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Review

Inoculating curiosity in fungal biology for a new generation of students

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ABSTRACT

How can a new faculty member assigned to teach a course in fungal biology go about designing a course that is both informational and relevant to the 21st century undergraduate? Recent calls for science education reform recommend a shift to more active learning pedagogies that encourage students to learn by solving problems or being actively engaged in the process of experimentation as opposed to the traditional lecture reliant on content delivery. While a valid idea, practically, how can such a shift in instruction be implemented? Consider that most current faculty members were taught through the traditional lecture-laboratory format. While creativity and experience in the classroom enables us to develop as effective instructors, the reality of the demands on faculty rarely provide the time to develop enough novel instructional resources when constructing new courses. Fortunately, we can draw up educational resources to aid us beyond our own experiences *via* internet. Unfortunately, there is currently no central portal for fungal biology educational resources. While some professional societies and groups have begun to include educational resources, none are comprehensive. Because fungal biology topics have traditionally been taught as mycology or phytopathology or medical mycology, content tends to be partitioned to these specific disciplines. The goal of this review is to consolidate and evaluate teaching resources for fungal biology available through the internet for undergraduate education. This review will provide educators with ideas and tools to train future fungal biologists for 21st century careers.

1. Introduction-the challenge

A transition has been occurring in biological/biomedical education. As the level of content has exploded over recent years, largely fueled by genomics, concerns have been raised about the effectiveness of the traditional lecture format. Is mastery of content the best way to train future scientists when this exponential increase of information is expected to continue? The consensus has been to call for reforms in undergraduate science education to better prepare students to manage the increasing influx of information effectively for careers in biology and medicine (American Association for the Advancement of Science, 2011; Association of American Medical Colleges and Howard Hughes Medical Institute,

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2009). As approaches in biological research become increasingly interdisciplinary, a content-driven approach may not adequately prepare the next generation of science workers for the challenges they will face. These reforms identify major overarching biological principles as the basis of instruction, with activities and content used to illustrate these principles. New approaches emphasize the need to provide opportunities for students to experience the discovery of science through experimentation, rather than memorization. This perspective is more reflective of how scientists actually work and requires mastering skills in critical thinking, problem solving, information literacy, communication, and teamwork. The challenge for educators is to revise courses according to these recommendations to better prepare students for future careers in science. How can this transition be implemented in our teaching?

Practically, a single instructor is challenged by the time, financial resources, energy, and creativity required to make a total rework of a course. However, harnessing the power of the internet makes available significant online resources to support active learning in fungal biology education. Some of these resources have been field tested and contain instructor notes, providing a greater likelihood that they will be successful for others. While these sites are obviously intended for educational instruction, there are other sites that are intended for medical or research professionals, but could be adapted for useful instruction. By using some of the same tools as professionals, students can develop skills that will continue to have relevance for them beyond their formal education. Many of these resources can also support the development of distance learning or online courses that are becoming more common at traditional brick and mortar colleges and universities.

Among the first to champion the internet as a resource for undergraduate education in fungal biology were Tom Volk and Kathy Hodge, both of whom created and maintained directories of internet sites for several years (Volk and Hodge, 1998). The challenge with creating a directory of fungal resources comes from earlier approaches that studied fungi, not as a single discipline, but subdivided into different disciplines based on the role each species played in its environment. Historically, the areas of mycology, plant pathology, and medical mycology have focused on discrete groups of fungi. Factual mycological content tends to be organized within these historical designations according to the fungal species important to a specific field of study. Because of this influence, there is no 'one stop shopping' for fungal biology.

This review provides a variety of online resources, both traditional and nontraditional, that can be used to restructure current fungal biology educational practices (Table 1). Resources whose primary focus is to support teaching are covered first, followed by resources intended for professionals or the public. Many of the teaching exercises have gone through classroom testing as well as peer-review. These exercises provide course activities and serve as templates for instructors interested in pedagogical methodologies. The teaching section concludes with some samples of courses on fungal biology. The review continues with coverage of resources not explicitly geared for undergraduate education, but that provide excellent tools if adapted for the classroom. Some of these resources are intended for professionals in the scientific or medical fields, while others provide links to the community for the general public. Professional sites could enable students to develop skills to navigate the same sites as the professionals they aspire to emulate. Sites intended for the general public can aid in identifying local expertise and identify opportunities for service-learning projects.

2. Professional society repositories

Professional societies are a natural fit for collecting and sharing resources. Membership is largely made up of teachers and scholars with a vested interest in developing repositories for sharing instructional resources. Existing organization and governance provides the stability needed to maintain and update these resources, making these sites among the most reliable for current and sustained repositories of information. While there is no single society that covers fungal biology in total, the American Phytopathological Society (APS), the British Mycological Society (BMS), and the American Society of Microbiology (ASM) have made commitments to support education, and host sites that are actively collecting resources appropriate for instruction on fungal biology at the university level.

The most substantial of these educational resources can be found at APS (American Phytopathological Society, 2016). As the primary focus is on the pathogens of plants, only a subset of the site's content is specific for those fungi that interact with plants. Resources include instructional material such as lectures, plant disease lessons for individual pathogens, laboratory exercises, simulations, and case studies. As well as traditional teaching content, resources on specific topics current to the field are available that could be integrated into curricula. APS presents a monthly Featured Review on current issues in phytopathology and provides instructor resources (upon registration) to support the book *Hungry Plant: Stories of Plant Diseases* (Schumann and D'Arcy, 2012). Other resources include an illustrated glossary and resource catalog. Pedagogy is supported with teaching articles from *The Plant Health Instructor*. Additional support through Instructor Communication provides sample exam questions, learning tools for student review, and teaching notes. All the submissions to the online repository have undergone peer-review and are supported by extensive references. In addition to significant content coverage, there are a variety of classroom-ready exercises that promote active learning and inquiry. APS provides multifaceted support by providing resources for basic content, application of content, practical instructor support, and scholarship of teaching as it applies to the instruction of phytopathology.

The BMS education site has developed content for pre-university levels and is in the process of expanding its holdings at the university level (British Mycological Society, 2016). Within Education and Outreach, they have initiated a section for practicals (laboratory exercises) currently containing two practicals on basic technical skills. Additional resources on this site that could be adapted to support for