Chapter 3

STRUCTURE AND FUNCTION OF THE CELL

I. How we learn about cells.
   A. Microscopy of Today
      1. Bright-field microscope
         a. 
         b. Magnification - the increase in the apparent size of the object
            (1) function of wavelengths;
         c. Resolution - measure of the clarity of an image.
            (1) is minimum distance between two objects before they are seen as one larger object.
            (2) 
      2. Electron microscopes - allow us to view the finer details of cells.
         a. 
         b. Transmission electron microscope (TEM)
         c. Scanning electron microscope (SEM) -

II. Cells Make Up Living Things
   A. Cells are the smallest units of living matter.
   B. Cells can be divided into three principal parts:
      1. Cell membrane -
         a. 
         b. 
      2. Cytoplasm and organelles
         a. Cytoplasm is the aqueous content between nucleus and cell membrane
         b. Organelles are subcellular structures within the cytoplasm
      3. Nucleus
         a. 

III. Plasma membrane
   A. outermost component of the cell.
      1. barrier to prevent the loss of cellular material
      2. Extracellular - substances outside membrane
      3. Intracellular - substances within the cell or inside the cell membrane.
   B. Functions:
      1. 
      2. 
      3. 
   C. Structure:
      1. 45-50% lipid; 45-50% proteins and 4-8% carbohydrates
      2. Lipid
         a. Phospholipids
(1) readily assemble to form a lipid bilayer
(2) Orientation of phospholipids
  (a)
  (b)

b. **Cholesterol**
   (1) interspersed among the phospholipid bilayer
   (2) determines the fluid nature of the membrane
      (a) critical to its nature.

3. **Fluid-mosaic model**
   a. The plasma membrane is neither rigid or static in structure
   b. Cell membrane is highly flexible
   c. Can change its shape and composition.
   d. The lipid bilayer is a liquid in which proteins float.
   e. Fluid nature important
      (1)
      (2)

4. **Functions of plasma membrane are determined by its proteins**
   a. Two types of membrane proteins
      (1) **integral or intrinsic** - extend from one surface to the other
         (a)
         (b)
      (2) **peripheral or extrinsic** - attached to either the inner or outer surfaces of the lipid bilayer.
         (a)
   b. Functions of membrane Proteins
      (1) **Channel proteins**
         (a)
         (b)
      (2) **Receptor molecules**
         (a) Ligand -
         (b) Ligand binding site -
         (c) Form an intercellular communications system
            i) Ligand binding triggers a specific cellular response.
   c. **Marker molecules**
      (a) mostly **glycoproteins** - proteins with carbohydrates attached.
      (b) allows cells to identify and attach to each other.
         i) 

   c. **Function of Membrane Proteins Is Dependent on 3 Dimensional shape.**
      (1) Channels can be opened or closed depending on the shape of the protein.
         (a) ligand-gated channels -
         (b) voltage-gated channels-
IV. **Nucleus Stores Genetic Information**

A. Stores genetic information determining structure/function of cells by regulating sequences of amino acids.

1.

2.

B. Structures (Fig. 4.6)

1. **Nucleus** is a prominent structure within the cell (diameter of about 5 μm).
   a.
   b.

2. **Nuclear envelope** is a double membrane that separates nucleoplasm from cytoplasm.

3. **Nuclear pores** (100 nm) fusion of inner and outer nuclear envelope which permit passage of molecules into or out of the nucleus.

4. **Deoxyribonucleic acid (DNA)** and associated proteins are dispersed throughout the nucleus.

5. **Chromatin** is a threadlike material made up of DNA, proteins called histones, and some RNA
   a.

6. **Chromosomes** are rod-like structures formed during cell division;
   a.

7. **Nucleoplasm** is semifluid medium of nucleus; has a different pH from cytosol.

8. **Nucleolus** are dark-staining spherical body in nucleus;
   a.
   b.

V. **Cytoplasm**

A. The **cytoplasm** is outside the nucleus but within the plasma membrane and consists of cytosol and organelles.

B. **Cytosol**

1. Consists of fluid portion, cytoskeleton, and cytoplasmic inclusions.

2. **Fluid portion of cytosol**
   a.
   b.

3. **Cytoskeleton**
   a. Cytoskeleton is a network of connected filaments and tubules that extends from nucleus to plasma membrane.
   b. Function:
      (1)
      (2)
   c. Highly dynamic -

4. **Cytoskeletal proteins**: microtubules, microfilaments, intermediate filaments
a. **Microtubules**
   (1) Structure:
      (a) Small hollow cylinders (25 nm in diameter and from 200 nm-25 μm in length).
      (b) Composed of alpha and beta tubulin
         i) 
         ii) 
   (2) Function
      (a) Cell division:

      (b) Transport of organelles
         i) motor molecules:
            a) kinesin:
            b) dynein:

b. **Intermediate filaments**
   (1) Structure:
      (a) 8-11 nm in diameter
      (b) form rope-like assemblies of fibrous polypeptides.
   (2) Function:
      (a) Provide mechanical support to cells.

      (b) form cell-to-cell junctions (eg. Keratin)

c. **Actin Filaments**
   (1) Structure:
      (a) long, thin fibers (about 7 nm in diameter) composed of two chains of globular actin monomers twisted to form a helix.
      (b) Occur in bundles, sheets or meshlike networks.
   (2) Functions:
      (a) support and determine the shape of the cell
         i) form a dense complex web just under the plasma membrane.
         ii) Interacts with myosin (a molecular motor)

      (b) support for microvilli

      (c) Cell division

      (d) amoeboid movement of cells

      (e) muscle fiber contractions
5. **Cytoplasmic inclusions**  
   a. Aggregates of chemicals either produced by the cell or taken in by the cell.  
      (1) Lipid droplets  
      (2) Glycogen granules  
      (3) Melanin-  
      (4) Lipochromes -

C. **Organelles**  
1. **Ribosomes**  
   a. Structure:  
      (1) Composed of two subunits  
      (2) assembled in the nucleolus of the nucleus.  
   b. Function:  
      (1) Protein syntheses  
      (2) Ribosomes coordinate assembly of amino acids into polypeptide chains (i.e., protein synthesis).  
   c. Location:  
      (1) **Free**  
      (2) **Polyribosomes**  
         (a) Free and Poly assemble proteins used inside the cell.  
      (3) **Attached to ER.**  
         (a) produce proteins for secretion from the cell or for internal use.  
2. **Endoplasmic reticulum**  
   a. **Endomembrane system** - an elaborate series of intracellular membranes that compartmentalize the cell.  
      (1) Composed of the nuclear envelope, the endoplasmic reticulum, the Golgi apparatus and several vesicles.  
      (2) These structures are connected either directly or by the transfer of vesicles from one to another.  
   b. Endoplasmic Reticulum (ER)  
      (1) Structure:  
         (a) broad flattened interconnected system of membranous channels.  
         (b) continuous with outer membrane of the **nuclear envelope**.  
         (c) **interior space is called cisternae**  
   c. **Rough ER** is studded with **ribosomes**;  
      (1) site where proteins are synthesized for secretion for internal use  
      (2)  
   d. **Smooth ER** is continuous with rough ER, but  
      (1) Structure: same as Rough ER but lacks ribosomes;  
      (2) Function:
(a) site of lipid and carbohydrate synthesis
  i) detoxification
(3) storage -
(4) forms transport vesicles.
  (a) transport vesicles carry proteins etc to either the Golgi apparatus or the plasma membrane

3. Golgi Apparatus
   a. Structure:
      (1) Golgi apparatus consists of flattened membranous saccules containing cisternae
      (2) stacked like dinner plates (3-20 deep).
   b. Function:
      (1) receives protein-filled or lipid filled vesicles that bud from the ER.
      (2) Modification of Proteins and lipids
         (a)
      (3) Concentration and packaging of molecules into vesicles..
         (a)
      (4) Delivery of modified proteins and lipids to:
         (a) the plasma membrane where proteins are secreted via exocytosis or incorporated into the plasma membrane.
         (b) other vesicles that contain enzymes used with the cell (ie. lysosomes).
      (5) The golgi apparatuses are most numerous in cells that secrete large amounts of protein and glycoproteins.

4. Secretory Vesicles
   a. Structure
      (1) membrane bound spheres that pinch off from the golgi and move to the surface of cell.
      (2) Function:
         (a) Insertion of new membrane material (phospholipids, cholesterol and proteins) into the plasma membrane.
         (b) Release of vesicular contents to the exterior of the cell.
   (3)
   b. Secretory vesicle accumulate in many cells and are released only when a signal is received by the cell.
5. **Lysosomes**
   a. **Structure:**
      (1) Lysosomes are membrane-bound vesicles produced by Golgi apparatus
      (2) contain hydrolytic enzymes for intracellular digestion.
   b. **Functions:**
      (1) Lysosomes digest the contents of vesicles received from the plasma membrane
      (2) Autodigestion (autophagia) - lysosomal digestion of parts of the cells they come from or even the whole cell.
         (a) important during development (e.g., tadpole tail absorption, degeneration of webbing between human fingers).
   c. **Missing or inactive lysosomal enzymes cause serious diseases.**
      (1) Pompe’s disease- lysosomes can’t break down glycogen.
         (a) Glycogen accumulates in heart, liver and skeletal muscle - result heart failure.
      (2) Nieman-Pick and Farber disease.- Lack of lysosomal enzyme to break down lipids.
         (a) lipids accumulate in phagocytic cells
         (b) abdominal pain, enlargement of spleen and liver, eruption of yellow nodules in skin
      (3) Hurler’s syndrome - unable to break down mucopolysaccharide
         (a) accumulate in lysosomes of connective tissue
         (b) mental retardation and skeletal deformities

6. **Peroxisomes**
   a. **Structure:** Vesicles that are smaller than lysosomes
      (1) Contain enzymes that break down fatty acids and amino acids
   b. **Hydrogen peroxide is a by product of the breakdown and is toxic to the cell.**
      (1) Peroxisomes contain the enzyme catalase
      (2) catalase - breaks down peroxide to water and oxygen
   c. Liver and kidney cells have many peroxisomes.

7. **Mitochondria**
   a. **Structure:**
      (1) Double membrane organelle
         (a) membranes are separated by a intermembranous space.
         (b) outer is smooth
         (c) inner has numerous folds called cristae
   b. **Function:**
      (1) Major sites of ATP production
         (a) major energy source for most endergonic chemical reactions within the cell.
      (2) Two major enzyme systems are responsible for oxidative metabolism and ATP synthesis
         (a) Citric acid cycle (Kreb’s cycle)\
i) (b) Electron transport chain

i) c. Cells with high energy requirements have a higher number of mitochondria.
   (1) mitochondria can divide as need increase
   (2) eg. muscle cells enlarge and need more ATP for contraction - increase in
       mitochondria number.

d. Mitochondria have their own DNA.
   (1) passed down from Mother only (no mitochondia in sperm).
   (2) makes maternal pedigrees easy to track
   (3) Used to track the origins of humans within a region.

8. Centrioles and Spindle Fibers
a. Centrosome - major microtubule organizing center of the cell.
b. Structure:
   (1) centrosome contains two centrioles
   (2) Centriole are small cylindrical organelles that lie at right angles to each other
   (3) The wall of the centriole is composed of nine evenly spaced, longitudinally
       oriented parallel units of triplets.
   (4) Each unit consists of three parallel microtubules joined together.
       (a) 9 + 0 pattern of microtubule triplets.
c. Function:
   (1) Centrosome is the center of microtubule formation.
       (a) Microtubules in turn influence the distribution of intermediate and actin
           filaments therefore centrosome is important in determining cell shape and
           movement.
   (2) Microtubules extending from the centrosome are very dynamic.
   (3) Microtubules called spindle fibers are important in cell division
   (4) Centrioles serve as basal bodies for cilia and flagella.

9. Cilia and Flagella
a. Cilia
   (1) Structure:
       (a) short, usually numerous hairlike projections that can move in an undulating
           fashion
       (b) generally limited to one surface of a cell.
       (c) the shaft of each cilium is enclosed by the plasma membrane.
       (d) matrix containing a cylinder of nine pairs of microtubules encircling two
           single microtubules (9 + 2 pattern of microtubules).
       (e) microtubules extend from the base to the tip of each cilia.
       (f) ATP is responsible for the movement of each cilia.
       (g) A basal body (a modified centriole) is located in the cytoplasm at the base
           of each cilia.
(2) Function:
   (a) Propel objects over the cell.
   (b) Power stroke in one direction and a recovery stroke in the other.

b. **Flagella**
   (1) Structure:
      (a) are similar in structure to cilia
      (b) longer than cilia and usually fewer in number
      (c) whip-like projections that move in whip-like fashion (e.g., sperm cells).
   (2) Function:
      (a) specialize in moving the cell

c. Cilia and flagella move when the microtubules slide past one another (dynein side arms move one doublet over its neighbor doublet and bending occurs.
   (1) Cilia and flagella have basal body at base of the structure within the cytoplasm
      (a) same arrangement of microtubule triplets as centrioles.
   (2) Cilia and flagella grow by the addition of tubulin dimers to their tips.

10. **Microvilli**
    a. Structure:
       (1) Small extensions of the plasma membrane (1/10 - 1/20 size of cilia)
       (2) Supported by microfilaments
    b. Function
       (1) increase the surface area of the cell.
       (2) Some are specialized as sensory receptors
          (a) hair cells of the inner ear.

VI. **Cell Functions**
    A. The integration of the part must be considered

VII. **Movement through the Plasma Membrane**
    A. The plasma membrane is selectively permeable.
       1. Different composition inside vs. outside the cell.
          a. I.e. enzymes, proteins, ions.
       2. Nutrients must enter, waste exit
       3. Because the cell is able to transport molecules selectively, the cell is able to maintain these critical concentration differences.
       4. Substances move across the plasma membrane in 4 ways: 1) directly through the bilayer, 2) through membrane channels, 3) with carrier molecules in the membrane 4) in vesicles.
          a. Lipids move directly through
          b. Polar molecules can not.
             (1) some water does pass through the membrane but most comes through channels with soluble ions such as Na+, Cl- and K+.
             (2) Large polar molecules move across on carrier proteins or through vesicle formation
B. Diffusion
1. **solute** - Substance or molecules that are dissolved in a solvent.
2. **Diffusion** - the movement of solute molecules from an area of high concentration to an area of lower concentration in solution.
   a. Diffusion is a property of random movement of molecules.
      (1) chances are greater that solute molecules will move from a higher concentration to a lower concentration.
      (2) This movement continues until an equilibrium is reached.
3. **Concentration gradient** is the concentration difference between two points divided by their distance.
4. Rate of diffusion is influenced by
   a. **Magnitude of the concentration gradient**
      (1)
   b. **Temperature**
      (1)
   c. **Size of the diffusing molecule**
      (1)
   d. **Viscosity of the solvent**
      (1)
5. Diffusion is an important means by which molecules move across the plasma membrane.

C. Osmosis
1. **Osmosis** - the diffusion of water (solvent) across a selectively permeable membrane such as the plasma membrane.
   a. A semipermeable membrane allows water but not all solvents to pass through the membrane.
   b. Water moves across the membrane from an area with proportionately more water to the side of the membrane with less water on it.
      (1)
   c. Large changes in water movement across the cell membrane can disrupt normal cell function.
2. **Osmotic pressure** - the force required to prevent movement of water by osmosis across a selectively permeable membrane.
   a.
   b. Three terms describe the osmotic pressure of solutions
      (1) **isosmotic** - solutions with the same concentration of solutes
      (2) **hyperosmotic** - the solution has greater concentration of solutes
      (3) **hypoosmotic** - the solution has a lower concentration of solutes (the more dilute solution)
   c. Three additional terms describe the tendency of cells to shrink or swell when placed in solution (Fig RBC)
Chapter 3

(1) **isotonic** - cell neither shrinks or swells
(2) **hypertonic** - cell shrinks due to high concentration of solutes in solution (crenation).
(3) **hypotonic** - cell swells due to lower concentration of solutes in solution (lysis).
d. Osmotic terms refer to concentration of solution, tonic terms refer to tendency of cell to swell or shrink.
   (1) Not all isosmotic solutions are necessarily isotonic.

D. Filtration
1. Results when a partition containing small holes is placed in a stream of moving liquid.
   a. Large molecules are held back.
2. Depends on the pressure difference on either side of the partition.
   a.
3. Filtration occurs in the kidneys - urine formation.
   a.

E. Mediated Transport Mechanisms
1. Many essential molecules such as amino acids, proteins and glucose cannot enter or exit the cell by simple diffusion.
2. Mediated Transport Mechanisms involve carrier molecules within the plasma membrane that move large, water-soluble molecules or electrically charge molecules across the membrane.
3. Process of mediated transport mechanisms-
   a. Molecule binds to carrier molecule.
   b. Three dimensional shape of carrier molecule changes.
   c. The bond molecule is moved to the opposite side of the membrane.
   d. Carrier molecule releases the molecule/ regains its original shape and is ready to transport another transport molecule.
4. Three characteristics of mediated transport
   a. **Specificity**: each carrier binds to and transports only one type of molecule
      (1)
   b. **Competition**: closely related structures may compete for the binding site.
      (1)
   c. **Saturation**: the rate of transport is limited by the number of carrier molecules.
      (1)
5. Three types of Mediated Transport Mechanisms
   a. **Facilitated diffusion**:
      (1) carrier mediated process that moves substances into or out of the cell from a higher to a lower concentration.
      (2) Does not require energy
   b. **Active Transport**
      (1) carrier mediated process that requires energy.
      (a) rate of transport depends on the number of carrier molecules and adequate ATP.
      (2) Can accumulate substances in much greater quantities on one side of the membrane.
(a) Can move substance from a lower concentration to a higher concentration.

(3) Can exchange one substance for another
(a) ie. Na+- K+ pump

c. Secondary Active Transport
(1) Two stage transport of a molecule from a low concentration to a higher concentration.
(2) An ion such as Na+ is pumped out of the cell against its concentration gradient (Na+/K+ pump).
(3) The diffusion of Na+ back into the cell down its concentration gradient provides the energy needed to pump some other molecule such as glucose into the cell from a low concentration to a high concentration.
(4) The transport molecule can move in the same direction as the ion powering the movement or in the opposite direction
(a) Same direction - cotransport (glucose)
(b) Opposite direction - countertransport (H+)

F. Endocytosis and Exocytosis
1. Endocytosis: bulk uptake of material through the plasma membrane by formation of a vesicle.
   a. Phagocytosis: cell eating
      (1) ingestion of solid particles
   b. Pinocytosis: cell drinking
      (1) contain particle dissolved in liquid rather than particles.
   c. Endocytosis is specific
      (1) cell that phagocytize bacteria and dying tissue do not phagocytize healthy cells.
      (2) Receptor mediated endocytosis
         (a) receptors on cell surface bind to specific molecules, the receptor and preferred molecule are then phagocytized.
         (b) This mechanism increases the rate at which specific substances are taken up into the cell.
   d. Both Phagocytosis and pinocytosis require energy (active processes).
2. Exocytosis
   a. Secretory vesicles fuse with the plasma membrane and the contents of the vesicle is expelled (exocytosis)
      (1) ie secretion of digestive enzymes of pancreas, mucus of salivary glands, milk from the mammary glands.

VIII. Cell Metabolism
A. Cell metabolism is the sum of all the catabolic (decomposition) and anabolic (syntheses) reactions in the cell.
B. Carbohydrates, lipids and proteins are broken down and the energy from these molecules is used to produce ATP.
C. Glucose through a process called glycolysis converts glucose to pyruvic acid within the cytoplasm of the cell.
D. Pyruvic acid can enter two different biochemical pathways depending on the availability of
1. Aerobic Respiration - when oxygen is available
   a. Pyruvic acid enters the mitochondria
   b. Through a series of chemical reactions called the citric acid cycle and electron transport chain pyruvic acid is converted to $\text{CO}_2 + \text{H}_2\text{O}$ and ATP.
   c. 36-38 ATP are produced from each glucose molecule
   d. Aerobic respiration requires $\text{O}_2$.
      (1) last reaction $\text{H} + \text{O}$ to from water.
      (2) reason for breathing
   e. Carbon from glucose released as $\text{CO}_2$.
      (1) $\text{CO}_2$ we breathe comes from the food we eat.

2. Anaerobic Respiration - without oxygen
   a. Converts pyruvic acid into lactic acid
   b. Net production is 2 ATP / glucose. (Vs 36-38 aerobic)
   c. Cell can function for short periods when $\text{O}_2$ is low.
   d. Ie during intense exercise.

IX. Protein Synthesis
   A. Cell structure and function would not be possible without proteins.
      1. Proteins form: cytoskeleton, enzymes, receptors, transport molecules, etc.
      2. The production of all proteins in the cell is under the control of DNA
   B. Structure of DNA
      1. Nucleotide - Adenine, Thymine, Guanine, Cytosine
      2. Two antiparallel strands
         a. extend in opposite directions
         b. each strand has a 5’ (phosphate end) and a 3’ end (hydroxyl)
   C. The sequence of nucleotides is the method of storing information
      1. Triplet code - 3 nucleotides code for one amino acid.
      2. Gene - All the triplets required to code for one specific protein
         a. Each gene is a composed of a precise order of triplet codes telling the cell to manufacture a particular protein
            (1) Ie. enzyme for digestion, antibody to fight a lethal infection, receptor protein in your brain that allowed you to understand this sentence.
      3. Genes
         a. Estimated 100,000 genes in 23 pairs of chromosomes in your body
         b. There are billions of letters that make up these genes
            (1) about a gigabyte of data

4. The production of protein from DNA involves 2 steps: transcription and translation.

5. Ribonucleic acid
   a. DNA directs the activities of the cell only by means of RNA
      (1) RNA consists of long chains of nucleotides like DNA
      (2) RNA vs DNA
(a) RNA is contains ribose (instead of deoxyribose)
(b) the base Uracil is present (not Thymine)
(c) RNA is a single strand (not a double)

(3) Three Types of RNA
(a) messenger RNA
(b) transfer RNA
(c) ribosomal RNA
   i) all three types are made in the nucleus from DNA codes.
   ii) all three types are necessary to make protein

D. Transcription - RNA Synthesis
1. One gene codes for one polypeptide chain
   a. Human cell contains 3 billion base pairs in DNA
      (1) Enough to make 3 million proteins but only 30,000 to 150,000 different proteins are made.
   b. Only a fraction of the DNA in each cell is used to code for proteins
   c. Remainder of DNA is inactive or redundant.
2. Transcription - synthesis of mRNA on the basis of the sequence of nucleotides in DNA.
   a. **RNA polymerase** breaks weak hydrogen bonds in DNA
      (1) DNA segments separate
   b. The RNA nucleotides combine through a dehydration reaction.
      (1) catalyzed by **RNA polymerase** enzyme
   c. RNA nucleotides pair with DNA nucleotides
      (1) Adenine pairs with uracil (not thymine)
      (2) Thymine in DNA pairs with adenine
      (3) guanine pairs with cytosine and vice versa.
   d. RNA synthesis only occurs in small region of the DNA
      (1) DNA has start and stop sequences that represent the beginning and end of a gene.
      (2) RNA synthesis only occurs between these sequences.
   e. Elongation occurs from 5' to 3'end of molecule.
3. Codons
   (1) Codon - groups of three nucleotides that carries the genetic code.
   (2) The number and sequence of codons in the mRNA are determined by the number an sequence of sets of three nucleotides called triplets in the segments of DNA that were transcribed.
   (3) CTA in DNA codes for GAU in mRNA which codes for the a.a. aspartic acid in the protein.
   (4) Each codon codes for a specific amino acid (a.a.)
      (a) 64 possible mRNA codons (only 20 a.a. are in proteins).
      (b) some a.a. have more than one codon
         i) ie. the a.a. alanine is coded for by CGA, CGG, CGT, CGC
   (5) Some codons perform specific functions.
      (a) AUG and GUG act as signals for starting transcription
      (b) UAA, UGA, UAG act as signals for stopping transcription of DNA to RNA.
(c) The region between the start and stop codon is transcribed into a stretch of RNA and is called a transcription unit.
i) A transcription unit codes for a protein or part of a protein.
(6) A molecular definition of a gene is all of the nucleic acid sequences necessary to make a functional RNA or protein.

b. Not all of a continuous stretch of DNA may code for parts of a protein.
(1) Exon - region of DNA that codes for part of the protein.
(2) Intron - regions of the DNA that do not code for the protein.
(3) Both introns and exons are transcribed into mRNA.
   (a) mRNA containing introns is called pre-mRNA.
   (b) -post transcriptional processing After transcription the introns in pre-mRNA are removed by enzymes and the functional part of the mRNA is spliced together.
E. Translation

1. Translation is the synthesis of protein at the ribosome in response to codons of mRNA.

2. Translation requires: a.a., mRNA, tRNA, and Ribosomes.
   a. tRNA - matches a specific a.a. to a specific codon of mRNA
      (1) One end of each kind of tRNA combines with specific amino acids.
      (2) The other end has an **anticodon** which consists of three nucleotides.
      (3) On the basis of pairing relationships between nucleotides, the anticodon can combine only with its matched codon.

   b. Ribosomes
      (1) Ribosomes consist of ribosomal RNA and proteins.
      (2) Align the codons of mRNA with the anticodons of tRNA.
      (3) Then join the a.a. of the adjacent tRNA molecules.

3. Translation
   (1) As amino acids are joined together a chain of a.a. or a protein is formed.
   (2) To start protein synthesis a ribosome binds to mRNA.
   (3) The ribosome also has **two binding sites** for tRNA.
      (a) One is occupied by a tRNA with its amino acid.
   (4) The codon of mRNA and the anticodon of tRNA are aligned and joined.
   (5) The other tRNA binding site is open.
   (6) The next tRNA binds to the open tRNA binding site where it is properly aligned with mRNA and with the other tRNA.
   (7) An enzyme within the ribosome catalyzed a synthesis reaction to form a peptide bond between the a.a.
   (8) The a.a. is now associated with only the second tRNA.
   (9) The ribosome shifts positions by three nucleotides.
   (10) The tRNA without the a.a. is release from the ribosome.
   (11) tRNA with the a.a. takes its position.
   (12) A tRNA binding site is left open by the shift.
   (13) Additional a.a. can be added as before.
   (14) Eventually a stop codon in the mRNA ends the production of protein which is released from the ribosome.

4. Post translational modification of proteins.
   a. Many proteins are longer when first made than they are in the final start (proteins).
   b. Extra pieces are cleaved out by an enzyme to make an active molecule.
   c. I.e. Proenzymes are not converted to active enzymes until they react a protected region of the body.
   d. Many proteins have side chains such as polysaccharides added to them. (Post-translational modifications)

5. After the initial part of the mRNA is used by a ribosome another ribosome can attach to the mRNA forming a polycytope.
   a. Single mRNA can be used to make many copies of the same protein.
Chapter 3

F. Regulation of Protein Synthesis
   1. Not all genes are turned on in every cell.
   2. Protein synthesis is not normally constant.

X. Cell Life Cycle
A. A cell cycle is a series of changes that a cell undergoes from the time it is formed until it has completed a division and reproduced itself.

B. **Interphase** - the first period of the cycle - from the formation of the cell to the start of cell division.
   1. Interphase is divided into G1, S and G2 phases.
      a. G1 - (first **growth** phase) - cell grows rapidly and is metabolically active.
         (1) Duration of G1 varies from hours to years
         (2) Centrioles replicate at the end of G1 in preparation for their role in cell division.
      b. S - (synthetic phase) - The DNA in the nucleus of the cell replicates so that the two future cells will receive identical copies of the genetic material.
      c. G2 - (second growth phase) - the enzymes and other proteins needed for the division process are synthesized and cell continues to grow.

C. **Mitotic Phase (M phase)** - actual division of the cell.
   1. Divided into Mitosis and Cytokinesis
      a. Mitosis - nuclear division and the duplicated chromosomes separate to form two genetically identical daughter nuclei.
         (1) Takes place in 4 successive steps.
            (a) Prophase
            (b) Metaphase
            (c) Anaphase
            (d) Telophase
      b. Cytokinesis - division of the cytoplasm after telophase

Events occurring at each Phase of the cell cycle.

**Interphase**
- The chromosomes are in an extended form and seen as chromatin in the electron microscope
- The nucleus is visible

**Prophase**
- The chromosomes are seen to consist of two chromatids joined by a centromere.
- The centrioles move apart toward opposite poles of the cell.
- Spindle fibers are produced and extended from each centrosome.
- The nuclear membrane starts to disappear.
- The nucleolus is no longer visible.

**Metaphase**
- The chromosomes are lined up at the equator of the cell.
- The spindle fibers form each centriole are attached to the centromeres of the chromosomes.
- The nuclear membrane has disappeared.

**Anaphase**
- The centromeres split, and the sister chromatids separate as each is pulled to an opposite pole.

**Telophase**
- The chromosome become longer, thinner and less distinct.
- The nuclear membranes form.
- The nucleolus reappears.
- Cell division is nearly complete.

**Cytokinesis**
- division of the cytoplasm