American Society for Virology
Curriculum Guidelines for Undergraduate Virology Education
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ASV Undergraduate Curriculum Guidelines Committee - Contributing Authors

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Preface

The COVID-19 pandemic has revealed the need to improve the understanding of virology among the populace. One way to help remedy this is to provide opportunities for college undergraduate students to learn virology, whether in a stand-alone virology class, or as part of a general microbiology, cell biology, or immunology course. Improved virology literacy will equip students with the knowledge and skills to disseminate accurate information to the general public. To provide a standard foundation for these students, and to provide guidance for educators, undergraduate virology curriculum guidelines are needed.

To address these challenges, in 2021, the ASV Education & Career Development Committee formed a task force, composed of virology educators and trainees, to develop learning goals and guidelines for undergraduate virology courses. This would help virologists and also non-virologists (*e.g.*, bacteriologists, cell biologists, immunologists) identify content and concepts that currently are most important for students to learn.

The members of the task force identified curriculum learning goals and key concepts that are central to virology. General concepts that any virology student should study and understand include (1) virus evolution and ecology; (2) virus structure and function; (3) virus replication cycle; (4) virus-host interaction; and (5) impact of viruses. The task force recognizes that while these five general concepts should guide content in a virology course, undergraduate virology courses will differ based on the level of the student in these courses. Also, as noted above, undergraduates may be taught virology in a stand-alone course, or within a general microbiology, cell biology, or immunology course. Undergraduate courses may or may not have a lab component. Furthermore, undergraduates majoring in biology or microbiology may have different short- and long-term goals compared to students in nursing and/or allied health programs. Due to these differences, the task force is recommending approaches for a stand-alone undergraduate virology course, and also when virology must be incorporated as a unit within a more-general course.

Instructors of an undergraduate virology course may wish to consider the following.

- *Background of students*. Because of the intimate relationship between a virus and its host, the content in an undergraduate virology course may be most accessible to students who have taken courses in molecular genetics and cell biology, to have background related to nucleic acid structure and function, nucleic acid replication, transcription and translation, and for understanding virus manipulation of host cell biology.
- *Background of the instructor*. Undergraduate programs in biology, microbiology, allied health, etc., may not have a faculty member with extensive training in virology. However, faculty with background in cell/molecular biology, immunology, microbiology, or biological chemistry should possess fundamental knowledge that, coupled with the guidelines and learning goals provided here, can be applied to communicating principles of virology to students.
- *Concepts vs. virus families*. Textbooks and courses tend to focus on either key concepts (*e.g.*, virus life cycle processes; pathogenesis) or virus families. These guidelines recommend a focus on key concepts, and the course instructor is encouraged to provide examples from a virus or two from each family to highlight key differences.
- *Laboratory*. A laboratory portion of an undergraduate virology course may not be feasible due to constraints on faculty and/or student time, available lab space, budgetary constraints, etc. Since much virology research uses techniques that are staples of cell biology, molecular biology, biochemistry, immunology, genetics, etc., students can be asked to apply that knowledge (from prior courses with lab components) to questions in virology. Similarly, use of the scientific literature can help bridge the absence of hands-on labwork. For those instances where a lab component is possible or required, some

examples of options for undergraduate virology labwork have been recently reviewed (Kushner and Pekosz, 2021).

- *Virology as a unit within a larger course*. Many undergraduate students lack opportunities to take virology as a stand-alone course. Virology tends to be introduced within microbiology courses. Because of the emphasis on bacteria, virology content in those courses tends to be constrained to bacteriophages and transduction, and lytic vs. lysogenic replication. In Section III of this document, recommendations for critical virology content for courses which feature a virology unit are provided.

I. Learning Outcomes for a stand-alone virology course

After an undergraduate virology course students should be able to:

1. Define and describe viruses in terms of their nucleic acid and basic structural composition, and provide examples.
2. Convey that viruses are obligate intracellular pathogens that infect a broad range of host organisms.
    a. Identify and recognize RNA and DNA viruses that affect microbes, plants, and animals by causing viral diseases including AIDS, cancer, flu, COVID-19, etc.
3. Detail the steps of the viral life cycle of diverse RNA and DNA viruses, providing biochemical mechanisms for attachment, entry, gene expression, genome replication, assembly, and release.
4. Identify and evaluate individual steps in a virus' replication cycle that can be effectively targeted by antiviral drugs for pharmaceutical intervention of viral diseases. Compare and contrast with established therapies for limiting viral infections including vaccines and therapeutic agents.
5. Describe how host immune responses prevent or limit viral replication and pathology, and how this process can be exploited to develop effective antiviral strategies and vaccines.
6. Recognize and apply the basic principles of virus transmission, viral pathogenicity, and viral evolution, combined with the societal factors, that contribute to virus emergence, especially for virus outbreaks that affect global health.
7. Explain how viruses impact the ecology and evolution of all of life, and appreciate the usefulness of viruses as model systems for a gaining fundamental understanding of cellular functions.
8. Recognize that virology is a continuously and rapidly evolving field, and that viruses and their proteins have been used to develop research tools, products, and therapeutics.
9. Appreciate these fundamental concepts which will prepare students to critically assess the accuracy of information (*e.g.*, by journalists and from social media) and to identify misconceptions regarding aspects of virology such as outbreaks.

II. Content recommendations for a stand-alone virology course

A. Virus Evolution and Ecology

1. Viruses evolve because of variation within their genomes introduced by a variety of processes including random mutation, recombination, and reassortment. These variants are then subjected to selection pressures exerted by their hosts and the environment or by random sampling *via* genetic drift.
2. Virus emergence and spread can be impacted by a variety of environmental, viral, and social factors.

3. Although viruses are ubiquitous in nature and infect all forms of life, much of the global virosphere remains unstudied.
4. Taxonomic classification and naming of viral species, overseen by the International Committee on the Taxonomy of Viruses (ICTV), resembles the taxonomical binomial nomenclature system used with cellular organisms.

B. Virus Structure and Function

1. Viruses come in a variety of shapes and sizes, from giant mimiviruses to tiny circoviruses.
2. Viruses are composed of viral nucleic acids surrounded by a protective protein shell, and in some cases a lipid envelope.
3. The Baltimore classification system groups viruses based on whether the genome is composed of DNA or RNA, is single- or double-stranded, and according to the mechanism by which viral messenger RNA (mRNA) is synthesized.
4. All viruses are obligate intracellular parasites that must utilize a host cell's molecular machinery (*e.g.*, ribosomes) to complete a productive replication cycle.
5. Subviral agents (viroids, satellites, prions, etc.) can have important environmental and disease impacts.

C. Virus Replication Cycle

1. Viruses are obligate intracellular pathogens and require living host cells in which to replicate.
2. Virus life cycles consist of sequential processes beginning with entry into a host cell and ending with release of new virions from the infected cell.
3. Virus replication cycles vary, impacted by their unique structures, genome organization, and host-cell specificity.
4. Expression of virus genes and replication of virus genomes requires a combination of cellular and viral factors as determined by the viral genome and site of replication.
5. Virus gene expression and replication are coordinated through dynamic spatiotemporal interactions with host cell factors.

D. Host-Virus Interactions

1. Not all viral exposures result in infection or disease.
    a. Some host-virus interactions can be beneficial for the host.
2. Virus infections can be acute, latent, or persistent; some are oncogenic.
3. The processes by which viruses cause disease involve interactions of virus and host factors at the cellular and organismal level.
4. After a non-lethal exposure to a virus, the host often develops a protective immune response against the virus (in some cases, also against related viruses).
    a. Vaccines also elicit a protective immune response.
5. Virus infection and disease can be prevented and/or treated using a variety of biological, chemical, and physical approaches.
    a. Vaccination has led to reduced morbidity and mortality for a wide variety of human and animal diseases.

E. Impact of Viruses

1. The study of viruses has been key to the understanding of cell and molecular biology, immunology, and infectious disease processes.
2. Viruses and their proteins can be used to develop research tools, products, and therapeutics.
3. The study of virology is rapidly evolving, and helps drive the development of novel techniques in fields such as genomics and computational biology, allowing scientists to better understand viruses and their roles in life.
4. Human lives and economics are impacted by viral diseases in humans and other organisms.
5. Viruses have large-scale effects on ecosystems and the environment.

III. Content recommendations for virology content when a unit within a larger course (*e.g.*, microbiology course)

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E. Impact of Viruses

1. Human lives and economics are impacted by viral diseases in humans and other organisms.
2. Viruses have large-scale effects on ecosystems and the environment.

Reference

Kushner, D.B. and Pekosz, A. 2021. Virology in the classroom: current approaches and challenges to undergraduate- and graduate-level virology education. Annu. Rev. Virol. 8:537-558. doi: 10.1146/annurev-virology-091919-080047.