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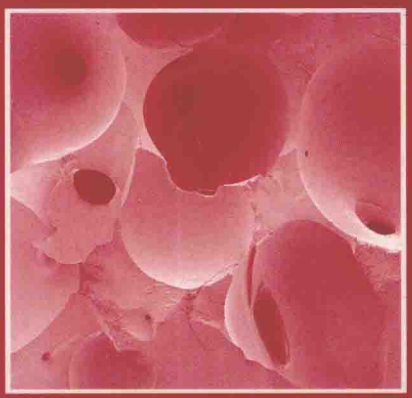

Biomaterials, artificial organs and tissue engineering

Edited by Larry L. Hench and Julian R. Jones

CRC

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1

Introduction

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1.1 Book and CD module

This book takes a novel approach to the teaching of the multi-disciplinary subjects of biomaterials, artificial organs and tissue engineering. These three areas of the broad field of biomedical engineering are included together in this volume because of their scientific, technological and clinical interdependence. For example, biomaterials are critical components in artificial organs and as scaffolds in tissue engineering. Understanding the interfacial interaction of living cells with man-made materials is fundamental to all three fields. Rapid advances in cell and molecular biology have an impact on the development of new biomaterials and their use in prostheses, artificial organs and tissue-engineered constructs. Keeping pace with rapid developments in these fields is a challenge.

The goal of this book is to meet this challenge in three ways:

1. The printed volume consists of 25 chapters organised into five parts. The five parts provide an introduction to and overview of living and man-made biomaterials; the various systems of the human body and their clinical needs for repair; various types of implants, devices and prostheses used to repair the body; the principles underlying alternative types of artificial organs; the scientific basis and applications of tissue engineering; followed by a discussion of socio-economic and ethical issues that influence the repair and replacement of parts of the human body. Each chapter corresponds to a 1- or 2-hour lecture in a one semester course at an advanced undergraduate level.
2. Each of the 25 chapters in the book is supplemented by an extensively illustrated lecture on CD-ROM. The CD-ROM is attached to the inside back cover of this book.
3. The CD-ROM also contains self-study questions for each chapter. These questions are designed to test your knowledge of each chapter and consolidate what you have learnt. Answers are provided separately so that you can review what you have learnt from each chapter.

The combined CD-ROM supplementary lectures, self-study questions and answers are referred to hereafter as the CD module.

1.2 Aims and objectives

The aims of the book and CD module are to:

1. Provide an understanding of the needs, uses and limitations of materials and devices to repair, replace or augment the living tissues and organs of the human body.
2. Establish the biomechanical principles and biological factors involved in achieving long-term stability of replacement parts for the body.
3. Analyse the principles and applications of engineering of tissues to replace body parts.
4. Examine the industrial, governmental and ethical issues involved in use of artificial materials and devices in humans.
5. Enhance the reader's awareness of the complex multi-disciplinary nature of the fields of biomedical materials, biomechanics, total joint replacements, artificial organs and tissue engineering, and the importance and methods of communication with a broad range of people including clinicians, patients, industrial and governmental personnel.

Core objectives of the textbook and CD module

After studying this book and CD module the student will be able to:

- Identify various components of the human body, describe their function and explain the effects of ageing on the structure and function of various groups of tissues and organs.
- Describe the major classes of biomedical implant materials, their means of fixation, their stability and advantages, and their disadvantages when used as implants, devices and in artificial organs.
- Explain the types of failure of implants, devices and prostheses in various clinical applications and the reasons for failure.
- Describe the physiological principles involved in the replacement of various parts of the body with artificial organs, transplants or tissue-engineered constructs and the clinical compromises involved.
- Interpret lifetime survivability data of medical devices, and relate clinical success to biomaterial characterisation, device design and clinical variables.
- Discuss the clinical and socio-economic factors in the use of implants, transplants, artificial organs and tissue-engineered constructs including industrial, governmental, regulatory and ethical issues.
- Defend the relative merits of replacing a body part with a tissue-engineered

construct, discuss the principles involved in growing body parts *in vitro* and describe the physiological and clinical limitations involved.
- Research the literature for new developments in replacement of tissues and organs.
- Communicate alternative means to repair or replacement of parts of the body to healthcare professionals, patients, business and government personnel.

Specific objectives

There are five parts to the book and CD module. The following list documents what the student will be able to do by the end of each part.

Part I: Introduction to materials (living and non-living)

- Describe the microstructure of metals, ceramics, polymers and composite materials.
- Relate the mechanical strength and fatigue of various materials to their microstructure.
- Compare the processing routes for manufacture of various materials and explain how processing affects microstructure, properties and reliability of the materials.
- Describe the parts of a cell and their importance in cell function, proliferation and differentiation.
- Identify the four types of tissues and describe their function.
- Define the concept of biocompatibility and describe how it is tested.
- Explain the mechanism and relevance of inflammatory changes to tissues in contact with biomaterials and their importance in wound healing and long-term prognosis for implants and artificial organs.

Part II: Clinical needs and concepts of repair

- Define and compare the differences between implants and transplants and their relative advantages and disadvantages.
- Classify the types of tissues and organs in the body and their function in relation to replacement by artificial materials.
- Describe the effects of ageing on the structure and properties of the skeletal, cardiovascular, sensory and other systems.
- Identify the various categories of implant materials and devices, and the means of their fixation to various physiological systems.

Part III: Applications

- Identify the bones, tendons and ligaments of the human skeletal

system and describe their mechanical properties as a function of ultrastructure, microstructure and macrostructure.
- Describe the repair mechanisms of the skeletal tissues as a function of mode of failure and age of patient.
- Select the types of fixation and joint replacement device required for various types of repair of the skeletal system and explain the advantages and disadvantages of use of each type of device related to the clinical problem addressed.
- Compare the physical properties of metallic alloys, medical polymers and bioceramics used for orthopaedic fracture fixation and total joint replacement.
- Analyse the sources of failure of orthopaedic prostheses.
- Describe the effects of elastic modulus on stress shielding of bone.
- Compare the relative merits of different total hip, total knee, shoulder and spine systems on long-term survivability by use of Kaplan–Meier survivability curves.
- Define bioactivity and compare bioactive fixation versus cement or morphological fixation of prostheses.
- Discuss polymeric materials that do not degrade in the physiological environment and their application in medical devices.
- Describe polymeric materials that undergo controlled rates of resorbtion in the body, such as those used in sutures, and the mechanisms of resorbtion and the effect of time and load on resorbtion rates.
- Describe the mechanisms of surface reactions that are involved in blood clotting and the surface characteristics of polymers that are haemocompatible and the blood contacting devices made from such materials.
- Understand how mechanical devices can replace the function of organ systems in the body, including the heart, blood vessels, lungs, kidneys and sensory organs.
- Describe the engineering design principles for effective function of artificial organs, including their performance in terms of their material properties, exchange processes, maintenance of appropriate blood flow and compatibility with the overall function in the body.
- Be capable of describing to healthcare professionals and patients the advantages, disadvantages and limitations of artificial organs.

Part IV: Tissue engineering

- Discuss for any given tissue engineering application the importance of evaluating sources of cells to promote repair, including somatic stem cells, embryonic stem cells and 'mature' cells from the tissue of interest.
- Discuss the basic principles of cell culture and characterise the various cell types using methods such as immunocytochemistry, scanning electron

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