National Exams December 2016

04-Bio-A1, Biomaterials and Biocompatibility

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

Question 1

Being the VP of Product Development and Acquisition for a large diversified international company, your job is to determine new product potential. This process will lead to the acquisition of any Research and Development firm that has patented a viable novel product process or the identification of any potential in-house developments. Monday morning you open a holographic message sent to you by the VP of Future Business Marketing, which has been sent to the CEO and the Board of Directors. The message details a market study completed on an R&D firm located in Kyoto Japan. Upon further reading, the product in question is a novel "off the shelf" bioengineered heart. Although this is the product, the only technical information provided was that the cell source is embryonic stem cells. Other than that, the message is an endless litany of stock price forecasts, market volatility etc. The conclusion of the message was that your company is seriously interested in acquiring this company, but does not know enough about the technology to determine if the company in question is simply trying to boost its stock value by fabricating rumours of success. Your role is to get the economic people up to speed on the biomaterials aspects of this potentially exciting product.

a) Document the major technical areas involved in engineering an off the shelf "heart".
b) Give criteria by which you would assess the "success" of the proposed design.

Question 2

A company affiliated with one for which you are working has recently developed a new method for genetically engineering skin cells in order that they overproduce a protein that is useful for the treatment of serious burn injuries. However, the company has no expertise in the field of polymers and biomaterials where they could possibly exploit this discovery in order to develop a skin substitute that will both cover the wound and treat it at the same time.

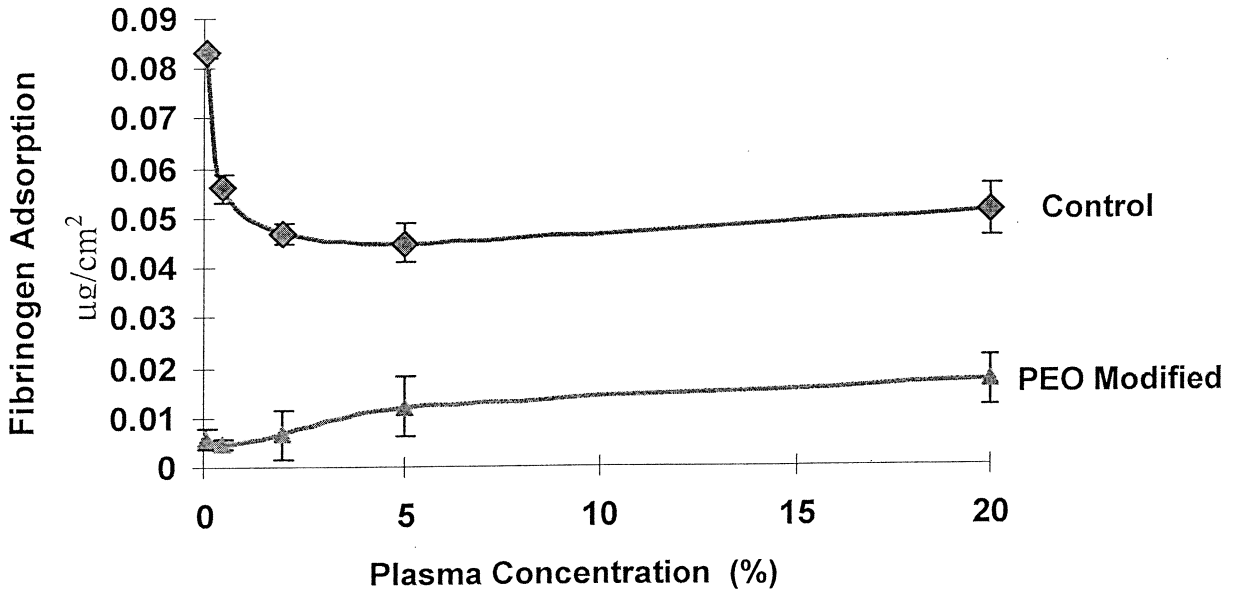
a) Discuss the properties of a "suitable" matrix in terms of what may be appropriate for maintaining these cells. What further information would you request from the cell biologists in order to make suitable judgments about the nature of the polymer that would be used.
b) What physical and mechanical properties would you consider in selecting a polymer for this application?

Question 3

a) Large diameter (>6 mm) vascular grafts made from Dacron or poly (tetrafluoroethylene) (PTFE) have enjoyed significant success for the replacement of diseased or damaged vessels. However, in cases where the vessel to be replaced has a diameter 5 mm or less, the only option for replacement is a patient's native veins. Explain in detail why this is the case, what the challenges are in terms of developing a successful small diameter vascular prosthesis and why you think this goal has yet to be achieved.

b) The following results were obtained for the adsorption of fibrinogen from plasma to two different surfaces, a control and a surface modified with polyethylene oxide. Explain the curves and their significance in terms of developing materials with improved blood compatibility.

c) It has recently been reported that phospholipids, molecules that mimic the membranes of cells, including red blood cells, can be put onto surfaces with high density and that these surfaces show low levels of protein adsorption. Explain why these surfaces may ultimately show promise in developing more blood compatible biomaterials.



Question 4:

Hip implants have undergone significant changes since their introduction in both materials and design. These changes have led to the development of more successful biomaterials in orthopedic applications.

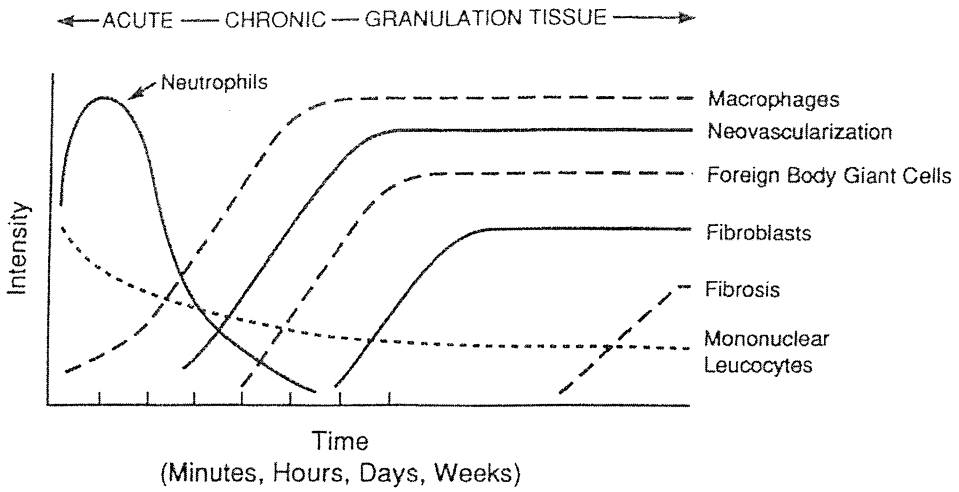
a) Outline the similarities and differences between the different hip replacement options.

b) Given the different complications, justify which would you recommend for:
   i) a man in his 40s
   ii) a woman in her 80s.

c) What other concerns would you have for these patients relating to the implant? Explain thoroughly.

Question 5:
Silicone breast implants have been the subject of considerable controversy, including a number of lawsuits. Several women who received silicone breast implants were later diagnosed with various autoimmune disorders.

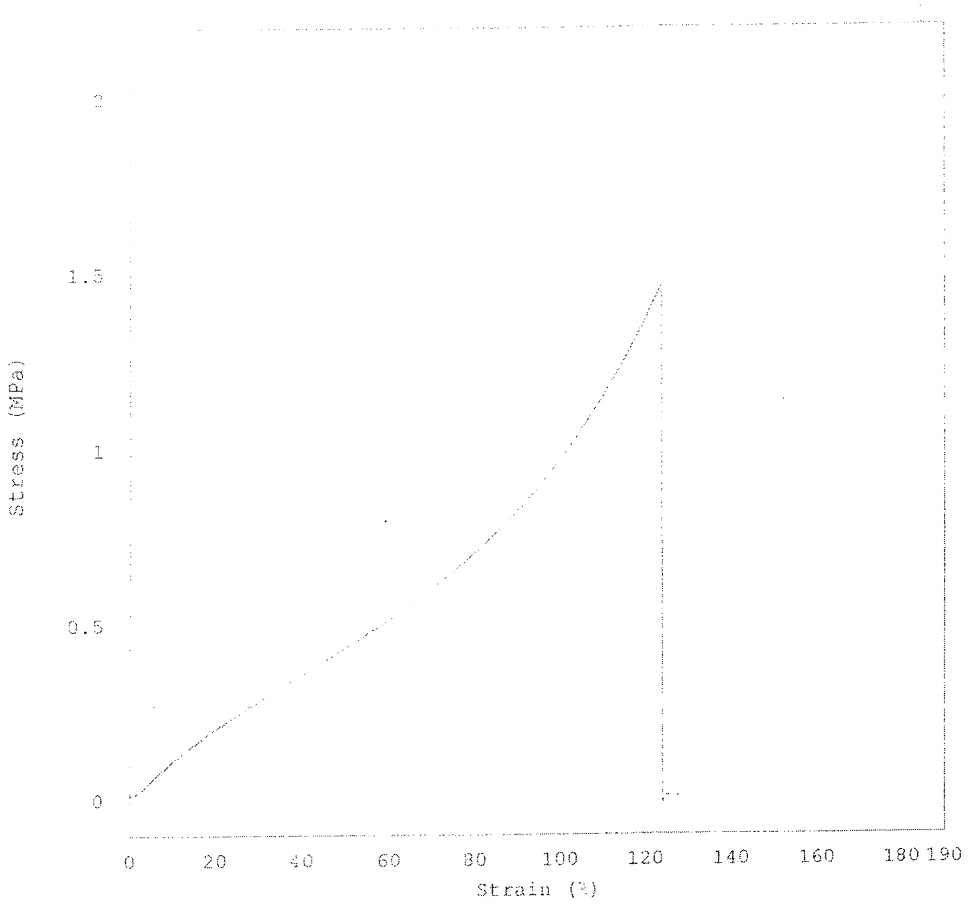
a) Given the following figure, what would be the expected interactions between silicone breast implants and the immune system?
b) Which of these interactions could potentially be related to autoimmunity?



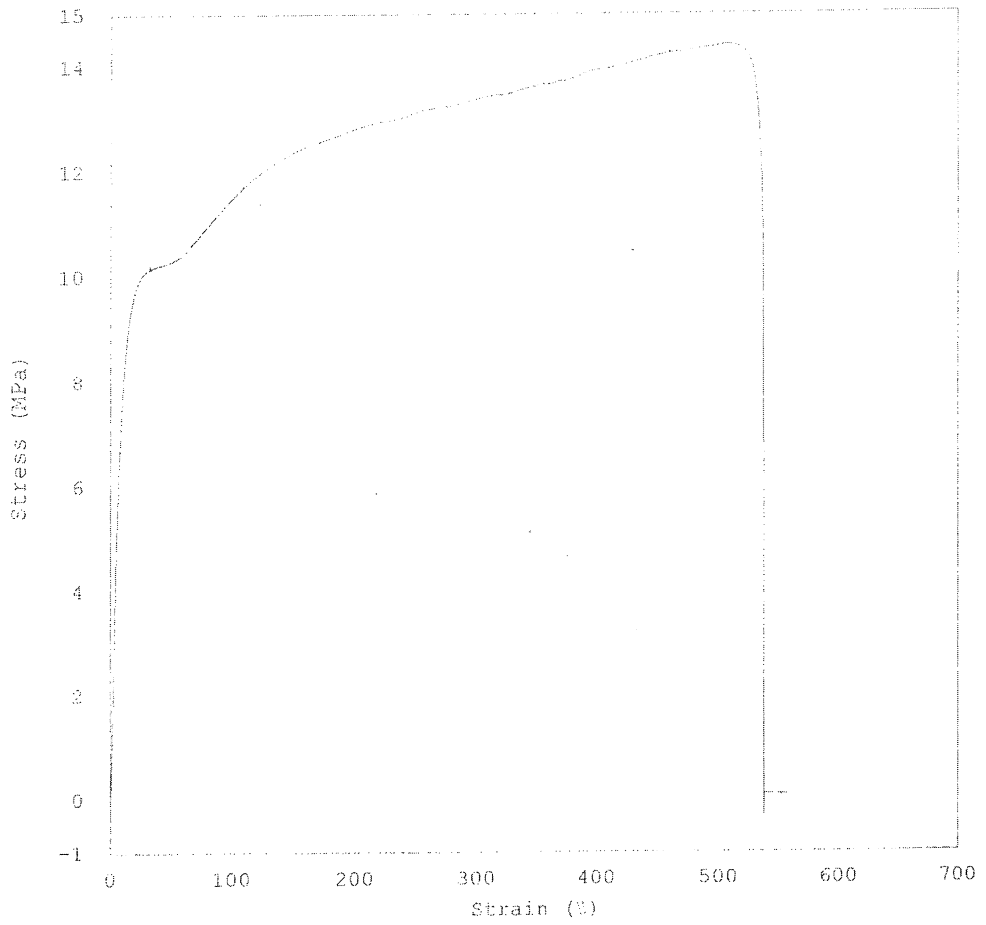
Question 6:
The following stress-strain curves and results (from three separate samples) were obtained for two proposed biomaterials to be potentially applied in soft tissue applications.

a) Describe the differences between the materials and how these properties might be essential for selecting a material.
b) Based on these properties, suggest potential applications for these materials. What other properties of the materials would be of interest prior to applying them to these tissues?

	Stress at Max. Load, (MPa)	% Stain at Max Load (%)
Material 1	1.464	61.44
Material 1	1.684	57.5
Material 1	1.671	54.0
Material 2	14.418	506.3
Material 2	13.482	668.8
Material 2	13.5	588.6



Material 1


15
14
12
10
8
6
4
2
0
-1
Stress (MPa)
0
100
200
300
400
500
600
700
Strain (%)

Material 2