How a Leopard Gets its Spots – David Little

Purpose

The main goal of this lab is to introduce students to the role that morphogenesis play in cellular differentiation and how this relates to DNA and animal morphology. Morphogens are the chemical signals which cells use to communicate during development. Using morphogens each cell can behave differently in spite of the fact that they all posses the same DNA. This lesson connects something most students in a biology class will learn about, DNA and protein synthesis, to tangible features of an animal: specifically leopard spots.

A secondary goal of this lesson is to get students thinking in computational terms. Morphogens and cells follow specific rules, which allow a great variety of patterns to emerge. Students will have to think about what sorts of rules could lead to interesting patterns.

Overview

The lesson is broken into three parts: a class discussion, a class activity, and a follow-up discussion. The class discussion has the goal of getting students to think about how we could go from many uniform cells to many different cells and how that would be important. The term 'cell differentiation' is defined. The class activity involves students trying to figure out what sort of rules could lead to cell differentiation given very strict limitations on what those rules can look like. Finally a followup discussion evaluates students understanding.

Student Outcomes

- Students will be able to define cell differentiation.
- Students will be able to define "morphogen".
- Students will be able to describe the role of DNA and protein synthesis in cell differentiation.
- Students will be able to describe how cell differentiation relates to animal morphology: specifically leopard spots.
- Students will be able to describe how a simulation can be used to test out ideas, and why you would want to do this.

Illinois state standards:

- 11.A.4e - Formulate alternative hypotheses to explain unexpected results.
- 12.A.4a - Explain how genetic combinations produce visible effects.
- 13.A.5c - Explain the strengths, weaknesses and uses of research methodologies including observational studies, controlled laboratory experiments, computer modeling and statistical studies.

Time

This activity will last roughly one 40-minute period.

Reach for the Stars is a GK-12 program supported by the National Science Foundation under grant DGE-0948017. However, any opinions, findings, conclusions, and/or recommendations are those of the investigators and do not necessarily reflect the views of the Foundation.

Level
Freshman/Sophomore Biology

Materials and Tools
The provided slides and a deck of cards.

Prerequisites
Students should be 1.) familiar with the *basic* anatomy of a cell (nucleus, cell wall and cytoplasm) 2.) be able to describe the structure of DNA 3.) be able to describe the basic steps involved in protein synthesis.

Teaching Notes

Part 1: Class Discussion

Slide 1: The class discussion should begin by piquing the students curiosity. I found that putting this slide up as students walk into the class room was effective. Start with some review: what is DNA for? How does this relate to proteins? Then motivate the lesson. If scientists new exactly how DNA translated into all of the parts of an animal, why would that matter? The goal for the discussion should be to get students to see the problems with connecting DNA to leopard spots, and why that is an interesting question. The key steps, which students should be guided through (but can hopefully generate on their own), involve:

1.) Each cell in an animal has the same DNA
2.) Somehow the proteins from that DNA get used.
3.) What needs to happen for an animal to have spots: there need to be different color hairs on the animal.
4.) What needs to happen for the hairs to be different colors: the cells, each with the same DNA, have to be different.

Slide 2: It might be worth pointing out to the students that the leopard spot question is part of a much more general question that scientists are very curious about. Review definitions of genotype and phenotype, and point out that the connection between these two is not always obvious.

Slide 3: By this slide the discussion should be in a place where students see that it is pretty weird that a bunch of cells all with the same DNA can have different behaviors. Define this set of different behaviors as cell differentiation, and then tell the students that it is there job to figure out how this can happen by playing a game.

Part 2: Class Activity

Slide 5: At this point, break students into groups and have them follow the rules on this slide. Their goal is to generate a set of rules that each student follows to get into a leopard spot (black on the outside, yellow on the inside). Students start in a large cluster (a blob of cells) and have to pass the cards around so that those on the outside are black cells and those on the inside are yellow cells. (A leopard spot). This will probably work better if the first few ideas are discussed as a class. Students are desperate to break the rules, so it helps to let them generate the ideas that break the rules, point out to them that they do break the rules, and then once it is clear everyone *actually* understands the limitations, have them break into groups. Then after 10 minutes or so, test out the ideas generated by simulating those rules as an entire class (which should stand up in an open space or hallway as a large cluster with at least three concentric rings of students). Use a deck of

cards as the proteins (remind students that there is only one kind of protein, so they can't look at the front of the card). Students will generally want to try out new ideas once the first few don't work. Let them experiment a little until they find some rules that seem to work, or students seem ready to move on.

Slide 6: Present this as one possible solution. It doesn't work terribly well unless students actually pass cards at random at a consistent rate. Most of the cards should end up near the center and fewer should be on the edges. One advantage of this not very good rule is that students often come up with better solutions themselves.

Slide 7: Conclude the activity, identifying to student that the main point of the exercise is to show them that by communicate with very simple messages you can get interesting patterns. These same sorts of simple rules are what cells use to differentiate. Then introduce the term morphogen, and ask students if they know what part of the class simulation represents the morphogens (the cards). Students may want to try out a few more ideas at this point, so let them.

Part 3: Follow up.

Start the follow-up discussion with an assessment of students understanding. Either as a class, in groups or individual, ask students to draw a diagram (boxes and arrows) showing how DNA is connected to leopard spots, by drawing arrows between the following terms. Walk through the first step with them (which should be review): DNA (is transcribed to) -> Proteins.

Leopard Spots
Proteins
Morphogens
DNA
Cell Differentiation

The diagram should resemble a form like this:

DNA (are transcribed to)-> proteins (some of which are)-> morphogens (which allow for) -> cell differentiation (which can create) -> leopard spots.

The goal of this assessment should be to catch any misunderstandings students have with the previously presented material. This is the teachers chance to clarify these misunderstandings.

If there is time for more, then there are two follow up commentaries provided in the slides.

1.) Ask students to think about how a computer simulation would have helped with the class activity. The point here is to show students that scientists think about such simple rules and try to work out the consequences of these rules just like the students have been doing, but that the can't spend all of their time walking around a room and need to learn things quickly.

2.) As a way of piquing curiosity, let students know that using just two proteins that interact with one another we can get some very interesting patterns. The final few slides show examples of the types of patterns that are possible.

Assessment

This lesson involves an informal follow-up assessment as part of the lesson where students help the teacher draw a diagram at the end of the class relating the different vocabulary terms introduced, connecting DNA to leopard spots.