HCOL Sophomore Seminar
Fall 2019

viruses: good news after all!
(viruses as major evolutionary, physiological, and ecological forces)

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office hours: by appointment

Course meeting times and location: Tuesday & Thursday, 2:50 – 4:05 in U Heights North MP

Course description

"Viruses are being redefined as more than just pathogens. They are also critical symbiotic partners in the health of their hosts."

"Our new understanding of the role of viruses in mutualistic symbiotic relationships with their hosts is expanding as our knowledge of the virome, through new sequencing technologies and bioinformatic strategies, is rapidly increasing."

Marilyn J Roossinck
Move over bacteria! Viruses make their mark as mutualistic microbial symbionts
J Virol 89:6532–6535. doi:10.1128/JVI.02974-14.

Metagenomic analyses have established that viruses are the most abundant and diverse biological entities. Further, the sequencing of the human genome revealed that viruses, together with evolutionarily related, mobile genetic entities occupy more than half of our genome. Together with recent research, these findings are leading to a paradigm change: viruses, while being parasites (as their propagation can take place only within cell-based organisms), are no longer perceived primarily as pathogens but are now being appreciated as important positive constituents of the biosphere. They are rooted in the pre-cellular world, have co-evolved with cell-based biological entities, and we now recognize that the interplay between cell-based organisms and viruses (and similar mobile genetic entities) has profoundly affected the evolution of presumably all cellular life forms. While many new properties/traits are thought to be the result of a continued arms race between these genetic parasites and their hosts, genome analyses have also revealed that hosts, as they evolved to their present forms, on numerous occasions have recruited genetic information from viruses or virus-like entities for proper functioning. Recent research further shows that such cooperation takes place also at the population level: viruses are now being recognized as important ecological forces, both on land and at sea.

The overall goal of this course is to discuss this paradigm change: comparable to how we finally appreciate that most of the bacteria that live with us are "true" symbionts, as they co-evolved with us and are essential for our health, viruses should now be considered as being overall

positive genetic entities. They were not only essential during evolution but likely are also important during ontogenesis, and while some of them can act as pathogens, likely many more actually help prevent diseases, for example by strengthening host physiology and immune functions and thus helping to fend off or at least limit the multiplication of “true” pathogens.

Course Objectives:

- Gain an understanding of how our current, but now outdated, view of viruses was formed during the past century.
- Develop an understanding of how perception of microbes (bacteria and viruses) is limited by technology: only metagenomic analyses allow to now start studying in depth the oftentimes mutualistic relationship between microbes and their hosts.
- Learn how results of recent research (mostly performed during the past decade, and after the genomes of humans and other species have been sequenced) started to change the perception of viruses from being seen primarily as pathogens to being perceived as actually important, overall positive biological entities.
- Gain an appreciation for viruses as essential drivers of the evolution of life on Earth.
- Develop awareness for how non-selective usage of (broad-spectrum) antivirals, just like non-selective applications of antibiotics, is likely ultimately harmful for the host organism.
- Participate in the creation of a class pamphlet that documents how recent research is about to fundamentally alter our perception of viruses, and which summarizes some of the newly-recognized evolutionary, physiological, and ecological roles that viruses play.

Course outline and format

Introductory reading:

Viruses throughout life & time: friends, foes, change agents. SE Greene & A Reid.
A Report on an American Academy of Microbiology Colloquium San Francisco. July 2013.
online at:
https://www.asmscience.org/content/report/colloquia/colloquia.51

The good viruses – viruses of the human body. E Dalwart. The Scientist. Nov 2016.
online at:
https://www.the-scientist.com/features/viruses-of-the-human-body-32614

The missing link. Viruses revise evolutionary theory. P Hunter. EMBO Rep. 2010 Jan;11(1):28-31. doi: 10.1038/embor.2009.267.
online at:
https://www.embopress.org/doi/full/10.1038/embor.2009.267

Symbiosis: Viruses as Intimate Partners. MJ Roossinck & ER Bazan. Annu. Rev. Virol. 2017. 4:123–39. doi.org/10.1146/annurev-virology-110615-042323.
online at:
https://www.annualreviews.org/doi/pdf/10.1146/annurev-virology-110615-042323

Move Over, Bacteria! Viruses Make Their Mark as Mutualistic Microbial Symbionts. J Virol. 2015 Jul;89(13):6532-5. doi: 10.1128/JVI.02974-14. Epub 2015 Apr 22.
online at:
https://jvi.asm.org/content/89/13/6532

Program:

The following program is tentative only. The actual schedule, the order of topics to be discussed during specific weeks, will be established during the course and will be the result of discussions among the students, in consultation with the instructor, and will depend on what the students choose to focus on as they undertake research on specific topics and also on the format with which they decide to summarize the result of their research.

During the first two weeks, we will start familiarizing ourselves with the four main themes (see below) using the introductory reading. After that, and using some of the material listed for the topics as points of departure, we will start discussing those themes in some more depth. Concurrently, or subsequently, two or three students together will choose to do in-depth research on one of those topics.

As a first result of their research, the students will then present their findings using an appropriate format (e.g. PowerPoint presentations, or similar platform). The presentations are supposed to be as interactive as possible because during the second phase of their work, the students, also based on the feedback they get during their presentations, will deepen their studies and will also create one or two pages (format: infographic or similar) that will be part of a pamphlet that will contain all the summaries.

Finally, because the course instructor's research focusses on a pathogenic virus (HIV-1), and because he thus cannot share first-hand experience about how scientist are tackling questions about how viruses and related genetic entities act as positive biological forces, or how these genetic entities can be identified in the first place, an external guest speaker will be meeting with the class to share her experiences: Dr. Irina Arkhipova, a molecular evolutionary geneticist who specializes on mobile genetic elements, which include viruses, will meet with the class during the second week of October. She will also give a seminar within the context of the MMG seminar series.

The four main themes that will be discussed during this course are:

A Virus-like genetic entities at the origin of life and contributions by viruses and similar movable genetic entities to the evolution of specific properties

B Newly-recognized roles of viruses in ontogeny and physiology

C Ecological roles of viruses: marine viruses are estimated to lyse a significant fraction of micro-organisms that populate the oceans on a daily basis. Such massive killing, which leads to the release of Carbon and other elements, is an obvious prerequisite for biochemical recycling processes at the global level.

D Engineering: comparable to how other microbes, including e.g. *S. cerevisiae* (baker's and brewer's yeast) is being used for industrial purposes, or how we are now starting to use

bacteria as therapeutics for specific diseases, viruses and genetically altered derivatives of them are being developed to fulfill various tasks.

Texts and other resources to be used:

for topic A:

A virocentric perspective on the evolution of life. EV Koonin & VV Dolja.
Curr Opin Virol. 2013 Oct;3(5):546-57. doi:10.1016/j.coviro.2013.06.008.

Paleovirology of '*syncytins*', retroviral *env* genes exapted for a role in placentation. C Lavaille et al.. Philos Trans R Soc Lond B Biol Sci. 2013 Sep 19; 368(1626): 20120507. doi:10.1098/rstb.2012.0507.

A viral (Arc)hive for metazoan memory. NF Parrish & K Tomonaga. Cell 2018 Vol 172(1):8-10. doi.10.1016/j.cell.2017.12.029.

Using bioinformatic and phylogenetic approaches to classify transposable elements and understand their complex evolutionary histories. Irina R. Arkhipova. Mobile DNA (2017) 8:19 DOI 10.1186/s13100-017-0103-2

for topic B:

What makes each brain unique. FH Gage & AR Muotri. Scientific American 306, 26 - 31 (2012) doi:10.1038/scientificamerican0312-26

Cellular and Molecular Mechanisms that Differentiate Human and Non-Human Neural Development - Fred H Gage. YouTube video published on Nov 20, 2017 by University of California Television (UCTV).

How are Humans Different from Great Apes? - Fred H. Gage. YouTube video published on Dec 14, 2017 by the American Academy of Arts & Sciences.

Herpesvirus latency confers symbiotic protection from bacterial infection. ES Barton et al. Nature. 2007 May 17;447(7142):326-9. doi:10.1038/nature05762.

for topic C:

Marine viruses--major players in the global ecosystem. Nat Rev Microbiol. 2007 Oct;5(10):801-12. doi:10.1038/nrmicro1750.

Going viral and Viral Soldiers. B Kirby & JJ Barr and J Madhusoodanan, respectively. The Scientist Sept 2013 and Jan 2016.

for topic D:

Fabricating genetically engineered high-power lithium-ion batteries using multiple virus genes. Y Jung Lee et al. Science 22 May 2009: Vol. 324, Issue 5930, pp. 1051-1055 doi:10.1126/science.1171541.

Using nature to grow batteries -TED talk by MIT professor Angela Belcher published on April 27, 2011 on YouTube: https://www.youtube.com/watch?v=SFW0TEFKCxk
or: same theme, but more recent, shorter video:
https://www.youtube.com/watch?v=IygCmIYOchg

Grading:

Active participation: 25%
Weekly written assignments that address reading of texts or other research on topic: 25%
Group presentation: 30%
Contribution to collectively produced summaries of research on various topics: 20%

Active Participation:
Attendance is mandatory. Active participation in class discussions is essential. Evaluation of class participation will focus on content/insight, not verbiage. Electronics are not permitted in class except for when web-based search tools (e.g. PubMed, genome data bases, etc) will be introduced at the beginning of the course or if they need to be accessed for specific inquiries later in the course.

Blackboard: Course materials, if provided by the instructor, will be made available on Blackboard. Required papers/texts will be posted no later than Friday of the preceding week.

Weekly written assignments:
Written summaries (typically no more than a page) need to be handed in on the day of discussion. They should critically address the main points of the reading of texts (research papers, reviews, etc) or consultation of various other information sources (web-based or also informal polls, interviews with experts, etc, that the students may undertake). The summaries are thought to serve as the basis for the class discussions and also for specific group work.

Group presentations and research summaries:
Groups of 2 to 3 students will present their research on a topic of their choice (to be approved by the instructor) in an ~30-minute PowerPoint (or similar format) presentation to the class. Verbal, and if appropriate also written feedback provided by the class will be used by the group to then continue their research and also to produce summary sheets that can be included in a brochure.

Final Paper:
There will be no final paper – instead, students are expected to invest a significant amount of time into the production of the summary sheets and thus the final brochure/pamphlet.