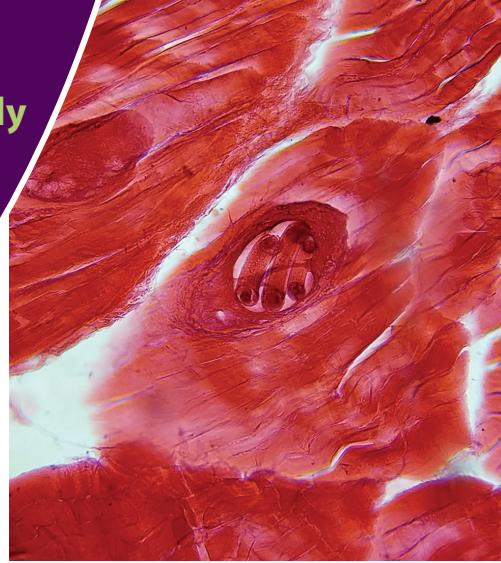


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ABSTRACT

Teaching biology laboratories remotely presents unique problems and challenges for instructors. Microscopic examination of specimens, as is common in parasitology labs, is especially difficult given the limited quantity of teaching specimens and the need for each student to have access to a microscope at their remote location. Observing images of parasites on the internet coupled with written exercises, while useful, is unrepresentative of real-world laboratory or field conditions. To provide a more realistic microscopy-centered synchronous experience for our parasitology class during the coronavirus pandemic, we used a smartphone mounted on a student microscope to livestream examination of parasite specimens to remote students via the Webex meeting app. This allowed two instructors, working from separate locations, to present and narrate the view of the specimens through the microscope in real time to the remotely located class. While less than ideal, livestreaming microscopic views of parasite specimens together with simultaneous instructor narration provided a reasonable remote substitute for a hands-on parasitology lab experience.

Key Words: parasitology lab; livestream; microscope; online laboratory instruction.

○ Introduction

While the SARS-CoV-2 pandemic quickly and radically altered college instruction in all subjects, laboratory courses arguably presented the largest challenges to teach remotely. A hands-on laboratory is an important component of an introductory parasitology course, providing experience in microscopy, parasite identification, and comparative anatomy of parasites. While there is a plethora of parasite images available on the internet, they are typically perfectly stained, digitally optimized, and represent a best-case diagnostic specimen, and therefore they are unrepresentative of what occurs in real-world laboratory or field conditions. Observation of preserved and mounted specimens is invaluable to truly appreciate parasite diversity and diagnostics, and important for integration and reinforcement of lecture material.

When tasked with teaching a parasitology lab remotely, with limited prep time, our goal was to replicate as best we could the desirable aspects of an in-person laboratory class. We wanted to include as much remote observation of the specimens in our parasitology teaching collection as possible to present a realistic experience for the students. To do this, we livestreamed video of our real-time examination of parasite specimens to the class using a smartphone camera and an online meeting platform. This allowed the class to view the specimens as they appear through a microscope in real time while we simultaneously described the anatomy, diagnostic features, aspects of the parasite's life cycle, and clinical significance. It also enabled students to ask questions and receive explanations and further demonstrations in real time. The livestream was recorded to allow viewing by those unable to attend in real time (e.g., those in disparate time zones) and to allow students to review the lab outside class hours. Live demonstrations were coupled with offline exercises to reinforce the material. These methods could easily be applied to other microscope-based laboratory classes and would work just as well with dissecting microscopes for larger specimens.

○ Streaming the Lab Course

The Webex meeting platform (version 40.10, Cisco Systems) was used to host the remote class. While we used this platform because it was the one available at our institution, other meeting apps such as Zoom would likely work as well. We used Leica DM750 student microscopes equipped with a smartphone adaptor (Gosky model GOPA001) that inserts into one of the microscope eyepieces. We added an eyepiece pointer to the smartphone adaptor to facilitate identification of parasite structures while streaming. To stream the view of the specimen through the microscope, the smartphone was mounted in the adaptor with the forward-facing camera aimed into the eyepiece (Figure 1). A step-by-step protocol (Protocol S1) is included in the Supplemental Material available with the online version of this article. The Webex app on the phone was used to log into the meeting. Simultaneously the instructor logged into the meeting on the computer to act as host and broadcast video



Figure 1. Microscope set up for livestreaming. **(A)** Side view showing smartphone mounted on a microscope eyepiece using a phone mount. **(B)** Front view showing a screen logged into a Webex meeting. The field of view can be seen on the smartphone.

of themselves. The volume on the phone was muted to prevent feedback with the computer microphone. Following introductory comments, the microscope phone was pinned to “everyone” by the instructor to lock the view on the microscope video feed while the instructor was still visible to students using their computer camera. The instructor operating the microscope would examine the specimens, and both instructors would make observations and comments about the specimen, highlighting important features as they were viewed, as well as related commentary about the life cycle, clinical features, and humorous anecdotes about the parasite to facilitate student interaction. Students were encouraged to ask questions contemporaneously using their microphones or the Webex chat function. The lab was recorded and uploaded to the Blackboard course management platform. This allowed students to revisit the lab recording to study and to access the material if they could not attend the live demonstration.

The parasitology lab was presented over 11 sessions and designed to complement lectures covering primarily eukaryotic parasites of medical and veterinary importance (Table S1). Students completed a short quiz on Blackboard at the beginning of the three-hour lab session, after which they joined the Webex meeting. Following announcements and a brief presentation about the forthcoming lab, the livestream was initiated, and the slides were demonstrated in order. As shown in Figure S1 and Video S1, images were clear with only a slight loss of resolution. We also demonstrated how to perform oil immersion microscopy, dissection of parasite-infected insects, and wet-mount slide preparation using the smartphone camera mounted on a tabletop tripod. A significant advantage of our approach is the ability to focus on the specimen dynamically, allowing demonstration of optical sectioning that is unavailable with static internet images. Additionally, the parasites are viewed in more realistic settings, so the morphological variations, artifacts, and variable staining can be illustrated. Slide scanning and specimen searching techniques were demonstrated as the instructors searched for suitable specimens to view, especially with the protist specimens. Also, unlike some remote lab courses that employ specialized smartphone apps (Hoog et al., 2020), this method uses readily available meeting apps to which students have free access. Finally, the ability of the instructor to describe

the important features of the parasite while actively visualizing the specimen is a distinct advantage over in-person labs in which the students work independently.

Technical problems were rare. We initially attempted to use both instructors’ microscopes so that one could demonstrate the current slide while the other prepared the next, but bandwidth limitations associated with home internet service made this unreliable. Having one instructor demonstrate the specimens while the other added additional commentary worked best, with few connection issues. Livestreaming from institutional office internet connections with higher bandwidth would likely allow both instructors to use their microscopes and cameras. Most students were able to access the lab in real time, and the availability of the recorded sessions allowed those who were in different time zones or who had internet connection problems to view the material at their convenience.

Assessments for the laboratory course comprised three elements: weekly pre-lab quizzes, practical exams, and notebook exercises. Short pre-lab quizzes encouraged the students to review the relevant laboratory and lecture materials prior to class. In the traditional lab setting, practical exams involved students moving between microscope stations to observe and answer questions about parasite specimens. In our remote course, images, most of which were captured specifically from our collection material, were used as a substitute, and the exam given through the Blackboard test function. Notebook exercises were designed to reinforce the laboratory material, highlight the morphology and anatomical features of the parasites that we covered, present commonalities between parasite groups, and facilitate exam preparation (see Supplemental Material available with the online version of this article). At the end of the semester, the exercises were compiled into a single pdf document to form a “lab notebook,” which was given a grade for completeness.

While teaching labs remotely is not new, our approach of using livestreaming to allow students to view microscope slides in real time is unique. Other remote options for teaching STEM labs include virtual lab simulations, prerecorded tutorials, data analysis exercises, online journal clubs, and asynchronous demonstrations of lab procedures (West et al., 2020; Delgado et al., 2021; Barnes et al., 2021; Chandrasekaran, 2020), none of which seemed appropriate for this type of specimen-based lab. However, the invaluable experience a hands-on laboratory course provides is impossible to replicate in a remote learning environment. For example, many of our students receive their first exposure to oil immersion microscopy in parasitology lab. While such experiences are difficult or impossible to replicate remotely, we feel that livestreaming the microscopic images of parasite specimens together with simultaneous instructor narration provided the best possible substitute for the hands-on experience.

○ Supplemental Material

The following are available with the online version of this article:

- Figure S1. Images captured from microscope livestream using a smartphone
- Table S1. Online parasitology labs
- Protocol S1. Livestream protocol
- Sample notebook exercise
- Video S1. Sample video of parasitology lab livestream

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