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SECOND SEMESTER EXAMINATION: 2014/2015

LEVEL 400: BACHELOR OF SCIENCE IN ENGINEERING

BMEN 402: TISSUE ENGINEERING AND BIOTECHNOLOGY (3 Credits)

TIME ALLOWED: 3 HOURS

Attempt **ALL** Questions

You may use the information provided on **Page 3**, where necessary.

1. Myocardial infarction (MI) or acute myocardial infarction (AMI), commonly known as a heart attack, occurs when blood flow stops to part of the heart causing damage to the heart muscle. If impaired blood flow to the heart lasts long enough, it triggers a process called the ischemic cascade; the heart cells in the territory of the occluded coronary artery die and do not grow back. A collagen scar forms in their place. As a result, the patient's heart will be permanently damaged. This myocardial scarring also puts the patient at risk for potentially life-threatening arrhythmias, and may result in the formation of a ventricular aneurysm that can rupture with catastrophic consequences. Additionally injured heart tissue conducts electrical impulses more slowly than normal heart tissue. The difference in conduction velocity between injured and uninjured tissue can trigger re-entry or a feedback loop that is believed to be the cause of many lethal arrhythmias.

   A tissue engineer would like to design a product to address the interrelated problems described above for a patient who has suffered MI, leading to heart tissue damage. Answer the questions below regarding this tissue engineering project.

EXAMINER: Elsie Effah Kaufmann, PhD

a) With reference to the preamble above, how may a tissue engineer use the "tools" of biotechnology to achieve the design goals? [5 marks]

b) Assuming a scaffold is required, list five specific **materials properties** that will be essential to the success of the project. [5 marks]

c) If a scaffold with 95% porosity is required and there is a choice of honeycomb or open pore architecture, which would you consider for optimal mechanical properties? Support your choice with appropriate calculations. [10 marks]

d) i) Are cells needed for all tissue engineering/ regenerative medicine projects? [3 marks]

ii) Assuming cells are needed for this project, what **specific type** will be needed? Critically assess the various options available by preparing a table of cell types showing advantages and disadvantages of each type and give five strong reasons for your choice of cell type. [12 marks]

e) i) A batch of 10 primary cells with a Hayflick limit of 55 is obtained. How many cells in total can theoretically be produced by culturing the cells? [5 marks]

ii) Why will it be unrealistic to expect the number in the question immediately above (i) to be produced in a practical setting? [5 marks]

f) For the expansion of cells in culture, dishes with circular culture areas of 100 cm^2 are to be used.

i) Estimate the number of cells in a confluent cell layer and state all relevant assumptions. [5 marks]

ii) Knowing that cell viability is compromised at oxygen partial pressure of 100 Pa, what is the critical volume of culture media in a static culture at which cells will begin to die due to hypoxia? [15 marks]

iii) List the measures a tissue engineer can take to avoid the challenges of cell death by hypoxia during the culture of cells in scaffolds. [5 marks]

iv) The tissue engineer acquires a perfusion bioreactor for the project. Calculate the minimum flow rate of culture medium necessary to prevent hypoxiainduced cell death if the scaffold is seeded with 10^6 cells. State all relevant assumptions. [15 marks]

2) Tissue Engineering is considered by some to be controversial and unethical.
   a) List five arguments to support this view. [5 marks]
   b) Provide one corresponding rebuttal to each of the arguments in (a). [10 marks]

Some Useful Information

Solubility of oxygen in culture medium (k):	8.93 nmol/ ml/ kPa
Diffusivity of oxygen through culture medium at 37°C (D):	2×10^{-5} cm^2/s
Maximum oxygen uptake by cells:	3×10^{-7} nmol/s/cell
Partial pressure of oxygen in cell culture incubator:	21 kPa

Diffusion rate in culture medium = $DkA(P_1-P_2)/d$

Where: d is the distance or thickness of the barrier to diffusion

A is the area for gas exchange

(P_1-P_2) is the difference in partial pressure on either side of the diffusion barrier