

Darwin's Theory of Evolution by Natural Selection

A new theory of biological species

Waseda University, SILS,
Introduction to History and Philosophy of Science

The Facts about Evolution

In the early modern period, due to colonialism and empire building, European naturalists, working in centralized botanical gardens and national zoos, investigated an unprecedented variety of animal and plant specimens. Starting in the 18th century, naturalists began to systematically investigate the fossil remains of various organisms and compare these with living organisms.

In the early half of the 19th century, it became clear that there had once existed entire families of flora and fauna (plants and animals) that had passed out of existence, and that moreover, in the periods – that is, geological strata – in which these creatures existed, much of the flora and fauna that are alive today did not exist.

The evidence for **large-scale biological change** was gathered slowly and was still ongoing when Darwin was working.

Various Theories of Evolution

Although there was a lot of disagreement about how these changes had taken place, and what they implied, by Darwin's time, most naturalists accepted that there had been some changes in biological species.

However, even if we accept that there has been change in species throughout the history of the earth, we might have several different theories about how this change occurred.

All of the theories advanced before Darwin argued for some kind of **directed change** – in some sense *responding to*, and hence *directly influenced by*, the environment and the actions of organisms.

Darwin tried to distinguish his theories from these by arguing that evolutionary changes were based only on **naturally occurring processes** – processes that are still occurring around us now.

The Theory of Evolution by *Natural Selection*

The theory of evolution by *natural selection* is a **theory** about the *mechanism by which* evolution occurred in the past, and is still occurring now. The basic theory was developed by both Darwin and Wallace, however, Darwin gave a much fuller **argument**.

The theory states that biological change takes place with two basic characteristics:

- 1) Variation: *Random variations* occur in the traits of individual organisms and are passed on to their offspring.
- 2) Struggle for existence: There is an existential competition that insures *advantageous traits are preserved* and disadvantageous traits are eliminated.

Local Circumstances, Local Advantages

A key result of **evolution by natural selection** is that it forces us to look at various binaries such as advantage and disadvantage, superior and inferior from a **local perspective**.

This means that there **cannot** be traits that are better in any **absolute sense** – there can only be traits that are better suited for a particular set of circumstances.

- ▶ In an anoxic environment, being able to consume sulfates is more useful than, say, general intelligence.

Within a species, individuals specialize at exploiting the environment in various ways, and over long periods this specialization creates divergence.

- ▶ A group of birds with longer beaks might prefer worms, while a group with stronger beaks might prefer nuts.
- ▶ Being attractive to, and interacting with, mates of the opposite sex is an exploitation of local circumstances.

The Place of *Homo sapiens*

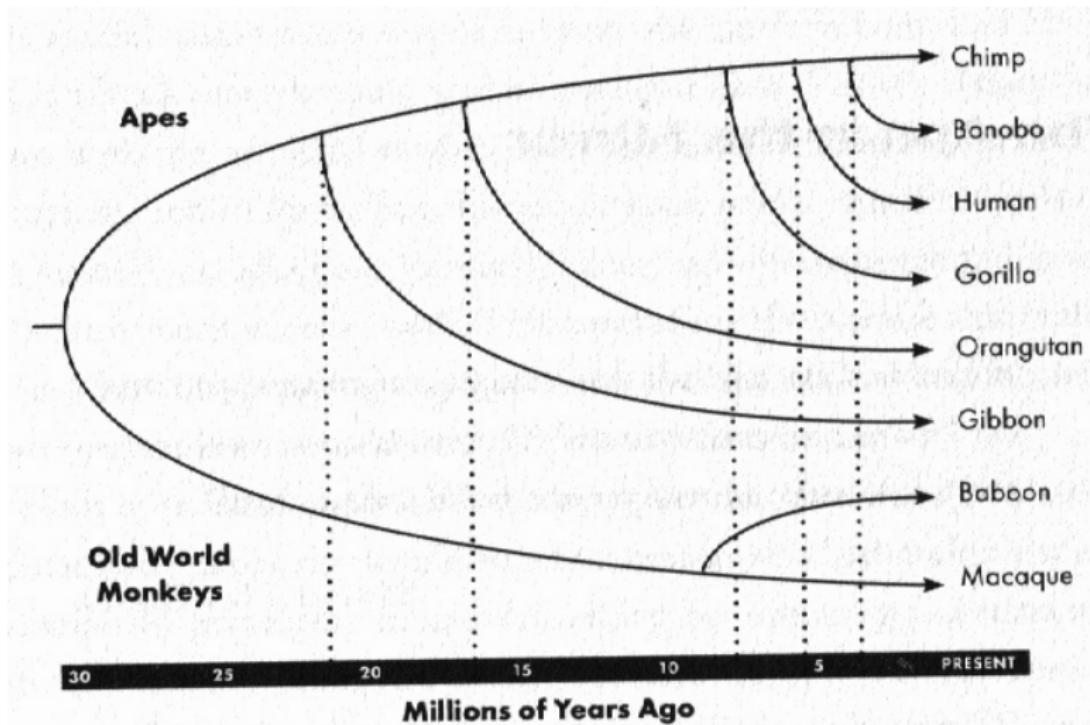
One of the most controversial aspects of the theory of evolution is the implications that it has for human beings.

According to current thinking, there were a number of other species (or varieties) of the *homo* genus that were closely related to humans, but which are now all extinct (*Homo habilis*, *H. erectus*, *H. ergaster*, *H. heidelbergensis*, *H. neanderthalensis*, *H. floresiensis*, etc.). *H. habilis* lived some 2.3 million years ago, whereas the Neanderthals died out about 24,000 years ago. The whole genus is thought to be about 2.5 million years old and to have diverged from the pan genus of great apes about 5 million years ago.

Key Point

Humans did not evolve from apes of the pan genus. **Both** pan apes and humans evolved from *now extinct* common ancestors. Moreover, we are still part of the ape family (Hominidae).

The Ape Superfamily



The term *homo sapiens* was coined by Carl Linnaeus in 1758.

Evolutionary Theories in the 19th Century

In the 19th century, there were many conflicting ideas about evolution and the meaning of the existence of variations among organisms. Many natural philosophers, believed that God had created a fixed number of **species** and that since that time there had been hybridization and mixing (**variation**), but no fundamental change.

In the 1790s, Darwin's own grandfather, Erasmus, had published poems putting forward the idea of evolution.

In the 1810s, Jean-Baptiste Lamarck outlined a comprehensive theory of evolution in which animals, *individually*, become more complex and better adapted and then pass these changes onto their offspring. This kind of theory is known as **Lamarkism**.

In 1844, *Vestiges of the Natural History of Creation* (Robert Chambers) presented a natural history in which all forms were in transformation and everything develops from previous forms.

19th Century Geology: Neptunism

In the 18th and 19th centuries the empirical study of rocks and minerals was of increasing economic importance. The earliest theories of rock formations were developed in the mining schools in the German states.

Abraham Werner (1749–1817), a professor at the mining school in Freiburg, set out a theory of stratification, in which he claimed that different types of rocks were laid down in different periods of the earth's history by the gradual drying of a primordial ocean.

In the early 19th century, this was combined with a hypothesis of cataclysmic changes and developed as a theory that helped geologists prospect for different types of rocks and minerals.

There were also conservative thinkers, who linked the primordial ocean of **neptunism** with Noah's flood mentioned in the Bible, but this was not the majority.

19th Century Geology: Plutonism

In the 19th century, it became clear that the same kinds of rocks had been formed in different periods of the earth's history, so geologists began to study the fossils embedded in the strata. It became clear that there were the same kinds of fossils at comparable levels all over the earth.

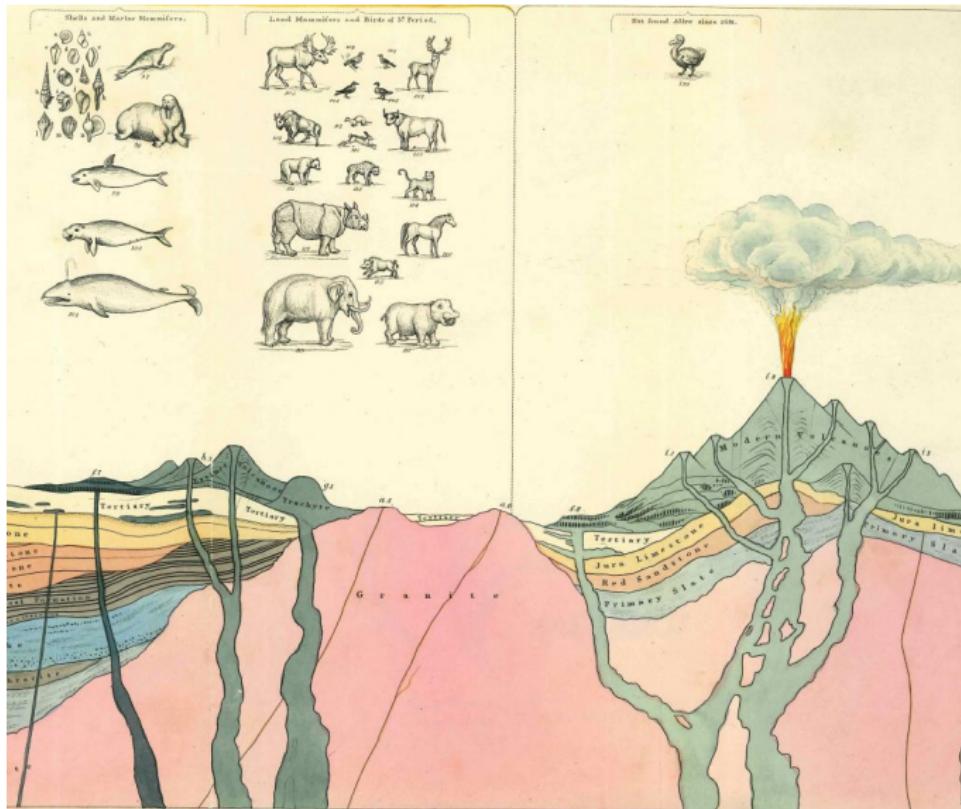
Geologists like James Hutton (1726–1797) and Charles Lyell (1797–1875) began to focus on the role of volcanoes and argued that the earth had a molten core – which was called **plutonism**. They argued that geological formations are not the result of cataclysmic changes in the past, but the long-term gradual result of processes we see around us now. This became known as **uniformitarianism**.

Hutton:

“We find no vestige of a beginning,—no prospect of an end.”

Naturalists began to contemplate **vast stretches of time**.

W. Buckland, *Geology and Mineralogy ...*



...Considered with Reference to Natural Theology, 1837

Malthus' Social Ideas

- ▶ Beginning in the end of the 18th century, the rising industrialism in Britain created a massive growth of urban poor. This lead to the rise of poverty as a social problem and to various attempts to address it.
- ▶ In 1798, Thomas Malthus (1766–1834) published his *Essay on the Principle of Population*.
- ▶ Malthus argued that human population increases **geometrically**, while food supplies increase **arithmetically**.
- ▶ This means that at some point, population growth will always outstrip food supplies and there will be a **struggle for existence**, especially among the poor.
- ▶ Thus, Mathus saw the conditions of poverty, *which had been created by the Industrial Revolution*, as a necessary fact of the human condition.
- ▶ This was a thoroughly pessimistic doctrine.

Charles Darwin (1809–1882)

- ▶ 5th child of a wealthy, agnostic doctor.
- ▶ Started in medicine, then graduated from Cambridge to be a pastor, but felt no sense of vocation.
- ▶ Took the opportunity to pay his own way as a naturalist on a surveying expedition: 5 years on HMS Beagle
- ▶ Became a respected member of the British scientific elite.
- ▶ **After 20 years**, published his ideas about evolution.
- ▶ Was very often sick with various psychosomatic disorders.
- ▶ Worked endlessly on scientific projects until the day he died.



SOUTH AMERICA



••• = outward leg
••• = homeward leg
===== = overland expeditions

**The Voyage of
HMS BEAGLE**

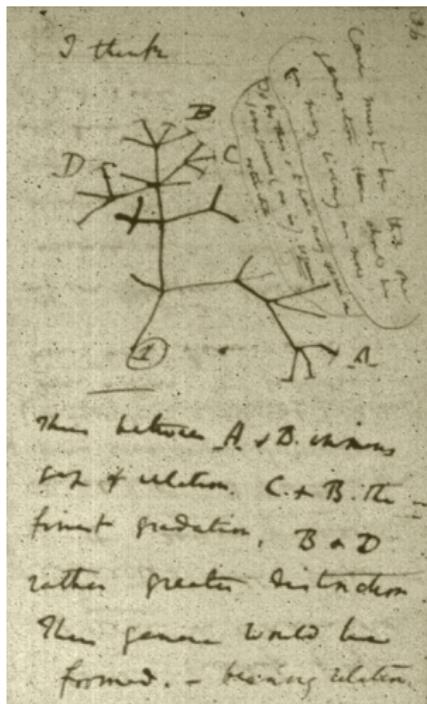
27th December 1831 - 2nd October 1836
(showing the exploration of
South America's coastline in greater detail)



The Voyage of the Beagle

- ▶ While on the voyage of the Beagle, Darwin read Lyell's *Principles of Geology*.
- ▶ He collected thousands of specimens of plants and animals and carried out extensive studies of the geography of South America and various Pacific islands.
 - ▶ He came to believe that the Andes were formed over long periods of time, by the landmass slowly rising and the seas receding.
 - ▶ He became convinced that the atolls of Pacific islands were produced by the coral growing as the mountains sank.
- ▶ In Tierra Del Fuego, he observed native people living in the wild and became convinced that humans are not so far removed from animals and show great diversity amongst themselves.
- ▶ In the Galapagos Islands, he observed considerable diversity but he collected erratically and did not even tag by island.

Secret Notebooks



Darwin's first sketch of his concept of speciation

When he returned to England, he sent out all of his specimens to be cataloged by experts.

- ▶ John Gould realized that all of the different types of birds that Darwin had collected on the Galapagos were **various species** of finches.

Darwin began to keep a series of *secret notebooks* in which he wrote his ideas about the "**transmutation**" of species. From the beginning, he was interested in the origin of life and the human species.

During this time, he read Malthus' *Essay*. This gave Darwin the idea for a mechanism for evolution.

Becoming Respectable

After returning from the voyage of the Beagle, Darwin began to publish his ideas about the geography of South America, handbooks of the flora and fauna of the places he visited and an account of his travels.

He made a name for himself as a naturalist and became a friend and colleague of many of the most important biologists in England.

Occasionally, he would try to interest someone in his ideas about **transmutation**, but no one was convinced.

Because Darwin was himself a member of the social elite, he tried to distance himself from other evolutionists, such as Lamarck and Chambers. Also, his wife was very religious.

- ▶ At this time, in Britain, evolution was regarded as a dangerous idea, associated with France, the revolution, and social and political unrest.

The Origin of Species, 1859–1872

When Darwin realized that the established scientists were not interested in his ideas, he began to cultivate the friendship of younger men who were on the rise such as Thomas Huxley (1825–1895) and Joseph Hooker (1817–1911). Over a period of many years, through correspondence, he tried to convince them of his ideas.

In the 1850s, he also started a correspondence with Alfred Wallace (1823–1913). This lead to Wallace sending Darwin a short paper in which he independently described a theory of evolution by natural selection.

It was decided by Lyell and Hooker, who both knew of Darwin's work, that the two men should make a joint presentation at the Linnean Society acknowledging their independent discovery. No one took any notice of this.

Darwin then spent over a year developing the argument which was published as *On the Origin of Species*, 1859.

The Origin of Species: Variation (Chaps. 1 & 2)

Chap. 1: Darwin pointed out that animal breeders artificially select preferred characteristics from domestic populations (pigeons, cows, dogs, etc.) in which there is a lot of random variation.

Over many generations these small differences produce very different types of animals (varieties of the same species).

Chap. 2: Darwin argued that a similar *selection occurs* in nature.

He then began to discuss the **nature of species**. He pointed out that it is often hard to demarcate between species; it is hard to decide what are different species as opposed to different varieties.

He argued that we could think of well-marked varieties as “incipient species” – that is, newly forming, or emerging.

The Origin of Species: Struggle for Existence (Chap. 3)

Chap. 3: Darwin argued that individual organisms and species are all in a **struggle for existence**.

- ▶ This was contrary to the prevailing view – that nature was harmonious and showed evidence of a beneficent creator – a doctrine known as **natural theology**.

Instead, Darwin claimed that life is a complex struggle – not always dramatically violent, as in predators and prey, but usually more subtle, as a plant struggling against drought, or the introduction of new species into a habitat, etc.

He argued that this struggle then resulted in what he called “natural selection.” In the 6th edition of the book, he adopted the terminology of Herbert Spencer and referred to the “survival of the fittest.”

The Struggle for Existence

The Origin of Species, 1872 (6th edition)

"A **struggle for existence** inevitably follows from the high rate at which all organic beings tend to increase. Every being...must suffer destruction during some period of its life...otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a **struggle for existence**, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the **doctrine of Malthus** applied with manifold force to the whole animal and vegetable kingdoms; for in this case there can be no artificial increase of food..."

The Origin of Species: Natural Selection (Chap. 4)

Chap. 4: In this chapter, Darwin explains the core of his theory:

- ▶ Nature varies, randomly.
- ▶ Some of variations are more advantageous than others.
- ▶ Because there is a struggle for existence, any advantage will be important, *however slight*.
- ▶ In the long run, those organisms that have a slight innate advantage will survive more often than those that do not, passing on their advantages to their offspring.

Through this mechanism, Darwin argued that a **population** will change by the accumulation of small, but favorable advantages, over *vast periods of time*.

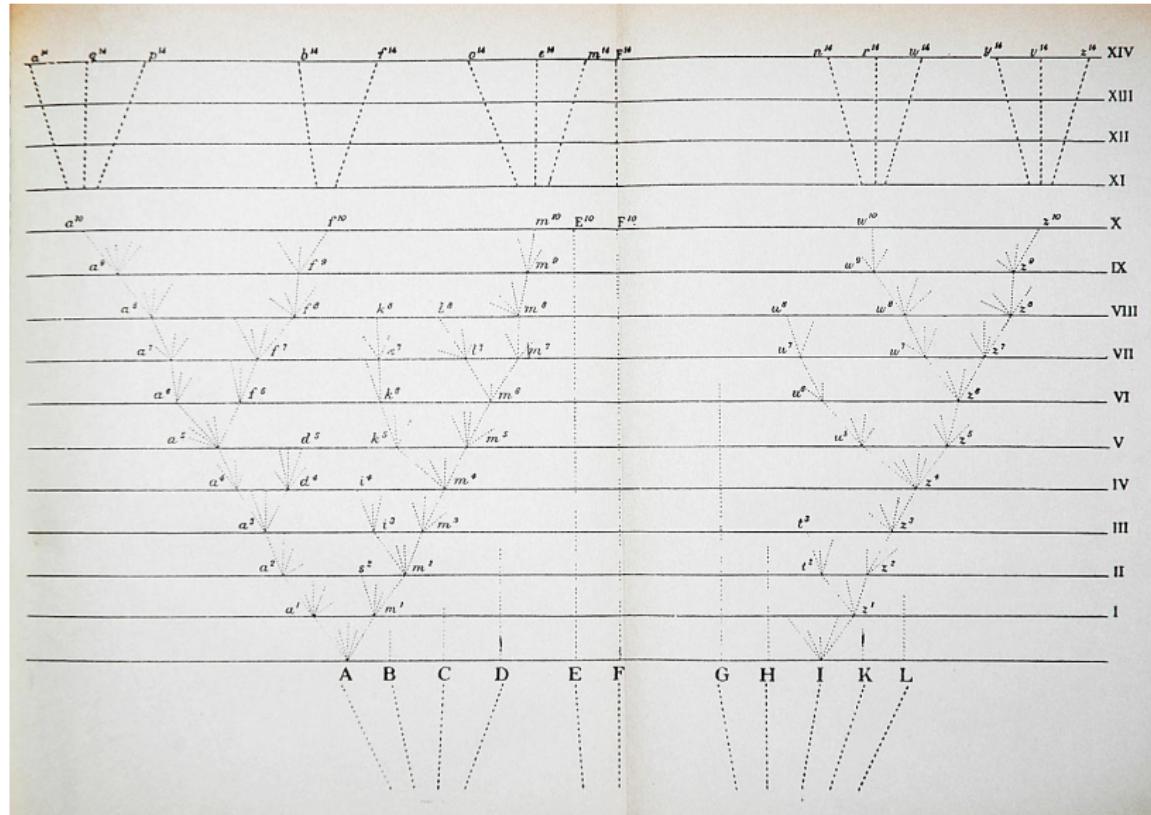
Again, he referred to artificial selection, calling natural selection “unconscious artificial selection.” But notice that nature does **not** choose preferred traits in the way that a breeder does.

Natural Selection

The Origin of Species, 1868 (5th edition), Introduction

"Owing to this struggle [for existence], variations, however slight and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be inherited by the offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term **Natural Selection**, in order to mark its relation to man's power of selection. But the expression often used by Mr. Herbert Spencer of the **Survival of the Fittest** is more accurate, and is sometimes equally convenient."

Darwin's concept of divergence



The diagram represents divergence against time, as earth strata

The Initial Reaction

The *Origin* was a very popular book, and went through six editions from 1859 to 1872. Darwin tapped into the thinking of the time and pitched evolution as a form of progress similar to the progress of the English nation that his contemporaries perceived. England was no longer as conservative as it had been when he was young and a belief in social progress using science and industry fit well with the evolutionary idea of biological progress.

Literal interpretations of the Bible were coming under increasing criticism and many were prepared to be convinced of the *fact of biological evolution*.

Darwin's close supporters, such as Huxley, Hooker and Lyell, were influential and helped Darwin carry out the social aspect of the argument for evolution.

The Reaction to Natural Selection

Although the *Origin* convinced many naturalists of the fact of evolution, many people remained skeptical about the theory of **natural selection**. People raised the following objections:

- ▶ It is random and open-ended.
- ▶ Is not a goal directed process.
 - ▶ Where the goal was implicitly understood as white, Victorian, upper-class males.
- ▶ It does not imply directed progress.
 - ▶ This was a challenge to the establishment and to the mercantile values of the rising middle class.
- ▶ Is not an open system, as in Lamarck's theory. That is, individuals cannot improve themselves throughout the course of their lives and pass on these improvements.

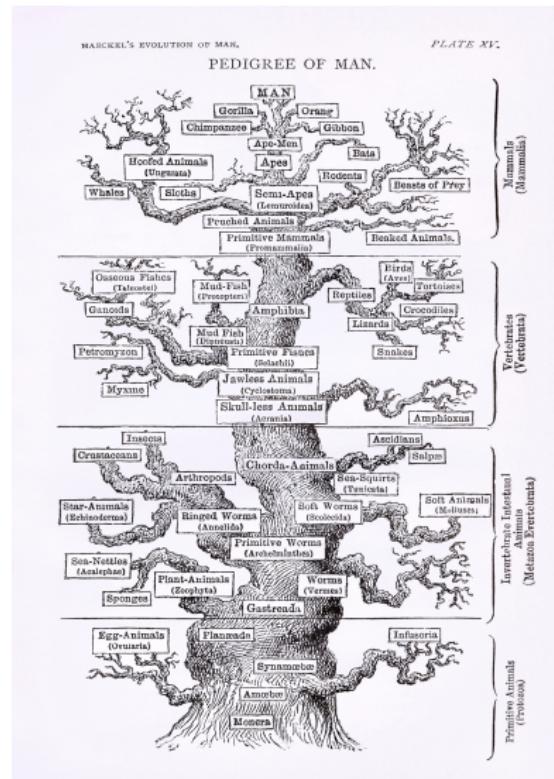
Most naturalists of the 1870s and 80s became evolutionists, and even called themselves "Darwinists," but did not accept **natural selection**, which was the core of Darwin's theory.

Darwinists without Natural Selection

Even many people who supported Darwin, did not accept, or understand, natural selection.

For example, Herbert Spencer, used Darwin's ideas to explain human progress towards fitter individuals – a very progressivist view of evolution.

Ernst Haeckel, an avid Darwinist, thought that evolution unfolded according to a plan, like embryonic development ("ontogeny recapitulates phylogeny").



Haeckel's "Tree of Life"

The Religious Reaction

Darwin's ideas gave a profound shock to the religious establishment, and to the naturalists who supported it with the theory of **natural theology**. Darwin's theory was perceived as being much more difficult to reconcile with a creative, all powerful god, than those of Copernicus, Galileo or Newton.

If we take natural selection seriously it is difficult to see how a god could have created *us*, and hence it is difficult to see how we could have any special place in a god's creation.

There were a number of public disputes between religious authorities, older naturalists and the Darwinists.

- ▶ Bishop Wilberforce and Huxley at the British Association for the Advancement of Science meeting.
- ▶ There was an ongoing debate in newspapers and journals.

A number of naturalists argued for "theistic evolution," and even many of Darwin's colleagues, such as Lyell and Wallace, could not fully accept the natural selection of human beings.

The Modern Synthesis

In the 1930s–40s, there was a revival of the theory of evolution through the mechanism of natural selection. It was argued that the new science of genetics made it clear that mutations in genes could be completely random and that these could then be adaptively selected for by purely environmental pressures.

The modern synthesis brought together all the different branches of life sciences and viewed their findings through the light of natural selection.

Dobzhansky, 1973:

“Nothing in biology makes sense except in the light of evolution.”

There was a renewed interest in the evolution of the human race and in thinking about the implications of evolution through natural selection as a basis for understanding our social and moral place in the world.

Natural Selection and Human Nature

Some of the most serious implications of the theory of natural selection are on our understanding of *human nature*.

If human beings evolved from a primate ancestor, it might mean that even our most “noble” traits – such as our ability to love, our feeling of the divine, our creativity, our love of knowledge, our concern for others, etc. – are not the gifts of a benevolent god, but are rather the chance results of natural processes.

While it is easy to see that our base traits – such as greed, lust, selfishness, etc. – would have helped our ancestors to survive, it has been more difficult to see this with our noble traits.

We are still in the process of developing models of behavior that show how these traits would have been advantageous to our ancestors. That is, scientists are currently still articulating the paradigm of natural selection to cover more and more phenomena.

Overview

Over the course of his life, Darwin went from being a devout Anglican, who had intended to become a minister and believed that the natural world was evidence of God's providence, to being an agnostic who believed that human beings were the chance result of natural processes.

The revolution in thought and worldview brought about by the theory of natural selection is one of the most profound to have effected us.

Although almost all biologists now accept natural selection, it is still difficult for many lay people to accept. It is still disputed from the perspectives of both religion and "common sense."

From the perspective of worldviews, we should remember that it often takes a long time for a new worldview to take hold. A change in worldview involves many cultural and social factors that do not always follow a clear logic.