Discovering Epigenetics

Summary
Epigenetics is a hot topic in the field of biology. Scientists are learning that the environment can cause changes in gene expression by methylating or acetylating DNA and histones. These modifications are important for cell specialization during embryonic development, but can also cause changes that lead to increased obesity or heart disease risk. Interestingly, these modifications can be transferred through generations. In this activity, students will learn about epigenetics using the PBS NOVA movie “Ghosts in Your Genes,” articles from the New York Times and Time Magazine, and the Utah Genetics website. This activity is designed for all levels of first year biology, but could be adapted for upper levels by increasing the complexity of the discussion (including methylation and acetylation of DNA and histones). It can also be adapted based on which articles you choose to assign (difficulty levels are listed).

Key Concepts
• Massachusetts Curriculum Frameworks:
  SIS1. Make observations, raise questions, and formulate hypotheses.
  3.1 Describe the basic structure (double helix, sugar/phosphate backbone, linked by complementary nucleotide pairs) of DNA, and describe its function in genetic inheritance.
  3.3 Explain how mutations in the DNA sequence of a gene may or may not result in phenotypic change in an organism. Explain how mutations in gametes may result in phenotypic changes in offspring.
  3.4 Distinguish among observed inheritance patterns caused by several types of genetic traits (dominant, recessive, codominant, sex-linked, polygenic, incomplete dominance, multiple alleles).

Objectives
At the end of this activity, students will be able to:
• Explain how phenotype is not determined solely by genotype.
• Define epigenetics.
• Describe the role of acetylation and methylation of DNA and histones in the expression of genes.
• Identify different environmental factors that influence gene expression.

Materials
• Printed or displayed picture of identical twins (included on PowerPoint)
• “Ghost in your Genes” movie from NOVA PBS, 2006
• Articles (included as PDFs):
  o “A pregnant mother’s diet may turn the genes around” by Sandra Blakeslee, New York Times, October 7, 2003 (better for higher level students)
  o “How the first nine months shape the rest of your life” by Annie Murphy Paul, Time, October 4, 2010 (better for average students)
  o “Why Genes Aren’t Destiny” by John Cloud, Time, January 18, 2010 (better for higher level students; if only one article is assigned, this might be the best option)
• Computer lab or laptop access for students

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Procedure

1. Opening questions (display pictures of identical twins, included in lesson) to discuss in small groups and then as a class:
   1. Looking at the picture of identical twins, compare and contrast their phenotype.
   2. Brainstorm possible factors that could have contributed to their similarities and differences (students will probably come up with environmental insults as examples, like smoking, tanning, etc).
   3. Discuss the effects of some of these factors – focusing on the fact that they change the genotype of the individual

2. Lead a discussion with the class: We’re going to discuss changes in phenotype that are NOT caused by genotype changes. How is that possible? Discuss the following topics (trying to let the students brainstorm answers to these questions). Students can pair up and discuss these questions in small groups and report back to the class, or you can lead a whole-class discussion.
   1. What makes one cell type different from another cell type (like muscle cell vs. liver cell), given that they have the same DNA?
   2. What could allow some genes to be expressed and others to not be expressed?
   3. Do you think you have any control over which genes get expressed or not (based on what you do during your life)?
   4. Thinking what we’ve just discussed, are there any other things that could have affected the phenotypes of these twins?

3. Show movie “Ghost in your Genes” from NOVA 2006 (purchase through PBS website or show clips from YouTube). Students should take notes that will help them answer the questions above.

4. Students should get back into small groups (or in a whole-class discussion) and discuss the questions from #2 again:
   1. What makes one cell type different from another cell type (like muscle cell vs. liver cell), given that they have the same DNA?
   2. What could cause some genes to be expressed and others to not be expressed?
   3. Do you think you have any control over which genes get expressed or not (based on what you do during your life)?
   4. Thinking what we’ve just discussed, are there any other things that could have affected the phenotypes of these twins?

5. Students should read articles for homework. You could assign only one article to the entire class or split them up and have different students read different articles. If they all read the same article, they can get into small groups to discuss what they learned from the articles. In their groups, they should discuss what epigenetic factor(s) were mentioned in each article. All articles are on included as PDFs and there are also worksheets for some of the articles that include guiding reading questions.
   1. “A pregnant mother’s diet may turn the genes around” by Sandra Blakeslee, New York Times, October 7, 2003 (better for higher level students)
   2. “How the first nine months shape the rest of your life” by Annie Murphy Paul, Time, October 4, 2010 (better for average students)
3. “Why Genes Aren’t Destiny” by John Cloud, *Time*, January 18, 2010 (better for higher level students; if only one article is assigned, this might be the best option)

6. Students will now go to the Utah Genetics website (http://learn.genetics.utah.edu/content/epigenetics/rats/) to experiment with epigenetics of rats. There is an included worksheet for this activity.

7. Summarize this final activity with the class and ask the final questions to be discussed in groups:
   1. Give an example of environmental conditions where an anxious mother rat who licks infrequently would have a selective advantage? In other words, under what conditions would being an anxious mom, creating anxious pups be beneficial?
   2. What are 3 examples of environmental conditions that affect human epigenetics, changing the phenotype of an individual, without changing the actual genetic code?

**Assessment**
- Discussion – teacher listens to in-class, small group discussions
- Assessment – questions about epigenetics on a test

**Additional Resources**
Utah Genetics epigenetics website: http://learn.genetics.utah.edu/content/epigenetics/rats/
Nova video about twins: http://www.pbs.org/wgbh/nova/body/epigenetics.html
Nova video “Ghost in your Genes”: http://www.pbs.org/wgbh/nova/genes/
Articles listed above
A Pregnant Mother’s Diet May Turn the Genes Around
New York Times, 10/7/03, Pages D1 and D4

1. What is epigenetics?

2. What are two ways methylation can affect gene expression (be specific)?

3. What % of your DNA is made of transposons and what are they?

4. How does color of mice relate to their weight?

5. Will the same treatment work in humans as mice for preventing obesity? Explain.

6. Name 2 diseases that doctors think may be influenced by methylation patterns.

7. What effect does “licking” have on a baby mouse’s genome and behavior?
Epigenetics
Explore the website http://learn.genetics.utah.edu/content/epigenetics/ to answer the questions below.

A. Click on "Gene Control," read the page and answer the following questions:

1. Describe the following characteristics when a gene is active:
   a. Is the gene tightly or loosely wound around histones?
   b. Are there many or few methyl molecules attached to the gene?
   c. Are there many or few acetyl molecules attached to the genes associated histones?
   d. Are there many or few mRNA transcripts?

2. Describe the following characteristics when a gene is inactive:
   a. Is the gene tightly or loosely wound around histones?
   b. Are there many or few methyl molecules attached to the gene?
   c. Are there many or few acetyl molecules attached to the genes associated histones?
   d. Are there many or few mRNA transcripts?

B. Go back to the main page and click on "Insights from Identical Twins." Read the page and answer the questions below:

3. Often, the physical characteristics of genetically identical twins become increasingly different as they age, even at the molecular level. Explain why this is so. (use the terms "environment" and "epigenome")

4. Name 3-4 environmental factors that influence the epigenome.

5. What is an imprinted gene?
C. Go back to the main page and click on "The Epigenome Learns from Its Experiences." Read the page and answer the questions below:

6. True or False. Cell signals play a role in shaping gene expression only during development.

7. What molecule is primarily responsible for carrying cell signals to DNA?

8. What are the two functions of gene regulatory proteins?

9. Are epigenetic tags passed to daughter cells?

“Lick Your Rats”
http://learn.genetics.utah.edu/content/epigenetics/rats/

Read the text on the first page, then click on “Investigate” to find out more about the effects that mom’s licking has on her rat pups. Finally, find out what kind of mother you are. Don’t do that until you have answered all questions on this page!

10. How can anxious behavior be an advantage for certain rats?

11. In rats, does licking by the mother activate, or deactivate her pup's GR gene?

12. Do high-nurtured pups have more or less GR protein?

13. Explain how cortisol and the GR protein work together in the brain to relax a rat pup. You may draw a diagram.
14. What physically happened to the GR gene when you licked your pup? Don’t just say it was activated or deactivated - explain using terminology from class.

15. The rat nurturing example shows us how parental behavior can shape the behavior of their offspring on a biochemical level. Relate this to humans and think about the personal and social implications. Record your thoughts.