Neurons and Glia

Introduction

- All tissues and organs of the body are composed of cells.
- There are about 100 billion neurons (nerve cells) in the human brain.
    - Sense changes in the environment, communicate these changes to other neurons, and command the bodies responses
- Glia (glial cells) outnumber neurons 10 to 1.
    - Insulate, support, and nourish neighboring neurons (we are probably quite ignorant of glial function).

The Neuron Doctrine

- Most cells are very small 0.01-0.05 mm (10-50 µm) and could not be studied until compound microscopes were developed.
- The brain is like "Jello" and could not be sliced until methods to "fix" and cut the tissue were developed.
- Nervous tissue is relatively creamy in appearance and could not be differentiated until chemical and optical staining methods were developed.
    - Franz Nissl introduced the use of a basic dye that stained the nuclei of all cells and also material around the nuclei in neurons.
    - The Nissl stain distinguishes between neurons and glia.

The Golgi Stain

- Camillo Golgi (1873) discovered that soaking brain tissue in silver chromate solution colored a small percentage of neurons in their entirety.
- The Golgi stain made it possible to visualize the cell body (soma) and thin tubes that radiate from the cell body
- The thin tubes are called neurites (processes) and consist of axons and dendrites.
- The cell body usually gives rise to a single axon that is usually quite long with a uniform diameter; branches often occur at right angles.
- The cell body usually gives rise to many dendrites that are usually very short and taper to a fine point.

Cajal's Contribution

- Santiago Ramon y Cajal began using the Golgi method in1888 and for the next 25 years worked out the circuitry of many regions of the brain.
- Golgi felt that the neuritis of different cells were fused together to form a network of continuous tubing.
- Cajal argued on the other hand that the neuritis of different cells are not continuous with one another and must communicate by contact, not continuity.
- The argument was not settled until the development of the electron microscope when Cajal's view was found to be correct.

The Prototypical Neuron

The Cell Body (Soma)

The Nucleus

- Contains the chromosomes with our DNA and genes.
- Expression of genes causes production of proteins.
- Transcription involves transcription factors binding to the promoter region of a gene.
- RNA polymerase binds to the gene and produces preRNA which is spliced to form mRNA

Rough Endoplasmic Reticulum

- Stacks of membranes covered with ribosomes
- Very abundant in neurons
- mRNA transcripts bind to the ribosomes, and the ribosomes translate the instructions contained in the RNA to assemble a protein molecule.

Smooth Endoplasmic Reticulum

- Has various functions
    - Some are continuous with the rough ER and are involved in the processing of proteins
    - Others are involved in the regulation of the internal concentrations of substances (such as calcium)

Golgi Apparatus

- Is involved in the post-translational chemical processing of proteins.
- Packages substances (such as proteins and peptides) into vesicles

Vesicles

- Membrane sacs pinched off from the Golgi apparatus that contain substances produced (such as proteins and peptides).

The Mitochondrion

- "Inhales" pyruvic acid and oxygen.
- The location of the Krebs cycle and electron transfer chain which produce ATP.

The Neuronal Membrane

- Encloses the cytoplasm.
- Excludes certain substances.
- Contains membrane proteins that:
    - Act as pumps to move substances through the membrane.
    - Form pores that allow substances to diffuse through the membrane.

The Cytoskeleton

Microtubules

- 20 nm in diameter and composed of tubulin polymers.
- Microtubule Associated Proteins (MAPs) anchor the microtubules.
- Run longitudinally in neuritis.

Microfilamens

- 5 nm in diameter and composed of actin polymers.
- Found throughout the neuron, especially in the neuritis.

Neurofilaments

- 10 nm in diameter and composed of long protein molecules organized as a cable.

Axon

- In multipolar neurons begins as the axon hillock.
- Have no rough endoplasmic reticulum and few if any free ribosomes.
- The protein composition of the axon membrane is different than the membrane of the cell body.
    - These different proteins allow the axon to act as a "telegraph wire."
- All proteins in the axon originate in the cell body

Axon Terminal (Synaptic Bulb)

- The end of the axon that comes in contact with another neuron or cell.
- Contain numerous mitochondria but do not contain microtubules.
- Contain synaptic vesicles.
- Have a dense covering of protein on the inner surface of the presynaptic membrane.

Synapse

- The site where axon terminal comes into contact with another neuron or cell.
- The end of the axon terminal is the presynaptic membrane.
- The adjacent part of the other cell is the postsynaptic membrane.
- There is a very narrow gap (20-50 nm) between the presynaptic membrane and the postsynaptic membrane.

Axoplasmic Transport

- Materials are enclosed in vesicles in the cell body, and the vesicles "walk down" the microtubules using kinesin proteins and ATP
    - Often referred to as anterograde transport
- Materials in the axon terminal "walk-up" the microtubules using dynein proteins and ATP.
    - Often referred to as retrograde transport

Dendrites

- Are the antennae of the neuron and serve as the postsynaptic membrane of a synapse.
- Possess small knob-like extensions called dendritic spines.
- Contain numerous mitochondria, polyribosomes, and a cytoskeleton.

Classifying Neurons

Based on Number of Neurites

- Unipolar neurons have a single neurite; most sensory neurons are unipolar.
- Bipolar neurons have two neuritis; some neurons in the eye are bipolar.
- Multipolar neurons have three or more neuritis; most neurons in the brain are multipolar.

Based on Dendrites

- The dendrites of neurons form many different shapes.
- For example, in the cerebrum some neurons have dendrites that form a star shaped pattern (stellate cells); other neurons have dendrites that form a pyramid shape (pyramidal cells).

Based on Connections

- Neurons that have neuritis in the sensory organs are often called primary sensory neurons.
- Neurons with axons that synapse with muscles are often called motor neurons.
- Most neurons in the brain and spinal cord synapse only with other neurons and are often called interneurons.

Based on Axon Length

- Neurons with long axons that extend from one part of the brain to another are sometimes called Golgi type I neurons.
    - In the cerebrum pyramidal cells have long axons.
- Neurons with short axons that do not leave a specific regions are sometimes called Golgi type II neurons.
    - In the cerebrum stellate cells have short axons

Based on Neurotransmitter

- Newer methods that allow identification of the neurotransmitters secreted by neurons have led to a scheme of identifying neurons based on their chemistry.
- For example, motor neurons all secrete acetylcholine are their synapses and thus are called cholinergic neurons.

Glia

Astrocytes

- About 20 µm in diameter.
- Fill spaces between neurons.
- Regulate chemical content of extracellular space.
- Envelope synaptic junctions.
- Restrict spread of neurotransmitters.
- Remove many neurotransmitters.
- Possess receptors for neurotransmitters.

Myelinating Glia

Oligodendrocytes

- Surround and insulate axons in the brain and spinal cord.

Schwann Cells

- Surround and insulate axons in nerves.

Other Non-Neuronal Cells

Microglia

- Phagocytic cells that remove debris from dead or degenerating neurons and glia.

Ependymal Cells

- Line the ventricles of the brain and central canal of the spinal cord.