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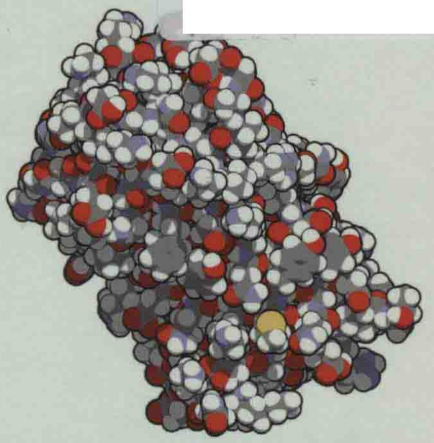
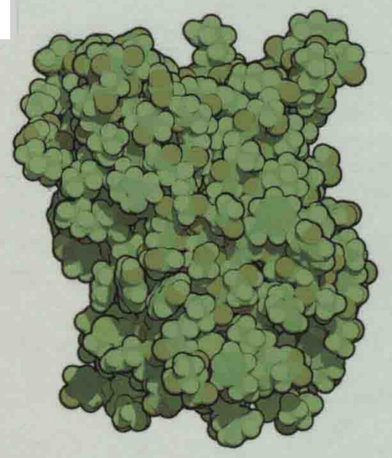
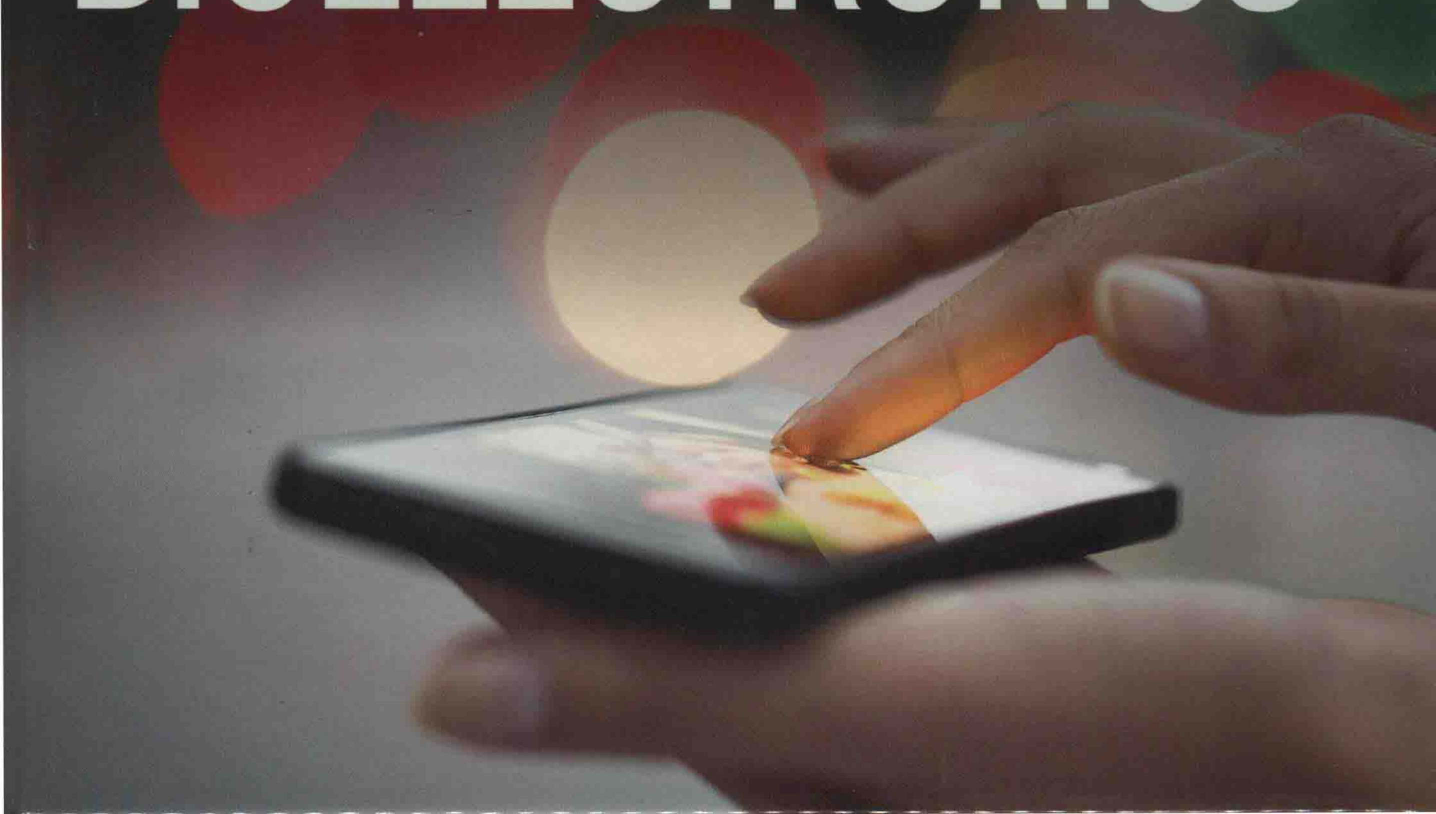




BIOSENSORS AND BIOELECTRONICS



BIOSENSORS AND BIOELECTRONICS

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PREFACE

The aim of this book is to provide the basics of the core concepts, methods, and instrumentation of biosensors, a multidisciplinary field requiring knowledge not limited to basic science, viz., biology, chemistry, and physics but also medicine and engineering. It is hoped that the reader will acquire the fundamentals and the state-of-the-art developments in this subject as it stands today. This book is dedicated to students, researchers, and R&D scientists who wish to understand, enhance, and broaden their knowledge and expertise on the fundamentals, technologies, and applications of biosensors. The book begins with the definition of biosensors and their classifications depending upon transduction and bioreceptor components. Molecular recognition based on geometry and forces of interaction plays an important role in biosensor development. Among the biosensor techniques, electrochemical biosensors are cost-effective, miniaturized, and applied for point-of-care application studies. Hence, their theory and methods are discussed in detail. Chapter 2 presents the advent of nanotechnology for development of highly efficient nanobiosensors. Organic conducting nanopolymers in organic electronics and electrochemical transistor, inorganic nanoparticles, and their nanocomposites as excellent transducers have shown to be biocompative. Hence, the nanocomposites provide an immobilization matrix for various bioreceptors. Chapter 3 focuses on enzymatic and their mimetic-based biosensors for the determination of various biomarkers. Several pathologies are identified by the presence of their specific markers, for instance, cytochrome c for measurement of apoptosis, nitric acid and metabolites as hypoxia markers, cholesterol for cardiovascular disease, etc. Their development, including their optimization and characteristics of biosensors for these biomarkers, has been demonstrated.

Chapter 4 presents the recent advances in antibodies research and their applications for immunosensor development. Electrochemical immunosensors for metalloproteins, nonmetalloproteins, and cancer cells using their specific antibodies are emphasized. In Chapter 5, the essential components for the development of biosensors instrumentation are discussed. Virtual electrochemical instrumentation development using labVIEW is presented. Also, hand held microcontroller-based electrochemical biosensors are assembled and applied for the measurement of various biomarkers including cytochrome c and nitric oxide metabolites. These chapters provide the essential background knowledge and up-to-date advances in this field. The book should thus serve as an introductory text for those who intend to specialize in either the theoretical or practical applications. It is hoped that this textbook will be a fruitful launch pad for many careers in biosensors and bioelectronics.

Many thanks are due to Dr Kalpana Bhargava and Dr Robson Benjamin for their constant support and cooperation as coeditors and authors of this book, all the contributing authors from a wide variety of disciplines, and the collaborators and researchers from around the globe for their achievements in this field and who have made valuable contributions that have made this book possible. It is a true pleasure to acknowledge the following: Prof. R. Murugesan, Prof. B. Kalyanaraman, and all teachers for their inspiration and guidance: Dr A. Rajendran, Dr Srigiridhar Kotamraju, Dr Shasi Kalivendi, Dr Anuradha Dhanasekaran, Dr Sushil Kumar Singh, Dr D. Christopher Durairaj, Dr S. Elango, Dr K. Arun Venkatesh, Mr K. Vairamani and all colleagues for their input and sharing knowledge; the principal and managing board of our institution for their encouragement and cooperation; Prof. George Malliaras and Dr D. Raja Shunmugam for their suggestions and critical comments; my wife and children for their perseverance and support during the preparation of the book; and Mr K. Harish for reading through the manuscript. I am also indebted to Dr S. Rajesh, Dr U.S.E. Arivudainambi, Dr S. Rajasingh, Dr S. Prakash, Dr P. Gurusamy, Dr V. Ramesh, Dr M. Pandiaraj, Dr T. Madasamy, Dr Manjulata Singh, Mr Aditya Arya, Mr M. Balamurugan, Mr G. Muneeswaran, Mr P. Santharaman and Mr R. Rajkumar for their contributions that enabled me to undertake this task and complete it. Finally, it has been a great experience to work with my publisher, Elsevier, and special thanks to them for their effort in making this book possible.

Dr Chandran Karunakaran

CONTENTS

CHAPTER 1

Introduction to Biosensors

Chandran Karunakaran[1], Raju Rajkumar[1], Kalpana Bhargava[2]
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Contents

Biosensors and Bioelectronics
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1.1 INTRODUCTION

Bioelectronics deals with the application of the principles of electronics to biology and medicine. Biosensor is a special type of bioelectronic device commonly used in bioanalysis. A sensor can be viewed as the "primary element of a measurement chain, which converts the input variable into a signal suitable for measurement." Over the past decade, many important technological advances have provided us with the tools and materials needed to construct biosensor devices. Since the invention of the Clark oxygen electrode sensor, there have been many improvements in sensitivity, selectivity, and multiplexing capacity of modern biosensors. *Biosensor* can be defined as a compact analytical device incorporating a biological or biologically derived sensing element either integrated within or intimately associated with a physicochemical transducer. Two fundamental operating principles of a biosensor are "biological recognition" and "sensing." Therefore, a biosensor can be generally defined as a device that consists of three basic components connected in series: (1) a biological recognition system, often called a bioreceptor, (2) a transducer, and (3) microelectronics. The basic principle of a biosensor is to detect this molecular recognition and to transform it into another type of signal using a transducer. The main purpose of the recognition system is to provide the sensor with a high degree of selectivity for the analyte to be measured. The interaction of the analyte with the bioreceptor is designed to produce an effect measured by the transducer, which converts the information into a measurable effect such as an electrical/optical signal. According to IUPAC recommendations 1999, a biosensor is an independently integrated receptor transducer device, which is capable of providing selective quantitative or semiquantitative analytical information using a biological recognition element (Thévenot et al., 1999). The purpose of a biosensor is to provide rapid, real-time, accurate, and reliable information about the analyte of interrogation. Ideally, it is a device that is capable of responding continuously, reversibly, and does not perturb the sample. Biosensors have been envisioned to play a significant analytical role in medicine, agriculture, food safety, bioprocessing, environmental and industrial monitoring (Luong et al., 2008).

1.2 BASIC PRINCIPLE OF A BIOSENSOR

The term *biosensor* is short for *biological sensor* and is a device made up of a transducer and a biological element that may be an enzyme, an antibody, or a nucleic acid. The biological element or bioelement interacts with the analyte being tested and the biological response is converted into an electrical signal by the transducer. Every biosensor has a biological component that acts as the sensor and an electronic component that detects and transmits the signal. In other words, the biological material is immobilized and a contact is made between the immobilized biological material and the transducer. The analyte binds to the biological material to form a bound analyte, which in turn produces the electronic response that can be measured. Sometimes the analyte is converted to a product that could be associated with the release of heat, gas (oxygen), electrons, or hydrogen ions. The transducer then converts the product-linked changes into electrical signals, which can be amplified and measured. If the bioelement binds to the analyte, the sensor is called an *affinity sensor*. If the bioelement and the analyte give rise to a chemical change that can be used to measure the concentration of a substrate, the sensor is called a *metabolic sensor*. If the biological element combines with analyte and does not change it chemically but converts it to an auxiliary substrate, the sensor is called a *catalytic sensor*. Figure 1.1 represents the basic principle of biosensor.

1.3 COMPONENTS OF A BIOSENSOR

A biosensor consists of three main elements: a bioreceptor, a transducer, and a signal processing system (David et al., 2008). Biosensors can be classified by their bioreceptor or their transducer types. The classifications of biosensors based on bioreceptors and transducers are represented in Figure 1.2.

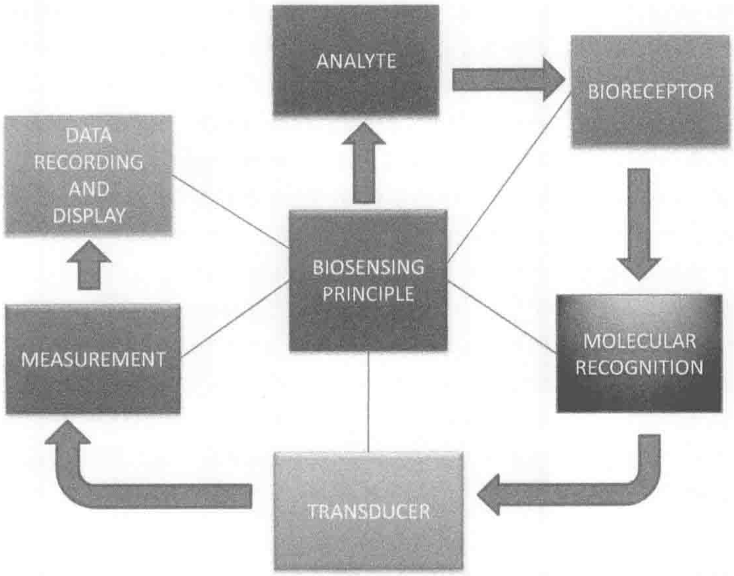

Figure 1.1 Basic principle of biosensors.

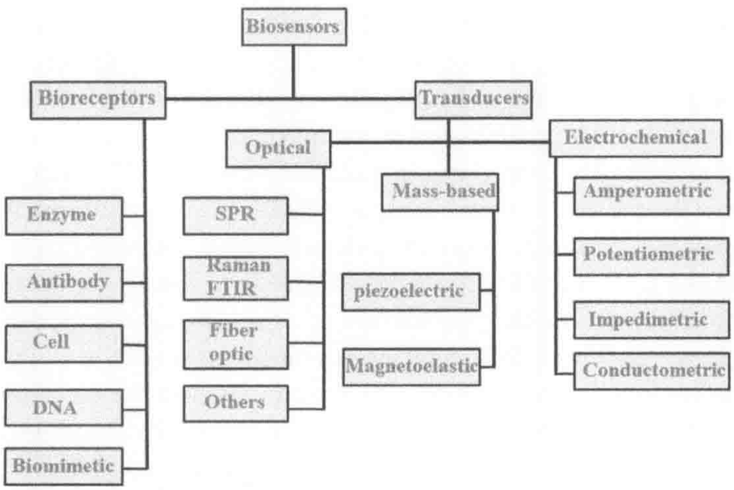

Figure 1.2 Classification of bioreceptors and transducers.

1.3.1 Bioreceptors

Bioreceptors or the biological recognition elements are the key to specificity for the biosensor technologies. The bioreceptor or biological recognition element is the significant distinguishing feature of a biosensor. The bioreceptor comprises the recognition system of a sensor toward the target analyte. A bioreceptor is molecular species that