[MCB143] Evolution of genomes, cells, and development

Instructors: Nicole King and Mike Levine

This course is intended for upper-division undergraduates seeking an interactive course based on modern concepts in evolution and comparative genomics. The course will emphasize the contribution of molecular evolution to a series of seminal events in life's history:

- Origin of life
- Origin of cells
- Origin of eukaryotes
- Origin of multicellularity
- Evolution of animal development
- Human origins

PREREQUISITES: Bio 1A, Bio 1B and MCB C100A or MCB 102; MCB 104 or MCB 140 recommended

READINGS will be selected from the primary literature, review articles, and sections from trade books (e.g. *Evolution of Individuality* by Leo Buss, *Life on a Young Planet* by Andrew Knoll, *Selfish Gene* by Richard Dawkins, and *From DNA to Diversity* by Carroll *et al*.)

TEXT (recommended, not required): Evolution (CSHL Press; Barton, Briggs, Eisen, Goldstein, and Patel)

STRUCTURE OF COURSE:

Two lectures and in-class exercises plus one discussion session per week
Field trips
Papers/quizzes

GRADING:

- Participation in class discussion (30%)
- Two in-class midterms (20% total)
- Writing assignments:
  - 5-page final paper (30%)
  - Preparatory writing exercises, e.g. literature search, practice abstract, outline of paper (20%)

***NOTE: there is no final exam in this class*

COURSE OUTLINE (subject to change)

Week 1: Introduction to molecular evolution
Key concepts: The intellectual history of molecular evolution; patterns and themes in molecular evolution; refresher on the structure of genes and genomes

Week 2: Phylogenetics and biodiversity
Key concepts: speciation and the branching tree of life, techniques used to characterize phylogenetic relationships, linking specific sequence changes to phenotypic evolution

Week 3: The concept of major transitions
Key concepts: the evolutionary history of major transitions, units of selection, patterns in the fossil record, the connection between microevolution and macroevolution
Science in action: Visit to the UCMP

Week 4: Origin of Life – the biochemical perspective
Key concepts: Urey/Miller experiments, experimental evolution with synthetic RNAs, biogeochemistry of early Earth

Week 5: Origin of Life – the genomic perspective
Key concepts: "LUCA", the molecular foundations for cellular life, "rewinding the tape," synthesizing minimal life forms

Week 6: Evolution of genomes and genes
Key concepts: Units of selection in genomes (domains/exons, genes, chromosomes, genomes), horizontal gene transfer, gene and genome duplication and divergence, domain shuffling, case studies from specific genes and genomes

Week 7: Origin and evolution of archaea and bacteria
Key concepts: Molecular systematics provides key insights into the evolution of archaea and bacteria, rooting the tree of life, evolution of the bacterial flagellum, biogeochemistry and bacterial evolution

Week 8: Origin and evolution of eukaryotes
Key concepts: synapomorphies of eukaryotes, phylogenetic relationships among eukaryotic lineages, mitochondrial symbiosis, enigma of amitochondrial lineages, eukaryotic physiology relative to archaea and bacteria (i.e. overcoming the surface:volume ratio constraint)

Week 9: Evolution of sex and recombination
Key concepts: phylogenetic distribution of sex and recombination, evolution of mating types, classes of genes involved in sex and recombination, strategies for detecting sex in uncharacterized species, evolutionary implications of sex

Week 10: Evolution of multicellularity – the cell biological perspective
Key concepts: evolutionary distribution of multicellularity, implications of multiple origins of multicellularity, cell biology of multicellularity in bacteria, *Dictyostelium,* plants, fungi, and animals

Week 11: Evolution of multicellularity – the genomic perspective
Key concepts: the transition to multicellularity and the origin of animals, molecular perspectives on the Cambrian radiation, calibrating molecular clocks

Weeks 12: Evolution of development I
Key concepts: conservation and innovation of developmental patterning mechanisms across animal phyla, intellectual history of evo-devo
Case study: evolution of HOX complex

Week 13: Evolution of development II
Key concepts: predicting the locus of evolution in developmental patterning (the cis vs. trans controversy), gene regulatory networks, linking DNA sequence evolution to morphological evolution
Case studies: skeletogenesis in sticklebacks, Pax6 in eye development and evolution, BMP4 and Darwin's finches, lens crystallins, antifreeze proteins, Ubx in arthropods

Week 14: Evolution of humans; future prospects in the study of molecular evolution
Key concepts: phylogenetic relationships among humans and other primates (extant and extinct), implications of missing lineages for reconstructing human origins, the elusive nature of human synapomorphies, insights from mtDNA (Allan Wilson), current frontiers in the study of evolution