Recommended Curriculum Guidelines for Undergraduate Microbiology Education

AMERICAN SOCIETY FOR MICROBIOLOGY

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In 2008-2009, two seminal 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 to work towards ensuring that students have a foundational and working understanding in biology. These reports focused on five overarching concepts: evolution; structure and function; pathways and transformations of energy and matter; information flow, exchange, and storage; and systems. In 2011, an ASM Task Force affirmed these five overarching biological concepts; identified a sixth category specific to microbiology, the impact of microbes; and identified two key skills, scientific thinking and microbiology laboratory skills. The result of the effort was the ASM Recommended Curriculum Guidelines for Undergraduate Microbiology Education, published in the Journal of Microbiology & Biology Education (Merkel, 2012).

Recognizing that the field of the microbial sciences has rapidly advanced since 2011, in 2022, ASM convened a new Task Force to evaluate and update the ASM Recommended Curriculum Guidelines for Undergraduate Microbiology. The Task Force convened a group of 12 ASM volunteers and ASM Staff from August 2022 to January 2024 to complete several iterative phases of revision:

- Phase 1: Revisions by the Task Force members.
- Phase 2: Collection of feedback from the microbiology education community, leaders at ASM, including members of the Council of Microbial Sciences, and microbiology subject matter experts. The Task Force made revisions based on the feedback received.
- Phase 3: Presentation of the ASM Curriculum Guidelines at the 2023 ASM Conference for Undergraduate Educators in Phoenix, Arizona. The Task Force made revisions based on the feedback received.

The 2024 ASM Recommended Curriculum Guidelines for Undergraduate Microbiology are divided into two parts and can be used to design both general microbiology courses and entire microbiology curricula. Part I identifies six microbiological concepts and 29 fundamental statements, and Part II identifies skill areas and competencies for microbiology. The six overarching concepts, broken down into 29 fundamental statements, provide the framework for core microbiology content that is of enduring and lasting value beyond the classroom and teaching laboratory. As such, these topics identify what all students in the microbial sciences should truly understand, as opposed to just obtaining surface-level knowledge, after studying a particular concept. The fundamental statements are deliberately framed as declarative statements, and they may be used to present major curriculum generalizations and recurrent ideas.

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2024 ASM Recommended Curriculum Guidelines for Undergraduate Microbiology Education

PART I. FUNDAMENTAL STATEMENTS

Important note: For purposes of the ASM Curriculum Guidelines for Undergraduate Microbiology, we consider the term "microbe" to encompass both cellular organisms (such as bacteria, protists, or fungi) and non-cellular infectious agents (such as viruses, prions, or viroids) that are not visible to the unaided eye.

Evolution

1. All cells, eukaryotic organelles (e.g., mitochondria and chloroplasts), and major metabolic pathways evolved from early progenitor cells.
2. The diversity of microbes has arisen because of processes that include horizontal gene transfer, mutation, reassortment, recombination, and natural selection in varying ecological niches favor the growth and survival of certain variants.
3. The evolution of microbes is impacted by their interactions with the environment and a variety of ecological forces, including other microbes, humans, and habitats.
4. Phylogenetic trees best reflect the evolutionary relatedness of all organisms although microbial lineages may be difficult to define due to horizontal gene transfer or lack of conserved genes.

Structure and Function

5. The structure and function of microbes are revealed by the use of microscopy, culture, and metabolic analyses, molecular methods, and bioinformatic tools.
6. The distinct structures and processes in microbes can be targets for interspecies competition, antimicrobial treatments, and host immunity.
7. Microbes have evolved structures adapted for specific functions that are often associated with a fitness advantage in a particular environment.
8. Microbes have unique genomes, structures, and/or biochemical characteristics that distinguish them from each other.
9. The replication of viruses is determined by their unique structures, DNA or RNA genomes, and the cells they infect.
10. Microbial reproductive cycles consist of sequential processes.
11. Obligate intracellular microbes require living host cells for replication.

Metabolic Pathways

12. Bacteria and Archaea exhibit extensive metabolic diversity, including nitrogen fixation, methane production, and anoxygenic photosynthesis, many of which are unique to these two domains.
13. Intrinsic factors, such as genotype, metabolism, and cell structures, impact the survival and growth of microbes.
14. Extrinsic factors, such as abiotic and biotic interactions in the environment, can impact survival and growth of microbes.
15. Most microbial life is currently unculturable and therefore both cultivation-dependent and cultivation-independent techniques are used to identify microbial populations and their potential metabolic pathways.

Information Flow and Genetics

16. Genetic variation can influence microbial structures and their functions.
17. Although the flow of information from DNA to RNA to protein is universal in all cells, aspects of the processes of replication, transcription, and translation differ between Bacteria, Archaea, and Eukarya.
18. The regulation of gene expression is influenced by external and internal molecular cues and signals.
19. Non-cellular infectious agents, such as viruses, prions, viroids, and satellites, are dependent on host cell processes in order to replicate.

Microbial Ecology

20. Microbes are ubiquitous, found in diverse and dynamic ecosystems, where they use available resources and often form complex communities.
21. Microbes and the environment interact with and affect each other.
22. Most microbes interact with hosts in beneficial or neutral ways, with a minority having a detrimental impact on their host.
23. The health of the environment and all organisms (microbes, plants, humans, other animals) are closely linked and interdependent, as described by the One Health paradigm.

Impact of Microbes

24. Microbes and their communities are essential for supporting all life as we know it.
25. Microbes are used as models that provide fundamental knowledge about life processes.

26. Humans leverage microbes and their products to address problems and improve quality of life.
27. The extent of microbial diversity is largely unknown, and exploration of this diversity is critical to understanding microbes and their role in the biosphere.
28. A minority of microbes are pathogens that can cause diseases and harm host organisms, society, and ecosystems.
29. The extent of microbial damage can be minimized by host-derived and external factors, including the microbiome, antibiotics, and immunity.

<u>PART II. SCIENTIFIC THINKING AND MICROBIOLOGY LABORATORY SKILLS</u>

1. Apply scientific methods:
    a. Investigate microbial systems.
    b. Formulate hypotheses and design well-controlled experiments.
    c. Analyze, troubleshoot, and interpret results from a variety of methods. Draw evidence-based conclusions.
    d. Document and communicate the methods, results, and conclusions.
    e. Collaborate, give and receive feedback, update method and reassess conclusions.
    f. Use quantitative reasoning and computational skills, such as mathematical reasoning, graphing, and statistics to evaluate and interpret data in microbiology.
2. Properly prepare, view, and analyze specimens using microscopy.
3. Apply appropriate microbiological, molecular, serological, and bioinformatics methods to isolate and differentiate microorganisms.
4. Estimate the number of microorganisms in a sample by direct or indirect means.
5. Practice microbiology in a responsible and safe manner, using appropriate safety equipment and adhering to emergency procedures and guidelines.
6. Effectively communicate fundamental concepts of microbiology with consideration of scientific and non-scientific audiences.
7. Identify, interpret, and evaluate credible sources of information and cite them appropriately.
8. Describe the intersection between science and society, such as emerging technologies, policy development, the importance of ethics in the scientific process, and recognize the historical and ongoing contributions of diverse scientists.