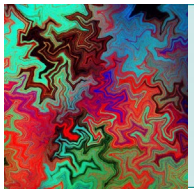

Synchronized Division

hhmi | BioInteractive

Phenomenal Image Educator Materials

HOW TO USE THIS RESOURCE

The image for this resource, which shows synchronized division in a sand dollar embryo, can serve as a phenomenon 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 "Teaching Tips" sections provide options for incorporating the image 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 a reproduction of the image and the "Background Information" section.

KEY CONCEPTS

A. Following fertilization, animals go from being a single cell to multicellular through mitosis.
B. Mitosis produces daughter cells that receive identical genetic information from a parent cell or a fertilized egg (zygote).
C. Differences among cell types within a multicellular organism are typically due to differences in gene expression, not genetic material, among cells.

NGSS PERFORMANCE EXPECTATIONS

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

BACKGROUND INFORMATION

Just six hours after fertilization, a sand dollar (*Dendraster excentricus*) egg has become a busily dividing embryo. Sand dollars are echinoderms, a group of invertebrates related to vertebrates like fish and humans. The embryo in the image is in an early stage of development, consisting of nearly 128 cells formed into a hollow, fluid-filled ball called a blastula. Certain groups of cells in the blastula are synchronized to divide at the same time through mitosis, a type of cell division.

Most of the cells in this blastula are midway through their eighth division, as indicated by the chromosomes aligned in the center of each cell. However, a small cluster of cells in the upper-right corner of the image are on a different schedule. The four smallest cells at the center of the cluster are beginning their last division before the embryo becomes a larva. These four cells will eventually give rise to the sand dollar's germ cells, which make sperm or eggs. The cells in the immediately surrounding area have just completed their sixth division. These cells will ultimately play an important role in various developmental processes, such as cell differentiation, the formation of the digestive system, and the development of an exoskeleton called a test.

Despite their different characteristics and roles, all of the sand dollar's cells (except for eggs or sperm) are genetically identical due to mitosis.

Technical Details: This image shows approximately one-third of an early *Dendraster excentricus* blastula, stained for microtubules and projected from serial optical sections obtained via confocal microscopy.

Image Credit: George von Dassow, PhD, Oregon Institute of Marine Biology, Charleston, OR.

IMPLEMENTATION SUGGESTIONS

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

Engagement, establishing prior knowledge, and providing context:

- Begin the lesson by telling students that they'll be examining an image of an organism's cells early in that organism's life. Show students the image and ask them to make observations using the sentence stems "I notice …", "It reminds me of …", and "I wonder …"
    - It may be helpful to indicate the boundaries around one cell so that students understand they are observing multiple cells.
- Use a think-pair-share protocol to have students share their observations about the image. Record class observations, noting when students make similar observations and drawing attention to the range of student-generated questions.
    - Students may observe that they see what look like multiple cells. They may note that most of the cells look similar to one another, but that some cells in the upper-right corner and around the edges of the image look different.
    - Students familiar with cell division may note that chromosomes appear to be lined up in the middle of many cells (indicating that these cells are in metaphase), or that spindle fibers and centrioles are present.
    - Students may wonder how many cells total are present, what kind of organism is shown in this image, why some cells look similar at this stage of development, and why other cells develop differently. Students may also wonder about the structures present, particularly DNA, spindle fibers, and centrioles, and may make analogies about what each structure reminds them of.
- Tell students that this image is of a sand dollar, a type of invertebrate related to sea urchins and sea cucumbers. It may be helpful to show additional images or videos of sand dollars and other echinoderms, particularly living sand dollars moving. Students may only be familiar with sand dollar tests, the hard shell-like exoskeletons that are found on beaches, and might not know what live sand dollars look like.
- Ask students to consider the following questions if they haven't already: "How does an organism go from one cell, a fertilized egg (zygote), to many cells? And how do different types of cells within the same organism arise?" Repeat the think-pair-share protocol above to record student thinking about this question, listening for commonalities.
- At this point, have students read the "Background Information" for the image, noting any key terms. After students are done reading, have them consider how mitosis can produce cells that are genetically identical to the parent cell, but that look and behave differently from one another. Record student thinking, particularly if it changes after reading the "Background Information," and use their responses to transition into the following explorations and investigations.
    - Students may correctly say that organisms grow through cell division (mitosis). However, they may struggle with the concept that different cell types arise from different patterns in gene expression, not from different cells having different genes from one another.

Exploration, assessment, and extension:

- Exploration/Investigation:
    - Have students watch either the "Human Embryonic Development" animation (more appropriate for introductory high school biology classes) or the "Differentiation and the Fate of Cells" animation (more appropriate for advanced biology classes).
        - As they watch, students should reconsider the guiding question from the previous section: "How does an organism go from one cell, a fertilized egg (zygote), to many cells?" In particular, students should note how many germ layers arise and what each layer eventually forms.

        - It may be helpful to download the transcript for the animation and provide it to students. They can read the transcript as they watch, noting key terms, then rewatch the animation before addressing the guiding questions.
    - Students can explore the "Eukaryotic Cell Cycle and Cancer" Click & Learn, using the accompanying worksheet appropriate to their level of biology. This Click & Learn includes a review of when and how cell division occurs, as well as what regulates cell division.
        - Depending on students' familiarity with cell division concepts, it may be useful to supplement this resource with a review of chromosome structure, structures involved in mitosis (e.g., spindle fibers), and the phases of mitosis.
    - Have students explore the "Genetic Mutations and Disease" Click & Learn. This resource shows that embryonic cells develop into different cell types. It also demonstrates how mutations that arise during development can have various effects, depending on the cell type in which the mutation occurs and when during development the mutation occurs.
        - Students should pay particular attention to the definitions of cell division, differentiation, and development. They should also learn to distinguish between germ and somatic cell mutations.
        - Students may have the misconception that all differences in cell types arise from mutations and not from different genes being expressed. It may be helpful to discuss that mutations are relatively rare, random events and that most mutations are neutral. Therefore, the likelihood of cells reliably developing mutations that lead to the different cell and tissue types needed for multicellular life is vanishingly low.
- Assessment:
    - Ask students to suggest what kinds of data could be collected to investigate the claim that cells within multicellular organisms usually have the same DNA.
        - Students may suggest collecting DNA samples from multiple tissue types in a single organism or group of organisms. They may also suggest collecting and comparing DNA samples from cells of the same organism at different points in that organism's development.
        - Note that there are some exceptions to this claim. Cells that may not have the same DNA include gametes (eggs and sperm) and immune cells that undergo gene rearrangements. An organism may also have cells with different DNA due to chimerism; one way this can occur is through organ transplantation.
- Extension:
    - Explore another example of gene expression variation between tissues with the *Making of the Fittest: Evolving Switches, Evolving Bodies* suite of resources. These resources show how different tissue types within a fish's body give rise to different structures, despite having the same genes.
        - In particular, the hands-on activity "Modeling the Regulatory Switches of the Pitx1 Gene in Stickleback Fish" explores how gene expression can vary among tissue types, leading to different structures.

TEACHING TIPS

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

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