Recommended Curriculum Guidelines for Undergraduate Microbiology Education

AMERICAN SOCIETY FOR MICROBIOLOGY

2012

CONTRIBUTING AUTHORS

ASM Task Force for Curriculum Guidelines

Susan Merkel, **Chair**
Department of Microbiology
Cornell University, NY

Jackie Reynolds, Chair
Department of Biology
Richland College, TX

Kai "Billy" Hung
Department of Biological Sciences
Eastern Illinois University, IL

Heidi Smith
Biology Department
Front Range Community College, CO

Amy Siegesmund
Department of Biology
Pacific Lutheran University, WA

Ann Smith
Department of Cell Biology and Molecular Genetics
University of Maryland, MD

Ex Officio

Neil Baker, Chair, ASM Education Board
The Ohio State University (Professor Emeritus)

Amy Chang, Director, ASM Education

Ad Hoc Reviewers

2011 ASMCUE attendees

Please send comments to education@asmusa.org

ASM Recommended Curriculum Guidelines for Undergraduate Microbiology Education

In 2008-2009, two reports, *Vision and Change in Undergraduate Biology Education: A Call to Action* (American Association for the Advancement of Science) and *Scientific Foundations for Future Physicians* (Howard Hughes Medical Institute and the American Association of Medical Colleges), called for sweeping changes in how biology is taught in the 21st century. These reports urge faculty to refrain from presenting science as a sea of facts and work towards ensuring that students have a foundational understanding in biology. In addition, the reports state that to be scientifically literate, students need to understand five overarching concepts: evolution; structure and function; pathways and transformations of energy and matter; information flow, exchange, and storage; and systems.

In response, in 2009 ASM established a curriculum task force to update the ASM Curriculum Guidelines for Undergraduate Microbiology Education. That year, the task force set out to identify key concepts and skills that are (i) central to microbiology and (ii) useful to define curriculum learning goals for general microbiology. In 2010, the Task Force reviewed approximately 25 undergraduate microbiology courses for majors in both microbiology and/or biology programs and nursing and/or allied health programs.

During a January 2011 meeting in Washington D.C., the Task Force affirmed the five overarching concepts in biology mentioned above; members also identified a sixth overarching concept specific to microbiology – the impact of microbes. All six overarching concepts provide a framework for key microbiological topics that are deemed to be of lasting importance beyond the classroom. The Task Force identified 27 topics ("Fundamental Statements," #1 – 27 below) related to each overarching concept. These topics identify what students should have a deep understanding of, not just do or have surface knowledge of, as a result of studying a particular concept. The topics are deliberately framed as declarative statements and may be used to present major curriculum generalizations and recurrent ideas.

In addition to its focus on the conceptual understanding of microbiology, Task Force members identified two key skills, scientific thinking (#28 – 31 below) and microbiology laboratory skills (#32 – 38 below), for which students' development of competency would have enduring and lasting value beyond the classroom and laboratory. The task force presented the proposed concepts and skills at the ASM General Meeting and the ASM Conference for Undergraduate Educators in 2011, and finalized the document in 2012. The ASM Recommended Curriculum Guidelines for Undergraduate Microbiology Education were published in *Journal of Microbiology and Biology Education* (Merkel, JMBE May 2012, pp 32 – 38).

The ASM Recommended Curriculum Guidelines for Undergraduate Microbiology are divided into two parts. Part 1 identifies concepts and statements (#1 – 27), and Part 2 identifies competencies (#28 – 31) and skill areas (#32 – 38) for introductory microbiology.

Part 1: Concepts and Statements

Evolution

1. Cells, organelles (e.g., mitochondria and chloroplasts) and all major metabolic pathways evolved from early prokaryotic cells.
2. Mutations and horizontal gene transfer, with the immense variety of microenvironments, have selected for a huge diversity of microorganisms.
3. Human impact on the environment influences the evolution of microorganisms (e.g., emerging diseases and the selection of antibiotic resistance).
4. The traditional concept of species is not readily applicable to microbes due to asexual reproduction and the frequent occurrence of horizontal gene transfer.
5. The evolutionary relatedness of organisms is best reflected in phylogenetic trees.

Cell Structure and Function

6. The structure and function of microorganisms have been revealed by the use of microscopy (including bright field, phase contrast, fluorescent, and electron).
7. Bacteria have unique cell structures that can be targets for antibiotics, immunity and phage infection.
8. Bacteria and Archaea have specialized structures (e.g., flagella, endospores, and pili) that often confer critical capabilities.
9. While microscopic eukaryotes (for example, fungi, protozoa and algae) carry out some of the same processes as bacteria, many of the cellular properties are fundamentally different.
10. The replication cycles of viruses (lytic and lysogenic) differ among viruses and are determined by their unique structures and genomes.

Metabolic Pathways

11. Bacteria and Archaea exhibit extensive, and often unique, metabolic diversity (e.g., nitrogen fixation, methane production, anoxygenic photosynthesis).
12. The interactions of microorganisms among themselves and with their environment are determined by their metabolic abilities (e.g., quorum sensing, oxygen consumption, nitrogen transformations).
13. The survival and growth of any microorganism in a given environment depends on its metabolic characteristics.
14. The growth of microorganisms can be controlled by physical, chemical, mechanical, or biological means.

Information Flow and Genetics

15. Genetic variations can impact microbial functions (e.g., in biofilm formation, pathogenicity and drug resistance).
16. Although the central dogma is universal in all cells, the processes of replication, transcription, and translation differ in Bacteria, Archaea, and Eukaryotes.

17. The regulation of gene expression is influenced by external and internal molecular cues and/or signals
18. The synthesis of viral genetic material and proteins is dependent on host cells.
19. Cell genomes can be manipulated to alter cell function.

Microbial Systems

20. Microorganisms are ubiquitous and live in diverse and dynamic ecosystems.
21. Most bacteria in nature live in biofilm communities.
22. Microorganisms and their environment interact with and modify each other.
23. Microorganisms, cellular and viral, can interact with both human and nonhuman hosts in beneficial, neutral or detrimental ways.

Impact of Microorganisms

24. Microbes are essential for life as we know it and the processes that support life (e.g., in biogeochemical cycles and plant and/or animal microbiota).
25. Microorganisms provide essential models that give us fundamental knowledge about life processes.
26. Humans utilize and harness microorganisms and their products.
27. Because the true diversity of microbial life is largely unknown, its effects and potential benefits have not been fully explored.

Part 2: Competencies and Skills

Scientific Thinking

28. Ability to apply the process of science
    a. Demonstrate an ability to formulate hypotheses and design experiments based on the scientific method.
    b. Analyze and interpret results from a variety of microbiological methods and apply these methods to analogous situations.
29. Ability to use quantitative reasoning
    a. Use mathematical reasoning and graphing skills to solve problems in microbiology.
30. Ability to communicate and collaborate with other disciplines
    a. Effectively communicate fundamental concepts of microbiology in written and oral format.
    b. Identify credible scientific sources and interpret and evaluate the information therein.
31. Ability to understand the relationship between science and society
    a. Identify and discuss ethical issues in microbiology.

Microbiology Laboratory Skills

32. Properly prepare and view specimens for examination using microscopy (bright field and, if possible, phase contrast).
33. Use pure culture and selective techniques to enrich for and isolate microorganisms.
34. Use appropriate methods to identify microorganisms (media-based, molecular and serological).
35. Estimate the number of microorganisms in a sample (using, for example, direct count, viable plate count, and spectrophotometric methods).
36. Use appropriate microbiological and molecular lab equipment and methods.
37. Practice safe microbiology, using appropriate protective and emergency procedures.
38. Document and report on experimental protocols, results and conclusions.