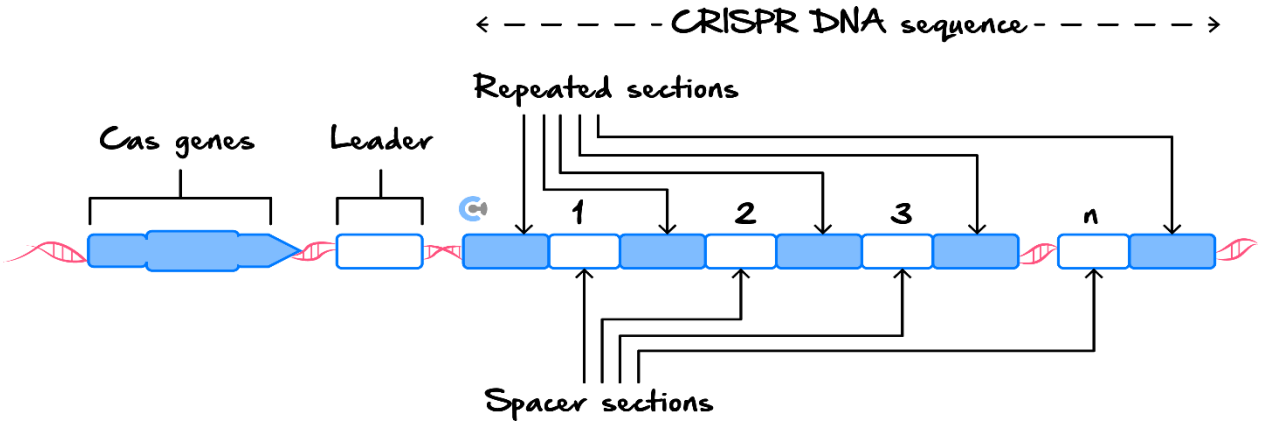
Question 24 (9 marks)

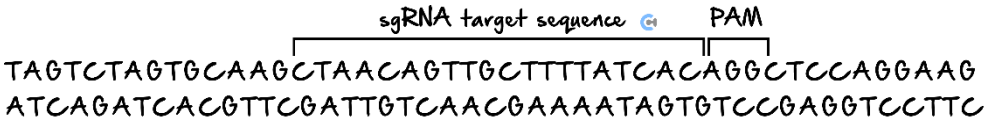
a. Prokaryotes contain a CRISPR DNA sequence, which consists of nucleotide repeated sections and spacer sections. The diagram below illustrates the positioning of these sections in part of the prokaryote circular chromosome.



Outline the function of the CRISPR DNA sequence in prokaryotes. In your answer, state the origin of the spacers. (4 marks)

b. Sickle-cell disease and β-thalassemia are two human blood disorders. Both diseases are the result of mutations in the haemoglobin β gene. In both diseases, the ability of the red blood cells to carry oxygen is reduced. Scientists are developing a treatment that involves turning off a gene in stem cells. This will increase the oxygen-carrying capacity of the blood in people with these disorders. The scientists are using the CRISPR-Cas9 gene-editing technique to locate and edit the gene in stem cells. The gene is called *BCL11A*.

The scientists designed a single guide RNA (sgRNA) to locate a sequence of nucleotides within the *BCL11A* gene, as shown below.



Source: H Frangoul et al., 'CRISPR-Cas9 Gene Editing for Sickle Cell Disease and β-Thalassemia', The New England Journal of Medicine, vol. 384, no. 3, 2021, p. 254, <www.nejm.org/doi/full/doi/10.1056/NEJMoa2031054>

i. Write the nucleotide sequence that must be used on the sgRNA to locate the targeted sequence within the *BCL11A* gene. (1 mark)

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ii. Describe the function of the PAM sequence adjacent to the sgRNA target sequence. (2 marks)

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c. Scientists have successfully edited the *BCL11A* gene. Initially, two patients were treated. Some of each patient's stem cells were extracted and then genetically modified. Each patient then had their own cells returned to them. Both responded well, with significant and sustained increases recorded in their haemoglobin levels. The two patients no longer needed blood transfusions to survive. However, both patients had some adverse reactions. The scientists have since treated another 75 patients.

Identify an ethical concept that the scientists would have needed to consider before proceeding with the treatment of the additional 75 patients. How would they justify the continuation of the treatment in new patients? (2 marks)

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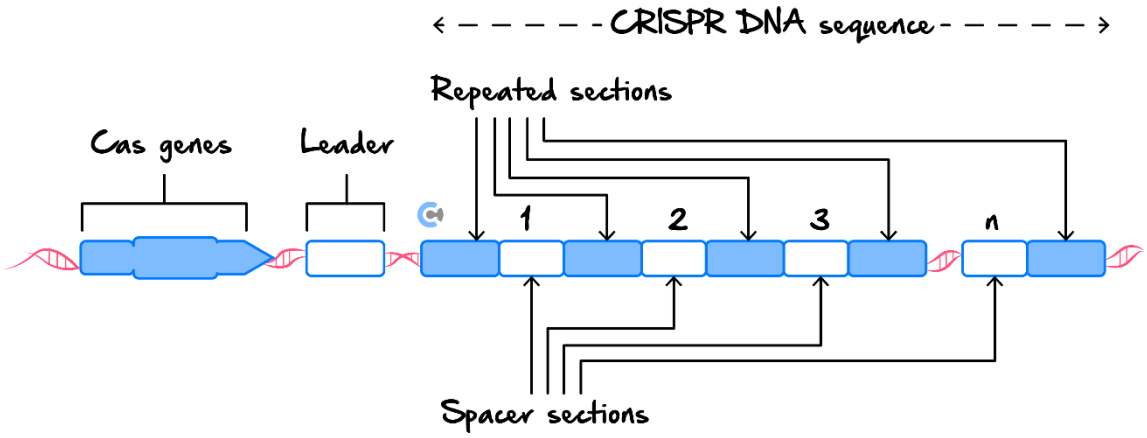
Question 25 (9 marks)

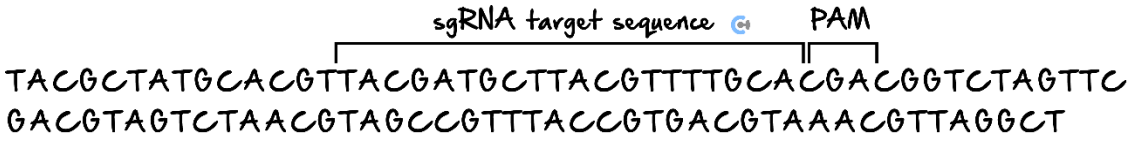
a. Prokaryotes contain a CRISPR DNA sequence, which consists of nucleotide repeated sections and spacer sections. The diagram below illustrates the positioning of these sections in part of the prokaryote circular chromosome.



Outline the function of the CRISPR DNA sequence in prokaryotes. In your answer, state the origin of the spacers. (4 marks)

b. Cystic fibrosis is a genetic disorder caused by mutations in the *CFTR* gene, which leads to the production of a faulty protein responsible for chloride ion transport in cells. Scientists are developing a treatment that uses CRISPR-Cas9 to correct a common mutation, Δ*F*508, in the *CFTR* gene in lung epithelial cells. This treatment aims to restore proper chloride ion transport and reduce the symptoms of cystic fibrosis.

The scientists designed a single guide RNA (sgRNA) to locate and edit the mutated sequence within the *CFTR* gene, as shown below.



i. Write the nucleotide sequence that must be used on the sgRNA to locate the targeted sequence within the *CFTR* gene. (1 mark)

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ii. Describe the function of the PAM sequence adjacent to the sgRNA target sequence. (2 marks)

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c. Scientists have successfully corrected the *CFTR* gene. Initially, two patients were treated. Some of each patient's lung epithelial cells were extracted and then genetically modified. Each patient then had their own cells returned to them. Both responded well, with improved lung function and a reduction in cystic fibrosis symptoms. The two patients no longer required intensive respiratory treatments. However, both patients experienced mild inflammatory side effects. The scientists have since treated another 75 patients.

Identify an ethical concept that the scientists would have needed to consider before proceeding with the treatment of the additional 75 patients. How would they justify the continuation of the treatment in new patients? (2 marks)

Question 26 (8 marks)

The CRISPR-Cas9 complex is a gene-editing technology used in a variety of contexts.

a. Describe the role of the CRISPR-Cas9 complex in a bacterium. (2 marks)

b. Describe the function of a spacer in a bacterium. (1 mark)

Recent clinical trials have used the CRISPR-Cas9 complex to treat sickle cell anaemia in adults. In the treatment, the bone marrow stem cells of an individual with sickle cell anaemia are extracted and mixed with a CRISPR-Cas9 complex that is designed to disrupt the adult haemoglobin gene. Once the gene is disrupted, the stem cells are placed back into the individual. The cells then differentiate and express foetal haemoglobin, which alleviates the symptoms of sickle cell anaemia.

c. Describe how a CRISPR-Cas9 complex could target and disrupt the adult haemoglobin gene. (3 marks)

d. As CRISPR-Cas9 technology becomes increasingly common, questions have been raised about its use in medical treatments for babies. A survey consisting of five questions about the use of CRISPR-Cas9 technology in the treatment of babies is planned to assess the general public's opinion on the topic. The questions are shown in the table below.

Question number	Question
1	Do you think the technology will only be available to the wealthy?
2	Do you think the technology will be used by some in morally unacceptable ways?
3	Do you think the technology will be used before the health effects are fully understood?
4	Do you think the technology will lead to the development of other new medical advances?
5	Do you think the technology will help people live longer and better-quality lives?

Describe the ethical concept of beneficence and identify one question in the survey that refers to beneficence. (2 marks)

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Question 27 (10 marks)

Golden rice is a special form of rice that was developed to combat vitamin A deficiency, which is a major cause of preventable blindness in developing countries where there is not sufficient access to eggs, liver, and dairy which are all rich in vitamin A.
Given that rice is a staple food in many of these countries, scientists thought that developing a form of rice that would have increased vitamin A levels would improve this issue of vitamin A deficiency, and they achieved this by adding the PSY gene from a daffodil and the CRTI gene from a soil bacterium. This causes the rice to store beta-carotene, in the grains of rice rather than the leaves, giving them that distinctive golden colour.

a. Define the term 'GMO' and describe specifically the type of GMO golden rice that would be considered to be. (2 marks)

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b. Why might it be beneficial for the rice to store the beta-carotene in the grain and not in its leaves? (2 marks)

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c. Discuss some of the biological implications that may result from the use of golden rice widely. (2 marks)

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d. Discuss, with reference to the principles of beneficence and justice, the ethics of introducing golden rice into widespread use across Southeast Asia. (4 marks)

Question 28 (13 marks)

The development of more precise genetic editing technologies, such as CRISPR-Cas9, has brought life to the prospect that genetic editing can become popular, safe, and effective in the near future. Some visionaries have suggested that this may usher in a new era wherein human embryos can be edited for desirable traits and characteristics, as well as protecting them from potential diseases as well.

a. Describe how CRISPR-Cas9 could be applied in an experiment to edit a gene causing disease in an embryo. (3 marks)

b. What are some concerns regarding the usage of CRISPR-Cas9 to edit human embryos? (3 marks)

c. Using a consequences-based approach, and the principles of beneficence and justice, compare and discuss the ethics of using CRISPR-Cas9 to fix known disease-causing abnormalities as opposed to "preference" edits (e.g. parents wanting blue eyes not brown.). (5 marks)

Currently, despite the promise, there are still concerns over the efficacy of the CRISPR-Cas9 treatments, and multiple rounds of trials are required before approvals can be granted.

d. With reference to the principle of non-maleficence, discuss the need for extensive clinical trials before making this technology available to a wider public. (2 marks)

Question 29 (9 marks)

Bt cotton is a type of cotton that contains two genes from a soil bacterium, *Bacillus thuringiensis*, enabling it to produce insect-resistant proteins. Australian farmers of Bt cotton use only 15% of the quantity of the insecticide that was once needed to protect their cotton crops. However, Bt cotton is not as resistant to the main insect pest of cotton crops, *Helicoverpa*, as it has been in the past. In Australia, Bt cotton is picked by machine, but in India, it is picked by hand. Workers in India have developed skin allergies, which have been attributed to Bt cotton proteins. Traditionally, farmers have saved money by keeping seeds from one year's crop to plant the following year. However, it is illegal for farmers to keep Bt cotton seeds because these seeds have been declared the legal property of the company Monsanto. Every year, cotton farmers must buy more seeds from Monsanto.

a. Is Bt cotton transgenic or cisgenic? Justify your answer. (2 marks)

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b. Discuss the social implications of the use of Bt cotton. (2 marks)

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c. How might Bt cotton result in increased crop yields? (1 mark)

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d. Discuss, using a consequences-based approach and applying the principle of justice, the ethics of this model of Bt cotton. (4 marks)

Space for Personal Notes

Question 30 (14 marks)

The Tasmanian Tiger, or the Thylacine, was a marsupial that lived in Australia, before it went extinct after the arrival of European settlers, with the last one dying in captivity in 1931.

Recently, there has been talk about using DNA manipulation technologies to "revive" the thylacine and bring it back, by editing it with current species still present today. Researchers claim that this would be 'de-extinction' and will bring the thylacine back to life, but in reality, an exact replica of the original animal will not be created, rather, it will be a hybrid creature.

There are a number of concerns that have been raised over this project.

The researchers claim that this is a step in reversing the damage done ecologically by the settlers, and bringing the ecosystem back to balance, whereas critics claim that this may actually end up having adverse impacts on an ecosystem that has adapted to modern challenges.

Further to this, concerns have been raised over how the embryos will be born, whether through a surrogate or otherwise, and the welfare of the thylacines after birth.

a. Describe some of the social and biological implications of this plan. (3 marks)

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b. Would these be considered GMOs, and if so which type? Explain. (2 marks)

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c. With reference to the principles of beneficence and respect, discuss the ethics of this plan of reviving the thylacine. (4 marks)

d. Why it might be problematic to claim that this is a 'de-extinction' of the thylacine? (3 marks)

e. Explain the difference between the virtues-based and duty-based approaches to ethics. (2 marks)

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