TIPS, TRICKS & TECHNIQUES

Photomicroscopy Made Easy by Converting Cell Phones into "CellCams"

NABT BioClub RECOMMENDATION

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Abstract

Photo and video microscopy expand the utility of microscopic observations in education, but attachments needed for this have been prohibitively expensive or too fragile to allow students individual access to these techniques. We describe a do-it-yourself method using inexpensive materials that allows students to build an adaptor that will allow them to turn their cell phones into "CellCams" that they can use to capture microscopic images and videos. Activities are presented that give students ways to learn about concepts of microscopy using their self-collected images.

Key Words: *Photomicroscopy; microscope; microorganisms; cell phone; smartphone; adaptor; do-it-yourself.*

Introduction

The value of using microscopes to enable observations of nature at the subvisible scale was dramatically demonstrated by Antoni van Leewenhoek in the mid-1600s (Pedrotti, 2009). At that time, scientists used carefully constructed line drawings to communicate what was seen through the microscope. With the advancement of technology in modern times, photomicroscopy has become the favored method for capturing magnified images of samples. Photomicroscopy has traditionally required a camera mounted on the eyepiece or on another component of the microscope. Most commonly this is done with specialized microscopes, cameras, and/or attachments that allow the image passing through the ocular lens to be perfectly aligned and focused on the camera's sensor plate. These products tend to be expensive and fragile, and this has prohibited their wide use in education, particularly with middle and high school students who are learning about microscopy for the first time.

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Cell phones all come equipped with a decent to good-quality camera that allows taking pictures of sufficient quality for educational purposes. Student ownership of these phones has increased rapidly in recent years, and many applications are available for editing and sharing photos taken with them. A cell phone camera can be used to capture an image from a microscope without any attachments, but holding the camera the correct distance from the ocular lens and properly aligned with the beam of light is difficult and frustrating. Commercial products are available that allow the attachment of cell phones to microscopes, but these are also expensive and could be damaged by novice student use. Here, we describe a simple method using inexpensive materials that allows students to build their own adaptors that will convert their cell phones into "CellCams" capable of taking photos and videos through a microscope's ocular lens.

Materials

- Paper-towel or toilet-paper tube (4.5 cm diameter)
- Foam weather-strip tape (1–2 cm wide)
- Adhesive shelf-lining paper
- Ruler
- Scissors and/or small knife
- Popsicle sticks
- Rubber bands
- Pen or pencil
- Cell phone with camera function

The materials are shown in Figure 1. It takes about 15–20 minutes to construct the CellCam adaptor.

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Figure 1. Supplies needed to make CellCam adaptor.

○ Procedure

There are two types of CellCam adaptors to accommodate two locations of cameras on cell phones: mid-mounted and corner-mounted varieties. Students should base construction of their adaptor on the camera position of the phone they will be using. When using the CellCam, students should remove any protective casings surrounding the phone to facilitate use of the phone's camera. While this activity is tailored for flat-profile phones, flip-phone models can also be accommodated with the mid-mounted adaptor.

Mid-mounted CellCam Adaptor

1. Measure and mark a paper-towel or toilet-paper roll 4 cm from one end. Cut around the roll to make a 4-cm-tall cylinder.
2. Cut a 13.5-cm strip of 1-cm-wide foam weather-strip tape. Remove the adhesive backing, and firmly press the weather strip around the inside of the roll so that it is flush with one end. Save the adhesive backing for the next step.
3. Measure and mark the edge of the adhesive backing at 3.0 cm, 6.8 cm, and 9.8 cm. Wrap this strip around the outside end of the roll without the inner foam ring.
4. Make a mark on the roll at the end of the strip, then transfer the three marks measured in step 3 onto the roll. These marks should be made 1 cm from the edge of the roll.
5. Cut four vertical slits in the roll at the locations marked in step 4. Each slit should be just long enough to allow a popsicle stick to be inserted into it, and should be made carefully so that it is as close to vertical as possible.
6. Cut a piece of adhesive shelf-lining paper that is 4 × 15 cm. Remove the adhesive backing, and wrap the paper around the roll to cover it completely.
7. Cut through the paper to reopen the slits cut in the roll in step 5.
8. Insert one popsicle stick through two slits that are 3 cm apart, and then insert another popsicle stick through the remaining two slits. The completed CellCam adaptor should now look like the one pictured in Figure 2.

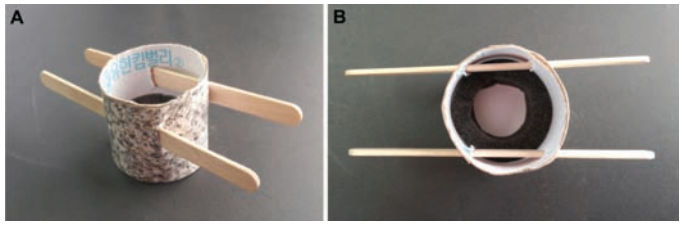

Figure 2. CellCam adaptor for mid-mounted camera phones: (**A**) side view; (**B**) top view.

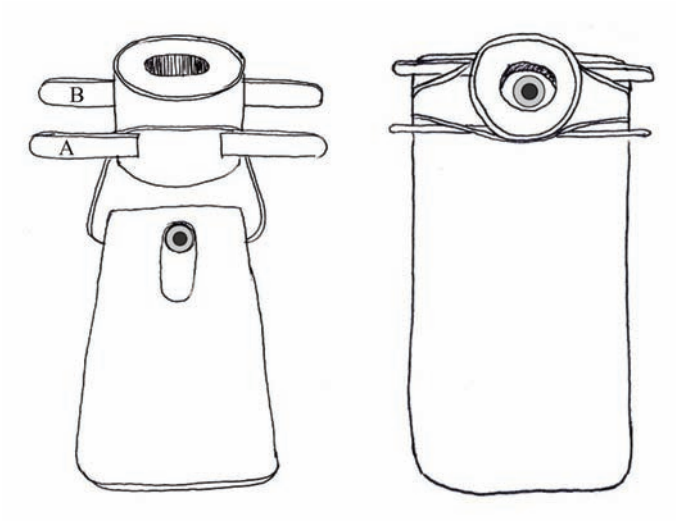

Figure 3. Attachment of the CellCam adaptor to a mid-mounted camera phone.

Attaching the CellCam adaptor to the phone: Place one rubber band around popsicle stick A, and stretch it around the phone as shown in Figure 3. The weather-strip side of the adaptor needs to be away from the phone. Align the adaptor so that the camera is well centered. If the location of the phone's camera is such that popsicle stick B is over the phone, a second rubber band can be used to better secure the adaptor, as shown in Figure 3.

Corner-mounted CellCam Adaptor

1. Remove any protective casing from the phone to be used, and measure the depth of the phone.
2. Place a toilet-paper roll over the back-mounted camera of the phone and position the roll so that the camera is well centered, as shown in Figure 4.
3. While holding the roll in place, mark the bottom of the roll where it meets the side and top edges of the phone.
4. Transfer these marks up 3.5 cm from the bottom of the roll, and draw a horizontal line connecting the marks.
5. Draw a second line that is above and parallel to the first horizontal line. The spacing between these lines needs to be equal to the measured depth of the phone from step 1.
6. Use a small knife or scissors to cut along the lines drawn in steps 4 and 5 to create the slot for phone insertion.

Figure 4. Alignment of the adaptor tube with the cell phone camera.

7. Cut two 13.5-cm strips of 1-cm-wide foam weather-strip tape (or one strip of 2-cm-wide weather-strip tape). Remove the adhesive backing, and press the weather strip around the inside of the roll. If using 1-cm-wide weather-strip tape, adhere the first piece 1 cm up from the inside bottom edge of the tube, and adhere the second piece below this one so that it is flush with the bottom of the tube.
8. Cut a piece of adhesive shelf-lining paper with dimensions equal to the height of the tube (approximately 10 × 15 cm long). Remove the adhesive backing and wrap the paper around the roll to cover it completely.
9. Cut through the paper to reopen the slots cut in the roll in step 6.

Attaching the CellCam adaptor to the phone: Insert the camera corner of the phone into the slot of the adaptor with the camera facing down, as shown in Figure 5.

Using the CellCam

The CellCam can be used to capture images or video of specimens being viewed through a microscope. It can be used with dissection or transmission light microscopes, with either one or two eyepieces. The object to be photographed should be initially brought into focus using the microscope in a traditional manner. Once the image is centered and in focus, a CellCam can be attached to the microscope's eyepiece to capture the image.

To capture an image, turn on the phone's camera application and attach the adaptor to the phone. Check to make sure that the camera is placed at the center of the adaptor tube. Slowly insert the weather-strip tape side over the eyepiece of the microscope, and gently slide it into place. The light passing through the eyepiece will initially be seen as a small, bright circle. Keep this circle centered on the phone screen, and *slowly* push the adaptor over the eyepiece tube. Keep pushing down until the field-of-view circle fills

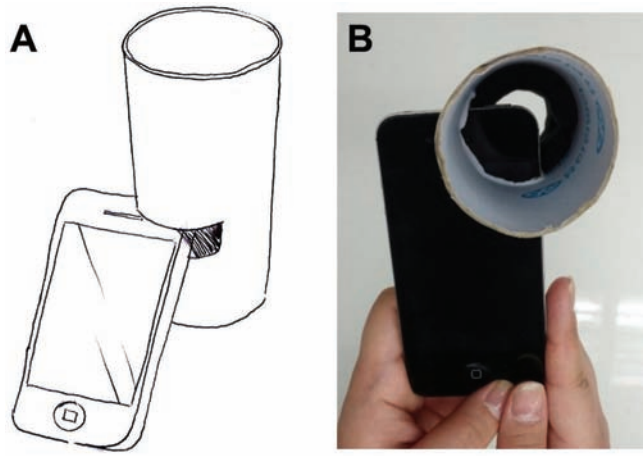

Figure 5. (**A**) Insertion of the phone into the corner-mounted CellCam adaptor. (**B**) Top view of phone with CellCam adaptor attached.

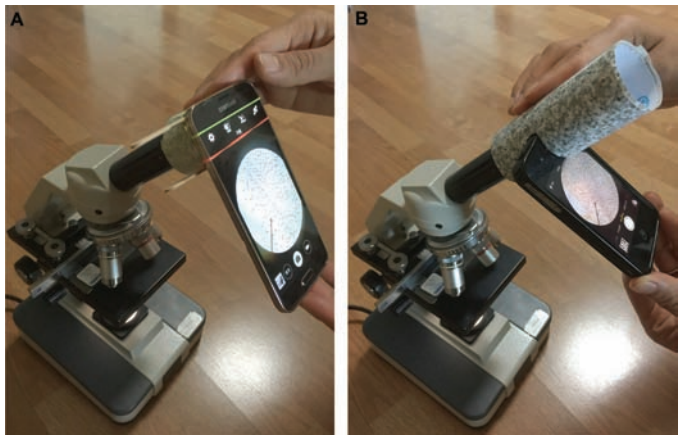

Figure 6. CellCam mounted on a microscope, showing proper alignment of image: (**A**) mid-mounted camera version; (**B**) corner-mounted camera version.

the screen and the edges of this circle are in sharp focus, as shown in Figure 6. It is helpful to keep one hand on the adaptor tube and use the other hand to support the phone to keep the image well centered. The camera should automatically adjust exposure to produce a clear image of the specimen. At this point, photos or videos can be taken.

Tips for Use & Troubleshooting

When using the CellCam for the first time, it is best to attach and adjust the position of the CellCam very slowly. It is easy to tilt the CellCam out of alignment with the image. Because of microscope optics, movements of the image on the phone screen will appear backward in relation to the movement of the phone on the eyepiece tube. With practice, students should be able to make needed adjustments for positioning of the CellCam with better predictability and control. It is important that the phone's camera be as close to centered as possible within the adaptor prior to attaching the CellCam to the microscope. Students should be made aware that positioning should be checked every time.

○ Suggested Activities

Field-of-View Size Determination

Place a transparent plastic ruler on the stage of the microscope and view it under low power, with the millimeter marks showing across the middle of the field of view. Use the CellCam to photograph this image (Figure 7). Students can then calculate the magnification seen on their phone screen by measuring the space between a single-millimeter increment. This measurement will be the total magnification seen on their phone and can be used to determine the dimensions of other specimens viewed using this microscope under low power.

Example: If a 1-millimeter increment measures 11 mm on the cell phone screen, the total magnification is 11×. If a student takes a photo of an eyelash using the same microscope and objective lens, and measures the diameter of the eyelash on the phone screen as 1.0 mm, then the actual diameter of the hair will be 1.0 mm / 11 = 0.09 mm.

This magnification seen on the CellCam screen can easily be adjusted for the other objective lenses on the microscope. For example, if the low-power objective lens is 4× and the magnification seen on the phone screen is 11×, and the other lenses are 10× and 40×, then the following correspondences would apply:

Objective lens	CellCam magnification
4×	11×
10×	27.5×
40×	110×

The dimensions of other small items can be estimated in this way (e.g., rice, sand, salt, cheek cells, pond microbes). However, it is important to note that this applies only to the original ("zoomed out") setting of the phone's camera, and if the student "zooms in" the magnification will increase to an uncertain degree. If the instructor has access to a stage micrometer or to microscopes with calibrated ocular micrometers, these can be used to provide more precise determination of total magnification of images captured by students with their CellCams.

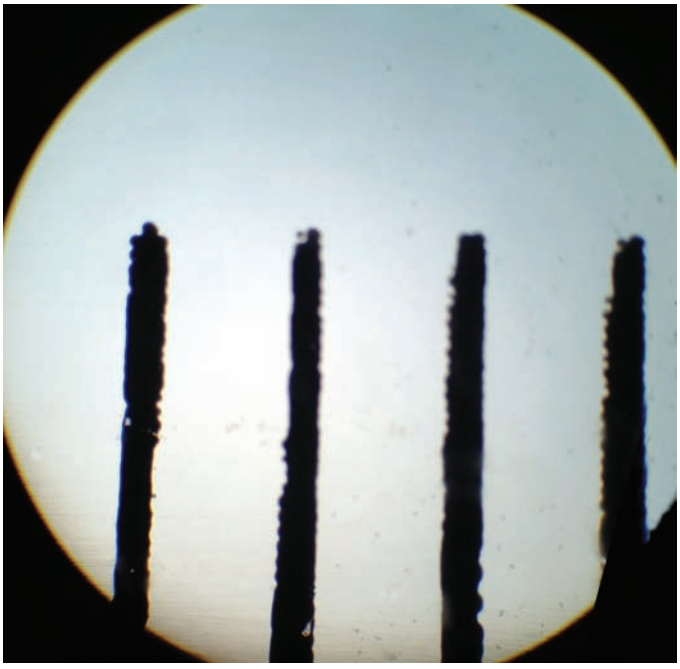

Figure 7. Clear plastic metric ruler viewed with 40× total magnification and photographed with a CellCam.

Eye on Pond Water

Pond water is reliably a fascinating source material for observing a wide array of microorganisms. Algae, protozoa, insect larvae, and microscopic worms are abundant and are readily viewable with standard light microscopes. However, asking students to draw what they see in pond water is difficult because many of the organisms are motile and observed only for a brief time. Use of a CellCam can greatly enhance a student's ability to record what they observe by first capturing what they see as photos or videos. In addition to improved anatomical observations, use of a CellCam allows students to better answer questions such as these: How many different types of microorganisms did you detect in your sample? How big were the various microorganisms in relation to each other? How did different microorganisms interact with each other? These and many other questions can be investigated by taking advantage of images and videos that students capture with their CellCams.

Other Possibilities

Many items look amazingly different when viewed under a microscope. Figure 8 shows examples of interesting samples photographed with a CellCam.

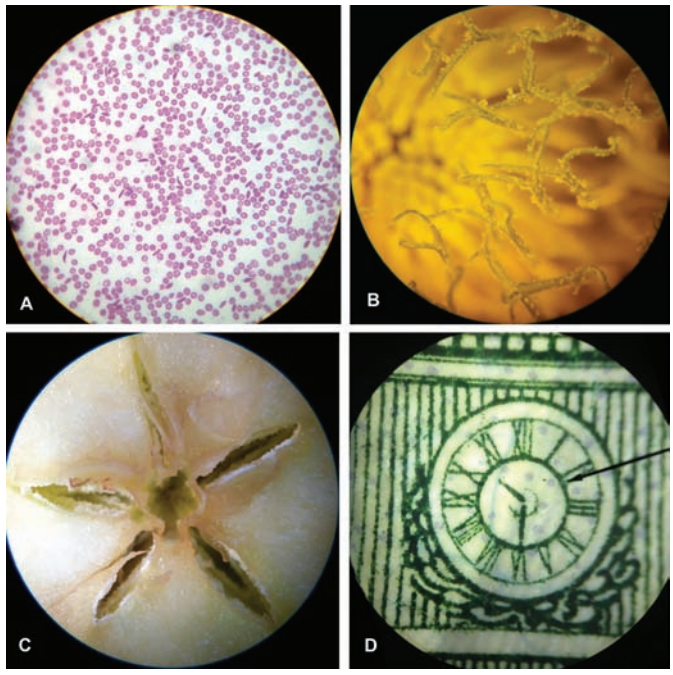

Figure 8. Examples of CellCam captured images. (**A**) Prepared slide of sickle-cell blood viewed with transmission light microscope at 400×. (**B**) Dandelion anthers viewed with dissection microscope at 30×. (**C**) Transversely cut apple viewed with dissection microscope at 7×. (**D**) Clock tower on Independence Hall on the back of a $100 bill viewed with transmission light microscope at 40×.

The only limit to the types of photos taken with the CellCam is a student's imagination, and this may well be its best application. Simply encourage your students to apply their own ideas to discover how various objects appear at the microscopic level. In this way, you can tap their creativity and inspire them to explore the previously unseen microscopic world.

○ Acknowledgments

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Reference

Pedrotti, P.W., Jr. (2009). Antoni van Leeuwenhoek "Father of Microbiology." Available online at http://www.vanleeuwenhoek.com/.

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