Evidence of a Common Origin of Life on Earth

- Common genetic code and expression
- Common cell structure
- Common developmental patterns
- Common tissue & organ structure

Aspects of a Common Origin of Life on Earth

- Origin of Life
- Origin of Baupläne
  Bauplan: "Life Plan"; the underlying basic body structure and layout.
- Origins of Diversity within Baupläne

Paradigms for understanding the Common Origins of Life on Earth

- *Paradigm*: An overall framework, pattern or premise to which subsequent evidence is made to conform.
- *Metaphysics*: of or relating to reality beyond what is perceptible to the senses.

Alternative Metaphysical Paradigms for understanding the Common Origins of Life on Earth

- Common Design — origin and commonality by intelligent, deliberate design (creation/intelligent design).
- Common Ancestry — origin and inherited commonality resulting from descent from common ancestors (evolution).
- Common Source — origin and commonality from import of an external stock (immigration).

The many faces of EVOLUTION

- *Evolution*: change over time.
- *Biological Evolution*: the change in the frequency of genetic variations (alleles) in a population of organisms over time. "Descent with modification" — the *theory* of evolution.
- *The Evolutionary Paradigm*: the origin and nature of the universe are products of natural forces independent of significant contributions from intelligent operations.

The many faces of EVOLUTION

- ***Micro**evolution*: the modification and variation of components within the bauplan.
- ***Macro**evolution*: the origin of novel body structures, physiological processes, or developmental patterns; major alterations of the bauplan.

Three Questions / Three Models

- One paradigm fits all? Or different answer to each question?

	Design	Evolution	Immigration
Origin of **Life**	?	?	?
Origin of **Baupläne**	?	?	?
Origin of **Diversity**	?	?	?

Charles Darwin

- Flunked pre-Med! ☞ Divinity school?
- Amateur naturalist for 5 years on *HMS Beagle*.
- Read Lyell — Earth changed gradually.
  - Did life change too?
- Found fossils in S.Am., some who were different from their living descendants.
  - "descent with modification"

The voyage of *HMS Beagle*, 1831–1836

- Captain/Scientist Robert FitzRoy

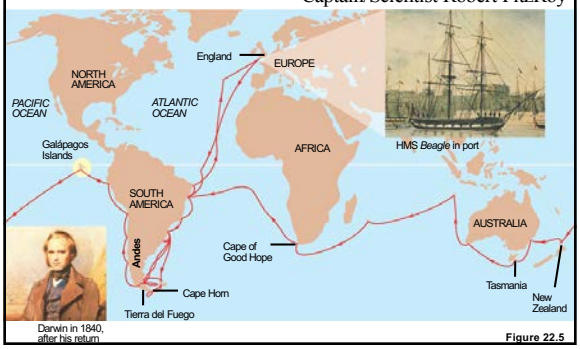


Figure 22.5

Darwin & Galapagos

- Variation in tortoises, iguanas, & finches of young volcanic Galapagos.

Darwin's Considerations

- Upon return to England, Darwin became a recluse. (Wealthy family: so didn't need to work.)
- Gained fame by publishing accounts of the voyage.
- Influenced by British elite industrial society and the philosophy of Thomas Malthus:
  - **Society is hindered by assisting the weak. More poor are born than can survive anyway.**
  - **Society profits by favoring the successful and letting the feeble die off.**

Darwin's Considerations

- Had observed "**descent with modification**" — change over time (evolution) among species.
  - Fossils
  - Island biogeography
- Knew of individual **heritable** variation within species.
  - Do some have survival-enhancing traits?
- Read how artificial **selective breeding** could produce changes.
- Sought a biological justification for Malthus' philosophy of the "**struggle for existence**" and capitalist exploitation of the poor and imperialist domination of "primitive" cultures
  - Resources are limited
  - More are born than can survive

On the Origin of Species…

- Alfred Russell Wallace wrote to Darwin suggesting a model of "natural selection". To avoid being "scooped", Darwin rushed to finish publishing his version (23 years after the voyage).
- In 1858, at the same public symposium where Wallace had his paper read, Darwin released a draft of

On the Origin of Species
by Means of Natural Selection
or
The Preservation of Favoured Races
in the Struggle for Life

- Its two points:
  1. **Pattern: descent with modification**
  2. **Process: natural selection**

Popular acceptance

- Good theory → good metaphysical paradigm?
- Still widespread belief in medieval concept of spontaneous generation
  - Rotting meat→maggots; old broth→bacteria, etc.
- Primitive microscopes revealed little cell structure → presumed to be simple
- Social & technological revolution → intellectual elitism
  - Malthus, Marx, Freud, Nietzsche
- Fervent publicizing by social commentators
  - Thomas Huxley (in England), Ernst Haeckel (in Germany)

Bumps in the road

- 1864 — Louis Pasteur and others refuted spontaneous generation
- Rise of United States as technological & political power → democratic idealism
  - "All men are created equal"
  - Rejection of Darwinian justification for Malthus' elite social & racial classes

Academic interest wanes

- 1865 — Gregor Mendel publishes work on genetics. Strongly critical of Darwin.
  - Variations are limited
  - Extrapolation of natural selection to origin of species unjustified

- 1900 — Mendel's work rediscovered → development of genetic theory
  - Although Darwinian influence upon social & philosophical perspectives continues, biological significance is trivialized

"Neo-Darwinian" Synthetic Theory

- 1937 —T. Dobzhansky, *Genetics and the Origin of Species*
  - introduced concept of mutations to evolutionary process
- 1941 — Geological Society of America organizes a meeting to produce a *synthetic theory of evolution* reinterpreting Darwin in the context of genetic theory
  - Major players:
    - geneticists Theodosius Dobzhansky & G. Ledyard Stebbins
    - zoologists Ernst Mayr & Julian Huxley
    - paleontologists George Gaylord Simpson & Glenn L. Jepsen

Dobzhansky, Mayr, Huxley

- 1949 —G.G. Simpson, *Meaning of Evolution*
  - joined paleontology, taxonomy, biogeography to the study of the genetics of populations.

Biogeography & Convergent Evolution

- Barriers to dispersal cause evolution of different **biotas**.
- Similar habitats cause **convergent** evolution.
- Australian mammal herbivores & carnivores are marsupials.
- Animals in neo- & paleotropics have closest relatives within their respective continents.

Biogeography & Convergent Evolution

- Similar adaptations by unrelated taxa in similar environments

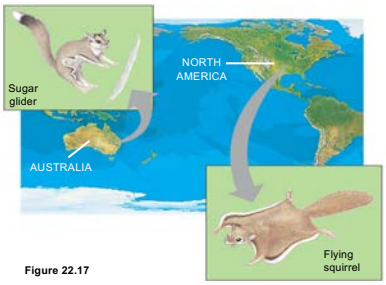
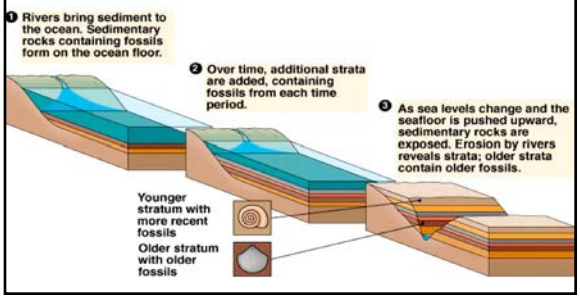


Figure 22.17

Sedimentary Fossils

- Sedimentary rocks reveal fossils



Fossils & the French

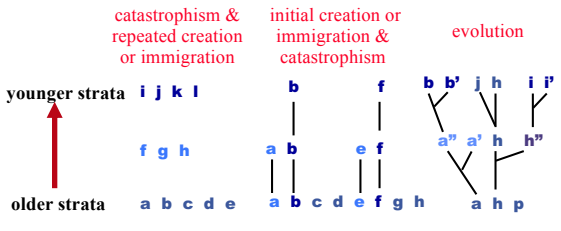
- Deeper, older strata have quite different organisms.
- Upper strata have more familiar organisms.
- Cuvier (~1800) studied Paris fossil strata
  - his **catastrophism** explained extinctions, but not origin of new forms.

Pre-Darwinian early hypotheses

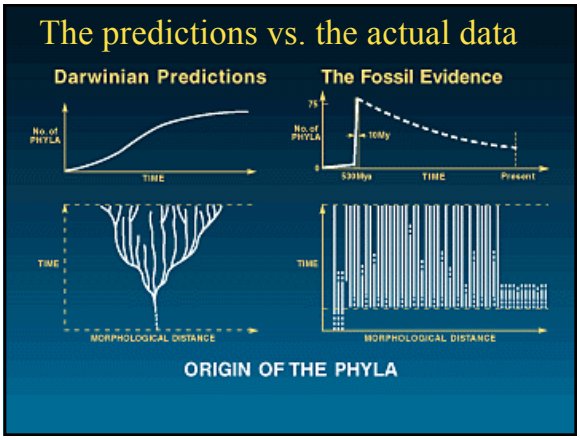
- Naturalists extended evolving Earth to evolving life on Earth.
- Comparative anatomists also suspected evolutionary change.
- Lamarck was first to suggest fossils progressing in form. (early 1800's)
  - Proposed evolution resulted from **inheritance of acquired characteristics.**
  - Rejected by observations of inheritance, but still circulated in public press.

Patterns in the Fossil Record

Predictions of the paradigms



The predictions vs. the actual data



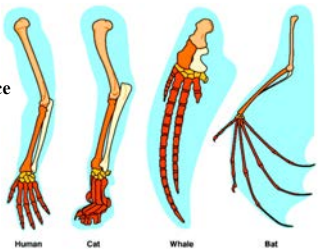
Persistence of form

Modern examples not significantly different from earliest known fossil samples

- horseshoe crab - 450 myo
- oysters - 450 myo
- scorpion – 320 myo
- shrimp – 170 myo
- flies & termites in amber – 25-30 myo

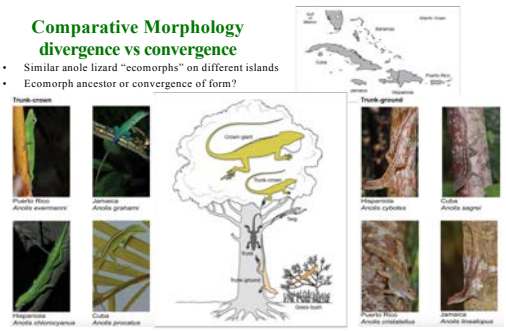
Homologous vs. Analogous Structures

- **Homology**: similar form presumed from **divergence** from a common ancestor.
- **Analogy**: similar form presumed from **convergence** to a similar environment.



Comparative Morphology
divergence vs convergence

- Similar anole lizard "ecomorphs" on different islands
- Ecomorph ancestor or convergence of form?

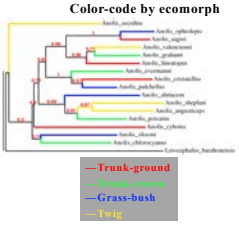


Comparative Morphology
divergence vs convergence

- Cladogram from mitochondria DNA

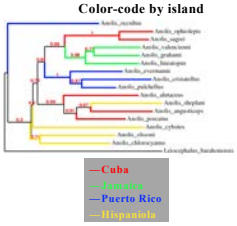
Similar ecomorphs by convergence
Not closely related

Color-code by ecomorph



—Trunk-ground
—Trunk-crown
—Grass-bush
—Twig

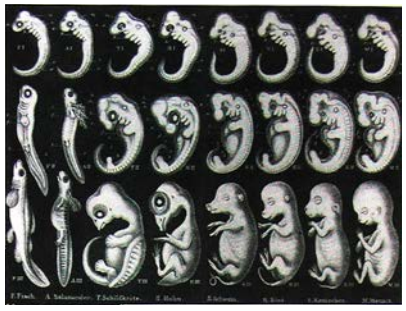
Color-code by island



—Cuba
—Jamaica
—Puerto Rico
—Hispaniola

Embryonic Homology

- 1870 - Ernst Haeckel produced a set of woodcut illustrations showing earlier stages of vertebrate embryos with greater similarities than adult forms
- **"ontogeny recapitulates phylogeny"**
- Darwin called it the "by far the strongest single class of facts in favor of" evolution.



Embryonic Homology?

- Embryologists complained that Haeckel had been suspiciously selective in his choice of subjects, and had exaggerated the similarities of the early stages
- Never the less, these illustration were (are) widely published in popular media and textbooks
- 1997 — Photographs of the real embryos reveal how distorted Haeckel's pictures are.

"It looks like it's turning out to be one of the most famous fakes in biology."
— *Science* 1999

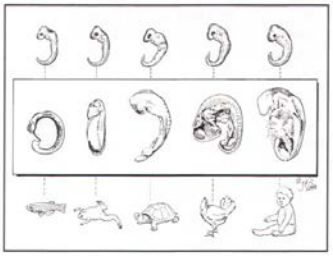


Figure 1-2: A comparison of Haeckel's drawings with accurate drawings of vertebrate embryos.

From M.K. Richardson (1997) *Anatomy & Embryology*

Embryonic Homology or Analogy?

- Also, it became apparent by 1970s that the *earliest* stages of these embryos were very *different*.
- Thus, any similarities at these later stages must be convergent rather than homologous!

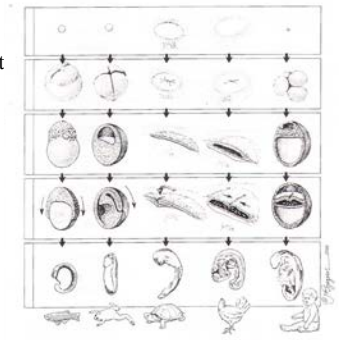
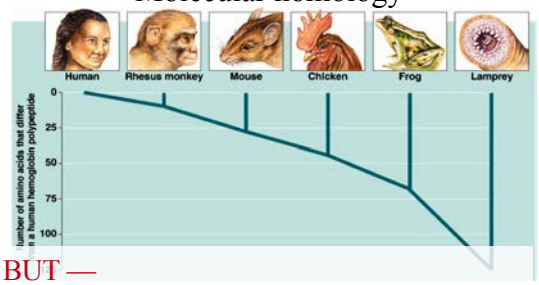


Figure 1-3: A drawing of the early stages of vertebrate embryos.

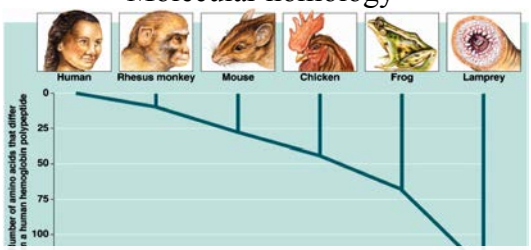
Molecular homology



BUT —

- Different molecules yield different patterns
- The pattern is ***not*** consistent with the pattern from comparative anatomy.

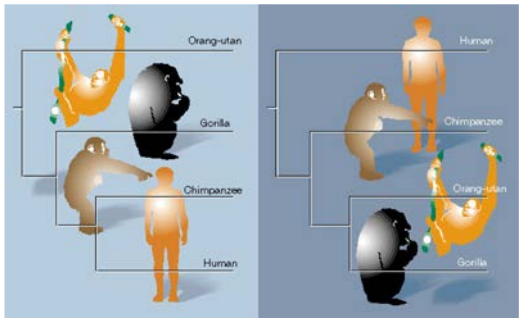
Molecular homology



"Clarification of the phylogenetic relationships of the major animal phyla has been an elusive problem, with analyses based on different genes and even different analyses based on the same genes yielding a diversity of phylogenetic trees."

(Michael Lynch, "The Age and Relationships of the Major Animal Phyla," *Evolution* 53 (1999): 323.)

Molecular vs. morphological systematics

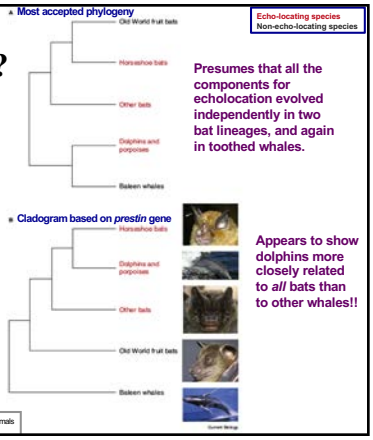


Molecular (left) and morphological views of relationships among primates. Bones, molecules, or both? (20 July 2000) *Nature* 406: 230-233

Molecular convergence??

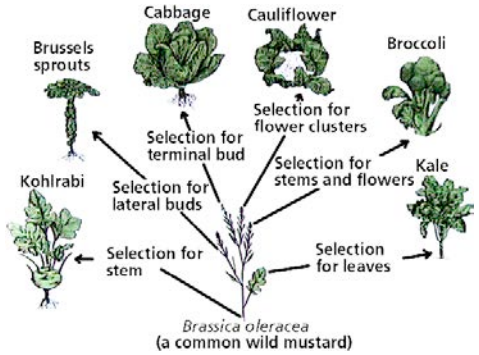
If proteins/DNA can be related by function, they cannot be valid indicators of phylogeny!

(**Analogy**, *not* **homology**)



Molecular Evolution: Gene Convergence in Echolocating Mammals (2009) Current Biology 20: R62-64.

Artificial Selection

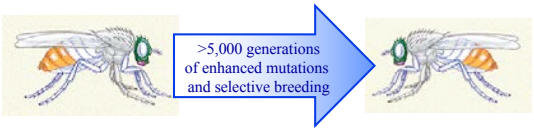


ARTIFICIAL SELECTION

NATURAL SELECTION

Lab Studies: **Fruit Flies**

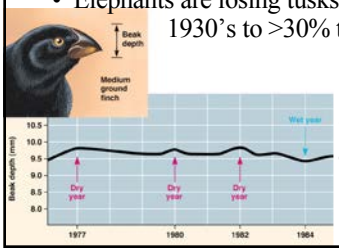
- Rate of evolutionary change is related to generation time.
- Fruit flies have two-week generation time.
- Studies of fruit flies date to 1920's



Drosophila melanogaster Drosophila melanogaster

Natural Populations Evolve Today

- Diseases quickly evolve antibiotic resistance.
- Elephants are losing tusks - up from 3% in 1930's to >30% today.



- Darwin's Finches evolve w/ El Nino.

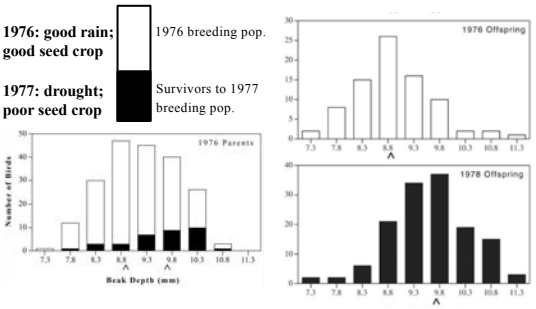
Beak Depth in medium ground finch (*Geospiza fortis*)

1976: good rain; good seed crop

1977: drought; poor seed crop

1976 breeding pop.

Survivors to 1977 breeding pop.

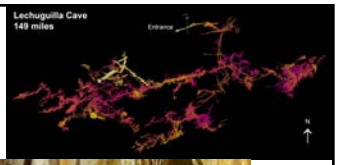


Same range; different means

Lechuguilla Cave

Carlsbad Caverns National Park, New Mexico

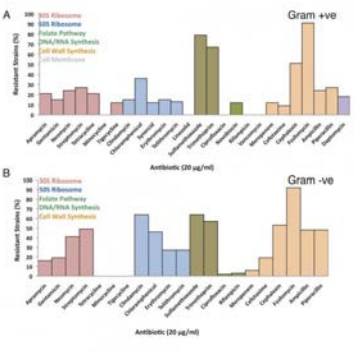
Microbial community isolated from any human activity and anthropogenic products



Antibiotic resistance in bacterial strains isolated from Lechuguilla Cave

- **93 bacterial strains** (59 gram-negative; 34 gram-positive)
- **26 antibiotics /** 6 resistance mechanisms

Resistance to most antibiotics already present in bacteria never exposed to medical or agricultural products



Bhullar K, *et al.* (2012) Antibiotic Resistance Is Prevalent in an Isolated Cave Microbiome. PLoS ONE 7(4): e34953.

Evidence for Evolution Present

- Breeding of plants and animals
- Lab studies of captive populations
- Field studies of living populations

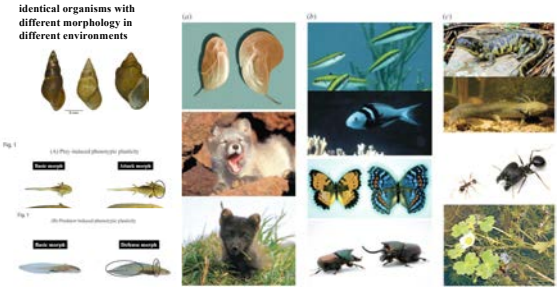
- Can observations of **micro**evolution really be projected to conclusions about **origins** or even mechanisms of **macro**evolution???
  - *Modification of existing features vs. acquisition of new features or body plans.*

Limitations on Neodarwinian theoretical mechanisms

- Mutations
  - Mutations are destructive alterations in previously existing complex systems
    - Do not explain origin of the complex systems
  - At least in multicellular organisms, most (all?) genes have pleiotropic effects (diverse effects on multiple body functions)
    - Even if mutation enhances one function, it disrupts many others
- Natural selection
  - In K-selected species, birth rate is reduced to keep population growth below carrying capacity
    - Avoid excess production and limit competition
  - In r-selected species, fecundity is so high that random success of juvenile survival overrides directional selection effects
  - Natural selection is more often stabilizing than is diversifying
    - Individuals very different from pop mean are less likely to survive or mate

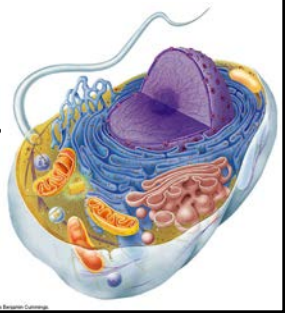
Phenotypic Plasticity
Adaptation *without* evolution

Ecomorphs: genetically identical organisms with different morphology in different environments



Origin of the cell: The problems of irreducible complexity

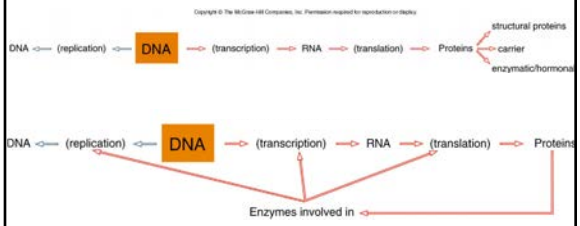
- Cells are complex.
- Most of the components, processes, and pathways need to be already present and functioning for any one component to work.



What does a cell need?

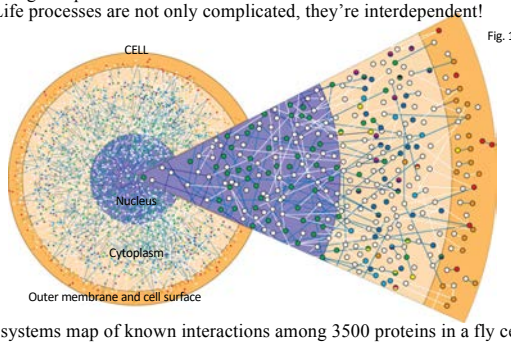
- Selective isolation from environment (plasma membrane)
- Energy (ATP)
- Instructions (DNA)
- Machinery to carry out instructions and regulate processes (proteins)
- Compartmentalization of incompatible or specialized activities in time or space (organelles)

A problem of origins: which came first?



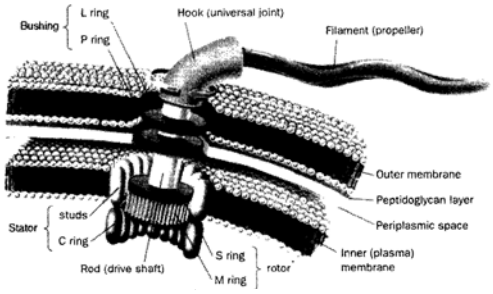
Emergent Systems

- Emergent Systems Analysis: mapping all interactions within the holistic living complex.
- Life processes are not only complicated, they're interdependent!



A systems map of known interactions among 3500 proteins in a fly cell

The problems of irreducible complexity: molecular machines

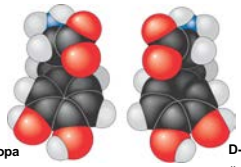


Drawing of a bacterial flagellum showing the filament, hook, and the motor imbedded in the inner and outer cell membranes and the cell wall. From Voet and Voet, *Biochemistry*, 2d ed. © 1995 John Wiley

Stereo Isomers (Enantiomers) — mirror-image macromolecules

One of the great mysteries of the origin of living cells —

- All non-biological synthesis reactions of organic molecules produce both D- and L- isomers in equal yield.
- And all non-biological reactions using organic molecules as reactants react with both D- and L- isomers equally.
- Yet, living cells are constructed only of D-sugars and L-amino acids!
- ∴ not a product of natural reactions?



L-Dopa (biologically active)

D-Dopa (biologically inactive)

Three Questions / Three Models

- The **Theory** of Evolution = microevolution
  - Important central concept of biology & ecology

	Design	Evolution	Immigration
Origin of **Life**	?	?	?
Origin of **Baupläne**	?	?	?
Origin of **Diversity**		**Microevolution** •Biogeography/convergence •Fossil record •Artificial selection •Field observations	

Three Questions / Three Models

- Extrapolations of microevolution to macroevolution not as solid. Alternative mechanisms?

	Design	Evolution	Immigration
Origin of **Life**	?	?	?
Origin of **Baupläne**	•Fossil record •Artificial selection	**Macroevolution** •Homology	⊘
Origin of **Diversity**		**Microevolution** •Biogeography •Fossil record •Artificial selection •Field observation	

Three Questions / Three Models

- About equal proponents of each paradigm.

	Design	Evolution	Immigration
Origin of **Life**	•**Irreducible complexity** •**Anabolic kinetics** •**Selected isomers** •**Molecular machines**	•**Abiotic synthesis of simple organics** •**Phase separation by lipid micelles**	•**Hydrocarbons in stellar clouds** •**Amino acids in meteor rocks**
Origin of **Baupläne**	?	?	⊘
Origin of **Diversity**		✓	