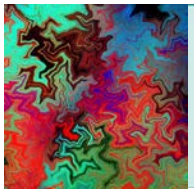

Why Two Heads?

HOW TO USE THIS RESOURCE

The images for this resource, photographs of planarians taken through a microscope, show the ability of some planarian species to regenerate lost or damaged body parts. These images can serve as anchoring phenomena to explore the key concepts described below.

The pedagogical practice of using phenomena to provide a context for understanding science concepts and topics is an implementation practice supported by the Next Generation Science Standards (NGSS). Phenomena are observable occurrences that students can use to generate science questions for further investigation or to design solutions to problems that drive learning. In this way, phenomena connect learning with what is happening in the world while providing students with the opportunity to apply knowledge while they are building it.

The "Implementation Suggestions" and "Teacher Tips" sections provide options for incorporating the images into a curriculum or unit of study and can be modified to use as a standalone activity or to supplement an existing lesson. The student handout includes reproductions of the images and the "Background Information" section.

KEY CONCEPTS

A. Regeneration replaces damaged or lost structures in adult organisms through mitotic cell division. Genetic factors and feedback preserve the orientation of the body axis (polarity) during regeneration.
B. Some organisms possess greater regenerative potential than others because of different types and numbers of stem cells. Planarians serve as model systems in the study of regeneration.

NGSS PERFORMANCE EXPECTATIONS

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

BACKGROUND INFORMATION

Planarians are simple multicellular animals called flatworms. They can detect light by using eyespots on their heads. They can also sense and respond to chemicals in their environment by using chemoreceptors on the sides of their bodies. Planarians both eat food and release waste through a tube called a pharynx, which sticks out of the middle of their body.

More than 100 years ago, scientists figured out that some planarians can regenerate parts of their bodies. Because of their simple nervous system, planarians do not feel pain when cut, only pressure. When cut, a planarian regenerates its missing end. How is this possible? Planarians have adult stem cells called neoblasts throughout their bodies. When a planarian is cut, its neoblasts multiply to make more stem cells. These stem cells then differentiate into the cells needed to replace the missing body parts. These regeneration abilities are far beyond those of the human body. However, understanding how planarians are able to regenerate lost tissues and body parts may provide clues for how to improve wound healing in humans.

How a planarian regenerates depends on where the planarian was cut. Figure 1 shows several images of a planarian that was cut across the top of its head, as shown by the dashed white line. The images show how the planarian's stem cells multiplied over the days postamputation (dpa) and eventually formed a new head.

A piece cut from a planarian can even form a new planarian. This new planarian regrows a head and a tail region in the appropriate places most of the time. Figure 2 shows two planarians from the same species. The one on the left is a typical individual for this species. The one on the right regenerated from a cut planarian treated with RNAi. RNAi is a technique that uses small pieces of RNA to turn off the function of specific genes. In this case, scientists used RNAi to turn off the gene for a protein that regulates polarity. Polarity is a property of organisms that have distinct ends, for example, distinct heads and tails. Polarity is maintained by proteins and other molecules throughout the organism's body. Because of RNAi, this planarian could no longer produce an important protein for maintaining polarity. As a result, the planarian's stem cells incorrectly formed two heads instead of one head and one tail.

IMPLEMENTATION SUGGESTIONS

The following suggestions outline several options for incorporating the images into a unit of study as the anchoring phenomenon:

Engagement, establishing prior knowledge, and providing context:

- Split students into groups of two. Have them examine Figure 2 and record what they notice. After a few minutes, ask them to mark the statements they wrote as observations ("O") or inferences ("I").
    - This task could serve as a quick formative assessment of students' current understanding of the differences between observation—in this case, what they see—and inference, their interpretation or explanation of what they see.
- Ask each group to share one observation or one inference from their list. Groups should avoid repeating what was shared prior to their turn. Make a master list of these observations and inferences. Ask students to review the master list, discussing reasons that statements were described as observations or inferences. Ask students for some ideas about what data they would collect or examine to support or refute their inferences.
- Invite students to ask questions about the images using stems such as "I wonder about …" or "What caused …?" As a class, discuss these questions and possible answers. These will be refined through further investigation, discussion, and experimentation.
- Ask students to think about a time when they got a cut or scrape. Have them write down or draw what happened as the injury healed. Students may include that the cut bled and then stopped bleeding, that the site around the cut became red or inflamed, and that the wound scabbed over and eventually healed and/or produced a scar.
- Tell students they will now be looking at an image of a planarian that was cut horizontally to remove part of its head. Ask students to examine Figure 1 and to annotate the image with what they think is happening.
    - The dashed white line shows where the planarian was originally cut. The unit "dpa" stands for "days postamputation."
- Ask students to consider how the replacement of the planarian's head is similar to or different from wound healing in humans. It may be helpful for students to make a chart of the similarities and differences (such as a Venn diagram) in order to organize their thinking.
    - One similarity that students may mention is that both processes involve cell division by mitosis. One difference is that wound healing produces limited numbers of new cells, whereas regeneration forms many different types of new cells. The cells formed during regeneration are derived from multiple stem cells and can re-form lost structures.
- Have students read the "Background Information" section, paying attention to the terms "regenerate," "polarity," and "stem cells." It may be helpful to have students summarize the information to one another and to pause between paragraphs to do so.
- Ask students to return to the observations, inferences, and questions that they listed earlier. They should now add to or revise their previous questions. They should also reconsider what data they would collect in order

to investigate their questions (for example, what affected the planarian's ability to regenerate?). Use this to transition to the following explorations and investigations of cell division, differentiation, gene expression, gene silencing, RNAi, and stem cells. (See the "Resource-Pairing Suggestions" below for sequencing options.)

Exploration, assessment, and extension:

- Explore/Investigate:
  - Provide students with living planarians and have them complete the laboratory investigation "Planaria Regeneration Activity."
  - Have students use "The Eukaryotic Cell Cycle and Cancer" Click & Learn to examine phases of mitosis and what regulates each of these phases.
  - Show the *Scientists at Work* video *Identifying the Key Genes for Regeneration*, which shows the results of RNAi experiments on planarians. These experiments investigate the roles of key genes involved in the regulation of polarity and head regeneration.
  - Have students work through the "RNA Interference" Click & Learn to learn more about how RNAi works.
- Assessment:
  - Using images and information from the *Identifying the Key Genes for Regeneration* video or other research, have students propose a model for how the planarian in Figure 2 developed two heads, emphasizing the role of polarity.
- Extension:
  - Planarians are a model system for investigating regeneration at the molecular and cellular level. Have students discuss why planarians are an ideal model system for studying regeneration. Then ask how studying regeneration at the molecular level might explain the formation of the two-headed planarian in Figure 2.
  - Regenerative medicine aims to find ways to repair tissues and organs, and to replace damaged or missing human body parts. Have students consider how learning more about the regenerative processes that occur in planarians may lead to a better understanding of human wound healing and the possible regeneration of limbs and other structures.

TEACHING TIPS

- Present students with the images first, before they read the background information.
- Background information may be edited to support student proficiency, course sequence, etc.
- The images may be projected in lieu of handouts.
- Printed images can be laminated for use in multiple classes.

RESOURCE-PAIRING SUGGESTIONS

Use these images to:

- investigate mitotic cell division, differentiation, growth, and the role of genes in these processes
- lead into a unit on homeostasis, feedback, and cell signaling
- support a unit on the importance of mRNA in normal cell functioning and gene expression
- introduce a lesson on stem cells

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