Bio120 Sp08 Topics covered for Exam 1

Lecture 1

- Principles of Life:
  - Evolution (that from generation to generation, all of life evolves)
  - Heritable Information
  - Development/growth/stages
  - Energy conversion
  - Efficient use of Energy
    Cells and systems have many chemical feedback mechanisms for tight regulation of metabolites
  - Life is Cellular
  - (From a more on Earth life is made, mainly, of the same elemental ratios)

- Life can be viewed as
  - Being composed of many layers of complexity or organization
  - Having emergent properties between levels of organization
  - Explanations for observable phenomena are always reducible

Lecture 2

- Elements of Life
  - Many elements that affect many organ system
  - Know the difference between: **trace elements**, **micronutrients**, **macronutrients**
    Be able to offer one example of each type and what organ systems require it or suffer from an excess of it

- Common molecules of life
  - Sugars
    Composed of C, O and H
    Most common form is 6-member ring (hexose)
    Mainly made by plants via photosynthesis
    Mainly broken down for energy by animals
    Stored as linked hexose rings
    - Plants have **starch**
    - Animals use **glycogen**

    Cellulose is also vital to plants
  - Lipids
    Composed of C, O and H
    Know that they have two regions
    - Hydrophilic heads and hydrophobic tails

    Automatically arrange themselves into "bubbles" in water
    Are the
  - Proteins
    Composed of C, O, H, N and S
    They are chains of amino acids
    The can be structural (usually fibrilous, fibers)

The can be globular
Many proteins are capable of making chemical reactions possible, these are known as enzymes

- Nucleic Acids
  - Composed of C, O, H, N and P
  - The central component of DNA or RNA

Lecture 3

- The Cell
- Three domains and five kingdoms of Life
  - Archaea
    - Archaea bacteria
  - Eubacteria
    - bacteria
  - Eukaryote
    - Fungi
    - Animals
    - Plants
- All the bacteria are known as prokaryotes
  - Evolved at least 3.6 billion years ago, probably sooner
  - Earth is estimated to be about 4.54 (I wrote 4.6 on the board) billion years old
- Eukaryotes are thought to have evolved from archaea, but the exact time of the first eukaryotes is unknown
  - Mitochondrions and chloroplasts, once free living, were engulfed by pre-eukaryotes and became organelles
    - They still have their own DNA as evidence of their once independent lifestyle
    - Mitochondria were most likely adapted as organelles because they were the most effective bacteria at producing cellular
    - Chloroplasts were similarly adapted for their efficiency in creating sugars from solar energy
  - The external membrane of pre-eukaryotes invaginated to surround the nucleus in it's own membrane
    - This process probably was also the evolutionary mechanism of other major organelles, the endoplasmic reticulum and Golgi apparatus
    - From Golgi small round organelles bleb out
      - Lysosome, for engulfing and breaking down old and dysfunctional organelles or proteins
      - Endosomes, for trafficking proteins around the cell
        - The cytoskeleton offers "roads" for endosomes to travel on.
- The interior of all cells is structurally held together by a cytoskeleton
- The exterior of most cells are covered in proteins
  - In prokaryotes this is often a capsule

- In eukaryotes this is extra cellular membrane

- Cells are mobile
    - Flagella and cilia (euky)
    - Or just flagella (proky)
        Pili are used in mating (proky)

- **The value of membranes**
    - Lysosomes are very acidic inside, how does that acidity stay in there? Membranes repel ions from moving across them because of their water-loving external charge layered against a water-fearing internal charge.
    - Only small, uncharged molecules can move across membranes. This process is called **diffusion**, and in the case of water it is called **osmosis**. Gases (like oxygen and nitrogen) easily diffuse across membranes.
    - Membranes contain proteins embedded within them that are capable of helping charged molecules and large molecules move across the membrane. These are **transporter** proteins.
        If the molecule is going from a high concentration (of it's type of molecule) on one side to a lower concentration (of it's type of molecule) on the other, than no energy is required to move the molecule and this is **passive** transport. For example, an ion channel can be opened and closed to let certain type of ion move from high to low concentration. The opening of the channel is a regulated process, which requires some energy, but the transport process is still passive.
        If the molecule is going from low to high concentration, energy is required to move the molecule and this is called **active** transport.
    - Each membrane of each organelle (even different regions of membrane in large organelles) is uniquely embedded with different types of proteins. On the cell's surface the membrane can vary significantly from region to region, and will vary quite greatly in any single celled organism.
    - Another unique structure on the cell membrane is a **receptor**. This is a type of protein essential to cell-cell communication that receives chemical signals. The type of receptors, transporters, channels and whatever else is what gives each part of the cell surface specific functionality.

Lecture 4

- Cell division
    - Three reasons: growth, repair, reproduction
    - Prokaryote (bacterial) cell division (for growth)
        Single large circular chromosome duplicates
        Chromosomes separate
        Bacterial cell divides (see movie)
        a.k.a. binary fission
    - Eukaryote cell division: Mitosis (for growth and repair)
        Many linear chomosomes
        Chromosomes must duplicate
        Centromere versus teolomere

Sister Chromatids made
Diploid versus haploid
- Cells always diploid after mitosis

- Steps of Cell cycle

see movie (2 hours in 5 min)
Most of cycle is interphase
- G1: Gap 1 (for growth)
- S: Synthesis of DNA (doubling DNA)
- G2: Gap 2 (for growth)

Cells enter mitosis (short part of cycle)
- Prophase
  - Centrioles duplicate
  - DNA condensing into visible chromosomes
- Prometaphase
  - Nucleus breaks down
  - Other organelles (like Golgi) fragment
  - Chromosomes attach to microtubules from mitotic spindle (centrosome)
    Attach at centromere with kinetocore
- Metaphase
  - Chromosomes get lined up between spindles and for the "metaphase plate"
- Anaphase
  - Chromosomes separate by action of kinetocore
  - One sister chromatid goes to each pole to ensure perfect chromosome number in each new nuclei
  - Microtubules degenerate behind moving chromosomes
- Telophase
  - Nucleus reforms around chromosomes

Cytokinesis
- This usually begins during telophase, but some organisms create many nuclei within one large cell and do not require this step.
- In animal cells
  - Contractile ring pinches membranes apart
- In plant cells
  - New cellulose cell wall forms between cells
  - Cells do not pinch apart

- **Cell cycle and Cancer**
    - Cell cycle is regulated by checkpoints

        Special proteins that mark the "time" of the cell cycle accumulate and degrade in the cytoplasm throughout the cell cycle (these proteins are called **cyclins**)
        - when one protein accumulates to a critical levels that part of the cell cycle is completed and these accumulated proteins signal for the creation of a new cyclin that accumulated during the next phase of the cycle
        - When a cyclin is done serving its role, it degrades
        - There are over one hundred of these proteins and they control the cell cycle to ensure every little event is completed before the next step takes place (yes, our description of the interphase steps is drastically simplified)

        Cyclins advance the cell cycle, they are moving it forward
        - If a cell in G1 is given some cytoplasm (contains cyclins) from a cell in cytokinesis then the G1 cell will jump into cytokenesis
        - If the reverse is done, nothing will happen to the cell in cytokinesis because it has already completed G1
    - There are three major checkpoints

        before S

        before mitosis

        before cytokinesis
    - If the checkpoints breakdown, then a cell can end up proliferating out of control. This is cancer.

        This gives rise to neoplastic growths, often called tumors

        The growths produce cells that are not truly regulated by their neighboring cells in a normal way and the result is that the tumor cells could end up migrating (as cells do when we develop as organisms)

        Migrating cells results in a malignant tumor

        The migrating cells get into the blood stream and find their way all over the body, where they can settle down and begin unregulated growth again

        This can be painful for the organism and is usually life threatening
    - Depending on the source of the tumor, the cancer is given different names

        Carcinoma (epithelial tissue)
        - Squamous Cell Carcinoma (skin)
            - Basel Cell Carcinoma (cells under the skin - most common cancer)
            - Melanoma (melanin (pigment) producing cell)
            - Squamous cell carcinoma (cells closer to surface)
        - Adenoma (organ lining)

        Sarcoma (connective tissue)

        Myloma (plasma cells, bone marrow)

Leukemia (white blood cells, in the blood, “liquid”)
Lymphoma (lymphatic system, “solid”)

- UVA and UVB (ultra violet spectrum light) from the sun gradually pummels our skin
  The rays can hit the DNA in cells causing the DNA to mutate
  This probably happens pretty often because most mutations will not affect cell function
  On the unlucky occurrence that a few of the cyclin genes are mutated, in such a way that they loose to capacity to control the cell cycle, then the skin cell becomes cancerous
  Hence study yourself for “pre-cancer” growths, and learn to distinguish these from moles, so dermatologists can remove them
  - Non-circular, asymmetric, shape
  - Non-smooth borders
  - Multiple colors
  - Large size, bigger than pencil eraser

Lecture 5

- Meiosis
  - Cell division for reproduction
  - Cells begin diploid
    Duplicate DNA
    Divide into two diploid cells (2N, two sets of chromosomes)
    Divide again into two haploid cells (1N, one set of chromosomes)
    The haploid cells are the gametes
    - Ovum (Eggs)
      - Oocytes are cells that become eggs, it has been thought that the number of these oocytes are limited to what a woman is born with, but this dogmatic view is probably incorrect according to new data
      - Cytokinesis is asymmetric, moving more resources into one larger cell at each division
      - The result are three small haploid cell (polar bodies) that are recycled **and** one large haploid ovum with all the resources necessary to support a developing embryo after fertilization
      - Ovum are the largest cells of the body BTW
      - Once an ovum is made, it is released for fertilization (once a month) and is only viable for a few days
    - Sperm
      - Spermatocytes are cells that become sperm
      - Each haploid cell matures into a sperm
      - By end of maturation, sperm have a limited lifespan and are constantly replenished
  - SIDENOTE: A polyploidy cell is more than 2N
    Amphibians are often polyploidy
    Plants are often polyploidy

- The MAJOR point to meiosis is gene shuffling to create genetic variability, and this happens during Meiosis I, the first division, which is like mitosis except for these two differences
    - During Prophase I: **exchange of genetic material between non-homologous chromosomes**
        - Chromosomes are duplicated into sister chromatids
        - The pairs of sister chromosomes are grouped as tetrads
        - Chromosome strands of opposite sister chromatids cross-over and switch strands
            - Maternal centromeres become attached to paternal telomeres
            - Genetic material between the paternal and maternally inherited chromosomes is swapped around
        - Prophase I can be very long, ensuring that this process is done correctly and frequently
        - The proteins for crossing-over are only expressed (available) during prophase I of meiosis, ensuring this process doesn't occur in other cell divisions
    - During Anaphase I: **independent assortment of chromosome**
        - The chromosomes separate, such that all maternal and all paternal centromeres are shuffled. That is the daughter cells of this division will have a mix of chromosomes that cam from the individual two parents (and crossed over parts throughout those chromosomes).
- Meiosis II, the second division
    - Essentially identical to mitoisis
- A THIRD source for genetic variablility between generation are **mutations**
    - Mutations that occur in the gonads, specifically those in the oocytes and spermatocytes, will be passed on to offspring
    - Mutations that occur elsewhere in the body are not passed on to offspring
    - (I forgot to discuss this in lecture) As we grow older, the potential for accumulation of harmful mutations in the gonads increases, hence older woman and older men are more at risk of having diseased offspring than younger parents
        - For example, older woman are at a much higher risk of having children with Down Syndrome
        - Older men are at much higher risk of having children with polydactyly

- Genetics (covers pages 196-201 in book, add to syllabus)
    - Mendel and his peas

        Carefully crossed (selectively bred) pea plants in the 1860s

        Studies traits with two pure-breeding characteristics
        - Pure-breeding: plants that always have one characteristic from one generation to the next
            - Wrinkled peas versus smooth peas
            - Seven traits in total

        If the two pure breeding plants with different characteristics are crossed only one plant types is seen in the next generation
        - One characteristic is dominant, the other recessive

        If two of the progeny of this cross are crossed together, the recessive character reappears in their progeny
        - The recessive character is not lost, but seen in one quarter of the offspring
        - Thus there is a repressed factor segregating between generations
        - LAW OF SEGREGATION says there are two factors for each trait and these factors are between the progeny

        If multiple traits (i.e. pea texture and flower color) are pure bred in the same plant, and plants with opposite characteristic are crossed in the same way as above, then the progeny express the two dominant characteristics. If these progeny are crossed, the next generation shows that the recessive characteristics are both expressed (as predicted by the LAW OF SEGREGATION)
        - Interestingly, the two characteristics (texture and color) appear independent of each other in the second generation.
        - Plants are not both smooth and pink any more often than expected, the predicted 9:3:3:1 ratio (four combinations of two characteristics) is always observed
        - LAW OF INDEPENDENT ASSORTMENT says each trait is transmitted from generation to generation randomly
    - Connecting Mendel to Meiosis

        The LAW OF INDEPENDENT ASSORTMENT is akin to traits being coded for genes on different chromosomes, because chromosomes are also assorted randomly

        NOT COVERED IN LECTURE: If the traits are coded by genes on the same chromosome, and the genes are very close to each other, than the traits would appear connected and Mendel would not had observed the predicted 9:3:3:1 ratio
        - Lucky for Mendel, none of the seven traits he studied are linked

        NOT COVERED IN LECTURE: Crossing over makes it possible for genes on the same chromosome to segregate independently,
        - such as if one was close to the telomere are the other close to the centromere they are very far apart on the same

chromosome
    - This may seem pretty complicated and you may want to look it up but I will not test you on it
- Non-Mendelian genetics

  Basically, our traits follow the same rules that Mendel discovered but there are two types of exceptions to be aware of
    - Complex traits, are controlled by more than one gene
        - Height
        - Eye color
        - Skin color
        - Etc.
    - Many traits are influenced by their environment, gene expression isn't just dominant versus recessive, it can be strong and weak based on environmental factors
        - "Nature versus Nurture"

          your behavior reflects something about your gene expression, but your upbringing changes how you behave
        - Plants from different altitudes (example in your text)
        - How much you eat affects how much insulin (and glucagon) your body produces

          Insulin controls blood-sugar levels (along with a chemical called glucagon)

          Over eating leads to type II diabetes, which is due to too much insulin
- Human Genetics: Sex Determination

  The X and Y chromosome assort independently of each other

  A Punnet square (see slide) demonstrate why children are 50/50 male and female according to the view that sex chromosomes are the determinant of sex (the old view)

  Two genes control human sex (the new view)
    - SRY on Y chromosome for maleness
    - DAX1 on X chromosome for femaleness

  Initially we are sexless, then…
    - If a Y is present our gonads become testies, which release androgens and make the body male
    - If no Y is present our gonads become ovaries, which release estrogens to make the body female

  Much of sexual development doesn't occur until puberty, the expected sex is based on the gonads present

  Curiously at least 1:400 individuals is not a normal XX or XY person, and even at that an XX or an XY could be sexually abnormal if there is an imbalance in SRY and DAX1
- Things that go wrong during meisos

  During crossing over

- Too much of one chromosome moves over
  - Creates a deletion of genetic material on one
  - Creates a duplication of genetic material on the other
- Some times

During assortment

- Non-disjunction event, a chromosome goes to the wrong mitotic spindle
- Creates sperm with no sex chromosome or two X or two Y
- Creates ovum with two X or no X

- An odd number of sex chromosomes

YO (Y with nothing) is lethal

XO (similar to one copy of DAX1 gene) causes Turner Syndrome

- 1:2000
- Female gonads, reduced
- Thick necks
- Underdeveloped
- Intermediate torso shape
- Sterile, no puberty
-

XXY (similar to two copies DAX1 and one copy of SRY) is Klinefeleter's Syndrome

- 1:850
- Male gonads, reduced
- Breasts develop
- Intermediate body proportions
- Sterility not uncommon

XYY (1 DAX1, 2SRY) is Jacobs Syndrome

- 1:1000
- Tall with acne

XXX (3 DAX1)

- 1:1000
- Mild mental deficit, usually undiagnosed

XXXX (4 DAX1)

- Mental retardation is common

XXXXX (5 DAX1)

- Severe mental retardation

Lecture 6

- Genomes
  - Made of DNA
  - Your have 23 chromosomes in your genome
  - Your cells are diploid, thus each cell has 46 chromosoemes
  - A chromosome is made of a single long condensed strand of DNA

Some DNA has the instructions to make proteins (coding region)

Coding regions are located within genes

Between genes are non-coding DNA

Even within genes there is some non-coding DNA

- Coding DNA in a gene = exon
- Non-coding in a gene = intron

- Genome size
    - See the slide about relative genome size compared to gene number
        Mammals have larger genomes than most organisms
        - Humans and mice have a very similar number and length of genome

        Certain organisms have much more DNA than humans
        - Lungfish
            - Complex ancient fish
            - Can stay out of water for a very long time *hence name
        - Salamanders
            - Could be polyploid organisms
            - Also complex
                Lungs and gills
                Regenerates limbs
                Complex sensory system on skin
        - Giant Ameobas
            - **MASSIVE** genome
    - Sequencing of genomes is a major accomplishment
        Fred Sanger sequence first organism
        Craig Venter sequenced the human genome
        - Now Ventor is trying to assemble the first organism for synthetic DNA (read handout)
        -

Much of the following information refers to what happens in Eukaryotic cells only! Because prokaryotes lack organelles, they handle these processes somewhat differently and we do not have the time to study these nuances (although they are fascinating).

- **The central dogma** a simple view of how information moves
    - DNA makes DNA: Replication
    - DNA makes mRNA: Transcription
    - mRNA makes Protein: Translation
- How does a gene make a protein?
    - DNA is a double helix structure
        A series of bases runs along a phosphate backbone
        Adenosine, Thymine, Guanine, Cytosine can be an any order
        The order of the bases produces the genetic code
        The strands bind together because the sequences pair together
        - The pair is called a **base pair**
        - A pairs with T
        - G pairs with C
    - How are the genes read?
        Each strand can only be read in one direction
        The two strands are read in opposite directions
        Both strands have information on how to make proteins

Only one strand can instruct how proteins are made at a time
- Each strand can not be an exon in the same position

- Via transcription the DNA on one strand is converted to an **immature message RNA (mRNA)**
- The immature mRNA is "processed" into a mature mRNA
  Introns (see above) are removed from the mRNA
  Exons are joined, or spliced, together into a contiguous mRNA
  This process is **splicing**
    - This occurs to add variability to a gene
    - The proteins that splice can leave in introns or leave out parts of exons or whole exons
        - This is called alternative splicing
    - The result is often several versions of mature mRNA from a single gene
        - Thus the genome is more complex than mere gene number, as some organisms can do a lot of alternative splicing and others do virtually none
- The **mature mRNA** is now shuttled out of the nucleus to the surrounding cytoplasm via **nuclear pores** (openings in the nuclear membrane)
- The nucleus is surrounded by **rough ER**
  The rough part are ribosomes
- In the surrounding cytoplasm the mRNA are met by **ribosomes**
  Ribosomes are made of protein and RNA
  The RNA in the ribosomes is special, it is not a massage to make proteins, instead it assists in the ribosome's function
- Ribosomes read the mRNA and read the code (originally in the DNA, now copied as an RNA), the process is called **translation**
  The ribosomes assemble new, immature proteins according to the code's specifications
- The **immature proteins** are pushed into the endoplasmic reticulum as they are assembled by the ribosomes
  The lumen (inside) of the ER is where proteins mature
    - Maturation involves getting into the correct shape and addition of sugars on some parts of the correctly folded protein

  Once matured by the ER the protein leave the ER via an endosome called a **transport vesicle**, bound for the Golgi Apperatus
- At the Golgi Apperatus, a multi-sided protein sorting and shipping center
  The vesicles arrive at the **cis-surface** of the Golgi Apperatus
  Inside the Golgi Apperatus, proteins are further matured and sorted out according to their final destination
    - Proteins could be bound for any place in the cell
    - Again, new vesicles deliver mature proteins to their target destination
    - Each vesicle is chemically distinct on its' surface according to its destination and leave the Golgi form the **trans-**

surface
    - This process is called **protein trafficking**
- Finally the **mature proteins** are in their proper place serving their function

Mature proteins are often only function as multi-proteins complexes

If they need to complex with themselves, this is yet another maturation step that would be required along the passage from ER to Golgi

- The video was for your entertainment, and your glee of realizing how simple I kept a process like translation

General exam preparation hint

- Your reading in the book covers more information than I did in some ways, and less in others, your book is only meant as a reference and I try to guide you to the pages that may have the answers you seek via the assigned readings.

- You should study your notes, compare them to these notes, compare them to the slides (posted on LL) and refer to the book to resolve questions

- Reading the book in advance of class is recommended, don't stop now, just don't try and understand it all until you've attended class and know what to focus on.