ORGANIC EVOLUTION

Teacher's Guide

TVOntario

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INTRODUCTION

Series Outline

For centuries the Biblical account of creation was firmly fixed inthe minds of most individuals. But in the early part of the eighteenth century, the doctrine of special creation was questioned by naturalists such as Carolus Linnaeus, Georges Leclerc, comle de Buffon, and Jean- Baptiste de Lamarck. The Lamarckian theory of the inheritance of acquired characteristics was attractive but unacceptable to most people. However, the work of Gregor Mendel, ***which*** was rediscovered about 100 years after Lamarck, indicated that acquired characteristics could not-be inherited.

Charles Darwin's contribution to science was twofold:
-he presented evidence to: prove that organic evolution has occurred;
-he devised a theory to explain how it operates.
Darwin referred to this evolutionary mechanism as natural selection. One of the major weaknesses in Darwin's evolutionary theory was that it could not account forthe occurrence of variation.

It was Mendel's experimentswith the common pea plant that later came to support -Darwin's theory. From the principles of Mendelian genetics the Hardy-Weinberg law was established. This law states that if mating is random, if mutations and selection do not occur, and if the population is large, then gene frequencies in a, population remain constant from generation to generation. Variation occurs due to the process of meiosis and the phenomenon of crossing over. The thorough shuffling of the paternal and maternal genes in the gametes results in an astronomical number of gene combinations that could occur in **a populatlon.of** interbreeding organisms. Although continual reshuffling will aker the combinations of the genes, according to the Hardy-Weinberg law the frequencywith which the different kinds of genes appear in the population will not be altered.

If the law fails, ·it must be due to some internal or external pressures that disturb the equilibrium of the·population. Factors, such as natural selection, sexual selection, directional and disruptive selection, and geographic isolation resulting in random genetic drift are all possible causes of a change in the gene frequencies.

But the ultimate source of evolution is a mutation that establishes an alternative allele at a given site on the. chromosome and makes possible an altemative phenotype. The alteration of the DNA molecule's structure and the consequent alteration in the genetic code result in a mutation.

The change in the gene pool resulting in an increased frequency of the mutant gene in the population is a gradual process that may occur over eons. This idea·of Darwin's is referred to as gradualism. Other scientists challenged this idea and suggested that major changes occur suddenly and are then followed by long periods of **stability,** hence the theory of punctuated **equilibrium**. The debate on :these two theories continues.

PROGRAM 1 /In The Beginning

Objectives

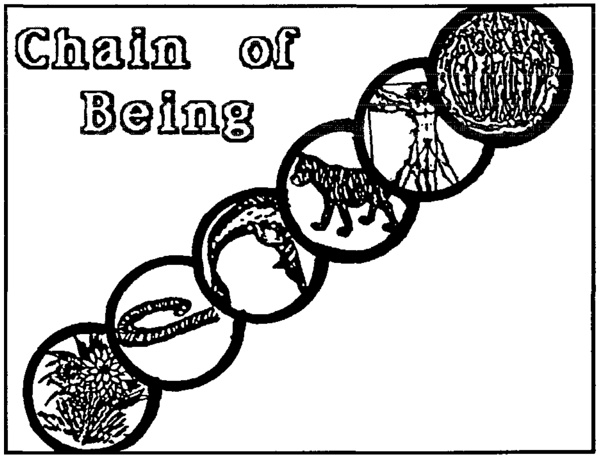
Students should be able to do the following

1. Describe the work of Bishop Paley.
2. Describe the contributions of Carolus Linnaeus.
3. State the views put forth by le comte de Buffon.
4. Describe Lamarck's theory.

Program Description

In the beginning God created the heaven and the earth and the living things that populate it. The very vivid Biblical account remained firmly fixed in the minds of most people for centuries. It was not until the eighteenth century that some people began to think more deeply about aspects of the origins of life.

Bishop Paley attempted to survey the facts of natural history to show that a grand design existed. He commented on the remarkable ways in which plants and animals were adapted to their environments and said that these adaptations could not have arisen by chance. According to Paley, this proved the existence of a creator guiding the natural world. Fixed and unchanging, all beings were ranked in ascending order from lowest to highest. This divine ranking he called *the great chain of being.*



Carolus Linnaeus was convinced of the essential correctness of the Biblical views. He believed that all species were created and had changed very little, if at all, since creation. Linnaeus recognized the species as the basic natural unit of life, and the key to his system was structural similarity. He grouped plants and animals according to their shared characteristics and divided them into orders, families, genera, and species. This provided the basis of today's expanded taxonomy.

Linnaeus gave every organism he knew two names. The first word of the name is the *genus* to which it belongs. The second is the so-called descriptive name or species.

But if species were related through genus, could the species have evolved from some form of prototype? Linnaeus believed that the number of species was fixed, and these species did not change. Organisms that did not fit into his system he simply ignored. If he had understood that such organisms were in the process of change, the theory of evolution might have developed long before Darwin. The idea of spontaneous generation suggested serious flaws in the theory of fixed species.

Georges Leclerc, comte de Buffon, believed that ancestral forms of life arose spontaneously-that one form of life became modified by the organism's response to its environment to give rise to another form. He thought the original organism acted as a template to create a degenerate type. Therefore, a species could diverge from the ancestral form and could be modified by its environment. Buffon argued against the theory of catastrophism that maintained the changes that had occurred on the earth since its creation were the result of a number of "catastrophies," of which the Biblical flood was one. He stated in his *Histoire Naturelle*

> We ought not to be affected by causes which seldom act and whose action is always sudden and violent. These have no place in the ordinary course of nature. But operations uniformly repeated, motions which succeed one another without interruption, are causes which alone ought to be the foundation of our reasoning.

One of the greatest naturalists, Jean-Baptiste de Lamarck, thought of evolution in terms of independent lines ratherthan common ancestry. Each line originated by spontaneous generation, with the most complex originating earlier and the simple forms originating quite recently. He believed that organisms had an inner drive for perfection and were driven by some need to become complex. In his Histoire Naturelle he wrote:

> They feel certain needs, and each felt need, stirring their inner consciousness, immediately causes fluids and forces to be directed toward the point of the body where an action capable of satisfying the need can take place. But if there exists at this point an organ appropriate to such an action, it is stimulated to act; and if no organ exists and the felt need is pressing and sustained, little by little the organ is produced and develops by reason of its constant vigorous use.

Lamarck proposed that the environment brought about evolutionary changes. The famous example of the giraffe's long neck illustrates Lamarck's theory. He believed that as giraffes fed on the leaves of trees, they stretched their necks a little to reach the highest leaves. These slightly elongated necks were inherited by their offspring who in turn stretched their necks even more. Supposedly, over generations the ***giraffe*** acquired an elongated neck. Through this example he developed the theory of *inheritance of acquired* characteristics. Lamarck thought that by using a certain part of its body, an animal could change that part to fit the environment better. Conversely, by disuse a body part would begin to disappear.

Lamarck's theory as well as the work of other scientists paved the way for further thought and discovery in organic evolution.

Before Viewing

Introduce the topic of organic evolution by suggesting that many biologists, as well as theologians, believe in God as the creator of the world. But they also believe that God gave living creatures the ability to adapt to changing environments and that because of this ability, living creatures have evolved into today's species.

After Viewing

Many experiments have been performed to look for evidence suggesting that characteristics could be affected by the individual's life experiences or activities. Discuss the famous experiments performed by German biologist August Weismann in the 1870s. In his experiments he cut off tails of mice for several successive generations. According to Lamarck, these tailless populations should have started to produce offspring with shorter tails because the tails were not used. Unfortunately for Lamarck, all the mice in all the generations had tails of the same length as those of the original mice.

ACTIVITY 1: Field Trip

Take the students to a museum of natural history. Have them find out how fossils are formed. Ask them to sketch two orthree extinct animals and explain why they thinkthese animals became extinct.

ACTIVITY 2: Field Trip

Take the students through a wooded area or field. Note the organisms that have special characteristics to help them survive in this environment.

ACTIVITY 3: Guest Speaker

invite an expert in the area of evolution or an environmental scientist to speak to your class and answer any questions on the effects of environment on evolution.

ACTIVITY 4: Review

Describe Lamarck's theory of how species acquire new characteristics. Use an example in your discussion.

Objectives

After viewing the program and completing several activities, students should be able to do the following:

1. Recognize the implications of evolution for all living things.
2. Recognize that natural selection is the selection of the more "fit" over the less "fit" organisms.
3. Recognize that evolution is an essentially irreversible process.
4. State the physical and biological checks that slow down or prevent some changes.
5. Summarize how natural selection works.

Program Description

It is important to see Darwin's revolutionary ideas in the context of the scientific information available to him. Darwin was unaware of Mendel's ideas on genetics and unable to explain his observations in terms of genes and chromosomes. However, he did think in terms of inherited variations passed from one generation to the next.

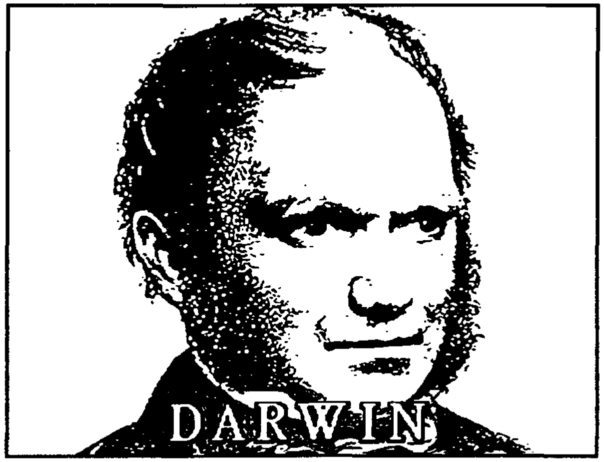
Darwin held that all modern living forms descended with modifications from extinct earlier forms, which in turn had descended from extinct ancestral forms. The modifications were random or "undirected"; that is, they rose without reference to the needs of the plants and animals bearing them. Darwin hoped to prove that the idea of independently created creatures-the Biblical theory-was incorrect. He knew that breeders could "create" desirable plants and animals by selecting parents that already had the desired traits. These traits were likely to be inherited by the offspring.

Darwin noted the close resemblance in the "selection" that occurs in the regulated breeding of horses and the "selection" that occurs in nature. There must be genetic variability in both cases. Breeders "select" what they desire from existing stock; the horses that best meet these requirements are the most likely to pass on desirable traits to their offspring. In nature, the selection-natural selection-is done by the environment (climate, soil, food, competition with organisms, etc.). The organisms that survive and produce offspring are the ones that are best adapted to their natural environment.

Malthus suggested in his "Essay on the Principle of Population" that mankind multiplies geometrically, although the means of subsistence do not. He maintained that the human race was reproducing at such a rate that inevitably it would outgrow its food resources, and a calamitous struggle for survival would occur. In Darwin's mind, this generated the notion that an average individual produces more offspring than can survive, permitting selection to occur. His definition of natural *selection* started from the premise that there are checks on the number of surviving offspring an individual produces. These include physical factors such as climate, disease, limited food supply, and predation. Darwin's conclusion was:

> As many more individuals of each species are born than can possibly survive, and as, consequently, there is a frequent recurring struggle for existence, it follows that any being, if it vary however slightly in any manner profitable to itself, under the complex and somewhat varying conditions of life, will have a better chance of surviving and thus be naturally selected. From the strong principle of inheritance, any selected variety will tend to propagate its new and modified form.

Darwin applied the terms natural *selection* and *survival of the fittest* (a term that Darwin did not coin, but accepted) to this preservation of favorable individual variations and the destruction of injurious variations. This means, as the program illustrates, that organisms with variations that help them cope with their environment have a better chance of surviving; consequently they leave more offspring, some of which may retain the



useful variations. Organisms with variations not suited to their environment leave few, if any, offspring and lose in the struggle for existence. Eventually, the naturally selected variety becomes the dominant variety. Darwin called this process of survival and reproduction of species best adapted to their environment *descent with modification.*

Massive testimony to the evolutionary theory is found in fossils; before the advent of the science of genetics, paleontology supplied the most convincing evidence for the principle. Fossils in rock layers of different ages show a distinct progression of change from the simpler to the more complex forms of life. An incomplete but consistent history of life on earth has been revealed through dating of fossilized remains of extinct forms.

In Darwin's time, many scientists incorporated fossil evidence into the theory of *catastrophism .* This theory posited that great cataclysms (such as the Old Testament flood) wiped out all life forms, which were gradually replaced by entirely new species, most built on previous designs. With each succeeding geological era, these scientists reasoned, a number of species built on a new design.

Charles Lyell countered catastrophism with the theory of *uniformitarianism,* which held that historical changes on earth were due not to a series of catastrophes but to regular, gradual changes. Having long observed such processes as erosion, Lyell proposed that the features of the earth's surface were the result of physical forces operating slowly over enormous periods of time. Given enough time, mountains could disappear in the sea or new ones could emerge on land, and rivers could change their courses or form deep canyons, as the program's animation shows.

Darwin applied the general principle of Lyell's theory of geological evolution to living things. Like geological change, he reasoned, organic evolution proceeds slowly and relentlessly.

In summary, Darwin believed that evolution works in the following way.

- Populations tend to overproduce. They produce more offspring than are likely to survive.
- The members of a population vary one from another and these variations are inherited.
- In nature, members of a population must struggle to survive, and not all will survive.
- Since members of a population are not identical, some are likely to be better suited to survival. Those best suited to the environment will survive and have offspring. This ensures that variation is preserved if it is useful and rejected if it is injurious.

Before Viewing

1. Ask students to observe a local bird group or a common local plant and watch for evidence of variation and the struggle to survive. Suggest that they conjecture which individuals are best adapted for survival and how this might lead to trait changes in the population as a whole. Another way to approach this topic is to show pictures of fossils that trace gradual changes or examine a local fossil record to show how varieties of organisms have changed.

2. Ask the class to name some well-known organisms that failed to adapt and became extinct. The mammoth, mastodon, pterodactyl, brontosaurus, tyrannosaurus, and sabre-toothed tiger became extinct in prehistoric times. The passenger pigeon and puptish became extinct while our very recent ancestors stood by and watched-or helped. Why did they disappear? Change of climate, decrease in food supply, sluggish activity, low intelligence and overhunting are some of the reasons.

After Viewing

1. Begin discussion of the theories relating to evolution, perhaps using as a springboard the fact that although every female frog lays several hundred eggs each spring, the population of frogs in a pond remains relatively constant. Establish the facts about overproduction including the role of enemies and unfavorable environment. What is meant by the "fittest" organisms?

2. A wide variety of discussions and research projects can proceed from the question "How do humans make use of selection?" Breeding plants and animals for characteristics more desirable to humans has produced more and better food. Microbes used in the preparation of foods, chemicals, and pharmaceuticals are under constant observation for the appearance and selection of more useful strains. New techniques in genetic engineering expand the usefulness of selection in exciting, controversial ways.

ACTIVITY 1. Simulating Formation of Fossils in Sedimentary Rock

Demonstrate one or more of these methods in class, before assigning individual projects.

A. "Fossils" In plaster

In this demonstration, the plaster represents the sediments that are deposited by a slow-moving stream, a muddy embankment, or a swamp.

Method

1. **Prepare a mixture of plaster of Paris and water** to the consistency of pancake batter; stir until smooth and pour a layer 2.5 cm deep into an aluminum foil pan.
2. Coat a variety of leaves or shells with petroleum jelly and lay them on the plaster.
3. Coverthese with another layer of plaster of Paris.
4. After it has hardened, remove the plaster from the pan and crack it open to find the casts or imprints made by the embedded objects. The actual molds, especially of solid objects such as shells, can be likened to what might be found when a fragment of sedimentary rock is cracked open.

B. "Fossils" in ice

This experiment shows how no decay takes place when bacteria do not have access to tissue, or when conditions are unfavorable to their growth.

Method

1. Place objects (leaf, insect, fresh fruit, etc.) in water in the compartments of an ice-cube tray and freeze.
2. When partially frozen, add more water to ensure that the embedded objects are completely covered in ice. Each ice cube shows the "fossil" embedded in ice.

C. "Fossils" in gelatin

Method

1. Soak 8 ml of unflavored gelatin in 60 ml of cold water.
2. When the water has been absorbed, stir in 180 ml of hot water.
3. Pour this into waterproof paper boxes or glass dishes and refrigerate.
4. When the mixture is partially congealed, embed a small insect (preferably hard-bodied, such as a beetle) in the gelatin.
5. After the gelatin has hardened, tear off the paper box or remove from dish.

The product is an insect "fossil," resembling actual fossils created when ancient insects, mainly ants and small flies, became embedded in drops of resin that trickled down the bark of evergreens.

ACTIVITY 2. Observing Variations Due to Environment

Members of the same species of plant may show variations due to environmental factors such as the amount of sunlight they receive or the amount of water in their growing medium. These variations can be observed on a field trip to a stream or a take's edge and in the laboratory. Have students observe plants in one or both of these environments and make careful notes on their observations.

1. On afield trip to a stream or lake, have students collect specimens of the plants that grow both in water and on land. How do leaf shape and color vary as the plant's environment becomes dryer?
2. In the laboratory, have students monitor the growth of plant seedlings in brilliant sunlight (or artificial light) and that of seedlings in relative darkness. How do leaf color and plant shape vary with decreasing light? (Variegated coleus provide spectacular results.)

Make certain that students understand that what the environment is changing is not the genetic **pattern** of the species, but the expression of this **pattern.** A range of variation already exists in the plant's genetic makeup, permitting the plant to manifest itself according to the demands of its environment. To test this point, gradually change the environment of a coleus plant grown in relative darkness by exposing it to increasing amounts of light. After several weeks does the appearance of the plant change substantially? (Before and after photographs may prove useful here.) Environmental adaptation, then, is not the same as genetic adaptation.

When the organism is in an environment where this variation is not a hindrance, the organism survives and reproduces more of its kind. In fact, the variation may be beneficial and thereby have special survival value. Have students explain such examples of adaptation in cacti, sun-loving plants, shade-loving plants, and dandelions.

ACTIVITY 3. Natural Selection in Tadpoles

A few years ago a biologist looked into a small pond with a gray, muddy bottom and counted about 500 tadpoles. Most were dark, but 75 were white (albinos). The next morning tracks of a raccoon were seen at the edge of the pool. The biologist counted only 49 white tadpoles that day; the next morning only 27; and the third morning only 9. On the fourth morning he found only 7 albino tadpoles. On that day he carefully estimated the number of dark tadpoles to be about 400. On each of the four mornings there had been fresh raccoon tracks.

1. If the raccoon was wholly responsible for the disappearance of tadpoles, how many of the dark ones had it eaten? How many white ones had it eaten?

2. Why do you suppose the raccoon caught more white tadpoles than dark ones?

3. What prediction would you make for the pond's tadpole population the following year?

4. if this pond had a white, sandy bottom, which color tadpole would the raccoon probably catch more frequently?

Note: It is reasonable to assume that after four days the raccoon continued to reduce the size of the tadpole population. Observation of such populations indicates that predators can reduce them to one-quarter of their size. There is almost no chance that the seven white tadpoles will survive to become adult toads. Therefore the population next year will probably contain fewer albino tadpoles.

ACTIVITY 4. Evolution of a New Species

Species A lives and flourishes in Zone 1, which is in the lowlands and has a warm, moist climate. Zone 2, also in the lowlands, is too dry for Species A to live successfully. Zone 3 is in the mountains,where the environment is too harsh. Zone 4 is in the lowlands, but its climate is too-cool.

Let us now assume that the lowlands of Zone 1 begin to sink slowly; probably just a few centimetres every century. The sea will someday begin to cover Zone 1, and Species A's territory will gradually become smaller and smaller. Thus, not all Species A individuals will be able to find food or places to live. In time the species may become extinct, when the sea covers Zone 1 entirely.

But let us try to imagine what is occurring overtime where Zones 1 and 2 meet. Zone 2 has an environment that is warm and dry; one in which Species A cannot flourish. But Species A has a large population. When individuals mate, some of the resulting offspring may be a little more successful in a warm, dry climate than the rest of Species A. As the generations pass, those variations that allow individuals in Species A to live fairly well in warm-dry environments will increase as geological conditions change.

After many generations we would expect to find some individuals with the characteristics that enable them to live in a warm, dry climate. These can then push theirway into Zone 2. The same process could be happening where Zone 1 meets Zone 4. In other words, some of the individuals of Species A may have changed sufficiently to live in a cool, moist environment.

After thousands of generations, the sea will have entirely covered Zone 1, and all living individuals in Species A will be in Zones 2 and 4, and can be called Species A-2 and Species A-4, respectively. By now these two groups will be completely separate-geological change has heightened the mountain barrier between them, preventing any combination of groups. After thousands more years, the A-2 population will have changed in many ways that have better adapted them to the warm-dry environment. Similar changes will have occurred with A-4. But, as A-2 and A-4 become increasingly adapted to their different environments, they become less like each other. In fact, they may become so different that they can be recognized as two separate species.

Discussion

1. In the evolution of Species A into A-2 and A-4, what was the effect of the land's sinking?

2. What was the environmental effect of the mountain range in Zone 3?

3. Draw a map showing land, water, and species distribution at the "start" of the evolution process and another showing them at the "end."

4. The ancestor of all domesticated dogs is thought to have been a wild animal resembling a wolf. You have seen many different breeds of dogs. How do you think they came to exist?

This study is adapted from *Interaction of Man and the Biosphere: Inquiry in Life Science. pp.* 324-327 (see Further Reading).

ACTIVITY 5. **Review** *Questions*

Ask the students to answer the following questions.

1. Explain the term natural *selection.* What role does it play in evolution?

2. How would you compare the selective

breeding of horses with evolution of horses as it occurs in nature?

3. How would Charles Darwin explain the development of long necks in giraffes?

4. What is artificial selection? How has selective breeding been used?

PROGRAM 3 */Factoring In Mendel*

Objectives

Students should be able to do the following:

1. Recognize the fact that natural selection by itself cannot account for evolution.
2. Describe Mendel's experiment dealing with round and wrinkled seeds in the common pea plant.
3. Recognize that characteristics are preserved from generation to generation.
4. State the Hardy-Weinberg law and recognize its limitations.

Program Description

Natural selection by itself cannot account for evolution - hereditary transmission and some variation must be present. Inheritance is now understood very clearly, due to Mendel and his successors, and to workers in molecular genetics. Variation, in large part, is due to the phenomenon of mutation, which is discussed in Program 6. Some of the other evolutionary forces are isolation, which prevents interbreeding between species, and population sizes. This is discussed in Program 5. The solution to the problem of how variation is maintained arose when the Mendelian laws of inheritance were established. The units of hereditary information received by the zygote from one gamete do not blend with the units received from the other gamete but retain their identity. The information is reassorted and may be manifested in the following generation.

The program describes Mendel's experiments with the common pea plant where he cross-pollinated round peas with wrinkled peas. The outcome of the F1 generation was 100 percent round peas. Self-pollinating the F1 peas, Mendel then noted that in the offspring of the F2 generation, the wrinkled characteristic reappeared in the ratio of 3:1 - round to wrinkled. The crossing of two heterozygous pea plants resulted in the well-known Mendelian ratio of 3:1 for the dominant characteristic. These experiments established the fact that factors-units of heredity we now call *genes* - are neither destroyed nor blended, but rather preserved from generation to generation.

The program concludes by demonstrating mathematically how the Hardy-Weinberg model proves that the rata of dominant to recessive traits remains constant in a large breeding population. The concept of genetic equilibrium refers to a state of balance. Gene frequencies are said to be in equilibrium when they remain constant from generation to generation. Such equilibrium, under random mating and free from external forces, implies that genotypic frequencies will also be constant in successive generations. The Hardy-Weinberg law makes use of a formula derived from the F2 results of a monohybrid cross. Recall that when Mendel crossed a smooth seed with a wrinkled seed, he found the following results in the F2:

$$RR + Rr + rr$$

Algebraically, RR is R^2 and rr is r^2. Using these expressions we get the formula: $R^2 + 2Rr + r^2$. This represents the frequency of the genes and genotypes in a stable population. "R" and °r" are gene frequencies, R^2, 2Rr, and r^2 are the frequencies of the phenotypes.

Let us examine a gene pool in which the gene frequencies are p(R) = 0.8 and q(r) = 0.2. These, in the absence of selective advantage of one generation type over another and of mutation, are also the gametic frequencies. The genotypic frequencies are readily obtained from the following table:

		Ova	
		R=0.8	r=0.2
Sperm	R=0.8	RR 0.64	Rr 0.16
	r=0.2	Rr 0.16	rr 0.04

The population thus consists of 64% RR's, 32% Rr's, and 4% rr's. As long as the population is not disturbed, the gene frequency will remain constant.

Before Viewing

Review the principles of inheritance as revealed by Mendel. Refresh the students' memories by citing examples of monohybrid crosses. A review of the binomial expression would also enhance the value of the Hardy-Weinberg law.

After Viewing

During the Industrial Revolution in England, the soot particles in the air and the pollutant-laden rains changed the color of tree trunks. This change in color was to have an influence on the color of certain populations of moths. H.B. Kettlewell felt he had gathered direct evidence to support the idea of natural selection. He had shown that the genetic makeup of a population of living things can change under certain environmental conditions.

Discuss population genetics and the Hardy-Weinberg law by analyzing the story of the moths as described in H.B. Kettlewell, "Insect Survival and Selection for Patter" *(Science 148:1290-96, 1965)* or in the BSCS biology texts.

ACTIVITY 1: Why Are Some *Pea Seeds Wrinkled and Some Not?*

Mendel discovered that the shape of pea seeds is under genetic control. Plants with genes for wrinkled seeds always produced offspring with wrinkled seeds, and plants with genes for smooth seeds always produced offspring with smooth seeds. How then does the gene affect the seed coat to cause it to be wrinkled or smooth? After completing this investigation, students should be able to explain how the variation between round and wrinkled peas is the result of differences in the molecular activity of enzymes. Students should also have a better idea of how genes exert their influence in determining characteristics of individuals. This investigation is found in Biological *Science -A Molecular Approach,* 4th ed. Investigation 14-A, *pp.634-636.* (see Further Reading)

ACTIVITY 2: Inheritance of Traits in Fruit Flies)

This activity will demonstrate how the wing shape trait is inherited in fruit flies. Having completed this activity, students should be able to distinguish between male and female fruit flies, describe the differences between fruit flies showing normal and vestigial wings, trace the life cycle of a fruit fly, tell which trait is recessive and explain the ratio of each type of offspring resulting in each generation. The investigation may be found in Biology, *The Science of Life*, Investigation *10-1, pp.276-281.* Further investigations with Drosphilia maybe found in Biological Science *-A Molecular Approach,* 4th ed. Investigation *13-B, p.630* (see Further Reading).

ACTIVITY 3: Random Selection in a Large Population

Upon completion of this activity, students should be able to explain how a population's genetic makeup remains constant if no external forces are involved. This activity is in the form of a game.

There are 120 cards (similar to playing cards) representing genes for color in an insect. There are 60 light gene cards (recessive) and *60* dark gene cards (dominant). Another 20 cards are marked "eaten by birds" and 10 cards are marked "escaped from birds." Shuffle *30* light and *30* dark cards and give each student a pair of cards. Record the number of dark insects and light insects on the chalkboard. Shuffle the cards marked "eaten by birds" and "escaped from birds" together and deal one card to each student. Since it is assumed that the birds show no preference in color of insects eaten, this is called "random selection." During Summer 1 only those insects with escape cards live to reproduce and donate genes to the next generation. Those insects that receive eaten cards do not reproduce, and their genes are removed from the population. Record the number of dark and light insects that escape as well as the number of dark and light alleles that remained in the population during Summer 1. Collect the cards and make up a new set of *60* cards, having a dark-to-light ratio identical to the ratio of dark-to-light alleles that were retained the previous summer. The game continues for four or five summers.

Sample Results

	Summer 1		Summer 2		Summer 3		Summer 4	
	Dark	Light	Dark	Light	Dark	Light	Dark	Light
Number of insects that begin summer	21	9	20	10	22	8	19	11
Number of insects that live to reproduce	7	3	8	2	7	3	8	2
Number of genes that may be reproduced	9	11	10	10	8	12	11	9

Questions

1. What determines the selection of insects to be eaten?

2. What happened to the ratio of dark to light insects between Summer 1 and Summer 5?

3. What happened to the ratio of dark to light alleles in the population during the five summers?

4. Predict what might happen to the color composition of the population over the next 20 years.

For further details refer to *Interaction of Man and the Biosphere - Inquiry in Life Science,* Investigation 12.3, p.321. You may wish to use Investigation 12.4, Nonrandom Selection in a Large Population, as a follow-up. (see Further Reading)

ACTIVITY 4: Review

Have your students do the following activities.

1. With specific reference to Mendel's experiments with the seeds of pea plants, describe how characteristics are preserved from generation to generation.

2. State the Hardy-Weinberg law. What is its significance in evolutionary theory?

Hardy-Weinberg Law

$$p^2 + 2(pq) + q^2 = 1$$

PROGRAM 4 /The Meiotic Mix

Objectives

Students should be able to do the following:

1. Describe the process of mitosis.
2. Describe the process of meiosis.
3. Explain the significance of melosis.
4. Describe the process of crossing over.
5. State why the potential genotypes in the human are so great.
6. Identify the genetic material found in chromosomes.

Program Description

Mendel demonstrated through his experiments with pea plants that individual characteristics were not blended but survived from generation to generation. He explained how a particular phenotype could suddenly reappear in a population, the specific gene forthat phenotype having been masked in previous generations.

Once in a while a gene will produce a different phenotype and due to some change in the environment, this particular variation may be favored over another. As a result, natural selection acting on this specific phenotype could bring about evolution of the species.

In the early part of the twentieth century, biologists discovered that chromosomes contained specific genetic information that determined the function and appearance of an organism. They observed that in order for two nuclei derived from one nucleus in the parent cell to contain the same quantity and quality of chromosomes as the parent, each of the original chromosomes had to replicate itself. The chromosomes would then line up along the centre of the cell; each half of the chromosomes would be pulled to opposites ends of the cell and the cytoplasm would divide into two new cells. As a result, two daughter cells are produced, each identical to the parent cell. The name given to this process is mitosis. The replication of chromosomes and the equal separation of these duplicated chromosomes into the daughter cells are the key features of mitosis. The chromosomes provide a "blueprint" for the proper functioning of the cell, and therefore, forthe whole organism. However, while continuity is guaranteed, the process of mitosis does not explain variability.

It was nature's invention of sexual reproduction that enabled organisms to generate variability. When two gametes fuse during fertilization, each parent contributes one member of each pair of chromosomes to the offspring. As a result of mitosis and cell division, all cells, except the gametes of an individual, contain the same amount of genetic material. These cells are said to contain the diploid number (2N) of chromosomes. If gametes were each to contain 2N chromosomes, upon fusion of the two gametes (egg and sperm) to form a zygote, the zygote would contain 4N chromosomes and each cell derived from it would contain 4N-an abnormal amount. Therefore, if sexual reproduction is to be successful, the number of chromosomes must be halved by a special type of nuclear division known as meiosis. When the now haploid (N) egg combines with the haploid (N) sperm, the diploid number (2N) of chromosomes is restored, with chromosomes from each parent. The stages of meiosis (as well as crossing over) are illustrated in Figure 4-1 on the following page.

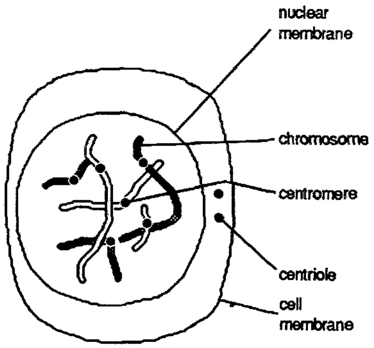
Meiosis selects chromosomes by random assortment. If we considerthe number of chromosomes in the human gamete - 23, due to random assortment there are 2^{23}, or in excess of eight million possible combinations of chromosomes in each gamete. Crossing over, the exchange of sections of genetic material between members of homologous pairs of chromosomes, leads to an even greater variability in the possible gene combinations of a gamete. The potential diversity of human genotypes becomes so enormous that it exceeds the total number of molecules in the universe. Crossing over, coupled with random assortment, produces an astronomical number of potential genotypes.

Although Darwin was not aware of meiosis at the time, he realized that some mechanism must be present to account for the countless variations, thus giving rise to the evolution of a new species.

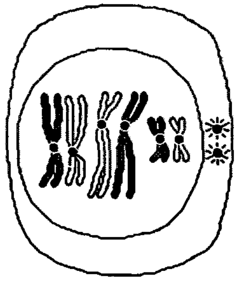
In 1953 Watson and Crick reported that variability was due to the genetic material, DNA, within the chromosomes. The DNA double helix molecule resembles a spiral ladder, the rungs composed of four nitrogenous bases, adenine, thymine, guanine, and cytosine, that are bonded together in varying sequences to form the genetic code. During both mitosis and meiosis, the DNA molecule unzips, each strand rebuilding its

Figure 4-1

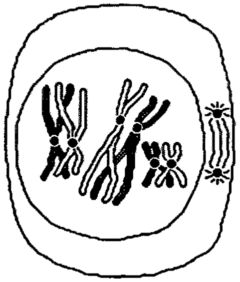
Meiosis



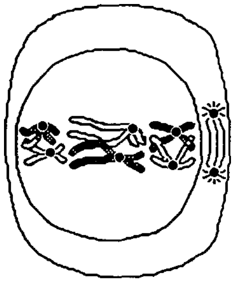
a) The diploid number of chromosomes



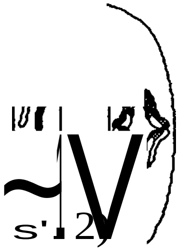
b) Replication and pairing of homologous chromosomes



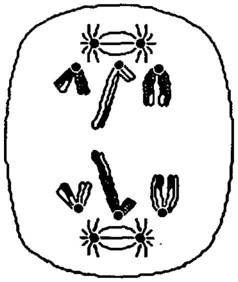
c) Crossing over has occurred



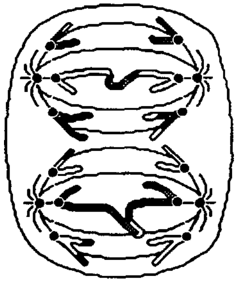
d) Chromosomes align along centre of cell



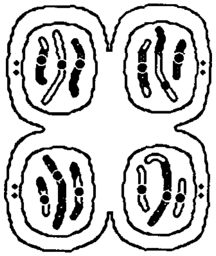
e) Spindle formation homologous chromosomes move to opposite ends of the **cell**



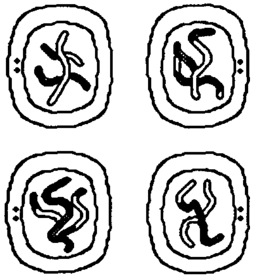
f) Homologous chromosomes are separated



g) Chromatids are pulled to opposite ends



h) Four nuclei appear, each enclosing the haploid number of chromosomes



i) Cytoplasm divides to form four daughter **cells**

organism. This DNA replication is the foundation of meiosis- a way of reshuffling genes to produce constant variation.

Before Viewing

Review the processes of mitosis and meiosis. This program briefly mentions mitosis and emphasizes the fact that meiosis is the foundation of genetic variability.

After Viewing

Discuss the process of meiosis emphasizing the two main ideas: random assortment and crossing over. These two factors (as well as mutation) are the key to genetic variation. Refer to Figure 4-2 for a more detailed picture of crossing over on the following page.

ACTIVITY 1: The Site of Genetic Material

In order to see chromosomes within the nucleus of a cell, the cell must be treated and stained. The chromosomes will take on the stain only if the cell is undergoing cell division. Such cells are to be found near the tips of young growing roots. Bean or onion root tips are suitable forthis activity.

Method:

1. Collect in a "test tube four bean or onion root tips and soak them in acetic alcohol for four hours. This "fixes" the cells.

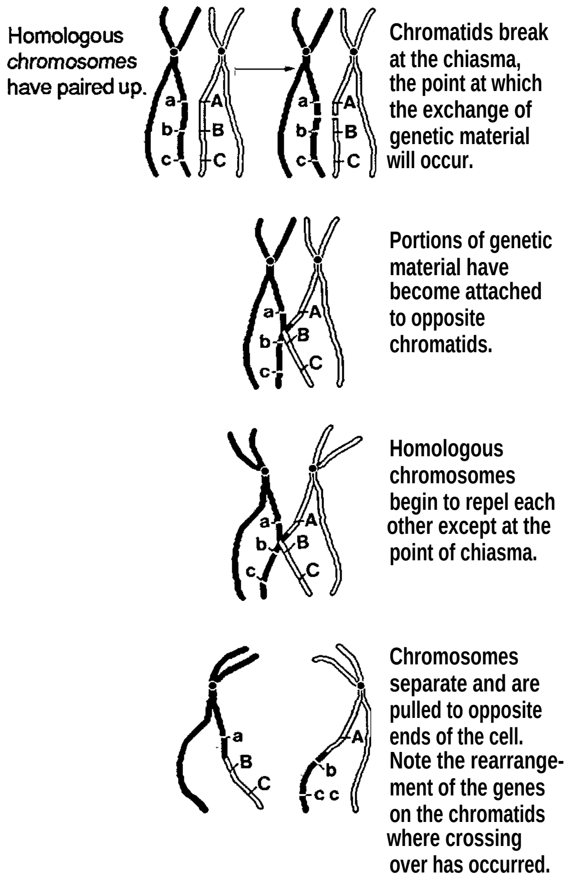
2. Wash root tips thoroughly in water, transfer them to a small test tube and cover with dilute hydrochloric acid. Place the test tube in a water bath at 60°C for exactly six minutes.

3. Carefully transfer root tips to a second small test tube, cover with Feulgen's reagent and set aside for one hour in darkness. This stains the roots red.

4. Then cut 2 mm from the end of each root tip, place on separate slides and add one drop of 45% ethanoic acid to each slide. Then thoroughly squash each root tip with the flattened end of a glass rod.

Figure 42

Crossing Over



5. Place a cover slip over each preparation, warm briefly over a small flame. Squash material by gently pressing the slide between folds of papertissue.

6. Examine each slide under the high power objective of the microscope.

The threadlike structures inside the nuclei are the chromosomes. Have the students draw the cells showing the stages of mitosis.

ACTIVITY 2: Meiosis

To see chromosomes in meiosis, choose immature flowers that are higher up on the stalk rather than the ones in which the anthers are beginning to turn yellow. Dissect out the inflorescences, fixing them immediately in Clarke's fluid (25 ml glacial acetic [ethanoic] acid, 25 ml ethanol) for 24 hours.

Method

1. Dissect out the anthers, place them on a watch glass and cover them with nine drops of acetic orcein and one drop dilute hydrochloric acid.

2. Gently heat the watch glass until mist rises from the stain, but do not boil.

3. Leave the watch glass covered for at least five minutes.

4. Place anthers on separate slides. Add one drop of 45% ethanoic acid. Place a cover slip over each preparation, press gently on coverslip with the flattened end of a glass rod.

5. Observe under high power objective of the microscope. Have students draw the different stages of meiosis.

ACTIVITY 3: Observing Chromosomes in the Salivary Glands of Fruit Fly Larvae

The salivary gland chromosomes of the fruit fly are very enlarged and can be observed with classroom microscopes underthe high power objective. If you are planning to do the activity for Program 3 dealing with fruit flies, you should have a good stock of fruit fly larvae at this time. This activity may be found in Biology, *The Science of Life,* Teacher Ed., p.T92 (see Further Reading). When the procedure is completed, the students will be able to observe banding within the chromosome. Doing the demonstration is worthwhile because it clarifies some of the abstract character of the chromosomes that may exist in the minds of your students.

ACTIVITY 4: Law of Independent Assortment

This activity allows the student to use homemade chromosomes to aid in the understanding of independent assortment. Using the homemade chromosomes, the students will follow pea plant genes through the process of meiosis. By comparing class results, the students will be able to draw some important conclusions about independent or random assortment. Although this activity is very simple, it is fun. It may be found in *Discovering* Biological *Science,* Activity 30.4, p.441 (see Further Reading).

ACTIVITY 5: DNA and Inherited Traits

This investigation is a dry lab. An excellent example of the use of logic and the scientific method to solve a problem, this investigation enables student to see how the hypothesis concerning the role of DNA in inherited traits was developed. When the students have completed the activity, they should be able to:

- describe the difference between bacteria that cause pneumonia and bacteria that do not;
- describe part of an experiment that demonstrates that the presence or absence of a capsule is an inherited trait;
- provide a hypothesis to explain how the offspring of pneumonia bacteria without capsules developed capsules. This activity is found in Biology, *The Science of Life,* Investigation 10-2, p.285 (see Further Reading).

ACTIVITY 6: Review

Ask your students the following questions:

1. How does the pattern of inheritance help you to understand the mechanism of evolution?

2. Should the knowledge that you have now concerning inheritance lead you to renounce Lamarck's theory, i.e., that stretching the neck in the *giraffe* could affect the DNA of the gametes, thereby affecting later generations? State your reasons.

3. Once in awhile, during meiosis, the chromosomes fail to separate properly and the gamete so formed contains the diploid number of chromosomes. If such a diploid sperm were to fertilize a haploid ovum, a) what effect would you expect this to have on the zygote and offspring and, b) if the zygote grew into a normal individual, what might happen when the individual produced gametes by meiosis?

4. A horse and donkey when mated produce a mule that is healthy but sterile. With specific reference to chromosomes and meiosis, suggest an explanation for this phenomenon.

5. A short-wing, grey-bodied Drosophila is crossed with a normal-winged, black-bodied Drosophila. A short-winged, black-bodied offspring is produced. Explain how this could happen if a) the genes for body color and wing size are on different chromosomes, and b) if these genes are on the same chromosomes.

PROGRAM 5 /The Population Picture

Objectives

Students should be able to do the following:

1. Explain the gene pool concept.
2. Define organic evolution.
3. State that selection and survival factors can afterthe expected gene frequency distribution in a population.
4. Explain what is meant by sexual selection.
5. Describe how divergence leads to speciation.
6. Use the laws of probability to predict the likelihood of the occurrence of a particular event.

Program Description

The population represents an immense gene pool, an enormous reservoir of genetic variation. As individuals die, their genes leave the pool; as they reproduce, new combinations of their genes are added to the pool. Evolution consists of overall changes in the frequencies of genes in the population pool. According to the Hardy-Weinberg law, the population of alleles should remain constant in the population generation after generation. If for some reason the Hardy-Weinberg law fails, it must be due to some internal or external force that has disrupted the stability of the gene pool. For example, if a particulartraft such as fleetness of foot is favored, the individual possessing it lives to pass on his attributes, i.e., the allele for fleetness gains a larger constituency in the gene pool. A change in the frequency of various alleles in the population is termed organic *evolution.*

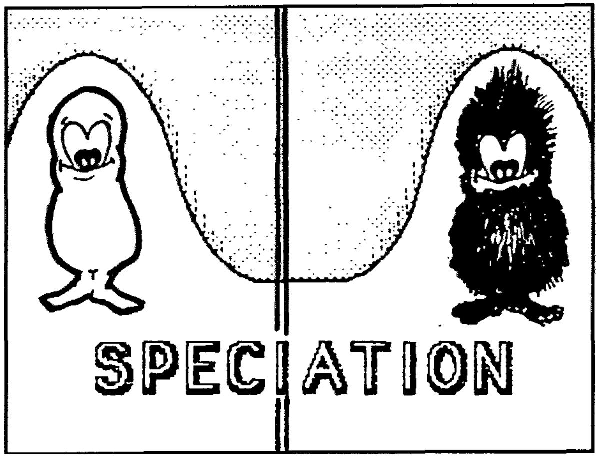
Gene frequencies are said to be in equilibrium when they remain constant from generation to generation. Such equilibrium under random breeding and free from disturbing forces implies that genotypic frequencies will also be constant in future generations. But this equilibrium can be distributed by what Darwin referred to as sexual *selection.*

There are well- established behavior patterns of courtship and mating in many species. The individual who displays a more vigorous courtship may confer selective advantages and donate a greater share of his genes to the gene pool. This success has been termed survival of *the fittest.* But natural selection tends to favor the average and removes the extremes. Species tend to be very stable. Natural selection fine tunes the population according to environmental conditions.

As there is a "struggle for survival," the environmental factors such as climate, food, disease, and predators will determine which particular varieties of the organisms of a population will survive to reproduce. In this competition, individuals with certain characteristics will more often survive to have offspring than the individuals without these valuable traits. If selection is of the stabilizing kind, an equilibrium may still persist. Under directional selection this would not be the case. At some point, natural selection may favor one extreme and the frequency of the allele that conferred the selective advantage would increase. Over time the population would shift in one direction.

Natural selection may also split a population into two directions -this is called *disruptive selection.* As time goes on, each pool evolves in response to its environment. Eventually the two groups have their own set of traits. If the two groups were brought back together, they could still interbreed to produce fertile offspring and thus would be considered one sexually reproductive species. But if isolation persists and further changes occur, eventually the two groups would not be able to interbreed at all, even if they could get together. At this point the two groups have become separate species.

Evolution of a new species is called *speciation.* Speciation occurs as a result of geographic isolation and the evolution of separate gene pools in response to their own environments. Speciation usually results from divergence. In the reproduction of small populations, chance alone can play a significant role in determining the gene pool. The equilibrium of the genetic pool can be



changed by chance processes rather than by natural selection. When the population multiplies, certain genes may appear more often, others may appear much less often until they eventually disappear altogether. This phenomenon is known as *random genetic drift.*

Although meiosis is constantly shuffling and reshuffling genes, this process alone cannot account forthe progression of a species from a lowerform to a more highly-developed individual. As you will observe in Program 6, mutation is also a prime source of variation.

Before Viewing

Review the principles set forth by Hardy and Weinberg before viewing the program.

After Viewing

Follow up the ideas of geological disruption by working through the following problem: A canyon in North America separates two demes of a species of chipmunk (Species A). The chipmunks on the north side of the canyon are adapted to life in a forest. The deme of chipmunks on the south side is adapted to desert life. Another species of chipmunk (Species B) is adapted **only** to the desert.

1. Which species probably has the greater number of genetic variations?
2. Describe the probable genetic variations of this species.
3. Which species has the greater gene flow? What is the effect of this on the population?
4. Which species is better protected against environmental change? Explain why.
5. Which species demonstrates the better traits for survival? Explain why.

ACTIVITY 1: Is "Different" Better?

In this investigation the students examine data dealing with humans, the seeds of a plant and the finches of the Galapagos Islands. The students compare variations within each of the areas, measure the variations, and graph the data. The usefulness of such data in supporting hypotheses about how species are formed should be discussed.

Materials

ruler

25 cm of string

graph paper

10 bean seeds

Design (Part A)

Eye See!

Tie a knot 5 cm from the end of the string. Hold the string across the bridge of your partner's nose and position the knot exactly at the outer corner of one eye. Extend the string to the outer comer of the other eye. Mark the string at that point. Measure the distance between the knot and the mark to the nearest millimetre and record the information. Your partner now repeats the procedure on you, measuring your eye-width.

Interpreting the Data

1. Collect the data from the entire class and arrange all of the eye-width measurements in a table. Make your table similar to the following one, substituting eye-width measurements for height measurements. Determine the smallest and the greatest eye-width measurements in the class. The table of heights of Canadian men uses intervals of 2 cm. In your eye-width table, use intervals of 3 mm. Suppose that 98 mm and 101 mm are two columns in your table. To which would you assign a measurement of 100 mm?
2. Prepare a graph of these eye-width measurements. Record the range of measurements, from the smallest to the greatest, on the horizontal axis. Record the number of individuals per 3 mm interval on the vertical axis. Examine the axes of the graph of heights of Canadian men. Plot your data for eye-widths. Connect the plot-points with a series of straight lines, in what is called a straight-line graph. Now, note the smooth curve of the graph of heights of Canadian men. How does it differ from your straight-line

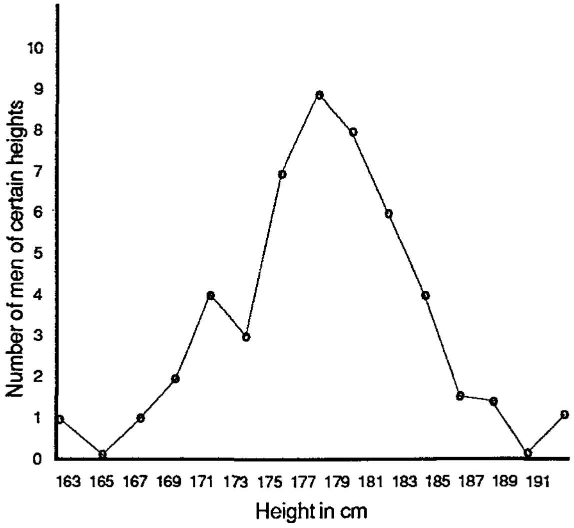
graph? Your plot-points for eye-width should enable you to draw, free-hand, a similar curve.

Height of 50 Canadian Men (All Heights to the Nearest 2 cm)

Height in cm	163	165	167	169	171	173	175	177	179	181	183	185	187	189	191
Number of men	1	0	1	2	4	3	7	9	8	6	4	2	2	0	1

3. An optometrist measures the width of your eyes before he fits you with glasses. Suppose that all of the thousands of measurements of eye-width that have been made by Canadian optometrists were plotted on a graph similar to the one you have made for your class data. Would the general shape of the optometrists' graph be more like the straight-line graph or the smooth curve? Explain your answer and describe one advantage of using a large number of measurements.

Height Distribution of 50 Canadian Men



Design (Part B)

Alike as Peas in a Pod

Obtain 10 dry bean seeds (e.g., lima bean seeds) and place each one on a small square of paper. Number the squares of paperfrom 1 to 10. Record in a table the length of each seed, to the nearest millimetre. Identify each seed in your table by its number.

Determine the greatest and smallest measurements recorded in the class. Select a suitable interval of measurement and label a set of jars for the whole range of measurements. Sort the seeds into the jars according to length. Count the seeds in each jar and record this information in a table.

Interpreting the Data

4. Prepare a graph of the seed measurements. What descriptive labels will you put on the horizontal axis and the vertical axis? Draw a straight-line graph connecting all of the points. Draw a smooth curve, free-hand.

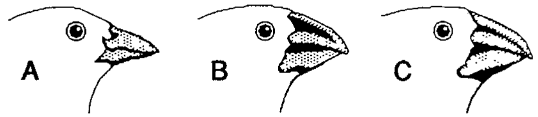
5. Compare your graphs for Part A and Part B. In which of them-the one for eye-width or the one for seed- length - is there less difference between the smooth curve and the straight-line graph? Account for your answer.

6. Which seeds contain the most stored food? Would this variation be advantageous to the embryonic plants inside such seeds? Explain your answer.

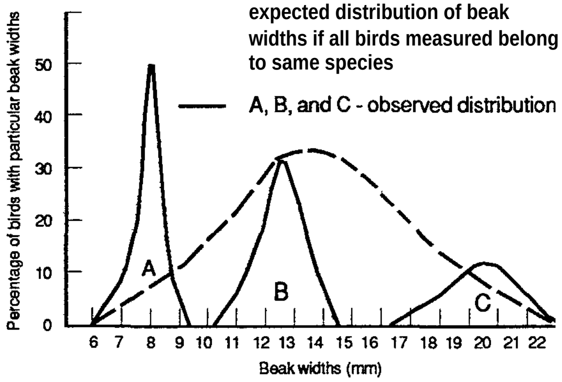
Design (Part C)

Every Finch Has its Beak!

imagine that you have been given an opportunity to go to the Galapagos to study variation in Darwin's finches. Soon after arrival, you spot three ground finches (see below?). The three birds are identical in plumage. Their bills vary considerably in size and shape. Are these three ground finches members of the same species? One way of tackling this question would be to examine the shape of the beaks of a large number of birds. From your experience with eye-width and seed-length measurements, you would expect the beak-measurement data to provide a bell-shaped curve. Many characteristics of a species provide such a curve when large numbers of individuals are examined.



Beak Widths in Darwin's Finches: Identical Birds or Different Species



The finches of the Galapagos have been attracting the attention of biology students ever since Darwin's visit, and in 1939 the English biologist David Lack went to the islands to study variation in the birds. He collected data on the size of the beaks of many ground finches like those illustrated. When he made a graph of a large number of measurements, instead of getting a bell-shaped curve he got three distinct bell-shaped curves that did not overlap.

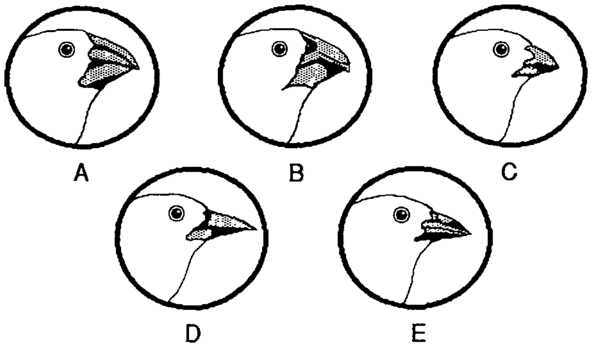
What did this mean? Lack wondered whether it might mean that there were three distinct species, rather than a single one with a variable beak-size. To determine that, Lack would have to collect other data about the finches. Suggest what other studies would be necessary.

Now, focus your attention on the variation in beak-size in finches, and its possible significance. Some data about the sizes and shapes of the beaks of other finches is given in this table:

A COMPARISON OF DARWIN'S FINCHES (BASED ON DATA GATHERED BY DAVID LACK)

Group name	Chief food	Comments
A. Ground finches	Seeds	Four types that differ in size and habit
B. Vegetarian finches	Fleshy part of cactus, buds, leaves, fruit	Parrot-like bills, feed on cacti or trees
C. Insectivorous tree finches	Insects	Feed on insects found in trees
D. Insectivorous ground finches	Insects	Warbler-like, search ground vegetation for insects
E. Woodpecker finches	Insects from under the bark of tree cacti	Lack the long tongue of the woodpecker; use cactus spine to probe trunk for insects under the bark

Predominant beak-shape



Interpreting the Data

7. Explain why Lack's data on variations in beak-size enabled him to hypothesize that there are three distinct species of ground finches.

8. Examine the data in the table on four distinct kinds of finches, and identify three obvious differences in beak-structure.

9. Note the diet of each group of finches. How are the structure of the beak and (perhaps) the feeding habits suited to the diet in each case?

10. One speculation about the origin of Darwin's finches is that a flock of finches reached the Galapagos from the mainland of South America a very long time ago - perhaps a million years or more.

Answer the following questions with speculations.

a) What do you think such "ancestral" finches might have looked like?
b) Could the ancestral finches have been birds of various species that arrived on the islands at different times? Explain your answer.
c) Assume that a single small flock of colonizers did give rise to the 14 different species that now exist on the islands. Forthis to occur, how important would be the fact that the Galapagos consists of many small islands and not just one large one?
d) How important would it be to the colonizers to arrive on the islands at a time when there were:
    i) no other species with exactly the same requirements,
    ii) few or no predators, and
    iii) no parasites that could use the finches as host organisms?

Explain your answers.

This activity can be found in *Understanding Living Things,* Section 12.6, p.405 ©Copyright 1977 by D.C. Heath & Co. (see Further Reading). Reprinted with permission.

ACTIVITY 2: Changing Gene Frequencies in a Population by Genetic Drift

Any force that disrupts the stability of a gene pool is an evolutionary factor. In this activity the specific factor that will alter the frequencies of genes in a population is the size of the population. It is a very simple activity but the questions that arise from the exercise are excellent.

Purpose

One way in which the frequencies of genes in a population can be modified is by changing the size of the population. For example, if the number of rabbits in Australia were reduced from fifty million to forty million, the frequencies of all genes in the gene pool would be reduced by 20%. Such changes in the population are of little importance because, as is well known, rabbits could quickly replenish or even surpass the *lost* numbers and reconstruct the former gene pool.

A different kind of effect begins to appear, if one reduces a population to very small numbers. Then the relative frequencies, as well as the absolute frequencies, may be changed merely by chance. In the same way, if one flips a coin fifty million times, he will get very close to hall heads; but if he flips it only four times, he may very well get heads three or one out of four trials. When the population again multiplies, certain genes may be much less, others much more, frequent.

This phenomenon is known as *genetic* drift. It will be studied by means of the model gene pool.

Materials

(per team)

1 bag of 50 red beans
1 bag of 50 white beans
2 empty cans

Procedure

In this and several later studies we will utilize a model gene pool consisting of two colors of beans in a bag. Our population consists of some species of diploid organism. This organism, like ourselves, has paired chromosomes with two genes at each locus. The two genes may be the same or they may be alleles - alternate genes for the same position. In our model we shall study only one gene locus, and at that locus there are only two alleles - red and white.

We shall make the assumption that the organisms in our population, like ourselves, are cross-fertilizing and interbreed freely. These are important assumptions of the Hardy-Weinberg principle.

In the present investigation we shall produce small populations from a large parent population. Start by placing 50 white beans and 50 red beans in a bag. These are the parent population.

Then draw at random 20 beans from the bag and place them in an empty can. Draw 4 other beans and place them in the other empty can. The beans in these cans represent two small populations that are derived from the larger parent population.

Record your team's results in Table 1. Add the results of the other teams in your class.

Questions

1. According to the Hardy-Weinberg principle, what proportions of red and white beans would you expect in the derived populations?
2. How do the actual results compare with the expected results?
3. Do the results deviate less if you average the results of all teams?
4. In which of the derived populations do the results more nearly approach the expected proportions, the 20 bean or the 4 bean population?
5. How do you explain the deviation of your results from the expected results?
6. Is it possible by reproducing rapidly, that one of the small derived populations could produce another large population in a single genera-

Table 1
Results of Genetic Drift Study

LARGE POPULATION		SMALL POPULATION			
100 GENES		20 GENES		4 GENES	
Red	White	Red	White	Red	White
50	50				

tion? How would the large third generation population differ from the large parental population?

7. In what natural situations might a population undergo similar fluctuations?

8. What precautions did you take to insure that the derived populations were produced randomly?

This activity is found in BSCS ***BiologyLab Block, Evolution,*** Investigation 1, p.1 (see Further Reading). Reprinted by permission of D.C. Heath & Co.

ACTIVITY 3:

a) A Population Model

This exercise provides students with an opportunity to compare the mathematical results of the Hardy- Weinberg formula with the results of a population model activity. The taster versus nontaster trait is considered.

In this investigation you will compare genotype frequencies for two generations in a model population.

Materials

(per team)

paper
pencil
100 red and 100 white beads of uniform size
string
box
calculator, if available

Procedure

1. Use red beads to represent the T(taster) allele and white to designate the t(nontaster) allele.
2. Tie the beads together in 100 pairs to represent individuals:

   20 pairs of 2 red beads: homozygous tasters, TT;
   50 pairs of 1 red and 1 white: heterozygous tasters, Tt;
   30 pairs of 2 white beads: homozygous nontasters, ft.

3. Place these 100 pairs of beads in a box, mix them thoroughly, and have one person at a time withdraw, at random, two pairs of beads. Record each mating.
4. Assume that each pairof parents produces four offspring and that the genotypes of these four progeny are those that are ***theoretically*** possible in single gene pair inheritance. Tally the offspring from each of the 50 matings; then total the number of TT, Tt, and, tt offspring.
5. Calculate the genotypic frequencies of the offspring. (You will need these calculations to compare with your results in Activity 3b).)

Questions and Discussion

1. How do the genotypic frequencies of the offspring in your matings compare with the genotypic frequencies of the parents? Explain your results.
2. The Hardy-Weinberg formula is a theoretical model that works if a population fulfills two criteria. These were met in the model population you have just studied. What are these criteria, and how are they related to natural selection? (You may want to use a specific example such as the sickling cell when you considerthis question.)
3. Why is a theoretical model, such as the Hardy-Weinberg formula, an important tool in **biology?**

b) Selection

This investigation takes a look at what would happen to the frequencies of tasters and nontasters if individuals with one or the other gene had a survival advantage. This should be used as a follow-up to 3a) and a comparsion of the data should be made.

Assume an extreme hypothesis-individuals with the ttgenotype are also sterile.

Materials

(per team)

paper
pencil
200 red beads and 100 white beads of the same size
string
box
calculator, if available

Procedure

1. Begin, as you did in Activity 3a), with initial genotype frequencies of 20 TT, 50 Tt, and 30 **tt (**G0 original generation). Calculate gene frequencies in the reproductive gene pool for the next generation (G1) using the Hardy-Weinberg checkerboard and a table like Table 2. Rememberthat tt individuals are sterile.

2. Represent the original generation (G_0) as follows:

20 pairs of red beads- TT
50 pairs of 1 red and 1 white bead - Tt
30 pairs of white beads- tt

3. Place 100 pairs in a box, mix them thoroughly, and have one person at a time withdraw, at random, two pairs of beads to represent a mating. Record all matings.

4. Assume that each pair of *fertile* parents produces four offspring, and the genotypes of these four progeny are those that are theoretically possible in single gene pair inheritance. (Fertile pairs are TTx TT, TTx Tt, and Ttx Tt, all other pairs are sterile.)

Calculate gene and genotype frequencies for the offspring and set up a table like Table 2.

5. Using the frequencies you determined in step 4, set up 100 bead pairs to represent the second generation (G_1).

6. Repeat steps 3 through 5 until you have data for 5 generations (G_0 through G_4).

Table 2
PTC Gene Frequencies

GENOTYPE	NUMBER	GENES	TOTAL OF GENE TYPE	% OF TOTAL GENES	GENE FREQUENCY
TT	20	40*T*	90	45	*T*=0.45
Tt	50	50*T* 50*t*			
tt	30	60*t*	110	55	*t*=0.55

Questions and Discussion

How do your calculations (step 1) for the second generation (G_1) compare with your sampling results for G1

2. What is happening to the frequency of the recessive gene? In which genotype in G4 are most of the recessive genes found? How does this compare with G_0?

3. Compare your data from Activity 3a) with those from this investigation. Is selection alone enough to explain the differences? Explain your answer.

4. Even under extreme selection, can a recessive gene be eliminated from a gene pool?

Both activities are found in BSCS, Biological *Science, Interaction of Experiments and Ideas,* Investigations 11-11 and 11-13. (See Further Reading.) Reprinted by permission of Prentice Hall Inc. and Biological Sciences Curriculum Study.

ACTIVITY 4: Review

Ask your students to do the following review activities.

1. Explain the gene pool concept.
2. Discuss the evolutionary factors that could upset the principles of the Hardy-Weinberg law.
3. Explain the origin of species by means of natural selection.

PROGRAM 6 */Mutation And All That*

Objectives

Students should be able to do the following:

1. Explain the significance of DNA.
2. Define the term mutation.
3. List some causes of mutations.
4. Recognize the fact that most mutations are harmful.
5. Explain the concepts of gradualism versus *punctuated equilibrium.*

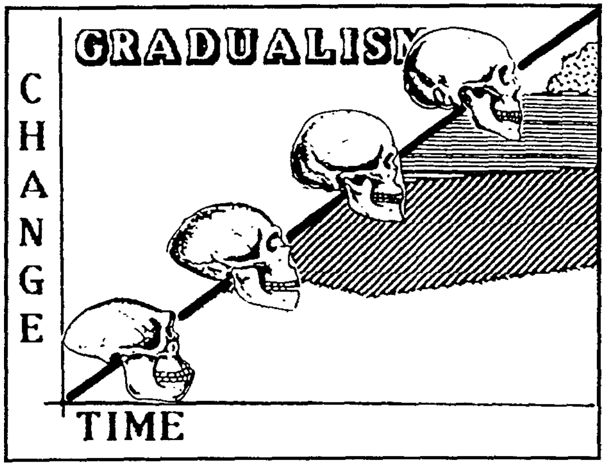
Program Description

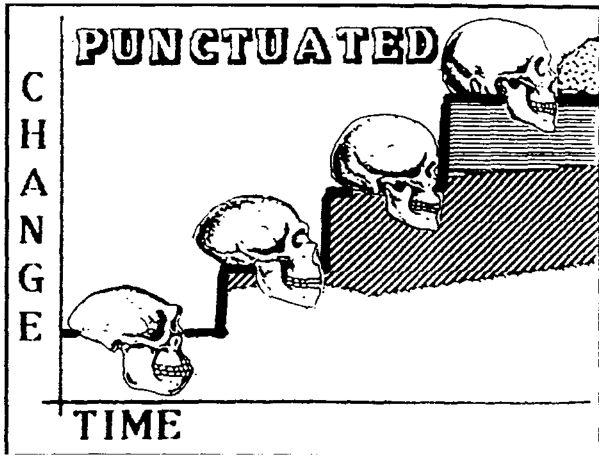
It is the recombination of genes that continually creates new phenotypes. Nature then selects which organisms will survive and thrive and which will eventually become extinct. We have already learned that meiosis reshuffles genes and sorts them into new combinations and thus causes variation. But the prime source of variation among members of a population is mutation.

The DNA molecule is made up of a sequence of bases that form the genetic code. During protein synthesis the code is transferred to a messenger RNA and carried to the ribosome where amino acids are linked up in proper sequence to form a specific protein. The amino acids are the building blocks of proteins and proteins are the critical molecules that determine the form and function of the organism. Thus, one could say that the DNA code is the essence of life. But genes can change as a result of errors in the replication of the DNA. Short wave ionization can alter the DNA and ultraviolet light can break the DNA strands. It is of obvious importance to assess the effect of an increase in radiation on the health of individuals and, as a result of mutations in their reproductive cells, the health of their offspring. Chemicals within the cells can mimic the bases and be substituted for the regular base pairing, thus rendering the cell dysfunctional.

A mutation occurring in a gamete can affect the entire organism arising from this cell. Since the mutant form of the gene is inherited, the mutation will persist in subsequent generations. In this way wholly new evolutionary "ideas" are introduced into the gene pool occasionally. A mutation is defined as a spontaneous change in a gene or a chromosome that may produce an alteration in the characteristics under its control and be passed on to the offspring. Mutations may be considered beneficial if the result is advantageous to the offspring. But in most instances new mutations are harmful to the organisms in which they arise. This is because they are changes to a genetic makeup that has been refined by natural selection for a long time. The changes in living species take place over many millions of years and new species arise through the gradual accumulation of tiny advantageous modifications. Darwin termed this process gradualism.

But according to fossil evidence there were gaps and very little evidence of gradual change. Therefore, some biologists and paleontologists proposed a different view of evolutionary change that they called *punctuated equilibrium.* According to this view, new species do not arise gradually but appear by the development of major variations in a relatively short period of time. As a result, records show long periods of equilibrium or stability, punctuated by occasional major changes. However, the rate of mutation and the rate of evolution are still a subject of speculation.





Before Viewing

Review the DNA molecule and briefly discuss its structure, replication, the role of messenger RNA, the function of the ribosome, and the fact that amino acids are the building blocks of protein. The program makes considerable reference to the DNA molecule.

After Viewing

Students may have difficulty grasping the idea that most mutations are harmful. The program does stress that mutations are the source of new genes and new species. Therefore, how can mutations be harmful? Emphasize the fact that present-day plants and animals are highly specialized and well adapted to their environment. Further mutations are more likely to be disadvantageous than helpful.

ACTIVITY 1: Debates

Students could plan short debates on topics such as: the role of mutations and recombination in evolution, the significance of barriers in the formation of new species, random genetic drift and its effect on populations of organisms, the differences between natural selection and artificial selection, and the role of lethal mutations.

ACTIVITY 2: Changing Gene Frequencies in a Population by Mutation.

In this activity the students study the manner in which mutations can help produce evolutionary change. It is a simple but effective activity. The concepts derived from the exercise are very significant.

Procedure

In order to facilitate the procedure, we shall assume an unnaturally high mutation rate in our model gene pool. Let the red genes mutate to white at the rate of one mutation for every ten red genes each generation. And let one in every ten genes mutate to red in each generation.

Begin with a population of 50 red beans. Represent the passage of a generation by transferring the beans from one can to the other. For each generation replace every tenth red bean with a white bean. And when there are sufficient white beans, round the total to the nearest 10 and replace every tenth white bean with a red bean. Count the totals in each generation. Graph the changes that occur in each generation as mutations change the gene frequencies. See Figure 6-1. Stop when you reach an equilibrium between reds and whites.

In the great majority of instances new mutations are harmful to the organisms in which they arise. Let us suppose that the white mutants in this investigation are extremely disadvantageous and, therefore, each organism that possesses two genes dies before he can reproduce.

In our model this is accomplished by picking two beans at a time from the population just graphed. Each pair of beans represents a diploid individual organism. If you pick two white beans together, discard them. Place all the other pairs in a can. When you have finished, count the beans of each color and record the data for this generation on the appropriate graph. See Figure 6-2.

In the can you have just filled, let mutations occur; that is, replace every tenth red bean with a white bean and vice versa. Then again transfer the beans two at a time to another can, discarding the white pairs. Record the results after each generation on the graph. See Figure 6-2.

Carry this procedure on until the number of white beans stops decreasing.

Questions

1. Why do you suppose mutations are usually harmful?

2. How can mutant genes be maintained in a population when they are selectively destroyed?

3. Why are there more red-to-white mutations in an all-red population than in an even red-white population?

4. If two alleles occur at the same frequencies and mutate at the same rates, how can mutations change the gene pool?

5. What are the major roles of mutations in evolution?

6. What advantage might be attached to maintaining at low frequencies, genes that are generally harmful?

This activity may be found in BSCS, ***Biological Lab Block, Evolution,*** Investigation 4, p.6. (see Further Reading) Reprinted by permission of D.C. Heath & Co.

ACTIVITY 3: Review

Explain how knowledge of DNA and mutation aids in the understanding of the mechanism of evolution.

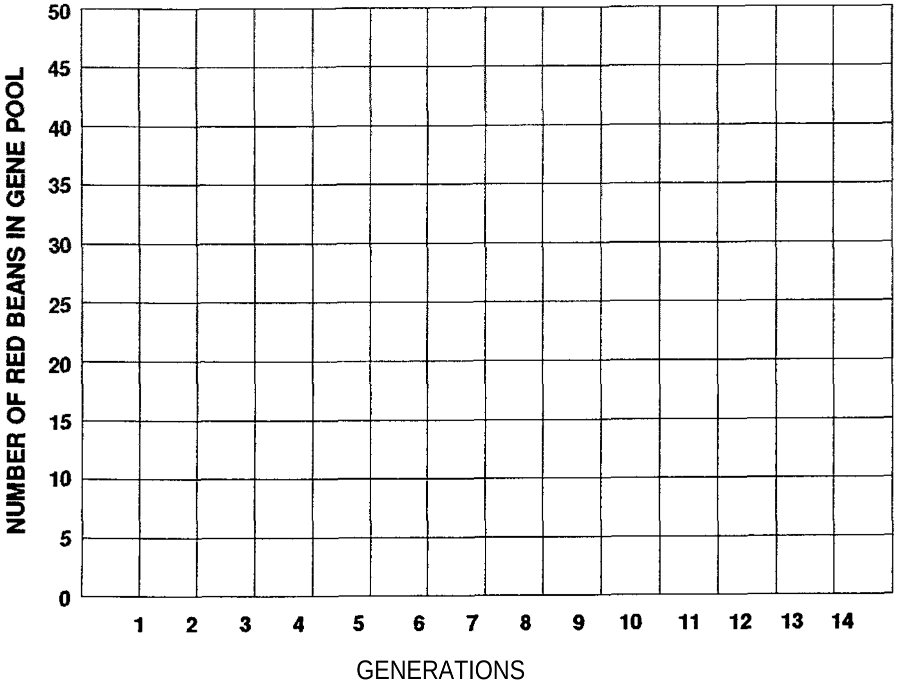


Figure 6-1 Changing gene frequencies due to mutations

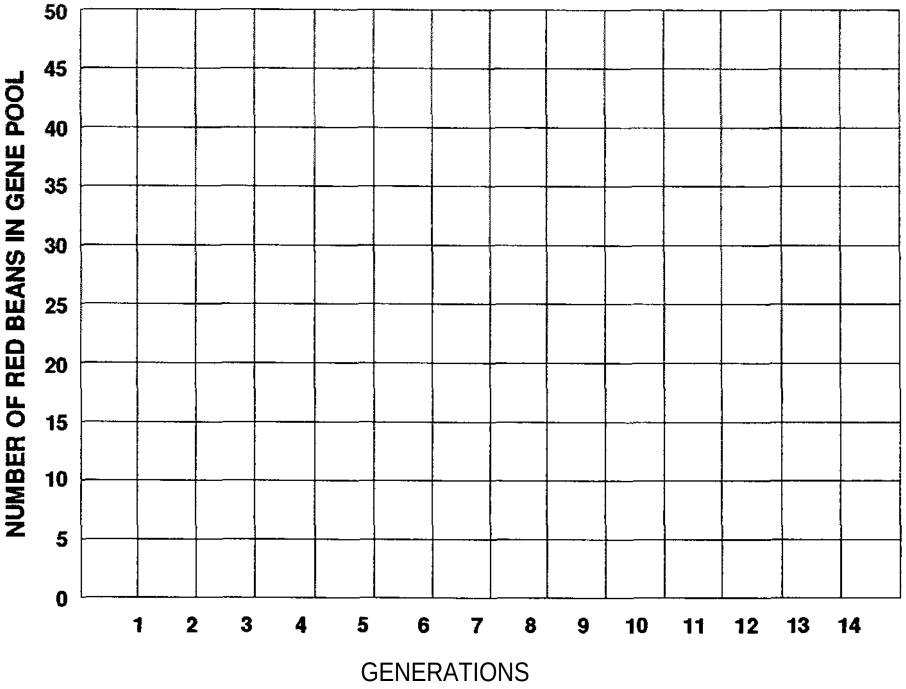


Figure 6-2 Changing gene frequencies due to mutations

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