BIOLOGY 579: MOLECULAR EVOLUTION AND CONSERVATION GENETICS (revised Nov 4, 2010)
BIOSCIENCES 767: MOLECULAR EVOLUTION

KARL J. FRYXELL FALL, 2010

The field of molecular evolution originated in the 1960s, in a series of papers in which Emile Zuckerkandl and Linus Pauling established the (then radical) assertion that biological evolution occurs through the slow and steady accumulation of changes in DNA and protein sequences in all species (as well as occasional gene duplications). Fundamental discoveries have followed in every subsequent decade – such as the neutral theory, the discovery that all genes belong to gene families, the development of evo/devo methods of understanding the evolution of regulatory genes, and increasingly sophisticated, whole-genome statistical tests of sequence evolution. The field of molecular evolution has become the conceptual foundation of genomics and drug discovery, and the basis of our methods of gene discovery and biotechnology.

These concepts and data now give us the ability to understand the process of evolution in considerable detail, and provides an incredibly detailed "fossil record" of the origins and functions of each of our genes. The interpretation of these data is accelerating, and will help to answer the question of who we are and where we came from. It is also having a major impact on biotechnology and the biomedical sciences, and is widely used in analyzing the functions of genetic pathways.

Molecular evolution has many applications in conservation genetics, such as molecular assays of the effective population size of a species, a molecular definition of species boundaries , and a more detailed understanding of why and when a minimal population size may be needed for the long-term survival of the species.

Grades. Students registered in this class will be required to write one term paper. Your paper should use one of the assigned articles as a starting point. These articles will be assigned on a "first come, first served" basis, one student per paper, so choose early if you wish to have a choice. You will then be our student "expert" on the paper you chose. You might be called on to render your opinion on that topic during relevant class discussions. In any case, you will be required to present a brief, verbal summary of your term paper to the entire class (10 min, no PowerPoint slides, handouts encouraged, but maximum of 3 pages of handouts per student) at a class meeting in December. Your presentation(s) will be graded, and will count for 10% of your grade. Your completed term paper(s) is also due on the last day of class and will count for 40% of your grade. The term paper must be typed, with at least ten pages of text (preferably longer, double-spaced, not counting the title page) and at least twenty references on a separate page. (15 pages and 30 ref for Ph.D. students.) Late papers will be receive a penalty of 10% per day.

Each week, following the lecture, we will have an open-ended discussion. I will provide about several discussion questions as a starting point. You are expected to participate actively in these discussions (it helps to have read the papers) and your participation will count for 10% of your course grade. We will also have a written final examination. The final exam questions will be similar (or identical) to the discussion questions. The final exam will consist of five 1-page essay questions (closed book). You will choose four of the five questions to answer. The final exam will count for 40% of your grade.

Readings. There is one required text for this course, "Fundamentals of Molecular Evolution" (2nd edition) by D. Graur and W.-H. Li (2000). The assigned reading also includes articles in scientific journals, which are available through the GMU library E-journals web link, and some of which are also available on paper in the Fenwick Library or Prince William library.

Dates, Times, and Contact Information. This course meets Thursdays at 4:30 - 7:10 pm, in Robinson Hall, room A101. My office hours this semester will be Fridays, from 11 am – noon in Discovery Hall 305. Phone: 703-993-1069 E-mail: kfryxell@gmu.edu Web site: http://mason.gmu.edu/~kfryxell

Sept 2. Introduction

Sept 9. Basic rates and patterns of DNA sequence change

text, pp. 9-29; 35-38; 100-131.

Petrov, D. A., and D. L. Hartl (1999) Patterns of nucleotide substitution in *Drosophila* and mammalian genomes. *Proc. Natl. Acad. Sci. USA* **96,** 1475-1479.

Ran, W., and P. G. Higgs (2010) The influence of anticodon-codon interactions and modified bases on codon usage bias in bacteria. *Mol Biol Evol* **27,** 2129-2140.

Sept 16. The neutral and nearly neutral theories of molecular evolution

text, pp. 47-59.

Gojobori, T., E. N. Moriyama and M. Kimura (1990) Molecular clock of viral evolution, and the neutral theory. *Proc. Natl. Acad. Sci. USA* **87,** 10015-10018.

Ohta, T. (1995) Synonymous and nonsynonymous substitutions in mammalian genes and the nearly neutral theory. *J. Mol. Evol.* **40,** 56-63.

McDonald, J. and M. Kreitman (1991) Adaptive protein evolution at the *Adh* locus in *Drosophila*. *Nature* **351**, 652-654.

Sept 23. Population bottlenecks, positive selection, and genetic diversity

text, pp. 57-65.

Orengo, D. J., and M. Aguade (2010) Uncovering the footprint of positive selection on the X chromosome of Drosophila melanogaster. *Mol Biol Evol* **27,** 153-160.

Glenn, T. C., W. Stephan, and M. J. Braun (1999) Effects of a population bottleneck on whooping crane mitochondrial DNA variation. *Conservation Biol.* **13,** 1097-1107.

Ohta, T. (1993) Amino acid substitution at the *Adh* locus of *Drosophila* is facilitated by small population size. *Proc. Natl. Acad. Sci. USA* **90,** 4548-4551.

O'Brien, S. J. (1994) Genetic and phylogenetic analysis of endangered species. *Annu. Rev. Genet.* **28**, 467-489.

Sept 30. The molecular clock hypothesis and phylogenetic trees

text, pp. 113-117; 139-155; 160-163.

O'hUigin, C. and W. H. Li (1992) The molecular clock ticks regularly in muroid rodents and hamsters. *J. Mol. Evol.* **35,** 377-384.

Fournier, G. P., and J. P. Gogarten (2010) Rooting the ribosomal tree of life. Mol Biol Evol **27:** 1792-1801.

Heled, J., and A. J. Drummond (2010) Bayesian inference of species trees from multilocus data. Mol Biol Evol **27:** 570-580.

Oct 7. Speciation and genetic coalescence in populations

text, pp. 155-160; 165-181; 217-228.

Palumbi, S. R., F. Cipriano and M. P. Hare (2001) Predicting nuclear gene coalescence from mitochondrial data: the three-times rule. *Evolution* **55**, 859-868.

Venditti, C., A. Meade and M. Pagel (2010) Phylogenies reveal new interpretation of speciation and the Red Queen. Nature **463:** 349-352.

Drosophila Consortium (2007) Evolution of genes and genomes on the Drosophila phylogeny. *Nature* **450**, 203-218.

Oct 14. Gene duplication and the evolution of gene families

text, pp. 249-322.

Fryxell, K. J. (1996) The coevolution of gene family trees. *Trends Genet.* **12,** 364-369.

Hiwatashi, T., Y. Okabe, T. Tsutsui, C. Hiramatsu, A. D. Melin *et al.*, 2010 An explicit signature of balancing selection for color-vision variation in new world monkeys. *Mol Biol Evol* **27,** 453-464.

Kang, K., S. R. Pulver, V. C. Panzano, E. C. Chang, L. C. Griffith *et al*. (2010) Analysis of Drosophila TRPA1 reveals an ancient origin for human chemical nociception. *Nature* **464,** 597-600.

Oct 21. *Hox* genes and the evolution of body plans

Hueber, S. D. (2008) Shaping segments: Hox gene function in the genomic age. *Bioessays* **30**, 965-979.

Lemons, D. et al. (2006) Genomic evolution of Hox gene clusters. *Science* **313**, 1918-1922.

Osborne, P. W., and D. E. Ferrier (2010) Chordate Hox and ParaHox gene clusters differ dramatically in their repetitive element content. *Mol Biol Evol* **27,** 217-220.

October 28. Specific tissues and the evolution of developmental patterns

Yuan, F., G. D. Bernard, J. Le and A. D. Briscoe (2010) Contrasting modes of evolution of the visual pigments in Heliconius butterflies. *Mol Biol Evol,* in press.

Koshiba-Takeuchi, K., A. D. Mori, B. L. Kaynak, J. Cebra-Thomas, T. Sukonnik *et al*. (2009) Reptilian heart development and the molecular basis of cardiac chamber evolution. *Nature* **461,** 95-98.

Shubin, N., C. Tabin and S. Carroll (2009) Deep homology and the origins of evolutionary novelty. *Nature* **457,** 818-823.

November 4. The adaptive evolution of proteins

Jermann, T. M., J. G. Opitz, J. Stackhouse, and S. A. Benner (1995) Reconstructing the evolutionary history of the artiodactyl ribonuclease superfamily. *Nature* **374,** 57-59.

Wlasiuk, G., and M. W. Nachman (2010) Adaptation and constraint at Toll-like receptors in primates. *Mol Biol Evol* **27,** 2172-2186.

Cherry, J. L. (2010) Highly expressed and slowly evolving proteins share compositional properties with thermophilic proteins. *Mol Biol Evol* **27,** 735-741.

November 11. no class. Work on your term paper!

November 18. Sex and sex chromosomes

text, 117-119; 402-412.

Bellott, D. W., H. Skaletsky, T. Pyntikova, E. R. Mardis, T. Graves *et al*. (2010) Convergent evolution of chicken Z and human X chromosomes by expansion and gene acquisition. *Nature* **466,** 612-616.

Smith, C. A., K. N. Roeszler, T. Ohnesorg, D. M. Cummins, P. G. Farlie *et al*. (2009) The avian Z-linked gene DMRT1 is required for male sex determination in the chicken. *Nature* **461,** 267-271.

Hughes, J. F., H. Skaletsky, T. Pyntikova, T. A. Graves, S. K. van Daalen *et al*. (2010) Chimpanzee and human Y chromosomes are remarkably divergent in structure and gene content. *Nature* **463,** 536-539.

November 25 – Thanksgiving Holiday!

December 2. Human evolution

Konopka, G., J. M. Bomar, K. Winden, G. Coppola, Z. O. Jonsson *et al*. (2009) Human-specific transcriptional regulation of CNS development genes by FOXP2. *Nature* **462,** 213-217.

Lalueza-Fox, C. et al. (2007) A melanocortin 1 receptor allele suggests varying pigmentation among Neanderthals. *Science* **318**, 1453-1455.

Green, R. E., J. Krause, A. W. Briggs, T. Maricic, U. Stenzel *et al*. (2010) A draft sequence of the Neandertal genome. *Science* **328,** 710-722.

December 9. Student verbal presentations of term papers

Written term papers are due today!

Dec 16 - FINAL EXAM (4:30 pm - 7:15 pm in ST II, room 018)