Close the Textbook & Open "The Cell: An Image Library"

NABT BioClub RECOMMENDATION

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Abstract

Many students leave the biology classroom with misconceptions centered on cellular structure. This article presents an activity in which students utilize images from an online database called "The Cell: An Image Library" (http://www.cellimagelibrary.org/) to gain a greater understanding of the diversity of cellular structure and the correlation of a cell's structure to its function. Additionally, students develop an awareness of the structural variation of organelles across organisms.

Key Words: *Cell biology; image library; teaching.*

"Are all mitochondria orange?" "Are nuclei always purple?" "Ribosomes must be all the same size and shape." Perhaps all science teachers have heard similar statements and questions in their own classrooms. We may at first be puzzled by them; however, given the idealized way in which cells are depicted in textbooks, it is no surprise that many students leave the biology classroom with misconceptions centered on cellular structure. For example, many students acquire the misconception that all mitochondria assume the "football" shape that is often depicted in texts (Storey, 1990), but they can actually span a range of shapes, existing as individual organelles or forming a highly branched "interconnected tubular network" (Karp, 2005, pp. 183). In light of such misconceptions and the call for the integration of biology and imaging sciences (Sullivan, 2000), teachers are encouraged to utilize "The Cell: An Image Library" (http://www.cellimagelibrary.org/; hereafter "The Cell") when teaching units on the diversity of cellular structure and the correlation of a cell's structure to its function.

Students often believe that biological images can only reveal structure but not function.

This approximately 3- to 4-day lesson (9–12) invites students to use The Cell while addressing the following objectives:

- Convey the importance of the relationship between structure and function.
- Develop an awareness of the diversity of cellular architecture.
- Articulate the function of cellular organelles.
- Compare and contrast images from various techniques of microscopy.

These student objectives are aligned with the *Next Generation Science Standards* (see Addressing the Standards, Table 1). Prior to this lesson, it is helpful if students understand the cell theory and use of a light microscope as well as specialized instruments such as scanning, transmission, and confocal microscopes.

○ What Is "The Cell: An Image Library" & Why Use It?

Thanks to the American Society for Cell Biology's new digital image repository and library, your days of searching the Web for a common-use image of a mitochondrion or Golgi apparatus are over. This database, which is freely accessible to the public, contains images, videos, and animations of cells from collections, publications, and practicing scientists (Orloff et al., 2013). In addition, the annotations that accompany the images and videos in The Cell result in it being a highly useful tool for science education (Orloff et al., 2013). Students often believe that biological images can only reveal structure but not function. Analyzing biological images can offer students new insights into structure and function through visualization of processes at the molecular, cellular, and system-level scales (Kelley et al., 2008).

Despite the recent call for imaging sciences and analysis to be integrated into science curricula (Sullivan, 2000; Kelley et al., 2008), some biology teachers may have limited experience with the field of microscopy. In fact, many teachers have never had the opportunity to sketch a cell while looking through a microscope (Araújo-Jorge et al., 2004), and these teachers may be uncomfortable incorporating microscopy images into their teaching. Interpreting cell visualizations produced by others can be an important skill in science. Affording students the opportunity to systematically create their

The American Biology Teacher, Vol. 76, No. 3, pages 201–207. ISSN 0002-7685, electronic ISSN 1938-4211.
DOI: 10.1525/abt.2014.76.3.9

Table 1. Addressing the Standards.

Next Generation Science Standards
Science and Engineering Practices: *Developing and Using Models* • Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-2)
Disciplinary Core Idea: *LS1.A: Structure and Function* • Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1) • Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2)
Crosscutting Concepts: *Systems and System Models* • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions – including energy, matter, and information flows – within and between systems at different scales. (HS-LS1-2) *Structure and Function* • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-LS1-1)

own representations of cells lets them demonstrate their conceptual understanding (Van Meter & Garner, 2005). This lesson provides a mechanism for teachers to expose students to microscopy images from actual research projects.

○ Engage: What Is a Cell?

At the beginning of a unit on cells, students are directed to draw what they think a cell looks like. By purposefully leaving this task vague, we encourage students to use their creativity and imagination to visually describe their understanding of a cell. As a result of constructing an image of a cell, students are equipped with a framework they can use to incorporate new knowledge, and teachers have the ability to diagnose misconceptions while tailoring instruction for the remainder of the unit. Because drawing has been shown to be effective in helping learners overcome limitations of static print material, effectively organize their knowledge, and foster new scientific understanding (Ainsworth et al., 2011), teachers should collect the students' sketches so that they can be revisited later in the unit.

To start my students thinking about the history of cell biology, I pose the following question: "Why do we call them cells?" After allowing groups 5–10 minutes to brainstorm, each group shares their idea with the whole class. Students are then asked "In what other contexts have you heard the word *cell*?" As students call out responses, the teacher writes them on the board. Typical student responses include *battery cell*, *cell phone*, and *jail cell*. The teacher then sketches a row of jail cells on the board and asks students how this diagram is related to the structure of cells. This leads into a discussion on the proximity of cells to one another. Students are then asked to think about the bars of jail cells and how they could be related to biological cells. Typically, a student will describe how the bars allow certain things in and out of the jail cell but not others; it is here that teachers should direct students' attention to the idea of semipermeable membranes.

After students have drawn a cell and discussed the origin of the term *cell*, teachers should project "The Inner Life of the Cell" (http://multimedia.mcb.harvard.edu/) to the front of the class. Teachers may want to mute the video, because the narration is very detailed and likely to overwhelm students who are just beginning their tour of the cell, but a brief search of the Internet will reveal many versions of this type of video, including some with only music in the background. It is recommended that teachers periodically pause the video to ask students "What is happening?" and "What processes are taking place?" For example, a teacher may stop the video when it shows a mitochondrion bouncing back-and-fourth against elements of the cytoskeleton, and students almost always say they are amazed to see the remodeling of microtubules, the way ribosomes come together on mRNA, and the budding of vesicles from the Golgi apparatus.

○ Explore: Inspecting Images

At the beginning of this section of the unit, teachers should begin familiarizing students with The Cell by modeling how to derive information from the images (Figure 1) as well as how to use the website's advanced search feature. Student groups utilize the handout "Using the Cell" (Figure 2) to guide their exploration of The Cell as each individual records image data in his or her science notebook. Each group is assigned a specific type of cell to examine. For example, teachers may wish to require students to examine neurons, skeletal muscle, cardiac, blood, and epithelial cells. As students are using The Cell, teachers should continually check in with each group as a means of formative assessment to ensure that each group is headed in the correct direction and using appropriate scientific information to answer the questions on the student handout. While checking in with each group, I remind them to be detailed in their research, because they will be making a digital presentation as experts on their cell type (Table 2). In particular, teachers are encouraged to pay attention to how students are taking notes on the variation in size, shape, and origin of the cells.

○ Explain: Speaking Structure, Fostering Function

After completing the cell type analysis, each group uses a form of digital media, such as Glogster (http://www.edu.glogster.com) or Prezi (http://www.prezi.com), to present an overview of their assigned cell

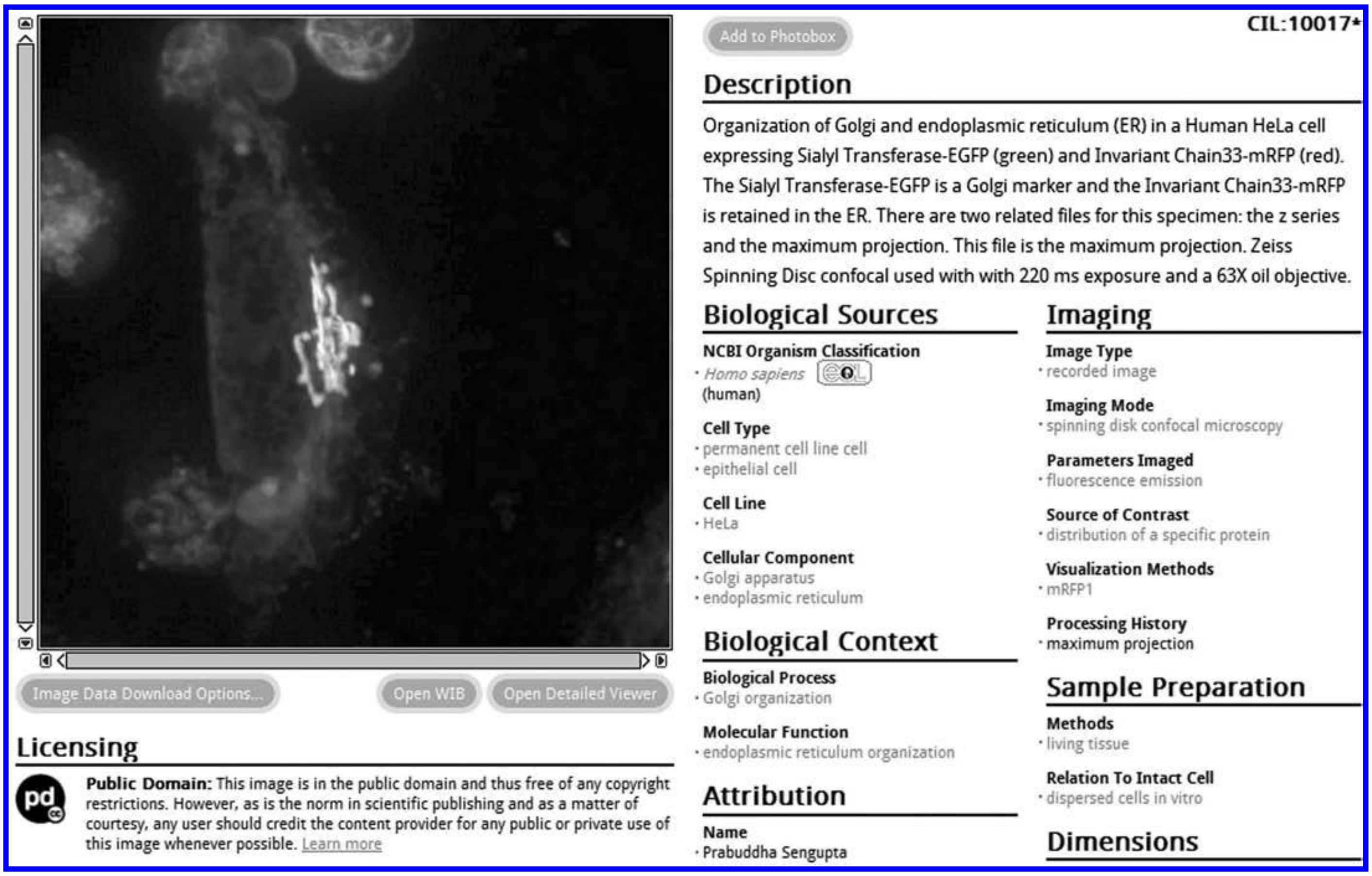

Figure 1. Example of data record from "The Cell: An Image Library."

type's structure and function. While students are constructing their presentations, they should be reminded to include how the specific structural differences of their tissue type result in a cell specialized for its given function. For example, a group that was assigned liver cells might discuss its extensive network of endoplasmic reticulum and the role it plays in detoxification of the body.

Student groups take turns using the class computer and projector to share their digital presentation with the rest of the class. Teachers who have a class website may consider uploading the presentations so that students have the ability to review the images as needed. At the conclusion of the presentations, a class discussion on the relationship between structure and function allows teachers the opportunity to address any misconceptions. For example, students may be unaware that plants contain both mitochondria and chloroplasts, not realize that chlorophyll is sequestered in thylakoid membranes, or confuse cell junctions of animals and plasmodesmata of plants. If students display similar misconceptions, they are encouraged to complete the extension activity in which they compare and contrast specific characteristics of organelles found in both plants and animals.

○ Extend: Charting a Course for Cellular Concepts

After students have used The Cell to recognize the diversity of cellular architecture, this extension activity gives them the opportunity to research specific similarities and differences between organelles found in both plants and animals. In order to expand on the traditional chart comparing the organelles of plants and animals, each group of students will focus on a specific organelle to analyze in terms of structure, abundance, role, and composition. For example, one group of students might explore the Golgi apparatus's characteristics and find that in plants the width of space between cisternae can vary across individual organelles and that cytoskeletal filaments are commonly found between these "flattened sacks," whereas in animals the amount of space between cisternae tends to remain fairly constant across individual organelles and there is an absence of filaments between the sacks. Another group might examine ribosomes and discover that they are relatively similar in structure and size between plants and animals; however, ribosomes contained within mitochondria and chloroplasts are much smaller than those that are attached to the endoplasmic reticulum or free floating and are very similar to ribosomes in prokaryotes. In this activity, students are encouraged to utilize books, articles, and the Internet to research their assigned organelle and develop a rationale for any similarities and differences. Students can use various forms of digital media, such as Zooburst (Figure 3), Glogster, or Prezi, to present their findings.

○ Evaluate: Reflecting & Remembering

After their presentations, students are asked to draw a cell again. After they have completed this second image, teachers should return their initial drawings and instruct them to carefully compare and contrast the two images. Often, drawings before and after this activity are drastically different, with the preactivity drawings containing an

My Assigned Cell Type: ________________

1. Direct your browser to the *Cell Image Library* by typing http://cellimagelibrary.org/ in the navigation bar.

2. Click on "Cell Type" in the image library's navigation bar

3. Search the listing of cells for your assigned type and click on the images of interest. While scrolling though the library, take note of the variation in size, shape, and origin of the cells. Be prepared to create a digital presentation with the information you gather about your specific cell type. See guidelines below and record all of the following information in your notebook.

In your digital presentation, be sure to include the following:

- The cell's overall main function
- The most prevalent organelle(s)
- How these prevalent organelle(s) contribute to the cell's main function
- Detailed explanation of biological processes and context
- The cell's overall shape
- Images of the cell

4. Do the majority of micrographs resemble the image of an animal cell in your text?

5. Are you surprised at the variation among the images of your assigned cell type? Explain why or why not.

6. After selecting your assigned cell type in the image library, compare and contrast the images with one another. As you carefully examine each image, be sure to read the image's description and pay particular attention to which cellular structure the dye is staining. Also, be sure to download and save at least three to five excellent images of your cell type, as you will need them later. Also include reference information and a description of the biological processes depicted in each image in your science notebook; an example is below.

Cell Image Library Number (CIL): 11374
Basic Description
Golgi apparatus in a rat liver cell.

Biological Source(s):
Rattus (Rat)
Hepatocyte (liver cell)

Biological Context
Post-translational protein modification
Carbohydrate biosynthesis
Protein glycosylation

Imaging
Transmission Electron Microscopy (TEM)
Stained with broad specificity

7. Now, work in your groups to use digital tools, such as Glogster (http://www.edu.glogster.com) or Prezi (http://www.prezi.com), to create a presentation on the structure and function of your assigned cell type.

Figure 2. Using "The Cell."

Table 2. Digital Presentation Checklist.

• Function of cell
• Most prevalent organelle(s) and function(s)
• Detailed explanation of biological processes
• Overall shape of cell
• Images

overly simplified version of a cell like those contained in a textbook, whereas postactivity drawings are exceedingly specific versions of a cell (Figure 4). To assess learning, students are required to write a reflection on their experience using The Cell, compare and contrast their two drawings, and elaborate on their perception of microscopy in their science journal. Teachers are encouraged to prompt the students by providing open-ended questions such as "What are specific differences you notice between your two drawings? How is

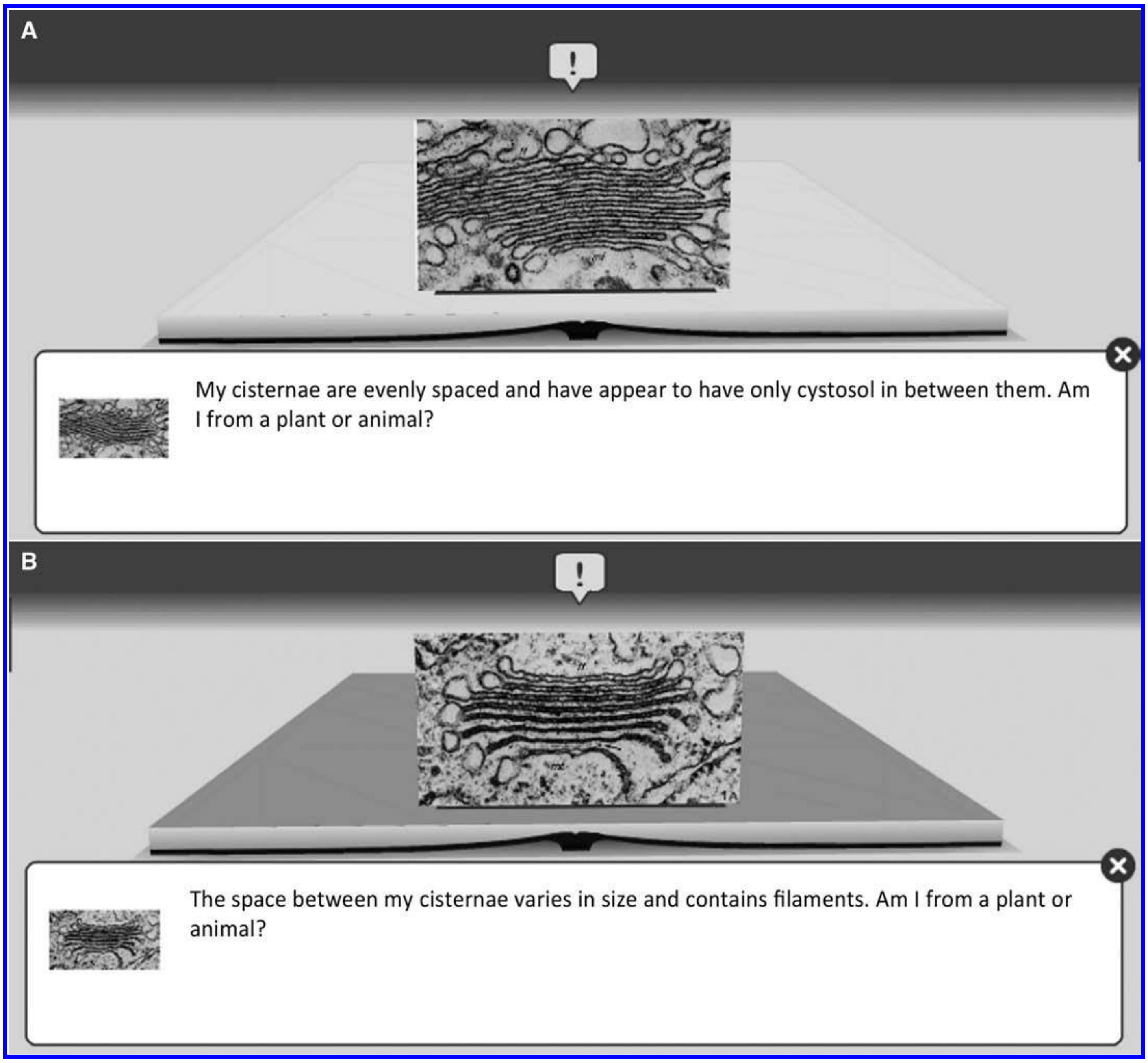

Figure 3. Example of Golgi Apparatus Group's Zooburst. Students use images to demonstrate that the structure of the Golgi apparatus can vary between plants and animals.

cellular structure related to function? Why do different cell types have varying numbers of organelles?" This journal entry allows teachers to evaluate how well students understand the relationship between cellular structure and function while diagnosing any misconceptions. In their responses, students should be sure to include the aspect of the activity they enjoyed the most in addition to stating one thing they would do differently.

○ Conclusion

Despite the fact that student misconceptions in cell biology have been documented (Storey, 1990, 1991, 1992), the vast majority of recent research into student misconceptions overlooks the field of cell biology and investigates such topics as energy and matter (Wilson et al., 2007), natural selection (Anderson et al., 2002), and genetics (Bowling et al., 2008; Smith et al., 2008). Peer evaluations and student reflections indicate that many students gain a great deal of insight into the relationship between cellular structure and function, as well as microscopy techniques, as a result of completing this activity. In their reflections, students often describe the activity as fun and engaging because it affords them the opportunity to learn about cells from images collected by real scientists, not a cartoon in a textbook.

After teaching this lesson, we noticed that students responded well to authentic scientific information and images. We have seen evidence of this in journal entries, pre/post drawings, and improved

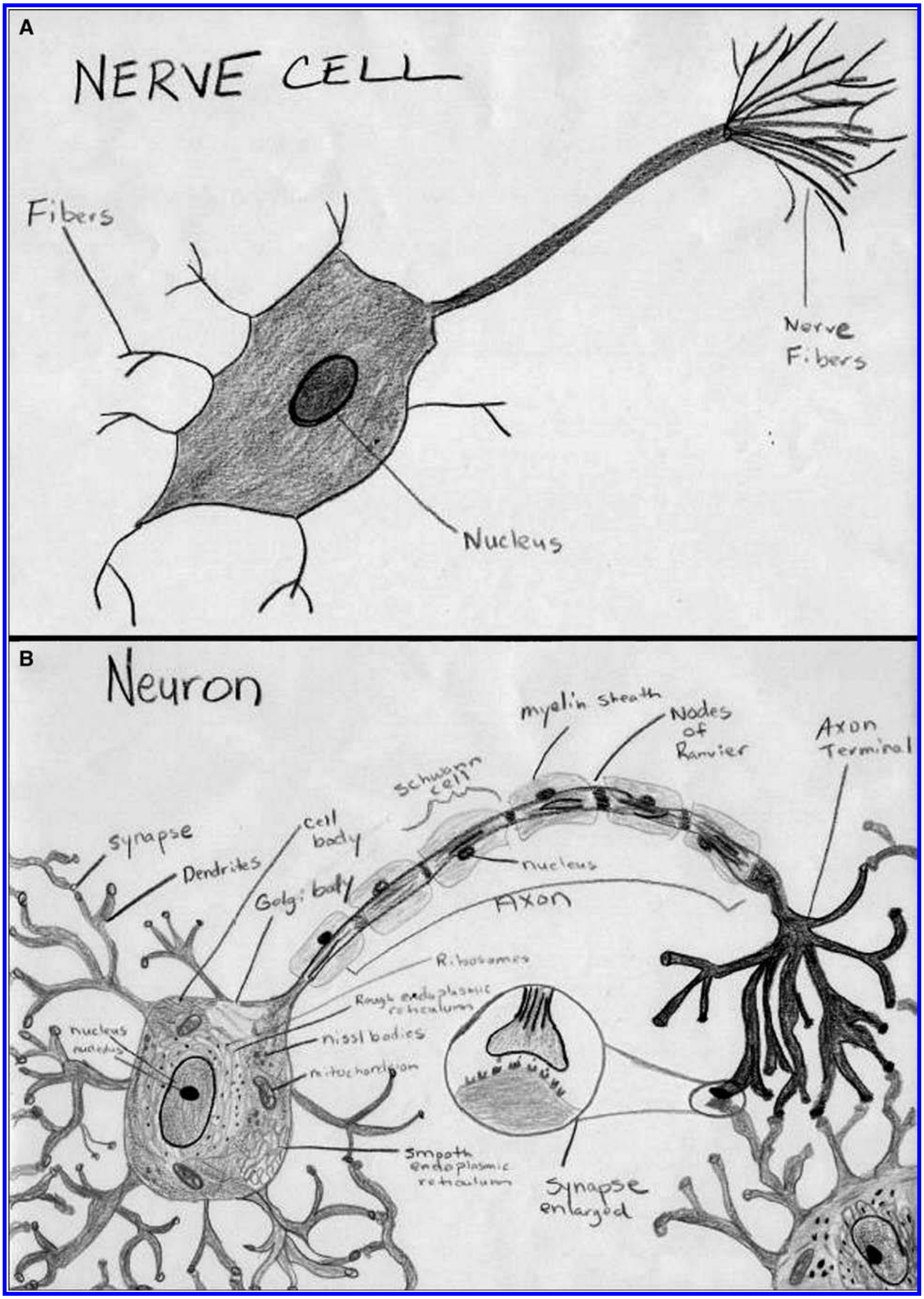

Figure 4. Examples of student's preactivity and postactivity drawings. Students' visual depictions of cellular structure and function greatly increased in level of detail and accuracy from before (A) and after (B) exposure to "The Cell: An Image Library."

performance on unit tests. For example, many students demonstrated a greater understanding and appreciation for the fact that cells are not static entities that occur in isolation, but rather exist in dynamic "communities," in addition to a conceptual understanding of the relationships among organelles, cell types, and functions.

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