The history of Evolutionary Biology

The beginning of evolutionary biology as a scientific discipline is the publication of Darwin's „The Origin of Species" on 1859.
What was happening before that?
The prerequisite for the birth of Evolution as a field of science is the understanding of the **changeability of species**. This concept is usually not understood in the indigenous cultures. Why?

Indigenous people see and remember nature usually in a relatively small region around their habitat. The species that are used by people are not changing within the 'human time' span. Species that are changing so fast are too small and thus invisible to the human eye. Neither is the geographical spread of the species is known (fox, fennec fox, Arctic fox). Thus - indigenous people lack the experience referring to the possibility of changeability of the species. Put it more modern way – they lack the data. So the key animals in different creation myths of the world are like those known today (in Estonia – some water birds)

The history of Evolutionary Biology

The beginning of evolutionary biology as a scientific discipline is the publication of Darwin's „The Origin of Species" on 1859.
What was happening before that?

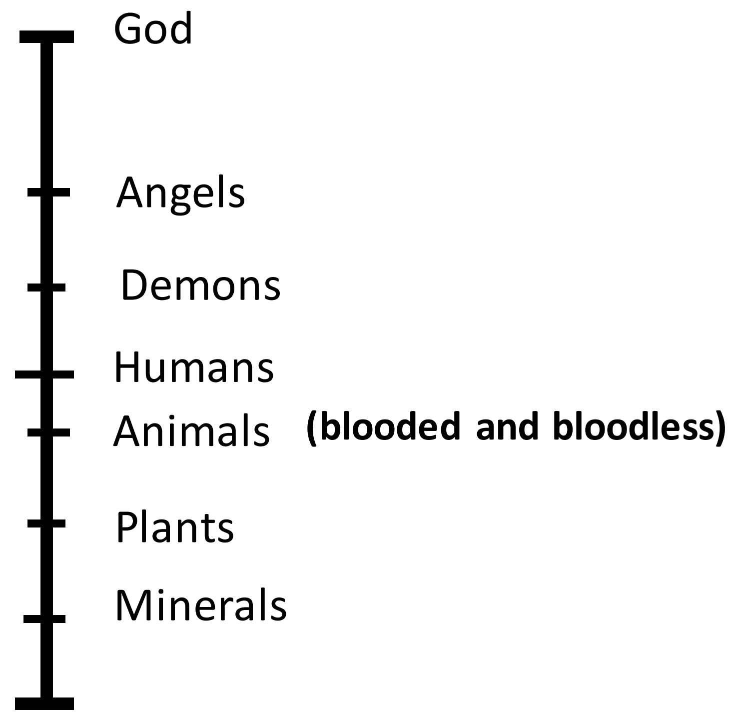
Changeability of species did also not fit into the world concepts of Middle Ages which stem from Ancient Greece and greatly influenced by Aristotele (*Aristotélēs*; 384–322 BC).

Though, there were philosophers and scientists also in Ancient Greece who disserted the topic of changeability of species, but later their ideas were not so popular as those of Plato and Aristotele

The history of Evolutionary Biology: Aristotele

Aristotélēs; 384–322 BC

Platon (~427 - ~347 BC)



Scala Naturae

Fixed Species – the un-changeability of species

Hierarchy of complexity – a ladder from simpler to more complex

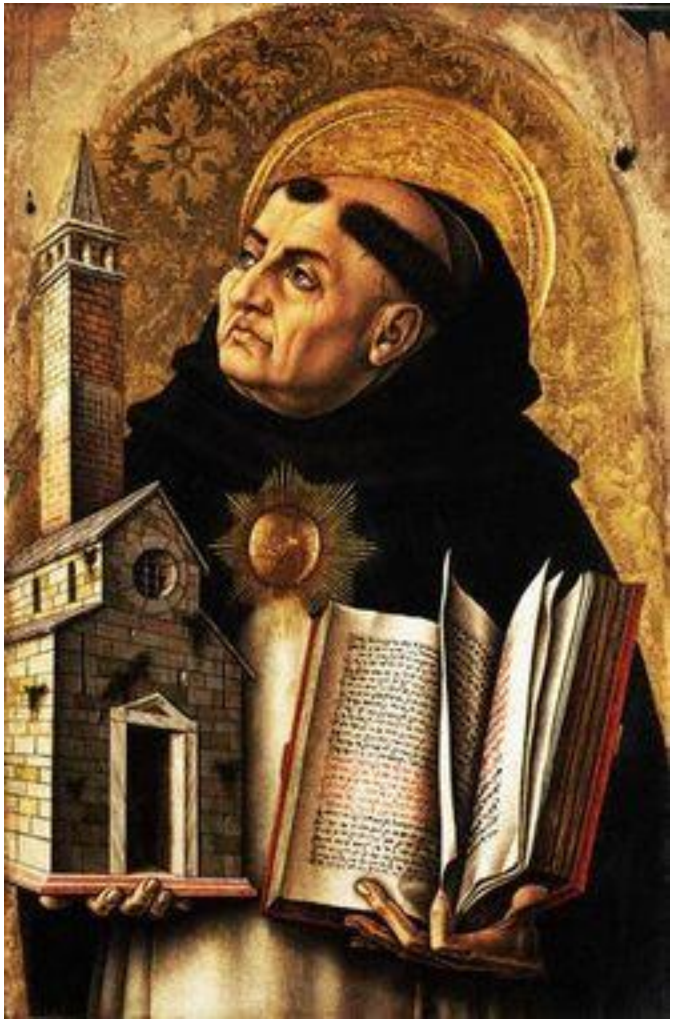
Intelligent designer – forsight (providence) of the Creator

Aristotele was the first systematisist

http://www.ucmp.berkeley.edu/history/aristotle.html

http://web.clas.ufl.edu/users/rhatch/pages/03-Sci-Rev/SCI-REV-Teaching/HIS-SCI-STUDY-GUIDE/0024_greatChainBeingCosmos.html

The history of Evolutionary Biology



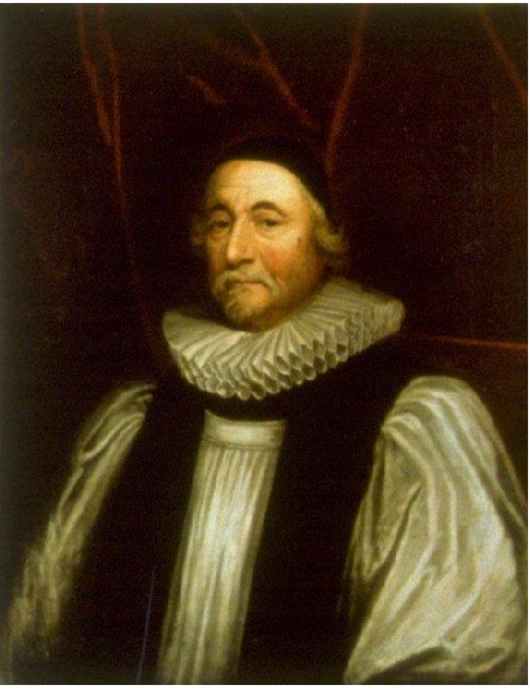
“Argument from design”

Thomas Aquinas
1225 – 1274

Aristotele had great influence on the Medeaval Christian world view. His writings had excessive influence and held back further studies, because everything was thought to be ‘ready’. **Thomas Aquinas** expressed that the miracolous adaptions of animals described by Aristotele are the best proof for the existence of God. Only the great wisdom and providence of God could form such perfect life forms.

This was the source of “Natural Theology” which stayed the major world view until Darwin. Nature was studied to better understand God’s creation miracle.

The history of Evolutionary Biology:



James Ussher, D.D.
Lord Archbishop of Armagh (1581-1656)


ANNALES
VETERIS TESTAMENTI,
à primâ Mundi origine deducti.

- The World was created on a Sunday 23d of October, 4004 years BP.
- Adam and Eve were send out from Paradise on the 10th of November the same year.

Ussher's identification of the day of creation: *Annales veteris testamenti, a prima mundi origine deducta* (1650)

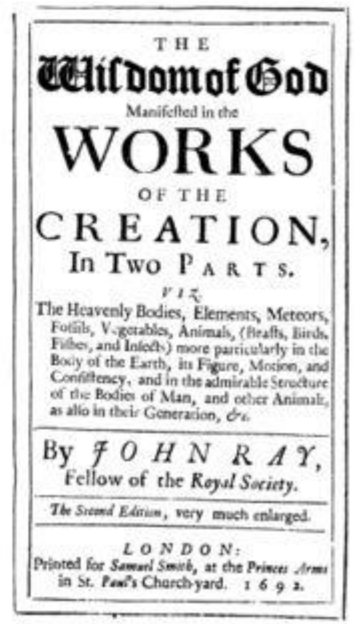
The history of Evolutionary Biology: Renaissance

By the end of the 15th centurey the direct observations become essential in the study of the surrounding world.

Discoveries among others by Copernicus, Galilei, Newton and arising of the mechanistic philosophy (Descartes's rationalism) where a relatively small number of basic mechanisms (natural laws) define the nature of a complicated universe.

Nevertheless, there was no principal change in the study of living nature. It was thought that God created the natural laws that definded the essence of the universe (Deism).

Species stayed intact and unchangeable on the Aristotele's Scala Naturae which only had changed its name to "Great Chain of Being".


THE
Wisdom of God
Manifested in the
WORKS
OF THE
CREATION,
In Two Parts.
VIZ.
The Heavenly Bodies, Elements, Meteors, Fossils, Vegetables, Animals, (Beasts, Birds, Fishes, and Insects) more particularly in the Body of the Earth, its Figure, Motion, and Consistency, and in the admirable Structure of the Bodies of Man, and other Animals, as also in their Generation, &c.
By JOHN RAY, Fellow of the Royal Society.
The Second Edition, very much enlarged.
LONDON: Printed for Samuel Smith, at the Princes Arms in St. Paul's Church-yard. 1692.

1627 – 1705
John Ray

One of the first classifications of plants. The first concept of species from him.

The Wisdom of God manifested in the Works of the Creation (1691)

The history of Evolutionary Biology: 18th century.
Geology and the chainging of the Earth

The stability of God's creation through time applied also to the inanimate nature. This dogma was broken earlier than the unchangeabilty of the living world.

The birth of Geology as a Scientific discipline.

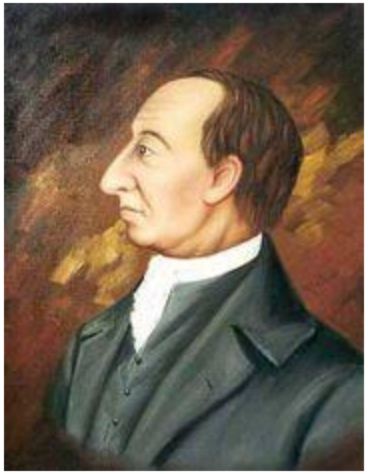
Main problems for geology were the terrestial sedimentary rocks and fossils.

It was understood that terrestial sedimentary rocks had formed on the sea bed.

Question: how did the sea bed become main land?

- **Vulcanism – Voclanic activities lifted the land up from the sea.**
- **Neptunism – the sea retreated**

James Hutton (the founder of geology) spoke about constant change - terrestrial rocks are eroded to the sea where they settle and then, due to earthquakes caused by the internal heat of the Earth, rise up to become main land again. He thought of these as equilibrium processes and concluded that "we find no vestige of a beginning, no prospect of an end."



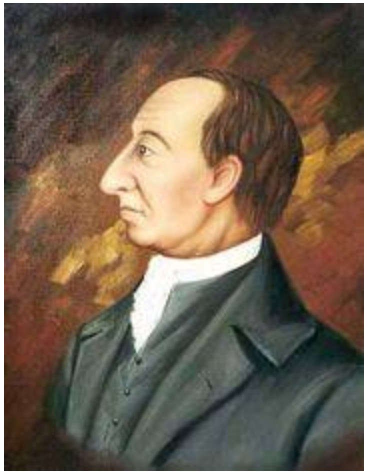
James Hutton
1726 - 1797

The history of Evolutionary Biology: 18th century. Geology and the chainging of the Earth

Hutton J. 1794. *An investigation of the principles of knowledge and of the progress of reason, from sense to science and philosophy, Vol. 2.* Strahan and Cadell, Edinburgh.

...if an organised body is not in the situation and circumstances best adapted to its sustenance and propagation, then, in conceiving an indefinite variety among the individuals of that species, we must be assured, that, on the one hand, those which depart most from the best adapted constitution, will be the most liable to perish, while, on the other hand, those organised bodies, which most approach to the best constitution for the present circumstances, will be best adapted to continue, in preserving themselves and multiplying the individuals of their race.

With this sentece he implies that already half a century before he understands Darwinism...



James Hutton
1726 - 1797

The history of evolutinary biology. Geology: fossils – changing of life forms

Georges Cuvier

1769-1832

Was appointed in 1795, at the age of 26, as assistant to the professor of comparative anatomy at the Muséum National d'Histoire Naturelle.

Founder of vertebrate paleontology.

Legacy:

Anatomical body-plans of animals:

vertebrates

anthropod

molluscs

crustaceans

Cuvier was responsible for the collection of vertebrates in the National Museum of Natural History. He mostly compared the anatomy of living species but also worked with fossils. He notcied that many fossils are of extinct species and saw that **different groups of exctinct species form layers in the sediments**. He found that the alternation of such layers reflect the (local) catastrophes that wiped out many species after what God created new species

CATASTROFISM

Cuvier was an ardent opponent of changeability of species. He grounded it within comparative anatomy with too complicated relations between body parts.

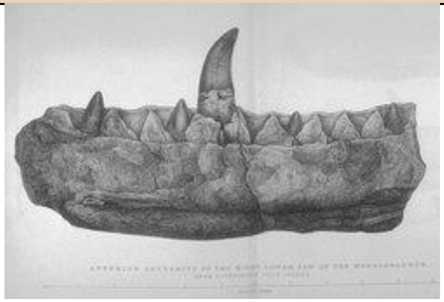
The history of evolutinary biology. Geology: fossils

Thanks to the relative dating of the fossile rock layers it became clear that through time the living nature has changed enormosly.

Adam Sedgwick (1785-1873)
(postulated - Cambrium, Devon)

Roderick Impey Murchison (1792-1871)
(postulated – Silurian ja Permian)

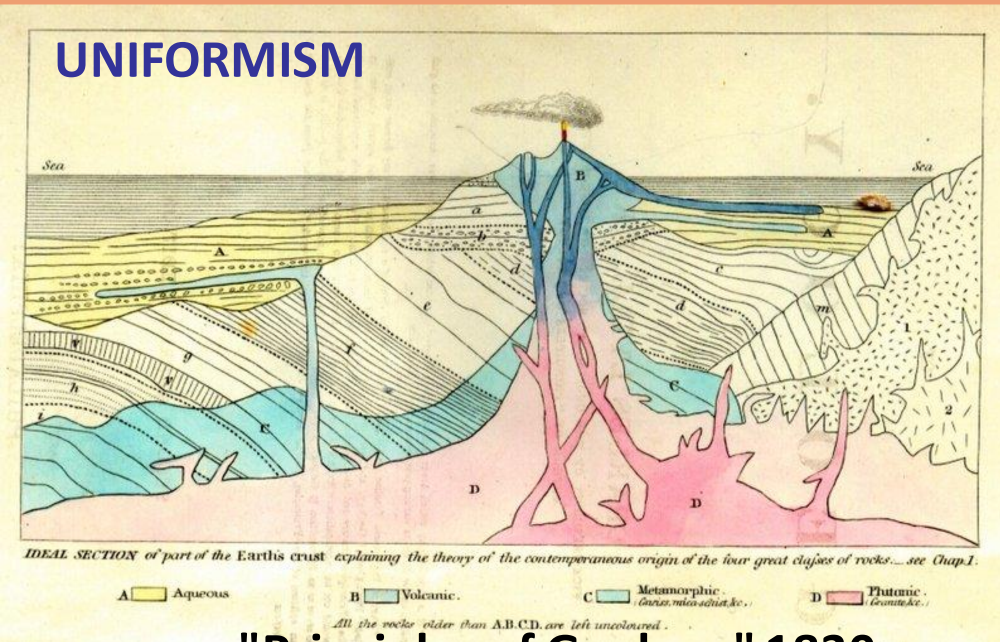
They studied the rock chronolgy in Wales and postulated the relative geological time scale up to (-540mln y.)



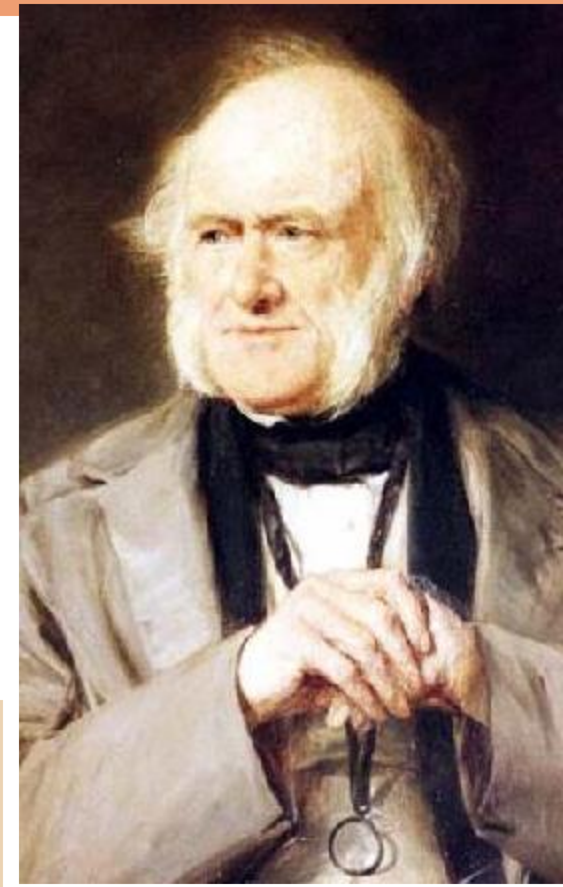
First dinosaur fossil from 1824
William Buckland (1784 - 1856)

Fish – reptiles - mammals

Still:- CATASTROPHISM



"Principles of Geology" 1830



Charles Lyell
(1797-1875)

Ideas stemming from Hutton's works led Lyell to claim that small changes happening today will eventually lead to great change. One of his main examples (also when talking about the age of the Earth) was the geology of Mt Etna. Eruptions at many different times had moulded the layers of volcanic rock that were interspersed with

so the volcano that seemed ancient to people was actually geologically young.

Lyell had great influence on Darwin. Also he tried to explain great changes through the sequence of small steps during long period of time.

History of Evolutionary Biology. Changing species before Darwin.

In the general relaxation of religious dogmas during the Age of Enlightenment there were thinkers who started to discuss the possible changeability of species. The main catalyst for this change is the general 'progress' of economy and society at that time.

Pierre-Louis Moreau de **Maupertuis** (1698 –1759)

"Vénus Physique" (1745)

- Discussed among other things also the dark skin of people from tropics. Did the sun directly influence the hereditary substance or was the variation of skin color hered randomly inherited?
- There was a vague discussion about natural selection
- Proposed also a theory of inheritance: "inheritance particles" and "self-organizing ability of organic substance"
- Showed that both male and female gender pass on inheritable characteristics to the offsprings. Studied variation statistically.
- He became the member of almost all European scientific associations and the president of Academy of Sciences in France and in Germany because he proved by measuring the latitudes in Lapland that earth is flattened toward the poles, as Newton had predicted.

History of Evolutionary Biology. Changing species before Darwin.

In the general relaxation of religious dogmas during the Age of Enlightenment there were thinkers who started to discuss the possible changeability of species. The main catalyst for this change is the general 'progress' of economy and society at that time.

Georges-Louis Leclerc, Comte de Buffon (1707 –1788)

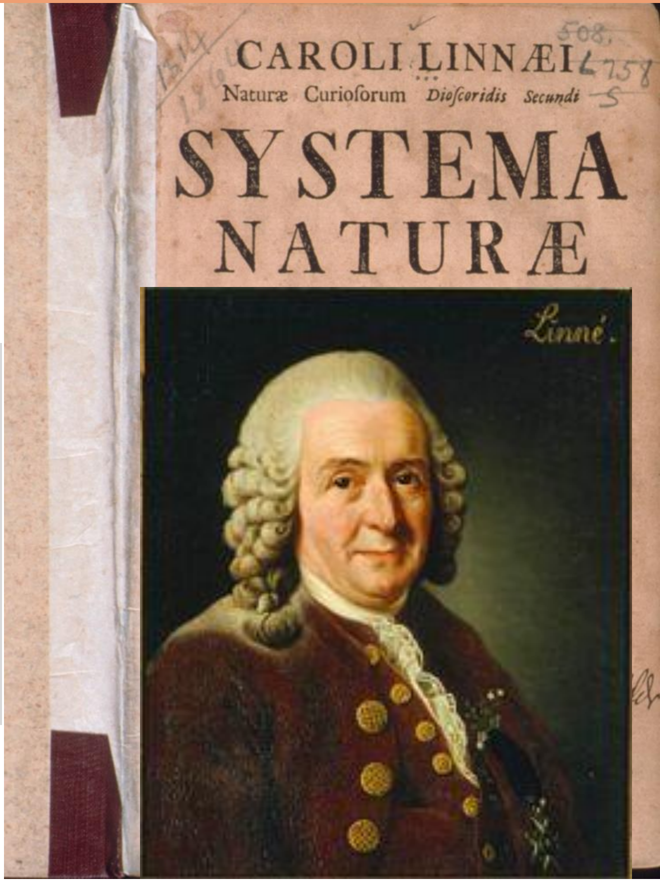
Histoire naturelle, générale et particulière (1749-1778: in 36+8 volumes

- Discussed if similar species (apes and humans) could have a common ancestor. At the same time all families are still created separately, developed the concept of "unity of type" for the comparative anatomy.
- Showed that many animals have relict characteristics that are not useful and explained them with change evolution).
- Showed that despite similar natural conditions in the different parts of the world, these distinct regions inhabit different animals (Buffon's law). He explained it with the changing climatic conditions that caused animals to move away from the centres of creation and species may have either 'improved' or 'declined'.
- From the cooling time of iron he calculated that earth is 75 000 years old (not created on 4004 BC which was the officially accepted time calculated from Bible by Archbishop James Ussher)

Carolus Linnaeus (1707-1778)

“The Earth's creation is the glory of God, as seen from the works of Nature by Man alone. The study of nature would reveal the Divine Order of God's creation, and it was the naturalist's task to construct a "natural classification" that would reveal this Order in the universe. “

The sexual basis of Linnaeus's plant classification was controversial in its day; although easy to learn and use, it clearly did not give good results in many cases. Later systems of classification largely follow John Ray's practice of using morphological evidence from all parts of the organism in all stages of its development. What has survived of the Linnean system is its **method of hierarchical classification** and custom of **binomial nomenclature**.



First editon 1735

Hierarchical classification system is important for the understanding of the ‘tree-like’ structure of life.

Thought that species are changing through hybridization, nevertheless did not see this as evoluton but possibility given by God.

Noticed the struggel for surviaval, but found it to be the mechanism to maintain the natural balance – the Godly order.

History of Evolutionary Biology. Changing species before Darwin.

In the general relaxation of religious dogmas during the Age of Enlightenment there were thinkers who started to discuss the possible changeability of species. The main catalyst for this change is the general 'progress' of economy and society at that time.

Erasmus Darwin

1731–1802;

Zoönomia (1794–1796)

The Temple of Nature (1803)

Charles Darwin's grandfather can be taken as a convinced evolutioninst but he did not bother to ground his ideas. In the posthumously published '*The Temple of Nature*' he portrayes the evolution of living nature from microorganisms to civilization as a poem.

Natural selection was the only idea that Erasmus did not thought of but his grandcild did.

Thus, Charles Robert Darwin’s contribution to evolutionary biology was not postulating the ideas of changing of the species and natural selection, but thorough **scientific proof of them**. In the foreword to the sixth edition of the “The origin of …” he writes that the first to discuss natural selection was Buffon.

History of Evolutionary Biology. Lamarck

Jean-Baptiste Pierre Antoine de Monet, Chevalier de Lamarck (1744-1829)

***Philosophie Zoologique* (1809)**

First real (coherent) evolutionary theory

On 1793 he became the professor of invertebrate zoology in the Muséum national d'histoire naturelle.

The continous nature of invertebrate fossil convinced him in the changeability of the species. On 1800 he proposed the main viewpoints of his evolutionary theory.

Why species are changing?

1. **Force that compels the change towards more complex.**

An inner force towards perfection.

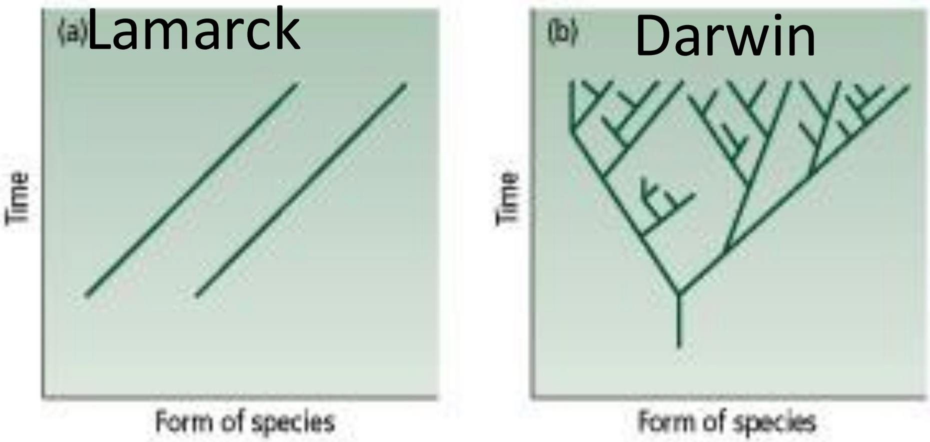
Species are moving up on the ladder of *Great chain of Being*. Mechanism is somewhat alchemical...

2. **Force that compels to adapt.** This move species horizontally on the ladder to adapt to local conditions and works though the differential intensity of using the characteristics of the species. Thought that it is also possible to adapt so specifically that any further changes becomes impossible.

Buffon's student

He was a devoted botanicist and knew well the Linnean system. He developed the detailed systematics for the invertebrates, which might be his most important contribution.

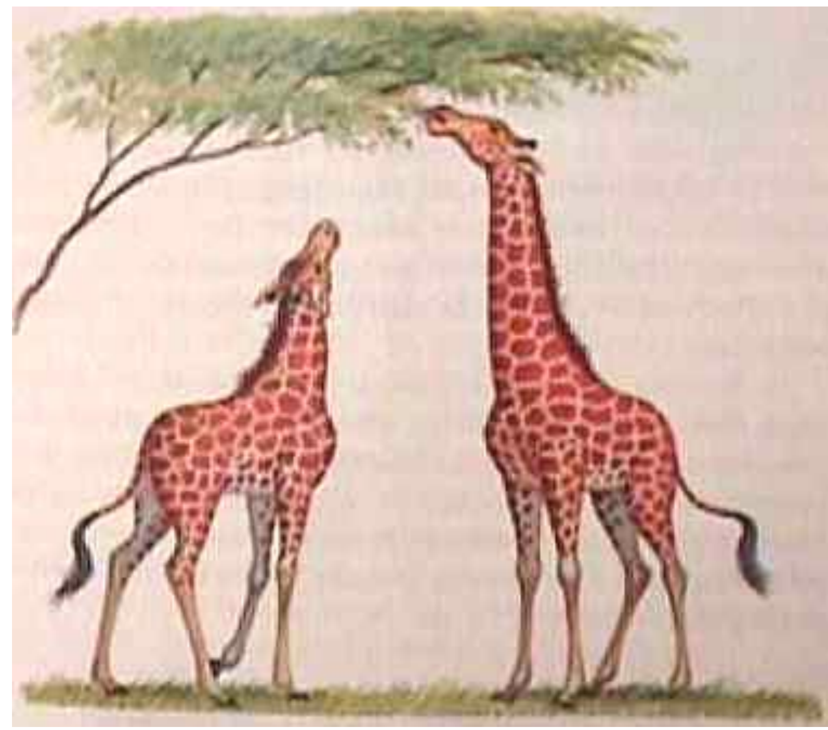
History of Evolutionary Biology. Lamarck



Lamarck's evolutionary theory is called Taransformism, to differentiate it from the Darwin's theory.

Figure 1.2
(a) Lamarckian "transformism," which differs in two crucial respects from evolution as Darwin imagined it. (b) Darwinian evolution is tree-like, as lineages split, and allows for extinction.

- **Primitive species are constantly sponaneously born.**
- **Species do not split nor go extinct.**



The *inheritance of acquired characteristics* was not central for Lamarck's theory. It was rather common opinion at that time (among those who even thought species could change). It became truly 'Lamarckian' when neo-Lamarckists started to stress upon this in the end of 19th century.

History of Evolutionary Biology. Sate of the art before Darwin.

Why Darwin was English and not French nor German?

Speculation:

During 19th century the paradigm of ‘progress’ (in society) was widely spread in Western Europe, but there were substantial differences in the nuances.

Germany

As a reaction to the mechanistic views (Newton, Descartes) rose the *Naturphilosophie*, which allowed for evolution, but handled it somewhat mystically, paralleling it with the individual development during the course of life.

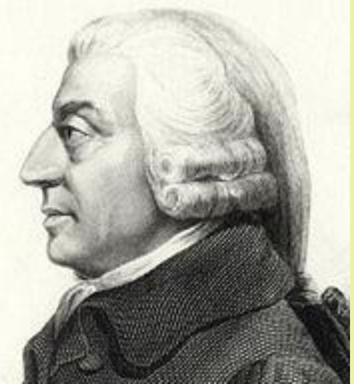
France

Progress was an inevitable result of gaining more knowledge, but human nature was held constant at the same time. This framework was not fertile for development of the ideas of evolutionary biology.

England

A pragmatically utilitarian philosophy arose, that saw competition between individuals as a way to effective economy eventually bringing benefits for all. Evolution as a topic was popular.

An Inquiry into the Nature and Causes of the Wealth of Nations (1776).

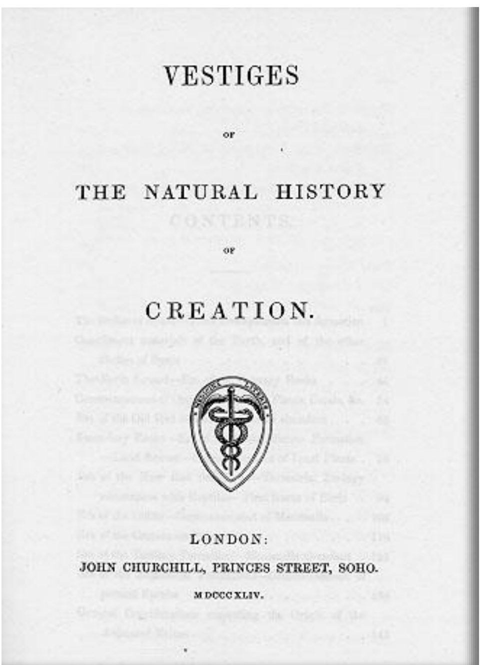


Adam Smith (1723 –1790)

Scottish political economist

History of Evolutionary Biology. Fertile England

Robert Chambers
(1802 –1871)



VESTIGES

OF

THE NATURAL HISTORY

OF

CREATION.

LONDON:
JOHN CHURCHILL, PRINCES STREET, SOHO.

MDCCCXLIV.

Vestiges of the Natural History of Creation, 1844

Relatively arbitrary (rather a story than science) work describing the evolution of cosmos, earth and living nature.

Speaks about the changing of species, adaptions and extinctions.

More important than it’s scientific content was the huge popularity of the book. It did not mean that everybody, especially scientist, agreed with it. Time was ripe for Darwin. It was 15 year so the first print of “The origin of species”

History of Evolutionary Biology. Sate of the art before Darwin.

In summary and with many generalisations the big picture before Darwin was the following:

Cuvier

Many species have gone extinct and the life on earth has changed a lot

…but species themselves do not change

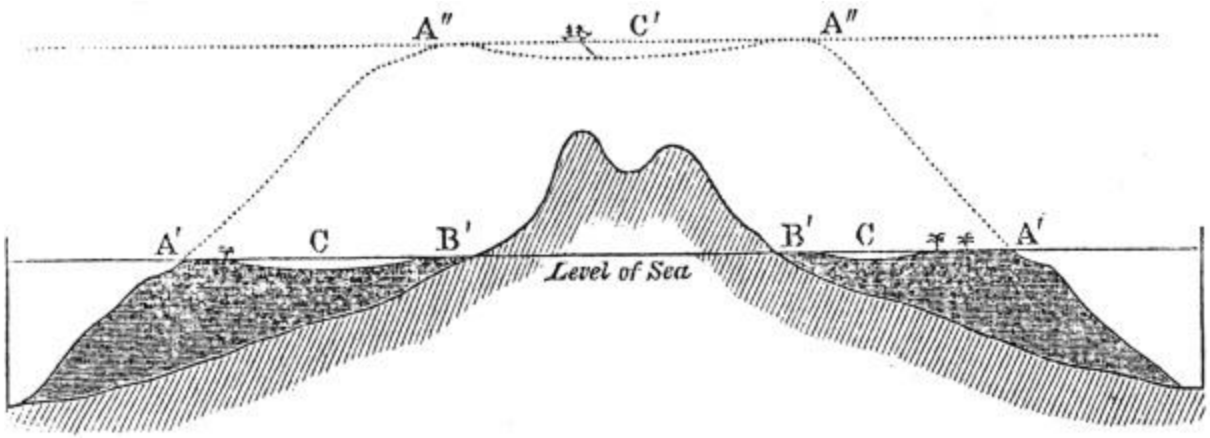
Lamarck

Species are changing and adapting,

…but don't split nor go extincg

Charles Robert Darwin
(1809–1882)

He was a naturalist from youth on but his father who was a doctor made him study medicine. In Edinburgh he studied medicine and then in Cambridge to become a pastor. Nevertheless he spent most of his time in the research of sea invertebrates and beetles.
Beagle (1831-1836): he read Lyell's "Principles of Geology" and supported the uniformism theory in the formation of choral reefs.
Could today's processes explain also the abundance of species and adaptions?



History of Evolutionary Biology. Darwin

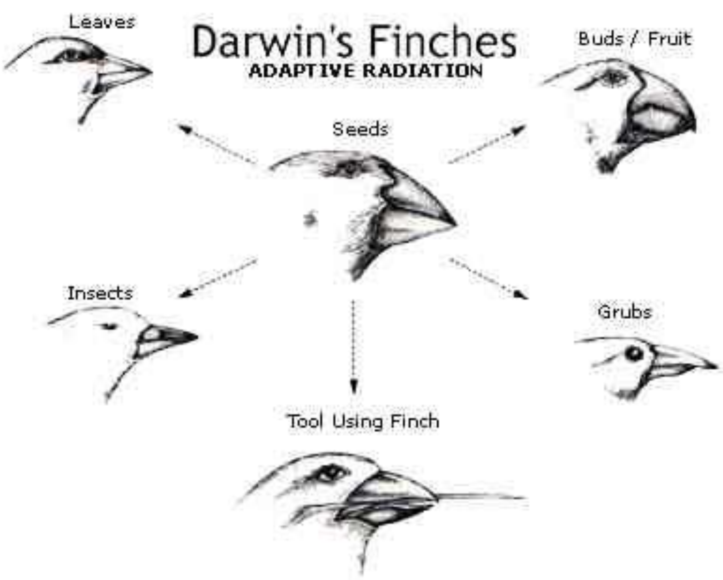
As a researcher on Beagle he noticed the geographic variation of similar species. For example the Galapagos finches varied on different islands.

He did not let unnoticed how many fossils that he avidly collected in South America resembled the species of today but were still different from them.

So the facts of life compelled to admit that species change.

When back in England he did not find it reasonable to come out with the changeability of species before he had clarified the causes and mechanisms behind it.

The most important was that the mechanisms would explain the adaptions.

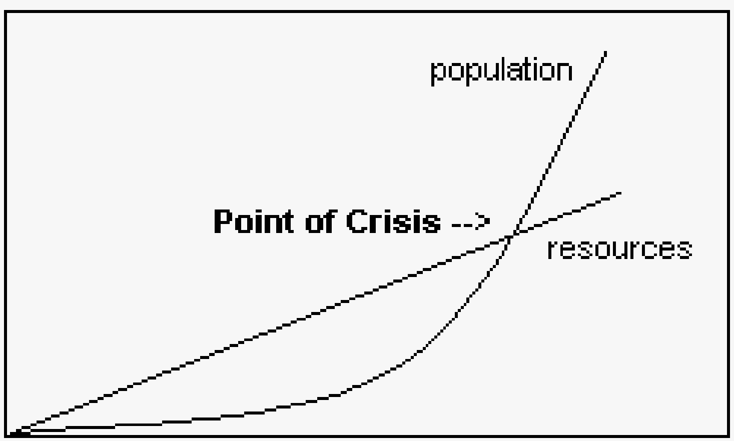


In 1838 he accidentally read by the works of Malthus

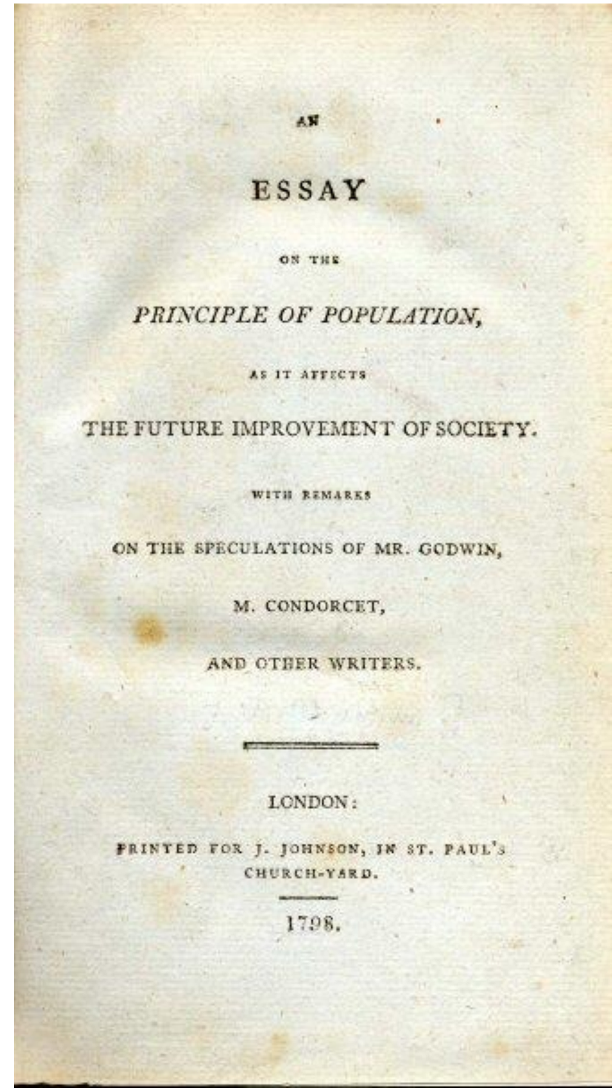
History of Evolutionary Biology. Darwin

Thomas Malthus (1766-1834)

"Essay on the Principle of Population" (1798).



Malthus' Basic Theory



AN

ESSAY

ON THE

PRINCIPLE OF POPULATION,

AS IT AFFECTS

THE FUTURE IMPROVEMENT OF SOCIETY.

WITH REMARKS

ON THE SPECULATIONS OF MR. GODWIN,

M. CONDORCET,

AND OTHER WRITERS.

LONDON:

PRINTED FOR J. JOHNSON, IN ST. PAUL'S CHURCH-YARD.

1798.

History of Evolutionary Biology. Darwin 1838

Darwin’s “a theory by which to work”

- Individuals are different
- Differences are inhertable
- More are born than survive
- Fight for survival – the more adapted ones survive and give progeny and become more plentyful
- In different conditions different individuals are “more fit” so different species form

Darwin did not hurry. In his contemporary time and before that similar ideas had been ‘tossed to air’ (Chambers, Vestiges). He wanted to be sure and come out with a theory where all would be scientifically and thoroughly proved. He worked on these problems for 20 year studying both artificial selection in pigeons and morphology of barnacles.

Analogously to the specialisation of workforce in Adam Smith’s theory of economics he described how the branching of species is beneficial for them.

Fig. 2.

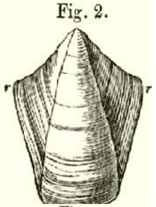


Fig. 4.

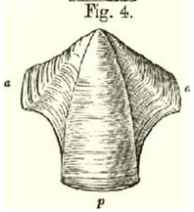
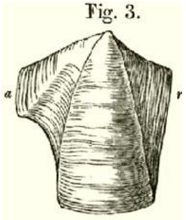


Fig. 3.



Darwin’s pigeonry

Alfred Russel Wallace
(1823-1913)

In 1858 Wallace disclosed to Darwin his ideas about evolution that were very similar to those of Darwin. Also he had read Malthus.

A joint presentation of these ideas was organized in the Linnéan Society in London. As often happens, for a start people did not understand much and the president of Linnéan Society summarized the year or 1858 with words: "1858 was a year ..which has not, indeed, been marked by any of those striking discoveries which at once revolutionionise … the departement of scienc on which they bear"

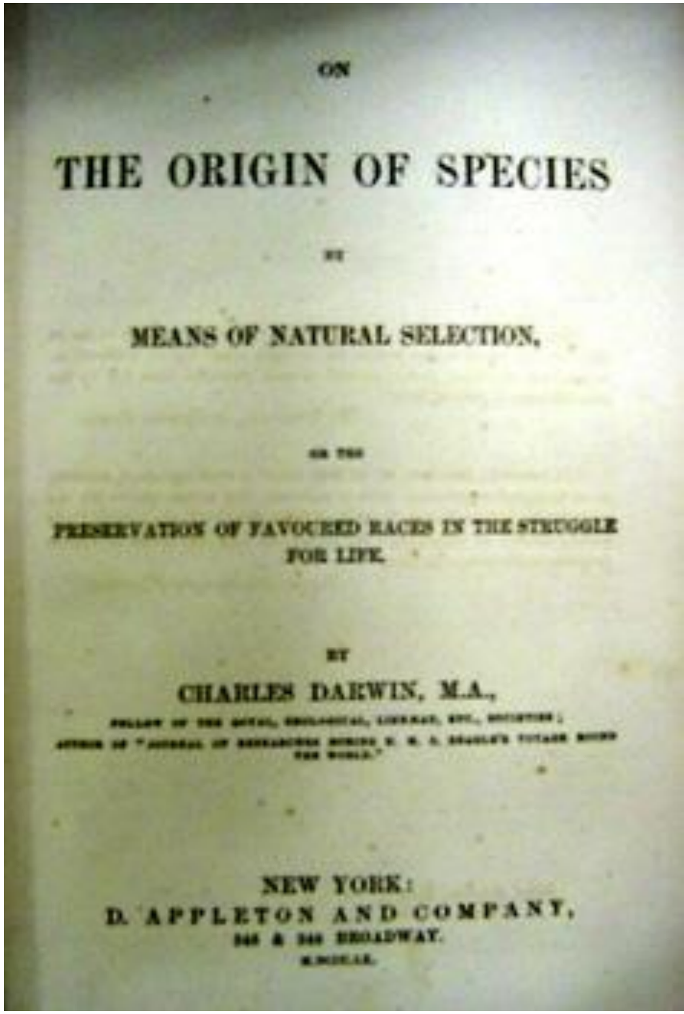
History of Evolutionary Biology. Darwin 1859

Origin of Species (1859)

Darwin offered two interconnected theories: evolution (changeability of species and branching into new species with extinction of many) and natural selection (as a mechanism of evolution).

Reaction:

- Evolutsion, ok
- Natural Selection (?)


ON

THE ORIGIN OF SPECIES

MEANS OF NATURAL SELECTION,

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

BY

CHARLES DARWIN, M.A.,

NEW YORK:

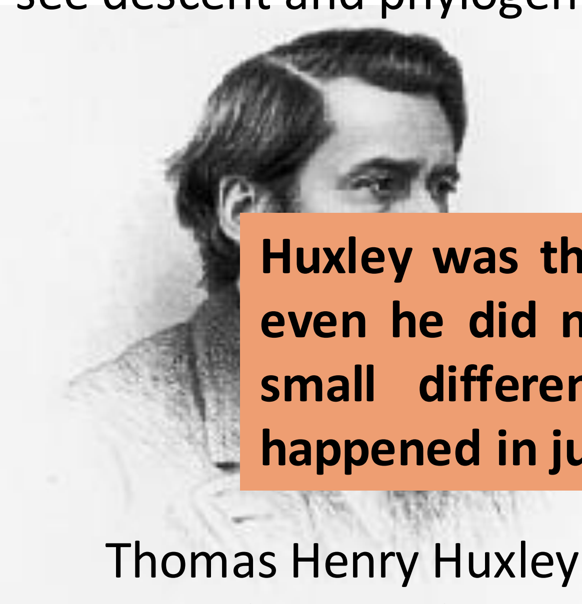
D. APPLETON AND COMPANY,

BROADWAY.

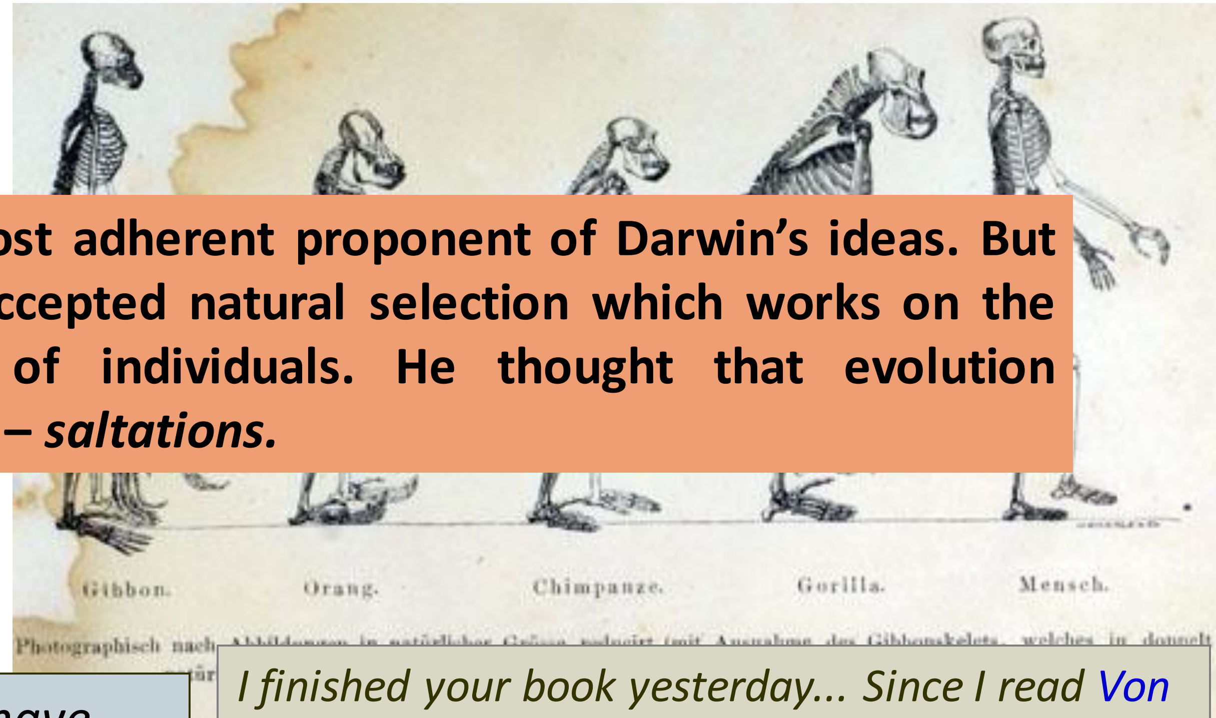
Origin of Species (1859)

History of Evolutionary Biology. The reception of Darwin’s ideas.

Biologists and especially comparative anatomists who had until now (in the footsteps of Cuvier) studied the body-plans of different animals quickly reoriented and started to see descent and phylogeny.



Thomas Henry Huxley
(1825-95)



Huxley was the most adherent proponent of Darwin’s ideas. But even he did not accepted natural selection which works on the small differences of individuals. He thought that evolution happened in jumps – *saltations.*

"How extremely stupid not to have thought of that!" was Thomas Henry Huxley's reaction to Darwin's On the Origin of Species. Huxley's confidence and candor earned him the reputation as "Darwin's bulldog,"

I finished your book yesterday... Since I read Von Baer's Essays nine years ago no work on Natural History Science I have met with has made so great an impression on me & I do most heartily thank you for the great store of new views you have given me...

Letter of T. H. Huxley to Charles Darwin, November 23, 1859, regarding the *Origin of Species*

He developed further the theory of recapitulation
Ontogeny copies phylogeny

He was a avid proponent of 'Darwinism'. It did not matter that he understood it differently than Darwin. He thought that selection happened between 'variants' that were the result of the directed processes and saw evolution happening in steady direction towards more complexity that peaked with humans (and not all humans).

Ernst Heinrich Haeckel
(1834-1919)

"In order to be convinced of this important result, it is above all things necessary to study and compare the mental life of wild savages and of children. At the lowest stage of human mental development are the Australians, some tribes of the Polynesians, and the Bushmen, Hottentots, and some of the Negro tribes.
In many of these languages there are numerals only for one, two, and three: no Australian language counts beyond four. Very many wild tribes can count no further than ten or twenty, whereas some very clever dogs have been made to count up to forty and even beyond sixty."

History of Evolutionary Biology. The reception of Darwin's ideas

Darwin's theory tells that evolution is the branching (of species) following the adaptions to new conditions.
There is no need for hierachy nor direction from simpler to more complex. Unfortunately this was what many Darwin's contemporary 'evolutionists' were seeking for.

Thus, the theory of evolution was accepted but often in a distorted way.

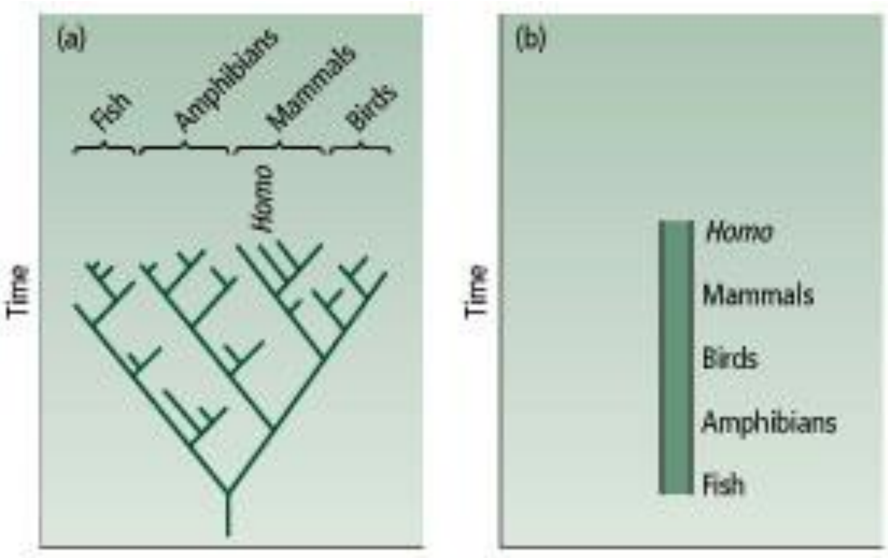


Figure 1.6
(a) Darwin's theory suggests that evolution has proceeded as a branching tree; note that it is arbitrary where *Homo* is positioned across the top of the diagram. *Homo* is often placed at the extreme right, but does not have to be. The tree should be contrasted with the popular idea (b) that evolution is a one-dimensional progressive ascent of life. Darwinian evolution is more like a tree than a ladder (cf. Figure 1.2).

During the 50 years after Darwin's "The orgin of species" was published only two works came out that dealt with natural selection.

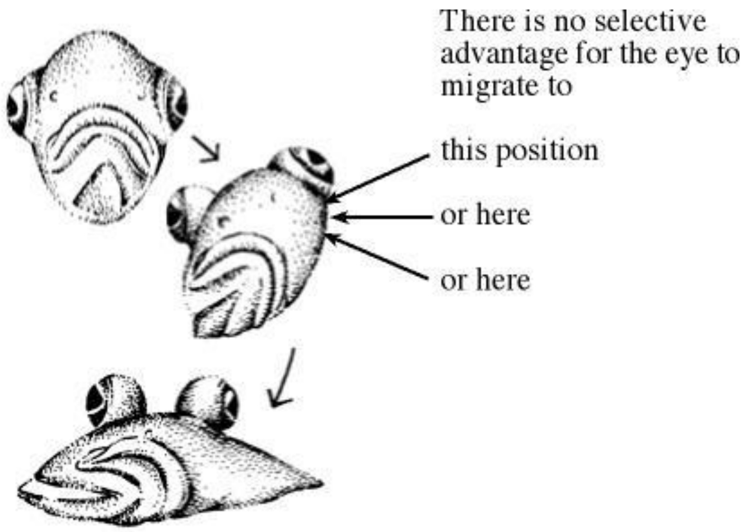
In 1899. Herman Bumpus showed that the length of the wings of the sparrows that were killed during the storm was either longer than average or shorter than average. – ***Stabilizing selection***

Walter Frank Raphael Weldon showed that the shape of shrimps in Plymouth strait changed through selection (slimmer shrimps died less)
- ***Directional selection***

Critique of Natural Selection during 19th century:

- Natural selection does not work with "blending inheritance"
- randomness (not predetermination)
- Intermediate stages are not fit
- The age of Earth seemed too young (according to erosion – 96, or 40...400 MYA).
- Inappropriate world view

George Jackson Mivart "Genesis of species" 1871:
NS does not explain the intermediate stages



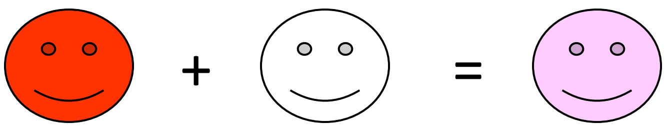
The explanation was that the wing-less ancestors of birds had propensity to have progeny with a bit larger wing stumps, even though they did not have any use of them initially.

"directed mutation"? (Lamarck)

Darwin took Mivart's critique seriously:
Replied that even a "unfinished" characteristic could be useful (light sensitive layers – eye)

History of Evolutionary Biology. The reception of Darwin's ideas

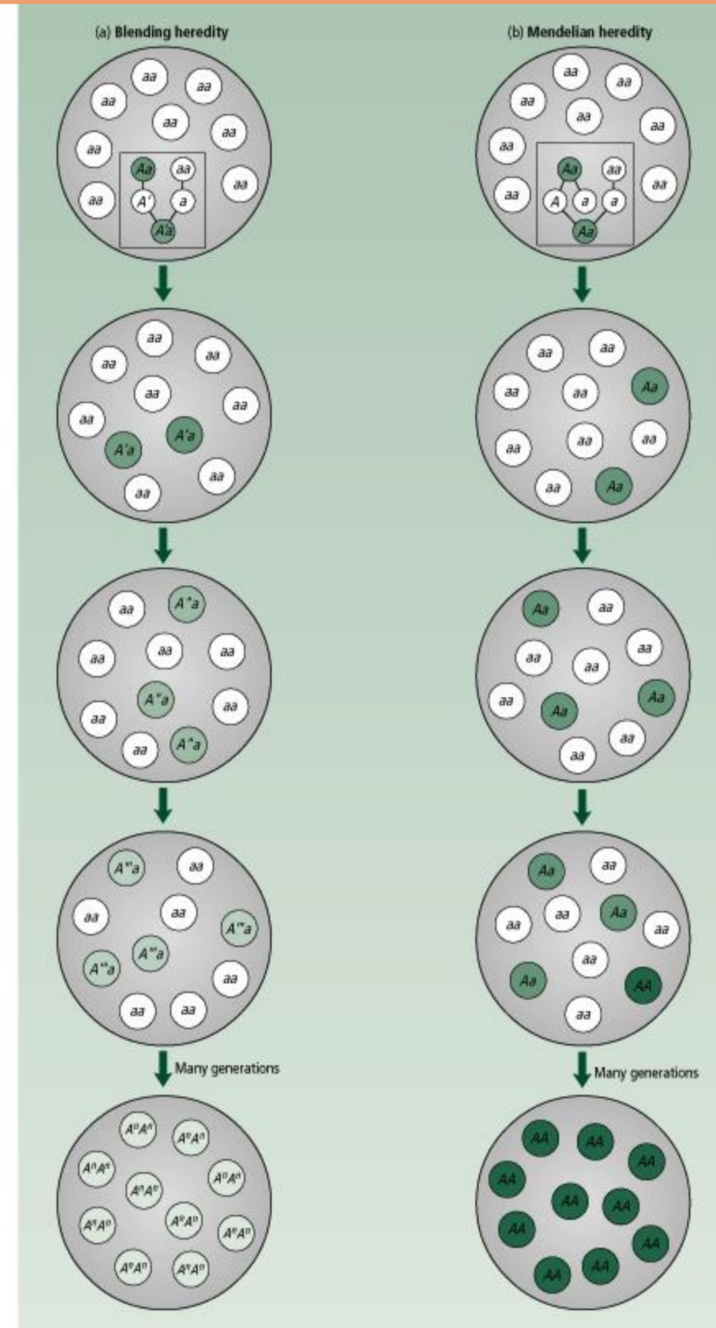
Darwin did not have a functional explaination for the inheritence, so the public did not accept the theory of natural selection.



- theory of "blending" inheritance;

In case the dark allele is the advantageous one then according to the Mendelian theory Darwinian adaptation happens but with blending heredity it does not.

Figure 2.11 Two populations with 10 individuals each (real populations would have many more members), one with blending heredity and the other with Mendelian heredity. (a) Under blending heredity, a rare new advantageous gene is soon blended away. (b) Under Mendelian heredity, a rare new favorable gene can increase in frequency and eventually become established in the population. See text for explanation.



Also Darwin accepted *inheritance of acquired characteristics* (IoAC).
He thought his own heredity theory– pangenesis (gemmules were inherited)

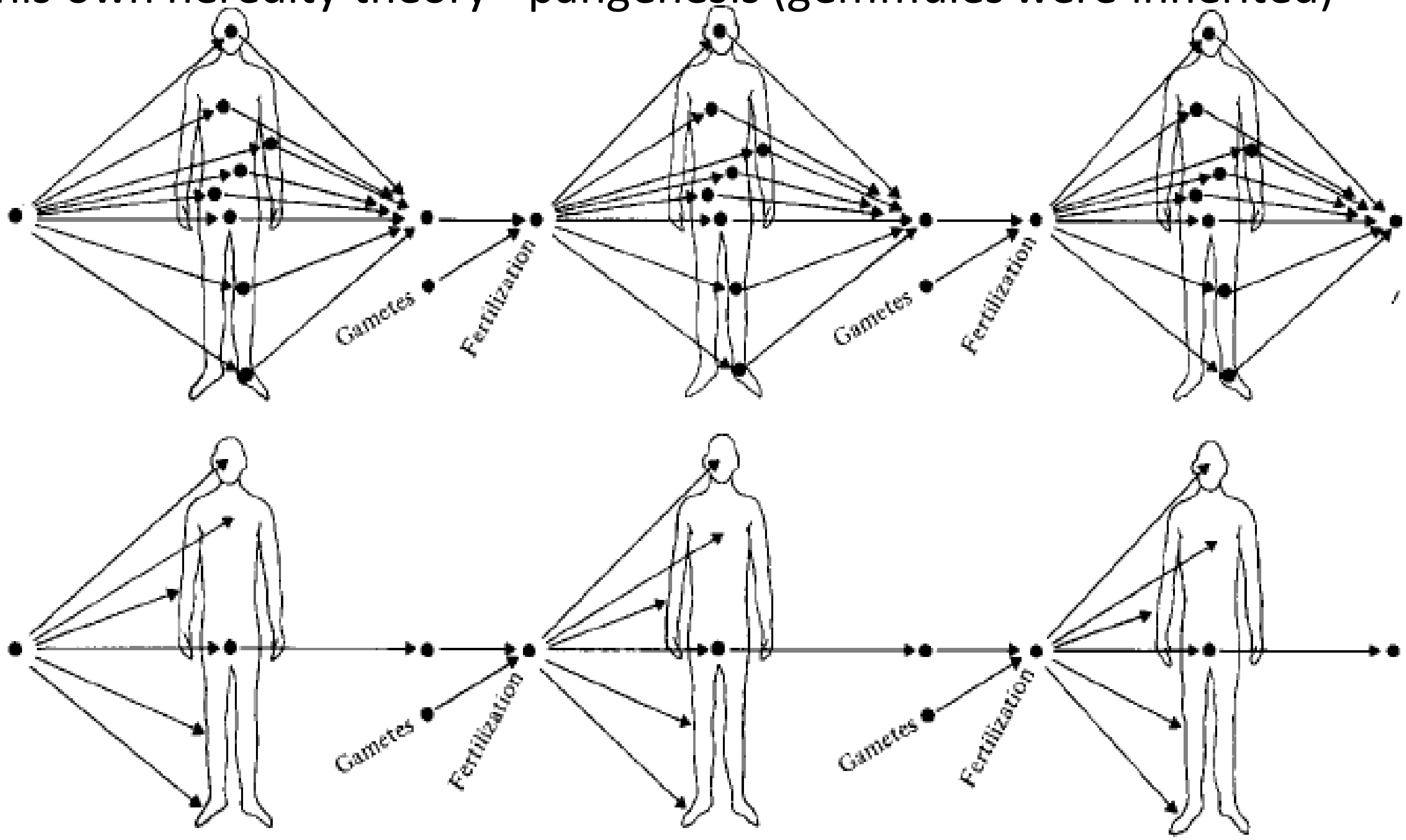


Fig. 6.1 Darwin's theory of pangenesis contrasted with Weismann's later germplasm theory.

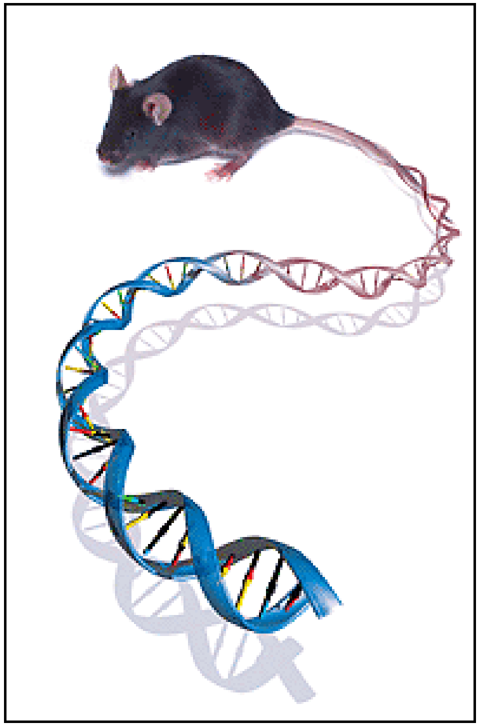
August Weismann (1833-1914), works from 1883, 1888

Weisman's research showed that IoAC is not true: *germ* and *soma* plasmas

What if an organ from an organism is taken? In example the tail from a mouse?

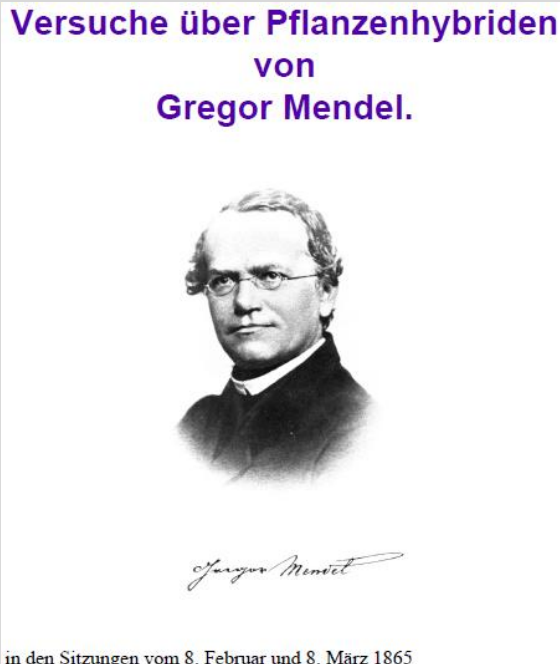
Weismann amputated tails from 5 generations of mice and showed that the tails of the progeny do not get shorter (1887-1889).

Cells that become *gametes* are separated at an early stage from the developmental pathways of the rest of the cells of an organism. Thus the changes that affect body's cells during the lifetime of the organism will not affect germ cells.



Weismann was one of the very few people who understood and supported evolution through natural selection.

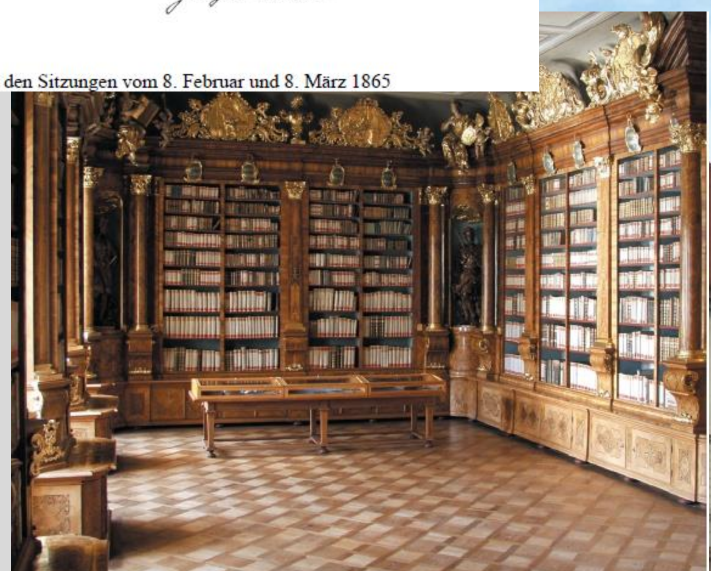
History of Evolutionary Biology. Mendel (to recall)



Versuche über Pflanzenhybriden
von
Gregor Mendel.

in den Sitzungen vom 8. Februar und 8. März 1865

Gregor Mendel
(1822 –1884)



Untouched: The present library at St Thomas's abbey remains largely unchanged since Mendel's time. (Picture: Stepan Bartos.)

Heritage site: The church of St Thomas's abbey in Brno, Czech Republic. Friars are not reclusive but active in the community and Gregor Mendel was a teacher alongside carrying out his studies in natural history and ground-breaking work on genetics. The abbey is now seeking a new role in commemorating Mendel's scientific achievements. (Picture: Stepan Bartos.)

History of Evolutionary Biology. Mendel (to recall)

The Law of Uniformity:
states that hybrids of pure breeding lines show uniform phenotype. The phenotype depends on the interaction of genes: dominance, codominance, intermediance

The Law of Segregation:
states that every individual organism contains two alleles for each trait, and that these alleles segregate (separate) during meiosis such that each gamete contains only one of the alleles.

Law of Independent Assortment:
states that the alleles of two (or more) different genes get sorted into gametes independently of one another.

Mendelian genetics (Khan Academy)
https://www.khanacademy.org/science/biology/classical-genetics/
Have a look – good material for studying.

History of Evolutionary Biology. Mendel (to recall)

1822-1884

1866

If only Gregor Mendel hadn’t worked in Brno but….

The journal he published his works in was present in more than 100 European libraries. It is more likely that the reason why his work was not widely recognized untlil around 40 years later is that nobody, including probably himself, did not understand the importance of it.

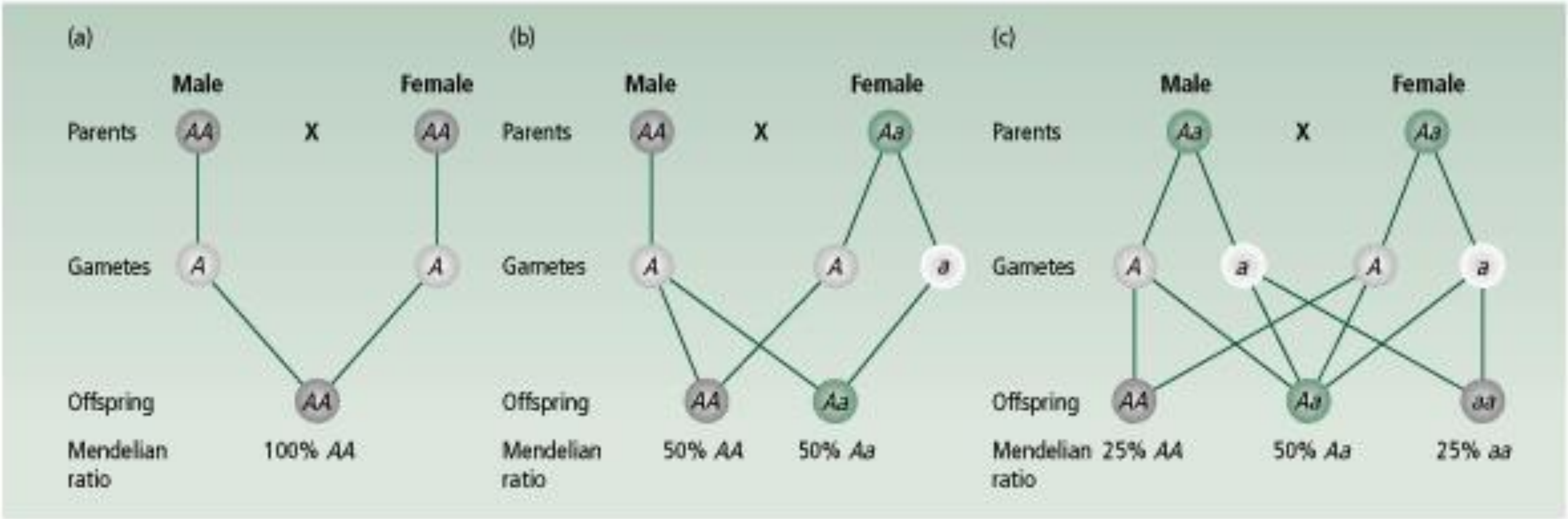


Figure 2.8

Mendelian ratios for: (a) an $AA \times AA$ cross, (b) an $AA \times Aa$ cross, and (c) an $Aa \times Aa$ cross.

Opinion

Why didn't Darwin discover Mendel's laws?

Jonathan C Howard

Published: 24 February 2009

Journal of Biology 2009, **8**:15 (doi:10.1186/jbiol123)

Nature of the Offspring from Illegitimately fertilised Dimorphic Plants.

—		Number of Long-styled Offspring.	Number of Short-styled Offspring
Primula veris . .	Long-styled form, fertilised by own-form pollen during five successive generations, produced.	156	6
" " . .	Short-styled form, fertilised by own-form pollen, produced .	5	9
Primula vulgaris .	Long-styled form, fertilised by own-form pollen during two successive generations, produced.	69	0
Primula auricula .	Short-styled form, fertilised by own-form pollen, is said to produce during successive generations offspring in about the following proportions .	25	75

Figure 6

Darwin's table summarizing the results of *Primula* crosses. Note especially the last line referring to the *Primula auricula* data, where the recessive and dominant forms respectively are cited as occurring in a 1:3 ratio in crosses between heterozygous dominant (short-styled) individuals. Reproduced from [5].

History of Evolutionary Biology. Mendel (to recall)

The importance of Mendel's findings:

He showed that phenotypic characters are determined by particulate inheritable units which are present in organisms as pairs.

This finding was important as it helped to interpret the cytological findings and through both to understand heredity.

History of Evolutionary Biology. Rediscovery of Mendel

HUGO DE VRIES (1848-1935)

CARL ERICH CORRENS (1864-1933)

Erich von Tschermak-Seysenegg

ERICH VON TSCHERMAK-SEYSENEGG (1871-1962)

Mendel's work was rediscovered in 1900, when three scientists independently reached the same conclusions. While doing so they understood that it had indeed been published 34 years ago and gave all credit to Mendel

History of Evolutionary Biology. Chromosome theory

<u>1902:</u>

Walter Sutton, Theodor Bover
Chromosome theory :
Mendels heredity has to do with chromosomes.
They saw that gametes have half the chromosomes of somatic cells.

Ascaris lumbricoides

FIGURE 1.29. Theodor Boveri's studies of chromosomes in the roundworm *Ascaris*' eggs answered many questions about the number and behavior of chromosomes in germ and somatic cells.

1.29, reprinted from Boveri T., 1910, *Die Potenzen der Ascaris-Blastomeri bei abgaederter Furchung, Zugleich ein Beitrag zur Frage qualitativungleicher Chromosomen-Teilung. Festschrift zum sechzigsten Geburtstag Richard Hertwigs*, Band III, Gustav Fisher, Jena

History of Evolutionary Biology. Reception of natural selection

The end of 19th century – biometrics vs saltationists.
They did not agree on how evolution proceeds – small steps or big leaps.
Neither of them knew how inheritance works – hence there was no solution at sight

Biometrics:

Worked with/created statistical methods to study natural selection in continious traits in populations. They "liked" Darwinian selection as both their data and the theory suggested small gradual changes in populations.

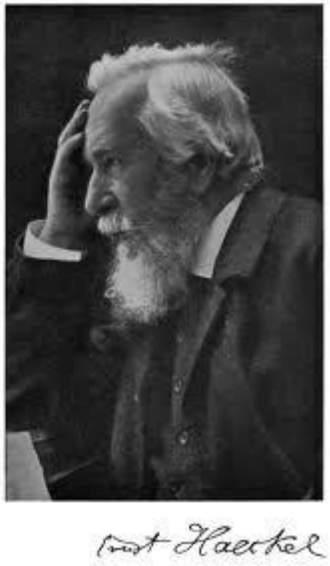
Galton, Weldon, Pearson

FIGURE 1.26. Karl Pearson (*left*), W.F.R. Weldon (*middle*), and Francis Galton (*right*).

1.26 left, National Library of Medicine; **1.26 middle**, Courtesy of CSHL Library and Archives; **1.26 right**, Galton F., 1908, *Memories of My Life*, Methuen & Co., London, collection of CSHL Library and Archives

The end of 19th century – biometrics vs saltationists.
They did not agree on how evolution proceeds – small steps or big leaps.
Neither of them knew how inheritance works – hence there was no solution at sight

William Bateson, 1922.



Saltationists

Natural selection works between differentiated forms. Natural selection cannot produce new forms by gradual accumulation of small adaptive changes.

Huxley, Haeckel, Bateson

History of Evolutionary Biology. Mendelism and Darwinism

Upon rediscovery of Mendel, the disagreement between biometrics and saltationists increased

Early propagators of Mendel were far from gradual nature of the natural selection theory – they were more obsessed with macromutations.

Biometrics did not support mendelism (was named genetics soon) because they saw in their data that continuous characters are inherited hence the hereditary mechanism must be continuous rather than discrete(particular) as Mendels

1900 – ca 1920

mendelism biometrics

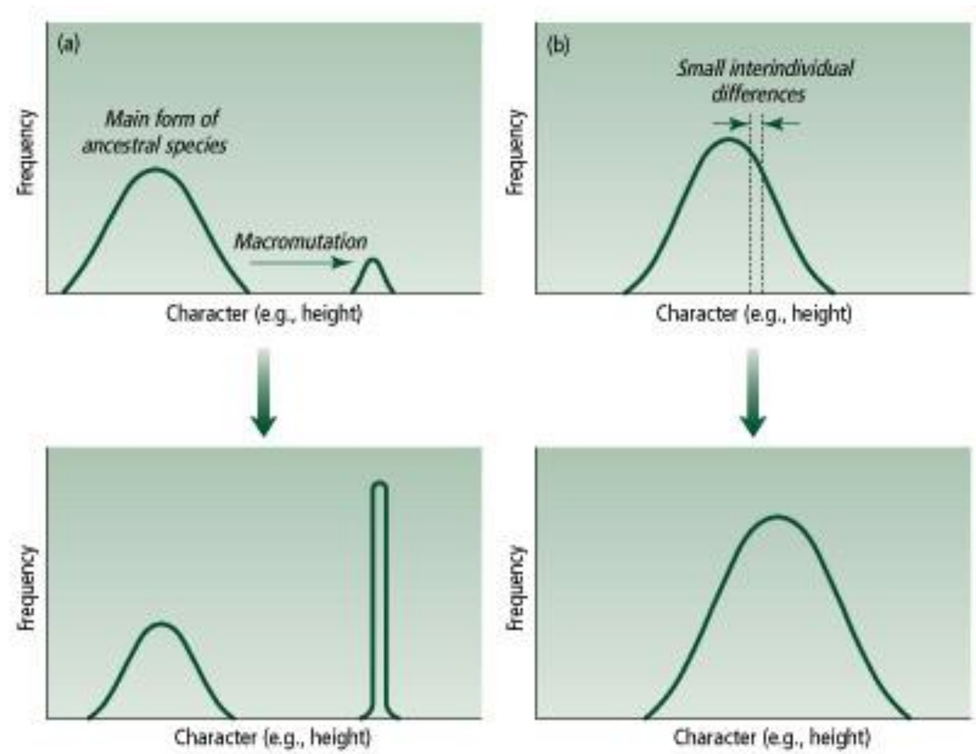


Figure 1.7
Early Mendelians and biometricians. (a) Early Mendelians studied large differences between organisms, and thought that evolution happened when a new species evolved from a "macromutation" in its ancestor. (b) Biometricians studied small interindividual differences, and explained evolutionary change by the transition of whole populations. Mendelians were less interested in the reasons for small interindividual variations. The figure is a simplification — no historic debate between two groups of scientists lasting for three decades can be fully

Early mendelists (geneticists) regarded mutation to be the driving force of evolution. They argued that natural selection cannot produce anything new and hence was not crucial for the appearance of new species

Wilhelm Johannsen (coined terms gene, phenotype, genotype) showed that in pure breeding lines (homozygous for the trait) natural selection did not have an affect. Selection can select one of the pure breeding lines(clones) from a group.

However we know now that there is no controversy – in natural populations there is always ample variation for selection to act upon

http://www.stat.berkeley.edu/~terry/Classes/s260.1998/Week4/week4/node2.html

Continuous traits and the gap between mendelists and darwinists (biometrics)

H. Nilsson-Ehle showed in 1909 that many genes can affect the same trait hence producing a continuous variation of the phenotype .

He worked with wheat – and the trait was the colour of the grains. He showed that with only three biallelic loci with additive effect could account for continuous variation of the phenotype.

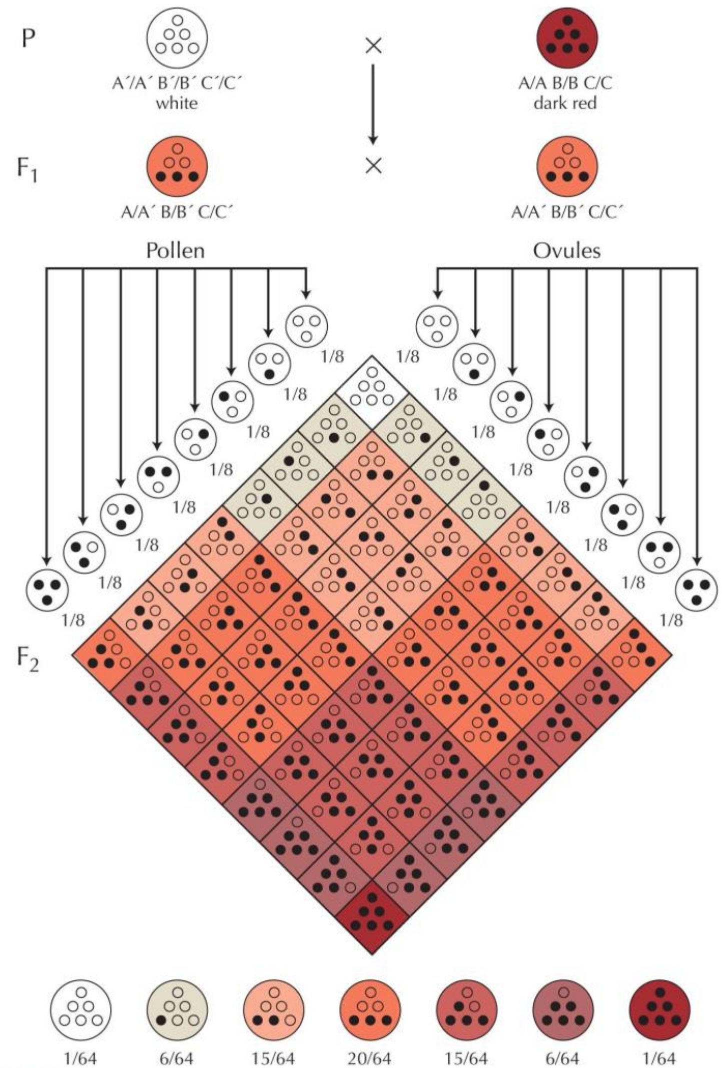


FIGURE 1.32. A cross between two parental lines that differ at three Mendelian genes can lead to almost continuous variation. One parent is homozygous for alleles A, B, C and has dark red seeds; the other is homozygous for alleles A′, B′, C′ and has white seeds. The F_1 has intermediate-colored seeds, and in the F_2, there is wide variation. If seed color depends on the number of alleles inherited from one or the other parent, as shown here, then the 64 different F_2 genotypes show seven different average phenotypes; in practice, this would appear virtually continuous. We discuss this kind of variation in detail in Chapter 14.

1.32 redrawn from Nilsson-Ehle H. 1914 Vilka erfarenheter hava hittills vunnits rörande möjligheten av växters

Continuous traits and the gap between mendelists and darwinists (biometrics)

Additive interaction of genes can lead to continuous variation in the phenotype

Among many ground-breaking discoveries in genetics, the T.H. Morgans "fly-room" also showed the existence of many mutations with mild effect. Together with the understanding of additive interaction between genes it paved the way to reconcile genetics and darwinism.

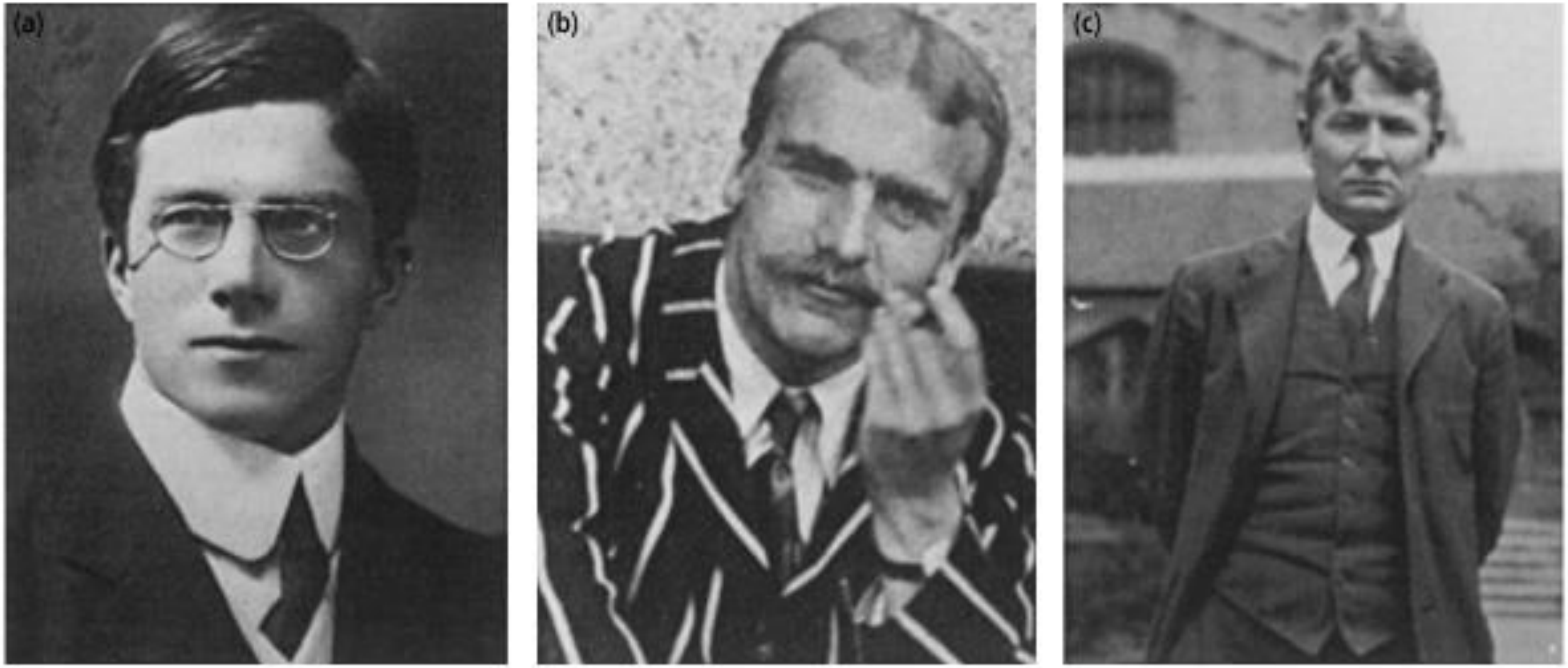
Thomas Hunt Morgan

Linkage groups; chromosomes, sex chromosomes etc.

Neo-Darwinism: 1920-1937, in the "west"

Synthesis of Mendel's theory of inheritance and Darwins theory of natural selection into a coherent evolutionary theory

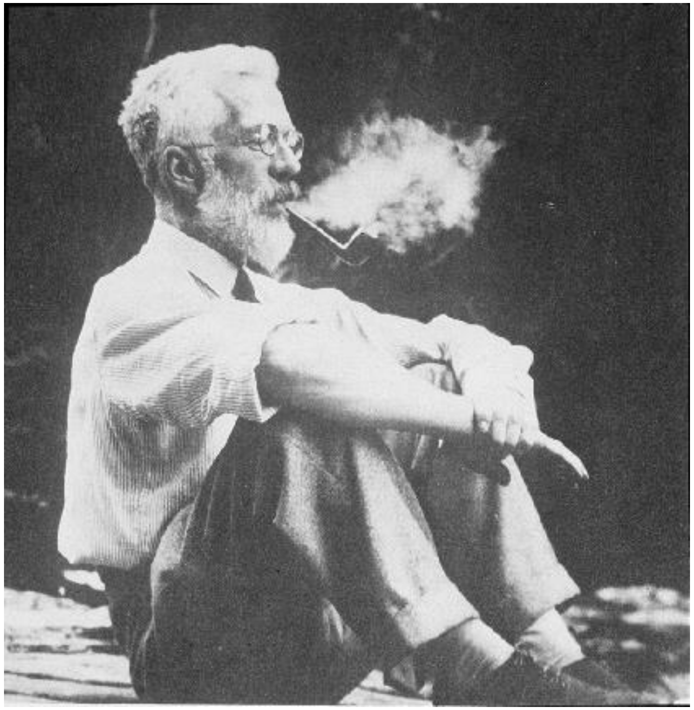
Ronald Aylmer Fisher — J.B.S. Haldane — Sewall Wright



statistician — biochemist — mathematical biologist /geneticist

Figure 1.8
(a) Ronald Aylmer Fisher (1890–1962) in 1912, as a Steward at the First International Eugenics Conference.
(b) J.B.S. Haldane (1892–1964) in Oxford, UK in 1914.
(c) Sewall Wright (1889–1988) in 1928 at the University of Chicago.

History of Evolutionary Biology. The modern synthesis; neo-Darwinian synthesis



R.A. Fisher (1918) showed mathematically how inheritance of continous traits can be explained within the framework of Mendelian inheritance if one takes into account the additive interaction of genes

- He founded Quantitative Genetics

Mendel's laws give based to the statistical correlations between phenotypic characters between parents and offspring

He showed how the variance and correlation of phenotypic traits between relatives can be used to tease apart the genetic and environmental components and how to distinguish, within the genetic component the additive, dominance and epistatic components.

He developed a widely used method in statistics - analysis of variance.
https://en.wikipedia.org/wiki/Analysis_of_variance

Neo-Darwinism: 1920-1937, in the "west"

Ronald Aylmer Fisher	J.B.S. Haldane	Sewall Wright
Genetical Theory of Natural Selection (1930)	The Causes of Evolution (1932)	Evolution in Mendelian Populations (1931)
How natural selection gradually changes a population through allele frequency changes in many loci, each with a minor effect.	Natural selection in a Mendelian system. Showed mathematically how (strong) natural selection will change the allele frequencies at one or a few loci with Mendelian inheritance.	Inbreeding, random genetic drift. Shifting balance theory – natural selection works faster if the population is structured into many smaller subpopulations.

Neo-Darwinism in Russia: was developing fine and had quite good working contacts with scientists in Europe and USA. One of the more lasting contributions was studying natural (rather than lab) populations (this is a grouse oversimplification!)

Sergei Tšetverikov (1880-1959) Waves of Life, 1905
О некоторых моментах эволюционного процесса с точки зрения современной генетики, 1926

- Studied populations of butterflies, invertebrates and Drosophila
- Showed that in natural populations lots of variability is hidden in heterozygous state (1926). Mutational processes are similar in nature and in the lab but in the former populations are closer to panmictic.
- Teacher of T. Dobzhanski

Aleksandr Serebrovski (1892-1948)
Studied animal genetics (linkage) in Moscow (chicken, Drosophila). Coined terms genofond (gene pool), genetic analysis, genogeography. His pioneering work in population genetics and evolutionary theory synthesized Darwinism and genetics, anticipating in important respects the evolutionary synthesis of the 1930's and 1940's

Neo-Darwinism in Russia basically ended in 1948 when Trofim Lysenko and his followers overtook the genetics and especially agricultural genetics (animal breeding etc.) scene. There were no scientific arguments but in a totalitarian society one only needed “ideological” arguments. All the geneticist were called facists and many were executed.

The pseudo-scientific ideas of Lysenkoism built on neoLamarckian concepts of the heritability of acquired characteristics. Lysenko's theory rejected Mendelian inheritance and the concept of the "gene"; it departed from Darwinian evolutionary theory by rejecting natural selection.

https://en.wikipedia.org/wiki/Lysenkoism

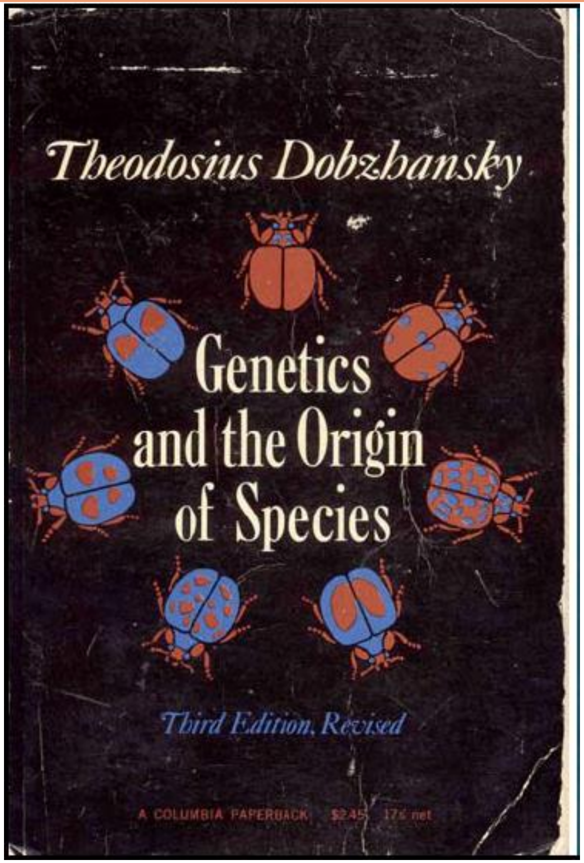
На совещании передовиков урожайности по зерну, трактористов и машинистов молотилок с руководителями партии и правительства. Товарищи **Сталин, Андреев, Микоян** и **Косиор** слушают речь академика **Т. Д. Лысенко.**

Снимок сделан в Кремле 29 декабря 1935 года.

Theodosius Dobzhansky (1900-1975)

"Nothing in Biology Makes Sense Except in the Light of Evolution",

Unites the theoretical neo-Darwinian synthesis with the study of genetics in natural populations. From this formulates what is a species and how they are created.

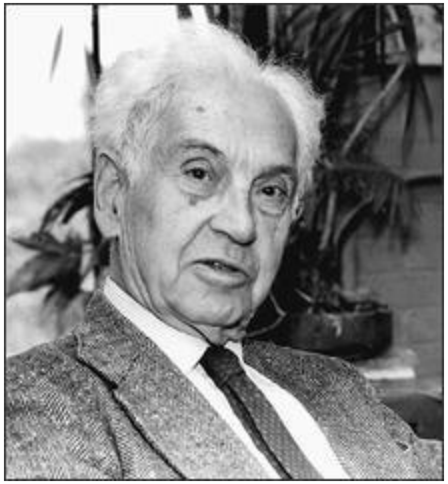


1937-1970

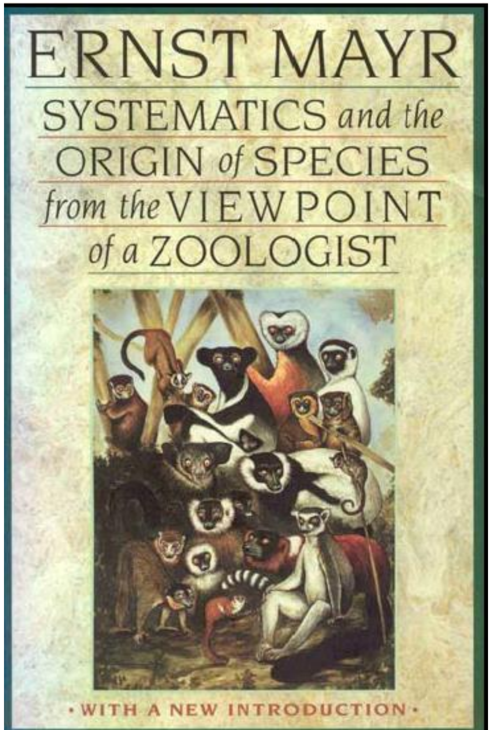
http://www.usfca.edu/fac-staff/dever/Dobzhansky_light.pdf

Systematics

Formulated the biological species concept to replace typological species concept. A species is defined through ability to interbreed and produce viable offspring.

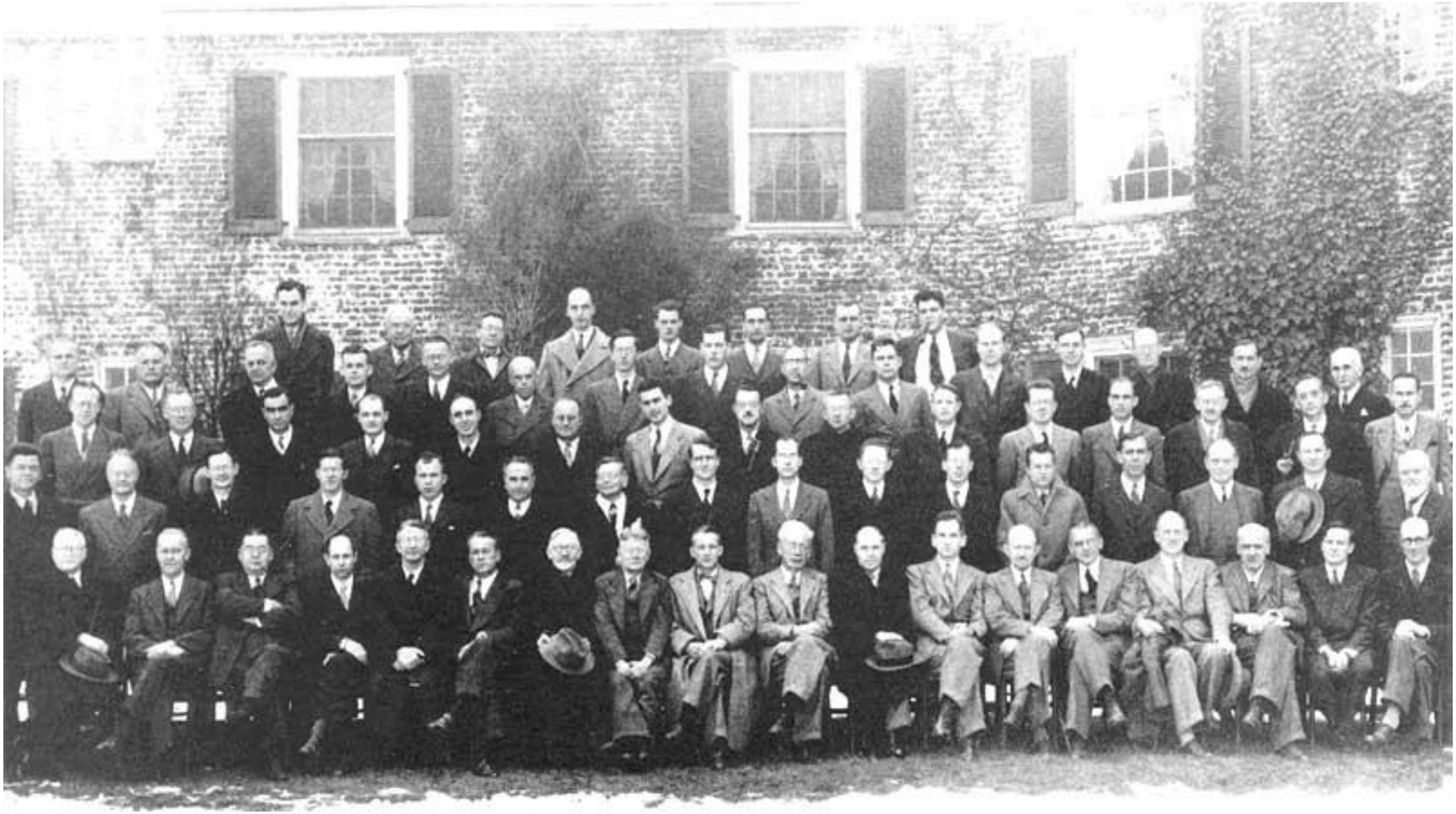


Ernst Mayr
1904-2005



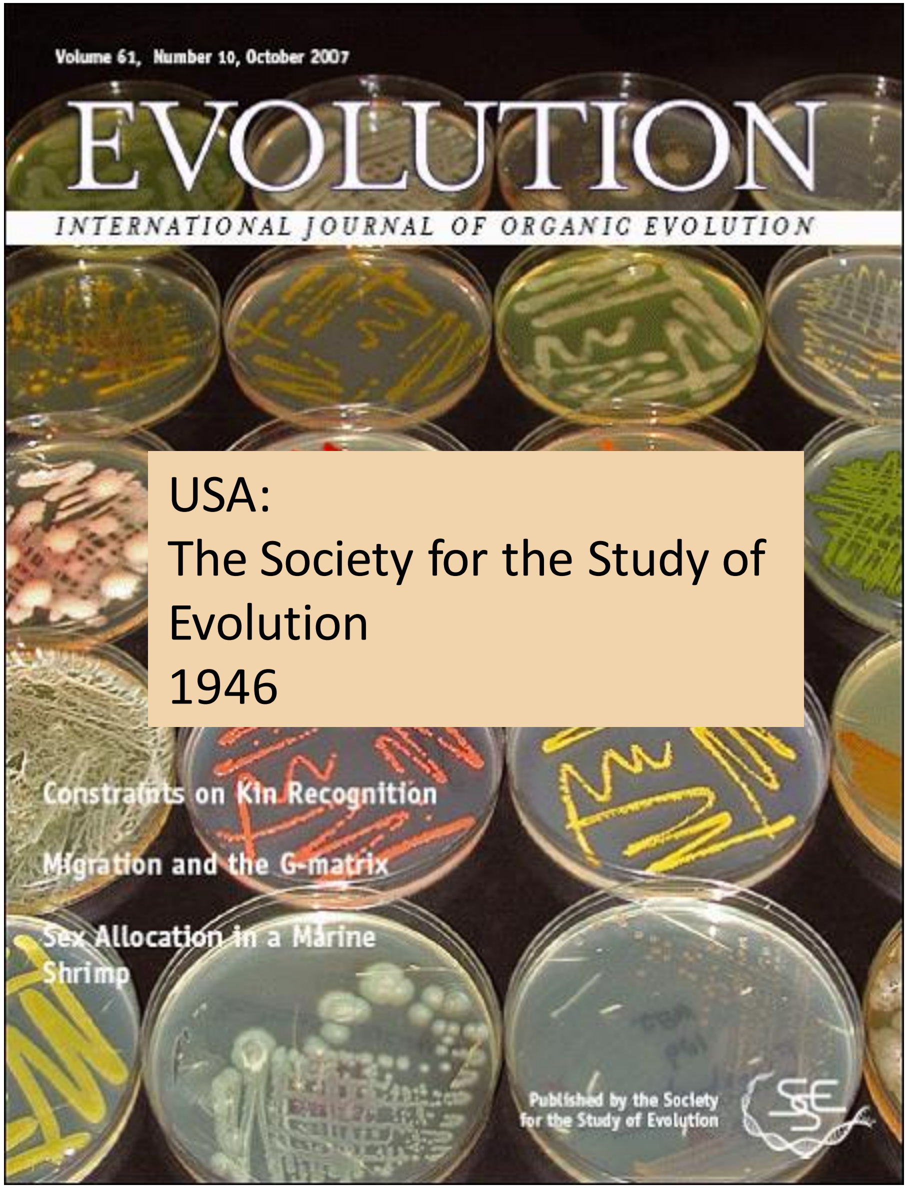
1942

Allopatric and parapatric speciation

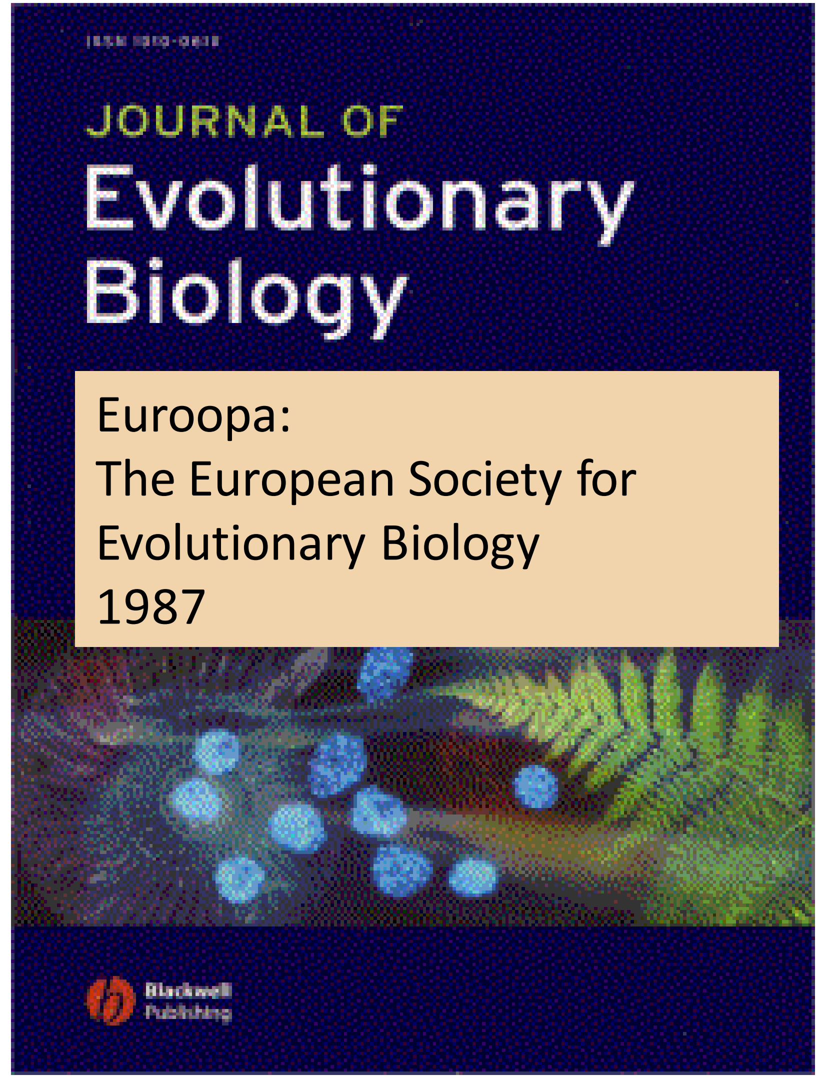


1947 Princeton

History of Evolutionary Biology. Acceptance of neo-Darwinian synthesis 1937-1947



USA:
The Society for the Study of Evolution
1946



Euroopa:
The European Society for Evolutionary Biology
1987

History of Evolutionary Biology. Acceptance of neo-Darwinian synthesis 1937-1947

Synthesis of Mendelian genetic and Darwinian natural selection

- Genetic variation is passed on through generations it does not erode or get blended
- Environment cannot trigger specific changes in genes. Acquired traits do not get inherited
- The constant renewal of variation through mutations which are random in terms of fitness

Adaptations arise only through natural selection

- Several processes/mechanisms are responsible for Evolutsion (mutation, drift, migration, natural selection). But only natural selection produces adaptations
- Even very minute differences can be selectively advantageous or disadvantageous and on very weak selection can lead to big differences over a long time.

Pisut evolutsiooni mõistmisest.

TABLE 2.1. *Understanding of Evolution*

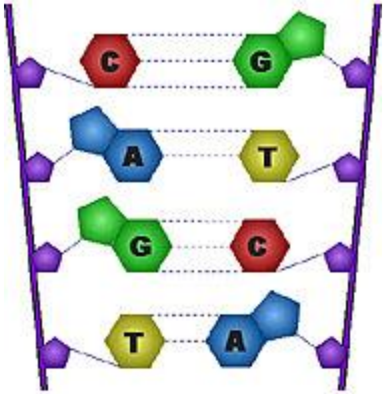
Criterion	Popular Ideas	Evolutionary Biology
Definition of evolution	Speciation	Change in traits of populations over generations
Most common form of evolution	Speciation	Changes in populations short of speciation
Reason for speciation	Goal of evolution	One outcome of evolution, which has no goal
Direction of evolution	Toward speciation	Multiple, changing directions
Time required for evolution	Long (thousands or millions of years)	Long or short (hours for bacteria)
Cause of evolution	Natural selection only	Anything that influences traits of populations over generations, including natural selection, sexual selection, methodical selection, unconscious selection, sampling effects, genetic engineering

Pisut evolutsiooni mõistmisest.

TABLE 2.1. *Understanding of Evolution*

Criterion	Popular Ideas	Evolutionary Biology
Role of people in evolution	None – we cause artificial selection, not natural selection	Important because we affect traits of many populations over generations
Composition of species	Unitary	Made up of populations with overlapping genes and traits
Options people create for species	Survive in same form or go extinct	Survive in same form, evolve, or go extinct
Extinction	Only species can go extinct	Any population can go extinct
Status of evolution today	Largely complete	Continuing (no more complete or incomplete than other periods)

Note: Not everyone thinks of evolution the same way as evolutionary biologists. This table highlights some of the most common differences. This book builds its arguments on the ideas in the evolutionary biology column.



Motoo Kimura
1924-1994

On the molecular level one can observe evolution – decent with modification – either by looking at DNA or protein sequence differences over generations

The interplay between drift and selection at the molecular level – in molecular evolution.

The Neutral Theory of Molecular evolution

The main driving force behind developing the Neutral Theory of Molecular Evolution (NTME) was the advancement in getting data on variation on the molecular level – two-dimensional electrophoresis.
This is not yet protein sequencing but just differentiating them by electric charge and size.

1968
Nature

Evolutionary Rate at the Molecular Level

by
MOTOO KIMURA

National Institute of Genetics,
Mishima, Japan

Calculating the rate of evolution in terms of nucleotide substitutions seems to give a value so high that many of the mutations involved must be neutral ones.

NATURE, VOL. 217, FEBRUARY 17, 1968

1969
Science

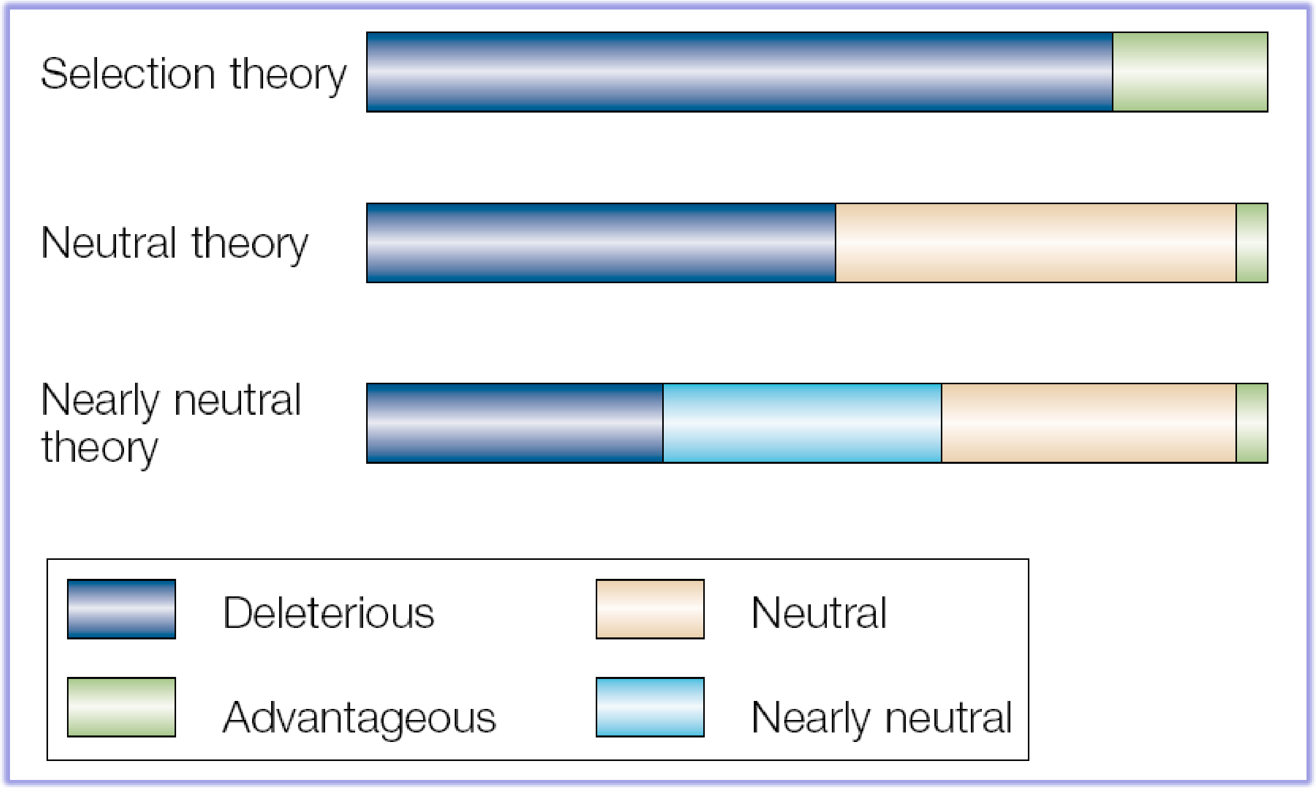
Non-Darwinian Evolution

Most evolutionary change in proteins may be due to neutral mutations and genetic drift.

Jack Lester King and Thomas H. Jukes

The Neutral Theory of Molecular evolution

Neutral and selectionist model differ in the relationship of beneficial and netural chanes in molecular level.
Neutralists do not negate the evolution of adaptions through selection!



The Neutral Theory of Molecular Evolution

The three main ideas of Kimura and King & Jukes in favour of NTME:

1. The overall speed of evolution and level of diversity are both too high to be explained only by natural selection
2. Molecular clock – the speed of evolution seems constant
3. Greater functional constraint leads to slower evolution

The Neutral Theory of Molecular Evolution – initial ideas

Neo-Darwinistic evolutionary theory says about the rate of evolution and the retention of diversity (polymorphisms) in the population.

- In order for the beneficial mutations to be fixed the individuals carrying other alleles must die – this gives the rate limit to evolution (genetic load, cost of NS).

- The only mechanism that was thought to **retain** the variation within the population was *heterozygote advantage* (with lesser fitness of homozygotes) that puts a similar upper limit to the genetic diversity of the population.

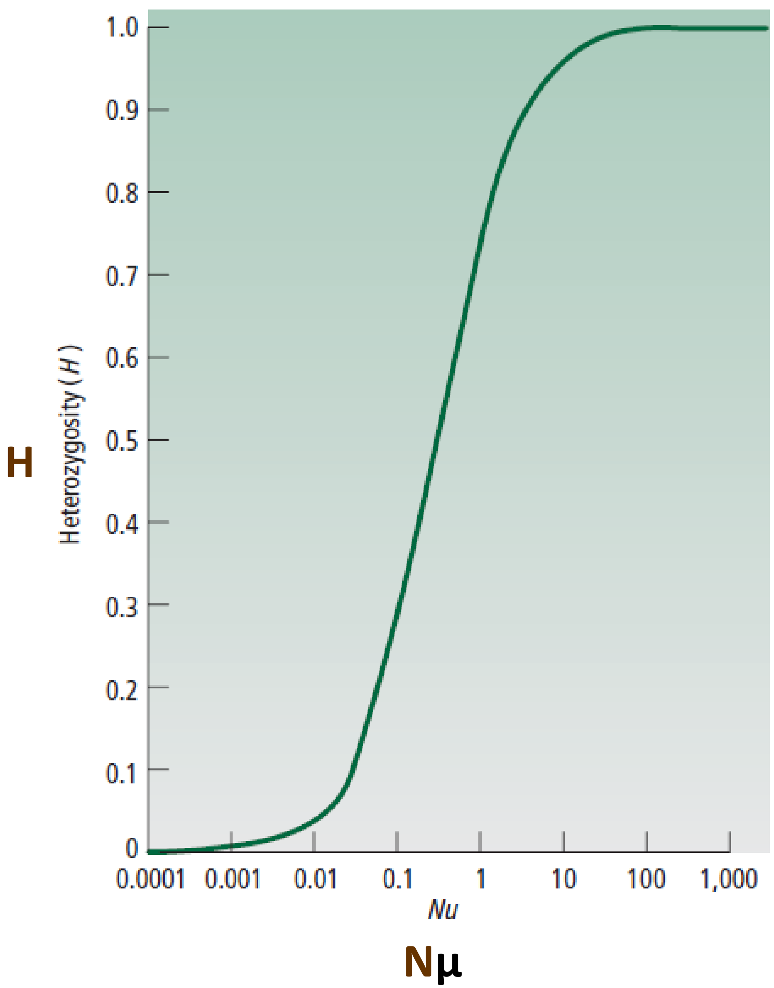
The Neutral Theory of Molecular Evolution – Kimura explains

The mutation rate and variability are too high

The experimental results from protein sequences done in 1960-s gave much higher evolutionary rate and much more genetic variation than the contemporary understanding based only on natural selection allowed for.

Kimura had a simple solution: „Most of the mutations must be neutral"

The Neutral Theory of Molecular Evolution – Kimura explains



Kimura: no problem if most of the Polymorphisms are neutral.

Heterozygotes are transient because of the mutational process.
There are two important factors in retaining the heterozygosity:
Mutation rate **μ and also** *population size***.**

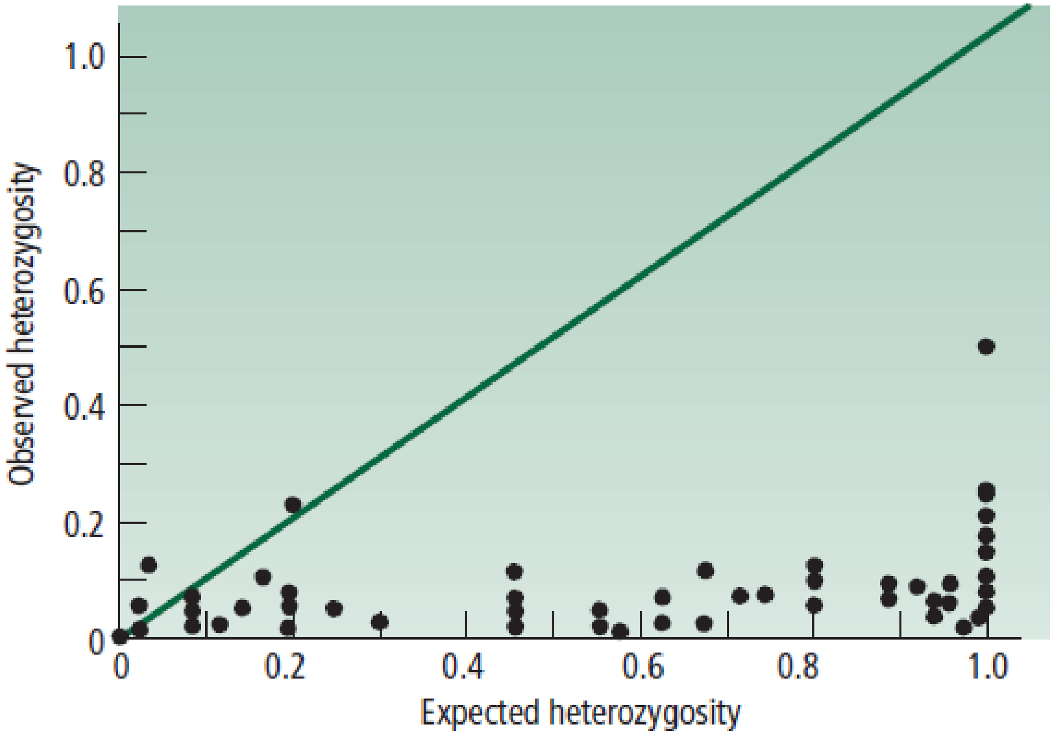
$$H^* = \frac{4N\mu}{4N\mu + 1}$$

The Neutral Theory of Molecular Evolution – Kimura's problem

COUNTERARGUMENT

$$H^* = \frac{4N\mu}{4N\mu + 1}$$

Within populations the larger populations have less heterozygozity (H) than assumed by the neutral theory. **μ–mut.rate**



Expected heterozygosity in two populations:
$\mu=10^{-3}$; $N_1=10$ or $N_2=1000$

$$H_1 = \frac{4*10*10^{-3}}{1+ 4*10*10^{-3}} = 0{,}038$$

$$H_2 = \frac{4*1000*10^{-3}}{1+ 4*1000*10^{-3}} = 0{,}8$$

Figure 7.5
Observed levels of genetic variation (measured as heterozygosities) are too constant between different species, with different population sizes, than the netural theory predicts. Each point gives the observed heterozygosity (*y*-axis) for a species (total 77 species), plotted against the "expected" heterozygosity from estimates of the population size and generation length of the species and assuming a neutral mutation rate of 10^{-7} per generation. Species with large population sizes appear to have too little genetic variation, relative to the neutral theory's prediction. Redrawn, by permission of the publisher, from Gillespie (1991).

Nevertheless, the observed heterozygosity does not go too high, regardless of large population size (N).

The Neutral Theory of Molecular Evolution – Kimura's problem

Kimura:
Variation & mutation rate are too large because these would result in a too high genetic load, price of NS and load of segregation.

It turned out that selection is rather "*Soft*" than "*Hard*" (acts upon additional fertility), it takes the costs of genetic load and NS down.
The fitness of genes in different loci is often not multiplicative and heterozygous advantage (over-dominance) is not the only selection that retains the polymorphisms.
The general heterozygosity is lower than the NTME predicts.

Thus, the paradox of the too high price of the NS and too high variation are not the best arguments to support the neutral theory of molecular evolution.

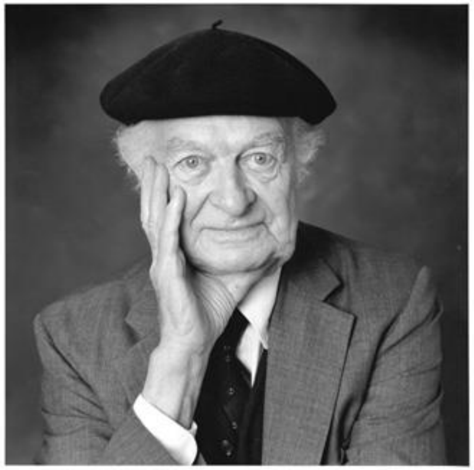
The Neutral Theory of Molecular Evolution
– initial ideas

The three main ideas of Kimura and King & Jukes in favour of NTME:

1. The overall speed of evolution and level of diversity are both too high to be explained only by natural selection
2. Molecular clock – the speed of evolution seems constant
3. Greater functional constraint leads to slower evolution

Molecular clock – 1962 – the first description of the idea

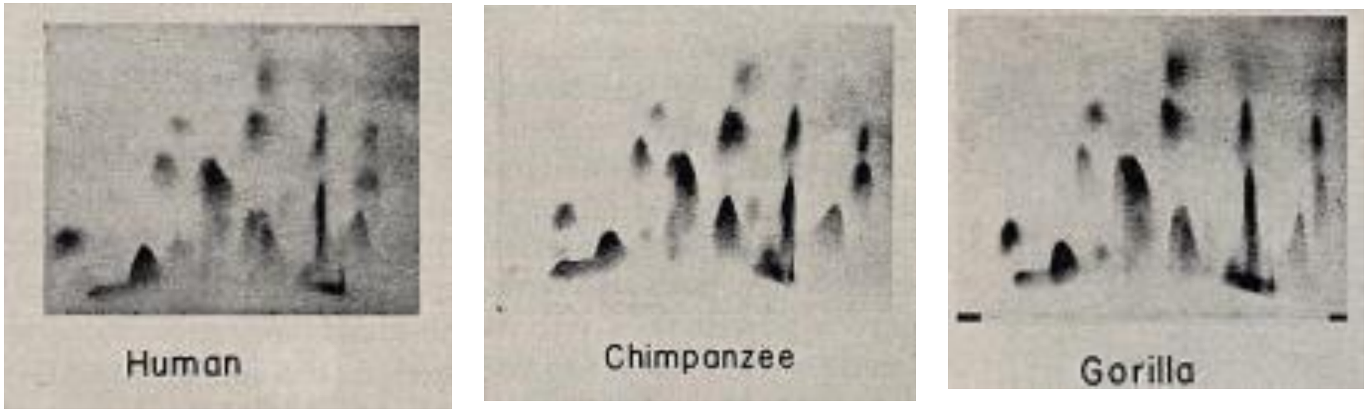
(1922-2013)

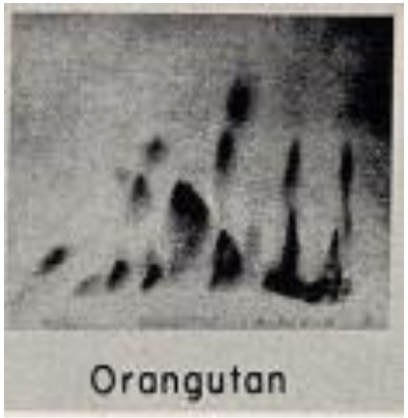


(1901-1994)

1965 **E. Zuckerkandl and L. Pauling – term "molecular clock"**

Comparison of hemoglobins of different species:





Number of differeneces in the amino acids

Time of divergence

Molecular clock – presentation of the hypothesis 1962, 1965

1965 E. Zuckerkandl and L. Pauling – **molecular clock**

Comparison of hemoglobins of different species:

The evolutionary rate of a protein is nearly the same within different evolutionary lineages!

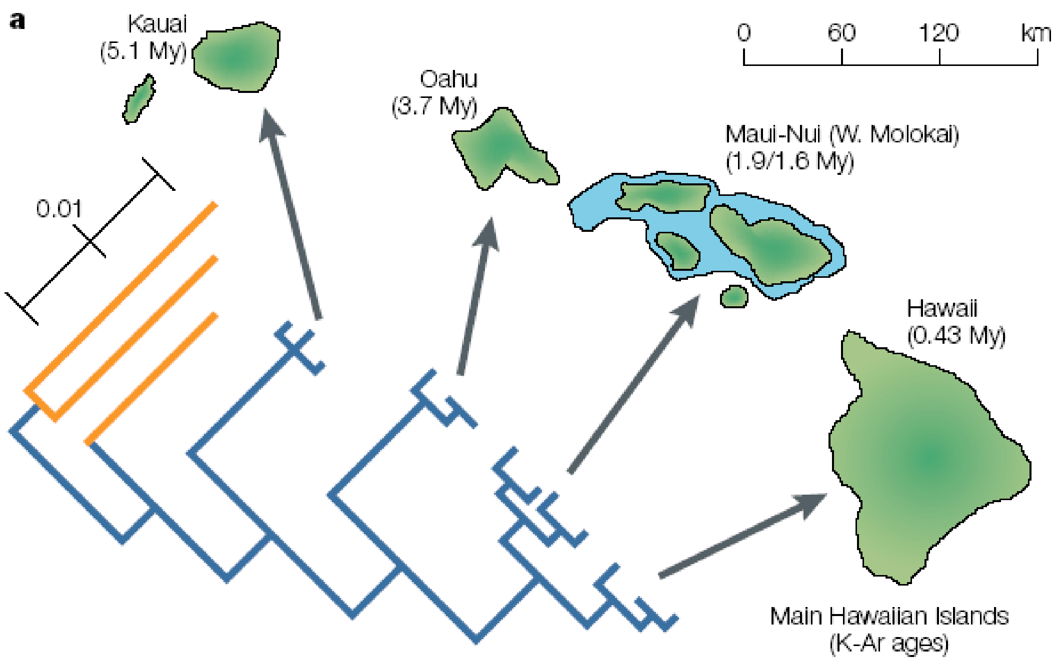
Immense potential for the reconstruction of splits and phylogenetic relationships between species.

	Number of AA differences	Time of divergence
Human – mouse	16	70 mya
Human – bird	35	270 mya
Human – frog	62	350 mya
Human – shark	80	450 mya

1 substitution per

11 – 18 M years

Molecular clock – and example from Hawaii



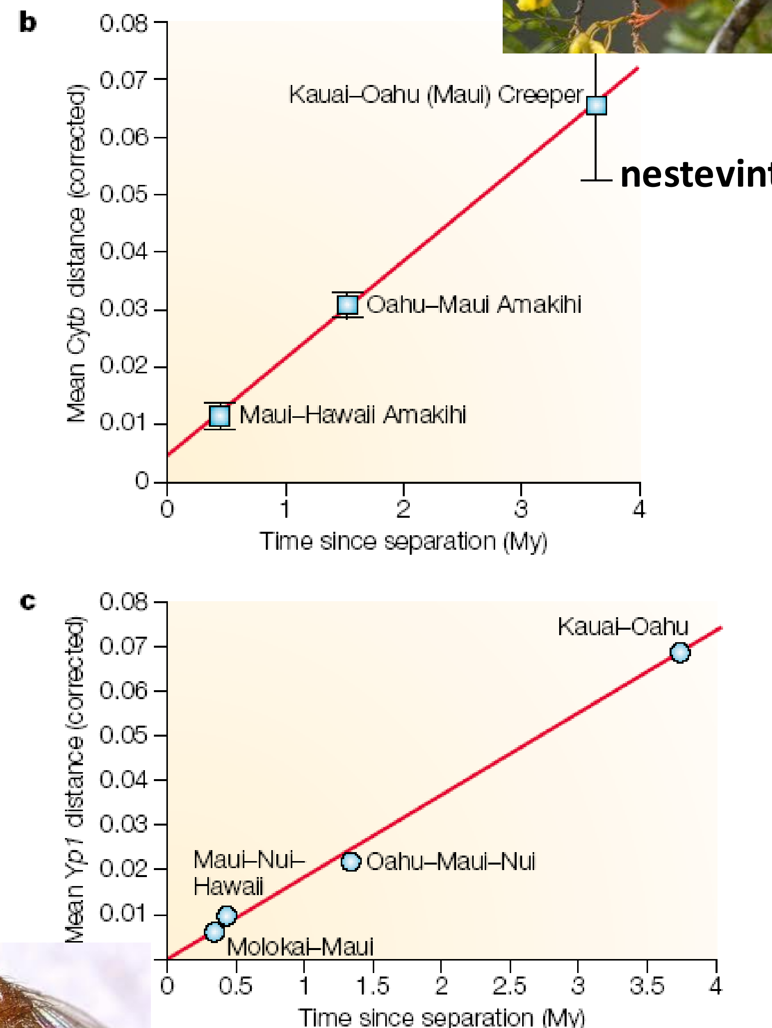
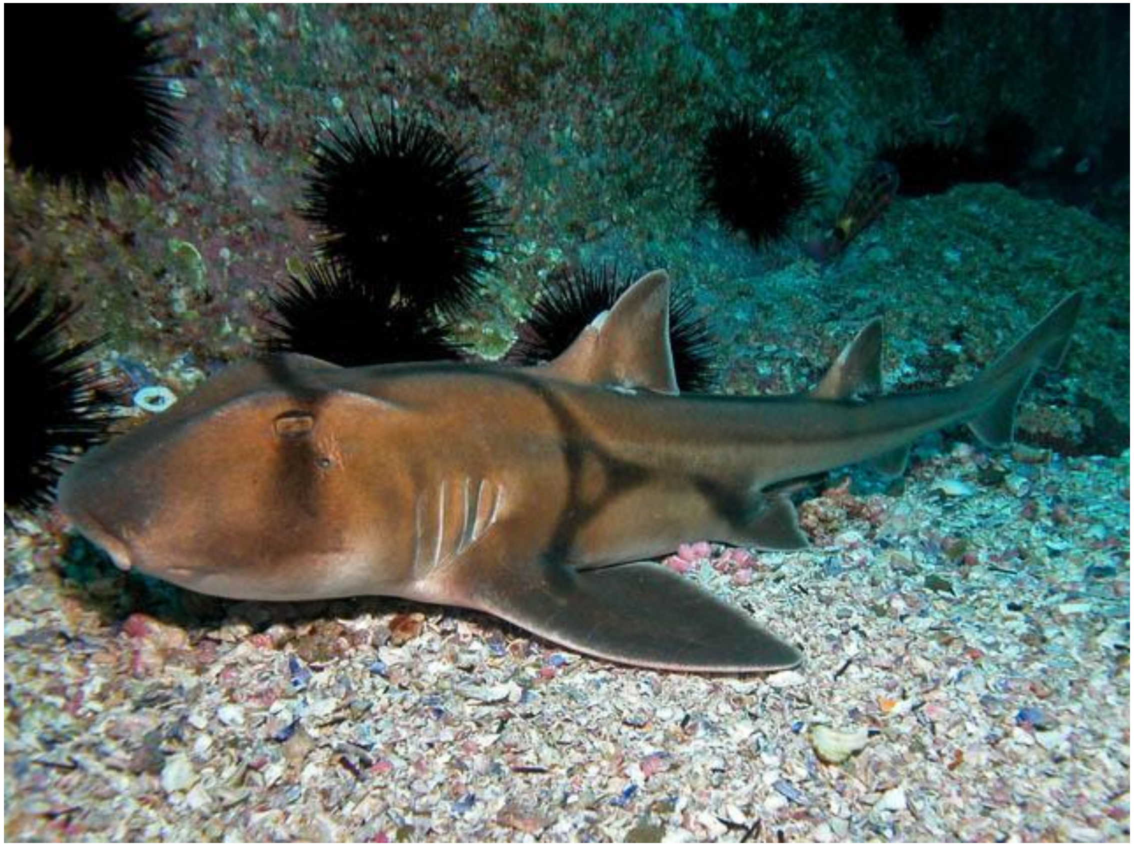


Figure 2 | **A molecular clock for the Hawaiian islands. a** | The volcanic origin of the Hawaiian islands has produced a chain of islands of increasing geological age. The phylogenetic relationships of island endemic birds (for example, the drepananine (honeycreeper) species such as the amakihi, *Hemignathus virens* and the akiapolaau *Hemignathus wilsoni*, shown in the tree) and fruitflies (*Drosophila* spp.) reflect this volcanic 'conveyer belt', with the species of the oldest islands forming the deepest branch of the tree, and the younger islands on the tips of the tree. Orange lines represent the outgroups. **b,c** | Molecular dates for *Hemignathus* (panel **b**) and *Drosophila* (panel **c**) confirm this order of colonization, and produce a remarkably linear relationship between genetic divergence and time when DNA distance is plotted against island age. My, million years. Fig reproduced with permission from REF. 10 © (1998) Blackwell Publishing.

Molekular clock – different from the rate of phenotypic

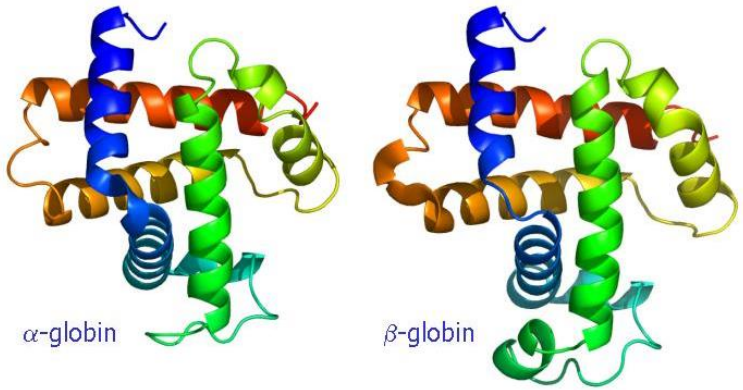
Molecular clock is constant, which is different from the heterogeneous morphological clock that is based on the non-random selection process.



***Heterodontus portusjacksoni*, "living fossil", similar to the 300 million year old fossils**

Molekular clock – difference from the rate of *functional change*

	Difference in aminoacids
Human α vs β globin	147
Carp α vs human β globin	149
Shark α vs β globiin	150



Thus, regardless of the hindering of the morphological evolution in the shark lineage the molecular evolution has not stood still.

Molecular clock – presentation of the hypothesis 1962, 1965

Molecular clock

1965 **Emile Zuckerkandl ja Linus Pauling**

Classical synthetic evolutionary theory thought of polymorphisms as *stable.* Kimura says that polymorphism is a *transient* phase in the molecular evolutions.

According to the neutral theory the main force in MOLECULAR evolution is not NS but mutation and drift.
During long time periods the *cumulation rate* of fixed substitutions equates to the appearance of neutral mutations because deleterious mutations are eliminated and beneficial ones have a marginal ratio. This provides us the clock.

Molekular clock – “ticking” rate

Molekular clock: does it tick in the real time or generation time?

Darwinian explanation: better accordance with real time, because selection acts through environment in real time.

Molekular clock – “ticking” rate

FIrst, what causes mutations?

- **UV radiation and chemical mutagnes.** **(main oppinion on 20th cen)**

  Clock ticks in real time
- **Mutations appear during meioses.**

  Clock ticks in generation time.
- **Mutatsios appear during replication.** **(main oppin. by the end of 20th cen)**

  Generation time *affects* the ticking of the clock

(The number of mitoses from gamete to gamete is important. The species with longer generations have more of them, but this does not compensate for the difference in the length of generations.)

Molekular clock – generation times and substitutions

The human generation time is 30 y and in every generation there is in average from gamete to the gamete (there is difference between genders) 230 replications.

The generation time of rats is 1 y and every generation has 43 replications from gamete to gamete.

Thus, there number of replicatons, in real time:

Human: 3*230=690
Rat: 90*43= 3870

The ratio of generations is 30/1

Replication ratio from gamete to gamete is 5/1

Clock has the generation effect (it does not tick in generation nor real time).

How does the clock really tick? What does the data show?

1977, comparing proteins it was found that clock ticks rather in absolute time!

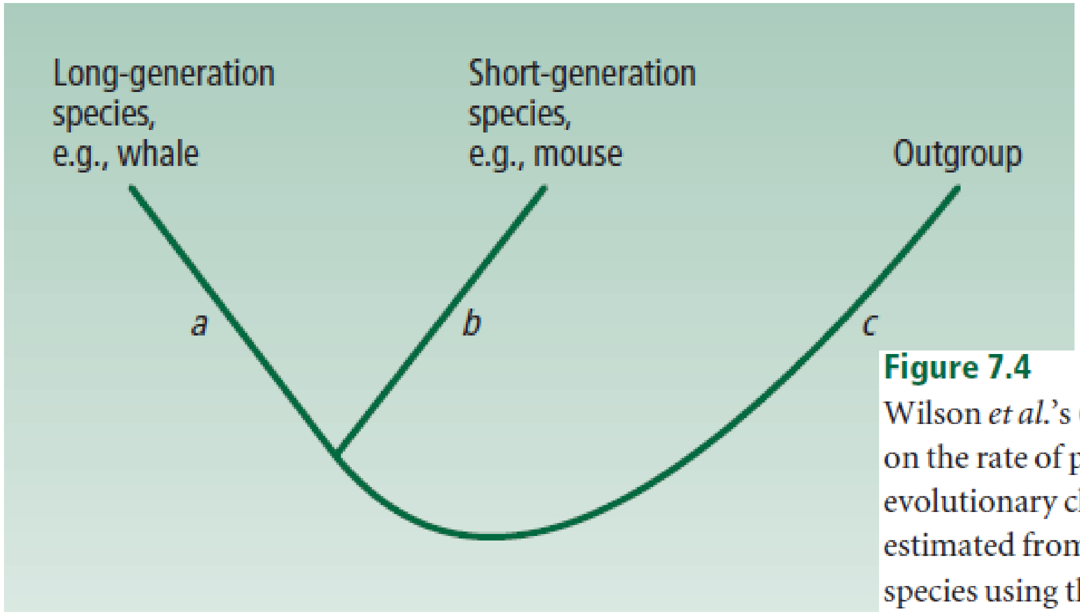


Figure 7.4
Wilson *et al.*'s (1977) method to test for a generation time effect on the rate of protein evolution. *a*, *b*, and *c* are the numbers of evolutionary changes in the three segments of the tree; they are estimated from the pairwise molecular differences between the species using the method of Box 7.2. The "outgroup" can be any species known to have a more distant common ancestor with the pair of species being compared. The evidence suggests that $a \approx b$ for many molecules and species pairs, whereas *a* would be less than *b* if generation time influenced evolutionary rate.

Molekular clock – generation times and substitutions

DNA: **clock has generation effect in the synonymous positons.**

Table 7.4

Rates of evolution in silent base sites are faster in groups with shorter generation times. There are estimates for various pairs of species, and each estimate is an average for a number of proteins; the number of sites is the total number of base sites (for all proteins) that have been used to estimate the rate. The divergence times, which are in millions of years, are uncertain; a range of estimates (in parentheses) have been made. Modified from Li *et al*. (1987).

Species pairs	Number of proteins	Number of sites	Divergence	Rate ($\times 10^{-9}$ years)	Generation time
Primates					
Man vs chimp	7	921	7 (5–10)	1.3 (0.9–1.9)	Long
Man vs orang-utan	4	616	12 (10–16)	2 (1.5–2.4)	
Man vs OW monkey	8	998	25 (20–30)	2.2 (1.8–2.8)	
Artiodactyls					
Cow vs goat	3	297	17 (12–25)	4.2 (2.9–6)	Medium
Cow/sheep vs goat	3	1,027	55 (45–65)	3.5 (3.0–4.3)	
Rodents					
Mouse vs rat	24	3,886	15 (10–30)	7.9 (3.9–11.8)	Short

NMET – functional constrains in different gene regions

The three main ideas of Kimura and King & Jukes in favour of NTME:

1. The overall speed of evolution and level of diversity are <u>both too high</u> to be explained only by natural selection
2. Molecular clock – the speed of evolution seems constant
3. Greater functional constraint leads to slower evolution

NMET – functional constrains in different gene regions

When only NS would be responsible for the fixation of new alleles we should see faster evolution (more changes in time unit) in the “more important” regions of the genome (or proteins).

The reality is quite the contrary.

NMET – functional constrains in different gene regions

Functional constrains – AA level

Kimura , functional constrains – slower evolution

Fibrinopeptides

9 substitution per site per 10^9 years

The proteins that interact with other proteins evolve faster

900 x difference

0,01 substitution per site per 10^9 years

Histones

Histones are slow

- interact with DNA

Page & Holmes 1998

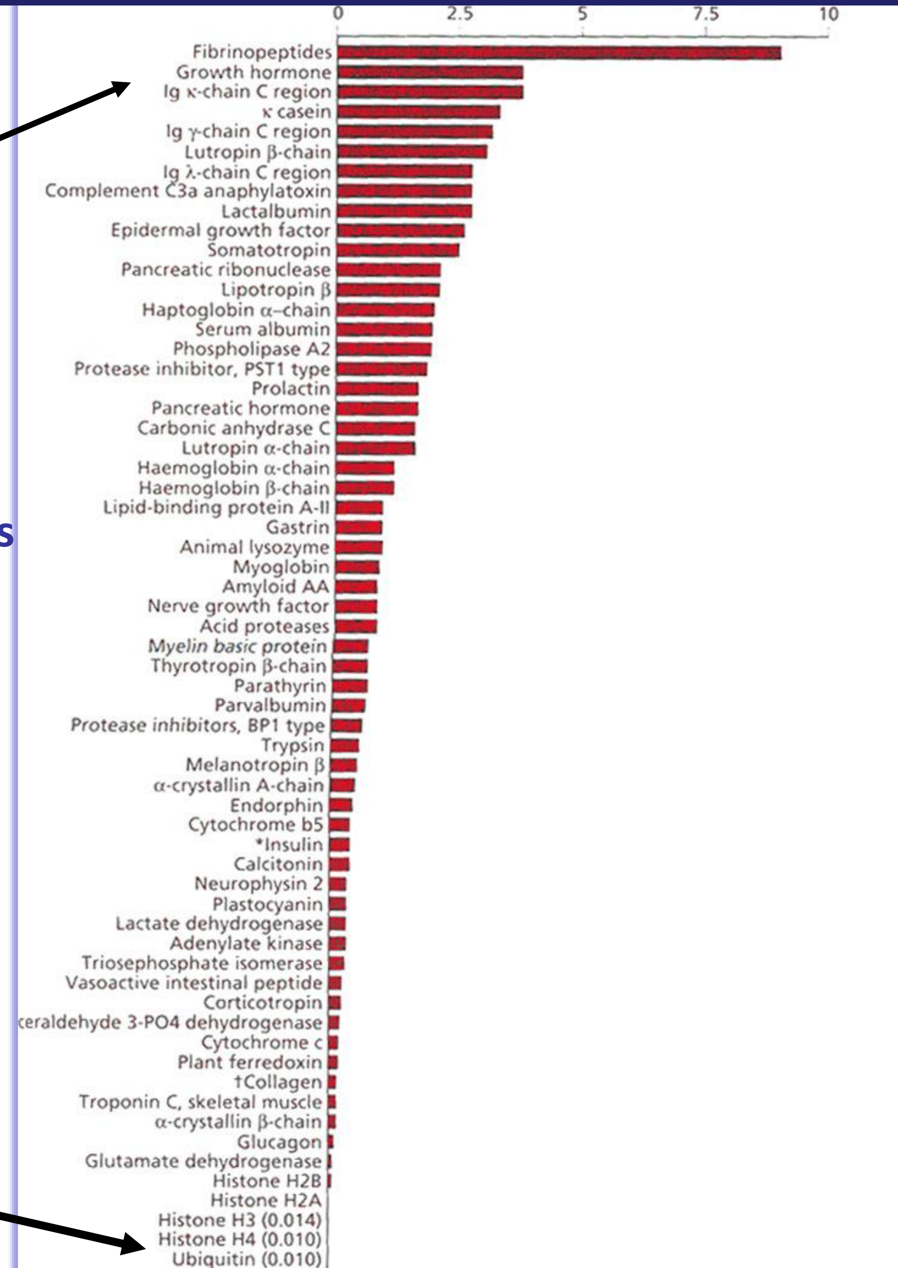


Fig. 7.4 Rates of amino acid substitution for various mammalian proteins. *Excluding guinea pig and coypu, the phylogenetic position of which has been debated (see section

NMET – functional constrains in different genes

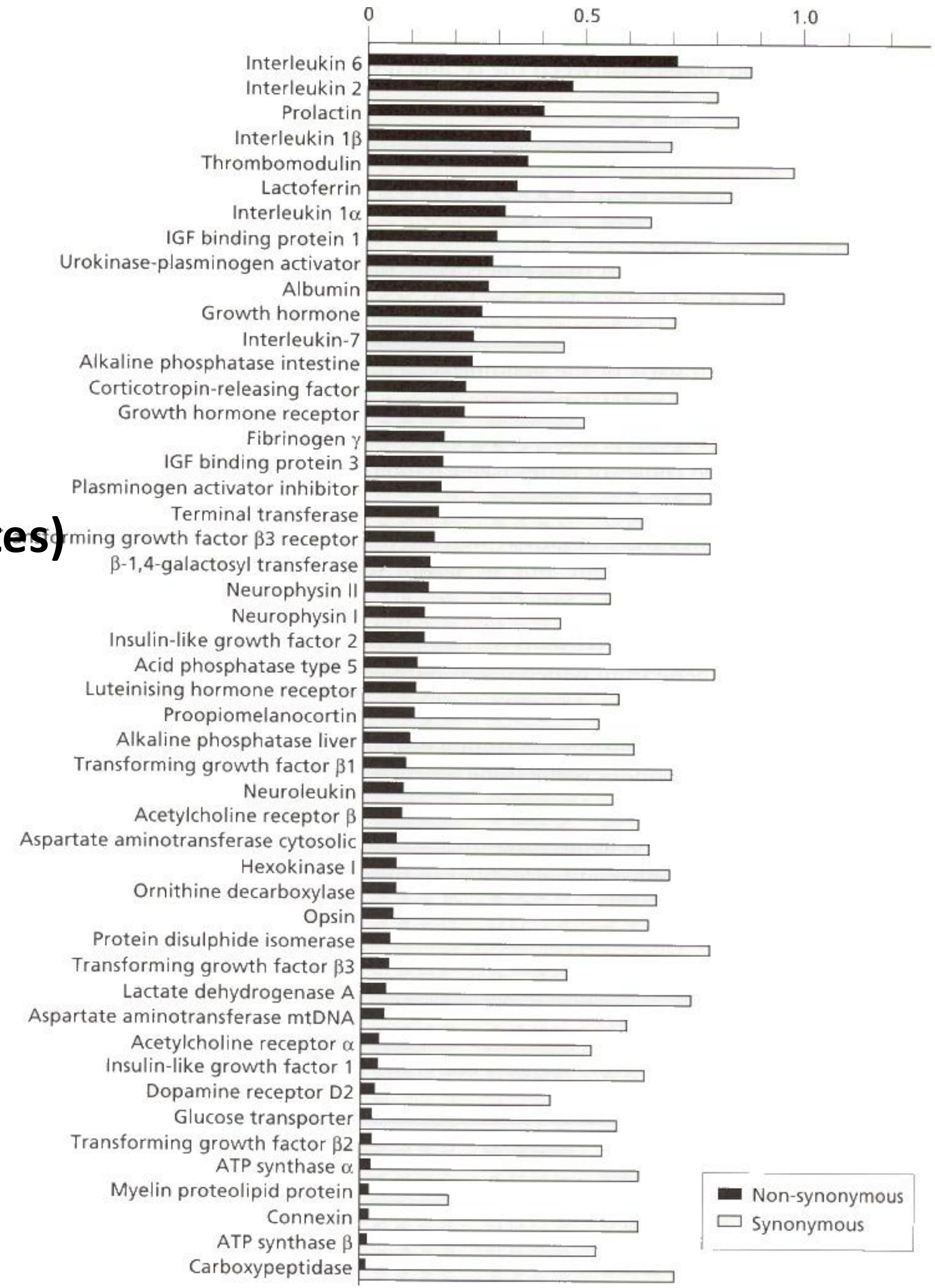
Functional constraints

Syn

Non-syn

49 genes

(combined primates, rodents and ungulates)



Page & Holmes 1998

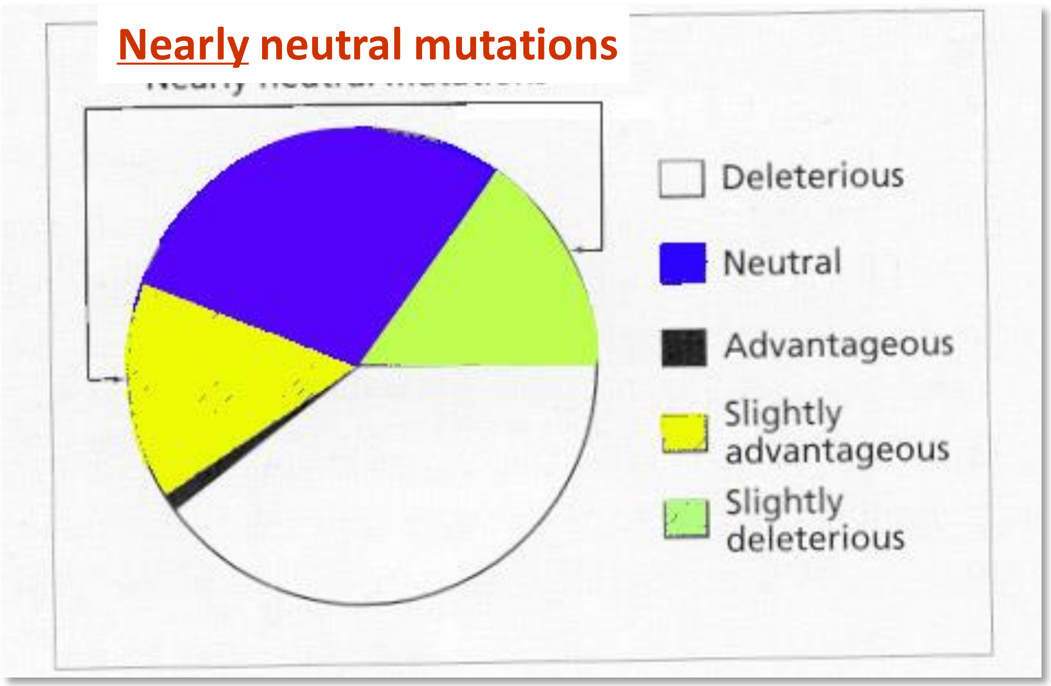
Results of discussion about Kimura's NMET arguments:

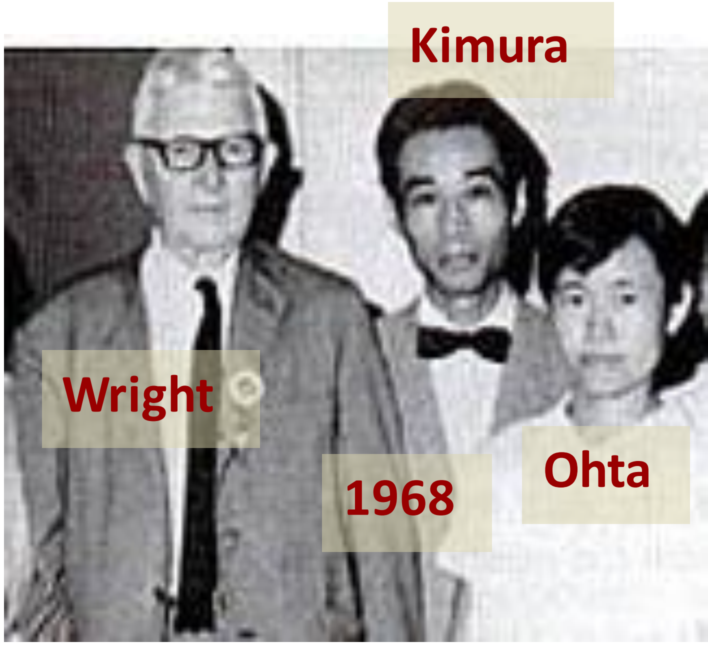
The three main ideas of Kimura and King & Jukes in favour of NTME:

1. The overall speed of evolution and level of diversity are <u>both too high</u> to be explained only by natural selection
2. Molecular clock – the speed of evolution seems constant
3. Greater functional constraint leads to slower evolution

First is weak, but the other two are acceptable.

Nearly Neutral Theory of Molecular Evolution





Listen to the presentation of Tomoko (>1h), how this idea came upon him: http://online.kitp.ucsb.edu/online/infobio01/ohta/

NNMET - nearly neutral molecular evoluton theory

Purely neutral theory had several draw-backs.

- **The generation effect was larger to the synonymous clock than to the non-synonymous clock.**
- **Molecular clock is not constant enough (it could be explained by the changing of the generation lenght in time).**
- **Heterozygosity in large populations is too small compared to the predictions by the neutral theory and in general too similar in different species.**
- **Gentetic diversity and evolutionary rate do not correlate like like the neutral theory predicts.**

NNMET - nearly neutral molecular evoluton theory

Tomko Ohta (Kimura's student) came out with the nearly neutral molecular evolution theory, where she brings in the slighlty beneficial and slightly deleterous mutations. When the theory of purely neutral evolution the size of the population was not important, then now it is.
In a small population where drift has stronger effect, the slightly beneficial mutations act *as neutral* and are affected by drift. In a larger population their fate is affected by selection.

NNMET - nearly neutral molecular evoluton theory

Nearly neutral theory provides solutions to Kimura's model:

Heterozygosity in large populations is too small compared to the predictions by the neutral theory and in general too similar in different species.

In large populations the slightly deleterious mutations are affected by selection and they are eliminated, so they do not contribute to the diversity.
In small populations they are drifting similarly to the neutral mutations.

NNMET - nearly neutral molecular evoluton theory

Nearly neutral theory provides solutions to Kimura’s model:

Clock is not constant enough

For the clock to oscillate it is enough when the <u>population sizes</u> are changing in. The same logic: when population size decreases, the ever bigger proportion of slightly deleterious mutations become as neutral and they can fixate, so the rate of evolution goes faster.

NNMET - nearly neutral molecular evoluton theory

Nearly neutral theory provides solutions to Kimura's model:

Presumption: the species with long generation time are usually with smaller population size

The generation effect is larger to the synonymous clock than to the non-synonymous clock

Within the species with long generation time:

a) **DNA is copied less times during a year, but**
b) **The smaller population sizes of these species make the slightly deleterious mutations act as neutral.**

Thus the clock is made slower by „a" (generation effect) and „b" speeds up the non-synonymous clock.

NNMET - testing neutrality

As of the early 2000s, the (nearly) neutral theory is widely used as a "null model" for so-called null hypothesis testing.

It is tested if the observed evolution follows the neutral model, when not then it is investigated, because processes that are under selection are thought more interesting.

Tests of neutrality

NT pressumes that the rate of fixation of mutations depends only on the mutation rate (molecular clock)

- Thus the fixation rate should be similar within species and between species

Fixated changes are a random sample of all mutations.

- **Thus the ratio of non-synonymous substitutions to the synonymous substituions should stay the same.**

“There is no single statistic which is best for testing the most general departures from neutrality” (Watterson 1977).
You have to know, what to look for!

NNMET - testing neutrality

dN – non-synonymous substitutions
dS – synonymous substitutions

dN/dS - small	(0.1 – 0.2)	purifying (negative) selection, non-synonymous substitutions are lost.
dN/dS - medium	(0.2 – 1)	Either positive selection or relaxations of purifying selection, not sure which.
dN/dS - large	(>1)	Positive selection - there are more non-synonymous substitutions

Example: in HLA loci dN/dS is positive

At the same time we have to consider the dynamics of homoplasy, - the probabiliy of hitting the same position increases through time, which takes to the saturation of synonymous substitutions.

summary

1. **Molecular evolution; random genetic drift**
2. **Neutral molecular evolution theory (Kimura) explained:**
   a) **The fast accumulation of mutations**
   b) **Molecular clock**
   c) **Dependencies from the functional constraints**
   d) **High level of polymorphisms in the natural populations**
3. **Nearly neutral molecular evolution thoery is looking at the relationship between drift and selection depending on the size of the population and solves the problems that arose with NMETist.**
4. **Syn/NonSyn and testing for selection**