Very phys- Chapter 7: The Nervous System

1) Organization of the nervous system- most cells cannot divide but be repaired
    a) Divided into two parts
        i) Central nervous system (CNS): brain and spinal cord
            (1) Tract: Collection of axons in the CNS
            (2) Nuclei: group of cell bodies inside the CNS
        ii) Peripheral nervous system (PNS): cranial and spinal nerves
            (1) Nerve: collection of axons in the PNS
            (2) Ganglion: group cell bodies inside the PNS
    b) Tissues is composed of two types of cells
        i) Neurons- conduct impulses
        ii) Glial cells (neuroglia) that support the neurons
            (1) Two types found in the PNS:
                (a) Schwann cells- form myelin sheaths around peripheral axons
                    (i) Myelinated axons conduct impulses more rapidly, even unmyelinated axons in the PNS have a neurilemma
                (b) Satellite cells- support cell bodies within ganglia of the PNS
            (2) Four types found in the CNS
                (a) Oligodendrocytes- form myelin sheaths around axons in CNS
                    (i) Myelin gives tissues a white color (white matter)
                (b) Microglia- phagocytize foreign material **"clean up crew"**
                    (i) **Originate from bone marrow**
                (c) Astrocytes: regulate the external environment of neurons (most abundant)
                (d) Ependymal cells- line the ventricles and secrete CSF
2) Classification of neurons via structure
    a) Dendrites: receive impulses and conduct a graded impulse toward a cell body
    b) Axons: conducts action potentials (AP) away from the cell body
        i) Vary in length from few mm to m
        ii) Connected to the cell body via the axon hillock where AP's are generated
        iii) Can form many branches called axon collaterals
        iv) Covered in myelin w/ open spots called nodes of Ranvier
    c) Three different types of structural forms
        i) Pseudounipolar neurons- single short process that branches like a T to form a pair of longer processes **Ex: sensory neurons**
        ii) Bipolar neurons- have two processes, one on either end **Ex: found in the retina of the eye**
        iii) Multipolar neurons- (most common) have several dendrites extending from one axon
            Ex: motor neurons
3) Classification of neurons via function- based on direction impulses are conducted
    a) Sensory neurons- conduct from sensory receptors to the CNS
    b) Motor neurons- conduct impulses from the CNS to target muscles or glands
        i) Somatic- reflexes of the body & voluntary control of skeletal muscles
        ii) Autonomic- innervate involuntary targets
            (1) Sympathetic- "fight or flight" Parasympathetic "rest and digest"

c) Association/interneurons- located completely within the CNS & integrate functions of the nervous system

4) Function of the nervous system
   a) Respond to chemical and physical stimuli
   b) Conduct electrochemical impulses- Axonal transport
      i) Anterograde transport- from cell body to dendrites and axon; uses kinesin motors
         (1) Kinesin proteins move synaptic vesicles and mitochondria
      ii) Retrograde transport- from dendrites and axon to the cell body; uses dynein motors
         (1) Dynein proteins move membranes and vesicles **Ex: tetanus, rabies & herpes viruses**
   c) Release chemical regulators
   d) Enable perception of sensory stimuli, learning memory and control of muscles and glands
5) Regeneration of a cut neuron
   a) In the PNS:
      i) The cut piece of the neuron is degenerated and phagocytosed by Schwann cells, then the cell forms a regeneration tube
      ii) Growth hormones are released and growth of axon sprouts occur
      iii) New axon eventually connects to the undamaged axon
   b) In the CNS: not as able to regenerate
      i) "Death receptors" are released and promote apoptosis (cell suicide)
      ii) Inhibitory proteins in the myelin sheath and glial scarring from astrocytes occur and prevent regeneration
         (1) Ex: glycoproteins inhibit the growth by binding to a Nogo receptor on the axon
      iii) Injury in the CNS stimulates growth of axon collaterals but not central neurons
   c) Neurotrophins- promote neuronal growth in the fetal brain; Four types-
      (1) Nerve growth factor (NGF)
      (2) Brain-derived neurotrophic factor (BDNF)
      (3) Glial-derived neurotrophic factor (GDNF)
         (a) Needed in the adult brain to maintain spinal motor neurons & to sustain neurons in the brain that use dopamine
      (4) Neurotrophin-3, Neurotrophin 4/5
      ii) In adults neurotrophins aid in the maintenance of sympathetic ganglia and the regeneration of sensory neurons
6) Astrocytes- (the most abundant glial cell) Have long processes with end-feet that associate with blood capillaries and axon terminals
   a) Functions
      i) Take up K+ from the extracellular environment to maintain ionic gradient of neurons
      ii) Take up extra neurotransmitter (NT) released from axon terminals and recycles them
         (1) Mainly recycles and converts glutamate (major excitatory NT) →glutamine
         (2) Glutamine can be used to reform glutamate and/or form GABA (major inhibitory NT)
      iii) End feet around capillaries take up glucose from the blood for use by neurons to make ATP
         (1) Converted first to lactic acid which neurons use as energy to metabolize it into CO_2 and H_2O for the production of ATP
         (2) MRI and PET scans which visualize brain locations by their metabolic activities, are based on the functions of astrocytes and neurons

iv) Make lactate, which active neurons rely on for aerobic respiration. Astrocytes can store glycogen and make lactate from it
    (1) **Lactate has been shown to help consolidate long term memories in the hippocampus**
v) Needed for the formation of synapses in the CNS; few form in the absence of astrocytes
vi) Regulate neurogenesis in the adult brain- differentiation of glial cells & neurons
vii) Forms the blood brain barrier
viii) Release gliotransmitters that can stimulate or inhibit neurons
    (1) Glutamate, ATP, adenosine and D-serine

b) Astrocytes are considered excitable because they respond to stimulation by vhanges in their Ca2+ concentration. AP's in neurons can produce a change in Ca2+ which stimulates the astrocytes to release ATP and prostaglandin E2 from the end feet causing vasodilation or an increase in blood flow

7) The Blood Brain Barrier
a) Capillaries in the brain do not have pores b/t adjacent cells like the rest of the body. They are joined by tight junctions
    i) Substances can therefore only be moved via bulk or active transport-making it very **selective**
    ii) Movement is transcellular through the epithelial cells
    iii) Astrocytes influence the production of enzymes which produce GDNF which can destroy toxic substances
    iv) The tightness of the BBB presents problems when using chemotherapy drugs because they do not penetrate the brain as easily as other organs
        (1) Ex: Parkinson's patients that need dopamine are given a precursor, L-dopa, instead because it can cross the BBB but dopamine cannot

8) Electrical Activity in Axons
a) Resting membrane potential of neurons is -70mV (High K inside & High Na outside at rest)
    i) Established by negative molecules inside the cell
    ii) Na+/K+ pumps – 3 Na out and 2 K in
    iii) Neurons & muscle cells can change their membrane permeability which is either called excitability or irritability
        (1) Neurons maintain a RMP of -70mV
        (2) Cardiac muscle cells maintain a RMP of -85mV
    iv) Depolarization (excitatory)- positive charges flow into the cell (usually Na+)
    v) Repolarization- a return to the resting membrane potential (RMP)
    vi) Hyperpolarization-(inhibitory) negative charges flow into the cell
        (1) Caused by either positive charges leaving the cell or negative charges entering (Cl-)
b) Ion Gating in Axons- changes in the membrane controlled by flow of ion channels
    i) K+ has two channels:
        (1) Not gated (always open)- aka leakage
        (2) Volatage gated- open when a particular threshold is reached, closed at RMP
    ii) Na+ has one channel which is voltage gated and closed at rest
    iii) The membrane is less permeable to Na+ than K+ at rest

9) Nernst Equation for K+ and Na+
a) $E_{potassium}$= 61/1 * log 5/150= -90mV
b) E_{sodium}= 61/1*log 145/12= +66mV