Cell Bio Post-Exam 3 Information

- Basic Food/Energy Info:
  - Carbon compounds release energy when oxidized
  - Calorie: amount of energy needed to raise 1g of water by 1°C
    - Food labels are marked in kilocalories
  - Glucose is the main form of stored energy in the body
    - Conversions of glucose:
      1. CO_2 + H_2O + energy
      2. Lactate + energy (pathway used in the absence of oxygen)
      3. Stored as glycogen in muscle or liver tissues
      4. Fat pathway
    - Energy released through its oxidation
- Energy and Reactions:
  - Free energy change determines reaction spontaneity (negative value = spontaneous reaction)
    - Still requires a sufficient level of activation energy
  - Cellular energy is carried via molecules like ATP or electron-carrier molecules (NADP+/NADPH, NAD+/NADP, FAD+/$FADH_2$)
    - More inorganic phosphates = more energy available in molecules like ATP
- Glycolysis: metabolism of glucose into pyruvate and energy-carrying molecules
  - Basics of Steps:
    - Step 1: glucose phosphorylated by hexokinase enzyme into glucose 6-phosphate
    - Step 2: glucose 6-phosphate rearranged into fructose
    - Step 3: fructose phosphorylated into fructose 1,6-bisphosphate
    - Steps 4-5: modified fructose broken down into two glyceraldehyde 3-phosphate molecules (3 carbons apiece)
    - Step 6: Glyceraldehyde 3-phosphate is oxidized and phosphorylated while NAD+ is reduced to NADH
    - Step 7: ADP molecule phosphorylated to ATP
    - Steps 8-9: Phosphate on main molecule moved and H_2O is released
    - Step 10: Pyruvate and ATP are produced
  - Occurs in the cytoplasm
  - Overall reaction: glucose + $2NAD^+$ + 2ADP + $2P_i$ $\rightarrow$ 2Pyruv. + 2NADH + 2ATP (net)
    - 4 ATP total are produced (2 per glyceraldehyde 3-phosphate molecule) for a net gain of 2 ATP
    - Also known as substrate-level phosphorylation
- Pyruvate after Glycolysis:
  - Can enter the citric acid cycle if oxygen is present (see later notes)
  - Will be fermented if oxygen is not present
    - Yeast fermentation:
      1. Pyruvate converted into acetaldehyde and CO_2
      2. Acetaldehyde converted into ethanol and NADH oxidized to NAD+
    - Muscle fermentation:
      1. Pyruvate converted into lactate and NADH oxidized to NAD+
  - Gluconeogenesis: regeneration of glucose from lactate
    - (Is the other half of the Cori cycle of glucose breakdown and reformation)

- Citric Acid Cycle: production of electron-carrier molecules through the oxidation of Acetyl CoA and citrate
    - Basics of Steps:
        - *Before Cycle:* Pyruvate is oxidized into Acetyl CoA and CO_2; NAD+ is reduced to NADH
        - Step 1: 4-carbon oxaloacetate and Acetyl CoA oxidized to citrate, releasing H_2O
        - Step 2: Citrate rearranged
        - Step 3: Rearranged citrate molecule oxidized to a 5-carbon molecule and CO_2, NAD+ reduced to NADH
        - Step 4: 5-carbon molecule oxidized to a 4-carbon molecule and NAD+ reduced to NADH
        - Step 6: 4-C oxidized and GTP produced
        - Step 7: 4-C oxidized again and FAD reduced to $FADH_2$
        - Step 8: H_2O added to 4-C molecule
        - Step 9: 4-C oxidized to oxaloacetate and NAD+ reduced to NADH
    - Occurs in the mitochondrial matrix
    - Overall Reaction: Acetyl CoA + oxaloacetate + $2H_2O$ + $3NAD^+$ + FAD + GDP + P_i → 3NADH + $FADH_2$ + GTP + $2CO_2$ + oxaloacetate
    - Electron carrier molecules are fed into the electron transport chain
- ATP Production:
    - 3 components of the chemiosmotic hypothesis:
        - High-energy electrons
        - Electron transport system producing a H^+ gradient
        - ATP-synthesizing enzyme (ATP synthase) using energy from the H^+ concentration gradient
- Electron Transport Chain: series of inner mitochondrial membrane enzymes utilizing high-energy electrons to create a H^+ gradient across the membrane
    - Proteins in the ETC and functions:
        - First enzyme (NADH dehydrogenase complex) oxidizes NADH to NAD^+
        - Ubiquinone carries electrons to next enzyme (cytochrome b-c_1 complex)
        - Cytochrome c carries electrons to next enzyme (cytochrome c oxidase)
            1. H^+ and O_2 reduced to H_2O
            2. All enzymes participate in the creation of the hydrogen ion gradient
            3. Acetyl CoA gets into the matrix via symport transport with the hydrogen ions (also inorganic phosphates); called the proton-motive force
    - Voltage gradients drive the exchange of ADP and ATP
- Photosynthesis: $6CO_2 + 6H_2O$ + energy → glucose + $6O_2$
    - Energy comes from sunlight
    - Carbon is fixated to its lowest energy state by the Dark Reaction/Calvin Cycle
        - Net Reaction: $3CO_2$ + 9ATP + 6NADPH → glyceraldehyde 3-phosphate + 9ADP + $6NADP^+$ + $8P_i$
        - Key enzyme of the reaction is ribulose bisphosphatase/Rubisco (need a lot of it because it is inefficient)
    - Occurs in chloroplasts
    - Photosystems make up the Light Reaction
        - Photosystem II: light and a water-splitting enzyme split $2H_2O$ into O_2 and $4H^+$; high-energy electrons extracted by a carrier molecule
        - Cytochrome complexes use energy from electrons to drive proton pumps

        - Photosystem I: light excites electrons again and they are donated to $NADP^+$ to produce NADPH
            1. NADPH molecules will be utilized in the fixation of carbon/Dark Rxn.
- Viagra Dog:
    - Two cells involved in the erection pathway:
        - Endothelial/neuronal cell
        - Smooth muscle cell
    - Basic steps:
        - NO serves as the first messenger in the signal transduction pathway (activates guanylyl cyclase enzyme)
        - Guanylyl cyclase activates cGMP which serves as the likely second messenger in addition to Ca^{2+}
        - cGMP Activates PKG (phosphoprotein kinases) molecules
        - PKG molecules can cause relaxation or contraction of myosin light chains
    - Effects:
        - Vasodilation: constriction of veins restricting blood flow out of an organ system
            1. Viagra causes vasodilation because it is a PDE-5 inhibitor; PDE-5 degrades cGMP. The degradation of cGMP initiates the process for relaxation. Inhibiting the degradation of cGMP therefore causes vasodilation to continue.
- Signaling Molecules:
    - Three ways they work:
        - Activate enzymes in cell directly
            1. Ex. NO gas in vasodilation (see Viagra Dog)
        - Bind to intracellular receptors (protein receptors inside the cell in question)
        - Bind to plasma membrane receptors (protein receptors located on the plasma membrane of the cell)
    - Three types of cell surface/plasma membrane receptors:
        - ion channel-linked receptor: signaling molecule opens an ion channel in the plasma membrane
        - G-protein linked receptor: signaling molecule activates phosphorylation/activation of a GTP-binding protein acting as a molecular switch
            1. GTP-binding proteins are monomeric or trimeric
            2. Activated G-proteins may open/close ion channels OR activate enzymes that produce second messengers
                - Sometimes activated trimeric G-proteins dissociate into subunits that have different functions (called alpha and beta-gamma subunits)
                - Some important second messengers are cAMP (cyclic AMP) and Ca^{2+}
                    - ✓ Can activate cAMP-dependent protein kinases (proteins that phosphorylate molecules)
        - Enzyme-linked receptor: signaling molecule binds to a protein with a catalytic domain or an associated enzyme activated by molecular binding
            1. Pathways often utilize phosphorylation using protein kinases or phosphatases
            2. Three main examples:
                - Tyrosine kinase receptors binding growth factors

            - <u>Tyrosine-kinase associated receptors</u> binding immune signals (cytokines, interferons, etc.)
            - <u>Receptor serine/threonine kinases</u> binding members of the transforming growth factor family

- Four Main Signaling Systems (Integrated Examples of Signaling Molecules and Pathways):
    - <u>Neuronal signaling</u>: localized release of neurotransmitters
        - Is a type of cell surface/plasma membrane receptor signaling
        - Ex. Acetylcholine and the heart
            1. Parasympathetic nervous system causes the release of acetylcholine
            2. Binds to muscarinic receptors on cardiac smooth muscle cells
            3. G-protein activated and dissociated into subunits
            4. Beta-gamma subunit opens a K+ ion channel that hyperpolarizes the cell and slows the heartbeat (Toxin questions could come from this)
    - <u>Endocrine signaling</u>: signaling via hormones & global blood system
        - Is a type of intracellular signaling
        - Ex. Testosterone
            1. Produced by the testes (especially during male puberty)
            2. Binds to testosterone receptors in cells which activate and enter the nucleus
            3. Binds to DNA and acts as a gene regulatory protein which causes transcription of "male" genes
            4. Leads to development of secondary male sexual characteristics (What happens if there is no testosterone receptor? — Female secondary sexual characteristics)
        - Ex. Cortisol
            1. Corticosteroid hormone involved in the response to stress (increases blood pressure and blood sugar levels; suppresses immune system)
        - Hydrophobic hormones are signaling molecules that bind to intracellular receptors
    - <u>Paracrine signaling</u>: local neighborhood signaling via generalized release of molecules in an area
        - Is an example of enzyme-linked signaling
        - Ex. Platelet Derived Growth Factor (PDGF)
            1. Binds to tyrosine kinase receptor and stimulates catalytic activity
            2. Ras eventually activated and causes GTP to bind to G-proteins
            3. Activates MAP-3K that phosphorylates MAP-2K and then MAP-K
            4. MAP-K causes many responses eventually leading to binding of a gene regulatory protein to DNA
    - <u>Contact-Dependent signaling</u>:
        - Ex. Developing nerve cell inhibits nerve cell development in cells contacting it