Evolution - Biosystematics
There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

[conclusion of *Origin of Species*]
1. Tremendous diversity of life!
2. Structural complexity of these organisms
3. Apparent purposive or adaptive nature of their features
Questions Evoked?
1. How has organic diversity originated, how is it maintained?
2. How have complex organisms come into being?
3. What forces have molded their adaptive features?
4. When and where did the various organisms appear?
5. Why have organisms (including humans) appeared?
Thomas Burnet (1681)

- Typical pre-18th century view of Earth and its changes
Thomas Burnet (1681)

- Typical pre-18th century view of Earth and its changes

“no truth concerning the Natural World can be an enemy of religion; for Truth cannot be an enemy to Truth, God is not divided against himself”

“We think him a better Artist that makes a Clock that strikes regularly at every hour from the Springs and Wheels which he puts into the work, than he that hath so made his Clock that he must put his finger to it every hour to make it strike”
Jean Baptiste Lamarck (1744-1829)

- Early evolutionary thought - “ladder thinking”
Lamarck’s “Ladder”

- Continuum between physical and biological world (after Aristotle)
- *Scalae Naturae* (“Ladder of Life” or “Great Chain of Being”)
Lamarck’s “Ladder”

- Life progresses upward due to an internal drive towards perfection = transmutation

- Why are primitive organisms still around?
  - Spontaneous generation of new life constantly

- Mechanism of change?
  - Inheritance of acquired characters
Lamarck’s “Ladder”

Lamarck’s (1809) fourteen level ladder hierarchy

- There is no one linear ladder (Georges Cuvier)

1. Les Mammifères.
2. Les Oiseaux.
3. Les Reptiles.
4. Les Poissons.
5. Les Mollusques.
7. Les Annelides.
8. Les Crustacés.
9. Les Arachnides.
10. Les Insectes.
12. Les Radiers.

Animaux vertébrés.

Animaux invertébrés.
Lamarck’s later “Tree”

- Lamarck (reluctantly) influenced by Cuvier’s arguments

- Appended table in 1809 (vol. 2 of *Philosophie Zoologique*) showing two lines of spontaneous generation with subsequent branching

Lamarck’s 1809 appendum
By 1815 Lamarck announced his conversion to branching as the fundamental pattern of "evolution"

"In its production of the different animals, nature has not fashioned a single and simple series"
Lamarck’s later “Tree”

• His last book (*Analytical System of Positive Knowledge of Man*, 1820) has gone largely unnoticed

“Reptiles come necessarily after fishes. They build a branching sequence, with one branch leading from turtles to platypuses to the diverse groups of birds, while the other via lizards toward the mammals. The birds then build a richly varied branching series, with one branch ending in birds of prey.”

S.J. Gould, 1999
Robert Chambers (1844)

- The only pre-Darwin “evolution” book that English speakers could read in 1840s and 1850s
Robert Chambers (1844)

- Darwin later stated that *Vestiges* – although flawed – set the stage for acceptance of his ideas of evolution set down in his book *Origin of Species* in 1859.

- Immediate criticism on one main point by some in the public: denial of special creation for each species.
Robert Chambers (1844)

- Bosanquet (Biblical scholar) published his rebuttal the next year and based it primarily on the issue of special creation.
Robert Chambers (1844)

"VESTIGES OF THE NATURAL HISTORY
OF CREATION"

EXPOSED, ETC.

The recent publication of the book entitled "Vestiges of the Natural History of Creation," is very much to be regretted; and still more is it to be regretted that it is obtaining a rapid circulation, if not a very general approval; and that the public taste or discernment has not passed upon it an immediate sentence of condemnation and rejection from the stage, on its first representation. We may very well remember the eager curiosity and pleasure with which the reading public, especially the increasing class of female philosophers, received the dozen first numbers of Miss Martineau's publications, on the Poor and the Poor Laws. It was not till the poisonous Circean cup had been very deeply imbibed, that those who were suffering from its infection discovered that their passion for such draughts was that of a blunted and a morbid appetite. It became the fashion at that time to write libels against the poor; to philoso-

VESTIGES OF THE NATURAL HISTORY

the maiden gem of truth and singleness of purpose; divorced from the sacred and ennobling rule and discipline of faith. Without this, philosophy is a wanton and deformed adultress.

Before giving an outline of the scheme and theory which is elaborated in the "Vestiges of Creation," and combating the evil tendency and intention of the work, we think it right to show the depth and strength of the poison to which we would provide an antidote; and the principles and conclusions to which these speculations have brought their author; or being first in the author's mind, have dictated the work, and animated the growth of it.

The design of the work is to show that there has been no such thing as creation, in the sense in which we receive it from the Mosaic History and Revelation; that there is no such thing as a Special Providence; that the very notion of it "is ridiculous."—

"For how can we suppose that the august Being, who brought all these countless worlds into form by the simple establishment of a natural principle flowing from his mind, was to interfere personally and specially on every occasion when a new shell-fish or reptile was to be ushered into existence on one of these worlds? Surely this idea is too ridiculous to be for a moment entertained."—(p. 155, 2d edition.)

No, the great truth which is to be received is, that God made all things from eternity, even the infinity of the universe, by one fiat; since which, He has reposed, and not interfered with the affairs or the order of Crea-
Charles Darwin (1859)

Darwin himself never uses the word "evolution" in *Origin of Species*.

He calls the process "descent with modification".
only figure in *Origin of Species* - illustration of
‘descent with modification’
The three main claims of Darwinian evolution

• Living species are related by common ancestry [descent]

• Change through time occurs not at the organism but at the population level

• The main cause of adaptive evolution is natural selection [modification]
Evolution - a definition

The change of genetic materials (DNA, genes, chromosomes = genotype) and thus physical attributes (morphology, physiology = phenotype) within and among populations and species through time and space.
Evolution vs. Religion?

Some conflict already early on between religion and ideas of evolution

1860 debate between Bishop Samuel Wilberforce of Church of England and Thomas Henry Huxley ('Darwin’s bulldog')
“Surely God’s power and glory were revealed more clearly in natural laws than in a peppering of miraculous interventions.”

William Benjamin Carpenter — Christian physiologist and paleontologist — after reviewing Darwin’s *Origin of Species*

No conflict among many scientists of faith
Evolution vs. Religion?

“A Natural Law is as sacred as Moral Principle”

“Every scientific truth goes through three states: first, people say it conflicts with the Bible; next, they say it has been discovered before; lastly, they say they always believed it”

Louis Agassiz
Evolution vs. Religion?

*BioLogos* – one positive example of scientists and theologians working together
Evidence for Evolution

By DAVID QUAMMEN
Photographs by ROBERT CLARK

Evolution by natural selection, the central concept of the life's work of Charles Darwin, is a theory. It's a theory about the origin of adaptation, complexity, and diversity among Earth's living creatures. If you are skeptical by nature, unfamiliar with the terminology of science, and unaware of the overwhelming evidence, you might even be tempted to say that it's "just" a theory. In the same sense, relativity as described by Albert Einstein is "just" a theory. The notion that Earth orbits around the sun rather than vice versa, offered by Copernicus in 1543, is a theory. Continental drift is a theory. The existence, structure, and dynamics of atoms? Atomic theory. Even electricity is a theoretical construct, involving electrons, which are tiny units of charge, and that no one has ever seen. Each of these theories is an explanation that has been confirmed to such a degree by observation and
Evidence for Evolution

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

Theodosius Dobzhansky

Anatomists, cellular biologists, prokaryote geneticists, membrane and protein transport physiologists, gene sequencers, genomicists, etc.
Evidence for Evolution

Nothing in biology makes sense except in the light of evolution

Theodosius Dobzhansky

... their data only makes sense assuming that chloroplasts are modifications of an ancient blue green bacterial ancestor — endosymbiotic event
Evidence for Evolution -
Common Ancestry

- Classification ✔
- Hierarchical distribution of traits ✔
- Homology ✔
- Vestigial Structures ✔
- Fossil record ✔
- Biogeography ✔
- Variation among populations ✔
- Speciation ✔
- Agreement between gene trees ✔

✔ = examined in this course to various degrees

"trees"

use "tree" metaphor
Darwin’s “Tree Thinking”

Genealogical tree of Queen Victoria (1819-1901)  

Pigeon breeding lineages from ancestral rock pigeon
Darwin’s “Tree Thinking”

Rose pedigree

Indo-European Language Tree (with reticulations)
Darwin’s “Tree Thinking”

Darwin’s 1st species notebook (1837)

Speciation

Extinction
1. Hierarchical Classification

Darwin’s major finding was a scientific explanation (using the tree metaphor) for:

(1) why organisms appear similar to other organisms,

and (2) why these organisms appear related in a hierarchical (nested) fashion

Common ancestry!
• Groups of species appear *more similar* than they do with other groups

• That observation alone could be consistent with a number of explanations of the origin of life’s diversity
Darwin’s simple explanation was that each species did not independently acquire every character.
1. Hierarchical Classification

Characters are “fossil” footprints indicating ancestry

- but rather each inherited it from a common ancestor who first derived it — a “fossil” footprint

![Diagram showing hierarchical classification with vascular tissue, chloroplasts, water-tight egg, and four limbs highlighted.](image)

- **Vascular tissue**
- **Chloroplasts**
- **Water-tight egg**
- **Four limbs**

= shared-derived characters
• Groups are “nested” within successively larger groups, each “clade” defined by its own set of evolutionary novelties

1. Hierarchical Classification

The distributions of characters in a hierarchical fashion is only explained by “trees”
On the ordinary view of each species having been independently created, we gain no scientific explanation of any one of these facts. We can only say that it has so pleased the Creator . . . that He has impressed on them the most extraordinary resemblances, and has classed them in groups subordinate to groups.

"Unless one is willing to take the position that God has placed these decapitated AREs [ancient repetitive elements] in these precise positions to confuse and mislead us, the conclusion of a common ancestor for humans and mice is virtually inescapable. This kind of recent genome data thus presents an overwhelming challenge to those who hold to the idea that all species were created ex nihilo."
2. Evidence through Homology

Character modification — homologous parts

Evolution thus predicts that species descended from a common ancestor should share homologous characters - derived from the same structure(s) - but that they will show divergence in these characters through time

The forelimb of all these vertebrates are homologous but modified:

Unrelated species (different ancestors) will show convergence in similar niche
2. Evidence through Homology

“On my theory, unity of type is explained by unity of descent”  Darwin, 1859

• Darwin’s work on orchids convinced him that all species possess the basic homologous floral parts
• although these are highly modified for roles in quite different pollination systems
2. Evidence through Homology

EvoDevo studies now provide genetic bases for the homology (or not) of basic features in plants and animals.

And how they have been modified.

ABC model of floral identity.
2. Evidence through Homology

- few gene differences involved in quite different looking flowers (*Mimulus* - monkey flowers)
- transcription factors not structural genes important in trait differences
2. Evidence through Homology

Molecular tinkering - major process for forming the diversity of life

*Hox* Genes - EvoDevo

Gene family, spatial organization, development
2. Evidence through Homology

Molecular tinkering - major process for forming the diversity of life

*Hox* Genes - EvoDevo

Halteres into wings
Antennae into legs
3. Vestigial Structures

Vestigial structures — homologous parts

Evolution predicts that species occupying very distinct environments from that of a common ancestor might show vestigial structures

Rudimentary tooth in lower jaw of a baleen whale
3. Vestigial Structures

Vestigial structures — homologous parts

Evolution predicts that species occupying very distinct environments from that of a common ancestor might show *vestigial structures*

The *pelvic girdle* seen in reptiles and mammals as an adaptation for support in tetrapods, is vestigial in whales — it is a “*fossil* footprint” of their ancestry and serving no function today in swimming descendants of tetrapods.
3. Vestigial Structures

Vestigial structures — homologous parts

Parasitic and non-green dodders retain “fossil” non-functional chloroplasts as a vestigial structure inherited from a common ancestor with morning glories.
4. Fossil Record

‘Missing links’ — transitional forms

• fossil record is rich & consistent with information from hierarchical relationships based on morphology and DNA
4. Fossil Record

‘Missing links’ — transitional forms

- *Archaefructus* in terms of age and morphology is consistent with an early basal angiosperm
- fossils often now placed in phylogenetic analyses
4. Fossil Record

‘Missing links’ — transitional forms

“I see no difficulty in a race of bears being rendered, by natural selection, more and more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale.”

Darwin, in *Origin of Species*
Paleontologist Phil Gingerich with 40 my old *Basilosaurus* with small hind legs in Egypt.

Now a wealth of fossils showing transitional forms from a putative ancestral Mesonychid type to modern whales has been uncovered. Early stages were clearly terrestrial.
4. Fossil Record

‘Missing links’ — transitional forms

- what should ‘missing links’ look like?
- intermediate between chimps and humans?
- No! that is ‘ladder of life’ or “progression” thinking
- each species is a ‘tip’ species with its own derived traits
4. Fossil Record

‘Missing links’ — transitional forms

• what should ‘missing links’ look like?

• in tree thinking, ‘missing links’ are seen in a progression from a common ancestor with a sister species

• the common ancestor may or may not look like the sister tip species

what features did this common ancestor possess?

- Larger body mass
- Tool-use
- Likely iconic narrative construction capacity

Extended sustained introspective attention on iconic narratives
5. Biogeography of Life

"... that grand subject, that almost keystone of the laws of creation, Geographical Distribution"

Darwin needed two chapters in the Origin of Species to cover his ideas on geographical distributions of organisms

“I am prepared to go to the stake, if requisite, in support of the chapters on the geological and geographical distribution of life.”

Thomas Huxley after reading the Origin of Species
5. Biogeography of Life

Law of Representative Species - repeated biogeographical observation

Closely related species replace themselves across a continent
5. Biogeography of Life

Convergent Forms on Different Continents - repeated pattern

Succulent stemmed
Cactaceae restricted to the American continents

Succulent stemmed
*Euphorbia* restricted to Africa and Madagascar
5. Biogeography of Life

Congruence of distribution patterns and earth history

Distributions of organisms, extant and extinct, provided the first evidence in 1920 for the then heretical idea of continental drift

- **Glossopteris** - Permian “fern”
- **Mesosaurus** - Permian freshwater reptile
- **Cynognathus** - Triassic land reptile
- **Lystrosaurus** - Triassic land reptile
6. Direct Observation

Evolutionary change in formation of crop plants

Documenting change within 100s or 1000s years due to human or artificial selection - often with “major” phenotypic modifications but due to small numbers of genes.

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**Diagram Description:**

- **T. monococcum** (einkorn)
- Unknown wild wheat
- Sterile hybrid
- Spontaneous chromosome doubling about 8,000 years ago
- **T. turgidum** (wild emmer)
- **T. tauschii** (a wild relative)
- **T. aestivum** (a common bread wheat)

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**Explanations:**

1. **2n = 14 AA × 14 BB → 14 AB**
   - About 11,000 years ago, humans start cultivating wild wheats. The species *Triticum monococcum* has diploid number 14 (two sets of 7 chromosomes, shown as 14 AA). It hybridizes with another species that has the same chromosome number.

2. **14 AB → 28 AABB**
   - AB hybrid offspring are sterile but self-fertile; an interbreeding population of AB plants arises by asexual reproduction. About 8,000 years ago, by unknown events, polyploidy arises in the population. Some plants (*T. turgidum*) are tetraploid (AABB), with a chromosome number of 28 (two sets of 14). They are fertile. (A chromosomes can pair with each other, and so can B chromosomes, during meiosis.)

3. **28 AABB → 14 DD × 42 AABBDD**
   - Later, an AABB plant hybridizes with *T. tauschii*, a wild relative with a diploid number of 14 (two sets of 7 DD). Today, populations of the hybrid descendants (*T. aestivum*) provide wheat for bread. Their chromosome number is 42 (six sets of 7 AABBDD).
6. Direct Observation

Evolutionary change within and among populations

Directional selection in size of o’hia flowers in 150 years due to loss of long-beaked honeycreeper species

*Metrosideros* – o’hia
6. Direct Observation

Origin of recent species

- origin of new polyploid species in last 150 years (multiple times in different places)!

Tragopogon - goat’s beard

Doug & Pam Soltis
6. Direct Observation

Origin of old species

Helianthus anomalous

H. annuus

Re-synthesized in the lab

H. paradoxa

Loren Rieseberg
7. Molecular Evolution

Organisms contain within themselves a “DNA fossil footprint”

![The Tree of Life](image)
7. Molecular Evolution

Organisms contain within themselves a “DNA fossil footprint” . . . and different stories are told by different genomes & genes
On the ordinary view of each species having been independently created, we gain no scientific explanation of any one of these facts. We can only say that it has so pleased the Creator . . . that He has impressed on them the most extraordinary resemblances, and has classed them in groups subordinate to groups.