BSc Degree Examinations 2019-20
SECURE EXAM

Department:
BIOLOGY

Title of Exam:
Food and fuel

Time Allowed:
1 hour and 30 minutes

Allocation of Marks:
Total marks available for this paper: 60
The marks available for each question are indicated on the paper.

Instructions for Candidates:
Answer all questions in the spaces provided on the examination paper. This is an open book exam, and you are allowed to view notes you have brought in to the exam.

Materials Supplied:
Calculator

For marker use only:

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Do not write on this booklet before the exam begins
Do not turn over this page until instructed to do so by an invigilator
1. A biotechnology company has identified three genes involved in wheat resistance to a fungal pathogen that leads to wheat rust disease and subsequent large decreases in yields. They have a low yielding variety that has resistance through these three genes and want to incorporate this trait into a high yielding commercial variety. They are considering both genetic engineering and selective breeding to create a high yielding variety with wheat rust resistance.

a) Compare selective breeding to genetic engineering and discuss the following: speed of trait incorporation, speed of product to market, potential hurdles. (4 marks)

b) After further research the company has found that the high yielding variety has copies of the resistance genes but they are expressed at low levels compared to the low yield resistant variety. They have decided to use a genetic engineering strategy using CRISPR/Cas9.

i) Outline a suitable transformation method they could use. (3 marks)
ii) Give a brief overview of the mechanism of CRISPR/Cas9 gene editing (4 marks) and explain how it can be used to (a) introduce additional copies of the three genes into a neutral site of the wheat genome (3 marks) and (b) upregulate the homologous genes found in the high yielding variety (3 marks).

iii) The company’s main target will be the US: if their engineered wheat variety doesn’t contain any foreign genes (i.e. Cas9 or antibiotic resistance genes) it won’t need to undergo GM approval and instead can go straight to the market. Outline the engineering strategy that should be used to ensure this. (3 marks)
2. A cattle farmer has maintained a herd of 100 cows for 20 years. Each one of these cows emits approximately 100 kg of CH$_4$ (methane) a year.

a) Over the next 100 years, according to the UNFCCC method of calculating emissions, what will be the net CH$_4$ emissions from this herd, expressed in equivalent CO$_2$ emissions? (2 marks)

b) Without doing any further calculations, comment on the accuracy of the above calculation. (4 marks)

c) The farmer would like to reduce emissions from the herd so decides to reduce the size of her herd by 10 cows. Using a more appropriate formula than used for question “2.a”, calculate the net CH$_4$ emissions of this herd over the next 100 years expressed as equivalent CO$_2$ emissions. Assume the herd is reduced within the first year and then maintained at 90 cows. (3 marks)
d) What would be the net CH$_4$ emissions of this herd over the next 60 years, rather than 100 years, expressed as equivalent CO$_2$ emissions? (1 mark)

e) In addition to CH$_4$ emissions, evaluate the importance of other factors you would take into account when designing a life cycle analysis study investigating the greenhouse gas emissions of beef purchased from European supermarkets. (10 marks)
3. The Quorn fungus *Fusarium veneatum* is produced in a 155 m³ culture vessel. The growth medium contains glucose as a carbon and energy source, and a fully grown culture yields 10 g of fungal biomass per litre.

(a) A batch culture is initiated by inoculation with 5 L of of *F. veneatum* containing 10 g/L fungal biomass.

(i) Assuming a growth rate, $\mu = 0.17$ h⁻¹, calculate the time taken for the 155 m³ culture to reach a biomass concentration of 10 g/L. (4 marks)

(ii) What assumptions have been made about growth of the culture in making this calculation? (2 marks)

(b) Once the culture has reached full growth, the vessel is switched from batch to continuous culture, with a dilution rate of 0.17 h⁻¹. Assuming a biomass concentration of 10 g/L is maintained, calculate the amount of *F. veneatum* biomass produced per day. (4 marks)

(c) In a chemostat, why is it not possible to maintain growth with a dilution rate equal to the maximum growth rate ($\mu_{\text{max}}$) (2 marks)? Speculate on how this might be overcome in the Quorn fermentation. (2 marks)
(d) Summarise the main advantages and disadvantages of using continuous culture for Quorn production. 

(4 marks)

(e) Describe an industrial-scale fermentation process that is typically run in batch mode, and why this is important for the product. 

(2 marks)

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THE SPACE ABOVE THIS LINE SHOULD BE SUFFICIENT FOR YOUR ANSWER

End of Exam