

ARTICLE

Documenting Laboratory Procedures with Video

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Demonstrating laboratory procedures in person during class time can be time-consuming. When procedures are done under a microscope, live demonstration is also impractical because of the limited number of students who can view the demonstration at once. Creating videos beforehand, which students can watch before class and

review during lab sessions, solves both of these problems. This article suggests ways to make and distribute high quality video of microscopic procedures.

Key words: video, editing, demonstration, microscope, dissection

Laboratory instructors are always looking for ways to demonstrate procedures more clearly, use class time more effectively, and reduce student frustration. As technology has become less expensive, video has become an option for most instructors. Video offers several advantages over live demonstrations. It can often show things that are difficult to demonstrate in person, such as dissection under a microscope. It can save time, since a well-edited video can be watched more quickly than a live demonstration. Students can (and do) watch complex parts several times, seeing things that they might miss in a live demonstration. Students can use videos to learn procedures before class. Finally, video can be used to document, preserve, and share expertise. In the following sections, I suggest many ways to optimize video quality, some easy and some difficult. However, keep in mind that a poor quality video may be better than none at all.

PLANNING

First, ask whether video is the best way to make your point. Sometimes, a clear diagram and written description may suffice. If so, they are often faster to produce, as well as requiring less time for a viewer to use. Be clear about what the video should accomplish. Should it train students to carry out procedures in lab? Should it illustrate how a procedure works, in general, for students in a lecture class? These purposes suggest different levels or types of detail. For the former, concentrate on the steps the viewer will have to take, leaving explanations for a separate text; for the latter, you might concentrate on reasons behind some steps and omit others entirely. If the video is intended for wide distribution, avoid referring to specific makes of equipment if possible, since viewers elsewhere may have different equipment.

Next, given the purpose of the video, decide what must be included and what can be omitted. Keep the video as short and simple as possible while still accomplishing its goals. After listing the necessary steps and details, make an outline and storyboard. The storyboard would include simple diagrams of the scenes that will appear in the video, corresponding to each step of the procedure. At this point, it should be clear which scenes are necessary.

EQUIPMENT

Camera

Newer consumer video cameras are high definition format (1920×1080 pixels, often called HD or 1080p). Older CCD cameras are usually standard definition (640×480, often called SD). In general, higher resolution is preferable, but there are trade-offs. Relative to SD, HD video is slower to process in editing and takes more storage space and internet bandwidth. Furthermore, the 16:9 aspect ratio of HD, designed for movie theaters, is not appropriate for the microscope view. A 4:3 SD ratio is more suited to the view through a microscope. I suggest shooting video in HD and then cropping to a 4:3 ratio (1440×1080 pixels) before exporting to a video file.

If your video does not require a microscope, there are many camera options. Even a phone camera will do, although you will get better results from a camera with optical zoom and macro features. For greater flexibility, many digital SLRs shoot HD video and offer the benefit of interchangeable zoom lenses with adjustable aperture. When recording without a microscope, use a tripod with a pan/tilt head. If possible, use a high quality (expensive) head, which will pan and tilt smoothly, producing video without jerky transitions.

Look for a camera that can easily export video to a computer for editing. Cameras with FireWire (also called iLink) can be controlled directly by video editing software and provide uncompressed video. These cameras often record to MiniDV tapes, which can be useful for archiving raw video. Other cameras store compressed video directly on secure digital (SD) cards, which can be read into a computer with a card reader. Capturing video from a camera with only HDMI or S-Video output requires additional hardware, described below.

Microscope and Adapter

Microscopic procedures benefit most from video because they are the hardest to demonstrate live. When selecting a microscope to purchase (or borrow), high optical quality is desirable but not absolutely required. More important is that the microscope objective has the necessary range of magnification. A zoom knob for continuous magnification change is ideal.

The next consideration is connecting a video camera to the microscope while maintaining stereoscopic vision. Some adapters replace an eyepiece for still photos, but this will not work for video, since the demonstrator needs two eyes to perform the dissection. Instead, use a microscope with a trinocular head or add a camera port (also called a phototube) between the stereo head and the objective. Beware of phototubes that block one eyepiece to shunt the image to the camera. This arrangement makes dissection impossible. Instead, find one with a beam-splitting prism to preserve stereoscopic vision. Some phototubes include a diaphragm to adjust depth of field, a desirable option.

In addition to a phototube, you will need an adapter to mate the camera to the phototube. Choice of microscope adapter may limit camera options. Most adapters can attach easily to C-mount CCD cameras, while C-mount adapters are readily available for most DSLR lens mounts. Options for standard video cameras are more limited. It may be best to purchase an adapter and camera that have been tested and shown to work together. Microscope manufacturers offer such packages at high price, while other vendors (e.g., Martin Microscope, Micro-Tech-Lab) sell kits for a variety of microscopes. Most such kits include a 0.5× lens to make the image falling on the camera sensor approximate that seen by the microscope user. Figure 1 illustrates two types of setups.



Figure 1. Microscopes and adapters. *Left:* phototube with adapter and dSLR. *Right:* trinocular microscope with adapter and dSLR. Images courtesy of Micro-Tech-Lab, www.LMScope.com.

Lighting

In general, more light means better video, so use brighter lighting than usual. For work under a microscope, a pair of dual gooseneck light guides is ideal, giving nearly double the amount of light you would normally use in a dissection, with a lot of flexibility to determine the position of light sources. Avoid microscope-mounted ring lights, since they make distinctive circular reflections on the subject. For scenes outside the microscope, use dedicated video lights if available, but shop lights and some desk lamps (300-500W halogen bulbs) work as well and are less expensive.

Oscilloscope

In electrophysiology, it is often useful to show an electrical signal along with a microscopic view (e.g., of an electrode advancing). This can be done in several ways. A camera aimed at an oscilloscope can produce a high quality image.

This works best with old non-digital storage oscilloscopes. It can be difficult to find one now with good phosphors and storage; check eBay and other dealers in used equipment. One could instead use SnagIt or Snapz Pro software to record the computer screen during data acquisition. Some data acquisition software (e.g., ADInstruments LabChart) can produce screen video automatically.

Video Capture

Many cameras that record to MiniDV tapes also have iLink output. This allows you to record onto a tape and later use Apple Final Cut or Adobe Premiere, without additional hardware, to copy video onto a computer. This has the advantage that you can record to tape for long periods and later transfer only the good segments to the computer for editing. The tapes can then serve as archives for outtakes and images that might later be useful.

There are also relatively inexpensive USB, FireWire, and Thunderbolt devices that can take a video signal from any camera source (HDMI, S-Video, component video, etc.), digitize it, and record it directly onto the computer. Two reasonably priced examples are the Matrox MXO2 Mini MAX, which can also speed up video encoding, and the Black Magic Designs H.264 Pro Recorder. These are just two that I have researched and found promising; I have not used them. Compatibility with nearly any video source is a major advantage of this option. However, since video goes straight into the computer, long recordings generate large files unless you start and stop recording frequently, a distraction when concentrating on production.

PRODUCTION

Once the equipment is present and the video is planned, what can be done to ensure a high-quality product? You may not be happy with your first attempt and producing a good video will take several tries. However, a poor-quality video is more useful than no video. A first draft is usually good enough to use with a class and provides an opportunity to test your storyboard. It is best to find that some critical detail is unclear before going to the trouble to optimize every aspect of a video for final distribution.

The main component of good video is visual quality: focus, good lighting, and lack of visual distractors. Most of the following suggestions are for dissection videos under a microscope but the principles apply to any video.

Focus and View

Set up the camera so that it displays a live image on a monitor while recording. Many cameras have multiple output ports, often including HDMI. Connect the HDMI port to the input of a computer monitor (many of which have HDMI as well as DVI ports). Use the monitor to check the focus and field of view. Focus the microscope for your eyes (a piece of graph paper with fine lines is a good subject), and then check focus on the monitor. Adjust the camera adapter so that the monitor image is as sharp as possible. Good adapters have a focusing ring for the purpose; more primitive ones may require loosening a setscrew and moving a tube up or down to achieve focus. Next, determine the camera's field of view. Focus on a

piece of paper and then, while looking at the monitor, draw a rectangle on the paper corresponding to the visible edges of the monitor. Now look into the microscope. When recording video, you must work within that rectangle. If the rectangle is much smaller than your view through the microscope, you may get a better match by increasing the magnification of your eyepieces.

Lighting and Glare

Most video cameras automatically adjust their sensitivity to record in low light. However, the resulting images are noisy and grainy. Bright light gives the highest quality images. Bright light also allows you to reduce aperture to increase depth of field if the camera adapter has a diaphragm. However, lights also cause glare. Anything reflective can have distracting and detail-obscuring glare: wet tissue, the surface of saline, and dissecting tools. Because camera images are higher contrast than human vision, glare that seems mild when you see it through the microscope could completely obscure details in the recorded image. Look at the video monitor to judge glare in an image.

Glare can be reduced in several ways. Subtle changes in the angle of a light guide can make a big difference. When dissecting under saline, fill the dish completely. This keeps glare out of the field of view when a dissecting tool is brought into the dish and light reflects off the resulting meniscus (Fig. 2). Tools, especially flat ones like scalpel blades, also cause glare. Check glare while holding tools at different angles and use positions that reduce glare.

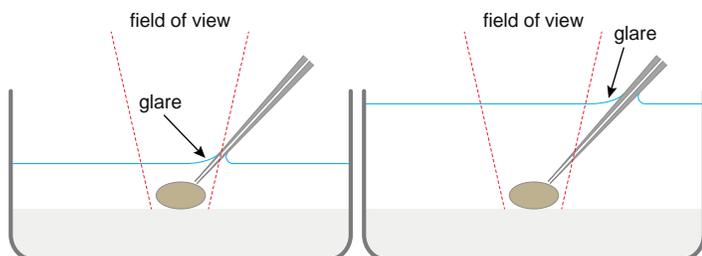


Figure 2. Meniscus and glare. *Left*: low saline level brings the meniscus and glare into the field of view. *Right*: high saline level keeps the meniscus and glare out of view.

Visual Distractions

Extraneous visual detail and movement distract the viewer and result in inefficient video compression. To reduce extraneous detail (visual noise), use a fresh dissecting dish without pin marks in the substrate. Keep the preparation cold; bubbles often form as saline warms and are especially distracting because they are sources of glare. Use a pipette to remove floating bits of tissue or dust as the dissection proceeds.

Reducing extraneous motion requires changing some dissection habits and working more slowly than usual. Support your forearms to reduce shaking; a stack of paper towels makes an inexpensive armrest. When moving a tool from one area to another, remove it completely from view before bringing it into view where it will be used next. This will make editing easier. Move or rotate the preparation as little as possible and do so slowly and smoothly. These movements can be sped up in editing.

Similarly, zoom in or out slowly and speed it up later. If the microscope has fixed magnifications, the transition can be smoothed in editing. Avoid refocusing if possible. Focus when zoomed in and then zoom out. Because of the greater depth of field at lower magnification, focus will be maintained.

Tricks

Thin white nerves over white muscle are hard to see even under the best conditions with a good stereomicroscope. The problem is worse in video, which lacks stereoscopic depth cues. Adjust lighting so that relevant structures cast shadows. Grasp a structure and wiggle it. We often detect motion better than faint contours and motion parallax can reveal a structure. If necessary, apply a light stain, such as Janus green, to the tissue (possibly noting that students should not do so in their preparations). Glass electrodes are also hard to see in saline; try gently marking one with ink to make it more visible. Finally, arrows added in editing may highlight hard-to-see structures.

Multi-Camera Work

A split screen can enhance videos of procedures in which action simultaneously takes place under the microscope and outside it (Fig. 3). Place the second camera on a tripod to capture the external action. When editing, you will need to synchronize the two tracks. Use light flashes that appear in all camera views or make sounds that will occur in the audio tracks of all cameras. The flashes and sounds can be lined up during editing.

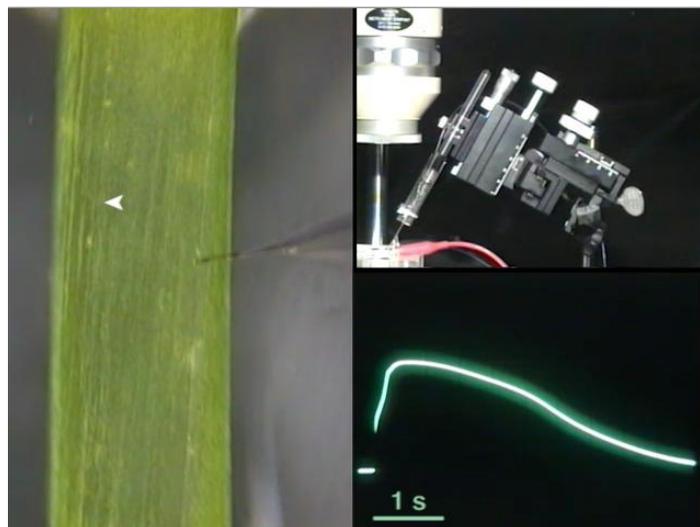


Figure 3. Split-screen video. Images from three cameras were combined to simultaneously show the view under the microscope (a cell of *Chara corallina*), the micromanipulator, and an action potential. From Wytttenbach et al. (2014).

Narration

Narration and/or subtitles can make a video much more useful to students. When planning the storyboard for a video, write down the narration that should go with each scene. Do not attempt to record narration while dissecting, since you need full attention to visual quality. Instead, work slowly to leave enough time for added narration. If you leave too much time, it can be cut or sped up in editing. Record the voice separately and add it as a sound

track when editing. Also, record 10-30 seconds of silence under the same conditions, to use as filler when editing.

Sound

Dissection does not need a sound track, beyond narration. However, an electrophysiology video might have an audio track with the sound of action potentials (APs). For good sound quality, feed the AP signal directly into a camera via its audio input rather than relying on a built-in microphone to capture APs played through a speaker. (If you do both, APs can be used to synchronize multiple cameras.)

Assistant

Although it is possible to create a good video alone, an assistant can be very helpful. The assistant can watch the monitor and warn that the dissection is moving out of the field of view or may notice glare or other problems that the dissector, concentrating on the procedure, may miss. An assistant is especially useful for multi-camera work, checking all monitors, starting and stopping recording, and adjusting the external camera as needed.

EDITING

In addition to condensing raw video, editing can add labels and subtitles to make a video more useful. Although free software such as iMovie can accomplish both of these goals at a basic level, Apple Final Cut and Adobe Premiere offer more and better options. They are expensive but many campuses have site licenses or make them available in a library or media services center.

Condensing

If there is a single video track, as in most dissection videos, place it in the editor's timeline and start trimming. If there is more than one video track, you must first align all tracks, stacked in the timeline. Use audio and/or light flash cues to do this. Final Cut and Premiere can scale and place each video image to fill the screen as needed. Once this is done, lock the tracks together so they are edited as a unit.

When editing for conciseness, start by cutting out gaps in the action and any fumbles that were corrected (easiest if you took dissecting tools completely from view before moving them to a different location). Next, speed up magnification changes and rotation or movement of the preparation. Preview accelerated sequences to ensure that they look natural. Finally, apply cross-fade transitions to any cuts that look abrupt; not all cuts will need a transition.

Most research on instructional video suggests that a length less than 6 minutes is best for student engagement (e.g., Chan et al., 2010; Guo et al., 2014). There is no need to repeat or spend extra time to emphasize points, since students can scroll back and watch confusing segments again at their discretion. In my experience, dissection videos can be 3-4 minutes or can be broken into logical units of that length. This produces smaller files that can be downloaded more quickly when presented online.

Labels

Most video editing software can freeze a frame for a set duration and add labels to it. Labels could indicate

relevant structures as they appear or show the next steps in the dissection (e.g., arrows indicating direction of incisions). In addition to text and arrows, consider outlining structures if their borders are unclear at first glance.

The first and last frames of a video are special. The first is seen until the video starts to play and the last is seen after the video stops. These are excellent places to put labels (Fig. 4). Making the first frame a title for the video wastes the opportunity to start with a labeled image and gives little information to the viewer.

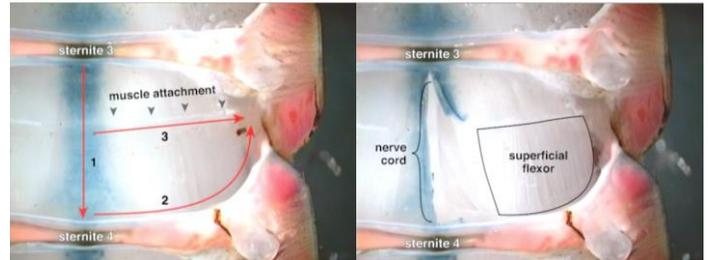


Figure 4. First and last frames of a dissection video. *Left:* The first frame shows incisions to be made. *Right:* The last frame shows the exposed nerve and muscle. From Wytttenbach et al. (2014).

Narration and Subtitles

After condensing and labeling the video, add narration as a new audio track. Cut it up and align phrases with the video. If you paced dissection to match the narration, everything should fit. If you find that the narration of a segment takes longer than the video, you can extend the video by freezing a frame or slowing a segment. Finally, fill any gaps in the narration track with snippets of silence recorded under the same conditions as the narration, since sudden silence will highlight the subtle background noise in any recording.

Subtitles should recapitulate the narration rather than add new information. Subtitling is difficult but is appreciated by the hearing-impaired and may be required for some forms of distribution. Also, a lab full of students watching narrated videos can be noisy. An easy, but inflexible, way to add subtitles is to treat them as labels. Make a new video track with the subtitles and place it under the video. The problem with this is that the subtitles cannot be changed once the video is exported and viewers cannot turn them off. It is better to add text tracks to the video. The video player can turn off subtitles and multiple languages are supported. This technology is in flux, so I am not giving details here. Search online for information about srt and vtt formats, text files that specify the timing and placement of subtitles. Subler (free, Macintosh only) can add text tracks as subtitles; I have not found any equivalent for Windows.

Export

Finally, export the video. You will need to experiment with the editing software settings to make the right trade-off between quality and file size. Choose h.264 as the video codec and AAC as the audio format, since they can be played on almost all devices. You also need to choose the video size. If the raw video is HD and you want a 4:3

aspect ratio, you could crop to 1440×1080 and export 1440×1080, 720×540, or 640×480. The raw video for *Crawdad* (Wytttenbach et al., 2014) came from 640×480 CCD cameras and the first version, delivered on CD-ROM in 1999, was reduced to 320×240 to make files that could play directly from a slow CD drive. Even this small size worked surprisingly well. You may want to export the video in several sizes to see what works best in your application.

DISSEMINATION

If your video is only for local use (PowerPoint, hard drives of teaching lab computers), almost any format will work and file size is not a consideration. Unfortunately, internet delivery is more complex. A full treatment of video formats and web browsers is beyond the scope of this paper, in part because the technology is in flux, but I will make some generalizations. If you export h.264-encoded video in an MP4 container, you can show it in PowerPoint, play it from the hard drive of a computer, and deliver it online to all major computer and phone operating systems.

The HTML5 specification supports JavaScript control of multiple video and audio tracks, combining several files into a single video, and subtitling. However, no browser yet supports all of these features. While all current browsers can play h.264/.mp4 video without plug-ins, control over tracks and subtitles is lacking. If you need that kind of control, embed QuickTime video in your web page rather than using the HTML5 video element. QuickTime gives the viewer the ability to turn video, audio, and subtitle tracks on and off, but is limited to platforms that QuickTime

supports (Windows, OS X, and iOS). For up-to-date information and details of delivering video to browsers, search the internet for “HTML5 video” and “QuickTime JavaScript.”

CONCLUSIONS

Producing basic video for the immediate needs of a class need not be difficult. Given the many advantages of video to teach lab procedures, even a hastily planned unedited video can be better than none at all. Start slowly, test with your class, and make incremental improvements.

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Received April 25, 2015; accepted April 30, 2015.

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