Outline for my lecture introducing the vertebrate Nervous System: Given during Spring 2001

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 um diameter (larger diameter → 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)