Chapter 1

EVOLUTIONARY BIOLOGY

WHAT IS EVOLUTION?

The word evolution comes from the Latin word *evolvere*, which means to unfold or unroll.

-To reveal the hidden potentialities.
-It has come to mean "change".

Biological evolution refers to the change in the characteristics of groups of organisms over many generations, over time.

The development or **ontogeny** of an individual organism is not considered evolution.

- Individual organisms do not evolve.
- Populations of organisms evolve; they undergo *descent with modification*.

Changes that are passed from one generation to the next are considered evolutionary; these are genetic changes.

- The resurgence of antibiotic resistant diseases is an example of natural selection.

BEFORE DARWIN

Darwin's theory of biological evolution revolutionized the prevailing worldview in the West that had existed from the time of Plato and Aristotle.

Plato, 428-348 B. C. Greek Philosopher.

"Idea" or "form" is real and everything else is a reflection of this reality. The essence, form or idea is imperfectly imitated by its physical and material representations. The real world is the world of ideas, and what we see on earth is only an imitation of those ideas. The essence or form of a structure could be understood from its function, since the function dictated the form. Species became the initial mold for all later replicates of that species. An individual organism has imperfections. Variations between organisms of the same species are accidental imperfections.

- Theory of essentialism.

Aristotle, 384-322 B. C. Greek philosopher.

Aristotle developed the Plato's concept of immutable essence into the notion that species have fixed properties. Aristotle proposed that the last stage of development, the adult form, explains the changes that occur in the immature forms (teleological explanation); the advanced stages influence the earlier stages. He also proposed that all living forms are linked in a progression from imperfect to most perfect. He called this the **Scale of Nature** (Scala Naturae).

Christian thought elaborated on Platonic and Aristotelian philosophy that existence is good and the God's benevolence is complete, therefore, He must have bestowed existence on every creature giving each its own essence.

Since order is superior to disorder, God's creation must follow a plan, especially a gradation from imperfect to perfect.

- Inanimate objects to plants to invertebrates up to vertebrates, human, and finally, angels.
- Scala Naturae or Scale of Nature or the Great Chain of Being.

The Principle of Plenitude

The legacy of Plato to European thinking about the natural world has been expressed as the Principle of Plenitude (Lovejoy, 1936; Rolfe, 1985). This was the belief that all possible kinds of things exist in the world already and nothing more can be created. Aristotle's legacy was more complicated but has been summarized by Rolfe as the concept of continuity and gradation between adjacent kinds of being when hierarchically arranged (1985, p. 300). Together, the Principle of Plenitude and the Great Chain of Being led to the belief, from medieval times, that a continuous chain extended from the inanimate world of non-living matter, such as earth and stones, through the animate world of plants, zoophytes, and the lowest forms of animal life, upwards to the quadrupeds and eventually through Man to the realms of angels and finally to the Christian God. This belief also entailed the view that just as nothing new could be created; neither could anything be exterminated, since this would counteract the will of God (Rolfe, 1985, p. 10).
http://web.ebscohost.com/ehost/detail?sid=6d39832c-5e3c-4e74-838e-0cc78ec17b1b%40sessionmgr11&vid=1&hid=15&bdata=JnNpdGU9ZWhvc3QtbGl2ZSZzY29wZT1zaXRl#db=aph&AN=9601260762
Aristotle, the Scale of Nature, and modern attitudes to animals - In the Company of Animals
Social Research, Fall, 1995 by Juliet Clutton-Brock

Linnaeus, Carolus. 1707-78, Swedish medical doctor, botanist and taxonomist,

Linnaeus is considered the founder of the **binomial system of nomenclature** and the originator of modern scientific classification of plants and animals. He used the species as the basic unit in building his system upward to larger categories. He grouped related species into genera, and related genera into orders, and so on. In his mind, this species had been related in the mind of the Creator.

Hutton, James. 1726-97, Scottish geologist.

Hutton formulated controversial theories of the origin of the earth in 1785. He was of the opinion that the earth must be very old.

- **Uniformitarianism:** the doctrine that past geological changes in the earth were brought about by the same causes as those now taking place. It stressed the slowness and gradualness of rates of change.

Lyell, Sir Charles. 1797-1875, English geologist.

Lyell argued in his book that, at the time, presently observable geological processes were adequate to explain geological history. He thought the action of the rain, sea, volcanoes and earthquakes explained the geological history of more ancient times. Lyell conclusively showed that the earth was very old and had changed its form slowly, mainly from conditions such as

erosion. Lyell was able to date the ages of rocks by using fossils embedded in the stone as time indicators. Lyell helped win acceptance of James Hutton's theory of **uniformitarianism** and of Charles Darwin's theory of evolution.

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

- Lamarck was born in Bazentin-le-Petit, France. Sent to a Jesuit school in Amiens.
- He received a classical education until 1759.
- That year, his father died, and Lamarck entered the military and began to study plants. In 1768 he left military service and studied medicine in Paris for four years, during which time he became interested in meteorology, chemistry, and shell collecting.
- Lamarck was elected to the Academy of Sciences and became an associate botanist in 1783,
- His most significant work was done when he began to work at the Jardin du Roi (King's Garden) in 1788.
- When the garden was reorganized in 1793, Lamarck's ideas helped to frame the structure of the new Museum of Natural History.
- He became professor of insects and worms in the Museum of Natural History, a division he named invertebrate zoology.
- Lamarck's theoretical observations on evolution, referred to in the early 19th century as transformism or transmutation, preceded his extensive observational work on invertebrates.
- Lamarck accepted the view that animals in nature were arranged on one continuous "scala naturae".
- First biologist to actively propose evolution.
- Lamarck died with little scientific recognition of his work or his ideas. Not until the second half of the 19th century were Lamarck's ideas seriously considered again.

LAMARCKISM

Lamarck proposed the principle of the **inheritance of acquired characteristics**.

Lamarck based his theory of evolution in part on his study of the fossils of marine invertebrates, was that species do change over time.

He believed, furthermore, that animals evolve because unfavorable conditions produce needs that animals try to satisfy.

Species not only become extinct but also undergo a gradual modification through time.

Organisms have an **inner perfecting principle** that …

- could sense the needs of the environment
- respond by developing adaptations…
- mostly from simple to complex.

Their environment does not passively alter organisms.

A change in the environment causes changes in the needs of organisms living in that environment, which in turn causes changes in their behavior.

Two **mechanisms** are involved in evolution:

- Principle of use and disuse.

- Inheritance of acquired characters.

Lamarck viewed evolution as a process of increasing complexity and "perfection," not driven by chance.

- "Nature, in producing in succession every species of animal, and beginning with the least perfect or simplest to end her work with the most perfect, has gradually complicated their structure." *Philosophie zoologique*.

While the mechanism of Lamarckian evolution is quite different from that proposed by Darwin, the predicted result is the same: adaptive change in lineages, ultimately driven by environmental change, over long periods of time.

Lamarck did not believe in extinction: for him, species that disappeared did so because they evolved into different species.

Lamarck's *Philosophie zoologique* mentions the great variety of animal and plant forms produced under human cultivation (Lamarck even anticipated Darwin in mentioning fantail pigeons!); the presence of vestigial, non-functional structures in many animals; and the presence of embryonic structures that have no counterpart in the adult.

Lamarck believed that the Earth was very old.

Charles Darwin, 1809-1882.

- Charles Robert Darwin was born in Shrewsbury, England in 1809. The son of an eminent local doctor, Dr Robert Darwin, Charles was born into a modestly wealthy family.
- He was the grandson of Erasmus Darwin, English naturalist, and promoter of the idea of evolution.
- Darwin studied medicine at Edinburgh University from 1825 to 1827.
- He transferred to Christ's College, Cambridge in 1828 with the intention of becoming a minister in the Church of England.
- He was a mediocre student and did not like classical education. His interests were in natural history, botany, geology, collecting and hunting.
- In 1831, with the help of his botany professor John Henslow and his uncle Josiah Wedgewood, he took the post of naturalist on board the **H.M.S. Beagle** on a scientific mission to South America.
- By the time of his return in 1836, he had become an authority on many forms of life.
- Between 1842 and 1844 he developed his **theory of natural selection**, although he did not announce his work until 1858.
- In 1859 he published a considerably expanded version of his researches in the controversial ***Origin of Species by Means of Natural Selection***.

- He published ***The Descent of Man*** in 1871.

THE VOYAGE OF THE BEAGLE

H.M.S. Beagle, under the command of Captain Robert Fitzroy, left for Patagonia, South America, in 1831 with Charles Darwin on board.

At this time Charles did not believe in evolution, including his grandfather's theory, as any evidence presented so far could not convince him.

The Beagle reached South America in 1832 and Charles took care to observe the flora and fauna.

Charles went then to Buenos Aries where he saw fossils of more ancient animals, including a mastodon.

He experienced a violent earthquake in Chile that raised the land in some places between 2 and 10 feet.

Darwin was most interested in the plants and animals on the Galápagos, a group of 16 large islands (and many smaller) off the coast of Ecuador.

- Giant tortoises inhabit every one of the islands, which gave the island chain its name, from the Spanish Galápagos, meaning tortoise.
- Each island has its own type of tortoise, distinguishable by the shape and pattern of its shell.
- Darwin was astonished that the islanders felt that this was due to the difference in environment on each island.
- Darwin also observed the finches, which varied in size and shape from island to island.
- Their beaks also varied depending on which food they ate and some even had extra long tongues for grabbing certain types of foods such as insects, nuts or seeds.

Island animals and plants were different to those on the mainland but a relationship could be seen. What was even stranger though, to Darwin, was the fact that organisms on different islands varied, but still seemed related.

ALFRED RUSSEL WALLACE, 1823-1913.

- 8 January 1823: Alfred Russel Wallace born at Usk, Monmouthshire.
- mid/late 1837: Joins the eldest brother William in Bedfordshire to learn the surveying trade.
- 25 April 1848: Wallace and Bates leave England for Amazonian South America to begin a natural history collecting expedition.
- March 1854: Leaves England for the Far East to begin a natural history collecting expedition.
- 20 April 1854 to 20 February 1862: Collecting expedition in the Malay Archipelago.
- February 1858: Writes *'On the Tendency of Varieties to Depart Indefinitely From the Original Type'* and sends it off to Charles Darwin for comment.

- 1 July 1858: Wallace and Darwin's writings on natural selection are presented at a meeting of the Linnaean Society.
- November 1859: "*On the Zoological Geography of the Malay Archipelago,"* the paper describing Wallace's Line is read before the Linnaean Society; Darwin's "On the Origin of Species" is published.
- 1 April 1862: Returns to English soil.
- 7 November 1913: Dies at Old Orchard.

"In February of 1858, while suffering from an attack of malaria in the Moluccas (it is not fully certain which island he was actually on, though either Gilolo or Ternate seems the likely candidate), Wallace suddenly, and rather unexpectedly, connected the ideas of Thomas Malthus on the limits to population growth to a mechanism that might insure long-term organic change. This was the concept of the "survival of the fittest," in which those individual organisms that are best adapted to their local surroundings are seen to have a better chance of surviving, and thus of differentially passing along their traits to progeny. Excited over his discovery, Wallace penned an essay on the subject as soon as he was well enough to do so, and sent it off to Darwin. He had begun a correspondence with Darwin two years earlier and knew that he was generally interested in "the species question"; perhaps Darwin would be kind enough to bring the work, titled 'On the Tendency of Varieties to Depart Indefinitely from the Original Type,' to the attention of Lyell? "
http://www.wku.edu/~smithch/index1.htm

Other interesting sites about A. Wallace:
http://rsnr.royalsocietypublishing.org/content/59/2/125
http://wallace-online.org/
http://people.wku.edu/charles.smith/index1.htm

DARWIN'S EVOLUTINARY THEORY

Darwin's evolutionary theory has **two theses**:

1. Descent with modification: All living and extinct species have descended without interruption from one or several original forms of life. These new species accumulated changes over great expanse of time and now look different from one another.

2. Natural Selection: Useful variation will allow those organisms that possess them to survive and reproduce, and pass these good variations to their offspring.

DARWIN'S THEORY OF NATURAL SELECTION.

Fact #1 - Without constraints, populations will grow exponentially, producing an ever more rapidly growing number of organisms.

Fact #2 - In spite of this prediction, the numbers of individuals in a population remains near equilibrium, fluctuating above and below some mean value.

Fact #3 - Resources are limited.

Conclusion: From these three facts, Darwin concluded that *there was a struggle for existence*. Darwin combined this with two additional facts:

Fact #4 - Individuals are unique. There is individual variation. This came from observing animal breeding.

Fact #5 - Much, but not all, of the individual variation is heritable. This observation also came from animal breeders. Some of the observed variation is environmental, some is genetic.

Conclusion: These facts led Darwin to the conclusion that some individuals are better equipped to survive and reproduce (Natural Selection) in their struggle for existence.

Through many generations of time, evolution is the result. Darwin used **"descent with modification."**

Mayr (1982) stated that Darwin's Theory of Evolution included five theories:

1. **Evolution** as such: lineages of organisms change over time.
2. **Common descent**: all life can be represented as a single family tree where there is common ancestor to all species.
3. **Gradualism**: gradual changes produced new species; this is in contrast with **saltation**, the hypothesis that proposes that evolution occurs by sudden leaps.
4. **Population change**: evolution occurs due to the proportion of individuals in the population that inherit a given characteristic.
5. **Natural selection**: survival and reproduction.

A big gap in Darwin's theory was the lack of an explanation about the origin of the variations found in a population: where do these variations come from?

- Darwin's theory was a "**variational theory**" in which populations change due to survival reproduction and selection of certain genes.

- Lamarck's theory was a "**transformational theory**" in which the individual changes, is transformed, and then passes those traits to the offspring.

Difference between Darwin's and Wallace's theories:

- Darwin emphasized the struggle between individuals and species as the selector of the most fit. Wallace emphasized the environmental forces as the selector.

Blending Inheritance.

This was the prevailing hypothesis about the inheritance of traits.

- Maternal and paternal contributions blend in the offspring.
- As a result, a new adaptation will be diluted in successive generations and eventually disappear.

Therefore, variation should decrease and not increase.

Darwin never knew that Gregor Mendel had solved the problem of inheritance in a paper published in 1865.

EVOLUTIONARY THEORIES AFTER DARWIN

After Darwin's theory was proposed in the 1850s there was period of substantial controversy and several theories were proposed, which included neo-Lamarckism, orthogenetic and mutationists theories.

A great deal of information was accumulated after the 1870 due to the work done in paleontology, comparative morphology and comparative embryology

- **Neo-Lamarckism**: several theories based on the idea of the inheritance of acquired characteristics

- **Orthogenetic theory**: evolution proceeds toward a predetermined goal and does not require natural selection. No mechanism was ever proposed for this theory.

- **Mutationist theory**: geneticists observed that mutations arise and produce new variations in the population, therefore, natural selection was not necessary for evolution to occur; the mutants represent new species.

THE EVOLUTIONARY SYNTHESIS

This synthesis incorporates the information obtained by geneticists, systematists and paleontologists into the theory of evolution proposed by Darwin.

Mutations and natural selection *together* cause adaptive evolution.

Mutations are the raw material of natural selection.

Mutations, recombination, natural selection and other processes operating within species account for the origin of new species and for the major, long-term features of evolution (macroevolution).

Fundamental Principles of Evolution

1. The phenotype is different form the genotype; phenotypic differences may be due to genetics or environmental factors.

2. Environmental effects do not affect genes passed on to the next generation; acquired characteristics are not inherited.

3. Genes retain their identity and do not blend.

4. Genes mutate usually at a slow rate.

5. Evolutionary change occurs in the population.

6. The rate of mutation is too slow for mutation alone to cause evolutionary change, the shift from one genotype to another. Change in genotype proportions in a population can be caused by genetic drift (random fluctuations) and by survival of the fittest (nonrandom; natural selection).

7. Natural selection can, under certain circumstances, bring about substantial evolutionary change in a realistic amount of time.

8. Natural selection can change the frequency of alleles that may recombine with other genes that affect the same trait, and give rise to new phenotypes.

9. Natural populations are variable and can change rapidly when environmental conditions change.

10. Populations in different geographic regions differ in characteristics that have a genetic basis.

11. The number of different genes forms the basis for differences between populations of the same species and between species. This supports the hypothesis that species evolved in a series of small steps.

12. Differences between geographic populations of a species are often adaptive and are the consequence of natural selection.

13. Phenotype alone does not define a species; there are different phenotypes within an interbreeding population. Different species represent different gene pools and do not exchange genes with other species.

14. **Speciation** is the origin of two or more species from a common single ancestor. Speciation occurs by the genetic differentiation of a geographically segregated population.

15. There are many gradations of phenotypic differences in living organisms assigned to species grouped under the same genus, genera to families, etc. Higher taxa arise by the sequential accumulation of small differences rather by the sudden appearance of a new "type".

16. The fossil record has many gaps among quite different kinds of organisms, but it also includes examples of gradation from ancestral forms to newer one.

EVOLUTIONARY BIOLOGY SINCE THE SYNTHESIS

Since the 1950s advances in genetics and molecular biology have revolutionized the study of evolution.

In the sixties, evolutionary theory has expanded into ecology, animal behavior and reproductive biology.

Molecular evolution: analysis of the processes and history of change in genes.

- **Neutral History of Molecular Evolution**: a hypothesis that holds that the evolution of DNA sequences occurs by genetic drift rather than by natural selection.

- **Evolutionary Developmental Biology**: studies how developmental processes both evolved and constraints evolution: **Evo-Devo** for short. It tries to understand and determine the ancestral relationships of organisms and the processes involved in development.

- **Evolutionary Genomics**: deals with the variation and evolution of multiple genes and entire genomes.

PHILOSOPHICAL IMPLICATIONS

The theory of evolution changed the essentialism of Plato and Aristotle and placed variation in its place.

- Every characteristic of a species can vary and radically so if given enough time.

The theory of evolution changed the static concept of the world for one of change.

- Change and not stasis is the natural order.
- Random purposeless variation acted on by blind, purposeless natural selection provided a revolutionary new kind of answer to almost all questions that begin with "Why?".
- The structures of organisms have a function, not a purpose.

ETHICS, RELIGION AND EVOLUTION

Creationist movement: literal reading of the creation stories found in the Bible.

The supposition that natural is good is called by philosophers the Naturalistic Fallacy.

There are no ethical or moral principles in science.

Science does not deny or affirm the existence of a Creator.

EVOLUTION

A **hypothesis** is an educated guess; an informed conjecture of what may be true.

A **scientific theory** is a mature, coherent body of interconnected statements, based on reasoning and evidence that explain a variety of observations.

Evolution is a fact that is explained by the evolutionary theory.

Descent with modifications is supported by evidence provided by paleontology, geographic distributions of species, comparative anatomy, embryology, genetics, biochemistry and molecular biology.

How modifications occur and how ancestors give rise to diverse descendants constitutes the theory of evolution.

A body of ideas about the causes of evolution, including mutation, recombination, gene flow, isolation, random genetic drift, the many forms of natural selection, and other factors, constitute our current theory of evolution.

Like all theories in science, it is incomplete.