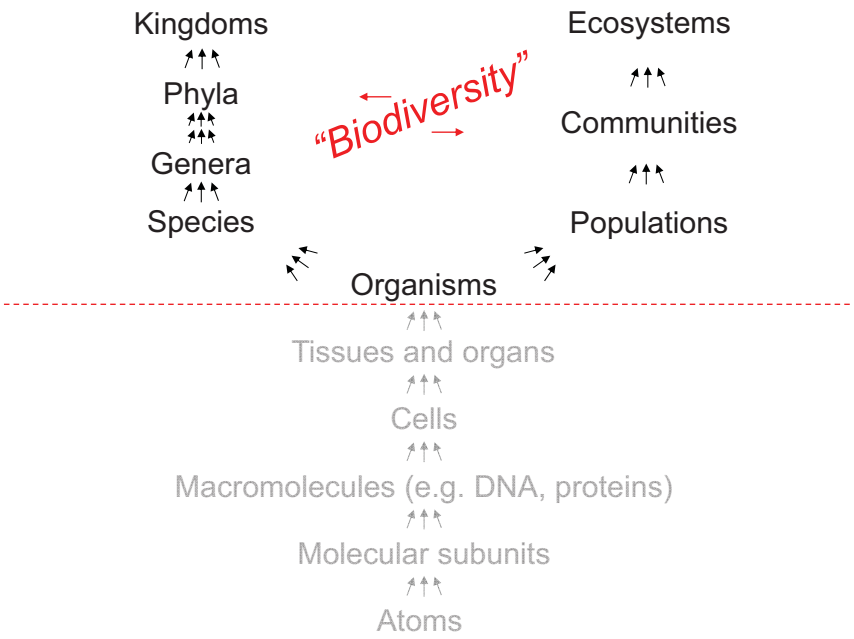
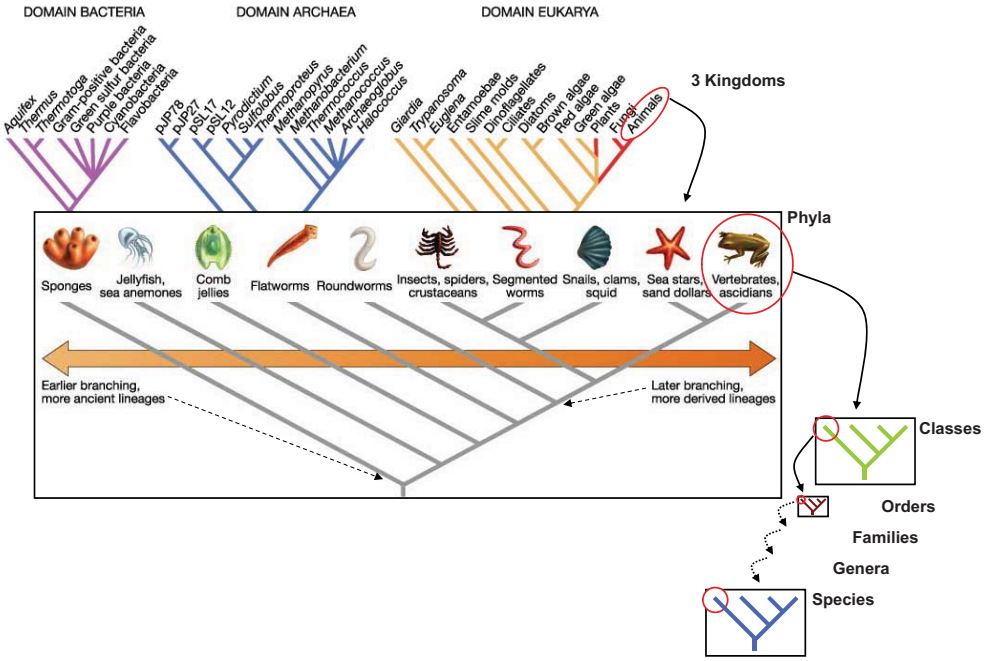
Biology is hierarchical



Biology is hierarchical



Part III. Conserving biodiversity

I. How populations work

II. How communities & ecosystems work

III. The origins of biodiversity

- Species: what are they, how are they distinguished, and how do they arise?
- Phylogenetic trees: how are they read, how are they produced, and how are they used?
- Units 8-10: Surveys of biodiversity and evolutionary innovations

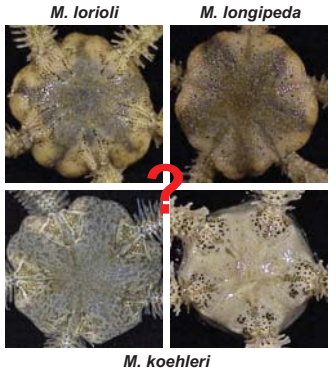
A. What are species?

Taxonomic units that are **"evolutionarily independent"**

→ gene flow becomes low enough that lineages can diverge

B. How can species be identified?

- ***morphological distinctiveness*** – useful for quick surveys of diversity



"morphological species concept"

✓ practical?

✗ understanding of divergence?

✗ reliable?

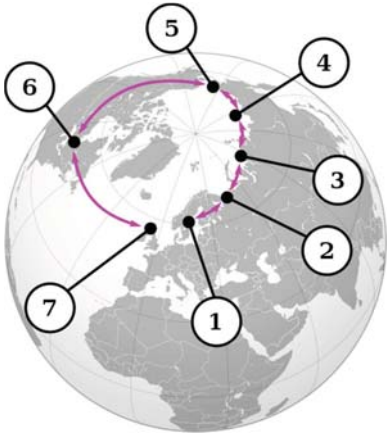
A. What are species?

Taxonomic units that are **"evolutionarily independent"**
→ gene flow becomes low enough that lineages can diverge

B. How can species be identified?

- ***morphological distinctiveness*** – useful for quick surveys of diversity
- ***reproductive isolation*** – no or inviable hybridization, confirms lack of gene flow

***Larus* gulls form a "ring species"**



"**biological species concept**"
✗ practical?
✓ understanding of divergence?

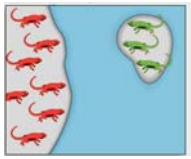
C. How do species arise?

3 steps: genetic **separation** → genetic **divergence** → reproductive **isolation**

1. Genetic **separation** of populations…
→ **allopatric speciation** – involves separation by geography

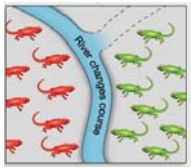
2. Genetic **divergence**…
…can occur through:

founder effect



colonization of a new habitat

limited gene flow
genetic drift
change in selection
sexual selection



vicariance – division of range
rising of a land bridge (Panama)
rising water level (Greenland, Madagascar)
continental separation (ratites on 3 continents)
etc.

3. Reproductive **isolation** (after recontact)…

…can occur through:
- ***prezygotic* reproductive isolation** > *no cross-fertilization*
- ***postzygotic* reproductive isolation** > *hybrids are less fit*
  > *"reinforcement"*

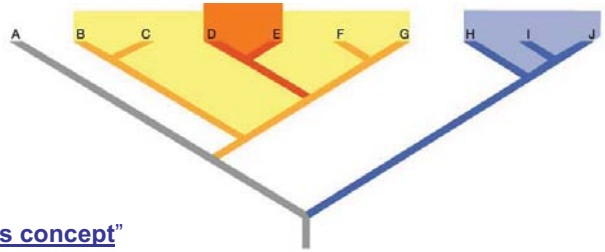
A. What are species?

Taxonomic units that are **"evolutionarily independent"**
→ gene flow becomes low enough that lineages can diverge

B. How can species be identified?

- ***morphological distinctiveness*** – useful for quick surveys of diversity
- ***reproductive isolation*** – no or inviable hybridization, confirms lack of gene flow

- ***monophyly*** – history holds information about evolutionary relationships



"**phylogenetic species concept**"
✓ practical?
✓ understanding of divergence *pattern?*

C. How do species arise?

3 steps: genetic **separation** → genetic **divergence** → reproductive **isolation**

1. Genetic **separation** of populations…
→ **allopatric speciation** – involves separation by *geography*

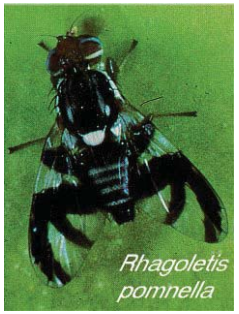
→ **sympatric speciation** – involves separation by *ecological habits*
- e.g., differences in preferences (habitat, food, mates)

Ex. **Apple maggot fly *(Rhagoletis pomnella)***

➢ **alternate feeding preferences promote assortative mating**

some do it on apples…

some on hawthorns…



C. How do species arise?

3 steps: genetic **separation** → genetic **divergence** → reproductive **isolation**

1. Genetic **separation** of populations…

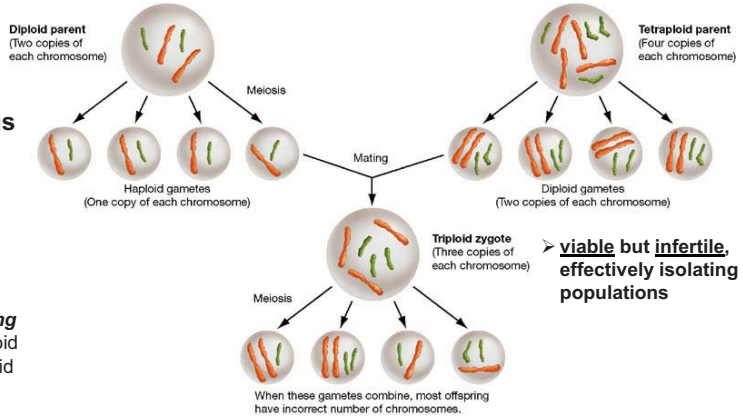
→ **allopatric speciation** – involves separation by *geography*

→ **sympatric speciation** – involves separation by *ecological habits*
- e.g., differences in preferences (habitat, food, mates)

→ **stasipatric speciation** – involves isolation by *chromosomal incompatibility*
- e.g., polyploidy, large chromosomal rearrangements

Ex. grey tree frogs

chromosomal doubling
Hyla chrysocelis = diploid
H. versicolor = tetraploid



➢ **viable but infertile, effectively isolating populations**

Part III. Conserving biodiversity

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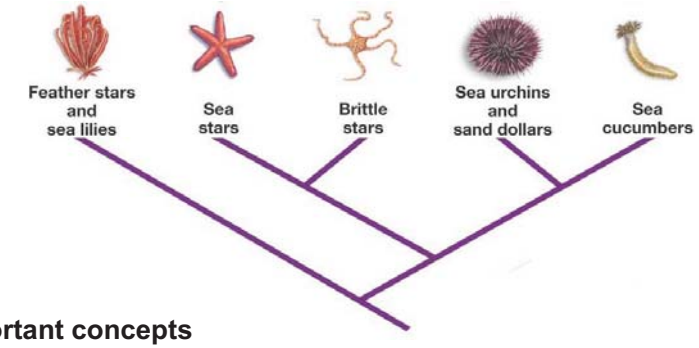
D. How to read a phylogenetic tree

phylogeny = *hypothesis of evolutionary relationships*
(pictured as a tree of branching events)

Ex. Phylogeny of taxonomic classes in the phylum Echinodermata



Important concepts
- What is a **common ancestor**?
- What is a **most recent common ancestor**?
- What is a **clade**?
- What is a **sister taxon**?
- What is meant by **more closely related**?

- Extant taxa are **relatives,** not **ancestors.**
- **Ancestors** were replaced by **descendents**.

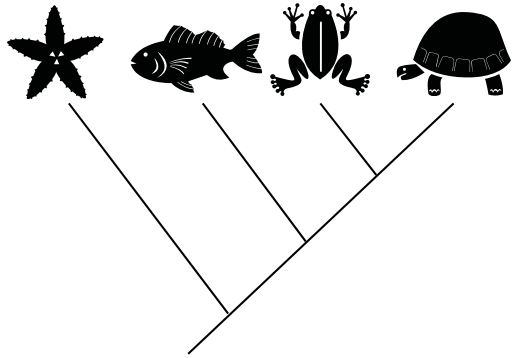
D. How to read a phylogenetic tree

➢ ***A phylogenetic tree is a nested hierarchy of sister groups***

SINGLE CHOICE. According to this phylogeny…

1. the sister group to frogs is
a) bony fish
b) turtles
c) echinoderms
d) echinoderms + bony fish

2. the sister group to fish is:
a) echinoderms
b) amphibians
c) amphibians + turtles
d) echinoderms + amphibians + turtles

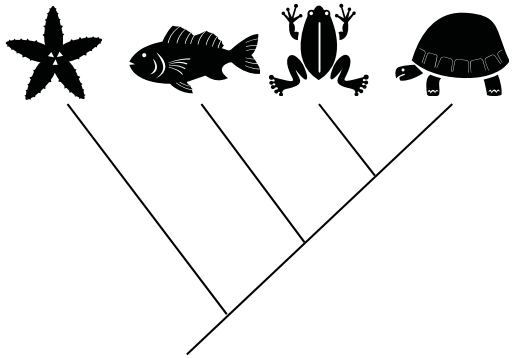


D. How to read a phylogenetic tree

➢ ***Reading a phylogenetic tree is like reading a map of history***

MULTIPLE CHOICE. According to this phylogeny, which of the following is true?

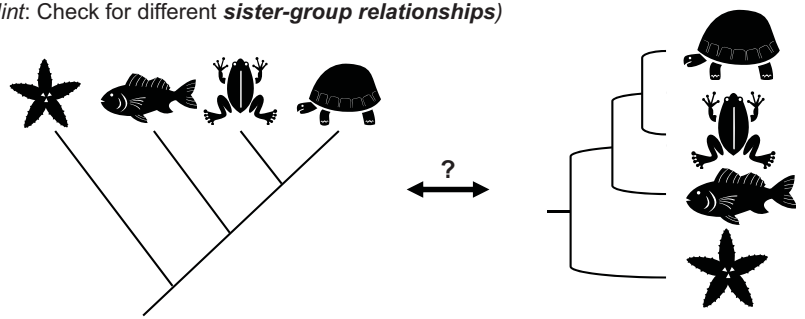
a) The frog is more closely related to the **Turtle** than to the **Seastar**
b) The fish is more closely related to the **Turtle** than to the **Seastar**
c) The fish is equally related to the **Frog** and the **Seastar**
d) The seastar is equally related to the **Fish** and the **Turtle**
e) The turtle is more closely related to the **Fish** than to the **Seastar**

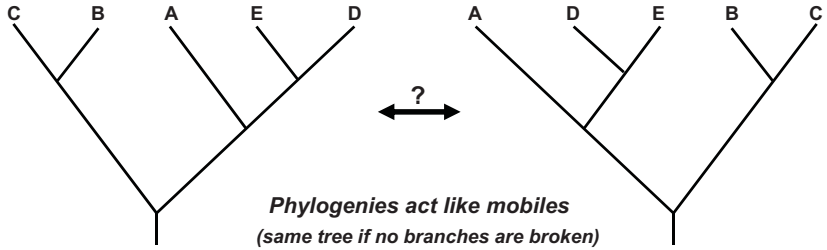


D. How to read a phylogenetic tree

Are these trees different?

(Hint: Check for different ***sister-group relationships****)*



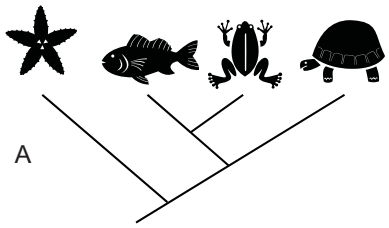


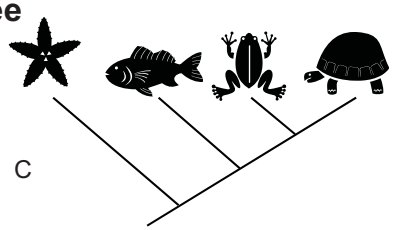
Phylogenies act like mobiles
(same tree if no branches are broken)

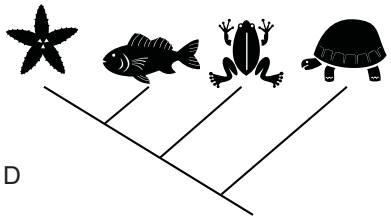
D. How to read a phylogenetic tree

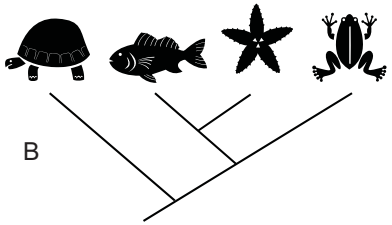
How many different phylogenetic hypotheses are shown?

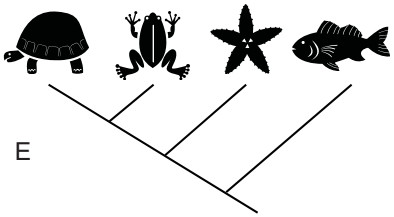
Hint: Look for different *sister-group relationships*









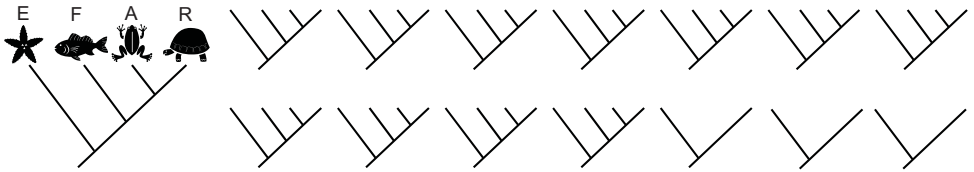


How many are possible?

E. How to *infer* a phylogenetic tree

Phylogenetic inference: which phylogenetic hypothesis is best supported?

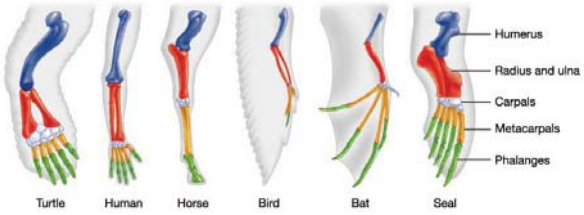
Ex. Possible hypotheses for 4 taxa (15 total)



We expect that closely related taxa will share *homologies*
(= traits in common because they come from a common ancestor)

Ex. the tetrapod forelimb

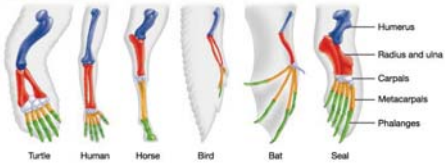
- **Different functions**
  (paddling, grasping, walking, flying)
- **Different morphologies**
  (horse vs. seal vs. bat vs. bird?)
- **But common bones reveal homology**



E. How to *infer* a phylogenetic tree

Phylogenetic inference: which phylogenetic hypothesis is best supported?

Ex. the tetrapod forelimb



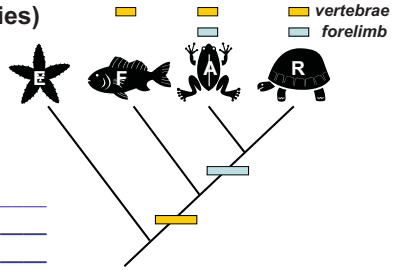
For phylogenetic inference, we must distinguish two levels of homology:

derived – a trait found **only** in the clade of interest (indicates membership in the clade)

ancestral – a trait that existed **before** the clade of interest arose

Only "shared *derived* traits" (= synapomorphies) show close evolutionary relationships

Q: Why?



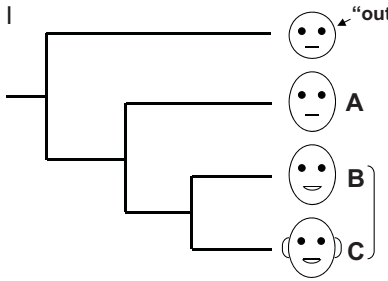
Qs: For which clade are…

…vertebrae a shared, derived trait? _____

…vertebrae a shared, ancestral trait? _____

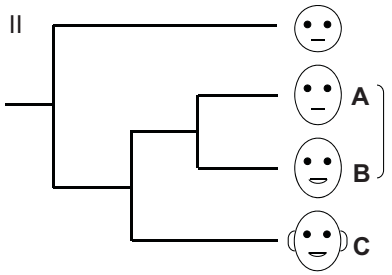
…forelimb a shared, ancestral trait? _____

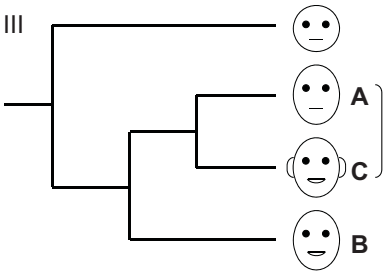
E. How to *infer* a phylogenetic tree



Ex. 3 species (A,B,C) + outgroup
3 traits (long head, smiling mouth, ears)

1. **How many hypotheses are possible?**
   Hint: how many ways can you draw sister-group relationships?
2. **Which species are closest relatives?**
   Hint: what is the simplest way to account for distribution of traits?
3. **Which traits were "informative"?**





E. How to infer a phylogenetic tree

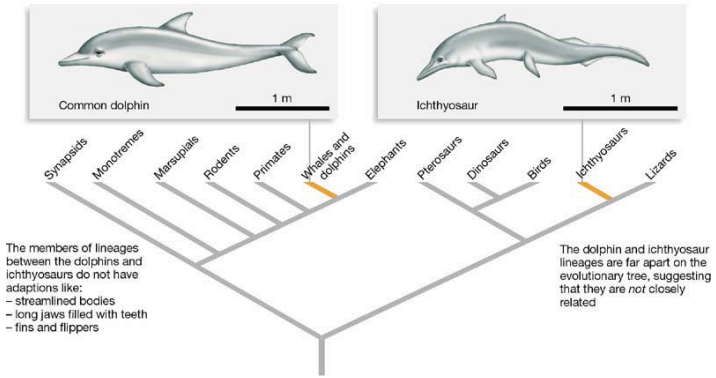
Complication: traits may be shared for different reasons

- common ancestry (**homology**)
- derived independently (**homoplasy**)

Examples of homoplasy

Ex. wings in bats & birds

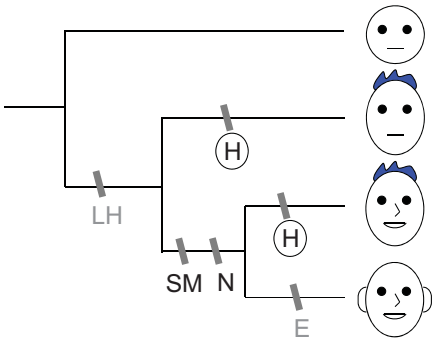
Ex. swimming and feeding morphologies of dolphins and ichthyosaurs



E. How to infer a phylogenetic tree

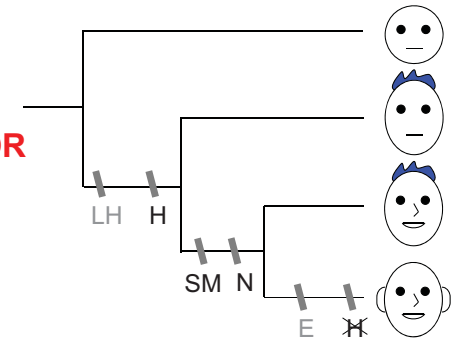
one pattern could be caused by different evolutionary histories

1. **homoplasy**: independent evolution of hair
   (H) – homoplaisic event



OR

2. **homology**: plus one reversal to hairless
   ⋈ – loss



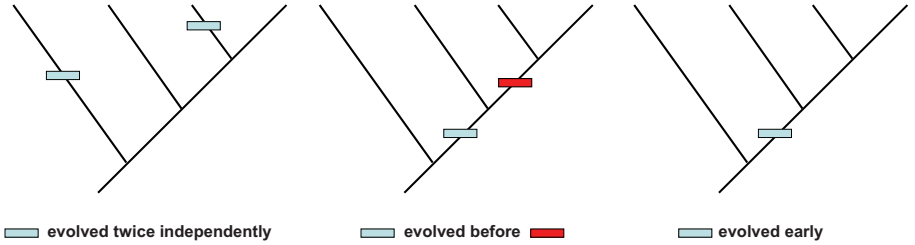
In either case, 2 evolutionary events needed to explain distribution of hair

F. How phylogenetic trees are used

1) To study **trait evolution**

Find the best supported phylogenetic hypothesis	→	"Map" traits to infer evolutionary changes

frequency? ***order?*** ***timing?***

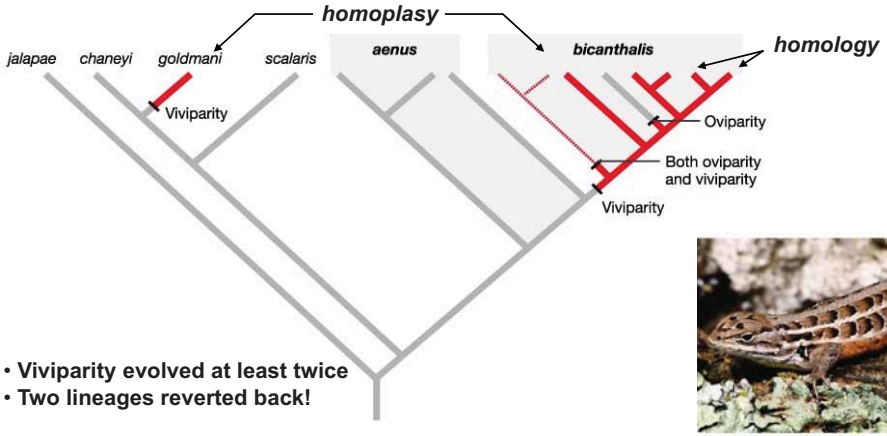


F. How phylogenetic trees are used

1) To study **trait evolution**

Find the best supported phylogenetic hypothesis	→	"Map" traits to infer evolutionary changes

Ex: Molecular phylogeny for *Sceloporus* lizards → **Evolution of viviparity**: (1) how many times? (2) how often? (3) when relative to other traits?

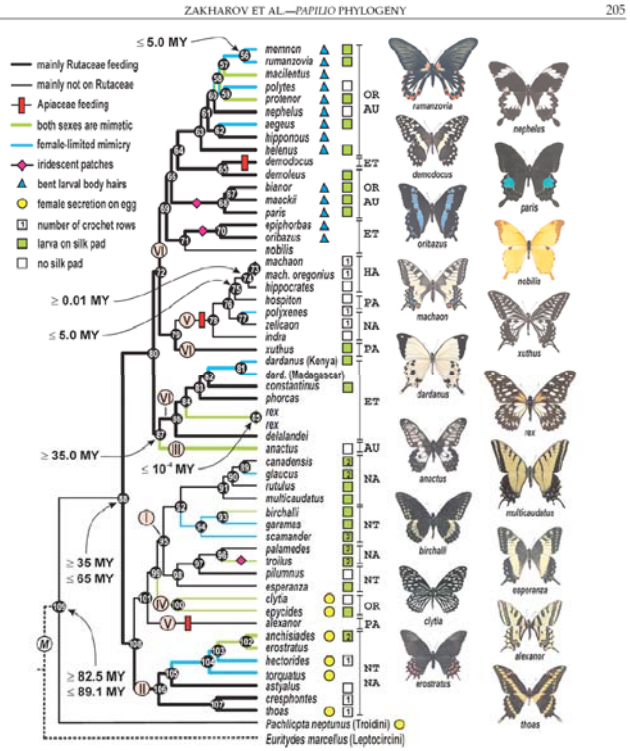


- **Viviparity evolved at least twice**
- **Two lineages reverted back!**

F. How phylogenetic trees are used

1) To study **trait evolution**

Ex. Mapping ecological traits onto a molecular phylogeny for Papilio butterflies

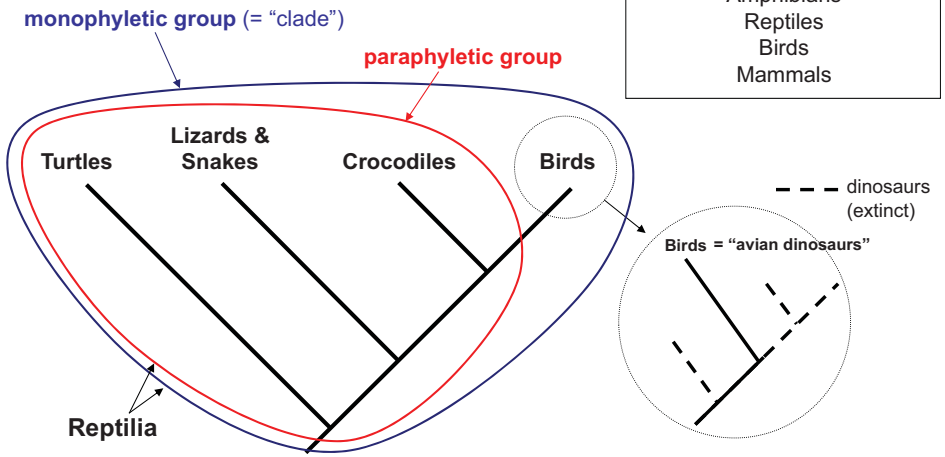


Zakharov et al. 2004
Syst. Biol. 53(2) 193 - 215

F. How phylogenetic trees are used

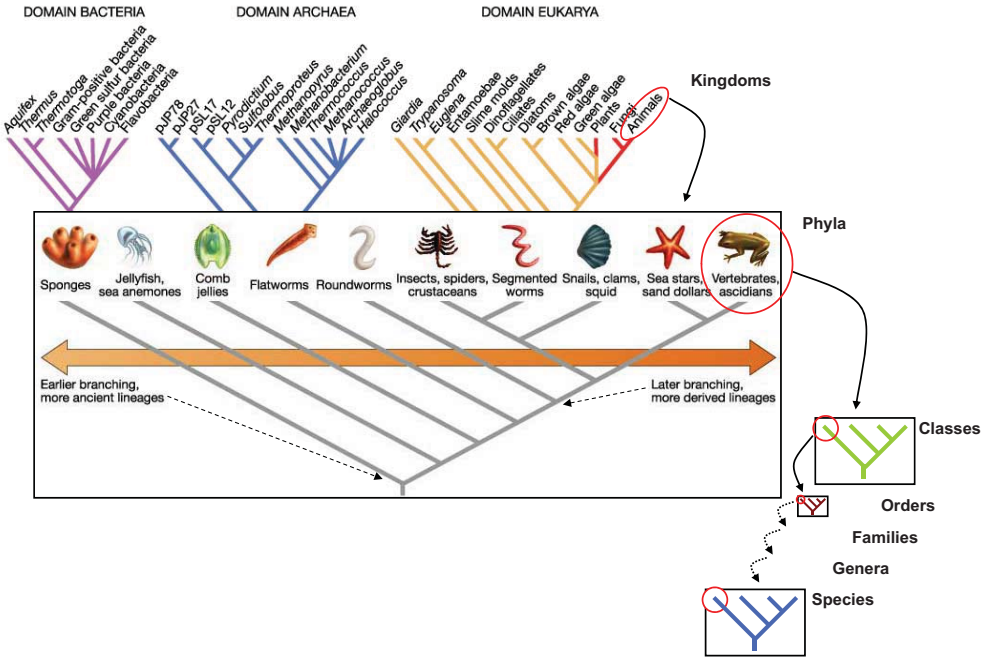
2) To refine classification (**taxonomy**)

5 classes of vertebrates?
Fish
Amphibians
Reptiles
Birds
Mammals



Q: Why is a paraphyletic grouping a problem?
Q: Should "birds" be considered reptiles?
Q: Are "birds" paraphyletic or monophyletic?
Q: Are birds distinguishable from dinosaurs?

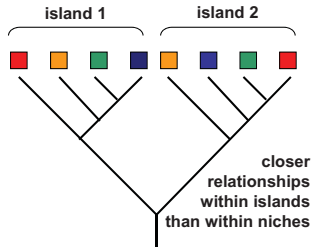
F. How phylogenetic trees are used: constructing the tree of life

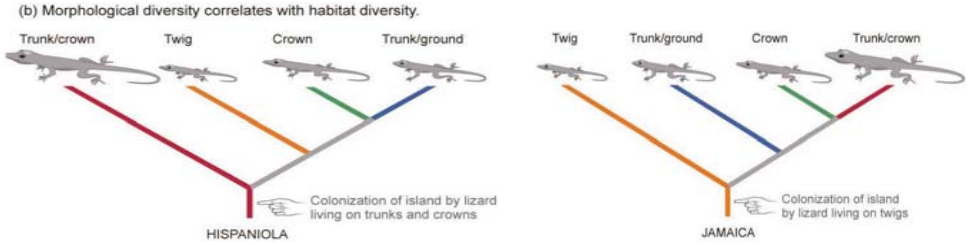


F. How phylogenetic trees are used

3) To reconstruct the history of ***adaptive radiations***

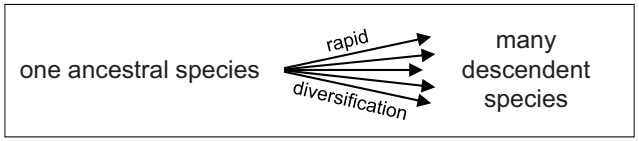
Ex. Anolis *lizards in the lesser Antilles*





F. How phylogenetic trees are used

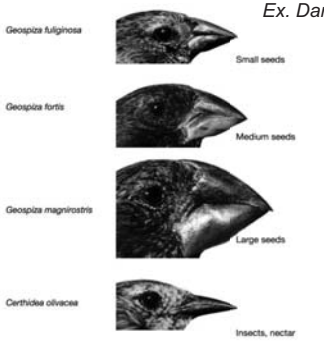
3) To reconstruct the history of adaptive radiations



What triggers adaptive radiations?

1. ecological opportunities (**open niches**)

Ex. Darwin's finches

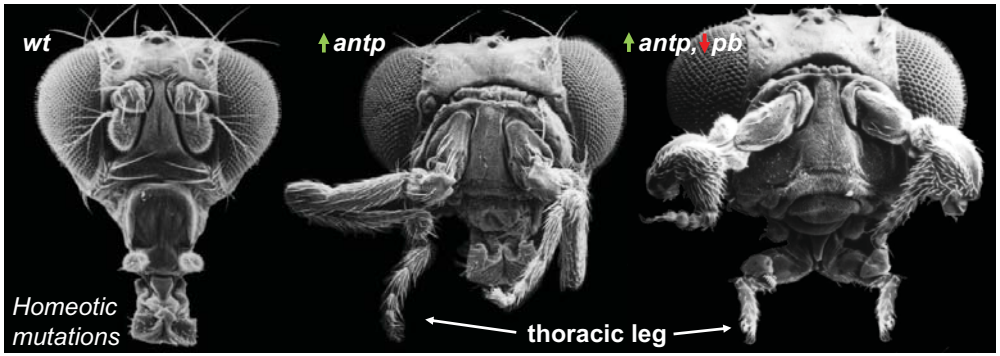


2. morphological opportunities (**innovative structures**)

Ex. arthropod limbs

G. How does innovation arise?

Microevolutionary processes (**selection, mutation, drift, migration**) **?** → **Life's diversity**



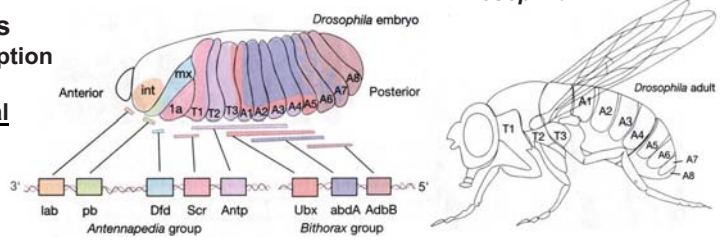
DNA —*transcription*→ RNA —*translation*→ Protein —*roles*→ ***Structural***, ***Enzymatic***, ***Regulatory*** —*binding*→ DNA

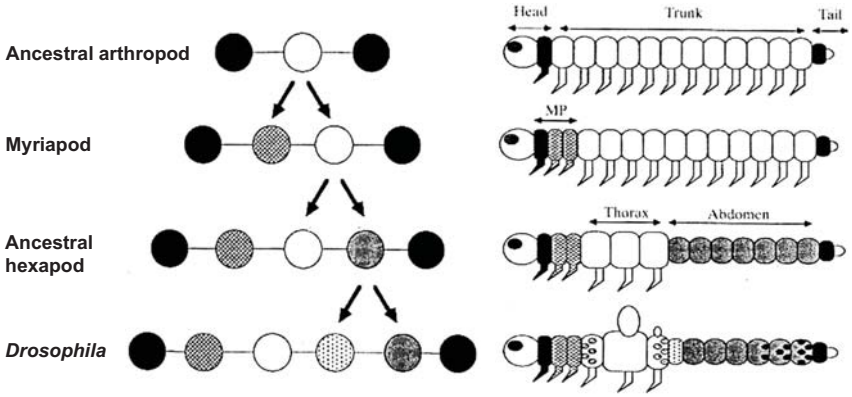
G. How does innovation arise?

Regulatory genes

- code for transcription factors
- specify <u>positional</u> information

HOM* gene expression in *Drosophila





G. How does innovation arise?

Regulatory genes

- code for transcription factors
- specify <u>positional</u> information
- small changes have large effects on the phenotype