

Evolutionary Theory: Observational Background

Note that the time scales associated with the formation and evolution of the Earth and of Life were essentially unknown in Darwin's time. The same is true of chemical and isotopic indicators of life. The fossil record was also sparse.

Charles Lyell (1797-1875)

“Principles of Geology” (1830 - 33)

“Geological Evidences of the Antiquity of Man” (1863)

- Stratification and classification of rocks
- Igneous, Sedimentary, and Metamorphic formations
 - Indications of long-term processes: “Deep Time”
- Geophysical Theory: Catastrophism *versus* Uniformitarianism

Charles Darwin (1809-1882)

“Journal and Remarks” or “The Voyage of the Beagle” (1839)

- Fossils of large extinct mammals - related to living species
 - Fossil seashells and Petrified Wood at altitude
- Geological Activity: Earthquakes and sea floor rising (Theory of Coral Atolls)
- Speciation: Argentine Rheas; Galápagos Tortoises, and “Darwin's Finches”

Hypotheses Regarding the Mechanisms of Evolution

Stasis *ab initio* & Essentialism

Evolution does not occur to any significant extent, certainly not to the extent of speciation (Essentialism).

III

Exogenesis & Panspermia

Life did not originate on Earth but arose elsewhere.

Simple life forms were carried through space, eventually arriving at Earth.

These simple forms then evolved to more complex life forms.

Separate species might represent descendants of different initial forms.

III

Abiogenesis & Spontaneous Generation

New “simple” life forms arise spontaneously from non-living matter.

More complex life forms (presumably) evolve from these.

This process is more-or-less continuous and ongoing.

Examples: Mice in granaries, maggots in meat, microorganisms, ..

But: Francesco Redi (1668), Needham vs. Spallanzani (c. 1745), Pasteur (1859)

... However, the origin of life on Earth was almost certainly abiogenic ...

III

Predestination & “Preprogrammed Evolution”

Life arose from one or more initial (simple) life forms.

Later forms “evolved” from these initial forms.

The initial forms were probably the ancestors of species.

The “instructions” for subsequent “evolution” are present in the initial forms.

(In other words, subsequent evolutionary development is “preordained”)

Usually there was a presumption of “upward” evolution toward an ideal form.

Expectation: Every evolutionary change represents an improvement.

.....

None of these “Theories of Evolution” address the question of how life arose in the first place - nor do the ideas put forward by Lamarck, Darwin, and Wallace.

Evolution is regarded as a process that begins with one or more simple forms of life and leads, by some mechanism, to complex forms and diverse species.

The persistence of simple life forms (archaea, bacteria, eukaryotes) strongly suggests that evolution includes a branching process (which essentially amounts to speciation) - if one can assume that these simple forms are also descendants of common ancestral forms.

Transmission of Acquired Characteristics: Lamarckism

Jean-Baptiste Lamarck (1744-1829)

Lamarck believed that new life forms continually arose by spontaneous generation (*cf. supra*) and then evolved by the “inheritance of acquired traits.”

- Over the lifetime of an individual the frequent and continuous use of any organ will gradually strengthen, develop, and enlarge that organ
 - giving it power in proportion to the time it is so used.
- Conversely, the permanent disuse of any organ by an individual weakens that organ, progressively diminishing its capacity - until it may even disappear*.
- All such changes are preserved *via* reproduction, and passed on to offspring
 - provided that the acquired changes are common to both parents
 - or parent in the case of a single parent (parthenogenesis or agamospermy)
- This process will continue, generation after generation, until the animal reaches its “limit of development” - some ideal ultimate form

* Injury and (ritual) mutilation are excluded as drivers of this form of evolution.

Descent with Modification and Natural Selection

Charles Darwin (1809 - 1882)

**“On the Origin of Species by Means of Natural Selection, or The Preservation of Favored Races in the Struggle for Life”
(1859)**

and

Alfred Russell Wallace (1823-1913)

**“On the Tendencies of Varieties to Depart Indefinitely From the Original Type”
(1858)**

Basic Components of Darwinian Theory

“... There is grandeur in this view of life ...”

VISTA - Variation Inheritance Selection Time Aaptation

Descent with Modification

Offspring resemble their parent(s), exhibiting a mixture of their traits

Copies are sometimes imperfect: Mutation

(Observed)

Natural Selection

Environmental conditions favor (or disfavor) certain traits

Favorable traits tend to promote survival and reproduction

Favorable traits persist in subsequent generations

(Observed)

Speciation

Principal drivers of speciation are specialization and spatial isolation.

Genetic drift can also lead to speciation.

(Observed)

Some (Verified) Predictions of Darwinian Theory

The existence of “genes”: a physical/chemical mechanism of inheritance.

Convergent evolution (*e.g.*, “cacti”, “eyes”, “wings”, “fins”, ...)

Coevolution (*e.g.*, Darwin’s orchid and moth, diseases, parasites, ...)

Summary: Requirements for Darwinian Evolution

A set of characteristics or traits defining the population

These are the characteristics which define the taxon/clade or species/variety

Phenotype

A means of establishing those characteristics in members

A “construction plan” governing the growth and development of individuals

Genotype

A means of transferring this genetic information to offspring

Replication of genetic information and reproduction - mitosis and meiosis

Chromosomes

A means of modifying information at or before reproduction

Genetic mixing . Random or induced mutations, copying errors, ..

Blending and/or Mutation

and

A process which determines which modifications persist

Persistence through the reproductive viability of offspring

Natural Selection

Mechanisms: Darwin's Pangenesis

“The Variation of Animals and Plants Under Domestication” (1868)

Offspring resemble their parent(s): Theory then requires some mechanism by which parental traits are transferred to offspring. Darwin offered a “provisional hypothesis” for this mechanism, called **Pangenesis**, an attempt to explain this (imperfect) parental resemblance, atavism, hybrid traits, and phenomena such as healing or regeneration. This hypothesis remained tentative and eventually failed, its mechanisms and predictions being unsupported by observation.

The Pangenesis Hypothesis

In the parent(s):

- Body cells and organs produce “gemmules” which circulate through the body
- Gemmules contain information (plans) describing their organ of origin
- Gemmules collect in the reproductive organs and are passed on at fertilization
- Gemmules received from earlier generations can also be passed on.

In the offspring:

- Some gemmules can suppress the effects of others. (Dominance?)
- Gemmules would manifest themselves at various times during development.
- Some would be dormant, becoming manifest only after some generations.

Fragments:

- Darwin did not exclude Lamarckian Evolution as a source of “modification”. His principal contribution (and that of Wallace) was to incorporate **Natural Selection** as a driver of evolutionary change and speciation.
- Unlike Darwin’s “gemmules” an organism’s **genome** (singular) is present in all cells of the organism - and is not organ specific.
- The genome carries ancestral (as well as parental) information; expression of one particular trait over another is subject to certain dominance rules.
- Variation arises in part through genetic combination and is constrained by the ancestral history transmitted *via* the parental genomes.
- Mutation is essentially a random process providing no “direction” to evolution. Indeed, mutations are usually detrimental to the organism.
- Drivers of mutation include copying errors, damage, horizontal gene transfer, ..
- Surviving modifications and traits are not necessarily (or even usually) optimal; they are just improvements with respect to prior traits, given the prevailing environment. (Much “design” is bad or inefficient design.)
- It is **Natural Selection** that provides direction to evolution. That direction can change with time and environment: **genotype + environment = phenotype**

Upcoming Topics

Mendelian Genetics

Darwin + Mendel = “Evolutionary Synthesis”

Genotype + Environment = Phenotype

Biochemistry and Genetics: Chromosomes, Genes, and DNA

C+C & T+A(or U): Replication 3 bases per codon; AAA, UGA, UAG as “stops”

Classification: Taxonomy & Cladistics

Origins of Life

Is there life elsewhere in the Universe?

Digressions on Lamarckism

Lamarckism and Marxism: Lysenko and Soviet Agriculture

Commentary: Social Darwinism, Racism, Naziism, Eugenics

Characteristics can be acquired and transmitted: “Stress in Plants”

Evolution in other contexts

Evolution (and speciation) of languages

Social and cultural evolution (“memes”)

Genetic computation

End-of-Semester Scheduling for Fall 2008

Astronomy 301G

Section M01

Final Exam (Exam #3)

Friday 5 December

9:30 AM - 10:20 AM

BX 102

Similar format and rules as for previous exams

Class Presentation: How Many Trees of Life?

Monday 8 December

8:00 - 10:00 AM

BX 102

Exam Scheduling for Fall 2008

Astronomy 110G

Sections M01, M02, and M03

Pre-Final Review Session

Wednesday 3 December

2:30 - 4:30 PM

Science Hall 117

Final Exam (Exam #3)

Monday 8 December

10:30 AM - 12:30 PM

BX 102

Same format and rules as for previous exams