Biology Independent Project

Hello Students,

This resource packet includes a project that you can work on independently at home. You should also have project packets for some of the other courses you are enrolled in. These projects are standards-aligned and designed to meet the Remote Learning instructional minutes guidelines by grade band.

High school project packets are available for the following courses:

- English 1
- Algebra
- Biology
- US History
- English 2
- Geometry
- Chemistry
- World Studies
- English 3
- Algebra 2
- Physics
- Civics
- English 4

### High School Biology Project: How does a cut on my hand heal?

<table>
<thead>
<tr>
<th>Estimated Time</th>
<th>~ 225 minutes of project time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Level Standard(s)</td>
<td><strong>HS LS 1-4.</strong> Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.</td>
</tr>
<tr>
<td>Caregiver Support Option</td>
<td>Caregivers can assist by reading and discussing text and data with the student.</td>
</tr>
<tr>
<td>Materials Needed</td>
<td>Initial and final models, Model Revisions template, drawing and coloring materials, paper, pencil</td>
</tr>
<tr>
<td>Question to Explore</td>
<td>How does a cut on my hand heal?</td>
</tr>
<tr>
<td>Student Directions</td>
<td>Students will gather several different types of evidence from text, data, and models to determine how cell division contributes to how a cut heals. More detailed directions are given in the task. Please write <strong>ALL</strong> responses on a separate sheet of paper or in your notebook.</td>
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</table>

### Lesson Credits
- Text in Investigation 1 Adapted From: [The Cellular Biology of Wound Healing by M.C. Regan and A. Barbul](#)
- Images in Investigation 1 Adapted From: [Szczepankiewicz A, Lackie PM, Holloway JW. Altered microRNA expression profile during epithelial wound repair in bronchial epithelial cells. BMC](#)
Phenomenon Introduction

Jamie gets home from school and decides to have a snack. She gets out an apple, a knife and some peanut butter. While slicing the apple, the knife slips and Jamie cuts her finger. The wound is very deep, and wow did it hurt. The wound immediately starts to bleed, so she rinses the cut under running water then places a Band-Aid over the wound.

Over the course of several days, she removed and replaced the Band-Aid three different times. She was curious how the wound was going to heal, so she took a picture of the wound each time she changed the Band-Aid. She has shared her pictures below.

![Day 1, Day 5, Day 10 pictures]

1. What do you notice happening to the wound over time? Share as many specific observations that you can. Write them on a sheet of paper.

When she was putting together these pictures to share, Jamie started to think about how the skin on her finger “knows” how to heal the wound. Throughout this investigation, you will gather evidence to help Jamie explain:

How does a cut on my finger heal?
Before conducting any investigation to gather evidence, you’ll have a chance to share your current thinking on how and why this cut on the finger heals, just as scientists would. Then, you’ll gather evidence to help you revise your current thinking and finally generate a new explanation.

1. On the three model templates below, draw out and explain your thinking about how the cut on Jamie’s finger heals over time. Be sure to...
   a. include what is happening inside the cells
   b. any processes you think are taking place and the timing of those processes.
(1) Normal Skin Without a Cut

Explanation:

(2) Skin 5 Days After The Cut

Explanation:
Investigation 1: How do cells close the wound after a cut?
To help us begin to figure out how cells move into the cut, we’ll obtain information from two authentic scientific texts. The first text describes the process that cells undergo in the days following a cut.

1. As you read the first text below, annotate it for any information that you can find that you think will help you answer the investigation question, “How do cells close the wound after a cut?”

**Text 1: The Cellular Biology of Wound Healing**

**Inflammatory Phase (Day 0-5)**
The healing response is initiated at the moment of injury. Initially, blood fills the wound. During this time, platelets and collagen come together forming a temporary clot. This accumulation of cells also initiates the formation of a **fibrin mesh** that strengthens and stabilizes the clot and unites the wound edges.

**Proliferative Phase (Day 3-14)**
**Endothelial cells** from the side of the venule closest to the wound begin to migrate into the
extracellular matrix area. While these events are proceeding deep in the wound, restoration of epithelial integrity is taking place at the wound surface. Re-epithelialization of the wound begins within a couple of hours of the injury. Epithelial cells, arising from the edges of the wound or dermal epithelial cells within the wound bed, begin to migrate under the scab and over the underlying viable connective tissue. The epidermis immediately adjacent to the wound edge begins thickening within 24 hours after the injury. Marginal basal cells at the edge of the wound lose their firm attachment to the underlying dermal layer, enlarge, and begin to migrate across the surface of the temporary matrix filling the wound. Fixed basal cells in an area near the cut edge undergo a series of rapid mitotic divisions, and these cells appear to migrate by moving over one another in a leapfrog fashion until the defect is covered. Once the defect is bridged, the migrating epithelial cells lose their flattened appearance, become more columnar in shape and increase in mitotic activity. Layering of the epithelium is re-established and the surface layer is eventually keratinized [29].

Maturation Phase (Day 7 to 1 Year)
Almost as soon as the extracellular matrix is laid down, its reorganization begins. Initially, the extracellular matrix is rich in strong, flexible proteins, which forms a temporary fiber network. This serves as a foundation for migration and ingrowth of cells while active remodelling of the wound and scar continues for up to 1 year after the injury and appears to continue at a very slow rate for life.

2. What do you think is the central idea of the text above that will help us figure out “How do cells close the wound after a cut?” Write you response on a sheet of paper and consider the following:
   a. How the space opened by the cut is filled with cells.
   b. How different types of cells reform the structure of the wounded skin.

The second text you will analyze is a set of images gathered using microscopy as scientists investigated the patterns of cellular regrowth that occur to cells grown in a petri dish following a simulated wound.
Text 2: Stages of Wound Repair in Bronchial Cells

These images were obtained from bronchial cells grown in a petri dish. Cells were grown until they completely covered the surface of the dish, and at time = 0 hrs, the cells were damaged by scraping a “wound” through the middle of the petri dish, as shown in Panel A, 2 hours after the scrape. The remainder of the panels show stages of wound repair at different time points. A = 2 hrs, B = 4 hrs, C = 8 hrs, D = 16 hrs, E = 24 hrs, F = 48 hrs post-wounding.

**Optional:** To view a video of the above diagrams, visit this link: [https://www.youtube.com/watch?v=oi0F4nXSj6I](https://www.youtube.com/watch?v=oi0F4nXSj6I)

Write your responses to the following questions on a sheet of paper:

3. What patterns do you notice in the behavior of the bronchial cells over time as they respond to the wound?

4. Looking at what you found in both Text 1 and Text 2, what can you conclude about how a cut on your hand heals? Cite evidence to support your conclusions.
Investigation 2: How does my body reproduce skin cells?

To help you figure out how more new skin cells are formed to replace those that were damaged when Jamie’s finger was cut, you’ll first read about a new idea: the cell cycle. Then, you’ll analyze data from two different experiments on the rate of the cell cycle in wounded skin tissue. You’ll find evidence in the data from these experiments to determine how the body reproduces skin cells in a cut.

Stages of the Cell Cycle

To divide, a cell must complete several important tasks: it must grow, copy its genetic material (DNA), and physically split into two daughter cells. Cells perform these tasks in an orderly, predictable series of steps that make up the cell cycle. The cell cycle is a cycle, rather than a linear pathway, because at the end, the two daughter cells can start the exact same process over again from the beginning.

In eukaryotic cells, or cells with a nucleus, the stages of the cell cycle are divided into two major phases: interphase and the mitotic (M) phase.

- During **interphase**, the cell grows and makes a copy of its DNA. Interphase can be split into three parts: G1, S, and G2.
- During the **mitotic (M) phase**, the cell separates its DNA and its cytoplasm, forming two new cells with identical genetic material.

1. From this text, what information can you conclude about the cell cycle that will help us understand how the cut on Jamie’s finger heals? Respond on a sheet of paper.

You will now use the ideas about the cell cycle that you just gathered to compare two authentic science experiments that were performed that investigated the rate of the cell cycle in injured skin cells versus uninjured skin cells. You’ll consider the benefits and limitations of each experiment, compare their outcomes, and analyze their data to determine the effect of a wound on the cell cycle in skin cells.

2. When comparing two experiments with similar objectives, it is often helpful to consider the benefits and limitations of the experiment design for each experiment. As you read the descriptions of the two experiments, record what you find on each of these topics in the table below.
<table>
<thead>
<tr>
<th>What is the goal of this experiment?</th>
<th>Experiment A</th>
<th>Experiment B</th>
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<tbody>
<tr>
<td>What similarities do you notice about the design or goals of these experiments?</td>
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</tr>
<tr>
<td>In what important ways are the goals or designs of these experiments different?</td>
<td></td>
<td></td>
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<tr>
<td>What are the advantages of the way this experiment was designed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What are the limitations of the way this experiment was designed? (That is, what can you NOT conclude from this experiment?)</td>
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**Experiment A**

**Experiment B**
Experiment A: Mitotic Activity of Wounded Human Epidermis

Aim
In this experiment, the lead scientists Dr. Sullivan and Dr. Epstein were aiming to determine how mitosis proceeds in healing of wounded skin on the human epidermis.

Methods
We made seventeen to twenty-five wounds, 5 mm long and 2—4 mm deep, with a razor blade on the outside of the lower legs of four healthy white males, 25-35 years old. During the following four days, biopsies were obtained at six hour intervals and each wound was examined by biopsy once. Colcemid, a drug that stops the cell cycle, was then injected intradermally at the wound site to suspend mitotic activity. The biopsy specimens were fixed immediately in 10 percent formalin, a preservative, and put into paraffin wax. Mitotic activity was estimated by counting the number of dividing cells seen in 4000 intact nuclei at 400x microscopy on each side of the wound. Eight sections selected at random from each specimen were examined. The approximate mitotic index was expressed as dividing nuclei per 1000 interphase nuclei.

Results
The figure below shows the epidermal mitotic response to wounding in four different subjects over a 96 hour period. Mitosis/1000 indicate the number of cells that were dividing per 1000 cells sampled.
Experiment B: The Origin & Mode of Fibroblast Migration & Proliferation in Granulation Tissue

Aim
Spyrou, Watt, & Naylor were looking to determine how mitosis proceeds in healing of wounded skin on the rat epidermis.

Methods
The wound site of the rat was clipped, wet shaved, and swabbed with disinfectant. A square 15 x 15 mm wound was made by excising the skin with a scalpel. All 28 rats used were adult males (270-290 g, 3 months old). All animals were weighed daily and 10 tracings of the wound area were made at exactly 24 h intervals in quietly restrained but not anaesthetised rats. Animals in groups of 4 received 1 mg/kg of pure colchicine by injection in the test area 4 h before being euthanized each day (1, 2, 3, 4, 5, 6, and 7) after wounding. All tissue specimens were fixed then processed in paraffin. Epidermal cells were assessed using light microscopy at a magnification of 1250x using oil immersion. Based on microscopic appearance, interphase nuclei were differentiated from mitotic. All mitotic nuclei were located and counted. The results were expressed as nuclei in division per total cell nuclei.

Results
The mitotic indices (% of cells undergoing mitosis) were calculated in every animal from days 1 to 7. The graphs below show mitotic activity by day. Samples were taken from both the wound site (test) and an unwounded site (control).
Now that you have compared the design and objectives of the two experiments, analyze the data to see what patterns you can determine.

3. What patterns do you notice in the amount of cells undergoing mitosis in each of the experiments?

<table>
<thead>
<tr>
<th>Experiment A</th>
<th>Experiment B</th>
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4. How does the amount of cells undergoing mitosis in the cells taken from the wound compare to the amount of mitosis in cells taken from non-wounded tissue (controls) in each experiment?

<table>
<thead>
<tr>
<th>Experiment A</th>
<th>Experiment B</th>
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5. What features of the experiment design ensure that each experiment is controlled? Why?

<table>
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</tr>
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Respond to the questions below on a sheet of paper:

6. How do the outcomes of the two experiments compare to one another? Are the outcomes consistent? Why or why not? Cite evidence to support your conclusions.

7. Looking at what you found in both Experiment A and Experiment B, what can you conclude about how a cut on your hand heals? Cite evidence to support your conclusions.

Investigation 3: “How does gene expression for cells in the cut change?”

To help us figure out how cells change in response to the cut to help it heal, it will help us to look at a new idea called gene expression. You’ll recall that all of our traits, such as skin color, hair color, height, and many more, are controlled by the DNA in our genes. The genetic code in the DNA undergoes a process of transcription to make mRNA and translation to make proteins, which are the molecules that give rise to traits.
Many genes are not always producing traits, however. At times, some genes can be turned on and some can be turned off. For example, one gene called INS produces a protein called insulin, which regulates how your body handles the sugar that enters your blood after eating a sugary snack. INS is usually turned off in your pancreas cells. But when you eat that sugary doughnut, the gene turns on, making insulin to help your body metabolize the sugar you just ate. If you then stop eating, your body responds again by turning the gene off, and no more insulin is made.

Overall then, cues from the environment, like the sugar molecules in the doughnut you ate, are responsible for turning some genes on and off. These environmental molecular factors that turn genes on and off are called transcription factors.

8. From this text, what information can you conclude about the cell cycle that will help us understand how the cut on Jamie’s finger heals? Respond on a sheet of paper.

Scientists were curious if similar changes to gene expression occur when you cut your skin. Below, you will see data taken from an experiment where scientists investigated gene expression when skin cells respond to a wound. In this study, instead of insulin as shown in the above example, scientists were interested if the expression of a protein called keratin was turned on or off more in wounded skin cells. Keratin proteins are the most common proteins found in hair, nails, and skin, and they provide the underlying structure to each of these tissues.
Keratin Gene Expression Experiment

Aim
In this experiment, Dr. Mazzalupo aimed to figure out if more keratin proteins are made in response to a cut.

Methods
Scientists made a small cut in the skin of embryonic mice, and then they isolated cells from both the cut site and an uncut site as a control. Scientists extracted keratin mRNA from these cells and used it to measure the degree to which four different keratin genes were turned on or off in response to the cut.

Results
In the data below, you will see the different levels of gene expression for four different keratin genes. Brighter bands on the image indicate that more mRNA is present in the sample, and therefore, the gene is being more highly expressed (more turned on).

The columns represent the relative amounts of mRNA for each of the keratin proteins K6a, K6b, K16, and K5. GAPDH is a control mRNA that is always turned on in cells. 0 h corresponds to mRNA taken at the time of the wound, 12 h indicates mRNA taken 12 hours after the wound, and UnW indicates mRNA taken from cells on the same mouse away from the wound site.

Respond to the questions below on a sheet of paper:
9. What features of the experiment design ensure that the experiment is controlled? Why?

10. What patterns do you notice in this data?

11. Based on this data, what can you conclude about how a cut on your hand heals? Cite evidence to support your conclusions.
Using Evidence to Construct a Final Model

After gathering evidence from each of the activities and investigations, you'll now revise the model you made originally to help us answer our driving question, "How does a cut on your hand heal?" In the templates below, sketch your final models and record your final explanations. Be sure to...

- Include evidence that you've gathered that supports your explanation.
- Annotate the cell cycle diagram that is given to show different rates of mitosis.
- Draw how cells grow to cover the cut skin tissue.
- Pick two aspects of your model that you revised from your initial model, and explain what evidence supports those revisions.

(1) Normal Skin Without a Cut

Explaination:
(2) Skin 5 Days After the Cut

Explanation:

(3) Skin 10 Days After the Cut

Explanation:
Reflections (write your responses on a sheet of paper)

1. What did you learn from this task about how scientists develop models to explain phenomena in the world?

2. How does this task make you think differently about what happens to your skin when you are cut?
Glossary

Adjacent: next to or adjoining something else.

Anaesthetized: to give an anesthetic to (a person or animal), especially to induce a loss of consciousness.

Biopsies: an examination of tissue removed from a living body to discover the presence, cause, or extent of a disease.

Connective Tissue: tissue that connects, supports, binds, or separates other tissues or organs within an animal.

Dermal: relating to the skin or dermis.

Endothelial Cells: refers to cells that line the inside surface of blood vessels and body forming a bond between circulating blood and the rest of the vessel wall.

Epithelial Cells: cells that come from surfaces of your body, such as your skin or the lining of your mouth and digestive system.

Euthanized: put (a living being, especially a dog or cat) to death humanely.

Excised: having been cut out surgically.

Extracellular Matrix: is a three-dimensional network of large molecules, such as collagen, enzymes, and proteins, that provide structural support to surrounding cells.

Fibrin Mesh: long strands of tough insoluble protein that are bound to the platelets.

Fixed: fastened or set securely in position.

Flank: the side of a person's or animal's body between the ribs and the hip.

Intradermal: about, or below a dermal tissue layer (typically the skin) and describes the location where medication is injected.

Keratinized: to add a fibrous protein (keratin) to cells to form the main structural constituent of hair, feathers, hoofs, claws, horns, etc.

Marginal Basal Cells: a type of cell in the innermost layer of the epidermis (skin) situated on the edge or border of a wound.

Mitotic Index: the ratio of the number of cells undergoing mitosis (cell division) to the number of cells not undergoing mitosis.

Mitotic Division: in eukaryotic cells, a process that occurs when a parent cell divides to produce two identical daughter cells.

Oil Immersion Microscopy: a technique used to increase the resolving power of a microscope; a technique that makes the viewing field more clear visually.

Preservative: a substance used to preserve cells, foodstuffs, wood, or other materials against decay.

Transcription Factor: is a protein that controls the rate of transcription of genetic information from DNA to messenger RNA.