Name ____________________________ **Period** _________

AP Biology **Date** ______________________

LAB ____. POPULATION GENETICS

PRE-LAB

1. Explain what is meant by a population being in Hardy-Weinberg equilibrium.

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2. List and briefly explain the 5 conditions that need to be met to maintain a population in Hardy Weinberg equilibrium.

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   b. ____ :

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   c. ____ :

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   d. ____ :

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   e. ____ :

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In 1908, G.H. Hardy and W. Weinberg independently suggested a mathematical approach to study evolution. In this approach, evolution is viewed as changes in the frequency of alleles in a population of organisms. The Hardy-Weinberg theorem can be used to predict the frequencies that one would expect of different genotypes in a population. Of what value is such a prediction? It provides a yardstick by which changes in a population — changes in allele frequency, and thereby evolution — can be measured. One can study a population and ask: Is evolution occurring for a specific gene? Then one can hypothesize and further investigate: What force(s) is acting on this population to cause this change over time?

CASE 1. A TEST OF AN "IDEAL" HARDY-WEINBERG POPULATION

In this case, the whole class will represent a breeding population. As an "ideal" case, we will try to maintain the five Hardy-Weinberg conditions that would keep allele frequencies the same from generation to generation. To model random mating, students must choose another student as a mate at random. In this simulation, neither sex (male or female) nor genotype influences mate selection.

1. As the breeding population, the class will start out with an equal percentage of dominant and recessive alleles in the gene pool. To simulate this all individuals will start out as **heterozygotes** (*Aa*).

2. As heterozygotes, each individual will be given a cup with two *A* alleles (2 black chips) and two *a* alleles (2 white chips). These alleles (chips) represent the gametes produced during meiosis. (Remember meiosis produces 4 gametes.) When mating each "parent" contributes one of these alleles to their offspring, just as any parent supplies a *haploid* set of chromosomes to their new offspring.

3. To mate and produce an offspring, each "parent" will select a gamete out of their mate's cup. This will give the "parents" a pair of haploid gametes (sperm & egg). Put these two gametes together (fertilization) to make a *diploid* offspring. Only one of the parents records this genotype as their offspring in the Data Table below.

4. Each parental pair, must produce two offspring, so the gametes (chips) must be returned to the original cups, so a second pair of gametes can produce a second offspring in the same manner. Only the other parent then records the genotype of their offspring in the Data Table.

5. This generation has now reproduced, and as with many organisms, after reproduction these parents *senesce* and die. The two student partners will now become the next generation by assuming the genotypes of the *two offspring* they just produced.

6. Each student should obtain, if necessary, new chips representing the alleles that would be produced from meiosis in this new individual. For example, if you are now *aa*, then your gametes would be *a*, *a*, *a*, *a* and you would place 4 white chips in your cup.)

7. Each student should now seek out a *new mate* at random from the other individuals in the classroom. Remember the sex and genotype of your classmates should be disregarded.

8. Pool class data for data analysis.

Name ____________________________ **AP Biology**

CASE 1. IDEAL HARDY WEINBERG POPULATION

A. INDIVIDUAL DATA

	Initial	F1	F2	F3	F4	F5
My Genotype						

B. CLASS DATA

	Surviving genotypes					Surviving alleles		
Generation #	**AA**	**Aa**	**aa**	**Total Individuals**		**A**	**a**	**Total alleles**
Parental								
F1								
F2								
F3								
F4								
F5								

9. Complete the table below: For the population (class data), what are the **theoretical allele & genotype frequencies** in the initial parental generation? Based on the Hardy-Weinberg theorem, what would the **theoretical allele & genotype frequencies** be for the 5^{th} generation? What are the **actual allele & genotype frequencies** at the end of the 5^{th} generation?

	Frequency of genotypes				Frequency of alleles	
Generation #	**p^2 (AA)**	**2pq (Aa)**	**q^2 (aa)**		**p (A)**	**q (a)**
Parental (H-W theoretical)						
F5 (H-W theoretical)						
F5 (actual)						

10. Do the class results for the p and q values of the 5^{th} generation agree with the predicted values? ________________________________

11. What does this mean about the population? ____

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12. What major assumption(s) were not strictly followed in this simulation for a population in Hardy-Weinberg equilibrium?

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CASE 2. SELECTION AGAINST HOMOZYGOUS RECESSIVE

In the natural world, not all genotypes have the same rates of survival. The environment may favor some genotypes while selecting against others. In Case 2, we will create a more realistic simulation by applying a selection pressure to the population. In this Case, you will assume that the homozygous recessive individuals never survive (100% selection against), and that heterozygous and homozygous dominant individuals survive 100% of the time.

13. Start again with your initial heterozygote genotype (2 white chips & 2 black chips). Produce your "offspring" as you did in Case 1. This time however, if your offspring is *aa* it does not survive to reproduce. Since we want to maintain a constant population size, the same two parents must try again until they produce two surviving offspring. Record your surviving offspring in the Data Table below.

14. As in Case 1, after successfully reproducing, you become your surviving offspring and mate at random with another individual in the population. Record the genotype of your offspring in the Data Table below.

15. Pool class data for data analysis.

A. INDIVIDUAL DATA

	Initial	**F1**	**F2**	**F3**	**F4**	**F5**
My Genotype						

B. Class Data

	Surviving genotypes					Surviving alleles		
Generation #	**AA**	**Aa**	**aa**	**Total Individuals**		**A**	**a**	**Total alleles**
Parental								
F1								
F2								
F3								
F4								
F5								

16. Complete the table below: For the population (class data), what are the **theoretical allele & genotype frequencies** in the initial parental generation? Based on the Hardy-Weinberg theorem, what would the **theoretical allele & genotype frequencies** be for the 5th generation? What are the **actual allele & genotype frequencies** at the end of the 5th generation?

	Frequency of genotypes				Frequency of alleles	
Generation #	p^2 (AA)	2pq (Aa)	q^2 (aa)		p (A)	q (a)
Parental (H-W theoretical)						
F5 (H-W theoretical)						
F5 (actual)						

17. Do the class results for the p and q values of the 5th generation agree with the predicted values? ______________________________

18. How do the new p and q frequencies compare to the parental frequencies?

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19. What major assumption(s) were not strictly followed in this simulation for a population in Hardy-Weinberg equilibrium?

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20. Predict what would happen to the p and q frequencies if you simulated another five generations?

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21. Since homozygous recessives are strongly selected against, would you expect the recessive (a) allele to be completely removed from the population? In other words, in a large population would it be possible to completely eliminate a deleterious (or even lethal) recessive allele. Explain.

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22. Describe a real-life example of selection against a homozygous recessive genotype.

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CASE 3. HETEROZYGOUS ADVANTAGE

From Case 2, it is easy to see what happens to the lethal recessive allele in a population. However, data from human populations, sometimes show an unexpected high frequency of a deleterious allele in some populations. Sometimes there is a slight advantage to being heterozygous for a trait rather than homozygous dominant. So the situation is now more complicated: homozygous recessives are still strongly selected against and do not survive to reproduce, but now, in addition, homozygous dominants have a lower reproductive rate than heterozygotes. We will incorporate this fact into our simulation.

23. Keep everything the same as in Case 2 (all homozygous recessives do not survive to reproduce), but now if your offspring is *AA*, you must flip a coin. If the coin lands heads up, the offspring **does not** survive; if the coin lands tails up the offspring **does** survive.

24. As in Case 1 & 2, after successfully reproducing, you become your surviving offspring and mate at random with another individual in the population. Record the genotype of your offspring in the Data Table below. This Case will be run for 10 generations.

25. Pool class data for data analysis.

A. INDIVIDUAL DATA

	Initial	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
My Genotype											

B. CLASS DATA

	Surviving genotypes					Surviving alleles		
Generation #	**AA**	**Aa**	**aa**	**Total Individuals**		**A**	**a**	**Total alleles**
Parental								
F1								
F2								
F3								
F4								
F5								

	Surviving genotypes					Surviving alleles		
Generation #	AA	Aa	aa	Total Individuals		A	a	Total alleles
F6								
F7								
F8								
F9								
F10								

26. Complete the table below: For the population (class data), what are the **theoretical allele & genotype frequencies** in the initial parental generation? Based on the Hardy-Weinberg theorem, what would the **theoretical allele & genotype frequencies** be for the 5th and 10th generations? What are the **actual allele & genotype frequencies** at the end of the 5th and 10th generations?

	Frequency of genotypes				Frequency of alleles	
Generation #	p^2 (AA)	2pq (Aa)	q^2 (aa)		p (A)	q (a)
Parental (H-W theoretical)						
F5 (H-W theoretical)						
F5 (actual)						
F10 (H-W theoretical)						
F10 (actual)						

27. Explain how the changes in p and q frequencies in **Case 3** (Heterozygote Advantage) compare with the frequencies in **Case 1** (H-W Equilibrium) & **Case 2** (Selection)?

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28. Do you think the recessive allele will be eliminated in Case 3? Explain.

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29. What is the impact of heterozygote advantage to genetic variation in a population? Explain.

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30. Describe a real-life example of heterozygote advantage.

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Case 4. Genetic Drift

Remember that even though natural selection is creating adaptive change, it is not the only force molding a population. Equally important are the forces of random chance that can cause changes over time in a population even though they are not adaptive. We will simulate this by creating smaller population the classroom.

1. The class will be divided into several smaller sub-populations. These populations will remain isolated from each other and cannot interbreed.

2. Keep the mating process the same as in Case 1 (all individuals survive and reproduce). As before, after successfully reproducing, you become your surviving offspring and mate at random with another individual, but only in your sub-population. Record the genotype of your offspring in the Data Table below.

3. Record class data — from other sub-populations — for data analysis.

A. Individual Data

	Initial	**F1**	**F2**	**F3**	**F4**	**F5**
My Genotype						

B. Sub-Population Data

	Surviving genotypes												**Surviving alleles**								
Generation #	**AA**			**Aa**			**aa**			**Total Individuals**			**A**			**a**			**Total alleles**		
Parental																					
F1																					
F2																					
F3																					
F4																					
Group	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
F5																					

4. Complete the table below: For the population (class data), what are the **theoretical allele & genotype frequencies** in the initial parental generation? Based on the Hardy-Weinberg theorem, what would the **theoretical allele & genotype frequencies** be for the 5th generation of any sub-population? What are the **actual allele & genotype frequencies** at the end of the 5th generation for each sub-population?

CLASS DATA

	Surviving genotypes				Surviving alleles	
Generation #	**p^2 (AA)**	**2pq (Aa)**	**q^2 (aa)**		**p (A)**	**q (a)**
Parental (H-W theoretical)						
F5 (H-W theoretical)						
Group 1 F5 (actual)						
Group 2 F5 (actual)						
Group 3 F5 (actual)						

5. Compare the initial parental genotype and allele frequencies in the different sub-populations in the classroom.

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6. Compare the final genotype and allele frequencies in the different sub-populations in the classroom.

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7. What do these results indicate about the importance of population size as an evolutionary force?

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8. How is this issue significant in conservation biology and endangered species conservation?

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9. Describe a real-life example of genetic drift.

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Hardy-Weinberg Problems

10. In fruit flies, *Drosophila melanogaster*, the allele for normal-length wing is dominant over the allele for vestigial wings (vestigial wings are stubby little curl that cannot be used for flight). In a population of 1,000 individuals, 360 show the recessive phenotype. How many individuals would you expect to be **homozygous dominant** and how many would be **heterozygous** for this trait?

a. Choose the letters you will use to represent the alleles & genotypes:

Dominant allele	
recessive allele	

Homozygous Dominant	
Heterozygous	
Homozygous recessive	

b. Translate to known frequencies:

p (Dominant allele)	
q (recessive allele)	

p^2 (Homozygous Dominant)	
2pq (Heterozygous)	
q^2 (Homozygous recessive)	

c. Choose which Hardy-Weinberg formula you will primarily use:

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d. Solve. Neatly show work below. Write final answer in box.

ANSWER

11. The allele for unattached ear lobes is dominant over the allele for attached earlobes. In a population of 500 individuals, 25% show the recessive phenotype. How many individuals would you expect to be **homozygous dominant** and how many would be **heterozygous** for this trait?

a. Choose the letters you will use to represent the alleles & genotypes:

Dominant allele	
recessive allele	

Homozygous Dominant	
Heterozygous	
Homozygous recessive	

b. Translate to known frequencies:

p (Dominant allele)	
q (recessive allele)	

p^2 (Homozygous Dominant)	
2pq (Heterozygous)	
q^2 (Homozygous recessive)	

c. Choose which Hardy-Weinberg formula you will primarily use:

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d. Solve. Neatly show work below. Write final answer in box.

ANSWER

12. The allele for the hair pattern called "widow's peak" is dominant over the allele for no "widow's peak". In a population of 1,000 individuals, 510 show the dominant phenotype. How many individuals would you expect of each of the three possible **genotypes** for this trait?

a. Choose the letters you will use to represent the alleles & genotypes:

Dominant allele	
recessive allele	

Homozygous Dominant	
Heterozygous	
Homozygous recessive	

b. Translate to known frequencies:

p (Dominant allele)	
q (recessive allele)	

p^2 (Homozygous Dominant)	
2pq (Heterozygous)	
q^2 (Homozygous recessive)	

c. Choose which Hardy-Weinberg formula you will primarily use:

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d. Solve. Neatly show work below. Write final answer in box.

ANSWER

13. Rh refers to a protein maker on red blood cells. In the United States about 16% of the population is Rh negative. The allele for Rh negative is recessive to the allele for Rh positive. If the student population of a high school in the U.S. is 2,000, how many students would you expect of each of the three possible **genotypes** for this trait?

a. Choose the letters you will use to represent the alleles & genotypes:

Dominant allele	
recessive allele	

Homozygous Dominant	
Heterozygous	
Homozygous recessive	

b. Translate to known frequencies:

p (Dominant allele)	
q (recessive allele)	

p^2 (Homozygous Dominant)	
2pq (Heterozygous)	
q^2 (Homozygous recessive)	

c. Choose which Hardy-Weinberg formula you will primarily use:

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d. Solve. Neatly show work below. Write final answer in box.

ANSWER

14. In certain African countries 4% of the newborn babies have sickle-cell anemia, which is a recessive trait. Out of a random population of 1,000 newborn babies, how many would you expect of each of the three possible **genotypes** for this trait?

a. Choose the letters you will use to represent the alleles & genotypes:

Dominant allele	
recessive allele	

Homozygous Dominant	
Heterozygous	
Homozygous recessive	

b. Translate to known frequencies:

p (Dominant allele)	
q (recessive allele)	

p^2 (Homozygous Dominant)	
2pq (Heterozygous)	
q^2 (Homozygous recessive)	

c. Choose which Hardy-Weinberg formula you will primarily use:

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d. Solve. Neatly show work below. Write final answer in box.

ANSWER

15. In a population, the **dominant phenotype** of a certain trait occurs 91% of the time. What is the frequency of the dominant allele?

a. Choose the letters you will use to represent the alleles & genotypes:

Dominant allele	
recessive allele	

Homozygous Dominant	
Heterozygous	
Homozygous recessive	

b. Translate to known frequencies:

p (Dominant allele)	
q (recessive allele)	

p^2 (Homozygous Dominant)	
2pq (Heterozygous)	
q^2 (Homozygous recessive)	

c. Choose which Hardy-Weinberg formula you will primarily use:

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d. Solve. Neatly show work below. Write final answer in box.

ANSWER
