OPEN ACCESS Freely available online

CourseSource

Teaching Tools and Strategies

A 360˚ View of COVID-19

Nikolaos Tsotakos[1], Victoria Del Gaizo Moore[2], Lisa Z. Scheifele[3], Michael J. Wolyniak[4], Joseph W. Chihade[5], Joseph J. Provost[6], and Jennifer A. Roecklein-Canfield[7*]

[1]School of Science, Engineering, and Technology, Penn State Harrisburg

[2]Department of Chemistry, Elon University

[3]Department of Biology, Loyola University Maryland

[4]Department of Biology, Hampden-Sydney College

[5]Department of Chemistry, Carleton College

[6]Department of Chemistry & Biochemistry, University of San Diego

[7]Department of Chemistry & Physics, Simmons University

Abstract

In March 2020, institutions underwent a massive transition to distance learning as a result of the COVID-19 pandemic. With so little time to devise new materials to maximize learning in the new virtual environment, instructors devised a variety of innovative strategies for completing the Spring 2020 semester. While highly disruptive, the pandemic also brought mainstream attention to a wide array of scientific concepts and provided an opportunity to teach students about science in real-time. Teaching topics related to COVID-19 can be approached from many different disciplines such as virology, immunology, biochemistry, genetics, public health, pharmacology, systems biology, and synthetic biology. By bringing together lessons devised by each of the authors on their own, we offer a series of curriculum modules that can be used either collectively or in parts to provide students with a multidisciplinary look at the virus and to answer their own curiosity about the disease that will define their generation.

Citation: Tsotakos N, Del Gaizo Moore V, Scheifele LZ, Wolyniak MJ, Chihade JW, Provost JJ, Roecklein-Canfield JA. 2021. A 360˚ View of COVID-19. *CourseSource*. https://doi.org/10.24918/cs.2021.41

Editor: Lisa M. McDonnell, University of California San Diego

Received: 9/1/2020; **Accepted:** 6/17/2021; **Published:** 11/30/2021

Conflict of Interest and Funding Statement: None of the authors has a financial, personal, or professional conflict of interest related to this work.

Supporting Materials: The list of all 73 supporting files can be found on page 4.

***Correspondence to:** jennifer.canfield@simmons.edu

Learning Goals

Collectively, the lessons presented here achieve the following learning goals:

- Students will understand the interactions between biological molecules and describe how interactions that impact specificity or affinity lead to changes in biological function
- Students will understand how a mutation arises and how it could affect the organism and the gene from fitness to expression
- Students will understand how mutations can be used to track the origin and spread of a pathogen
- Students will understand the biology of both humoral and cellular immunity
- Students will understand the physiology of inflammation
- Students will understand different classes of drugs and their mechanism of action
- Students will understand the structure and phases of clinical trials
- Students will understand current topics in the pharmaceutical industry
- Students will understand issues surrounding science and policy that govern how public health officials act
- Students will have explored the ways in which epidemiologists work to understand the origins and spread of disease
- Students will understand how new genetic technologies can play an important role in detecting and rapidly responding to emerging pathogens
- Students will understand how host proteins that interact with a virus can be identified and how this information can be used to understand replication of the virus
- Students will understand the parts of a scientific paper and gain practice in analyzing and interpreting data

Because these activities cover a topic of such current importance and take a multi-faceted and comprehensive approach, collectively they cover the learning goals of several academic societies, including the American Society for Biochemistry and Molecular Biology, the Genetics Society of America, and the American Society for Microbiology as well as many of the skills covered in the Science Process Skills Learning Framework. Alignments of the activities and the associated learning frameworks (where appropriate) can be found in Table 2.

INTRODUCTION

The 2020 COVID-19 pandemic has forced faculty to confront a host of unique pedagogical challenges. The need for virtual classes has been especially difficult for upper-level skill-based laboratory courses for which few virtual labs exist. Some resources exist, such as HHMI's Biointeractive teaching resources and Labster's virtual lab exercises; in addition, alternatives to hands-on labs are emerging and essential principles for online science labs are beginning to be delineated (as shown in this April 2020 article, "How to Rethink Science Lab Classes" from *Inside Higher Ed*). Yet, current resources do not fill the enormous need and the crisis has highlighted the need for the development of innovative and authentic learning tools that can be delivered virtually.

This project focused on developing modules related to COVID-19 from numerous disciplinary perspectives. These modules are ready to integrate into both in-person and virtual courses. Harnessing the opportunity to teach material rooted in an ongoing, real-world situation both gives the instructor a new lens to view their usual course content and provides a connection between the students and the material. The just-in-time and relevant nature of the modules has the potential to energize and enhance the classroom. Rather than being intimidated by the rapidly changing and precarious teaching landscape, we have leveraged the pandemic to enhance our teaching. We adapted lessons and strategies that we had previously implemented and tested in face-to-face classrooms and then developed innovative virtual teaching strategies and lab activities. We have therefore developed a curricular series that can be incorporated into multiple life science courses; the individual modules can be used alone or in combination. Assessment of the curriculum modules and dissemination of this information across the greater education community will be central to fully realizing and building on the curricular pieces.

This collection is the product of several life scientists joining forces to create a package of educational materials that could be used to meet the needs of their classes and students during the COVID-19 pandemic. The authors have a common passion for undergraduate education, and each wanted to take advantage of the unique opportunity of a scientific global crisis to enhance student understanding of course topics and to further students' appreciation for the relevance of their course material. Several of the authors have served on the Education Committees of the American Society for Biochemistry and Molecular Biology and American Society for Cell Biology, have developed National Science Foundation-supported initiatives for developing undergraduate education resources, and have established pedagogical mentoring initiatives in these organizations and the Council on Undergraduate Research. The curricula presented here represent the sum total of the significant expertise brought forth by this group of authors.

We and others have been active in developing innovative content and pedagogies related to the COVID-19 pandemic (2, 3, 4, 5). While Biochemistry is the most common course that we collectively teach, we each teach courses in other disciplines ranging from medicinal chemistry to genetics, bringing together varied and complementary skills and expertise. What makes our collection of resources unique is the multidisciplinary, or 360-degree, coverage of the SARS-CoV-2 virus and COVID-19 pandemic that the resources provide. The "ability to tap into the interdisciplinary nature of science" is one of the core competencies cited in the *Vision and Change* report (6) and interdisciplinary training is recognized as necessary for students to be able to solve real-world problems and be prepared for the 21st-century workforce (7). Thus, it is our hope that while we focus on COVID-19 here, our approach of taking a 360-degree view of a scientific problem will become a model so that multidisciplinary and interdisciplinary educational resources surrounding a central concept or issue will become more commonplace.

The curriculum package presented here is deliberately modular in nature to allow an instructor to pick and choose the concepts that best fit their pedagogical needs. However, it is important to note that the modules interrelate strongly and could easily work together as part of a more comprehensive and multidisciplinary examination of the virus. In addition to modules dedicated to traditional scientific considerations of the virus from molecular, biochemical, structural, and chemical perspectives, we also provide materials that allow the instructor to combine these ideas with the public health, ethical, and societal considerations that affect how COVID-19 and similar world pandemics have been historically treated and how society is currently grappling with pandemic management. Importantly, the majority of these modules are ready for use both in the face-to-face classroom and online, providing much-needed flexibility and versatility for the instructor.

The package of pedagogical activities presented here (Table 1) carries importance beyond the immediate and necessary response to the COVID-19 pandemic. It is likely that "the new normal" post-pandemic will feature the adoption of several of the virtual and distance learning modalities made popular in 2020 (8). Even when the pandemic ends, instructors will still have to meet the needs of students whose job and family commitments, for example, make it difficult to attend synchronous classes. Moreover, as more and more institutions consolidate and share resources, it is expected that distance and virtual classes will become more common. While COVID-19 has presented many hardships and challenges in undergraduate education, there is a unique opportunity for students to learn about science as it is being discovered and reacted to by researchers, educators, and the public. This series of lessons embraces the unique scientific learning opportunities embedded in the COVID-19 pandemic for undergraduates and faculty.

ACTIVITIES AND IMPLEMENTATION

This collection includes 25 independent activities spanning eight different primary disciplines (Table 1). Each module has a cover sheet with detailed notes for the instructor. For each module, we also provide the activity with full instructions for the students and any necessary data files. In designing these activities, each of us as instructors had to quickly learn specifics of the biology of SARS-CoV-2 and the spread of the COVID-19 pandemic. For other instructors who are new to teaching these topics, we recommend activity 22 as an initial student activity as it includes a set of Powerpoint slides that introduce basic concepts in virology and the biology of SARS-CoV2 as well as a student activity in which they create a mind map to organize terms and concepts related to the biology of SARS-CoV-2 and COVID-19. In addition, there are numerous excellent resources that provide an introduction to the virus and pandemic including videos and animations about the virus life cycle, evolution, and detection tests. Excellent review articles can also be found about SARS-CoV-2 transmission and pathogenesis (9), potential drug therapies (10), vaccines and health disparities (11). Overviews, animations, and simulations designed for the general public are also available (12,13) and could also provide good introductions for both faculty and students. We caution, however, that one of the challenges of teaching about an emerging field as it is being aggressively investigated is that new research can rapidly revise previous models, and information from these resources will likely be subject to at least minor modification in the future.

The strength of this curriculum is the modular nature of the 25 activities which can be mixed and matched to meet the needs of many different courses and learning environments. To illustrate how different modules have been selected and woven into a course, the following are accounts from two faculty that utilized several modules in their courses.

During Fall 2020, a semester-long hybrid biochemistry elective course titled “Medicinal and Pharmaceutical Chemistry” wove information about COVID-19 into the curriculum. Rather than using miscellaneous diseases to introduce drug categories or vaccines as the instructor has done in the past, they focused on COVID-19 instead. The goal of using these modules was to introduce and illustrate several core concepts such as different drug classes, clinical trial structure, and pregnancy categories of drugs.

The first week of class started with an introduction to SARS-CoV-2 and COVID-19 by having students watch an illustrated summary video of COVID-19 put out by Yale University which is a 15 minute overview of how the virus infects the body to cause symptoms. For the first student activity, students were assigned to groups to work on creating a mind map (Module 22) and each group was given a set of the terms to focus on which they had to research and present to the class. To aid in their development of the mind map, a zipped folder was posted on the course LMS with multiple primary literature articles which provided background information as well as links to online resources for the students to use. Students had 1 class period to work synchronously in break-out rooms on Zoom while the professor popped in and out of break-out rooms checking in on them and answering questions. The next class period each group presented their specific set of terms and how they fit together, and then the groups got together again in break-out rooms to finish assembling the whole map with all of the terms. This activity engaged the students with the material and each other, made sure all had been exposed to sufficient background information about SARS-CoV-2, and set the tone for reading, researching, and working on projects related to COVID-19 for the semester.

For the second student activity, the course used Module 6 in which the students self-selected into small groups of 3-4 students. Module 6 involves choosing an article from a science magazine that is related to COVID and presenting that article in a succinct way. The professor modeled a presentation for them as they were preparing. The groups worked outside of class on their presentations and then delivered the presentation in a specific format (set time, define key words, write a summary sentence that is 20-30 words, give 1 slide with who, what, where, when, how, and why, and cite sources).Students had to take notes on each other’s presentations because there would be 1 question on the upcoming exam/presentation, to keep everyone accountable for active listening and learning something from the presentations. Each group also had to write 3 potential quiz questions, which had them engage with the material in a different way to think about the material metacognitively. The students liked being able to pick their own articles because they could choose a topic based on their interests such as vaccine development, diagnostic testing, and technology. Many conversations were sparked after the presentations related to the articles so the module served as a jumping off point for class discussion and Q&A.

By the end of these two modules, the students were interested and invested in the science of COVID-19 as it related to the course topic, allowing them to engage with the pandemic from intellectual and curiosity standpoints rather than social and emotional ones.

For a junior level biochemistry lecture, various modules were, and are planned to be used, for remote/hybrid instruction. The goal of using these modules was to illustrate basic concepts of nucleic acids, amino acids, protein structure, and structure/function relationships. The course started with a concept map to drive student understanding of common concepts of COVID-19 and start conversations about the biochemistry and molecular biology of the infection (Module 21). Next, students were given a series of biochemical questions on COVID-19 and asked in groups to prepare videos answering the questions for the class. This assignment led to a deeper conversation about the topic by following up with a robust discussion board and independent worksheets using the student-generated videos (Module 22). The molecular biology of reverse transcriptase and molecular tests (Module 23) were then used to focus on the early semester concepts of nucleic acids. After the basic course concepts of amino acids and protein structure were introduced, rather than transition to the traditional hemoglobin or antibody structure/function discussion, the class examined the structure and function of the SARS-CoV-2 spike protein by viewing an interview with the author of a recently published paper on the S protein (Module 24). In the upcoming semester, the instructor plans to extend this instruction of structure/function relationships by supplementing this work to highlight the novel mutations of spike protein and relate these to the molecular function and viral outcome. At the end of the term, students were asked to apply their knowledge to interpret a series of social media and press articles for their bias and validity (Module 25). This allowed for a complete integration of many of the COVID resources without the material being a side topic or distraction.

The above examples are a few ways to mix and match the activities presented here. Instructors can choose which modules to use in their courses based on which ones best suit their own classes. To help guide readers with other combinations, synergistic pairings are suggested in Table 3. Other matches are possible or even just the use of a single module could be beneficial. Please note that as most of these activities are open-ended and discussion based, answer keys are explicitly not provided. The corresponding authors are available for any questions or clarifications.

SCIENTIFIC TEACHING THEMES

Active Learning

Active learning is central in all of the lessons presented and elements to engage students with the material is incorporated into each. Individual literature searching and analysis, small group work, class discussions, oral and written presentation of material and database searching are some of the pedagogies employed. Multiple examples of proposal development, formulating hypotheses, and the use of discussion boards and activities, such as making concept maps or Venn diagrams, can be found in the lessons. Each module has a cover sheet where the specifics of active engagement for that lesson are outlined.

Assessment

Both formative and summative assessment is incorporated into the presented lessons. Many assessments ask students to apply their skills, such as the ability to align genomes, in either the lesson itself or in future projects, exams, written reflections, lab reports, or homework assignments. Specific delineation for each lesson can be found on the cover sheets.

Inclusive Teaching

Inclusive teaching practices are included in each lesson and can be found on their cover sheets. Some examples include use of free software and online databases, student self-selection of project topics, options for how to complete an assignment, and inclusion of reflection components.

SUPPORTING MATERIALS

- S1. COVID 360 – Activity 1 cover sheet
- S2. COVID 360 – Activity 1 Systems biology worksheet
- S3. COVID 360 – Activity 2 cover sheet
- S4. COVID 360 – Activity 2 Synthetic biology pre-class worksheet
- S5. COVID 360 – Activity 2 Synthetic biology in-class activity
- S6. COVID 360 – Activity 2 Synthetic biology group activity
- S7. COVID 360 – Activity 3 cover sheet
- S8. COVID 360 – Activity 3 Reading list for COVID-19 and Society
- S9. COVID 360 – Activity 4 cover sheet
- S10. COVID 360 – Activity 4 Dexamethasone case study
- S11. COVID 360 – Activity 5 cover sheet
- S12. COVID 360 – Activity 5 COVID-19 clinical trials research activity
- S13. COVID 360 – Activity 6 cover sheet
- S14. COVID 360 – Activity 6 Student presentations on Current Topics about COVID-19 from Drug Discovery News
- S15. COVID 360 – Activity 7 cover sheet
- S16. COVID 360 – Activity 7 Case study in immunology
- S17. COVID 360 – Activity 8 cover sheet
- S18. COVID 360 – Activity 8 Immunology Literature review
- S19. COVID 360 – Activity 8 Immunology Literature review template
- S20. COVID 360 – Activity 9 cover sheet
- S21. COVID 360 – Activity 9 Immunology Journal club
- S22. COVID 360 – Activity 9 Immunology Journal club rubric
- S23. COVID 360 – Activity 10 cover sheet
- S24. COVID 360 – Activity 10 Concept map of cytokine storm
- S25. COVID 360 – Activity 11 cover sheet
- S26. COVID 360 – Activity 11 Sequence alignment and phylogenetic trees
- S27. COVID 360 – Activity 11 Sequences for alignment
- S28. COVID 360 – Activity 11 MEGA alignment file
- S29. COVID 360 – Activity 11 MEGA session file
- S30. COVID 360 – Activity 11 MEGA results example, original tree
- S31. COVID 360 – Activity 11 Phylogenetic tree results
- S32. COVID 360 – Activity 12 cover sheet
- S33. COVID 360 – Activity 12 Primer design for diagnostic kit part 1
- S34. COVID 360 – Activity 12 Primer design for diagnostic kit part 2
- S35. COVID 360 – Activity 13 cover sheet
- S36. COVID 360 – Activity 13 Genetics and physiology activity
- S37. COVID 360 – Activity 14 cover sheet
- S38. COVID 360 – Activity 14 Structural analysis of the main protease
- S39. COVID 360 – Activity 15 cover sheet
- S40. COVID 360 – Activity 15 Structural analysis of the spike protein
- S41. COVID 360 – Activity 16 cover sheet
- S42. COVID 360 – Activity 16 Primer design for bacterial expression
- S43. COVID 360 – Activity 16 Spike protein fragments for cloning
- S44. COVID 360 – Activity 16 pET24-SUMO DNA sequence
- S45. COVID 360 – Activity 17 cover sheet
- S46. COVID 360 – Activity 17 Cloning and protein expression of main protease
- S47. COVID 360 – Activity 17 Bradford Assay setup
- S48. COVID 360 – Activity 17 Bradford pre-cleavage raw data
- S49. COVID 360 – Activity 17 Bradford pre-cleavage analysis
- S50. COVID 360 – Activity 17 Bradford post-cleavage raw data
- S51. COVID 360 – Activity 17 Bradford post-cleavage analysis
- S52. COVID 360 – Activity 18 cover sheet
- S53. COVID 360 – Activity 18 Cloning and protein expression of spike protein
- S54. COVID 360 – Activity 19 cover sheet
- S55. COVID 360 – Activity 19 Protease kinetics assays
- S56. COVID 360 – Activity 19 PNPA Standard Curve
- S57. COVID 360 – Activity 19 Kinetics data with fixed substrate concentration
- S58. COVID 360 – Activity 19 Michaelis-Menten kinetics data
- S59. COVID 360 – Activity 20 cover sheet
- S60. COVID 360 – Activity 20 Antigen immunoassay design
- S61. COVID 360 – Activity 21 cover sheet
- S62. COVID 360 – Activity 21 Analysis of virus structure/function relationships and video creation
- S63. COVID 360 – Activity 22 cover sheet
- S64. COVID 360 – Activity 22 Concept map for terms related to SARS-CoV-2
- S65. COVID 360 – Activity 22 PowerPoint introduction to COVID-19
- S66. COVID 360 – Activity 23 cover sheet
- S67. COVID 360 – Activity 23 COVID-19 Therapeutics
- S68. COVID 360 – Activity 24 cover sheet
- S69. COVID 360 – Activity 24 ACE2-Spike protein interactions
- S70. COVID 360 – Activity 25 cover sheet
- S71. COVID 360 – Activity 25 COVID-19 Mutational analysis
- S72. COVID 360 – Activity 22 Concept Map Example 1
- S73. COVID 360 – Activity 22 Concept Map Example 2

ACKNOWLEDGMENTS

The authors would like to express their gratitude to their respective institutions, and the American Society of Biochemistry and Molecular Biology for bringing them together.

REFERENCES

1. Qiang Z, Obando AG, Chen Y, Ye C. 2020. Revisiting Distance Learning Resources for Undergraduate Research and Lab Activities during COVID-19 Pandemic. J. Chem. Educ. Article ASAP. doi: 10.1021/acs.jchemed.0c00609.
2. Woelk K, Whitefield PD. 2020. As Close as It Might Get to the Real Lab Experience— Live-Streamed Laboratory Activities. J. Chem. Educ. Article ASAP. doi: 10.1021/acs.jchemed.0c00695.
3. Procko K, Bell JK, Benore MA, Booth RE, Del Gaizo Moore V, Dries DR, Martin DJ, Mertz PS, Offerdahl EG, Payne MA, Vega QC, Provost JJ. 2020. Moving biochemistry and molecular biology courses online in times of disruption: Recommended practices and resources - a collaboration with the faculty community and ASBMB. Biochem. Mol. Biol. Educ. 10.1002/bmb.21354. doi:10.1002/bmb.21354.
4. Noel TC, Rubin JE, Acebo Guerrero Y, Davis MC, Dietz H, Libertucci J, Sukdeo N. 2020. Keeping the Microbiology Lab Alive: Essential Microbiology Lab Skill Development in the Wake of COVID-19. Can. J. Microbiol. 10.1139/cjm-2020-0373. doi:10.1139/cjm-2020-0373.
5. Davis MC, Libertucci J, Acebo Guerrero Y, Dietz H, Noel TC, Rubin JE, Sukdeo N. 2020. Finding the Silver Lining During a Global Pandemic: Opportunities for Curriculum Innovation in Microbiology Education. Can. J. Microbiol. 10.1139/cjm-2020-0374. doi:10.1139/cjm-2020-0374.
6. American Association for the Advancement of Science. 2011. Vision and Change in Undergraduate Biology Education: A Call to Action, Washington, DC.
7. Tripp B, Shortlidge EE. 2019. A Framework to Guide Undergraduate Education in Interdisciplinary Science. CBE Life Sci. Educ. 18:2:es3. doi: 10.1187/cbe.18-11-0226.
8. Glassey J, Magalhães FD. 2020. Virtual labs – love them or hate them, they are likely to be used more in the future. Educ. Chem. Eng. 33: 76–77. doi:10.1016/j.ece.2020.07.005.
9. Harrison AG, Lin T, Want P. 2020. Mechanisms of SARS-CoV-2 Transmission and Pathogenesis. Trends Immunol. 41(12): p1100-1115. doi:10.1016/j.it.2020.10.004.
10. Dro□d□al S, Rosik J, Lechowicz K, Machaj F, Kotfis K, Ghavami S, Łos MJ. 2020. FDA approved drugs with pharmacotherapeutic potential for SARS-CoV-2 (COVID-19) therapy. Drug Resist. Updat. 53: 100719. doi:10.1016/j.drup.2020.100719.
11. Lopez L, Hart LH, Katz MH. Racial and Ethnic Health Disparities Related to COVID-19. JAMA. Published online January 22, 2021. doi:10.1001/jama.2020.26443
12. Zimmer, Carl. "The Coronavirus Unveiled," October 9, 2020. https://www.nytimes.com/interactive/2020/health/coronavirus-unveiled.html.
13. Burdick, Alan. "Monster or Machine? A Profile of the Coronavirus at 6 Months." The New York Times. The New York Times, June 2, 2020. https://www.nytimes.com/2020/06/02/health/coronavirus-profile-covid.html

Table 1: Activities included in the COVID 360 Collection and corresponding Supporting Files provided.

Activity Number	Discipline	Type of Activity	Time Needed	Topic	Supporting Files
Activity 1	Systems biology	Primary literature analysis	2-3 hours in class and/or homework (in-person or virtual)	Protein interactions of SARS-CoV-2 and how they can be used to predict useful drugs against the virus	S1. COVID 360 – Activity 1 cover sheet S2. COVID 360 – Activity 1 Systems biology worksheet
2	Synthetic Biology	Primary literature analysis	50-75 minute class (in-person or virtual)	Construction of the SARS-CoV-2 genome from chemical precursors and how this technology can aid in pandemic response	S3. COVID 360 – Activity 2 cover sheet S4. COVID 360 – Activity 2 Synthetic biology pre-class worksheet S5. COVID 360 – Activity 2 Synthetic biology in-class activity S6. COVID 360 – Activity 2 Synthetic biology group activity
3	Science and society	Historical analysis	One or more 50-75 minute classes (in-person or virtual) depending on depth of discussion	Contextualization of COVID-19 against other significant instances of disease influencing society	S7. COVID 360 – Activity 3 cover sheet S8. COVID 360 – Activity 3 Reading list for COVID-19 and Society
4	Medicinal and Pharmaceutical Chemistry	Primary literature analysis; Research and analysis skills	2-3 hours in class and/or homework (in-person or virtual)	Identify chemical and biological aspects of a drug and its target using Dexamethasone as a case study (with ties to the physiology of inflammation and cytokine storm)	S9. COVID 360 – Activity 4 cover sheet S10. COVID 360 – Activity 4 Dexamethasone case study
5	Medicinal and Pharmaceutical Chemistry	Small group project; database search; concept map; oral presentation	One or more 60 minute classes (in-person or virtual) depending on optional self-pacing and class discussions	Explain the different phases of clinical trials and why each is necessary. Specific clinical trials currently relevant to COVID-19.	S11. COVID 360 – Activity 5 cover sheet S12. COVID 360 – Activity 5 COVID-19 clinical trials research activity
6	Medicinal and Pharmaceutical Chemistry	Scientific Media analysis; Research skills; presentation	One or more 60 minute classes (in-person or virtual)	Analysis and short presentation of a science media article about current topics of COVID-19 in the medical and pharmaceutical industry.	S13. COVID 360 – Activity 6 cover sheet S14. COVID 360 – Activity 6 Student presentations on Current Topics about COVID-19 from Drug Discovery News
7	Immunology and virology	Case Studies	50-minute class	Broad to specific overview of the biology of SARS-CoV-2 and the impact on the immune response.	S15. COVID 360 – Activity 7 cover sheet S16. COVID 360 – Activity 7 Case study in immunology
8	Immunology and virology	Primary literature analysis (literature review)	One to five 50-75 minute classes (in-person or virtual)	Read, interpret, and analyze data about SARS-CoV-2 from the broad immune response to directed therapies.	S17. COVID 360 – Activity 8 cover sheet S18. COVID 360 – Activity 8 Immunology Literature review S19. COVID 360 – Activity 8 Immunology Literature review template

Activity Number	Discipline	Type of Activity	Time Needed	Topic	Supporting Files
9	Immunology and virology	Journal club (in-person or virtual)	One or more 50-75 minute classes (in person or virtual)	Interpretation and analysis of a journal article about SARS-CoV-2 in a formal oral presentation	S20. COVID 360 – Activity 9 cover sheet S21. COVID 360 – Activity 9 Immunology Journal club S22. COVID 360 – Activity 9 Immunology Journal club rubric
10	Immunology and virology	Concept map	One to two 50 min classes (in person or virtual)	Introduction to the immunology of SARS-CoV-2 and terms related to the virus and COVID-19	S23. COVID 360 – Activity 10 cover sheet S24. COVID 360 – Activity 10 Concept map of cytokine storm
11	Genetics	Computational activity	50-minute lab (in-person or virtual)	Using phylogenetic trees to understand the molecular evolution of SARS-CoV-2	S25. COVID 360 – Activity 11 cover sheet S26. COVID 360 – Activity 11 Sequence alignment and phylogenetic trees S27. COVID 360 – Activity 11 Sequences for alignment S28. COVID 360 – Activity 11 MEGA alignment file S29. COVID 360 – Activity 11 MEGA session file S30. COVID 360 – Activity 11 MEGA results example, original tree. S31. COVID 360 – Activity 11 Phylogenetic tree results
12	Genetics	Computational activity	50-minute class (in-person or virtual)	Design a diagnostic kit for SARS-CoV-2	S32. COVID 360 – Activity 12 cover sheet S33. COVID 360 – Activity 12 Primer design for diagnostic kit part 1 S34. COVID 360 – Activity 12 Primer design for diagnostic kit part 2
13	Genetics	Database activity; Discussion	Two 50-minute classes (in-person or virtual)	Gene structure and expression of ACE2 and TMPRSS2 receptors and sex differences in symptom severity	S35. COVID 360 – Activity 13 cover sheet S36. COVID 360 – Activity 13 Genetics and physiology activity
14	Biochemistry	Computational activity	2-4 hour computational exercise.	Structural analysis and substrate specificity of SARS-CoV-2 main protease	S37. COVID 360 – Activity 14 cover sheet S38. COVID 360 – Activity 14 Structural analysis of the main protease
15	Biochemistry	Computational activity	2-4 hour computational exercise.	Structural analysis and domain structure of SARS-CoV-2 Spike protein	S39. COVID 360 – Activity 15 cover sheet S40. COVID 360 – Activity 15 Structural analysis of the spike protein

Activity Number	Discipline	Type of Activity	Time Needed	Topic	Supporting Files
16	Biochemistry	Experimental design	1-2 hour in class or homework exercise.	Primer design for bacterial expression of viral proteins	S41. COVID 360 – Activity 16 cover sheet S42. COVID 360 – Activity 16 Primer design for bacterial expression S43. COVID 360 – Activity 16 Spike protein fragments for cloning S44. COVID 360 – Activity 16 pET24-SUMO DNA sequence
17	Biochemistry	Interpretation of wet lab data	One or two 1-2 hour in class or homework exercises.	PCR cloning and protein expression of SARS-CoV-2 main protease	S45. COVID 360 – Activity 17 cover sheet S46. COVID 360 – Activity 17 Cloning and protein expression of main protease S47. COVID 360 – Activity 17 Bradford Assay setup S48. COVID 360 – Activity 17 Bradford pre-cleavage raw data S49. COVID 360 – Activity 17 Bradford pre-cleavage analysis S50. COVID 360 – Activity 17 Bradford post-cleavage raw data S51. COVID 360 – Activity 17 Bradford post-cleavage analysis
18	Biochemistry	Interpretation of wet lab data	One or two 1-2 hour in class or homework exercises.	PCR cloning and protein expression of SARS-CoV-2 Spike protein fragments	S52. COVID 360 – Activity 18 cover sheet S53. COVID 360 – Activity 18 Cloning and protein expression of spike protein
19	Biochemistry	Interpretation of wet lab data	One or two 1-2 hour in class or homework exercises.	SARS-CoV-2 main protease kinetics assays	S54. COVID 360 – Activity 19 cover sheet S55. COVID 360 – Activity 19 Protease kinetics assays S56. COVID 360 – Activity 19 PNPA Standard Curve S57. COVID 360 – Activity 19 Kinetics data with fixed substrate concentration S58. COVID 360 – Activity 19 Michaelis-Menten kinetics data
20	Biochemistry	Experimental design and interpretation of wet lab data	1-2 hour in class or homework exercise.	Antigen immunoassay design and interpretation	S59. COVID 360 – Activity 20 cover sheet S60. COVID 360 – Activity 20 Antigen immunoassay design
21	Biochemistry	Video creation and computational activity	1 hour instructional time with 3-4 asynchronous work	Analysis of the domain structure of the spike protein	S61. COVID 360 – Activity 21 cover sheet S62. COVID 360 – Activity 21 Analysis of virus structure/function relationships and video creation

Activity Number	Discipline	Type of Activity	Time Needed	Topic	Supporting Files
22	Biochemistry	Mind/Concept Map	20-30 min of in class instruction and 1-2 hours homework	Terms related to SARS-CoV-2 and COVID-19	S63. COVID 360 – Activity 22 cover sheet S64. COVID 360 – Activity 22 Concept map for terms related to SARS-CoV-2 S65. COVID 360 – Activity 22 PowerPoint introduction to COVID-19 S72. COVID 360 – Activity 22 Concept Map Example 1 S73. COVID 360 – Activity 22 Concept Map Example 2
23	Biochemistry	Small group research project	2-3 hour homework.	Potential therapeutics for COVID-19	S66. COVID 360 – Activity 23 cover sheet S67. COVID 360 – Activity 23 COVID-19 Therapeutics
24	Biochemistry	Potential therapeutics for COVID-19	3-4 hours independent or in class time	Analysis of CE-Spike Protein plus video interview with paper authors	S68. COVID 360 – Activity 24 cover sheet S69. COVID 360 – Activity 24 ACE2-Spike protein interactions
25	Biochemistry	Primary literature analysis	3-4 hours of homework time	Analysis of naturally occurring mutations in the Spike protein during the pandemic, and analysis of how research results are presented to the public	S70. COVID 360 – Activity 25 cover sheet S71. COVID 360 – Activity 25 COVID-19 Mutational analysis

Table 2: Alignment of Activities in the COVID 360 Collection with Learning Frameworks from Professional Societies (society where appropriate is listed and all others: the link to CourseSource Learning Frameworks collection: [Courses | CourseSource])

Activity Number	Discipline	Activity Description	Society	Learning Goal
1	Systems biology	Primary literature analysis	ASM	How is the synthesis of viral genetic material and proteins dependent on host cells?
				How do microorganisms, cellular and viral, interact with both human and non-human hosts in beneficial, neutral, or detrimental ways?
2	Systems biology	Primary literature analysis	ASM	How can cell genomes be manipulated to alter cell function?
			ASBMB	What is a genome?
3	Science and society	Historical analysis	No specific society	Reviewing prior research
				Connections between science and societal response both in the past and the present.
				Students should be able to identify and critique scientific issues relating to society or ethics.
4	Medicinal and Pharmaceutical Chemistry	Primary literature analysis of medical treatments of COVID-19 patients;	ASBMB	What factors determine structure? How are structure and function related?
				What skills are needed to access, comprehend and communicate science?
5	Medicinal and Pharmaceutical Chemistry	Small group project to introduce clinical trial structure and then research a specific COVID-19 clinical trial	ASMB	What is the scientific process?
				What skills are needed to access, comprehend and communicate science?
6	Medicinal and Pharmaceutical Chemistry	Scientific media analysis of an article COVID-19 in the medical and pharmaceutical industry.	GSA	Students should be able to tap into the interdisciplinary nature of science.
			ASBMB	What skills are needed to access, comprehend and communicate science?
7	Immunology and virology	Case Study to introduce the COVID-19 immune response	ASM/ ASBMB	Systems: How do microorganisms, cellular and viral, interact with both human and non-human hosts in beneficial, neutral, or detrimental ways.
				Given a case study, students should be able to identify both scientific and societal ethical aspects.
8	Immunology and virology	Literature analysis of SARS-CoV2 biology	No specific society	Science Process Skills: Reading research papers.
			ASBMB	Students should be able to identify, locate and use the primary literature
9	Immunology and virology	Journal Club presentation about viral biology and therapy	No sepcific society	Science Process Skills: Communicating Results
			ASBMB	Students should be able to use visual and verbal tools to explain concepts and data.
10	Immunology and virology	Concept Map on basic immunology of COVID-19 and the cytokine storm	ASM	Systems: Describe innate physical defenses in the human body that are used to fend off an infection.
11	Genetics	Sequence alignment and construction of phylogenetic tree	GSA	What are the processes that can affect the frequency of genotypes and phenotypes in a population over time?
			NIBLSE	What is the role of computation in hypothesis-driven discovery processes within the life sciences?
				How can bioinformatics tools be employed to analyze genetic information?

Activity Number	Discipline	Activity Description	Society	Learning Goal
12	Genetics	Primer design for diagnostic test	GSA	Students should be able to design an experiment using appropriate controls and appropriate sample sizes.
13	Genetics	Discussion about the expression of ACE2 and symptomatology of COVID-19	ASMBMB	What is a genome?
				What skills are needed to access, comprehend and communicate science?
			ASCB	How can and why do cells with the same genomes have different structures and functions?
14	Biochemistry	Structural analysis and substrate specificity of SARS-CoV-2 main protease	ASBMB	What factors determine structure?
				How are structure and function related?
				What is the role of noncovalent intermolecular interactions?
15	Biochemistry	Structural analysis and domain structure of SARS-CoV-2 spike protein	ASBMB	What factors determine structure?
16	Biochemistry/ Genetics	Primer design for bacterial expression of viral proteins	GSA	What experimental methods are commonly used to analyze gene structure and gene expression?
17	Biochemistry	PCR cloning and protein expression of SARS-CoV-2 main protease	ASBMB	How are a variety of experimental and computational approaches used to observe and quantitatively measure the structure, dynamics and function of biological macromolecules?
18	Biochemistry	PCR cloning and protein expression of SARS-CoV-2 spike protein fragments	ASBMB	How are a variety of experimental and computational approaches used to observe and quantitatively measure the structure, dynamics and function of biological macromolecules?
19	Biochemistry	SARS-CoV-2 main protease kinetics assays	ASBMB	How do enzymes catalyze biological reactions?
				What is the scientific process?
20	Biochemistry	Antigen immunoassay design and interpretation	ASBMB	How are a variety of experimental and computational approaches used to observe and quantitatively measure the structure, dynamics and function of biological macromolecules?
21	Biochemistry	Video creation and computational activity on the Spike protein	ASBMB	Students should be able to use databases and bioinformatics tools.
				Students should be able to use visual and verbal tools to explain concepts and data.
22	Biochemistry	Mind/Concept Map	ASBMB	
23	Biochemistry	Small group research project on potential therapeutics	ASBMB	Students should be able to give and take directions to be an effective team member.
24	Biochemistry	Primary literature analysis of the Spike protein	ASBMB	Students should be able to identify, locate and use the primary literature.
25	Biochemistry	Primary literature analysis: how results are presented	ASBMB	Students should be able to identify, locate and use the primary literature.

Table 3: Synergistic cross-disciplinary pairings of modules

Module combinations	Main ideas of each module	Why they work together
22	Mind/concept map overview of COVID-19	Begins with a broad overview of the topic of COVID-19, then moves into the immune response to the virus, and finally explores a specific anti-inflammatory drug that can be used to treat patients
10	Intro to immunology of COVID-19	
4	Chemical and biological aspects of a COVID-19 drug	
6	Present current topics from a science magazine	Both modules deal with scientific writing but one deals with communication between scientists and the other with communication to the public
25	Critique COVID-19 research in lay press	
1	Protein interactions of SARS-CoV-2 and predicting useful drugs	All three focus on drug treatments for COVID-19: The first explores how we can predict drug targets and which drugs are likely to be effective against the virus, then covers how drugs are vetted clinically, and finally studies different drugs that are actually used to treat COVID-19 patients.
5	Clinical trials	
23	Potential therapeutics	
24	Primary literature analysis of spike protein	These three are tied together by a focus on the spike protein, but lead students through different scientific skills: first reading and understanding a primary research article, then using that knowledge and applying it to lab work in which the spike protein is cloned and expressed in cells, and finally a journal club presentation to bring all the students' new knowledge together
18	PCR cloning and protein expression of spike protein	
9	Journal Club Presentation	
2	Construction of SARS-CoV-2 genome and pandemic response	These three activities all focus on changes within the viral genome and their potential consequences. The first covers the broad topic of the viral genome, how it can be studied, and how variants can be understood, the second discusses how the virus has evolved over time, and the third covers the mutations that it has acquired as it has evolved and their consequences
11	Molecular evolution of SARS-CoV-2	
25	Mutations of spike protein	