What is speciation? Darwin and the "Origin of Species"

Today:

Introduction to course
Readings from Darwin 1859
The only diagram in the "Origin of Species"
The "Modern Synthesis"
… and now!

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https://canvas.harvard.edu/courses/142806
OEB 140 Speciation: how do species evolve?
Spring 2025 MW 10-11 Friday discussion section* 10-11
* or "field trips" to Harvard Museums

COURSE DETAILS
Instructor: James Mallet
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OEB 140 Speciation. Course description. https://canvas.harvard.edu/courses/142806
TIMETABLE
USEFUL BOOKS
Speciation is the part of evolutionary biology that deals with the emergence of distinct biological forms and biodiversity on our planet. …

This new course will survey modern ideas on speciation, and will include the following topics:
•History of ideas in speciation; pre-Darwin, Darwin & Wallace, 1930-1940s, recent.
•What are species? Species concepts and species delimitation.
•What is needed to understand speciation? The population genetics of gene flow, mutation, drift, and selection
•What is being selected? Genes? Individuals? Populations? Species? The "levels of selection" debate.
•The concept of reproductive isolation
•[Brief introduction to coalescent theory and the multi-species coalescent] (Maybe)
•The geography of speciation, including allopatric, parapatric, and sympatric speciation
•Ecological "races" and ecological speciation
•Behavioral divergence and mate choice, including "reinforcement"
•Hybrid inviability and hybrid sterility between species
•Idealized population genetic models of speciation
•Chromosomal evolution, genomic rearrangements, and speciation
•Speciation: Natural selection or genetic drift? Sympatry, Parapatry, Allopatry
•Beyond the species: macroevolution and diversification
•Applications in conservation and biodiversity

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Species topics

First: a little history.
Does speciation differ from "microevolution?"

- What are species? Species "concepts."
- How do species differ from each other?
- How many species are there?
- Species-level biodiversity.

} Next few sessions

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How do species evolve?

Early ideas: Greek philosophers, Lucretius etc.
Probably evolution was a hypothesis
e.g. species of mammals being obviously related

Puritanical Christians: God created species

Lamarck: French enlightenment, post Revolution
Had some ideas about evolution

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

Lamarck became an excellent taxonomist of both plants and marine animals.

Philosophie Zoologique (1809): "Thus, among living bodies, nature, as I have already said, definitely contains nothing but individuals which succeed one another by reproduction and spring from one another; …"

"Nevertheless, to facilitate the study and knowledge of so many different bodies it is useful to give the name of species to any collection of like individuals perpetuated by reproduction without change…"(p. 44)

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Lamarck's link between affinities & evolution

"The aim of a general arrangement of animals is not only to possess a convenient list for consulting, but it is more particularly to have an order in that list which represents as nearly as possible the actual order followed by nature in the production of animals; an order conspicuously indicated by the affinities which she has set between them."(p. 56)

"Meanwhile, I shall show that nature, ...has really formed a true scale in each of these kingdoms as regards the increasing complexity of organization..." (p. 58)

-- evolution explains the difficulty of defining species

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Lamarck's ideas

God was the creator: but he created according to fixed laws! Evolution is a demonstrable fact (via affinities).

Spontaneous origins of life

Progressive evolution from simple to complex

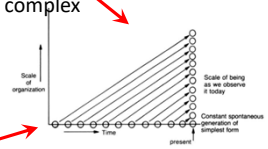

Fig. 10. Lamarck's Theory of Organic Progression.

Each point on the scale of being we observe today has been derived by progression from a separate act of spontaneous generation. The lower down the scale the organism is today, the more recently its first ancestor was produced. Thus, evolution is not a system of common descent but consists of separate lines progressing in parallel along the same hierarchy.

Bowler 1989

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Lamarck's ideas

But maybe not all progressive!

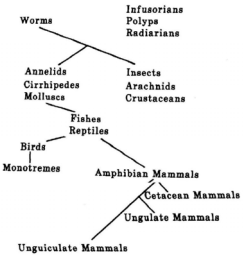
In a later addition, Lamarck added what looks very like a tree – i.e. branching

Philosophers argue that he still believed in linear evolution

Did not believe in extinction!

TABLE

SHOWING THE ORIGIN OF THE VARIOUS ANIMALS



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Lamarck's first and second laws

"FIRST LAW: In every animal which has not passed the limit of its development, **a more frequent and continuous use of any organ gradually strengthens, develops and enlarges that organ**, and gives it a power proportional to the length of time it has been so used; while the **permanent disuse of any organ imperceptibly weakens and deteriorates it,** and progressively diminishes its functional capacity, until it finally disappears.

SECOND LAW: **All the acquisitions or losses wrought by nature on individuals, through the influence of the environment** in which their race has long been placed, and hence through the influence of the predominant use or permanent disuse of any organ; all these **are preserved by reproduction to the new individuals which arise, provided that the acquired modifications are common to both sexes**, or at least to the individuals which produce the young."

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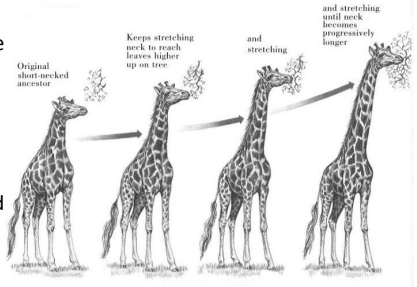
Lamarck:
What explains progressive evolution?
Inheritance of acquired characteristics

Fun fact: Lamarck married Julie Mallet – maybe my relative?



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Charles Lyell, geologist, 1797-1875

SIR CHARLES LYELL

Principles of Geology: Being an Attempt to Explain the Former Changes of the Earth's Surface, ***by Reference to Causes Now in Operation***. 3 vols. 1830-33

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Principles of Geology 1830

Lyell, taking his lead from earlier geologists, Hutton and his biographer Playfair, was an advocate of "uniformity" in science, labelled **"uniformitarianism"** by a contemporary philosopher (Whewell). Lyell argued that uniform patterns of causality are likely to act over long periods of time. Rapid, and cataclysmic changes in some parts of the world are not ruled out, but the majority of the total change over time has been achieved in many steps, according to laws of science still acting today.

Understanding of volcanic eruptions, sedimentation and sedimentary rocks had improved to make it clear that the earth was very old indeed, at least millions of years.

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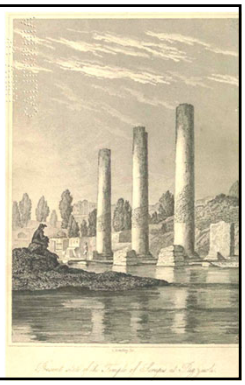
Principles of Geology 1830
Lyell's Frontispiece & quotation

"Amid all the revolutions of the globe the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same."

– Playfair, Illustrations of the Huttonian Theory, § 374.



Temple of Serapis, Pozzuoli, Italy

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Charles Lyell: God overruled uniformitarianism!

The fossil data therefore strongly implied that strict interpretations of the Bible and other creation stories were incorrect. The earth together with its millions of animals and plants could not have been created in seven days, 4004 BC.

Lyell read and carefully enumerated Lamarck's arguments in his book, but disagreed with evolution: by 1832 (in Vol 2, Ch. 8) Lyell proposed the following hypothesis for the origins, and spatial and temporal distribution of all of the many species of plants and animals:

"But without dwelling on the above and other refuted theories, let us inquire whether we can substitute some hypothesis …. The following may, perhaps, be reconcileable with known facts:—Each species may have had its origin in a single pair, or individual, where an individual was sufficient, and species may have been created in succession at such times and in such places as to enable them to multiply and endure for an appointed period, and occupy an appointed space on the globe."

Special creation!

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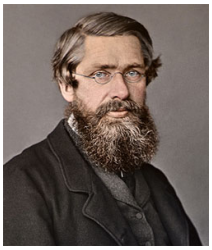
Alfred Russel Wallace 1823-1913



1844 Read "Vestiges of the Natural History of Creation," published anonymously by the journalist Robert Chambers (Lamarckian). Also read Lyell, Malthus.

1848 Collecting trip to the Amazon with his friend Henry Walter Bates "to help solve "the problem of the origin of species".

1852 Wallace shipwrecked on trip back to England, lost entire collection. (Bates stays in the Amazon for 8 more years, discovers mimicry).

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Alfred Russel Wallace 1823-1913

1854 Undaunted. Off to Indonesia, and New Guinea etc.

1858 Suffering malarial fever on Island of Ternate. A new theory! Natural selection. **Writes immediately to the famous: -- Charles Darwin.**

"I was suffering from a sharp attack of intermittent fever, and every day during the cold and succeeding hot fits had to lie down for several hours … . Then it suddenly flashed upon me that … *the fittest would survive*. … I became convinced that I had at length found the long-sought-for law of nature that solved the problem of the origin of species."

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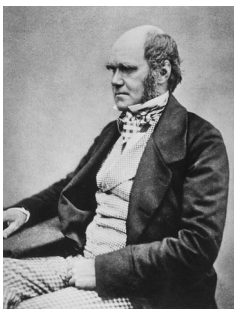
Charles Darwin 1809-1882

Naturalist, Voyage of the Beagle 1831-1836
1837: Starts notebook on origin of species
1838: Reads Malthus "An Essay on the Principle of Population"
1842: Sketch of theory of natural selection
1844: "Vestiges…" published by Chambers
Darwin writes books about geology. Then monograph on barnacles 1846-1854
1858: Letter from Wallace: natural selection independently discovered!



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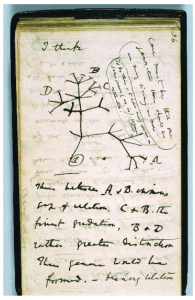
Darwin 1837 notebook

"I think

[diagram]

"Case must be that one generation then should be as many living as now. To do this & to have many species in same genus (as is) requires extinction.

"Thus between A & B immense gap of relation. C & B the finest gradation, B & D rather greater distinction. Thus genera would be formed. - bearing relation..." (page 36 ends - page 37 begins) "to ancient types with several extinct forms…"



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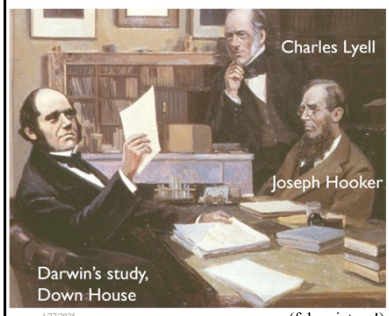
1858 Origin of species by natural selection



(fake picture!)

1858: Darwin receives Wallace's letter

Consults with friends Charles Lyell and Joseph Hooker

Publication of Wallace's paper is arranged, plus Darwin's earlier abstracts:

"On the Tendency of Species to form Varieties; and on the Perpetuation of Varieties and Species by Natural Means of Selection."

1859: On the Origin of Species ...

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Darwin's 1859 argument for origin of species

The struggle for existence: natural selection (microevolution)

- Population growth – "Geometric Increase" (Malthus)
- But population growth cannot continue for ever! Limits to growth
- Variation among individuals of a species
- Some individuals "fitter" than others – more offspring
- Variation can be inherited
- Therefore only the fitter variants will survive

Principle of divergence and speciation

- Extinctions evident from the fossil record
- Principle of divergence: intermediates are less fit, die out, extremes survive
- Divergence leads to branching pattern in the "great tree of life"

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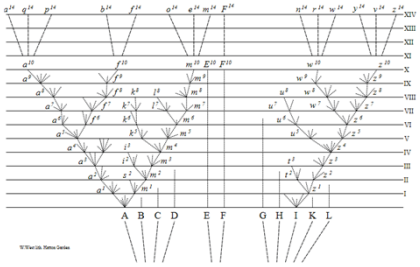
Darwin 1859 On the Origin of Species...

A long book – 500 pages. But it was "an abstract!"

He lightened up the book with only a single diagram!



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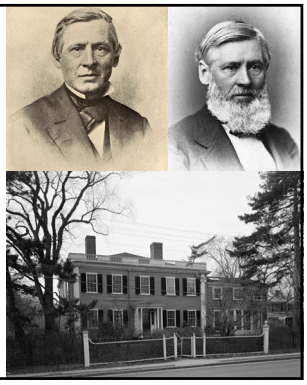
Asa Gray – Darwin's advocate in USA

- Believed in God
- But also supported evolution
- Lived in Cambridge, MA and founded the Herbaria at Harvard and a Botanical Garden (now buildings)
- Unfortunately, due to construction in the Herbaria we can not visit them as part of our "field trips" this year



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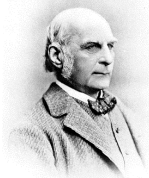
After Darwin



Francis Galton

The "eclipse of Darwinism"

After 1859 most people (scientists, anyway) convinced of evolution

But did not agree with natural selection being the cause

- Lamarckian use and disuse of parts
- Massive sports leading to new species, rather than gradualism

Also, Darwin's understanding of blending inheritance – "gemmules" - was wrong

"The Eclipse of Darwinism"

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Mendel rediscovery

1900 Mendel rediscovery. General acceptance of particulate in heritance, not blending.

Led to more confusion. Macromutations, not natural selection, became popular for causing new species.

William Bateson & Walter Frank Raphael Weldon ca. 1890

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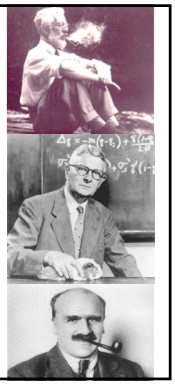
Modern Synthesis. Part I

1930 Ronald A. Fisher: The Genetical Theory of Natural Selection. Book
1931 Sewall Wright: Evolution in Mendelian populations. Paper
1932 JBS Haldane: The Causes of Natural Selection. Book

- Mendelian genetics worked just great with evolution by natural selection.
- Didn't discuss origin of species much. Agreed with Darwin: species were just "varieties" that had diverged a bit more



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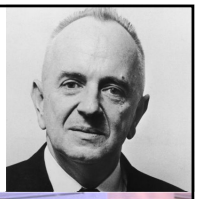
Modern Synthesis. Part II. Species

1937 Theodosius Dobzhansky: Genetics and the Origin of Species. Book
1942 Ernst Mayr: Systematics and the Origin of Species. Book

- They argued Darwin was wrong about species and speciation. D. didn't understand species!
- Species are "reproductively isolated"
- Species are special. Speciation is difficult.
- Speciation requires special mechanisms, like separation of populations by geography



Crazy: I actually met Ernst Mayr, here in Cambridge MA, in 1999!

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Ernst Mayr's career

Harvard prof: 1953-2005
Director, MCZ: 1961-1970

career:	Ernst Mayr	James Mallet
lifespan	100 yrs	~70 yrs so far
books	21	0.05
papers	863	~250
prizes & awards	35	1
honorary degrees	17	0

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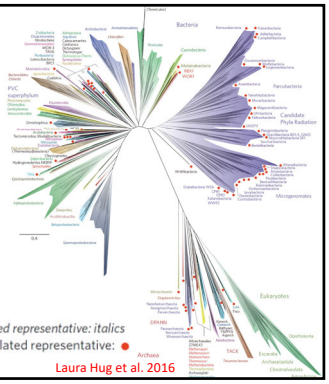
Speciation: 2020s

- Fossil fuels
- Genetic drift & stochastic processes in evolution
- Levels of selection: gene, individual, population
- Nuclear power & nuclear weapons
- Molecular genetics: DNA sequencing, genomics
- Phylogenetic methods
- Climate change
- The internet



Major lineages with isolated representative: italics
Major lineage lacking isolated representative:

Laura Hug et al. 2016

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