ASMCUE 2010
Learn Something New: Molecular Phylogenetics
Jim Smith, Michigan State University

Outline for today’s session
- Molecular Phylogenies: New Glasses!
- What Should Our Students Know About Phylogenies?
- Interpreting and Building Molecular Phylogenies

Molecular Phylogenies: New Glasses!
- Inferences of Organismal Relationships
- Detecting Horizontal Gene Transfer
- Phylogeography
- Implications of Coalescence

New Glasses: Three Domains of Life
Based on 16S rRNA (and other) genes

Molecular Phylogenies have provided tremendous insights into Evolutionary Relationships, e.g., who is related to whom, and how closely!
(Homage to Carl Woese!)

New Glasses: Fungi are more closely related to animals than they are to plants!

Molecular Phylogenies have provided tremendous insights into Evolutionary Relationships, e.g., who is related to whom, and how closely!

Animal Morphology/Development Phylogeny
from Freeman 2e (2005)

Animal DNA Phylogeny
from Freeman 3e (2008)
Molecular Phylogenies: New Glasses!

- Inferences of Organismal Relationships
- Detecting Horizontal Gene Transfer
- Phylogeography
- Implications of Coalescence

\[ \text{Does repA move by horizontal transfer?} \]

Ma et al. 2007. *AEM* 73:1287-1295

Yes! Phylogenies from plasmid repA sequences and chromosomal gyrB/rpoD sequences are not congruent.

Ma et al. 2007. *AEM* 73:1287-1295

Phylogeography of H5N1 influenza

Combining phylogenetic trees with GIS data via Google Earth to study the spread of H5N1 influenza

Coalescence Theory - Key Concept: Lineage Sorting

Who was “mitochondrial Eve”?

The mtDNA sequence that each of us carries coalesces to a single sequence that existed in Africa approx. 140,000 years ago.

Check out:
National Geographic’s “The Genographic Project”
https://genographic.nationalgeographic.com

Coalescence Theory - Humans Still Share Alleles with Chimpanzees!!

What should our students know about (molecular) phylogenetics?

- Students should know what a phylogeny is!

MINUTE PAPER - WHAT IS A "PHYLOGENY"?

- A phylogeny is a hypothesis of relationship!

Talk to your neighbor!
What should our students know about (molecular) phylogenetics?

- Students will be able to explain that a phylogeny is a hypothesis of relationship!
  - There are alternative hypotheses that can (and should) be discussed and evaluated!

- At right: Fifteen possible phylogenetic trees for rat, rabbit, dog, and cat, rooted with opossum as the outgroup.

What should our students know about (molecular) phylogenetics?

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- At right: Fifteen possible phylogenetic trees for rat, rabbit, dog, and cat, rooted with opossum as the outgroup.

What should our students know about (molecular) phylogenetics?

- Students will be able to explain that a phylogeny is a hypothesis of relationship!
  - There are alternative hypotheses that can (and should) be discussed and evaluated!

- Students will be able to explain that phylogenetic analysis, and hence the study of evolution, is a scientific endeavor.

What should our students know about (molecular) phylogenetics?

- What's the BIG IDEA??!!

- Which of the two organismal groups, represented by the individuals at right, are most closely related (and why)?

- RECENCY OF COMMON ANCESTRY IS THE BIG IDEA!!

- Cows and lungfish are the closest relatives (in our tree of interest) because they share the most recent common ancestor!
Which two are the closest relatives?

Molecular Phylogenies

- You're only as good as your sequence data!
- (Double-check the data!!)

Molecular Phylogenetics Can Be Confusing!

- Bootstraps and Decay Indices
- Phylograms and Cladograms
- Rooted and Unrooted Trees
- Strict and Majority Rule Consensus
- Posterior probabilities
- Jukes-Cantor and K2P Distances
- Heuristic Searches and Branch Swapping
- Likelihood Ratio Tests
- Synapomorphies and Sympleomorphies
- Acctran and Deltran Optimization
- Hot and Cold Markov Chains
- Burn-ins (and Burn-outs?)

Don’t lose the forest for the trees!!
Interpreting and Building Molecular Phylogenies

- Four Major Methods
  - Distance Methods - Neighbor-joining
  - Character State Methods - Maximum Parsimony
  - Model-based Methods - Maximum Likelihood
  - Bayesian Inference
- Which to Use?

What would Ron Debry do?
Editor-in-Chief, Systematic Biology

Which Method if Preferred?
- Search ISI Web of Science for “Phylogeny” in 2009
  - Applied and Environmental Microbiology (11), and Journal of Bacteriology (7)
    - Moynihan et al. Neighbor-joining (NJ)
    - Foster et al. NJ, Parsimony
    - Wattam et al. Maximum Likelihood
    - Sakwinska et al. NJ, Maximum Likelihood, Bayesian
    - Lafi et al. NJ, Parsimony, Likelihood
    - Miyatake et al. NJ
    - Vallance et al. Parsimony
    - Kim et al. NJ, Parsimony
    - Krauss et al. Maximum Likelihood, Bayesian
    - Mullins et al. NJ

Which Method if Preferred?
- Search ISI Web of Science for “Phylogeny” from 2005 - 2009
  - and “Neighbor-joining” – 238 articles
  - and “Distance” – 764 articles
  - and “Parsimony” – 1,684 articles
  - and “Maximum Likelihood” – 1,510 articles
  - and “Bayesian” – 1,636 articles

Many students will start with Neighbor-joining
- MEGA4 is free!
- It’s fast and easy!
- It gives a nice looking tree!
- Most of the time, the tree isn’t that different from trees obtained using other methods of phylogenetic inference!
The Neighbor-joining Tree – Theoretically Problematic?

- Where is the alternative hypothesis, and how is it generated?
- Basis for comparisons?
- A “Just-So” Story?

Teaching Phylogenetics on the basis of pairwise similarity matrices may pull students away from a rich, empirical hypothesis testing framework!

Students may lose sight of phylogenies as hypotheses (with alternatives to compare).
Students may lose sight of common ancestry as the major evolutionary concept!

Are organisms related because they are similar, or are they similar because they are related?

The Phenetics/Cladistics Debate

Are organisms related because they are similar, or are they similar because they are related?


“Someday someone will write the history of this infighting; perhaps only those who were there will believe it.”
Joe Felsenstein

Thanks for your time!

- Slides from today’s session:
  http://www.msu.edu/user/jimsmith/asmcue_2010.pdf
- Reference Material on Course Web Site:
  https://www.msu.edu/course/zol/855/f09/
- Email me:
  jimsmith@msu.edu