Chapter 2
Retinal Prosthetics

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ABSTRACT

In this chapter, the authors briefly introduce the neuroanatomical basis for vision and explain how the retina processes visual information. Pathology of the retina and the conditions that cause photoreceptor degeneration and lead to blindness are then given, followed by the main part of the chapter in which they present an overview of the concept of restoring vision with visual prosthetics. The focus is specifically on retinal prostheses and electrical stimulation parameters used with these devices. Both in vitro and in vivo animal studies from the last decade are surveyed, together with the latest results from human trials conducted in multiple research centers worldwide. Eventually, the authors discuss current open issues of the technology, such as implant placement, biocompatibility, electrode design, and safety. In the final section, they give their opinion on future developments and perspectives.

1. INTRODUCTION

According to the World Health Organization (n.d.) there are currently 285 million visually impaired people world-wide, of which 39 million are blind. Eighty percent of cases with visual impairment can be avoided of cured. For the remaining 20% there is no cure. Retinal diseases, such as age-related macular degeneration and retinitis pigmentosa, are in the group without any cure. These diseases cause the degeneration of the photoreceptors in the retina which leads to a reduction of visual acuity and, in worst cases, complete blindness. Following photoreceptor degeneration, other layers of the retina remain partially intact. The concept of retinal prostheses was developed to restore useful vision in blind patients by activating this remaining inner retinal network using electrical stimulation.

The topic of this chapter are electronic devices that are implanted in the eye and used to restore vision in cases where there is no other means to do so. We first give a brief introduction to the neuroanatomical basis for vision and explain how the retina processes visual information from the point the light enters the eye until the signal reaches higher brain centers and forms visual perception. Pathology of the retina and conditions that cause the degeneration of the photoreceptors and lead

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to blindness are also included in this background section, followed by the presentation of the concept of artificial vision restoration with prosthetics.

The next section focuses on retinal prostheses. This is the main part of the chapter. State of the art in the field is presented, including a comprehensive literature survey that covers articles published in relevant scientific journal throughout the last decade or so. In section that follows we discuss device placement, electrical stimulation parameters, biocompatibility, safety issues, and electrode design challenges specific to high-resolution implants. Differences between results from in vitro and *in vivo* animal studies are also discussed. The chapter concludes with perspectives and future developments.

We feel this book as a whole would be a much needed addition to the sparse literature available today. We hope that a presentation of the latest developments in neural prosthetics research in such a concentrated and unified form will find an audience among graduate students, engineers and scientists alike.

2. BACKGROUND

2.1 Structure of the Eye

The eye is a complex organ though which we perceive vision. The round shape of the eye is maintained by its outermost layer which is called the sclera (Figure 1). Light enters the eye through the part of this layer that is called the cornea. Underneath the sclera is the choroid, the second layer that carries blood vessels. It delivers the necessary blood supply to all the structures of the eye. The colored part of the eye, the iris, is the frontal part of the choroid. Its function is to control the aperture size of the pupil, the opening through which light enters the eye. The innermost layer is the retina. Its function is to convert light that enters the eye into bioelectric signals. The inside of the eye is filled with two fluids, separated into different compartments by the lens. The larger section contains the gel-like vitreous humor, and the smaller front section contains a clear fluid called the aqueous humor.

Figure 1. Structure of the eye. There are three main layers. The outermost layer is the sclera, underneath which lies the choroid, and the innermost layer is the retina.