Repair and Redesign of Physiological Systems

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Design and Nature

Objectives

Our understanding of the modern world is largely based on an ever increasing volume of scientific knowledge. Engineering designers have at their disposal a vast array of relationships for materials, mechanisms and control, and these laws have been painstakingly assembled by observation of nature. As space activity accustoms us to cosmic scales, and as medicine and biology to the molecular scale of genetics, we have also become more aware of the rich diversity of the structural world around us.

The parallels between human design and nature has inspired many geniuses through history, in engineering, mathematics and other subjects. Much more recently there has been significant research related to design and invention. Even so, current developments in design engineering, and the huge increase in biological knowledge, together with the virtual revolution in computer power and numerical modelling, have all made possible more comprehensive studies of nature. It is these developments which have led to the establishment of this international book series.

Its rationale rests upon the universality of scientific laws in both nature and human design, and on their common material basis. Our organic and inorganic worlds have common energy requirements, which are of great theoretical significance in interpreting our environment.

Individual books in the series cover topics in depth such as mathematics in nature, evolution, natural selection, vision and acoustic systems, robotics, shape in nature, biomimetics, creativity and others. While being rigorous in their approach, the books are structured to appeal to specialist and non-specialist alike.

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Repair and Redesign of Physiological Systems

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Preface

Surgical repair of the human body is where design and nature intersect most significantly because here manmade technology serves to enhance and even prolong human life. Engineers and clinicians have long been collaborators working to improve the human physical condition and in this volume we have contributors from both fields revealing current state of the art in restoring normal function to human physiology.

Making good the effects of wear and tear through adjustment or replacing worn parts is a familiar part of the ownership experience for consumers of everyday objects. If a fault is persistent then a redesign may alleviate the problem. However, repair and redesign of human physiology is quite a different prospect because, as we shall see in this volume, no two humans are the same and 'spare parts' may be unacceptable or even be in very short supply.

Planning and assessing a course of action for repair and redesign of physiological systems increasingly relies upon computer simulations in order to better understand function. The Physiome project briefly described in chapter 2 is an engineering approach to computational physiology that models anatomical structure and function at multiscales; in particular, a model of the gastro-oesophageal junction reveals the contributions of different elements of surgery on the ability to swallow. In chapter 1, chapter 3 and chapter 7, we see the role of Computational Fluid Dynamics in understanding the patient-specific blood flow patterns of bypass grafts, heart chambers and nasal airways respectively. CFD now enables us to predict the results of surgical intervention pre-operatively.

Alternative technologies to the given physiology are addressed in chapter 6 with regard to Ventricular Assist Devices, which presents challenges of biocompatibility and minimising damage to the blood caused by the excessive stresses of mechanical action. A diseased heart is prone to failure, which can be resynchronised or defibrillated by a signal generator acting through a wire located inside the heart. Chapter 5 addresses the effectiveness of echocardiography and electrocardiogram in assessing suitability for Cardiac Resynchronisation Therapy. Chapter 10 describes Biolistics, a radically new delivery technology that uses pressurised gas to accelerate treatment particles so that they penetrate the skin and thus target particular cells within the outer skin layers. This addresses a major constraint on making full use of immunotherapies, which is the limited ability to deliver genes and drugs to the required site in the body, specifically skin and mucosal sites.

Chapter 8 and chapter 9 address repair and redesign issues of dental practice. In dental care, the trend has been to treat decay and restore teeth rather than remove diseased teeth. New systems, based on mature engineering technologies such as laser and abrasive cutting, CADCAM, adhesives and inserts, allow teeth to be repaired more conservatively. Increased demand for cosmetic improvements means a shift from disease-oriented treatment to life-style driven cosmetic treatments

such as orthodontics, whitening and veneering. Laser scanning, CT and MRI are used to reverse engineer key features of the patient's jaw for a patient-specific solution. Finite element analysis is used to assess loads and stresses.

We thank the authors for their vital contributions and also their patience in waiting for this volume to come to fruition.

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