

UNIT 4 STUDY GUIDE FOR BIO 181

CHAPTER 12: The Cell Cycle

Cell Cycle and Mitosis:

- List and describe some of the functions of cell division.
Reproduction (asexual and sexual), growth, development, cell replacement, injury repair
- Define “cell cycle”.
 - Name the 3 main stages of the cell cycle, and describe the major events of each stage.
Interphase (with G1, S, and G2; active cell growth, including multiplication of organelles and DNA replication); Mitosis (division of the nucleus into two nuclei); cytokinesis (division of the cell and its cytoplasm into two cells).
 - What must happen to the DNA of a cell before the cell divides? Why?
Must replicate so that each new daughter cell gets a complete set of genetic instructions.
 - What is the total amount of genetic information inside a cell called?
Genome
 - What is the difference between somatic and gametic cells? How does the number of chromosomes in each compare?
*Somatic cells = cells of the body, including muscle, nerve, adipose, connective, epithelial, etc.
Gametes = sex cells for reproduction, specifically sperm and ova. The number of chromosomes in gametes is 1/2 that of somatic cells for a particular species.*
 - What types of cells undergo the cell cycle (prokaryotic, eukaryotic, etc.)?
Only eukaryotic, strictly speaking, if the cell cycle includes mitosis. Prokaryotes must grow and replicate DNA as well, but when they undergo binary fission, there is no nucleus and no membrane bound organelles.
- Describe the structure and composition of chromosomes, and describe (and draw) how a chromosome’s structure compares before and after the ‘S-Phase’ of interphase
 - Do sister chromatids exist before or after the S-Phase?
After.
 - What are sister chromatids (define)?
Two genetically identical DNA molecules, containing the same genes and alleles, and attached at a centromere (region of unreplicated DNA).
 - What is a centromere?
The region where sister chromatids are attached on a chromosome.
 - What material / chemical compounds make up a chromosome?
Chromatin (DNA + proteins)
- Describe the events that occur during the G1 and G2 phases of interphase.
 - When do these events occur in relation to the S-Phase?
G1 is before the S phase, and includes active protein synthesis for cell growth. G2 occurs after the S-phase, and continues protein synthesis, although emphasizing those used for mitosis and cytokinesis.
 - What proportion of the cell cycle is taken up by the events of interphase?
About 90%.
 - What is the cell trying to accomplish during these respective phases?
Answered above.
- List AND draw the 5 stages of mitosis in the correct order, and describe the most significant events of each stage.

Prophase: chromatin begins to condense; centrosomes begin to move to opposite poles with microtubules (spindle fibers) beginning to develop.

Prometaphase: kinetochore microtubules attach to centromeres of chromosomes; nuclear envelope is dismantled; chromatin continues to condense.

Metaphase: All chromosomes move to the metaphase plate (equatorial region) of the cell where they are separated and dispersed.

Anaphase: DNA finishes replication in the centromere region, and sister chromatids separate, becoming independent chromosomes. Spindle fibers shorten, and motor molecule proteins “walk” the new chromosomes up the spindle fibers as they themselves are dismantled.

Telophase: New nuclear envelopes develop around each new set of chromosomes.

a) What are centrosomes, and what is their function?

Non-membrane bound organelles from containing microtubule organizing centers. By the time mitosis begins, each cell contains a pair of centrosomes.

b) What are spindle fibers, and where do they come from?

Microtubules specifically used for moving newly formed chromosomes, and for assisting the cell in cell division.

c) What is a kinetochore, and what is its function?

The structure of a centromere where motor molecule proteins are located for chromosome movement.

d) Describe the differences (in function) between kinetochore and nonkinetochore microtubules.

The former are attached to the kinetochores of chromosomes, and they assist in chromosome migration during mitosis. The latter span the length of the cell, and they help the cell to elongate and divide during cytokinesis.

e) What are the chromosomes doing at each stage?

Answered above.

6. Describe how plants and animals differ in their mechanism of cytokinesis. Explain why plants cannot divide their cells in the same way as animals.

Animals form a belt or draw-string of microfilaments around the middle of the cell. The microfilaments slide past each other, contracting. Because they are attached to protein elements of the plasma membrane, as the microfilaments contract, they draw the plasma membrane inwards, forming a cleavage furrow. Eventually the microfilaments constrict to the point of dividing the cell into two daughter cells. In contrast, plant cells have a cell wall, which prevents the cells from dividing in the manner of animal cells. Instead, plant cells send vesicles, containing cellulose, from the Golgi apparatus to the middle of the cell. The vesicles coalesce and form new cell walls and plasma membranes, dividing the cell into two daughter cells.

7. Describe how prokaryote cell division contrasts with eukaryote cell division.

Prokaryotes do not have a nucleus, so there is no mitosis. The replicated DNA attaches to each end of the prokaryotic cell, anchoring itself. The cell undergoes binary fission, dividing into two daughter cells.

8. Describe some of the variations in mitosis among various eukaryotic groups (i.e., dinoflagellates vs. diatoms vs. other eukaryotes), and discuss any similarities to binary fission.

In dinoflagellates, diatoms, and yeast, the nucleus remains intact and spindle fibers are found within the nucleus. In most other eukaryotes, the nucleus disappears, as described above. In dinoflagellates, the nucleus divides in a manner very similar to binary fission of prokaryotes.

9. Describe how the cell cycle control system works, and how cell division is regulated.

a) What is a checkpoint, and how is it regulated?

A control point in the cell cycle where protein signals determine whether the cell enters the next stage of the cell cycle or not. Some of the signals “report” whether the cell is ready internally, and others report signals from the external environment of the cell.

- b) What might cause a cell to enter the G₀ phase?
If the “go ahead” signals are not there, then the cell enters a nondividing state.
- c) Explain how density-dependent inhibition and anchorage dependence may control cell division.
At some point, when cell density becomes high, nutrients and energy cannot get to cells as quickly, and the cells respond by going into a nondividing state. Also, in animals, cells must be attached to something, like extracellular matrix, to go into G₀.
10. Explain how the cell cycle of cancer cells is different from normal cells, and describe some hypotheses for the differences.
Cell cycle in cancer cells is out of control (there is no regulation, growth factors do not regulate as they should).
- a) Compare and contrast benign tumors, malignant tumors, and metastasis.
Transformed cells are cancerous. Normally ones immune system identifies and destroys such cells.
Benign tumor: abnormal cells remain at the site of origin, and most benign tumors do not impair functions of organs.
Malignant: tumor becomes invasive enough to impair functions of one or more organs. This person has cancer.
Metastasis occurs when cancer cells lose their attachments to one another and move to other sites in the body. New tumors can develop, spreading the cancer.

CHAPTER 13: Meiosis and Sexual Life Cycles

11. Differentiate between asexual and sexual reproduction, and the type of cell division used in each strategy.
Asexual: new organisms develop from cells produced by mitosis. Essentially cloning. Mitosis is used for asexual reproduction.
Sexual: gametes with ½ the number of chromosomes (usually haploid cells) fuse (fertilization), forming a new organism (zygote). Meiosis produces gametes.
12. Explain why meiosis must occur in sexually reproducing organisms.
Chromosome number must be reduced by ½.
13. Describe and draw the sexual life cycle of animals.
See Figure 13.5 in your textbook.
14. List the stages of Meiosis I and Meiosis II, and describe the significant events at each stage (especially crossing over and independent assortment; when do these happen, how do they happen, and what are the results of these events?). Identify the point at which cells become haploid. Identify the way by which diploid cells produce haploid cells (i.e., what stage(s) of meiosis are crucial for producing haploid cells?).
Both meiosis I and II consist of prophase, metaphase, anaphase, and telophase. The events of meiosis I are significantly different from those of mitosis. Specifically, homologues find each other during prophase I (synapsis) and undergo crossing over (exchange equivalent fragments of nonsister chromatids). During metaphase I, homologues randomly align themselves on opposite sides of the metaphase plate so that pairs of chromosomes are dispersed around the middle plane of the cell. This random alignment is called independent assortment, and along with crossing over, is an important process for producing genetically different gametes. After meiosis I, daughter cells are haploid (each having 1 set of chromosomes, no pairs, although each chromosome still has sister chromatids). The events of meiosis II are identical to mitosis so that sister chromatids separate, producing 4 haploid cells by the end of meiosis. Phew!
15. Explain how independent assortment occurs, and name the stages of meiosis during which this event happens. Explain the “random fertilization of gametes” that occurs when sexually reproducing organisms mate, and explain how both independent assortment and random fertilization produce variations among organisms.

See answer above. By gametes randomly fertilizing, a tremendous number of genetically diverse offspring are possible from two parents.

16. Describe what a karyotype is, and how it is prepared and interpreted.

A karyotype is a display of condensed chromosomes arranged in pairs. A karyotype can be used to screen for some genetic abnormalities. Somatic cells are cultured in a lab and arrested at metaphase of mitosis to visualize the chromosomes. The size and shape of each chromosome can be evaluated for abnormalities.

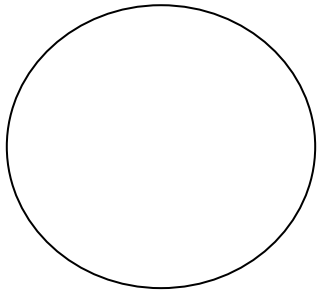
17. Define autosome, sex chromosome, somatic cells, gametes, homologues, genes, alleles, chromatin, chromosome, chromatid, centromere, kinetochore microtubules, nonkinetochore microtubules, metaphase plate, centrosome, cleavage furrow, tetrad, synapsis, haploid, diploid, and any other terms that come your way in lecture! ☺

Hmm. Yes. You are capable of looking these up. ☺

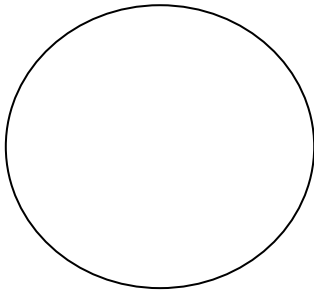
Problems (for both Mitosis and Meiosis):

1. A parasitic nematode worm has a diploid number of 6 ($2n=6$) in its somatic cells. Show the arrangement of the chromosomes as they would appear during the following stages:

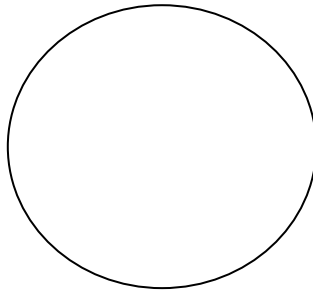
Mitosis: Prometaphase



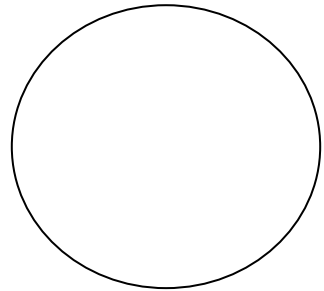
Metaphase



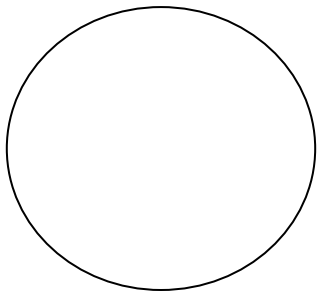
Anaphase



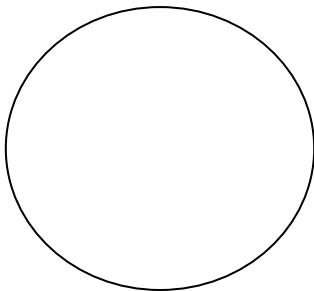
Telophase



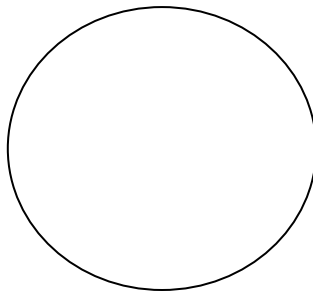
Meiosis: Prophase I



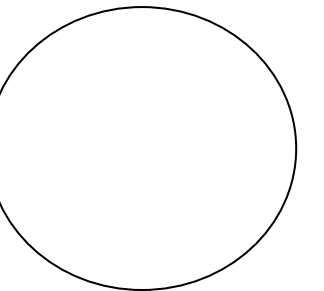
Metaphase I



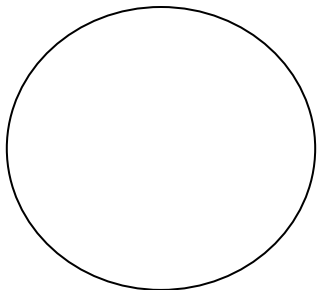
Anaphase I



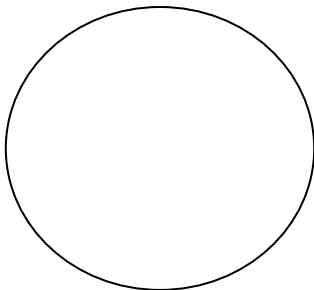
Telophase I



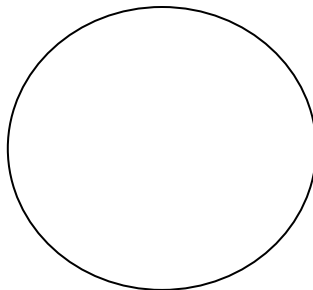
Prophase II (1 of 2 cells)



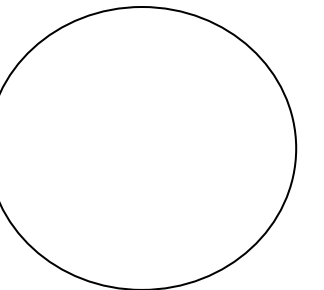
Metaphase II



Anaphase II



Telophase II



2. A cell begins interphase with 12 chromosomes ($2n = 12$).

(A) After the “S” phase of interphase, how many chromosomes are there? How many sister chromatids?

12 chromosomes, 24 chromatids.

(B) During anaphase of mitosis, how many chromosomes are there? How many sister chromatids?

24 chromosomes, 0 chromatids.

- (C) During anaphase of Meiosis I, how many chromosomes are there per cell?
12 chromosomes. The homologues are moving away from each other, but sister chromatids are still attached.
- (D) During anaphase of Meiosis II, how many chromosomes are there per cell?
12 chromosomes. Each cell started meiosis II with 6 chromosomes, however, when the sister chromatids separate, the chromosomes number is temporarily doubled until the cell divides.
- (E) After Meiosis II is complete, and cytokinesis occurs, how many chromosomes are there per cell?
6. All of the prior events have led to gametes have 1 chromosome of each pair for a haploid number of chromosomes.
3. A cell has a diploid number of 8 ($2n = 8$). If nondisjunction of one chromosome pair occurs during Meiosis I, how many gametes would be aneuploid by the end of meiosis? What would the chromosome numbers be in the resulting cells? Draw the outcome (what the cells would look like).
An error during meiosis I would affect all gametes, making 2 of them $n+1$, and 2 of them $n-1$. Therefore, two of the cells would have 5 chromosomes, and 2 would have 3 chromosomes.
4. A cell has a diploid number of 8 ($2n = 8$). If Meiosis I occurs normally, but nondisjunction of one chromosome pair in one of the cells occurs during Meiosis II, what proportion of the gametes would be aneuploid? Draw the outcome (what the cells would look like).
Two of the cells would be normal (n), but the two that result from nondisjunction in meiosis II would be aneuploid ($n+1$ and $n-1$).
5. A karyotype of a developing fetus shows that only one sex chromosome, the “X” chromosome, is present. How would you diagnose this person (i.e., what syndrome does this person have)? What symptoms are expected during this person’s lifetime?
Turner Syndrome. Phenotypically female, but sterile. Most have normal intelligence.
6. A mule is the offspring of a horse and a donkey (two different species). A donkey sperm contains 31 chromosomes, and a horse egg cell 32 chromosomes, so the zygote contains a total of 63 chromosomes. The zygote develops normally, producing the mule. However, a mule is sterile; meiosis cannot occur normally in testes or ovaries. Explain why mitosis is normal in mule cells, but meiosis fails to produce functional gametes in a mule.
Because meiosis involves chromosomes pairing up (homologues finding each other during prophase I), the mule does not have exact pairs of chromosomes (the set from the donkey was somewhat different from the horse set). Therefore, meiosis cannot take place normally. However, during mitosis, all 63 chromosomes simply line up along the metaphase plate and divide, passing all the chromosomes on to future daughter cells.

CHAPTERS 14 & 15: Mendel and the Idea of the Gene

Objectives:

1. Define the following: genetics, monohybrid cross, gene, allele, dominant, recessive, homozygous, heterozygous, Punnett Square, genotype, phenotype, principle of segregation, complete dominance, incomplete dominance, codominance, pleiotropy, polygenic inheritance, autosomes, sex chromosomes, sex-linked genes
Look these up. These are simple definitions that may be found in lecture notes, in your glossary, in the text of the chapters (look up in index), etc.
2. When Gregor Mendel crossed (mated) pea plants that were taken from different strains (e.g., purple vs. white flowers, tall vs. short plants), ALL offspring expressed the same phenotype. When these offspring were allowed to self-fertilize, the phenotype ratios for the offspring always were 3:1. Explain these results. Use the terms homozygous, heterozygous, dominant, recessive, allele, and gamete in your response.

Starting with the parent plants, each was “pure” for the characteristic being tested. Since every organism must have two copies of every gene, when gametes form, the gametes must only get one copy of every gene. Then, when reproduction occurs and a sperm fertilizes an egg, the resulting zygote has two copies of every gene again. In the case of the flower color, one parent only produced gametes with the dominant ‘P’ allele, and the other parent gametes with the recessive ‘p’ allele; each of the parents was homozygous for different alleles. All the offspring ended up with two alleles (two copies of the gene), and all were heterozygous. Since they all had a copy of the dominant allele, all had the same color (purple). Next, the F1 offspring went through meiosis; they produced 50% of their gametes with the ‘P’ allele and 50% with the ‘p’ allele. When they reproduced, the gametes fertilized randomly and therefore produced 1 PP: 2 Pp: 1 pp, which gave 3 purple to 1 white. The allele that is not expressed in the heterozygote is called the “recessive” allele, and the one that is expressed is “dominant”.

- Using a Punnett Square, be able to show and predict the genotype and phenotype ratios of offspring when the parents’ genotypes are given. See example problems below.
- Explain why genetic disorders caused by a dominant allele are much less common than genetic disorders caused by recessive alleles. Give at least two examples each of recessive and dominant disorders.
If a genetic disorder is caused by a dominant allele, then both homozygous dominant individuals AND heterozygous individuals will show the disease. When that happens, a greater proportion of organisms with that allele will die, and the dominant allele will become less common. But if the disease is caused by a recessive allele, then heterozygotes will NOT show the disease (only homozygous recessive individuals), and so the allele can be more common without showing any ill effect. See pgs. 277-279 in your textbook.
- Compare and contrast complete dominance, incomplete dominance, and codominance. Explain how each of these patterns of inheritance results.
Complete: heterozygotes show the phenotype of the dominant allele.
Incomplete: heterozygotes have a phenotype that appears intermediate or blended between the two homozygous phenotypes.
Codominance: Both phenotypes are observed.
See examples from lecture
- Explain how sickle disease serves as an example of pleiotropy.
Pleiotropy occurs when a single gene effects multiple phenotypes. If someone is homozygous for sickle cell disease, then not only is their hemoglobin protein in their red blood cells abnormal, but the blood cells themselves have an abnormal shape, and this leads to all sorts of phenotypic problems with kidneys, spleen, brain, etc.
- Explain how polygenic inheritance accounts for the great variations in human skin color, eye color, and height.
Polygenic inheritance occurs when MULTIPLE genes all affect a single phenotype. These genes could be on the same pair of homologous chromosomes (in which case the genes are said to be “linked”, or they could be on different pairs of chromosomes. In either case, there is a greater range of phenotypes observed because there is a wider range of combinations of alleles that can occur to give the phenotype. For example, your textbook shows what happens with eye color in humans; a great range of eye colors occurs because of the wide range of combinations of dominant and recessive alleles -- the more dominant alleles you inherit from those genes, the more dark pigment your cells produce, and the darker your eyes.

8. Define **linked genes**. Explain how the degree of linkage between genes affects the degree of genetic recombination in offspring.
Genes that are found on the same pair of chromosomes. Obviously, chromosomes can have hundreds to thousands of genes on them, so all the genes that are found on the same chromosome are linked. The closer the genes are to each other on the chromosome, the more likely the genes will be inherited together (crossing over will not separate the alleles of different genes onto different chromosomes).
9. Differentiate between autosomes and sex chromosomes. Define sex linked gene and give some examples. Explain why sex-linked disorders mostly affect males rather than females. Use Punnett Squares to solve genetic problems involving sex-linked genes.
The first 22 pairs of chromosomes in our cells are the autosomes, and they are the same between males and females. The 23rd pair is the sex chromosomes, and not only do they determine our gender in mammals (e.g., humans), but there are many other genes on those chromosomes (especially the "X" chromosome) that have nothing to do with sex / gender! Those are "sex linked genes". Examples include hemophilia and red-green color blindness. Because the "X" usually carries these genes, males have whatever genotype and phenotype that their mother gives them; the father has no influence, since he gave the male a "Y" chromosome. This leads to slightly different ratios of genotypes and phenotypes when compared to the inheritance of autosomes.
10. Describe how environmental factors may produce varying phenotypes. Give at least two examples.
A phenotypic range is called the norm of reaction. Some phenotypes are relatively strictly defined by genotypes (e.g., ABO blood types), but others are more significantly affected by environmental factors such as nutrition, disease, etc.
11. Explain how amniocentesis and chorionic villus sampling may be used to check for genetic disorders. Explain how ultrasound and fetoscopy may be used to check for genetic disorders. Which procedure carries the highest risk? The lowest risk?
See Figure 14.18 in your textbook, and pg. 280

Genetics Problems:

Use Punnett Squares to solve the following genetics problems.

- Tomato stems can be purple (dominant allele) or green (recessive allele). Predict the genotype and phenotype ratios of offspring if you cross a homozygous recessive and a heterozygous individual.
50% all around!!
- Tall pea plants (T) are dominant over dwarf pea plants (t). What would be the phenotype of a heterozygous plant?
Tall
 If two heterozygous plants were crossed and produced a large number of offspring, 30 of which were dwarf, approximately how many should be tall?
90. If you do the Punnett square, 1/4 of the offspring have the recessive phenotype (dwarf) and 3/4 dominant phenotype. So if 30 are dwarf, 3 times that many will be tall.
- The common grackle is a species of robin-sized blackbirds that are fairly common (hence the name) over most of the United States. Suppose that long tails (L) were **dominant** to short tails in these birds. A female short-tailed grackle mates with a male long-tailed grackle who had one parent with a long tail and one parent with a short tail. What is the male's **genotype**? What would be the genotype and phenotype ratios of the F1 offspring?
Male's genotype = Ll, female is ll. 50% of offspring would be Ll and long-tailed, 50% ll and short-tailed.

4. **Incomplete Dominance:** In Snapdragons, the allele for red flowers (R) is incompletely dominant over the allele for white flowers (r), such that the heterozygotes (Rr) are pink. Show the predicted genotype and phenotype ratios of offspring if you cross a pink flowered with a white flowered plant.
50% Rr (pink), and 50% rr (white)
5. **Incomplete Dominance:** Suppose you have rose plants in which flower color is controlled by a single gene that shows incomplete dominance (red = RR, white = rr, pink = Rr). If you only wanted offspring with either red or pink flowers but no white-flowered plants, what genotypes would you choose for the parents? If you crossed these two parents, what would the genotype and phenotype ratios of the offspring be?
Mate an RR with an Rr. All offspring would either be homozygous for RR, and so red, or Rr and pink. 50% RR (red) and 50% Rr (pink)
6. **Incomplete Dominance:** A naturalist visiting an island in the middle of a large lake observes a species of small bird with three distinct types of beaks. Those with short, crushing beaks (BB) consume hard shelled nuts, those with long, delicate beaks (bb) pick the seeds from pine cones, and those with intermediate beaks (Bb), consume both types of seeds though they are not as good at either. Assume that this difference in beak morphology is the result of incomplete dominance in a single locus gene. Predict the genotype and phenotype ratios of offspring if a bird with a beak for hard-shelled nuts mates with a bird that can eat both types of seeds. If during the lifetimes of the F1 birds only pine cone seeds are available, what proportion of the F1 birds will survive?
50% BB (eats hard shelled nuts) and 50% Bb (eats both types). Only Bb will survive, although they would not do as well, overall, as other birds from other matings, that have the bb genotype.
7. **X-Linked Traits:** Red-green color-blindness is inherited as an X-linked recessive trait. If a color-blind woman marries a man with normal vision, what would be the phenotypes and genotypes of their daughters? Their sons?
Daughters: $X^H X^h$ (both), so daughters have normal vision, but are carriers
Sons: $X^h Y$ (both), so both sons are colorblind. Bummer!
8. A rancher owns a bull with many desirable characteristics. Unfortunately, he also has a sex-linked trait that in the recessive form (X^n) leads to no pigment formation in the iris of the eye. This makes the bull very sensitive to sunlight and could lead to blindness. The rancher wishes to breed him to a cow that will minimize the chances of any offspring showing this trait. If the bull is mated with a female that is heterozygous for nonpigmentation, what will be the phenotype ratios of males and females?

If the rancher wanted to eliminate the nonpigmentation trait from the herd, what proportion of the males could be mated to achieve this effect? What proportion of the females?
9. **Complete Dominance:** Cystic fibrosis is inherited as a simple autosomal recessive allele. Suppose a woman who carries the trait marries a normal man who does not carry it. What percent of their children would be expected to have the disease? To be carriers? To be phenotypically normal?
0% have the disease; 50% are carriers, and all are phenotypically normal.
10. **Dihybrid Cross, complete dominance:** About 70% of Americans perceive a bitter taste from the chemical phenylthiocarbamide (PTC). The ability to taste this chemical results from a dominant allele (T) and not being able to taste PTC is the result of having two recessive alleles (t). Albinism is also a single locus trait with normal pigment being dominant (A) and the lack of pigment being recessive (a). A normally pigmented woman who cannot taste PTC has a father who is an albino

taster. She marries a homozygous, normally pigmented man who is a taster but who has a mother that does not taste PTC. Determine the genotype and phenotype ratios of their offspring.

11. **Dihybrid cross, incomplete dominance:** Raccoons have rings around their tails and a habit of washing their food in water before eating it. Suppose that both of these traits are controlled *via* incomplete dominance so that wide bands on the tail are BB, medium sized bands are Bb, and narrow bands are bb and that washing all their food is WW, washing some of their food is Ww, and washing no food is ww. If a raccoon with medium-sized bands who doesn't wash his food mates with a raccoon with narrow bands that washes some of her food, what proportion of their offspring will have narrow bands and not wash their food?
12. **Polygenic Inheritance:** Human eye color is determined by at least 2 genes found on different autosomes (2 pairs of homologues). Blue eyes result from inheritance of four recessive alleles, green from three recessive, hazel from two recessive, dark brown from one recessive, and black from four dominant. Using a Punnett Square, predict the ratio of genotypes and phenotypes if a green-eyed female mates with a hazel-eyed male (heterozygous for both genes).
13. **Sex Chromosomes / Autosomes, Epistasis:** Baldness in humans is a dominant, sex-influenced trait. This gene is on the autosomes, not the sex chromosomes. A man who is BB or Bb will be bald and will be normal only if he is bb. A woman will only be bald if she is BB and normal if she is Bb or bb (it's almost like B is dominant in males and b is dominant in females). If two parents are heterozygous for baldness, what are the chances of their children being bald? Use a Punnett square to illustrate this. Note: because the sex of a person *does* make a difference in how the gene is expressed, you need to set this up as a dihybrid cross to account for the sex of the children.
14. **Epistasis.** In sweet peas, purple flower color (P) is dominant over white (p), but there is also a control gene such that if the plant has a "C", the purple has "permission" to express itself. If the plant is "cc," the purple does not "have permission" to express itself and the flower will be white anyway. If a plant with homozygous purple, controlled flowers is crossed with a plant with white, heterozygous non-controlled flowers, determine the genotype(s) and phenotype(s) of the F1 generation. Then, determine the genotype and phenotype ratios if two heterozygous F1 offspring were to mate.

CHAPTER 16: MOLECULAR BIOLOGY OF THE GENE (DNA Replication)

Chapter 16 will NOT be on your final exam! We did not have time to cover this material.

Objectives:

1. Briefly summarize the contributions of each to our understanding of DNA:
 - (A) Griffith
 - (B) Avery
 - (C) Hershey and Chase
 - (D) Chargaff
 - (E) Rosalind Franklin
 - (F) Watson and Crick
2. Describe how DNA replication makes two identical copies of the double helix. Explain why the process is described as "semi-conservative."
 - (A) Why are the two strands of nucleic acid in DNA referred to as 'antiparallel'?
 - (B) What are "origins of replication"?
 - (C) What does DNA Polymerase do?

- (D) What does helicase do?
- (E) Why are there “leading” and “lagging” strands of daughter DNA? Describe how replication occurs along each of these.
- (F) What does primase do? Why is this enzyme necessary?
- (G) What does topoisomerase do? Single-strand binding protein?
- (H) What does DNA ligase do?
- (I) What does nuclease do, and why?
- (J) What are telomeres, and why does eukaryotic DNA, and not prokaryotic DNA, have them? What is the function of telomerase?

3. Explain the relationship between sister chromatids and the resulting two daughter DNA molecules following DNA replication.

CHAPTER 17: From Gene to Protein

1. Describe how the sequence of nucleotides in DNA indirectly determines the sequence of amino acids in a protein. What two general processes are involved in synthesizing a protein from the corresponding gene found on DNA [Hint: one occurs in the nucleus, the other in the cytoplasm]?

The DNA codes for a mRNA, and the mRNA carries the code to the ribosomes. The mRNA has codons, each of which codes for a specific amino acid in the polypeptide. Transcription makes RNA from DNA in the nucleus, and translation makes a polypeptide at the ribosomes in the cytoplasm.

2. Describe the processes of transcription and translation (what happens in each process?). Identify from the following list the molecules that are important in each process: DNA polymerase, RNA polymerase, ribosomes, DNA, mRNA, tRNA, amino acids, individual DNA nucleotides (A, T, G, C), individual RNA nucleotides (A, U, G, C). Explain what these molecules do (function).

Transcription: RNA polymerase unwinds the DNA double helix. Only the template strand is copied. The RNA nucleotides match the complementary nucleotides of the DNA molecule (C matches G, U in RNA matches A in DNA). After transcription stops, the genetic code from that one gene leaves the nucleus and goes to a ribosome.

Translation: a ribosome attaches to mRNA and moves along until it reaches the start codon (AUG). Then the first tRNA lines up in the P-site of the ribosome; the anticodon of the tRNA matches the codon of the mRNA. The next tRNA fits into the A-site, matching its anticodon to the codon of the mRNA. Next, the amino acid attached to the tRNA in the P-site moves over and bonds to the amino acid in the A-site. Then the ribosome moves down the mRNA by 1 codon, and the process repeats until a stop codon (UAG, UGA, or UAA) fits into the A-site. When it does, the ribosome detaches from the mRNA and the polypeptide is released to go to its next destination (e.g., inside RER).

3. Contrast template and coding strands of DNA; which is transcribed? Which contains the actual gene?

The coding strand has the genetic code -- in the form of A, G, C, T -- for making a polypeptide. The template strand matches the coding strand (for every A in the coding strand there would be a T in the template, for every G in coding, a C in template, etc.). The template strand is ‘copied’ by RNA polymerase to make a messenger RNA. By copying the template strand, the mRNA has the same nitrogenous base sequence as the coding strand, except RNA has ‘U’ instead of ‘T’.

So . . . in simpler form . . . by copying the template strand of DNA, the mRNA has the same sequence as the coding strand of DNA (except RNA has ‘U’ instead of ‘T’)..

4. Where in the cell do the processes of transcription and translation take place?

Already answered!

5. List and describe the steps in transcription. Include the role of the promoter, transcription unit, RNA polymerase, exons, and introns.

6. Distinguish between the functions of mRNA, tRNA, and rRNA. Also, *how* are they synthesized? *Where* are they synthesized?

All are synthesized in the nucleus by the process of transcription. mRNA carries the genetic code for making a polypeptide. The tRNA connects to a specific amino acid in the cytosol and takes it to the ribosome where the anticodon of the tRNA matches a codon on the mRNA. The rRNA combines with proteins to make ribosomes. The rRNA acts as a catalyst for translation.

7. Describe the structure of the ribosome and its function(s) during translation. What is the function of the “P-site”? The “A-site”?

Covered above. Ribosomes have a large and small subunit, both made in the nucleus.

8. Define each of the following: codon, anticodon, translocation, A-site, P-site, and peptide bond. How many different codons are possible? How many different amino acids are there? Do some amino acids have more than one codon? Give a couple examples.

Codon: 3-base sequence on mRNA, starting with the ‘start codon’ AUG, that codes for a specific amino acid.

Anticodon: found on tRNA, matches a specific codon on mRNA.

A-site: where new tRNA enters a ribosome

P-site: where a translocated tRNA fits after leaving the A-site. tRNA in the P-site holds onto the growing polypeptide until it is transferred to the tRNA in the A-site.

Peptide bond: type of covalent bond that forms between two amino acids to make a polypeptide.

There are 64 codons and 20 amino acids. Usually more than 1 codon codes for the same amino acid.

9. Draw and list the sequence of events that are necessary to (a) Initiate translation, (b) Elongate a polypeptide, and (c) Terminate translation.

10. Define “mutation”. Describe how a mutation in the DNA can affect the shape and ultimately the function of a protein. Differentiate among insertions, deletions, silent mutations, missense mutations, and nonsense mutations. Which of these are considered “frameshift” mutations? Which “type” of mutation would usually cause the most serious and detrimental effects? Why?

Additional Problems:

1. Draw a piece of DNA (gene) and label the template and nontemplate strands. Draw an enlarged portion of the gene, with the 2 DNA strands separated, and draw RNA polymerase and a growing RNA molecule.

2. Draw a series of pictures showing:

(A) steps of Initiation during translation

(B) steps of Elongation during translation

(C) steps of Termination during translation

See notes from lab. I listed 8 steps to translation. Initiation includes the attachment of the small ribosomal subunit to the 5' end of mRNA, moving to the first AUG (start codon), first tRNA matching

up to AUG, and large subunit attaching to complete the ribosome. Elongation involves the ribosome moving 'down' the mRNA so that new amino acids can be delivered to the A-site, where the existing polypeptide chain in the P-site bonds to the new amino acid. When the ribosome reaches a stop codon in the A-site, a releasing factor protein causes the complex to dissociate, releasing the polypeptide for any processing and development into a protein.

3. Shown below is double stranded DNA. The template and coding strands are indicated. Show the mRNA that would be transcribed from this DNA. Show the polypeptide that would be translated from this mRNA.

(template strand)
C C G T A C G G G A T A T C G A T G C G T A T T T C
G G C A T G C C C T A T A G C T A C G C A T A A A G
(coding strand)

GGCAUGCCCUAUAGCUACGCAUAAAG

Met-pro-tyr-ser-tyr-ala

4. There are several ways that genetic information can be changed or mutated. Bases can be added, deleted, or changed.
- (A) How will the sequence of amino acids change if an additional nucleotide, A, is inserted between the sixth and seventh nucleotide in the DNA sequence shown in problem 4? *The codons will be shifted because of the insertion, and different amino acids will be used beyond that point.*
- (B) How will the amino acid sequence change if the second "C" in the original template sequence is changed to an "A"? *Not at all, since that change occurs before the start codon.*
5. Mutations that have no effect on amino acid sequence are sometimes referred to as "silent mutations." Give some examples of single base substitutions that would be silent mutations. How might the redundancy of the genetic code (see Figure 17.5) provide a possible benefit to organisms? *If a DNA template originally has the sequence CAG, then the mRNA codon would be GUC, coding for valine. If a mutation happened in the template strand such that the "G" was substituted with a "C", the resulting mRNA codon would be GUG, which would still code for valine. Because of this redundancy, some mutations have no effect on polypeptide sequence. Since most changes to polypeptide sequences are detrimental (have a negative effect on how a protein functions), such redundancy would protect organisms, to some degree, from mutations that negatively effect protein structure and function.*