Lab Safety
Eating and drinking are not permitted in the laboratory. Students should wash their hands after completion of the lab activity.

Overview
This lesson is an introduction to the phenotypic effect of genetic mutations. In this series of four 45-minute lessons, students will have the opportunity to observe and compare wild type and mutant organisms from two species: *Drosophila melanogaster* (fruit fly) and *Caenorhabditis elegans* (roundworm). Observations will be made using either stereomicroscopes or magnifying glasses. Discussion of observations can include: the use of model organisms, methods of studying the function of genes, and the connection between genetic mutations, natural selection and genetic disease. The activities included in this lab may be adapted for both middle school and high school students.

Learning Outcomes
Students will be able to:
- observe, describe and record characteristics of wild type and mutant fruit flies and roundworms with the aid of microscopes (or magnifying glasses).
- compare and contrast physical characteristics of wild type and mutant organisms.
- analyze the life cycle of the fruit fly and the roundworm.
- explain the implications of genetic mutation in terms of natural selection and genetic disease
- describe how a change in the genetic code can impact the physical characteristics of an organism.
- recognize the value of model organisms in scientific research.

Prerequisite Knowledge & Skills

Knowledge
Students should:
- be familiar with the scientific method.
- have a basic understanding of inheritance of traits and the genetic code (A,T,C,G).
- know that a genetic mutation is the result of a change in the genetic code.
- understand the relationship between DNA, RNA, proteins and traits.

Skills
Students should:
- be familiar with using microscopes or magnifying glasses
- be able to conduct careful observations
- know how to record, analyze, and report data from conclusions

Misconceptions
Students may believe that**:**
- all mutations have a negative effect and that these mutations are always inherited.
- a mutation that occurs in a body cell can be passed to offspring.
- acquired traits, such as a mouse losing its tail in a mousetrap, can be inherited.
- organisms can willingly change their characteristics based on their surroundings or their individual needs.

Materials and Equipment
- Computers with Internet access
- Student lab notebook
- Sentence strips
- 15 clear plastic petri plates
- clear plastic tape
- 15 dissecting microscopes or magnifying glasses
- Wild-type fruit flies (*Drosophila melanogaster)*
- Mutant fruit flies (categorized into mutation types such as eye color/shape, wing shape, and body mutations) in labeled (eye, wing, body) Petri plates
- Wild-type roundworms (*C. elegans*)
- Mutant roundworms (categorized into mutation types such as blistered, dumpy, roller, and uncoordinated) in labeled (#1=Dumpy, #2=Roller, #3=Uncoordinated, #4=Blister) Petri plates

Lesson Structure

Pre-lab: Day 1
The Pre-lab activities will take two or three 45- minute class periods

Teacher Prep
- Become familiar with Lab Center: www.dnalc.org/labcenter/ , Exploring Mutant Organisms
- Print and copy **Background Reading** from **Student Lab Notebook** on the website
- Cut paper strips for Sentence Strips activity
- Make sure computers with Internet access are available

Before Class
Students will receive "Background Reading" for the lab activity to read for homework the night before starting the lab. They will write 2-3 questions they have about the background information. They will also highlight any unfamiliar terms.

During Class
Pair –Square (2 pairs) - Using the questions they developed from the homework assignment, each group of students comes to a consensus on one question that they find most interesting. Each group records this question on a sentence strip to be collected by the teacher and posted in the classroom. The teacher will also post one or two of his/her own questions.

Possible questions for pre-lab pair-share activity may include:
- What were the 80 mutations that Morgan saw in flies?
- What caused the flies to have these mutations?
- How many chromosomes do flies have?
- Why did scientists choose to study C. elegans instead of another organism?
- How do scientists mutate genes?
- What are some other organisms that scientists study to learn more about humans?
- What is gene therapy and how is it used?
- What are some problems with using gene therapy?

Vocabulary
(From **Background Reading**. See **Glossary** for definitions)
- *Caenorhabditis*
- Chromosome
- *Drosophila*
- Eukaryote
- Gene
- Genome
- Inheritance
- Lineage
- Model Organism
- Multicellular
- Mutation
- Nematode
- Wild-type

Mini-lesson - Major lab concepts will be taught using information and resources from the Dolan DNA Learning Center website (http://www.dnalc.org/labcenter/mutantorganisms/mutantorganisms_d.html).
1. Begin the mini-lesson with a class brainstorm: What is a mutant organism? Write down all student responses on chart paper. Accept all responses.
2. Using an LCD projector, show the class the spoken introduction to the "Exploring Mutant Organisms" activity.
3. Explain that for the next few days, students will be working on a series of activities called "Exploring Mutant Organisms." Today they will be working on gathering information about mutant organisms using the DNALC website.
4. Depending on the availability of resources in your school and the needs of your students, there are several approaches to exploring the website.

- For a more structured activity, pass out **Student Pre Lab Worksheets** found on the website under the **Student Lab Notebook**. Assign students to work individually or in pairs, exploring the different activities.
- For a whole class activity, use an LCD and/or Smartboard to explore the website. Some possible discussion questions are listed below:

Sickle Cell Anemia – Ask students to create a graphic organizer in which they compare the differences between a normal red blood cell and a red blood cell from a person with sickle cell anemia. Categories to compare include: DNA sequence, amino acid sequence, and hemoglobin traits.
Brenner: Why the worm? – What are four reasons Brenner uses to explain why scientists use worms as a model organism?
Model Organisms – Ask students to make a graphic organizer in which students list each model organism and one reason why scientists use it. Students should explain which organism they would most like to work with in a laboratory and support their answer with information from the website.
DNA Mutations – Students should explain two factors that can lead to changes in the DNA structure.
Accumulating Mutations – Ask students to explain what a molecular clock is and what this tells us about human evolution.
Relationships Between Creatures – List five life functions that are shared by all organisms. What does the conservation of these life processes tell us about the evolution of life? How does "the unification of life" explain why scientists study flies and worms to understand more about humans?
X-Ray Mutagenesis of Flies – Describe Hermann Muller's experiment. Include his question, hypothesis, experimental design (in general), and his results.
The First Fly Mutation – Describe Thomas Hunt Morgan's experiment. Include his question, hypothesis, experimental design (in general), and his results.

This website is rich in background information, so teachers may want to schedule 1-2 days to allow students sufficient time to explore the website in its entirety. If a formal lab report is required, students may use this information to assist them in writing the Introduction section.

Pre-lab: Day 2

Teacher Prep

- Prepare plates with sample flies for students to practice making observations.
- Prepare photocopies of **Fly Pictures and Fly Life Cycle** available on website in the **Student Lab Notebook**.
- Optional: Setup computer with internet access and LCD projector.

During Class

- Begin the lesson with an observation of the classroom population. Ask the students to respond to the question: *Although we are human, we have very different physical traits. What are some of the physical differences within our class population*? Give the students a few minutes to write their thoughts in their science journals. Then brainstorm the students' ideas on chart paper. Anticipated responses include: skin color, hair color, hair texture, height, eye color, etc. Be sure to distinguish between differences which are genetically based and those which are acquired or environmentally induced such as a suntan or dyed/ chemically altered hair.
- Ask students to guess what percentage of their DNA they share with their classmates. 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. Ask students how much of their DNA is similar to the chimpanzee or the banana? We share 98% of our DNA with chimpanzees and even approximately 50% of our DNA is similar to bananas.
- Mutations, or changes in genes, account for the variation that we see in traits today, as well as the differences we see between modern humans and our ancestors. When an organism's DNA changes, its traits can change. Through natural selection, certain traits are 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 > Our Family Tree and discuss what traits have been conserved in humans over the past 3.5 million years? What traits have changed? Why were some traits conserved over time? Emphasize that traits that were beneficial to survival were passed on to future generations.
- Ask students why they think fruit flies are a popular model organism in genetic research (about 60% of their genes are the same as ours). Possible answers include: they are easy to care for, have short life spans, reproduce quickly & abundantly (female fly can lay thousands of eggs in her lifetime), and don't raise any ethical red flags.
- Demonstrate how to use a microscope or magnifying glass to observe fruit flies and round worms. Remind the students how important it is to record detailed descriptions of the mutations they have observed.
- Review life cycle of fruit fly using photocopy. Students will only be able to see pupa and adult flies with stereoscopes or magnifying glasses.
- Teacher may collect or review answers to website companion assignments.
- As an exit strategy, ask each group to respond to one of the class questions that they may now be able to answer and hand in to teacher as they leave class.
- For a vocabulary exercise, these are some possibilities:
  a. Define the terms in their lab notebook
  b. Write a paragraph with any 5-6 vocabulary words that they should now understand.
  c. Use a word splash.
  For example: Put the following words on the board: DNA, *D. melanogaster*, *C. elegans*, model organism, mutation.. Ask the students how they would use the following terms in discussing the topic: Mutant Organisms.
  d. Make a concept map using 5-7 terms and adding any others they may decide they need
  e. Write a poem using words from vocab list
  f. Write a rap song using words from vocab list

Go to the following website to learn more about word splashes and concept mapping: http://biochemnetwork.com (New York State Biology Chemistry Professional Development Network) Go to "Toolbox of Instructional Strategies," and then "Connections to Prior Knowledge"

Lab Activity: Day 3

Teacher Prep

- If you have purchased live flies, they will have to be anesthetized, transferred into clear Petri plates using small paintbrushes and taped. Alternatively, if flies are placed in the freezer, they will die and can be reused several times.
- Separate flies into 4 categories: wild type, eye mutations, body mutations, and wing mutations. Place 10-20 flies of each type onto Petri dishes. Prepare enough plates so that each group of students receives 4 plates: one wild type and one of each mutant. Make sure to label the mutant plates with either eyes, wings or body.
- Print and photocopy **Student Observation Sheet Fruit Flies** from the **Student Lab Notebook.**

During Class

- Tell students, "You have been transported back in time to the year 1920. You are not students any more. Now, you are all working as lab assistants in Dr. Thomas Hunt Morgan's lab. Your lives are dedicated to carefully observing and experimenting with fruit flies. Today Dr.

Morgan has presented you with a set of flies that were exposed to radiation very early in development. What effect do you think the radiation will have on the physical characteristics of the flies? Why do you think this change will occur?" Ask students to record their hypothesis on the worksheet.

- Distribute to each group one Petri plate containing wild type flies. Ask students why they need to observe the wild type flies first. Reinforce the importance of the control group in the scientific method. Explain that first they will be observing normal, or wild type flies. Allow students 10 minutes to analyze wild type flies using microscopes or magnifying glasses. Record descriptions of eyes, wings and body on the worksheet. Include a drawing of a wild type fly.
- Next, distribute one plate of wing mutant flies, one plate of body mutant flies, and one plate of eye mutant flies to each group. Tell the students to analyze the flies on each plate and to record detailed descriptions and drawings of the mutations on the worksheet. Allow at least 20 minutes for students to make their observations and record their results.
- When students have completed the worksheet, pass out the **Fruit Fly Pictures** handout showing all of the different types of mutations. Ask the students to compare the images with their own observations. Did they find examples of all of the mutations? Why or why not?
- Students may complete their lab worksheets for homework.
- See **Teacher Guide** on Teacher desk on Lab Center for possible answers to student questions.

Lab Activity: Day 4

Teacher Prep

- Chunk *C. elegans* one day before lab. Prepare enough plates so that each group of students receives 5 plates: one wild type and one of each mutant (#1=dumpy, #2=roller, #3=uncoordinated, #4=blister). Remember to keep your labeling system secret so the students cannot identify the type of mutation before making observations.
- Print and photocopy **Student Observation Sheet Roundworms** for each student from the **Student Lab Notebook.**
- Print and photocopy the **Nematode Life Cycle** and **Nematode Structure** worksheets from the **Student Lab Notebook.**

During Class

- Tell students that today they are working in the lab of another scientist, one of the scientists that they heard speak on the Exploring Mutant Organisms website, Dr. Sydney Brenner. Show the clip "Brenner: Why the Worm?" to help set the scene.
- Explain that the students will be observing roundworms or *C. elegans*. They will observe wild-type and mutant organisms and will record their observations on the worksheets provided. Have the students write down a hypothesis (predict the effect of the mutations on the roundworms traits) on the worksheets.
- Pass out the photocopy of the *C. elegans* life cycle. (optional: Using a computer with LCD go to http://www.silencinggenomes.org/ click on "Methods" and then "Part I" to review the different stages of development in *C. elegans).*
- Distribute one Petri plate containing wild type (N2) roundworms to each lab group. Ask students why they need to observe the wild type flies first. Reinforce the importance of the control group in the scientific method. Explain that first they will be observing normal, or wild type roundworms. Allow students 10 minutes to analyze wild type roundworms using microscopes or magnifying glasses. Record descriptions of body shape & size, locomotion, and skin texture on the worksheet. Include a drawing of a wild type roundworm.
- Next, distribute one plate of each mutation type (four plates total) to each group. Tell the students to analyze the roundworms on each plate and to record detailed descriptions and drawings of the mutations on the worksheet. Allow at least 20 minutes for students to make their observations and record their results.
- When students have completed the worksheet, pass out the photocopy showing all of the different types of mutations. Ask the students to compare the images with their own observation, and to write the names of each specific mutation under the corresponding number on the observation sheet. Did they find examples of all of the mutations? Why or why not? .

Post Lab

Analysis & Discussion (See **Teacher's Guide** on Teacher Desk of Lab Bench for answers)

1. Discuss the students' observations. What mutations were seen? Which mutations might be beneficial or harmful to a fly or a roundworm, and why? What might happen to a fly or roundworm with an extremely harmful mutation, or an extremely beneficial mutation? Make connections with natural selection and adaptation.
2. Which organism was easier to observe: the flies or the roundworms? Which organism seems to be more similar to humans? Why?
3. Compare the life cycles of a fly, roundworm, and human. (You may use the photocopies of the fly and roundworm lifestyles for assistance with this comparison.) Did you see examples of the various stages in your samples? Are

similarities in life cycles important when selecting a model organism?

4. Discuss the origin of these mutations. How could exposure to radiation causes changes in the fly's physical characteristics? Use a flow chart to trace the progression of the mutation from the initial change in the DNA, through to a change in the RNA, protein and trait.
5. Discuss why many organisms today have the traits they do. Why do 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. Why do giraffes have long necks? Were they able to force themselves to have long necks as they reached for leaves on trees? This adaptation came about through random changes in the giraffe's DNA (mutations) that resulted in a change in its traits.
6. Discuss the breeding of animals for certain traits as an example of artificial selection. Review the benefits and drawbacks to selective breeding.
7. Revisit initial pre-lab questions. Which questions are you able to answer at this point? What additional information do you need to answer the remaining questions and where could you access this information?

Making Connections

- Ask students to make a concept map using at least 10 of the words found in the glossary.
- Have students imagine alternative mutations in the fruit fly. In a graphic organizer, students will describe the advantages and/or disadvantages that these mutations might provide for the organism.
- A great example of natural selection and genetic disease is sickle cell anemia. Discuss how the sickle cell anemia mutation actually confers resistance to malaria, but can also cause a debilitating blood disorder. For more background information on sickle cell anemia visit: http://www.pbs.org/wgbh/evolution/educators/course/session7/explain_b_pop1.html
- To 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 may present the information in the form of a brochure using the student worksheet found at http://www.dnai.org/teacherguide/guide.html under the activity title: *Model Organisms.*
- Students can debate the ethical, legal and social implications of using animals in research. One group can present the benefits of research using animals, while the other group presents the risks/drawbacks of such research.
- Discuss or research why certain genetic disorders are more predominant in certain populations of people. For example, Tay-Sachs is found predominantly in people of Ashkenazi-Jewish descent, Sickle Cell Anemia is found predominantly in people of African or Mediterranean descent, and Thalassemia, which is carried predominantly by Asians.

Further Explorations

- Students can research Charles Darwin, and what he learned from his travels on the HMS Beagle at http://www.pbs.org/wgbh/evolution/darwin/index.html.
- Show students a chromosome map for drosophila so that they can visualize the location of the mutation within the genetic code (www.exploratorium.edu/exhibits/mutant_flies/mutant_flies.html). Compare this with a chromosome map for a human showing the location of the sickle cell anemia mutation. (http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=gnd.section.98&ref=toc). Ask students to search for the location of other genetic diseases that they may be familiar with such as diabetes, Huntington's disease, Hemophilia, etc.
- Students can explore how mutations are portrayed in the media (movies, science fiction books, comic books, video games, etc.). Ask students to write a critical analysis explaining why this medium is or is not an accurate depiction of mutations and natural selection.
- Pollution can cause mutations in humans and other organisms leading to disease and death. Students can research chemical contamination around the world to understand the impact of these mutations. Some possible topics include: Hiroshima aftermath, Chernobyl explosion, Love Canal toxic waste dumping, and Bhopal Union Carbide disaster.
- Students can write up a formal lab report including: Introduction, Materials & Methods, Results and Discussion using the worksheets they have completed in class as resources.

Glossary

Caenorhabditis – a genus of roundworm used in genetic studies
Carcinogen – a cancer causing substance
Chromosome – made up of tightly wound DNA
DNA – Deoxyribonucleic Acid; a molecule that carries genetic information which is used to make proteins and traits
Drosophila – a genus of fruit flies used in genetic studies
Eukaryote – a cell that has a true nucleus
Evolution – a change in the inherited traits of a population over time
Gene – a piece of DNA that codes for a protein

Genetic Diversity – the variety of genes present in a population
Genome – the total genetic content in one set of chromosomes
Genotype – an organism's genetic information
Inheritance- when genetic information is passed on from parents to offspring
Lineage - descendents of one individual
Model Organism – a species that is studied by scientists to understand the workings of another organism
Multicellular – containing many cells
Mutagen – a substance that causes changes or mutations in DNA
Mutation – a change in the DNA sequence of a gene
Natural Selection – the process in which successful traits become more frequent in successive generations
Nematode – a worm belonging to the phylum Nematoda; characterized by unsegmented, cylindrical bodies
Phenotype – the physical or observable traits of an organism
Protein – a molecule made up of amino acids; used in the body for structure, as catalysts (enzymes) and as hormones
Radiation – a form of energy that damages the genetic material of cells; causes mutations in DNA
Variation – diversity; differences
Wild type – a normal or non-mutated version of a gene

Resources

Websites:
http://www.dnalc.org/labcenter/mutantorganisms/mutantorganisms_d.html
A Dolan DNA Learning Center Internet site.
This site provides background information, animations, videos and worksheets corresponding to the *Exploring Mutant Organisms* activity.

http://www.silencinggenomes.org/
A Dolan DNA Learning Center Internet site.
This site provides background information about *C. elegans* and videos showing wild-type and mutant locomotion.

www.dnaftb.org
A Dolan DNA Learning Center Internet site.
This site is an online 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.

www.exploratorium.edu/exhibits/mutant_flies/mutant_flies.html The Exploratorium's online exhibit, *Mutant Fruit Flies* with diagram identifying the location of some mutations on fruit fly chromosomes.

http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=gnd.section.98&ref=toc
A NCBI website with background information on sickle cell anemia and other genetic diseases. Also has useful chromosome maps for use with extension activities.

www.thirteen.org/curious/episodes/inside-the-fly-lab/
"Inside the Fly Lab" broadcast by WGBH and PBS, in the program series "Curious", January 2008 shows scientists in action as they study the fruit fly's brain and flight maneuvers.

Books:

Peters, David. (1991). *From the Beginning, The Story of Human Evolution.* Fairfield, NJ: William Morrow and Co.

Balkwill, F.R. & Rolph, M. (2002). *Gene Machines.* Woodbury, NY: Cold Spring Harbor Press.

Bilkwell, F.R. & Rolph, M. (2002). *Have a Nice DNA,* Woodbury, NY: Cold Spring Harbor Press.

Correlations

I. The Living Environment Core Curriculum

Standard 1: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.
Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing and creative process.
Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.
Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into natural phenomena.

Standard 4: Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.
Key Idea 1: Living things are both similar to and different from each other and from nonliving things.
Key Idea 2: Organisms inherit genetic information in a variety of ways that result in continuity of structure and

function between parents and offspring.
Key Idea 3: Individual organisms and species change over time.
Key Idea 5: Organisms maintain a dynamic equilibrium that sustains life.

II. Intermediate **Level Science Core Curriculum (Grades 5-8)**

Standard 1: Analysis, Inquiry, and Design
Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.
Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.
Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

Standard 4: The Living Environment
Key Idea 2:
Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.
Key Idea 3:
Individual organisms and species change over time.

Process Skills Based on Standard 4
General Skills
1. Follow safety procedures in the classroom and laboratory
4. Recognize and analyze patterns and trends
5. Classify objects according to an established scheme and a student-generated scheme

Living Environment Skills
6. Classify living things according to a student-generated scheme and an established scheme

Standard 6: Interconnectedness: Common Themes
Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

III. National Standards
Content Standard A: Abilities necessary to do scientific inquiry

Content Standard C: Life Science
Reproduction and Heredity
Diversity and Adaptations of Organisms

V. New York City K-8 Science Scope & Sequence
Grade 8 -Unit 1: Reproduction, Heredity, and Evolution
Heredity
- Genes and DNA LE 2.1a-e
- Mendelian genetics LE 2.2a-c
- Mutations LE 3.1a

Natural Selection: The Driving Mechanism Behind Evolution
- Sources of variation in organisms LE 3.1a

General Skills (from NYS Core Curriculum)
- Follow safety procedures in the classroom and laboratory.
- Recognize and analyze patterns and trends.
- Sequence events.

VI. NewYork City High School Science Regents Scope & Sequence
Living Environment
Unit 1: Scientific Inquiry
- The Role of Scientific Inquiry in Studying Biology Standard 1 – 1.1a, 1.1b, 1.1c, 3.1, 3.2, 3.3

Unit 7: Genetics and Biotechnology
- Mendel Overview Intermediate Core Curriculum LE 2.2a, 2.2b, 2.2c
- DNA/RNA 2.1a, 2.1b, 2.1c, 2.1f
- Protein Synthesis 2.1g, 2.1i, 2.1j, 2.1k
- Diseases 2.2e, 5.2h
- Mutations 2.1h, 2.2d, 2.2e, 5.2i
- Natural Selection 3.1a, 3.1b, 3.1c, 3.1d, 3.1e, 3.1f, 3.1g, 3.1h, 3.1i, 3.1j, 3.1k, 6.2a