




Evolution - Biosystematics

There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.
[conclusion of *Origin of Species*]

- 
1. Tremendous diversity of life!
 2. Structural complexity of these organisms
 3. Apparent purposive or adaptive nature of their features



Questions Evoked?

1. How has organic diversity originated, how is it maintained?
2. How have complex organisms come into being?
3. What forces have molded their adaptive features?
4. When and where did the various organisms appear?
5. Why have organisms (including humans) appeared?

Thomas Burnet (1681)

- Typical pre-18th century view of Earth and its changes



Thomas Burnet (1681)

- Typical pre-18th century view of Earth and its changes

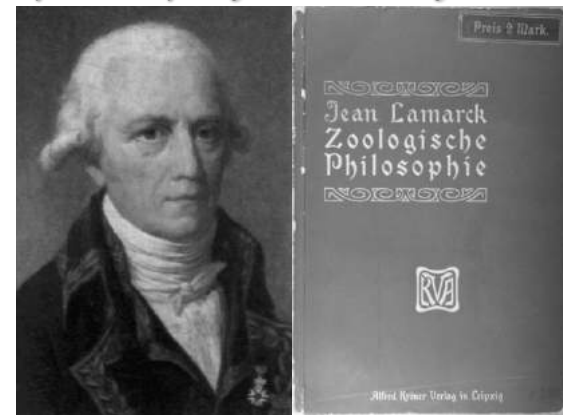


“no truth concerning the Natural World can be an enemy of religion; for Truth cannot be an enemy to Truth, God is not divided against himself”

“We think him a better Artist that makes a Clock that strikes regularly at every hour from the Springs and Wheels which he puts into the work, than he that hath so made his Clock that he must put his finger to it every hour to make it strike”

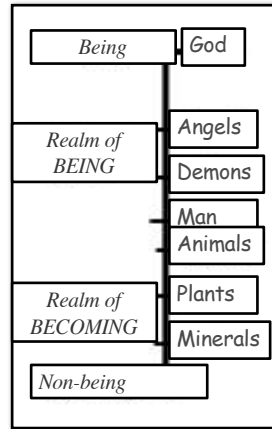
Jean Baptiste Lamarck (1744-1829)

- Early evolutionary thought - “ladder thinking”



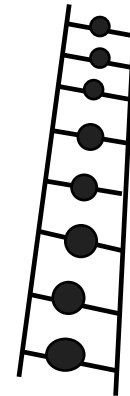
Lamarck's "Ladder"

- Continuum between physical and biological world (after Aristotle)
- *Scalae Naturae* ("Ladder of Life" or "Great Chain of Being")



Lamarck's "Ladder"

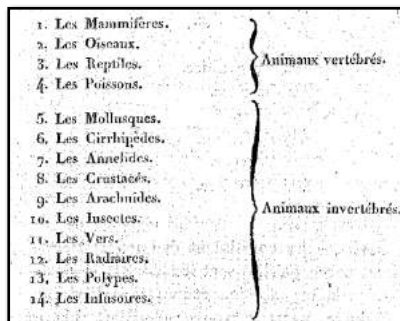
- Life progresses upward due to an internal drive towards perfection = transmutation
- Why are primitive organisms still around?
 - Spontaneous generation of new life constantly
- Mechanism of change?
 - Inheritance of acquired characters



Lamarck's "Ladder"

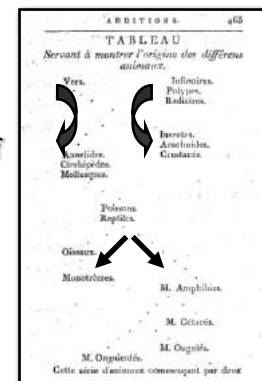
Lamarck's (1809) fourteen level ladder hierarchy

- There is no one linear ladder (Georges Cuvier)



Lamarck's later "Tree"

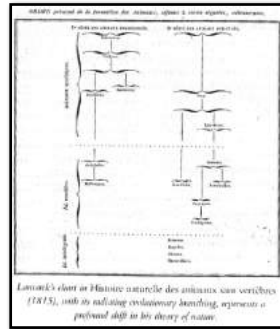
- Lamarck (reluctantly) influenced by Cuvier's arguments
- Appended table in 1809 (vol. 2 of *Philosophie Zoologique*) showing two lines of spontaneous generation with subsequent branching



Lamarck's 1809 appendix

Lamarck's later "Tree"

- By 1815 Lamarck announced his conversion to branching as the fundamental pattern of "evolution"
- "In its production of the different animals, nature has not fashioned a single and simple series"



Lamarck's 1815 "tree"

Lamarck's later "Tree"

- His last book (*Analytical System of Positive Knowledge of Man*, 1820) has gone largely unnoticed

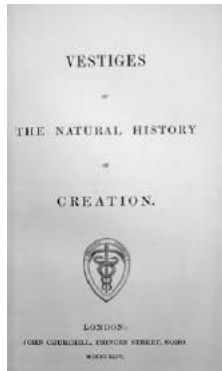
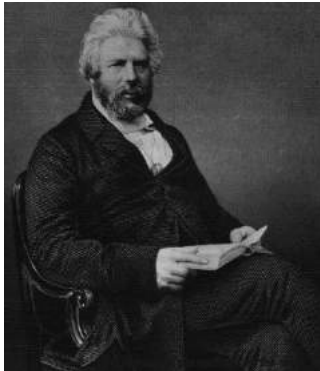
"Reptiles come necessarily after fishes. They build a branching sequence, with one branch leading from turtles to platypuses to the diverse groups of birds, while the other via lizards toward the mammals. The birds then build a richly varied branching series, with one branch ending in birds of prey."



S.J. Gould, 1999

Robert Chambers (1844)

- The only pre-Darwin "evolution" book that English speakers could read in 1840s and 1850s



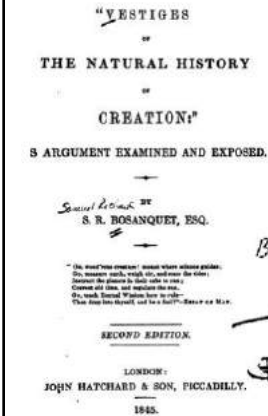
Robert Chambers (1844)

- Darwin later stated that *Vestiges* – although flawed – set the stage for acceptance of his ideas of evolution set down in his book *Origin of Species* in 1859



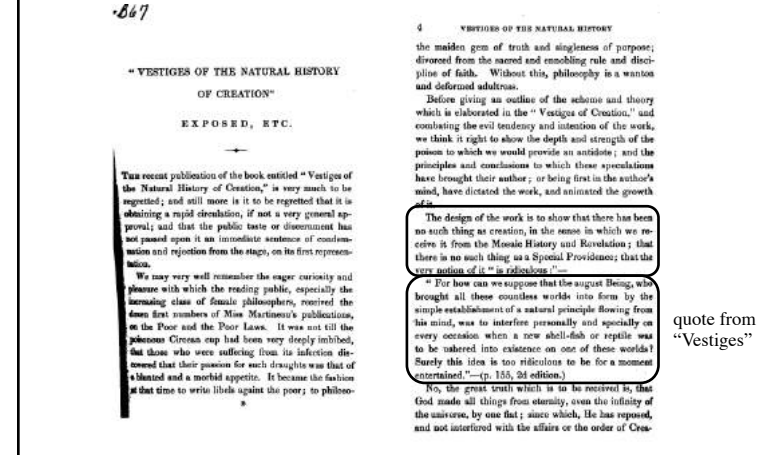
- Immediate criticism on one main point by some in the public: denial of special creation for each species

Robert Chambers (1844)

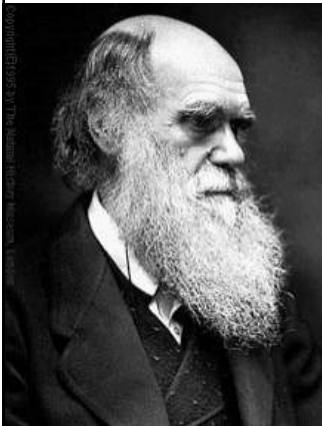


- Bosanquet (Biblical scholar) published his rebuttal the next year and based it primarily on the issue of special creation

Robert Chambers (1844)



Charles Darwin (1859)

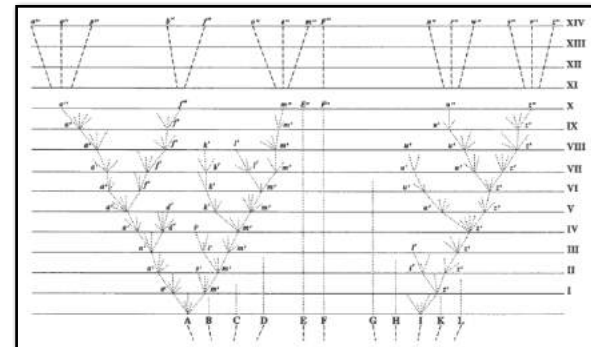


Darwin himself never uses the word "evolution" in *Origin of Species*.

He calls the process "descent with modification".



Darwin's "Tree-thinking"



only figure in *Origin of Species* - illustration of 'descent with modification'

The three main claims of Darwinian evolution

- Living species are related by common ancestry [descent]
- Change through time occurs not at the organism but at the population level
- The main cause of adaptive evolution is natural selection [modification]

Evolution - a definition

The change of genetic materials (DNA, genes, chromosomes = genotype) and thus physical attributes (morphology, physiology = phenotype) within and among populations and species through time and space

Evolution vs. Religion?



Some conflict already early on between religion and ideas of evolution

1860 debate between Bishop Samuel Wilberforce of Church of England and Thomas Henry Huxley ('Darwin' s bulldog')

Evolution vs. Religion?

"Surely God's power and glory were revealed more clearly in natural laws than in a peppering of miraculous interventions."

William Benjamin Carpenter — Christian physiologist and paleontologist — after reviewing Darwin's *Origin of Species*

No conflict among many scientists of faith



Evolution vs. Religion?

“A Natural Law is as sacred as Moral Principle”

“Every scientific truth goes through three states: first, people say it conflicts with the Bible; next, they say it has been discovered before; lastly, they say they always believed it”



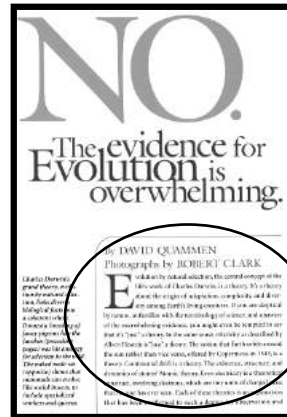
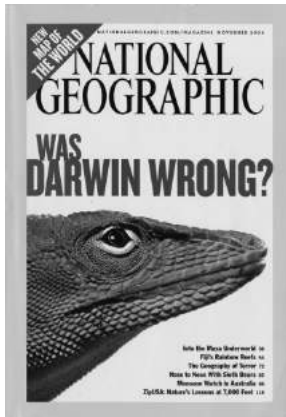
Louis Agassiz

Evolution vs. Religion?

BioLogos – one positive example of scientists and theologians working together

BIOLOGOS

Evidence for Evolution

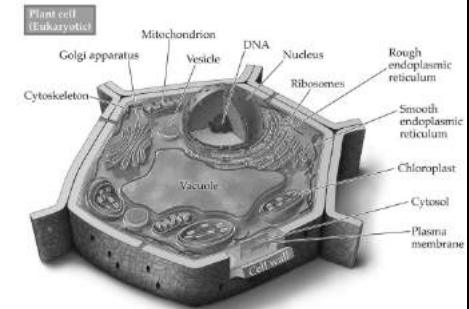


Evidence for Evolution

Nothing in biology makes sense except in the light of evolution

Theodosius Dobzhansky

Anatomists, cellular biologists, prokaryote geneticists, membrane and protein transport physiologists, gene sequencers, genomicists, etc. . . .

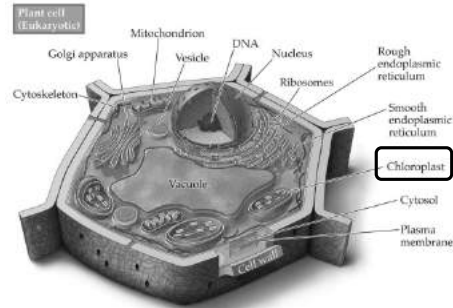


Evidence for Evolution

Nothing in biology makes sense except in the light of evolution

Theodosius Dobzhansky

... their data only makes sense assuming that chloroplasts are modifications of an ancient blue green bacterial ancestor — endosymbiotic event



Evidence for Evolution - Common Ancestry

- Classification ✓
 - Hierarchical distribution of traits ✓
 - Homology ✓
 - Vestigial Structures ✓
 - Fossil record ✓
 - Biogeography ✓
 - Variation among populations ✓
 - Speciation ✓
 - Agreement between gene trees ✓
- ✓ = examined in this course to various degrees
- “trees”
- use “tree” metaphor

Darwin’s “Tree Thinking”

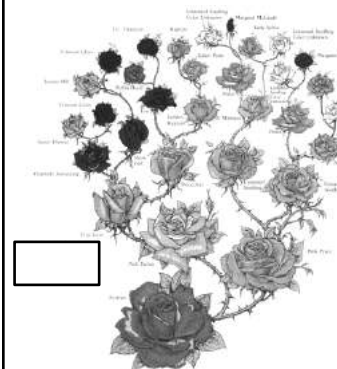


Genealogical tree of Queen Victoria (1819-1901)

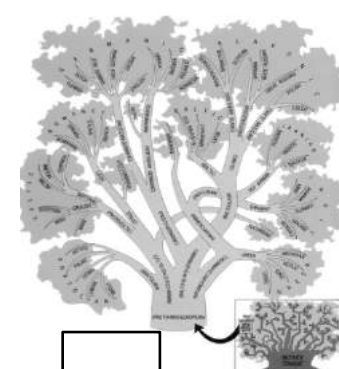


Pigeon breeding lineages from ancestral rock pigeon

Darwin’s “Tree Thinking”



Rose pedigree

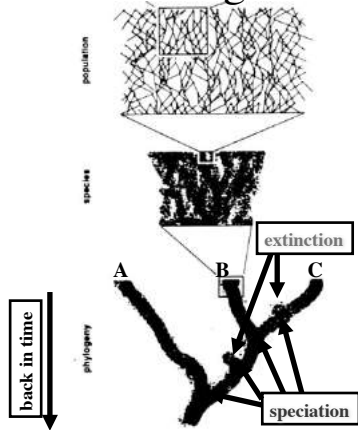


IndoEuropean Language Tree (with reticulations)

Darwin's "Tree Thinking"



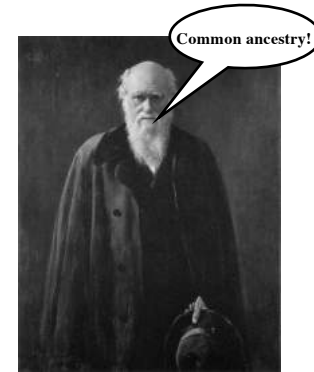
Darwin's 1st species notebook (1837)



1. Hierarchical Classification

Darwin's major finding was a scientific explanation (using the tree metaphor) for:

- (1) why organisms appear similar to other organisms,
- and (2) why these organisms appear related in a hierarchical (nested) fashion

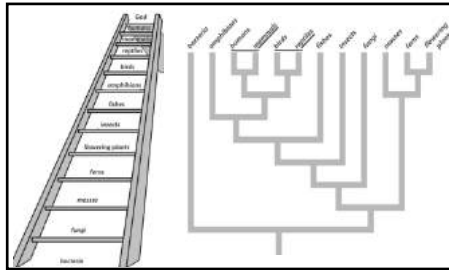


1. Hierarchical Classification

- █ Vascular tissue
- █ Chloroplasts
- █ Water-tight egg
- █ Four limbs



- Groups of species appear *more similar* than they do with other groups
- That observation alone could be consistent with a number of explanations of the origin of life's diversity



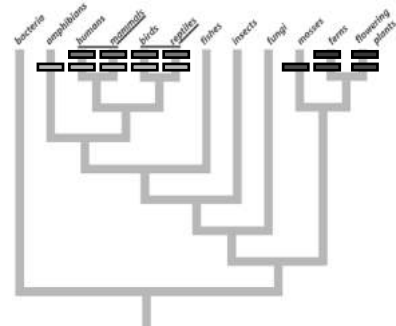
Ladder of Life

Phylogenetic Tree

1. Hierarchical Classification

- Darwin's simple explanation was that each species did not independently acquire every character

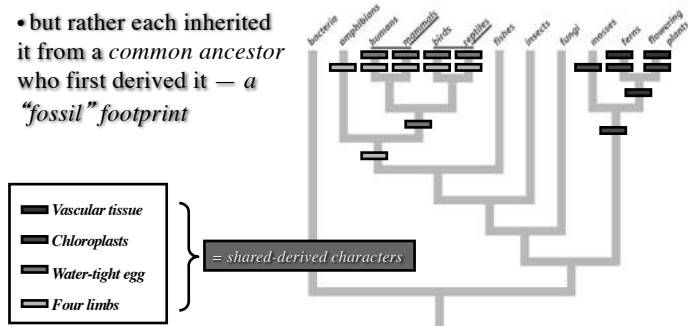
- █ Vascular tissue
- █ Chloroplasts
- █ Water-tight egg
- █ Four limbs



1. Hierarchical Classification

Characters are “fossil” footprints indicating ancestry

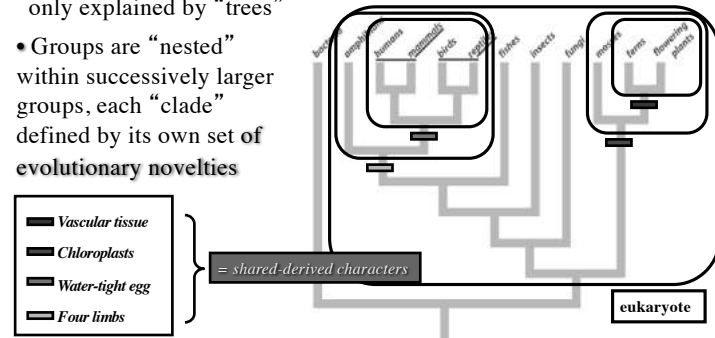
- but rather each inherited it from a *common ancestor* who first derived it – a “fossil” footprint



1. Hierarchical Classification

The distributions of characters in a hierarchical fashion is only explained by “trees”

- Groups are “nested” within successively larger groups, each “clade” defined by its own set of evolutionary novelties



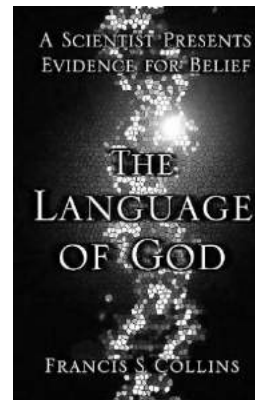
Tree of Life & Special Creation

On the ordinary view of each species having been independently created, we gain no scientific explanation of any one of these facts. We can only say that it has so pleased the Creator . . . that He has impressed on them the most extraordinary resemblances, and has classed them in groups subordinate to groups.



Darwin, *The variation of animals and plants under domestication*. 2 vols. 2nd edn. New York, D. Appleton & Co. 1883.

Tree of Life & Special Creation



"Unless one is willing to take the position that God has placed these decapitated AREs [ancient repetitive elements] in these precise positions to confuse and mislead us, the conclusion of a common ancestor for humans and mice is virtually inescapable. This kind of recent genome data thus presents an overwhelming challenge to those who hold to the idea that all species were created ex nihilo."

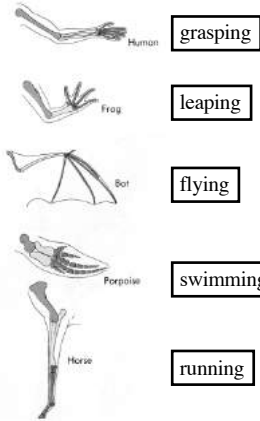
2. Evidence through Homology

Character modification — homologous parts

Evolution thus predicts that species descended from a common ancestor should share homologous characters - derived from the same structure(s) - but that they will show divergence in these characters through time

The forelimb of all these vertebrates are homologous but modified:

Unrelated species (different ancestors) will show convergence in similar niche



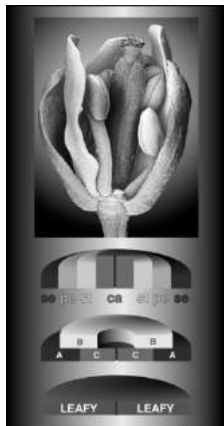
2. Evidence through Homology

“On my theory, unity of type is explained by unity of descent” Darwin, 1859

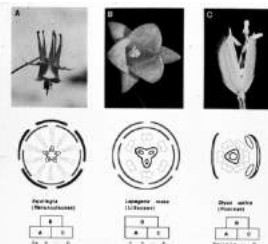
- Darwin’s work on orchids convinced him that all species possess the basic homologous floral parts
- although these are highly modified for roles in quite different pollination systems



2. Evidence through Homology



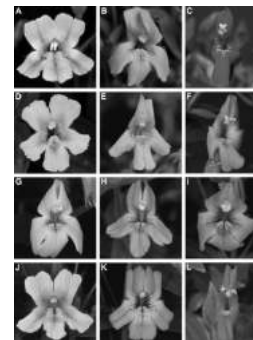
EvoDevo studies now provide genetic bases for the homology (or not) of basic features in plants and animals



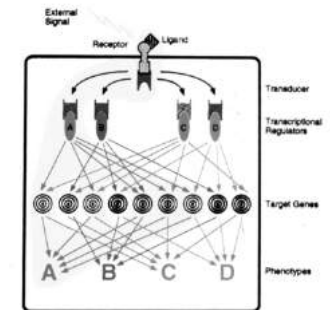
And how they have been modified

ABC model of floral identity

2. Evidence through Homology



- few gene differences involved in quite different looking flowers (*Mimulus* - monkey flowers)



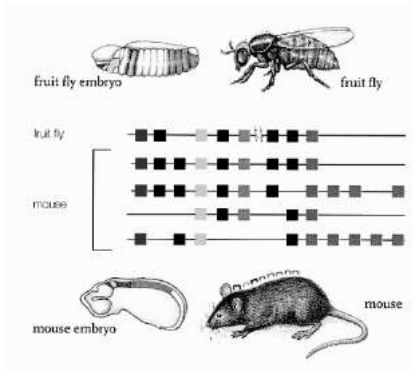
- transcription factors not structural genes important in trait differences

2. Evidence through Homology

Molecular tinkering - major process for forming the diversity of life

Hox Genes - EvoDevo

Gene family, spatial organization, development

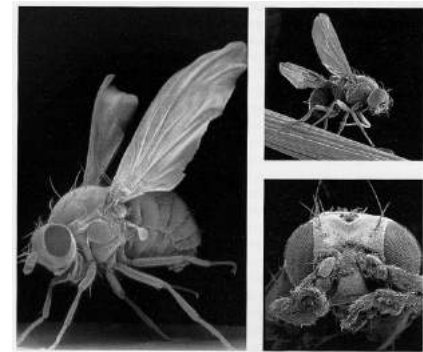


2. Evidence through Homology

Molecular tinkering - major process for forming the diversity of life

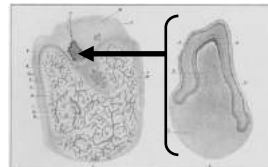
Hox Genes - EvoDevo

Halteres into wings
Antennae into legs

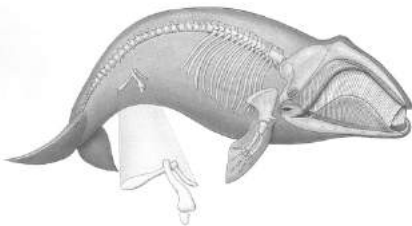


3. Vestigial Structures

Vestigial structures — homologous parts
Evolution predicts that species occupying very distinct environments from that of a common ancestor might show vestigial structures

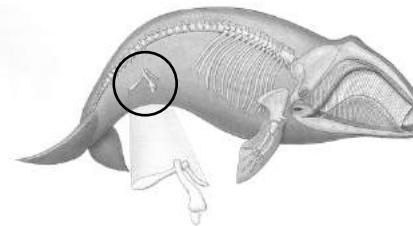


Rudimentary tooth in lower jaw of a baleen whale



3. Vestigial Structures

Vestigial structures — homologous parts
Evolution predicts that species occupying very distinct environments from that of a common ancestor might show vestigial structures



The pelvic girdle seen in reptiles and mammals as an adaptation for support in tetrapods, is vestigial in whales — it is a “fossil” footprint of their ancestry and serving **no function** today in swimming descendants of tetrapods.

3. Vestigial Structures

Vestigial structures — homologous parts

Parasitic and non-green dodders retain “fossil” non-functional chloroplasts as a vestigial structure inherited from a common ancestor with morning glories



Convolvulus – morning glory



Cuscuta - dodder

4. Fossil Record

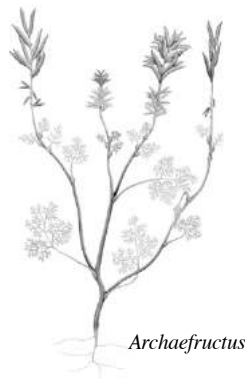
‘Missing links’ — transitional forms



• fossil record is rich & consistent with information from hierarchical relationships based on morphology and DNA

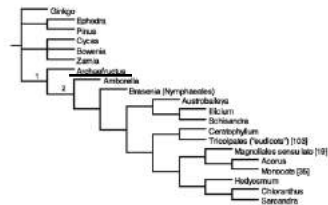
4. Fossil Record

‘Missing links’ — transitional forms



Archaeoartus

- *Archaeoartus* in terms of age and morphology is consistent with an early basal angiosperm
- fossils often now placed in phylogenetic analyses



4. Fossil Record

‘Missing links’ — transitional forms

“I see no difficulty in a race of bears being rendered, by natural selection, more and more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale.” Darwin, in *Origin of Species*



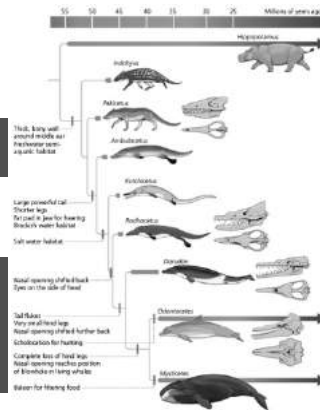
4. Fossil Record

- now a wealth of fossils showing transitional forms from a putative ancestral Mesonychid type to modern whales has been uncovered



Early stages were clearly terrestrial

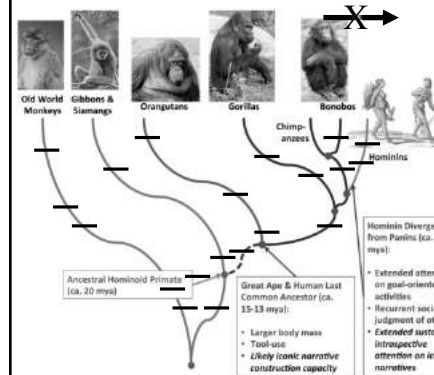
Paleontologist Phil Gingerich with 40 my old *Basilosaurus* with small hind legs in Egypt



4. Fossil Record

'Missing links' — transitional forms

- what should 'missing links' look like?



- intermediate between chimps and humans?

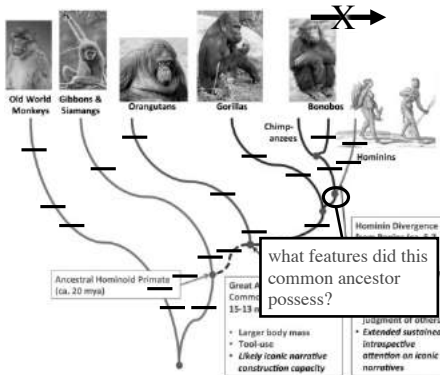
- No! that is 'ladder of life' or "progression" thinking

- each species is a 'tip' species with its own derived traits

4. Fossil Record

'Missing links' — transitional forms

- what should 'missing links' look like?



- in tree thinking, 'missing links' are seen in a progression from a common ancestor with a sister species

- the common ancestor may or may not look like the sister tip species

5. Biogeography of Life

" . . . that grand subject, that almost keystone of the laws of creation, **Geographical Distribution**"

Darwin needed two chapters in the *Origin of Species* to cover his ideas on geographical distributions of organisms

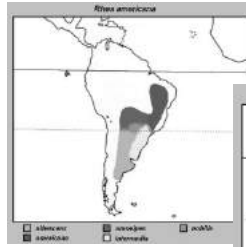


"I am prepared to go to the stake, if requisite, in support of the chapters on the geological and geographical distribution of life."

Thomas Huxley after reading the *Origin of Species*

5. Biogeography of Life

Law of Representative Species - repeated biogeographical observation



Closely related species replace themselves across a continent



5. Biogeography of Life

Convergent Forms on Different Continents - repeated pattern

Succulent stemmed Cactaceae restricted to the American continents



Succulent stemmed Euphorbia restricted to Africa and Madagascar



5. Biogeography of Life

Congruence of distribution patterns and earth history

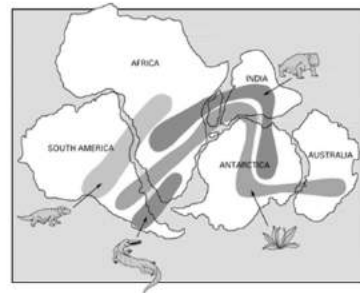
Distributions of organisms, extant and extinct, provided the first evidence in 1920 for the then heretical idea of continental drift

Glossopteris - Permian "fern"

Mesosaurus - Permian freshwater reptile

Cynognathus - Triassic land reptile

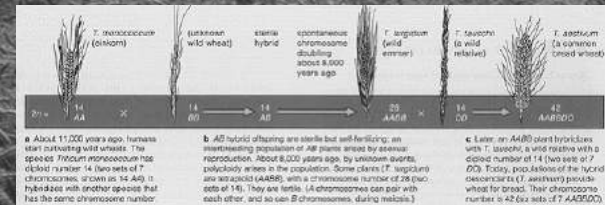
Lystrosaurus - Triassic land reptile



6. Direct Observation

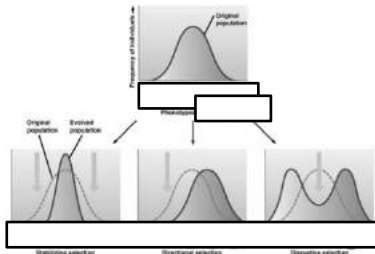
Evolutionary change in formation of crop plants

Documenting change within 100s or 1000s years due to human or artificial selection - often with "major" phenotypic modifications but due to small numbers of genes



6. Direct Observation

Evolutionary change within and among populations



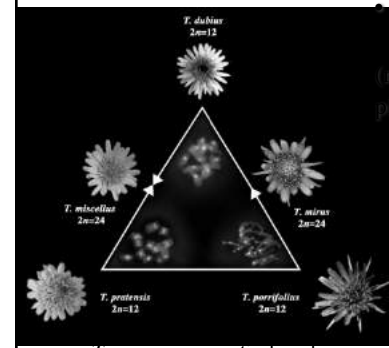
Metrosideros – o’hia

Directional selection in size of o’hia flowers in 150 years due to loss of long-beaked honeycreeper species



6. Direct Observation

Origin of recent species



Origin of new polyploid species in last 150 years (multiple times in different places)!



Doug & Pam Soltis

Tragopogon - goat's beard

6. Direct Observation

Origin of old species



H. annuus



H. paradoxus



Helianthus anomalus

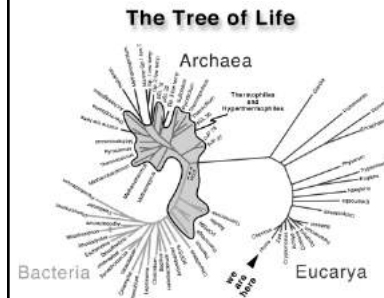
Re-synthesized in the lab



Loren Rieseberg

7. Molecular Evolution

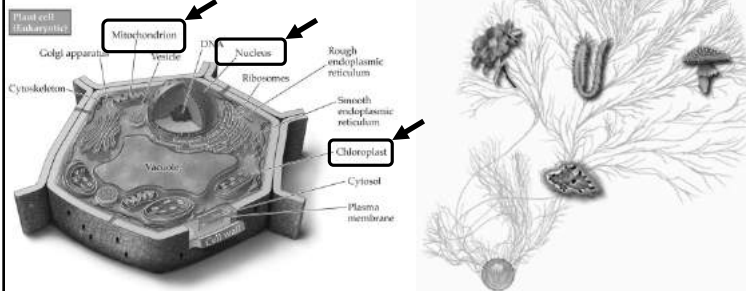
Organisms contain within themselves a “DNA fossil footprint”



7. Molecular Evolution

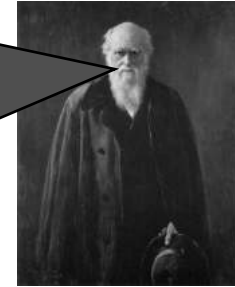
Organisms contain within themselves
a “DNA fossil footprint”

... and different stories are told
by different genomes & genes



The Fact of Common Ancestry

*On the ordinary view of each species
having been independently created, we
gain no scientific explanation of any one
of these facts. We can only say that it has
so pleased the Creator . . . that He has
impressed on them the most
extraordinary resemblances, and has
classed them in groups subordinate to
groups.*



Darwin, *The variation of animals and plants under domestication*.
2 vols. 2nd edn. New York, D. Appleton & Co. 1883.