Background

History

Thomas Hunt Morgan, who worked at Columbia University in the early 1900's, was the first researcher to use the fruit fly, *Drosophila melanogaster*, in the study of gene inheritance patterns. Fruit flies are tiny insects that feed on a fungus that grows on fruit, and they are an excellent species choice for the study of genetics. Their small size allows thousands of flies to be stored in a small space, and because they reproduce quickly, many generations can be grown and observed in relatively short time frames. Through his work Morgan identified 80 separate mutants and was the first person to demonstrate through experimentation, that one gene can be isolated to one chromosome. Morgan was awarded the Nobel Prize in 1933 for his work on fruit flies.

A gene is a sequence of DNA that encodes the information to make a protein and to determine how much of that protein will be made. The genetic sequence for a protein is called the genotype; the observed result, or the trait, is called the phenotype. Proteins have three major functions in cells: they provide structure, act as biological catalysts called enzymes and serve as hormones. Proteins in turn, confer human traits, or phenotypes. For example, keratin is the structural protein for hair. The chemical structure of keratin changes the shape of hair. Curly hair has a different chemical structure than straight hair.

Melanin is a pigment protein in skin and hair. If skin cells produce an abundance of melanin, the result is dark toned skin; if skin cells make less melanin the result is light-toned skin. If melanin is not produced, the result is a disorder called albinism (a total lack of melanin or pigment). Differences in traits are caused by changes in the genes that create these proteins. The genetic differences between people are referred to as genetic diversity or variability.

A change in the sequence of DNA, which encodes a gene, is called a mutation. Because a gene encodes the information for the production of a protein, a change in a gene may result in a change in the protein and therefore in the phenotype. A change in DNA results in a chemical re-arrangement of the DNA molecule. These changes occur specifically to the base pairs, re-arranging the nucleotides (adenine, thymine, guanine, and cytosine) or removing whole sequences. For the purpose of instruction it can be useful to compare DNA to a recipe. DNA contains the information for a trait. Thus it is expected that a change in the recipe will result in a change in the trait. However, not all mutations result in changes to traits. There are many mutations that are "silent." They have no effect upon the expression of a gene or upon a phenotype.

How do mutations occur?

Spontaneous mutations occur during DNA replication in the process of mitosis (cell division). There are enzymes in the cell that "proof-read" newly replicated DNA, but if they miss a change, this change gets incorporated into the DNA and will be maintained when the DNA is replicated in the future. There are many 'silent' mutations in DNA that do not have an effect on the health or the activity of the cell.

Mutations can also occur due to exposure to mutagens. Mutagens are substances that interact specifically with the DNA molecule and change the genetic sequence. Some mutagens are commonly known as carcinogens, substances that cause cancer. Ultra-violet radiation and smoking are both excellent examples of mutagens. Both of these interact with the DNA and can make changes to genes. It is known that both ultra-violet radiation and smoking can cause cancer.

Cancer is understood to be a genetic disease within the cell. Changes to genes with important replication or developmental functions in a cell have been implicated in the development and progression of cancer. This occurs when the genes that are supposed to control a cell's division are altered. Cancerous cells are typified by their inability to turn "off" their cell division stage. Normally a cell that is malfunctioning will destroy itself, but in this case the gene to instruct the cell to die is also mutated. The cell can no longer do the job it was meant for and it cannot destroy itself. It can only make more cells just like itself continuously. Cancer is also understood to be associated with an accumulation of mutations in the cell. That is, the cell requires a certain number of "hits", or changes to its genes, before it becomes cancerous. For this reason, exposure to mutagens increases the number of mutations in a cell and thereby increases the likelihood of a cell becoming cancerous. Therefore, exposure to a mutagen is a risk factor for the development of cancer.

The older a cell is, the greater the likelihood that it has accumulated mutations. Additionally, greater exposure to mutagens increases the likelihood that a cell will become cancerous. It is for these two reasons that older people have greater chances of developing cancer. However, it is important to note that mere exposure to a mutagen does not guarantee that a cell will become cancerous; rather, exposure increases the chances that enough mutations will be accumulated to result in a cell stuck in the "on" position. Cancer in humans is an excellent example of the harmful effects of mutagens. However, not all mutations are harmful, as will be discussed further.

Why Study Mutations?

The study of mutations is a tool used to explore the function of a gene. If a mutation in a gene elicits a phenotypic change, the function of the gene can be better understood. This is the case for all organisms, from bacteria to man, and is often an approach researchers use to determine a gene's function in a cell.

In humans, genetic mutations can often be associated with disease. For example, sickle cell anemia is a disease that results due to a mutation in a protein. Hemoglobin is the structural protein of red blood cells. The hemoglobin in red blood cells binds oxygen and carries it throughout the body. In the hemoglobin gene, a mutation that disrupts the shape of the protein changes the shape of the red blood cell from round to sickle. These hemoglobin molecules bind oxygen less favorably than normal hemoglobin does. This results in an anemic state. Also, the sickle shape of the red blood cell causes difficulties. Sickle cells do not move as easily through the veins and can accumulate at points inside the affected person. Sickle cell anemia provides an excellent example where a change in the hemoglobin gene results in a phenotypic change in cell shape and function. Understanding the function of healthy (or "wild-type") genes can help researchers to understand the mechanism of disease and develop potential treatments. This approach can lead to the use of gene therapy for genetic disease. Gene therapy is the use of healthy genes to treat an individual with a disease caused by mutation.

Mutations and Evolution

With the publication of "The Origin of Species" in 1859, Charles Darwin introduced his famous theory of Natural Selection. This theory was a result of observations he made on his famous trip on the HMS Beagle. He observed morphological differences between finches that lived on different islands in the Galapagos. Darwin hypothesized that the finches had originated from the same population and had spread out over numerous islands. Some birds developed physical traits, specifically distinct beak shapes, which gave them an advantage in their new habitats and made it easier for them to access food. Darwin suggested that these advantageous traits were passed on to the offspring and over the course of numerous generations the new trait became the predominant trait in the population

At the time that Darwin suggested his theory, DNA was not understood to be the basis of inheritance. However, it has been elucidated that changes in DNA, which underlie changes in morphology, are the mechanisms of evolution. Natural selection is a spontaneous event. An organism cannot make changes to its own DNA. Rather an existing change, which benefits an organism, will remain in the population and potentially become the predominant trait observed in that population. This process can also be referred to as "adaptation", not because the animal changes, but because, the animal has a trait that benefits it in the habitat where it lives and this trait may be "selected" for when it provides the animal with an advantage.

The long neck of the giraffe is an excellent example of natural selection. Giraffes with longer necks found it easier to access food. So long necked giraffes had a higher survival rate and thus more offspring.

Exploring Mutant Organisms

Description of Activity

This lesson is an introduction to the phenotypic effect of genetic mutations. In this 1-hour activity for children in grades 5-8, students have the opportunity to view mutant *Drosophila melanogaster* (fruit flies) using either stereomicroscopes or magnifying glasses. Discussion of observations can include the connection between genetic mutations, natural selection and genetic disease.

Learning Outcomes

Students will:

- observe the connection between genotype and phenotype.
- learn the life cycle of the fruit fly.
- view mutated fruit flies with the aid of microscopes (or magnifying glasses).
- describe and record the physical traits that were observed in fruit flies.
- realize the possible implications of genetic mutation, such as natural selection and genetic disease.

Assumptions of Prior Knowledge

Students should be familiar with the genetic code (A, T, G, and C) and should also know that a genetic mutation is the result of a change in the genetic code.

Misconceptions

Students might believe that all mutations have a negative affect and that these mutations are always inherited. They sometimes also believe that acquired traits (such as a mouse losing a tail in a mousetrap) can be inherited.
Students often have misconceptions about evolution and natural selection. For example, some believe that organisms can willingly change based on their surroundings, thus adapting to their environments.

Lesson

Materials and Equipment

- 15 Clear plastic petri plates
- Clear plastic tape
- 15 dissecting microscopes or magnifying glasses
- Wild-type fruit flies (*Drosophila melanogaster)*
- Mutant fruit flies (find mutations that are easy to see, such as eye color/shape, body color, wing shape)

Purchasing Information

- Assorted mutated and wild type fruit flies- Carolina Biological Supply Company
- Petri plates- VWR Scientific
- Dissecting microscopes – Leica

Before Class

- If you have purchased live flies, they will have to be anesthetized, transferred into clear petri plates using small paintbrushes and taped. Each plate should contain some wild-type flies, and a few of each mutant.
- Alternatively, if live flies are placed in the freezer, they will die and can be reused several times.
- Photocopy observation sheet for each student.

During Class

- Begin the lesson with an observation of the classroom population. Discuss how although we are all humans, we have physical traits that create variation within the population. Is variation a good thing?
- Ask students to guess what percent of one individual's genes are the same as another's. Surprisingly, the answer is 99.9% because we are all members of the same species! Only 0.1% of our genes account for the differences between individuals.
- Mutations, or changes in genes account for the variation in traits that we see today, as well as the differences we see between modern humans and our ancient ancestors. Show pictures or plastic molds of species such as *Homo erectus*. When an organism's DNA changes, its traits can change. Through natural selection, certain traits may be conserved, which can lead to the evolution of a species. If you have an Internet hook-up in the classroom, go to www.dnai.org >Applications> Human Origins and discuss the theory that all humans share a common ancestor.
- If time permits, students can also explore the connection between mutations and genetic disease at www.ygyh.org. Some mutations that cause disease are inherited and others are acquired through exposure to mutagens such as cigarette smoke or UV light.
- Explain that in this lab, they will observe the connection between mutations and changes in traits by observing fruit flies with mutations that were caused by exposure to radiation. Ask why a scientist

might want to mutate a fly, and discuss when in the life cycle this would be done (in the egg stage).
- Explain that fruit flies are a popular model organism in genetic research because they are genetically similar to humans (about 60% of their genes are the same as ours); they are easy to care for, have short life spans and reproduce quickly. A female fly can lay thousands of eggs in her short lifetime. A scientist named Thomas Hunt Morgan first observed fruit fly mutations. (www.dnai.org/timeline/index.html).
- Distribute laminated pictures of wild type and mutant flies. Review all of the traits that students will observe. Make sure to carefully observe the wild-type traits, as well as mutations.
- Demonstrate how to use a microscope or magnifying glass to observe the fruit flies, and remind the students how important it is to record the mutations they have observed.
- Distribute prepared petri plates and observation sheets. Give students at least 15 minutes to make their observations.

Analysis and Discussion

- Discuss students' observations. What mutations were seen? Which mutations might be beneficial or harmful to a fly, and why? What might happen to a fly with an extremely harmful mutation, or an extremely beneficial mutation? Make the connection to natural selection.
- A great example of natural selection and genetic disease is sickle cell anemia. Discuss how the sickle cell mutation actually confers resistance to malaria, but can also cause a debilitating blood disorder. It is believed that many of the mutations that cause disease in modern populations might have originally helped certain populations survive
- Discuss why many organisms today have the traits they do. Why to wild type fruit flies have brown bodies, and teardrop shaped wings? In a way, nature has chosen these traits because they increase chances of survival and reproduction.
- Discuss the breeding of animals for certain traits as an example of selection, but not by nature, by humans.

Further Explorations

Have students imagine alternative mutations in the fruit fly. The students will describe some advantages and/or disadvantage that these mutations may provide for the organisms.

To further explore human evolution, go to: http://www.dnai.org/teacherguide/guide.html.
You will see an activity called *Human Origins: The Prehistoric Race*. This is a printable board game, all about evolution and natural selection.

Students can research human conditions that are associated with genetic mutations on www.ygyh.org, and present their findings to the class.

Students can research Charles Darwin, and what he learned from his travels on the HMS Beagle.

Discuss or research why certain genetic disorders are more predominant in certain populations of people. For example, Tay-Sachs disease is found predominantly in people of Ashkenazi-Jewish descent, and Sickle Cell Anemia (and diseases like it) are found predominantly in people of African or Mediterranean descent.

Resources

Websites:

www.dnaftb.org
A Dolan DNA Learning Center Internet site.
This site is an on-line textbook with chapters ranging from inheritance to genetic engineering.

www.ygyh.org
A Dolan DNA Learning Center Internet site.
This site is a multimedia guide to 15 different genetic disorders.

www.dnai.org
A Dolan DNA Learning Center Internet site.
This site details the past, present and future of DNA science.

http://www.exploratorium.edu/exhibits/mutant_flies/mutant_flies.html
The Exploratorium's online exhibit, *Mutant Fruit Flies.*

Books:

From the Beginning, The Story of Human Evolution. David Peters. William Morrow and Co., 1991.

Gene Machines, Fran Balkwill and Mic Rolph. CSHL Press. 2002.

Have a Nice DNA, Fran Bilkwell and Mic Rolph. CSHL Press. 2002

Correlations

New York State
NYS Standard 4: Science
The Living Environment

- Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.
- Individual organisms and species change over time.
- The continuity of life is sustained through reproduction and development.
- Human decisions and activities have had a profound impact on the physical and living environment.

National
Content Standard A: Abilities necessary to do scientific inquiry
Understandings about Scientific Inquiry

- Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquires. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists.
- Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories.
- Scientists rely on technology to enhance the gathering and manipulations of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the explorations, depends on the technology used.
- Scientists explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modifications; and it must be based on historical and current scientific knowledge.

Content Standard C: Life Science
Reproduction and Heredity

- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.
- The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment.

Diversity and Adaptations of Organisms

- Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the earth no longer exist.

AAAS Benchmarks
Content Standard B: Heredity

- There is variation among individuals of one kind within a population
- For offspring to resemble their parents, there must be a reliable way to transfer information from one generation to the next.
- New varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits.

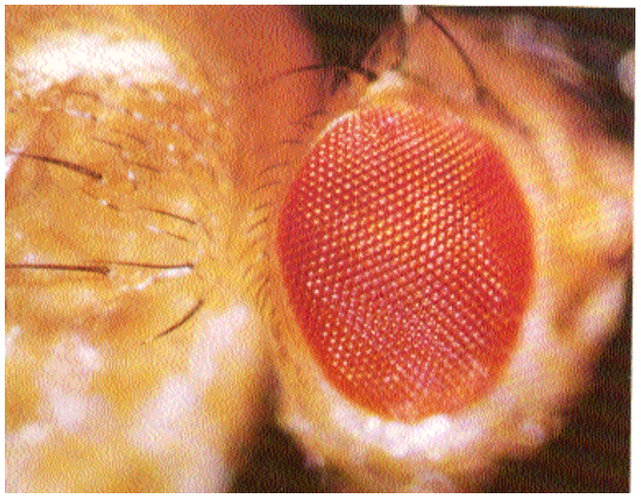
Content Standard F: Evolution of Life

- Individuals of the same kind differ in their characteristics, and sometimes the differences give individuals an advantage in surviving and reproducing.
- Fossils can be compared to one another and to living organisms according to their similarities and differences. Some organisms that lived long ago are similar to existing organisms, but some are quite different.

    - Small differences between parents and offspring can accumulate (through selective breeding) in successive generations so that descendants are very different from their ancestors.
- Individual organisms with certain traits are more likely than others to survive and have offspring. Changes in environmental conditions can affect the survival of individual organisms and entire species.

Exploring The Fruit Fly

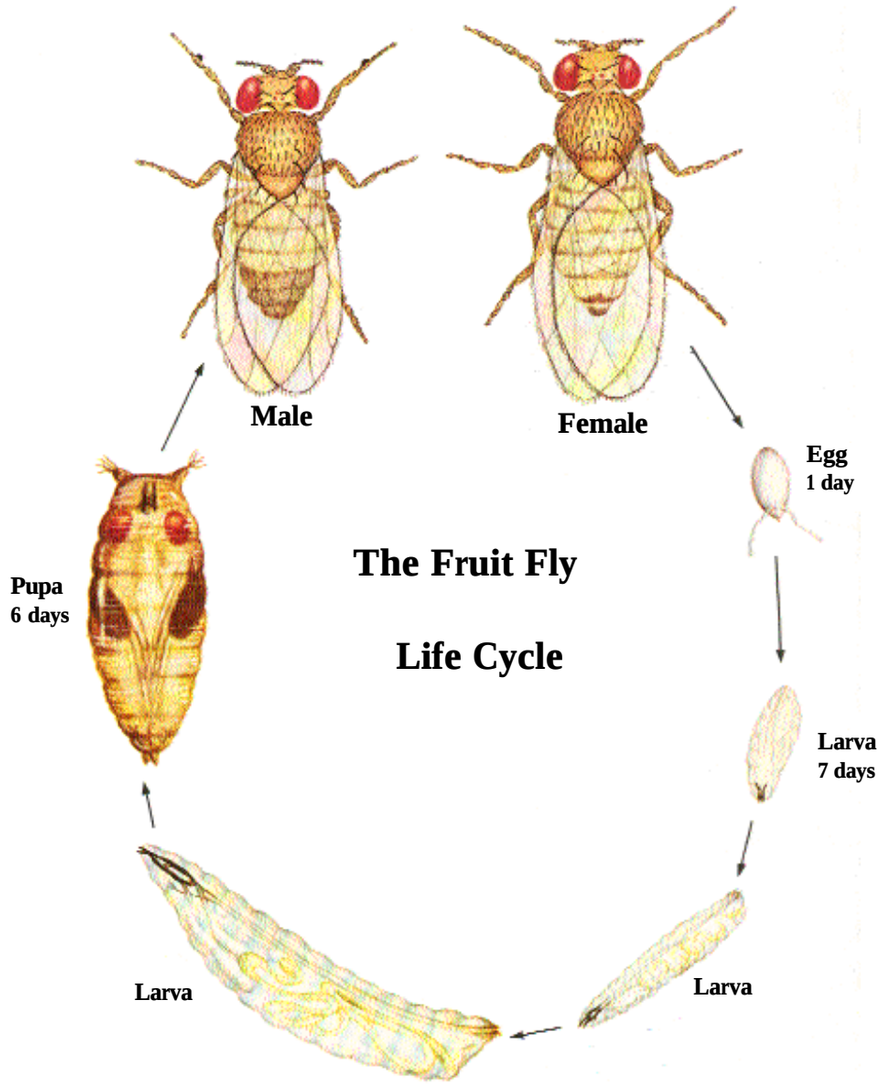
Wild Type Traits



Red Eyes

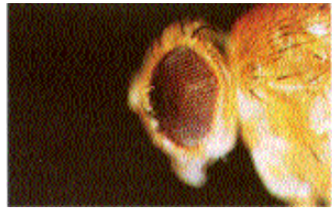
Brown Body and
Tear Drop Wings

Two Small Antennae

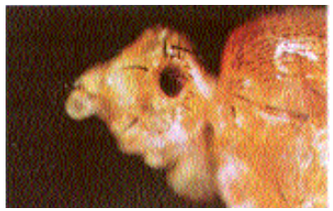


Eye Color and Shape Mutations

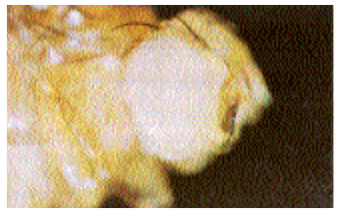
Bar Eyes



Black Eyes



Lobe Eyes



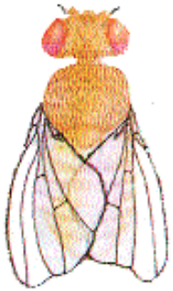
White Eyes

Wing Shape Mutations

Apterous

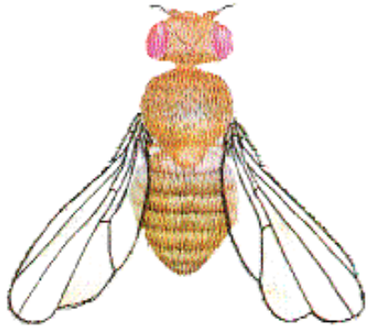
Vestigial or Crumpled

Curly



Dumpy

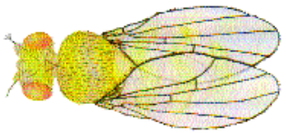
Scalloped



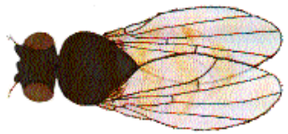
Curved

Rounded

Body Color Mutations



Yellow



Black

Body Mutations

Antennapedia

Geneticist: _____ Date: _____

Fruit Fly Observations

What mutations did you observe?

Eyes	Body
Wings	Other

Draw and label one example of a wild type fly and one example of a mutant fly:

Charles Darwin noticed great diversity among the finches he observed on the Galapagos Islands. These observations helped him to develop his famous theory of Natural Selection.

This finch eats seeds. Its beak is short, wide and well designed for breaking open seeds.

Geospiza fortis

This finch eats the prickly pear cactus. Its long, straight beak allows it to drink the nectar from the cactus flowers.

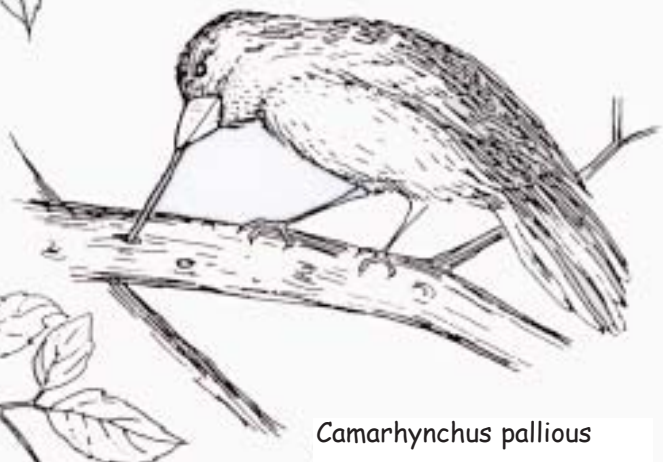
Geospiza scandens

Certhidea olivacea

This finch eats insects. Its thin, sharp beak helps it to catch isects.

Camarhynchus crassinostas

This finch eats buds, flowers and fruit. Its strong beak is used for crushing its food.



Camarhynchus pallious

This finch eats insects and grubs. It uses a twig in its beak to dig the grubs out of the bark of a tree.

Evolution

Evolution is the theory that species change over time. It helps us to understand why organisms look the way they do and how organisms of the past are related to organisms today. It also helps to explain relationships between different groups of living things.

Evolution occurs through a process called natural selection. If an organism has a trait that gives it an advantage in its environment this trait can be passed on to its offspring. In this way an organism with the advantage, called an adaptation, will live longer and have more offspring than an organism without the advantage. Organisms with the inherited advantage (or trait) become the most common in the population. In this way a group of organisms can change or evolve.

Can an organism force itself to adapt? No. Adaptations come about through random changes in an organism's DNA (mutations) that result in a change in the organism's traits. Mutations in DNA are the vehicles of evolution.