INSTRUCTIONS:

1. Read the questions carefully and write your answers in the space provided. If you need more space, clearly indicate WHERE the rest of the answer is located (for example, on the back of the same page). If there is something that you do not wish me to count, (for example, if you make an error) please cross it out.

2. Read each question carefully before starting to answer it so you don’t overlook any additional instructions. If you get stuck on a question, go on to another question and return to the original question later. It is a good strategy to read over the entire exam and then select the questions you feel most confident about to answer first.

3. In your answers to problems that require you to calculate a numerical answer, you must show how you set up your calculation to receive full credit for your final numerical solution.

4. A blank sheet of paper has been provided for you at the end of the exam which you may use as scratch paper.

GOOD LUCK!

Question #1: ___________________ (20 pts.)

Question #2: ___________________ (12 pts.)

Question #3: ___________________ (16 pts.)

Question #4: ___________________ (13 pts.)

Question #5: ___________________ (13 pts.)

Question #6: ___________________ (12 pts.)

Question #7: ___________________ (14 pts.)

Bonus: _________________________ (5 pts.)

TOTAL: _________________________ (100 pts.)
1. For each of the following, choose the one alternative that best completes the statement or answers the question (2 pts. each, 20 pts total).

_____ Which of the following is true about a sex-limited trait?
A.) Both sexes may have the genotype associated with the trait, but only one of the sexes shows the phenotype
B.) The trait will be dominant in one sex, recessive in the other
C.) Males will be hemizygous for the trait, since they only have one X chromosome.
D.) None of the above
E.) More than one above statements is true for a sex-limited trait.

_____ From a certain cross, you obtained a phenotypic ratio of 12: 3: 1. What does this tell you?
A.) There are 2 genes involved and they are on the same chromosome.
B.) There are 2 genes involved and they are on different chromosomes.
C.) There is 1 gene involved and the alleles of that gene show epistasis.
D.) There is 1 gene involved and there is more than two alleles for that gene.
E.) You made a mistake in performing your cross.

_____ Whether or not an individual shows the effects of a certain gene can depend on their:
A.) age
B.) diet
C.) gender
D.) All of the above
E.) None of the above: if an individual has a gene, they will show the effects.

_____ If two genes are not linked, then the expected phenotypic ratio resulting from a testcross is:
A.) 9:3:3:1
B.) 1:2:1
C.) 1:1:1:1
D.) 9:3:4
E.) 3:1

_____ A double heterozygote (AaBb) has its alleles arranged in repulsion. Which of the following gametes it produces would be a recombinant?
A.) AA
B.) AB
C.) bb
D.) Ab
E.) aB

_____ What does the coefficient of coincidence tell you?
A.) If crossing over in one region of the chromosome interferes with crossing over in another nearby region of the chromosome
B.) If two genes show epistasis.
C.) If two genes assort independently of each other.
D.) If two genes are on the same chromosome.
E.) None of the above.
In E. coli, DNA replication is
A.) unidirectional and dispersive
B.) bidirectional and semiconservative
C.) continuous and semiconservative
D.) bidirectional and conservative
E.) semidiscontinuous and dispersive

Which of the following statements does not apply to the Watson and Crick model of DNA structure?
A.) the two strands of the DNA are arranged in opposite orientation from one another
B.) the distance between the strands of the helix is uniform
C.) nucleotides within one strand can be arranged in any order
D.) the two strands of the helix are held together by covalent bonds
E.) the purines form hydrogen bonds with pyrimidines

The enzyme telomerase does which of the following?
A.) binds to the end of a replicating DNA molecule to allow DNA polymerase to add nucleotides to the 5' end of the daughter strand
B.) takes over for DNA polymerase to finish replicating the ends of a new DNA strand
C.) prevents DNA from replicating, therefore helping to prevent cancer
D.) helps fold DNA back into its proper shape in chromosomes after DNA replication is completed
E.) adds nucleotides to the end of chromosomes and therefore prevents the loss of important genetic material

In Siamese cats, fur color is dependent on the temperature of the hair follicles during the growth of the fur. What explains this?
A.) fur color is only dependent on environment, and there is no genetic component
B.) the gene that codes for hair protein is damaged by higher temperatures
C.) the proteins produced by the genes of the cat are sensitive to temperature
D.) higher temperatures prevent the genes for fur color from producing protein
E.) higher temperatures prevent the pigmentation from being deposited in the fur
2. Certain breeds of goats have beards, while others are beardless. You would like to learn more about the pattern of inheritance of this trait. You set up the following reciprocal crosses between true breeding bearded and beardless goats (12 pts. total).

<table>
<thead>
<tr>
<th></th>
<th>CROSS #1</th>
<th>CROSS #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P:</strong></td>
<td>Bearded male X Beardless female (purebred)</td>
<td>Beardless male X Bearded female (purebred)</td>
</tr>
<tr>
<td><strong>F₁:</strong></td>
<td>Males: all bearded</td>
<td>Males: all bearded</td>
</tr>
<tr>
<td></td>
<td>Females: all beardless</td>
<td>Females: all beardless</td>
</tr>
<tr>
<td><strong>F₂:</strong></td>
<td>Males: 3 bearded : 1 beardless</td>
<td>Males: 3 bearded : 1 beardless</td>
</tr>
<tr>
<td></td>
<td>Females: 3 beardless : 1 bearded</td>
<td>Females: 3 beardless : 1 bearded</td>
</tr>
</tbody>
</table>

(a) Give a plausible genetic explanation for the unusual phenotypic ratios in the F₂ generation. Please be precise and define your genetic symbols. (4 pts.)

(b) Using clearly-defined genotypic symbols, assign genotypes to each of the following: (1 pt. ea., 8 pts. total)

(i) **P generation:**

Bearded male: __________  
Beardless female: __________

Beardless male: __________  
Bearded female: __________

(ii) **F₁ generation:**

Bearded males: __________  
Beardless females: __________

(iii) **F₂ generation:**

Bearded females: __________  
Beardless males: __________
3. In *Drosophila*, the \( b \) allele produces **black body color**, and the \( b^+ \) allele of the same gene is responsible for the wild-type **brown body color**. A second set of genes is responsible for wing texture: the \( wx \) allele produces **waxy wings**, and the \( wx^+ \) allele is responsible for **non-waxy wings**. A third gene is responsible for eye color: the \( cn \) allele of this gene produces **cinnabar eyes** and the \( cn^+ \) allele produces red, **wild-type eyes**.

Female flies heterozygous for all three genes are test-crossed with males of the appropriate genotype (hint: remember what a test cross involves). The following types and numbers of offspring were produced:

<table>
<thead>
<tr>
<th>Phenotype of testcross progeny</th>
<th>Number</th>
<th>Genotype (for your own benefit)</th>
<th>Parental, SCOI, SCO II, or DCO?</th>
</tr>
</thead>
<tbody>
<tr>
<td>brown body, non-waxy wings, red eyes</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>black body, waxy wings, cinnabar eyes</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>brown body, waxy wings, cinnabar eyes</td>
<td>69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>black body, non-waxy wings, red eyes</td>
<td>67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>brown body, non-waxy wings, cinnabar eyes</td>
<td>382</td>
<td></td>
<td></td>
</tr>
<tr>
<td>black body, waxy wings, red eyes</td>
<td>379</td>
<td></td>
<td></td>
</tr>
<tr>
<td>brown body, waxy wings, red eyes</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>black body, non-waxy wings, cinnabar eyes</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total offspring</strong></td>
<td><strong>1000</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) In the spaces provided above classify each group of progeny as **Parental** (=non recombinant), **SCO I**, **SCO II**, or **DCO** (0.5 pt. ea., 4 pts. total).

b) What is the order of these three genes on the chromosome? How did you arrive at that conclusion? PLEASE LABEL REGION I and REGION II on this diagram!! (2 pts.)

c) Write the genotype of the heterozygous female flies used in the testcross indicating the order of the genes on the chromosomes and the linkage phase of the alleles (2 pts.).
3. cont...

d) Calculate the frequency of recombination between each of the three genes: Show all work for full credit. (You should have three sets of calculations; 2 pts. each; 6 pts. total)

% recombination between b and wx:

% recombination between b and cn:

% recombination between wx and cn:

e) Draw a map of the region of the chromosome containing these genes, showing all distances between the three genes. (2 pts.)
4. Squash produce fruit of three shapes, long, sphere, and disk, as pictured below:

A true breeding strain of squash with disk shaped fruit was crossed to a true breeding strain with long fruit. The offspring were then crossed with each other. The results of are as follows:

\[
\begin{align*}
\text{P:} & \quad \text{Disk fruit} & \times & \text{Long fruit} \\
\downarrow & \quad \downarrow \\
\text{F}_1: & \quad \text{All disk fruit} \\
\downarrow & \quad \downarrow \\
\text{F}_2: & \quad 270 \text{ disk:} & \quad 178 \text{ sphere:} & \quad 32 \text{ long} \\
\end{align*}
\]

A.) **Describe** the mode of inheritance of fruit shape in summer squash: how many genes are involved? In what way do these genes determine phenotype? (3 pts.).

B.) For each of the fruit type in the crosses shown above, write the genotype in the spaces provided (1 pt./blank, 6 pts. total)

C.) A farmer wants to develop a true-breeding strain of sphere shaped squash plants, but is worried because of the results of the cross shown above. You assure him that it is indeed possible to produce his desired strain and you could easily isolate this strain from his $F_2$ sphere shaped squash plants using a simple test cross.

i. What would constitute a true breeding variety of sphere shaped squash plants? (2 pts.)

ii. How could you use a testcross to isolate this variety from the $F_2$ sphere shaped squash plants? (2 pts.)
5. **(A)** According to a paper written by Chargoff (1950, *Experientia* 6: 201–209), the proportion of adenine in human DNA is about 30%. What are the proportions of the following? (1 pt. each, 3 pts. total).

- thymine: _______
- cytosine: _______
- guanine: _______

**(B)** The following diagram depicts DNA replication occurring in *E. coli*. Label the indicated structures by writing their names in the blanks provided (1 pt. each, 6 pts. total):

![Diagram of DNA replication](image)

**(C)** The following events, steps, or reactions occur during *E. coli* DNA replication. For each entry in column A, select the appropriate entry in column B (0.5 pts. each, 4 pts. total).

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creates a phosphodiester bond between two adjacent polynucleotide strands</td>
<td>A. primase</td>
</tr>
<tr>
<td>Unwinds the double helix</td>
<td>B. DNA polymerase I</td>
</tr>
<tr>
<td>Prevents the reassociation of complementary bases</td>
<td>C. DNA polymerase III</td>
</tr>
<tr>
<td>Forms on the lagging strand of DNA</td>
<td>D. helicase</td>
</tr>
<tr>
<td>Has a 5'→3' exonuclease function</td>
<td>E. SSB protein</td>
</tr>
<tr>
<td>Is an RNA polymerase</td>
<td>F. DNA ligase</td>
</tr>
<tr>
<td>Releases tension caused by DNA supercoiling</td>
<td>G. topoisomerase</td>
</tr>
<tr>
<td>Catalyzes DNA formation on the leading strand during replication</td>
<td>H. Okazaki fragment</td>
</tr>
</tbody>
</table>
6. Marfan syndrome is a disorder of the fibrous connective tissue, characterized by many symptoms, including long, thin fingers; eye defects; heart disease; and long limbs. It has been speculated that Abraham Lincoln may have had Marfan syndrome and Flo Hyman, an American volleyball star died after a match from a ruptured aorta due to Marfan syndrome. Use the pedigree below to answer the following questions.

(A) What is the mode of inheritance of Marfan syndrome? Give at least two reasons why you came to this conclusion (3 pts.)

(B) Does this trait show reduced penetrance? Explain (3 pts.).

(C) Does this trait show variable expressivity? Explain (3 pts.).

(D) If a trait is genetic, such as Marfan syndrome, how can two individuals with the same genotype show such different phenotypes as those seen in the pedigree above? (3 pts.)
7. In cucumbers, heart-shaped leaves (hl) is recessive to normal leaves (Hl) and many fruit spines (ns) is recessive to few fruit spines (Nl). The genes for leaf shape and number of spines are located on the same chromosome; previous mapping experiments indicate they are 32.6 map units apart. A cucumber plant has heart-shaped leaves and many spines is crossed with a plant that is homozygous for normal leaves and few spines. The F₁ offspring are then testcrossed.

(A) What is the **PHENOTYPE** of the plants that the F₁ offspring are mated to in the testcross? (2 pts.)

(B) What are the genotypes of the individuals in the testcross? (1 pts. each, 2 pts. total)

\[ F_1 \text{ offspring} : \_\_\_\_\_\_ \times \text{testcross individual: } \_\_\_\_\_\_ \]

(C) Draw the chromosomes present in the F₁ heterozygote (2 pts.):

(D) What is the name of the linkage phase shown in the F₁ heterozygote? (2 pts.)

(E) What percentage of offspring from the testcross will have heart-shaped leaves and many spines? (3 pts.)

(F) What percentage of offspring will have heart-shaped leaves and few spines? (3 pts.)
Bonus

Petal coloration in foxgloves is determined by three genes. $M$ codes for an enzyme that synthesizes anthocynin, the purple pigment seen in these petals; $m/m$ produces no pigment, resulting in the phenotype albino with yellow spots. $D$ is an enhancer of anthocynin, resulting in darker pigment; $d/d$ does not enhance, giving light purple petals. At a third locus, $w/w$ allows for pigment deposition in petals, but $W$ prevents pigment deposition except in the spots, so results in the white, spotted phenotype. Consider the following two crosses:

(i) In each case, give the genotypes of the parents and progeny with respect to the three genes (0.5 pts. Each, 4.5 pts. total)

(ii) Suppose you were to cross two individual with the genotypes $M/m; D/d; w/w$ x $M/M; d/d; W/w$. What phenotypic ratio would you expect in the offspring? (0.5 pt.)

<table>
<thead>
<tr>
<th>Cross</th>
<th>Parents</th>
<th>Progeny</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dark purple x white with yellowish spots</td>
<td>½ dark purple: ½ light purple</td>
</tr>
<tr>
<td></td>
<td>_________ x _________</td>
<td>nofollow(�ş)</td>
</tr>
<tr>
<td>2</td>
<td>White with yellowish spots x light purple</td>
<td>½ white with purple spots: ¼ dark purple: ¼</td>
</tr>
<tr>
<td></td>
<td>_________ x _________</td>
<td>light purple</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nofollow(�ş)</td>
</tr>
</tbody>
</table>