
Preface

In recent years, there has been an increase in the use of nanoparticles in various medical fields, including neuroscience. This increased use is a result of advances in our ability to control the nanoparticles' physical and chemical properties, allowing them to interact with various components of the nervous system in specific ways. Currently, there is an interest in understanding the basic principles that govern those interactions in order to take advantage of them to develop various biomedical applications. To reach that goal, there is a need to bring together the main techniques developed to quantify experiments using nanoparticles in the nervous system. These techniques include how to synthesize and functionalize nanoparticles, monitor and influence their delivery and uptake, identify and evaluate their lethal and nonlethal effects on the function and metabolic activity of the nervous system, and how to use them to affect the electrophysiological, cellular, or network activity intrinsically or through external stimuli. This book is a first step toward achieving that goal.

The book is divided into four broad areas of research:

1. Photostimulation
2. Thermal stimulation
3. Mechanical perturbation
4. Toxicity and physiological effects

The first three sections focus on methodologies where nanoparticles interact with some external source in order to perturb the neuronal system. The last one focuses on the effects resulting from having nanoparticles present in a neuronal system in the absence of any external stimuli. This division is somewhat arbitrary given that several chapters bridge two or more of these areas of research. We also want to note that although some very important topics in nanoparticle in neuroscience research may appear to be missing in this volume, such as strategies to functionalize and deliver nanoparticle, they are introduced and addressed in several chapters even if they are not the main focus of any one chapter. We encourage readers to review the contents of all chapters in order to take full advantage of all the different and complementary techniques contained within this volume.

In the following we address the basic ideas behind each area of research identified and briefly summarize the contents of the 16 chapters contained in this volume.

Photostimulation

The chapters in this section provide the techniques to utilize different wavelengths of light in combination with metallic nanoparticles to stimulate various types of neuronal cells including isolated neurons (Chapter 1), cultured neurons (Chapter 2), and brain slices (Chapters 1 and 3) with the primary goal of affecting their electrophysiological activity. In Chapter 1 the activity is monitored using voltage sensitive dyes, in Chapter 2 fluorescent imaging techniques, and in Chapter 3 whole-cell patch-clamp techniques.

Thermal Stimulation

In this section, the primary mechanism used to affect neurons is heat. In Chapters 4 and 5, heat is generated by stimulating magnetic nanoparticles with alternating magnetic fields or radiofrequency, resulting in neural modulation. In Chapter 4 the nanoparticles are synthesized using thermal decomposition, are composed of ferrites, and are coated in order to target specific cell surface receptors. In Chapter 5 the nanoparticles consist of genetically encoded ferritin iron-oxide nanocomposites which, when stimulated with radiofrequency, produce heat and affect modified temperature sensitive ion channels. These nanoparticles can also be stimulated with magnetic fields in which case they exert mechanical forces on the cell membrane that can be used for modulation, rendering this chapter relevant to Subheading 3 (mechanical perturbation) of this volume. Chapter 6 details a technique to utilize bare metallic nanoparticles for photothermal ablation of cells and organelles in brain slices. In addition, it provides a bridge to Subheading 4 of this volume by presenting a methodology to elucidate the nonlethal effects of gold nanoparticles on the firing rate of hippocampal cells.

Mechanical Perturbation

Another promising approach to affect neuronal function is to mechanically perturb the cells. As mentioned above, in Chapter 5 the authors describe a technique to exert mechanical forces on the cell membrane by stimulating magnetic nanoparticles with magnetic fields. These forces can affect specific ion channels and modulate the neuron's activity. Chapter 7 continues with the theme of stimulating superparamagnetic nanoparticles with magnetic fields. The nanoparticles can be targeted intracellularly to signaling endosomes or extracellularly to cell surface receptors and can be used to regulate growth cone motility, bridging Subheadings 3 and 4 (physiological effects) of this volume. In Chapter 8 the authors present a technique to stimulate neuroblastoma cells in culture by exciting piezoelectric nanoparticles with ultrasound waves. They monitor the electrophysiological activity with fluorescent imaging techniques. Chapter 9 is primarily concerned with affecting the uptake of chitosan-coated metallic nanoparticles by modifying the cell membrane's permeability via nanopore formation. The nanopores are formed through exposure to nanosecond pulsed electric fields and the changes in uptake are monitored using fluorescent imaging techniques.

Toxicity and Physiological Effects

Nanoparticle toxicity can be divided into lethal and nonlethal where the latter results in changes in the function and/or metabolic activity of neurons. Chapter 6 above and Chapters 10 through 14 primarily focus on the effects of nanoparticles on ionic currents as observed using electrophysiological recordings. Chapters 6 and 10 connect experimental data to computer models in order to identify which specific ionic channels in hippocampal slices (Chapter 6) and individual cultured cells (Chapter 10) are affected by bare metallic nanoparticles. The next two chapters study the effects of carbon-based nanoparticles on in vivo rat extracellular recordings (Chapter 11) and hippocampal slices monitored via the patch-clamp

technique (Chapter 12). In Chapter 13, the authors present a technique to assess the effects of different types of nanoparticles (synthesized, native, and physiological) on ionic currents and neurotransmitter uptake in nerve terminals isolated from rat brain cerebral hemispheres. Chapter 14 focuses on a coculture model that can be used to assess nanoparticle uptake, length of retention within the cell, and fate following cell division. It also includes a discussion on the physicochemical characterization of the nanoparticle's corona. Although it uses magnetic nanoparticles, some of the techniques presented can be applied to nanoparticles of other compositions. Chapter 15 is the only chapter in this volume that focuses on the lethal effects of nanoparticles. It details a technique to assess toxicity of lanthanide doped nanoparticles via death distribution in cell culture. In addition, it presents a technique to assess the spatial distribution of orally administered nanoparticles in various organs, including the brain, of mice. Chapter 16 is the only chapter in this volume that focuses primarily on the physiological effects of nanoparticles. It studies the role that nanoparticles can have as nucleation sites for amyloid aggregation and presents a technique to functionalize gold nanoparticles for use in amyloid fibrillation assays.

We hope all specialized audiences and graduate students find this compilation useful for learning the techniques necessary to quantify experiments using in the nervous system.

San Antonio, TX, USA
Fort Sam Houston, TX, USA

Fidel Santamaria
Xomalin G. Peralta

<http://www.springer.com/978-1-4939-7582-2>

Use of Nanoparticles in Neuroscience

Santamaria, F.; Peralta, X. (Eds.)

2018, XVI, 296 p. 98 illus., 66 illus. in color., Hardcover

ISBN: 978-1-4939-7582-2

A product of Humana Press