PRINCIPLES OF BIOLOGY LABORATORY

NATURAL SELECTION

I. OBJECTIVES:

After completing this laboratory exercise, the student should be able to:

1. Discuss the relationship of color of an organism to its survival.
2. Name at least one factor in an environment which can change the makeup of a population.
3. Define mutation and explain how it can modify a population.
4. Discuss ways in which mutation, natural selection, and evolution affect gene frequencies in populations of living things.

II. DEFINITIONS:

Gene (or Allele) Frequency: The ratio of the number of genes (alleles) of one type to the total of all alleles for a particular trait in a breeding population. Gene frequencies may be affected through time by natural selection and evolution.

Gene Pool: The sum total of all the alleles of all the genes of all the individuals in the population.

Evolution: Evolution can be defined as the change in gene frequencies in a population (not individuals) through time. Evolution also means that all organisms are united by ties of geneological descent. The FACT of evolution is the "descent of all living organisms through modification." The THEORY of evolution is "what exact mechanism caused the modification process."

Species: Generally speaking a species is a group of organisms that actually (or potentially) interbreed in nature and are reproductively isolated from other such groups under natural conditions.

Population: A group of organisms (animals or plants) of the same species living in the same area. Although there may be considerable differences between individuals of the population, the individuals are capable of interbreeding within the population.

Speciation: The process by which species are formed. One common way that new species arise is when populations of the same species become geographically separated from each other. After an adequate amount of time, each isolated population develops a gene frequency different from the other population, and members of these different populations can no longer interbreed with one another. These two populations have evolved into different populations. EVOLUTION has occurred giving rise to new species.

III. INTRODUCTION:

Darwinian evolution and Mendelian genetics merged when biologists stopped thinking in terms of individual organisms and genotypes and began thinking in terms of populations, genes, and allele frequencies. In natural populations, some alleles increase in frequency from generation to generation, and others decrease. If an individual has a favorable combination of alleles for a particular environmental condition, these alleles are more likely to be present in an increased proportion in the next generation. Thus the selection of these favorable alleles in the population is called **natural selection**. If, however, the combination of alleles is not favorable for that particular environment, these alleles will be reduced in successive generations or perhaps eliminated from the population.

An individual's fitness in its environment does not mean the physical well-being or optimal adaptation to the environment. The only measurement of an individual's fitness is the relative number of surviving offspring, that is, the extent to which its favorable genotype is present in succeeding generations. Evolution is the result of such accumulated changes in the gene pool. Gene pools change slowly over time. It should be noted that evolution acts on populations while natural selection acts on the individual.

Example: Many pest species have developed resistance to the poison intended to kill them. Urban rats have become resistant to warfarin, mosquitoes to DDT, bacteria (e.g., Staphylococcus aureus) to penicillin. In all these cases natural selection has operated to produce a radical shift in gene frequencies.

The dilemma began with the first application of the poison at a precise concentration. This first application may have killed 95% to 99% of the pest organisms. Those pest individuals that survived the first application, though very few in number, possessed a genotype which was resistant to the poison. Those individuals which were not resistant to the poison where killed and eliminated from the population gene pool. As the pest population grew in numbers, more individuals were present which contained the resistant genotype. **Natural selection selected for those individuals which had the best fit genotype for that particular environmental condition**.

In order to control the pest with the same type of poison, a higher concentration had to be used. Eventually, after successive applications of increasingly higher concentrations of poison, the entire pest population is essentially resistant to the poison. **Understand that if such alleles were not already in the population which was exposed to the poison, no pest species would have survived and the population would be wiped out.** In addition, new advantageous mutations can develop in a population and thereby improve resistance.

Natural selection is based on:

1. There is variation in traits within a species. Each species shows variation in traits.
2. Organisms have the ability to reproduce more offspring than the environment can support.
3. There is competition for limited resources.
4. Only those best suited to the environment will survive to reproduce and pass the characteristics on to their offspring.

III. SIMULATION OF NATURAL SELECTION:

Assume that a population of insects has been carried by a hurricane from its natural habitat into another area where the climate is the same, but the predators are different. In this simulation, the insect population will be represented by paper clips and the jungle environment in which the insects live is simulated by a piece of cloth. The predators on this population are birds which eat the insects they find. The birds are simulated by students removing the paper clips which they see.

1. Working as a lab table, get a piece of cloth and a container of paper clips. Two students will be "predators" and two students will be the "environment."
2. From the container, select 20 red paper clips and 20 green paper clips.
3. One student mixes the red and green paper clips and carefully sprinkles them over the cloth. **Be sure the paper clips cover the entire "jungle."** The "predator" student must not look at the jungle until told to do so.
4. At a given signal, the two "predator" students QUICKLY pick up 10 paper clips each from those on the cloth. A total of 20 paper clips is to be removed from the cloth. Return these paper clips to the container.
5. Remove the remaining 20 paper clips on the cloth. Count the number of red paper clips and number of green paper clips which remained on the cloth. Save these paper clips. This is your PARENT GENERATION.

   a. Paper clips remaining on cloth:

      Number of Red ____________________

      Number of Green ____________________

      (Red plus Green equals 20)

6. Put your data on the chalkboard and fill class data in Table I below, then proceed to #8 on next page.

TABLE I: First Parent Generation

	Red	Green
Lab Table 1		
Lab Table 2		
Lab Table 3		
Lab Table 4		
Lab Table 5		
Lab Table 6		
Lab Table 7		
TOTAL		
Per Cent		

TO FIND PER CENTS:

$$\frac{\text{Red}}{\text{Red + Green}} \times 100 = \underline{\quad\quad}\%\ \text{Red}$$

$$\frac{\text{Green}}{\text{Green + Red}} \times 100 = \underline{\quad\quad}\%\ \text{Green}$$

7. Use class data to answer the following questions.

   a. Which color insects (paper clips) decreased in the population?

   ____

   b. Explain why one color of paper clips was removed from the cloth more frequently than the other color.

8. Those insects which survived predation (being eaten by the birds) become the FIRST PARENT GENERATION in this simulation. Enter the number of the survivors (red and green paper clips) in Table IIA below, as FIRST PARENT GENERATION. To simulate reproduction, take enough red paper clips from the container to double the number of red paper clips. Repeat the process to double the number of green paper clips. After "reproduction," the population should consist of 40 "insects." These represent FIRST OFFSPRING. Record the number of red and green "insects" in Table IIB below.

TABLE IIA:
POPULATION AFTER PREDATION
(This should total 20.)

	red	green	blue	pink
FIRST PARENT GENERATION				
SECOND PARENT GENERATION				
THIRD PARENT GENERATION				
FOURTH PARENT GENERATION				

TABLE IIB:
POPULATION AFTER DOUBLING
(This should total 40.)

	red	green	blue	pink
FIRST OFFSPRING				
SECOND OFFSPRING			1	1
THIRD OFFSPRING				

9. Repeat steps 3, 4, and 5 on page 4. Enter the surviving individuals as SECOND PARENT GENERATION in Table IIA above.

10. Sometimes a color mutation (change) occurs spontaneously. This time, after the insects (paper clips) in the second parent generation reproduce (double), **substitute** one blue paper clip for one green paper clip in the offspring generation and one pink paper clip for one red paper clip. Record these numbers in Table IIB above as SECOND OFFSPRING.

11. Repeat the process two more times for the 3rd and 4th generations.
    a. Scatter the 40 paper clips.
    b. Quickly remove 20 paper clips.
    c. Count and record the remaining paper clips in Table IIA above.
    d. Double the remaining paper clips.
    e. Record the data in Table IIB above.

12. Record your 4th generation data on the chalkboard and on the class data in Table III below.

TABLE III: FOURTH PARENT GENERATION

	Red	Green	Blue	Pink
Lab Table 1				
Lab Table 2				
Lab Table 3				
Lab Table 4				
Lab Table 5				
Lab Table 6				
Lab Table 7				
TOTAL				
Percent				

13. Using class data, answer the following questions.

a. The percent of red "insects" in the population over four

generations (increased/decreased) ____________________
(Compare data from Tables I and III.)

b. The percent of green "insects" in the population over four

generations (increased/decreased) ____________________
(Again use Tables I and III.)

c. The (red/green) ________________ "insects" were best adapted for the environment.

d. Discuss the reason for your answer to "c" above.

e. What was the factor which caused the change in the population from half green-half red to predominantly one color?

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f. The pink paper clips were 2.5% of the population when they first appeared. The percent of pink "insects"

(increased/decreased) ______________________ during this simulation.

g. The blue paper clips were 2.5% of the population when they first appeared. The percent of blue "insects"

(increased/decreased) ______________________ during this simulation.

h. Based on the class data, is either mutation beneficial to the organism?

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i. Is either mutation harmful to the organism? _______________

j. Discuss the reasons for your answer to i above.

k. Why is variation necessary for the survival of the species?

This concludes this laboratory simulation. Please put all paper clips in the container and return the cloth and the container to the center tables.