

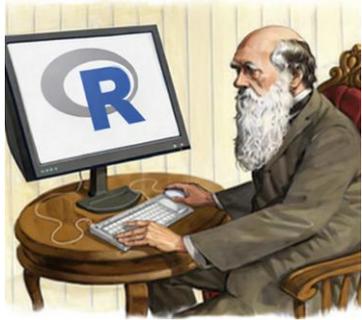
Lingua del corso/Language of the course ?

Tutto in italiano

Slides in Inglese e lezione in Italiano

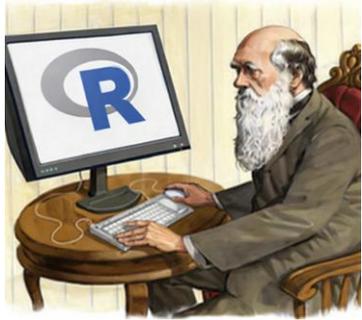
Everything in English

Notation used during the course

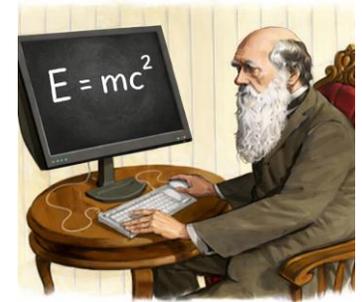


Optional slide with R code. Nothing will be asked about this slide in the written exam (only in the oral exam for additional points).

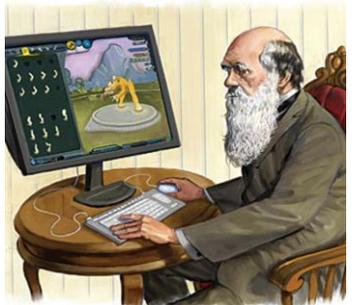
Notation used during the course



Optional slide with R code. Nothing will be asked about this slide in the written exam (only in the oral exam for additional points).



Optional slide with difficult mathematical formula. No question on the formula will be asked in the written exam. However, understand the concept of the model



A simple model (computational or formula). Questions could be asked on this slide.

`rnorm(N)`

The font `courier new` will be used for computer commands

If you want to install R and try the code

<https://rstudio-education.github.io/hopr/starting.html>



How to **Install R and RStudio** on **Windows 11** (2026)

YouTube · ProgrammingKnowledge

238.2K views · 26 Jun 2023

All the code will be available on Moodle

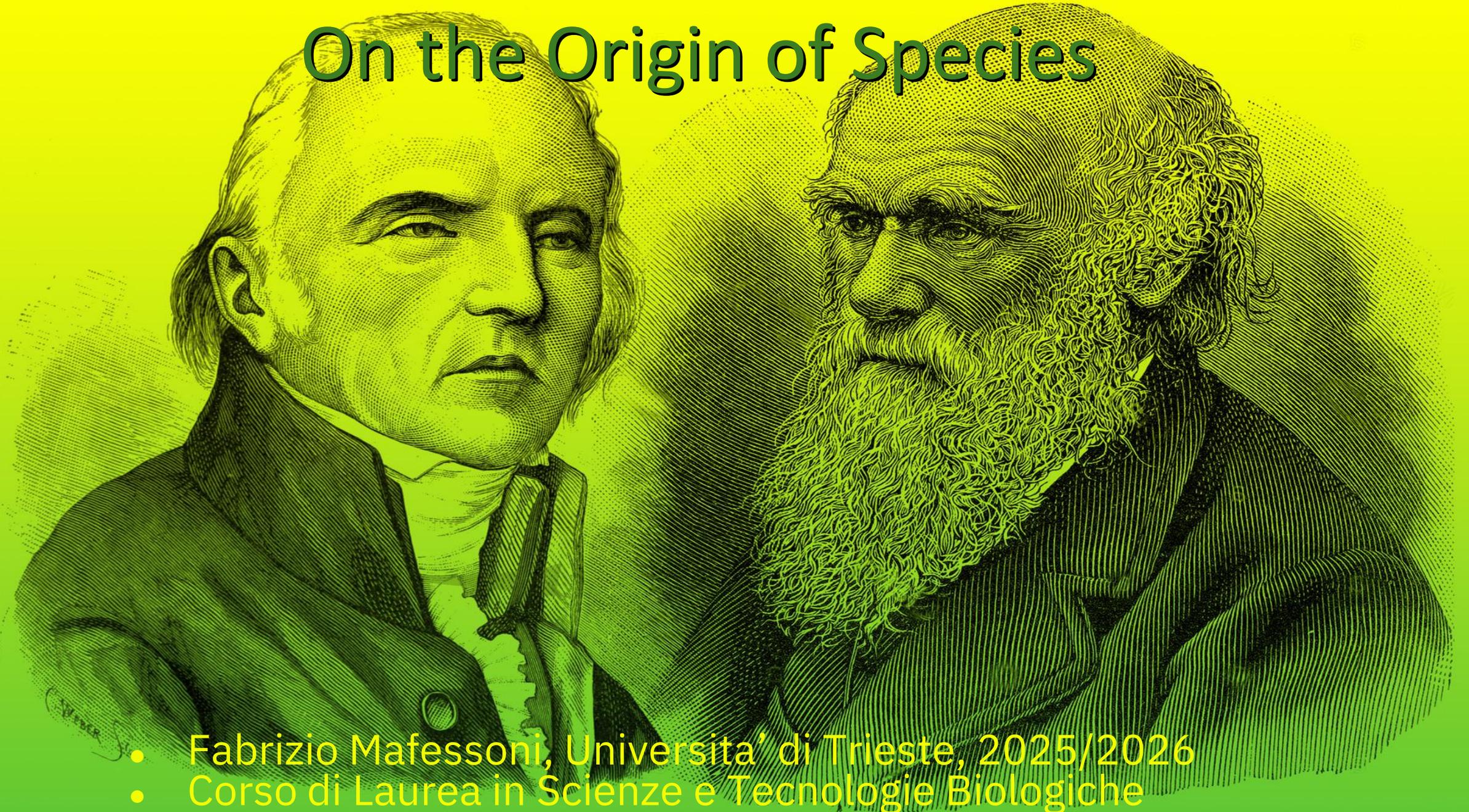


Dipartimento di Scienze della Vita / Laurea triennale (DM270) / SM51 - SCIENZE E TECNOLOGIE BIOLOGICHE / A.A. 2025 - 2026

638SM - BIOLOGIA EVOLUZIONISTICA 2025

[Course](#) [Settings](#) [Participants](#) [Grades](#) [Activities](#) [More](#) ▾

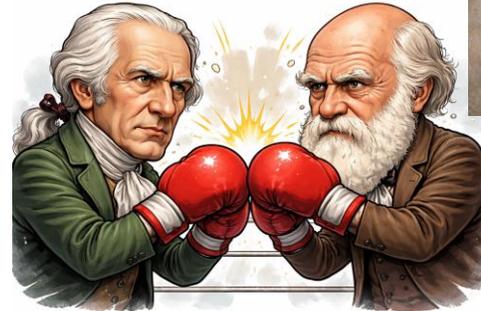
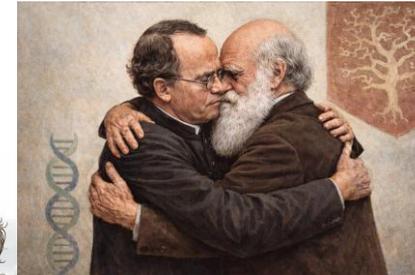
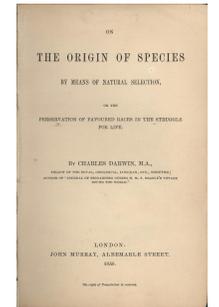
On the Origin of Species



- Fabrizio Mafessoni, Università di Trieste, 2025/2026
- Corso di Laurea in Scienze e Tecnologie Biologiche

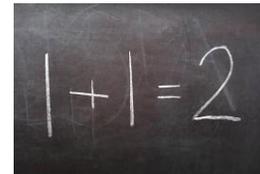
Today

- Modern historical origin of evolutionary thought
- Lamarck
- Darwin and the Origin of Species
 - Fundamental principles
- What Darwin got wrong about inheritance
- Weismann barrier
- Lamarck vs Darwin
 - Empirical evidence
 - From first principles
- Learning vs Evolution
 - Similarities
 - Interactions:
 - When learning helps evolution: Waddington and Baldwin's effect
 - When learning prevents evolution

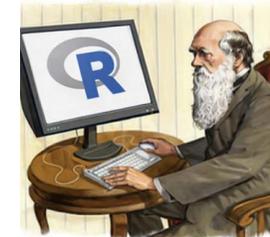
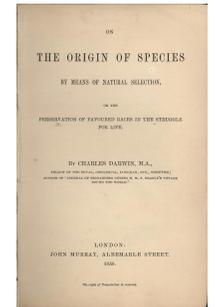


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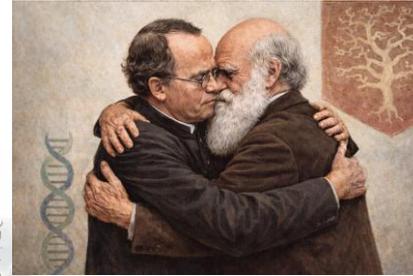
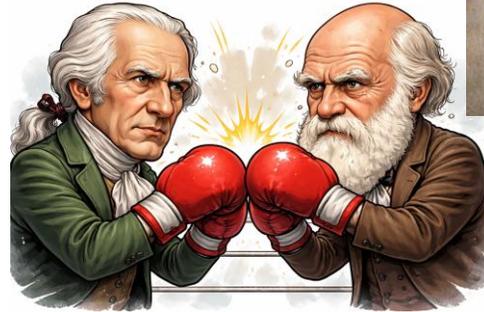
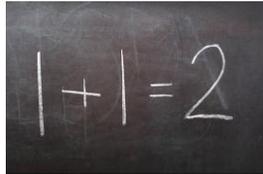
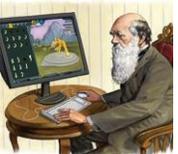


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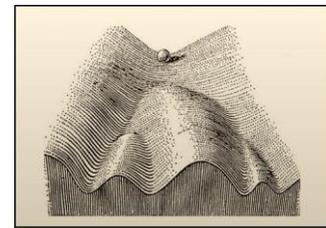
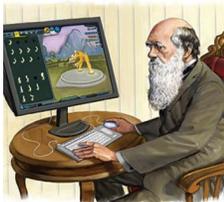
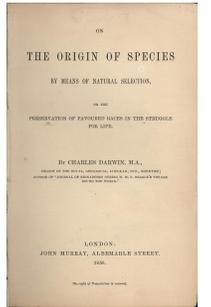


Next time

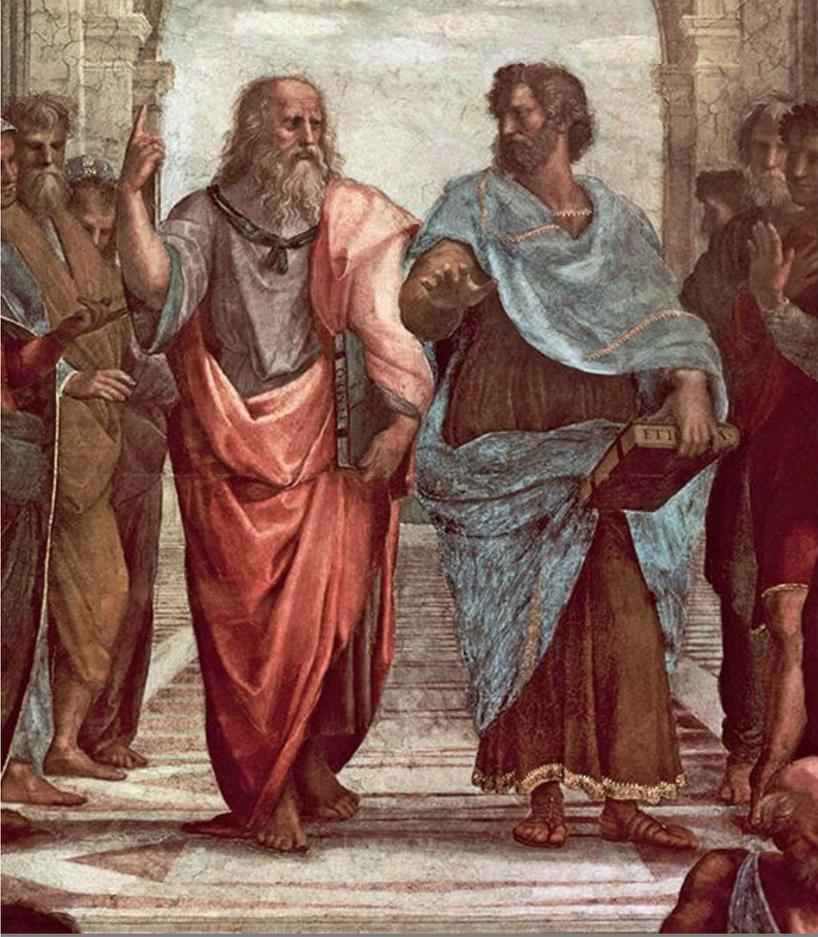
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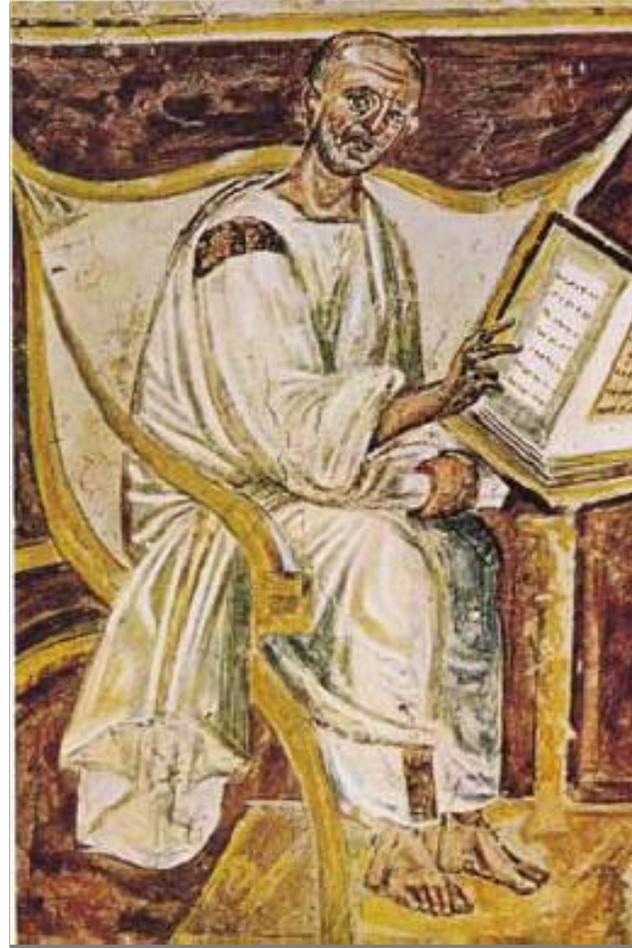
Geoffrey Hinton,
Nobel in
Physics 2024



Fixity of species



Plato
(Ca. 428-348 BC) Aristotle
(384-322 BC)



Augustine of Hippo
(354-430 AD)



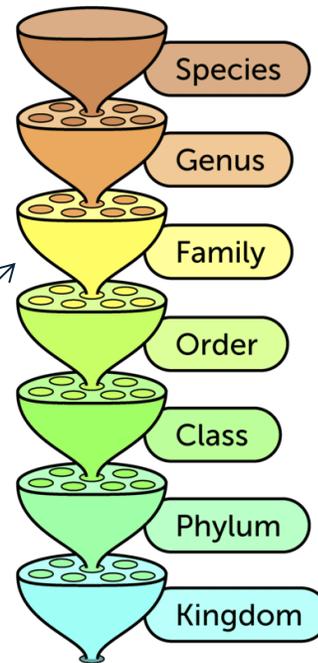
Thomas Aquinas
(1225-1274 AD)

The concept of fixity of species remained in the Modern age (XVII-XVIII century)

Carl Linnaeus (1707-1778)

- Systematic, **hierarchical (nested)** organization of life
- “Platonic” view of (fixed) species as **individuals possessing defining features that transcend them**

Not used by Linnaeus



Homo sapiens
Members of the genus Homo with a high forehead and thin skull bones.

Homo
Hominids with upright posture and large brains.

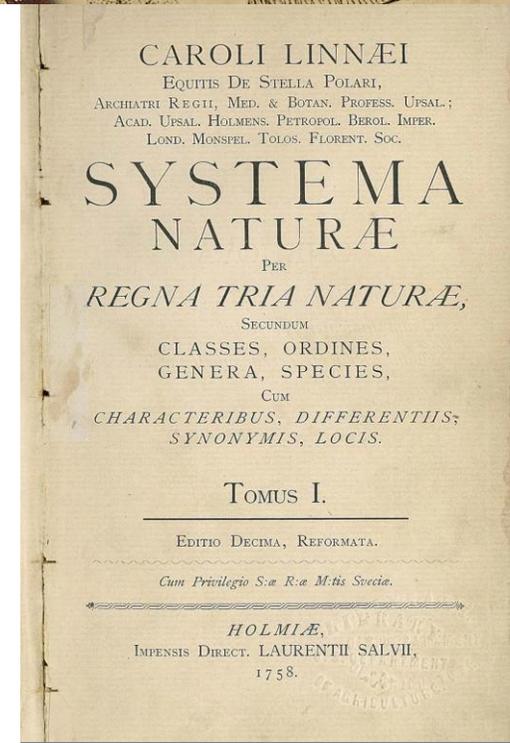
Hominids
Primates with relatively flat faces and three-dimensional vision.

Primates
Mammals with collar bones and grasping fingers.

Mammals
Chordates with fur or hair and milk glands.

Chordates
Animals with a backbone.

Animals
Organisms able to move on their own.

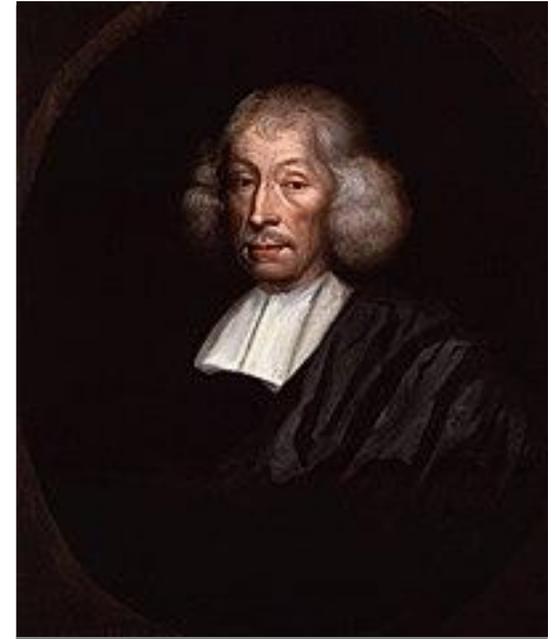


The concept of fixity of species remained in the Modern age (XVII-XVIII century)

Heritage of Aristotelian *essence* and *accident* in early biological definitions of species:

*... no matter what **variations occur in the individuals** or the species, if **they spring from the seed of one and the same plant**, they are **accidental** variations and not such as to distinguish a species ... Animals likewise that differ specifically preserve their distinct species permanently; **one species never springs from the seed of another** nor vice versa.*

- Explicitly considers **variation as accidental**
- Implies **fixity of species**



John Ray
(1627-1705)

However we start seeing the first modern definition of “species” (XVII century)

Species defined by:

- “morphological similarity”
- **reproductive continuity**



John Ray
(1627-1705)

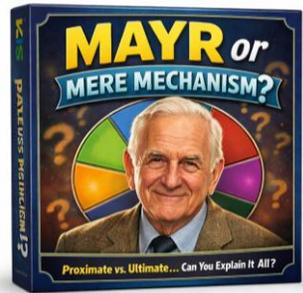
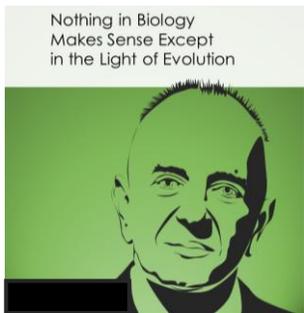
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Modern «biological concept of species» refined by Dobzhansky (1937) and Mayr (1942)

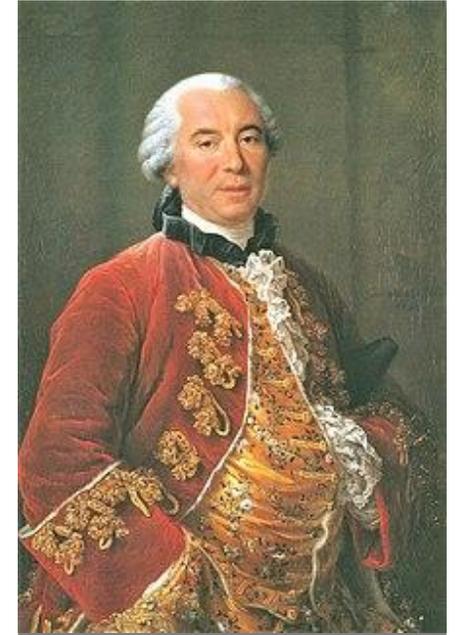
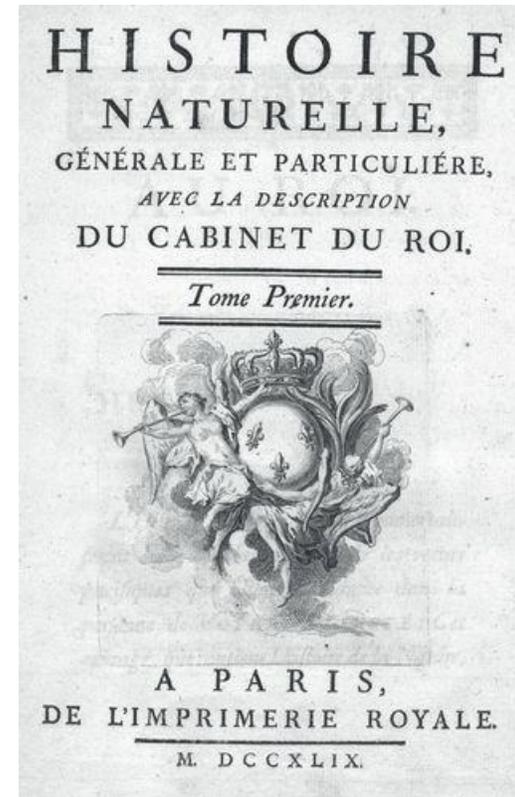


John Ray
14 (1627-1705)

Modern age (XVIII century)

Georges-Louis Leclerc, comte de
Buffon (1707-1788)

- Organizes **geological history** as fully **integrated with history of life!**
- **Estimates age of Earth** to 75k or, later, 2M years (based on cooling of metals)!
- Systematic observations on the distribution of animals and addressing its historical development (**biogeography**)



Modern age (XVIII century)

Georges-Louis Leclerc, comte de
Buffon (1707-1788)

- **Species “degenerated”** in time as they migrated to populate the planet!
- Human “races” followed this “degeneration” too!
 - Center of origin supposed to be in Europe!



A comparison of the ideas of Linnaeus and Buffon. Linnaeus believed that organisms spread from Mount Ararat, or another low latitude mountain following the Great Flood.

Buffon thought that life originated in northern Europe and spread southward, and to the New World.



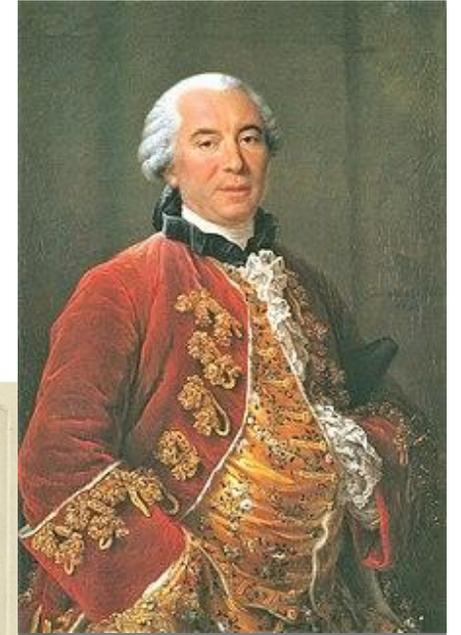
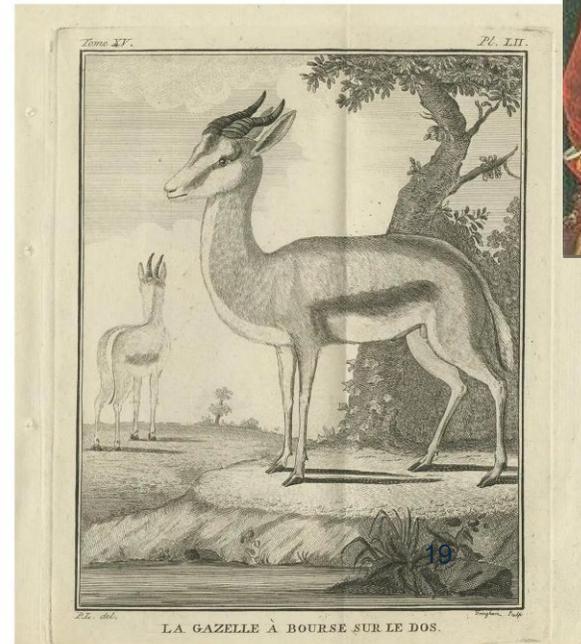
Modern age (XVIII century)

Georges-Louis Leclerc, comte de
Buffon (1707-1788)

- Criticises “abstract” Linnean species in favor of **reproductive and historical continuity** (“biological” species concept)

*... [it is] neither the number nor the collection of similar individuals which forms the species; it is **the constant succession and uninterrupted renewal** of these individuals which constitutes it.*

*... the **ability of its members to interbreed and produce fertile offspring**, a criterion that takes **precedence over similarities of anatomy or habits of life***



Modern age (XVIII century)

Georges-Louis Leclerc, comte de **Buffon** (1707-1788)

Limits of Buffon's heritage

- **Does not provide explicit mechanisms** for evolution
→ Many ideas seen a **speculative**
- Believed in (continued) **spontaneous generation**, thus limiting the scope for *transformation* and diversification!



Spontaneous generation

Recipe for Mice by Dr. Jan Baptista von Helmont



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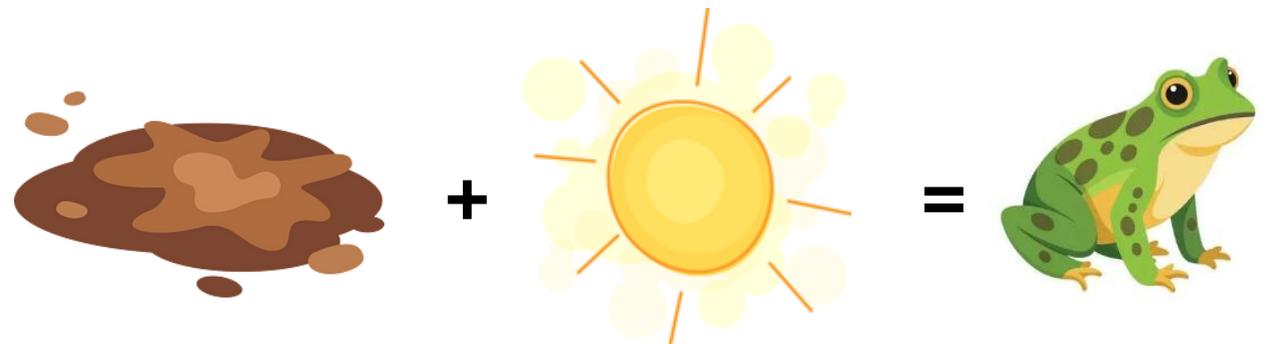


Modern age (XVIII century)



Spontaneous generation

Recipe for frogs

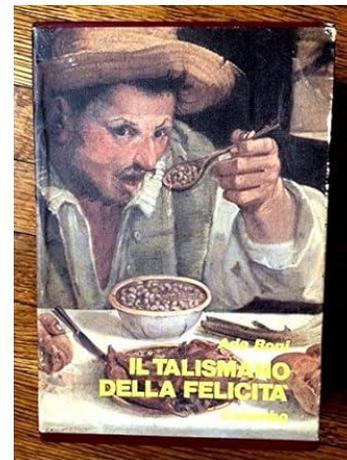


Modern age (XVIII century)



Spontaneous generation

Recipe for flies

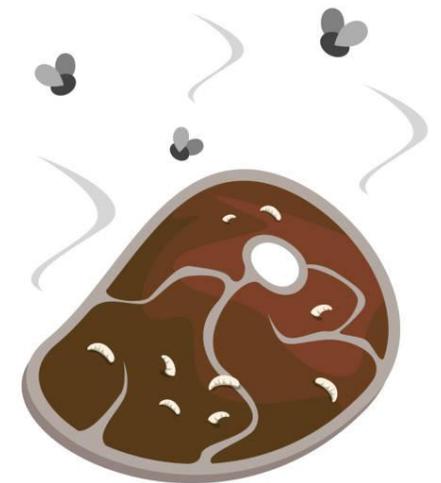
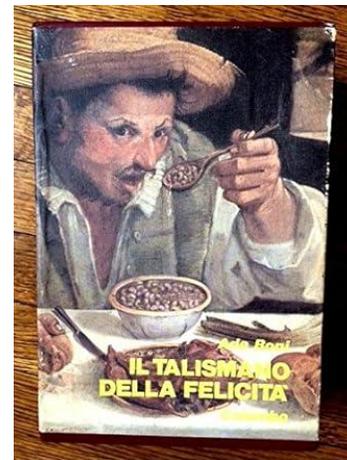


Modern age (XVIII century)



Spontaneous generation

Recipe for flies



Modern age (XVIII century)

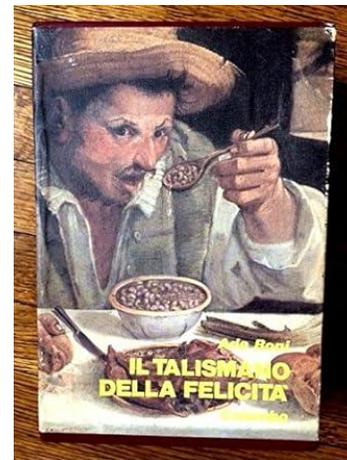
Georges-Louis Leclerc, comte de **Buffon** (1707-1788)

Well, I did not believe
in that...only for
«small creatures» or
microorganisms!!!

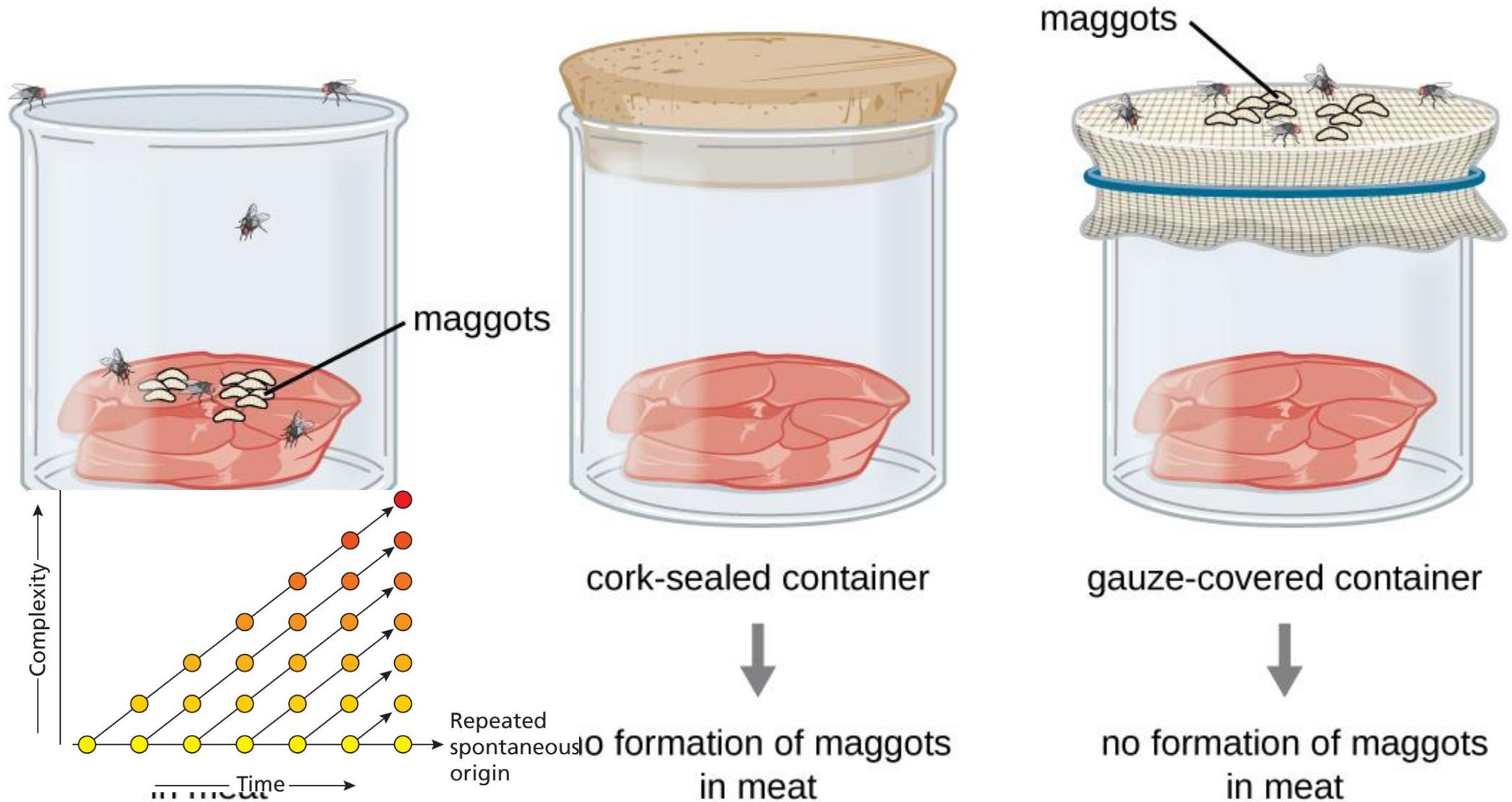


Spontaneous generation

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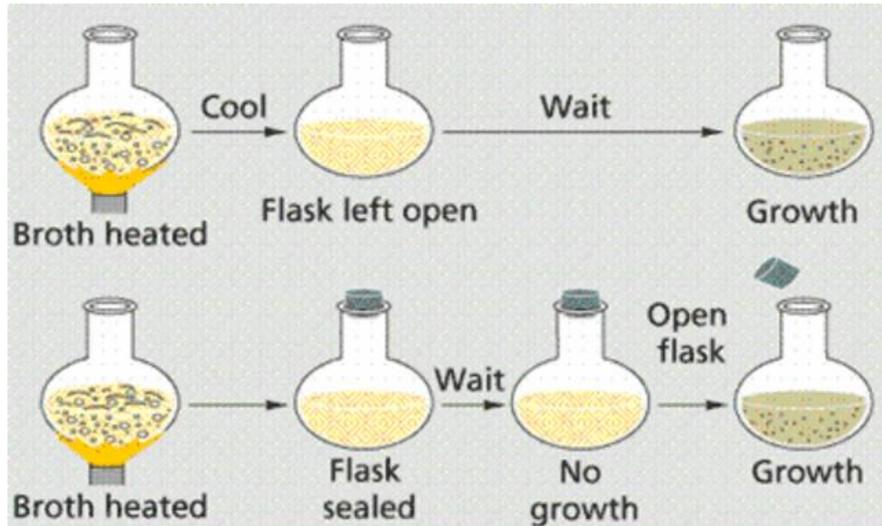


Francesco Redi's experiment (1668)

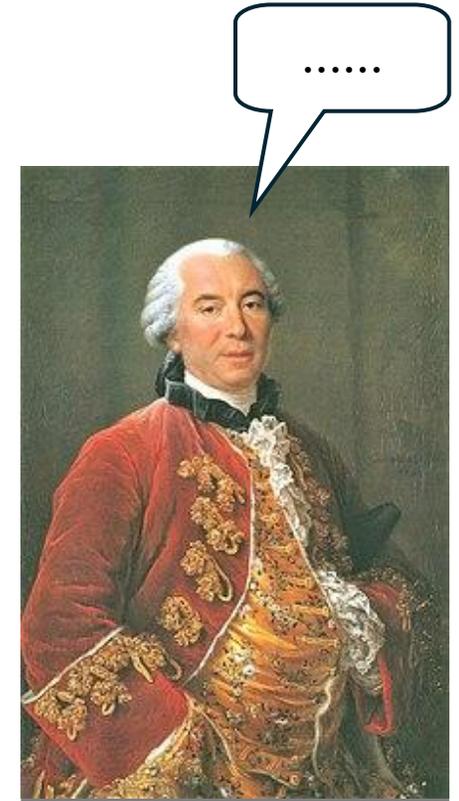




Lazzaro Spallanzani's experiment (1776)



People argued that it was simply because the «air was ruined»

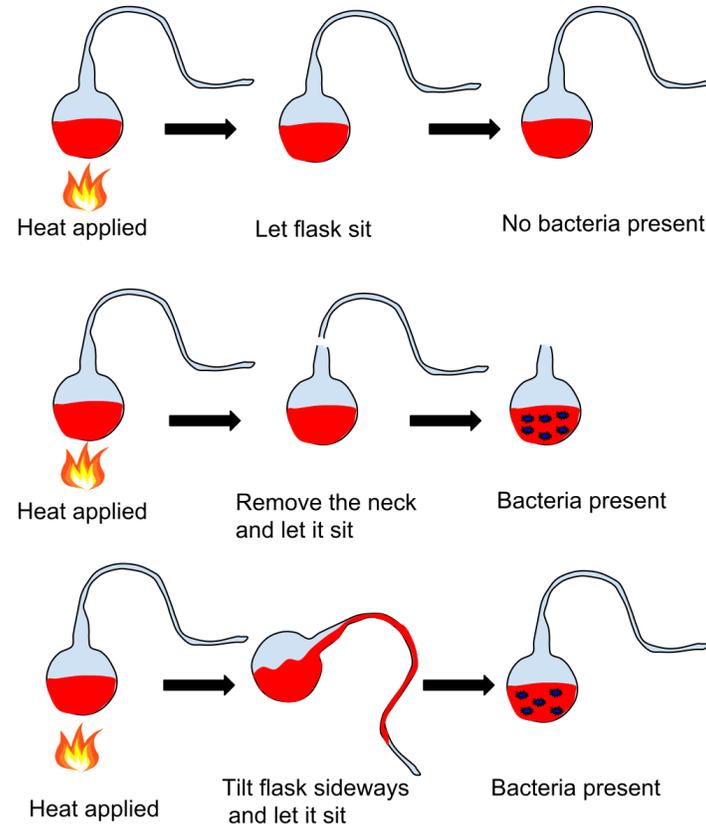
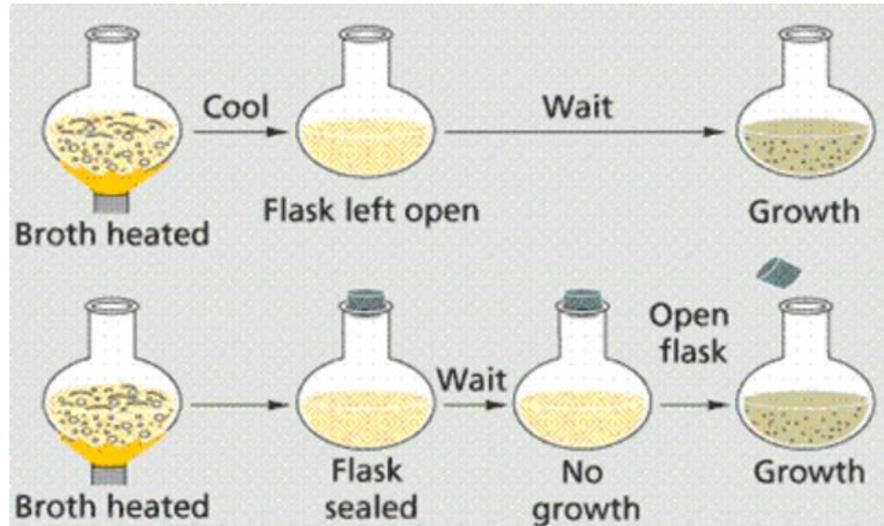




Lazzaro Spallanzani's experiment (1776)



Louis Pasteur's experiment (1859)



People argued that it was simply because the «air was ruined»

Evidence against fixity of species was already accumulating before Darwin

Georges Cuvier (1769-1832)

- Develops **comparative anatomy**
- Animals **belong to a few “types”** (*phyla*), **not on a single scale!**
- Fits **fossils** in zoological classification showing **“extinction”**
- Notes that **fossils in older strata are less and less similar to present fauna!**



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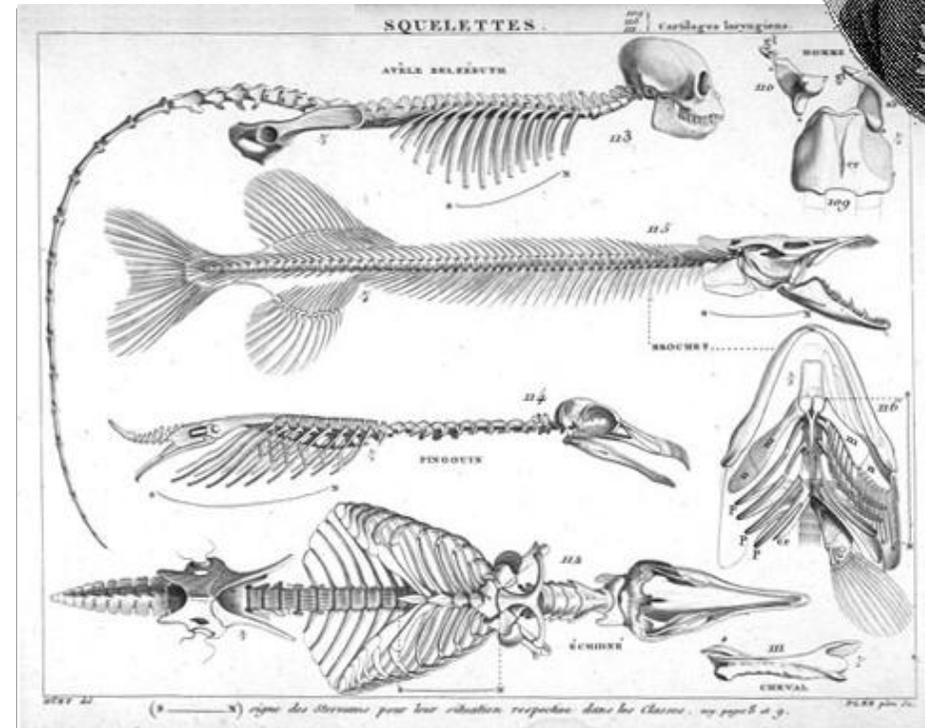
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- Notes that **fossils in older strata are less and less similar to present fauna!**
- **Catastrophism** to explain temporal distribution of fossils
- **But anti-evolutionist:** each species is so well coordinated, functionally and structurally, that it could not survive significant change



Evidence against fixity of species was already accumulating before Darwin

Étienne Geoffroy Saint-Hilaire
(1772-1844)

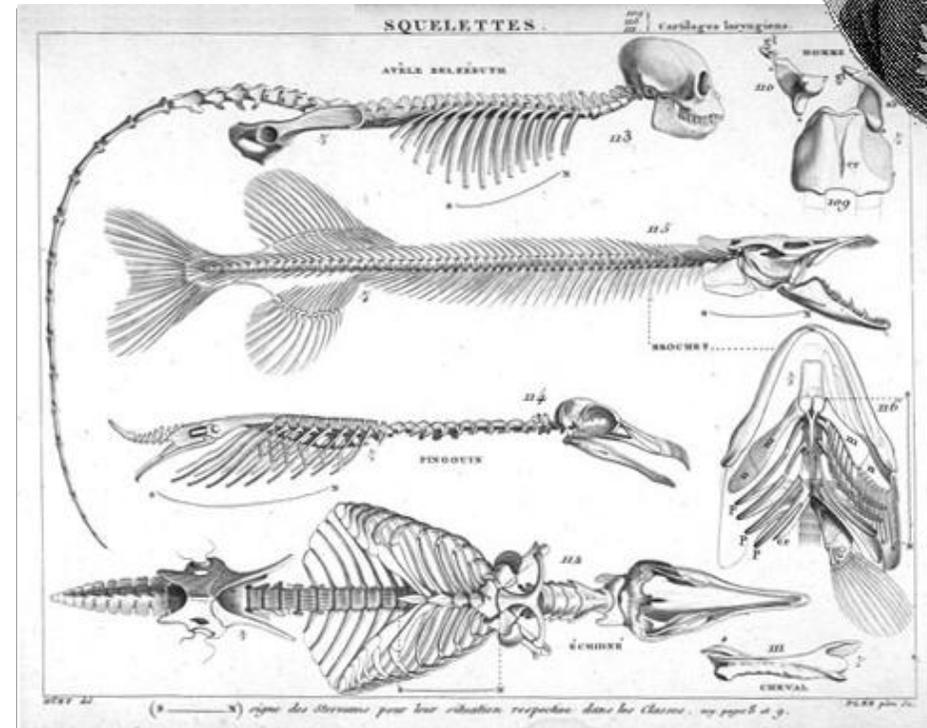
- **All** animals share a **common basic plan** (cfr. Cuvier)!
- Introduces **homology** as a concept (not as a word, though!)
- Explains **vestigial organs**
- **Semi-evolutionist** (?): ancestral species gave rise to **unchanging** modern forms through the **occasional appearance of successful monstrosities**



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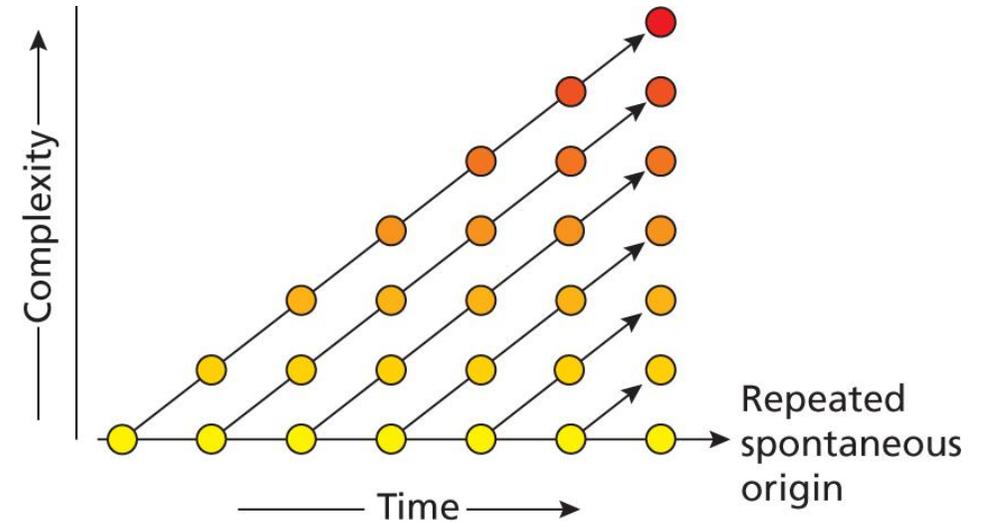
A first «mechanism» for the evolution of species

Jean-Baptiste Lamarck (1769-1832)

- **Strong assertor of evolution!**
- Believes in **spontaneous generation**



- Simple life forms (continually) emerge from inorganic matter, then “evolve” towards increased complexity
- “Tendency towards complexity”
- A *Scala Naturae* is formed



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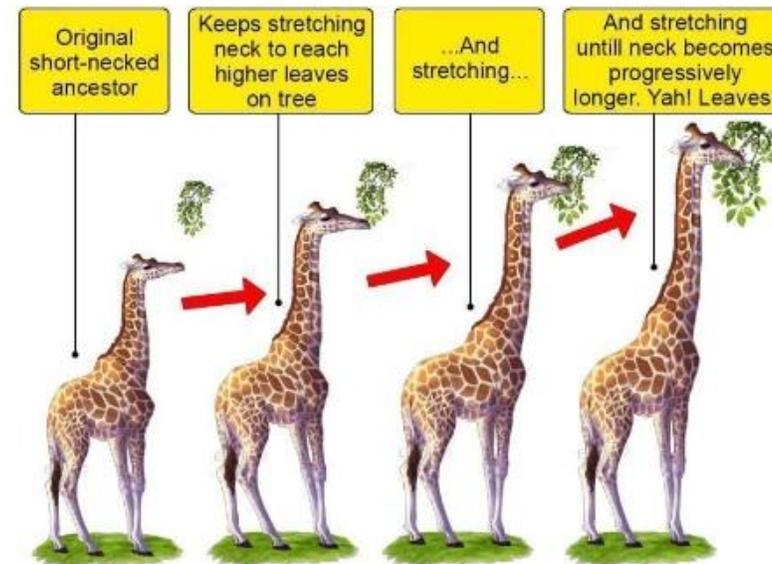
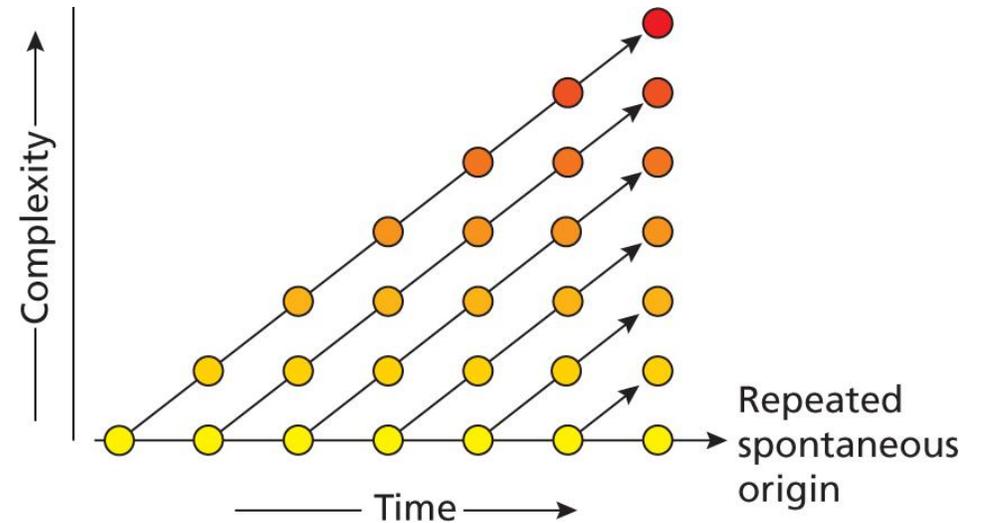
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 - **Inheritance of acquired characters** (effect of environment)
 - “Use and disuse” theory: the more you use a “trait”, the more this will evolve over generations



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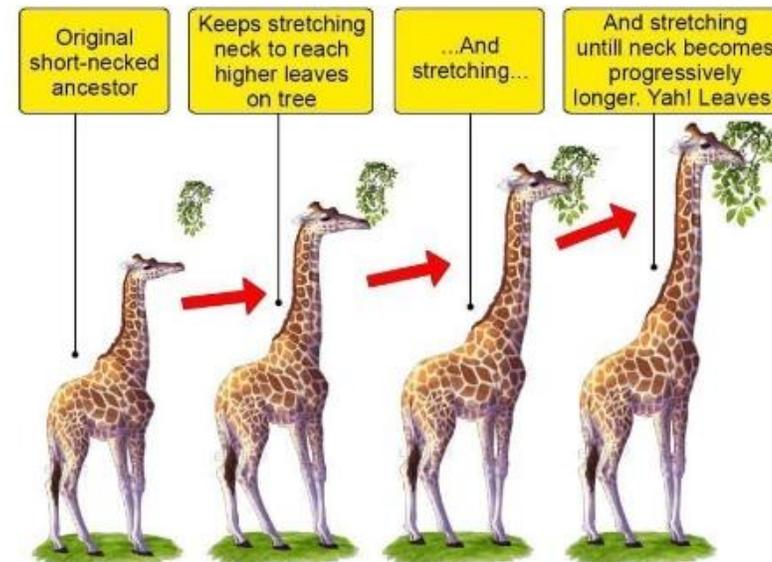
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Which problems do you see with this mechanism?



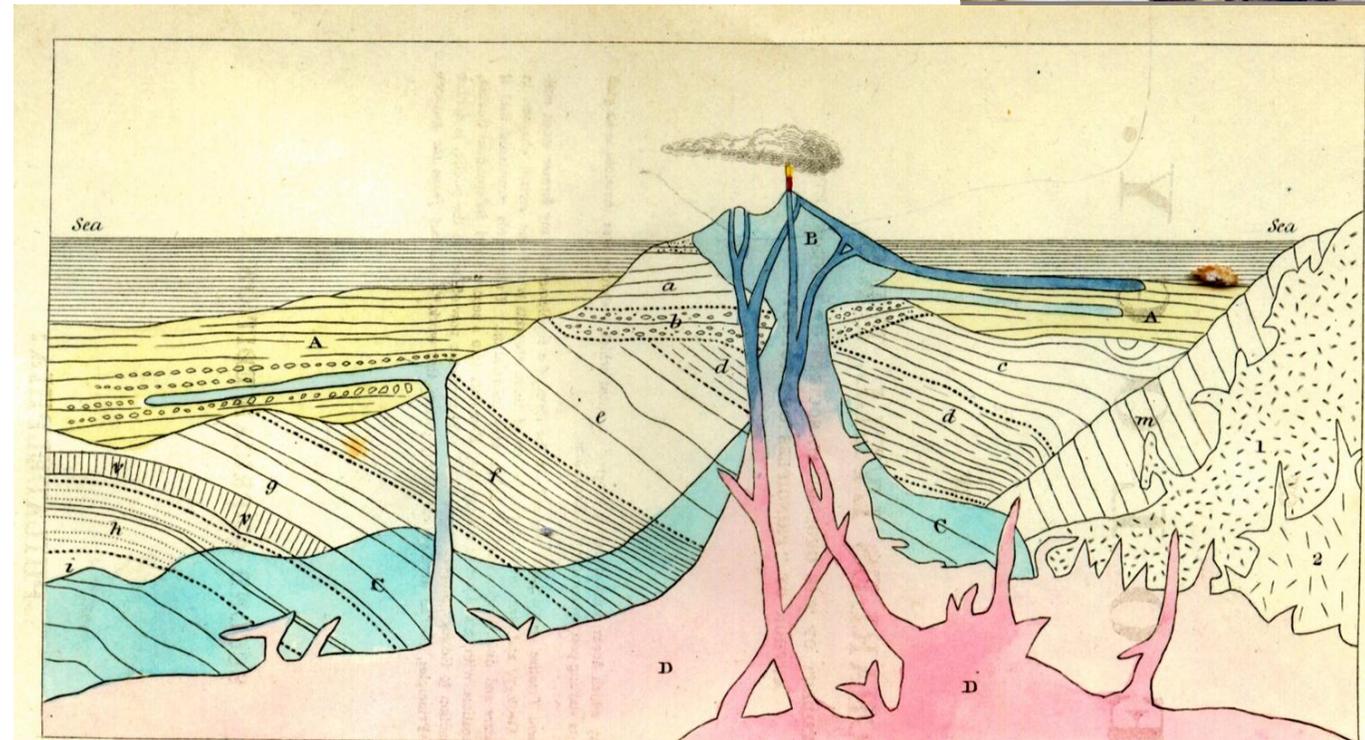
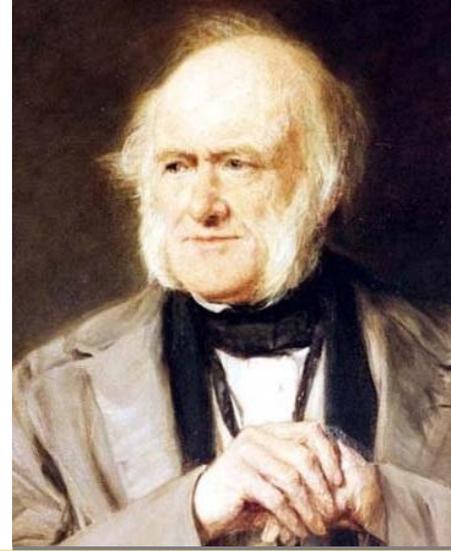
Charles Lyell

..in the meanwhile

(*Principles of Geology*, 1830-33)

- Champion of Uniformitarianism (vs Catastrophism):

The same processes acting today on earth shaped it gradually in the past (and can be used to extrapolate and infer the age of Earth: stratigraphy, erosion) → **Earth is old!**



IDEAL SECTION of part of the Earth's crust explaining the theory of the contemporaneous origin of the four great classes of rocks.—see Chap.I.

A Aqueous B Volcanic. C Metamorphic.
(Gneiss, mica schist, &c.) D Plutonic.
(Granite &c.)

All the rocks older than A.B.C.D. are left uncoloured.

Charles Lyell

(*Principles of Geology*, 1830-33)

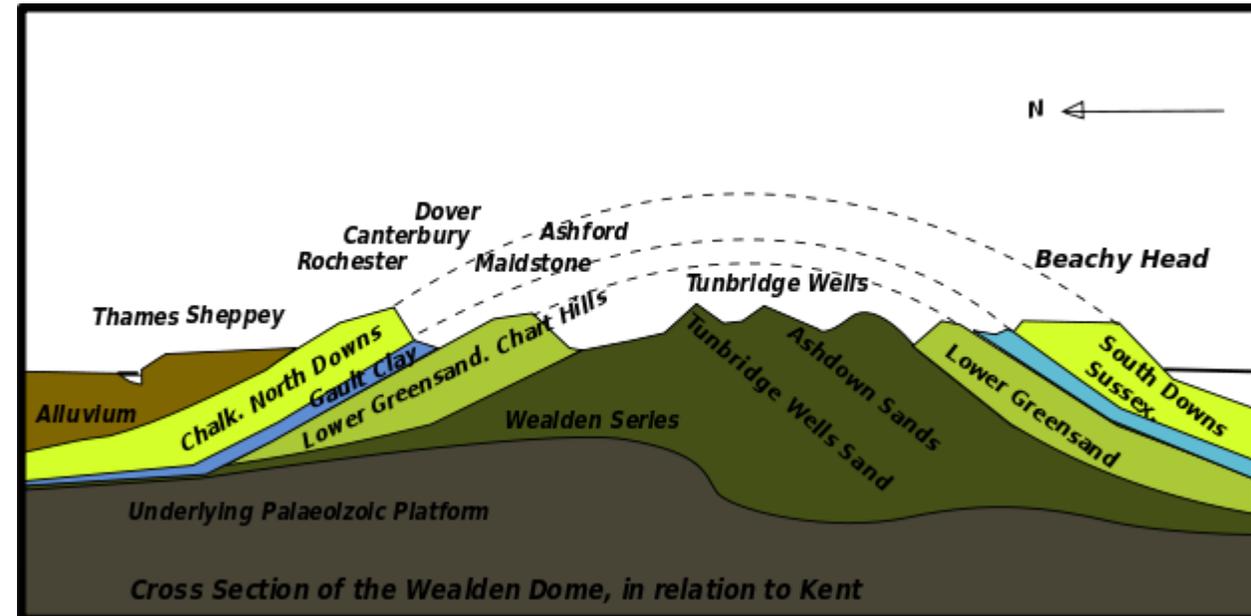
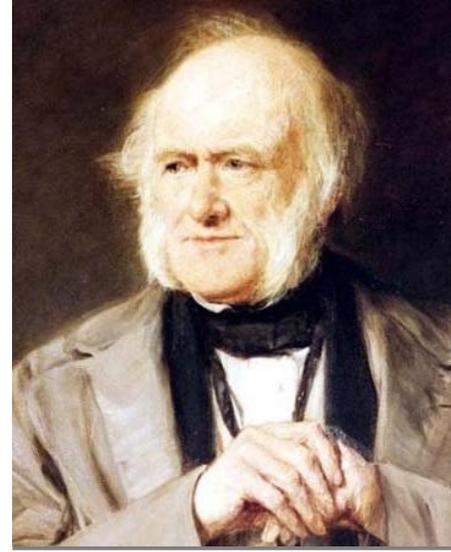
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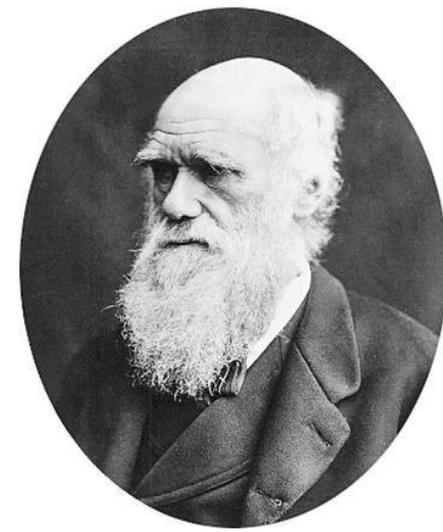
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- Darwin himself calculated **300 Ma from Cretaceous to present** (current estimates are ca. 65 Ma) assuming that Weald valley in Southern England was carved at 1inch/100 years



Estimated from erosion of England's cliffs





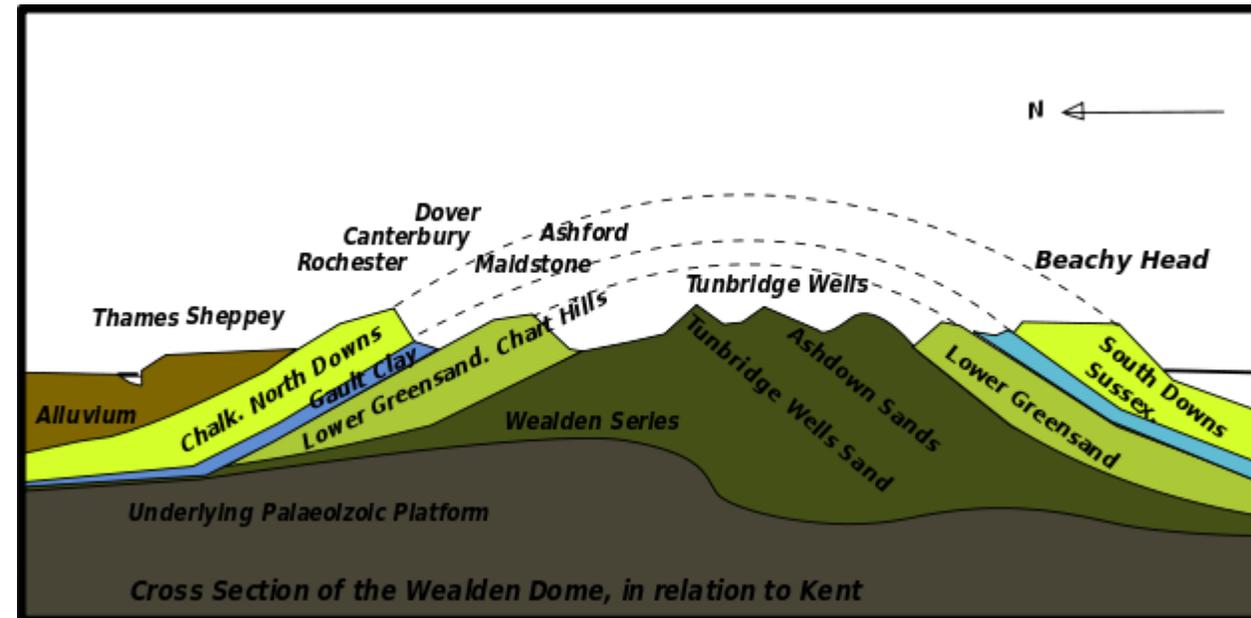
Earth is older than the biblical 6000 years

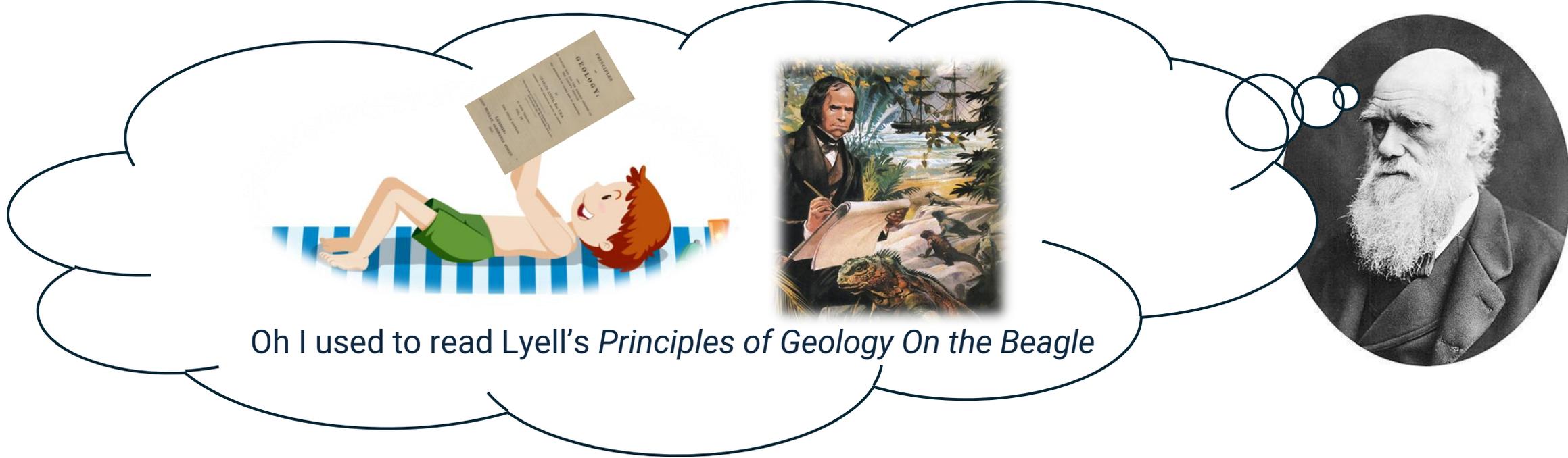


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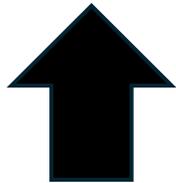


Estimated from erosion of England's cliffs





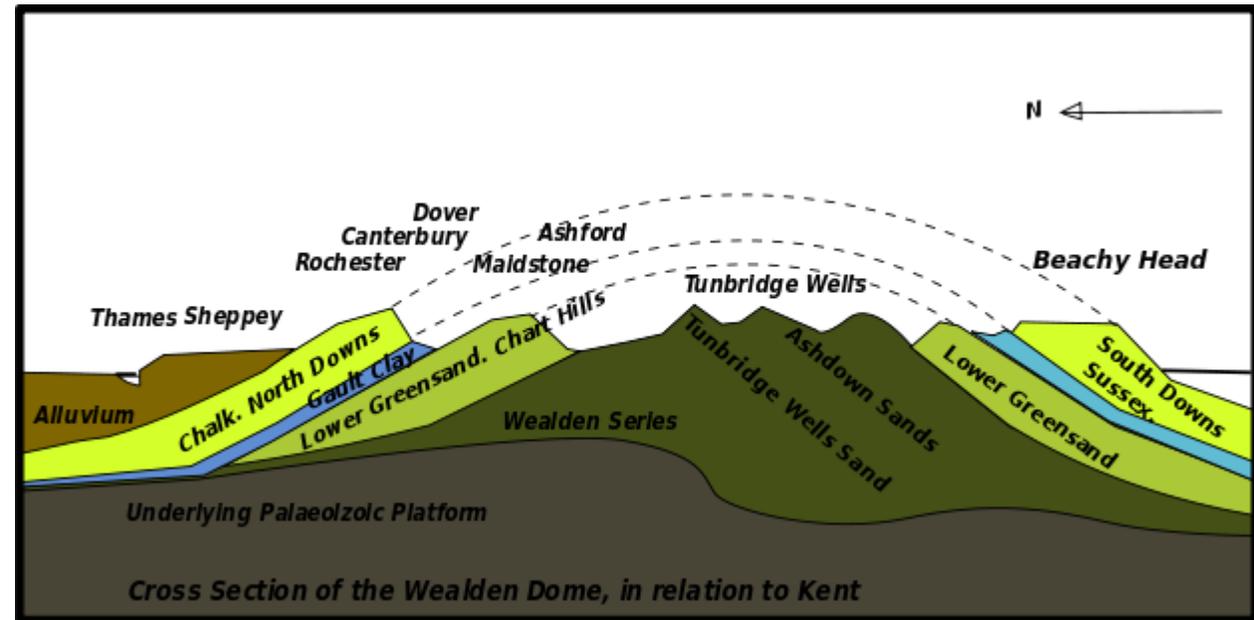
Earth is older than the biblical 6000 years

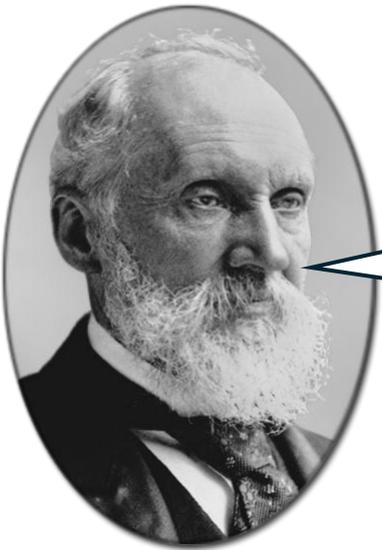


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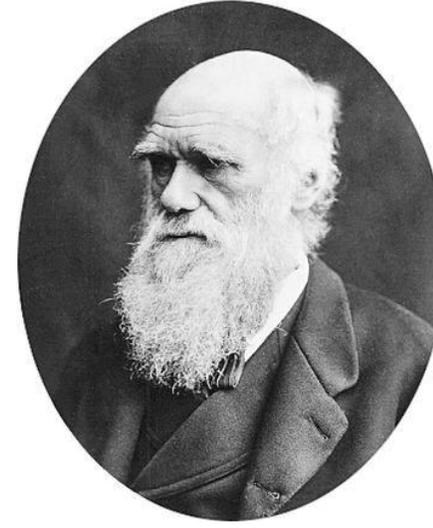


Estimated from erosion of England's cliffs

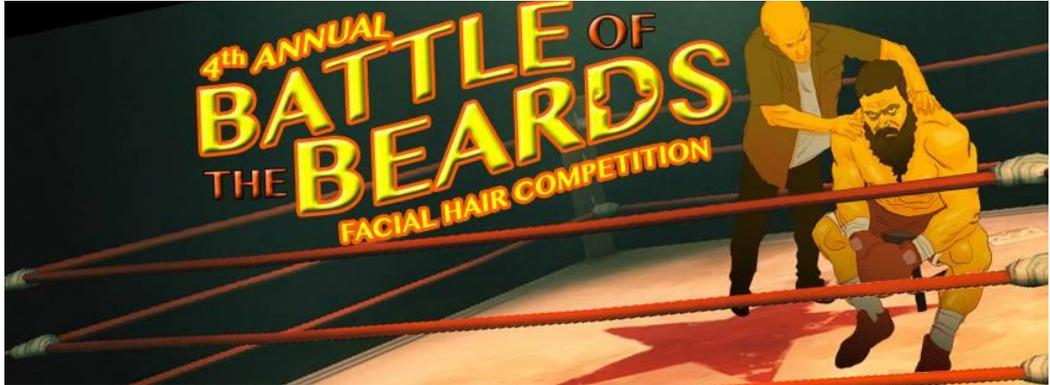




Ridiculous Darwin! Based on the **cooling of metals**, Earth must be at most **20 million years old!**

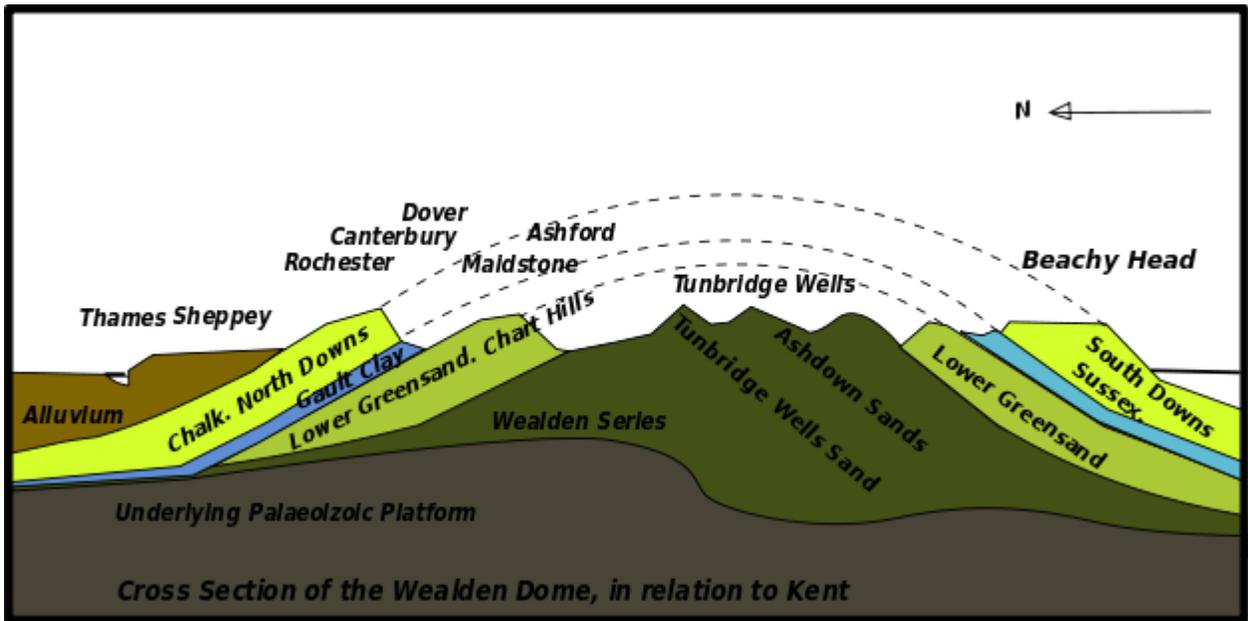


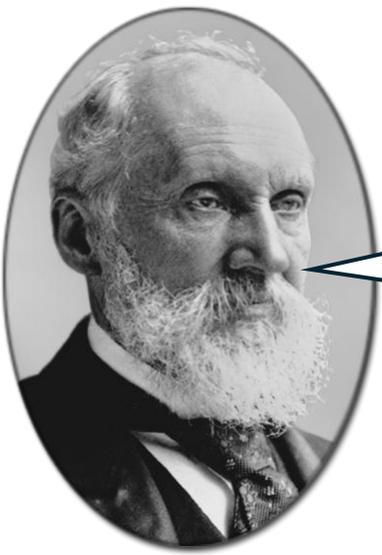
And I know because I am world renowned physicist and mathematician, I laid the foundation for thermodynamics and even temperature is called after me!!



- Darwin himself calculated **300 Ma from Cretaceous to present** (current estimates are ca. 65 Ma) assuming that Weald valley in Southern England was carved at 1inch/100 years

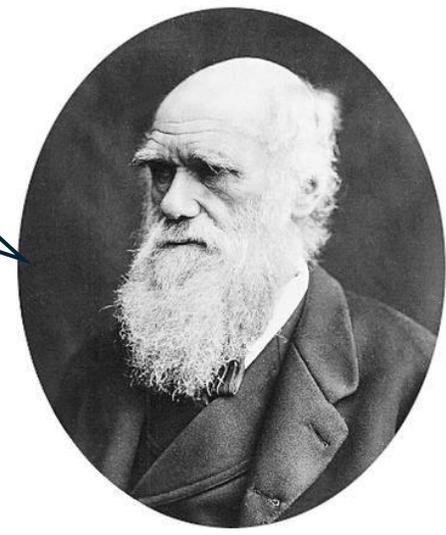
← Estimated from erosion of England's cliffs



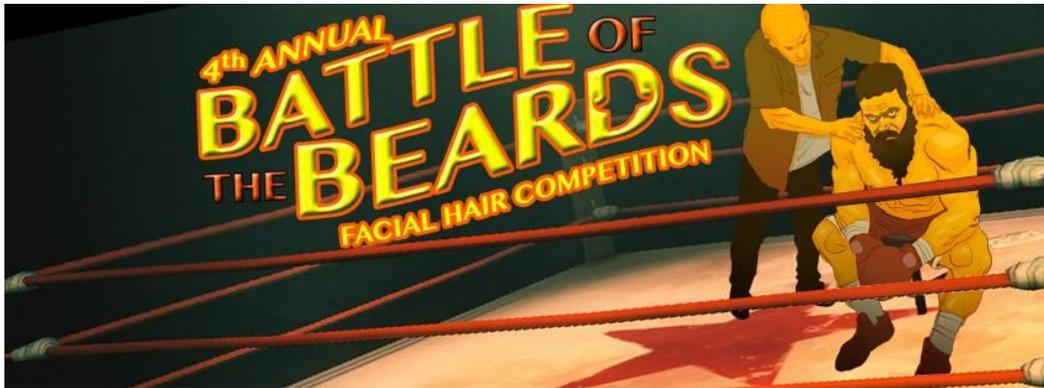


Ridiculous Darwin! Based on the **cooling of metals**, Earth must be at most **20 million years old!**

I am so ashamed, I will delete this part from II and III editions of «On the Origin of Species»!

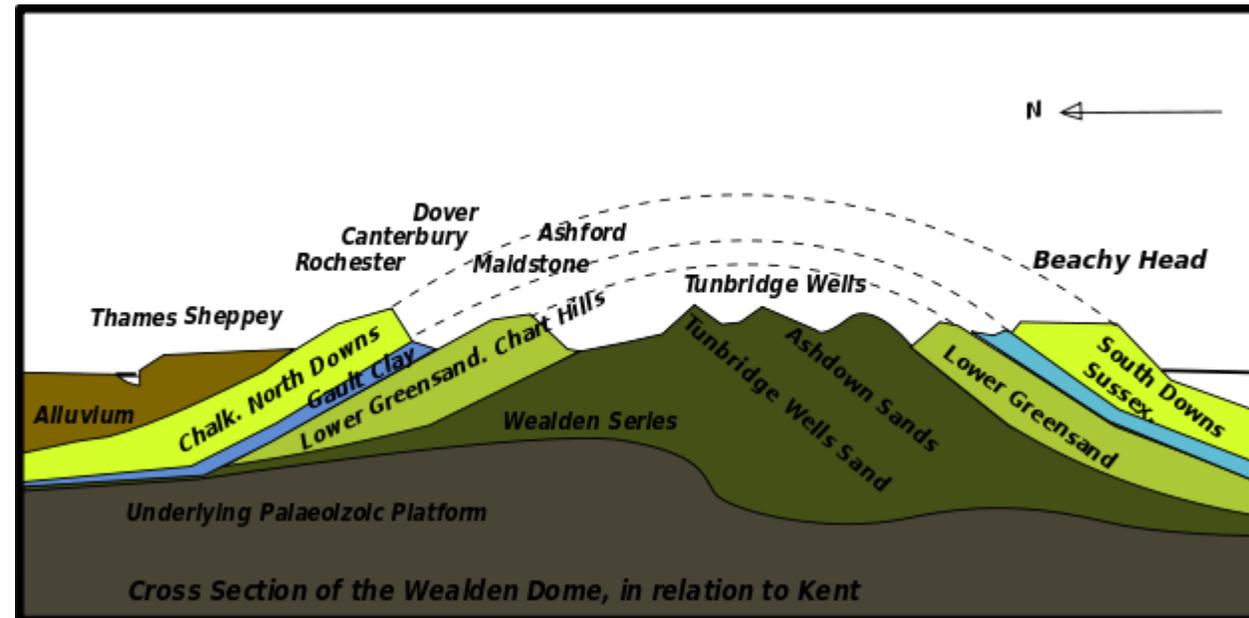


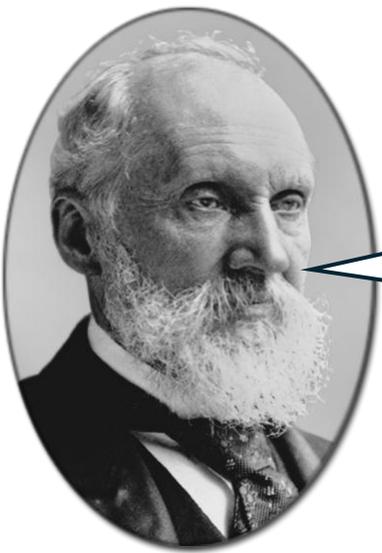
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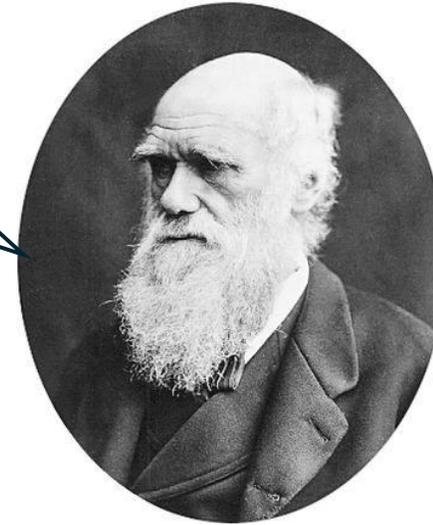
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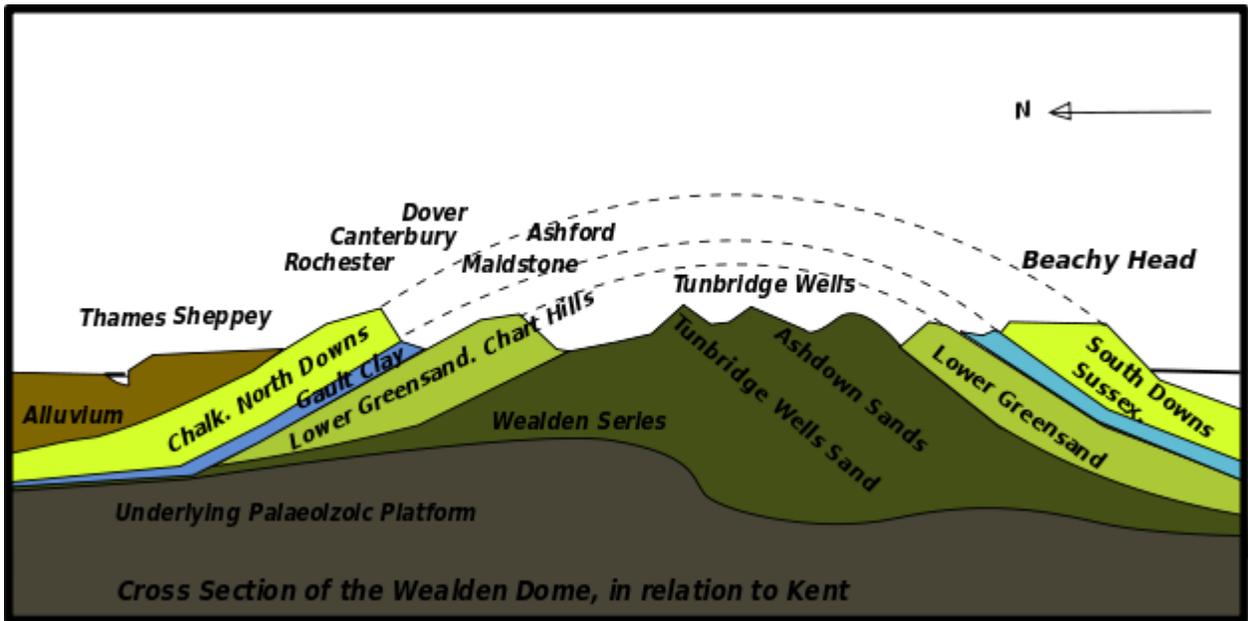
And I know because I am world renowned physicist and mathematician, I laid the foundation for thermodynamics and even temperature is called after me!!



Both models were too simplistic: one ignored radioactivity in Earth's core, the other that erosion is not totally uniform (more in storms)

- Darwin himself calculated **300 Ma from Cretaceous to present** (current estimates are ca. 65 Ma) assuming that Weald valley in Southern England was carved at 1 inch/100 years

← Estimated from erosion of England's cliffs





THAT TROUBLES OUR MONKEY AGAIN.

Female descendant of *Marine Ascidian*:—"REALLY, MR. DARWIN, SAY WHAT YOU LIKE ABOUT MAN; BUT I WISH YOU WOULD LEAVE MY EMOTIONS ALONE!"

Fun, 16 November 1872, in response to "The descent of man and selection in relation to sex", 1871



PROF. DARWIN.

This is the ape of form.

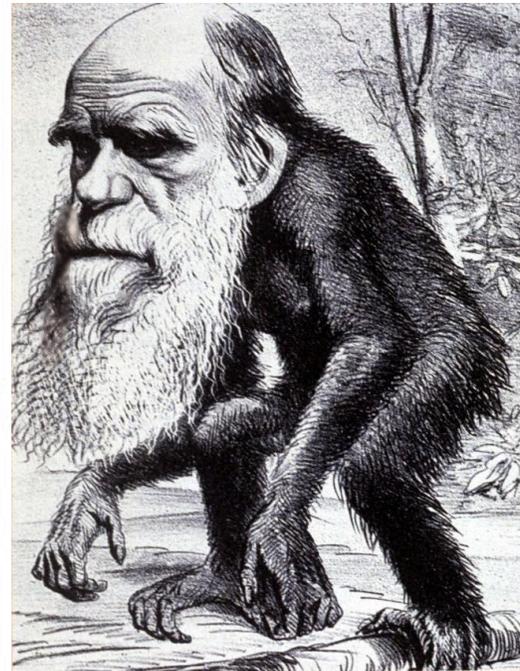
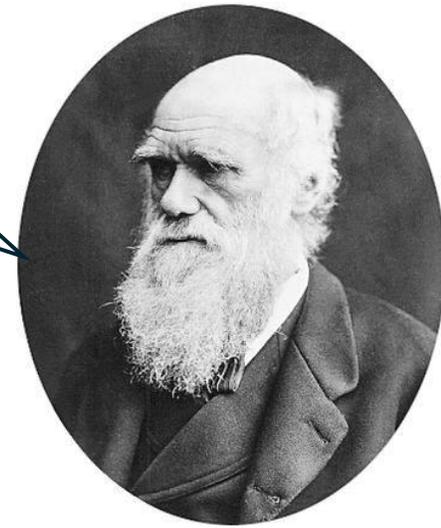
Love's Labor Lost, act 5, scene 2.

Some four or five descents since.

All's Well that Ends Well, act 3, sc. 7.

I am so **ashamed**, I will delete this part from II and III editions of «On the Origin of Species»!

And I am not new to being ridiculed..



The Hornet, 1871

The Hornet, 1861



THE LION OF THE SEASON.

ALARMED FRENCH. "MR. G G-G-O-O-RILLA!"



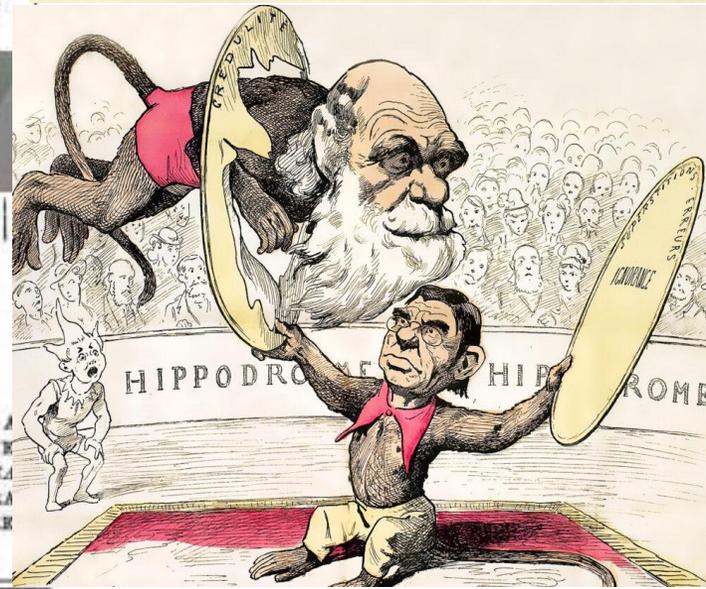
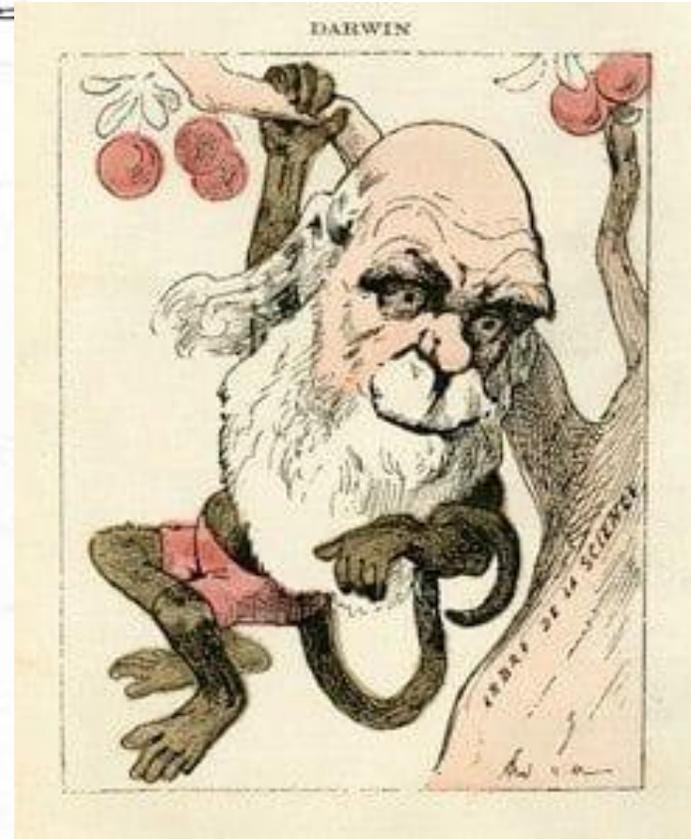
PUNCH'S FANCY PORTRAITS.—No. 54



CHARLES ROBERT DARWIN, LL.D., F.R.S.

IN HIS *DESCENT OF MAN* HE BROUGHT HIS OWN SPECIES DOWN AS LOW AS POSSIBLE—I.E., TO "A HAIRY QUADRUPED FURNISHED WITH A TAIL AND POINTED EARS, AND PROBABLY ARBOREAL IN ITS HABITS"—WHICH IS A REASON FOR THE VERY GENERAL INTEREST IN A "FAMILY TREE." HE HAS LATELY BEEN TURNING HIS ATTENTION TO THE "POLITIC WORM."

11344376

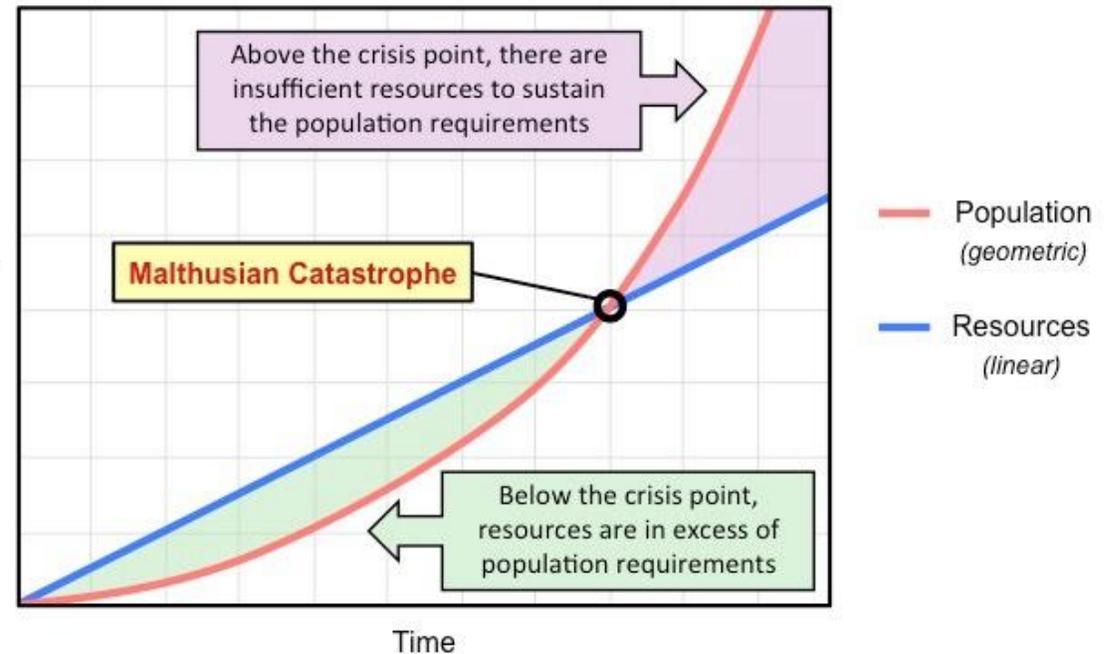


Influences on Darwin outside “biology”

Robert Malthus

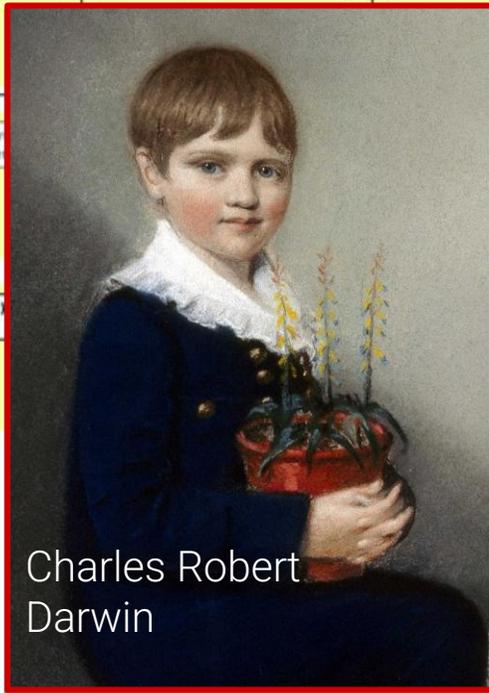
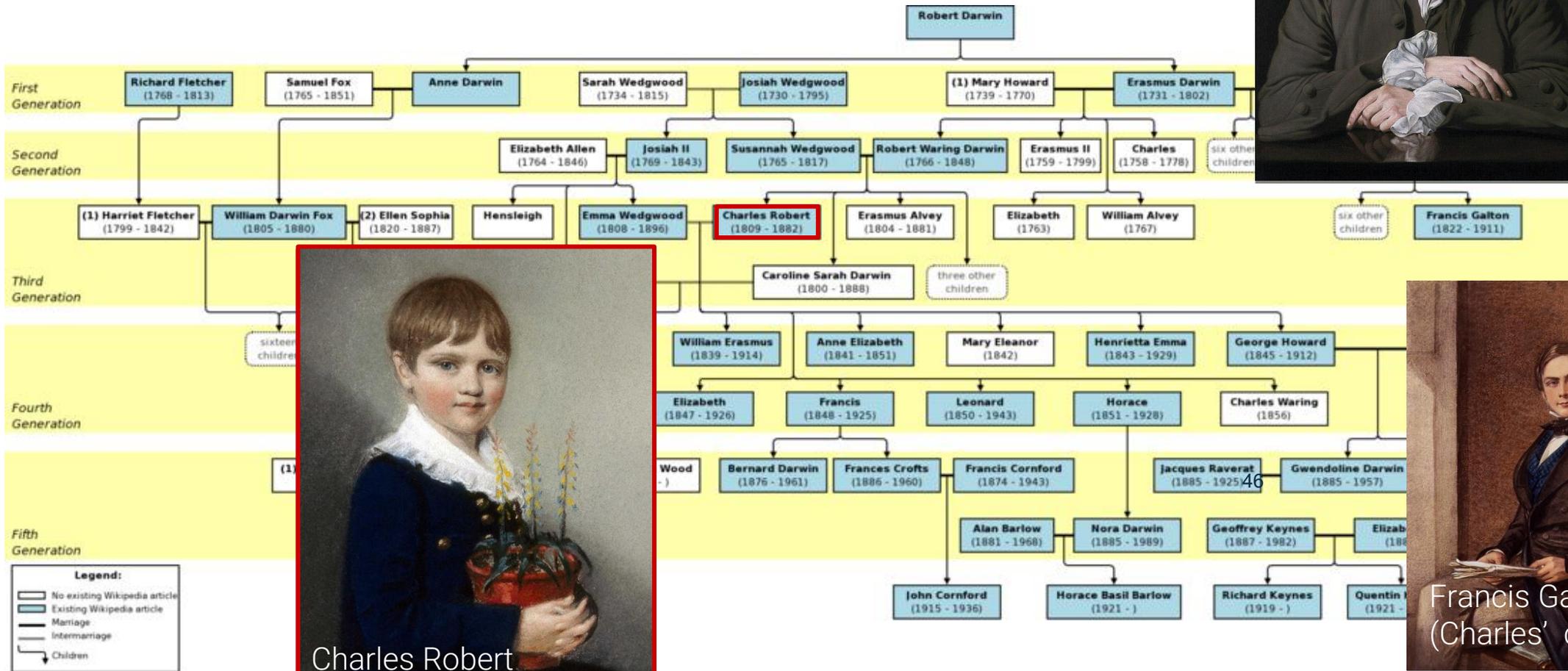
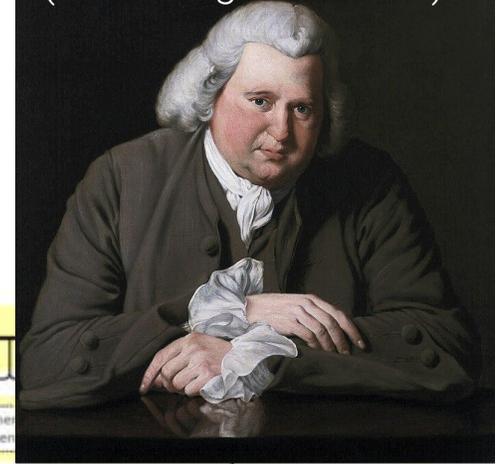
(*An Essay on the Principle of Population*, 1798)

- Exponential population growth
- Limited resources
- Reproduction is limited
- *Struggle for existence* (competition)

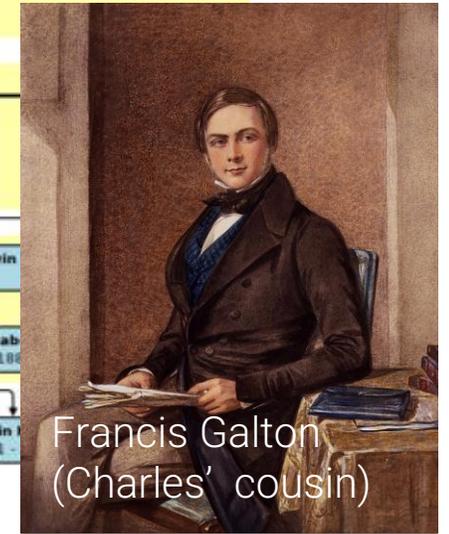


Meet the Darwins

Erasmus Darwin
(Charles' grandfather)



Charles Robert Darwin



Francis Galton
(Charles' cousin)

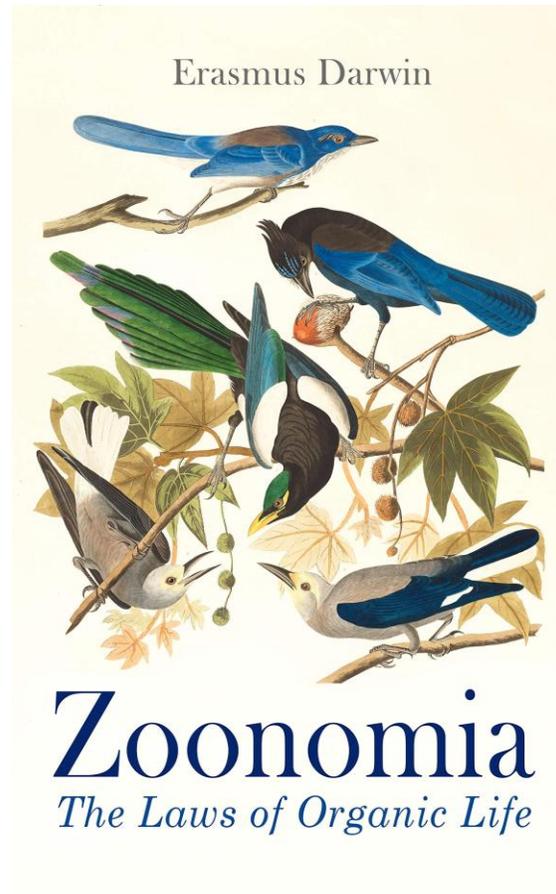
Erasmus Darwin (1731-1802)

Physician and naturalist

Would it be too bold [...to] imagine that all warm-blooded animals have arisen from one living filament?

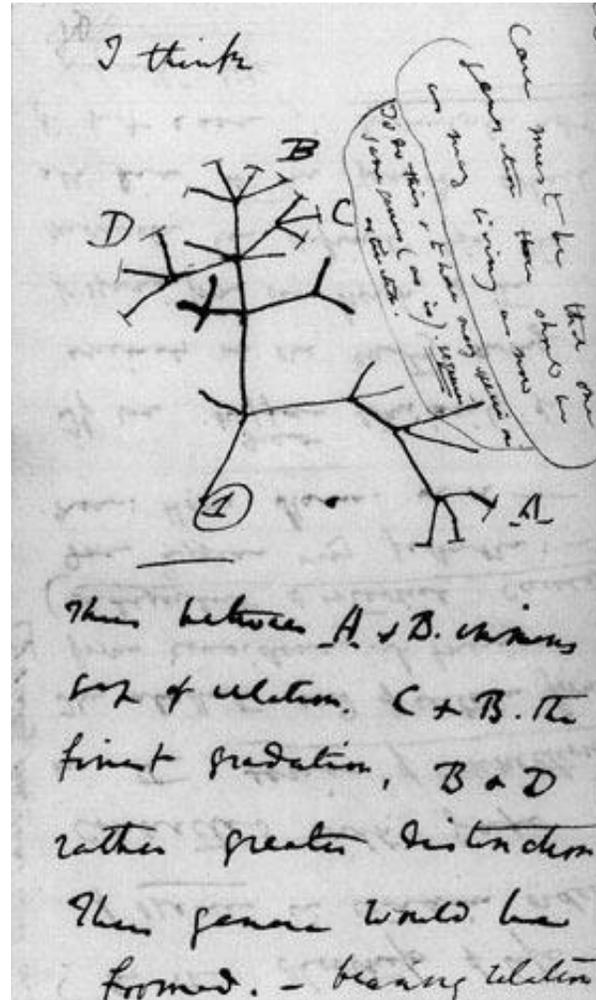
Zoonomia (1796)

One of the **very earliest claims** of a common origin for a large part of (if not all) organisms!



Erasmus Darwin (1731-1802)

Zoonomia is cited three times in the first four pages of **this** notebook from 1837!



The Project

Zoonomia is applying advances in DNA sequencing technologies to understand how genomes generate the tremendous wealth of animal diversity. We decided on “Zoonomia” as the name for our project — combining Greek terms for “animal” and “governing laws” — because it encapsulates what we aim to discover.

We were not the first to coin this term. In 1794, Erasmus Darwin, eminent physician, and grandfather to Charles Darwin, titled his book “Zoonomia; or the Laws of Organic Life”, and asked

would it be too bold to imagine, that in the great length of time, since the earth began to exist, perhaps millions of years...that all warm-blooded animals have arisen from one living filament...?

Erasmus’s insight is remarkable. Contemporary estimates place Earth’s age in the billions, not millions, of years. But Erasmus was correct that all species are related to one another, with any pair sharing a common ancestor in the distant past. This relationship offers a powerful tool for determining and understanding which parts of a genome are important.

DNA must be copied before it is passed from an ancestor to descendants. Copying is imperfect, so some changes arise over time. Changes that do not cause problems tend to accumulate and DNA sequence slowly drifts away from its initial spelling. Finding segments of DNA unchanged across species is, therefore, a powerful strategy to find those important for all animals.

By sequencing and comparing the genomes of hundreds of diverse mammals, *Zoonomia* is identifying segments unchanged across all species, as well as segments changed in just a few. We are discovering both the genomic basis of traits essential for all animals and changes that underlie the unique traits of individual species.



The Mammalian Tree

TREE VIEW

LIST VIEW

Conservation Status

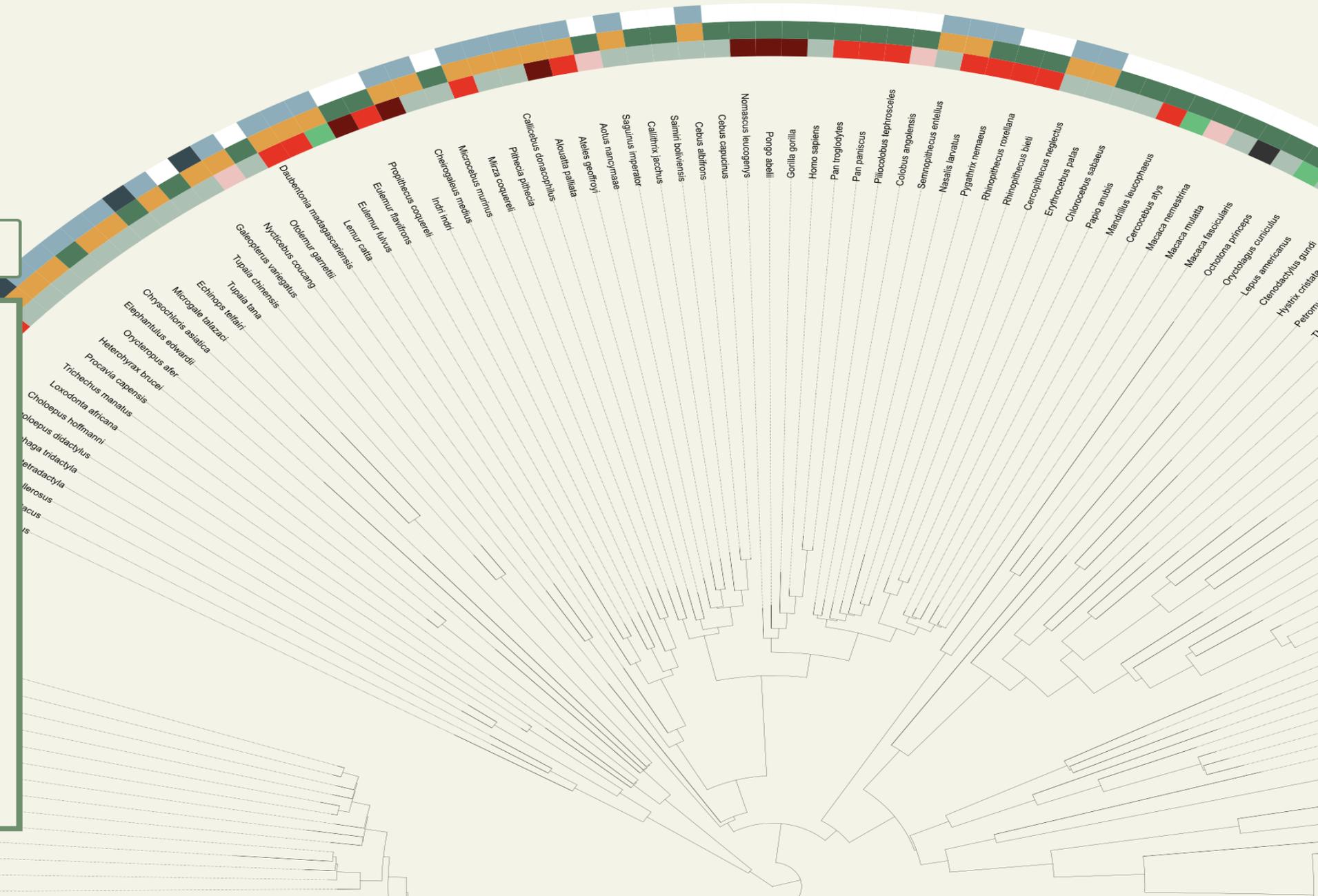
- Data-deficient
- Least Concern
- Near Threatened
- Vulnerable
- Endangered
- Critically Endangered

Assembly Source

- Zoonomia
- Existing Assembly

Assembly Method

- DISCOVER
- Upgraded DISCOVER
- Other



The perplexing figure behind a crucial virus database p. 332

Regulatory reforms to advance psychedelic therapies p. 347

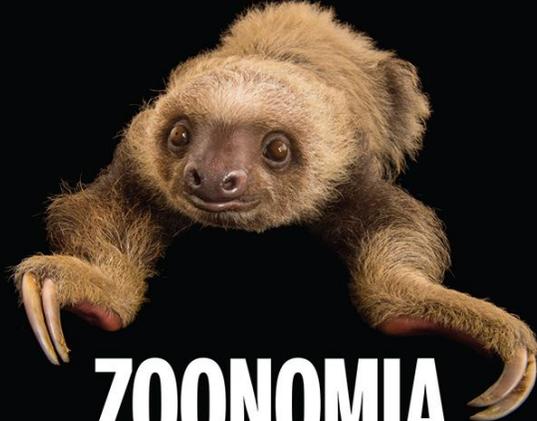
A compact galaxy in the early Universe p. 416

Science

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28 APRIL 2023
SPECIAL ISSUE
science.org



CRYPTOPROCTA FEROX



ZOONOMIA

Diverse genomes reveal mammalian secrets p. 356

CHOLOEPUS HOFFMANNI



DAUBENTONIA MADAGASCARIENSIS

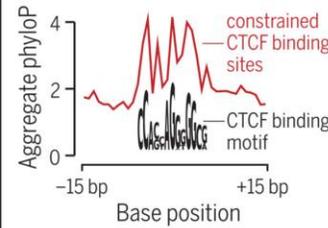


PHATAGINUS TRICUSPIS

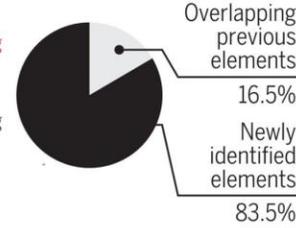


ECHINOPS TELFAIRI

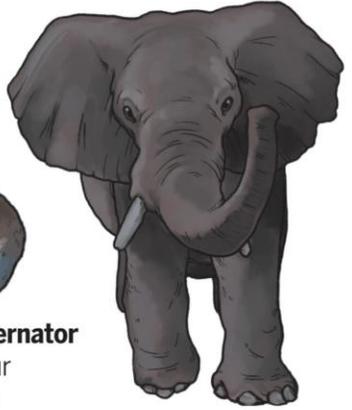
Single-base resolution of constraint



4552 new ultraconserved elements

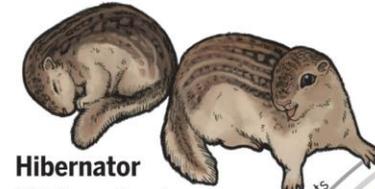


Large-brained Human *Homo sapiens*

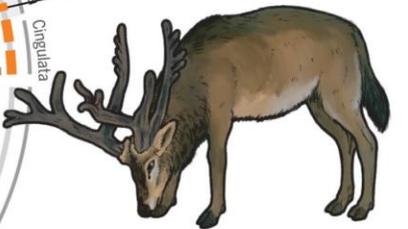


Threatened and hibernator Fat-tailed dwarf lemur *Cheirogaleus medius*

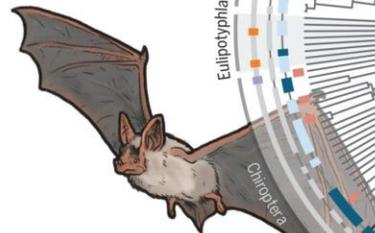
Endangered and high olfactory gene count African savanna elephant *Loxodonta africana*



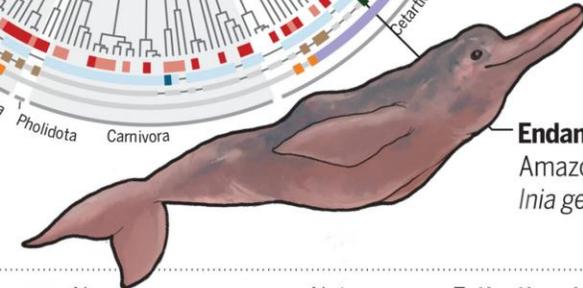
Hibernator Thirteen-lined ground squirrel *Ictidomys tridecemlineatus*



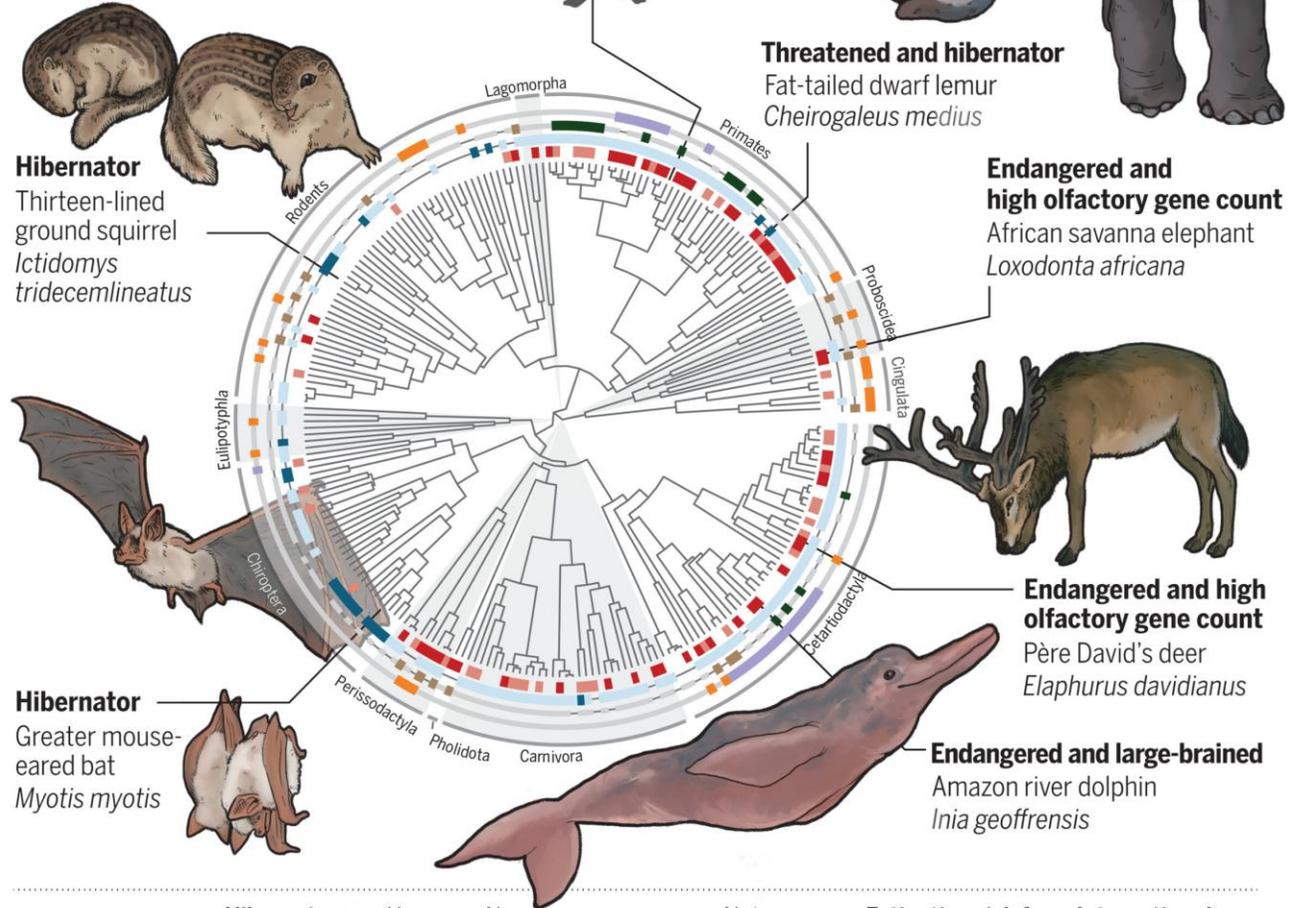
Endangered and high olfactory gene count Père David's deer *Elaphurus davidianus*



Hibernator Greater mouse-eared bat *Myotis myotis*



Endangered and large-brained Amazon river dolphin *Inia geoffrensis*



Hibernator: ■ Yes ■ No	— Not exceptional	Extinction risk from International Union for Conservation of Nature ■ Endangered or critically endangered ■ Vulnerable or near threatened
Brain size relative to body size: ■ Top 10% ■ Bottom 10%	— No data	
Olfactory receptor gene number: ■ Top 10% ■ Bottom 10% (predictor of olfactory capacity)		

The perplexing figure behind
a crucial virus database p. 332

Regulatory reforms to advance
psychedelic therapies p. 347

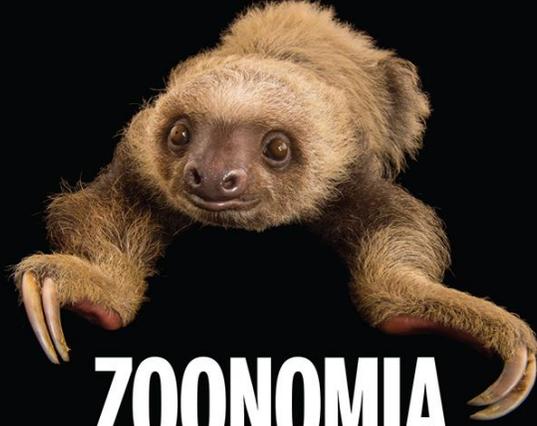
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early Universe p. 416

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CRYPTOPROCTA FEROX



ZOONOMIA

Diverse genomes reveal mammalian
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DAUBENTONIA MADAGASCARIENSIS



PHATAGINUS TRICUSPIS

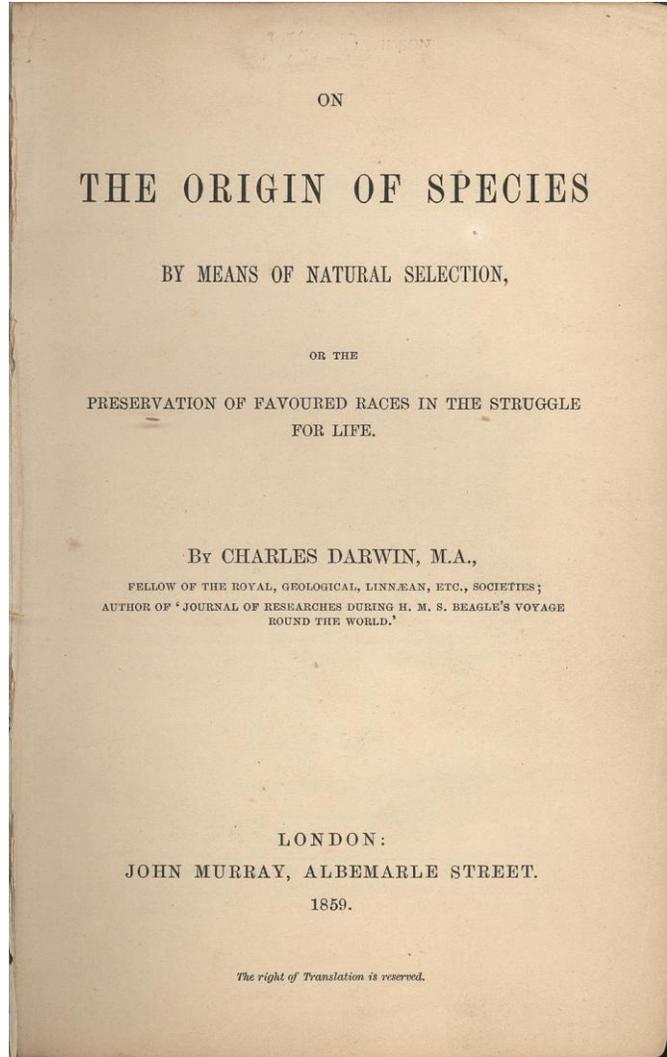


ECHINOPS TELFAIRI

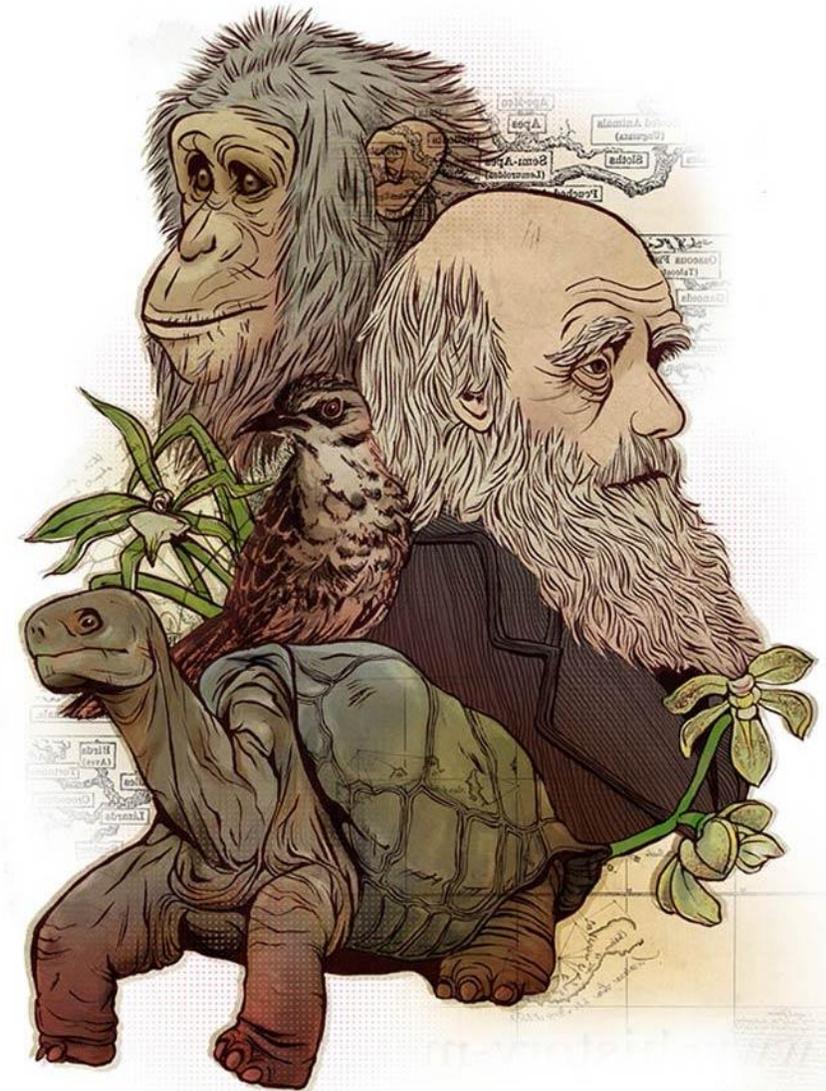
We will look at this awesome dataset in the context of:

- Molecular evolution and comparative genomics
- Conservation genomics
- Discovery of new genes
- Cancer genomics
- Rare diseases
- Domestication and breeding



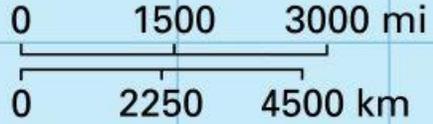
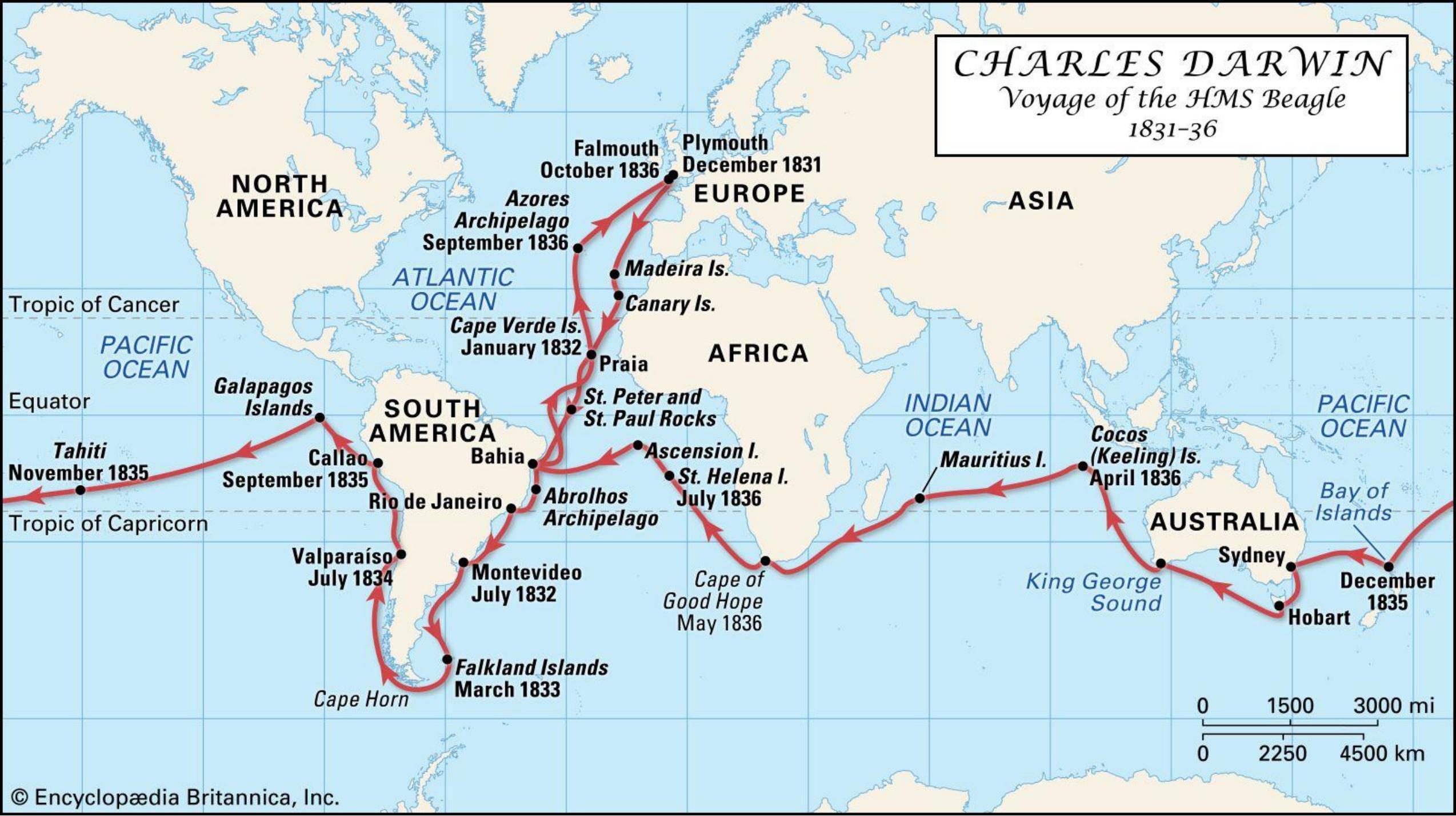


Charles Darwin
(1809-1882)
and
On the Origin of
Species

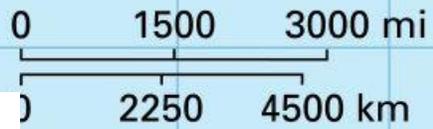
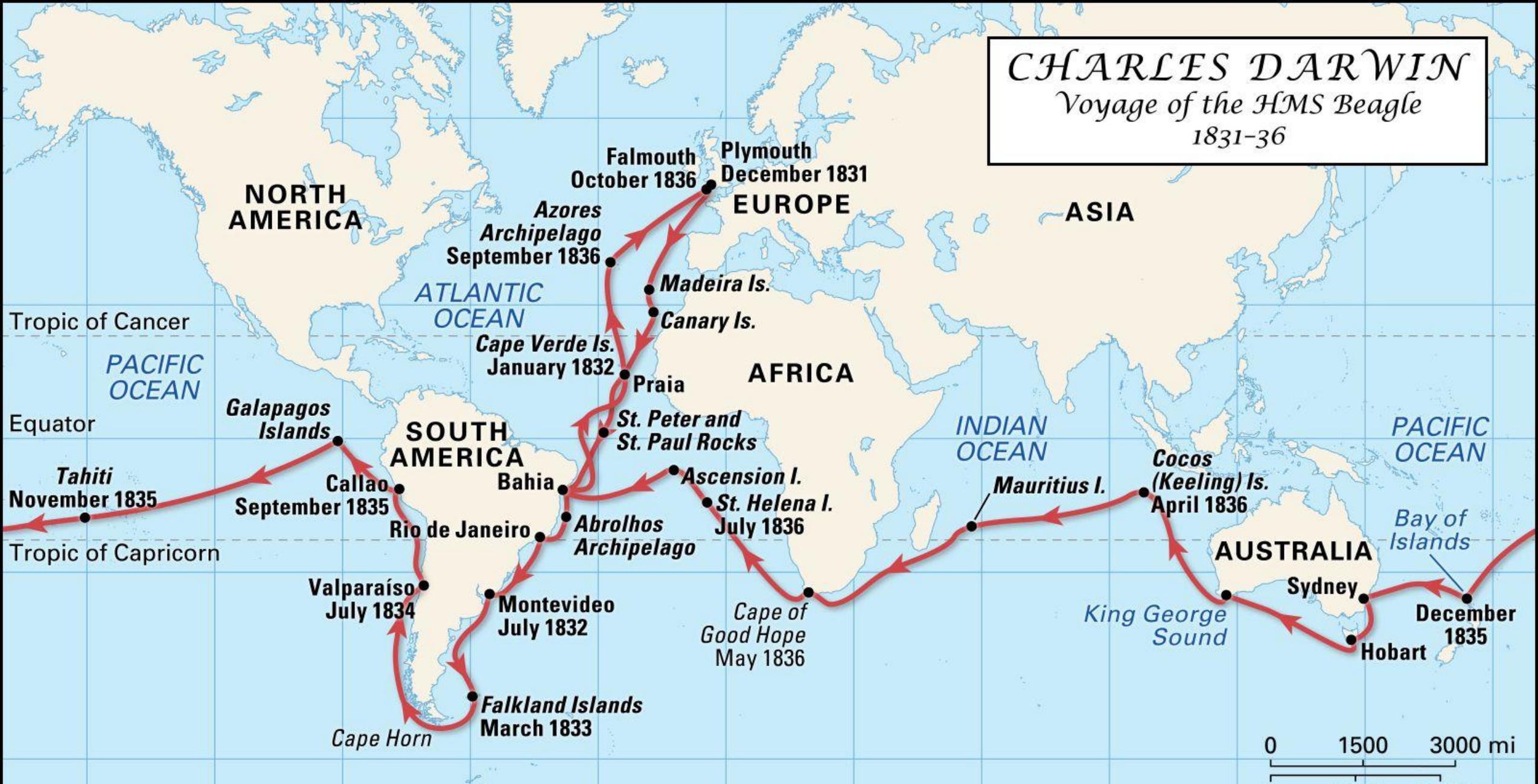




CHARLES DARWIN
Voyage of the HMS Beagle
1831-36



CHARLES DARWIN
Voyage of the HMS Beagle
1831-36

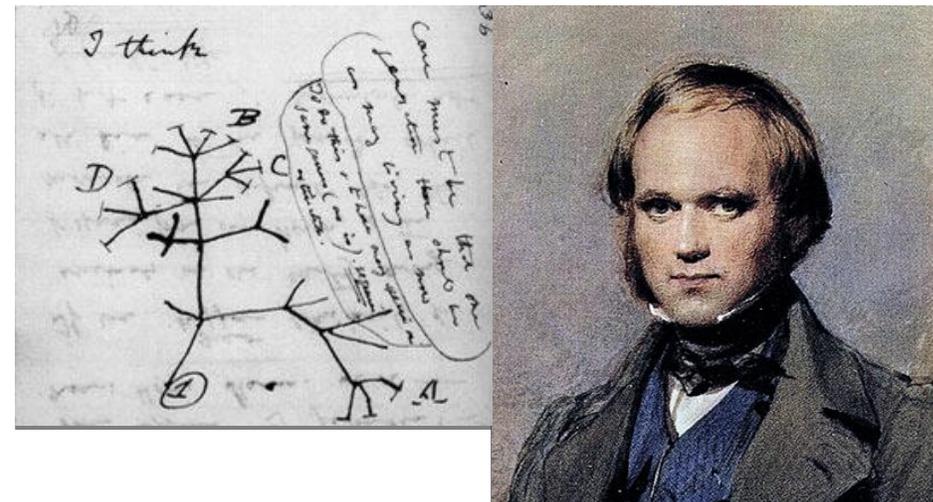


What did he see that impressed him so much?

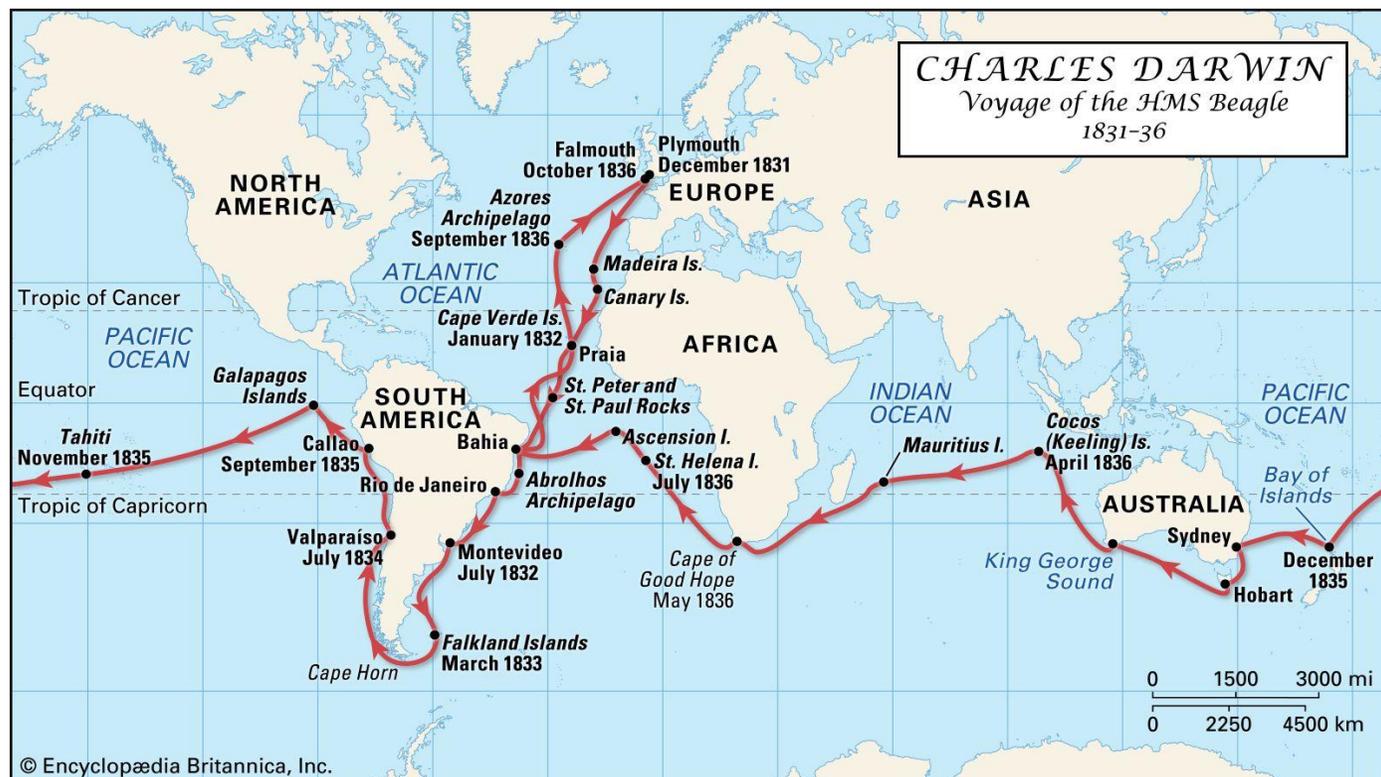
Charles (1809-1882)

When on board *HMS Beagle*, as naturalist, I was much struck with certain facts in the **distribution of the inhabitants of South America**, and in the **geological relations of the present to the past inhabitants of that continent**. These facts seemed to me to throw some light on the origin of species—that mystery of mysteries...

On the Origin of Species, Introduction, [pag. 1](#)



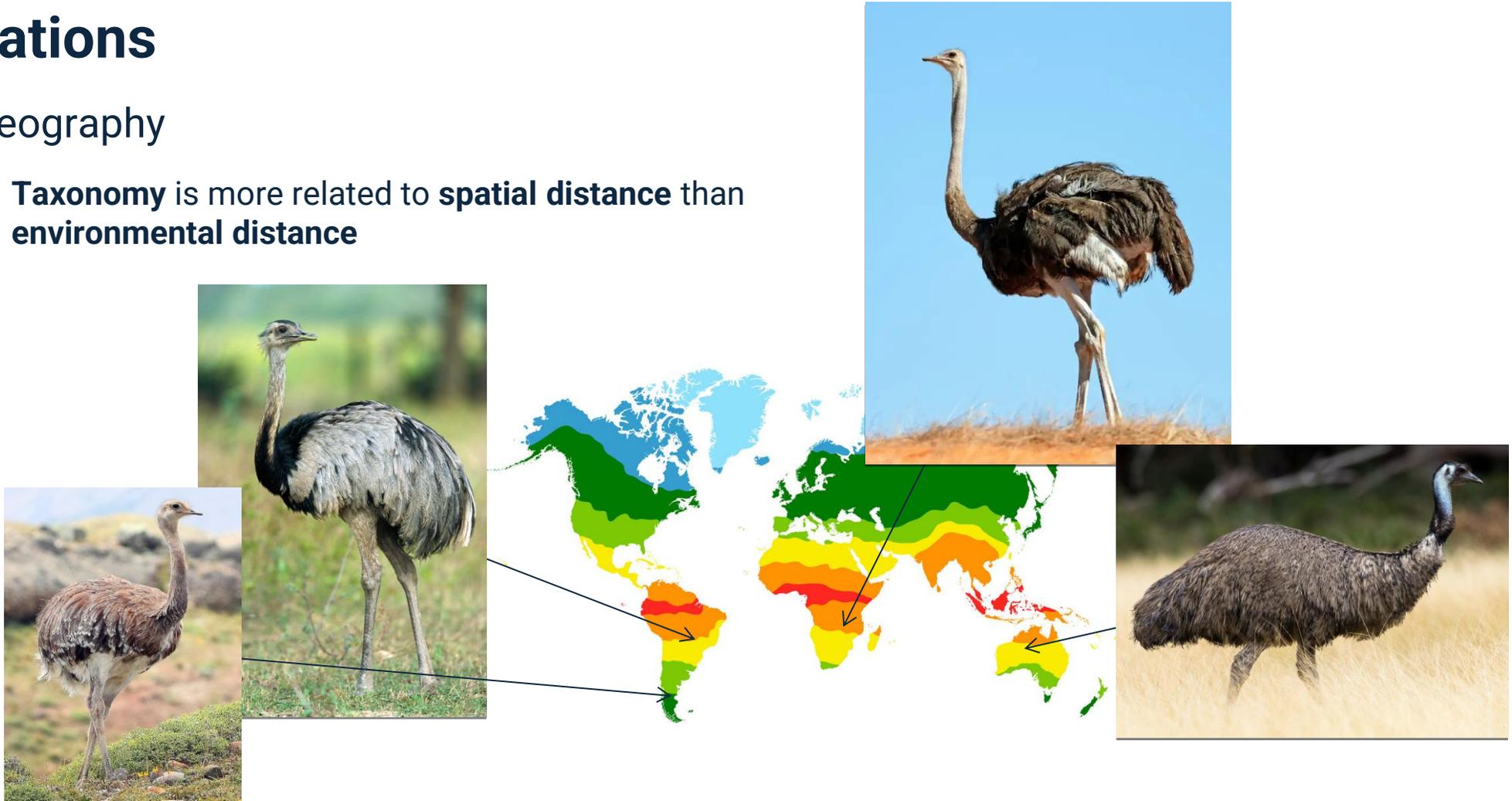
Voyage of the **Beagle**
(1831-1837)



The origin of species, 1859 (1st ed.)

Observations

- Biogeography
 - **Taxonomy** is more related to **spatial distance** than **environmental distance**

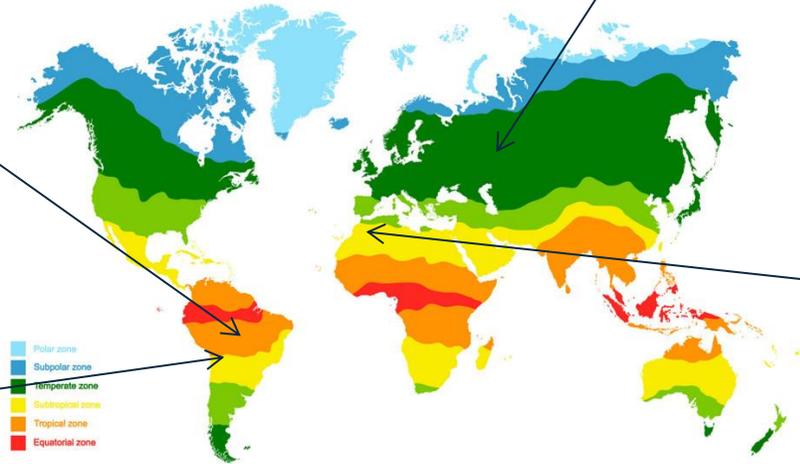
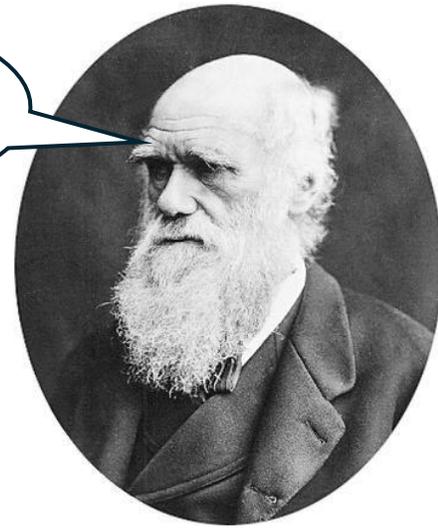


The origin of species, 1859 (1st ed.)

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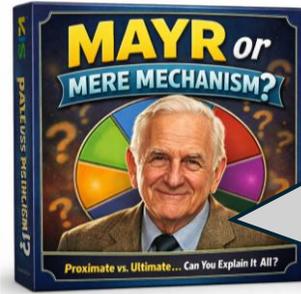
What do you notice?



The origin of species, 1859

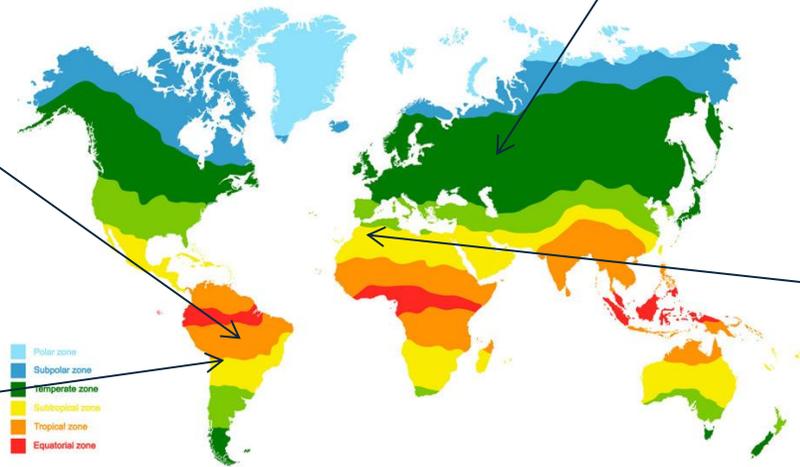
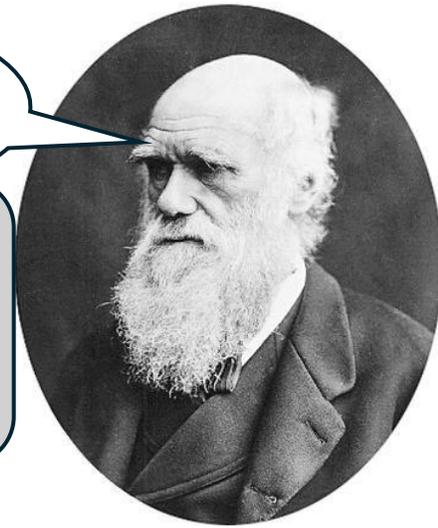
Observations

- Biogeography



What?!

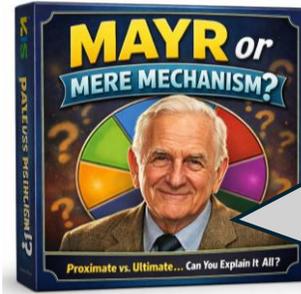
Cute «South american beaver» and «South American rabbit»!
Convergent evolution!



The origin of species, 1859

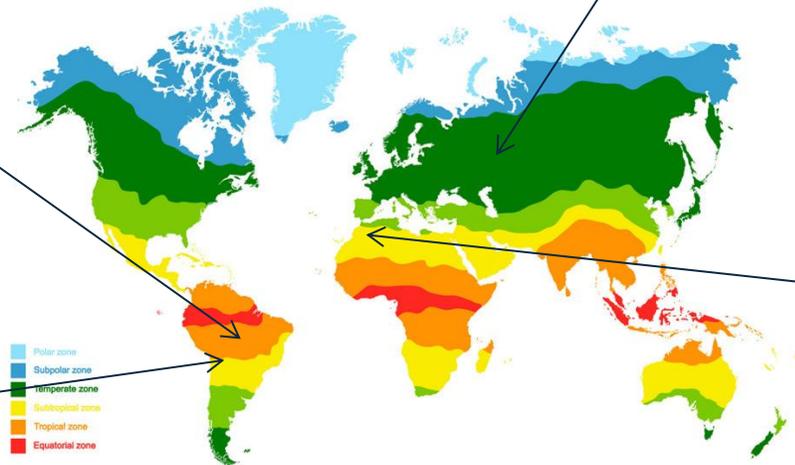
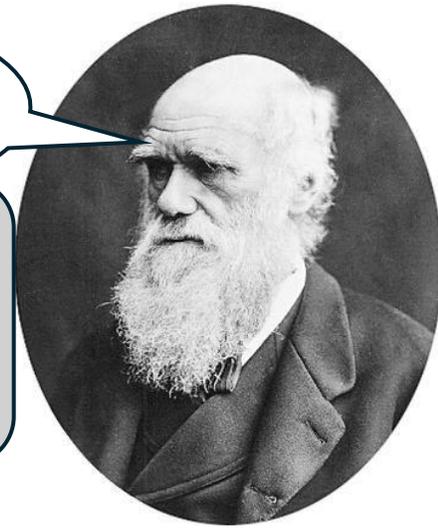
Observations

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 - **Taxonomy** is more related to **spatial distance** than **environmental distance**



What?!

Cute «South american beaver» and «South American rabbit»!
Convergent evolution!





Long gestations, generally **precocial** (born fully furred, eyes open, able to walk).



Short gestations, generally **altricial** (hairless, blind, helpless newborns).





Agouti



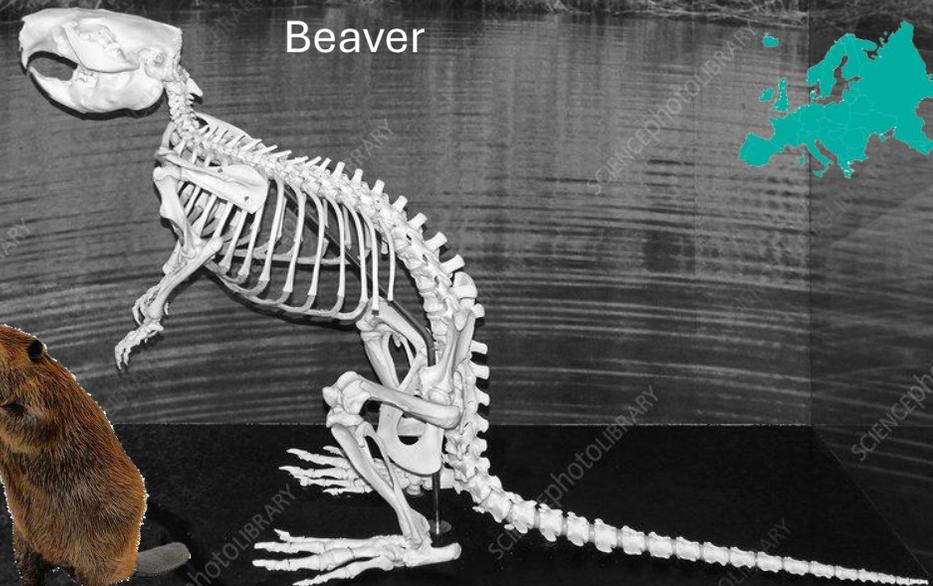
Rabbit



Capibara

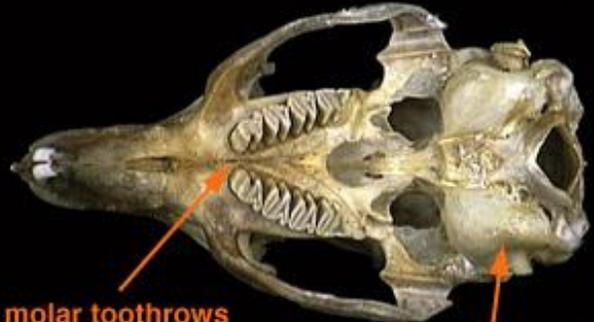
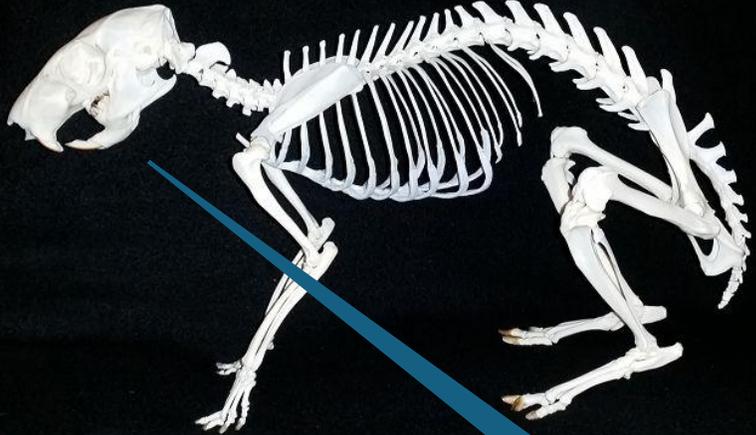


Beaver



Caviidae

Agouti



molar toothrows converge in front

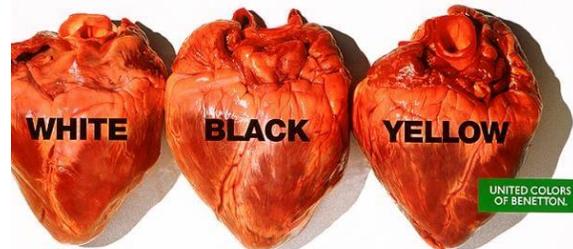
bullae enlarged

cheekteeth simple, made up of 2 enamel prisms

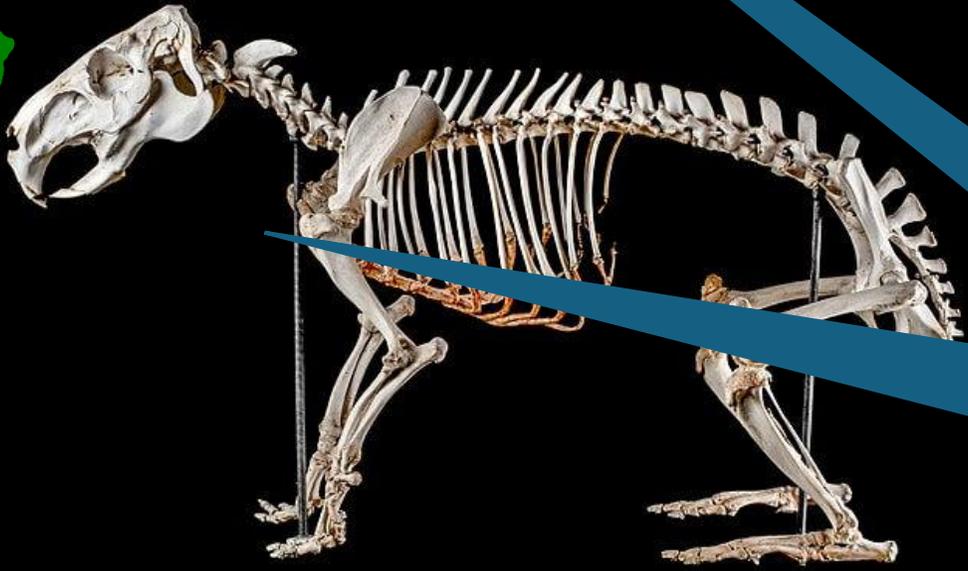


large paroccipital process

We (caviomorpha) have a very similar skeleton, though we look different on the outside (trust us)!

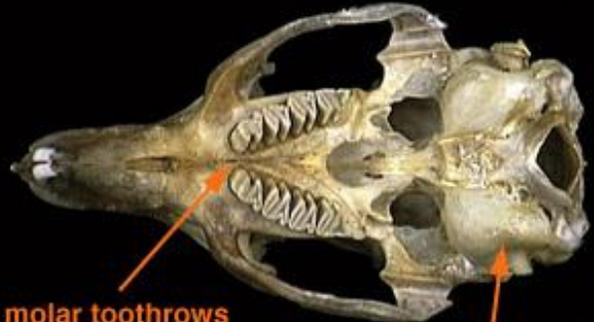


Capibara



Caviidae

Agouti



molar toothrows converge in front

bullae enlarged

Larger infraorbital foramen

cheekteeth simple, made up of 2 enamel prisms



large paroccipital process



Capibara

This is why often to classify taxonomically a species is useful to rely on seemingly insignificant morphological traits rather than «apparent» ones



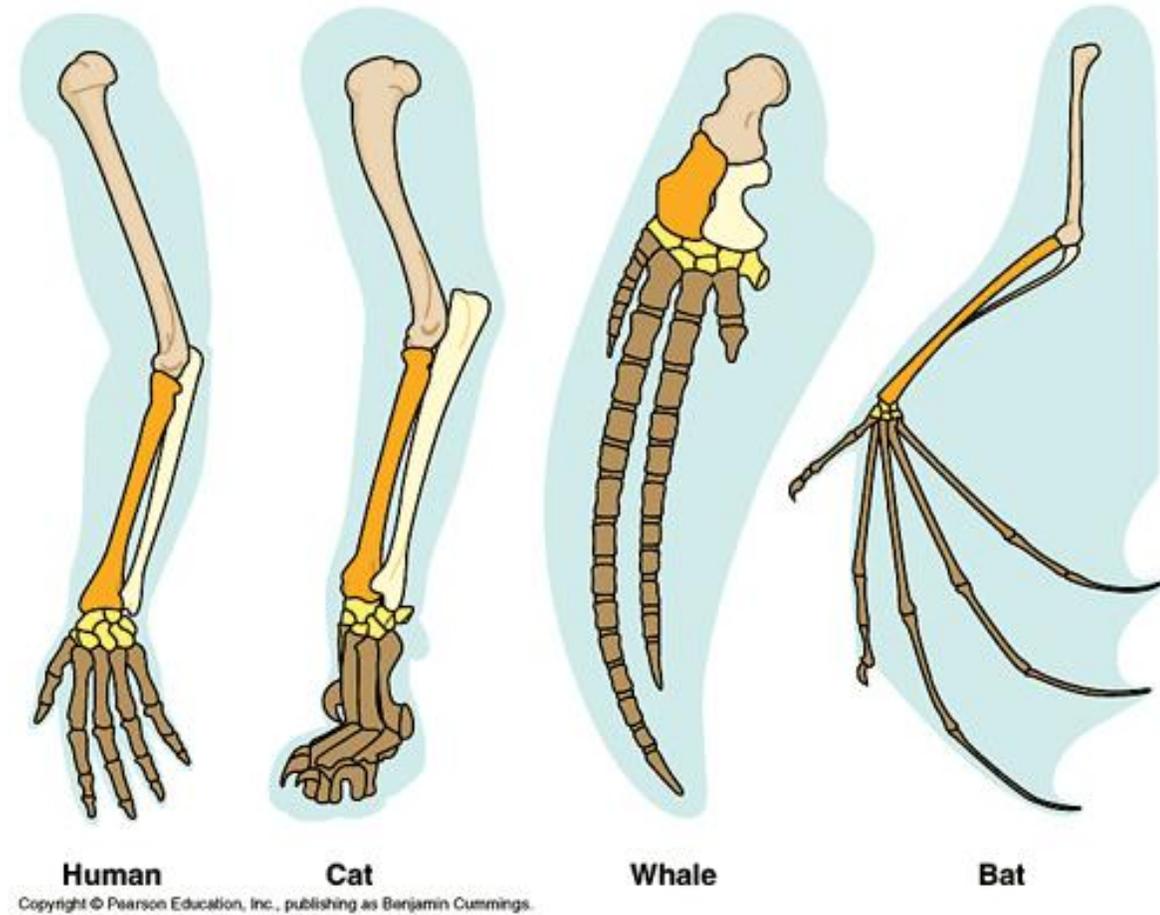
The origin of species, 1859 (1st ed.)

Observations

- Classification
 - Nested structure
 - Homologous structures

"What can be more curious than that the hand of a man, formed for grasping, that of a mole for digging, the leg of the horse, the paddle of the porpoise, and the wing of the bat, should [...] include the same bones, in the same relative positions?"

"the characters which naturalists consider as showing true affinity between any two or more species, are those which have been inherited from a common parent"

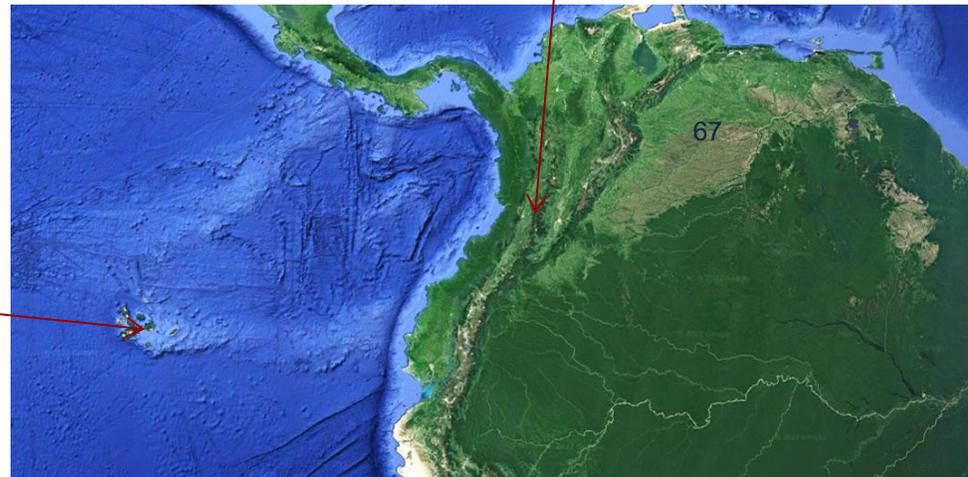
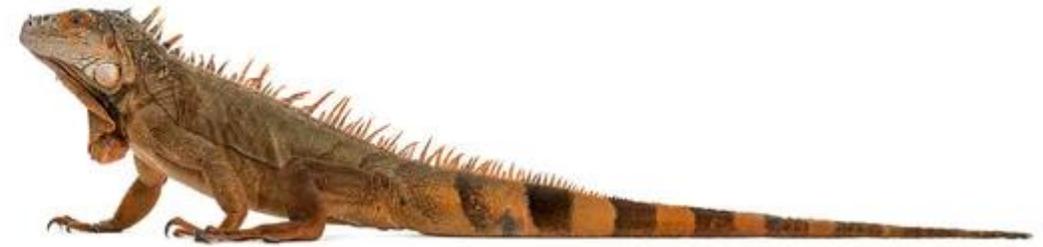


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The origin of species, 1859 (1st ed.)

Observations

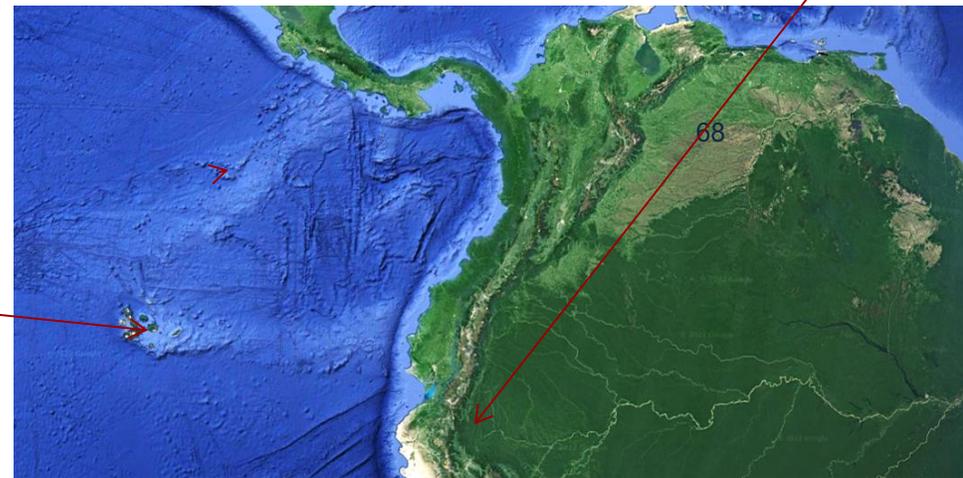
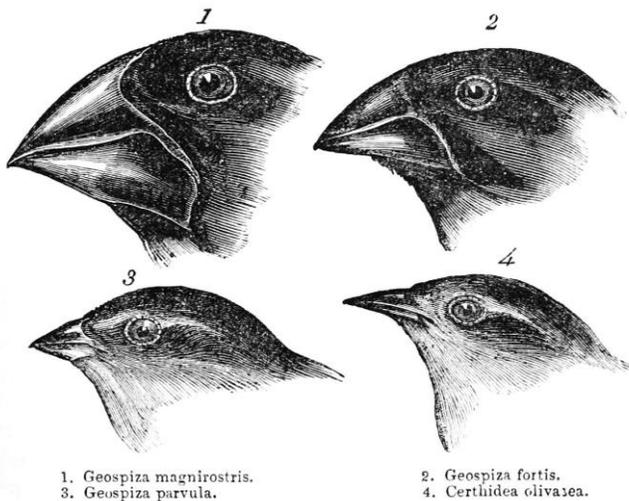
- Biogeography
 - Inhabitants of **islands** are similar to the closest **mainland** (Galapagos birds and reptiles, red grouse in Britain)



The origin of species, 1859 (1st ed.)

Observations

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The origin of species, 1859 (1st ed.)

Observations

- Biogeography
 - Many similar species in small locations

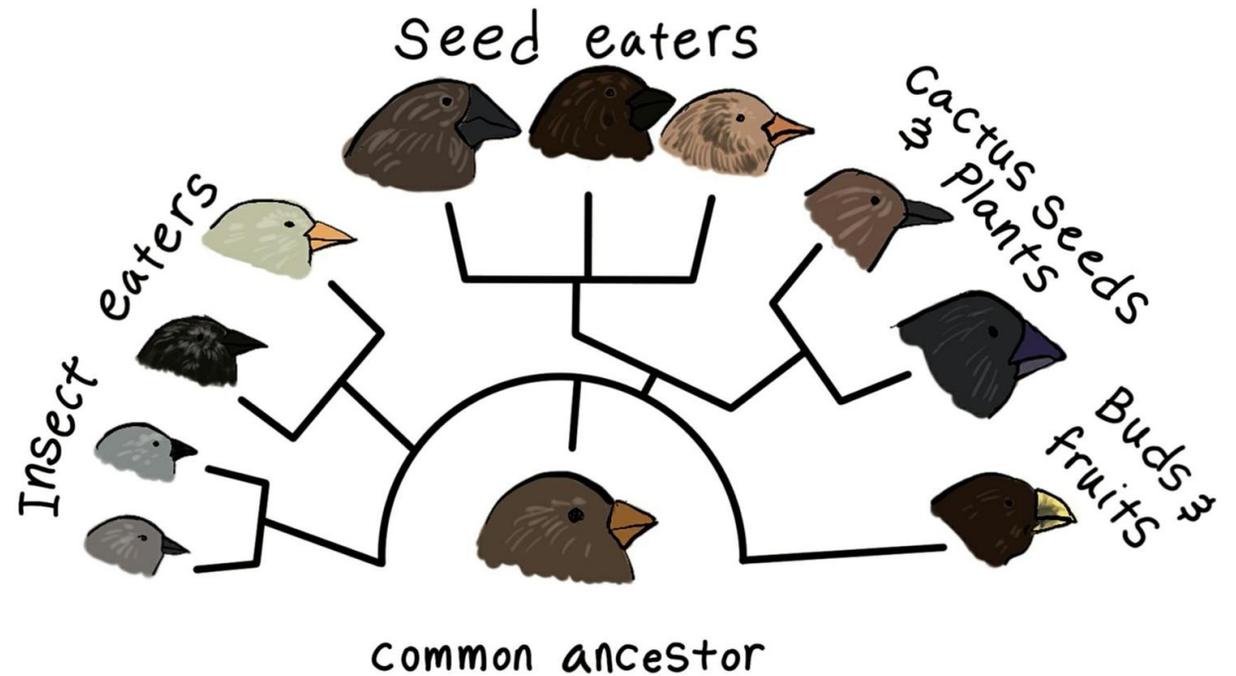


The origin of species, 1859 (1st ed.)

Observations

- Biogeography
 - Many similar species in small locations
 - Rapid “radiation” in Islands

Adaptive radiation: a single species rapidly adapts to fill available niches in an environment.

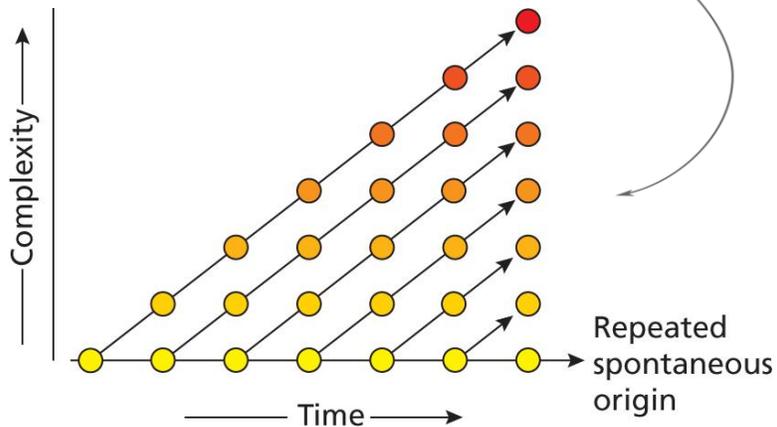


The origin of species, 1859 (1st ed.)

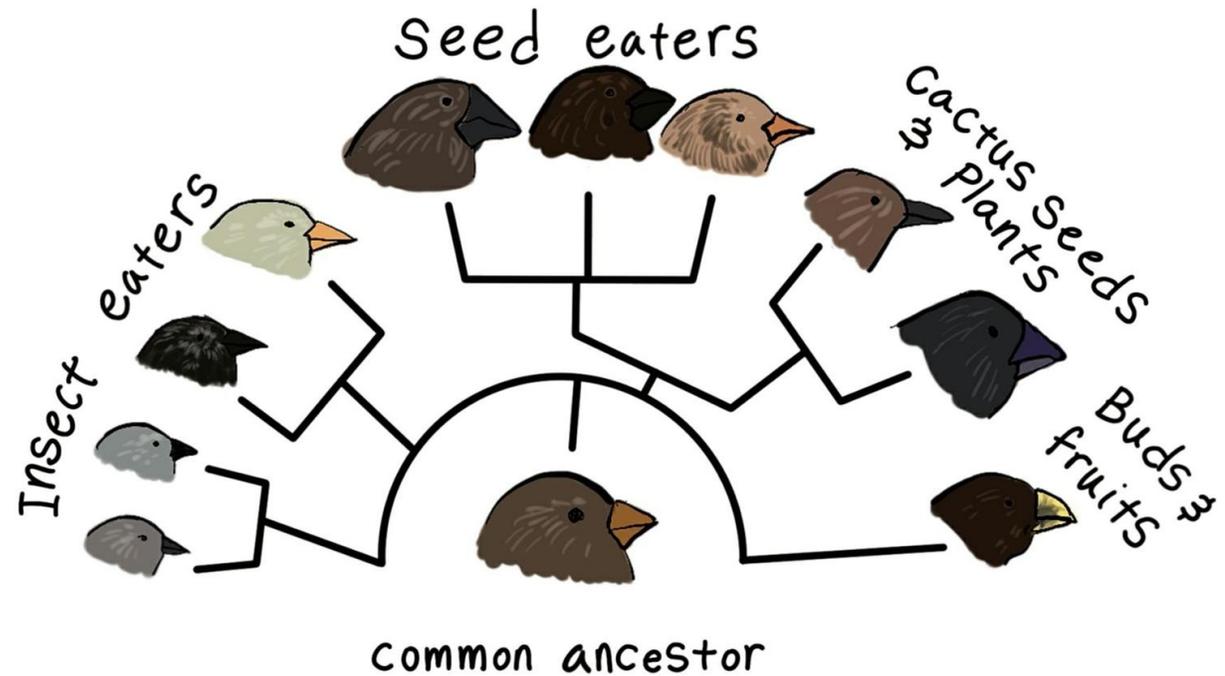
Observations

- Biogeography
 - Many similar species in small locations
 - Rapid “radiation” in Islands

Pace of modification is not constant (*cfr.* Lamarck), it depends on conditions!



Adaptive radiation: a single species rapidly adapts to fill available niches in an environment.

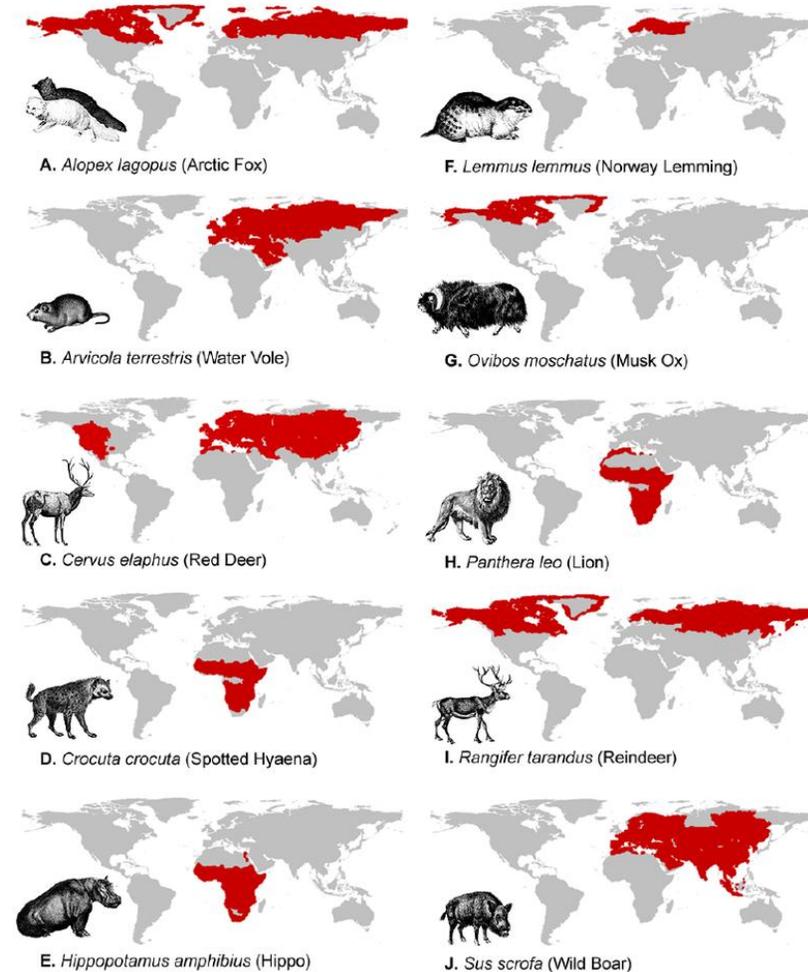


The origin of species, 1859 (1st ed.)

Observations

- Biogeography
 - The range of most species is nearly **continuous**

Would it make any sense without evolution as we know it?



The origin of species, 1859 (1st ed.)

Observations

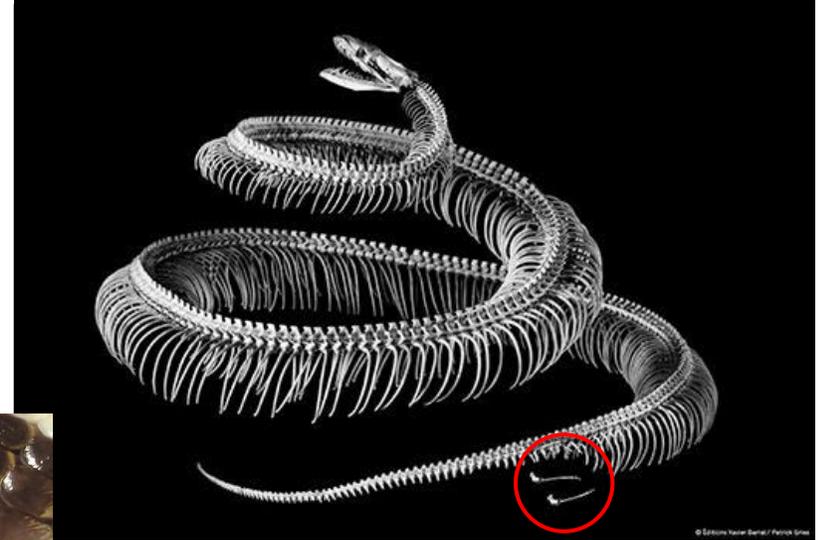
- Vestigial organs
 - Wings of flightless birds



The origin of species, 1859 (1st ed.)

Observations

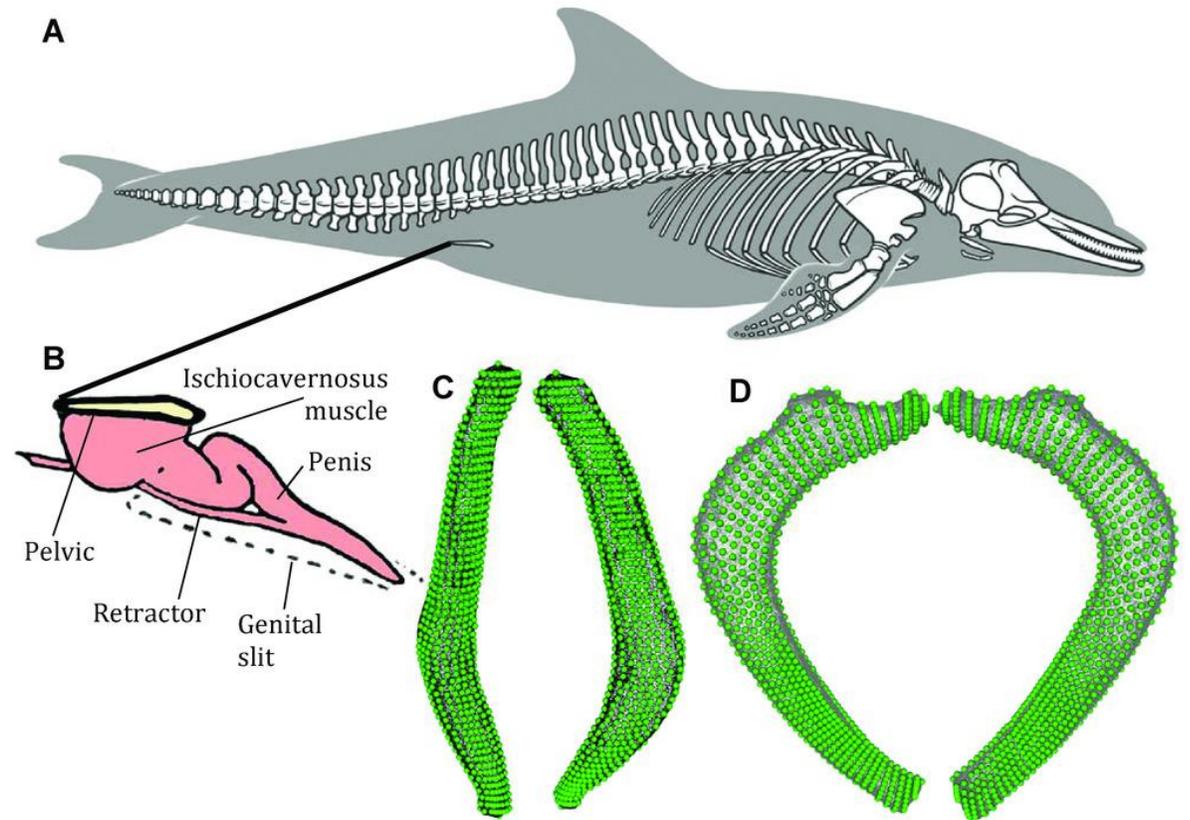
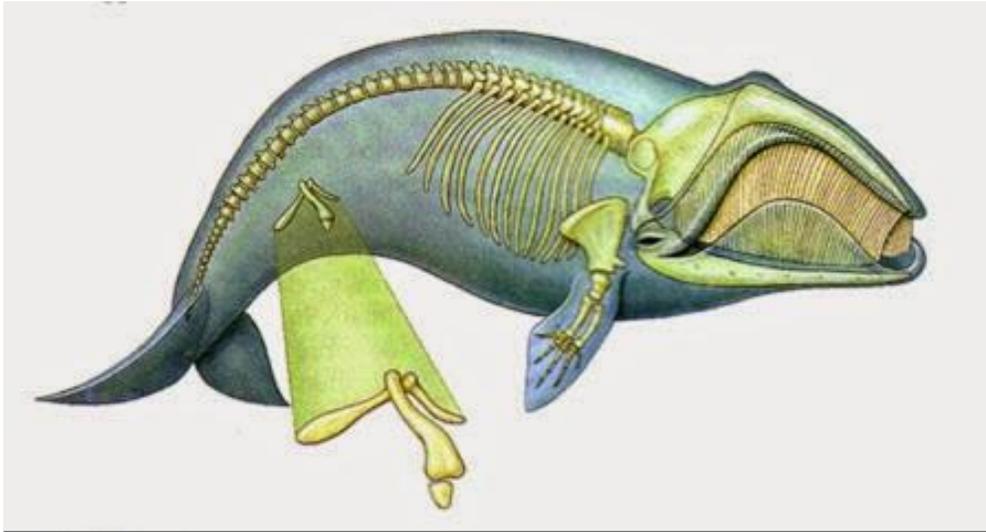
- Vestigial organs
 - Wings of flightless birds
 - Pelvis in **snakes**



The origin of species, 1859 (1st ed.)

Observations

- Vestigial organs
 - Wings of flightless birds
 - Pelvis in snakes and **whales**

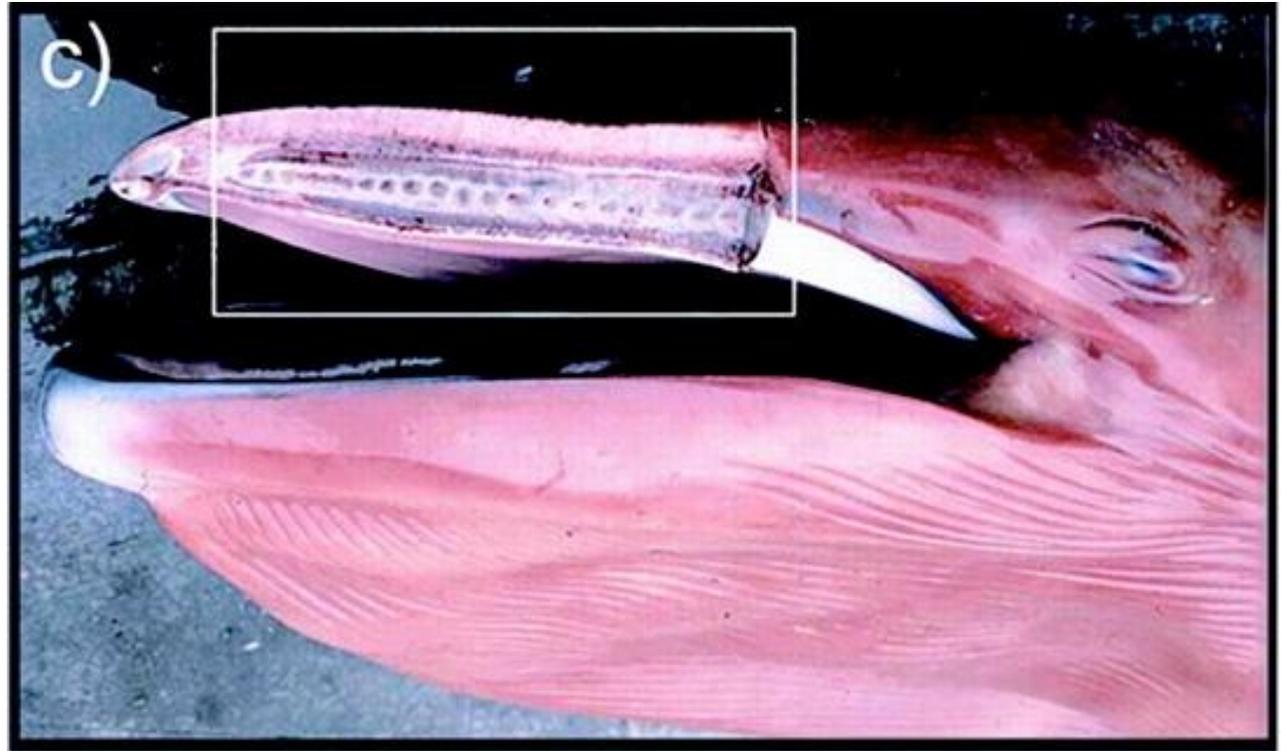


[Dines et al., 2014](#)

The origin of species, 1859 (1st ed.)

Observations

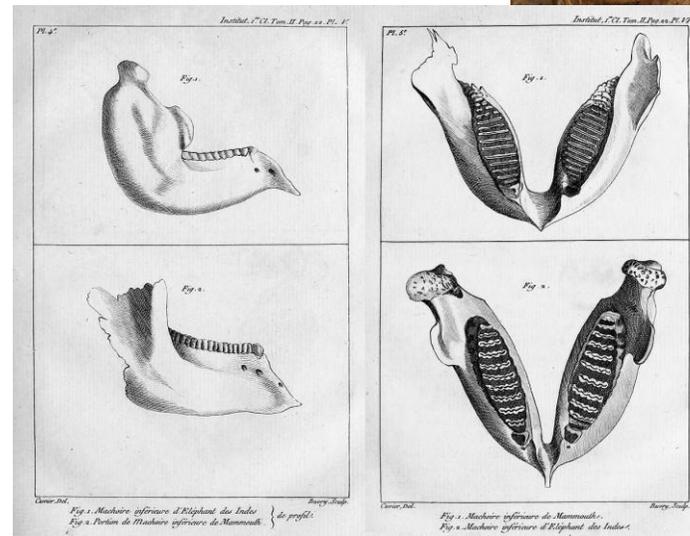
- Vestigial organs
 - Wings of flightless birds
 - Pelvis in snakes and whales
 - Teeth in embryos of baleen whales



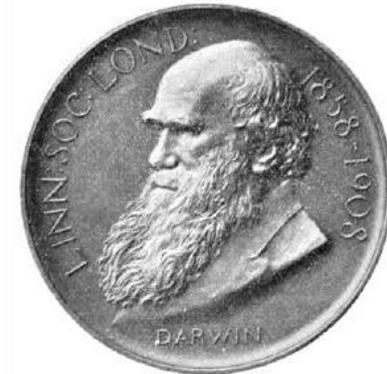
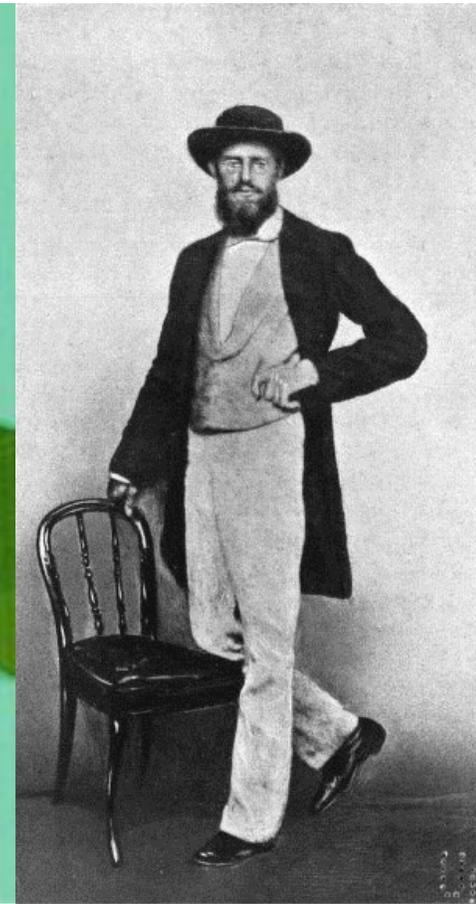
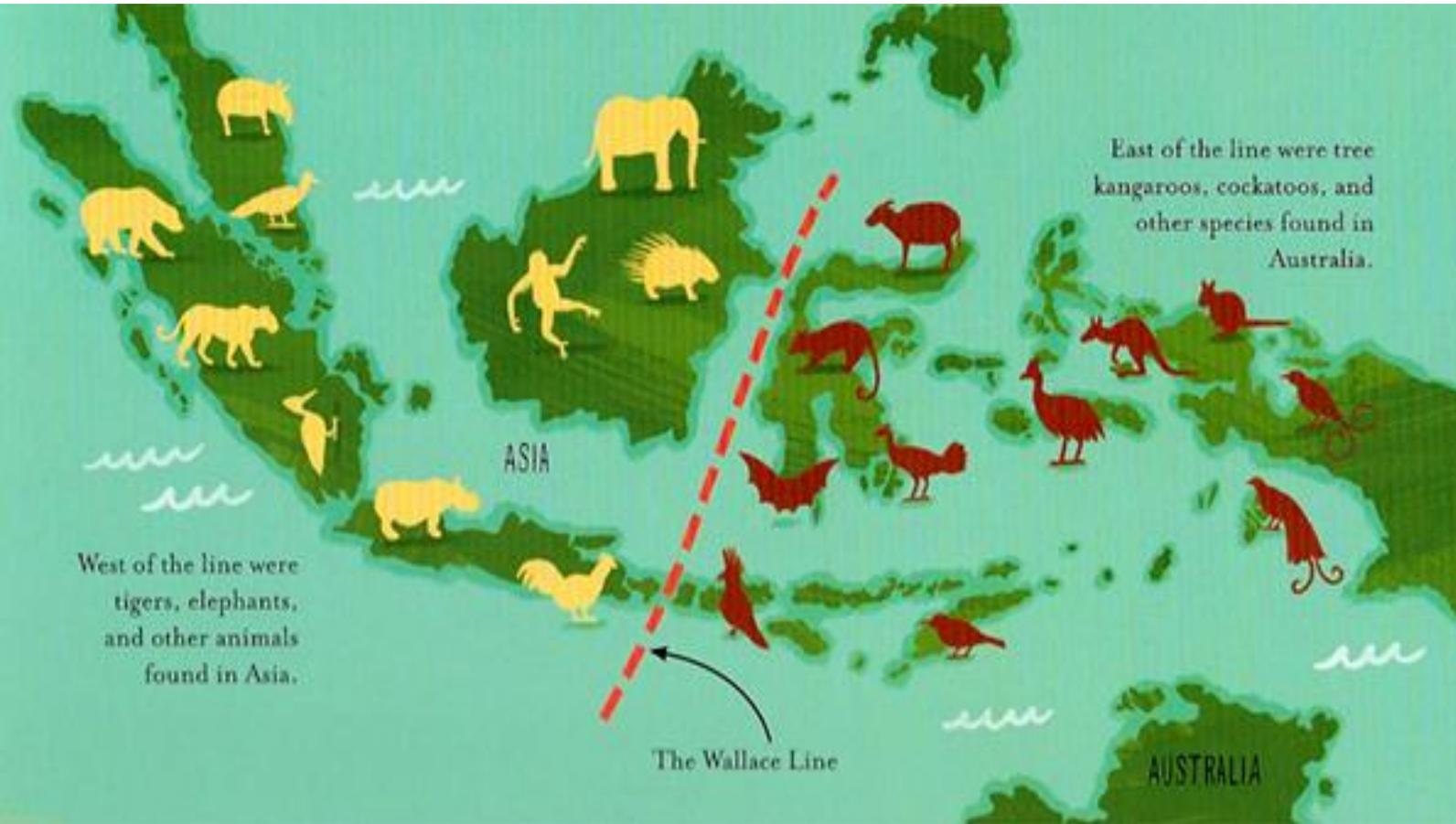
The origin of species, 1859 (1st ed.)

Observations

- Fossils
 - Forms **tend to appear continuously** for a certain interval of time (*strata*) and then disappear to never come back
 - **Recently extinct species are more similar to extant forms** (especially from the same area)



Biogeography gave the same ideas to Wallace almost at the same time

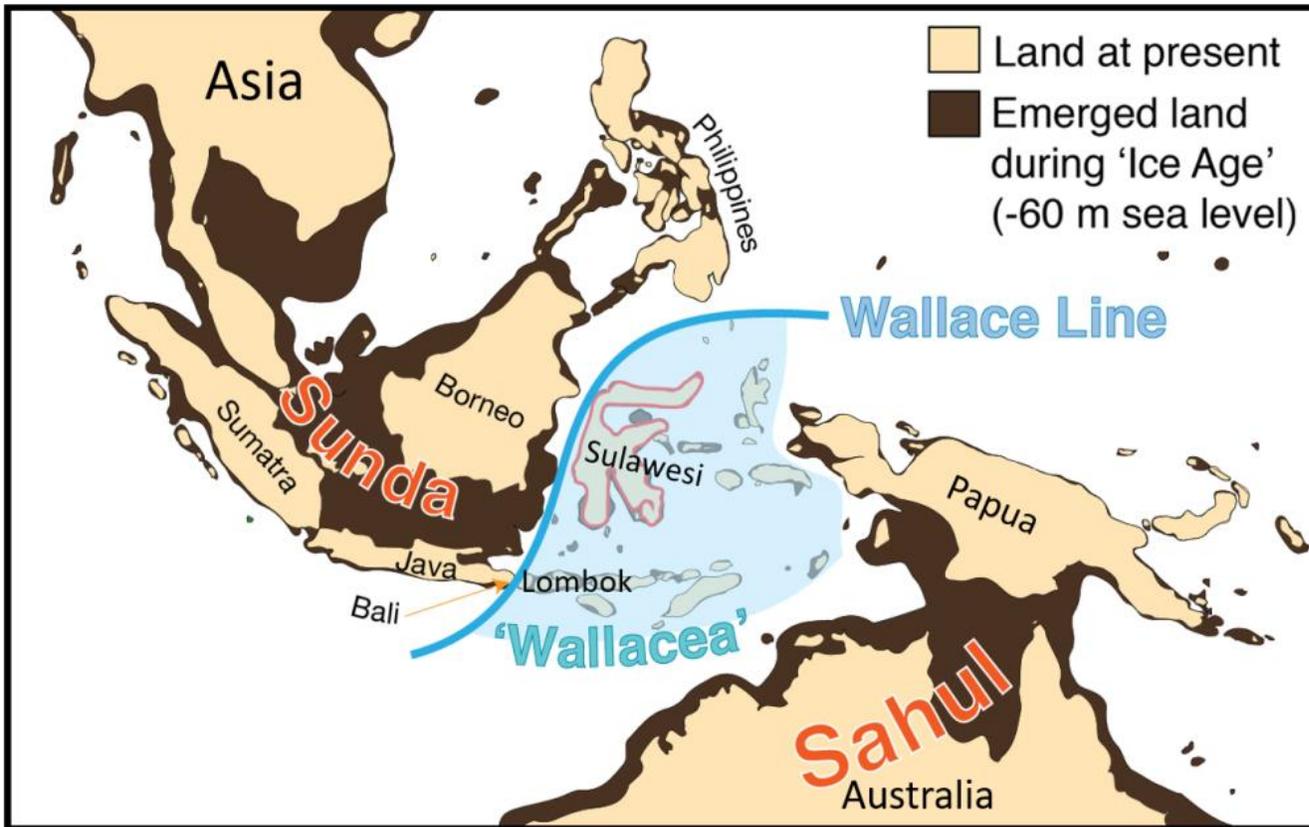


DARWIN-WALLACE MEDAL.
1st July, 1908.

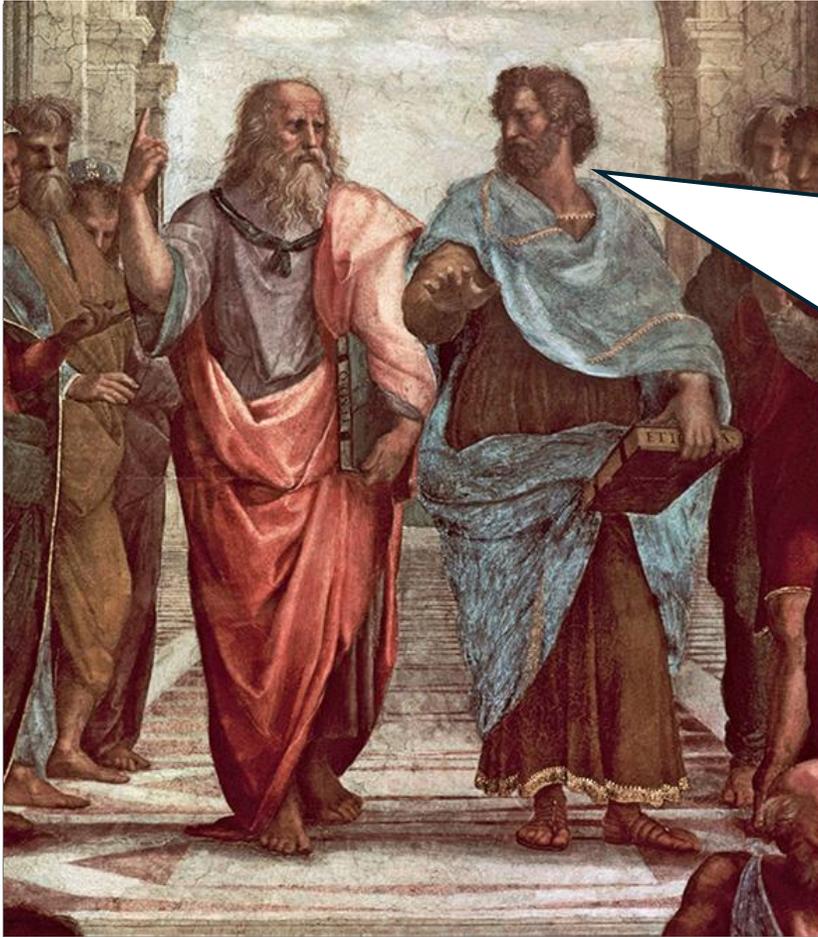
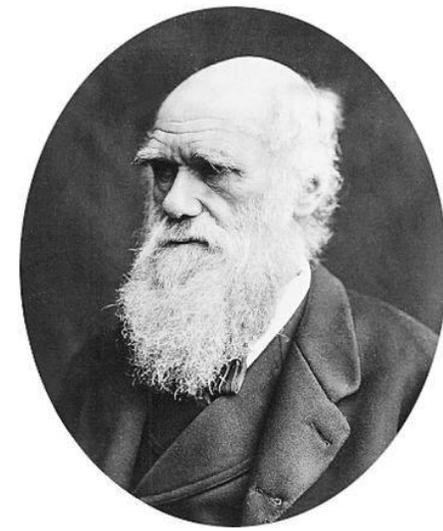
Biogeography of the Malay archipelago

Alfred Wallace (1823-1913)

Biogeography gave the same ideas to Wallace almost at the same time



The origin of species, 1859 (1st ed.)



Aristotles
(384-322 BC)

OK, let's say you convinced me that species are not fixed. But what is the **mechanism**? How can they acquire their «essence»?

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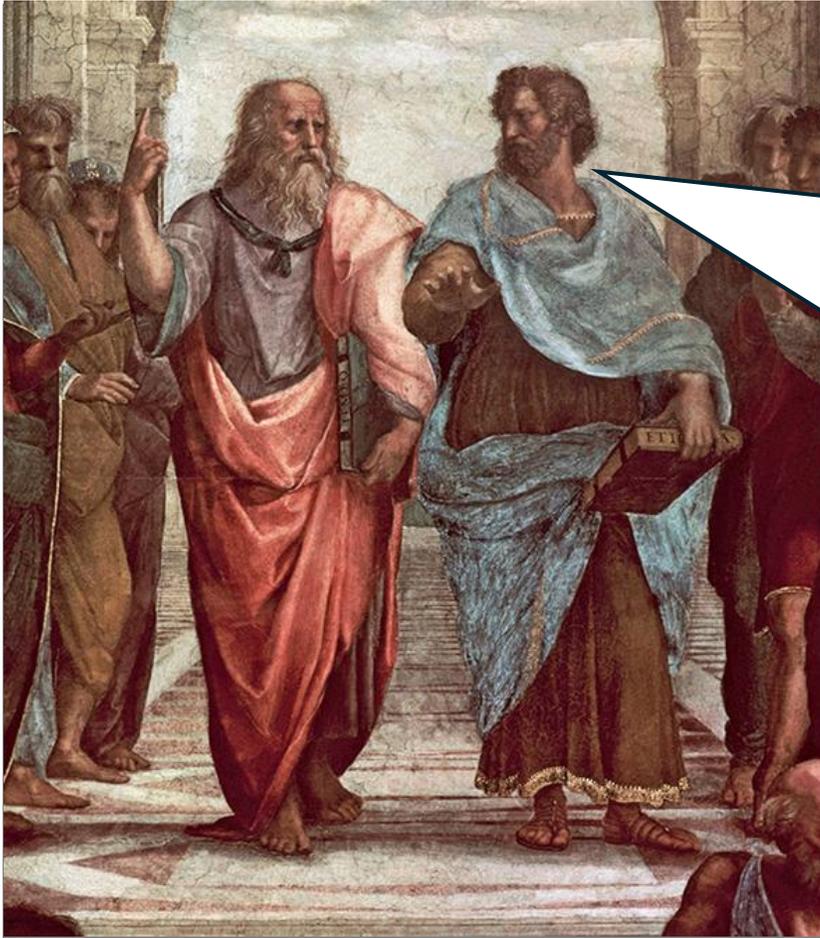
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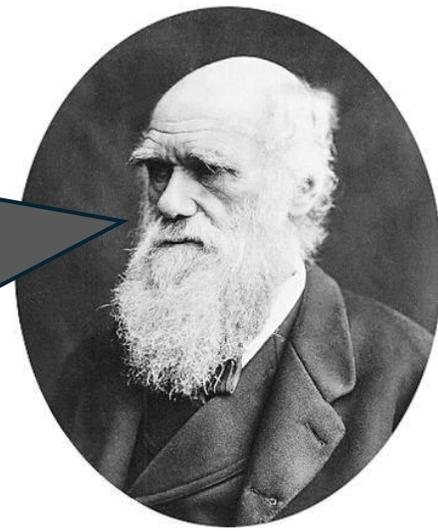
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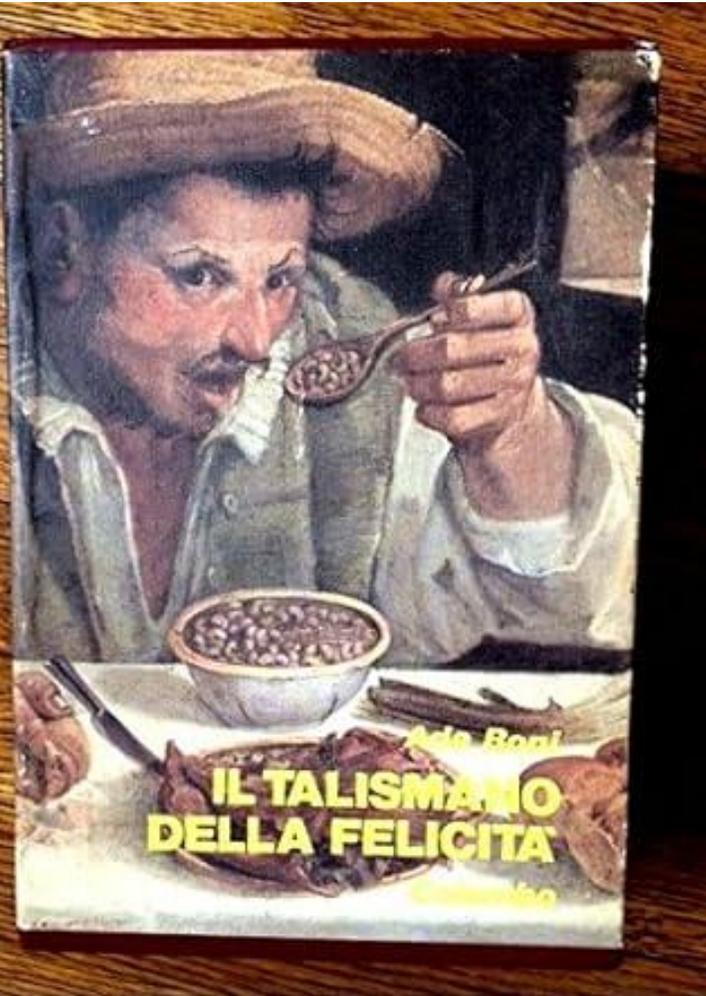
OK, let's say you convinced me that species are not fixed. But what is the **mechanism**? How can they acquire their «essence»?

Oh come on, now Aristotle!! Help me guys, what are the fundamental ingredients of Natural Selection?



What are the basic ingredients of natural selection?

In other words, what do we need to make it work?



«A Recipe for Natural Selection»

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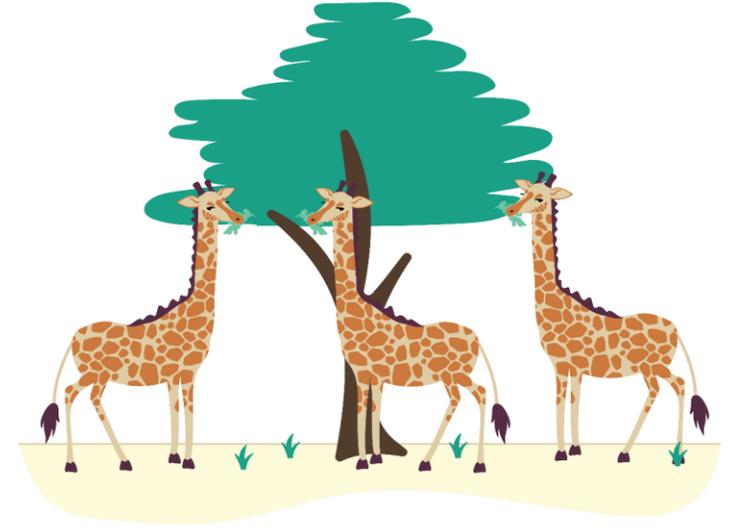
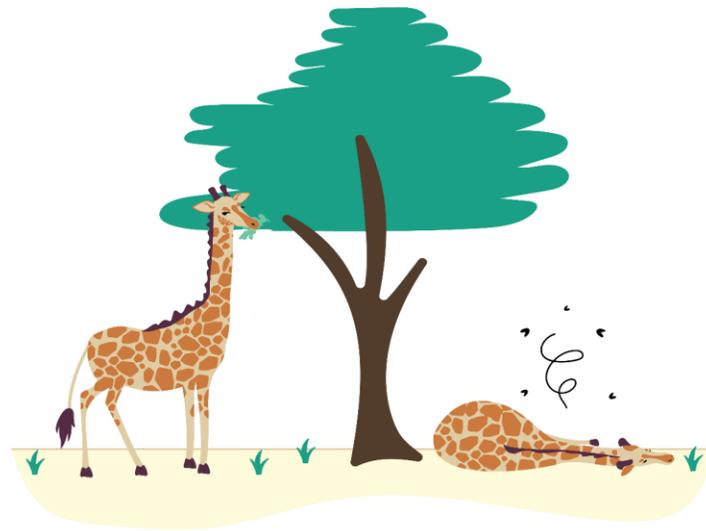
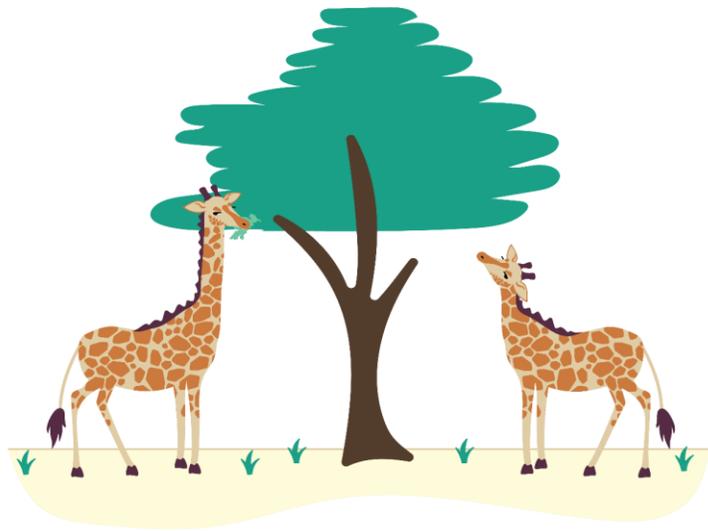
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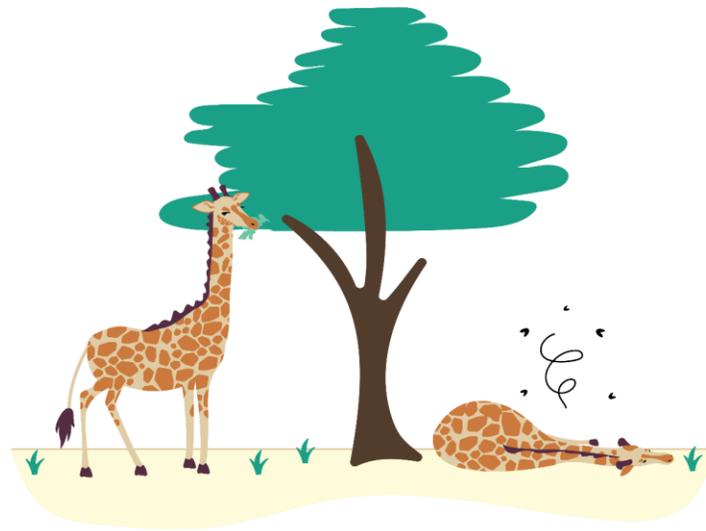
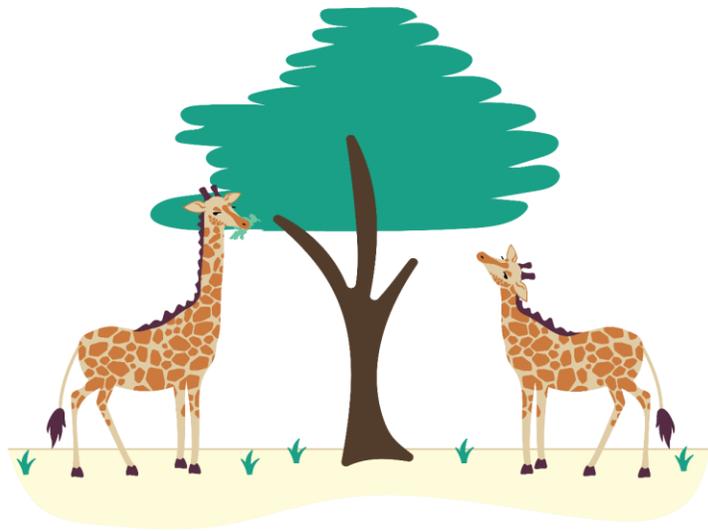
- Differential contribution to successive generations
 - Higher survival
 - Higher reproduction
 - ...



What are the basic ingredients of natural selection?

In other words, what do we need to make it work?

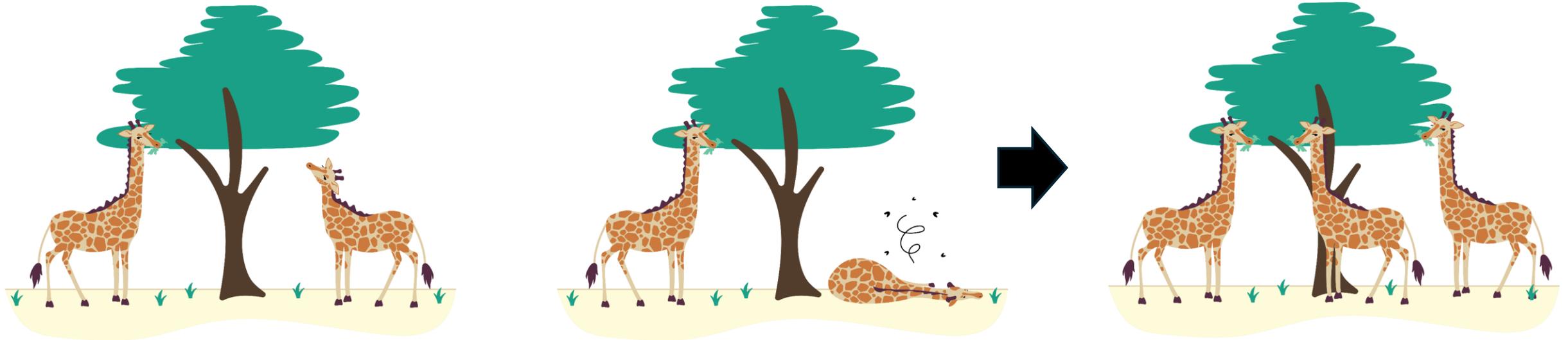
- Variability among individuals
- Differential contribution to successive generations



What are the basic ingredients of natural selection?

In other words, what do we need to make it work?

- Variability among individuals
- Differential contribution to successive generations
- Mechanism of inheritance



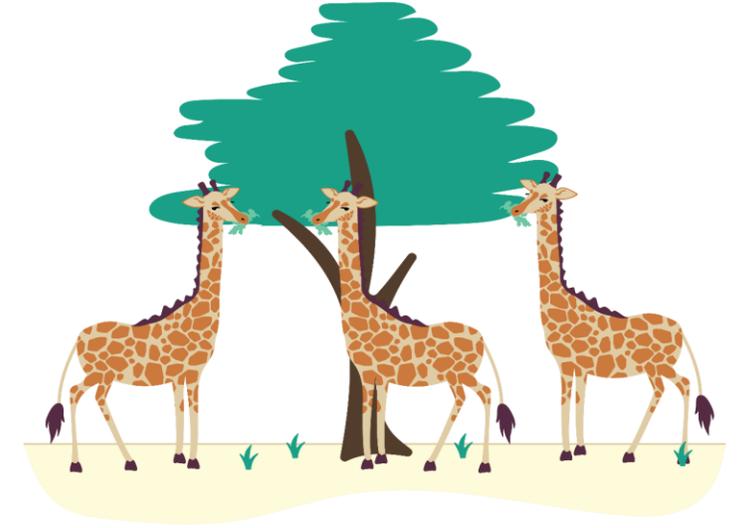
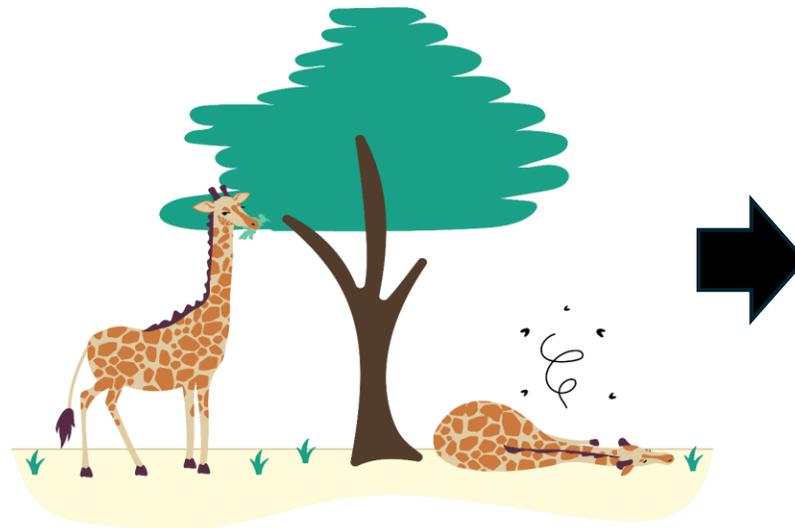
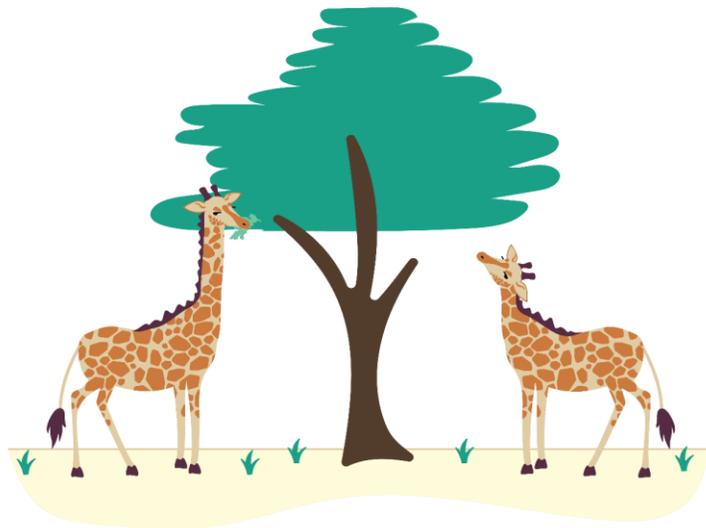
We would like to ask:

*Are **variability**, **genetic inheritance** and **differential contribution** all the ingredients for evolution?*

Are they sufficient?

Are they strictly necessary?

What are their implications?



Was Darwin's theory correct?

What are its predictions?

When does it work and when not?