Chapter 16
Neural Engineering

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ABSTRACT

This chapter provides a definition for Neural Engineering and briefly describes its history. An introduction to neuroscientific principles is presented to provide a basis for understanding neurally-engineered developments. Specific advances in neuroprosthetics are described, including visual prosthetics, cochlear implants, myoelectric artificial limbs, brain-computer interfaces, and functional neuromuscular stimulation applications. Other neural engineering applications and the future potentials of the field are also considered.

16.1. CHAPTER OBJECTIVES

This chapter presents a framework for defining and then understanding what Neural Engineering is, can do now, and might be able to do in the future.

16.2. INTRODUCTION

In some areas, the dreams of science fiction writers of the last millennium are being made into laboratory realities early in this one by neural engineers. A few who were blind can now experimentally see; many more who were deaf can now hear; some who were mute can now speak; and a number who were lame can now walk – all via neural engineering. Many of the public calls these advances "*miracles*". But, the restoration of these senses and abilities by neural engineered methods is not perfect, and restorations still pale in comparison to what a normally functioning sensory or motor system can do. However, some ability to interact with the environment is judged by nearly all to be better than having no such ability.

16.3. A COMPREHENSIVE DEFINITION OF NEURAL ENGINEERING

Many associate the term *neural engineering* only with *neuroprosthetics*. It certainly is a major but not the only component of the Neural Engineering field. A tautological definition of Neural

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Engineering could either be "*the application of engineering principles to the study and restoration of nervous system function*" or "*mimicking the nervous system's form and function to engineer devices, techniques and concepts*". The first goes from engineering to the neurosciences; and the second reverses the path of discovery and innovation. But, a definition of neural engineering expanded from that of Robinson (2000a) reflects the fact that neural engineering most often uses both paths simultaneously!

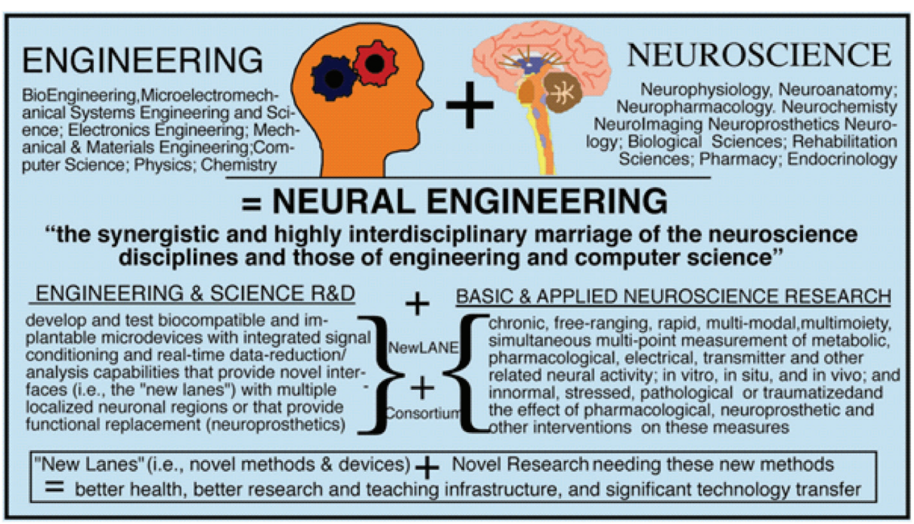
Neural Engineering is the highly interdisciplinary marriage of the neuro-scientific disciplines and those of engineering and computer science that aims to better understand and to mimic the functioning and dysfunctioning of the nervous system and to engineer appropriate augmentation and/or substitution for dysfunctioning parts of the nervous system.

As illustrated in Figure 1, Neural Engineering brings an impressively wide range of engineering and basic science disciplines together with an equally broad range of biological and medical sciences. It links basic and applied engineering and science R&D with basic and applied neuroscience. Rather than talk just about simple interfaces, the products of the neural engineering endeavor can be considered as wide streets or *lanes* through which information flows. These new lanes emphasize a systems approach to neural engineering development, where considerations include biocompatibility; implantability; the integrated nature of the electronics and transducers; real-time command, control, communication; multi-modalities; among many others.

16.4. HISTORICAL BACKGROUND AND LITERATURE OVERVIEW

Neural Engineering can be roughly divided into three parts: i) *neural instrumentation* and signals and systems analysis, ii) *neural reverse-engineering* (e.g., neuromorphic systems), and iii) *neural re-engineering* (i.e., neuro-rehabilitation). With regard to the first part, most neuroscientists, even today, do not understand the great role that engineering advances played in the development of modern neuroscience through advances in instrumentation and analysis techniques. The research on single nerve fibers that won Erlanger and Gasser their 1944 Nobel Prize was based on

Figure 1. Neural engineering marries engineering practice and neuroscience knowledge. ©2011, Robinson C.J. Used with permission.



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