UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATIONS, APRIL, 2000

Fourth Year - Program 5bme

MMS452S - BIOMATERIALS & BIOCOMPATIBILITY

Examiners - R.M. Pilliar, J.P. Santerre

Answer all 10 questions (see reverse side). Where appropriate, you may use point-form answers. (Answer Part A questions in one set of examination booklets and Part B in another).

Part A:

1. Polytetrafluoroethylene (PTFE) and ultra-high molecular weight polyethylene (UHMWPE) have both been used for acetabular cup components of artificial hip implants, however UHMWPE has proved to be the more successful of the two polymeric materials and is still in use today.

(5 marks) a) What structural features of the polymer chains could explain the improved performance of UHMWPE over PTFE.

(5 marks) b) Despite UHMWPE's success there are still a significant number of hip revisions done each year. UHMWPE has been attributed to causing a significant number of these failures. Briefly comment on the mechanism by which UHMWPE is implicated.

2. It has been proposed by a company that the wear of UHMWPE components in hip implants can be improved by incorporating a more lubricious polyurethane coating on the polyethylene.

(5 marks) a) How would you go about applying this polyurethane material to the surface of polyethylene such that a very stable layer is formed.

(5 marks) b) What do you think of this strategy? Will it result in a long-term successful outcome?

(10 marks) 3. It is said of synthetic vascular grafts that the outcome is often difficult to predict because of multiple parameters that influence the outcome. List five material characteristics of a synthetic graft that can influence the outcome of the implant healing process. Indicate their role on the process of healing and the function of the graft, and whether the parameter is more critical in the acute (immediately following implantation [i.e. hours to days]) or chronic (long-term [i.e. days to weeks]) phase of the implant.

(10 marks) 4. The human circulatory system is made up of vessels constructed of complex composite materials. These materials are designed to optimize both physical function and blood compatibility. If you were to design a composite (biological/synthetic polymer) graft, how would you proceed? Clearly define the starting materials and the rationale for the selection of these materials, the nature of any specific treatment and why the treatment was performed. The treatments must be outlined in the order of the actual process that you have conceived.

5. Biodegradation:

(4 marks) a) What are the two principal mechanisms by which human macrophage cells can promote the degradation of polymeric biomaterials?

(6 marks) b) Provide an example of polymer degradation for each pathway and very briefly highlight the principal features of the degradation process for your example.

Part B:

(6 marks) 6. a) Articular (hyaline) cartilage forms a unique tissue as part of a healthy synovial joint. Describe the structure of cartilage focussing on its extracellular components and the way that it is attached to bone. Indicate how its structural elements and their arrangements contribute to the excellent load-bearing properties of healthy synovial joints.

(2 marks) b) Indicate the significant changes that would have occurred to this structure in a severely degenerated osteoarthritic hip joint.

(2 marks) c) What is the major difference in mechanical characteristics (i.e. energy absorption capability, load-bearing ability) between a healthy hip joint and a total joint replacement consisting of a cast CoCrMo femoral component and an UHMWPE acetabular component.

(7 marks) 7. a) A company wishes to make a cementless knee implant system. Describe a bone-interfacing surface design that you would recommend for this implant to promote rapid osseointegration. Specify your choice of material(s) and the methods of fabrication to be used for implant fabrication. Give reasons for your choice.

(3 marks) b) List three necessary conditions for successful osseointegration of this cementless implant.

(4 marks) 8. a) What is the major difference between direct (primary) and indirect (secondary) fracture healing?

(3 marks) b) A manufacturer produces a biodegradable fracture fixation plate system (plate and bone screws) made of Self-Reinforced PLLA. Describe three potential advantages of such a system compared to a conventional 316L stainless steel plate and screw system.

(3 marks) c) Assuming the use of this Self-Reinforced PLLA system for repair of a fractured tibia, would you predict 'direct' or 'indirect' fracture healing? How could this be determined?

(3 marks) 9. a) Draw a diagram showing the differences in fatigue life versus probability of survival for; A) conventional bone cement, B) bone cement that has been centrifuged, and C) vacuum mixed and centrifuged bone cement. (Show all three curves on one diagram).

(3 marks) b) Give reason(s) for the observed differences.

(4 marks) c) A manufacturer introduces a carbon fibre-reinforced bone cement using 7 μm diameter x 2 mm long fibres uniformly dispersed throughout the pmma matrix. Give one possible advantage and one potential disadvantage of this modified cement. Would you recommend such a system for fixation of joint replacement implants? Explain.

(5 marks) 10.a) List five steps in the surface zone reactions that occur during development of 'bone bonding' at a non-loaded bioactive bioglass (e.g. 45S5) implant surface.

(1 mark) b) Why is this referred to as a 'surface reactive' bioceramic?

(3 marks) c) Describe the sequence of events that are thought to occur at the surface of a non-loaded cpTi implant placed in healthy bone?

(1 mark) d) How would premature implant loading alter the reactions for both these implants?