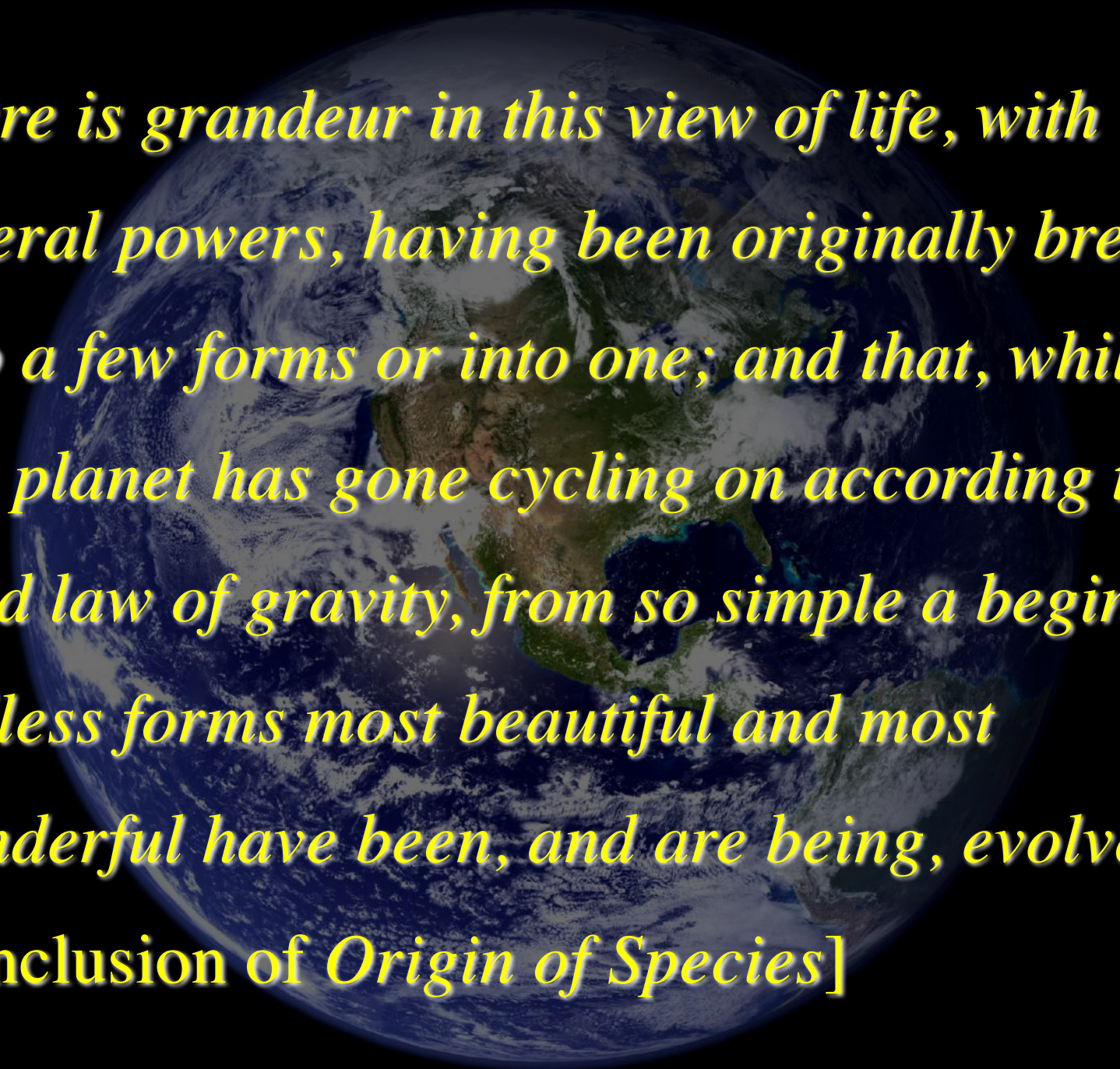


Evolution - Biosystematics



A view of Earth from space, showing the Americas and surrounding oceans. The text is overlaid on this image.

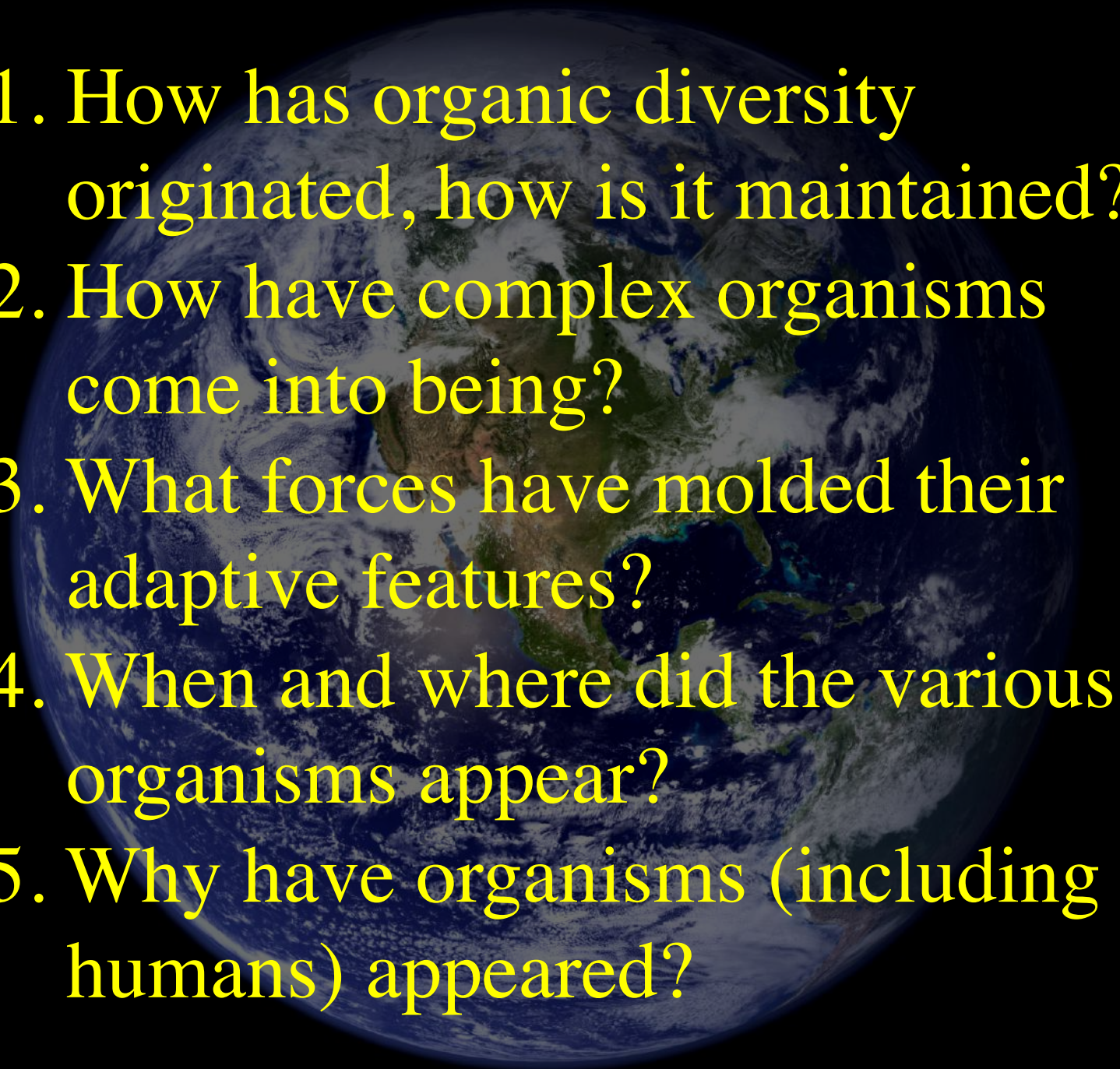
There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been,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

[conclusion of Origin of Species]

- 
- A satellite view of Earth showing the Americas and surrounding oceans. The text is overlaid on the image.
1. Tremendous diversity of life!
 2. Structural complexity of these organisms
 3. Apparent purposive or adaptive nature of their features

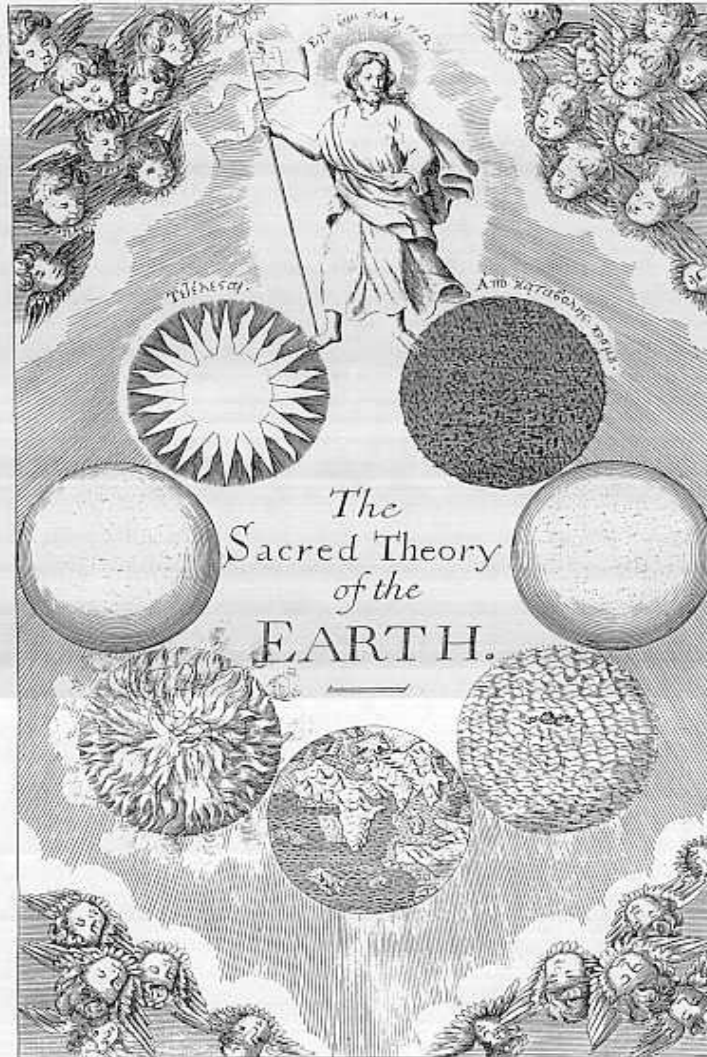
A satellite view of Earth from space, showing the Americas and the Atlantic Ocean. The text "Questions Evoked?" is overlaid in yellow. The image is a composite of satellite imagery, showing the Earth's surface with clouds and landmasses. The text is centered over the Atlantic Ocean, between North and South America.

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



THE
THEORY
OF THE
EARTH:
Containing an Account
OF THE
Original of the Earth,
AND OF ALL THE
GENERAL CHANGES
Which it hath already undergone,
OR
IS TO UNDERGO
Till the CONSUMMATION of all Things.

THE TWO FIRST BOOKS
Concerning The DELUGE,
AND
Concerning PARADISE.

The Second Edition.

LONDON,
Printed by R. Norton, for Walter Kettilby, at the Bishops-
Head in S. Paul's Church-Yard, 1691.

Thomas Burnet (1681)

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

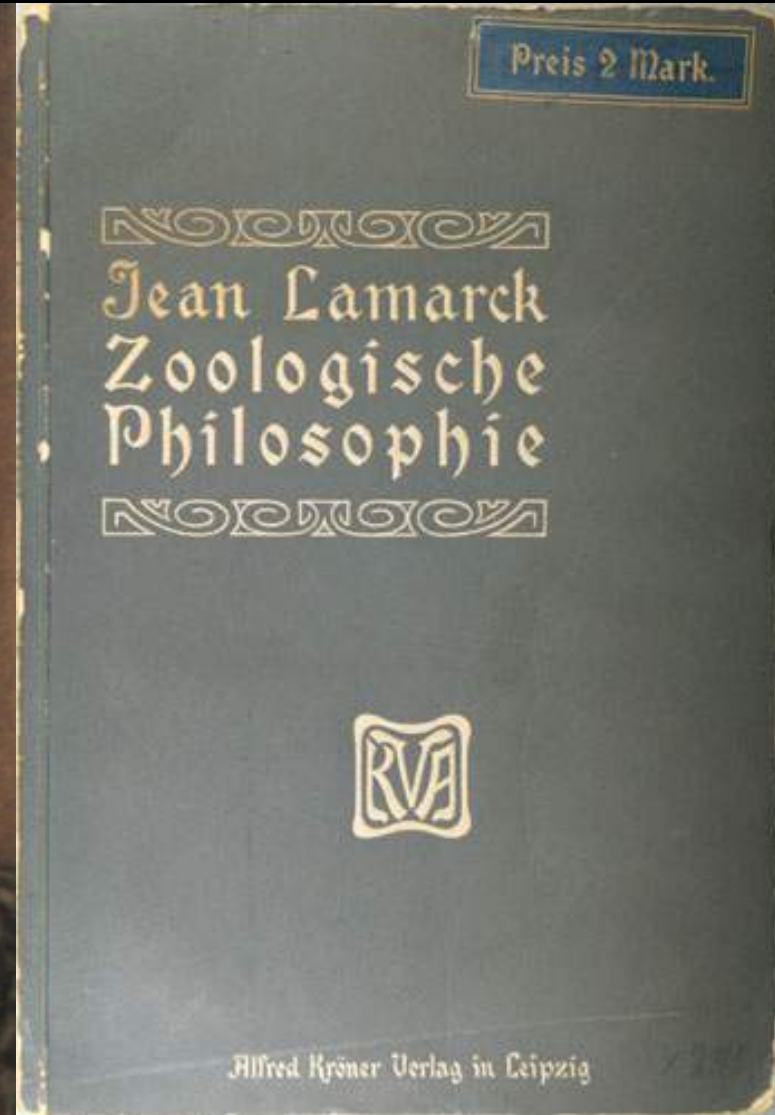
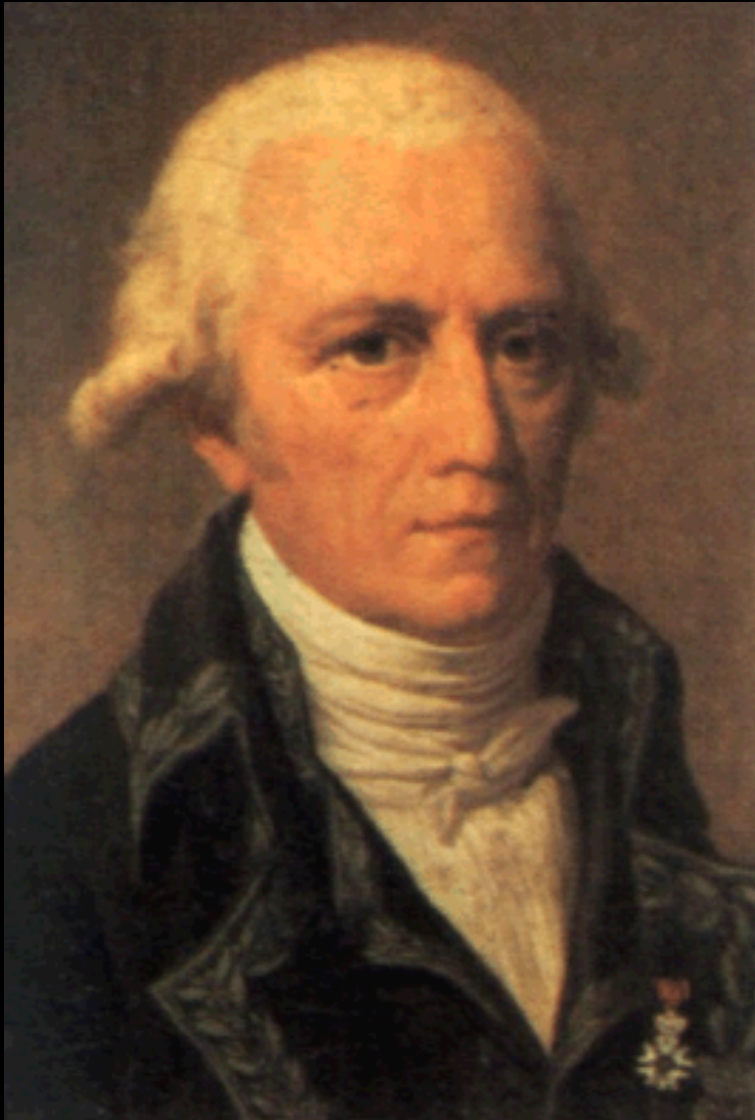


“no truth concerning the Natural World can be an enemy of religion; for Truth cannot be an enemy to Truth, God is not divided against himself”

“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**”

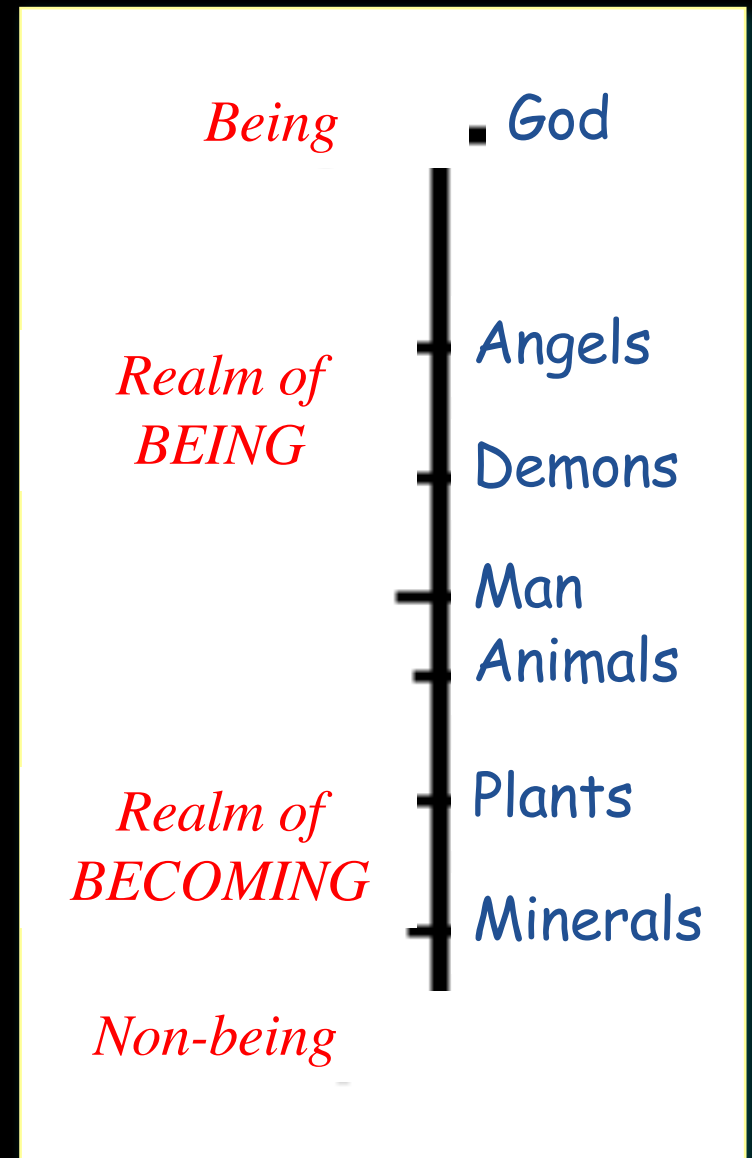
Jean Baptiste Lamarck (1744-1829)

- Early evolutionary thought - “ladder thinking”



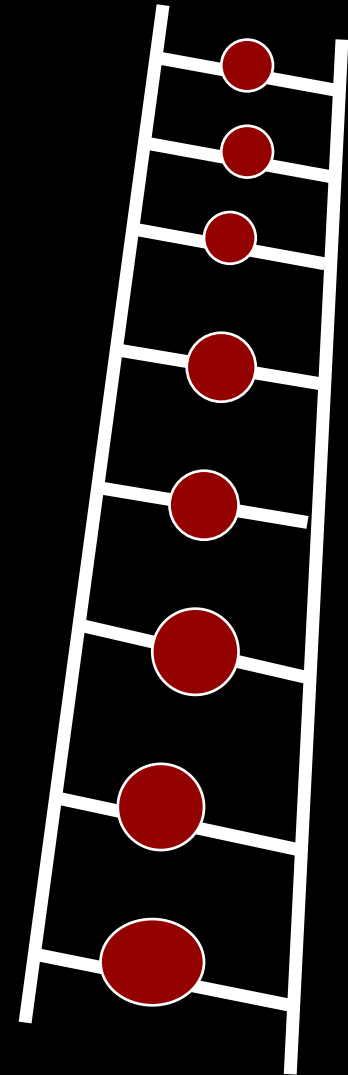
Lamarck's "Ladder"

- 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

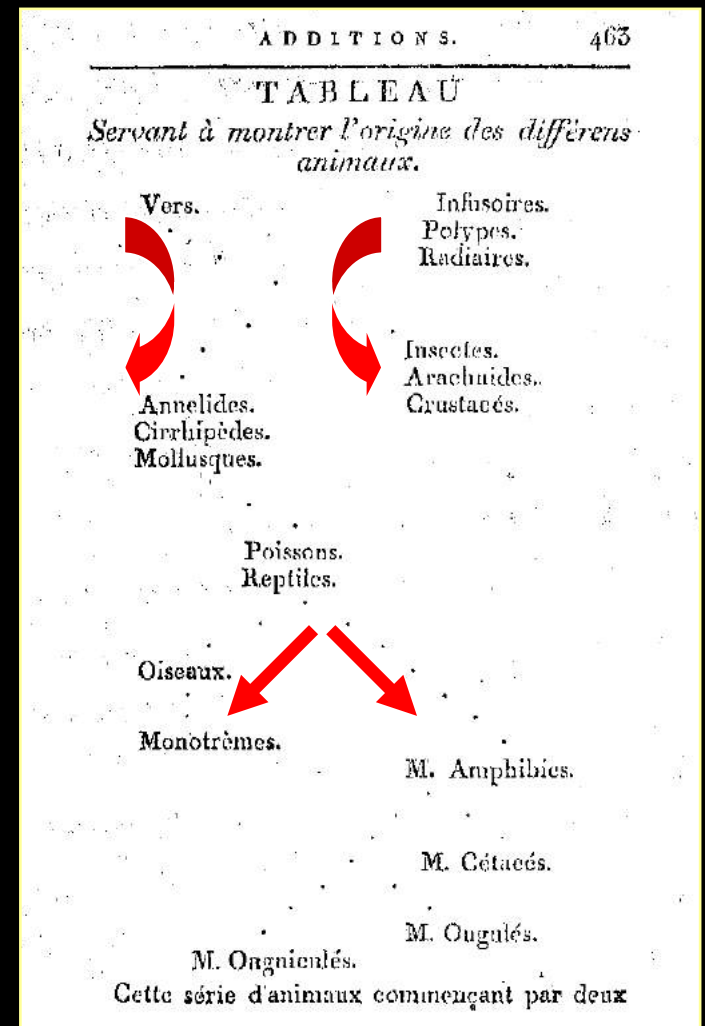
- There is **no one** linear ladder (Georges Cuvier)



1. Les Mammifères.	}	Animaux vertébrés.
2. Les Oiseaux.		
3. Les Reptiles.		
4. Les Poissons.		
5. Les Mollusques.	}	Animaux invertébrés.
6. Les Cirrhipèdes.		
7. Les Annelides.		
8. Les Crustacés.		
9. Les Arachnides.		
10. Les Insectes.		
11. Les Vers.		
12. Les Radiaires.		
13. Les Polypes.		
14. Les Infusoires.		

Lamarck's later "Tree"

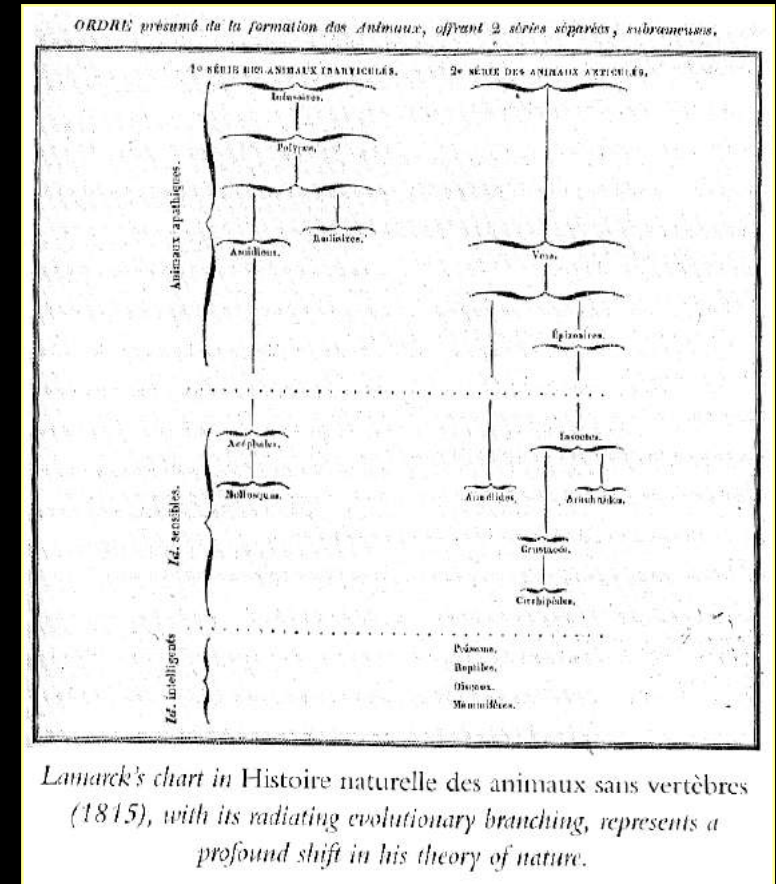
- Lamarck (reluctantly) influenced by Cuvier's arguments
- Appended table in 1809 (vol. 2 of *Philosophie Zoologique*) showing **two lines** of spontaneous generation with **subsequent branching**



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

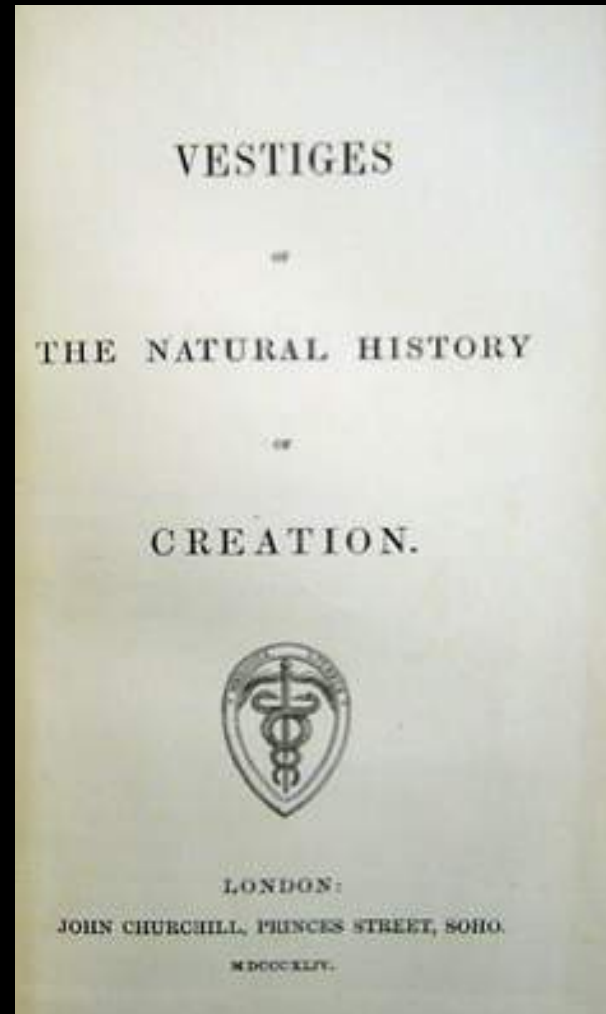
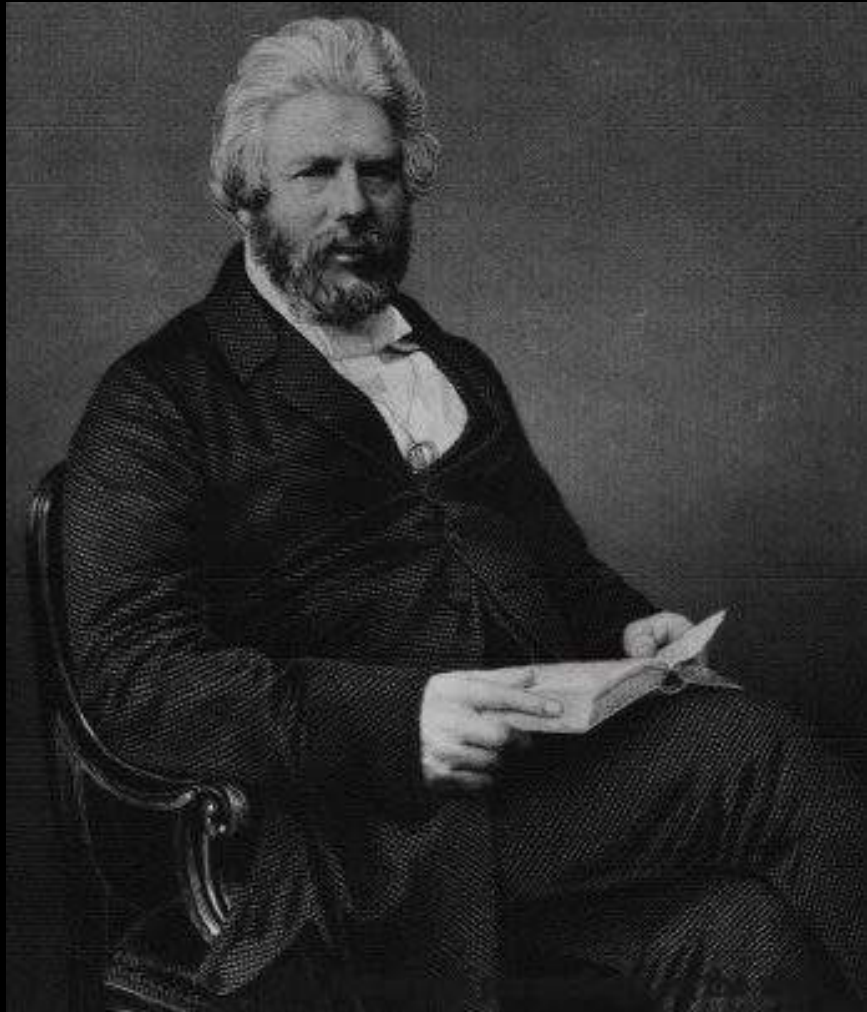
*“Reptiles come necessarily after fishes. They build a **branching sequence**, with one branch leading from turtles to **platypuses** to the diverse groups of birds, while the other via lizards toward the mammals. The **birds then build a richly varied branching series**, with one branch ending in birds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

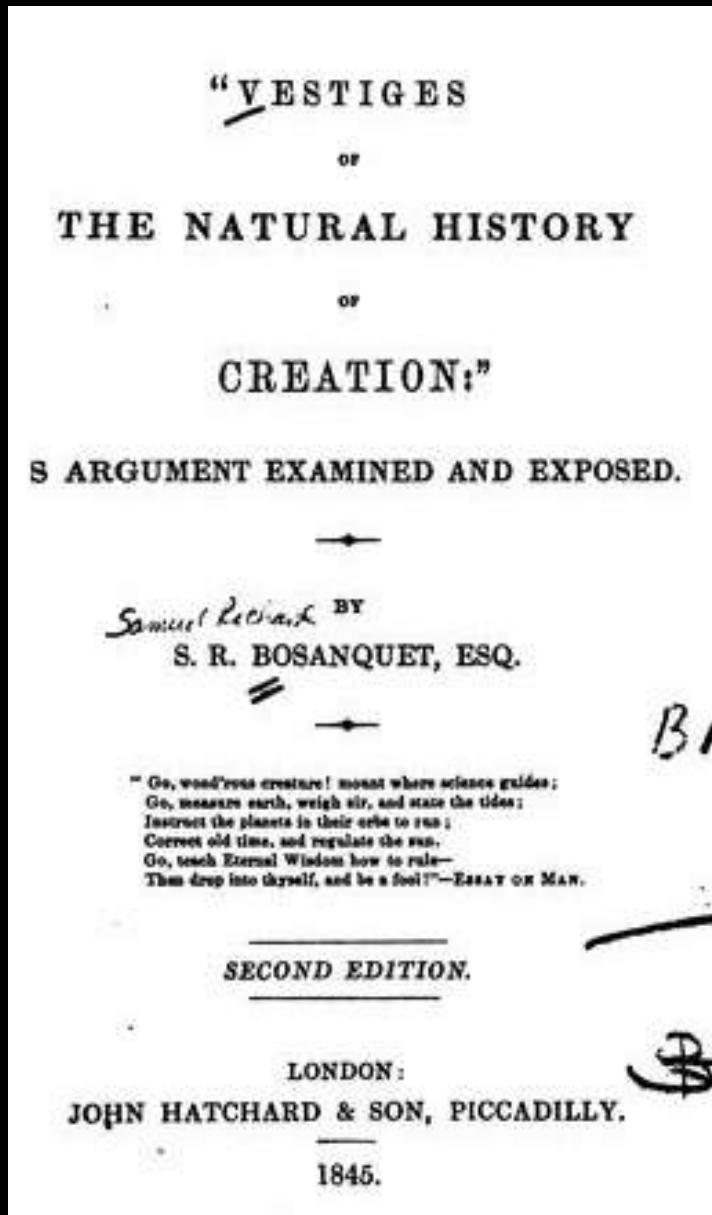
- Darwin later stated that *Vestiges* – although flawed – set the stage for acceptance of his ideas of evolution set down in his book *Origin of Species* in 1859



- 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)

.B67

“VESTIGES OF THE NATURAL HISTORY OF CREATION”

EXPOSED, ETC.

THE recent publication of the book entitled “Vestiges of the Natural History of Creation,” is very much to be regretted; and still more is it to be regretted that it is obtaining a rapid circulation, if not a very general approval; and that the public taste or discernment has not passed upon it an immediate sentence of condemnation and rejection from the stage, on its first representation.

We may very well remember the eager curiosity and pleasure with which the reading public, especially the increasing class of female philosophers, received the dozen first numbers of Miss Martineau’s publications, on the Poor and the Poor Laws. It was not till the poisonous Circean cup had been very deeply imbibed, that those who were suffering from its infection discovered that their passion for such draughts was that of a blunted and a morbid appetite. It became the fashion at that time to write libels against the poor; to philoso-

B

4

VESTIGES OF THE NATURAL HISTORY

the maiden gem of truth and singleness of purpose; divorced from the sacred and ennobling rule and discipline of faith. Without this, philosophy is a wanton and deformed adultress.

Before giving an outline of the scheme and theory which is elaborated in the “Vestiges of Creation,” and combating the evil tendency and intention of the work, we think it right to show the depth and strength of the poison to which we would provide an antidote; and the principles and conclusions to which these speculations have brought their author; or being first in the author’s mind, have dictated the work, and animated the growth of it

The design of the work is to show that there has been no such thing as creation, in the sense in which we receive it from the Mosaic History and Revelation; that there is no such thing as a Special Providence; that the very notion of it “is ridiculous:”—

“For how can we suppose that the august Being, who brought all these countless worlds into form by the simple establishment of a natural principle flowing from his mind, was to interfere personally and specially on every occasion when a new shell-fish or reptile was to be ushered into existence on one of these worlds? Surely this idea is too ridiculous to be for a moment entertained.”—(p. 155, 2d edition.)

No, the great truth which is to be received is, that God made all things from eternity, even the infinity of the universe, by one fiat; since which, He has reposed, and not interfered with the affairs or the order of Crea-

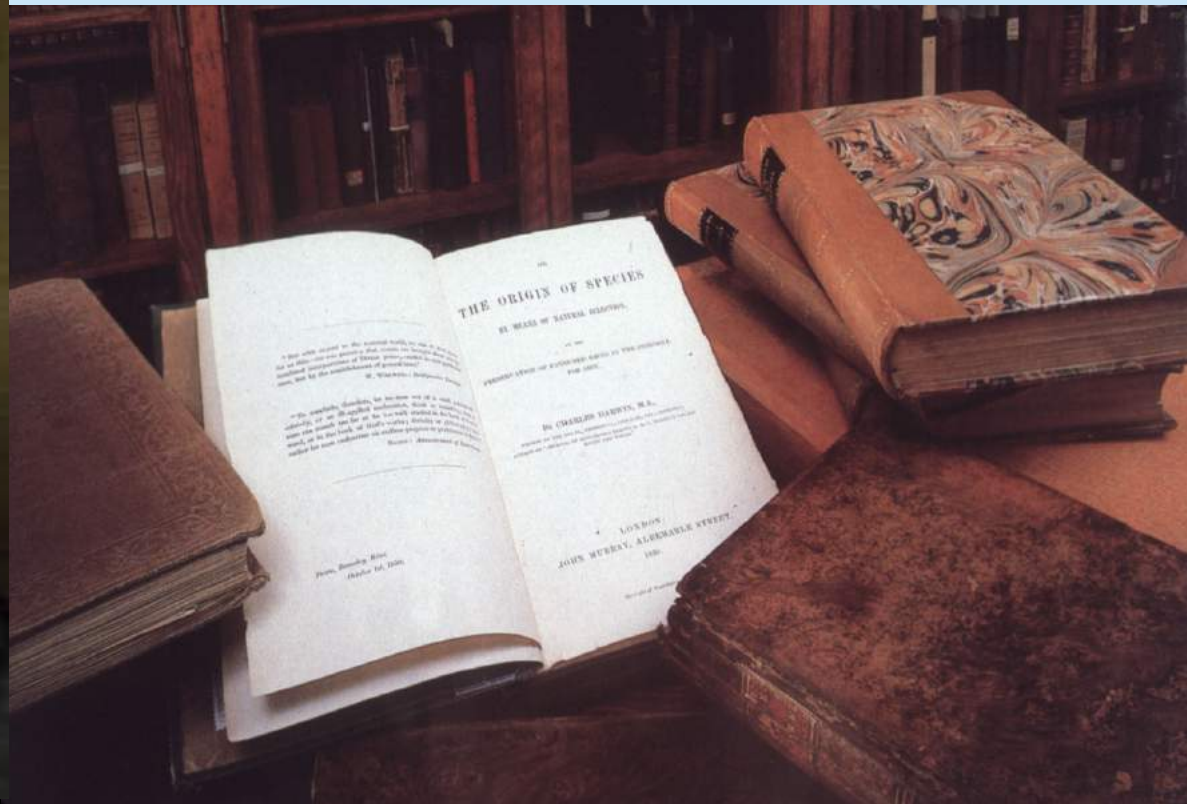
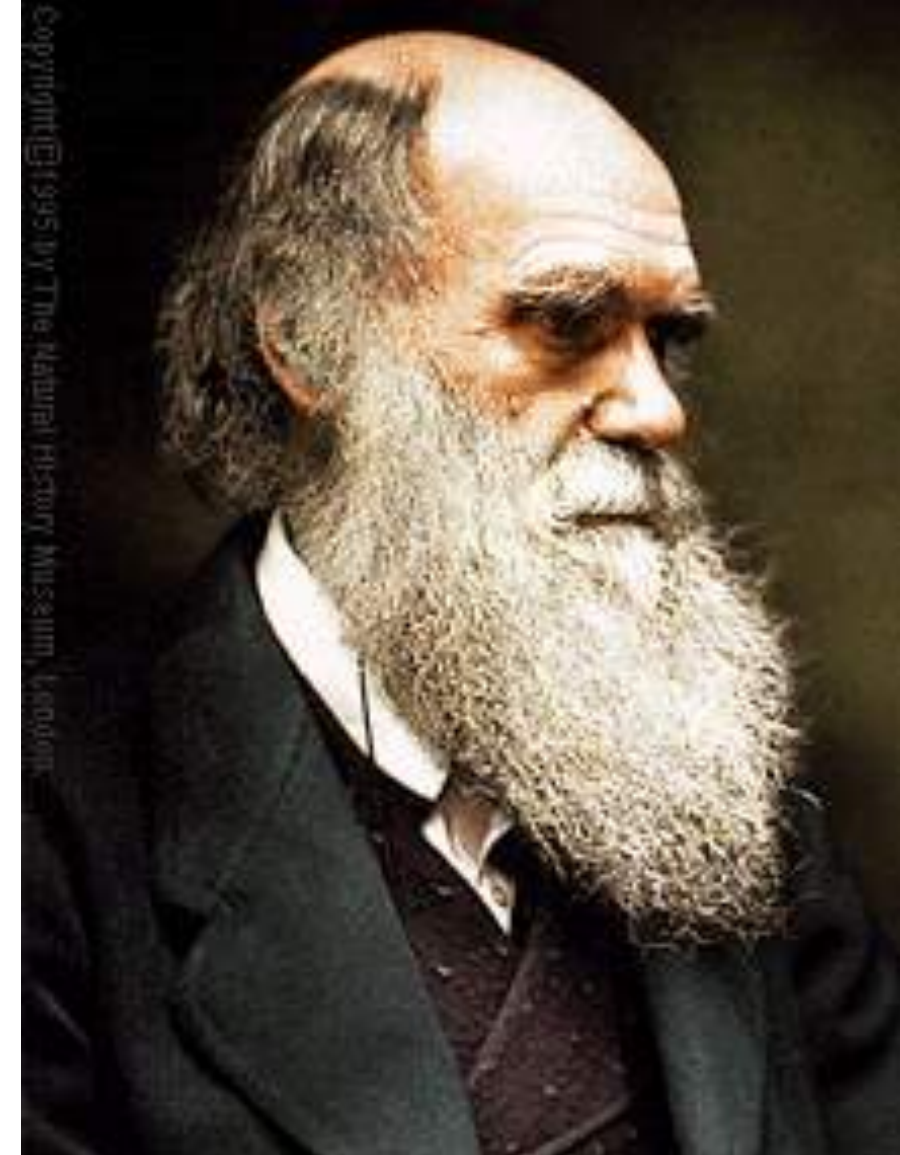
quote from
“Vestiges”

Charles Darwin (1859)

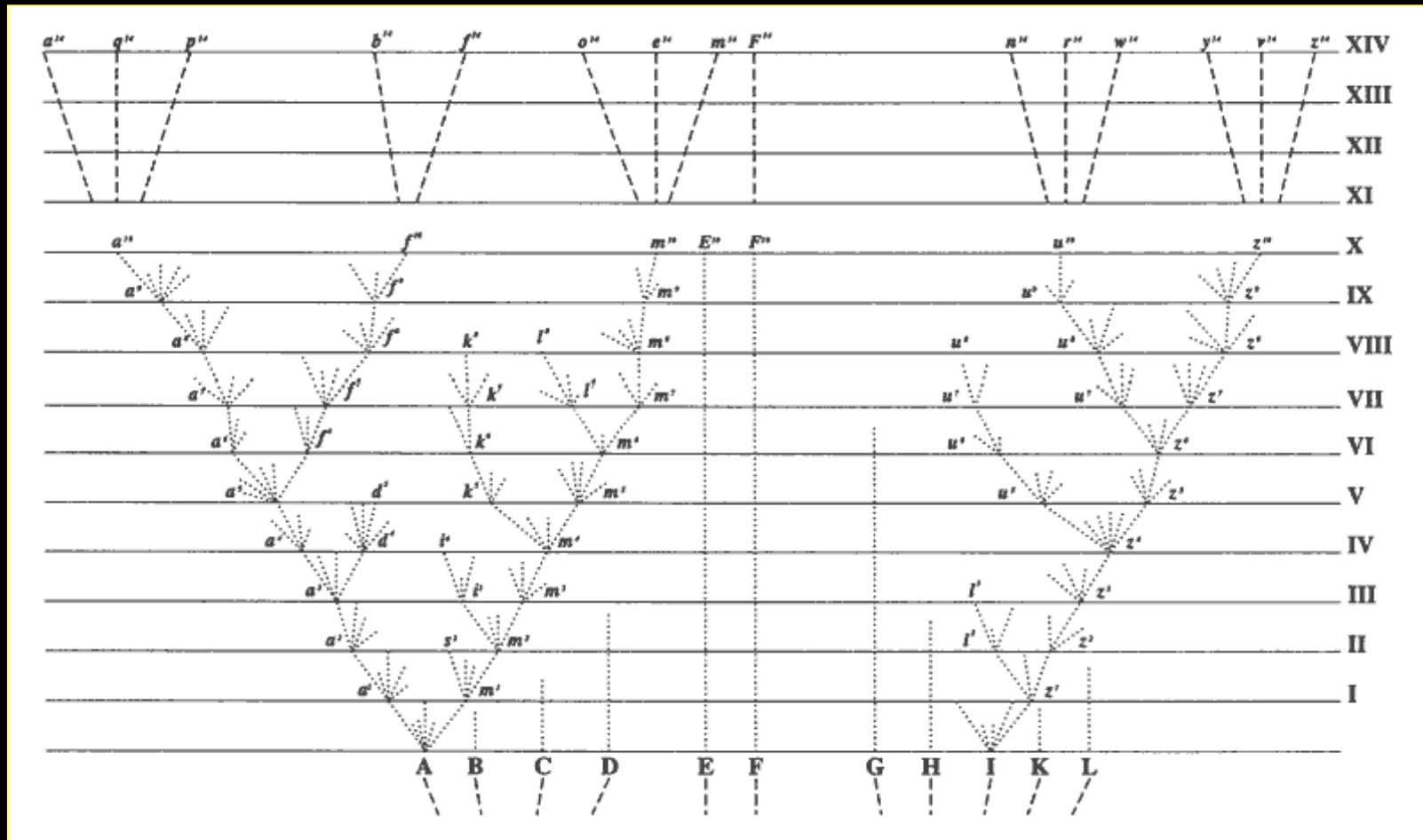
Darwin himself never uses the word "evolution" in *Origin of Species*.

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

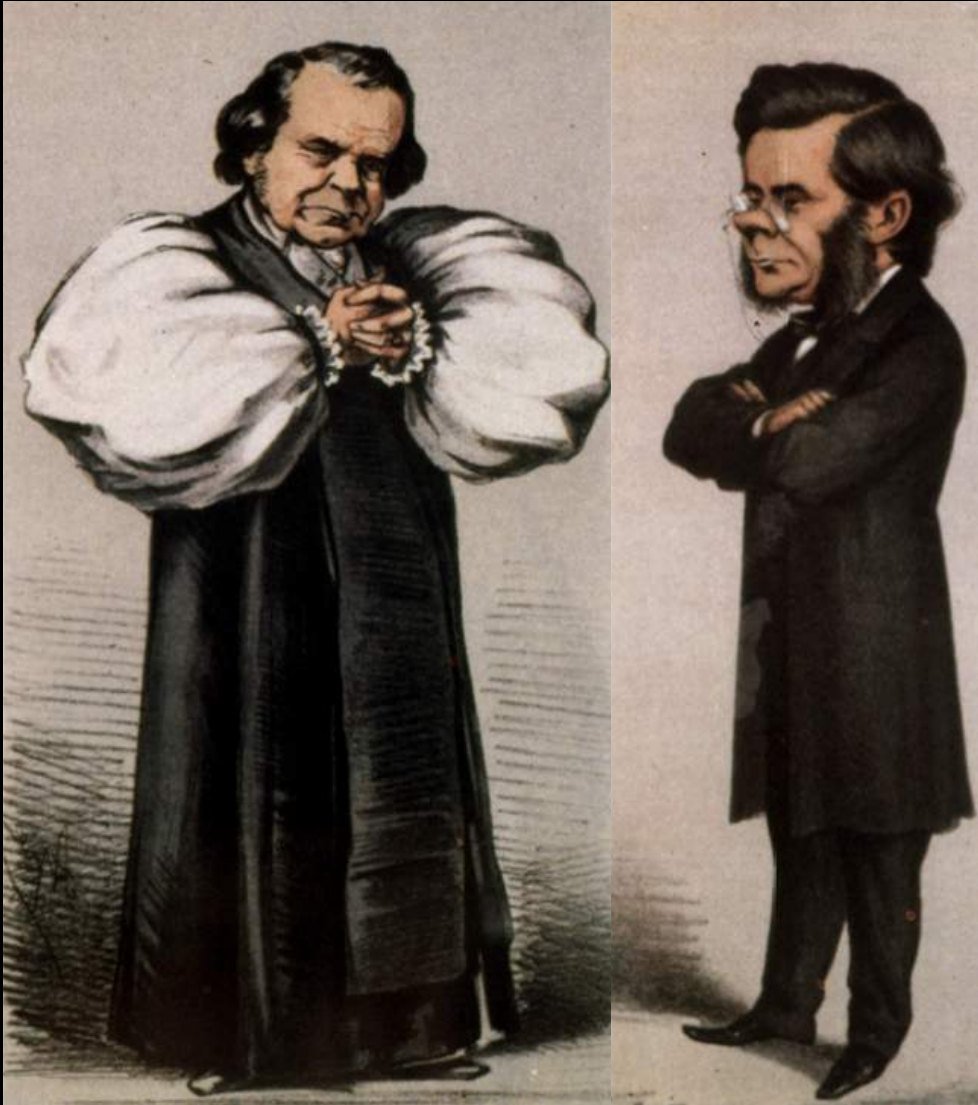
The change of genetic materials (DNA, genes, chromosomes = **genotype**)

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

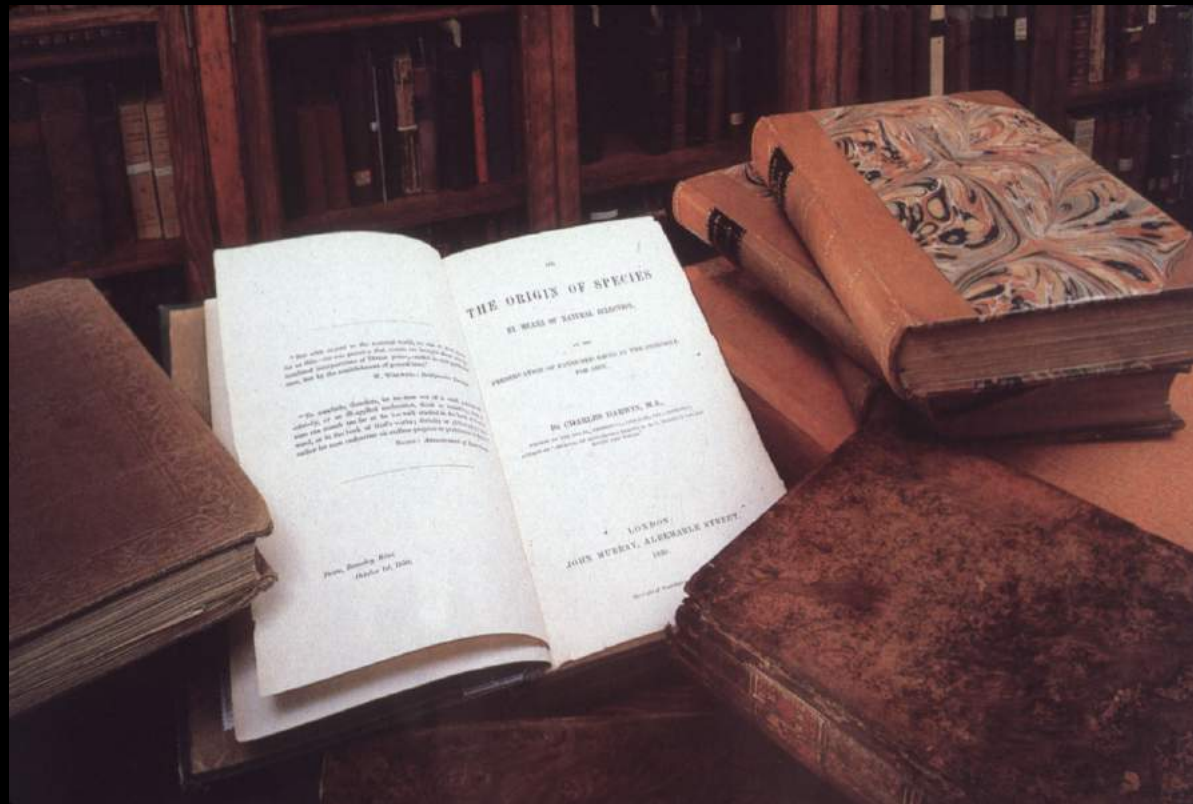
1860 debate between Bishop Samuel Wilberforce of Church of England and Thomas Henry Huxley ('Darwin' s bulldog')

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

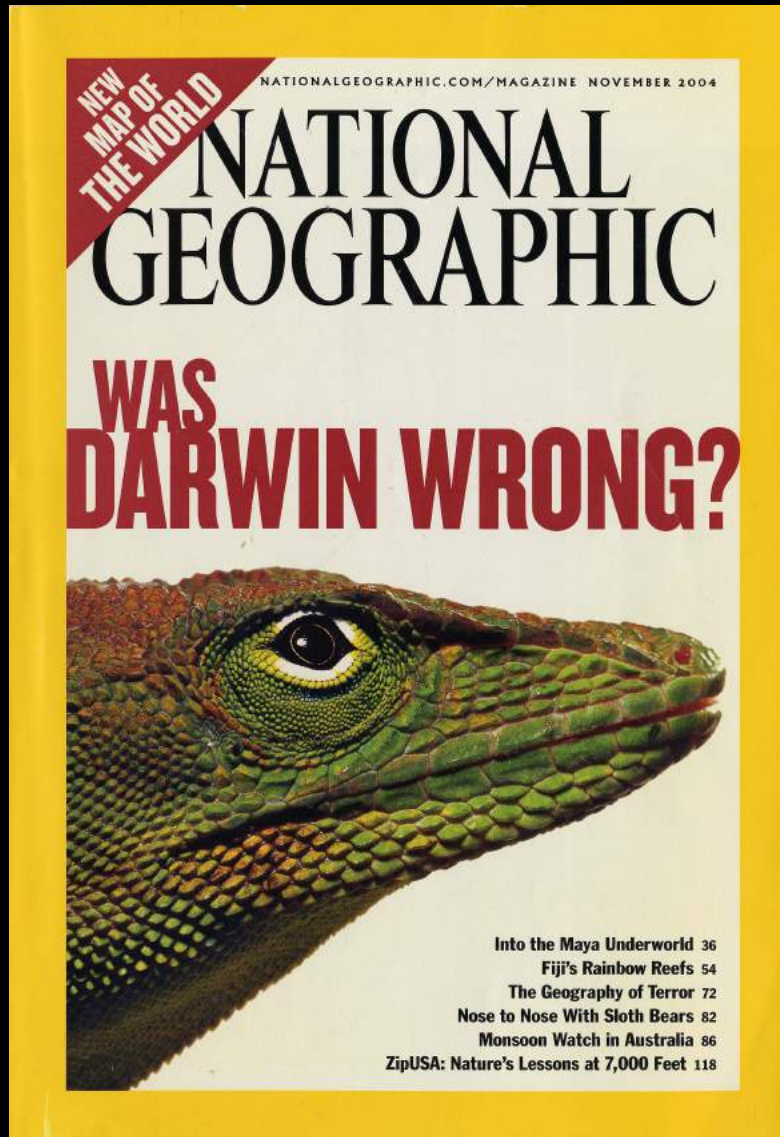
Evolution vs. Religion?

BioLogos – one positive example of scientists and theologians working together



BIOLOGOS

Evidence for Evolution



NO.

The evidence for Evolution is overwhelming.

By DAVID QUAMMEN
Photographs by ROBERT CLARK

Evolution by natural selection, the central concept of the life's work of Charles Darwin, is a theory. It's a theory about the origin of adaptation, complexity, and diversity among Earth's living creatures. If you are skeptical by nature, unfamiliar with the terminology of science, and unaware of the overwhelming evidence, you might even be tempted to say that it's "just" a theory. In the same sense, relatively as described by Albert Einstein is "just" a theory. The notion that Earth orbits around the sun rather than vice versa, offered by Copernicus in 1543, is a theory. Continental drift is a theory. The existence, structure, and dynamics of atoms? Atomic theory. Even electricity is a theoretical construct, involving electrons, which are tiny units of charged mass that no one has ever seen. Each of these theories is an explanation that has been confirmed to such a degree by observation and

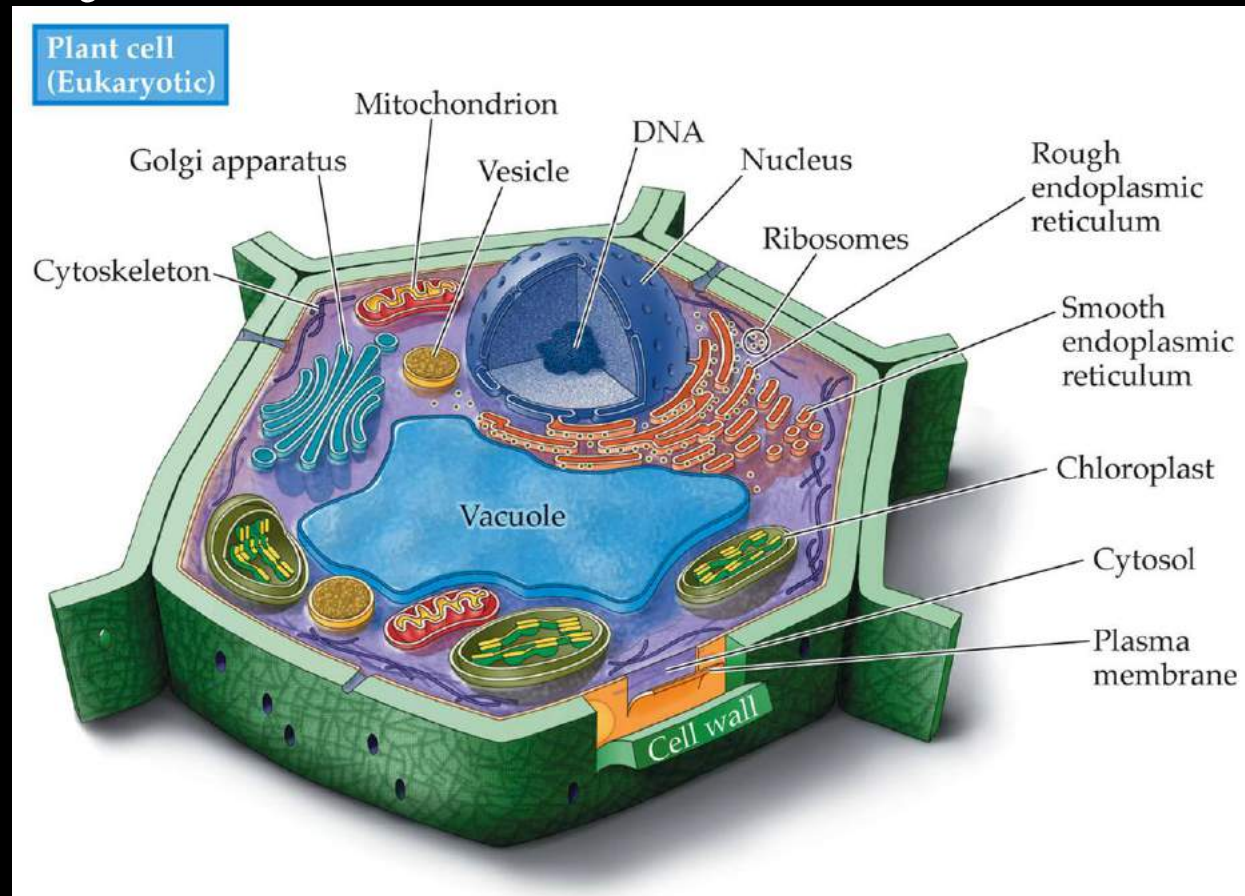
Charles Darwin's grand theory, evolution by natural selection, links diverse biological facts into a coherent whole. Domestic breeding of fancy pigeons like the Jacobin (preceding pages) was his analogy for selection in the wild. The naked mole rat (opposite) shows that mammals can evolve, like social insects, to include specialized workers and queens.

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.

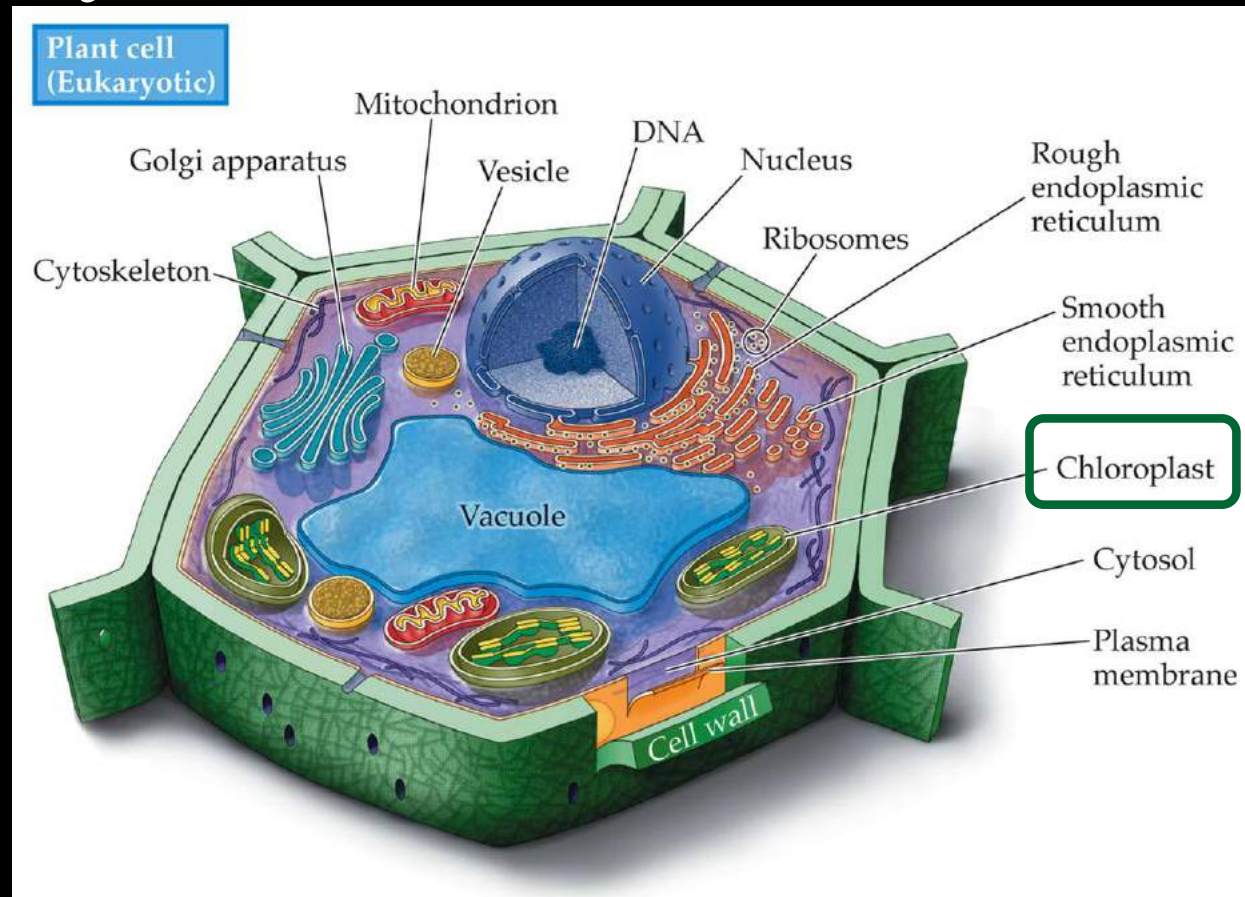


Evidence for Evolution

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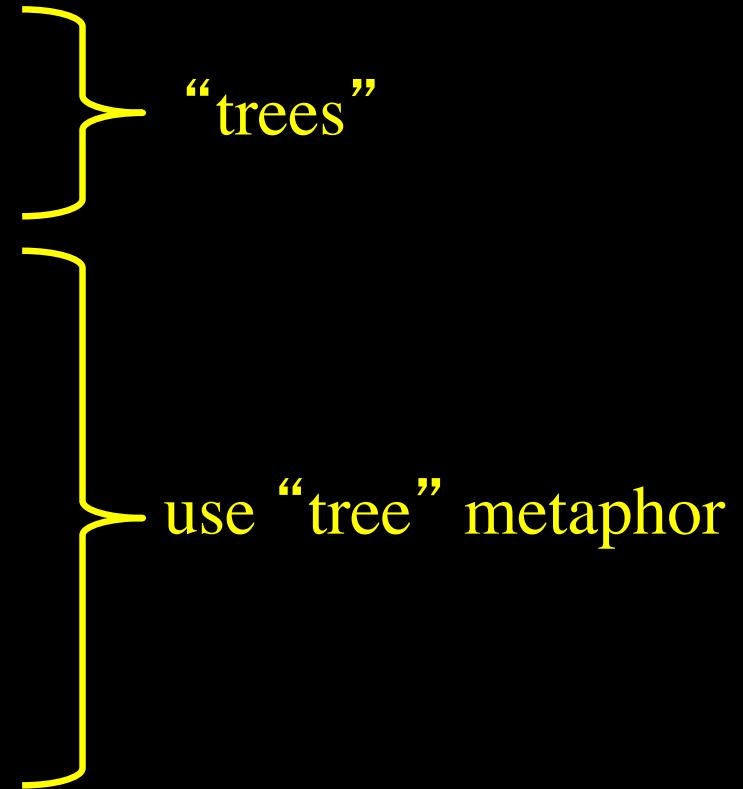
Theodosius Dobzhansky

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



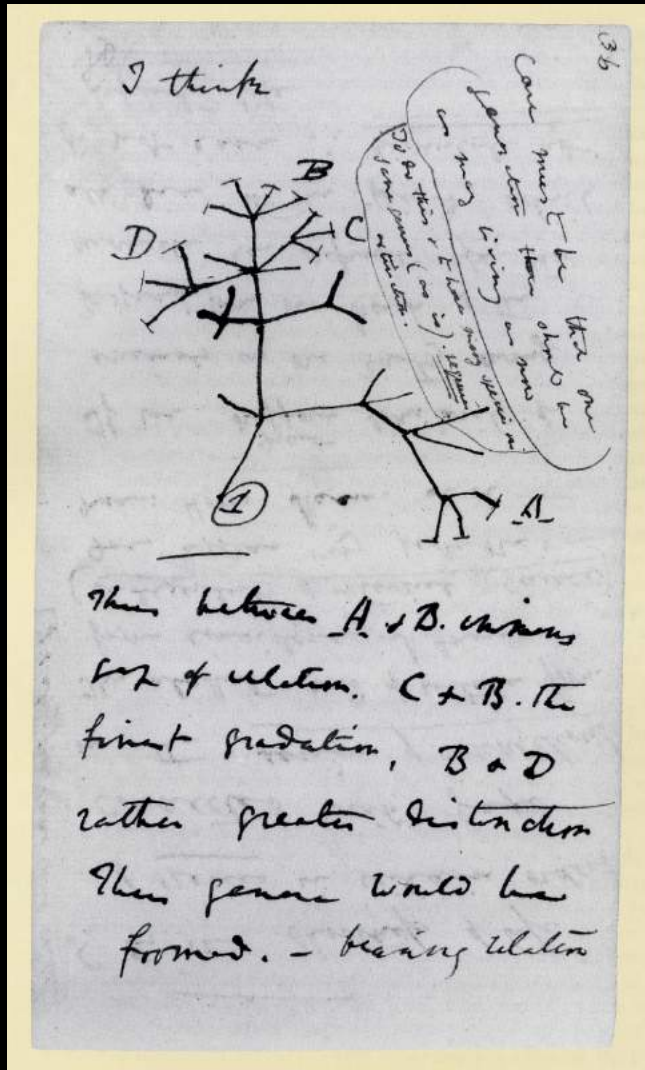
Evidence for Evolution - Common Ancestry

- Classification ✓
- Hierarchical distribution of traits ✓
- Homology ✓
- Vestigial Structures ✓
- Fossil record ✓
- Biogeography ✓
- Variation among populations ✓
- Speciation ✓
- Agreement between gene trees ✓



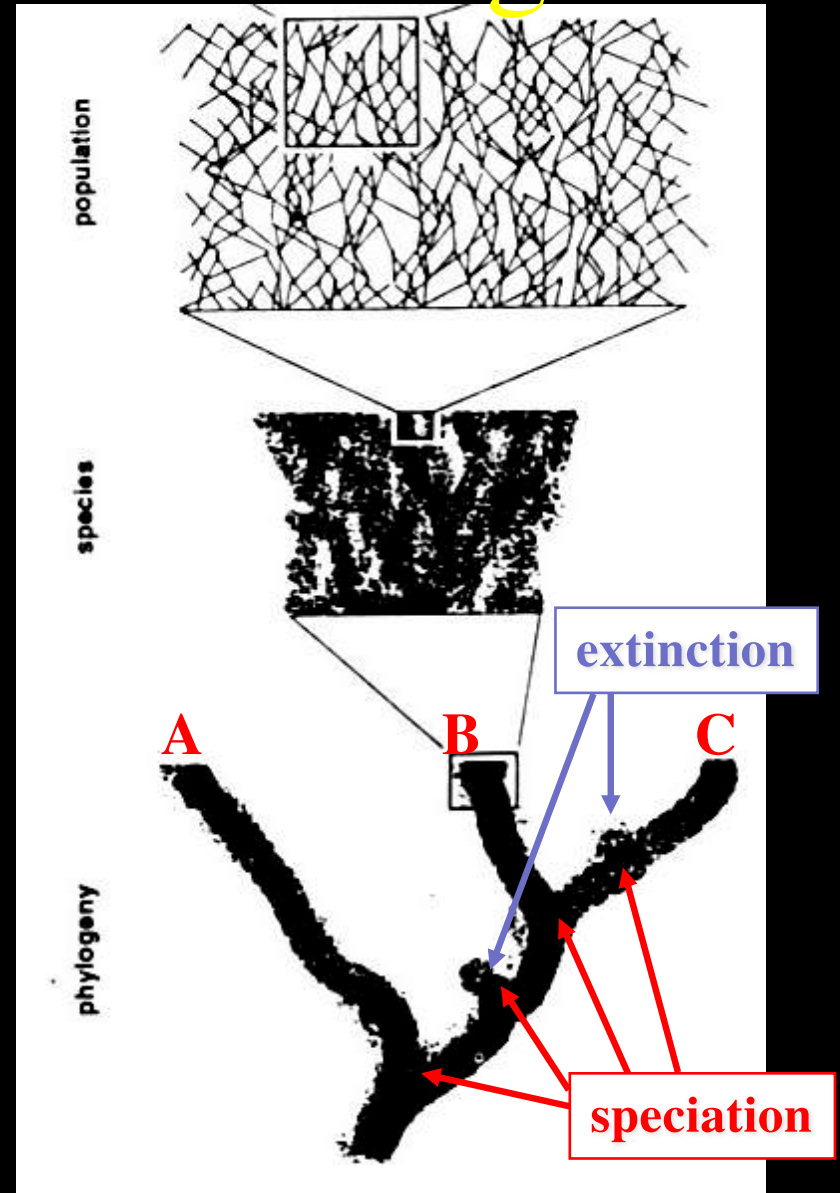
✓ = examined in this course to various degrees

Darwin's "Tree Thinking"



Darwin's 1st species notebook (1837)

back in time

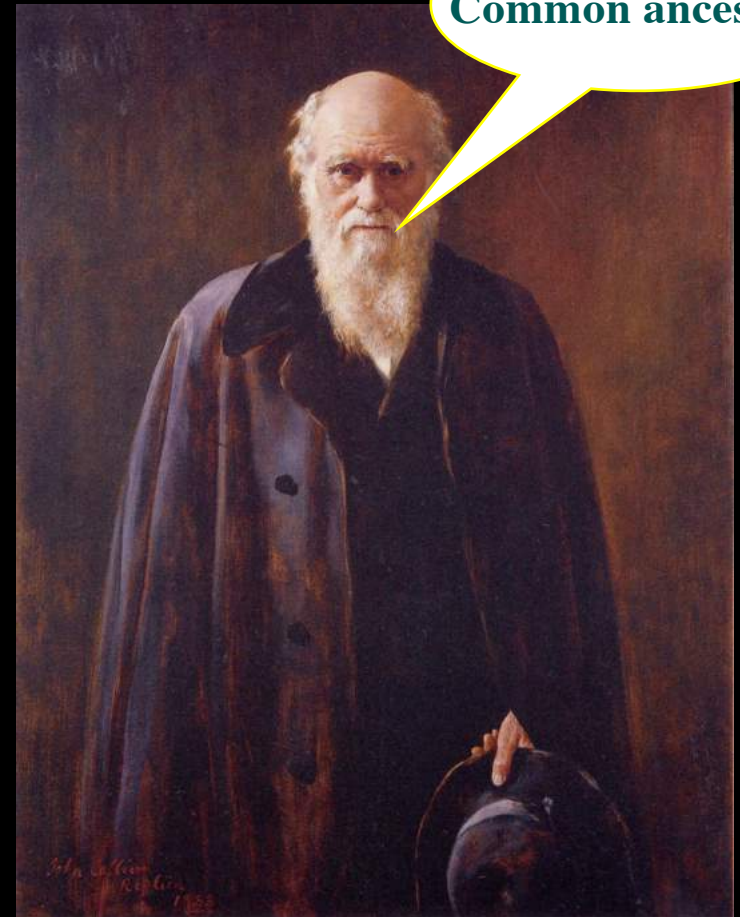


1. Hierarchical Classification

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**



Common ancestry!

1. Hierarchical Classification

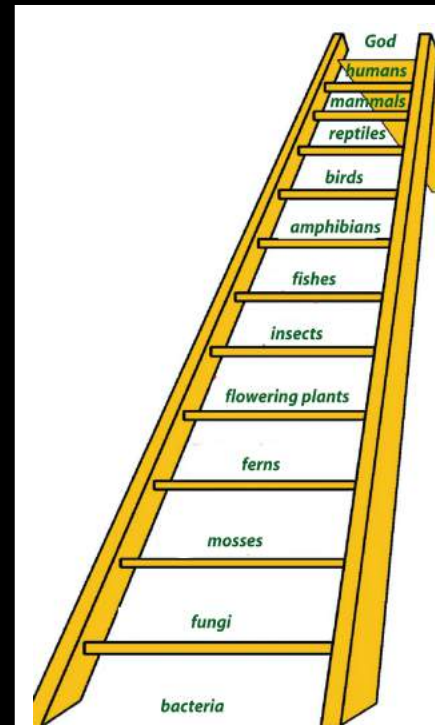
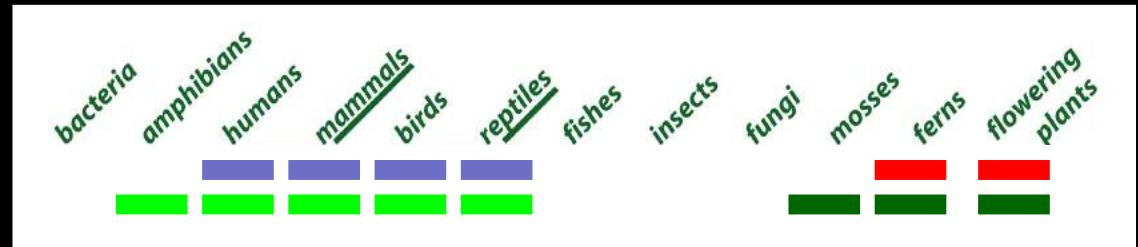
 *Vascular tissue*

 *Chloroplasts*

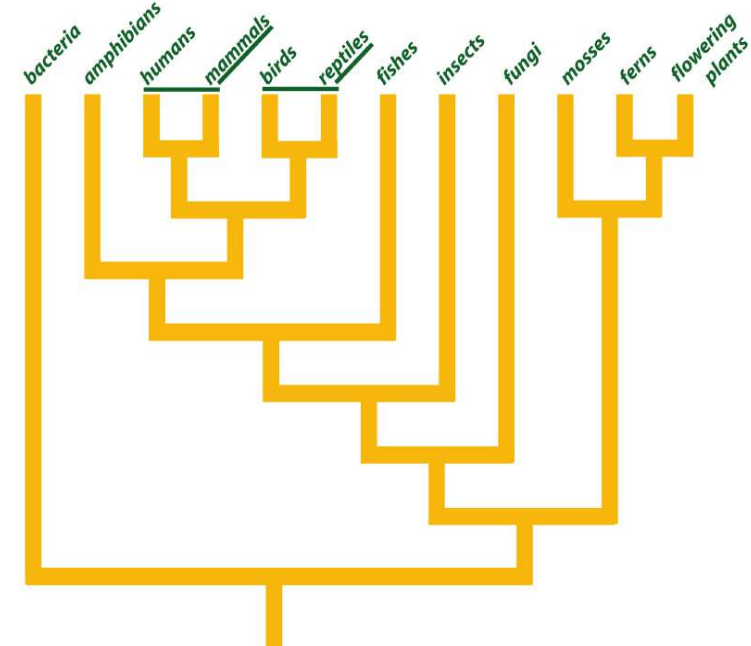
 *Water-tight egg*

 *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

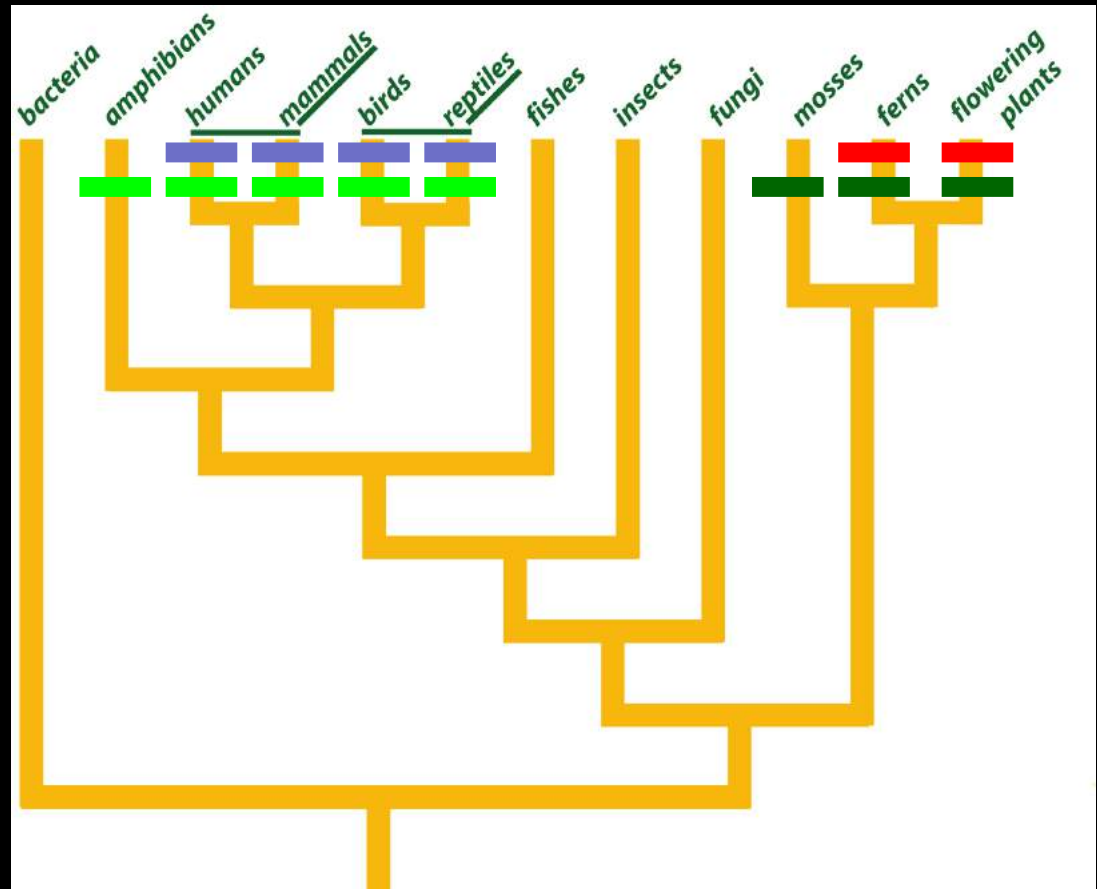


Phylogenetic Tree

1. Hierarchical Classification

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

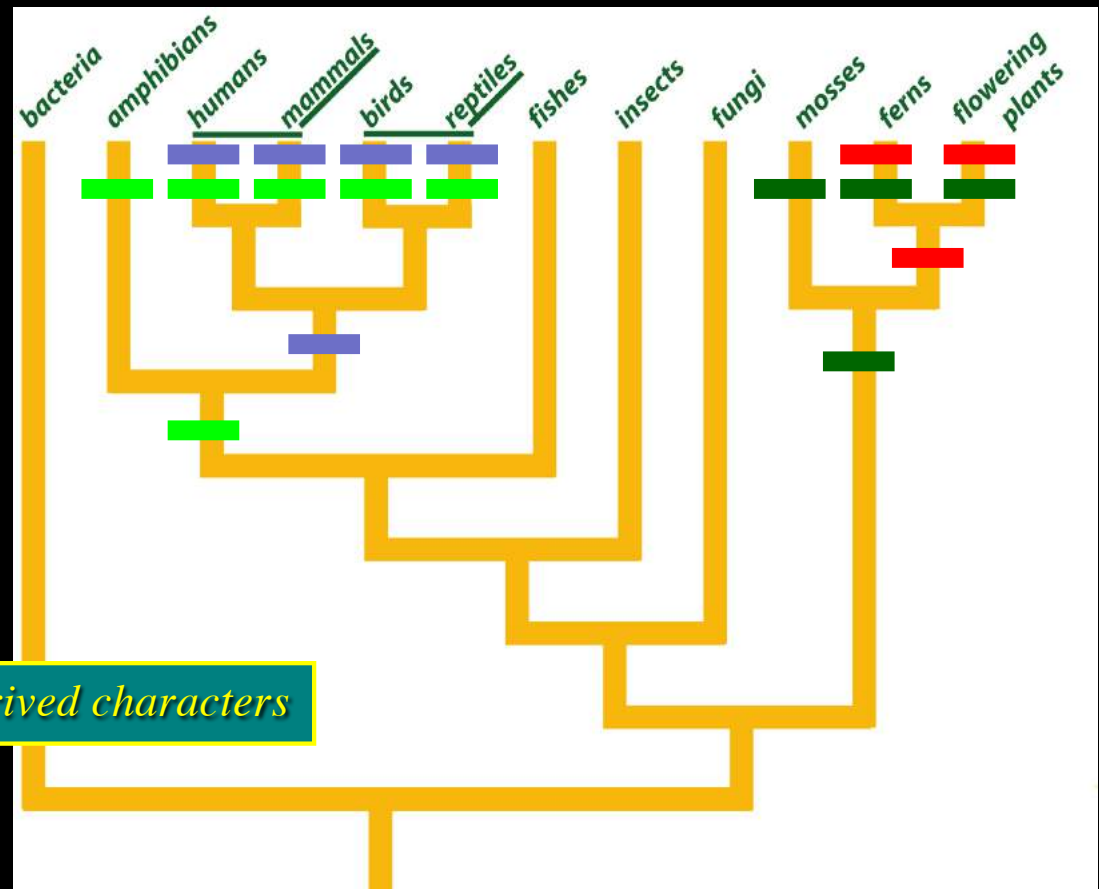
- *Vascular tissue*
- *Chloroplasts*
- *Water-tight egg*
- *Four limbs*



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



■ *Vascular tissue*

■ *Chloroplasts*

■ *Water-tight egg*

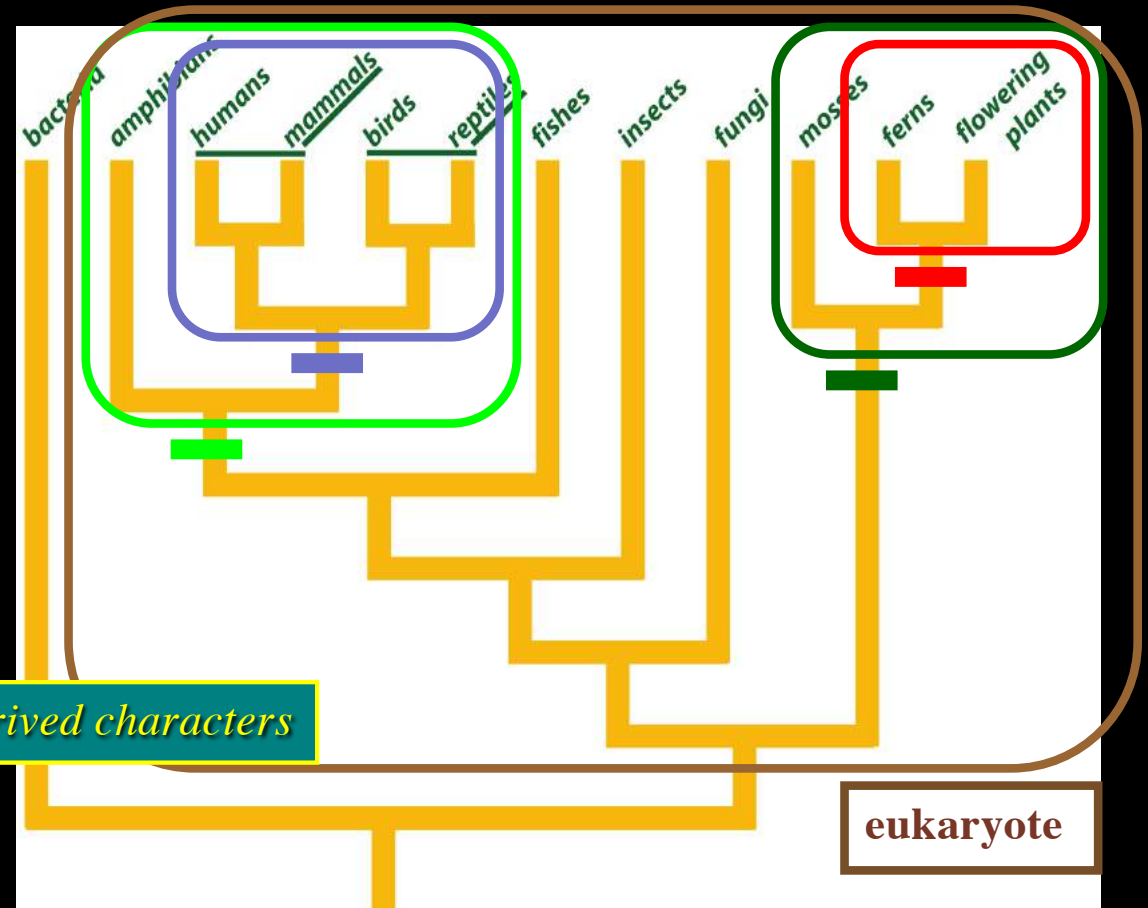
■ *Four limbs*

= shared-derived characters

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



Vascular tissue

Chloroplasts

Water-tight egg

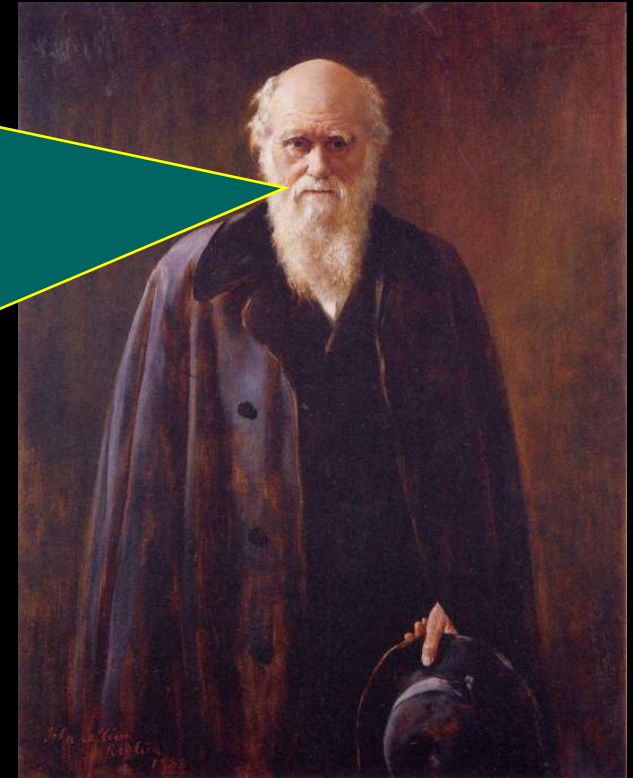
Four limbs

= shared-derived characters

eukaryote

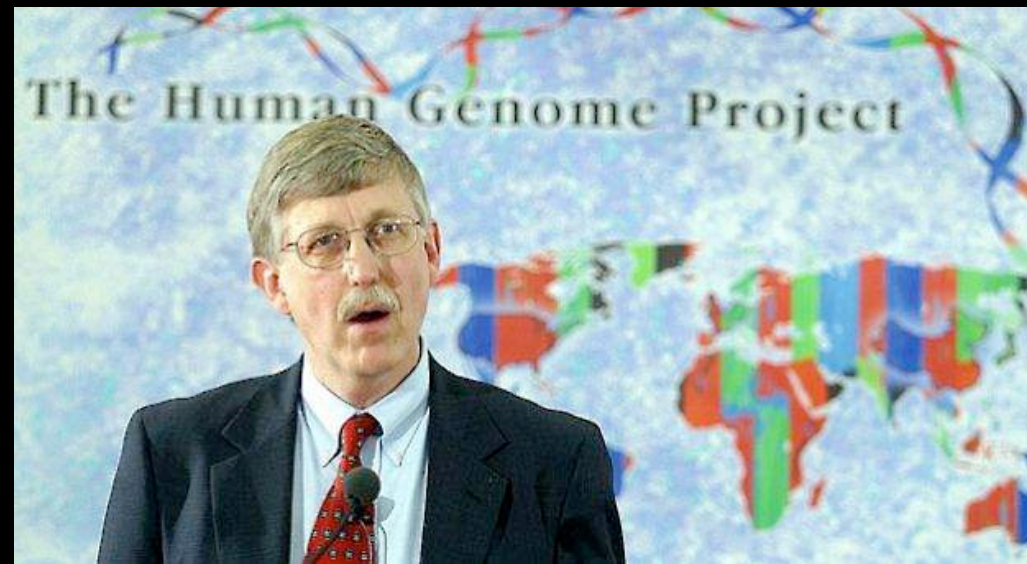
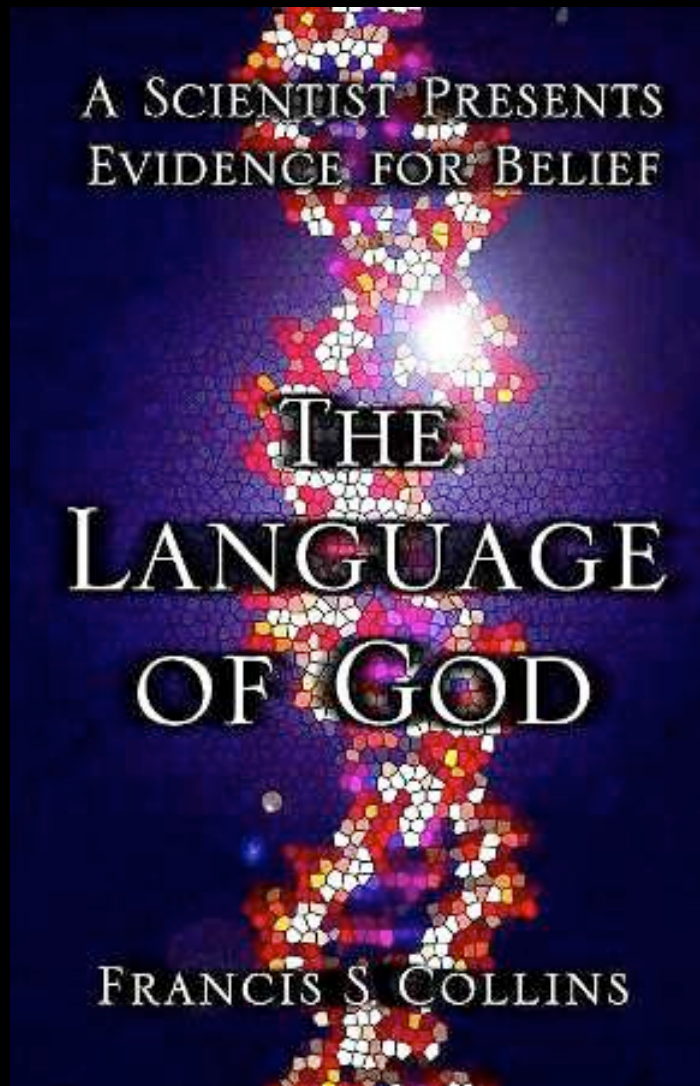
Tree of Life & Special Creation

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.**"

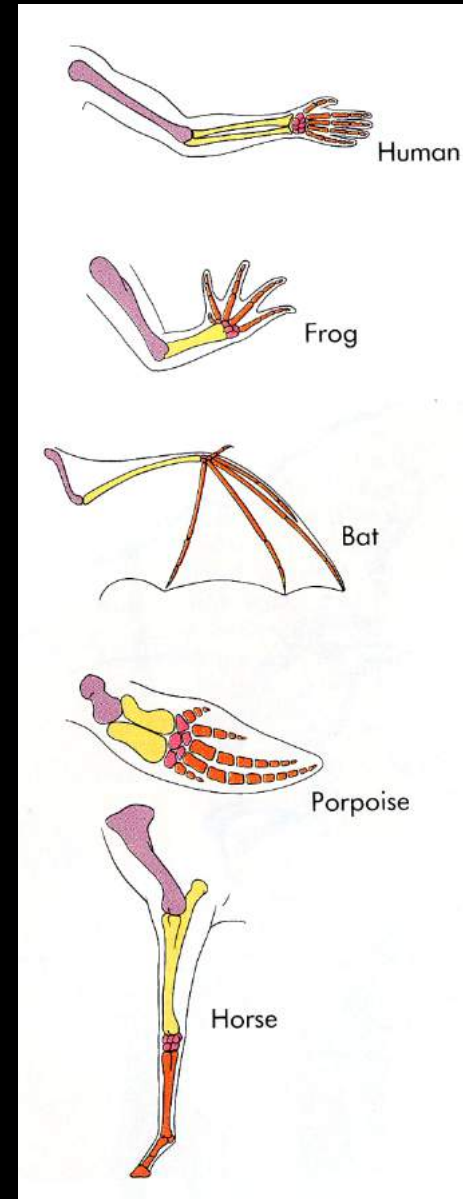
2. Evidence through Homology

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



grasping

leaping

flying

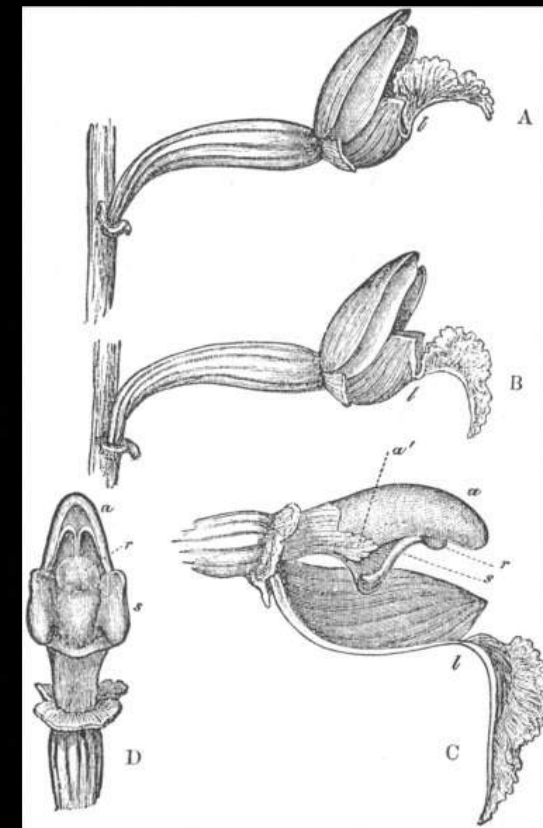
swimming

running

2. Evidence through Homology

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

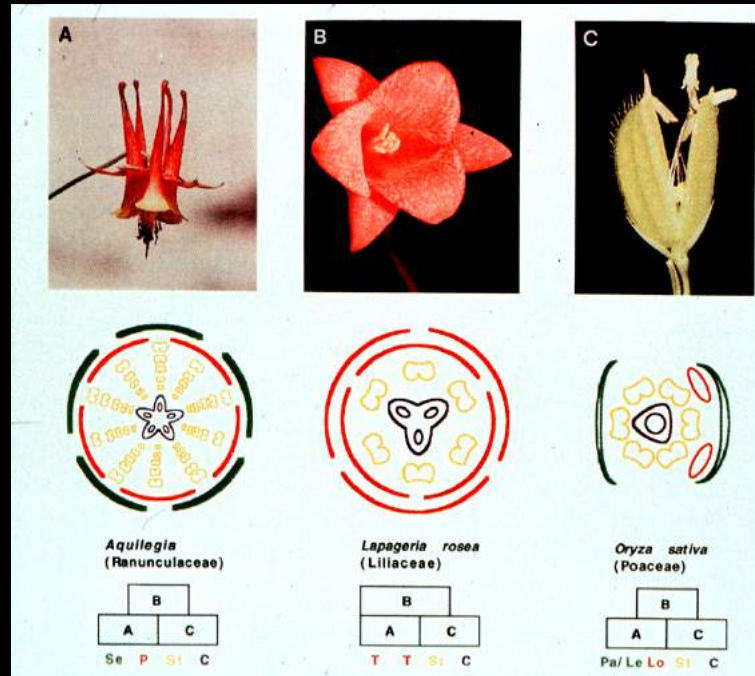
- Darwin's work on orchids convinced him that **all species possess the basic homologous floral parts**
- although these are **highly modified** for roles in quite **different pollination systems**



2. Evidence through Homology

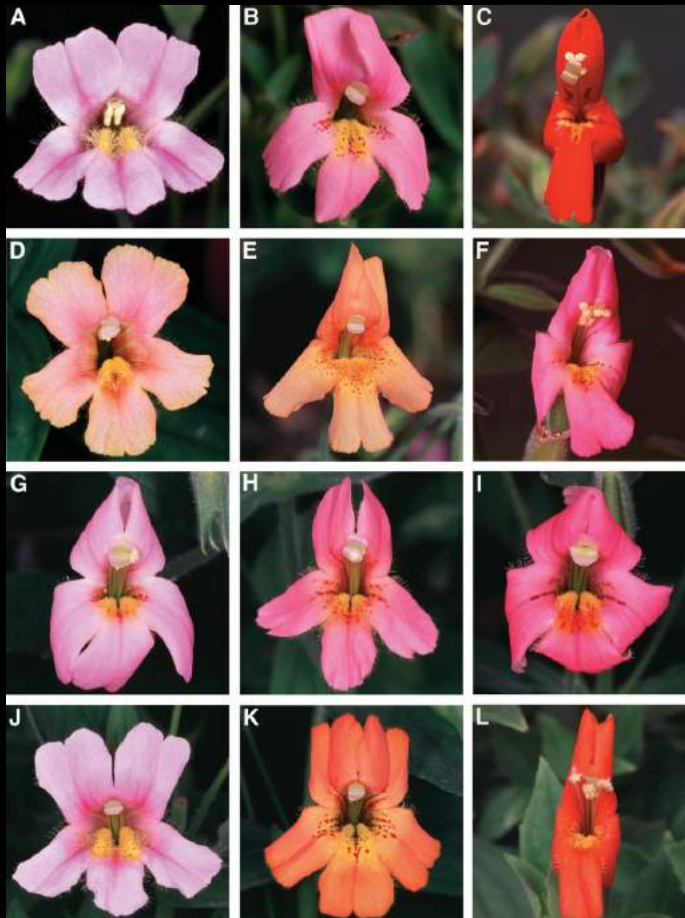
EvoDevo studies now provide **genetic bases** for the homology (or not) of basic features in plants and animals

And how they have been **modified**

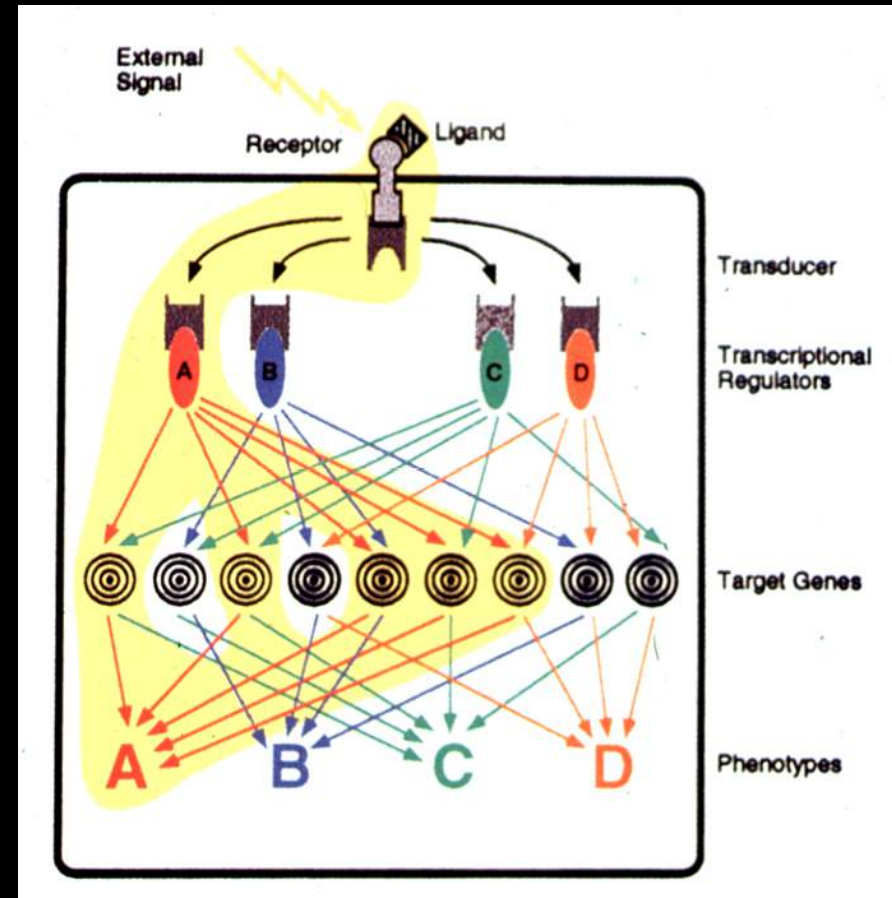


ABC model of floral identity

2. Evidence through Homology



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



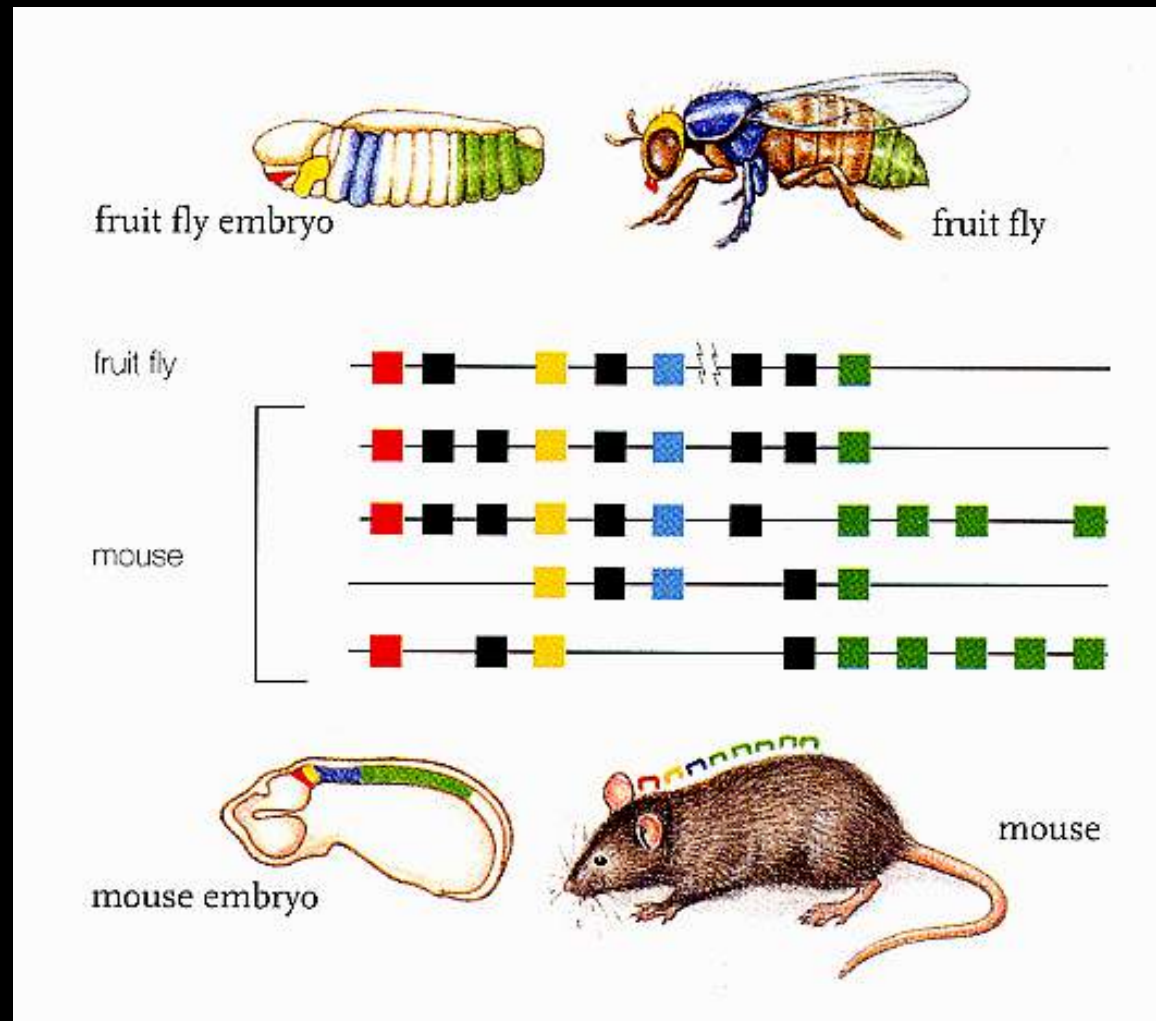
- **transcription factors** not structural genes important in trait differences

2. Evidence through Homology

Molecular tinkering - major process for forming the diversity of life

Hox Genes - EvoDevo

Gene family, spatial organization, development

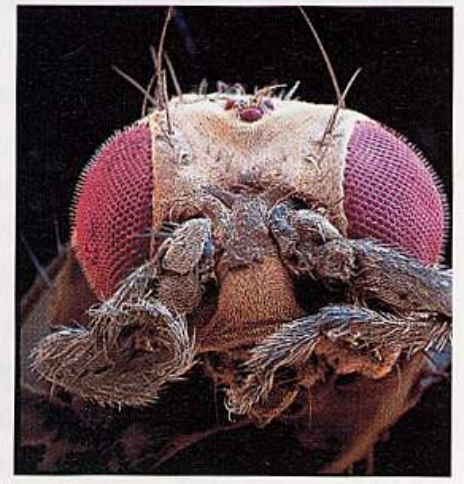


2. Evidence through Homology

Molecular tinkering - major process for forming the diversity of life

Hox Genes - EvoDevo

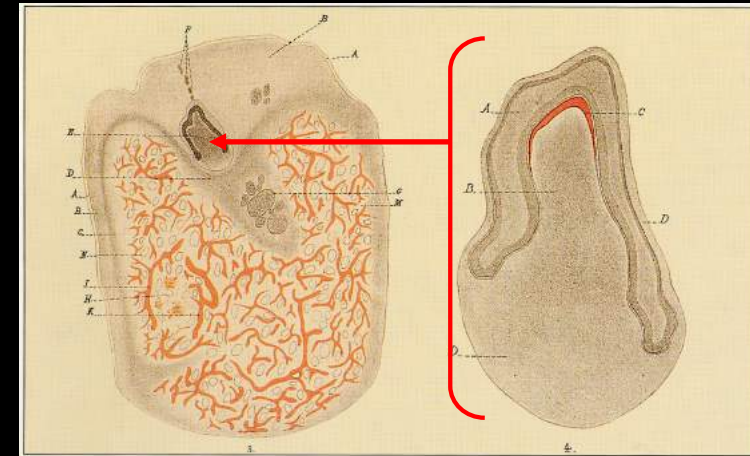
Halteres into wings
Antennae into legs



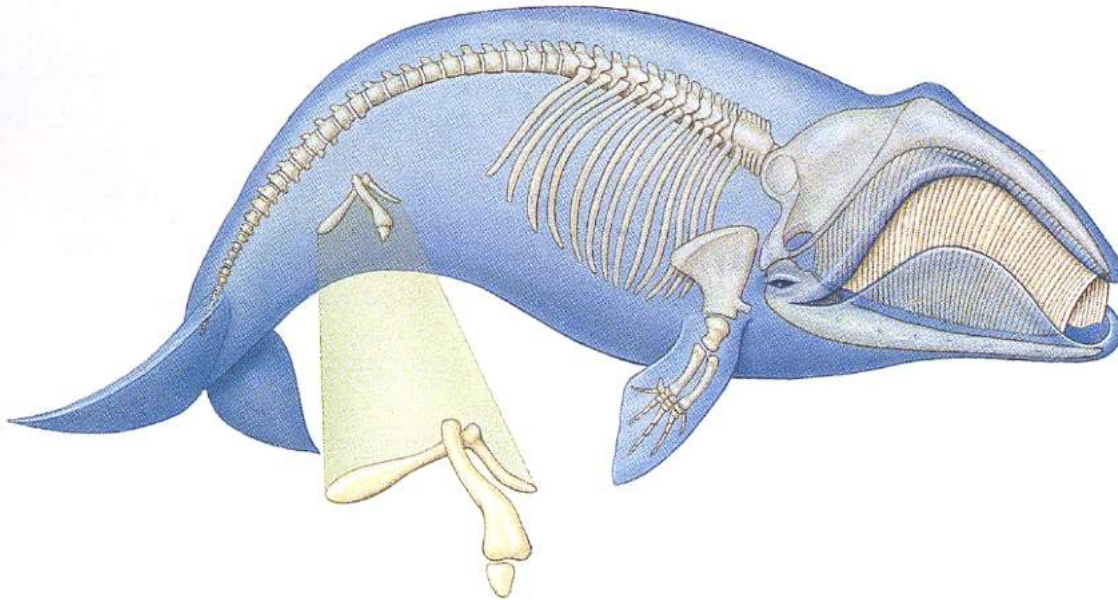
3. Vestigial Structures

Vestigial structures — homologous parts

Evolution predicts that species occupying very distinct environments from that of a common ancestor might show **vestigial** structures



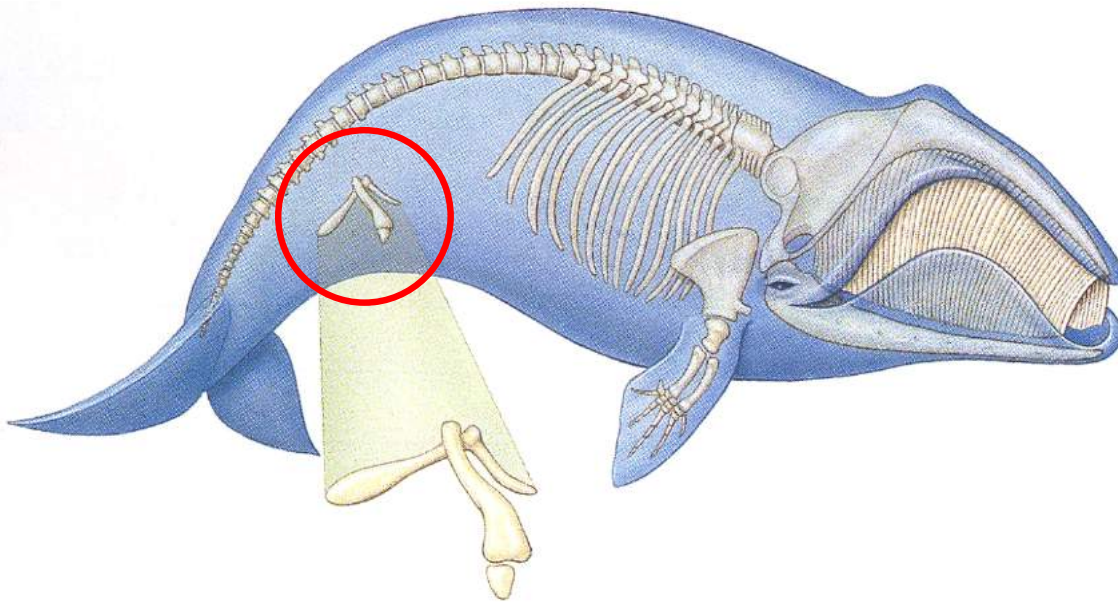
Rudimentary tooth in lower jaw of a baleen whale



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

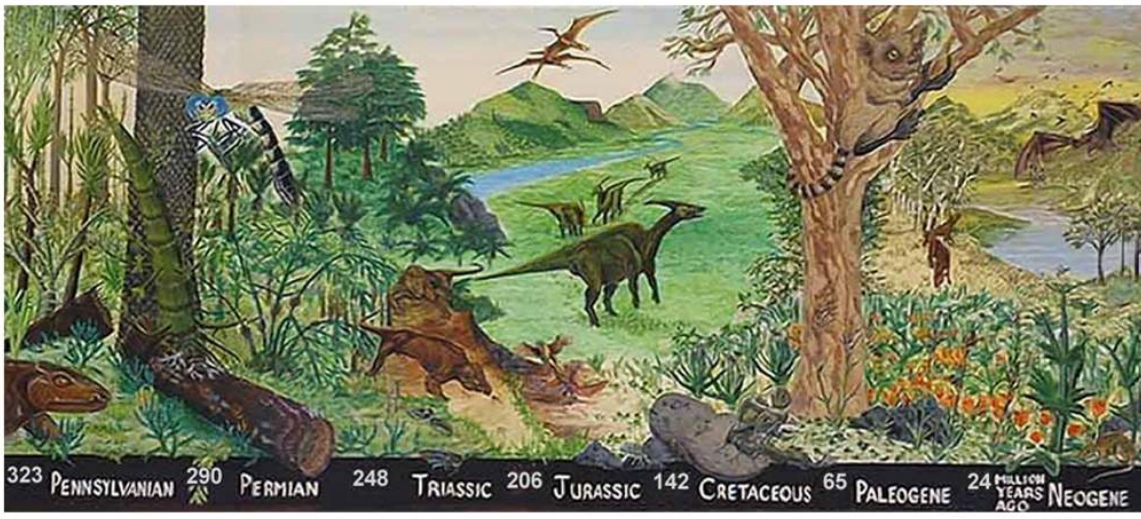


Cuscuta - dodder



4. Fossil Record

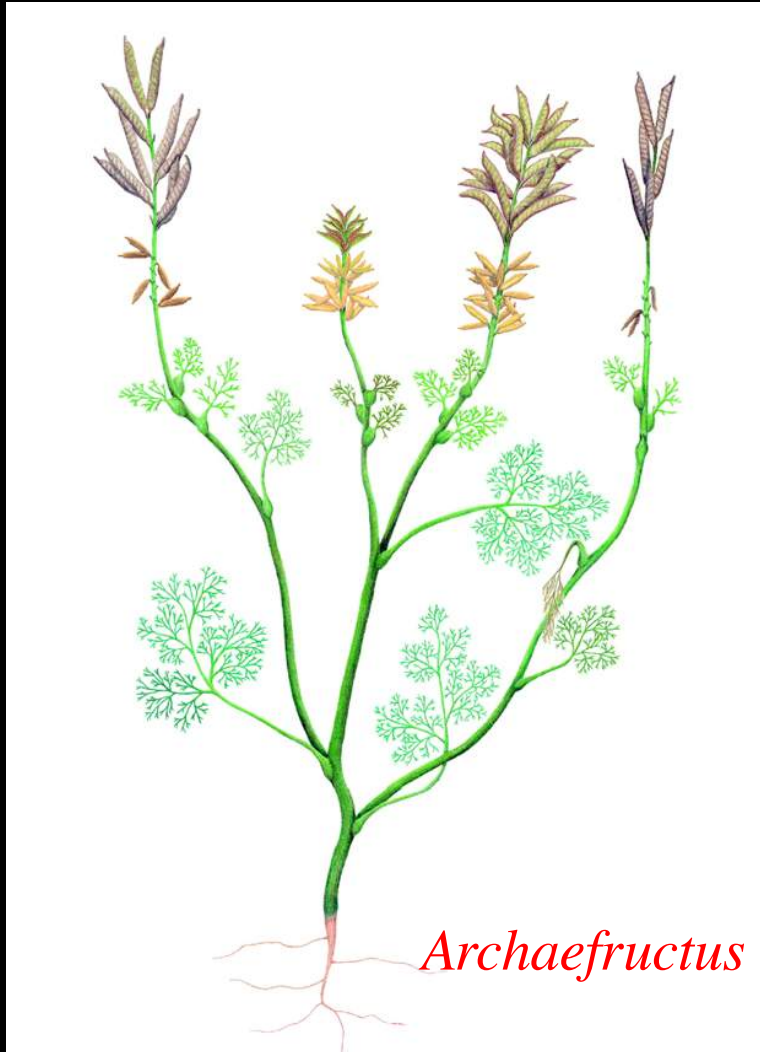
‘Missing links’ — transitional forms



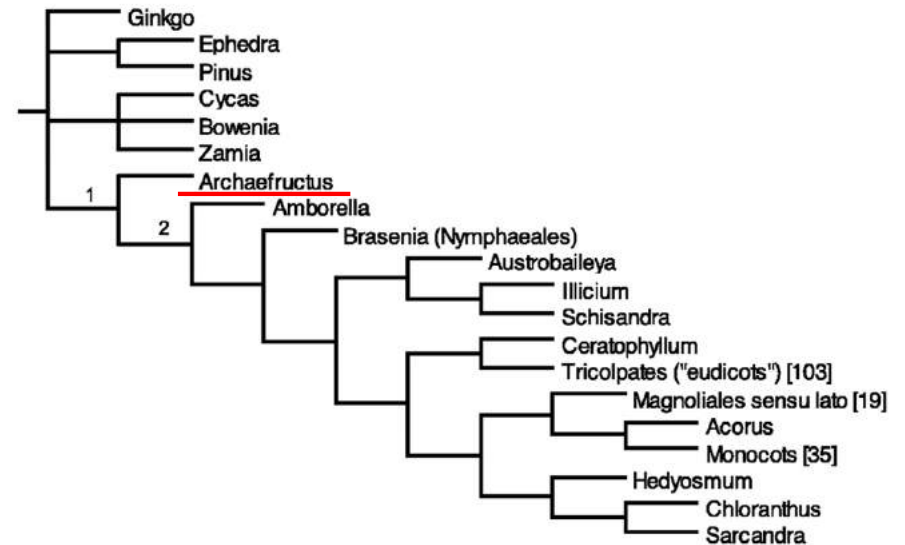
- fossil record is **rich** & **consistent** with information from hierarchical relationships based on morphology and DNA

4. Fossil Record

‘Missing links’ — transitional forms



- *Archaeofructus* 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*



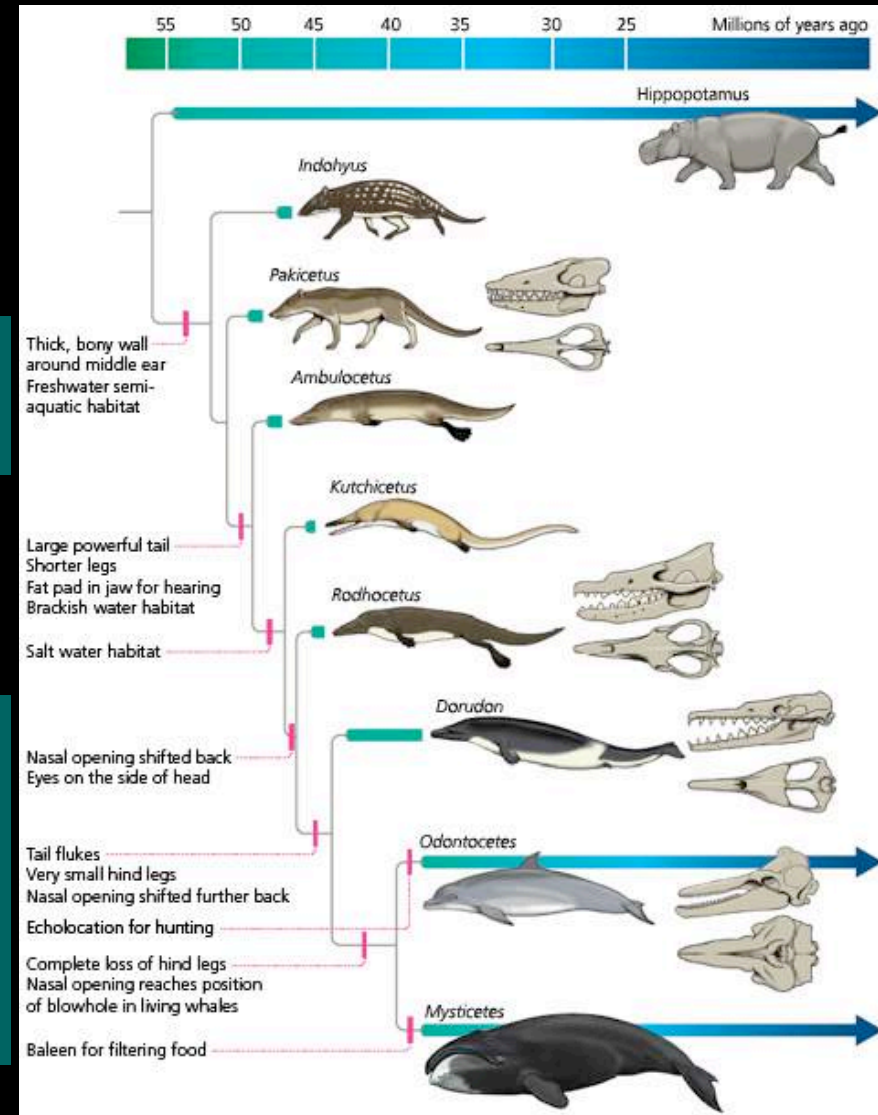
4. Fossil Record

- 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

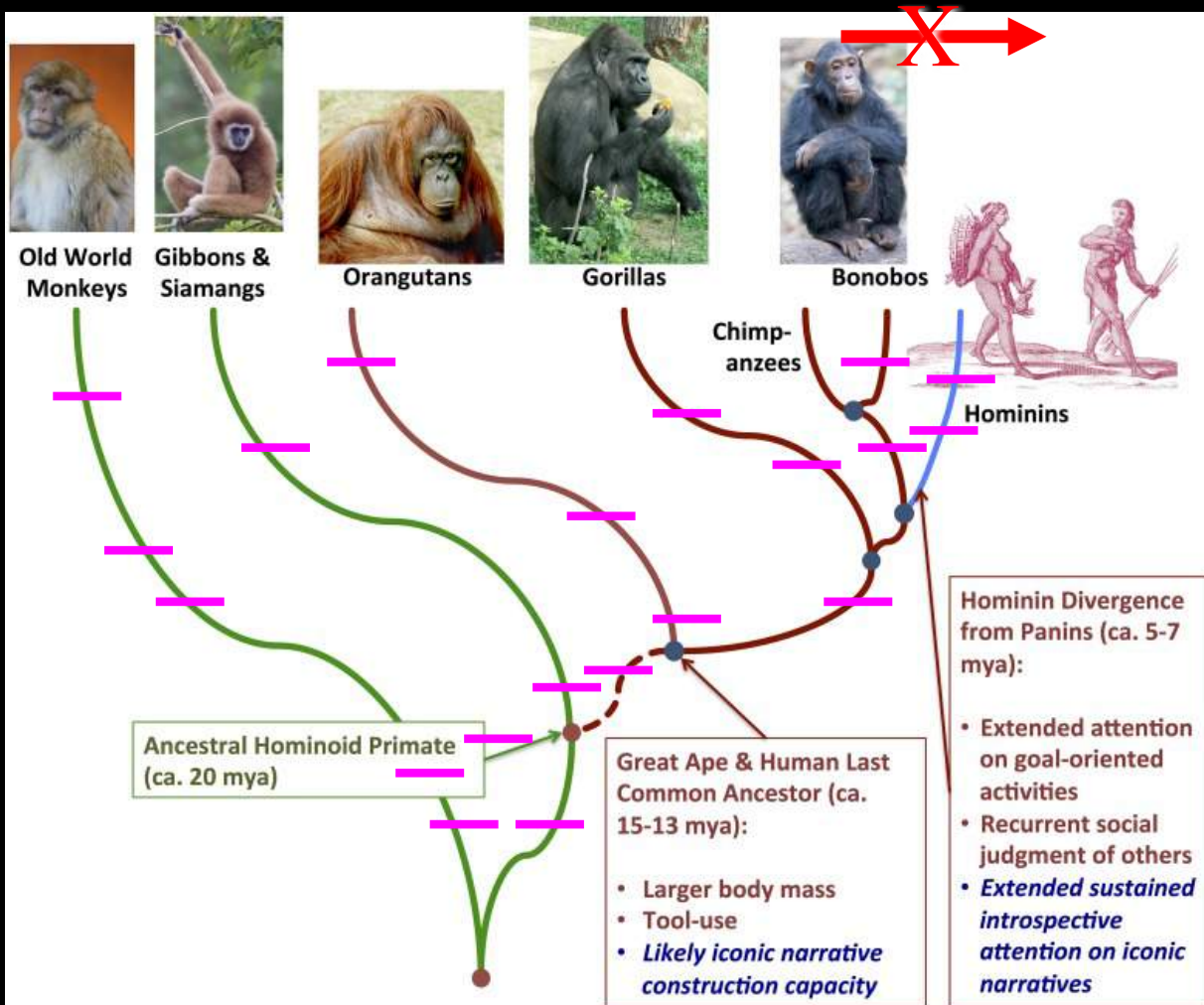
Paleontologist Phil Gingerich with 40 my old *Basilosaurus* with small hind legs in Egypt



4. Fossil Record

‘Missing links’ — transitional forms

- what should ‘missing links’ look like?



- intermediate between chimps and humans?

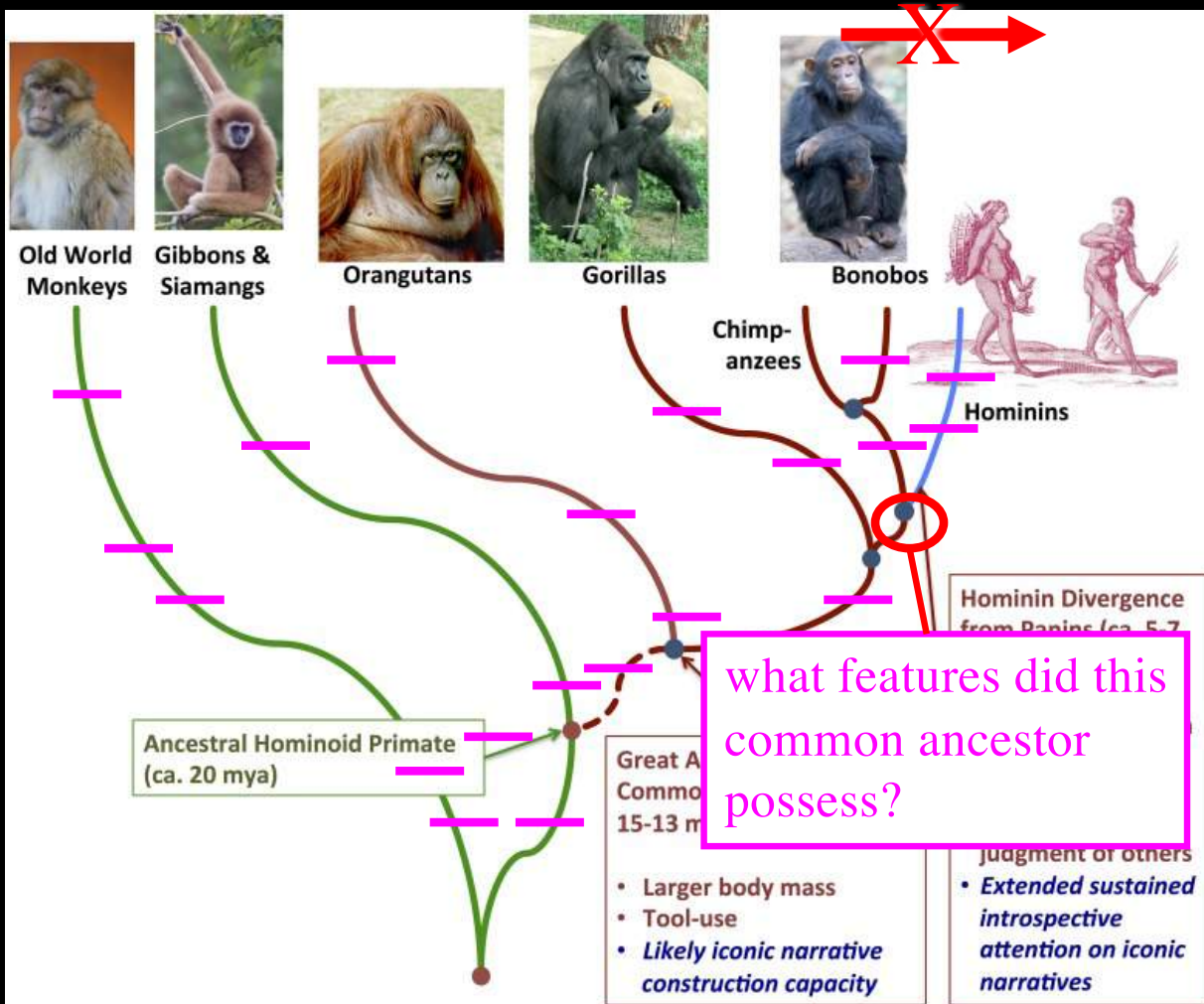
- No! that is ‘ladder of life’ or “progression” thinking

- 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

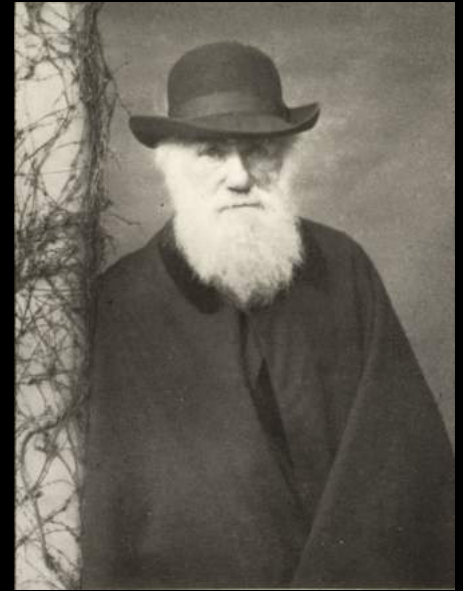
" . . . that grand subject, that almost keystone of the laws of creation, **Geographical Distribution**"

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."

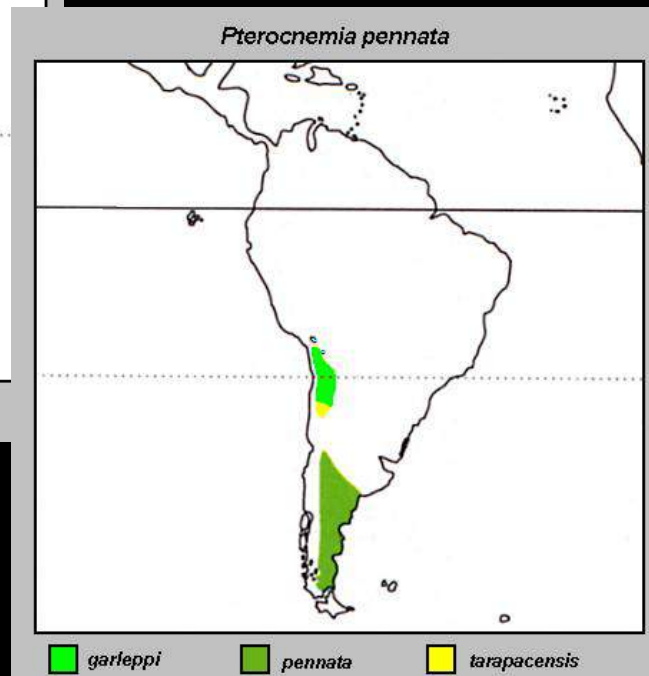
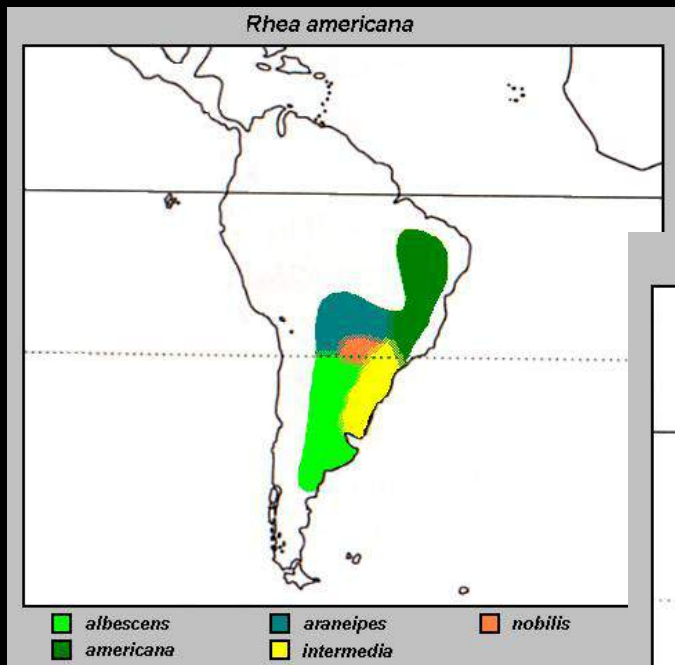
Thomas Huxley after reading the *Origin of Species*



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

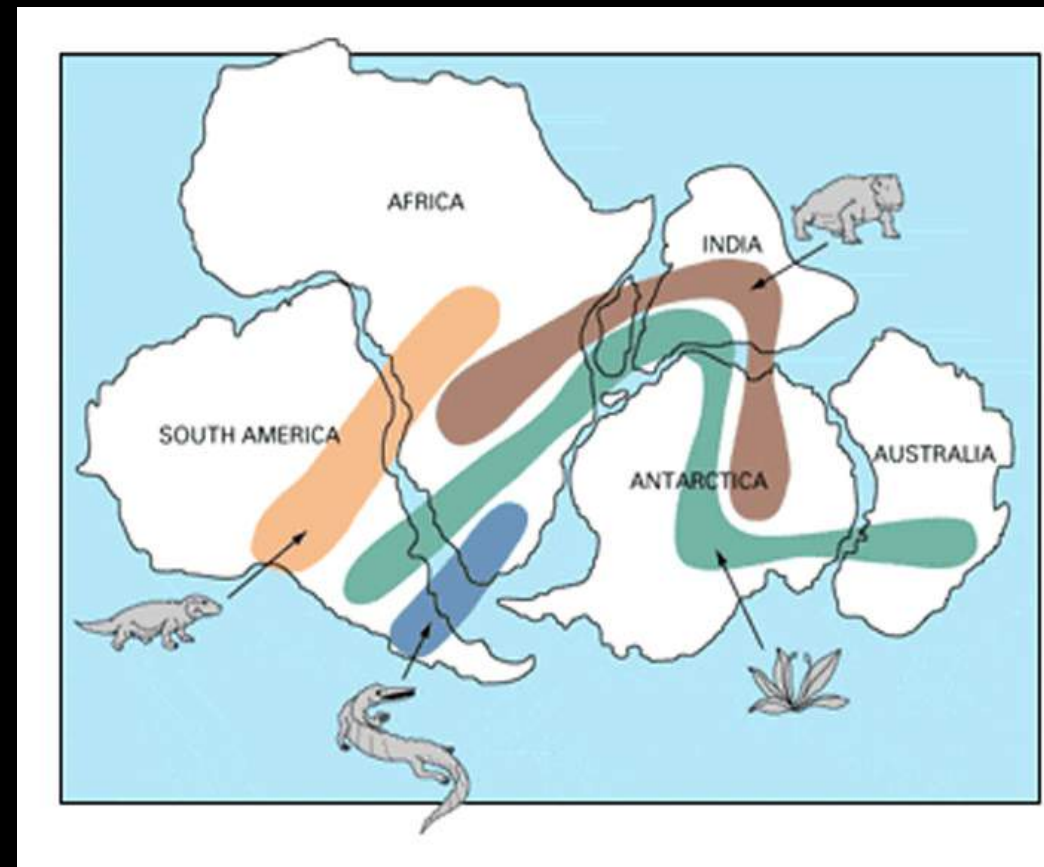
Distributions of organisms, extant and extinct, provided the first evidence in 1920 for the then heretical idea of continental drift

Glossopteris - Permian “fern”

Mesosaurus - Permian freshwater reptile

Cynognathus - Triassic land reptile

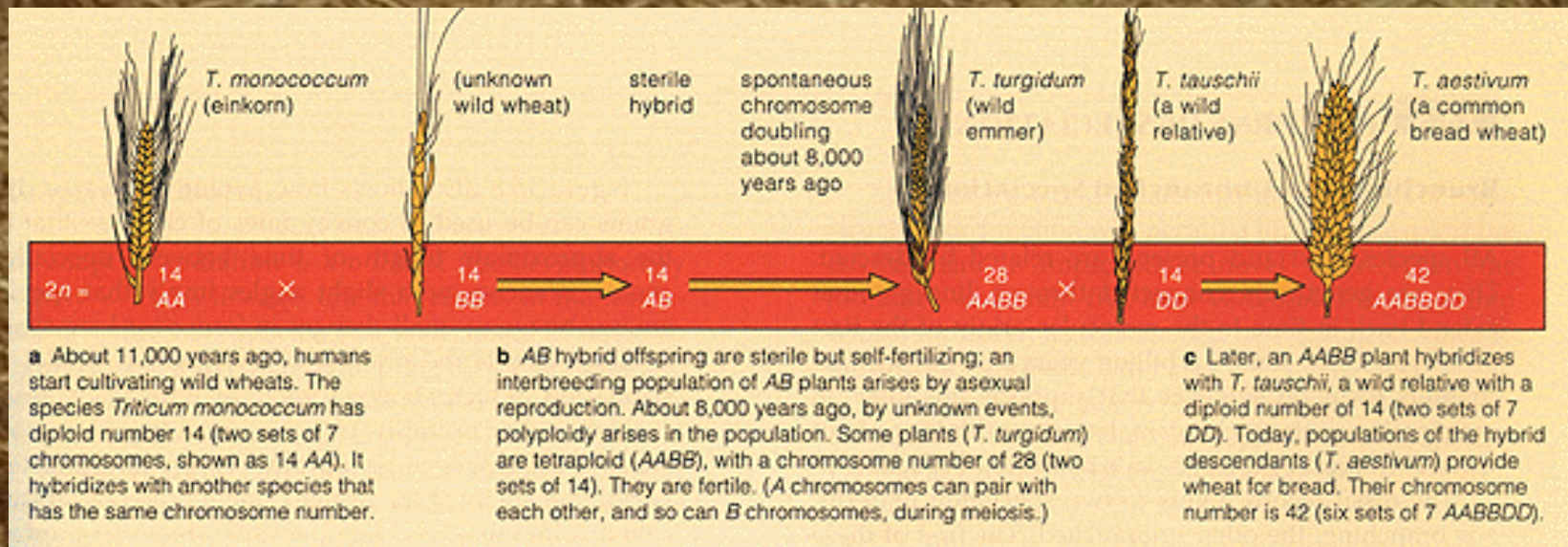
Lystrosaurus - Triassic land reptile



6. Direct Observation

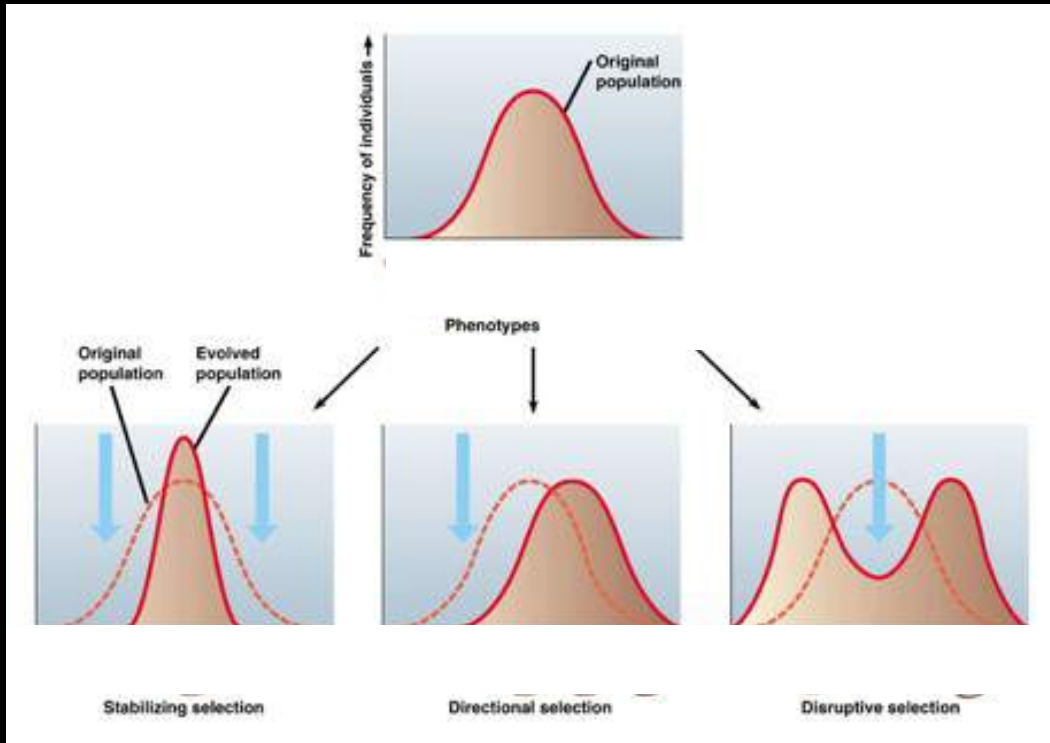
Evolutionary change in formation of crop plants

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

**HAWAII'S
BIRDS**

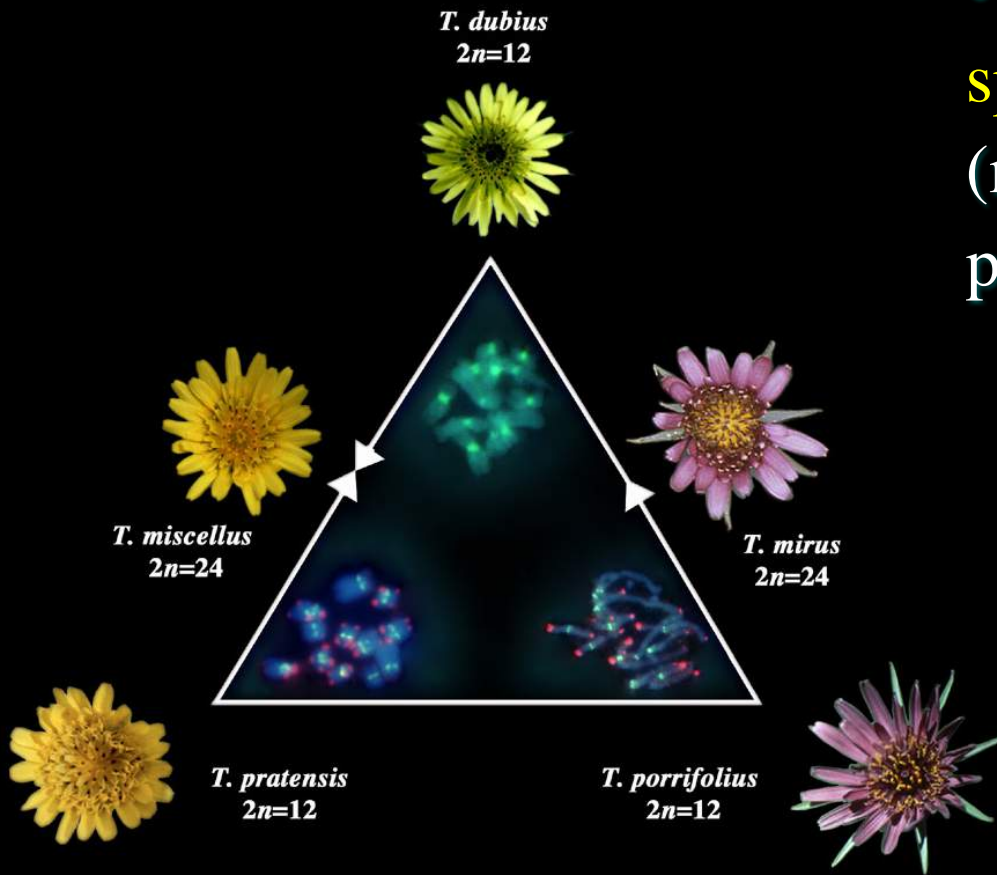


Directional selection in size of o'hia flowers in 150 years due to loss of long-beaked honeycreeper species

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. paradoxa



Helianthus anomalus

Re-synthesized in
the lab

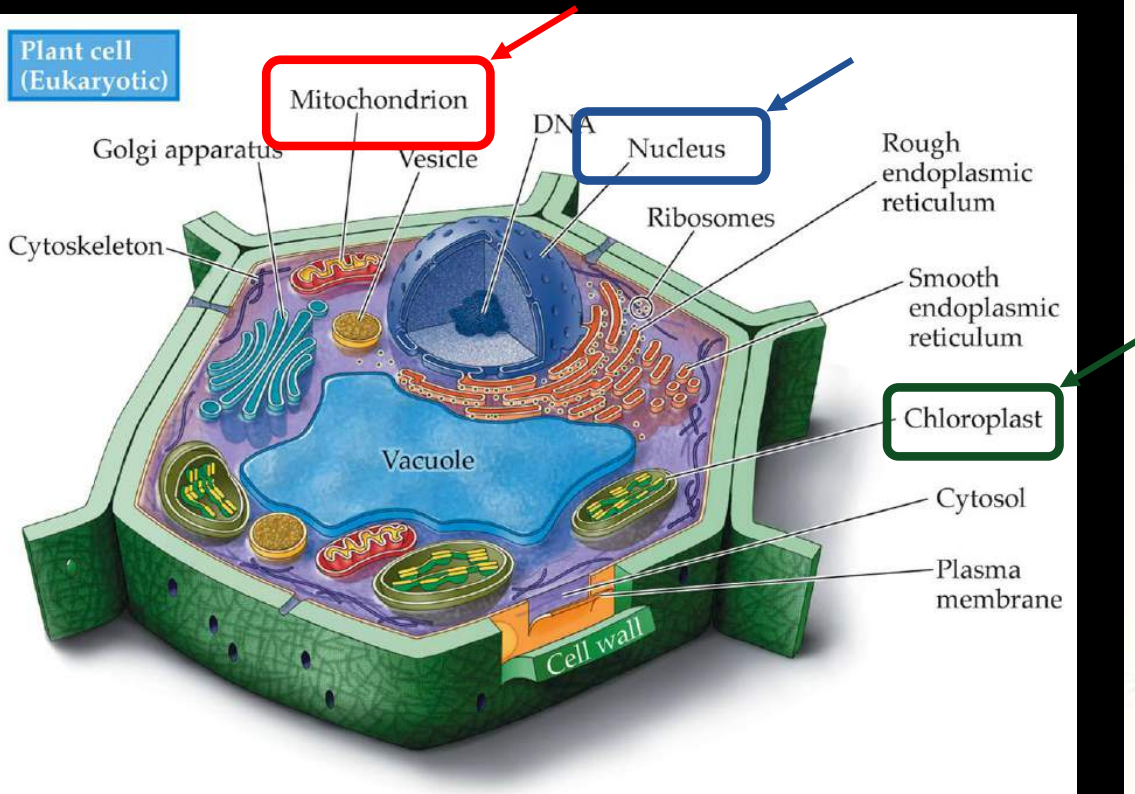


Loren Rieseberg

7. Molecular Evolution

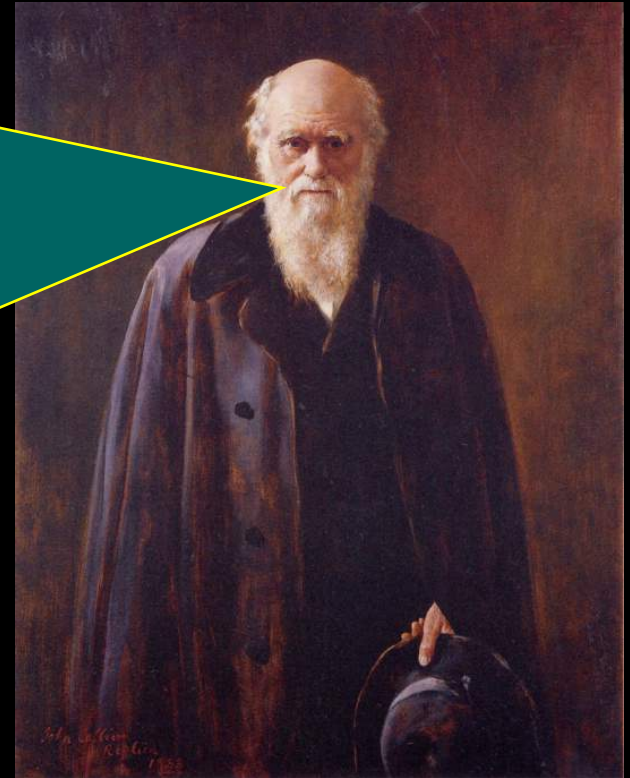
Organisms contain within themselves
a “DNA fossil footprint”

... 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.