NOVA

Regulating Genes

Student Worksheet

DAY 1
PART A. THE TASK: DEVELOPING ORGANISMS

You are about to look at a model of how genes work during the development of a simulated organism. We will focus on two DNA segments, one that includes a gene that influences where spots appear on the skin (the "spot" gene) and the other that includes a gene that influences the growth of appendages such as legs (the "appendage" gene).

You'll be able to watch the role the genes in these DNA segments play at three stages of the organism's development:

- Initial stage (single-cell fertilized egg)
- Early development stage (four-cell embryo)
- Developed creature

At each stage, close-up "lenses" will show the configuration of these DNA segments within the nucleus of a cell. Each segment shows a gene that codes for proteins, a non-coding region containing enhancers, and other non-coding DNA that does not immediately impact the gene. Note that the enhancer region includes receptors that allow specific proteins to bind to the DNA, activating the related gene. These proteins are represented here as stars, squares, triangles, and circles, and the receptors as shapes that allow these proteins to "lock" in place.

At the ***initial stage,*** you will see the two DNA segments in the nucleus of a fertilized egg. After the first run, you will have the opportunity to view a random mutation, which has taken place in one of the three regions of either DNA segment. (This is the mutation that was inherited by the fertilized egg.)

At the ***early development stage,*** you will watch the fertilized egg develop into a four-cell embryo. Then watch how proteins in each of those cells determine how the genes express. If your organism has a mutation, you can look for what happens differently here as a result of that mutation.

At the ***developed creature stage,*** you will see how the processes illustrated in the four-cell stage (and, by extension, in many other intervening stages of development) influence the visible traits we see in the developed creature. You can also analyze how the mutation affected the creature.

IMPORTANT! Do not "reload" your browser during this activity, or you will lose your saved creatures.

Step 1. First Run: Use the model to develop an organism.
Launch the "Regulating Genes" interactive. Read, and then close, the introduction. Then read and follow the instructions for the first stage of the model.

During your first "run," you can develop the organism, based upon the initial DNA composition. During later runs, you will be able to view a random mutation in the DNA and see its effects.

Observation Tips

- Examine a portion of the organism's DNA via the "close-up" view of each cell's nucleus.
- In the developing embryo, each cell produces its own proteins. This model highlights just one of many types proteins in each cell. The protein "shapes" shown are called transcription factors. In reality, each cell contains many different types of proteins.

As you go, record notes on the following:

a. Observe what happens to the genes in the four-cell embryo. Which genes are active and inactive, and how does this differ in each cell? Why?
b. Predict what will happen in the developed creature.
c. Analyze the outcomes in the developed creature.

Develop the organism to completion, then use the "Back" button to return to the stage when the four-cell embryo emerged. Review the steps as you answer the following questions.

Analysis Questions:

1. After the fertilized egg develops into the four-cell embryo, what happens to the DNA that you observed in the initial stage?
2. What does each of the four cells in the developing embryo represent?
3. During the four-cell embryo stage, describe what happens to the proteins in each cell.
4. During the four-cell embryo stage, what happens to the appendage gene in the "middle 1" and "head" cells? What causes the gene to turn on or off? How about the spot gene in the same two cells?
5. Based on your observations of each gene in the four-cell embryo, could you predict the traits that the organism developed? If so, what traits did you expect? Why did you predict this?
6. How could the genes that are turned on and off in the four-cell embryo have affected the traits of the developed creature?
7. What do you think might happen to the organism if one of the coding genes were mutated?

Step 2. Second Run: Click the "View Mutation" button, then develop an organism with a mutation in either the appendage gene or the spot gene.

After analyzing your first run, click the “New Creature” button to return to the very beginning. Note that your original, un-mutated, creature is saved in the creature gallery.

At the initial stage, click “View Mutation” to view a random mutation, which has taken place in one of the three visible regions of either DNA segment. (This mutation was inherited by the fertilized egg.)

Then follow the same steps as above to develop your organism.

Note: In this run, two types of mutation can occur:
Zigzag Line – the mutation caused a coding gene to be dysfunctional
Curvy Line – the mutation caused an alteration in a coding gene

As you go, record notes on the following:

a. Notice where the mutation occurred.
b. Observe what happens to the genes in the four-cell embryo. What is different as a result of the mutation?
c. Predict what will happen in the developed creature.
d. Analyze the outcomes of the mutation in the developed creature.

Once you have developed your second organism, click the “Back” button to replay its development. In the Data Log, record your findings from this run in the row for “Creature 2,” then answer the following analysis questions.

(Your teacher might want you to check with other groups in your class to see the variety of possibilities for the second run.)

Analysis Questions:

1. Where did your mutation occur?
2. After the fertilized egg develops into a four-cell embryo, what happens to the mutation you saw in the initial stage?
3. How did the mutation impact what happened in the four-cell embryo?
4. How did the mutation impact what happened in the developed creature? Is this what you expected would happen?
5. Does mutation increase the chances of survival for a given individual? Explain your answer.

Step 3. Develop organisms with random mutations
After your second run, click the “New Creature” button to return to the beginning. Note that your original, un-mutated, creature and your second, mutated, creature are both saved in the creature gallery. You can return to these at any time for comparison.

Using the same procedure as before, create 10 more creatures (or as many as you can). This time, the mutations may occur in the spot or appendage genes as before or they may occur in other parts of the DNA that come before the part of the gene that codes for spots or appendages.

Note: In this run, three types of mutation can occur:
Zigzag Line – the mutation caused a coding gene or other DNA to be dysfunctional
Curvy Line – the mutation caused an alteration in a coding gene
Shaped receptacle is created or sealed - A receptacle is added or subtracted from an enhancer

As you go, record notes on the following:

a. ***Notice*** where the mutation occurred.
b. ***Observe*** what happens to the genes in the four-cell embryo. What is different as a result of the mutation?
c. ***Predict*** what will happen in the developed creature.
d. ***Analyze*** the outcomes of the mutation in the developed creature.

Record the results each run in the Data Log and the "Creature Recording Template" and then answer these analysis questions:

Analysis Questions:

1. Where did your mutation occur?
2. How did the mutation impact what happened in the four-cell embryo?
3. How did the mutation impact what happened in the developed creature? Is this what you expected would happen?
4. Does mutation increase the chances of survival for a given individual? Explain your answer.

PART B. UNDERSTANDING MUTATIONS

Step 4. Refining the Explanations

In this section, compare the genetic profiles of the various organisms you made in your group.

a. Analyze the organisms you developed in your Data Log, using the analysis questions below.
b. Your teacher may ask you to discuss your findings with the entire the class or with another group.

Analysis Questions:

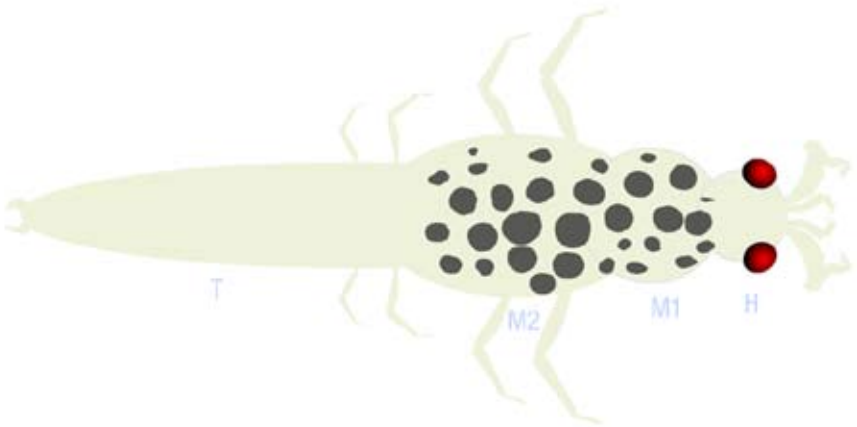
1. If a mutation occurs in the coding part of the gene (labeled "Coding Gene" in the close-up view), what happens to the organism?
2. If a mutation occurs in the non-coding/regulatory part of the DNA (labeled "enhancers" in the close-up view), what happens to the organism?
3. If a mutation occurs in other parts of the DNA (labeled "Other DNA" in the close-up view), what happens to the organism?
4. What types of mutations tend to have consequences that increase the chances of survival for an individual?
5. How do you think these mutations might be related to the differences between the traits expressed in different species?

Step 5. Preserving your data for the next phase

In order to use your results in the next class period, follow your teacher's direction either to print each developed creature from your creature gallery or draw each creature and its mutation(s) using the template provided in a separate handout.

Step 6. Taking it Further: You control the mutations

If there's time, take a careful look at the developed creature below. You and your group need to identify what mutations could result in the trait expression shown in the picture.



Based on the visible traits, draw the likely mutations that led to this creature.

1. Our creature has:
   appendages in these sections of its body: _____
   and spots on these sections of its body: _____

2. In the diagram below, draw or conceal the receptacles on each chromosome that control the gene's expression. (Note: there could be more than one mutation involved.)

Use these blank chromosomes to draw the mutations in the above creature's DNA.

DAY 2
SETTING THE STAGE: DEVELOPING THE POPULATION OF ORGANISMS

Refer to your printed or drawn representations of the 10+ creatures you and your group developed yesterday, showing both the developed creature and how its genes expressed in each of the cells of the four-cell embryo.

These creatures, combined with the ones developed by your classmates, will become a population of creatures who live together in a habitat (i.e., your classroom wall). Follow your teacher's instructions about hanging them on the wall so that they can be viewed as part of the entire population.

PART A. THE TASK: CONNECTING THE EVO TO THE DEVO

Step 1. Sorting by traits

Many of the creatures may look similar to each other and others may be quite different. If there are patterns that you see within the population, move groups of creatures together that you believe are similar to each other. Within the class population, see if there are three or four groups of similar creatures. You may wish to use number of appendages or color of spots as factors to consider.

Discussion Questions:

1. Is there reason to believe that some groups you have created might be better well suited to survival?
2. Is one group more or less likely to reproduce?

Step 2. Environment & Time

Whether traits provide an advantage or a disadvantage for an organism depends on the conditions in which it lives. Determine the viability of each trait group in the following conditions:

- What if the population moves near to water or in a wet, marshy area?
- What if the population exists in trees?
- What if they move to an area with little light?
- What if there is a drought?

Discussion Questions:

1. How do the mutations in the creatures relate to their ability to survive?
2. Is one group more or less likely to survive a natural disaster like an earthquake, fire, or flood?

What if one of the groups that you established in Day 1 was to move over a mountain range to find food? Or be cut off from the rest of the population due to a fire?

3. If all three groups in different locations survive, will they specialize to the point of becoming different species over many generations?
4. Which type of mutations are most likely to result in evolutionary change (the formation of a new species): mutation to the coding part of a gene, muta-

tion to the non-coding regulatory part of the gene (the enhancer) part of the gene, or mutation to other non-coding parts of the DNA?

PART B. UNDERSTANDING CONNECTIONS

Step 3. Journal Write
Take a few minutes to write down your best ideas to answer this question.

Based on what you have observed in the mutations of the organisms, what kinds of mutations are most likely to impact a organism's evolution? What evidence do you have to support this claim?

DAY 1 DATA LOG

Creature	Were spots or appendages affected by the mutation? (How?)	In which part of the chromosome did the mutation occur?	Result in developed creature?
DEFAULT	*No mutation in this run.*	*No mutation in this run*	*Appendages in middle 1 and middle 2, spots in middle 1*
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

DAY 1 CREATURE RECORDING TEMPLATE

Use this blank creature to draw the traits of each of the creatures you created.

Use these blank chromosomes to draw the mutations in the above creature's DNA.

Funding for NOVA is provided by ExxonMobil, Pacific Life, David H. Koch, the Howard Hughes Medical Institute, the Corporation for Public Broadcasting, and public television viewers. Funding for "What Darwin Never Knew" is provided by Promega Corporation and by the Wisconsin Alumni Research Foundation in support of the University of Wisconsin.