

Evolution

By Natural Selection

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The Idea of Progress

- The spirit of the times in 19th century, England especially.
- Derives from the Enlightenment and Rationalism and the Industrial Revolution.
- Steady upward direction to all life.
- Like a machine, but directed toward an end: perfection.

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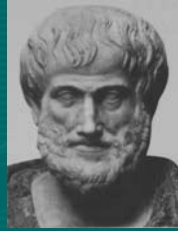
Naturphilosophie

- Nature is like an organism, alive and growing
 - Life follows a universal archetype.
- The Problem of Teleology
 - Goal directed activity.
 - How to reconcile with a blind mechanism?

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Science and Chance

- Aristotle
 - Accident vs. Necessity
 - Accidents don't repeat
 - E.g., Empedocles, the “Man-faced ox progeny.”
 - Things that happen by chance don't repeat, so ignore them.
 - Science concerns regularities, not exceptions.

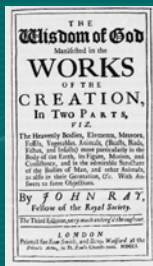


The Effect of Choice

- Newton on choice
 - Evidence of God's intervention
 - Uniform direction of planetary revolution about the sun
 - The nearly uniform plane of orbit of the planets
 - Gravitation – no mechanical cause evident
 - “Corrections” to the planetary orbits
 - The regularity of the parts of animals (cf. Query 31 of *The Opticks*)
- Compare this with Laplace's conclusion that he had no need for God.

The Design Argument

- God is revealed by his design in nature.
- An inexplicable regularity is evidence of God.
- Nature is a second Scripture.
 - “Natural Theology”
- Many works published that developed the Design Argument, e.g., John Ray's *The Wisdom of God Manifested in the Works of Creation*, 1701.



The Bridgewater Treatises

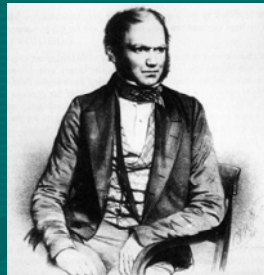
- The 8th Earl of Bridgewater left a bequest in 1829 for works “on the power, wisdom and goodness of God as manifested in the Creation.”
- 8 “Bridgewater Treatises” were published in the 1830s.
- One of them was: Charles Bell, *The Hand: Its Mechanism and Vital Endonments as Evincing Design* (1833).
 - An out and out attack on Lamarck’s theory.

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Charles Darwin

- 1809-1882
- Darwin came from wealthy middle-class English family, prominent in English intellectual life.



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Charles Darwin, 2

- His paternal grandfather was Erasmus Darwin, a member of the Lunar Society and an early evolutionist, with a theory something like Lamarck’s but not detailed.
- His maternal grandfather was Josiah Wedgwood, the famous potter, and also a member of the Lunar Society.



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Charles Darwin, 3



- Darwin's father was a prominent physician and expected young Darwin to follow him in the medical profession.

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Darwin's Education

- Darwin went first to the University of Edinburgh to study medicine.
 - But he did not like it and dropped out.
- Then he went to the University of Cambridge, ostensibly to study to become a clergyman.
- While at Cambridge he came under the influence of the clergyman/naturalist J. S. Henslow and became interested in becoming a naturalist himself.



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The Voyage of the Beagle

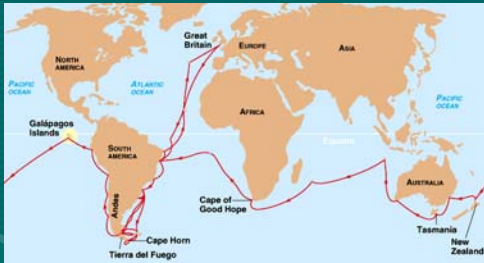


- The British admiralty was planning a long, round-the-world surveying voyage and wished to take a naturalist.
- Henslow nominated Darwin, and he got the position.

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The Voyage of the Beagle, 2



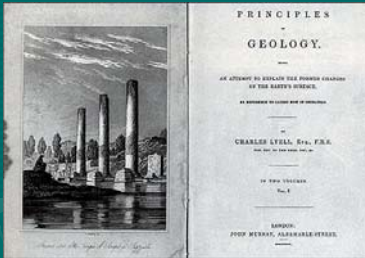
- Darwin took the position; sailed on the Beagle for 5 years, from 1831 to 1836.

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Darwin and Lyell's *Principles of Geology*

- Lyell's *Principles of Geology* was published during the years of the voyage.
- Darwin took *volume 1* with him. He had the others sent to him as they became available.
 - Darwin read these all very carefully.



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Darwin and Lyell's *Principles of Geology*, 2

- Lyell gave very good summaries of existing theories of flora and fauna including Lamarck's theory of evolution.
- Lyell himself believed that there was limited variation in plants and animals but no evolution into another life form was possible.
- But Lyell believed that geological formations occurred naturally with small changes over vast periods of time (i.e., uniformitarianism).

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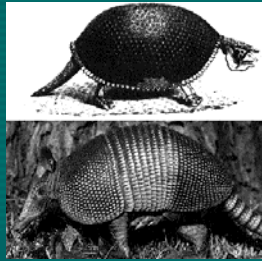
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Darwin's travels down the coast of South America

- Darwin noted that life forms were similar in all places, but had somewhat different form in the different climates encountered.
 - This was true of both plants and animals.
 - Plants became hardier as he moved away from the equator.
 - Animals had heavier fur, or thicker feathers, etc.
 - But changes were gradual as the climate changed.

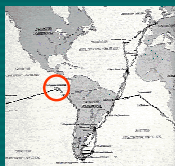
Darwin's in South America, 2

- They also appeared to vary over time.
- Fossils and other remains of extinct creatures were found in the same locale as living creatures structurally similar to the extinct ones, but perhaps varying enormously in size.
- E.g. the extinct *edentates* that were so much like the living (and much smaller) *armadillos*.

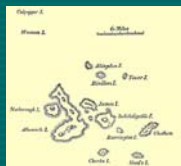


Above: A giant, extinct, edentate, reconstructed from fossil remains. Below, a living armadillo.

Darwin at the Galapagos Islands



Galapagos Islands circled



The Galapagos Islands.

- After travelling down the east coast of South America, the Beagle went up the west coast and then ventured out to the Galapagos Islands, 600 miles west of Ecuador. These are volcanic (therefore recent) islands, isolated from anywhere else. Both the climate and the terrain are similar from island to island.

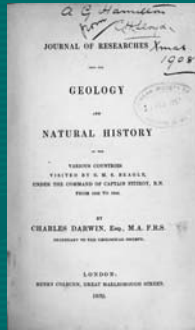
Darwin at the Galapagos Islands

- Darwin found that each island had its own special life forms.
- The giant tortoises had characteristic markings that could be used to identify their home island.
- Finches had anatomical differences (e.g. shape of beak) that were suited to different diets.



Darwin the naturalist

- When the five-year voyage was finally concluded, Darwin returned to England and wrote up his findings.
- His book, *Journal of Researches into the Geology and Natural History of the various countries visited by H.M.S. Beagle*, became a bestseller in 19th century England, going through many editions in Darwin's lifetime and establishing Darwin's reputation as a naturalist.



Darwin at Down



- Darwin married his 1st cousin Emma and settled down to a rural life in the village of Down, just outside of London, where they remained for the rest of their lives. They had 10 children.

Darwin at Down

- Darwin began a long and careful consideration of some of the problems that troubled him on the Voyage. He began to write these down in a series of notebooks in which he made observations. He continued this for 20 years.
- During those years, he made famous studies of barnacles – writing what is today still the definitive text on barnacles. He wrote about orchid breeding, cattle breeding, and breeding pigeons for show.

Darwin's Problem

- Species vary systematically from place to place and over long periods of time.
 - How could he explain the similarities?
 - How does inheritance work?
- Why were they not all identical?
 - If there is evolution, how does it work?

Lamarck's view

- Lamarck believed that species would adapt to changes in their environment and pass those changes on to future generations.
 - That might explain the differences in species up and down the coast of South America as the climate changed.
 - It might explain changes in species over vast amounts of time.
 - *E.g.* the extinct giant edentates and the present smaller armadillos.
 - But how could it explain the differences from island to island in the Galapagos, where the environment is virtually identical?

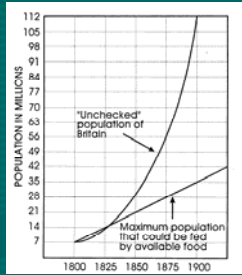
Darwin reads Malthus



- In 1798, the Reverend Thomas Malthus published his *Essay on Population*, in which he predicted that the human population was growing at a rate at which there would soon not be enough food to go around.

Darwin reads Malthus, 2

- Malthus argued that populations will tend to grow exponentially if there is ample food, doubling in about 25 years, as it had been doing in the United States according to a census in his time.
- Meanwhile any increase in the food supply depends on the amount of land under cultivation, which is necessarily limited.



An illustration of Malthus' projections for Britain in the 19th century.

Darwin reads Malthus, 3

- Malthus' book caused a sensation in the early 19th century as people began to worry about the possible scarcity of resources.
 - The book was recommended to Darwin as interesting reading. He read it in 1838—two years after returning from the Beagle voyage.
- Malthus' thesis made Darwin begin to wonder whether the same causes could not be at work in nature, with the effect of causing a competition at all times for available resources—across all species.
 - In typical Darwin fashion, he pondered this very slowly.

Alfred Russel Wallace



- 1823-1913
- Another 19th century naturalist.
- Wallace, 14 years younger than Darwin, came from a poorer family than Darwin and did not have Darwin's advantages.
- But he shared many of Darwin's interests.
- Wallace trained and worked as a land surveyor, then took up a career as a naturalist, collecting specimens from exotic locations, writing about them, and selling them to museums back home.

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Wallace reads Malthus

- Like Darwin, Wallace had travelled on long expeditions to far-away places, carrying Lyell's *Principles of Geology* with him as a basic reference text.
 - Wallace also was struck with the evidence for evolution, but, like Darwin, could not find a mechanism to explain it.
- In 1858, twenty years after Darwin had done the same, Wallace read the book by Malthus, while he was out on an expedition in Borneo.

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Wallace reads Malthus, 2

- Like Darwin, Wallace was struck by the applicability of Malthus' analysis to species in general.
- *Unlike* Darwin, who wanted mountains of supporting evidence, Wallace leapt at this explanation and wished to announce it to the world.
 - In just a few days, he wrote up a quick draft paper outlining his explanation and sent it to Darwin seeking his opinion of the paper and asking him to forward it on to a journal for publication if he thought it worthy.

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Darwin's crisis of conscience

- Darwin was shocked at Wallace's paper. Not only did Wallace seize upon the same main point from Malthus, Wallace sketched out its implications in much the same way that Darwin had been planning to do in the book he had been working on for 20 years.
 - Darwin wished to do the honourable thing by Wallace, but did not want to be upstaged by this much less thought-out hypothesis.

Darwin's crisis of conscience, 2

- Darwin sought the advice of two of his closest friends, Charles Lyell and Joseph Hooker, virtually the only people who knew what Darwin had been working on all these years.
 - Lyell and Hooker advised Darwin to send Wallace's paper to the Linnean Society in London, along with an excerpt from one of Darwin's notebooks and a copy of a letter Darwin had written to an American botanist the year before.
 - These would establish that Darwin had been at work on the same idea for much longer.

Darwin forced into action

- In July 1858, the three papers were read at the Linnean Society meeting and published shortly afterward.
 - They made very little impression on the Linnean Society members, who did not understand their significance.
- Though Darwin was not ready to go public with his ideas, Wallace's paper forced his hand. Darwin therefore began work on an "abstract" of his larger work, for publication the next year.

On the Origin of Species

- The “abstract” was called *On the Origin of Species by means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*.
 - It was published in **1859** – **remember this date**. It is the 7th date you need to remember in this course.
 - The “abstract” ran for about 500 pages.



“The Book that Shook the World”

- The 1st edition of *The Origin* sold out on the day of publication, Nov. 24, 1859
 - There were 27,000 copies sold in Britain in Darwin’s lifetime.
 - A total of 6 editions.
 - The 6th edition finally dropped the word “On” from the title.
 - There were editions in America and other English-speaking countries and many translations.
- The reaction to the book was strong and immediate. There was a greater immediate reaction to this book than to any other scientific work ever published.

Elements of Darwin’s Explanation of Evolution

- Continuous variation
- Selective Breeding develops different traits
 - Plant, cattle breeders, etc. select traits “artificially.”
 - Nature selects the variations with the best chance to survive in a given environment (“natural selection”).
- Sexual selection
 - Those who are most fit to survive are also most likely mate with each other and leave offspring.
- Vast amount of time available (as evidenced by geology).

Different views on the organization of species in nature

- The Scala Naturæ or Great Chain of Being
- Cuvier's "bush" – an ordered branching system with hierarchies
- Darwin's undirected branching evolution where lines continue so long as they fit their environment, but may become extinct if the environment changes or they may branch off and evolve into some other viable line. The result is a chaotic pattern that, if sketched looks like "*a bush pruned by a drunken gardener.*"

One generation in Darwin's evolutionary process

1. *Continuous variation:*
 - Many individuals born, exhibiting a variety of characteristics.
 2. *Natural Selection:*
 - Some are fit to survive, others are unfit or less fit, and do not survive to mate.
 3. *Sexual Selection:*
 - Of the remaining individuals, those with the most attractive characteristics (in general, the healthiest individuals) will mate and produce offspring.
- Thus, the next generation are the offspring of the fittest of the previous generation, whatever the criteria of fitness may be at any time.

Variation

- What is the cause of the variation assumed by Darwin?
 - This is the main weak point in Darwin's explanation.
 - For Lamarck, variation is caused by an organism responding to its environment, and then passing on that adaptation to the next generation.
- For Darwin (and Wallace too), variation was something observed as a fact.
 - No mechanism was found that would cause the variations to occur.

Pangeneses

- Darwin's inheritance theory
- Faced with having to explain inheritance somehow, Darwin adopted *pangeneses*.
 - All parts (cells) of the body produce small bits "gemmules" that go through the blood system and collect in the sex cells – the ova and sperm cells in animals.
 - These gemmules carry the imprint of the structure of the cells they came from.
 - Gemmules from each parent blend together to form new cells that have characteristics drawn from both parents.

Problems with the pangeneses theory

- How do these gemmules work?
- What is the mechanism through which they direct growth?
- How do they blend together, taking aspects of both parents?

Problems with pangeneses, 2

- If the gemmules emanate from the actual cells of the bodies of the parents, what about the offspring of amputees?
 - Such *ad hoc* explanations were less acceptable in science in Darwin's day. Though not necessarily wrong, they belonged in the realm of speculation, not scientific theory.



Darwin's attack on the Design Argument

- The Design Argument asserts that “Design implies a designer.”
- Darwin tried to show that designs in nature can arise without purpose or intention, merely as the result of natural selection.
- To show that that assertion of the Design Argument is invalid, Darwin only needs to show that *it is possible* that a design in nature could have arisen from natural causes.

The Logical Structure of the Design Argument

- The power of the Design Argument comes from its assertion that
 1. The order and design is apparent in nature – how individual organisms are purposely arranged for different functions, how species are interdependent, etc.
 2. That order and design could only have arisen by an intelligent creator: God.

Logic of the Design Argument, 2

- So long as the second point (that the apparent order implies a designer) is incontrovertible, the argument is airtight.
- However, it completely loses its power if it could be established that order and purpose could have arisen some other way – such as by the process of evolution by natural selection.

Logic of the Design Argument, 3

- Darwin was totally unable to prove that nature arose from evolution by natural selection, but if he could show that such a result (nature as we know it) was a conceivable possibility, then the Design Argument loses its power.

Logic of the Design Argument, 4

- Charles Bell's Bridgewater Treatise used the example of the hand, with all its marvelous adaptations, to illustrate design in nature, and assert that it proved the intervention of God.
- Darwin took this argument head-on with an even more complex organ, the eye.
 - He argued that a light-sensitive nerve could have survival value and over many generations become more and more refined until it evolved into an eye.

Weight of Evidence

- It was first in Darwin's theory of evolution that the general public (and even the scientific public) became aware that no scientific theories are ever "proven" in the sense of logically certain, but are nevertheless accepted because their explanations are so much better than any alternatives.
- Because living nature is so complex and has so many forms, Darwin's presentation is notable for its emphasis on the weight of evidence presented in favour of his theory.

Human Evolution

- In *The Origin*, Darwin hardly mentions human evolution at all. Darwin knew how controversial it would be, so he was willing to leave it alone.
 - His one hint in *The Origin*: “Light will be thrown on the origin of man and his history.”
- However, the public immediately drew the obvious conclusions and concluded that Darwin believed that humans descended from animals.

Darwin's Bulldog

- While Darwin preferred to remain a recluse and not discuss his theories, one of his disciples was more willing to engage in a good argument.
- Thomas Henry Huxley was a prominent zoologist and Darwin convert. He became known as Darwin's “Bulldog” because of his willingness to argue the case for evolution.



Thomas Henry Huxley

Wilberforce versus Huxley



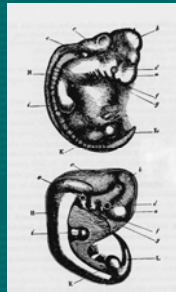
- The most famous debate over evolution happened in 1860, the year after the publication of *The Origin*.
- Samuel Wilberforce, Bishop of Oxford, taunted Huxley at a meeting of the British Association for the Advancement of Science, asking if Huxley was descended from an ape on his grandfather's or his grandmother's side.
 - Huxley took him on and made a fool of the Bishop.

Darwin on Man

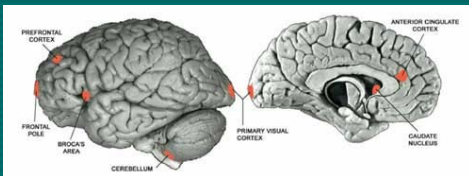
- Finally, in 1871, Darwin published his work on human evolution, *The Descent of Man*.
 - Darwin established the relationship between humans and primates (apes, monkeys)
 - As far as the human species itself was concerned, Darwin asserted that all humans were essentially alike.
 - A common view in his time was that different races were actually different species.

Darwin on Man, 2

- Darwin showed the similarity of humans to other animals at different stages of development.
- At right is a human embryo (top) and a dog embryo (bottom).



Darwinians join in



- Huxley obtained specimens of a human brain and a chimpanzee brain and showed their similarity in construction.
- Above: human brain on the left, chimp on the right. This is not Huxley's illustration, but it is similar.

Darwinians join in

- Other Darwinians followed Darwin's lead with embryos and showed the striking similarity of many creatures at the early stages of their fetal development.



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Other views in circulation in Darwin's time:

- The Great Chain of Being – humans were the top of the evolutionary chain, more “perfect” than other species
- Europeans were the top of a pecking order among humans.
- Microcephalic idiots were viewed as intermediate links between man and ape
- Anthropoid fossils – first discovered in 1836
 - Neanderthal Man (1886) – first thought to be recent
 - Java Ape Man (1891) had low cranial capacity
 - These thought to be missing links

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General Criticisms of Darwin's Theory

- Evidence for Natural Selection is lacking.
- There are no transitional species.
- The Design Argument
- Orthogenetic Trends
 - for example, sabre-tooth cats

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General Criticisms of Darwin's Theory, 2

- The age of the earth
 - Prominent physicist Lord Kelvin (William Thomson) in 1865 claimed that the sun (and therefore the earth) could not possibly be old enough for evolution to have taken place.
- Inheritance unexplained
 - Fleeming Jenkin (1867) argued that Darwin's theory of blending inheritance could not possibly lead to the preservation of favourable characteristics
- The Inheritance of Acquired Characteristics
 - As opposed to Natural Selection.

Social Darwinism

- The general application of Darwinian principles to society and human endeavor, rather than just to species evolution.
- In general, the chief new factor is the recognition of the importance of processes that happen over long periods of time.

Some examples of Social Darwinism

- Theology
 - The authority of the Bible, and the creation story in Genesis rethought.
 - The issue of the uniqueness of man as opposed to other species, as taught in many religious doctrines.
 - The Design argument, both supported and argued against.

Examples of Social Darwinism, 2

- Racism and Slavery
 - Darwin’s view: All races are equally human, therefore slavery is a historical accident of who happened to have power at a particular time
 - Another, opposed view, but which many people thought to be “Darwinian” was that Europeans were “more evolved” and therefore had a natural right to enslave other races

Examples of Social Darwinism, 3

- Politics
 - National Socialism (the Nazis) were based upon the notion that keeping the race pure would be an aid to the evolution of a super race (Ernst Haeckel’s view)
 - Capitalism and the *Laissez-faire* approach to economics viewed market forces as a sort of natural selection.
 - Therefore the self-made millionaire was seen as the highest form of evolution (William Graham Sumner’s view).
 - The “Invisible Hand” of Adam Smith was considered comparable to Natural Selection
 - Communism
 - The group viewed as more important than the individual in order to advance the cause of society.
 - Karl Marx wished to dedicate *Das Capital* to Darwin (who was horrified at the thought).

Examples of Social Darwinism, 4

- Sociology
 - Sociology, touted as the “Science of Society” needed a theoretical structure. Natural Selection provided a basis on which to explain why societies have taken the forms they have.
 - British popular philosopher Herbert Spencer (1820-1903) wrote extensively on the bases of many social sciences. He is the person who coined the term “Survival of the Fittest,” in 1858 – the year *before* the publication of the *Origin of Species*. (Darwin later incorporated the phrase in the subtitle of later editions of the *Origin*.)

Examples of Social Darwinism, 5

- Eugenics
 - A movement to help evolution along by sterilizing those who are seen as less likely to have ideal characteristics. In other words, using artificial selection (like animal breeders) to help natural selection.
 - Darwin's cousin, Francis Galton, was one of the leaders of the movement.
 - In Germany the National Socialist Party adopted eugenics as a central part of their political platform. After the Second World War, the movement fell into complete disrepute.

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Examples of Social Darwinism, 6

- Intelligence tests
 - Though Darwin viewed all humans as essentially the same, he did view them as exhibiting a range of characteristics, which would be better or worse from the point of view of survival value.
 - Such characteristics included mental abilities. Around the turn of the century, tests were developed to determine such abilities and used evolutionary theory as their justification.

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