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Divide & Conquer

Lauren Hackman
Pioneer Hi-Bred

Audrey Pohlmann
Blank Park Zoo

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Divide & Conquer

Graphic work by Joe Taylor

Lauren Hackman & Audrey Pohlmann

ABSTRACT: This article presents a modified biology lab used to teach the cell cycle. Many traditional versions of the onion root tip lab are delivered in a "cookbook" format to review what students have already learned about the phases of the cell cycle. This modified version illustrates how the onion root tip lab can be much more meaningful when turned into an inquiry-based, exploratory activity to scaffold from a concrete experience to the more abstract process of cell division. *This article promotes National Science Education Standards A, C, and G and Iowa Core Curriculum Standards 1, 2, and 5.*

A staple activity for teaching the phases of the cell cycle is the Onion Root Tip Lab. This lab is so popular that many web-based activities are now available online allowing students to look at cells going through the phases of cell growth and division without actually having to prepare and view slides under a microscope. While the images available are nice and neat, they misrepresent science as a set of conclusions rather than a process of investigation. Students miss out on this sense of discovery and do not practice the perseverance necessary to conduct scientific inquiry.

Prior to computer technology, students used light microscopes to view cross sections of onion root tips on pre-prepared, fixed slides. With the online activities, students look at images of onion root tip cross sections as part of a cell cycle tutorial. In both cases, a worksheet usually accompanies the lab that presents the purpose of the activity, a summary of the phases of cell division, a list of instructions, and follow-up questions to guide student observations. This traditional "cookbook" approach appeals to many teachers because it is straightforward, easy for students to follow, and requires little prep-time by the teacher. Pre-prepared slides and online images reduce the amount of time needed for the lesson and eliminate the messiness of preparing slides with real onions. However, we wonder to what extent important learning is lost along the way.

Unfortunately, without the concrete experience of handling the onions and preparing the slides, students often fail to make the connection that the samples they are viewing consist of real cells that have been growing and dividing to create a much larger organism. Cell growth and division is a highly abstract concept and the teacher's role in scaffolding between concrete and abstract representations is crucial for students' understanding. "Cookbook" labs also do little to promote skills in science inquiry. Scientific inquiry encourages students to actively carry out investigations during which they ask questions, make predictions, invent and reflect on laboratory procedures, and interpret data. The Onion Root Tip Lab is an example of a lab that can be transformed from an ineffective, concept review activity to a meaningful, inquiry-based, initial exploratory experience. This modification increases the cognitive work done by the student rather than for the student (Saunders, 1992).

Preparations for the Lab

A day or two before the lab, you will need to buy green onions and soak them in a container of water to stimulate new root

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growth. One onion for every five students should suffice. The other materials necessary to carry out the lab include light microscopes, Petri plates, microscope slides, cover slips, paper towels, forceps, disposable plastic pipettes, small containers of water, a dropper bottle of 1M hydrochloric acid (HCl), 1% toluidine dye, and razors wrapped in masking tape.

We take carefully planned measures to prevent any of the razors from leaving the classroom. We limit the number of razors to one per group and are always aware of how many razors the students have access to each class session to ensure that all are accounted for at the end of each class. Numbering each razor by writing over the masking tape makes it easy to quickly determine when a razor is misplaced and which group was responsible for it.

LAB SAFETY

The razor blades we use in this activity present a significant safety issue. To prevent accidents from happening, we explicitly address and model the proper usage of these tools with students. Having every students' attention is crucial during the discussion about the razors. Before the activity, the razors should be thoroughly wrapped with masking tape so that only a small corner of the blade is exposed. This small corner will be sufficient for cutting the onion tissue in this activity. The thick masking tape will keep students from accidentally gripping the blade and makes the blade easier to handle.

Additionally, we remind students about general safe laboratory procedures including wearing safety goggles, removing food and drink from the lab, and alerting the teacher immediately of any spills or accidents.

Setting up the Investigation

To introduce the activity we review the critical ideas that students must understand in order to complete the activity. Using this activity as an exploratory lab rather than a verification lab means students likely know little about the process of cell division. However, we use this activity after students have a good grasp of cell structure and function. At this point we want students to make some observations of cells dividing before we work to develop students' conceptual understanding of cell division. After students have observed cell division and understand the process, we will introduce the vocabulary so that students might label the process.

Rather than telling students what they need to know, we pose questions that draw out students' understanding of cell structure and the reasons why cells need to divide. Some questions to start discussion might include

- "What are some reasons why cells divide?"
- "What might happen to the cell if it never divided?"

If students have trouble answering the questions we draw upon prior activities they have completed. For example, our students know that an expanding cell's volume increases much more rapidly than cell surface, which results in an insufficient supply of nutrients to pass across the cell membrane to fulfill the needs of the cell. We also encourage students to consider what a dividing cell might look like. Many students benefit from drawing predictive pictures. This discussion prepares students to be introduced to the onion samples.

We hold up some onions and ask students

- "In what part of an onion might we find the most cells growing and dividing?"
- "How might this be similar or different from where we would find cells growing and dividing in animals?"

Once students come to the conclusion that plant cells are dividing in the roots and shoots, we tell students that they will be looking at cells from the tip of an onion root.

While we have students work in groups, every student prepares a slide. Not only is this an effective classroom management tool of keeping all students engaged, it also ensures that each group will have a decent sample to look at. Because some students have trouble preparing a slide that clearly shows individual cells, we prepare some extra slides ahead of time. Having some fixed slides may also be beneficial in case a large number of the samples do not turn out.

Sample Preparation

To begin the lab, we have each group cut one root from the base of the onion bulb. Each group member should then cut a 1 or 2 mm piece from the tip of the root and place it in a Petri plate. As the students make observations of the root tips, we ask

- "If we put this root tip under the microscope as it is, what trouble might we have in seeing the individual cells that make up the root tip?"

This question encourages students to think about the fact that the piece of root is too thick to be light transparent. Some students even note that the cells are white or colorless, which might make it hard to see them under the microscope. If students do not make this connection, then another line of questioning is

- "What might get in the way of us seeing what is inside of a cell?"

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- “What do you notice about the color of the root tip?”
- “What might we have to do to make the cells easier to see?"

Once students recognize the need to modify their sample so that pertinent observations can be made, we explain how the cells will be hydrolyzed and stained. We tell students that the roots will be soaked in acid for four minutes to break down the tissue and increase our ability to see inside the cell. For safety reasons, we personally add the one or two drops of 1M HCl to each student's root tip.

While the cells are hydrolyzing, we use the time to discuss and demonstrate the next few steps in the procedure. We explain that 1% toluidine blue dye will be added to the root tip to stain the colorless cells and make them easier to see. After the root has soaked in dye for 2 minutes, the excess dye will be rinsed off of the root tip. To help students save time and encourage them to always think about their actions, we ask how they could rinse the root tip without washing the sample off the slide into the collection container. Whenever possible, we want students making decisions and coming up with procedural ideas. Once the root is rinsed and covered with a cover slip, we ask students to suggest some ways we could further spread the root tip tissue.

After acknowledging and discussing students' ideas, we suggest that the slide should be placed cover slip-side down on a paper towel. Applying gentle pressure to the slide with a pencil eraser will squash and spread the root tip tissue. Again, we engage students by asking them why pressure should be applied to the slide and not the cover slip. Even when we give directions, we work to mentally engage students rather than having them blindly follow our directions.

Once the four minutes of hydrolyzing are complete and we have discussed and demonstrated the staining process, students' root tips are removed from the HCl with a forceps and placed on the slide. We remind students that HCl is an acid and ask how they should handle the root tips when transferring them from the Petri dish to their slides. We find that simply telling students to use forceps and to be careful with the solution does not convince us that they understand proper safety measures. To avoid excess use of the dye, we add a few drops to each student's sample.

While the cells are being stained we review proper handling of microscopes and have students bring the microscopes to their workstations. Once the microscopes are set up, students rinse and squash the root tips as was discussed and demonstrated earlier. Students are directed to look for evidence of cell division using the samples they have prepared.

Investigating Cell Division

While students look at their slides, we walk around the classroom to monitor student activity while helping students who are struggling. To encourage student success in locating dividing cells, we ask

- "What part of the cell structure would you look for when trying to see the boundary between cells?”
- "What part of the cell looks different from cell to cell?"

Once students think they have found a dividing cell, we ask questions like

- "What observations have you made that might indicate cell division?"
- "What do you think the cell(s) would have looked like just before this stage?"
- "What do you think the cell(s) would look like in a later stage of division?"
- "How could you test your predictions?"
- "What additional observations would you like to make to better understand cell division?"
- "How could you document or keep track of your observations for later discussion?"

Notice we are asking students to reflect on what they see and guiding their thinking so that they continue to seek additional observations and to make sense of their observations through drawings or note-taking. Rather than isolate themselves, we encourage students to compare their slides to the slides of other groups.

Making Sense of Observations

After viewing the slides, we ask students to draw the different cell stages they are seeing on the board. Every type of cell they have been observing should be accounted for without repeating any drawings. This may take place in several iterations, with students returning to the microscopes to be sure that all cells have been represented. We usually have students begin making the drawings on the board during investigation time as “new” observations are made.

Once all of the drawings have been recorded, we randomly number each one and ask students to organize the cells into a plausible progression that would explain how cells grow and divide. Beyond ordering the drawings, we encourage students to explain their rationale for arranging the cells in the manner they chose. Students will use their own wording to describe the process rather than being bogged down with technical terminology. By beginning with observations and then having students make sense of the ordering, students better internalize the vocabulary to be introduced next.

As students discuss their drawings, new vocabulary would greatly expedite their discussions. We pose the question

- "Imagine we repeatedly talk about a cell that is at the stage where the chromosomes are positioned at its center. What might be a convenient way to refer to this cell rather than describing the cell in detail every time?"

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Students may suggest that it would be easier to give a name to the cells that are in that particular state. Once students have organized their drawings into a sequence, we introduce technical terms such as interphase, mitosis, cytokinesis, chromosomes, etc.

Reflecting on their Investigation

To help students better understand the process and purpose of science we ask

- "In science there are many technical names to describe structures and processes. Why do scientists assign such technical terms?"

Students usually explain that terms are human constructs or useful ways for humans to organize the natural world. We want students to realize these assigned terms and organization are not inherent characteristics of nature. Rather they are the product of how humans are interpreting and labeling the natural world (Shideler, 1966; Campbell, 1953).

We also work to help students understand that science observation can be messy and difficult; an idea that does not surface when looking at pre-prepared slides or online images. We explicitly address this idea by relating what students have experienced with their own slides to the problems scientists face when lab experiments go wrong and must be restructured and repeated to attain manageable results. By helping students understand the messy, uncertain and human sides of science, we hope they will find science more interesting and better understand how science ideas are developed and changed.

The Teacher's Role

The success and effectiveness of these post-lab discussions depend greatly on the teacher's decisions, behaviors, and questions throughout the activity. An effective questioning pattern is one that includes open-ended, thought-provoking questions, appropriate wait-time that encourages students to process and share their responses, and follow-up questions that relate to student ideas and show students that their ideas are valuable. In addition, positive non-verbal behaviors encourage active participation. Common examples of such behaviors include using eye contact, holding an arm out to welcome more answers, raising eyebrows to encourage more comments, walking around the room to include all students, and smiling to convey interest in the ideas of all students.

While asking questions, waiting for answers, and exploring student thinking take significantly more time in the classroom, our goals for students extend far beyond simple ability to follow directions. We want students to be involved in their investigations and to think critically about their decisions – a habit that will serve them well in life, not just the science classroom.

Conclusion

Many common biology labs can be easily modified to better engage the thinking of students. These modifications include stripping away rote instructions, involving students in the decisions that affect the direction of the lab, and posing meaningful questions that compel students to think more deeply about what they are doing. We have provided an example of how to accomplish this through the classic Onion Root Tip Lab. Try this modified lab with your students, and then identify another lab that you use with students and make your own modifications. You might be surprised at the difference it makes in how students approach your labs, their motivation and ownership, and even how it rejuvenates your own curiosity and interest.

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Lauren C. Hackman *is a Research Associate in Genetic Marker Technology at Pioneer Hi-Bred. She can be reached at hackman_lauren@yahoo.com.* ***Audrey Pohlmann*** *is an education specialist at the Blank Park Zoo in Des Moines, Iowa. She can be reached at audpohl@gmail.com.*

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