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VCE Biology ¾

CRISPR-Cas9 & Bioethics [1.6]

Test

45 Marks. 1 Minute Reading. 40 Minutes Writing.

Results:

Test Questions	_____ / 45

Section A: Test Questions (45 Marks)

Question 1 (5 marks)

Tick whether the following statements are **true** or **false**.

Statement	True	False
a. CRISPR-Cas9 originates from a bacterial immune system designed to defend against viruses.		
b. The guide RNA (gRNA) directs Cas9 to its target by complementary base pairing with the viral DNA.		
c. The protospacer adjacent motif (PAM) is not necessary for Cas9 to bind and cut DNA.		
d. CRISPR-Cas9 cannot be used to make precise edits to an organism's genome.		
e. Non-homologous end joining (NHEJ) is a repair mechanism that introduces errors, often silencing genes.		
f. Ethical concerns about CRISPR include the inability of embryos to consent to genome edits.		
g. Virtue-based ethics focus on the outcomes of actions rather than the character of the individual.		
h. GMOs are always created using CRISPR-Cas9 technology.		
i. Beneficence involves minimising risks while maximising benefits in scientific practices.		
j. Cross-pollination between GM and non-GM crops cannot occur under any circumstances.		

Sub-Section: Multiple Choice Questions

Question 2 (1 mark)

Bacteria use CRISPR-Cas9 as an adaptive immune system against viruses. Imagine a scenario where a bacterium is exposed to a new virus. Which sequence of events best describes how CRISPR-Cas9 protects the bacterium?

A. The bacterial cell immediately destroys all viral DNA using Cas9.

B. The bacterial cell stores fragments of the viral DNA as spacers, transcribes them into RNA and guides Cas9 to cut matching viral DNA during subsequent infections.

C. The bacterial cell incorporates viral DNA into its genome to make itself immune to future infections.

D. The bacterial cell produces multiple Cas9 enzymes to eliminate the virus directly upon first contact.

Question 3 (1 mark)

Certain plants, like bananas and potatoes, possess genes that produce proteins conferring resistance to specific plant diseases. In a bid to enhance crop resilience, researchers have isolated these disease-resistance genes and inserted them into different plant species that are typically vulnerable to those diseases.

How are the modified plants, which now contain genes for disease resistance obtained from other species, referred to?

A. Hybrid

B. Transgenic

C. Polyploid

D. Recombinant

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Question 4 (1 mark)

Which of the following best describes how CRISPR-Cas9 is able to allow for the insertion of a desired gene?

A. CRISPR-Cas9 binds to the target DNA, cuts it, and allows random mutations to create the desired gene.

B. CRISPR-Cas9 uses the guide RNA to locate the target DNA, and cut it, and the cell's repair mechanisms incorporate a provided template containing the desired gene.

C. CRISPR-Cas9 directly inserts the desired gene into the genome without cutting the DNA.

D. CRISPR-Cas9 uses PAM sequences to synthesise the desired gene and incorporate it into the genome.

Question 5 (1 mark)

CRISPR-Cas9 uses a guide RNA to target specific DNA sequences. How does the guide RNA ensure specificity, and what would happen if the RNA sequence were only partially complementary to the target DNA?

A. The guide RNA aligns perfectly with any DNA sequence, allowing flexibility in targeting.

B. The guide RNA must be fully complementary to the target DNA; partial matches reduce cutting efficiency and increase off-target risks.

C. The guide RNA adapts to new DNA sequences over time, improving targeting.

D. The guide RNA binds to PAM sequences regardless of the target sequence, ensuring cuts are made.

Question 6 (1 mark)

If a bacterial cell fails to incorporate viral DNA spacers into the CRISPR locus, which part of the adaptive immune response is compromised?

A. The ability to transcribe spacers into crRNA.

B. The recognition of future viral infections.

C. The activation of Cas9 to cut viral DNA.

D. The detection of PAM sequences in the bacterial genome.

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Question 7 (1 mark)

Imagine CRISPR-Cas9 is applied in agriculture to enhance drought resistance in crops. Which of the following outcomes demonstrates a biological implication of this technology?

A. Farmers save money on irrigation systems.

B. Public concern arises about the safety of genetically modified crops.

C. The edited crops are more resistant but may reduce genetic diversity in wild populations.

D. Agricultural companies charge higher prices for drought-resistant seeds.

Question 8 (1 mark)

A student argues that CRISPR-Cas9 should be used in all cases where it can improve human health. Which ethical principle could be used to challenge this statement?

A. Beneficence, because it supports maximising good outcomes.

B. Justice, because the benefits may not be equally accessible to everyone.

C. Non-maleficence, because no technology is free of risks.

D. Integrity, because scientific transparency is required.

Question 9 (1 mark)

In bacteria, why does the PAM sequence play a crucial role in distinguishing self from non-self DNA?

A. It prevents the bacteria from cutting its own genome by ensuring Cas9 only binds to foreign DNA.

B. It allows the bacteria to transcribe its own spacers into crRNA without interference.

C. It identifies viral DNA sequences that cannot be stored in the CRISPR locus.

D. It enhances the efficiency of RNA transcription in bacterial cells.

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Question 10 (1 mark)

A group of scientists proposes using CRISPR-Cas9 to enhance intelligence in humans. What social and ethical concerns does this raise, and how might justice be implicated?

A. Enhancing intelligence is purely a biological matter, so social implications are irrelevant.

B. Justice concerns arise because such technology may only be available to wealthy individuals, increasing inequality.

C. Social concerns focus on whether intelligence is heritable, which is unrelated to justice.

D. Ethical concerns would be minimal as long as experiments are transparent.

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Sub-Section: Short Answer Questions

Question 11 (12 marks)

CRISPR-Cas9 is an exciting new gene editing tool that has allowed for more specificity and control when editing the genetic material of organisms, both in the lab and also in live experiments.

In prokaryotes, where it was first isolated, it has been shown to have a significant immune role in the cell.

a. What does CRISPR do in prokaryotes? (1 mark)

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b. Explain how CRISPR-Cas9 works in prokaryotes to achieve its aim. (3 marks)

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c. Describe the importance of having a PAM sequence for prokaryotes in the CRISPR-Cas9 system. (1 mark)

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Recently, in 2012, it was determined that CRISPR-Cas9 could be adapted from prokaryotes to provide an important tool for gene editing.

d. Explain what aspect of CRISPR allows it to be specific. (2 marks)

CRISPR has been put forward as a potential treatment option for babies for genetic diseases such as cystic fibrosis, where a mutation to a single gene can cause lifelong disease.

e. Explain how CRISPR-Cas9 can be applied to embryos with the potential for cystic fibrosis identified early. (3 marks)

f. Compare the importance and use of the PAM in prokaryotes and gene editing. (2 marks)

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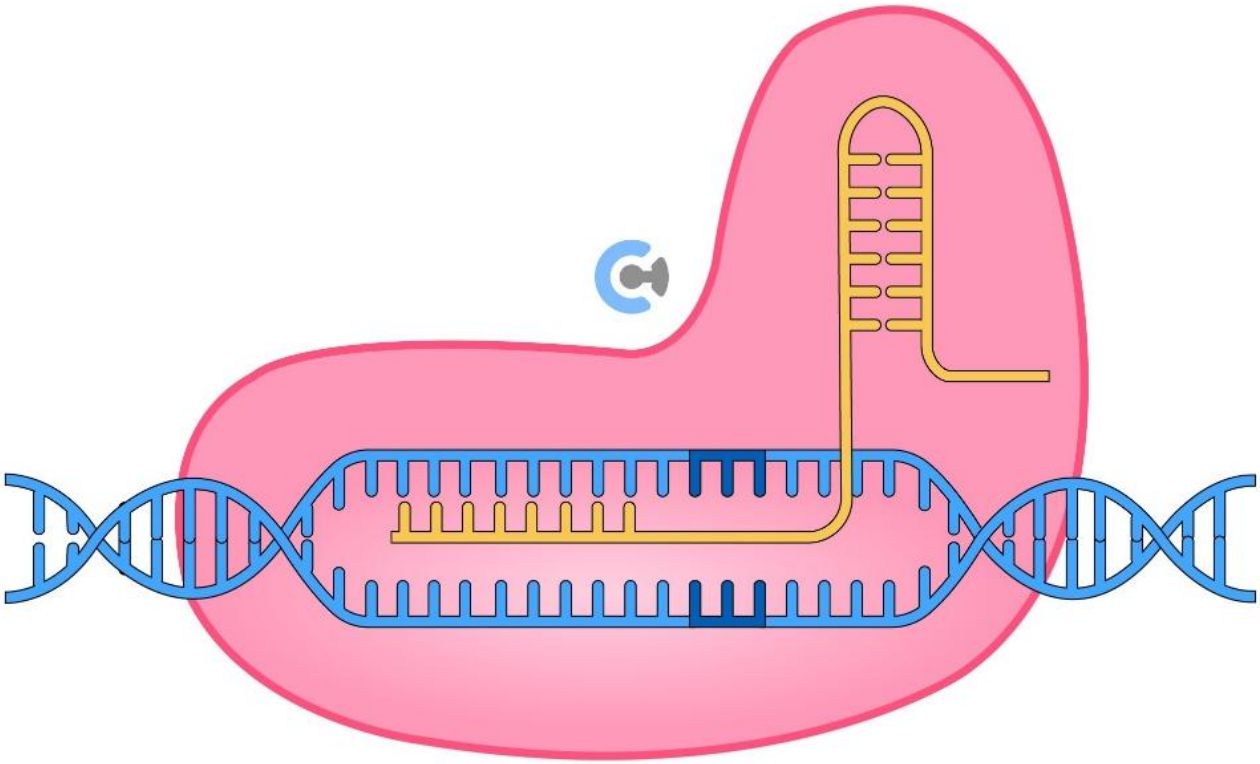
Question 12 (8 marks)

CRISPR-Cas9 is currently being studied to investigate potential treatments for leukemia patients. Leukemia is a type of cancer that affects the development and production of blood cells. Zebrafish have been used to model leukemia in order to investigate possible treatments for the disease. Scientists target and cut a specific gene area in Zebrafish that codes for a granulocyte colony-stimulating factor receptor protein (G-CSFR). This protein stimulates white blood cell production and is shortened in some leukemia patients. Through the creation of specific guide RNA and the use of CRISPR-Cas9, scientists have been able to induce the Zebrafish to develop the mutated version of the G-CSFR protein that is identical to the mutation in some leukemia patients. The mechanism the scientists used is referred to as gene knockout.



a.

i. In the figure above, label the guide RNA scientists used to target the G-CSFR gene. (1 mark)

ii. In the figure above, label the PAM sequence. (1 mark)

b. Describe the function of guide RNA in targeting the G-CSFR gene. (2 marks)

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c. Outline how the process of 'gene knock out' works in the process of inducing leukemia in the Zebrafish. (3 marks)

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d. Explain the role gel electrophoresis might play in the scientific process of inducing the G-CSFR mutation using CRISPR-Cas9 that causes leukemia in Zebrafish. (1 mark)

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Question 13 (11 marks)

Unbeknownst to many, Angad manages Contour by day and is also a mad scientist by night. Trying to generate the next generation of Contour tutors, he decides to try some CRISPR-Cas9 experiments to create superhuman Contour tutors who might aid his goals of dominating the VCE tutoring market, involving the use of human embryos.

Before he can do this, however, he has to run through countless trials so that he can get regulatory approval.

a. What are the independent and dependent variables of his experiment? (2 marks)

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b. Describe the relevance of the ethical principle of respect that Angad must consider when running his experiment. (3 marks)

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He didn't get favourable results so he decided to fake them, in order to try and convince the dreaded TGA that his program deserved approval.

c. Apply the principle of integrity and use a virtues-based approach to discuss the ethics of his decision. (4 marks)

Angad eventually did not receive approval from the TGA and he decided to pursue his experiments unapproved in his lab.

d. Why is this unethical? (2 marks)

Disclaimer: This is not how this works, please do not try to be Angad.

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