Description: This course introduces students to host-associated microbiomes; the genomic collection of bacteria, archaea, fungi, protozoa, and viruses present in a host ecosystem. In each lecture, we will focus on an anatomical location, and discuss the host and environmental pressures which select for the resident microbial community. The material is primarily in animals (mammals, birds, fish, amphibians) but includes some human-specific comparisons. This course will introduce ecological theories (e.g. environmental selection, neutral theory) in the context of microbial communities, the history of host-associated microbiology, and how technology has contributed to or limited our understanding of organisms and their critical role in our health and development. The skill-set objectives include group discussions, reading scientific literature, and scientific writing in a variety of styles and both technical and non-technical formats.

Credit Hours: 3
Prerequisites: BIO 200 or BIO 208 or BMB 155 or BMB 280 or SMS 201; or permission
General Education requirements satisfied: Population and Environment
Mode of Instruction: hybrid for 2021 Time: Synchronous with modifications to facilitate asynchronous
Digital Services, Hardware, Software: Brightspace, Zoom

Instructional Material: There is no required textbook for this class. All reading material will be provided as electronic journal articles via Brightspace and reflect current literature in host-associated microbial ecology.

Class format: Lecture-based course with regular in-class discussions on relevant topics in science. Lecture Schedule is 15 weeks of 39 total class days: D3 x 1H. Students who need accommodations to the class format or material may contact me as needed.

Course Goals:
• Introduce concepts, techniques, historical background, terminology, and technology of microbial ecology.
• Familiarize students with online resources, including sequence and other databases, as well as analysis tools.
• Discuss factors which shape host-associated microbiomes and how the microbiome can affect the host.
• Review current literature on host-associated microbial ecology.

Student Learning Outcomes:
As a result of taking this class, students will be able to:
• Describe the dynamics which shape host-associated microbiomes.
• Access online databases of scientific articles and databases.
• Review scientific journal articles and distill their findings while understanding their limitations.
• Communicate science in a variety of formats.
• Discuss topics related to science, such as recognition for achievements and the role of scientists in communicating results to the general public.

In meeting the Population and Environment requirements specifically, students will be able to:
• Describe how host-associated microbial ecosystems are affected by environmental (external to the body) conditions.
• Describe how climate change affects range and diet selection, and how this can impact gut microbial communities and animal survival.
• Describe vertical and horizontal transmission, as well as environmental exposure of microorganisms.
• Describe the effect of pollution and air quality on health and the microbiome.

**Attendance policy:** Students are encouraged to attend lectures, but it is understood that life often precludes this. All lectures will be live-streamed, and recorded and made available after class. Students who miss a significant number of classes, or who require additional accommodations, may contact me.

- Pregnancy, lactation, and parenting: I am happy to make accommodations for students based on pregnancy, lactation, and parental needs, as well as work with the Office of Equal Opportunities. Maine state and UMaine policy allows students who are nursing to breastfeed in any space, including in class. If a lactation space is required, please contact E.O. for arrangements. Pregnant on Campus Initiative, pregnancy and parenting resources in Orono [https://pregnantoncampus.studentsforlife.org/campus/umaine-orono/](https://pregnantoncampus.studentsforlife.org/campus/umaine-orono/)
- Food insecure? Need clothes? Check out the Black Bear Exchange’s Food Pantry: [https://umaine.edu/volunteer/black-bear-exchange/](https://umaine.edu/volunteer/black-bear-exchange/) or Old Town Crossroads Ministry.

**Class participation:** Students are expected to participate in discussions in class. I strive to create inclusive discussions, but if students still find it challenging to participate please notify me and I will alter the discussion format as needed.

**Late Assignments:** Assignments will be accepted after deadlines, but you might not receive feedback. Significant delays or frequently late assignments may result in grade penalties. Assignments will not be accepted after the last day of the semester.

**Classroom policy:** Supporting inclusion and community in science is an active process that involves both invitation, and support to ensure that the scientific community is and remains an equitable and inclusive place. Students are expected to conduct themselves in a professional and courteous manner, and to abide by University policies.

**Campus Policies:** “The University of Maine is an EEO/AA employer, and does not discriminate on the grounds of race, color, religion, sex, sexual orientation, transgender status, gender expression, national origin, citizenship status, age, disability, genetic information or veteran’s status in employment, education, and all other programs and activities.” Follow the links for more information.

- [Academic Honesty Statement*](https://www.umaine.edu/academic/guidelines/honesty/
- [Students Accessibility Services Statement*](https://www.umaine.edu/campuslife/student-life/student-accessibility-services/
- [Course Schedule Disclaimer*](https://www.umaine.edu/campuslife/student-life/course-schedule-disclaimer/
- [Observance of Religious Holidays/Events*](https://www.umaine.edu/campuslife/student-life/ioh/
- [Sexual Discrimination Reporting (Long)*](https://www.umaine.edu/student-life/ioh/
- [Sexual Discrimination Reporting (Short)*](https://www.umaine.edu/student-life/ioh/
- [UMaine Land Acknowledgement](https://www.umaine.edu/campuslife/student-life/local-community/

**I am a “mandatory reporter”**. If you disclose something to me, including in assignments, I am obligated to tell the campus Title IX office.

**Assignments:** Instructions, rubrics, and submission on Brightspace, but may be submitted in class/on paper. These will include written essays/discussion, “posters”, article reviews, drawn concept-network maps, or exploration of microbial ecology online resources such as databases (ex. NCBI, MG-RAST). Some homework is used to create portions of the essay exams or the final project.
- **Article Summaries:** Write a 1 paragraph non-technical summary of a scientific journal article on a recent class topic. You may use an article from class or of your own choosing, be sure to include the citation. You must summarize the background/hypothesis, at least one method, and the main results. For extra credit, post
your corrected assignment and link to the original article to a social media site and send me a link or screen shot. Instructions and submission on Brightspace.

- **Concept map**: Create a visual outline (diagram) to use as a study guide around the specified topic. Starting with a main idea or topic in the center, create branches out to secondary ideas, and so on, like a spider web, to create a map of important related topics. Instructions, examples, and submission on Brightspace.

**Take Home Exams**: Three short essay-style exams will demonstrate comprehension of the lectures and readings as students describe a specific aspect of microbiomes. Include at least 3 scientific references, including in-line citations and full citations in a reference list. This should be written for a more technical, scientific audience. Instructions, examples, and submission on Brightspace.

**Discussions**: We will have informal discussions in class throughout the semester, but there will also be Discussion topics in Brightspace and you may enter your comments there, instead. This is not graded.

**Group work**: 

- **Case studies**: In groups, students will discuss a case-study and create a decision tree/workflow about how to go about solving it. By the end of the day, one group member will submit a copy/screenshot to Brightspace. Asynchronous students can connect remotely later, and upload their notes to Brightspace.

**Final Project**: Students will create a **public outreach presentation** in the format of their choice. The aim is to discuss a particular aspect, ecosystem, problem, or unanswered question in host-associated microbiomes, and to present it in a way that would promote scientific literacy to the general public. Students may use material they generated in assignments or exams, but you may not submit these in the exact same version – you will need to rewrite and improve them in some way. Students will be graded on the quality of information, the creativity of the presentation, and the effectiveness of their communication.

- Students may opt to work alone or in groups of up to three.
- Format examples include: written essay (2 pg), pamphlet or poster, presentation (10+ slides), etc. If choosing the pamphlet, poster, or presentation, IN ADDITION, students must submit a long-form description of their topic, approximately 1/2 page (not including citations).
- Students may opt to generate an Op-Ed/Letter to the editor, with the goals of submitting to a local news agency or UMaine extension newsletter after revisions.
- Students may opt to generate a “concerned citizen” letter to a legislator, institution, or public policy makers, with the goal of informing them on an issue related to host-associated microbiology and how public policy can support health.
- Students may opt to generate a 1,500-word essay, with the goal of submitting this to Frontiers for Young Minds scientific journal under the Biodiversity designation as a Core Concept: [https://kids.frontiersin.org/specialties/biodiversity](https://kids.frontiersin.org/specialties/biodiversity). Your final project submission should follow journal guidelines: [https://kids.frontiersin.org/participate/authors](https://kids.frontiersin.org/participate/authors). Students will be main authors on this publication, and I will be last author, as I will facilitate editing and submission. For this version, students must be available to make edits and approve submission after the end of the semester.

**Grading (out of 100 points)**: Group work: 15 pts, Assignments: 40 pts, Take Home Exams: 30 pts (10 pts each), Final Project: 15 pts

A = 93–100; A− = 90–92; B+ = 87–89; B = 83–86; B− = 80–82; C+ = 77–79; C = 73–76; C− = 70–72; D+ = 67–69; D = 63–66; D− = 60–62; F = 0–59
<table>
<thead>
<tr>
<th>Day</th>
<th>Week</th>
<th>Lecture</th>
<th>Title, Objective, Assignments</th>
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<tbody>
<tr>
<td>M 8/30</td>
<td>0</td>
<td>0</td>
<td>Introduction to the course, explanation of the syllabus and course expectations, materials.</td>
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</table>
| M 8/30 | 1 | 1 | **Introduction to Microbial Ecology Theory and Technology**  
*What is a host-associated microbiome?*  
An introduction to what a host-associated microbiome actually is.  
- **Reading**: Gilbert_2014_life in a world without microbes  
- **Reading**: Ishaq_2019_microbes and social equity  
- **Assignment (2 pts)**: choose 2 songs to add to the Host-Microbe Interactions Playlist Discussion Topic on Brightspace. Due by end of Friday. |
| W 9/1 | 2 | 2 | *Who’s there? Major players in the microbial world.*  
An overview on different microorganisms.  
- **Discussion**: Are microbes a natural resource?  
- **Reading (choose 1)**:  
  - Caumette_2015_Historical elements of microbial ecology  
  - Gibbs_2012_history_vets_one_health  
  - Opal_2010_brief_history_micro_immunology |
| F 9/3 | 3 | 3 | *A brief history on the discovery of microorganisms.*  
The discovery of microorganisms, historical perspective, development of theories.  
- **Due (online)**: add 2 songs to our PlayList Discussion threads.  
- **Discussion**: Elitism, recognition, and credit for intellectual property  
- **Reading (choose 1)**:  
  - Barberan_2014_microbial_to_macroecology  
  - DAbramo_2020_historical_epistemiology_microbes  
  - Prosser_2007_ ecological theory in microbial theory  
- **Assignment (2pts)**: Learn to use NCBI, due next class. |
| M 9/6 | 2 | 2 | Labor day, no class |
| W 9/8 | 4 | 4 | *DNA technology and how it changed our view of the world.*  
A historical perspective and explanation of DNA technology.  
- **Due**: Learn to use NCBI  
- **Reading**: Clarridge_2004_16S and clinical microbiology, up to “Basics of sequencing”  
- **Optional Video**: Sanger Sequencing, [https://www.youtube.com/watch?v=ONGdehkB8jU](https://www.youtube.com/watch?v=ONGdehkB8jU) |
| F 9/10 | 5 | 5 | *Sequencing technology and how it revolutionized microbial ecology.*  
Current sequencing technology, comparisons, and different applications.  
- **Reading**: Clarridge_2004_16S and clinical microbiology, rest of paper  
- **Assignment (3pts)**: Article Summary on microbial tech or theory, due by next class |
| M 9/13 | 3 | 6 | *An introduction to phylogeny and how our understanding of biodiversity is changing.*  
Explanation of phylogenetics, genetic diversity, and what constitutes a species. In class group work, draw your group’s hair color ordination plot.  
- **Due**: article summary  
- **Reading**: de Queiroz_2005_ modern concept of species  
- **Assignment (5pts)**: quiz on Brightspace; “What is plagiarism”. Due in 1 week. |
| W 9/15 | 7 | 7 | *Other methods of profiling microbial communities.*  
Other microbial profiling techniques, stains, fluoroscopy, SEM/TEM, RAMAN.  
- **Reading**: Valm_2012_CLASI-FISH  
- **Reading**: Recorded lecture, “Translating sequencing data to journal articles.” |
**F 9/17** 8  |  *In-class or Zoom room group assignments*
---|---
1. (1 pts) Draw a concept map on microbial tech or theory. Upload final draft to Brightspace as a group assignment.
2. (2 pts) Come up with a research question/scenario about trying to find or visualize microbes in any location or host. Describe what technology you might use and why. You may set this in modern times or historical times. Upload final draft to Brightspace as a group assignment.

- **Take Home Exam 1 (10pts): due next Fri at noon**

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**Digestive Tract Ecosystems**

**M 9/20** 4 | 9  |  *“The oral microbiome.”*
---|---|---
Bacteria in the mouth are affected by salival production, and have systemic health effects.

- **Due:** quiz on Brightspace.

- **Reading (choose 1):**
  - Proctor_2017_nose_mouth_throat_humans
  - Ruparell_2020_canine_oral_microbiome
  - Barden_2020_oral_microbiome_calves
  - Borsanelli_2018_cow_periodontis

**W 9/21** 10  |  *“Monogastrics, ceca, and intestines.”*
---|---
Anatomy and the gut microbiome of monogastrics, a comparison of animal species.

- **Reading (choose 1):**
  - Moeller_2014_human_gut_microbiome
  - PachecoSandoval_2019_harbor_seal_gut
  - Kauter_2019_horse_gut_microbiome
  - Wasimuddin_2016_cheetah_gut

**F 9/24** 11  |  *“Coprophagy and microbes.”*
---|---
Coprophagy and why rabbits recycle, bats feces and humans don’t mix, dung beetles are helpful, and the benefits and drawbacks of the “cage effect” in mice and zebrafish.

- **Due:** Take Home Exam 1, due by noon

- **Reading:** Levesque_2020_hot_takes

- **Assignment (3 points):** Choose any animal, and write 1 paragraph about how their teeth/oral anatomy is tied to their diet, and what the major components of that would be (ex. Fat, protein, fiber). Include a photo of the teeth. Due two classes from today.

**M 9/27** 5  | 12  |  *“Gut microbiota of birds.”*
---|---|---
The unique digestive tract of birds, their gut microbiota, bats vs. birds vs. mammals.

- **Discussion:** How do we talk about conservation efforts when zoonotic disease and human land use is a higher priority in the conversation?

- **Reading (choose 1):**
  - Price_2015_digestion_and_aerial_lifestyle
  - Martinez-Garcia_2016_nest_microbiome_eggs
  - Oliveira_2020_raptor_microbiome
  - Watch dissertation defense, “The Effect of Nest Architecture on Nest Microclimate and Microbiome Assembly in Tropical Birds”
  - [https://www.youtube.com/watch?v=CfLzkWFbEIE&feature=youtu.be&fbclid=IwAR2Jd4g_rNgct55oru-rDDW1T0zYV_xvv31XA8syqTfoJkLq1UMXbIPaPl](https://www.youtube.com/watch?v=CfLzkWFbEIE&feature=youtu.be&fbclid=IwAR2Jd4g_rNgct55oru-rDDW1T0zYV_xvv31XA8syqTfoJkLq1UMXbIPaPl)

**W 9/29** 13  |  *“Ruminants- bacteria.”*
---|---
The rumen bacterial community, and its importance to the herbivore.

- **Due:** teeth and diet summary

- **Reading (option 1):** Henderson_2015_core_rumen_microbiome
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<th>Date</th>
<th>Reading (option 2):</th>
<th>Assignment (3pts):</th>
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<tbody>
<tr>
<td>F 10/1</td>
<td>Williams 2019_wildlife_microbiomes</td>
<td>Choose a ruminant species in Henderson et al. 2015 or Williams et al. 2019, and summarize in a paragraph, due two classes from today</td>
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**F 10/8**

“Ruminants: fungi, protozoa, archaea, and viruses.”

Bacteria aren’t the only members of the gut community.

- Reading (option 1): Ishaq 2015_prot methanogen moose
- Reading (option 2): Huws 2018_rumen_microbiome_agriculture

**M 10/4**

“Effect of diet on the gut microbiome.”

Specific nutrients in a diet create nuances in the gut microbiome. What are bats doing?

- Due: ruminant species summary
- Reading (option 1): Singh 2017_influence of diet
- Reading (option 2): Vangay 2018_immigration_gut_microbiome
- Assignment (3pts): Learn to use MG-RAST, due next class.

**W 10/6**

“Rumen acidosis.”

The effect of rumen acidosis in wild and domesticated animals, and microbial therapeutics

- Due: Learning to use MG-RAST
- Discussion: livestock paleo diet
- Reading (option 1): Ishaq 2017_rumen_microbes_SARA
- Reading (option 2): Felton 2017_wild_ungulates_acidosis

**F 10/8**

“The many benefits of fiber.”

How fiber affects the gut microbiota, including carnivores, the curious case of the panda.

- Reading (choose 1):
  - Zhao 2018_fiber and diabetes
  - Slavin 2013_fiber_health
  - Sonnenburg 2014_microbial_accessible_carbohydrates
- Assignment (3pts): make a concept map on gut microbiota. Due next class

**M 10/11**

Indigenous People’s Day, no class

**W 10/13**

“I don’t need that kind of toxicity in my life.”

How gut microbes detoxify plant-secondary compounds.

- Due: concept map on gut microbes
- Reading: Kohl 2016_woodrats and toxins

**F 10/15**

In-class case-study 1: How do we get into the gut?

- Group work (5pts of discussion grade): upload to Brightspace today
- Take Home Exam 2 (10pts): due next Fri at noon

**Nature vs. Nurture and Development of the Immune System**

**M 10/18**

“Vaginal microbiome.”

The vagina, drivers of the microbiome, comparisons across primates, and studies on smoking.

- Reading (choose 1):
  - Messman 2021_bovine_vaginal_microbiome
  - Nelson 2018_smoking_vaginal_microbiome
  - Zhang 2020_panda_vaginal_microbiome
  - Matějková 2020_field_mice_vaginal_microbiome
  - Miller 2016_comparison_vaginal_microbiome

**W 10/20**

“Pregnancy and microbial transfer at birth.”

Pregnancy changes to microbiome, in utero transfer, and developing neonatal microbiome.

- Discussion: Should we have neonatal probiotics?
- Reading (choose 1):
  - Zhang 2021_developing_gut_neonamte_ruminants
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| 10/22 | **“Vertical transmission of microbes by milk.”**  
Breastmilk and the development of the neonate GI microbiome, discussion of vertical transmission of microbes.  
- **Reading:** Yeoman 2018, effect of colostrum on calf rumen  
- **Due:** Take Home Exam 2, due by noon |
| 10/25 | **“Microbes and the nature vs. nurture debate.”**  
Generational effects of microbes, and nature (host) vs. nurture (environment) in microbiomes.  
- **Reading (choose 1):**  
  - Rothschild 2018, nurture over nature  
  - Wang 2018, rearing conditions in ducks  
  - Yan 2016, env filtering fish microbiome  
  - Prabhu 2020, wild domestic bovine microbiome  
  - Byrd 2020, gut microbes health disparities |
| 10/27 | **“Probiotics, prebiotics, and synbiotics.”**  
Do probiotics work? Federal regulations, assessment of efficacy, and theory.  
- **Reading (Option 1):** Gupta 2016, FMT in perspective  
- **Reading (Option 2):** Fijan 2014, microorganisms with claimed probiotic properties |
| 10/29 | **“Probiotics in animal industries.”**  
Improving health, feed efficiency, etc. Do dogs need probiotics?  
- **Reading:** Garcia-Marcorro 2019, Saccharomyces rumen  
- **Assignment (5pts):** Locate a product labeled as “probiotic”. Write down the product, the microbes used, and health claims included on the product. Do a literary search to find at least one scientific article associated with at least one microbe listed, and try to find out if that health claim is justified. Submit your notes in Brightspace, due next class. |
| 11/1 | **“Host-microbe interactions in the gut – part 1.”**  
GI tract microbiome and interactions with the epithelium and immune system, medication efficacy, how interactions here lead to systemic effects.  
- **Due:** probiotic summary |
| 11/3 | **“Host-microbe interactions in the gut – part 2.”**  
GI tract microbiome and interactions with the epithelium and immune system, medication efficacy, how interactions here lead to systemic effects.  
- **Reading (option 1):** Wilkinson 2018, microbiota drug interactions  
- **Reading (option 2):** Knoop 2020, breastfeeding allergies  
- **Assignment (3pts):** make a concept map on microbiota and health. Due next class. |
| 11/5 | **“Intestinal parasites and immune monitoring.”**  
Intestinal parasites, and origin of the Hygiene Hypothesis.  
- **DUE:** concept map on microbes and health  
- **Reading (choose 1):**  
  - Mamun 2020, parasites bacteria sheep  
  - Dunsand-Guzmán 2019, parasites microbes medicine  
  - Leung parasite microbes ecology  
  - Scudellari 2017, cleaning up hygiene hypothesis  
  - Shi 2017, microbiota and immune system |
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| 11/8  | 1    | “Seasonal effects on the gut microbiome.”
> What happens when food is scarce, and what happens during hibernation?
> **Discussion**: should we feed wild animals in the winter?
> **Reading (choose 1):**
  - Carey_2012_ground_squirrel_hibernation
  - Wiebler_2018_urea_hydrolysis_hibernating_frog
  - Sommer_2016_brown_bear_microbiota
  - Video: “Badger Talk: Hibernators and Their Microbes”, Edna Chiang, [https://t.co/oot87RtdQ6?amp=1](https://t.co/oot87RtdQ6?amp=1)
> **Take Home Exam 3 (10pts)**: due next Wednesday at noon

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<tbody>
<tr>
<td>11/10</td>
<td>1</td>
<td>Veterans’ Day, no class</td>
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| 11/11 | 1    | “Factors driving the skin microbiome.”
> Skin microbiota of humans, terrestrial mammals, and aquatic mammals.
> **Reading (choose 1):**
  - Kong_2017_skin_microbiome
  - Ross_2019_skin_microbiome_vertebrates
  - DeCandia_2019_mange_microbes
> **Bonus content**: AVS254_skin_problems_2021_bonus_content

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| 11/15 | 1    | “Lobster shell bacteria and climate change”
> Epizootic shell disease is a tricky business.
> **Reading (choose 1):**
  - Osvatic_2021_chemosynthetic_symbionents_sponges
  - Groner_2018_lobster_disease_climate
  - Miller_2020_whale_gut_microbiome

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| 11/17 | 1    | “Skin microbiota of amphibians and health.”
> Amphibians’ skin connects them to the environment – for better or worse.
> **Due**: Take Home Exam 3, due by noon
> **Reading (choose 1):**
  - BritodeAssis_2017_skin_microbiota_frogs
  - Hernández-Gómez_2020_AmphibianSkinMicrobiota
  - Brucker_2008_amphibian_bacteria_antifungals
  - Pounds_2006_climatechange_extinction
  - Greenspan_2017_climate_infection_vulnerability
> **Assignment (2 pts)**: Choose any animal and describe its skin/fur/exoskeleton, local environment, and what factors might affect their external microbiome. Due two classes from now.

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| 11/19 | 1    | “Lung microbiome and the difficulty of sampling.”
> Discussions on the lung microbiome connections to viral infections.
> **Readings**: Dickson_2015_lung_microbiome

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<th>Date</th>
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| 11/22 | 1    | “Horizontal transmission.”
> Sharing microbes, cohabitation, and how transfer can be mediated by the built environment.
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<th>Date</th>
<th>Assignment/Case Study</th>
<th>Reading/Discussion</th>
<th>Notes</th>
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</table>
| W 11/24 | Due: external anatomy and microbiome | **Reading (choose 1):**  
  - Song_2013_cohabiting_with_microbe  
  - Rader_2021_masks_infection_control  
  - Aguirre_2019_one_health_toxoplasmosis  
  Optional bonus content: AVS254_microbes_built_environment_bonuscontent_2021 | Thanksgiving, no class |
| F 11/26 |  |  | Thanksgiving, no class |
| M 11/29 | In-class case-study 2: How do we create an integrated view of microbiology, biology, environmental science, and social science? | **Group work (5pts): upload to Brightspace by the end of the day** |  |
| W 12/1 | “Captivity and the loss of biodiversity.” | **Discussion:** Do we have a right to microbes?  
**Reading (choose 1):**  
  - Clayton_2016_captivity_primate_microbiome  
  - vanLeeuwen_2019_captivty_relocation  
  - Leong_2018_biodiversity_and_socioeconomics  
  - Reese_2021_domestication_industrialization  
  - Prabhu_2020_wild_domestic_bovine_microbiome |  |
| F 12/3 | “Environmental microbes and health.” | **Reading (pick 1):**  
  - Griffin_2007_desert_dust_and_human_health  
  - Mills_2019_urban_biodiversity_and_health  
  - Jatzlauk_2017_env_microbes_and_asthma  
  - Trinh_2018_microbes_humans_animals_environment  
  - Reber_2016_Mvaccae_stress_reduction |  |
| M 12/6 | “The problem with pollution.” | **Discussion:** air quality, city planning, and income inequality  
**Reading (pick 1):**  
  - Allaire_2018_drinking_water_violations  
  - Kumpel_2016_intermittent_water_supply  
  - Pandey_2014_Contamination_Water_Resources  
  - Stillo_2017_contaminated_water_health_disparities  
  - Tessum_2019_air_pollution_and_racial_inequity |  |
| W 12/8 | In-class case-study 3: How do we reimagine the human ecosystem? | **Group work (5pts): upload to Brightspace by the end of the day**  
**Due:** Article summary on environment |  |
| F 12/10 | “Now what?” |  |  |
| F 12/17 |  |  | Final Project Due, hand in materials or give presentation by this date (see Final Project Description) |