

**REVIEW 4: HEREDITY & MOLECULAR GENETICS UNIT****A. Top “10” — If you learned anything from this unit, you should have learned:**

1. Meiosis produces haploid gametes
  - a. Meiosis 1 separates homologous pairs: reduction division
    - crossing over in Prophase 1
  - b. Meiosis 2 separates sister chromatids: produces 4 sex cells
2. Different versions of same gene are called alleles
  - a. dominant vs. recessive
  - b. homozygous vs. heterozygous
  - c. phenotype vs. genotype
3. Mendelian inheritance
  - a. monohybrid crosses
    - $Aa \times Aa = 3:1$  ratio
    - Law of Segregation
  - b. dihybrid crosses
    - $AaBb \times AaBb = 9:3:3:1$  ratio
    - Law of Independent Assortment
  - c. test cross
    - determine genotype of individual showing dominant phenotype
    - unknown ( $A\_$ )  $\times$   $aa$  (homozygous recessive)
4. Non-Mendelian inheritance
  - a. incomplete dominance (pink flower color), co-dominance (blood type), sex linked (mainly X-linked: color blindness, hemophilia), epistasis (coat color), pleiotropy (dwarfism, giantism), polygenic (skin color)
5. 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
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)
- b. transcription factors
  - proteins which enable bonding of RNA polymerase to gene

## 9. Mutations

- a. fuel for evolution = variation, genetic change
- b. gene duplication, point mutation, insertions, deletion

## 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, lacZ screening
  - gel electrophoresis: DNA moves in an electrical field (negative → positive), small pieces move further
  - PCR: DNA amplification

- RFLP: DNA fingerprinting
- Sanger sequencing: Human Genome Project

**B. Labs**

## 1. Genetics of Organisms (Fly Lab)

Be sure to review the procedures and the conclusions, and understand:

- a. How to determine genotype of individuals through crosses
- b. How to calculate Chi square values

## 2. Bacterial Transformation &amp; Restriction Analysis

Be sure to review the procedures and the conclusions, and understand:

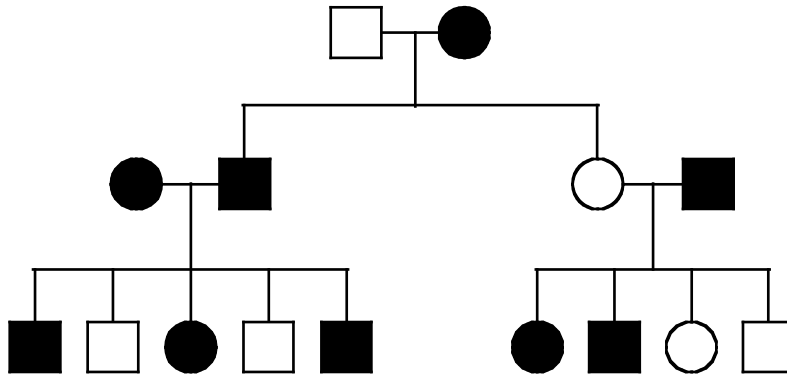
- a. How to set up a similar experiment
- b. How to interpret transformation results on LB vs. LB+amp plates
- c. How to interpret gel electrophoresis results in restriction analysis
- d. Controls vs. Experimental

**C. 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? (1990:4)
  - 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? (1990:44)
  - 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? (1999:9)
- One individual has the dominant phenotype and the other has the recessive phenotype.
  - Both individuals are heterozygous.
  - Both individuals have the dominant phenotype.
  - Both individuals have the recessive phenotype.
  - Both individuals have an unknown phenotype.
4. In peas the trait for tall plants is dominant ( $T$ ) and the trait for short plants is recessive ( $t$ ). The trait for yellow seed color is dominant ( $Y$ ) and the trait for green seed color is recessive ( $y$ ). A cross between two plants results in 296 tall yellow plants and 104 tall green plants. Which of the following are most likely to be the genotypes of the parents? (1999:28)
- $TTYy \times TTYy$
  - $Ttyy \times TTYy$
  - $TtYy \times TtYy$
  - $TtYy \times TTYy$
  - $TtYY \times Ttyy$
5. In humans, red-green color blindness is a sex-linked recessive trait. If a man and a woman produce a color-blind son, which of the following must be true? (1999:43)
- The father is color-blind.
  - Both parents carry the allele for color blindness.
  - Neither parent carries the allele for color blindness.
  - The father carries the allele for color blindness.
  - The mother carries the allele for color blindness.
6. Which of the following is the most likely explanation for a high rate of crossing-over between two genes? (1999:51)
- The two genes are far apart on the same chromosome.
  - The two genes are both located near the centromere.
  - The two genes are sex-linked.
  - The two genes code for the same protein.
  - The two genes are on different chromosomes.

7. 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? (1999:56)



- Sex-linked dominant
  - Sex-linked recessive
  - Autosomal recessive
  - Autosomal dominant
  - Incompletely dominant
- These two questions refer to the birth of a child with blood type A to a mother with blood type B. (1999:102-103)
- The father must have which of the following blood types?
    - AB only
    - Either AB or B
    - Either AB or O
    - Either AB or A
    - AB or A or O
  - If the father has blood type AB, which of the following statements is correct about the mother?
    - She contributes an  $I^B$  allele, which is recessive to the father's  $I^A$  allele.
    - She contributes an  $i$  allele, which is recessive to the father's  $I^A$  allele.
    - She contributes an  $I^B$  allele, which is codominant to the father's  $I^A$  allele.
    - She contributes an  $i$  allele, which is codominant to the father's  $I^B$  allele.
    - She is homozygous for the  $I^B$  allele.

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 F<sub>1</sub> generation had red eyes and long wings. (1994:106-108)

These F<sub>1</sub> flies were test crossed with purple-eyed, vestigial-winged flies. Their offspring, the F<sub>2</sub> generation, appeared as indicated below.

F <sub>2</sub> Generation	
125	red eyes, long wings
124	purple eyes, vestigial wings
18	purple eyes, long wings
16	red eyes, vestigial wings
283	Total

10. If in the F<sub>1</sub> and F<sub>2</sub> 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...
- are sex-linked
  - vary in dominance according to sex
  - are sex-influenced characteristics
  - are autosomal characteristics
  - follow the Mendelian rule of independent assortment
11. In the F<sub>2</sub> generation, the results are best explained by the fact that...
- the test cross with the F<sub>1</sub> flies resulted in sterile offspring
  - these genes for eye color and wing shape do not pass through the F<sub>1</sub> generation
  - these genes for eye color and wing shape are found on the same chromosome
  - crossing over decreases variability
  - the genes are sex-linked
12. If a single locus controls wing shape, then the alleles for this gene act as...
- dominant-recessive alleles
  - incomplete-dominance alleles
  - codominant alleles
  - multiple alleles
  - variable alleles

13. DNA replication can be described as (1990:70)

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

14. What would be the sequence of bases of an mRNA molecule that was transcribed from the sequence of DNA bases shown below? (1990:40)

GTAGTAGGT

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

**Questions 15–19:** Refer to the following list to answer the following questions. The answers may be used once, more than once, or not at all. (1999:92-95)

- a. transcription
- b. translation
- c. transformation
- d. replication
- e. reverse transcription

15. Process in which a protein is assembled at a ribosome.

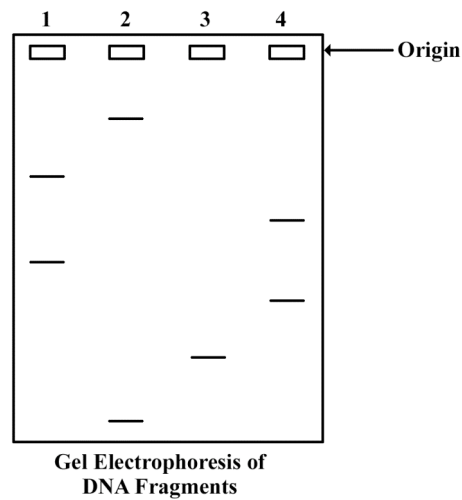
16. Process in which naked DNA is taken up by a bacterial or yeast cell

17. Process in which RNA is produced by using a DNA template.

18. Process that results in the production of cDNA from an RNA molecule

19. Process in which DNA is produced by using a DNA template.

**Questions 20–22** refer to an experiment that was performed to separate DNA fragments from four samples radioactively labeled with  $^{32}\text{P}$ . The fragments were separated by gel electrophoresis. The visualized bands are illustrated in the figure below.



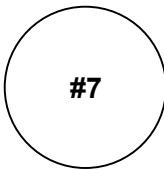
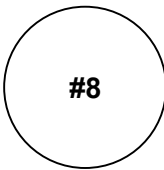
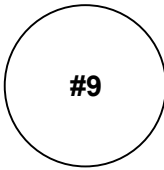
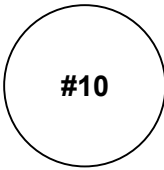
20. The electrophoretic separation of the pieces of DNA in each of the four samples was achieved because of differential migration of the DNA fragments in an electric field. This differential migration was caused by the
- relative amounts of radioactivity in the DNA
  - number of cleavage points per fragment
  - size of each fragment
  - overall positive charge of each fragment
  - solubility of each fragment
21. The DNA was labeled with  $^{32}\text{P}$  in order to
- stimulate DNA replication
  - inhibit the uptake of unlabeled ATP
  - show which fragments included the 5' end and which fragments included the 3' end
  - visualize the fragments
  - speed up the rate of separation by electrophoresis
22. Which of the following is an additional use of the gel electrophoresis technique?
- To express a gene
  - To separate proteins in a mixture
  - To ligate DNA fragments
  - To transform *E. coli*
  - To amplify genes

**Questions 21–25.** 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.

	Glucose Medium	Glucose Medium with Ampicillin	Glucose Medium with Ampicillin and Lactose
Bacterial strain with added plasmid (+)	#1	#2	#3
Bacterial strain with no plasmid (-)	#4	#5	#6

23. If no new mutations occur, it would be most reasonable to expect bacterial growth on which of the following plates?
- 1 and 2 only
  - 3 and 4 only
  - 5 and 6 only
  - 4, 5, and 6 only
  - 1, 2, 3, and 4 only
24. The scientist used restriction enzymes for what purpose in the experiment?
- To make the plasmid small enough to transform cells
  - To make cuts in the plasmid DNA
  - To make the plasmid enter the cells
  - To enable the fragments of DNA to form covalent bonds
  - To enable the plasmid to recognize the bacterial cells

25. 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?
- 1 and 2 only
  - 1 and 4 only
  - 4 and 5 only
  - 1, 2, and 3 only
  - 4, 5, and 6 only

	Lactose Medium	Lactose Medium with Ampicillin
Bacterial strain with added plasmid (+)	 #7	 #8
Bacterial strain with no plasmid (-)	 #9	 #10

26. If the scientist used the cultures to perform another experiment as shown above, using medium that contained lactose as the only energy source, growth would most likely occur on which of the following plates?
- 10 only
  - 7 and 8 only
  - 7 and 9 only
  - 8 and 10 only
  - 9 and 10 only

**D. Sample Free Response Questions**

1. 2005:2

The unit of genetic organization in all living organisms is the chromosome.

- a. Describe the structure and function of the parts of a eukaryotic chromosome. You may wish to include a diagram as part of your description.
- b. Describe the adaptive (evolutionary) significance of organizing genes into chromosomes.
- c. How does the function and structure of the chromosome differ in prokaryotes?

2. 2004:1

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.
- c. Production of offspring by parthenogenesis or cloning bypasses the typical meiotic process. Describe either parthenogenesis or cloning and compare the genomes of the offspring with those of the parents.

## 3. 2003B:1

A difference between prokaryotes and eukaryotes is seen in the organization of their genetic material

- a. Discuss the organization of the genetic material in prokaryotes and eukaryotes.
- b. Contrast the following activities in prokaryotes and eukaryotes:
  - replication of DNA
  - transcription
  - gene regulation
  - cell division

## 4. 2002:1

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)
  - restriction fragment length polymorphism (RFLP) analysis
- 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.

5. 2003:1

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
<b>F1</b>	0	45	55	0	1

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

<b>F2</b>	23	31	22	24	0
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- 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.
- 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.
- 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:

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

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