

I. Why do we need a nervous system? Why isn't an endocrine system enough?

1. We are large—lots to control
2. take in and integrate many sensory inputs
3. respond to these inputs—regulates behavior
 - a. send messages quickly—electrochemical signals
 - b. send messages to the right place—travel along cell processes
 - c. send the right messages (and to integrate them—later on)

example: touching a hot pot...

signal from sensory receptors on hand
specialized cells called neurons
to integration center (CNS)
to motor neurons—connected to muscle
100 m/s!!!!
Also connect to other neurons...

II. Anatomy

1. Nerve cells = Neurons
 - Afferent (carry sensory information to CNS)
 - Interneurons (in CNS)
 - Efferent (carry signals from CNS to muscles)
2. Parts of a Neuron
 - a. Soma = cell body (0.1 mm diameter)
 - b. Dendrites = where signal comes in (< 1 mm long)
 - c. Axon = where signal is transmitted (starts at hillock)
up to several m long, 1-10 μ m diameter (larger diameter $\rightarrow$ faster signal transmission)
 - d. synapses (up to 1000's connecting neurons)

e. unipolar, bipolar, multipolar

3. Associated cells (Glial cells = “glue cells”)

- a. physical protection/structural support (CNS)
- b. secrete the lipid myelin (includes Schwann cells)
 - insulates cells (wraps around one or more cells)
 - reduces permeability to ions
 - pumps extracellular fluid away from soma
 - reduces dehydration of neurons (in insects)
 - hemolymph neurotransmitters (in insects)
 - **faster signal transmission**

4. Nerves (bundles of neurons—both afferent and efferent)

III. Central Nervous System (vs. peripheral nervous system)

- 1. Ganglia
- 2. Brain
- 3. Spinal cord
- 4. Evolutionarily: centralization and cephalization

IV. Neuron membrane (one main reason why neurons work)

- 1. Potential difference—electrochemical (-70 mV)
 - a. Na^+ —more concentrated outside (150 vs. 15 mM – in mammals)
 - b. K^+ —more concentrated inside (150 vs. 10 mM - in mammals)
 - c. Cl^- —more concentrated outside (120 vs. 4 mM – in mammals)
 - d. Ca^{2+} and other ions (proteins, etc.) also play roles
- e. Why this potential difference? Other ions (larger molecules with negative charge inside cell, but impermeable to membrane).

1. Nernst equation, Goldman equation, and EMF

a. $E = [(RT)/(zF)] \ln (C_i / C_o)$
where E is the equilibrium membrane potential for a given ion type, R is the gas constant, T is the absolute temperature, z is the valence (charge) of the ion, and F is Faraday's constant (charge in a mole of ions)

b. If K is higher inside than outside, diffusion outward—EMF is inward (standardized as negative—when inside is negative).

c. $E = (RT/F) \ln \{ (P_K[K^+_o] + P_{Na}[Na^+_o] + P_{Cl}[Cl^-_i]) / (P_K[K^+_i] + P_{Na}[Na^+_i] + P_{Cl}[Cl^-_o]) \}$
where P_K is the permeability of the membrane to K^+ ions. Note that Cl^- is inverted (due to valence of negative 1). This determines the overall potential difference in the membrane for multiple ions, based upon unequal concentrations of each ion.

d. Gibbs-Donnan forces act to maintain this (due to the other large negative ions inside neurons).

1. Na^+/K^+ pumps (3 Na^+ out to 2 K^+ in)

- a. uses ATP
- b. always working

1. Voltage-gated ion channels (Na^+ and K^+)

- a. open in response to electrochemical stimulus (change in potential difference)