science | YORK UNIVERSITÉ UNIVERSITY

Department of Biology Course Outline

SC/BIOL 3300 3.00 Origins and Development of Biological Theories
Fall 2020

Course Description

An analysis of the origins and development of biological theories, which may include those in evolutionary biology, ecology, biodiversity, and molecular phylogenetics.

Prerequisites

Note: Open only to students in the third or final year of a biology program, or with permission of the instructor. Only open to students who have completed a minimum of 12 credits at the 2000 level in Biology courses. Course Credit Exclusion: SC/BIOL 4300 3.00

Course Instructors and Contact Information

Professor Jan Sapp
Email biol3300@yorku.ca
Office: Farquharson 306.

Schedule

Class time: Thursdays 14:30-17:30

Location: delivered remotely on zoom for live stream lectures. Students will require a computer and internet service. Lectures will also be recorded.

- For outside class time questions, I will provide “office hours” after class. You may also contact me at biol3300@yorku.ca.

Evaluation

Midterm test: 25% October 22- based on lectures and required readings. Jan Sapp, *Co-existence: The Ecology and Evolution of Tropical Biodiversity* (OUP 2016). Chapters supplied on course e-class. **The mid term test may be conducted with the aid of an online proctoring service. All students must write the test on October 13.**

Research Proposal: 15%, due date October 1. Assessment will be based on formulation of the questions of your essay highlighting the significance of the research you will write about, and how you will investigate the origins and development of that research. ~250 words, plus a bibliography indicating the literature you intend to study. **To be submitted through turnitin on the e-class site for the course.**

Student presentations (20%). Students will give 10 minute PowerPoint presentations of their individual work. Each student will be assessed **only on their own presentation** and lead class discussion. Students will work in groups on an over arching topic and will be responsible for coordinating their individual projects such that they are partitioned so as to form a coherent series, with little overlap.

Class participation: *All students will offer written evaluations of all talks. Note up to 10% of final mark will be deducted for lack of class attendance and participation; 10% off for three classes missed.*

Essays: 40% due December 6, -8 pages, double-spaced, 12 pt font (2000 words), plus references with scholarly formatting (***NOTE:*** *At least 7 journal articles and/or scholarly books must be used and properly referenced in the essay.* **Final essays will be submitted through turnitin on the e-class site for the course. Your aim to write an historical narrative required, Tell a story, not a textbook or Wikipedia entry: What? Where? When? Who? Why? How?. Avoid passive tense such as "it was found" etc. Who reported something: When? Where? Why? Based on what data?**

Final course grades may be adjusted to conform to Program or Faculty grades distribution profiles.

Important Dates

Dates of Tests/Exams, Due Dates of Major Assignments, First class, last class, drop date, etc.

First day of Class; September 10
Final day of Class December 3
Research proposals due: October 1
Mid term test: October 22
Reading week: October 10-16

Final term paper due: December 6

NOTE: for additional important dates such as holidays, refer to the "Important Dates" section of the Registrar's Website at http://www.yorku.ca/yorkweb/cs.htm

Resources

Course E-class: Jan Sapp, *Co-existence: The Ecology and Evolution of Tropical Biodiversity* (OUP 2016) Required readings for the lecture part of the course and lectures will be provided on moodle. PowerPoint slides will also be made available to the class through the course Moodle site.
See also "Getting started" on the course Moodle site for references to suggested topics

Learning Outcomes

Upon successful completion of this course, you should have acquired some understanding of some of the major changes that have occurred in evolutionary biology and ecology resulting from molecular phylogenetics. You should have improved your ability to read scientific literature critically, to write a scholarly report, and to give an oral presentation.

Course Content

The aim of this course is to introduce you to some major contemporary trends in evolutionary biology and ecology. My lectures will be focussed on the evolutionary ecology of tropical biodiversity. Your essays will be focussed on various contemporary issues in ecology and evolution and the impact of molecular phylogenetics**.** You will learn how to analyze primary scientific literature and situate the development of new research programs, and to examine the complex relations between theory and techniques. You will work in groups, write essays, and give oral presentations. Suggested research topics include: human microbiomes, evolutionary medicine, human origins, epigenetics, hybridization in evolution, convergent evolution origins of life, the origins and evolution of viruses, ecology and evolution of emerging infectious diseases, mass extinctions.

Class Schedule

September 10: **Introduction, methods for writing a term paper for this course, topics and forming groups.**

September 17: **Three Domains, Symbiosis and Lateral gene Transfer.**
Required reading- on moodle:
Gilbert, Scott, Jan Sapp, and Alfred Tauber, "A Symbiotic View of Life, We have never been individuals," *Quarterly Review of Biology* 87(2012): 325-341.

September 24: **Why are there so many kinds of plants and animals?**
Required readings: on moodle
Jan Sapp, *Co-existence: The Ecology and Evolution of Tropical Biodiversity (Oxford University Press, 2016)*
Chapters 1, 3, 4, 5

October 1: **How can so many species live together?**
Required readings:
Jan Sapp, *Co-existence: The Ecology and Evolution of Tropical Biodiversity*
Chapters 9, 10, 11, 13,

October 8: **Adaptations, cryptic species, insects and microbes (***proposals also due***)**
Required readings:
Jan Sapp, *Co-existence: The Ecology and Evolution of Tropical Biodiversity*
Chapters 15, 16, 17, 18

October 10-16 reading week
October 22: Test on lectures and required readings
October 29: workshop
November 7: Student Presentations
November 14: Student Presentations
November 21: Student Presentations
November 28: Student Presentations
December 3: Student Presentations

Course Policies

MISSED test or missed due date on assignment:

If you miss a test with a legitimate documented reason, permission **may** be granted to take a **makeup test**. ***Makeup tests may be conducted orally over zoom***. Remember a computer internet connection is a requirement of this course. All students must write the make up. If your internet happens to fail the hour of the test, tethering a cell phone should work.

Assignment and midterm dates are non-negotiable. They have been structured to distribute your workload over the term. There are no alternative assignments that can be completed for you to increase your mark, and the value of any missed assignment cannot be transferred to another.
20% of the value will be deducted for any assignment not completed on the due date.

Recording Lectures:
Images and material presented are subject to Canadian copyright law.
Audio- visual recordings are used ONLY as a personal study aid, and are NOT sold,

passed on to others, or posted online. The lectures are the intellectual property of the professor and cannot be distributed without permission.

University Policies

Academic Honesty and Integrity
York students are required to maintain the highest standards of academic honesty and they are subject to the Senate Policy on Academic Honesty (http://secretariat-policies.info.yorku.ca/policies/academic-honesty-senate-policy-on/). The Policy affirms the responsibility of faculty members to foster acceptable standards of academic conduct and of the student to abide by such standards.
There is also an academic integrity website with comprehensive information about academic honesty and how to find resources at York to help improve students' research and writing skills, and cope with University life. Students are expected to review the materials on the Academic Integrity website at - http://www.yorku.ca/academicintegrity/

Access/Disability
York University is committed to principles of respect, inclusion and equality of all persons with disabilities across campus. The University provides services for students with disabilities (including physical, medical, learning and psychiatric disabilities) needing accommodation related to teaching and evaluation methods/materials. These services are made available to students in all Faculties and programs at York University. Student's in need of these services are asked to register with disability services as early as possible to ensure that appropriate academic accommodation can be provided with advance notice. You are encouraged to schedule a time early in the term to meet with each professor to discuss your accommodation needs. Please note that registering with disabilities services and discussing your needs with your professors is necessary to avoid any impediment to receiving the necessary academic accommodations to meet your needs.
Additional information is available at the following websites:
Counseling & Disability Services - http://cds.info.yorku.ca/

Ethics Review Process
York students are subject to the York University *Policy for the Ethics Review Process for Research Involving Human Participants.* In particular, students proposing to undertake research involving human participants (e.g., interviewing the director of a company or government agency, having students complete a questionnaire, etc.) are required to submit an *Application for Ethical Approval of Research Involving Human Participants* at least one month before you plan to begin the research. If you are in doubt as to whether this requirement applies to you, contact your Course Director immediately.

Religious Observance Accommodation
York University is committed to respecting the religious beliefs and practices of all members of the community, and making accommodations for observances of special significance to adherents. Should any of the dates specified in this syllabus for an in-class test or examination pose such a conflict for you, contact the Course Director within the first three weeks of class. Similarly, should an assignment to be completed in a lab, practicum placement, workshop, etc., scheduled later in the term pose such a conflict, contact the Course director immediately. Please note that to arrange an

alternative date or time for an examination scheduled in the formal examination periods (December and April/May), students must complete an Examination Accommodation Form, which can be obtained from Student Client Services, Student Services Centre or online at http://www.registrar.yorku.ca/pdf/exam_accommodation.pdf (PDF)

Student Conduct in Academic Situations

Students and instructors are expected to maintain a professional relationship characterized by courtesy and mutual respect. Moreover, it is the responsibility of the instructor to maintain an appropriate academic atmosphere in the classroom and other academic settings, and the responsibility of the student to cooperate in that endeavour. Further, the instructor is the best person to decide, in the first instance, whether such an atmosphere is present in the class. The policy and procedures governing disruptive and/or harassing behaviour by students in academic situations is available at - http://secretariat-policies.info.yorku.ca/policies/disruptive-andor-harassing-behaviour-in-academic-situations-senate-policy/

Suggested Essay Topics

How has molecular phylogenetics changed

evolutionary and ecological theory?

Your aim to write an historical narrative required, Tell a story not a textbook or Wikipedia entry: What? Where? When? Who? Why? How?. Avoid passive tense such as "it was found" etc. Who reported something: When? Where? Why? Based on what data?

1. Punctuated evolution

a Hybridization

The scope and significance of hybridization in plants and animal evolution remains unresolved. N. H. Barton, "The Role of Hybridization in Evolution," *Molecular Ecology* 10(2001): 551-568. M. L. Arnold, *Natural Hybridization and Evolution* (Oxford Univ. Press, Oxford, 1997).

Plants: See L. H. Rieseberg, T.E. Wood, and E. Baack. "The Nature of Plant Species," *Nature* 440 (2006):524-527. L.H. Rieseberg, and J.H. Willis, "Plant speciation," *Science* 317 (2007): 910-914.

Animals: Thomas E. Dowling and Carol L. Secor, "The Role of Hybridization and Introgression in the Diversification of Animals," *Annual Revue of Ecology and Systematics* 28 (1997): 593–619.

b Wolbachia and speciation

Anrdt Telschow, "Walbachia-Induced Unidirectional Cytoplasmic Incompatibility and Speciation: Mainland-Island Model," *PLOS One* (2007)

Antonis Rokas, Walbachia as Speciation Agent, *TREE*15 (2000):44-45

Werren, J.H., Hurst, G.D.D., Zhang, W., Breeuwer, J.A.J, Stouthamer, R., & Majerus, M.E.N. (1994). Rickettsial relative associated with male-killing in the ladybird beetle (Adalia bipunctata). Journal of Bacteriology. 176, 388-394.

Werren, J.H. (1997). Biology of Wolbachia. Annual Review of Entomology, 42, 587-609.

Werren, J.H. 1998. Wolbachia and speciation, in *Endless Forms: Species and Speciation* (D. Howard and S. Berlocher, eds), pp. 245-260. Oxford University Press.

Werren, J.H. (2011). Selfish genetic elements, genetic conflict, and evolutionary innovation. *Proceedings of the National Academy of Sciences USA*, 108, 10863-10870.

c Viruses as agents of evolutionary change in animals and plants

J. Sapp, “Transcending Darwinism: Thinking Laterally on the Tree of Life," *History and Philosophy of the Life Sciences* 31 (2009): 161-182
F Ryan (2007) Viruses as symbionts. Symbiosis 44:11–21

Ryan FP, 2004. Human endogenous retroviruses in health and disease: a symbiotic perspective. Journal of the Royal Society of Medicine 97: 560-565.
Ryan FP, 2006. Genomic creativity and natural selection: a modern synthesis. Biological Journal of the Linnean Society ; 88: 655-72.

Ryan F. *Virolution*. 2009.

Gifford, R. & Tristem, M. (2003). The Evolution, Distribution and Diversity of Endogenous Retroviruses. *Virus Genes* 26(3), 291-315.

Harris, JR. (1998). Placental endogenous retrovirus (ERV): structural, functional and evolutionary significance. *BioEssays* 20, 307-316.

Lower, R, Lower, J. & Kurth, R. (1996). The Viruses in all of us: Characteristics and Biological Significance of Human Endogenous Retrovirus Sequences. *Proc. Natl. Acad. Sci. USA* 93, 5177-5184

2. Microbiomics

a.) **Cancer:** Ryan Thomas, “The Microbiome and Cancer : Is the Oncobiome Mirage Real?” *Trends in Cancer* 1 (2015): 24-35

b) **Diabetes:** G. Musso et al., “Obesity, Diabetes, and Gut Mixcrobiota,” Diabetes Care 33 (2010): 2277-2284

c) **Asthma** Y.J. Huang, ‘The Microbiome in Astham,” J. Allergy Clin. Immunology 135 (2015): 25-30. Amun Riser, “The Human Microbiome, Asthma, and Allergy,” *Allergy Asthma and Clinical Immunology* 11 (2015):-35

d) **Autism** Jennifer Mule et al The Gut Microbiome: A New Frontier in Autism Research Current Psychiatry Reports 15 (2013): 337Melinda Moyer, "Gut Bacteria May Play a Role in Autism, " *Scientific American* Sept 1 , 2014

e **SchizophreniaT**.G. Dinan et al., Genomics of schizophrenia: time to consider the gut microbiome? *Molecular Psychiatry* (2014) 19

f **Behavioral parasitology:** *Toxoplasma gondii, infective protist* Alter behavior of rodents: Aliot Barford, 'Parasite Makes Mice Lose Fear of Cats Permanently," Nature 2013. Many other cases: find them.

G. Microbiome of plants

3. **Evolutionary medicine**

What is evolutionary medicine? How is it defined? What is its scope? What are its aims?

RM Nesse et al.,; Bergstrom, CT; Ellison, PT; Flier, JS; Gluckman, P; Govindaraju, DR; Niethammer, D; Omenn, GS *et al*. (2009). Evolution in Health and medicine," PNAS 107 suppl 1800-1807

H Weiner (1 July 1998). "Notes on an evolutionary medicine". *Psychosom Med* **60** (4): 510–20.

GC Williams, Nesse RM (March 1991). "The dawn of Darwinian medicine". *Q Rev Biol* **66** (1): 1–22.

G Williams., Nesse R. (1991). "The dawn of Darwinian medicine". *The Quarterly Review of Biology* **66**(1):1–22.

George Williams, Nesse, Randolph M. (1996). *Why we get sick: the new science of Darwinian medicine*. New York: Vintage Books. ISBN 0-679-74674-9.

Stearns SC, Ebert D (December 2001). "Evolution in health and disease: work in progress". *Q Rev Biol* **76** (4): 417–32.

Wickham ME, Brown NF, Boyle EC, Coombes BK, Finlay BB (May 2007). "Virulence is positively selected by transmission success between mammalian hosts". *Curr. Biol.* **17** (9): 783–8.

Finlay BB, McFadden G (February 2006). "Anti-immunology: evasion of the host immune system by bacterial and viral pathogens". *Cell* **124** (4): 767–82..

Stearns SC (2005). "Issues in evolutionary medicine". *Am. J. Hum. Biol.* **17** (2): 131–40.

Robertson, KD; Wolffe AP (October 2000). "DNA methylation in health and disease". *Nat Rev Genet* **1** (1): 11–19.

4 Epigenetics and Evolution

What is epigenetics? When was it coined? What are its mechanisms? What are its meanings for development and evolution?

Nessy Carey, *The Epigenetics Revolution, 2012*

Joel Walsh, Epigenetics: The Death of the Genetic Theory of Disease Transmission, 2014

Eva Jablonka and Marion Lamb, Evolution in Four Dimensions 2005

Li, E, Beard C and Jaenisch R (1993). "Role for DNA methylation in genomic imprinting". *Nature* 366 (6453): 362–365.

Mark Ptashne, 2007. On the use of the word 'epigenetic'. *Current Biology*, **17**(7):R233-R236

Morris KV (2008). "Epigenetic Regulation of Gene Expression". *RNA and the Regulation of Gene Expression: A Hidden Layer of Complexity*. Caister Academic Press

Jablonka, Eva; Gal Raz (June 2009)."Transgenerational Epigenetic Inheritance," *The Quarterly Review of Biology* 84 (2): 131–176

Fraga, M. F. (2005). "Epigenetic Differences arising in Monozygotic twins," *Proceedings of the National Academy of Sciences* 102: 10604

5. Convergent Evolution

G. McGhee, *Convergent Evolution: Limited Forms Most Beautiful*

a) Convergent evolution of eyes

b) Convergent evolution of wings

c) Convergent evolution of fish

5. Human Origins:

Mitochondrial Eve

What is "mitochondria eve"?

What methods?

What conclusions?

Who did the research?

Cann, R.L., Mark S., and Allan C.W. (1987) Mitochondrial DNA and Human Evolution.

Nature **325(6099)**: 31-36.

Pääbo, S. (1996) Mutational Hotspots in the Mitochondrial Microcosm. *American Journal of Human Genetics* **59(3)**: 493-96.

Stringer, C., and Bräuer, G. (1994) Methods, Misreading, and Bias. *American Anthropologist* **96(2)**: 416-24.

Howell, N., Kubacka, I., and Mackey, D.A. (1996) How Rapidly Does the Human Mitochondrial Genome Evolve?. *American Journal of Human Genetics* **59(3)**: 501-09.

6. **Evolving humans**

A) STEM CELL RESEARCH

*Lederberg Joshua (1966). "Experimental Genetics and Human Evolution". The American Naturalist. **100** (915): 519–531.*

Trounson A, DeWitt ND (2013). "Pluripotent stem cells from cloned human embryos: success at long last". *Cell Stem Cell*. **12** (6): 636–8.

Check, E. 2005, "Where now for stem-cell cloners?", *Nature,* vol. 438, no. 7071, pp. 1058-1059.

Childress, J.F. 2004, "Sources of stem cells: Ethical controversies and policy developments in the United States", *Fetal diagnosis and therapy,* vol. 19, no. 2, pp. 119-123.

Cobbe, N. 2007, "Cross-species chimeras: Exploring a possible christian perspective", *Zygon,* vol. 42, no. 3, pp. 599-628.

Cyranoski, D. 2006, "No end in sight for stem-cell odyssey", *Nature,* vol. 439, no. 7077, pp. 658-659.

Daar, A.S., Bhatt, A., Court, E. & Singer, P.A. 2004, "Stem cell research and transplantation: Science leading ethics", *Transplantation proceedings,* vol. 36, no. 8, pp. 2504-2506.

Horst, M. 2005, "Cloning sensations: mass mediated articulation of social responses to controversial biotechnology", *Public Understanding of Science,* vol. 14, no. 2, pp. 185-200.

Hurlbut, W.B. 2007, "Ethics and embryonic stem cell research - Altered nuclear transfer as a way forward", *Biodrugs,* vol. 21, no. 2, pp. 79-83.

Lepinay, V.A. 2006, "The promises of the stem cells. Scientists, families and public health in the debate, about stem cells in the USA", *Sociologie Du Travail,* vol. 48, no. 3, pp. 350-366.

b Antibiotic Resistance

Mary Barber, Coagulase-positive Staphylococci Resistant to Penicillin," *Journal of Pathology and Bacteriology* 59 (1947):373-384.

Mary Barber, Staphylococcal Infection Due to Penicillin-Resistant Strains," *British Medical Journal* 1947: 863-865; 863, 865.

M. Barber, "Hospital Infection Yesterday and Today," *Journal of Clinical Pathology* (London) 14 (1961): 2-10.

Angela Creager, "Adaptation or Selection? Old Issues and New Stakes

in the Postwar Debates over Bacterial Drug Resistance," *Studies in the History and Philosophy of Biology and Biomedicine.* 38 (2007) 159–190.
T. Watanabe, "Infective Heredity of Multiple Drug Resistance in Bacteria," *Bacteriological Reviews* 27 (1963): 87-115.

H. C. Neu, "The Crisis in Antibiotic Resistance," *Science* 257 (1992):1064-1073

L. Mayer, Use of Plasmid Profiles in Epidemiologic Surveillance of Disease Outbreaks and in Tracing the Transmission of Antibiotic Resistance, Clinical Microbiology Reviews 1 (1988): 228-243.

Goossens H, Ferech M, Vander Stichele R, Elseviers M (2005). "Outpatient antibiotic use in Europe and association with resistance: a cross-national database study". *Lancet*. **365** (9459): 579–87.

Bengtsson B, Wierup M (2006). "Antimicrobial resistance in Scandinavia after ban of antimicrobial growth promoters". *Animal Biotechnology*. **17** (2): 147–56.

c The evolutionary ecology of infectious diseases

Zika Virus.

Lyme disease

COVID 19

Ecological factors Migration, climate change, agriculture

Evolutionary change in pathogens and hosts?

KE Jones et al, "Global Trends in Emerging Infectious Diseases," *Nature* 451(2008): 990-993

S.J. Schrag and P., Wiener, "Emerging infectious disease: What are the Relative Roles of Ecology and Evolution?" *Trends in Ecology and Evolu*tion 10 (1995): 319-324

Stephen Morse**,** *Plagues and Politics Factors in the Emergence of Infectious Disea*ses, Springer: 2001.

7 Origins of Life on Earth

Where and how did it happen?

Origin of Life and Hydrothermal vents

Mojzis S.J. *et al* 1996. "Evidence for life on earth before 3,800 million years ago". *Nature* **384** (6604): 55–59.

Wächtershäuser, G. (1990). "Evolution of the First Metabolic Cycles" *Proceedings of the National Academy of Sciences*. **87** (1): 200–4.

Gold, T. (1992). "The Deep Hot Biosphere". *Proceedings of the National Academy of Sciences*. **89** (13): 6045–9.

Tunnicliffe, V. (1991). "The Biology of Hydrothermal Vents: Ecology and Evolution," *Oceanography and Marine Biology: An Annual Review* **29**: 319–408.

A Lazcano, Miller S.L. (1994). "How long did it take for life to begin and evolve to cyanobacteria?" *Journal of Molecular Evolution* **39**: 546–554

Andrew Knoll, 2004. *Life on a young planet: the first three billion years of evolution on Earth*. Princeton University Press, Princeton, N.J.

William Martin, et al., " Hydrothermal Vents and the Origin of Life," *Nature Reviews Microbiology* 6 (2008): 805-814.

Steel, Mike & Penny, David 2010. "Origins of life: common ancestry put to the test". *Nature* **465** (7295): 168–9

Chandra Wickramasinghe, (2011). "Bacterial morphologies supporting cometary panspermia: a reappraisal".*International Journal of Astrobiology*. **10** (1): 25–30.

M Wainwright, (2003). "A microbiologist looks at panspermia". *Astrophys Space Sci*. **285** (2): 563–70

Zita Martins,; Botta, Oliver; Fogel, Marilyn L.; Sephton, Mark A.; Glavin, Daniel P.; Watson, Jonathan S.; Dworkin, Jason P.; Schwartz, Alan W.; Ehrenfreund, Pascale (2008). "Extraterrestrial nucleobases in the Murchison meteorite".*Earth and Planetary Science Letters*. **270**: 130–136.

Hoyle, Fred and Wickramasinghe N.C. 1981. *Evolution from space*. New York: Simon & Schuster.

8. On the origin of Viruses:

Bandea, C.I., 1983. A new theory on the origin and the nature of viruses. J. Theor. Biol. 105, 591–602.
Bubanovic I., Stevo N., Zlatibor A. (2005) Origin and evolution of viruses: Escaped DNA/RNA sequences as evolutionary accelerators and natural biological weapons. *Medical Hypotheses,* 65(5), 868-872.
Dimmock, N. J., Easton, A. J., & Leppard, K. (2001). *Introduction to modern virology* (5th ed.). Malden, MA: Blackwell Pub.
Forterre, P. (2006). The origin of viruses and their possible roles in major evolutionary transitions. *Virus Research, 117*(1), 5-16.
Hendrix, R.W., Lawrence, J.G., Hatfull, G.F., Casjens, S., 2000. The origins and ongoing evolution of viruses. *Trends Microbiol*. 8, 504–508.
Hughes, S. S. (1977). *The virus: A history of the concept*. London; New York: Heinemann Educational books; Science History Publications.
Koonin, E. V., & Dolja, V. V. (2006). Evolution of complexity in the viral world: The dawn of a new vision. *Virus Research, 117*(1), 1-4.
Prangishvili, D., Stedman, K., Zillig, W. (2001). Viruses of the extremely thermophilic archaeon Sulfolobus. *Trends Microbiol*. 9, 39–43.
Raoult, (2008). Redefining viruses: Lessons from mimivirus. *Nature Reviews. Microbiology, 6*(4), 315
Shackelton, . (2008). The role of alternative genetic codes in viral evolution and emergence. *Journal of Theoretical Biology, 254*(1), 128.
Shors, T. (2008). *Understanding Viruses*. Sudbury, Mass: Jones and Bartlett Publishers.Topley, W. W. C., Wilson, G. S., Collier, L. H., Balows, A., & Sussman, M. (1998). *Topley & wilson's*

microbiology and microbial infections (9th ed.). London; New York: Arnold; Oxford University Press.

9. What caused the Cambrian explosion?

Maloof, A. C.; Porter, S. M.; Moore, J. L.; Dudas, F. O.; Bowring, S. A.; Higgins, J. A.; Fike, D. A.; Eddy, M. P. (2010).”The earliests Cambrian record of Animals and Ocean Geochemical Change,” *Geological Society of America Bulletin*. **122** (11–12): 1731–1774.

Valentine, JW; Jablonski, D; Erwin, DH (1999). “Fossils, moelcules and Embryos: New Perspectives on the Cambrian Explosion,” *Development*. **126** (5): 851–9.

Valentine, J.W. (April 1995). "Why No New Phyla after the Cambrian? Genome and Ecospace Hypotheses Revisited" *PALAIOS* **10** (2): 190–194.