

OLLSCOIL NA hÉIREANN
The National University of Ireland

National University of Ireland, Galway

Trinity Examinations, 2001/02
Third Year Biomedical Engineering Examination

BIOMATERIALS

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Answer any 4 from Questions 1-5. Each question carries 15 marks.

Question 6 is compulsory: 40 marks.

Time Allowed: 3 hours

1. Expanded polytetrafluoroethylene (e-PTFE) sutures have been used with increasing frequency to replace chordae tendineae in mitral valves prolapsing because of myxoid change. A case was recently reported where implant failure led to severe mitral regurgitation 7 years after plastic repair and required mechanical prosthetic valve implantation.

- a. Explain the mechanism of failure and the possible explanations of the mechanisms? (9)
- b. What would you recommend for future replacements? (6)

2. In a recent report, the membranes present at the implant-bone interface were retrieved from two patients with titanium single stem hallux implants that had failed. Both patients had pain and valgus deformity of the hallux, and radiographs showed a radiolucent shadow around the implant stem, with thinning of the dorsal cortex of the proximal phalanx in one patient. After removal of the implants, arthrodesis of the first metatarsophalangeal (MP) joint was performed. Histological analysis of the membrane tissue at the implant-bone interface showed a synovial-like appearance. There was a fibrous tissue stroma adjacent to the bone surface, with multiple regions of scalloping covered by mononuclear cells. Multinucleated foreign body giant cells were sparsely observed and were similar to observations from failed total hip arthroplasties. The histological appearance is evidence that foreign-body granulomatous infiltration may be a causative factor of peri-implant osteolysis leading to aseptic loosening and failure of titanium single stem hallux implants.

- a. Explain the mechanism of failure and the possible explanations of the mechanisms? (9)
- b. What would you recommend for future replacements? (6)

3. You are working for an orthopaedic start-up company, and your supervisor has asked you to evaluate the possibility of constructing bone plates from a selection of materials: 316L SS, Ti6Al4V, cast CoCrMo, wrought CoNiCrMo, Al₂O₃, and carbon fibre-carbon composite.

- a. Which two would you choose based on biocompatibility? Why? (5)
- b. Which one would you choose for its strength? (3)

- c. Which one would you choose for its specific strength (s/r)? (3)
- d. If Ti6Al4V were the final choice, what would be its advantages and disadvantages? (4)

4. A polymeric, non-porous material (with dimensions $1 \times 1 \times 0.5\text{cm}^3$) is implanted subdermally.

- a. Describe the short-term (that is minutes-1day) responses of white blood cells at the site of implantation. (5)
- b. Describe the normal physiological responses of cells in the surrounding connective tissues a few days to a few weeks after surgery. (5)
- c. Discuss the pathologic complications that are pertinent and probable for this case. (5)

5. The major cause of vascular prosthesis failure is anastomotic intimal hyperplasia caused by the proliferation and migration of smooth muscle cells. Hepatocyte growth factor (HGF) is endothelium-specific, exerts a mitogenic action on endothelial cells, and has been shown in recent studies to suppress intimal hyperplasia formation. You are now developing a novel coating for stents in your start-up company using a unique ceramic coating that encapsulates this growth factor. Describe in detail the methods you would use to characterise this ceramic coating in-house? What useful information is gained by this characterisation? Your company contracts all biological assays to a GLP laboratory; hence, you are limited in what you can do in-house.

(15)

6. Choose any five medical devices from the following list
- Identify the biomaterials that are used in those applications. (5)
 - What is the selection rationale in choosing those biomaterials? (15)
 - What are the advantages and disadvantages in using those materials in that implant application? (15)
 - List the research activities that have been identified in the class with respect to these implants. (5)

1. Bone Substitutes
2. Hearing Aids
3. Human Heart Replacement
4. Intervertebral Discs
5. Sutures
6. Contact Lenses
7. Intraocular Lens
8. Bone Plates
9. Mechanical Heart Valves
10. Bone Screw
11. Tissue Adhesives
12. Root Canal Replacement
13. Wound Dressings
14. Vascular Grafts
15. Stents
16. Hip Joint
17. Catheters
18. Pacemakers
19. Shoulder Replacement
20. Rib Reconstruction
21. Knee Joints
22. Cochlear Implants
23. Tissue Heart Valves