

Chapter 2

Artificial Organs

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ABSTRACT

The market of tools, devices, and processes for medical treatments and diagnosis has been growing at a very fast pace, driven by the multi-disciplinary development of integrated innovative technologies. In this chapter, the way artificial organs design is currently taught is analyzed and discussed relative to the evolution of the methods of artificial organs design as substitution of physical and metabolic bodily functions. Particular attention is devoted to the evolution from empirical attempts at providing generic replacement of a single mechanical function to a more systematic multi-purpose approach that increasingly accounts for biological issues. As a result, at the forefront of research, the paradigm is shifting from mechanical/electronic prostheses towards the development in vitro of tissue engineered organs/tissues, where the artificial part is fully integrated with the biological counterpart. Personalized solutions for each patient rather than a generic solution good for all patients are also sought.

2.1. CHAPTER OBJECTIVES

This chapter aims at discussing possible improvements to the way courses on artificial organs design are currently organized in Universities to make them better adapt to the rapid evolution of the methods to design artificial organs and of the needs of healthcare systems, and qualify students to contribute creative innovation in the next decades. In particular, it shall be discussed:

- The growing importance of artificial organs in healthcare systems;
- The evolution of design methods of artificial prostheses/organs to substitute for physical or metabolic bodily functions;
- The main characteristics of artificial organs design that make it a challenging task;
- The current teaching of artificial organs design;
- The future perspectives in the teaching of artificial organs design.

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2.2. INTRODUCTION

The market of tools, devices, and processes for medical treatments and diagnosis has been valued at about 260 billion Euro in 2008, with an estimated market share of 51 billion Euro in Europe where the market grows at an impressive annual rate of about 9%, limited only by restricted health care budgets but faster than other innovative fields (Themedia, 2009; Vienken, 2011). In fact, the medical device market grows faster than the pharmaceutical market in spite of the fact that it is half as big in size (Rosen, 2008). Within this framework, in a recent report it was estimated by Global Industry Analysts Inc. that the global artificial organs market would exceed US\$ 9.7 billion in 2010, and would reach US\$ 15.4 billion by 2015 (Daily Finance, 2011; www.kidney-friends.net, 2011). Artificial devices and processes (often collectively referred to as “artificial organs”) are used to substitute for physical and metabolic bodily functions in a very broad range of therapeutic applications. To quote but a few, glasses, external and internal contact lenses, and tissue-engineered corneas are used to augment or restore eyesight. Hearing aids and cochlear implants are used to augment or restore hearing. Tracheo-aesophageal shunt valves and voice prostheses are used to restore or help rehabilitate speech. Internal and external mechanical prostheses are used to replace missing or failing joints or limbs (and parts thereof). Mechanical stents, valves and pumps are used to maintain blood vessels pervious and regulate blood flow. Mechanical devices are available for the temporary substitution of failing human heart (*the artificial heart*). Extracorporeal membrane devices are used to substitute for the mass exchange functions of kidneys (*the artificial kidney*) and lungs (*the artificial lung*). Extra- and intra-corporeal, purely artificial or hybrid processes are being developed to substitute for the very complex metabolic functions of pancreas and liver (*the artificial and bioartificial pancreas and liver*). Neural prostheses for Alzheimer’s and Parkin-

sonian patients are expected to be available in the next future. The artificial kidney is reported to be the largest market segment of artificial organs, and it is estimated to reach US\$ 4.6 billion (i.e., ca. 48% of the total artificial organs market) in 2010 and to continue its domination. Decades of research to acquire deeper knowledge of human physiology in the healthy and the diseased state and the multi-disciplinary development of integrated innovative technologies have made artificial organs the viable alternative to organ/tissue transplantation to address the donor organs/tissue shortage problem, at sustainable costs. Artificial organs (as well as medical devices as a whole) technologies and products are slowly converging towards technologies and products typical of the pharmaceutical industry, with cell biology (e.g. stem cells) and material science (e.g. nanotechnology) having increasing importance. This makes the “nuts and bolts” character of the early artificial organs slowly fade away. As a result, besides sustaining life, artificial organs are now designed and operated also to minimize disease or treatment complications and enhance the quality of patients’ life, as well as to facilitate the early patients’ return to an active social life.

The current demographic trends depict a diverse and even more challenging future scenario for biomedical engineering (BME). In fact, advancements in medical diagnosis, drugs and treatments, together with a healthier lifestyle, have brought about an unprecedented increase in longevity since World War II. Together with the birth rate reduction typical of developed countries, this is causing significant population ageing. The life expectancy of 22 additional years typical of a 25 years-old in 1900 is today forecast for a 65 years-old individual (Vienken, 2011). Unfortunately, human body is not designed to be fully functional for that long and wears before. Eyesight, hearing capacity, sense of balance, and joints (to quote but a few) deteriorate in elderly people. This exposes them to unwanted complications, significantly worsens the quality of their life, and dramatically

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