National Exams December 2011

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

Your company is currently considering acquiring a smaller company, which has as its primary product an artificial liver. While the artificial liver product is currently not in commercial development, representatives from the company comment that it is close to being so. Your job is to further explore this option. You have been told that the cell source for this product is embryonic stem cells and that the materials are primarily collagen based. Your role is to both assess the real potential of this product and to provide technical information on its potential for success to the economic people.

a) Describe the major technical areas involved in engineering something such as an artificial liver or other tissue engineered project.
b) Give criteria by which you would assess the "success" of the proposed design specifically related to the materials aspects of the device.

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 the viability of 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) There has been much research into techniques/systems/materials that reduce the problems associated with using biomaterials in blood contacting applications. Describe two potential options for improving the blood compatibility of biomaterials, discuss their potential for ultimately improving blood compatibility and describe any engineering challenges to implementing these to practice.

Question 4:

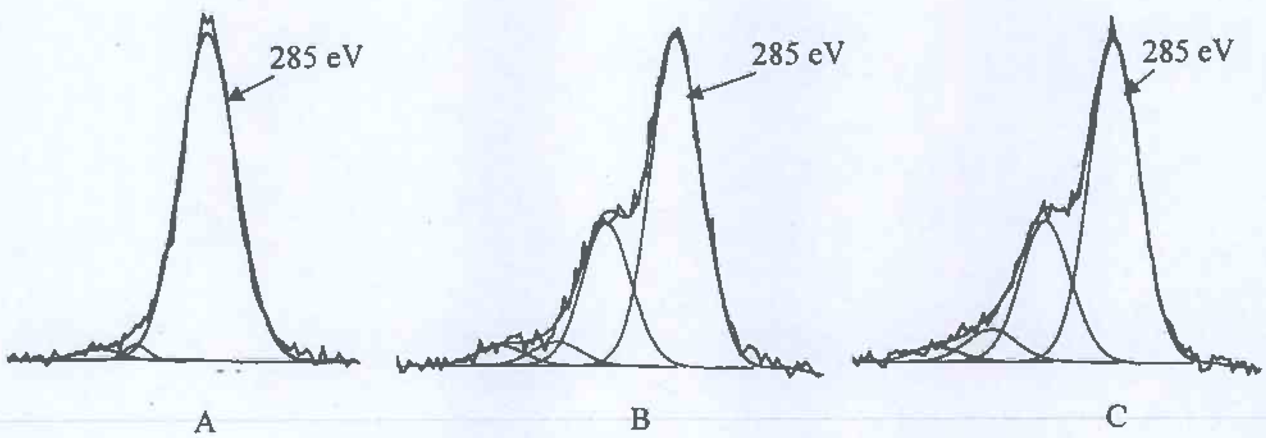
Hip implants have undergone significant changes since their introduction in both materials and design. These changes have led to the development of more successful biomaterials in orthopedic applications.

a) Discuss recent advancements in orthopedic materials engineering and why these changes have been so critical to the success of orthopedic implants.
b) Give biological perspectives as to why the current materials are more successful than their predecessors.

Question 5:
The response of the body to biomaterials has been suggested to be determined by the nature of the surface of the material. Therefore characterization of the biomaterial's surface is of significant importance.

a) X-ray photoelectron spectroscopy is an important surface characterization technique for both hard and soft materials, particularly for determining the chemistry of the surface. Explain the principles of XPS and how this technique can provide information about the chemistry of the surface.

b) The following three high-resolution C1s spectra were obtained. A represents a plain silicone surface, B represents modification of the silicone with poly(ethylene oxide), and C represents modification of the B surface with a protein. Discuss whether the spectra obtained are consistent with these modifications and why or why not.



Question 6:
Implantation of biomaterials leads to a host of reactions that can be characterized by a series of cellular reactions. There is currently a lawsuit pending related to composite temporal mandibular joint implants composed of silicone, poly(tetrafluoroethylene) and various metallic components.

a) Describe in general the expected wound healing response to these devices.

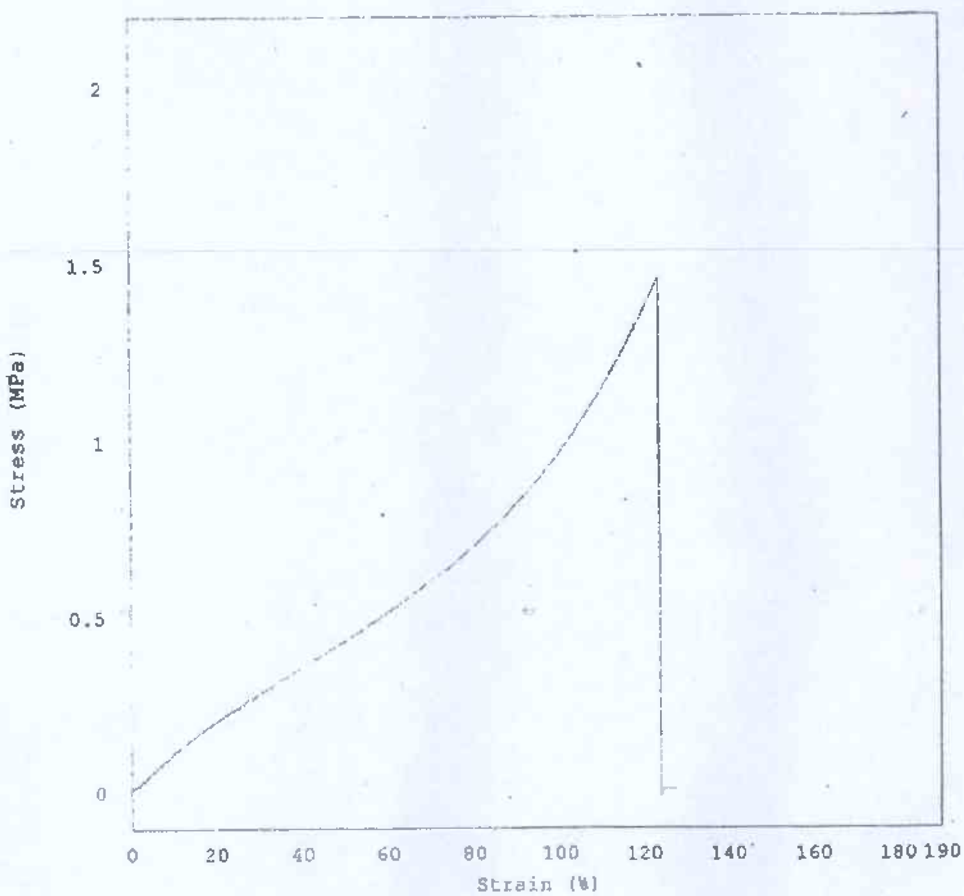
b) Which, if any, of these interactions could be related to the development of an immune response to the materials?

Question 7:
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.

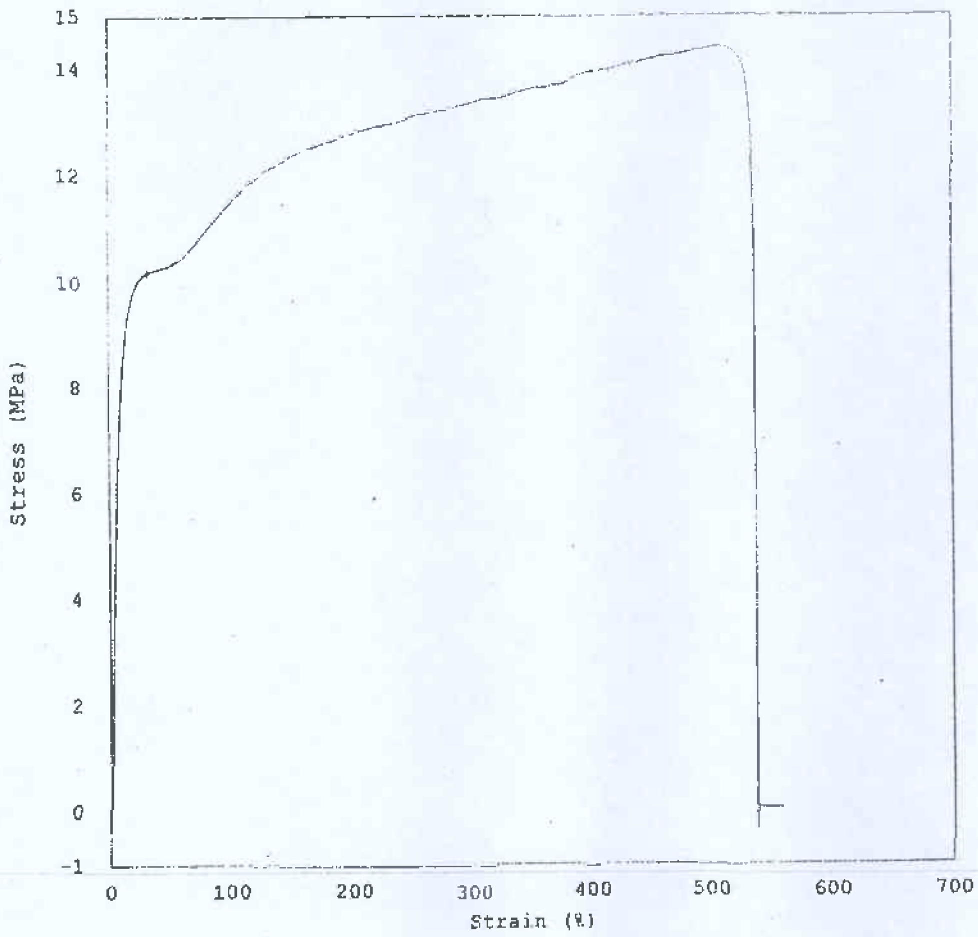
a) Describe the differences between the materials and how these properties might be essential for selecting a material.

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)	% Strain 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