Introduction to Neural Networks

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Engineering for Professionals Program

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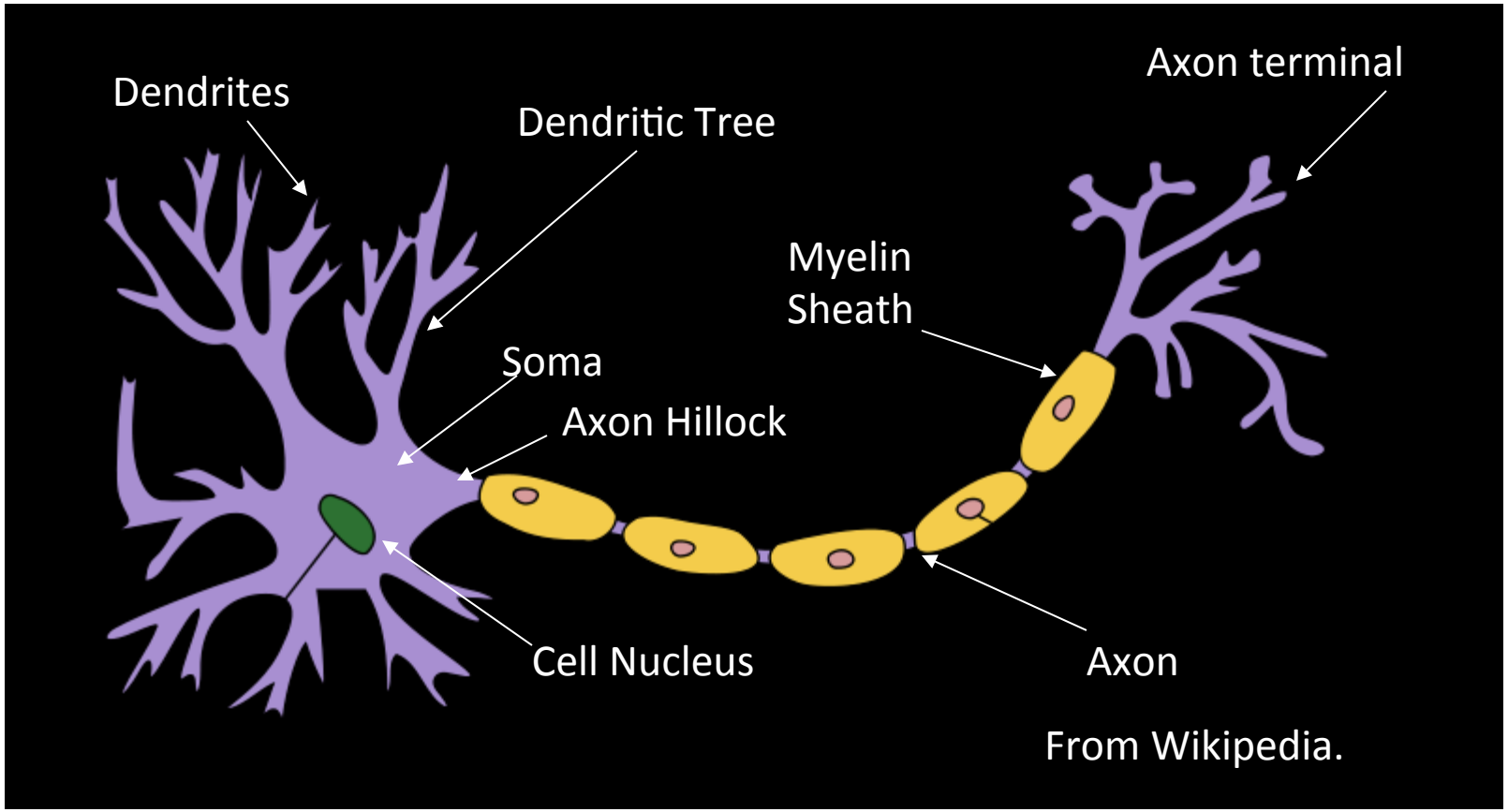
Module 1.2: The Biological Neuron

This Sub-Module Covers …

- The basic elements/components of biological neurons and serves as the foundation of our modeling efforts. We will cover:
  - The basic structure of the biological neuron.
  - Some of the electro-chemical properties of the neuron.
  - Mechanisms for signaling between and among neurons.
  - Mechanisms associated with neuronal excitation and inhibition.
- This sub-module is then followed by a short quiz.

A Biological Neuron

Nature's Communication Mechanism



The Ion Pump

- A basic mechnism of a living neuron.
- ‘Pumps out’ sodium ions from inside of cell, pumps in potassium ions.
- 3:2 --- 3 out for every 2 in.
- Results in a net positive charge on the outside of the cell membrane.
- Some ions randomly cross membrane.
- Ion movement attempts to neutralize charge.
- Various types of ‘channels’ that are open or close and let ions move through the membrane more easily.

Neuronal Connections

- Axon terminals have ‘synaptic buttons’ at a ‘synapse’.
- The synapse ‘connects’ to dendrites of other cells and so one cell can connect to many other cells.
- The length of the axon is relatively long compared to the dimensions of the cell body --- long distance communication!

So how do the cells ‘communicate’?

Open the Flood Gates!

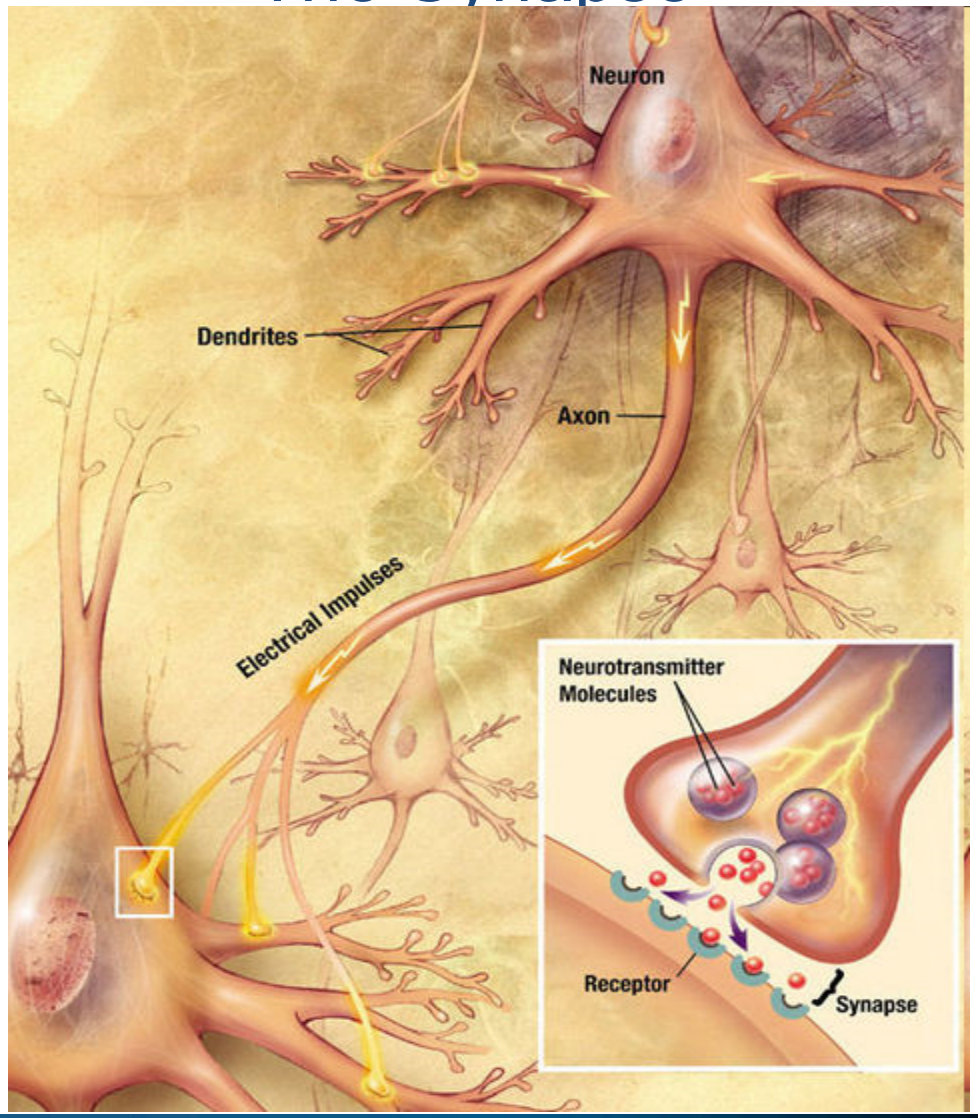
- Sometimes a channel is opened causing sodium ions to flood into the cell. E.g., ligand-gated channels near synapses. Causes local depolarization.
- This can cause nearby sodium channels to open. E.g., voltage-gated channels. Causes further depolarization.

The Action Potential

A simplified view

- The 'action potential' is essentially a pulse of electric charge that travels down an axon.
- It cascades down the axon changing the state of channels which cause an electric wavefront to expand causing further channels to change, etc. Just like dominoes.
- This pulse is triggered by electrical changes in the cell body.
- Inputs at synapses, affected by release of neuro-transmitters, trigger electrical changes (increase/decrease electric charge) in the neuron by changing the number of ions in the cell.
- These changes affect voltage dependent sodium channels through which ions can enter or leave a cell.

The Synapse



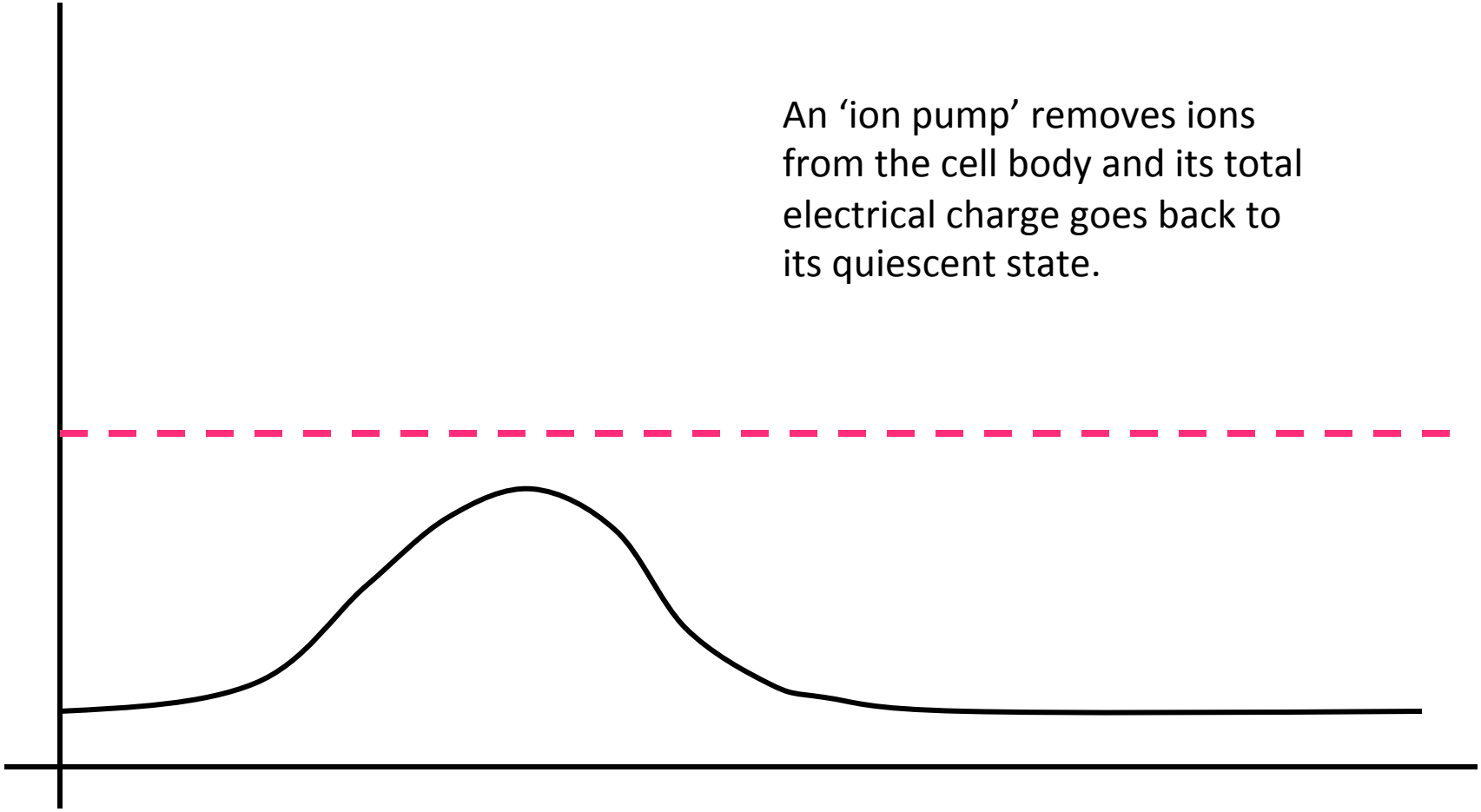
From Wikipedia

The Action Potential

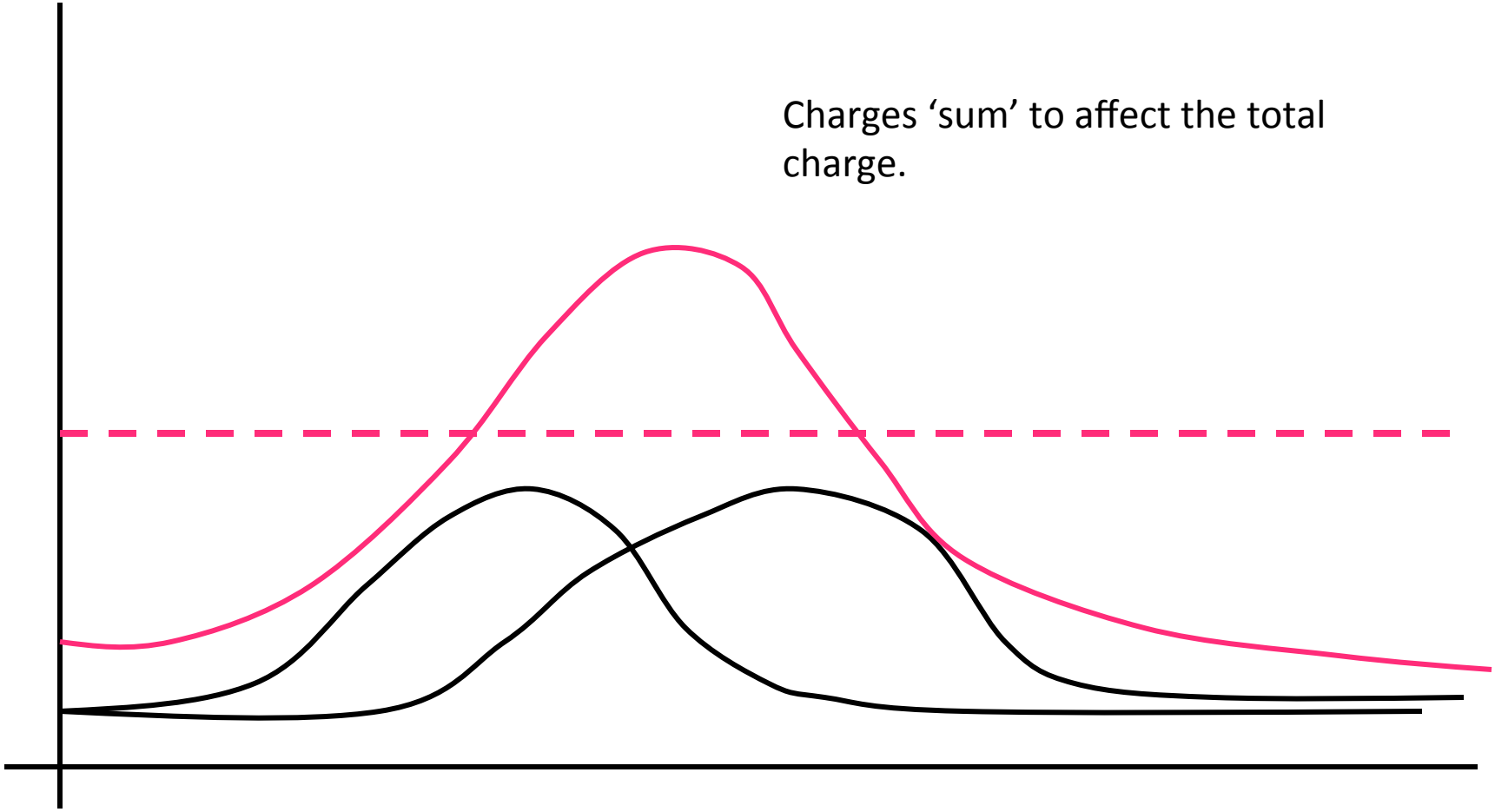
- Charge builds up and/or decays in a neuron.
- If the charge continues to build up and reaches a threshold value, the cell begins to discharge… i.e., the action potential is triggered.

The Action Potential

An ‘ion pump’ removes ions from the cell body and its total electrical charge goes back to its quiescent state.

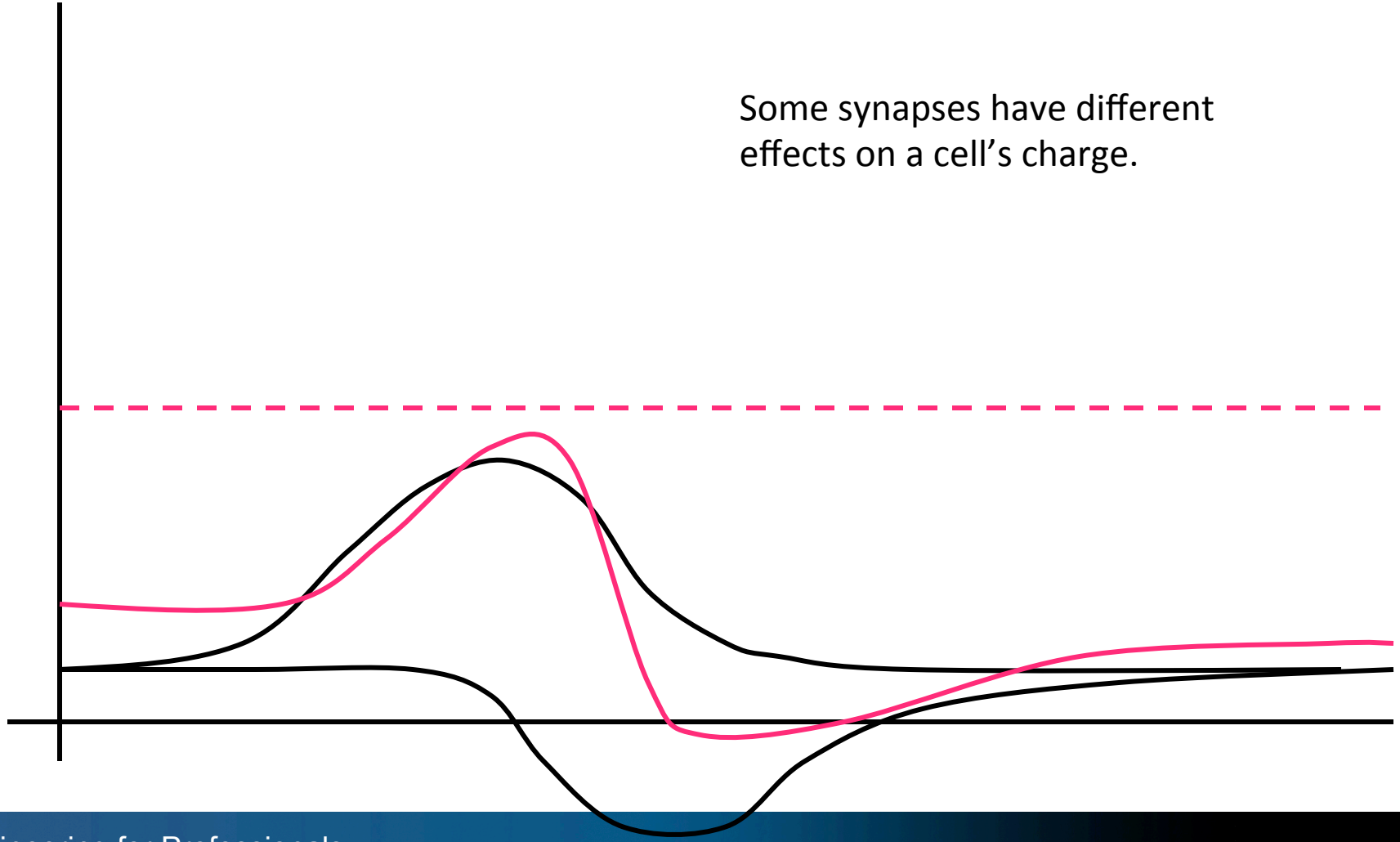


The Action Potential



The Action Potential

Some synapses have different effects on a cell's charge.



The Meaning of the Action Potential

- What does it 'mean' when it 'fires'? What good is that?
- Think in terms of evolution.
- What does it mean when several action potential impinge on a given neuron?
- What does the fact that the effect of an action potential 'decays'?

In the next sub-module…

- We will cover some of the issues surrounding the art and science of modeling.
- Before viewing the next sub-module, take the online quiz using the link following this presentation in the Module Content page.