History And the Pattern of Evolution

Basics in Evolution - April 17, 2023

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A Brief History of Evolutionary Theory

- Pre-Darwinian ideas
- Darwin and Wallace
- Modern Synthesis
- The Extended Synthesis
- The Neutral Theory of Molecular Evolution
- Mutation-Driven Evolution

Pre-Darwinian ideas

- Ancient
- George Louis Leclerc, Comte de Buffon (1707 - 1788)
- Erasmus Darwin (1731 - 1802)
- Jean Baptiste de Monet Lamarck (1744 - 1829)
- *Essay on Population* by T. R. Malthus (1766 - 1834)

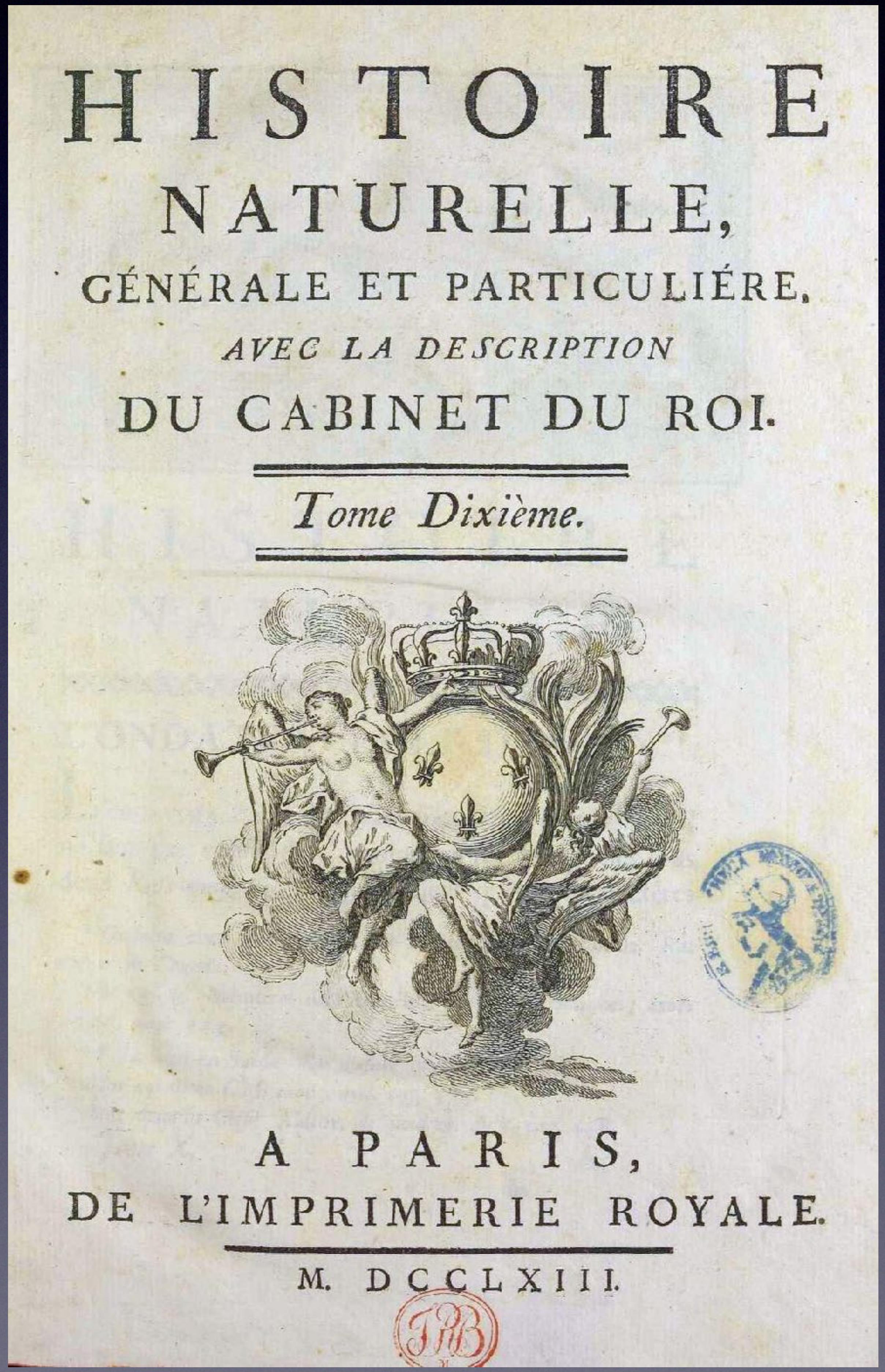
Ancient

- *Vitalists* versus *Mechanists*
    - In modern terms - can life be reduced to information?
- Anaximander (610 - 546 b.c.)
- Empedocles (493 - 433 b.c.)
- Aristotle (384 - 322 b.c)

Raphael: detail from School of Athens

George Louis Leclerc, Comte de Buffon

- Inspired by Newton - all parts and all activities of the world are interrelated
- All classification attempts (e.g. Linnaeus) are artificial abstractions
- Spermatozoa and similar bodies are units out of which individuals could be built
- Species change in type from time to time, but retain marks of previous type, e.g. disused toes in pigs
- Some species are degenerate forms of others. For instance the ape is a degraded form of man. the ass is degraded horse

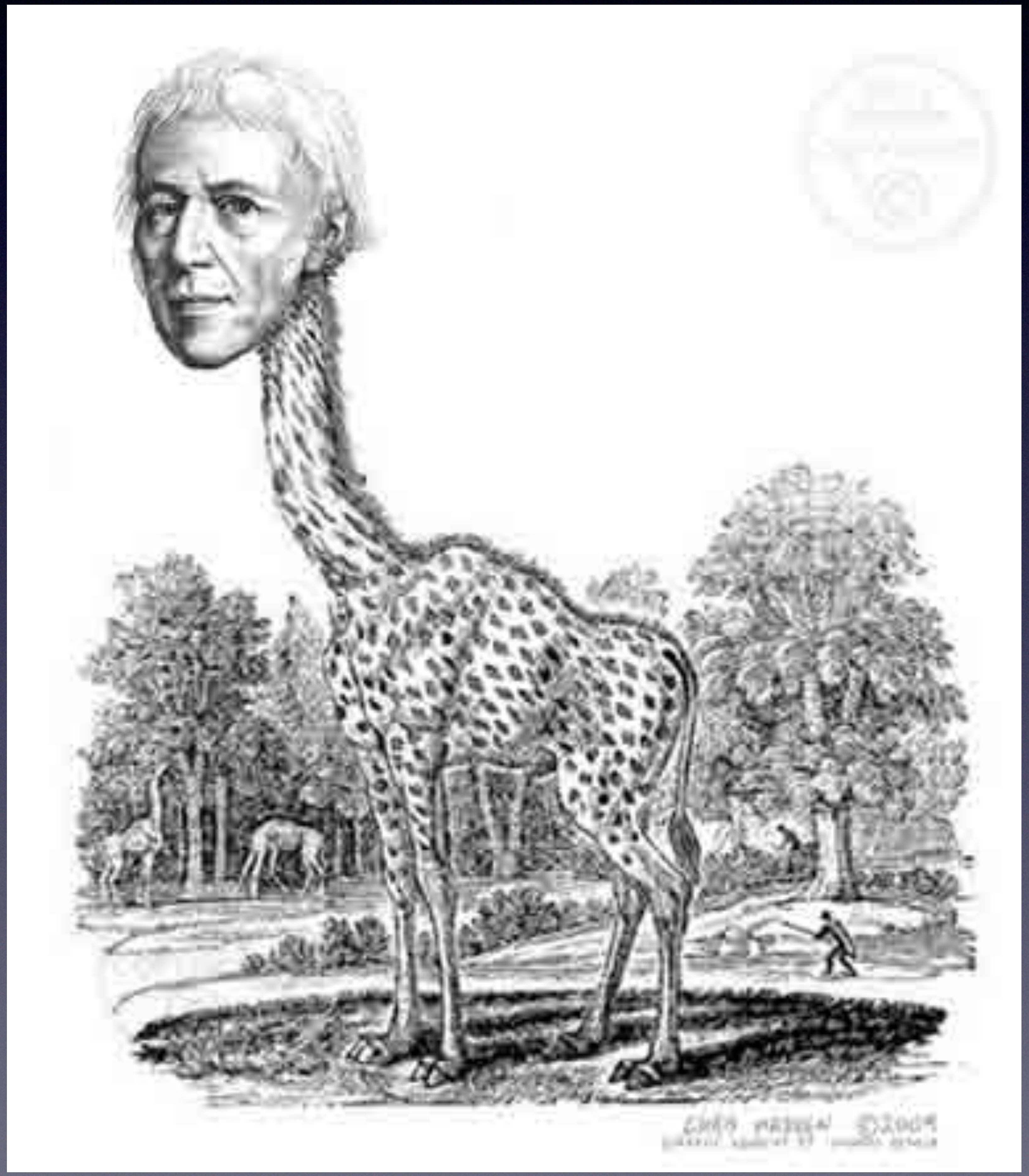

HISTOIRE
NATURELLE,
GÉNÉRALE ET PARTICULIÉRE,
AVEC LA DESCRIPTION
DU CABINET DU ROI.
Tome Dixième.
A PARIS,
DE L'IMPRIMERIE ROYALE.
M. DCCLXIII.

Erasmus Darwin

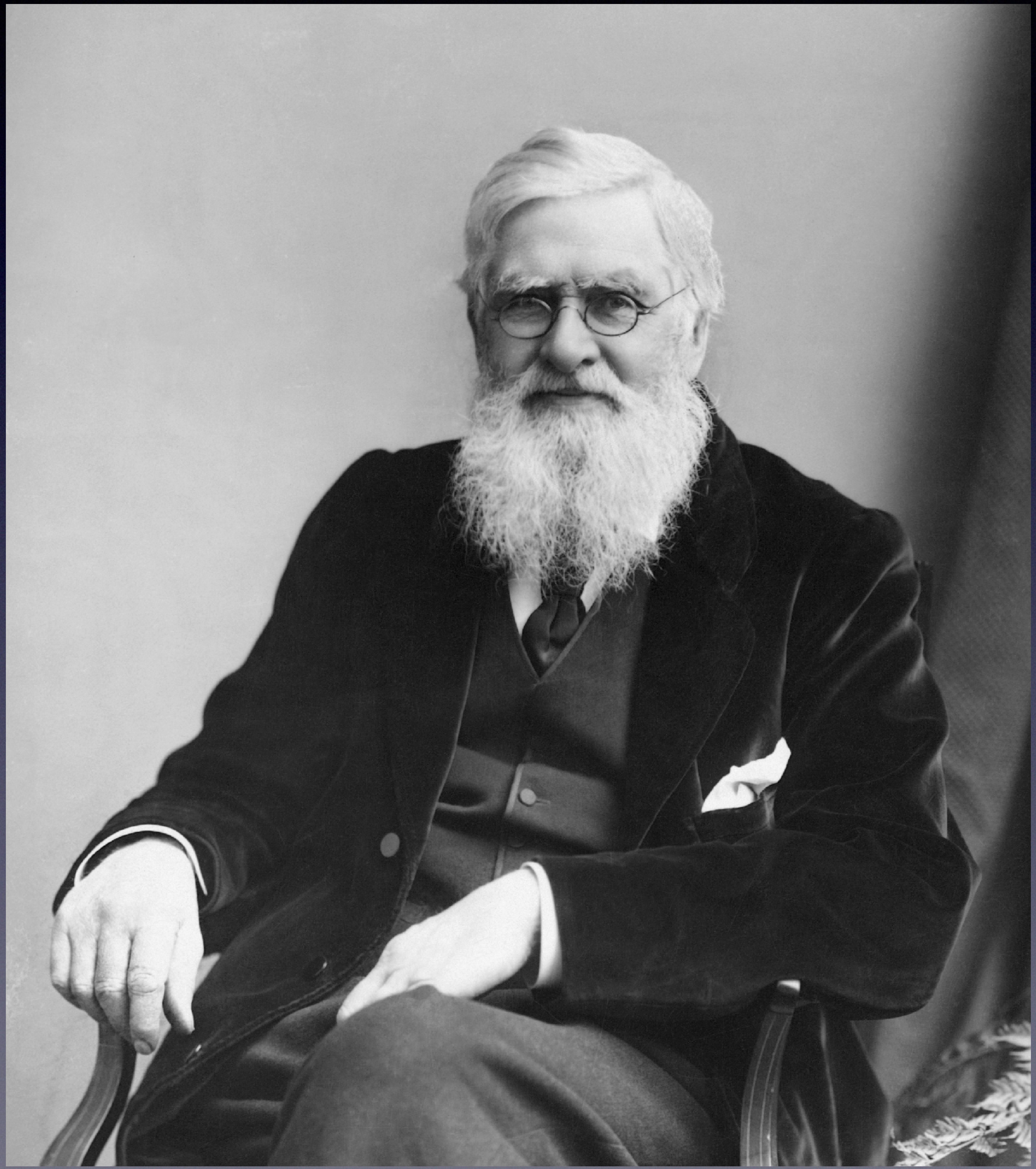
- "From the mouse and bat to the elephant and whale; one has to led to conclude that they have alike been produced from a similar living filaments."
- Changes are caused by environment and passed on to the offspring - *inheritance of acquired characters.*

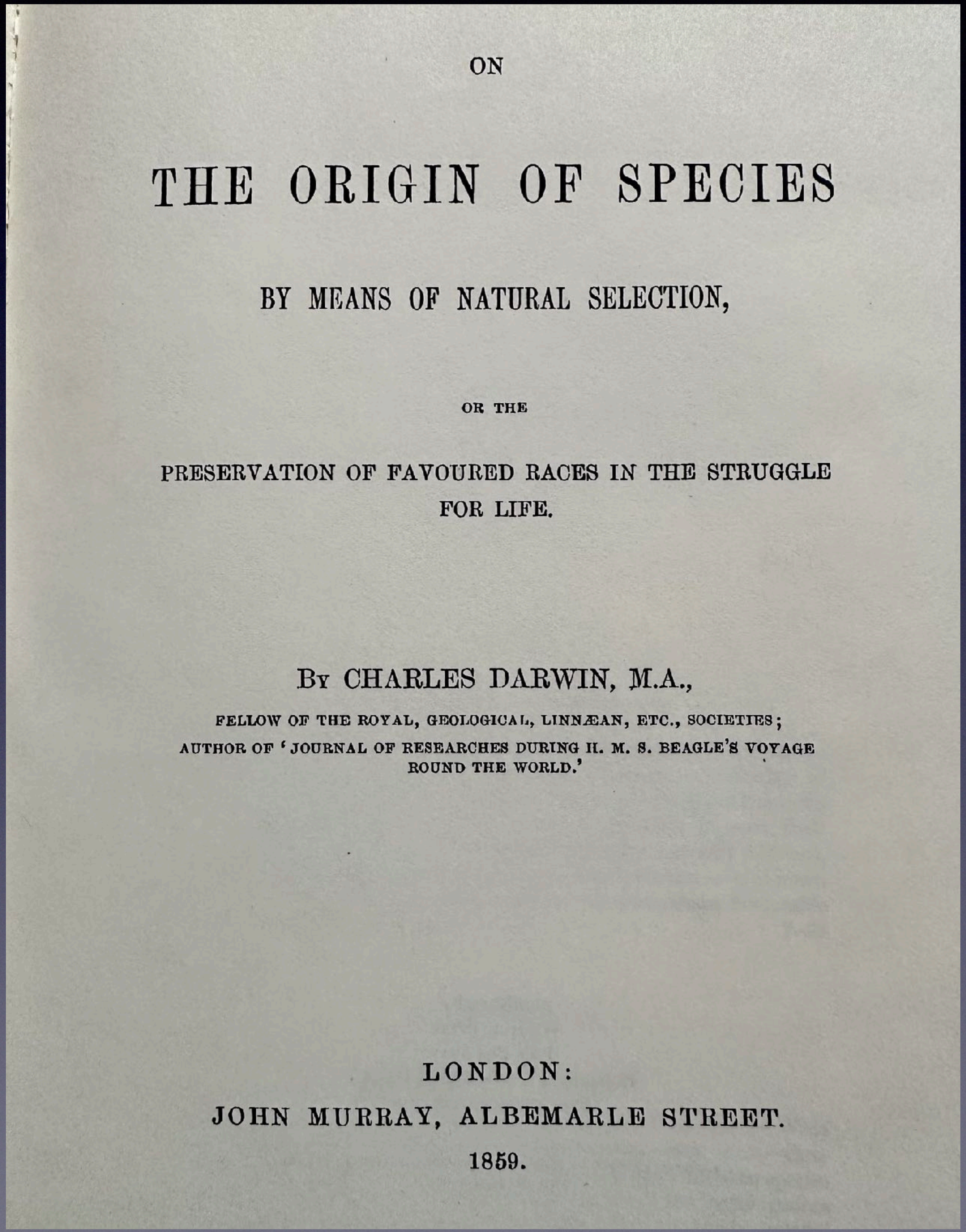
Jean Baptiste de Monet Lamarck

- Species vary under changing external influences
- There is a fundamental unity underlying the diversity of species
- Species are subject to a progressive development
- “Law of use and disuse” - inheritance of acquired characters (deer-like animal -> giraffe; eyes of animals living in darkness)



Charles Darwin and Alfred Russel Wallace





ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

BY CHARLES DARWIN, M.A.,

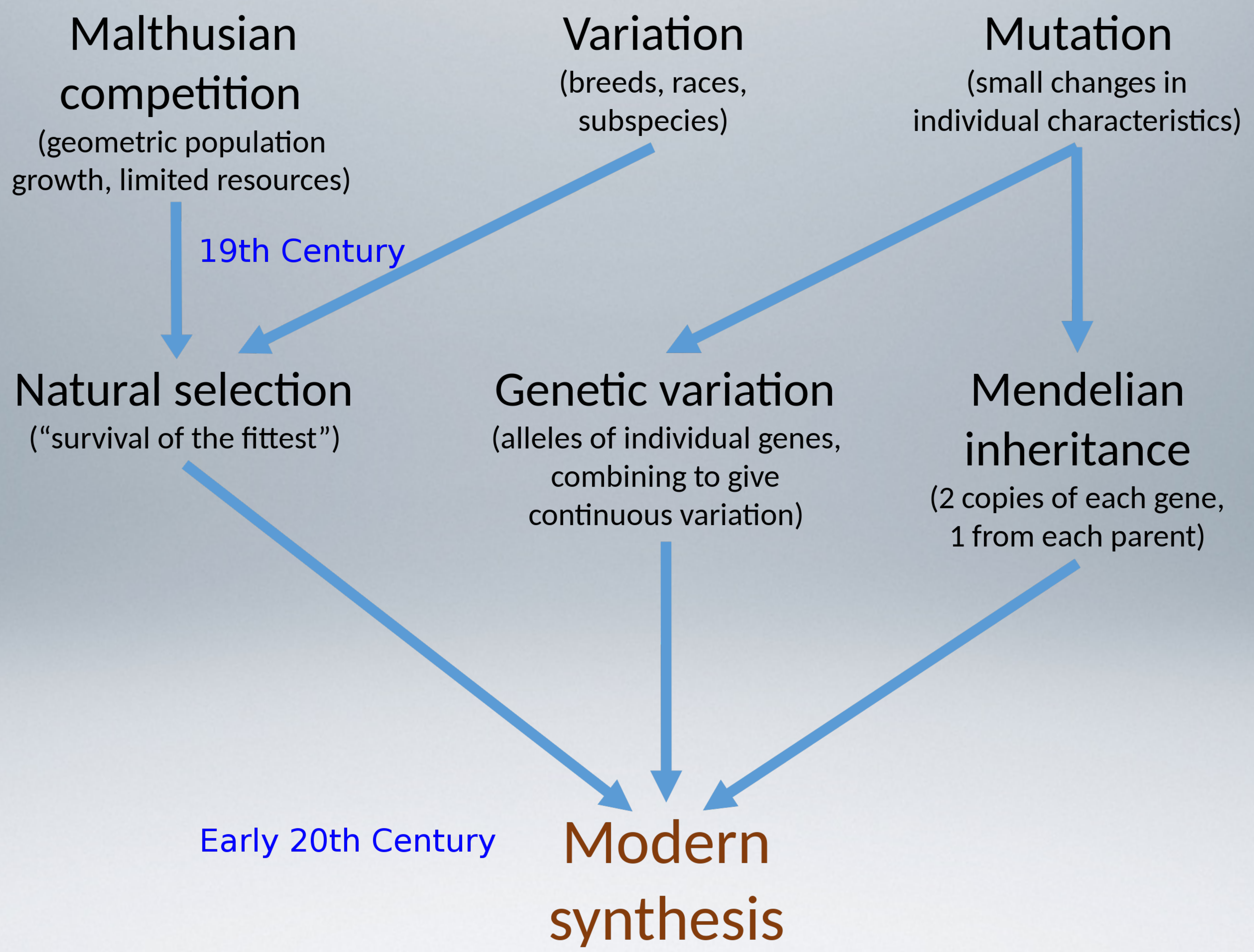
FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

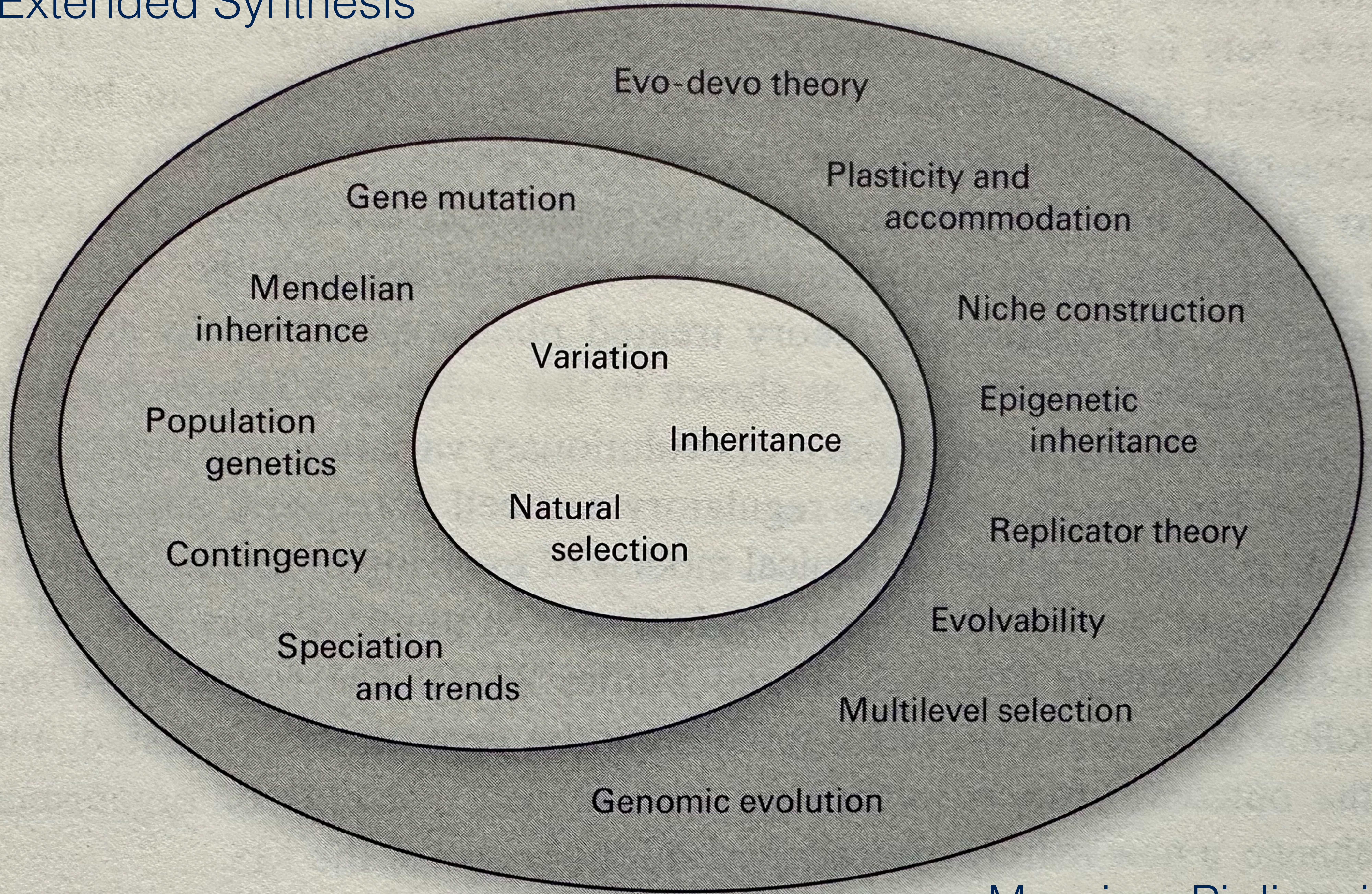
The essence of Darwinian Theory

- Most natural populations contain a large amount of variation on which natural selection can act
- Phenotypic variation is continues rather than discontinuous
- Not clear what causes this variation (use and disuse of characters, climate change, random changes)
- Evolution occurs gradually by means of natural selection
- Accumulation of the results of natural selection gradually increases interpopulational differences and eventually generates new species
- All organisms on earth were derived from a single proton-organism
- The similar organisms currently observed in different parts of the world have been generated by recent migration
- The discontinuity of paleontological data does not indicate that evolution occurred discontinuously but that the fossil record in incomplete

After: Nei M. (2013) Mutation-Driven Evolution


Malthusian competition
(geometric population growth, limited resources)
Variation
(breeds, races, subspecies)
Mutation
(small changes in individual characteristics)
19th Century
Natural selection
("survival of the fittest")
Genetic variation
(alleles of individual genes, combining to give continuous variation)
Mendelian inheritance
(2 copies of each gene, 1 from each parent)
Early 20th Century
Modern synthesis

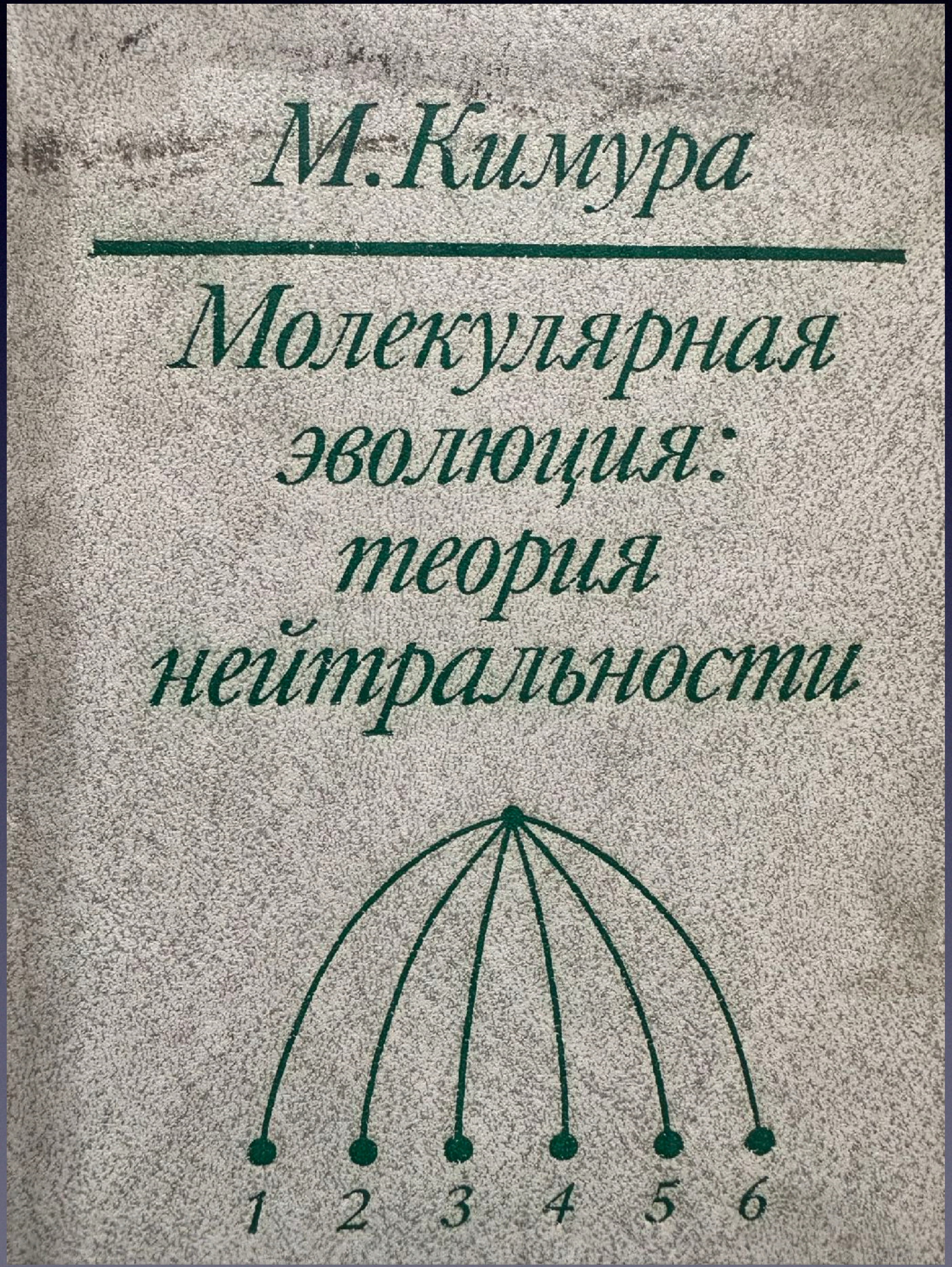
Extended Synthesis



Massimo Pigliucci

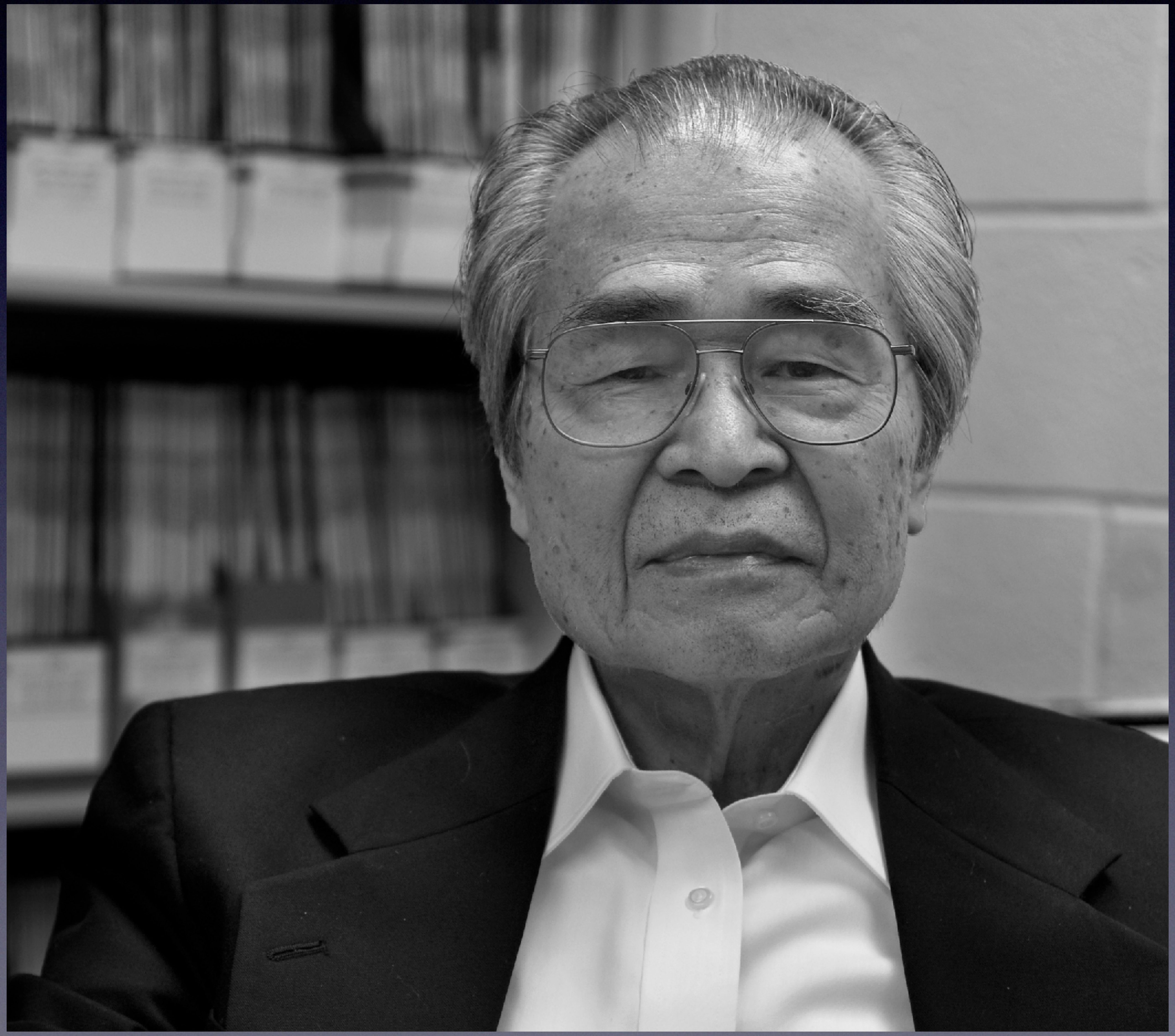
The Neutral Theory of Molecular Evolution

- The rate of evolution is constant as long as function of the protein is not altered
- Functionally less important molecules evolve faster
- Conservative substitutions occur more frequently then more disruptive ones
- Gene duplication must precede the emergence of a gene having a new function
- *Selective elimination of deleterious mutants and random fixation of selectively neutral or near neutral mutants occur far more frequently the positive Darwinian selection*



Mutation-Driven Evolution

- Mutation is a driving force of evolution while selection is a secondary factor
- Both molecular and phenotypic evolution are mostly governed by neutral processes
- The survival of niche-filling variants

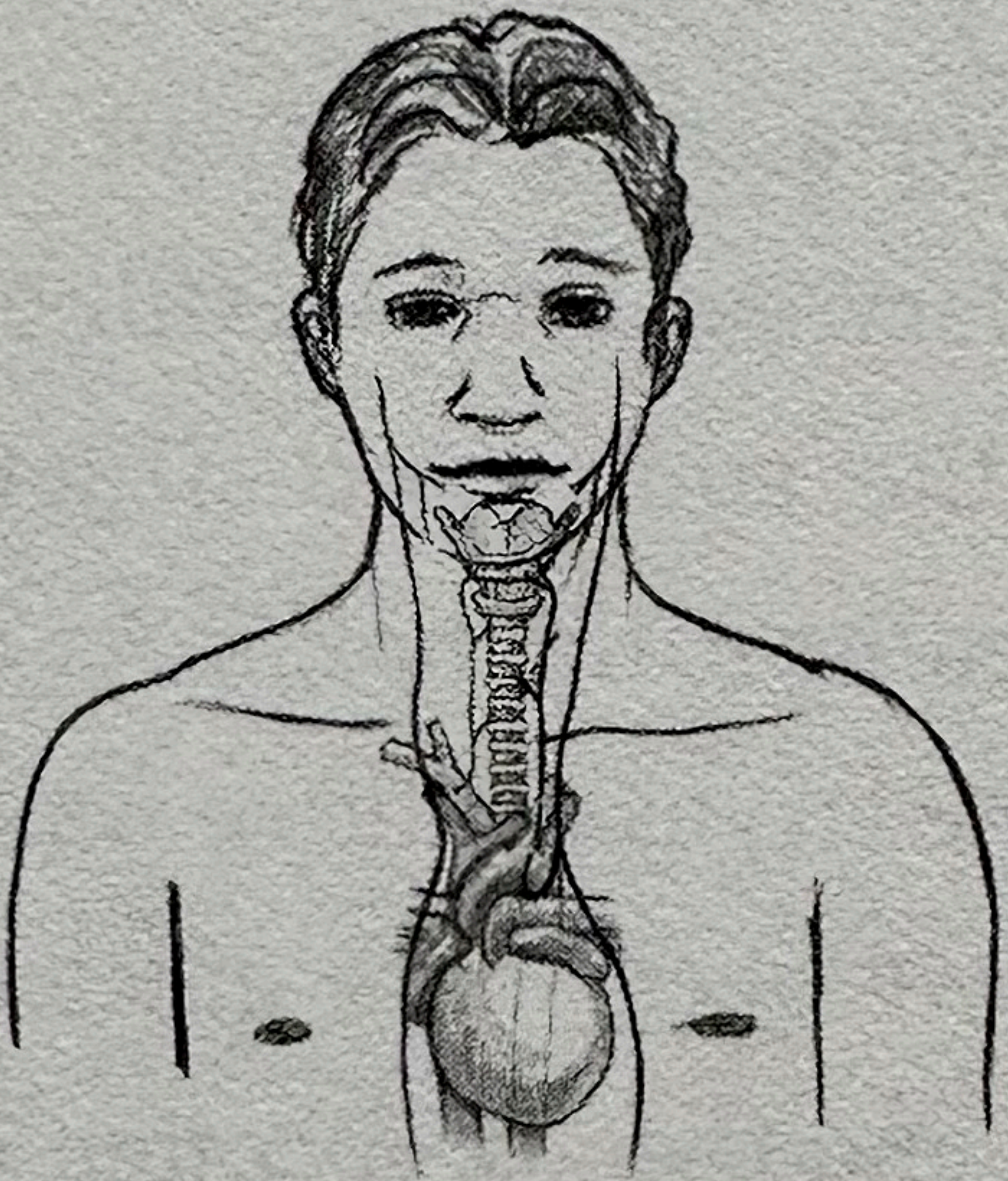


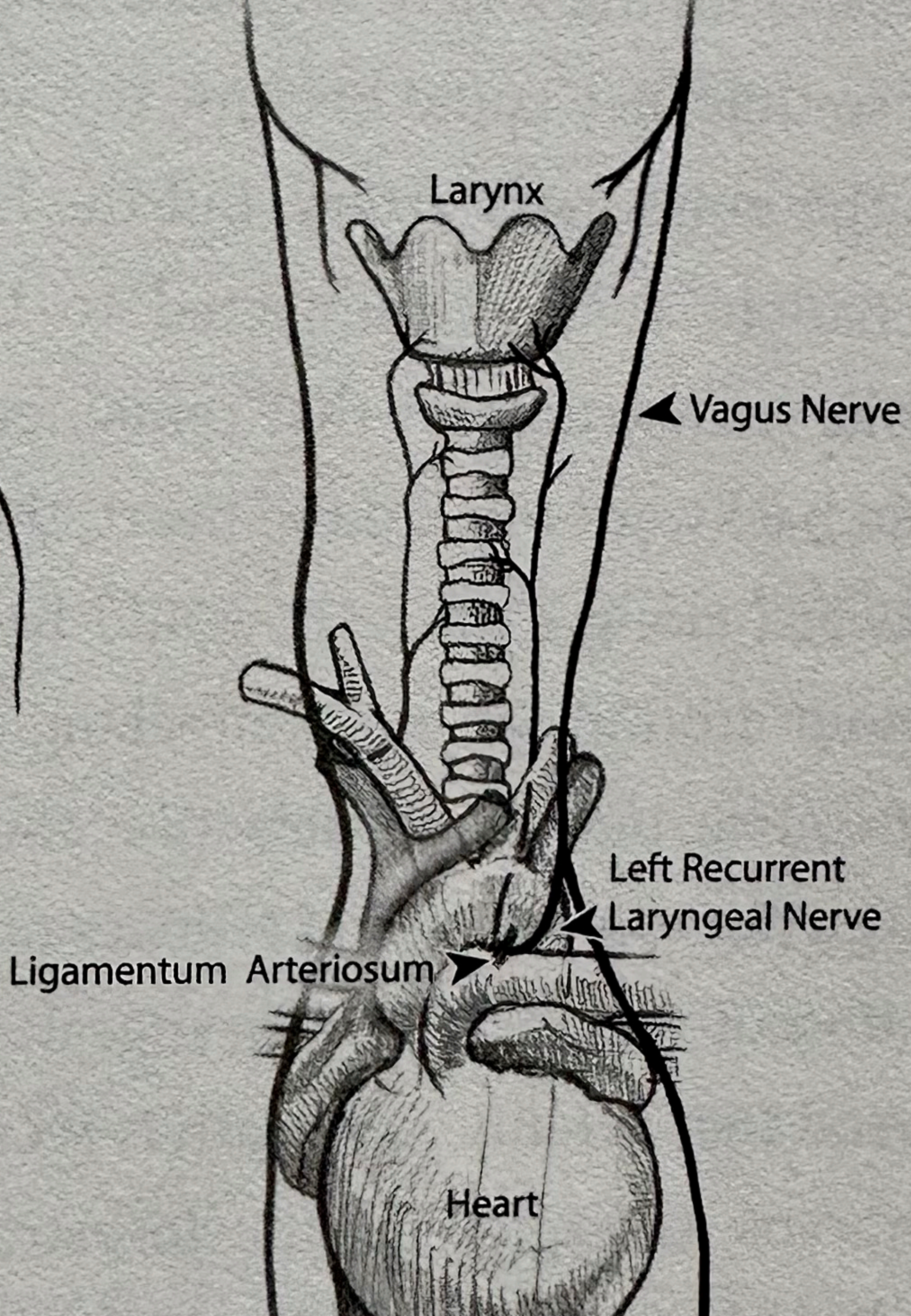
The Pattern of Evolution

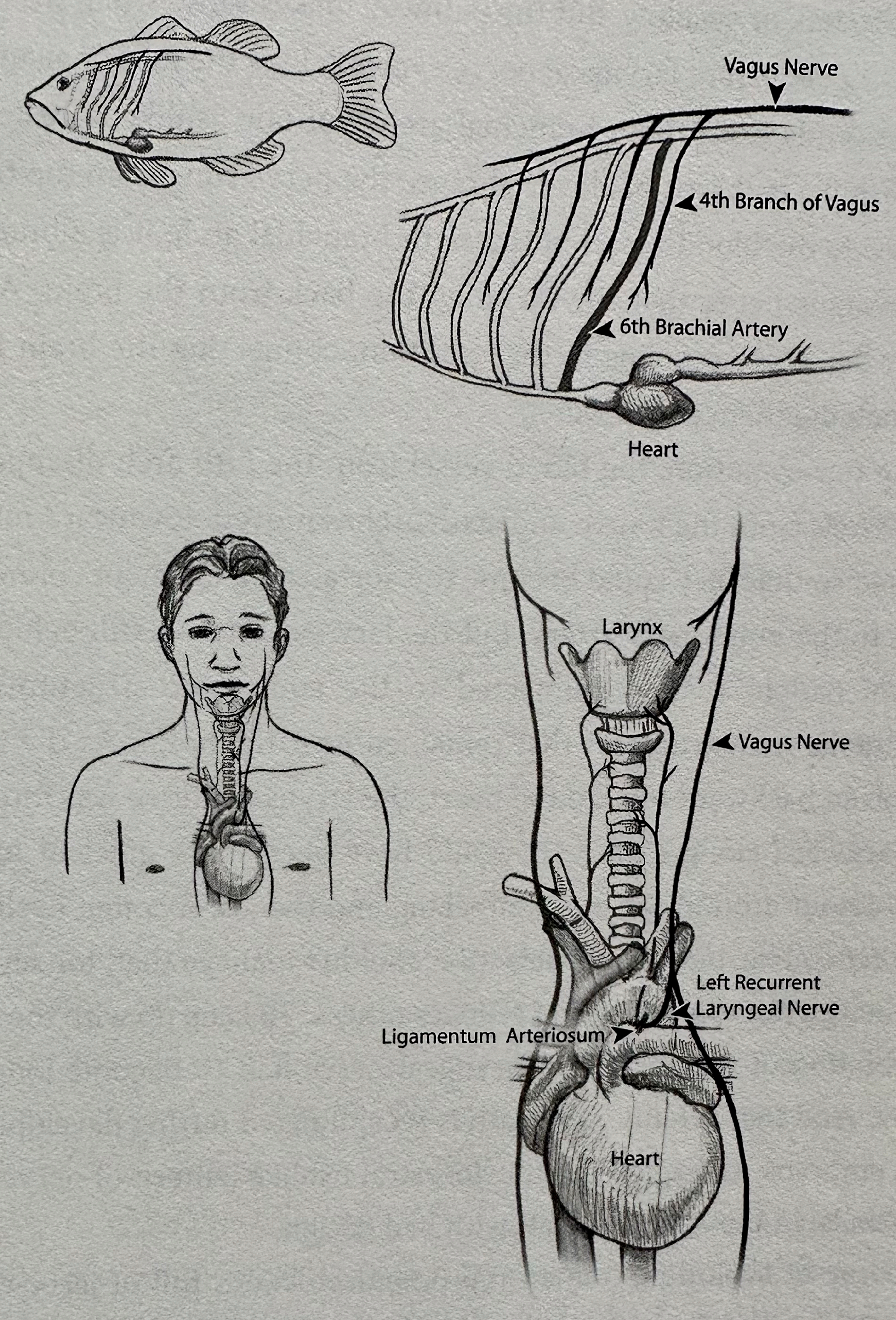

Microevolution

Microevolution

- selective breading
- natural populations
- vestigial structures
- directed evolution experiments

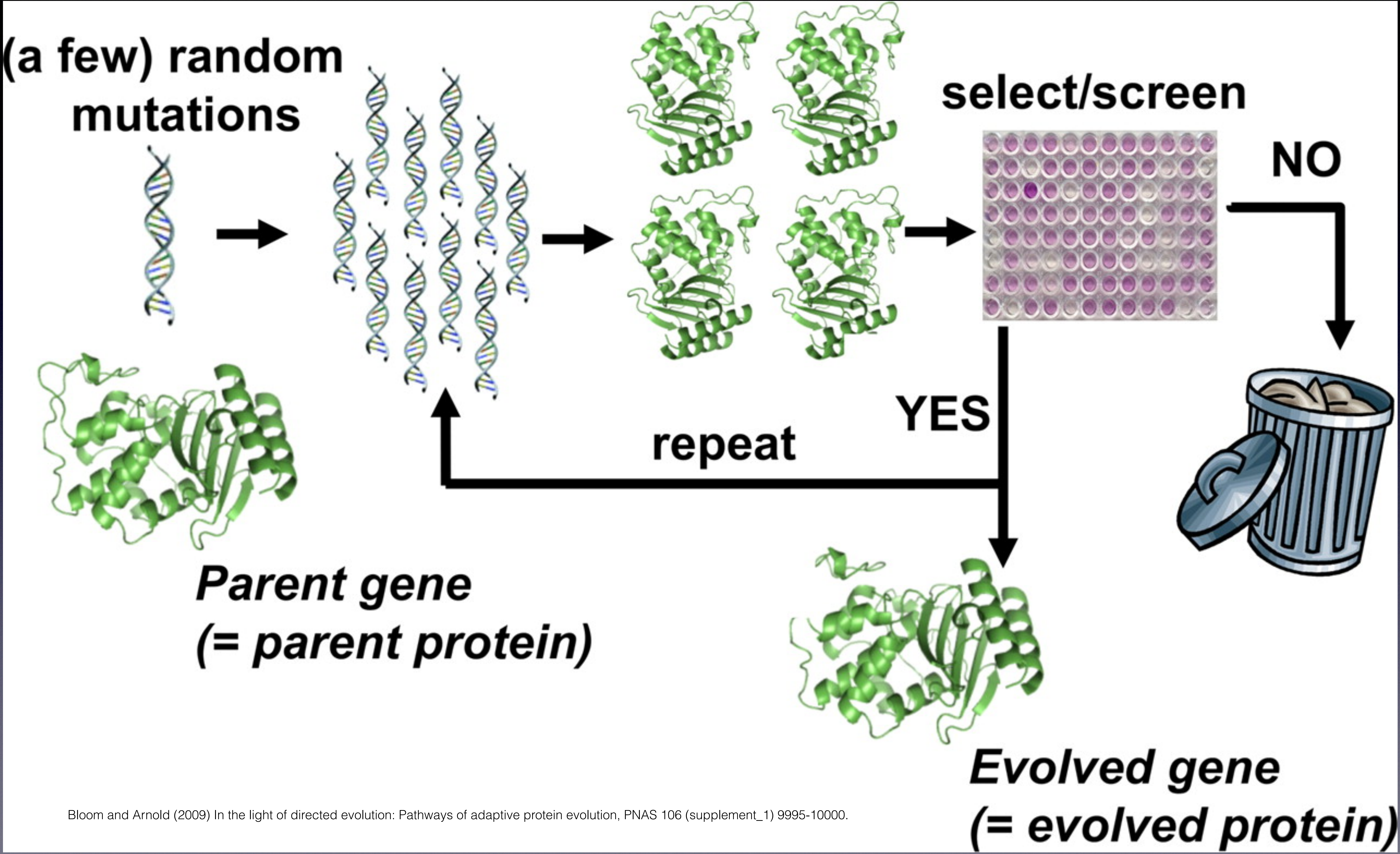



Larynx
Vagus Nerve
Left Recurrent
Laryngeal Nerve
Ligamentum Arteriosum
Heart



The circuitous path of the left recurrent laryngeal nerve in humans is evidence for their evolution from a fishlike ancestor.

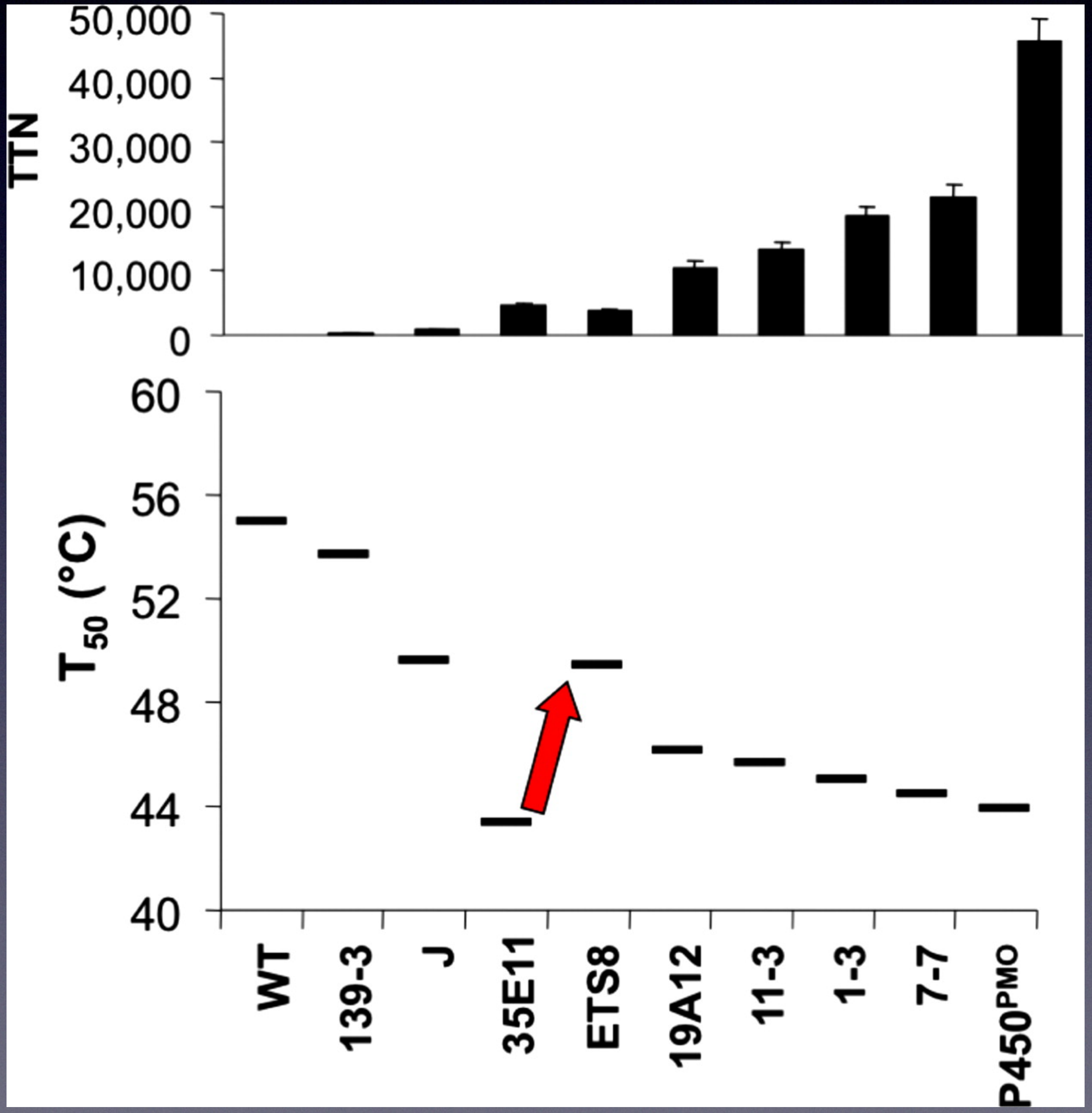
Coyne, Jerry A. Why Evolution Is True (p. 83).



Bloom and Arnold (2009) In the light of directed evolution: Pathways of adaptive protein evolution, PNAS 106 (supplement_1) 9995-10000.

Converting a Cytochrome P450 Fatty Acid Hydroxylase into a Propane Hydroxylase

- Wild-type P450 BM3 has only weak activity on long-chain alkanes
- Iterative rounds of random mutagenesis, recombination of beneficial mutations, and screening for activity on successively smaller alkanes led to the creation of P450 PMO
- This enzyme contains 23 amino acid substitutions relative to its wild-type ancestor
- At one point during the evolution, however, no further improvements in activity on propane were found



Evidence of Speciation

New Lineages from Old

Speciation As a Gradual Process

- The mosquito was introduced to the London Underground during its construction around 1900.
- It became infamous in the War for attacking people sheltering from the Blitz.
- Studies indicate several genetic differences from its above-ground ancestors. Interbreeding between populations is difficult suggesting that speciation may be occurring.

Macroevolution

- Extinction and succession
- Transitional forms
  - Pacific leaping blenny https://www.youtube.com/watch?v=KDE0ZSjP0_A

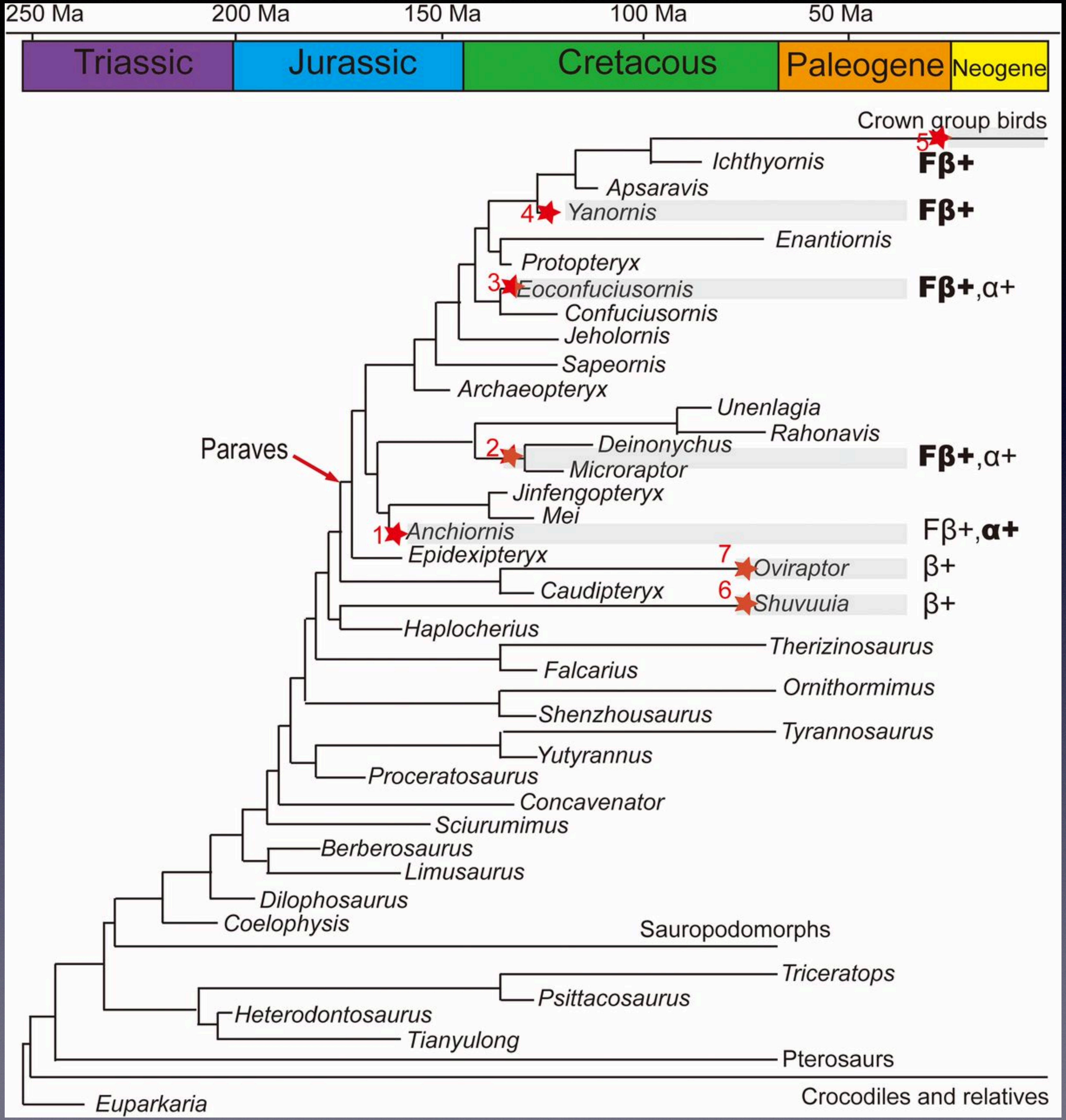
Sinosauropteryx

https://www.youtube.com/watch?v=gh9IysJ74Ng

Similicaudipteryx

https://www.youtube.com/watch?v=gh9IysJ74Ng

Source: http://www.wikidino.com/?page_id=1207

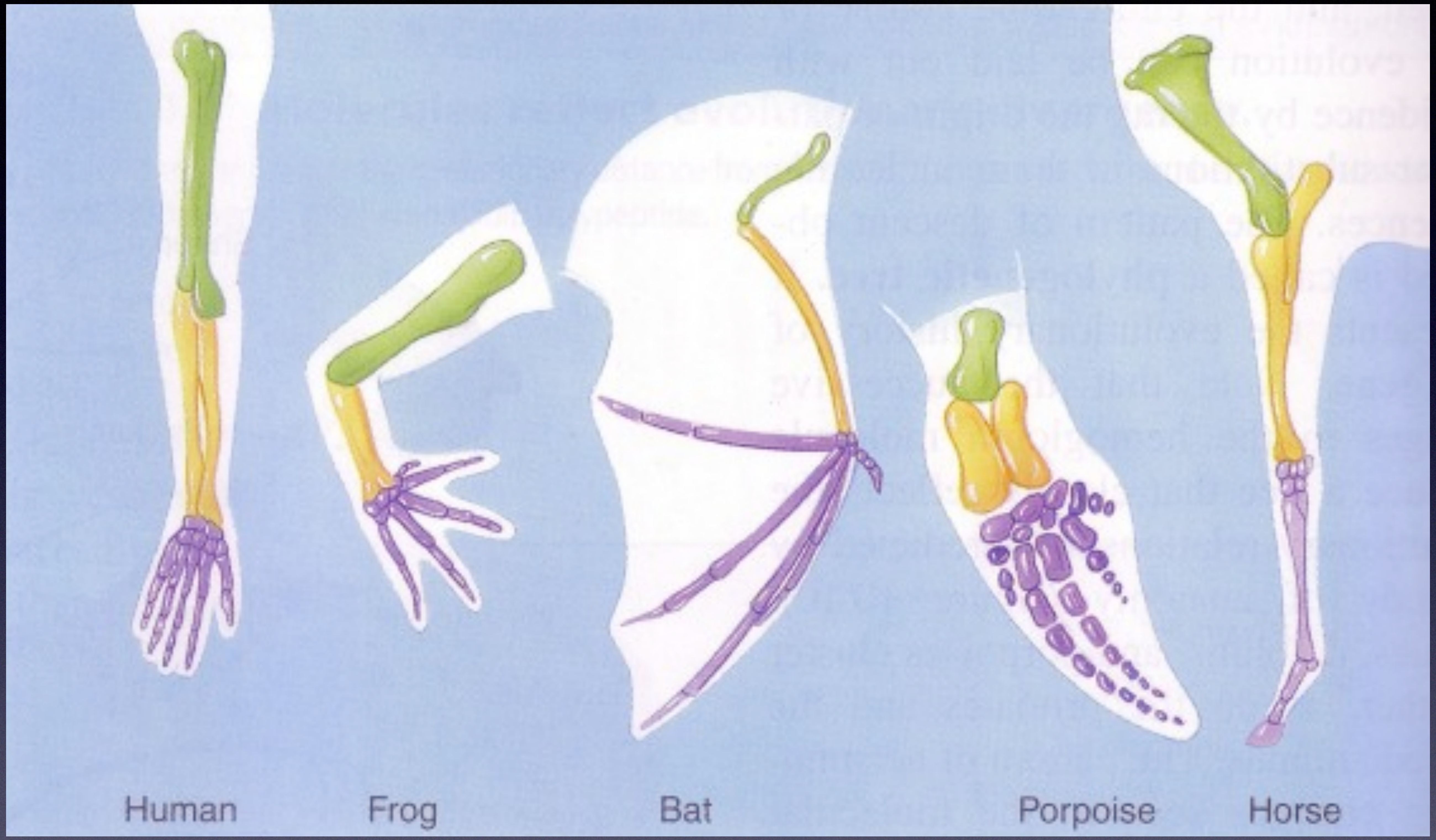


Time-scaled evolution of molecular composition and ultrastructure of feathers within a simplified Mesozoic avian and nonavian phylogeny (38), suggesting that the Anchiornis feather were composed of both feather β-keratins and α-keratins, but dominated by α-keratins, unlike feathers from younger fossils and mature feathers of extant birds, which are dominated by β-keratins. Filled stars showing the distribution of tested fossil feathers and related integumentary tissues used in this study: (1) Anchiornis (STM 0–214), (2) Dromaeosauridae indet. (STM5-12), (3) Eoconfuciusornis (STM7-144), (4) Yanornis (STM9-5), (5) Isolated flight feather (DY 1502006), (6) Shuvuuia deserti (IGM 100/977), and (7) Citipati (MPC-D). β+, positive reaction to the general β-keratin antiserum; Fβ+, positive reaction to the antiserum specific feather β-keratins; α+, positive reaction to the anti-pan cytokeratin antiserum; "Fβ+" in bold, thin β-keratin filaments is dominant in ultrastructure; "α+" in bold, thick α-keratin filaments is dominant in ultrastructure.

Pan et al. (2019) *PNAS*. 116 (8) 3018-3023


Common Ancestry

Homology



Two anatomical structures or behavioral traits within different organisms which originated from a structure or trait of their common ancestral organism. The structures or traits in their current forms may not necessarily perform the same functions in each organism, nor perform the functions it did in the common ancestor. An example: the wing of a bat, the fin of a whale and the arm of a man are homologous structures.

Homologs At The Molecular Level

```
cow       ATG---ACTAACATTCGAAAGTCCCACCCACTAATAAAAATTGTAAAC
sheep     ATG---ATCAACATCCGAAAAACCCACCCACTAATAAAAATTGTAAAC
goat      ATG---ACCAACATCCGAAAGACCCACCCATTAATAAAAATTGTAAAC
horse     ATG---ACAAACATCCGGAAATCTCACCCACTAATTAAAATCATCAAT
donkey    ATG---ACAAACATCCGAAAATCCCACCCGCTAATTAAAATCATCAAT
ostrich   ATGGCCCCCAACATTCGAAAATCGCACCCCCTGCTCAAAATTATCAAC
emu       ATGGCCCCTAACATCCGAAAATCCCACCCTCTACTCAAAATCATCAAC
turkey    ATGGCACCCAATATCCGAAAATCACACCCCCTATTAAAAACAATCAAC
```

Two sequences that share common ancestry. Significant sequence similarity usually suggests homology, however sequence similarity may occur also by chance and some homologous sequences may diverge beyond detectable similarity.

Old Pseudogenes Should Be Shared With Species Of Common Ancestry

TABLE 3

PCR Detection of Pseudogenes in Different Primates

Gene/species	Human	Chimpanzee 8 Myr[b]	Gorilla 9 Myr	Orangutan 16 Myr	Rhesus 25 Myr	Capuchin 36 Myr	Hamster[f] >85 Myr
α-Enolase Ψ_1 11 Myr[c]	+[a]	+	+	−	−	−	−
AS Ψ_7 16 Myr	+	+	−[d]	+	−	−	−
CALM II Ψ_2 19 Myr	+	+	+	+	−	−	−
AS Ψ_1 21 Myr	+	+	+	+	+	−	−
AS Ψ_3 25 Myr[e]	+	+	+	+	+	−	−
CALM II Ψ_3 36 Myr	+	+	+	+	+	+	−

[a] Detection of a single intense band of the appropriately sized fragment upon electrophoresis of the PCR products was positive (+) if present or negative (−) by default.

[b] Divergence times in columns are taken from Li and Tanimura (1987). The human/rodent divergence time is usually taken to be the time of the great mammalian radiation of 80–85 Myr ago (Li, 1997).

[c] Calculated divergence times are from Table 2.

[d] Both low- and high-stringency conditions failed to detect the pseudogene. Additional primer sets may be required.

[e] Two primer sets were required for the detection of this pseudogene; primers employed high- (AS Ψ_3, 670-bp amplicon) or low- (AS Ψ_3, 429-bp amplicon) stringency PCR conditions as described under Materials and Methods.

Mol Phylogenet Evol. 2000 Jul;16(1):127-30. doi: 10.1006/mpev.2000.0784.