An Introduction to Neuroscience

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Chapter 1

Introduction

This is a free, open-source, peer-reviewed, high-quality Introduction to Neuroscience textbook... or it soon will be.

At this stage, I have only Chapter **??** (Neurophysiology) posted in draft form. More to come!

Chapter 2

Neurophysiology - by Robert J Calin-Jageman

2.1 Introduction

Mary is visiting the office of Dr. Alfredo Quinones-Hinojosa, a neuroscientist, physician, and neurosurgeon who is known affectionately by his patients as "Dr. Q". Unfortunately, it is not a happy visit—Mary has been diagnosed with a glioma, a tumor caused by runaway cell division among the glial cells in her brain. Her first sign that something was wrong was a seizure, an episode of tremoring and muscle rigidity that left Mary exhausted and frightened. Now brain scans have revealed a glioma.

Mary is worried. Dr. Q patiently walks her through her prognosis, explaining how his team can conduct surgery to remove the glioma. "Will that stop the seizures?" Mary asks. "Maybe" says Dr. Q. But he warns that in almost 30% of cases, seizures persist even after a glioma is removed. How can that be? Why would a tumor cause seizures in the first place? And if the tumor is removed, shouldn't the seizures go away? These are some of the medical mysteries Dr. Q's research team is trying to solve. In fact, Mary decides to donate tissue from her removed tumor to be studied, and with that tissue and samples from other patients Dr. Q's team uncover something remarkable: compared to glioma patients who do not suffer seizures, those with seizures show increased expression of the mRNA for a specific protein, VGLUT1 (Feyissa et al., 2021). VLGUT1 acts to help load the excitatory transmitter glutamate into vesicles to be released. This finding inspires Dr. Q's team to formulate a new hypothesis: that excess VGLUT1 causes runaway excitation, explaining why some gliomas lead to seizures. There's still lots of work to do to test this hypothesis, but the cutting edge medicine and research of Dr. Q and his team reflect an emerging theme in our understanding of the nervous systems: The smooth functioning of neural circuits reflects an incredible ballet amongst protein machines working within each of our 86 billion neurons. The environment we live in can reshape which proteins are expressed and how, with profound implications for the functions of the brain.

In this chapter we'll explore neural communication. We'll see that neurons are constantly receiving messages from their partners and their outside world—messages that produce excitation, inhibition, or modulation. When a neuron is sufficiently excited, it generates an action potential—an electrical wave that spreads through the neuron, causing it to send its own chemical messages to all of its partners. In this way, neurons can form circuits, sending and integrating information to produce complex patterns of activity that muscles transform into behavior. How are neurons able to detect chemical signals, produce action potentials, and release transmitter? Through an amazing collection of protein machines: pumps that use energy to build up concentration gradients of electrically charged molecules, channels that monitor the neuron's environment and then switch open or closed to generate electrical currents, and a whole complex of machinery for both releasing transmitter to partner neurons and for detecting transmitter released from partner neurons. Let's dive in!

References and works cited

- Feyissa AM, Carrano A, Wang X, Allen M, Ertekin-Taner N, Dickson DW, Jentoft ME, Rosenfeld SS, Tatum WO, Ritaccio AL, Guerrero-Cázares H, Quiñones-Hinojosa A (2021) Analysis of intraoperative human brain tissue transcriptome reveals putative risk genes and altered molecular pathways in glioma-related seizures. Epilepsy Res 173:106618 Available at: https://linkinghub.elsevier.com/retrieve/pii/S0920121121000711.
- Quiñones-Hinojosa A (2011). *Becoming Dr. Q: My Journey from Migrant Farm Worker to Brain Surgeon*. University of California Press.

2.2 Neural communication

Learning objectives

By the end of this section, students will be able to:

- Objective 1: Describe the chemical communication that occurs *between* neurons, at synapses
- Objective 2: Describe the action potential, which moves information *within* a neuron
- Objective 3: Explain how neurons both synthesize information (by integrating inputs from many partners) and filter information (by having a threshold)

The 86 billion neurons in your brain differ dramatically in size, shape, and