GENETICS REVIEW

A. Top "10" — If you learned anything from this unit, you should have learned:

1. Different versions of same gene are called alleles
    a. dominant vs. recessive
    b. homozygous vs. heterozygous
    c. phenotype vs. genotype

2. Mendelian inheritance
    a. monohybrid crosses
        • Aa x Aa = 3:1 ratio
        • Law of Segregation
    b. dihybrid crosses
        • AaBb x AaBb = 9:3:3:1 ratio
        • Law of Independent Assortment
    c. test cross
        • determine genotype of individual showing dominant phenotype
        • unknown (A_) x aa (homozygous recessive)

3. Non-Mendelian inheritance
    a. incomplete dominance (pink flower color), co-dominance (blood type), sex linked (mainly X-linked: color blindness, hemophilia)

4. Chi-square analysis
    a. determining if observed results are significantly different from expected results
    b. know how to use formula when given & how to interpret results
        • degrees freedom (1 less than number of classes of results)
        • less than p=.05, then difference can be due to random chance alone & null hypothesis is accepted

5. Prokaryotic Inheritance
    a. Conjugation
    b. Plasmids

6. DNA & RNA
    a. DNA: ACTG nitrogen bases, double helix
        • A : T, C : G
    b. RNA: ACUG nitrogen bases, single helix

7. Central Dogma
    a. DNA → RNA →protein →trait
    b. transcription (DNA →mRNA)
        • in nucleus
        • RNA polymerase copies coding strand & produces mRNA
    c. translation (mRNA →protein)
        • in cytoplasm
        • codons on mRNA read by ribosome
        • matched to anticodons of tRNA
        • tRNA carries amino acids to mRNA & ribosome assembles polypeptide chain
        • start codon (Met) & stop codons, redundancy in code
        • universal code (single common ancestor)

8. Regulation of genes
    a. operons
        • prokaryotes
        • cluster of genes for enzymes in a pathway
        • controlled by repressor protein
        • repressible operon (synthesis pathway = tryp operon) vs. inducible operon (digestive pathway = lac operon)

9. Mutations
    a. fuel for evolution = variation, genetic change
    b. gene duplication, point mutation, insertions, deletion, nonsense, missence, frameshift

10. Biotechnology
    a. Scientists can modify an organism's genome by inserting foreign DNA

- bacterial transformation (human insulin gene in E. coli)
- possible because of universal genetic code

b. Techniques
- restriction digest: restriction enzymes, sticky ends
- transformation: restriction enzymes, sticky ends, ligase, amp selection
- gel electrophoresis: DNA moves in an electrical field (negative →positive), small pieces move further
- PCR: DNA amplification

B. Sample Multiple Choice Questions

1. *A* represents the dominant allele and *a* represents the recessive allele of a pair. If, in 1000 offspring, 500 are *aa* and 500 are of some other genotype, which of the following are most probably the genotypes of the parents?

a. Aa and Aa
b. Aa and aa
c. AA and Aa
d. AA and aa
e. aa and aa

2. *A* form of vitamin D-resistant rickets, known as hypophosphatemia, is inherited as an X-linked dominant trait. If a male with hypophosphatemia marries a normal female, which of the following predictions concerning their potential progeny would be true?

a. All of their sons would inherit the disease
b. All of their daughters would inherit the disease
c. About 50% of their sons would inherit the disease
d. About 50% of their daughters would inherit the disease
e. None of their daughters would inherit the disease

3. Which of the following best describes the parents in a testcross?

a. One individual has the dominant phenotype and the other has the recessive phenotype.
b. Both individuals are heterozygous.
c. Both individuals have the dominant phenotype.
d. Both individuals have the recessive phenotype.
e. Both individuals have an unknown phenotype.

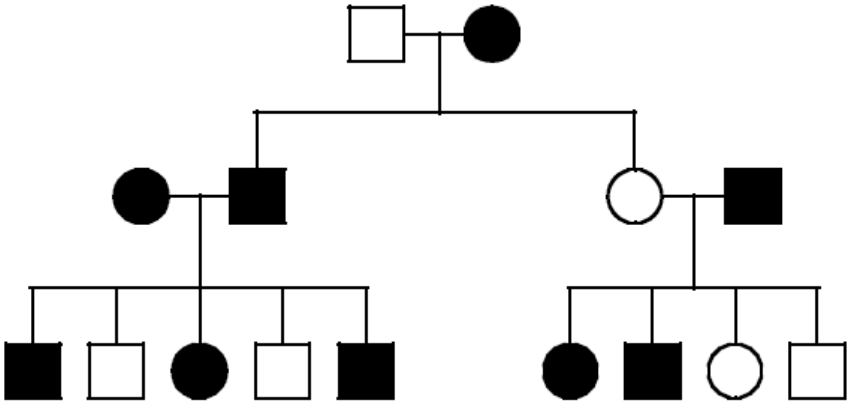
4. Which of the following is the most likely explanation for a high rate of crossing-over between two genes?

a. The two genes are far apart on the same chromosome.
b. The two genes are both located near the centromere.
c. The two genes are sex-linked.
d. The two genes code for the same protein.
e. The two genes are on different chromosomes.

5. DNA replication can be described as

a. semiconservative
b. conservative
c. degenerative
d. dispersive
e. radical

6. In the pedigree below, squares represent males and circles represent females. Individuals who express a particular trait are represented by shaded figures. Which of the following patterns of inheritance best explains the transmission of the trait?



a. Sex-linked dominant b. Sex-linked recessive c. Autosomal recessive d. Autosomal dominant e. Incompletely dominant

A male fruit fly (*Drosophila melanogaster*) with red eyes and long wings was mated with a female with purple eyes and vestigial wings. All of the offspring in the F1 generation had red eyes and long wings.
These F1 flies were test crossed with purple-eyed, vestigial-winged flies. Their offspring, the F2 generation, appeared as indicated below.

F2 Generation
125 red eyes, long wings
124 purple eyes, vestigial wings
18 purple eyes, long wings
16 red eyes, vestigial wings
283 Total

7. If in the F1 and F2 generations the same characteristics appeared in both male and females, it would be safe to assume that these traits for eye color and wing length...
   a. are sex-linked
   b. vary in dominance according to sex
   c. are sex-influenced characteristics
   d. are autosomal characteristics
   e. follow the Mendelian rule of independent assortment

8. In the F2 generation, the results are best explained by the fact that...
   a. the test cross with the F1 flies resulted in sterile offspring
   b. these genes for eye color and wing shape do not pass through the F1 generation
   c. these genes for eye color and wing shape are found on the same chromosome
   d. crossing over decreases variability
   e. the genes are sex-linked

9. If a single locus controls wing shape, then the alleles for this gene act as...
   a. dominant-recessive alleles
   b. incomplete-dominance alleles
   c. codominant alleles
   d. multiple alleles
   e. variable alleles

10. What would be the sequence of bases of an mRNA molecule that was transcribed from the sequence of DNA bases shown below?

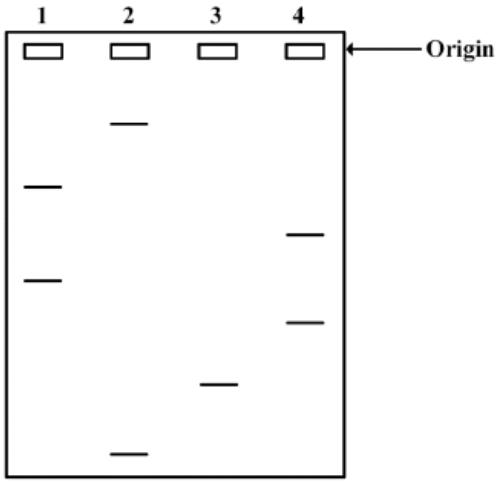
GTAGTAGGT

   a. GTAGTAGGT
   b. CAUCAUCCA
   c. UCGUCGUUC
   d. AUGAUGAAU
   e. CATCATCCA

11. Some strains of the bacterium *Streptococcus pyogenes* secrete poisonous substances called exotoxins. The gene encoding the exotoxins are thought to have originated in bacteriophages, which are viruses that infect bacteria.

Which of the following is the most likely mechanism by which the *S. pyogenes* acquired the ability to produce exotoxins?
   a. Bacteriophages engulfed cellular debris from dead bacteria.
   b. Bacteriophages in the environment activated bacterial cell division.
   c. Bacteriophage DNA became integrated in the bacterial chromosome.
   d. bacteriophage proteins were absorbed into bacterial cells by endocytosis.

Questions 12-14 refer to an experiment that was performed to separate DNA fragments from four samples radioactively labeled with 32P. The fragments were separated by gel electrophoresis. The visualized bands are illustrated in the figure below.



Gel Electrophoresis of DNA Fragments

12. The electrophoretic separation of the pieces of DNA in each of the four samples was achieved because of differential migration of the DNA fragments in an electric field. This differential migration was caused by the

a. relative amounts of radioactivity in the DNA
b. number of cleavage points per fragment
c. size of each fragment
d. overall positive charge of each fragment
e. solubility of each fragment

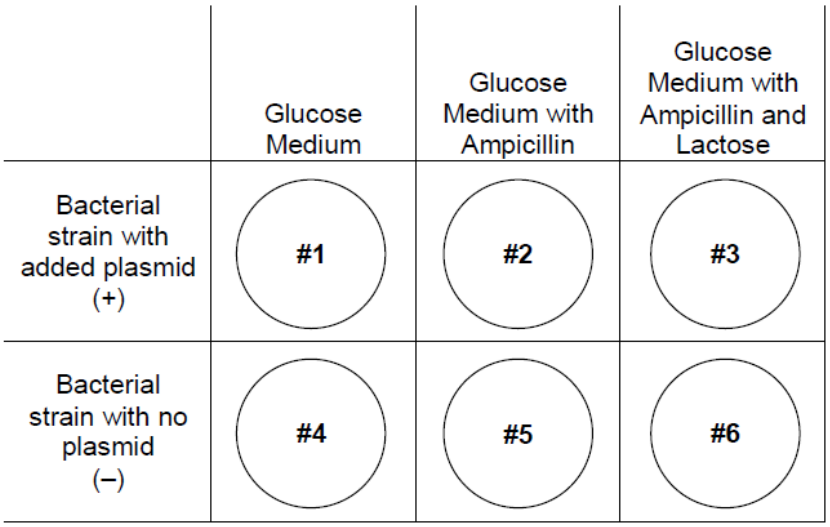
13. The DNA was labeled with 32P in order to

a. stimulate DNA replication
b. inhibit the uptake of unlabeled ATP
c. show which fragments included the 5' end and which fragments included the 3' end
d. visualize the fragments
e. speed up the rate of separation by electrophoresis

14. Which of the following is an additional use of the gel electrophoresis technique?

a. To express a gene
b. To separate proteins in a mixture
c. To ligate DNA fragments
d. To transform E. coli
e. To amplify genes

Questions 15-17 . A scientist is using an ampicillin-sensitive strain of bacteria that cannot use lactose because it has a nonfunctional gene in the *lac* operon. She has two plasmids. One contains a functional copy of the affected gene of the *lac* operon, and the other contains the gene for ampicillin resistance. Using restriction enzymes and DNA ligase, she forms a recombinant plasmid containing both genes. She then adds a high concentration of the plasmid to a tube of the bacteria in a medium for bacterial growth that contains glucose as the only energy source. This tube (+) and a control tube (-) with similar bacteria but no plasmid are both incubated under the appropriate conditions for growth and plasmid uptake. The scientist then spreads a sample of each bacterial culture (+ and -) on each of the three types of plates indicated below.



15. If no new mutations occur, it would be most reasonable to expect bacterial growth on which of the following plates?
    a. 1 and 2 only
    b. 3 and 4 only
    c. 5 and 6 only
    d. 4, 5, and 6 only
    e. 1, 2, 3, and 4 only

16. The scientist used restriction enzymes for what purpose in the experiment?
    a. To make the plasmid small enough to transform cells
    b. To make cuts in the plasmid DNA
    c. To make the plasmid enter the cells
    d. To enable the fragments of DNA to form covalent bonds
    e. To enable the plasmid to recognize the bacterial cells

17. If the scientist had forgotten to use DNA ligase during the preparation of the recombinant plasmid, bacterial growth would most likely have occurred on which of the following?
    a. 1 and 2 only
    b. 1 and 4 only
    c. 4 and 5 only
    d. 1, 2, and 3 only
    e. 4, 5, and 6 only

C. Sample Free Response Questions

1. Meiosis reduces chromosome number and rearranges genetic information.
    a. Explain how the reduction and rearrangement are accomplished in meiosis .
    b. Several human disorders occur as a result of defects in the meiotic process. Identify ONE such chromosomal abnormality; what effects does it have on the phenotype of people with that disorder? Describe how this abnormality could result from a defect in meiosis.

2. The human genome illustrates both continuity and change.
    a. Describe the essential features of two of the procedures/techniques below. For each of the procedures/techniques you describe, explain how its application contributes to understanding genetics.
        • the use of a bacterial plasmid to clone and sequence a human gene
        • polymerase chain reaction (PCR)
    b. All humans are nearly identical genetically in coding sequences and have many proteins that are identical in structure and function. Nevertheless, each human has a unique DNA fingerprint. Explain this apparent contradiction.

3. In fruit flies, the phenotype for eye color is determined by a certain locus. ***E*** indicates the dominant allele and ***e*** indicates the recessive allele. The cross between a male wild-type fruit fly and a female white-eyed fruit fly produced the following offspring.

	wild-type male	wild-type female	white-eyed male	white-eyed female	brown-eyed female
F1	0	45	55	0	1

The wild-type and white-eyed individuals from the F1 generation were then crossed to produce the following offspring.

F2	23	31	22	24	0

a. **Determine** the genotypes of the original parents (P generation) and **explain** your reasoning. You may use Punnett squares to enhance your description, but the results from the Punnett squares must be discussed in your answer.

b. Use a Chi-squared test on the F2 generation data to analyze your prediction of the parental genotypes. **Show** all your work and **explain** the importance of your final answer.

c. The brown-eyed female in the F1 generation resulted from a mutational change. **Explain** what a mutation is, and **discuss** two types of mutations that might have produced the brown-eyed female in the F1 generation.

Probability (p)	Degrees of Freedom (df)				
	1	2	3	4	5
.05	3.84	5.99	7.82	9.49	11.1

The formula for Chi-squared is:

$$X^2 = \sum \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

$\sum$ = the **sum of the values** (in this case, the differences, squared, divided by the number of expected)

Essential Text Content
Chapter 7: The Cell Cycle and Cell Division
Concept 7.1 Different Life Cycles Use Different Modes of Cell Reproduction
- Sexual reproduction by meiosis results in genetic diversity
- Sexual life cycles are diverse

Concept 7.2 Both Binary Fission and Mitosis Produce Genetically Identical Cells
- Eukaryotic cells divide by mitosis followed by cytokinesis
- Chromosomes separation and movement are highly organized

Concept 7.3 Cell Reproduction is Under Precise Control
- Cell division is regulated internally

Concept 7.4 Meiosis halves the Nuclear Chromosome Content and Generates Diversity
- Meitotic division reduces the chromosome number
- Crossing over and independent assortment generate diversity
- Meitotic errors lead to abnormal chromosome structures and number

Concept 7.5 Programmed Cell Death is a Necessary Process in Living Organisms

Chapter 8: Inheritance, Gene and Chromosomes
Concept 8.1 Genes are Particulate and Inherited According to Mendel's Laws
- Mendel used the scientific method to test his hypothesis
- Mendel's first experiments involved monohybrid crosses
- Mendel's first law states that the two copies of a gene segregate
- Mendel verified his hypothesis by performing test crosses
- Mendel's second law states that copies of different genes assort independently

- Probability is used to predict inheritance
- Mendel's laws can be observed in human pedigrees

Concept 8.2 Alleles and Genes Interact to Produce Phenotypes

- New alleles arise by mutation
- Dominance is not always complete
- Genes interact when they are expressed
- The environment affects gene action

Concept 8.3 Genes are Carried on Chromosomes

- Genes on the same chromosome are linked, but can be separated by crossing over
- Linkage is also revealed by studies of the X and Y chromosome
- Some genes are carried in chromosomes in organelles

Concept 8.4 Prokaryotes Can Exchange Genetic Material

- Bacteria exchange genes by conjugation
- Plasmids transfer genes between bacteria
- The evolution of drug-resistant bacteria is a major public health problem

Chapter 9: DNA and Its role in Heredity

Concept 9.1: DNA structure Reflects Its Role as the Genetic Material

- Circumstantial evidence suggested that DNA is the genetic material
- Experimental evidence confirmed that DNA is the genetic material
- Four key features define DNA structure
- The double-helical structure of DNA is essential to its function

Concept 9.2: DNA Replicates Semi conservatively

- Telomeres are not fully replicated in most eukaryotic cells
- Errors in DNA replication can be repaired
- The basic mechanism of DNA replication can be used to amplify DNA in a test tube

Concept 9.3: Mutations are Heritable changes in DNA

- Mutations can have various phenotypic effects
- Point mutations ae changes in a single nucleotide
- Chromosomal mutations are extensive changes in the genetic material
- Mutations have both benefits and costs
- We attempt to minimize our exposure to mutagens

Chapter 10: From DNA to Protein: Gene Expression

Concept 10.1 Genetics Shows the Genes Code for Proteins

- The concept of the gene has changed over time
- Genes are expressed via transcription and translation

Concept 10.2 DNA expression Begins with Its Transcription to RNA

- RNA polymerases share common features
- Transcription occurs in three steps
- Eukaryotic gene transcripts are processed by translation

Concept 10.3 The genetic Code in RNA is Translated into the Amino Acid Sequences of Proteins

- The information for protein synthesis lies in the genetic code
- Point mutations confirm the genetic code

Concept 10.4 Translation of the Genetic Code is Mediated by tRNAs and Ribosomes

- Transfer RNAs carry specific amino acids and bind to specific codons
- Translation occurs at the ribosome
- Translation takes place in three steps
- Polysome formation increases the rate of protein synthesis

Concept 10.5 Proteins are modified after Translation

- Many proteins are modified after translation

Chapter 11 Regulation of Gene Expression

Concept 11.1 Many prokaryotic Genes are Regulated in Operons

- Genes are subject to positive and negative regulation
- Regulating gene transcription is a system that conserves energy
- Operons are units of transcriptional regulation in prokaryotes
- Operator-repressor interactions regulate transcription in the *lac* and *trp* operons

Chapter 13: Biotechnology

Concept 13.2 DNA can Genetically Transform Cells and Organisms

- Genes can be inserted into prokaryotic or eukaryotic cells