

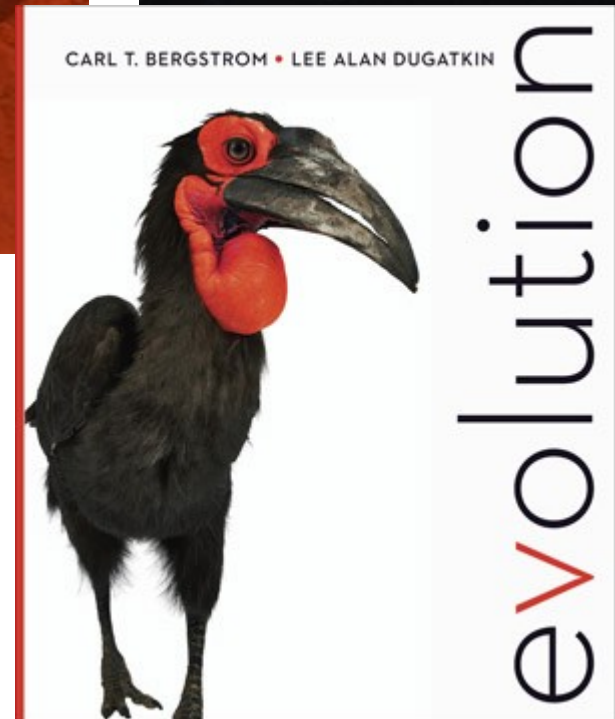
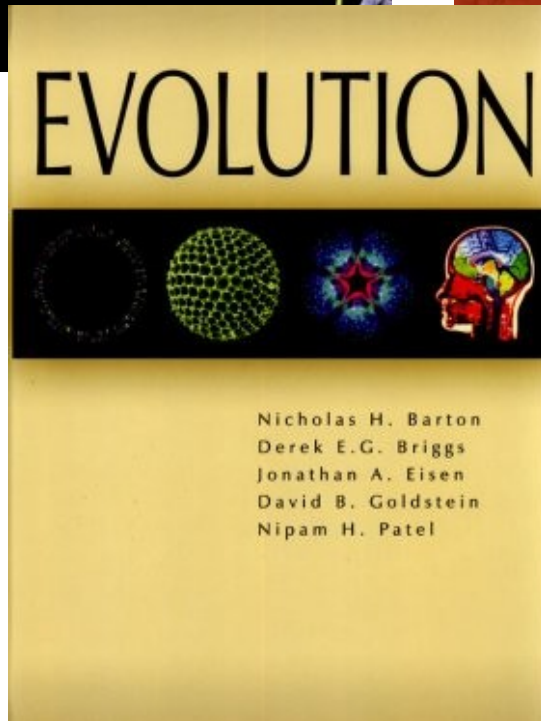
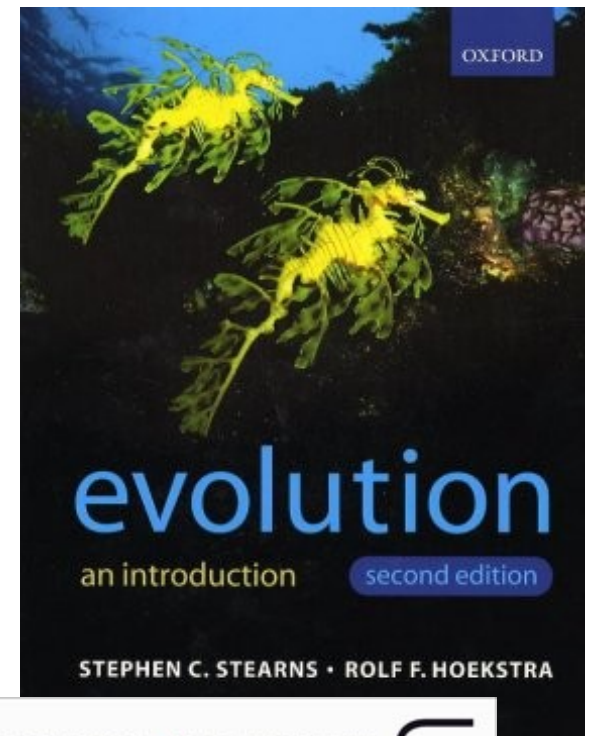
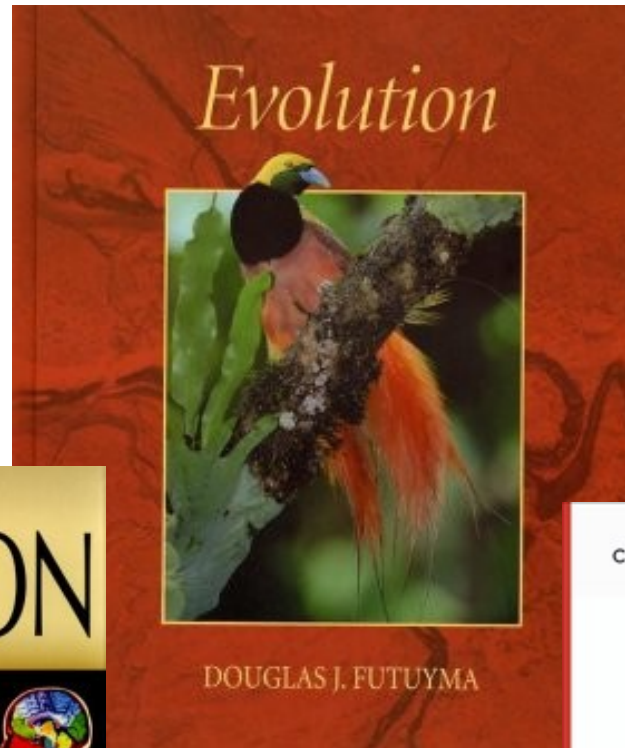
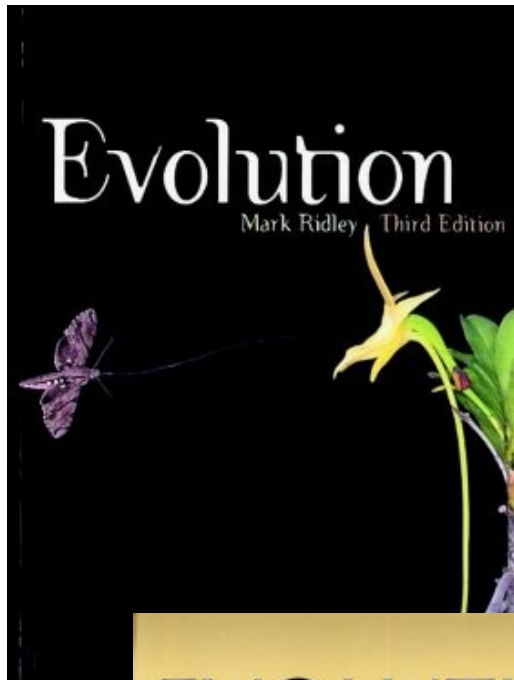


EVOLUTIONARY BIOLOGY

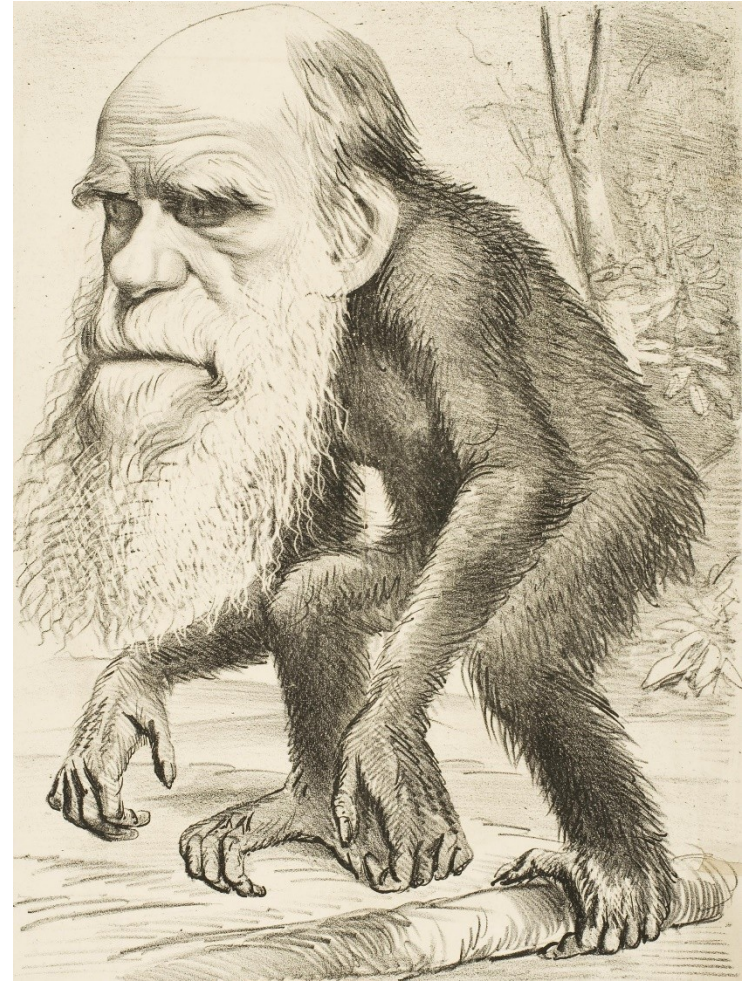
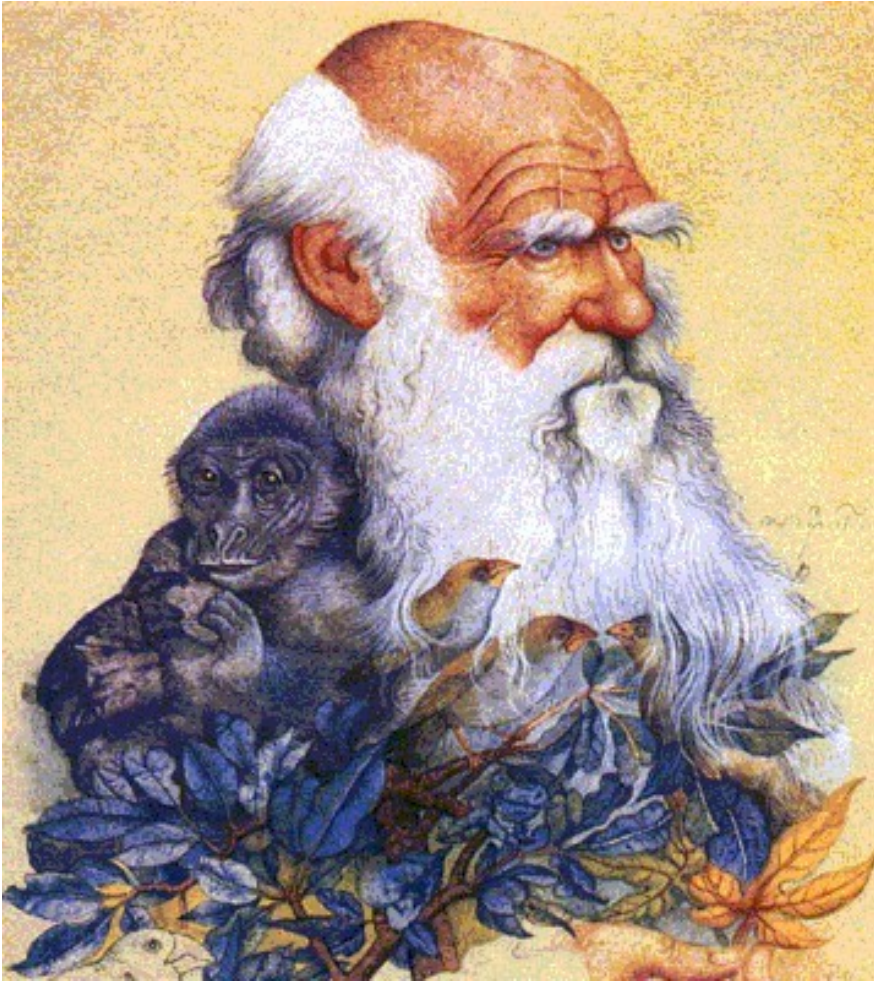
Miloš Macholán

Laboratory of Mammalian Evolutionary Genetics
Institute of Animal Physiology and Genetics, CAS
Veverří 97, 602 00 Brno
e-mail: macholan@iach.cz

Textbooks



EVOLUTION AND EVOLUTIONARY BIOLOGY

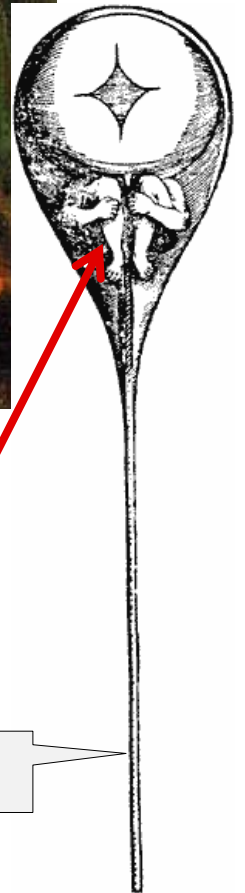


EVOLUTION (*evolvere, evolutio*) = unfold, unfolding (of a scroll of papyrus)

Albrecht von Haller (1774):

development of individual embryo

essentially ontogenetic development
according to a preset programme
(~ preformationism)

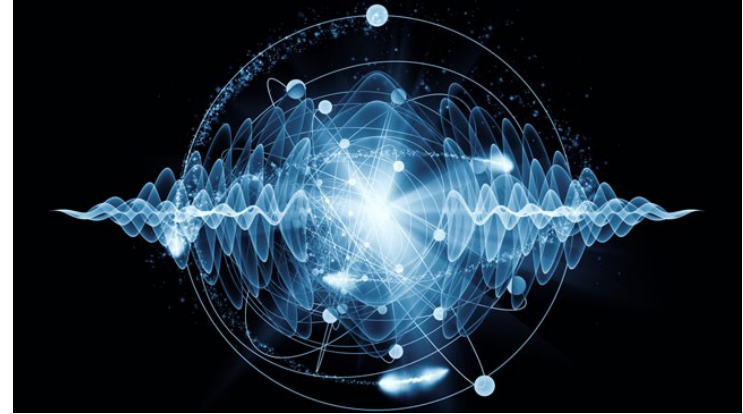


embryo

spermatozoon

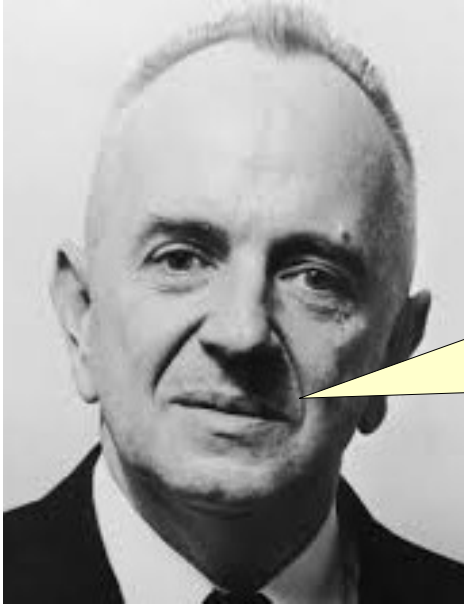
in a broad sense = **change**

(politics, economy, technology, scientific theories etc.)



BIOLOGICAL EVOLUTION = heritable change in the properties of populations of organisms over the course of generations
structure, function and organization of organisms or their parts,
behaviour and mutual relationships

CULTURAL EVOLUTION



Nothing in biology makes sense except in the light of evolution.

T. Dobzhansky (*American Biology Teacher*, 1973)

EVOLUTIONARY BIOLOGY

= scientific field studying principles of
biological evolution

properties and mechanisms of evolutionary process

PROPERTIES OF BIOLOGICAL EVOLUTION

living systems (reproduction, variability, inheritance)

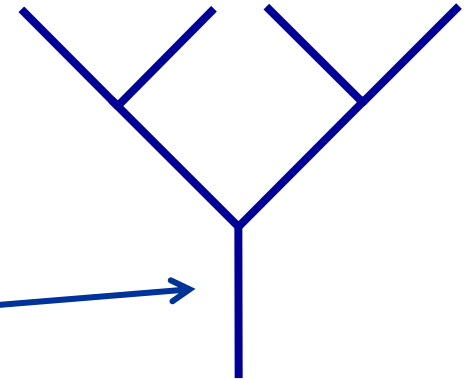
thermodynamic openness, dissipation^{*)}

systems with memory \Rightarrow **cumulation of changes**

unlimited heritability

adaptation, purposeful arrangement

cladogenesis



^{*)} = irreversible change of energy

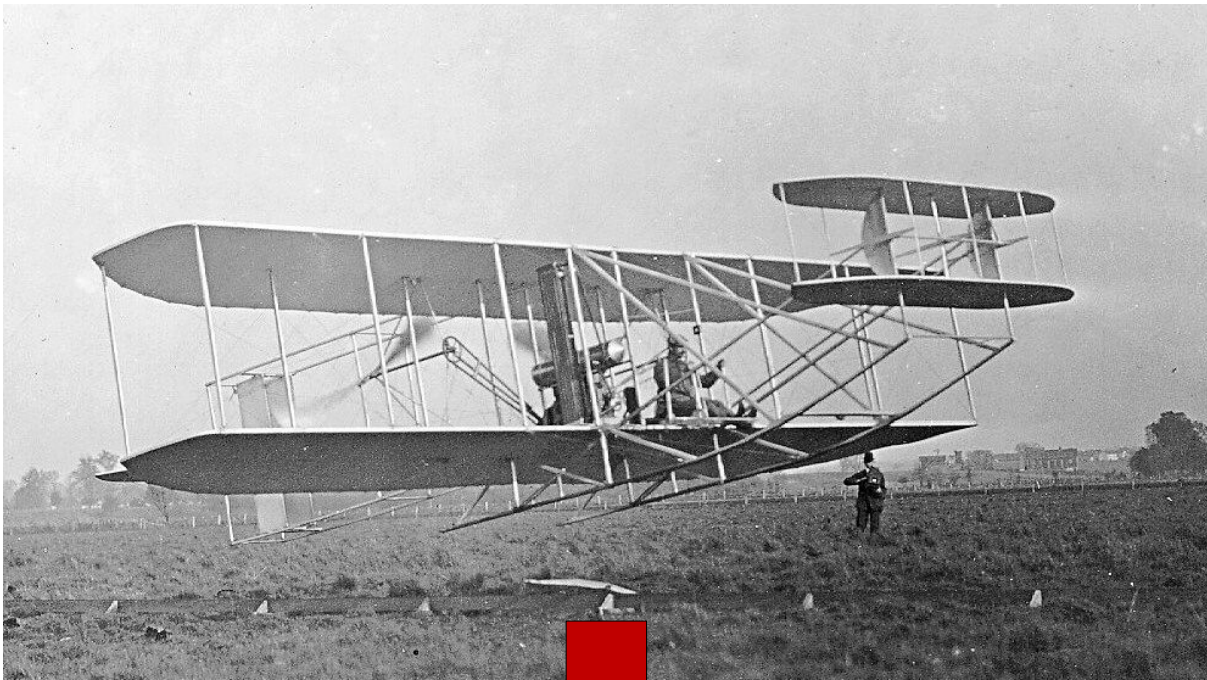
teleology: everything has its purpose

finalism: the doctrine that final causes determine the course of all events -

Teilhard de Chardin: „Omega Point“

PROPERTIES OF BIOLOGICAL EVOLUTION

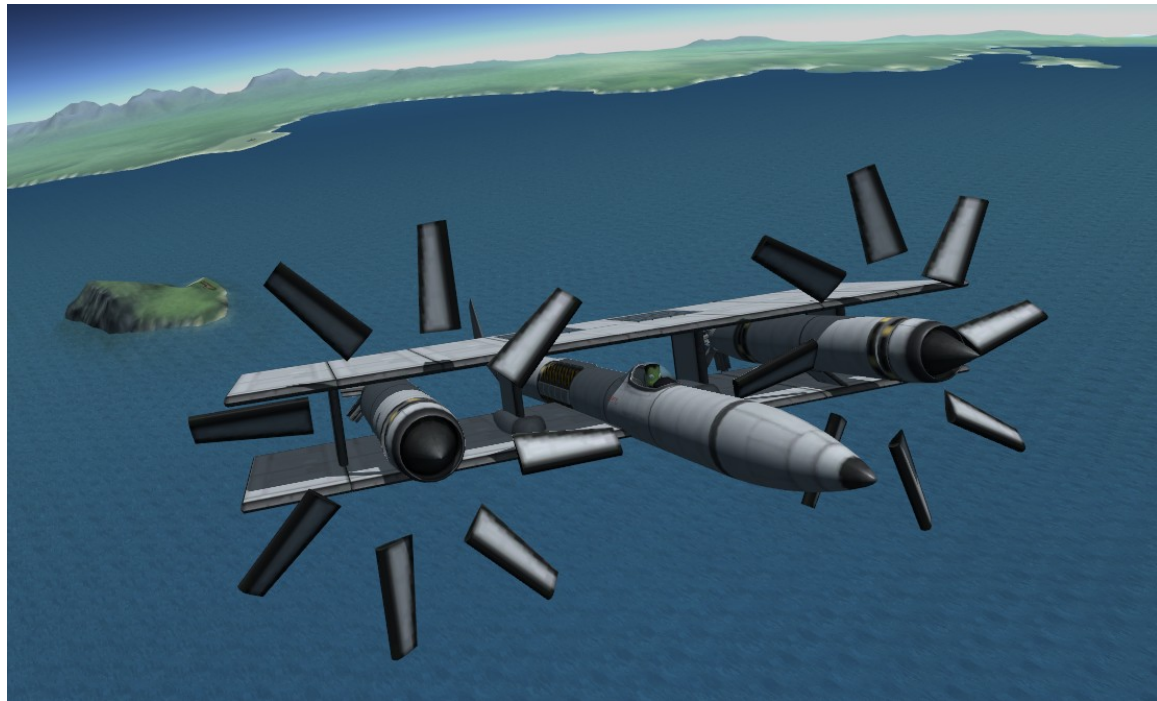
- IS random (both deterministic and stochastic processes and mechanisms)
- IS opportunistic, ie. doesn't find global optima

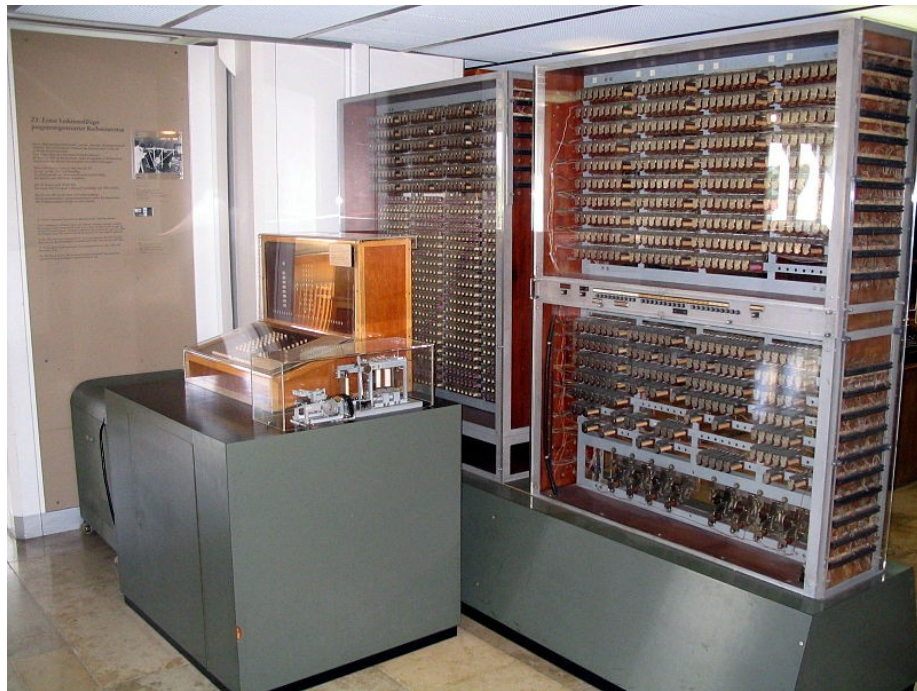
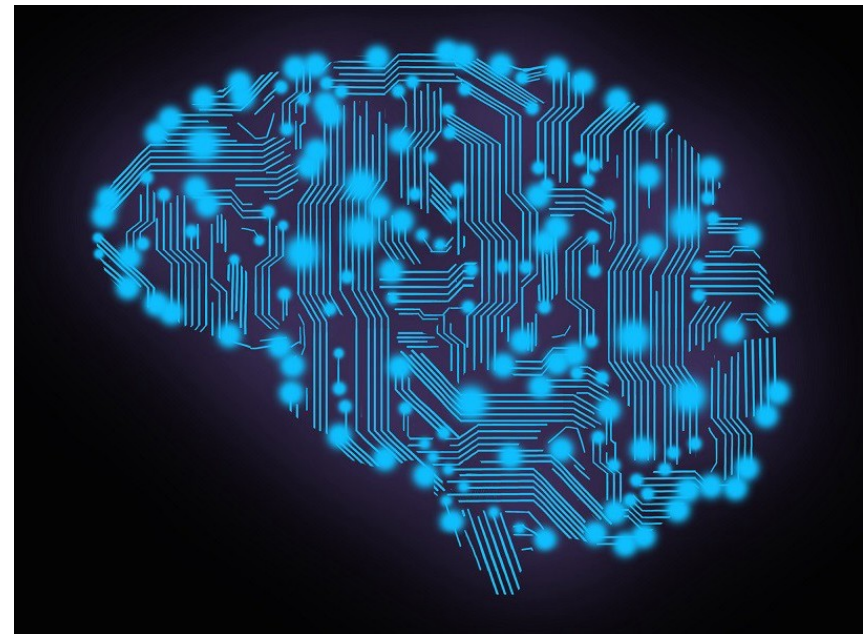


human
design
engineer



natural
selection





1939



2018

PROPERTIES OF BIOLOGICAL EVOLUTION

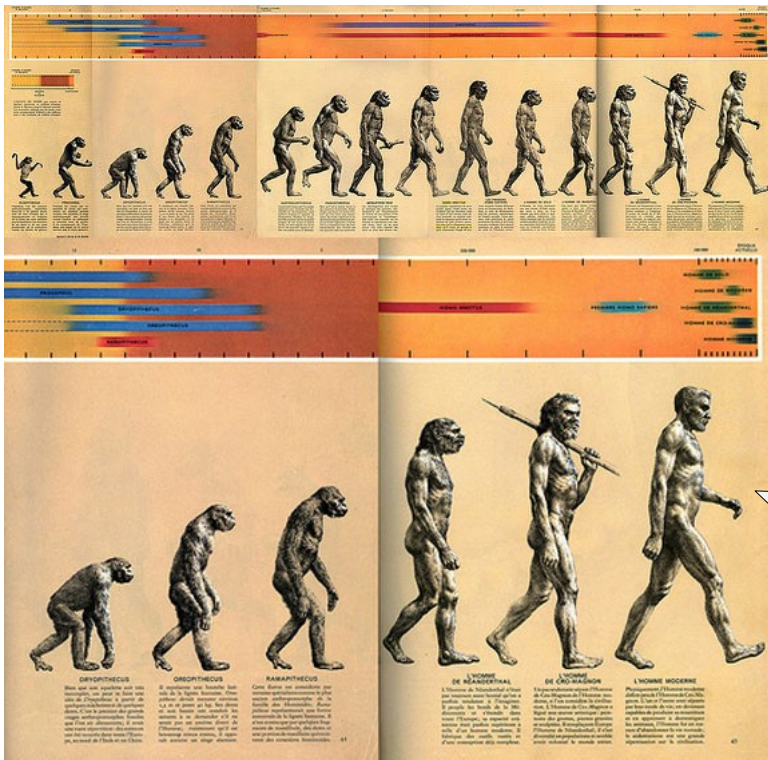
IS random (both deterministic and stochastic processes and mechanisms)

IS opportunistic, ie. doesn't find global optima

HAS NO purpose or goal (nor survival of species!)

IS neither moral nor amoral

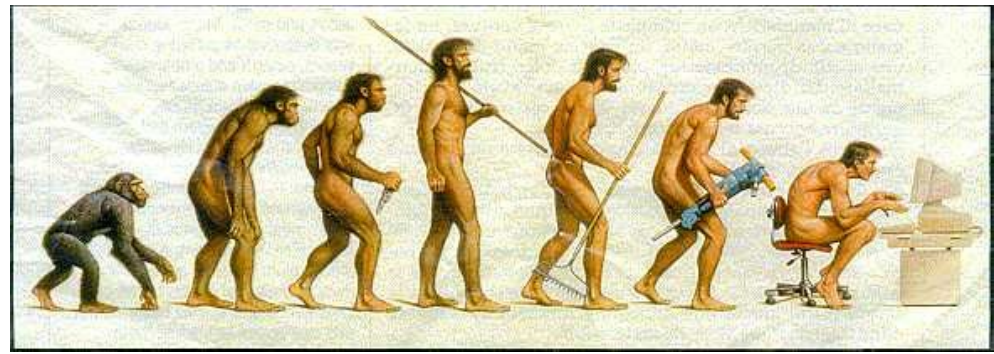
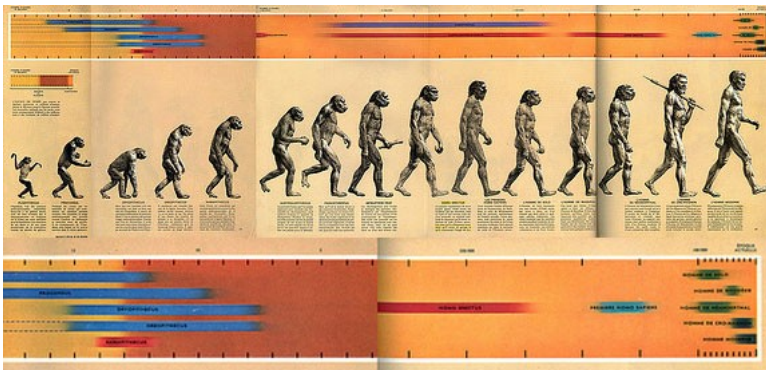
IS NOT progressive



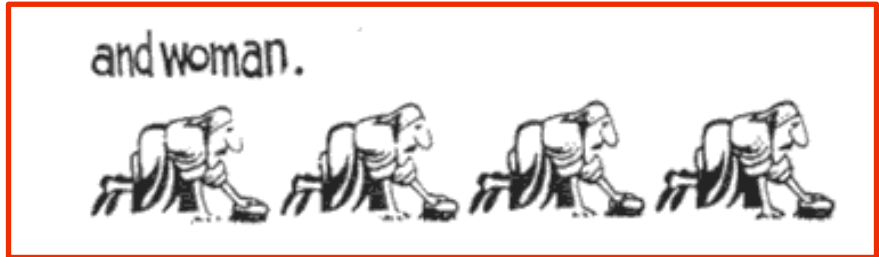
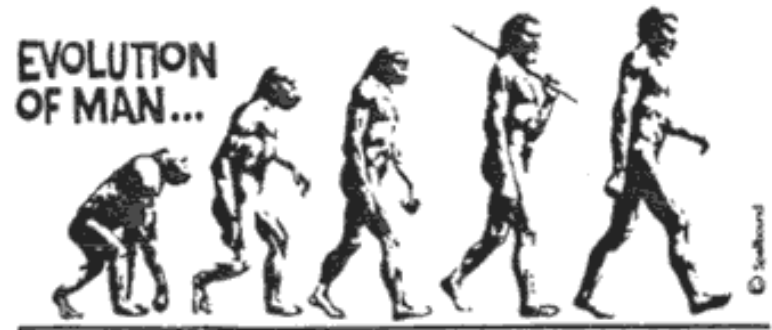
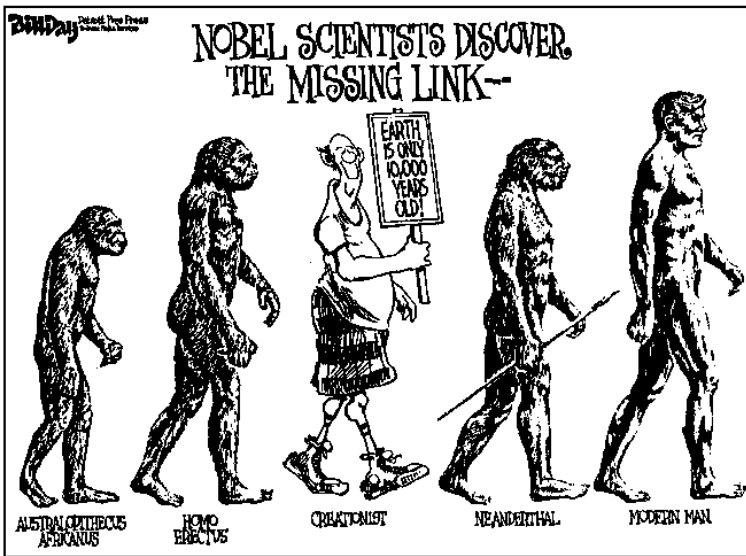
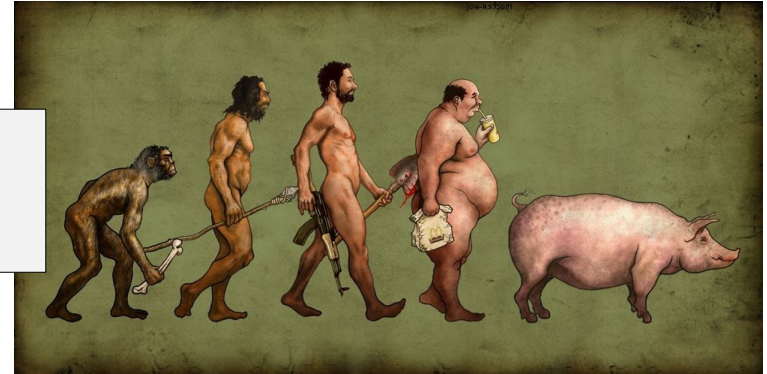
„march of progress“

T. H. Huxley (1863): *Evidence as to Man's place in Nature*



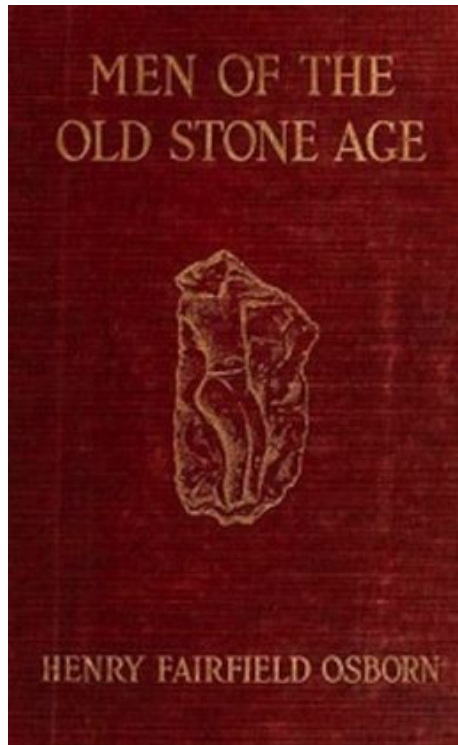
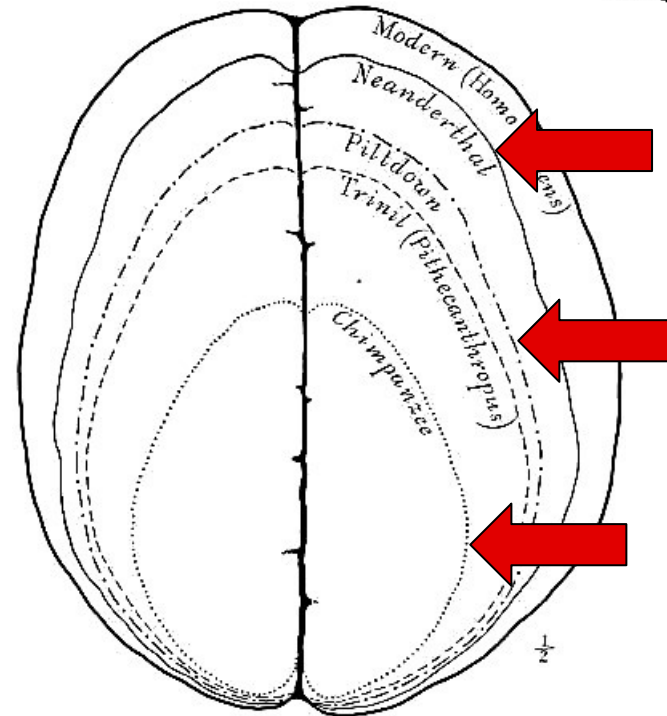
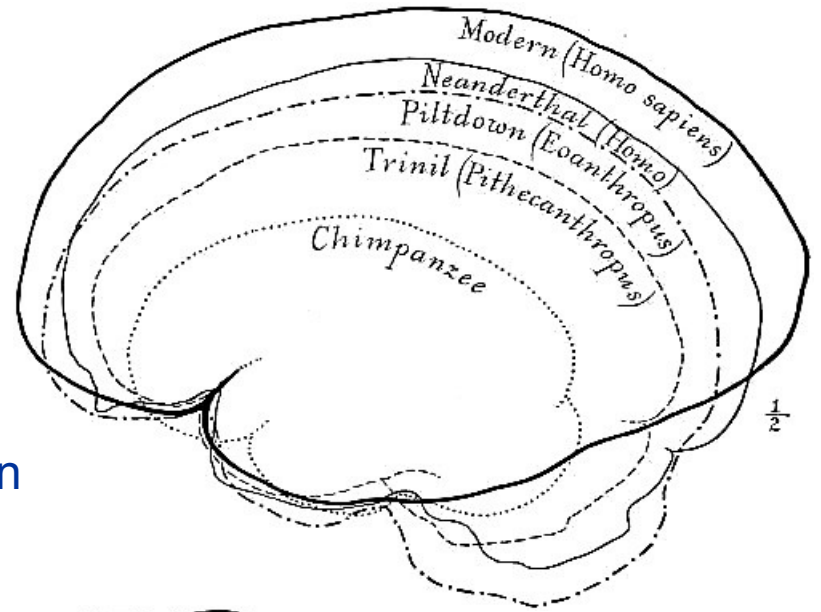


„march of progress“

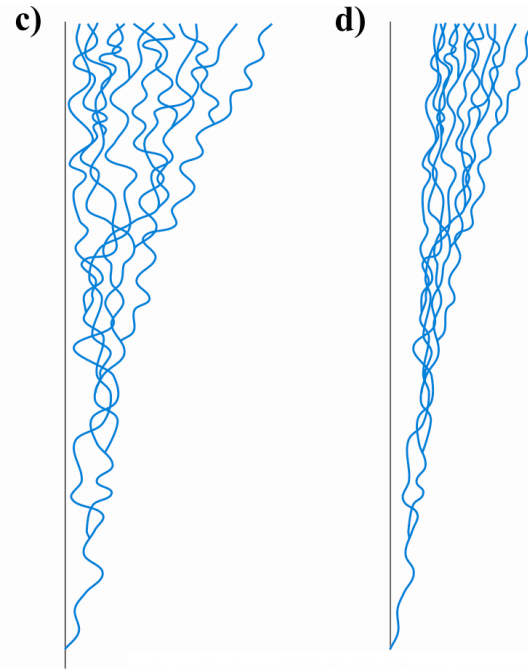
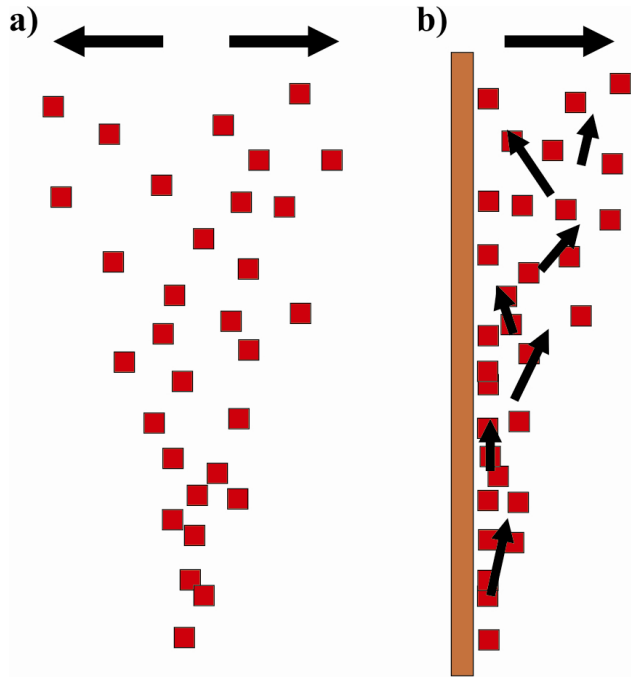




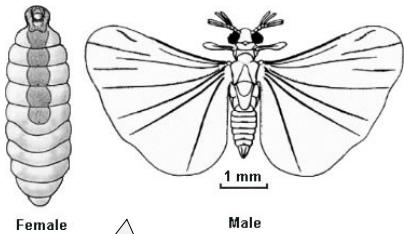
Henry Fairfield Osborn



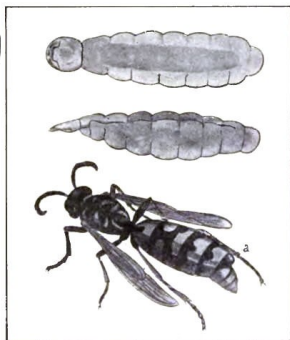
Evolution and progress



„wall effect“

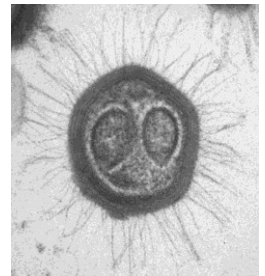
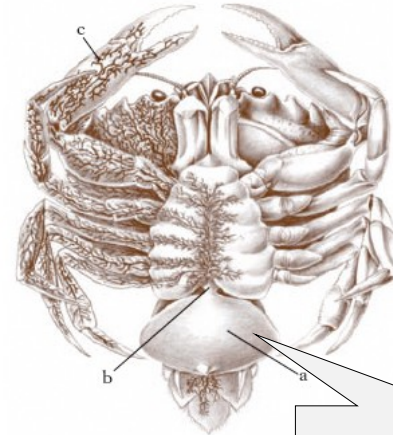
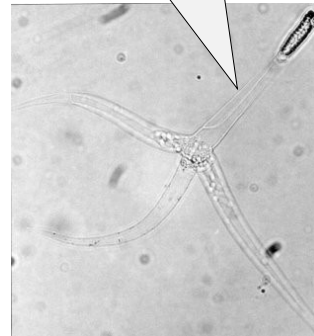


Strepsiptera



Female Strepsipteron, top and side views and a Styloized Wasp: a, end of the parasite projecting between the abdominal segments of the Wasp. (After Leuckart's Wandtafeln.)

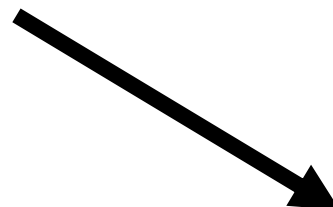
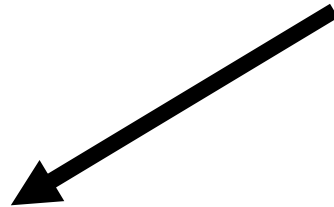
Myxozoa



Sacculina carcini

STRUCTURE OF EVOLUTIONARY BIOLOGY

2 principal questions:



History of life?

systematics
paleontology

Mechanisms of changes?

evolutionary genetics
e. ecology
e. developmental biology (evo-devo)
behavioural ecology
sociobiology, e. psychology
e. physiology
e. morphology

HISTORY OF EVOLUTIONARY THOUGHTS

The beginning of evolutionary biology = 1859 (Darwin's *Origin of Species*),
BUT:

evolutionary thoughts much older

only after the World War II evolutionary biology considered true science

History of evol. thoughts can be divided into the following stages:

before Darwin

Darwin's/Wallace's theory

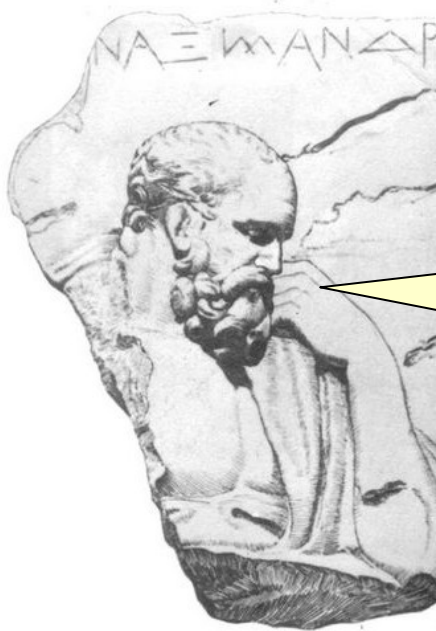
evol. theory at the turn of 19th and 20th century

Modern Synthesis and recent history

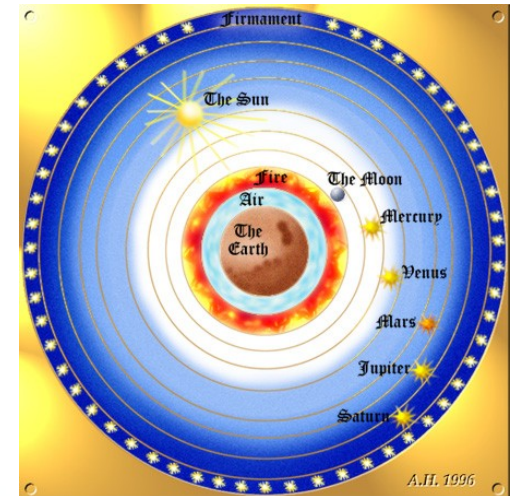
1. Before Darwin

A) Antient history and the Middle Ages:

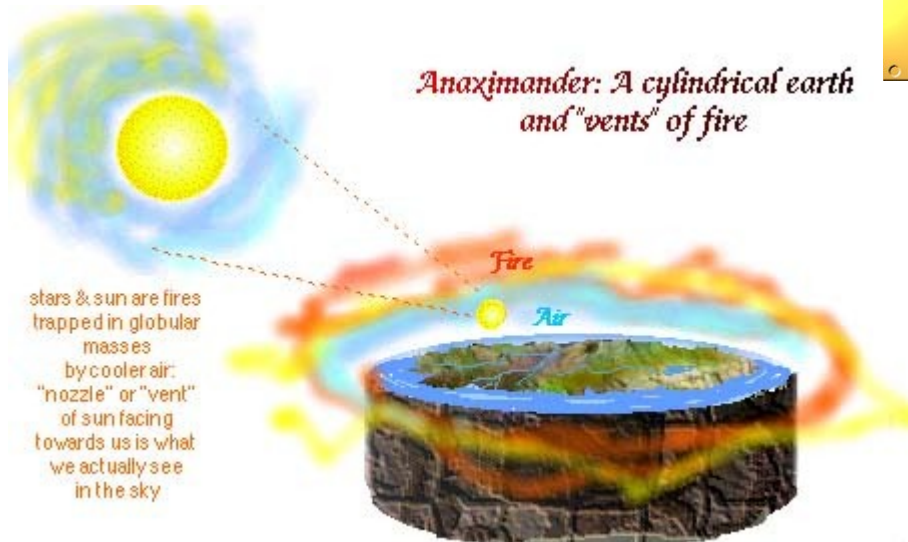
Anaximander of Miletus (ca. 610–ca. 546 BC)



humans
and animals
have evolved
from fish



*Anaximander: A cylindrical earth
and "vents" of fire*

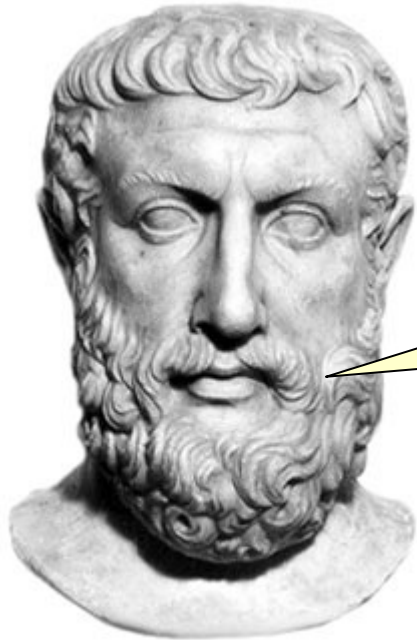


stars & sun are fires
trapped in globular
masses
by cooler air:
"nozzle" or "vent"
of sun facing
towards us is what
we actually see
in the sky

1. Before Darwin

A) Antient history and the Middle Ages:

Xenofanes of Colofon (ca. 570–ca. 475 BC)



fossils found in
sediments must
formerly have been
in water

1. Before Darwin

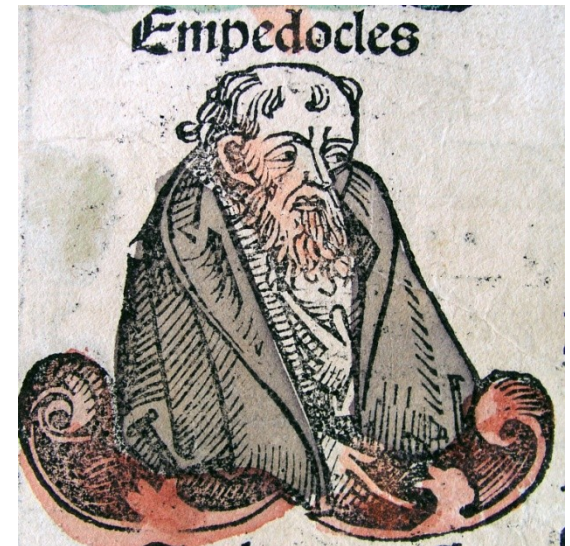
A) Antient history and the Middle Ages:

Empedocles z Acragas (ca. 492–432 BC)

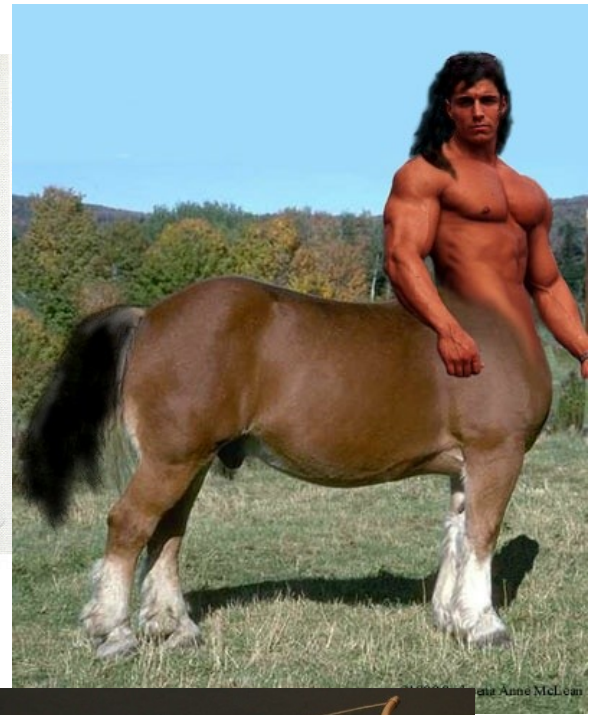
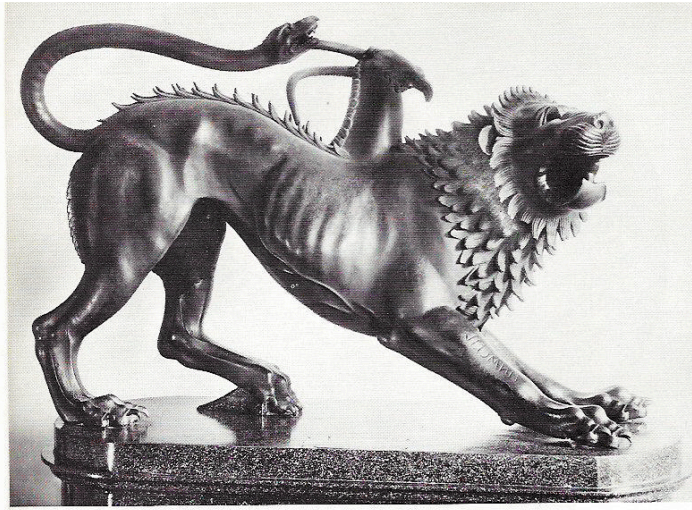
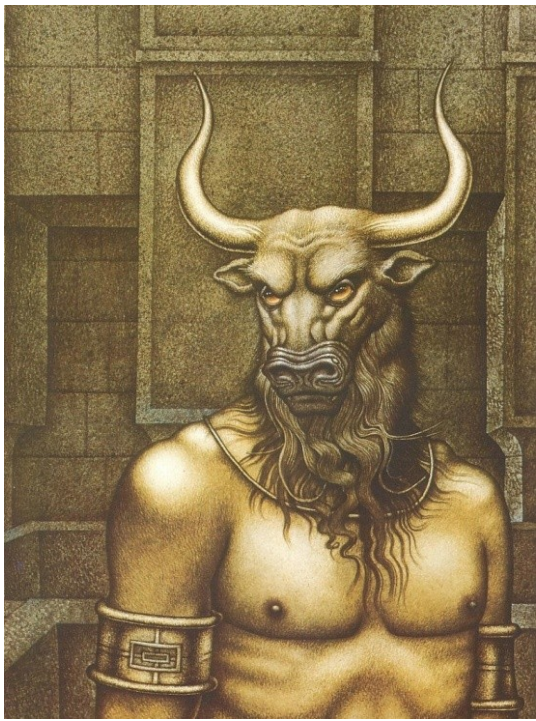


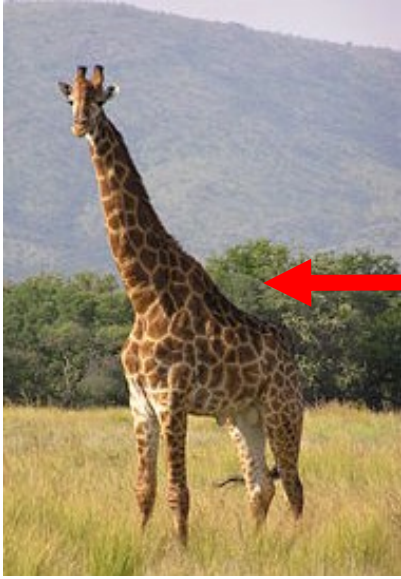
plants before
animals

random
combinations of
parts of organisms

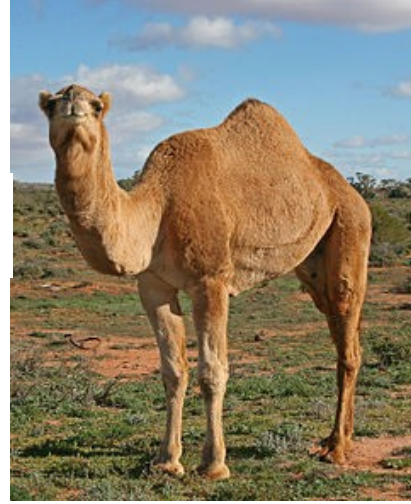








×



×



×



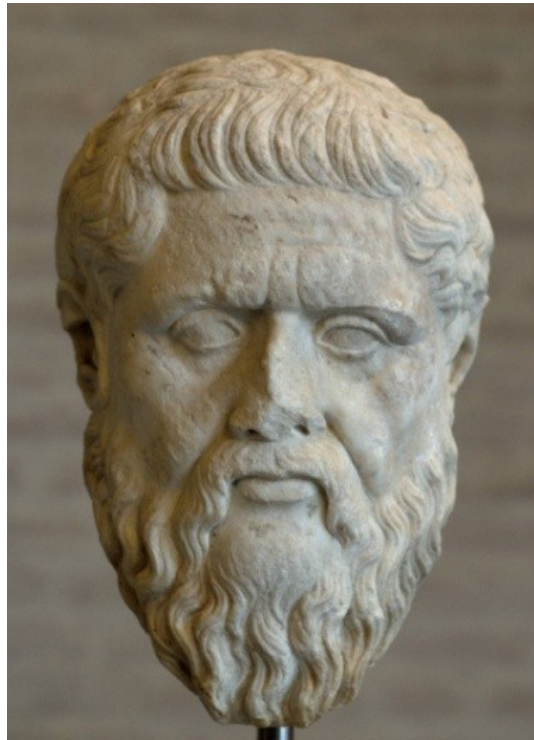
1. Before Darwin

A) Antient history and the Middle Ages:

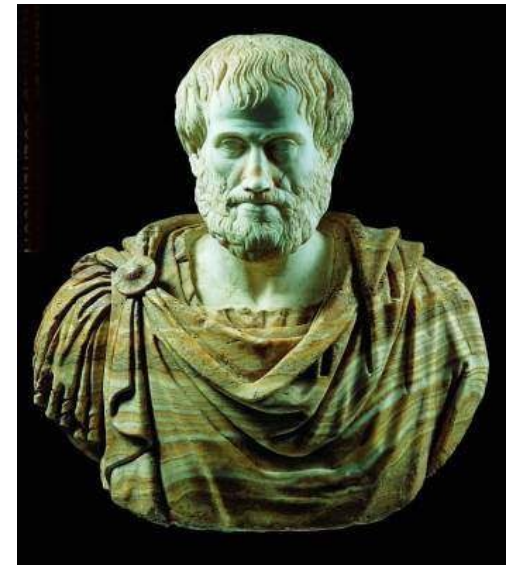
Christian philosophy:

Aristotle: first classification of organisms, linear hierarchy (→ *Scala Naturae*)

Plato: theory of Ideas (→ Christian God)

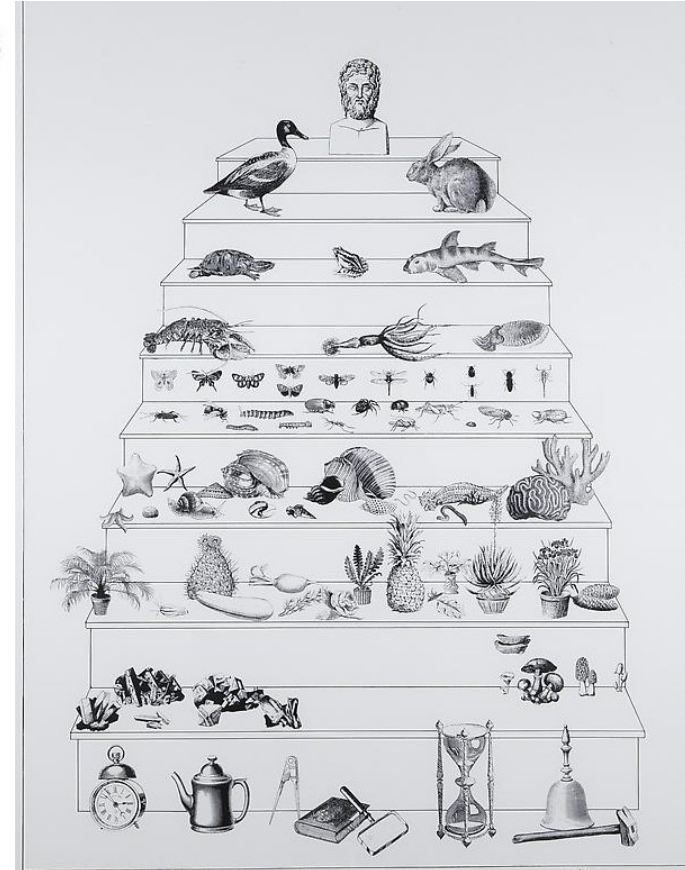
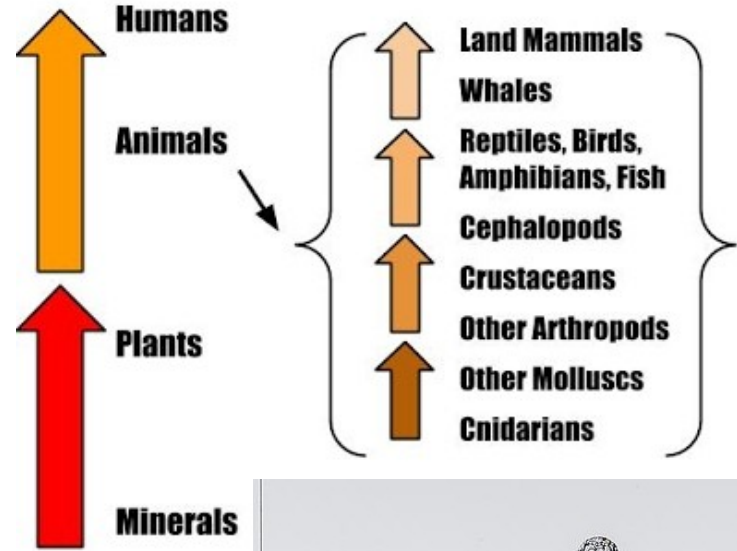
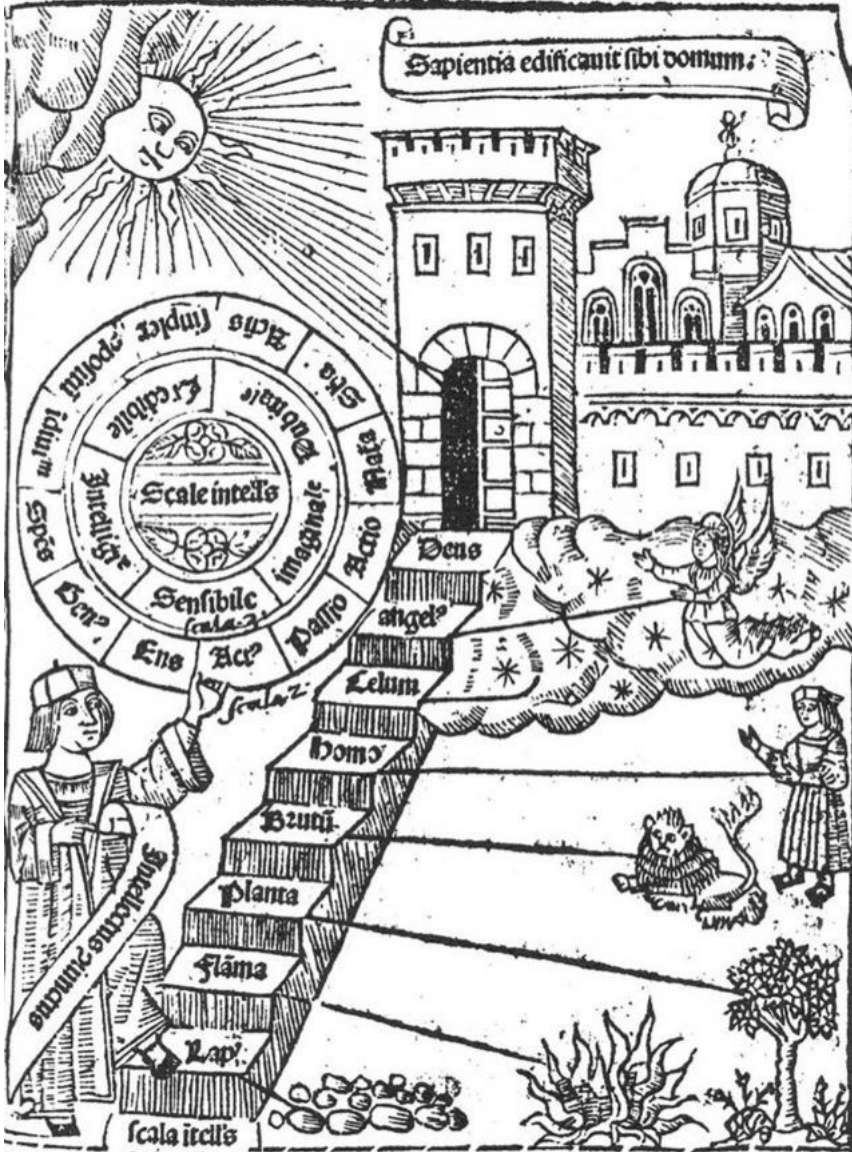


Plato
(427–347 BC)



Aristotle
(384–322 BC)

Scala Naturae („Great Chain of Being“)

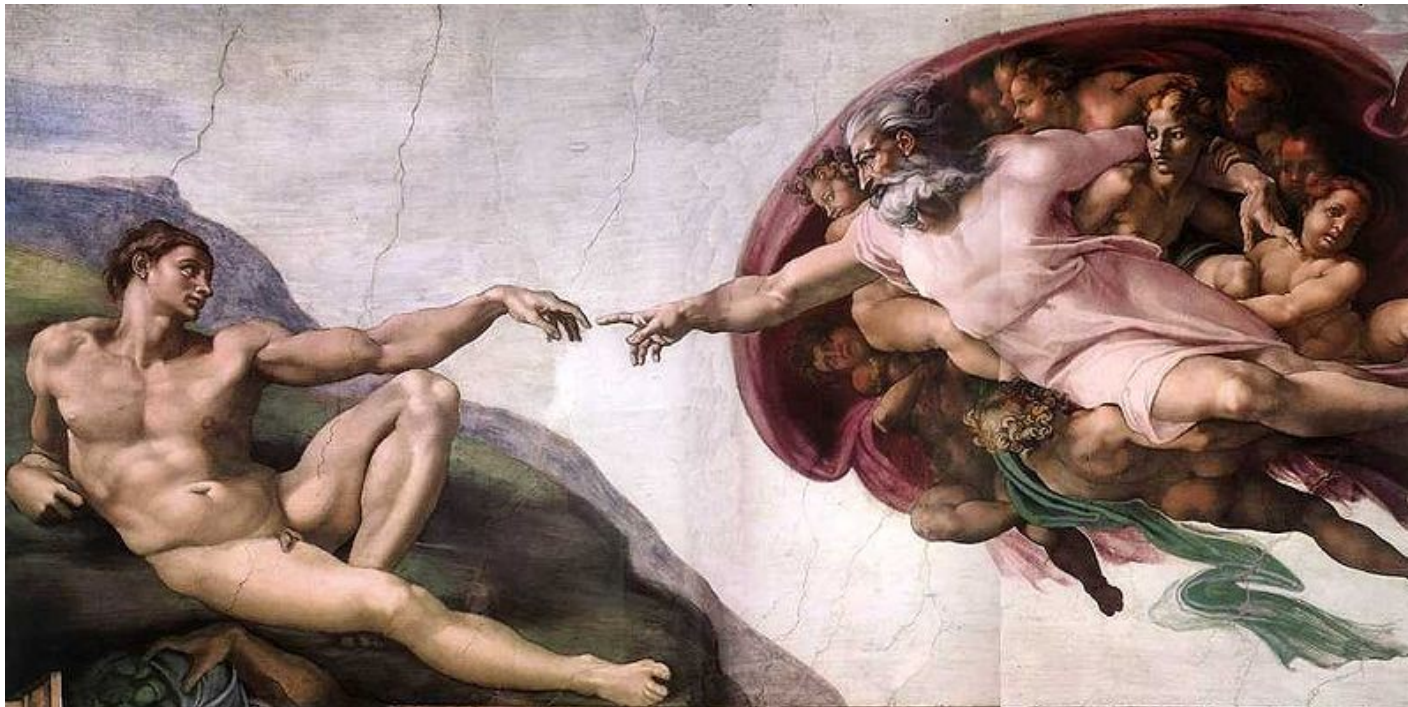




James Ussher – *Annalium pars posterior* (1654):
World created at dusk preceding 23th October 4004 BC
(~ 6000 years old)

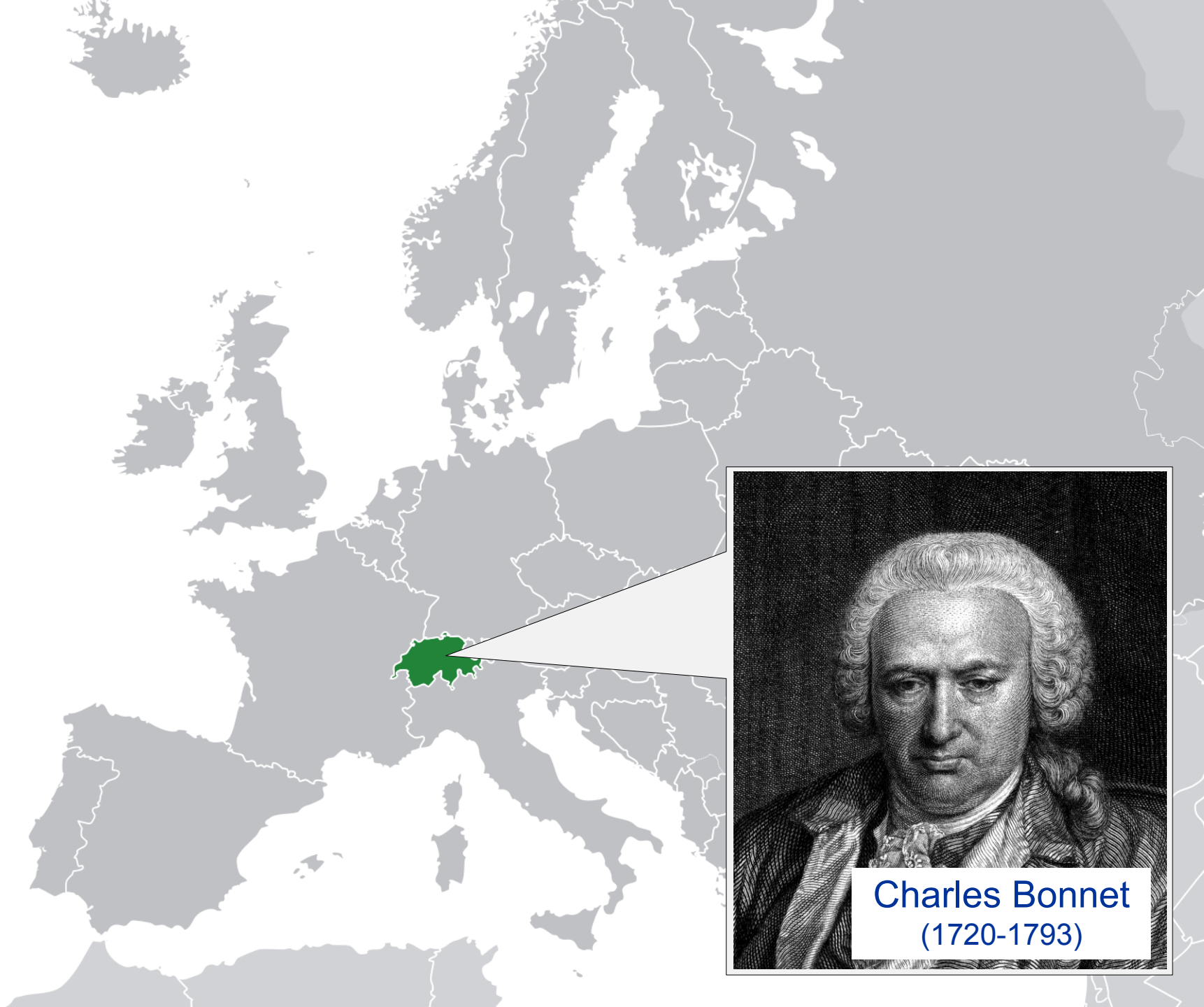
~ Isaac Newton: 3998 BC

literal reading of Bible = **creationism**



1. Before Darwin

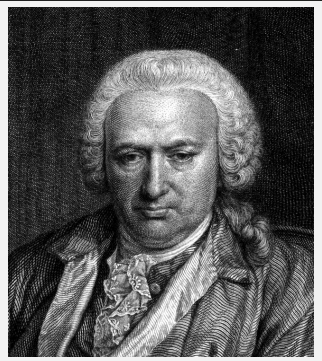
B) since the end of 17th century to the French Revolution:



Charles Bonnet
(1720-1793)

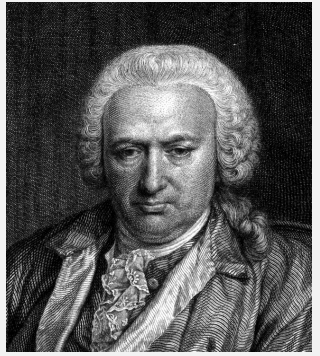


Lorenz Oken
(1779-1851)



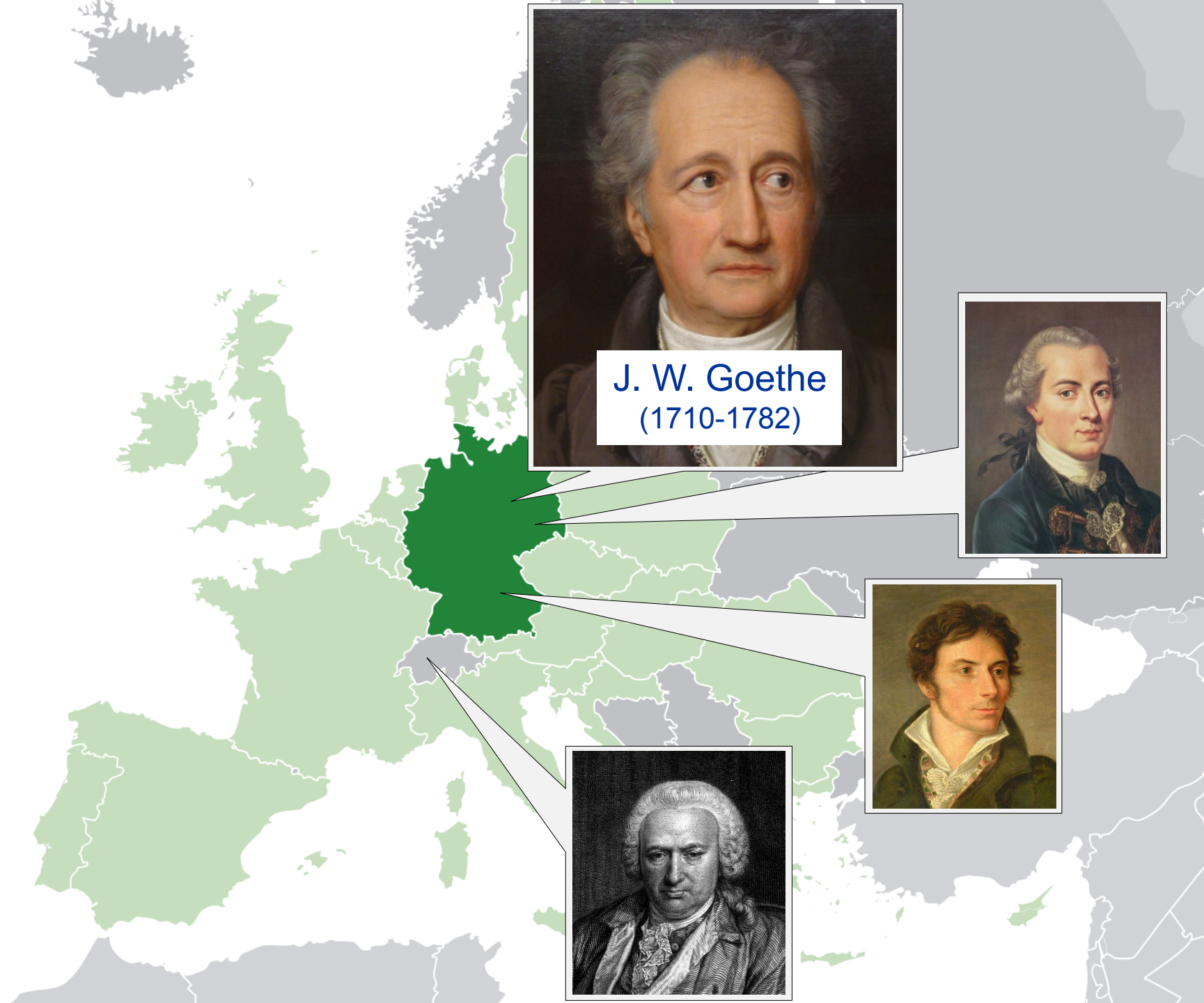
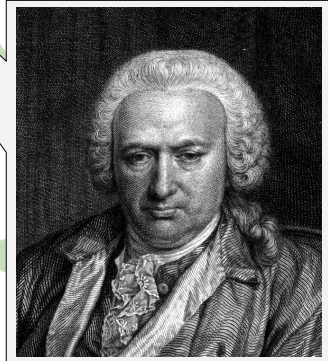
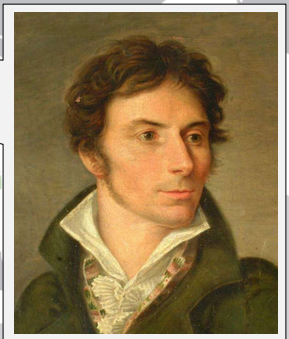


Immanuel Kant
(1724-1804)

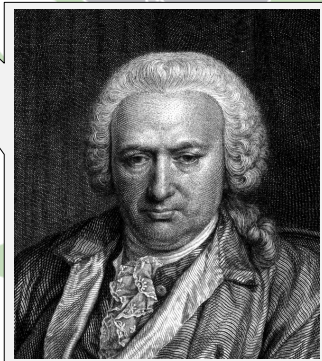
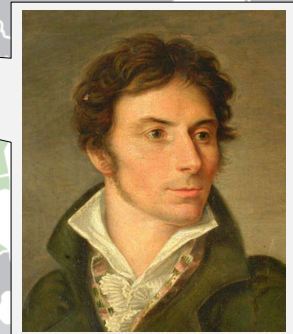
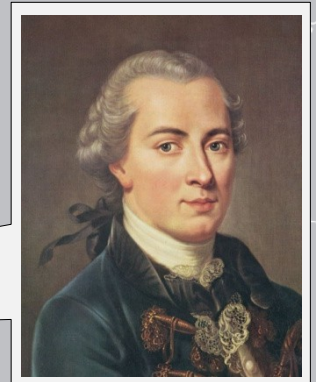




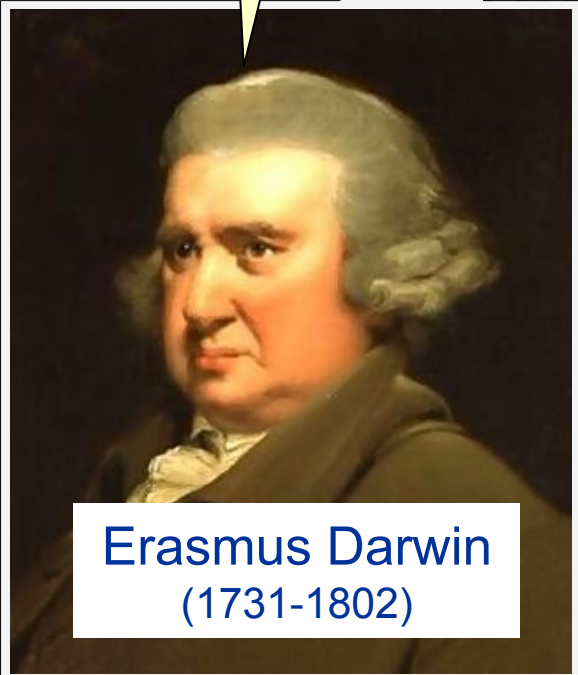
J. W. Goethe
(1710-1782)

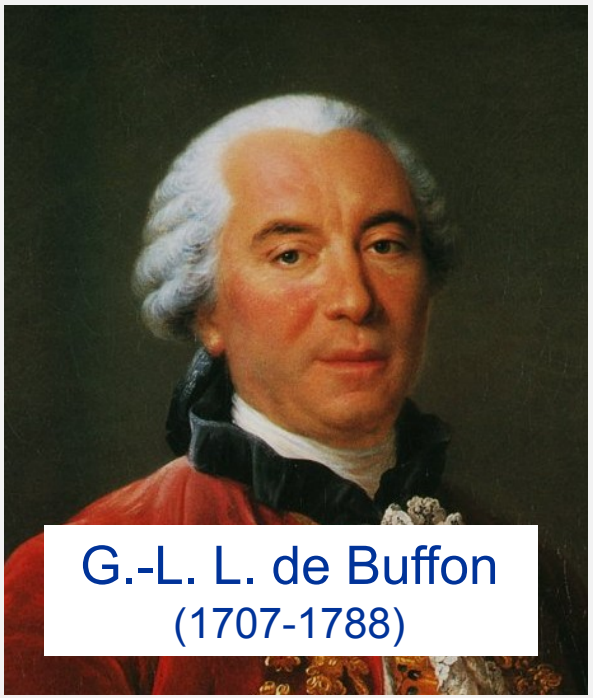


Zoönomia (1794):
„E conchis omnia“
(everything from
molluscs)

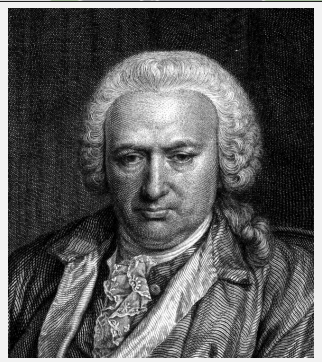
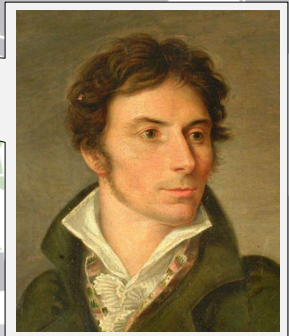
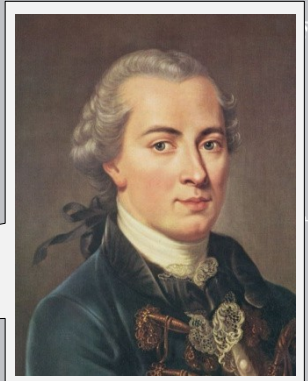
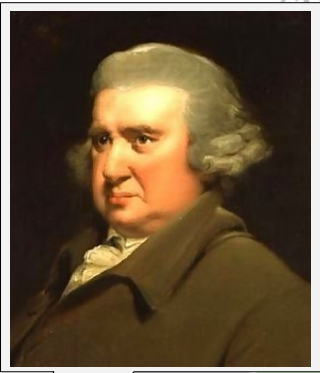


Erasmus Darwin
(1731-1802)





G.-L. L. de Buffon
(1707-1788)



Georges-Louis Leclerc de Buffon (1707–1788):

since 1749–1789: 26 volumes of *Histoire Naturelle*
(1789–1804 another 8 volumes)

age of Earth = 75,000 years

1766: related species from a common ancestor,
modification by climatic factors

1778: age 75 kya – 2-3 Mya



1. Before Darwin

C) 19th century:

**Jean Baptiste Pierre Antoine de Monet
de LAMARCK (1744–1829)**

1809: *Philosophie Zoologique*

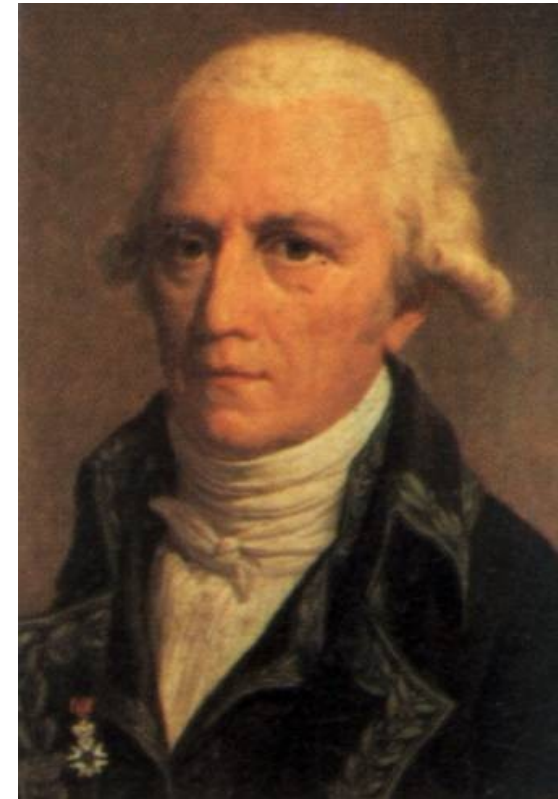
1. inherent tendency to change
2. inheritance of acquired characteristics

change of species towards higher organisation
(transformism)

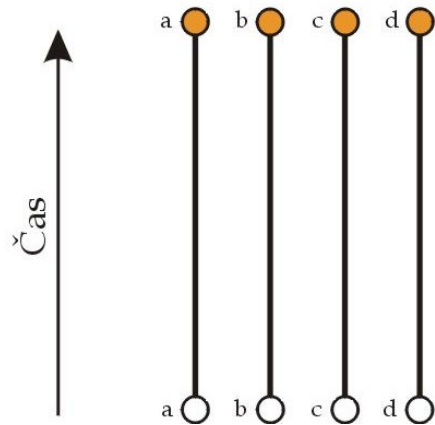
continual spontaneous emergence of simple
organisms

number of species unchanged

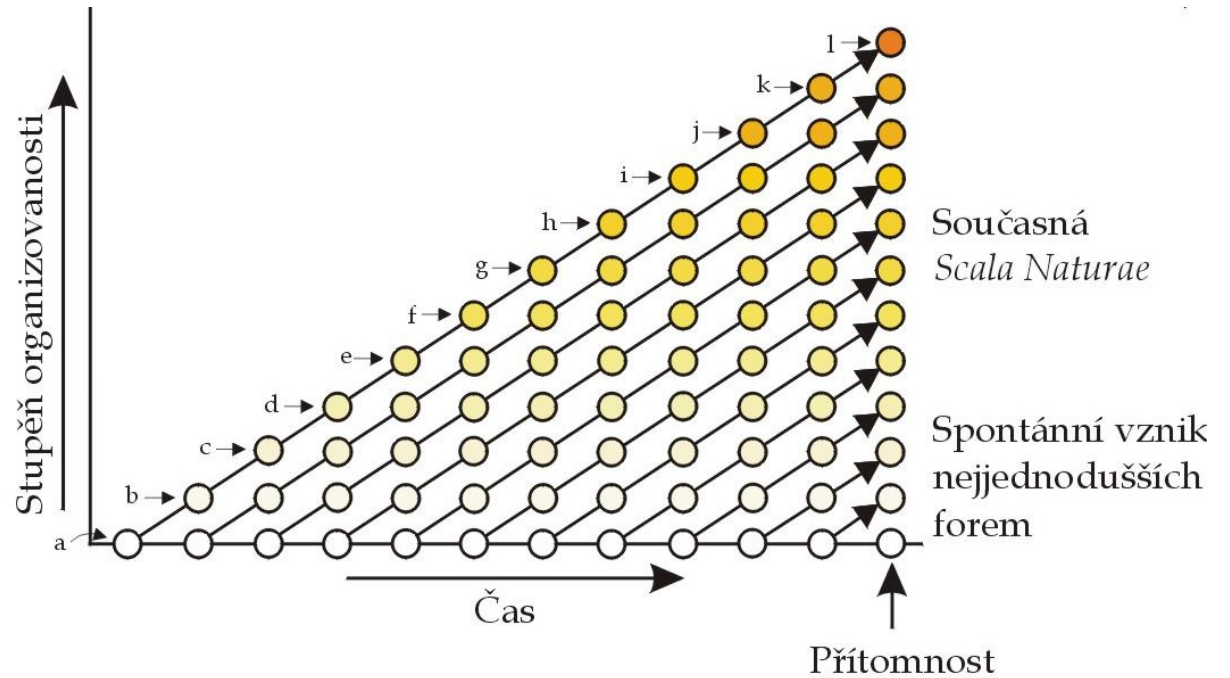
= LAMARCKISM



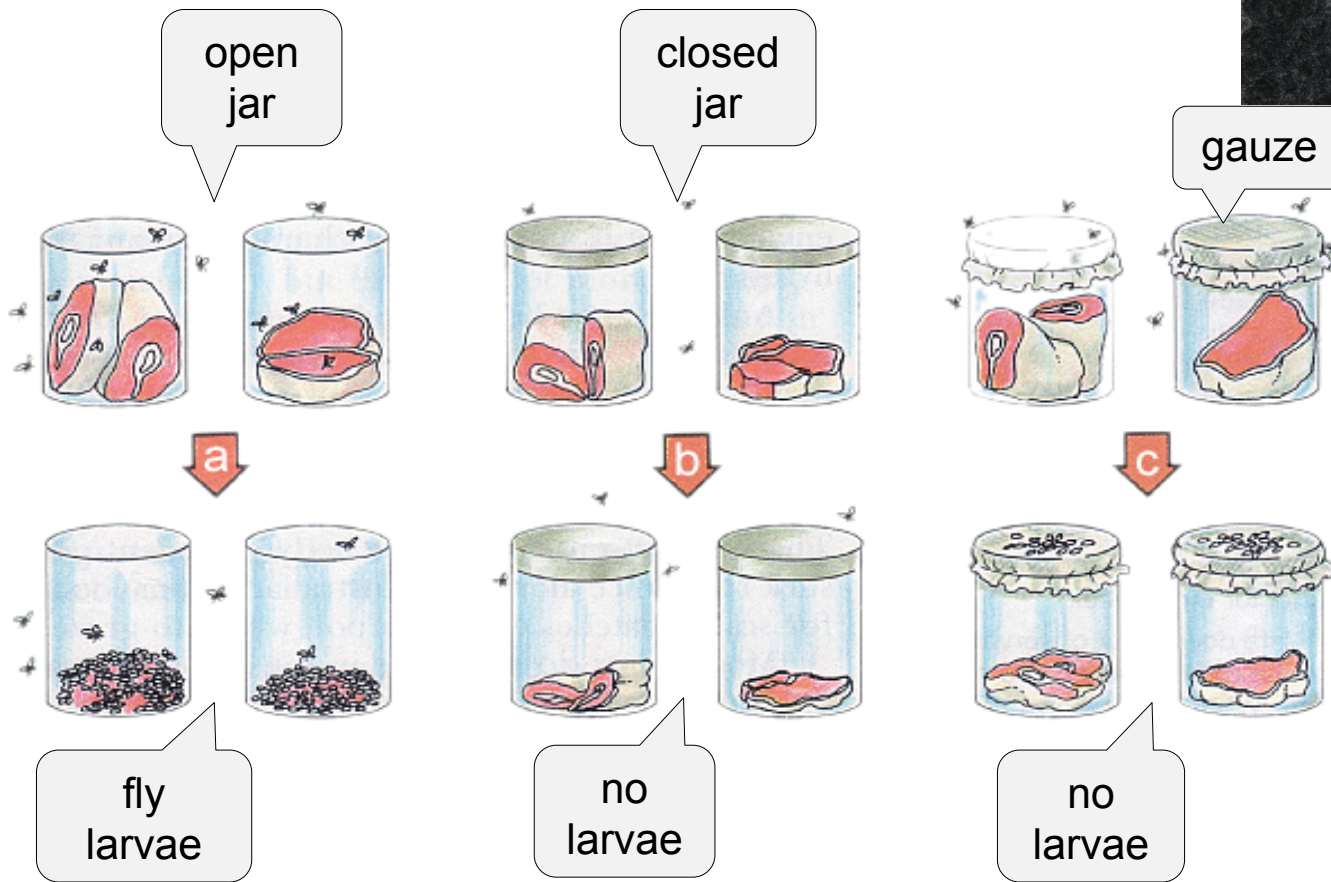
„classical“ creationism



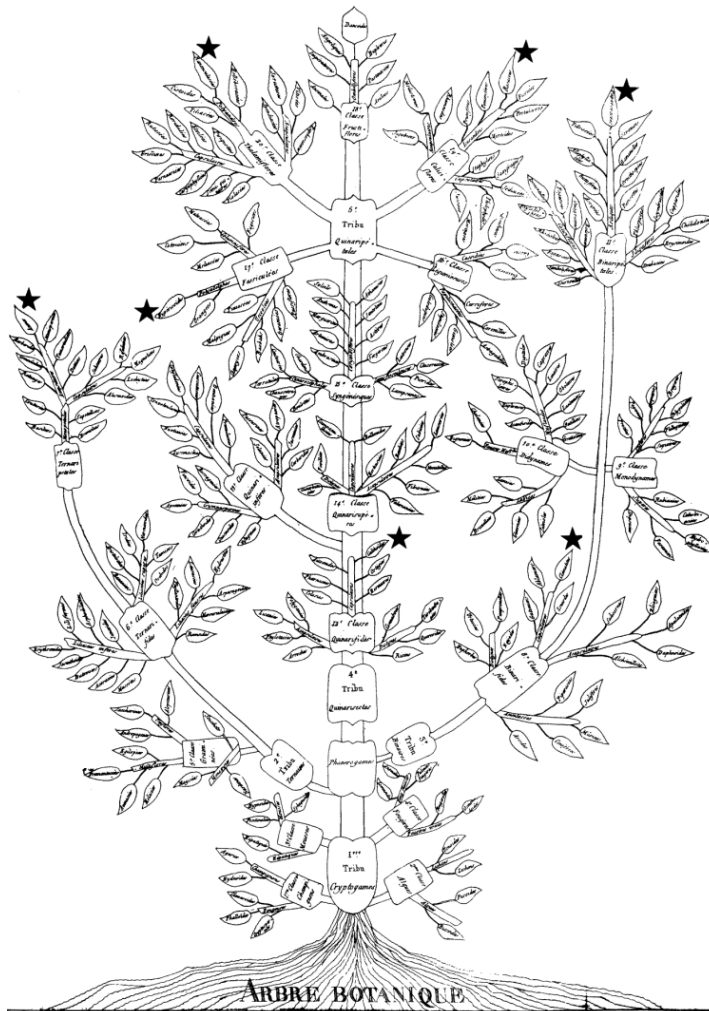
transformism



Francesco Redi (1626–1697)



A. Augier: *Essai d'une nouvelle classification des vegetaux* (1801)



ADDITIONS.

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TABLEAU

Servant à montrer l'origine des différens animaux.

Vers. Infusoires.
Polypes.
Radiaires.

Insectes.
Arachnides.
Crustacés.
Annelides.
Cirripèdes.
Mollusques.

Poissons.
Reptiles.

Oiseaux.

Monotrèmes.

M. Amphibies.

M. Cétacés.

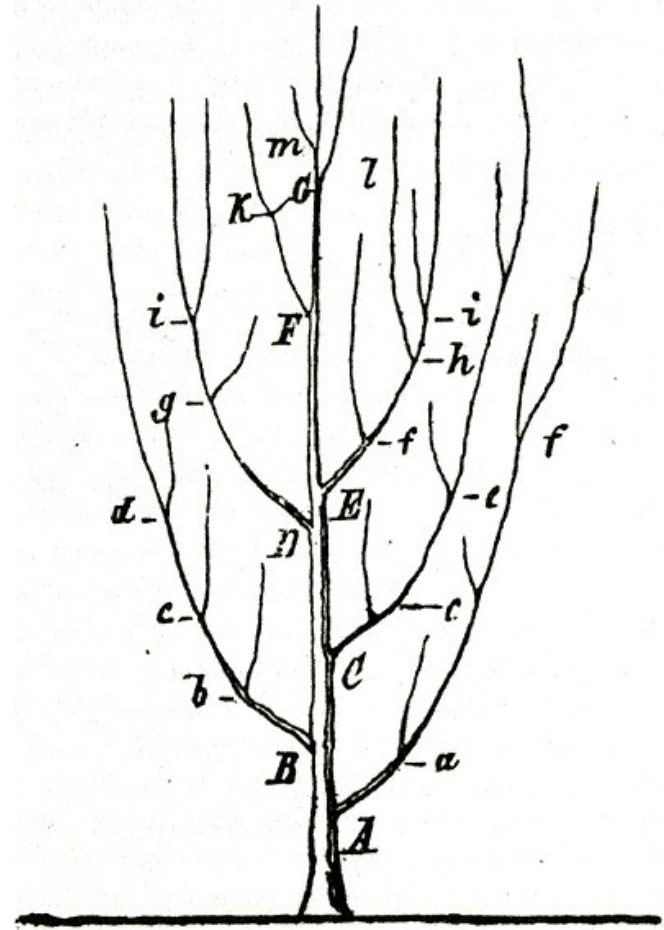
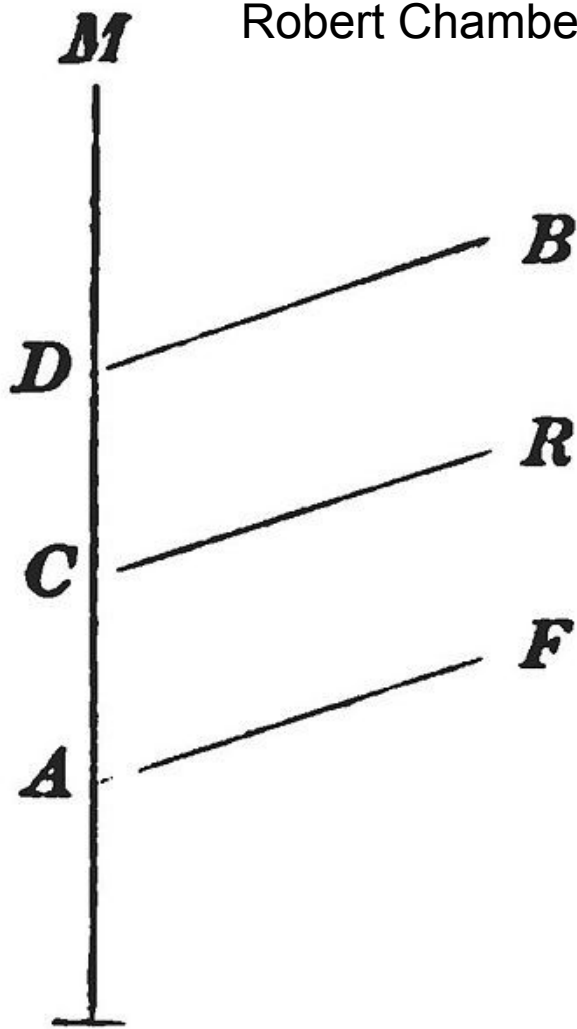
M. Ongulés.

M. Onguiculés.

Cette série d'animaux commençant par deux

J.-B. Lamarck: *Philosophie zoologique* (1809)

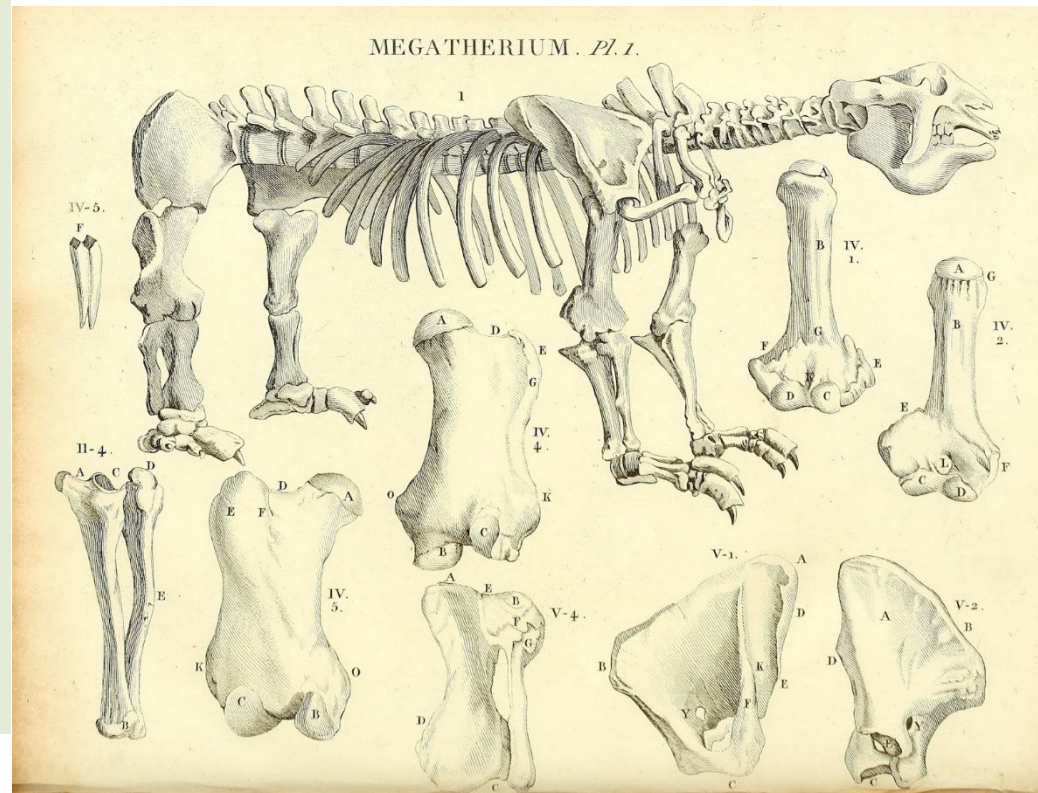
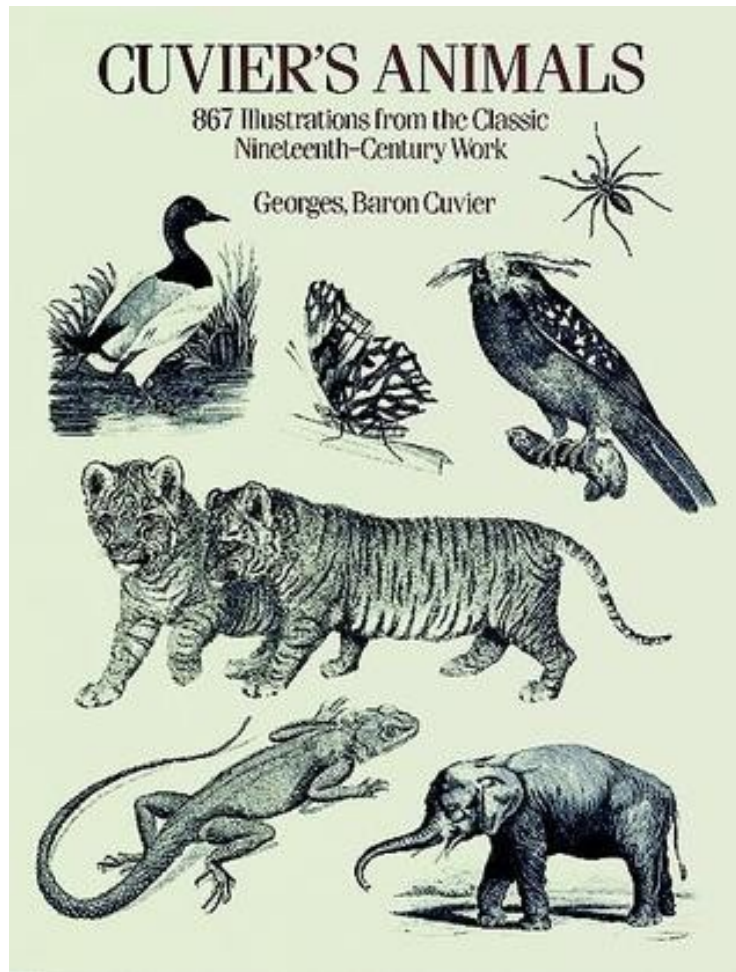
Robert Chambers: *Vestiges of the Natural History of Creation* (1844)



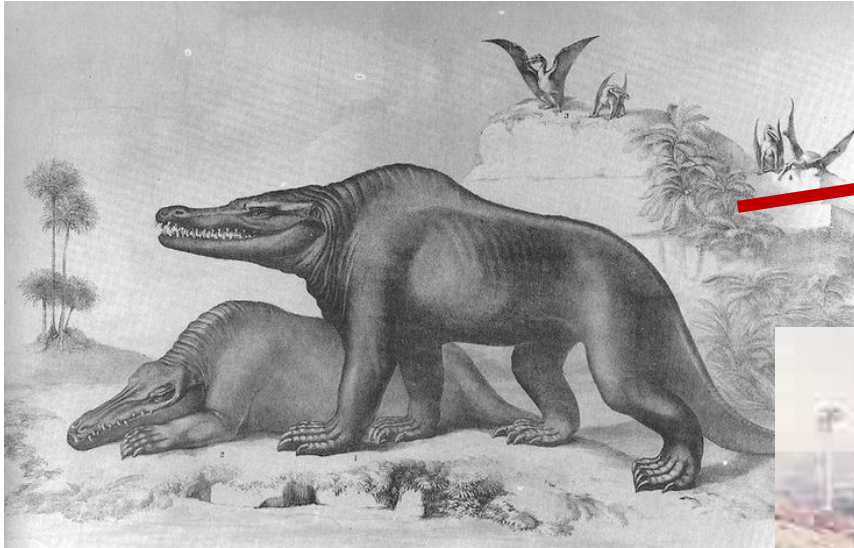
Heinrich Georg Bronn: *Untersuchungen über die Entwicklungs – Gesetze der organischen Welt während der Bildungszeit unserer Erd-Oberfläche* (1858)

critique of Lamarck's theory:

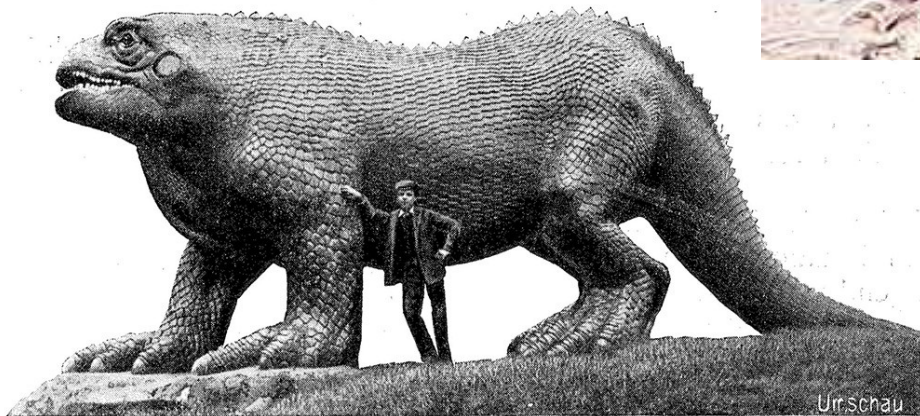
Georges Cuvier (1769–1832)



Megalosaurus: 1815–1824



Iguanodon: 1822





Hylaeosaurus: 1832



Megalosaurus
1824

Iguanodon
1825

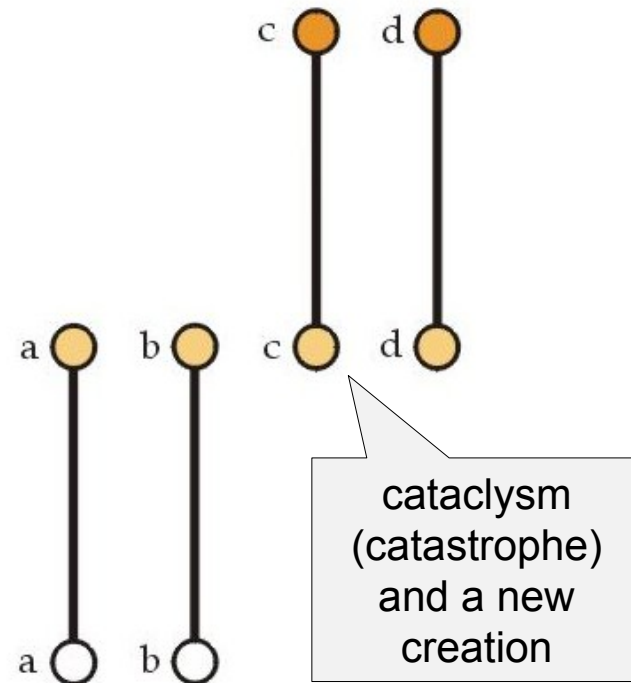
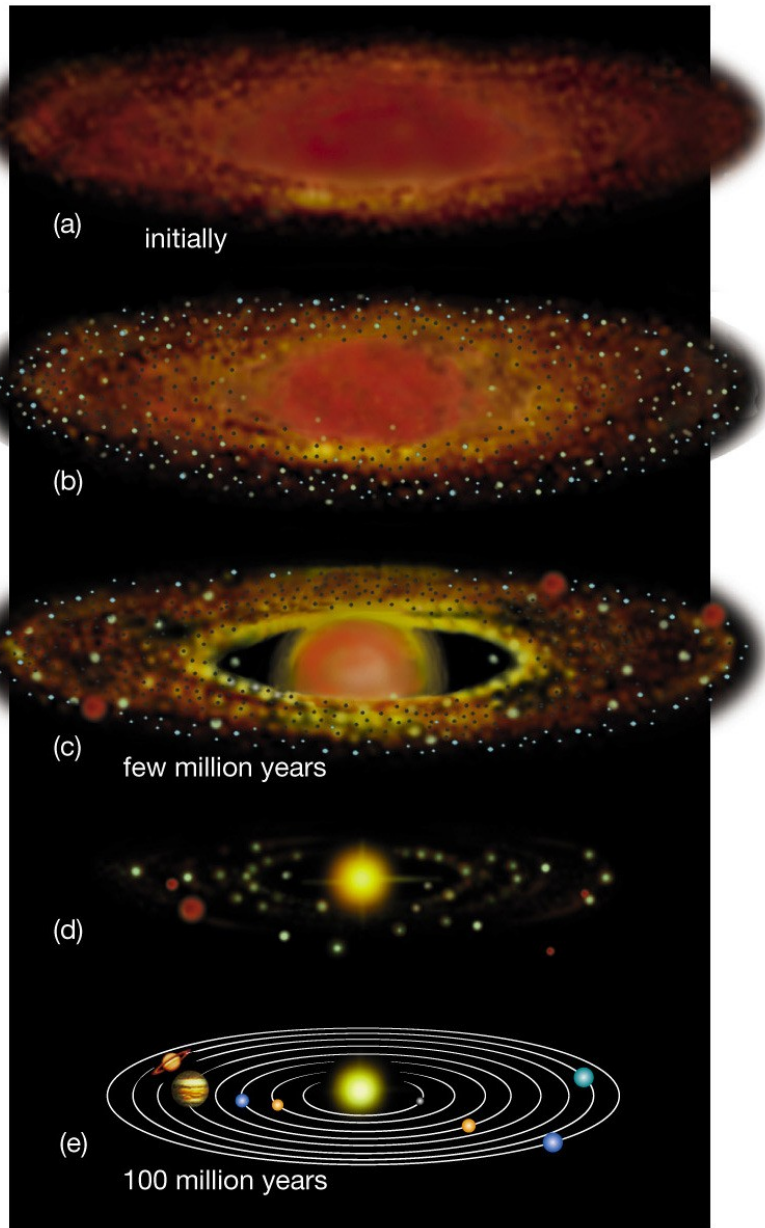
Hylaeosaurus
1833

Richard Owen's "Dinosauria"

nebular hypothesis:

gradual cooling down of Earth \Rightarrow
less favourable conditions in the past

catastrophism



Age of Earth

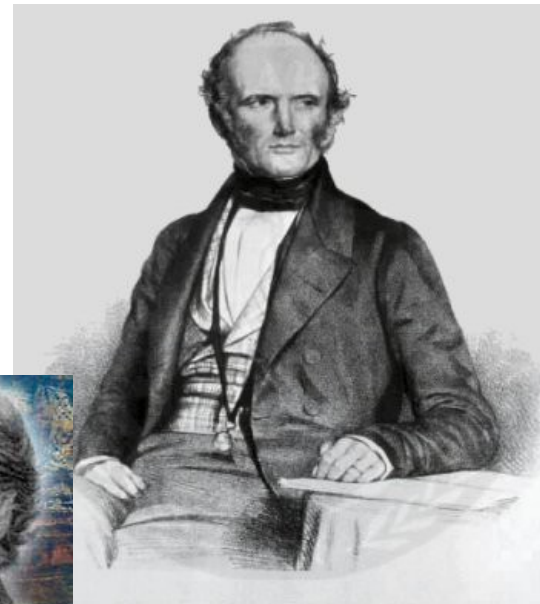
James Hutton (1726–1797): geological evidence suggests that Earth is inconceivably old ⇒ How can we use our observation and experiment for explaining changes on such the huge time scale?

→ we must rely on processes that we know at present

Charles Lyell (1797–1875):

uniformitarianism

Principles of Geology



C. Lyell



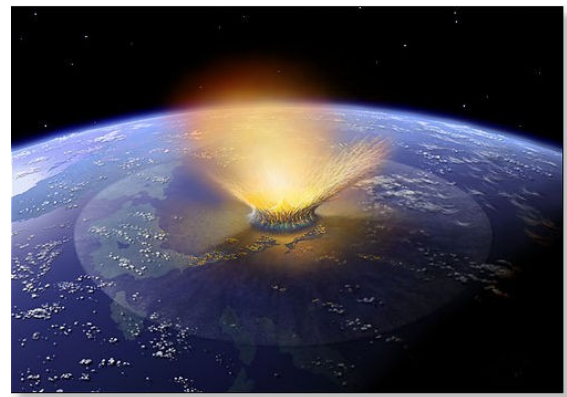
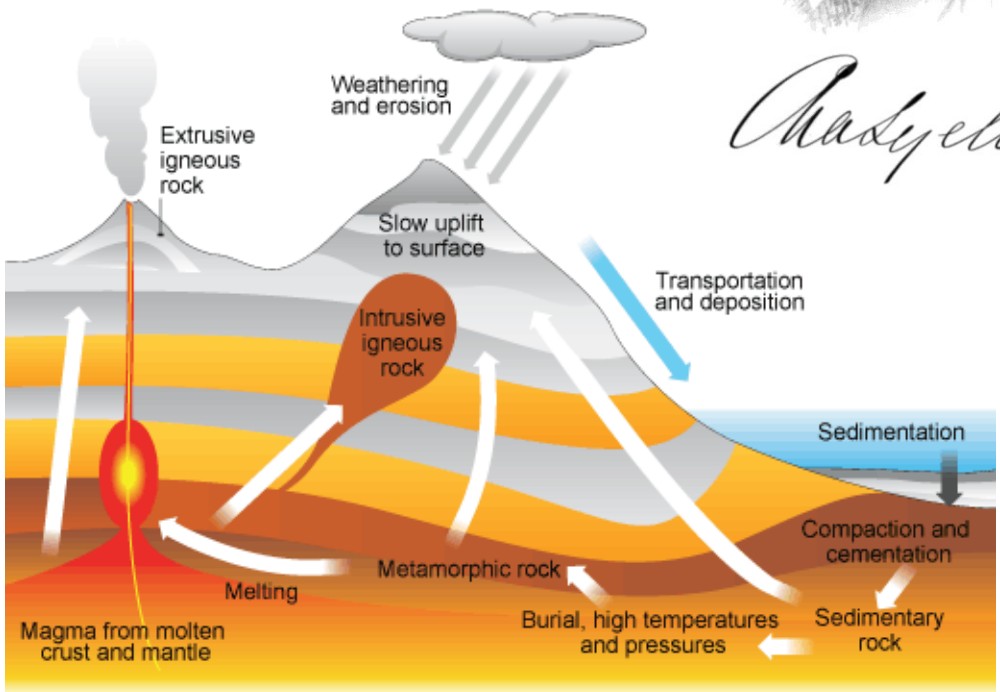
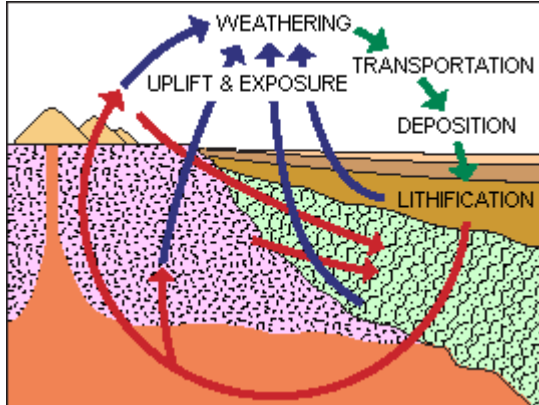
J. Hutton



uniformitarianism



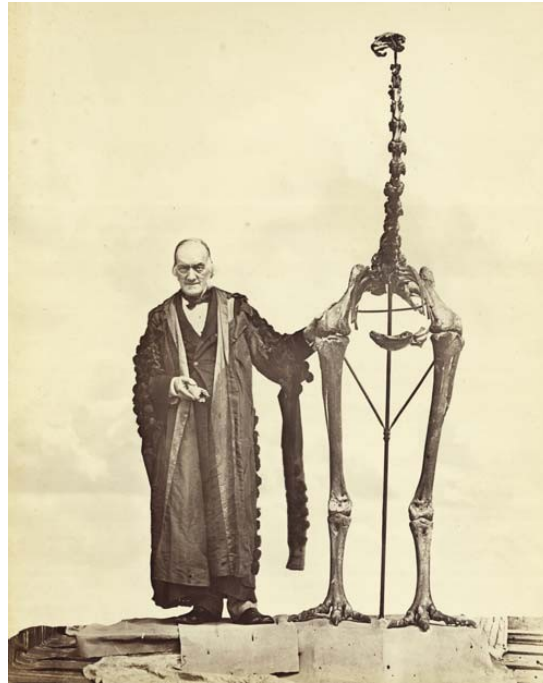
Charles Lyell



paleontology:



Richard Owen
(1804–1892)



natural theology: **William Paley** (1743–1805)

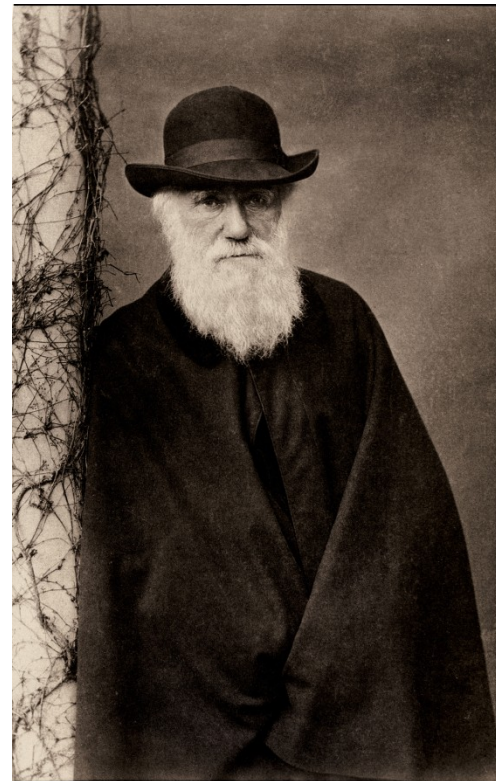
metaphor of God as a watchmaker



W. Paley

2. Darwin's/Wallace's theory

Charles Robert DARWIN (1809–1882)



* 12th February 1809 Shrewsbury



The Mount, Shrewsbury



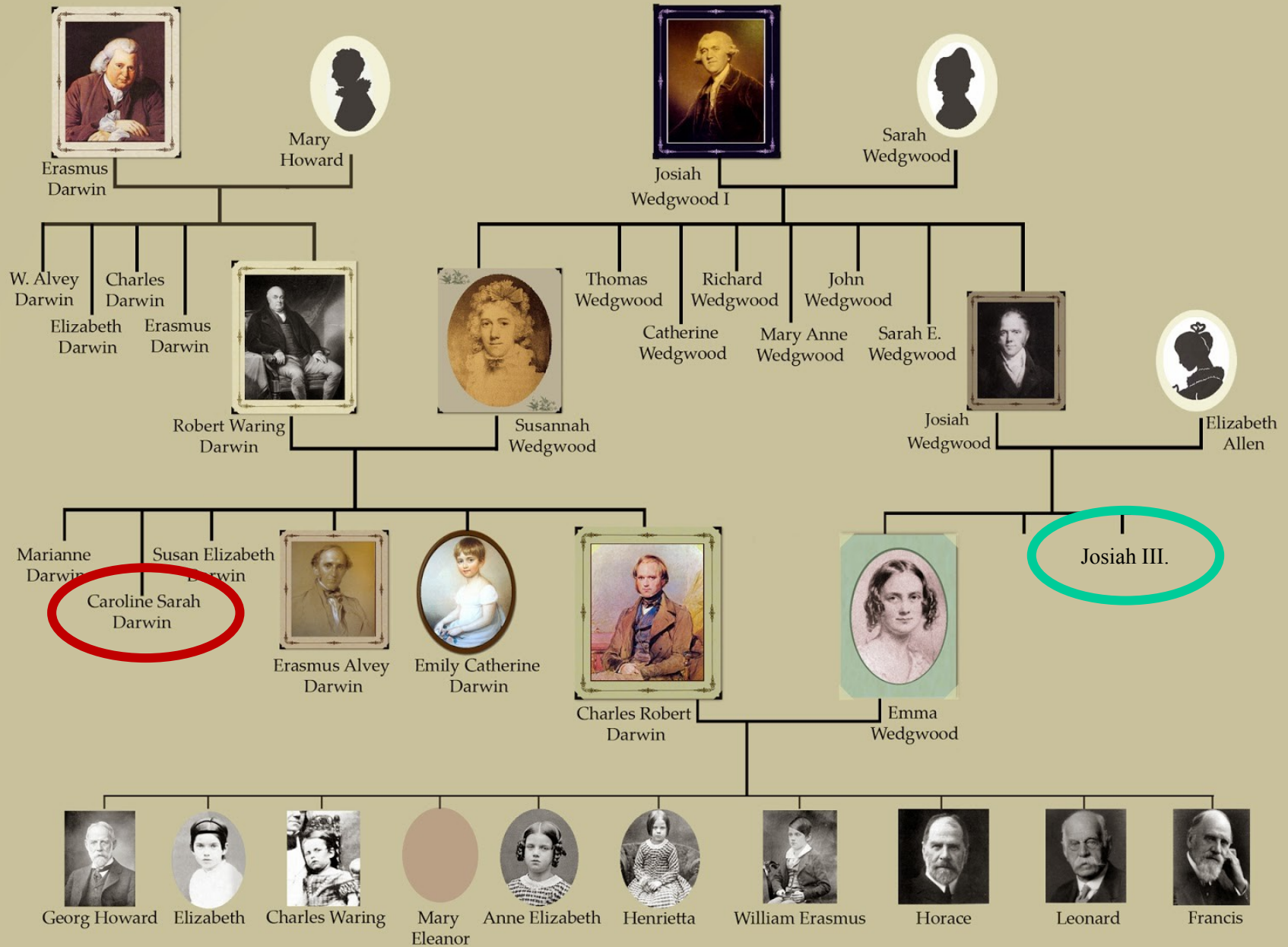
Erasmus Darwin



Josiah Wedgwood I.



Robert Darwin



Los Darwin

Wedgwood china



Est. 1759



October 1825: University of Edinburgh



January 1828: Christ's College,
University of Cambridge





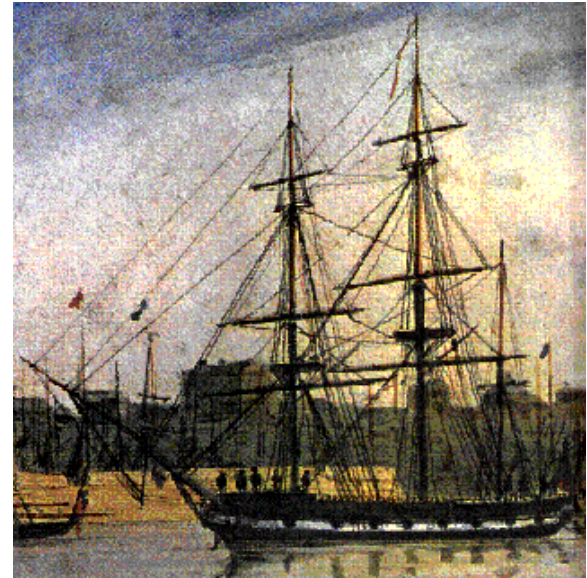
Adam Sedgwick
(1785–1873), geologist



John Stevens Henslow
(1796–1861), botanist, geologist



Robert FitzRoy
(1805–1865)



HMS Beagle
Plymouth 27.12.1831



HMS Beagle (1831–1836)



HMS Beagle (1831–1836)



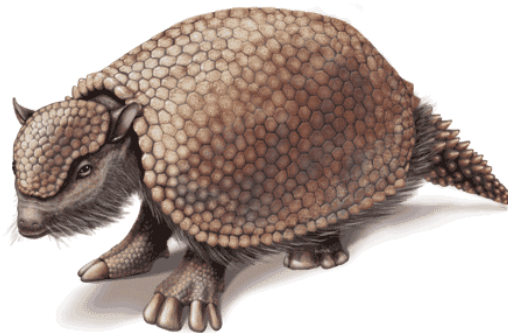
Charles Lyell

Principles of Geology (1830–1833)

HMS Beagle (1831–1836)



Megatherium



Glyptodon



„Rhea Darwinii“

Mastodon

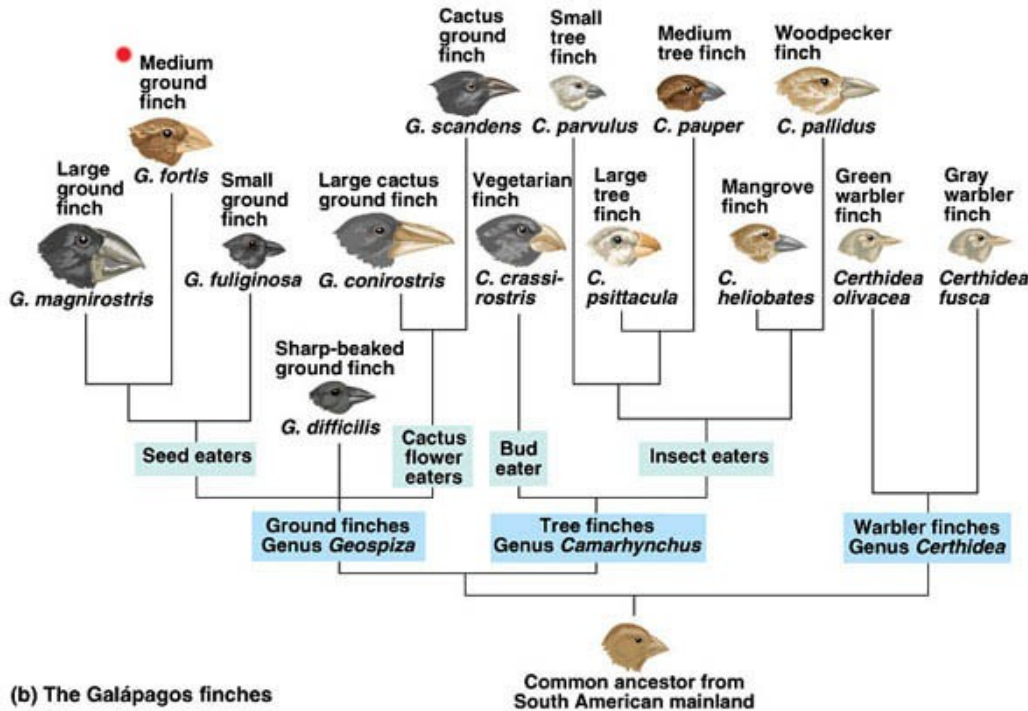
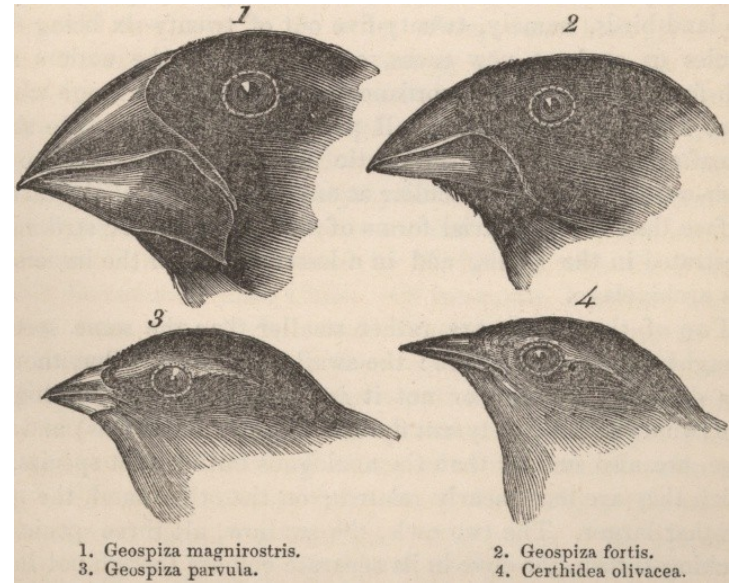
HMS Beagle (1831–1836)





John Gould

„Darwin’s finches“
(tanagers)



(b) The Galápagos finches



mockingbirds

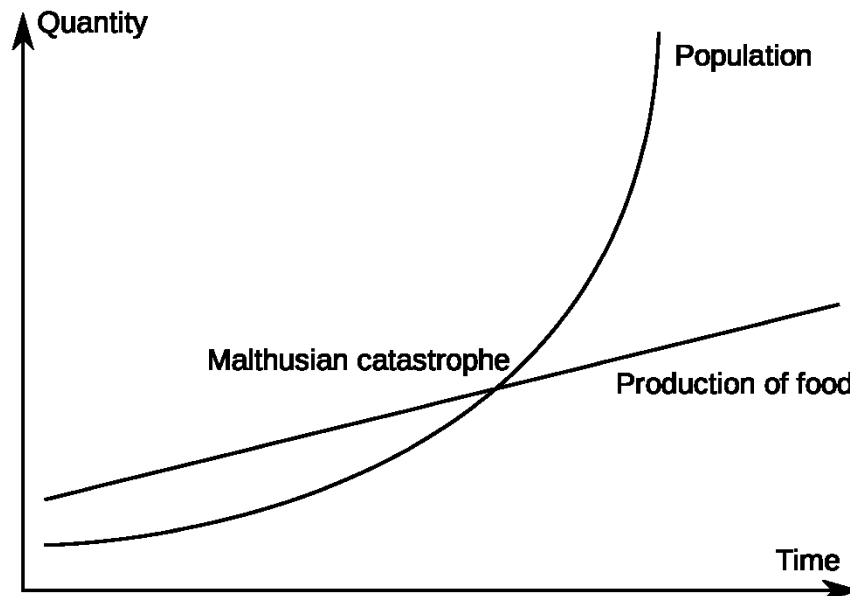
Thomas Robert Malthus (1766–1834)

1798, 1801: *An Essay on the Principle of Population*

decrease of birth and infantile mortality, increase of mean age \Rightarrow population growth

Great Britain (Glasgow, Liverpool, Birmingham, Manchester, London), Ireland, USA, Naples („city of beggars“)

[BUT: agricultural revolution (England, USA) \Rightarrow more sources, in USA the estimate included also immigrants]



deficiency of resources
 \Rightarrow less adapted
individuals don't
survive = natural
selection

1842: pencil-written 35-page outline of the theory of natural selection

1844: extension to 230 pages ... asks his wife Emma for publishing after his death

11th January 1844: letter to J. Hooker with the theory outline

I am almost convinced (quite contrary to opinion I started with) that species are not (it is like confessing a murder) immutable.

[1844, Darwin's letter to Hooker]

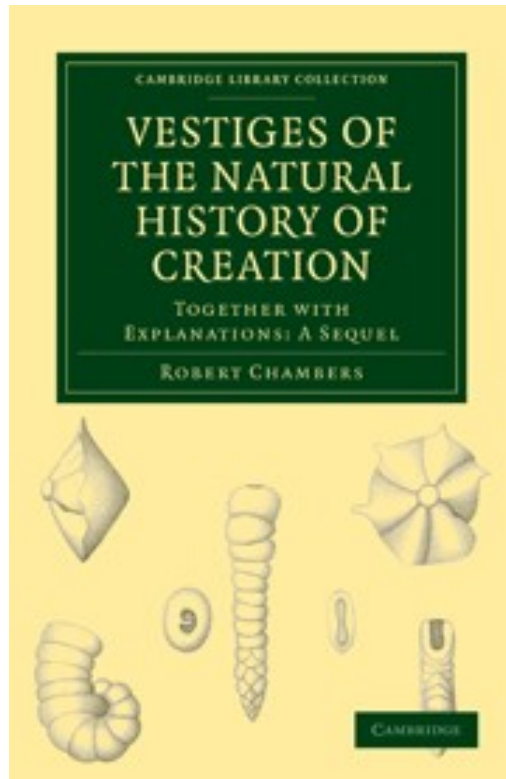


Robert Chambers (1802–1871)

1844: *Vestiges of the Natural History of Creation*)

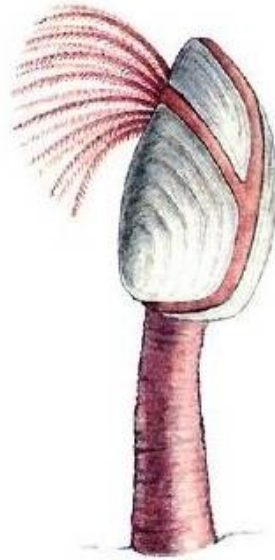
12 editions, in total 100,000 copies

authorship discovered as late as in 1884

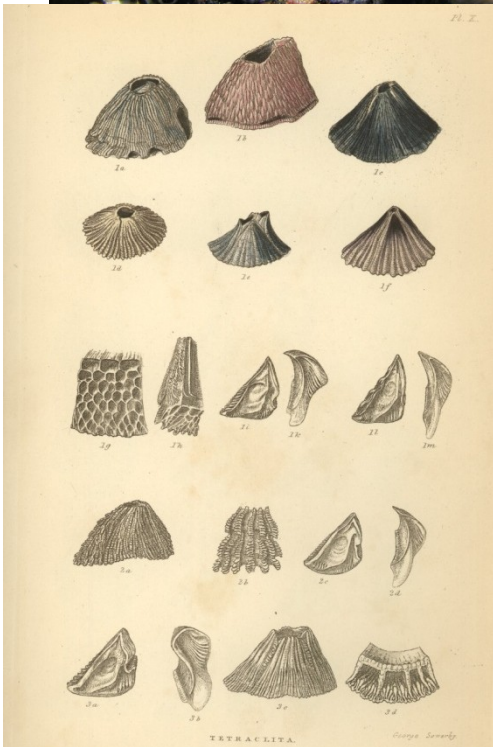




1846 ...



barnacles



1854: 2 books on extant barnacles and 2 books on extinct barnacles

1856: Darwin starts to work on a book on natural selection,
planned extent 1000 pages ...

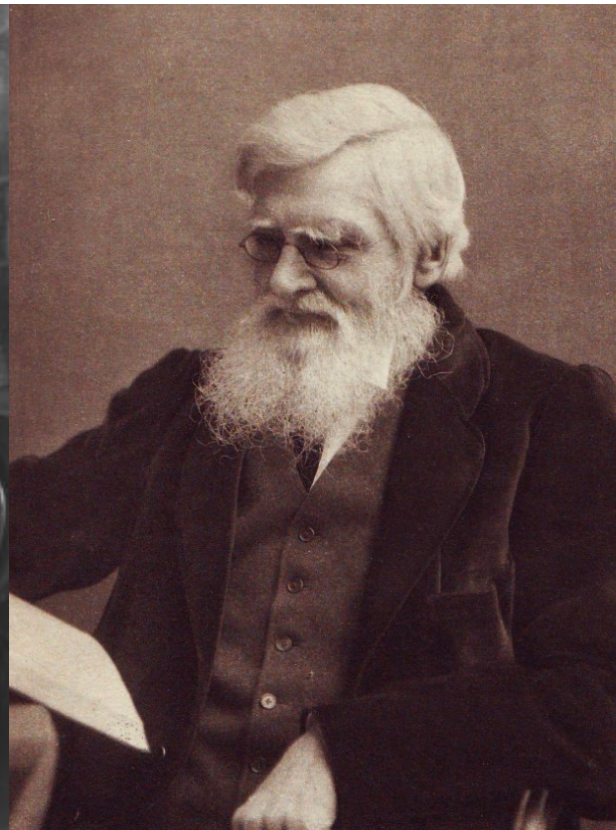
5th August 1857: theory outline to A. Gray

1858: letter from A.R. Wallace *On the Tendency of Varieties to Depart
Indefinitely from the Original Type*

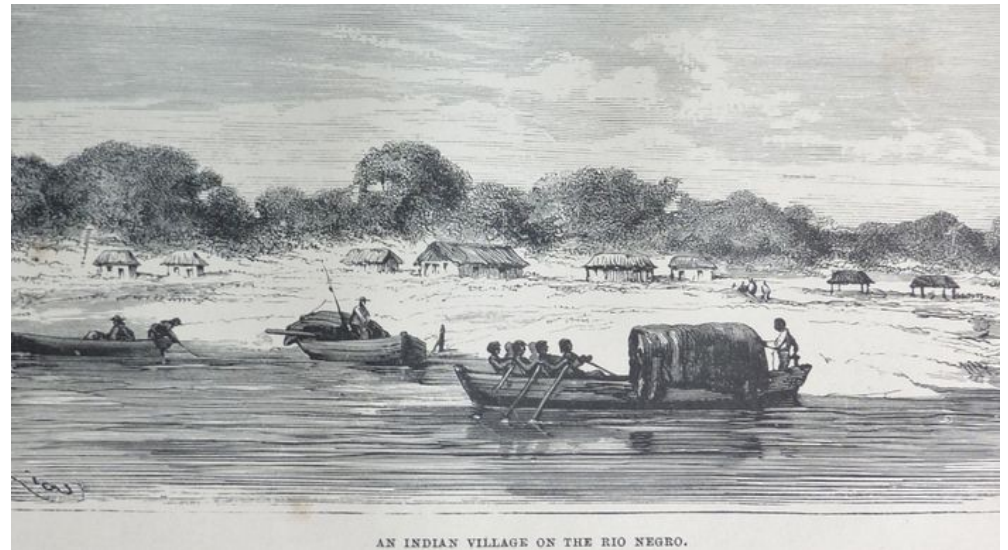


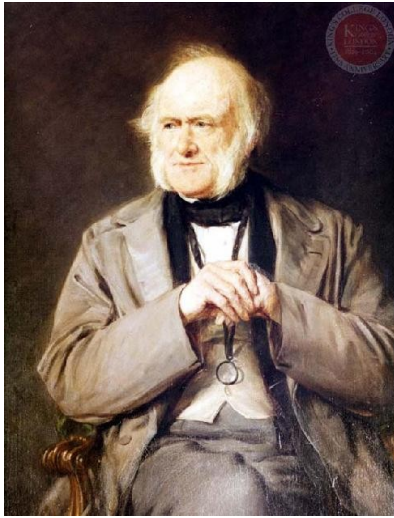
Alfred Russel Wallace

(1823–1913)



THE
RIO NEGRO
FROM OBSERVATIONS
made in the years 1851 and 1852
by
ALFRED R. WALLACE.

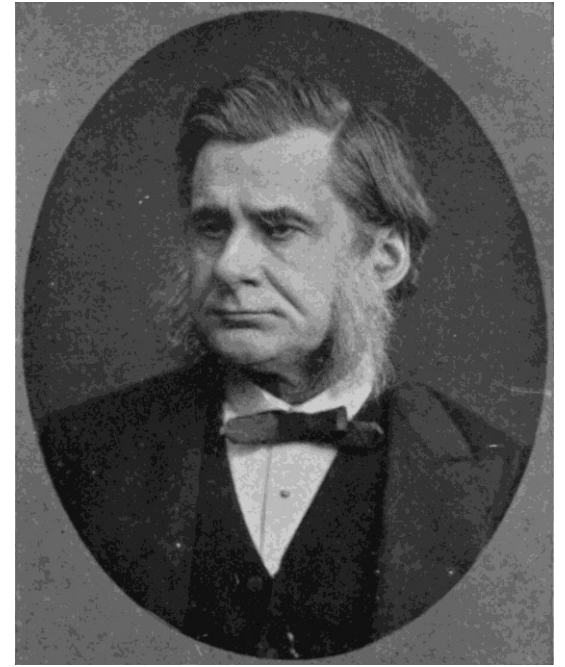




Charles Lyell
(1797–1875)



Joseph Dalton Hooker
(1814–1879)



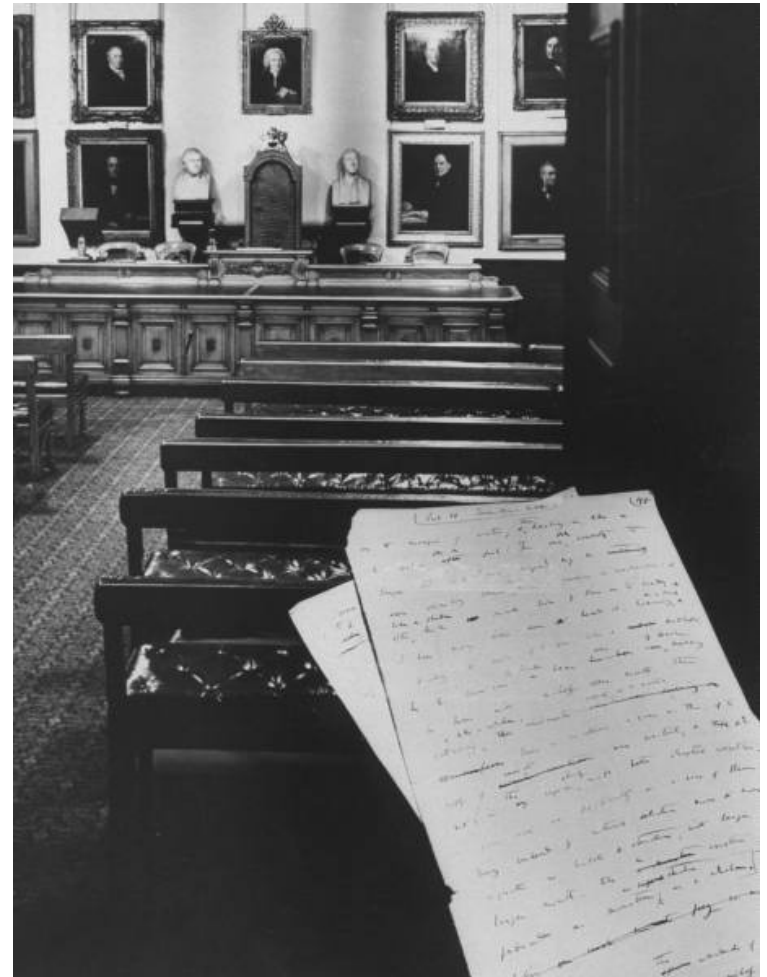
Thomas Henry Huxley
(1825–1895)



Asa Gray (1810–1888)

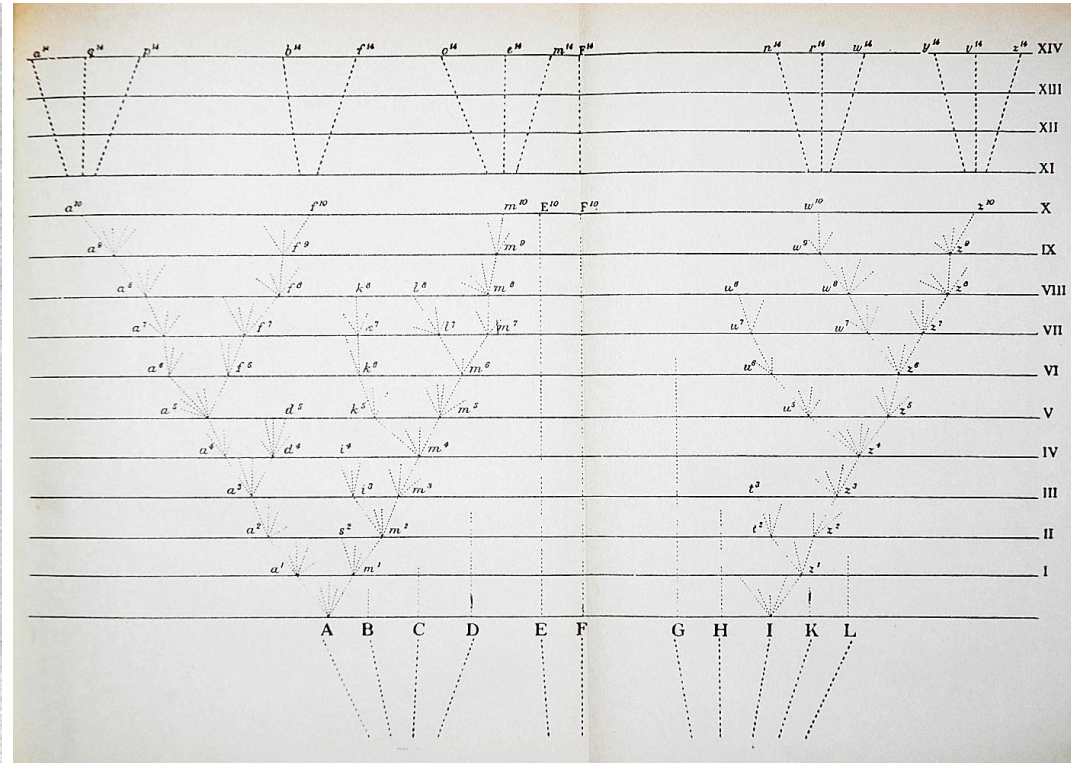
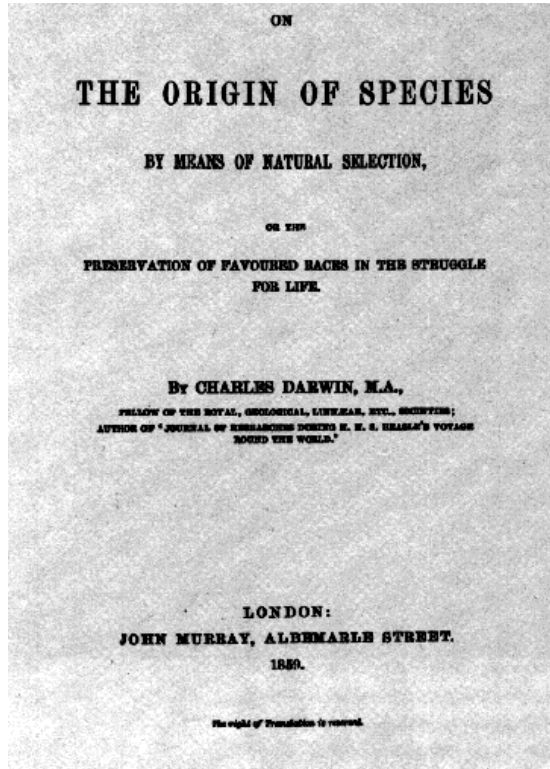
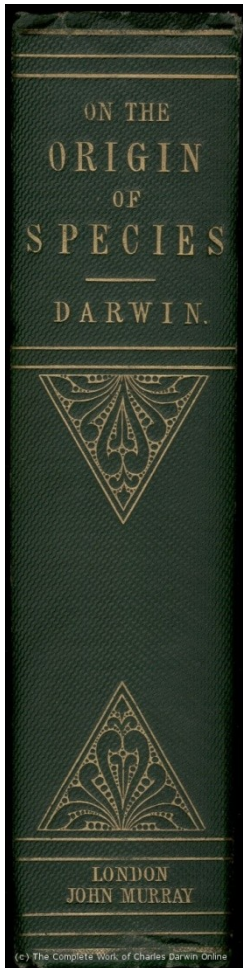
1st July 1858: Linnean Society of London

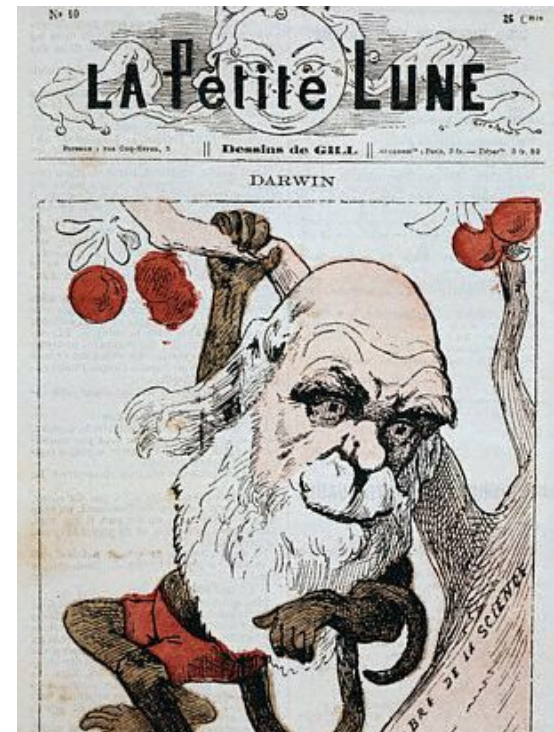
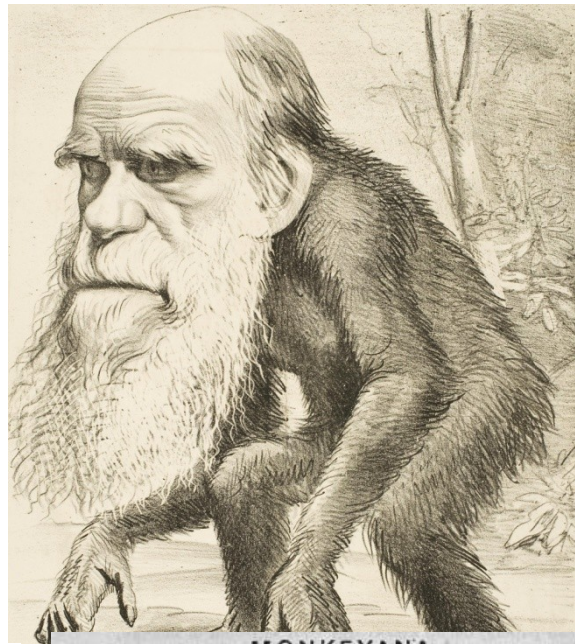
On the Tendency of Species to Form Varieties; and on the Perpetuation of Varieties and Species by Means of Natural Selection



24. listopadu 1859

On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life

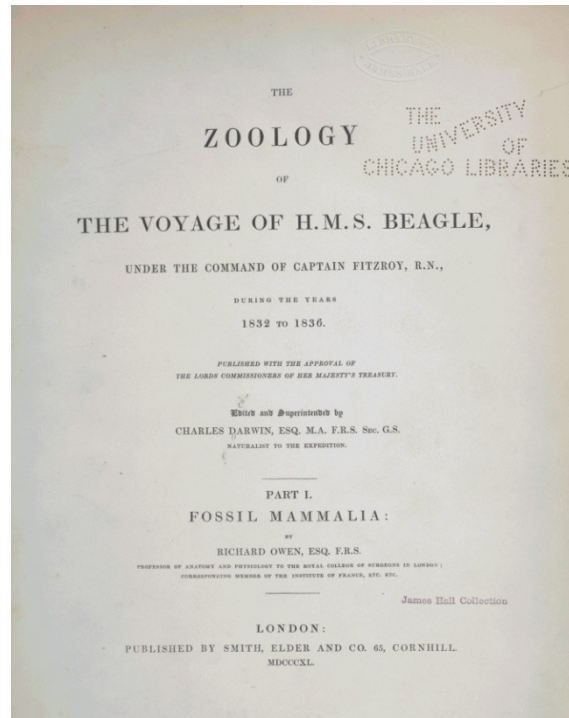




MEANWHILE...
JESUS AND DARWIN
WERE FIGHTING AGAIN.



Richard Owen

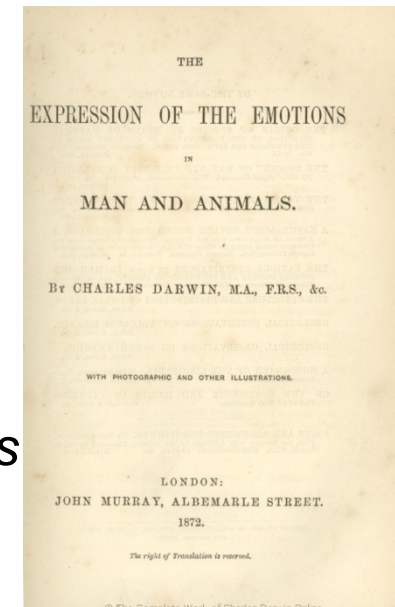
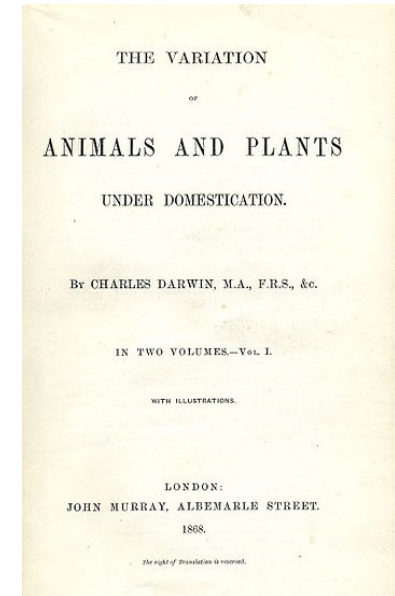
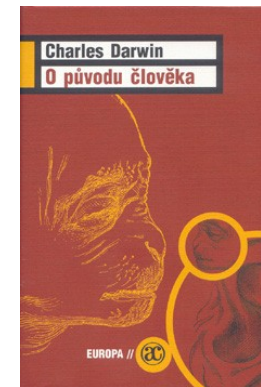
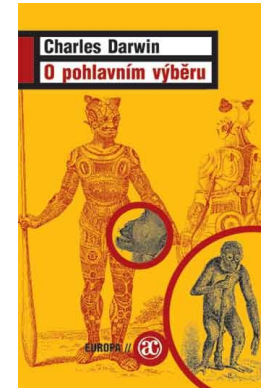
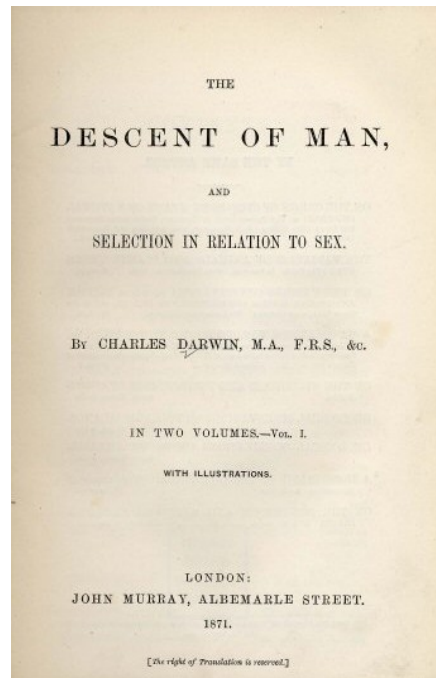
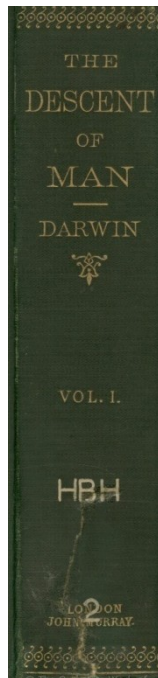
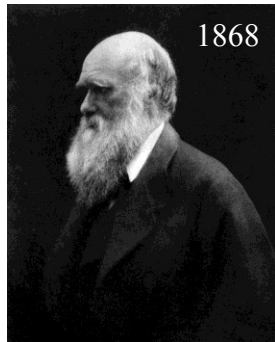


Samuel Wilberforce (1805–1873)



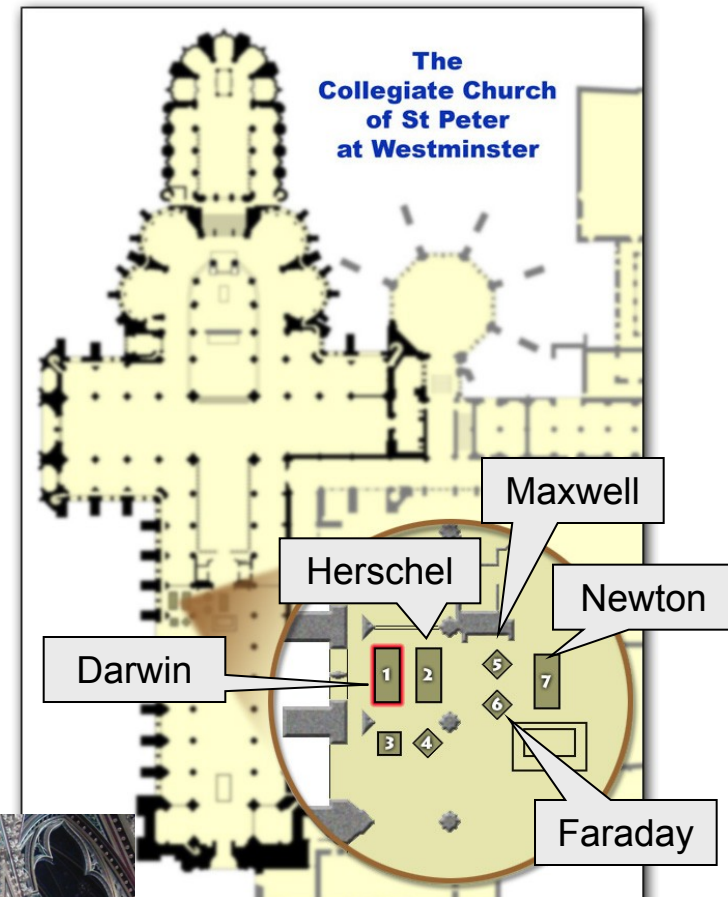
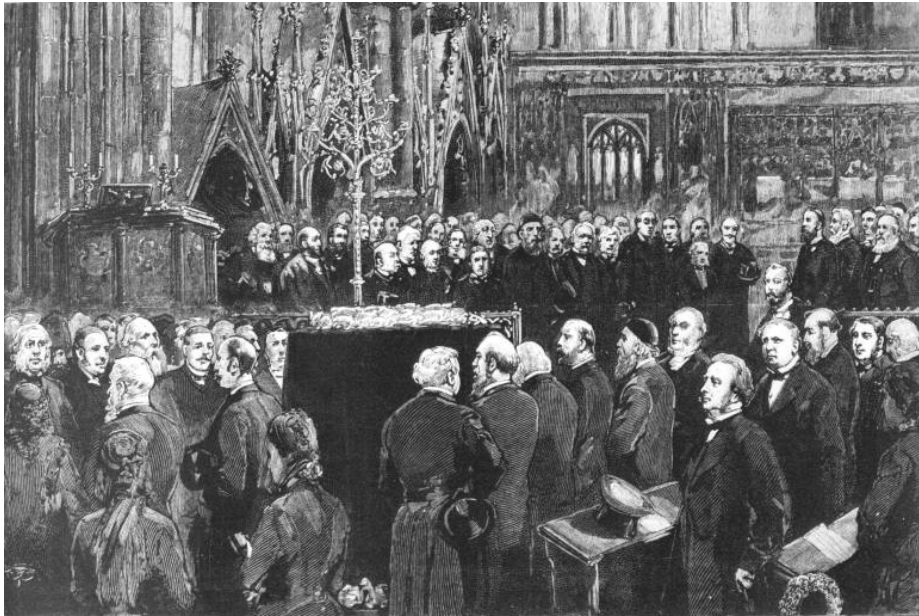
1868: *The Variation of Animals and Plants under Domestication*

1871: *The Descent of Man, and Selection in Relation to Sex*



1872: *The Expression of the Emotions in Man and Animals*

+ 19th April 1882, Down House



FUNERAL OF MR. DARWIN.
WESTMINSTER ABBEY,
Wednesday, April 26th, 1882.
AT 12 O'CLOCK PRECISELY.
Admit the Bearer at Eleven o'clock to the
SOUTH TRANSEPT.
(Entrance by Door at Poet's Corner.)
G. G. BRADLEY, D.D.
Dean.
N.B.—No Person will be admitted except in mourning.



HERSCHEL
HERSCHEL
ERE FAMA
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PLORATIS
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CIT
NERATIO
RRABUNT
5.
OS
MAIL

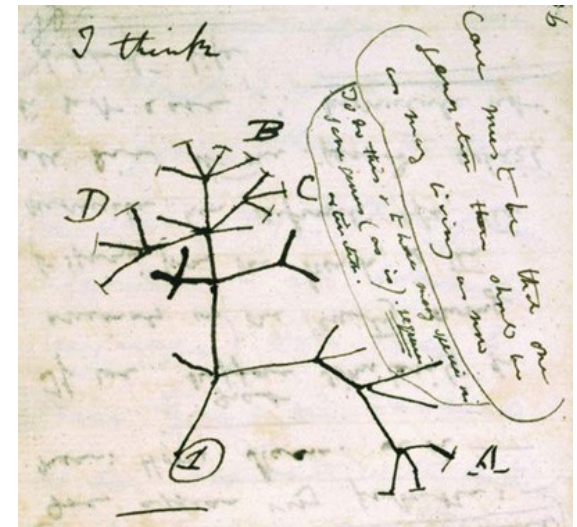
CHARLES ROBERT DARWIN
BORN 12 FEBRUARY 1809
DIED 19 APRIL 1882

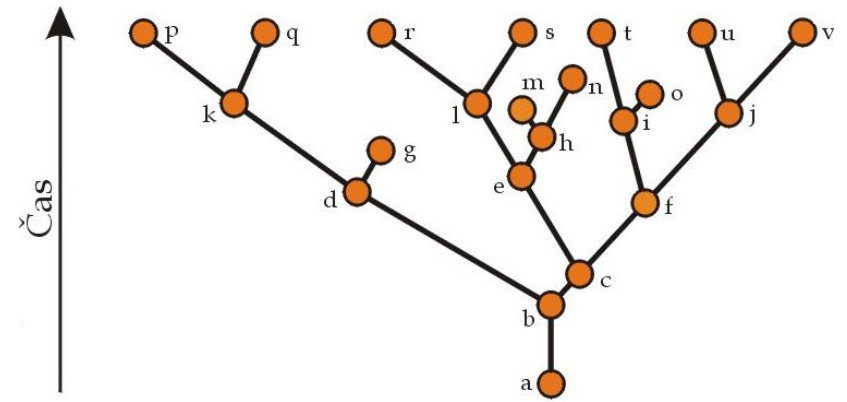
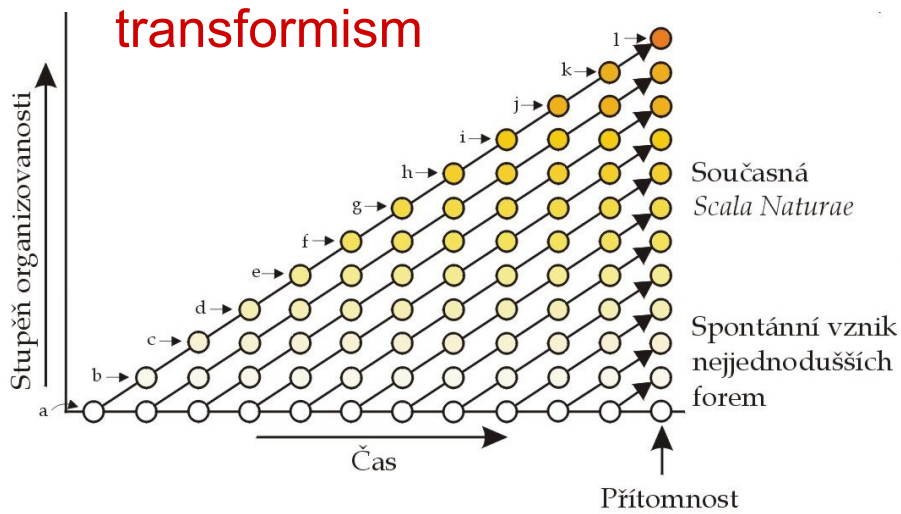
Darwin's theory = DARWINISM:



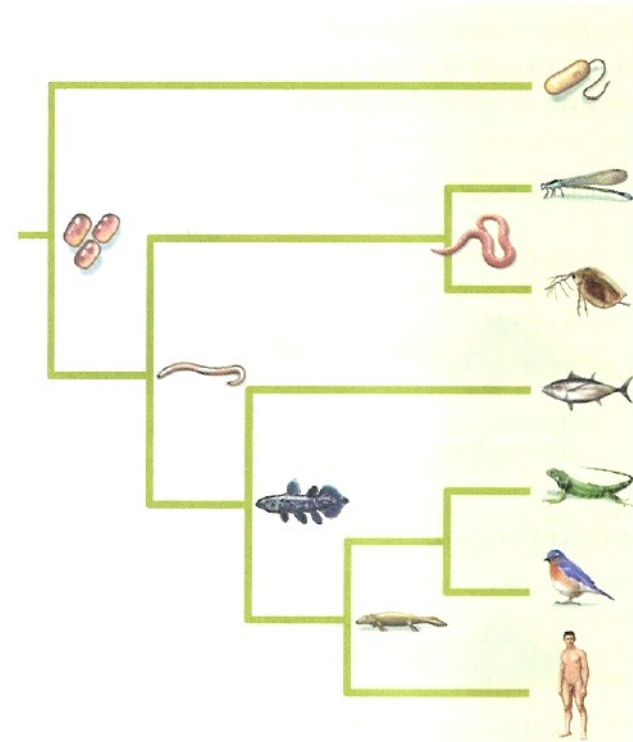
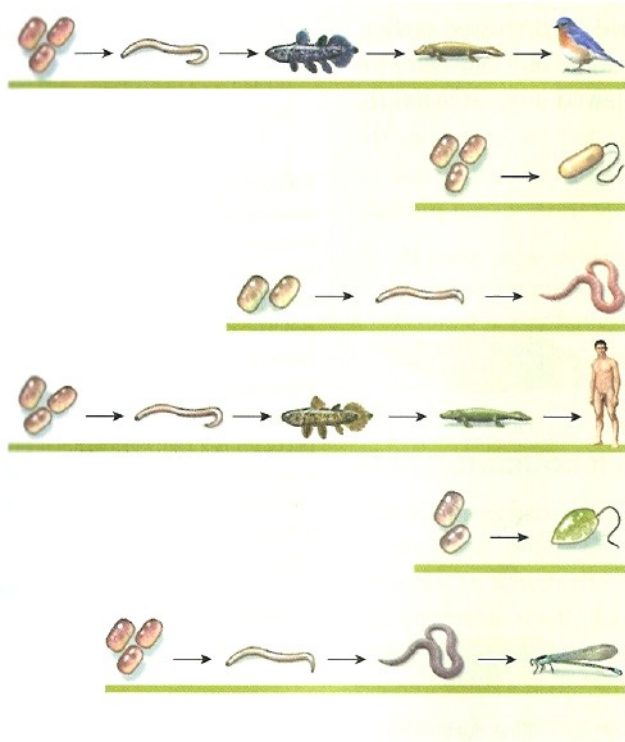
1. Descent of all species from a common ancestor
no action of a supernatural being
(materialistic explanation)
no abiogenesis, species emerge from other species
divergence by accumulating small changes
(no saltations, no catastrophism)

2. Theory of natural selection





Darwinism



Lamarck:

Transformational process



Mix of fine and coarse particles



Strike repeatedly



Fine dust

„population“ has changed because all individuals have changed (no selection)

Variational process



Mix of fine and coarse particles



Sift the soil



Fine dust

„population“ of smaller individuals because big ones have been selected out

Darwin:

3. Evolutionary theory at the turn of the century

Problems of Darwin's theory:

time: William Thomson, lord Kelvin
age of Earth max. 200 My

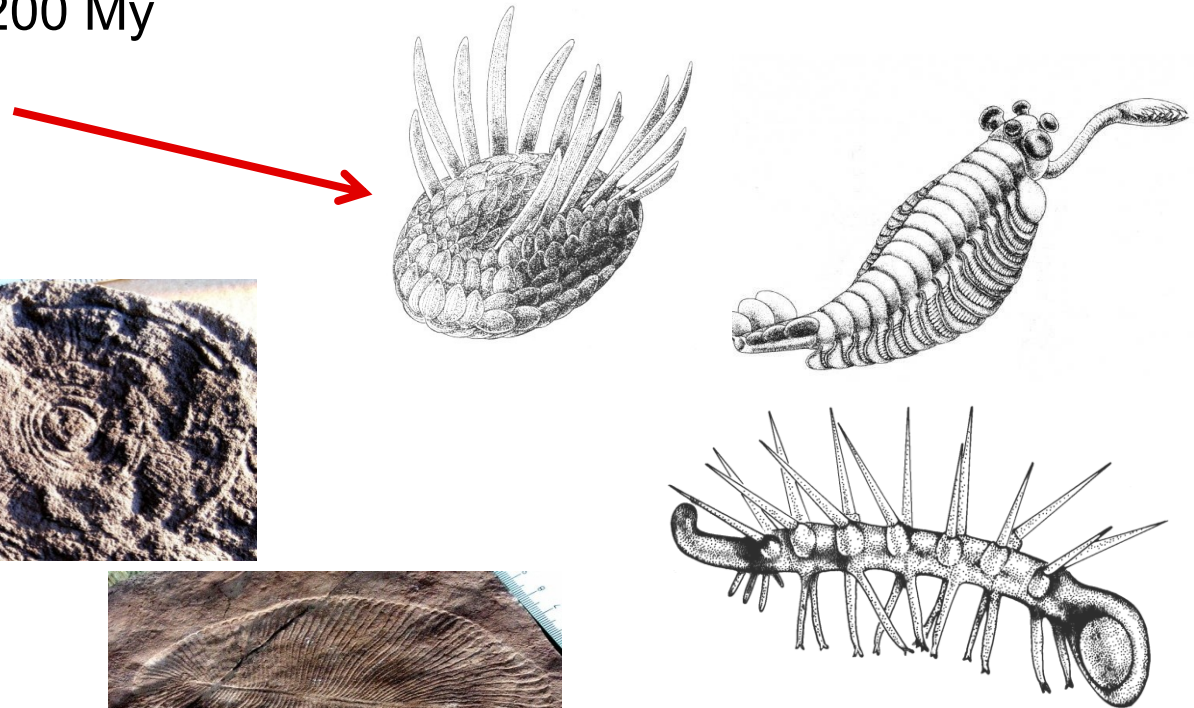
Cambrian fossils



stromatolites



Precambrian (Ediacaran fauna)



Problems of Darwin's theory:

origin of complex organs

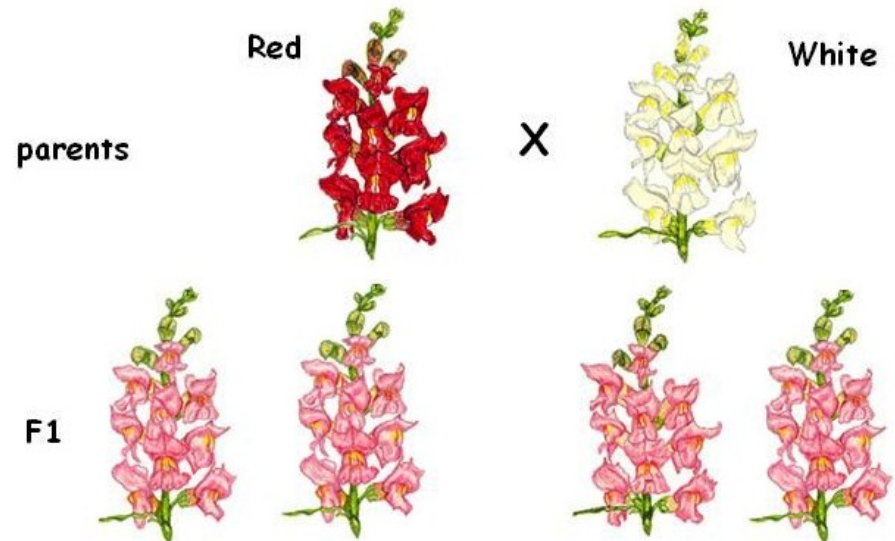
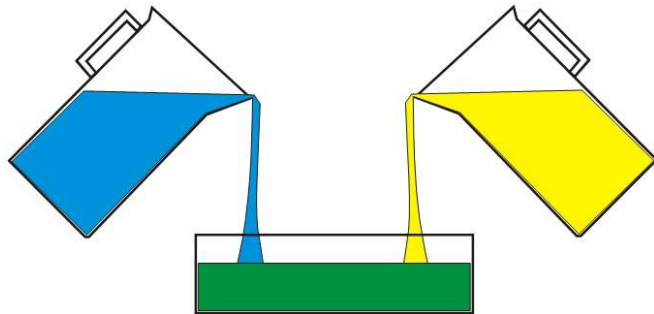
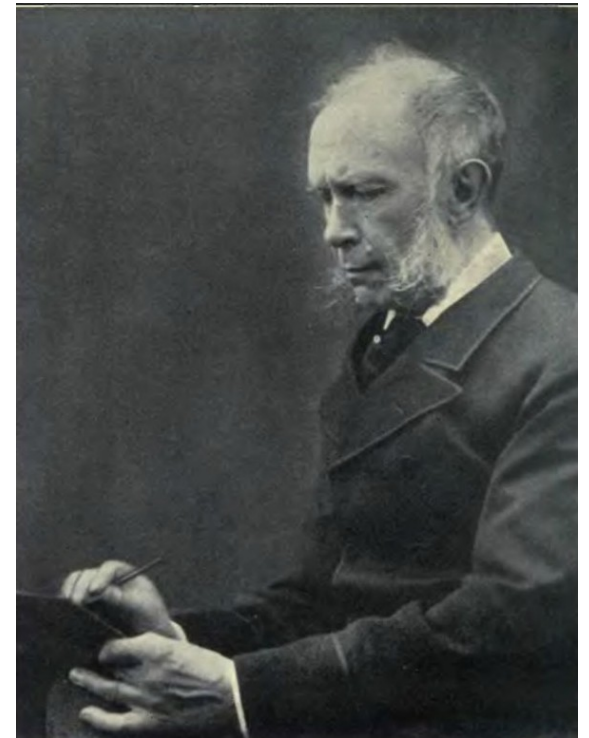


Problems of Darwin's theory:

ignorance of the theory of heredity:

blending heredity (× 1867 Fleeming Jenkin)

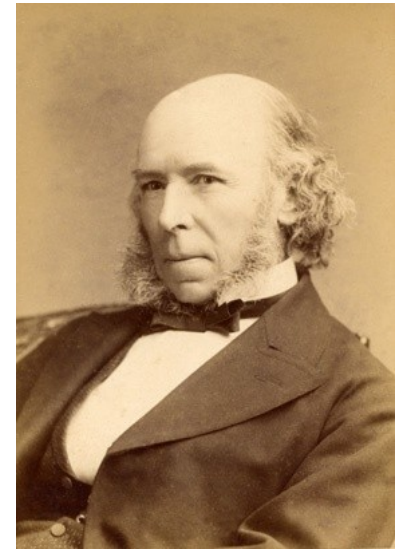
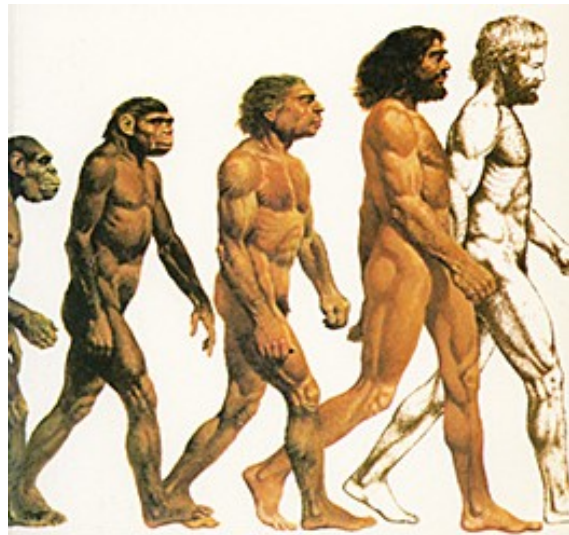
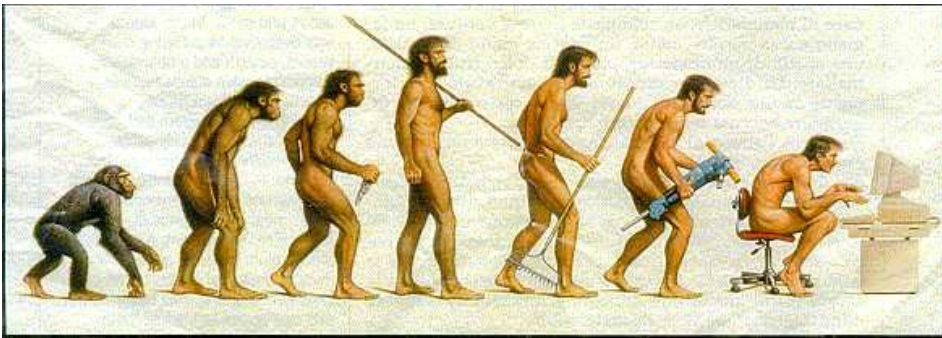
pangenesis (gemmules)



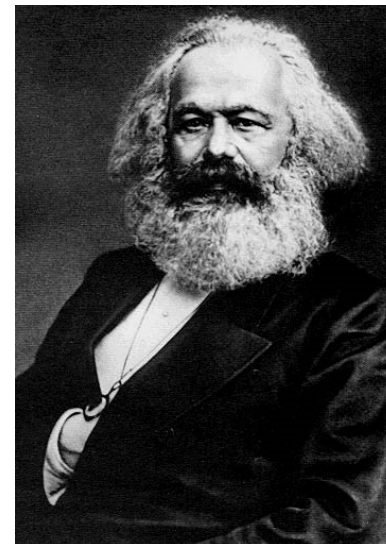
Herbert Spencer (1820–1903): social Darwinism

Marx, Engels: marxism

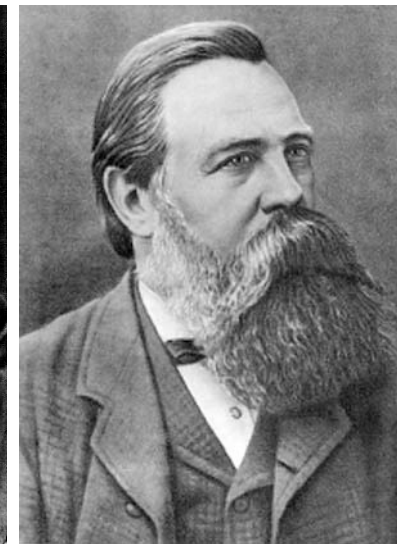
evolution as a progressive process



H. Spencer



K. Marx



F. Engels

ALTERNATIVE THEORIES

1. Orthogenesis:



Megaceros giganteus

finalism



2. Neolamarckism:

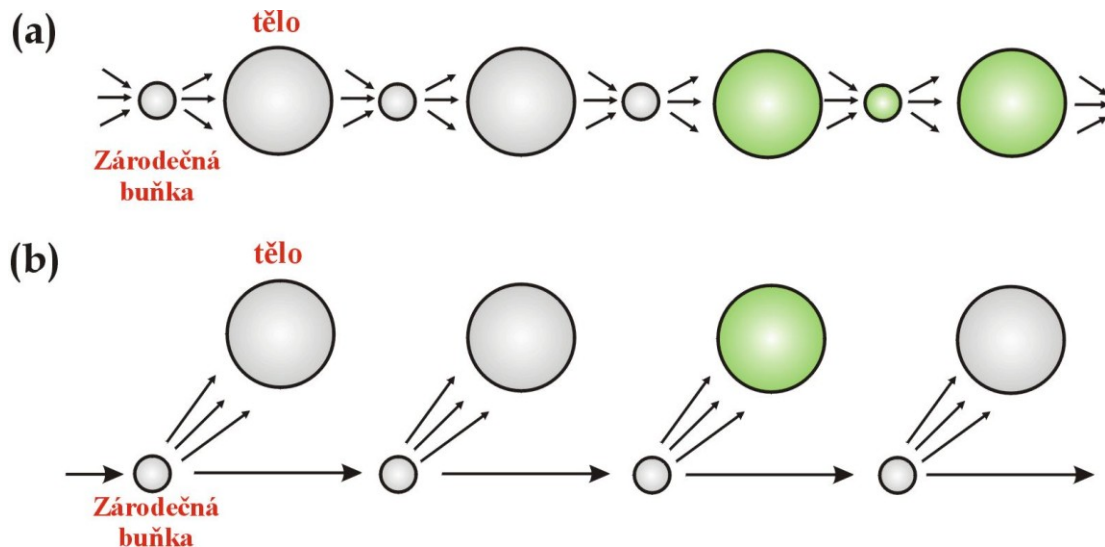
Paul Kammerer, Arthur Koestler

lysenkism: Trofim Děnisovič Lysenko

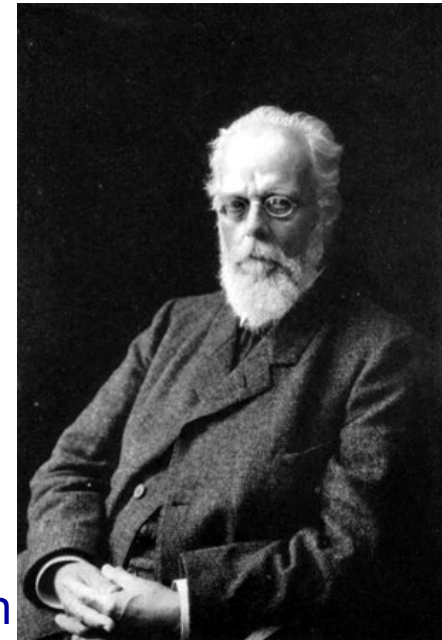
T. D. Lysenko



August Weismann:
soma + germen



A. Weismann



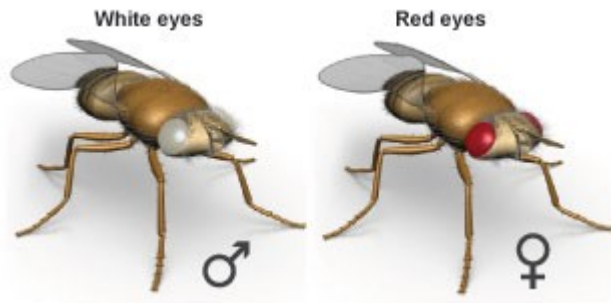
3. Mutationism:

1900: rediscovery of Mendel's laws

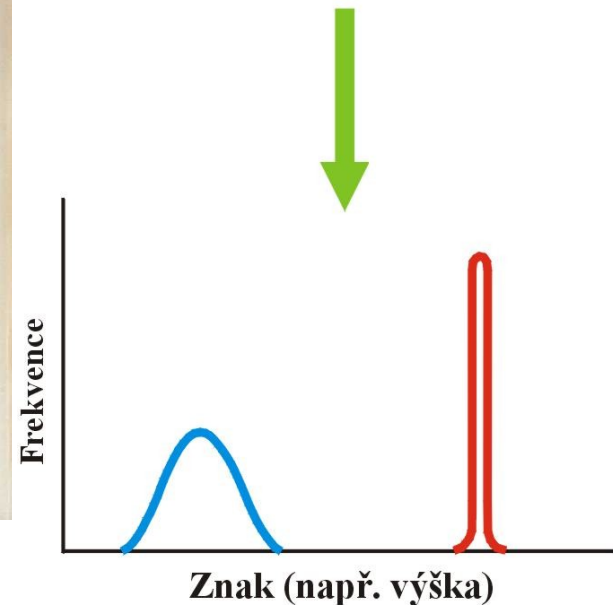
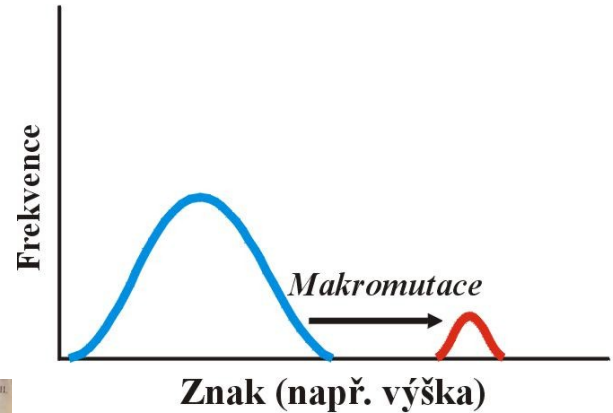
Hugo de Vries: the term mutation
evening primrose (*Oenothera lamarckiana*)

William Bateson, Thomas Hunt Morgan

discrete variation



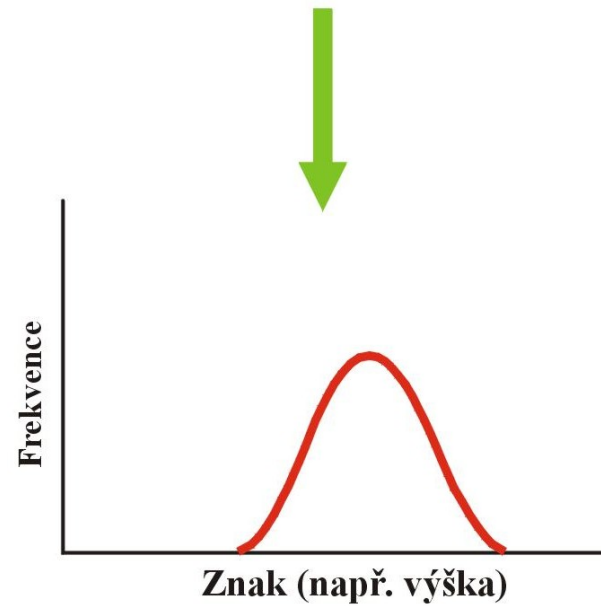
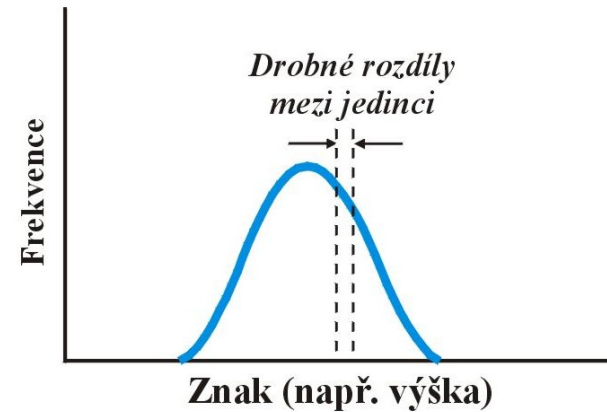
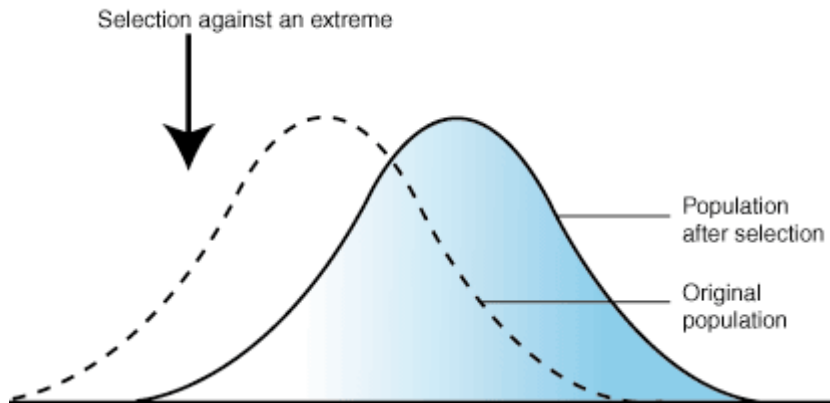
macromutations: Richard Goldschmidt
(1940) - „hopeful monsters“



× **biometricians:**

Francis Galton, Karl Pearson

continual variation



4. Modern Synthesis



RONALD A. FISHER



J. B. S. HALDANE



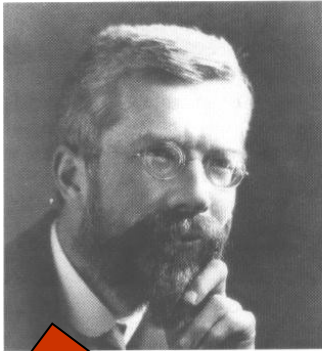
SEWALL WRIGHT

Ronald Aylmer Fisher (1890-1962)

John B. S. Haldane (1892-1964)

Sewall Wright (1889-1988)

Sergey Chetverikov (1880-1958)



R. A. FISHER



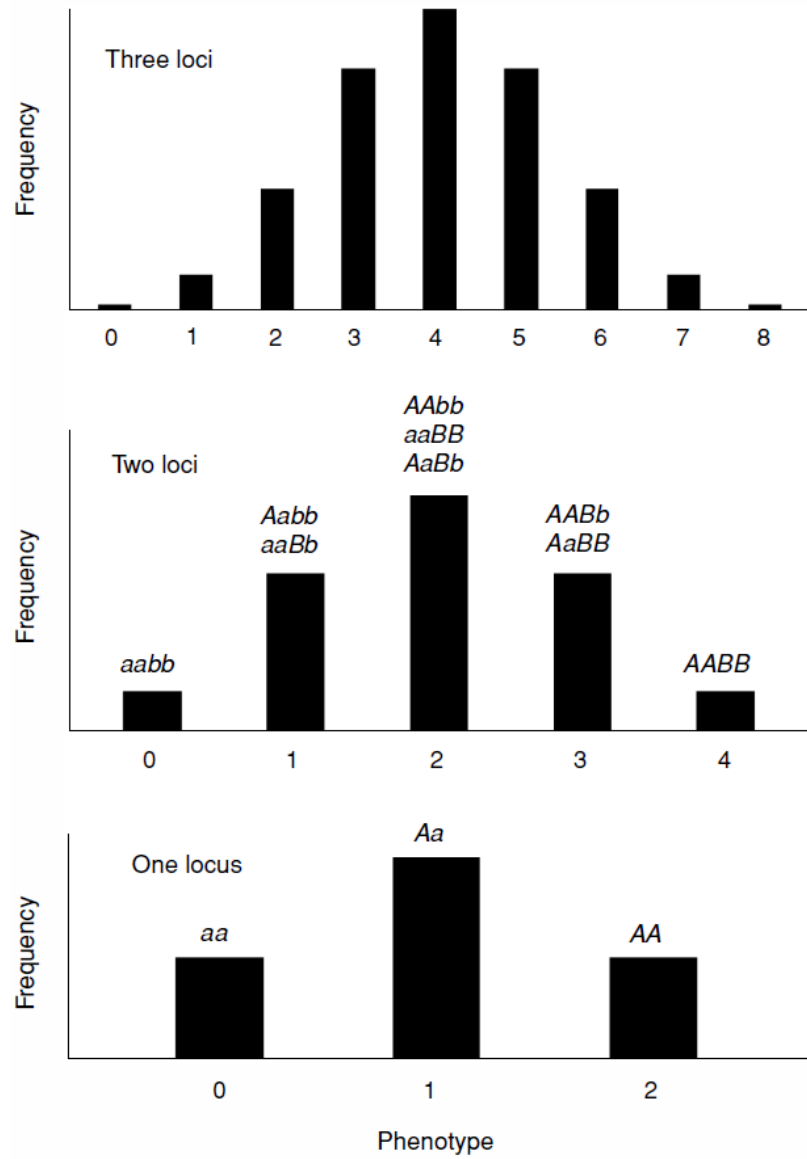
J. B. S. HALDANE



SEWALL WRIGHT



1918: results of biometricians
in agreement with Mendelism





R. A. FISHER



J. B. S. HALDANE



SEWALL WRIGHT



1918: results of biometricians
in agreement with Mendelism

1930: *The Genetical Theory of
Natural Selection*



1931: *Evolution in Mendelian
Populations*



1932: *The Causes of Evolution*

principles of population genetics

NEODARWINISM in a narrow sense

Theodosius Dobzhansky (1900-1975)

1937 – *Genetics and the Origin of Species*

Edmund B. Ford (1901-1988)

1964 – *Ecological Genetics*

Julian S. Huxley (1887-1975)

1942 – *Evolution: The Modern Synthesis*



Ernst Mayr (1904-2005)

George Gaylord Simson (1902-1984)

George Ledyard Stebbins (1906-2000)

1947 Princeton

1949 *Genetics, Paleontology, and Evolution*

Synthetic theory of evolution = Modern Synthesis

NEODARWINISM in a broad sense

Synthesis 1937-50

T Dobzhansky 1937 <i>Genetics and the origin of species</i>	4,591 citations
R Goldschmidt 1940 <i>The material basis of evolution</i>	1,009
E Mayr 1942 <i>Systematics and the origin of species</i>	4,380
J Huxley 1942 <i>Evolution, the modern synthesis</i>	1,891
G G Simpson 1944 <i>Tempo and mode in evolution</i>	1,684
I I Schmalhausen 1949 <i>Factors of evolution</i>	841
G L Stebbins 1950 <i>Variation and evolution in plants</i>	3,506



Dobzhansky



Goldschmidt



Mayr



Huxley



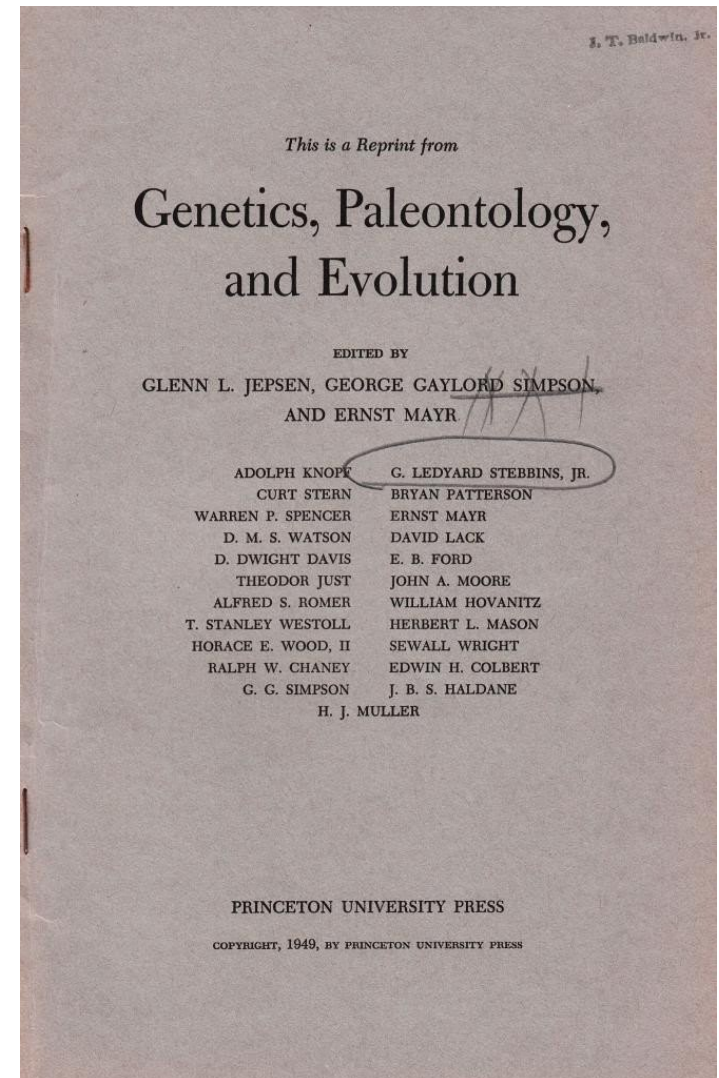
Simpson



Schmalhausen



Stebbins



Some principles of Neodarwinism:

phenotypic differences are caused by differences in genotype and partly by environmental influences

environment can change the mutation rate but not give rise to adaptive mutations

heredity is based on genes which maintain their identity from generation to generation

evolutionary changes take place in populations as changes of gene frequencies

there is no gene flow among species

not even macromutation can cause the origin of a new species

new species generally emerge by genetic divergence of geographically isolated populations

differences, processes and mechanisms on the supraspecific level (macroevolution) can be explained with the same principles as those on the infraspecific level (microevolution)

fossil evidence is in agreement with principles of evolutionary changes, no other mechanisms are necessary (lamarckism, orthogenesis, vitalism, mutationism)

CAN EVOLUTION BE PROVEN?

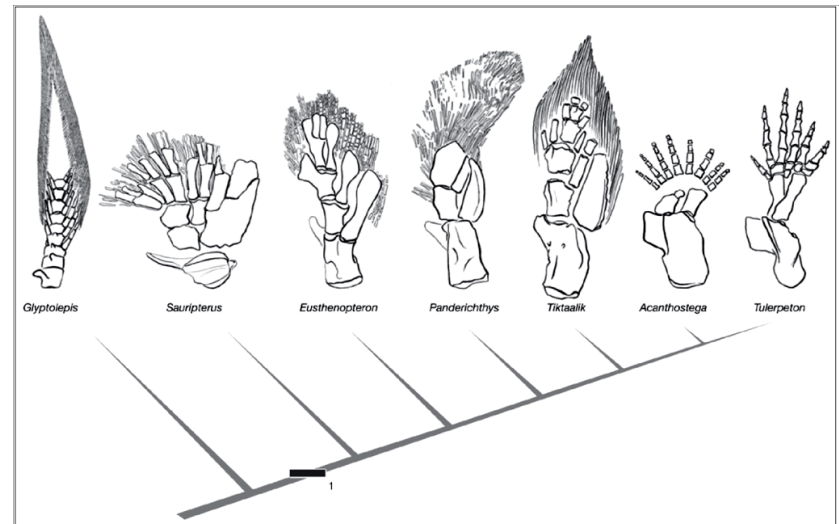
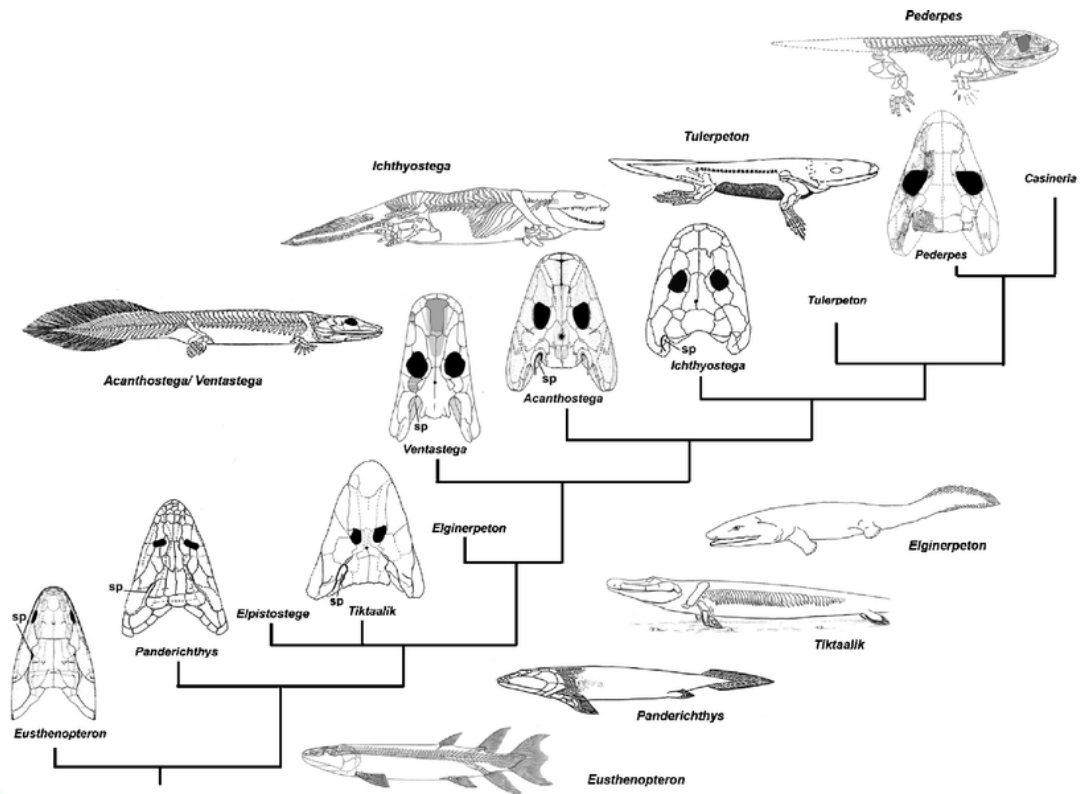
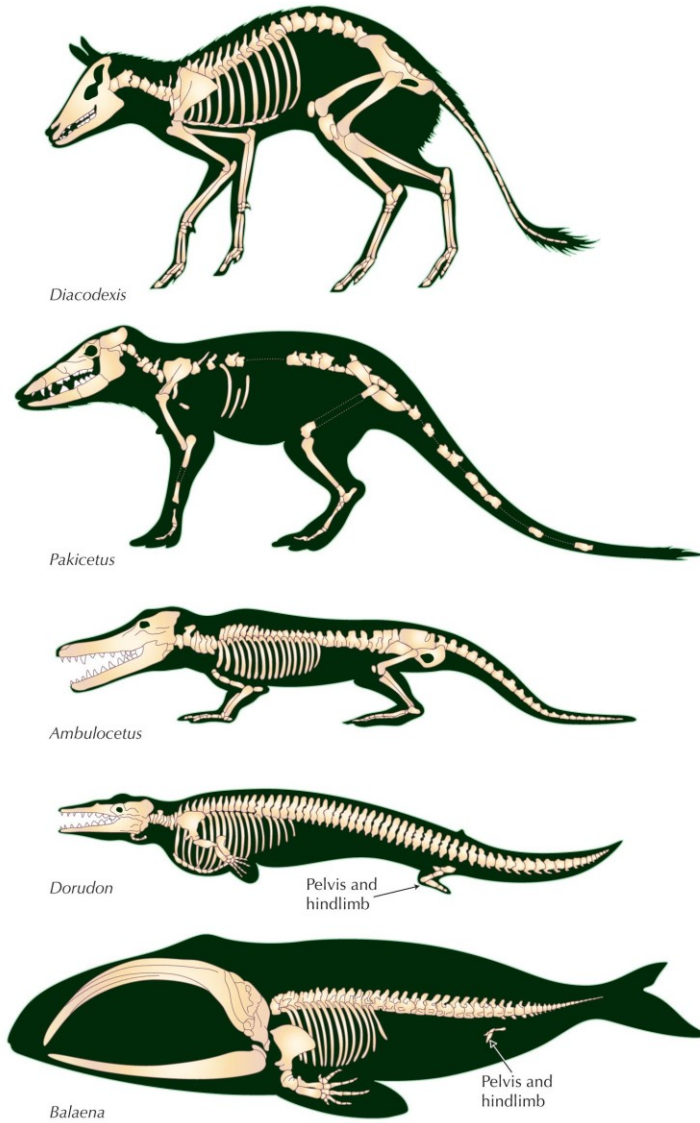
we can see evolution: *Primula verticillata* × *P. floribunda* → *P. kewensis*

Galleopsis pubescens × *G. speciosa* → *G. tetralit*



FIGURE 3.10. *Primula kewensis* (left) was created artificially by crossing *Primula verticillata* (middle) and *Primula floribunda* (right). It has twice as many chromosomes as its parent species and so can interbreed with neither.

transient forms?



evolution and geography

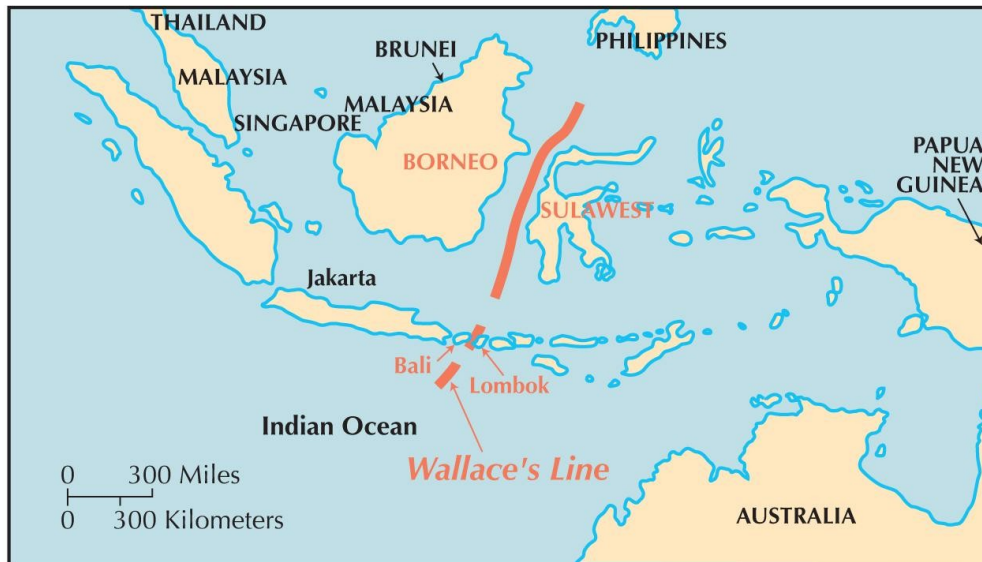
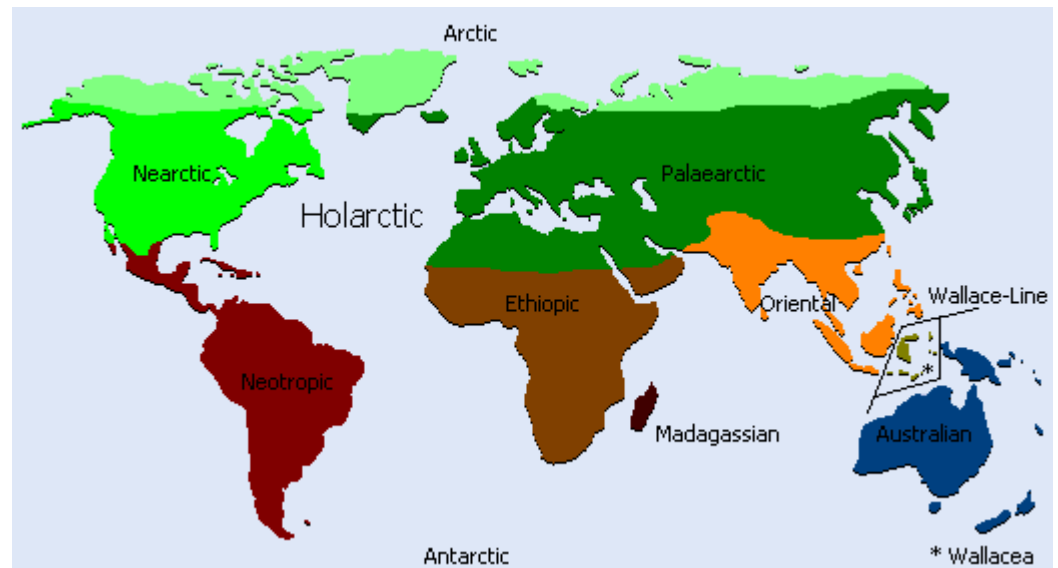
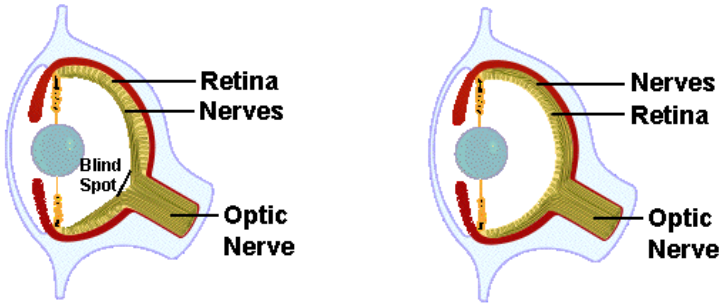


FIGURE 3.6. Wallace's Line (*thick red line*) separates two distinct present-day land faunas.

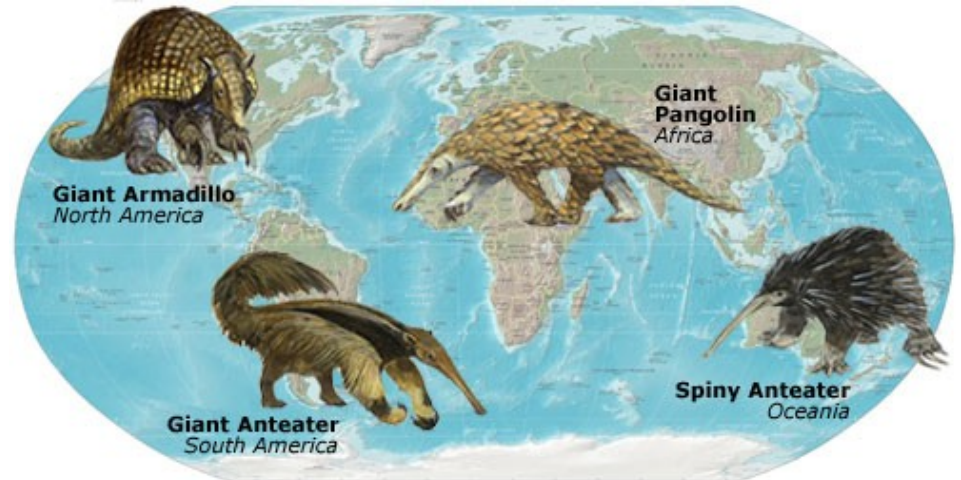
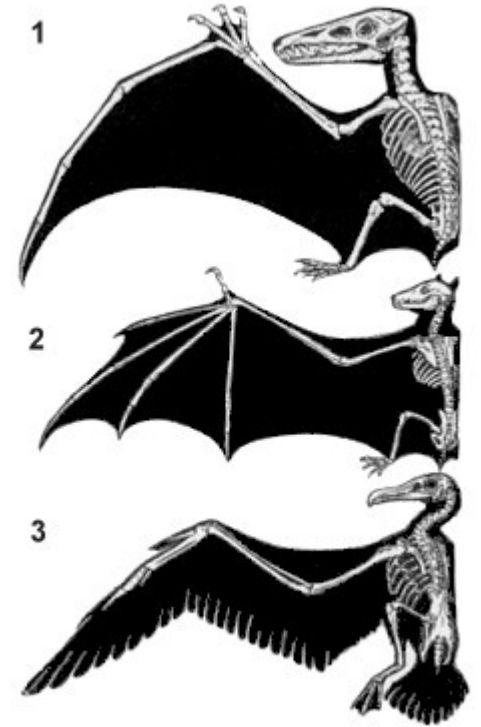
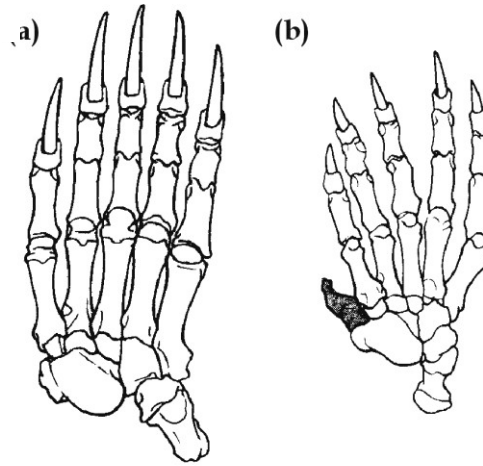
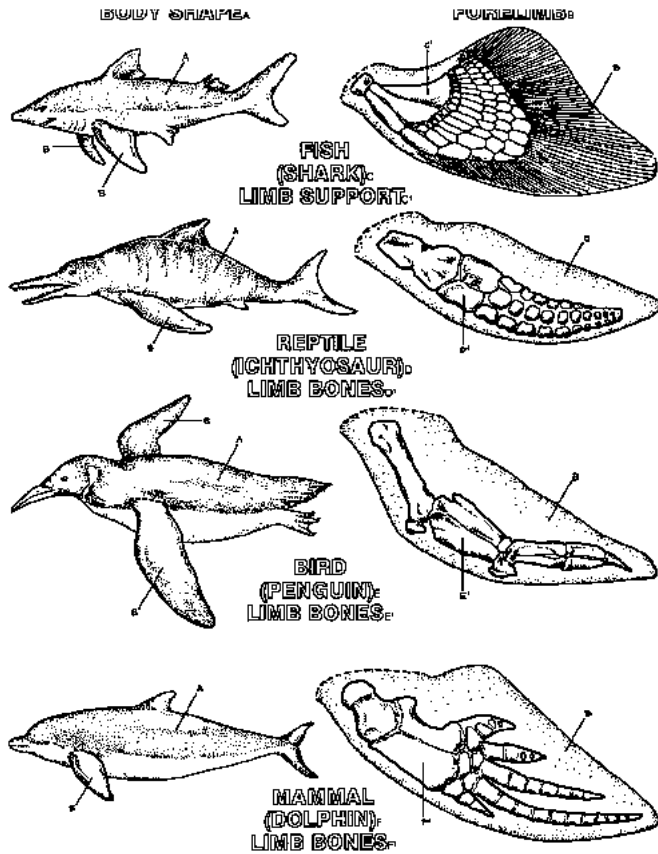
3.6, adapted from *Spice Island Voyage*, University of Limerick, Ireland Project

convergence

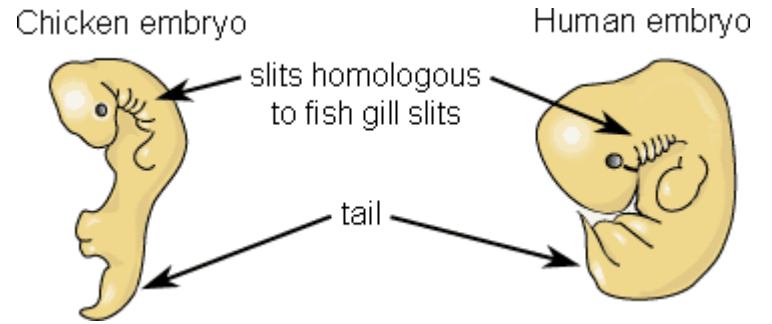
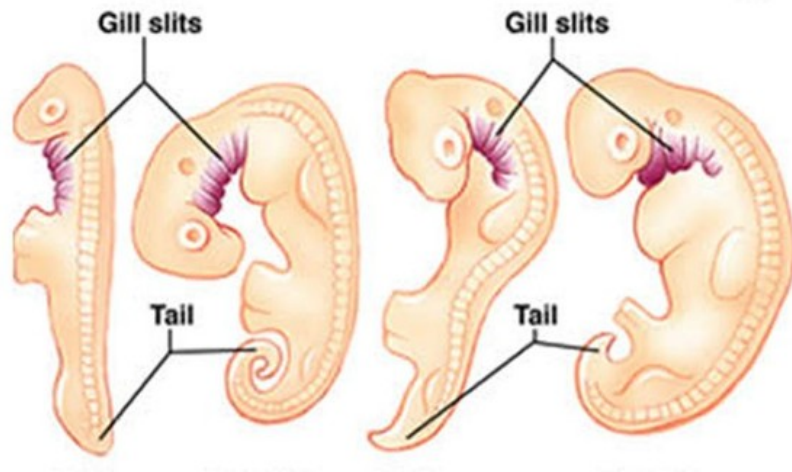


Vertebrate

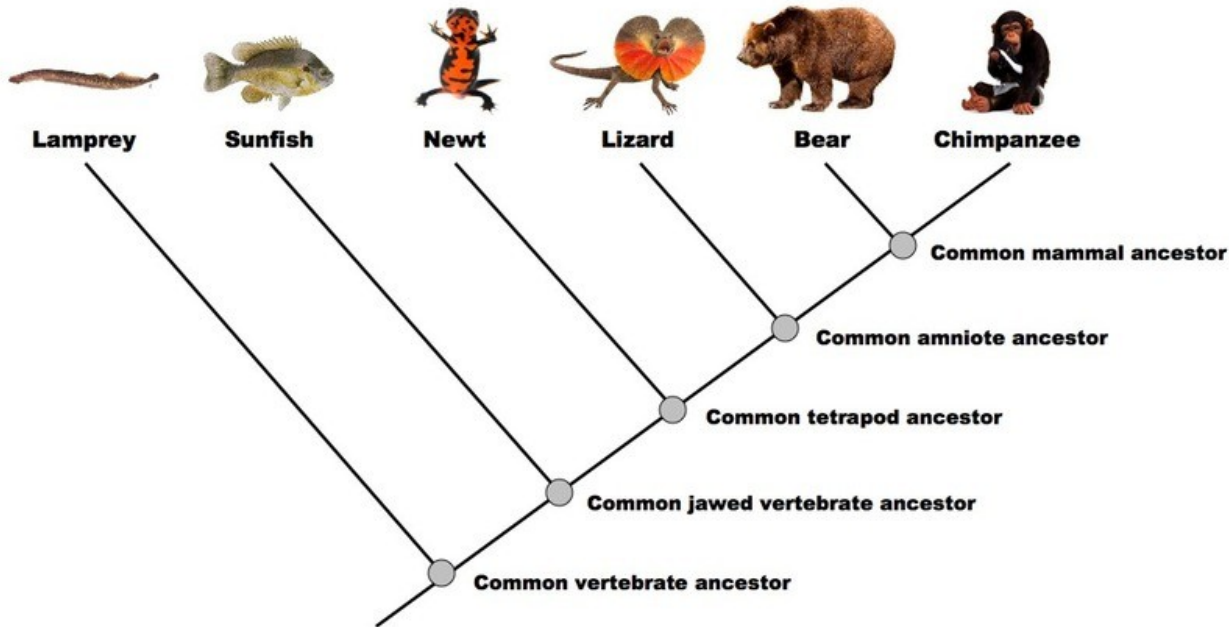
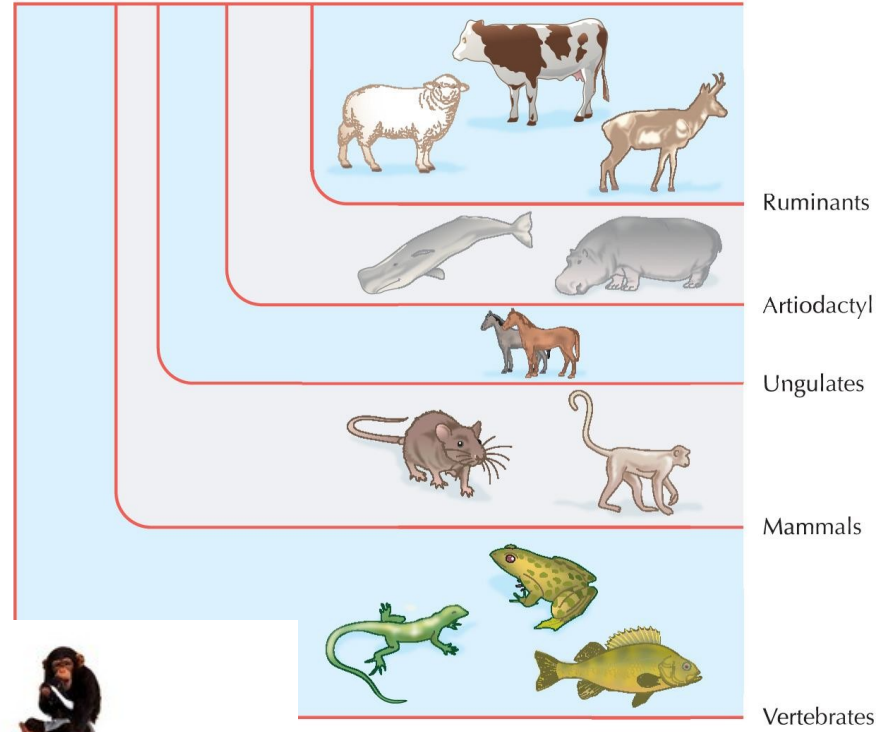
Cephalopod



embryonal development: gill slits, lanugo



hierarchical arrangement

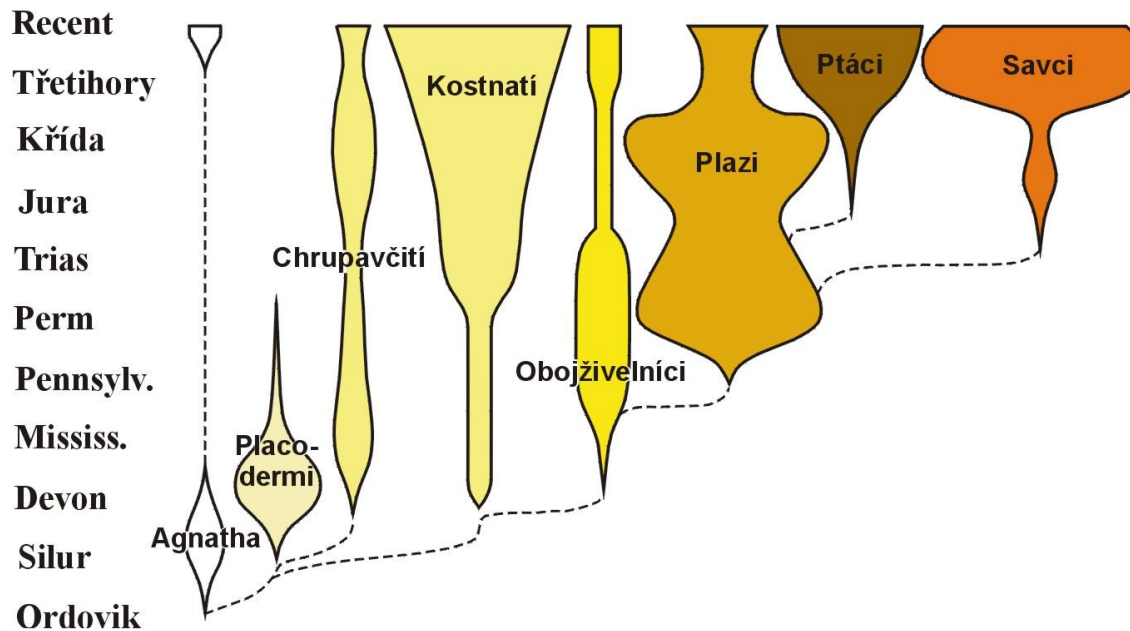


fossil evidence and phylogeny

(a) Podle anatomie byla evoluční sekvence moderních obratlovců



(b) Pořadí hlavních skupin obratlovců ve fosilním záznamu



rudimentary (vestigial) structures, atavism

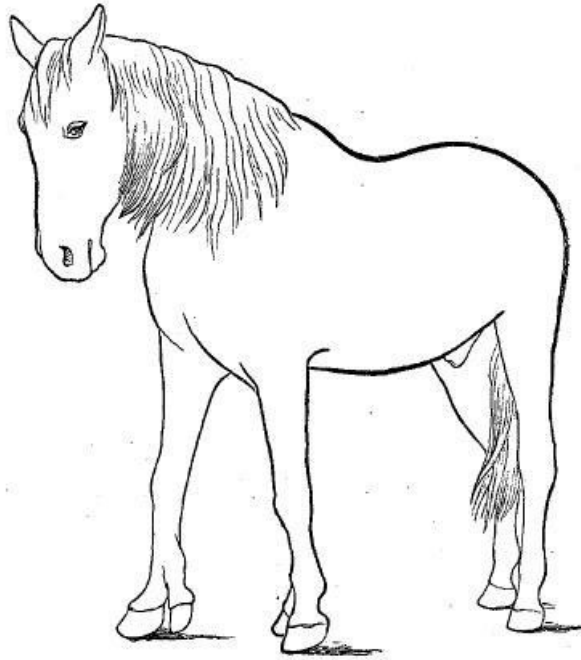
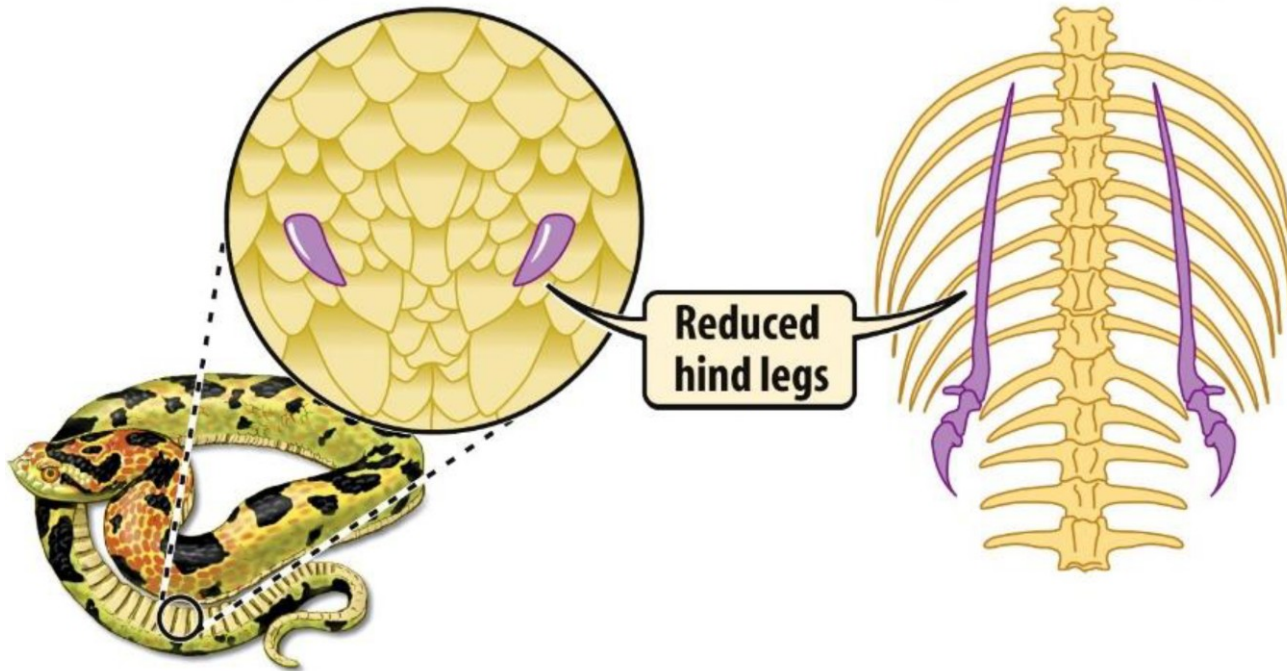
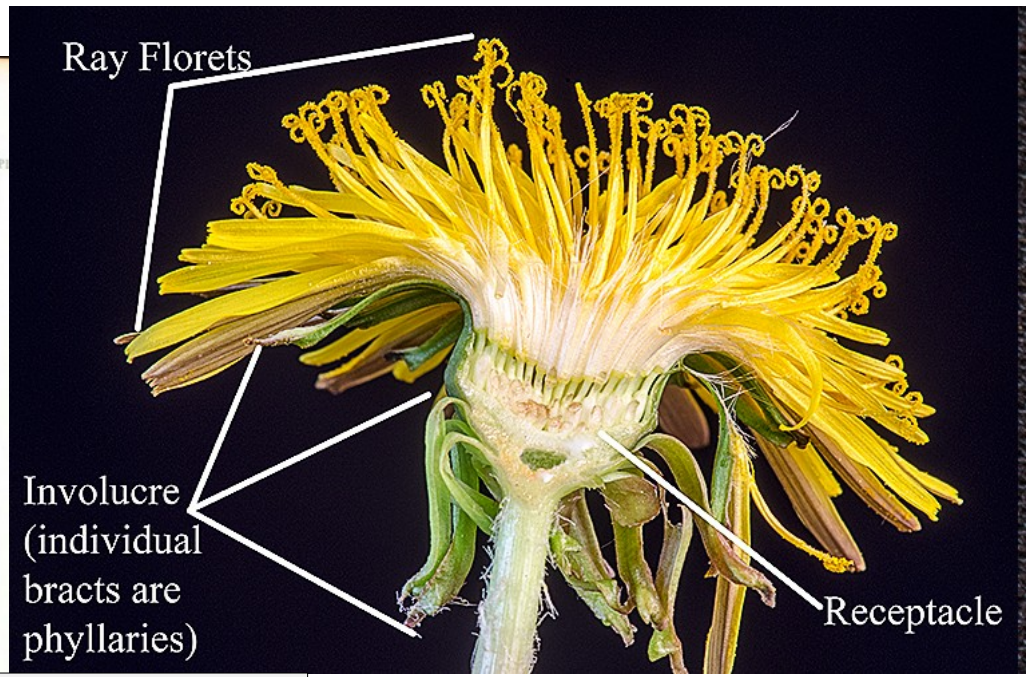


FIGURE 5.—“Clique, the horse with six feet,” showing two extra digits.

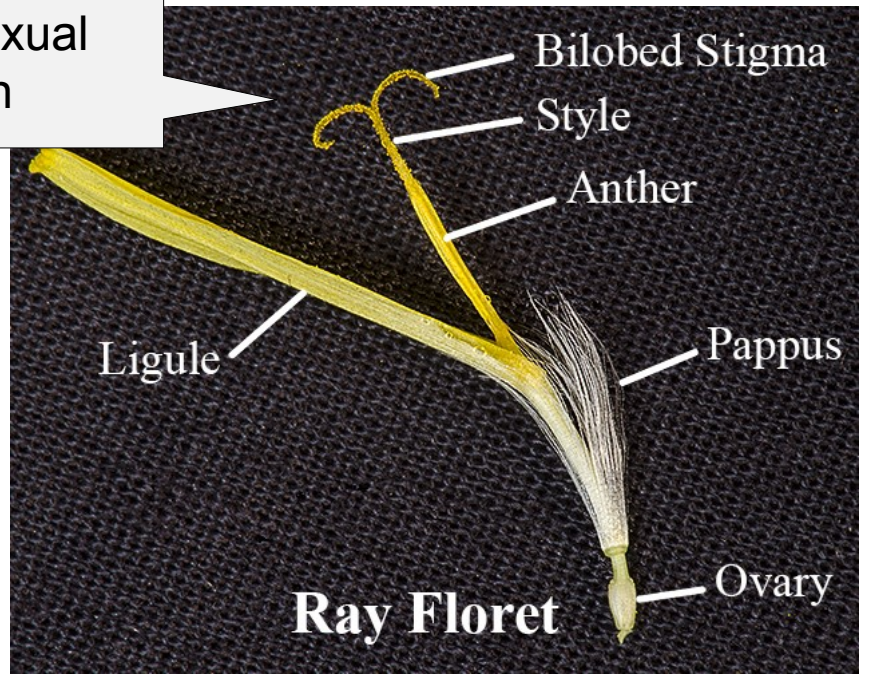


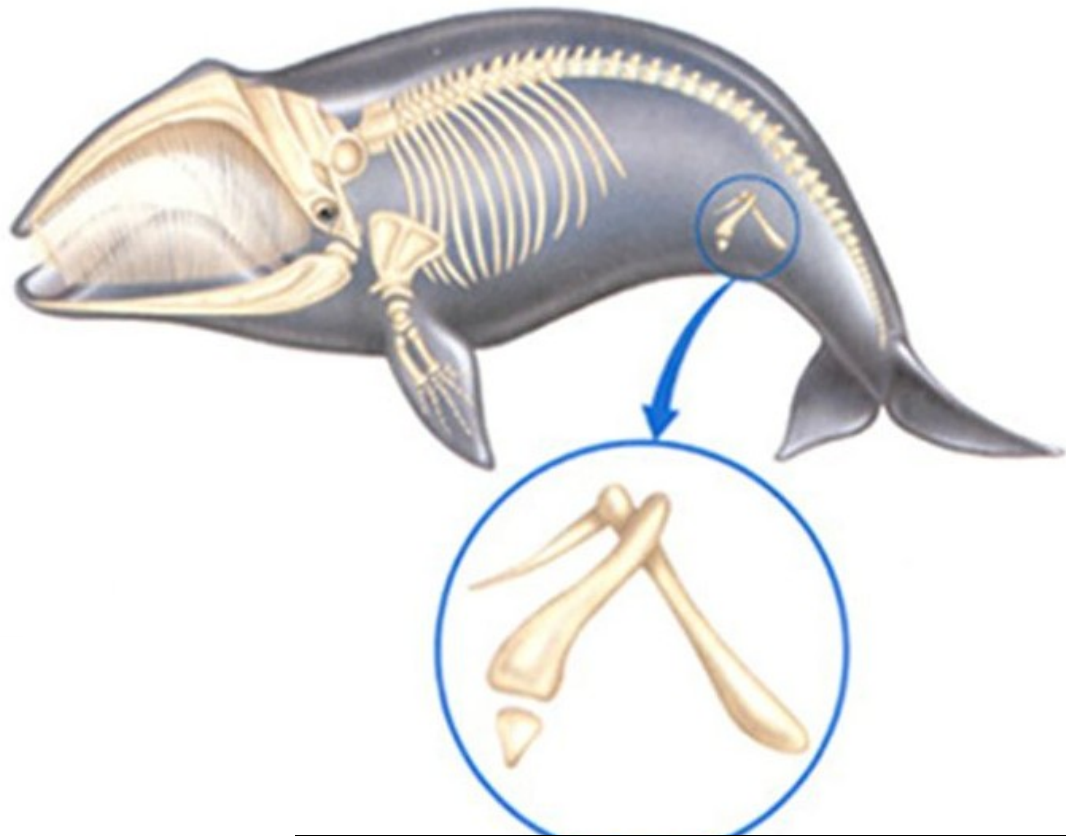
“NORFOLK SPIDER,” The Famous Six-Foeted Shire Horse.





pistills in asexual dandelion





genomic rudiments: pseudogenes

OR genes = genes of olfactory receptors:

mouse: ~1000 OR genes, series of duplications

humans: ~800 OR genes (ca. 3% of the genome), 400 inactivated!
pseudogenes more similar to primates etc., in accordance with phylogeny

dolphin: 80% OR genes inactivated, pseudogenes closest to land mammals

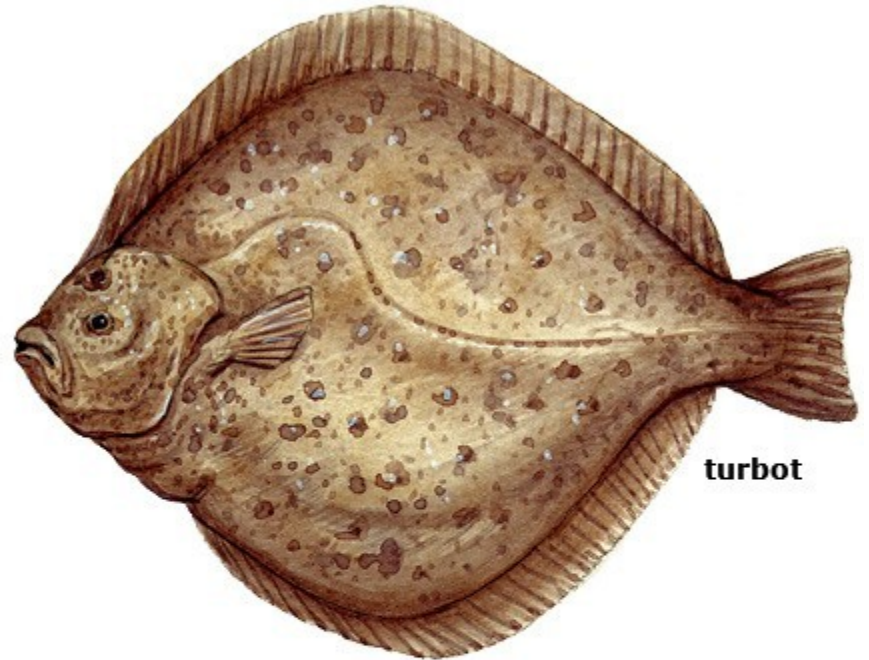
suboptimal traits: flatfish, flounder, sole



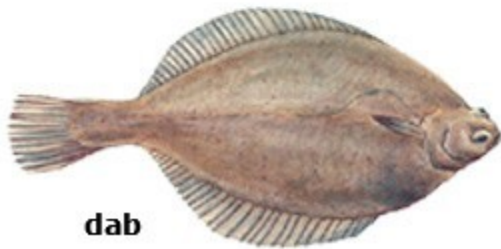
sole



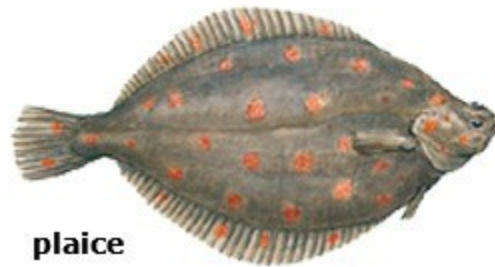
brill



turbot



dab

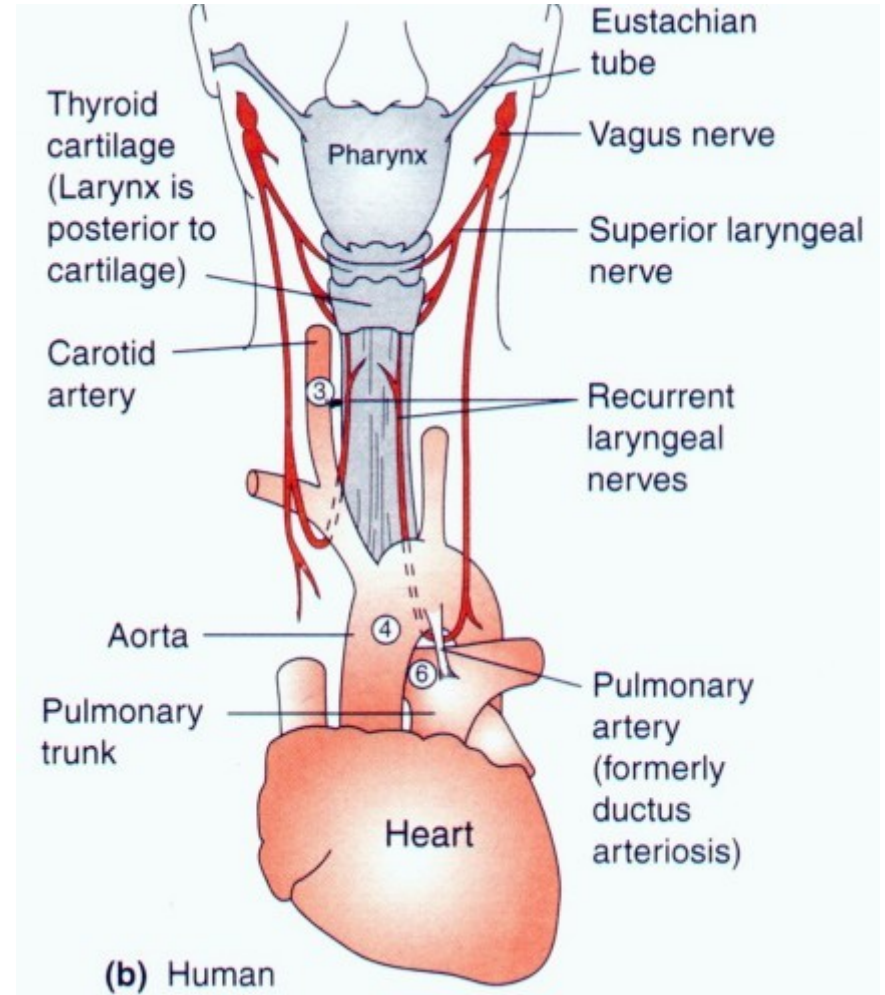
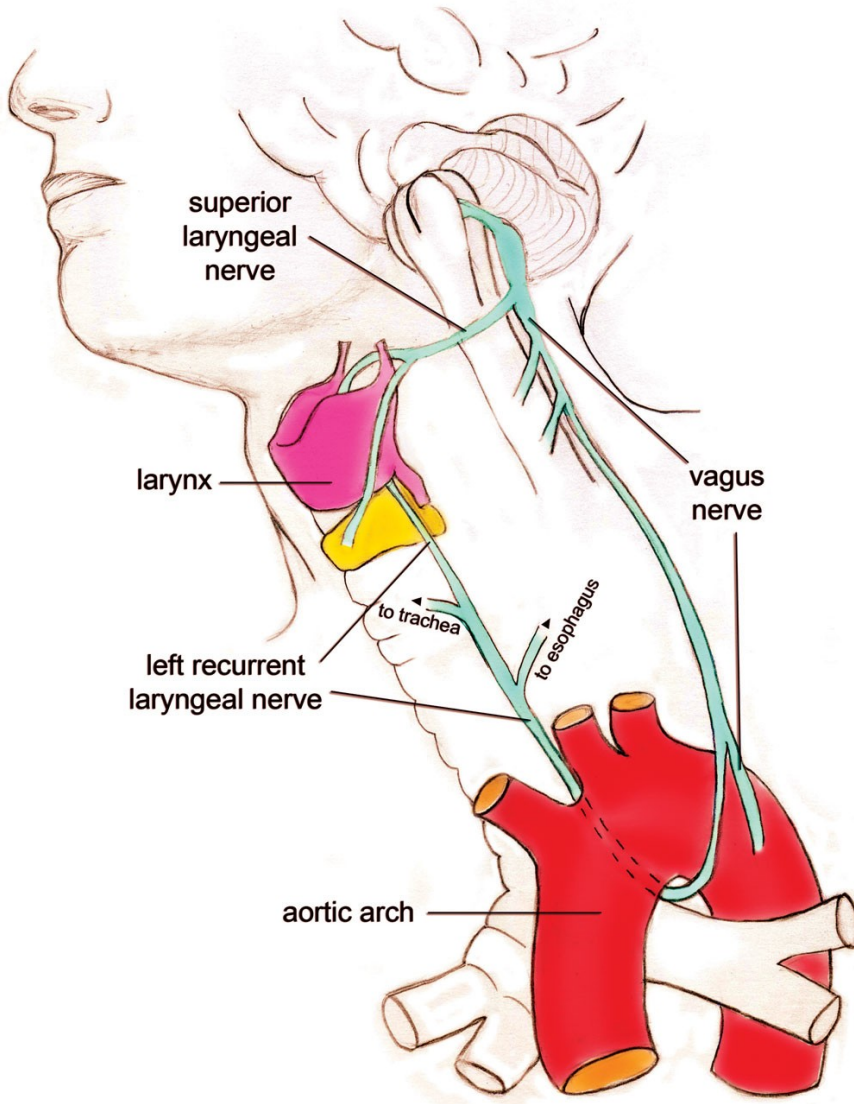


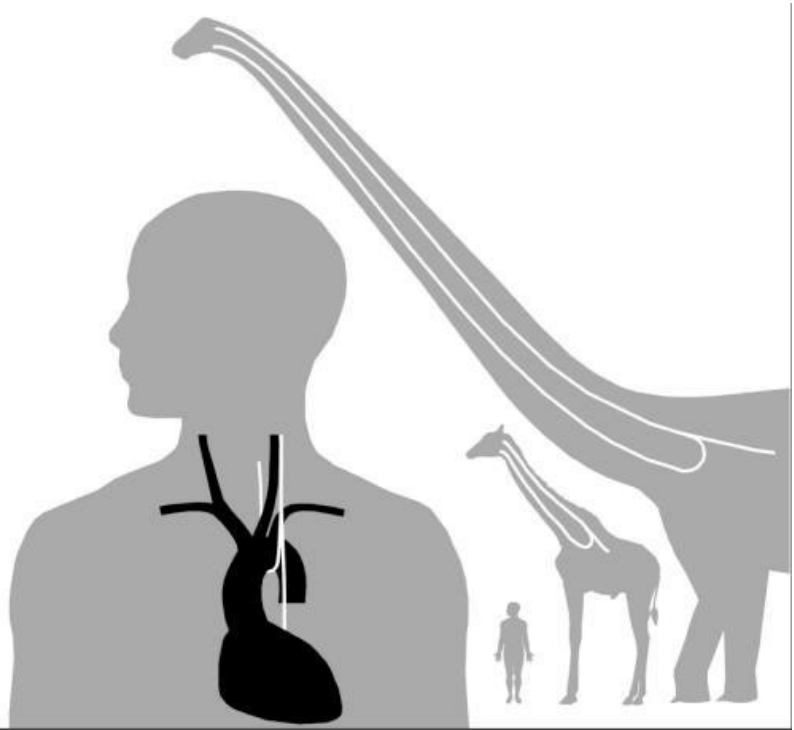
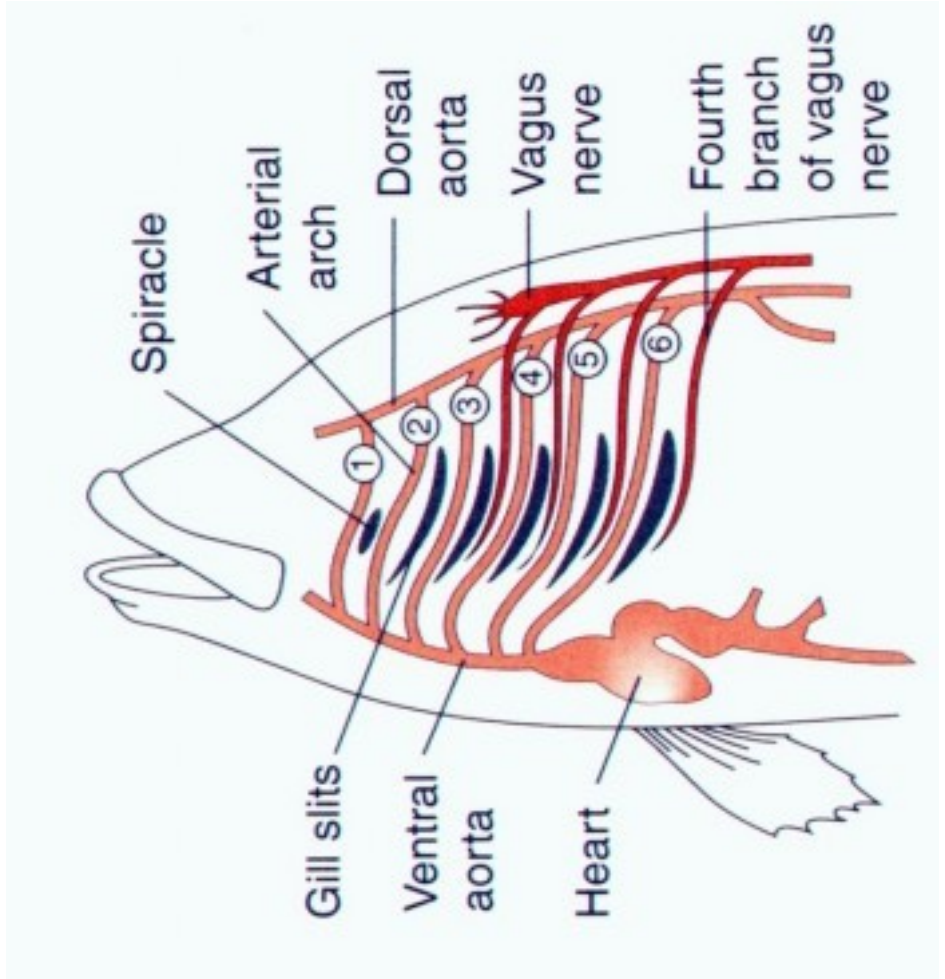
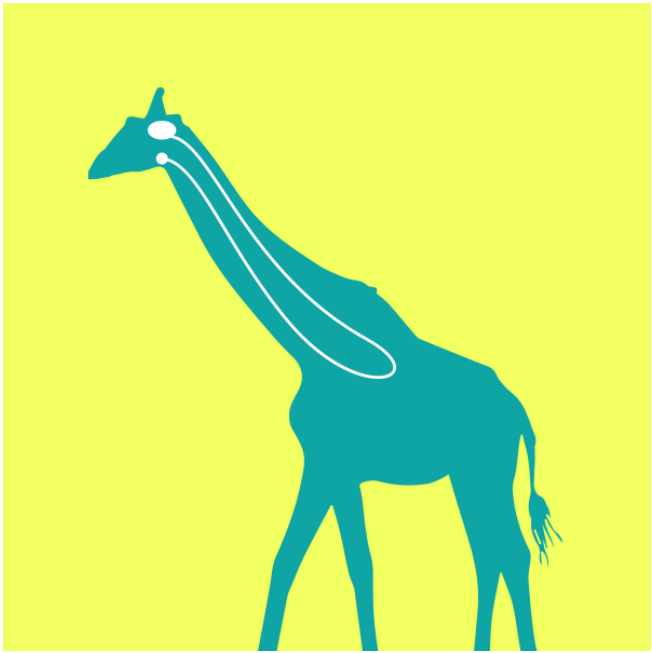
plaice

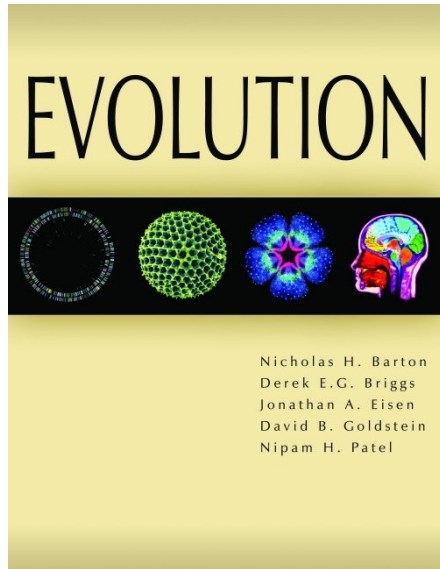


flounder

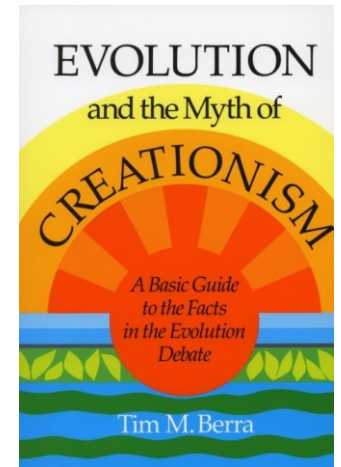
suboptimal traits: pharyngeal nerve



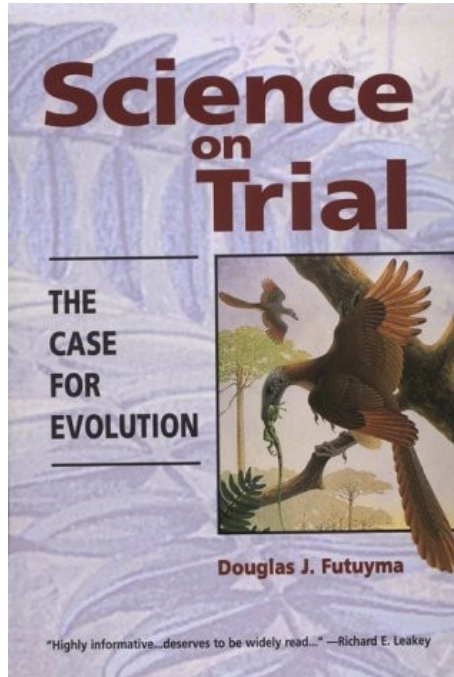




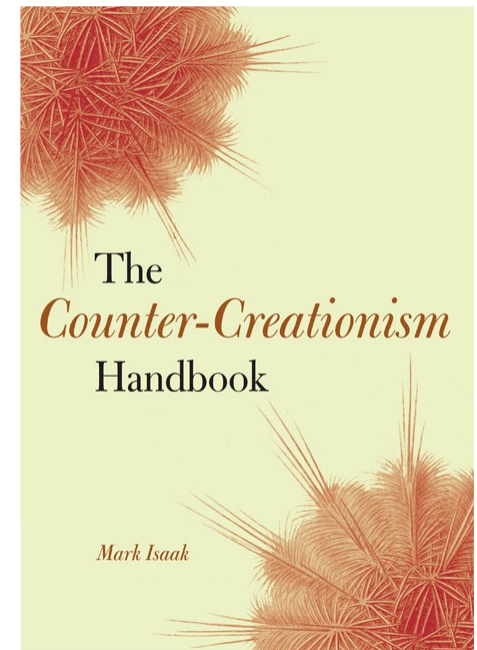
Berra TM (1990): *Evolution and the Myth of Creationism. A Basic Guide to the Facts in the Evolution Debate*



Isaak M (1995): *The Counter-Creationism Handbook*



Futuyma DJ (2007): *Science on Trial: The Case for Evolution*



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WHY



EVOLUTION



IS TRUE



JERRY A. COYNE

Jerry A. Coyne

Why
Evolution
is True



'Compelling...masterful...outstandingly good.'
Richard Dawkins, *TLS*



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