

GET1020 notes

Evolution is the change of living things over time - a process. It is not a law/force in nature that does things and is not progressive/has no direction. It is not about betterment/perfection

Creation stories

- Ancient Egyptians (c. 2700 BCE) that their gods created the world out of a lifeless sea of chaos. They also came to believe that after death, a person's soul faced judgement and was then sent to a place of reward or punishment.
- Norse/Viking believed the world was created by gods from the body of a giant (c. 500BCE)
- Batak of Sumatra believed a sky goddess came down to the sea with a handful of earth to live on- Sumatra. An underworld dragon sometimes rolls around which causes earthquakes.
- Australian aborigines believed that the first humans were regurgitated by a great rainbow serpent in the sky.
- Mayans of Central America believed that the creator gods made humans out of maize (the main food of the Mayans).
- Ancient Hebrews (c. 540-330 BCE) believed that the Earth is surrounded by a ring of water that's why the sky is blue.
- Eskimos believe that the Aurora Borealis/Northern Lights are their ancestors dancing in the sky

Estimated age of the Earth

- **James Usher (1650s): 6000 years.** This claim made it into the bible as footnote by the editor but convinced people that the bible 'said' that the Earth is 6000 years old.
 - This claim was in the footnotes of a 19th-century English bible with Genesis beginning at 4004 BC.
 - Calculated it by counting back generations of kings and rulers
- James Hutton (1726-1797): Earth existed forever; its age is infinite.
 - Theory of the Earth (1795) - geographical/geological unconformity
 - Thought there was a force in the Earth driving rock layers to move around and that if this occurred for infinitely long, all dry land would be washed away, leaving only water left
 - Used this thought to argue that God exists since he wouldn't let all the land get washed away, thus believed that there exists a counterforce that restored land, i.e. earthquakes that pushed land upwards
 - Believed in a circular system for the Earth
- Georges Buffon (1707-1788): estimated the Earth is 75,000 years old.
 - Estimated this by observing hot iron spheres cool down and extrapolated that data to the Earth's core's cool down
 - Believed that the Earth started as a huge glowing sphere that cooled down since the deeper you mined the hotter it got
 - The epochs of nature (1778)
 - species in different parts of the world are so different they must have been created separately there
 - speculated that species can change a little to fit environments but not into other species
- Ernest Rutherford and radiometric dating led to the discovery that the Earth is about 4.5 billion years

Theory of continental drift

- Alfred Wegener (1880-1930): basic idea - shapes of the lands fit like a jigsaw puzzle. The rocks in parts of South Africa and South America are identical. This is evidence that they are the same land. But no one believed him.

Plate tectonics 1950s-1960s

- Palaeomagnetism
- Sea floor spreading - Magnetic striping
- Plates

Ways to know how old the Earth is

- Radiometric dating
- Geology & Palaeontology
- Even some creatures alive today are older than 6000 years...
 - a Norway Spruce (tree) in Sweden had its roots carbon dated to 9550 years old
 - King Clone (creosote bush) in Mojave desert estimated at 11700 years old
- Dendrochronology, or tree-ring dating
- Stalactites in caves, some are over 190,000 years old
- Coral reefs and atolls - 5-8mm growth per year...
- Ice core drilling - 1.5 million years of unbroken records
- The speed of light - 'HE 1523-0901', is an estimated 13.2 billion years old, the oldest star yet discovered.

Current estimates of the age of the universe - From the cosmic microwave background radiation left over from the 'big bang, measurements etc. c. 13 billion years...

Fossils

- "Devil's toenail" - Gryphaea, a [genus of extinct oysters, marine bivalve mollusks](#)
- "snake stones" - Ammonites, [extinct](#) marine [mollusc](#) animals in the subclass **Ammonoidea** of the [class Cephalopoda](#). More closely related to living [coleoids](#) (i.e., [octopuses](#), [squid](#), and [cuttlefish](#)) than they are to shelled [nautiloids](#) such as the living [Nautilus](#) species.
 - Heads were carved on some pieces to make them resemble snakes.
- St. Hilda monument detail in Whitby has ammonites at the feet.



features of the famous transitional fossil?

- I. Feathers**
- II. Bony tail**
- III. Teeth**
- IV. Wings with claws**

- Nicolas Steno (1667): compared “tongue stones” with shark teeth
 - Named "tongue stones" because they look like a dragon's tongue
 - Came up with the **Law of original horizontality** and **Law of superposition**
 - Found a way to date sediment rocks. The lower layers have to be older because the sediments stack up horizontally
- Leonardo Da Vinci: noticed that fossils are not randomly scattered as if by a great flood, but grouped together, like with like, as if they were from the same habitat.
- 1860: the oldest fossil feather
 - 1861-1863: this feather was later found to belong to **Archaeopteryx** (feather, claws on wings)
 - Darwin predicted intermediate species' fossils will be found and this is exactly that, in between a bird and reptile



Other discoveries

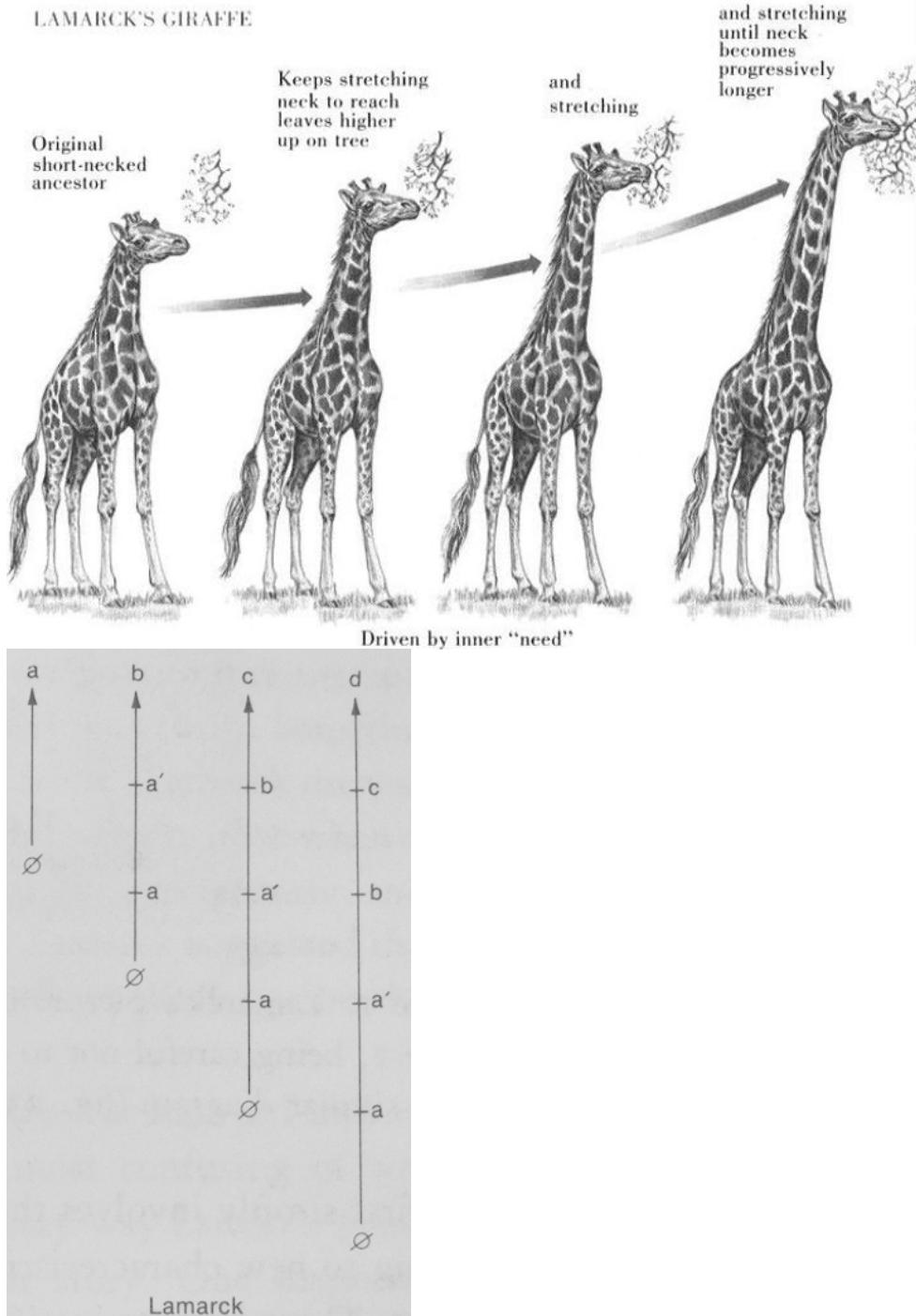
- Robert Hooke (1665): Micrographia, observations through various lenses.
 - Invented the microscope
 - Fossil originally meant "dug up thing" and he found cells on modern wood that look like those from a fossil wood
 - The word cell originated from a monk's monastery bedroom

- John Ray (1627-1705): thinks there are thousands of species and adaptation proves divine design
 - number of true species in nature is **fixed** and **limited** and, as we may reasonably believe, constant and **unchangeable** from the first creation to the present day
 - *The wisdom of God manifested in the works of the creation* (1691)
 - Carl Linnaeus (1707-1778): Species are clear cut & only come from previous parents.
 - catalogued every animal he came across and realised that it's impossible for Noah's Ark to fit all the animals on it
 - introduced the binomial nomenclature (genus & species)
 - classification proved there was divine design
 - did not believe in extinction

Table of the Animal Kingdom. (Linnaeus 1735)

- English encyclopedia (1854): branching tree arrangement of species & genera (hierarchical)
 - William Smith (1769-1839): Noticed that fossils are specific to the strata & order of the beds is the same everywhere those rocks are found.
 - Realised that the order of rock layers are always the same
 - Georges Cuvier (1769-1832): comparative anatomy. 1796 paper on living and fossil elephants, first person to propose 1800 age of reptiles.
 - 1808-1811: Paris Basin publications: fossils characteristic of different strata. There have been many revolutions
 - Realised environments of the same place changed across different revolutions
 - believed that the Mastodon (& many other species) is extinct
 - established extinction as a scientific fact
 - was highly revered in the scientific community
 - The Geohistory of Paris (1802-8): proof there was no great flood (ref Noah's Ark)
 - Jean-Baptiste de Lamarck (1744-1829): Inheritance of acquired characteristics. No extinction, instead: change
 - Common misconception of his theory was children inheriting exact characteristics of parents (i.e. children of blacksmiths immediately inheriting their huge muscles)
 - **The complexifying force:** all living things were compelled to level up
 - **The adaptive force:** adaptation of organisms to their environment via acquired characteristics
 - Believed in spontaneous generation/life springing into existence from nothing
 - explains presence of primitive things by saying that there are multiple starting lines for different species and that life was still springing into existence in the present
 - No one believed him because Georges Cuvier demolished his reputation

LAMARCK'S GIRAFFE



Life originates at the base of each lineage = \emptyset

- Mary Anning (1799-1847): famous for finding fossils
- Extinct reptiles Ichthyosaurus and Plesiosaurus (1824) skeletons found in Liassic strata of southern England.
- There were reptiles, not dinosaurs

- **ichthyosaur is any of several extinct fishlike reptiles, of the order ichthyosauria that had a body somewhat like a porpoise**
- **ichthyosaurus is any of various extinct fishlike marine reptiles of the order ichthyosauria of the triassic period to the cretaceous period.**

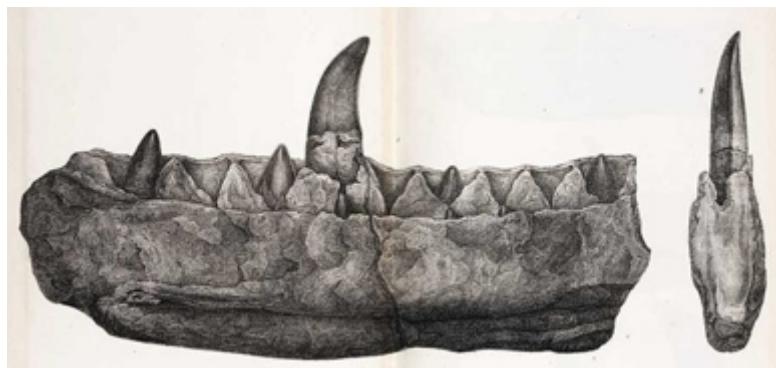
'a more ancient Dorset' by Henry De la Beche c. 1830



W. Conybeare's cartoon of Buckland entering the den of extinct hyenas in Yorkshire in 1821.



- Megalosaurus bucklandii (1827), dinosaurs were named by Richard Owen in 1842, meaning "terrible lizards"



- Henry de la Bache, painted the first depiction of a world with only ancient extinct animals alive
- Rev. William Buckland (1784-1856): tried exotic animals, tortoise tracks, menagerie
- *Bridgewater Treatise: geology and mineralogy considered with reference to natural theology* (1836)



- Louis Agassiz: first to propose there had been an ice age (1837), studied glaciers
- Charles Lyell (1797-1875): Principles of geology (1830). Was teased for being 'uniformitarian' - the **power of natural change now is the same as the past** (e.g. magnitude of earthquakes)
 - Argued against sudden revolutions. Instead, there was **gradual change** but did not believe in evolution
 - Geological processes have always been slow. There is **no progress or direction**. History of life was not progressive, but circular. Hated the idea of progressive history of life since he thought it may lead people to believe in evolution which he hated
 - Temple of Serapis: markings/different shades on bottom parts of the pillars. He address the question of successive appearance and disappearances of species (gradual nature)
 - The astronomer John Herschel wrote to Lyell to praise the book.
 - Hated Lamarck's theory of evolution as he was very disturbed that humans are closely related to animals and Lamarck proposed that humans descended from animals and are not special
 - was a **HUGE** scientific influence for Charles Darwin
- Vestiges of The Natural History of Creation: published anonymously, written by Robert Chambers (publisher and writer). His version of how nature works
 - super controversial because it made a lot of scientific mistakes and debunked all religious views of nature and proposed that nature worked on its own via the Theory of Development (evolution)

Charles Darwin

The Mount



- Dr Robert Darwin (1766-1848), Charles Darwin's father
- Dr Erasmus Darwin (1731-1802), Darwin's grandfather
- Susannah Wedgwood Darwin, Darwin's mother

Born in Shrewsbury, England, was baptized at the Parish Church of St. Chad's. Went to Unitarian Chapel (taken to church by his mum until 1817 when she died). Attended Shrewsbury Grammar School (1818-1825), Edinburgh University (1825-1827), University of Cambridge (1828-1831)

- Originally went to Edinburgh University very early on by his father to study medicine
- Hated human anatomy because the lecturer was boring and the lecturer would just read off his grandfather's notes. Operations also had no anesthesia and he had to watch a child get operated on
- Father heard he hated medicine so he suggested that Darwin became a **clergyman**, which still required a degree from an English university so he was sent to Cambridge. **A clergyman is a male religious leader.** **Priests, rabbis, ministers, or imams are all considered clergymen if they're male.**
- Four ranks of students in colleges in Cambridge:
 - Noblemen: very rich
 - Fellow commoners: rich. could pay to receive a higher ranking
 - Pensioners: normal student
 - Sizars: students who had to get scholarships/provisions and had other people pay for their education. Wore a different gown to show their inferior status and had to serve other higher ranking students at meal time
- Students had to wear their cabin gowns at all times to identify themselves as students of the university and would get expelled if caught without their gowns

Had a conventional religious upbringing and an interest in fine arts but only when he was a student at university

Stood in front of everyone at the lectern to read readings from the bible to other students before

Collected beetles as a hobby. Darwin's first publish was to defend the work of missionaries!!

Darwin's first scientific paper: 'On the Ova of Flustra', 1827 - he announces that he has discovered organs of motion, and, secondly that the small black body hitherto mistaken for the young of *Fucus lorense* is in reality the ovum of *Pontobdella muricata*".

- Burke and Hare killed people to sell the bodies to anatomy classes

Darwin took further classes in 'Practice of Physic', 'Midwifery', 'Chemistry', Robert Jameson's Geology and Zoology: c. 100 lectures, 5 days a week for 5 months November-April.

Dr Robert Grant (1793-1874): expert on marine invertebrates

- freethinker & fierce Lamarckian
- introduced Darwin to scientific jealousy and competition
- studied "animal-plants" called Flustra

Robert Jameson had 2 schools of thought of where rocks came from

- Neptunists: rocks came from aquatic watery environments
- Plutonists: rocks came from volcanoes

Rev. John Stevens Henslow (1796-1861), Cambridge professor of botany:

- Set up botanic gardens for scientific study
- Darwin loved him and took his botanist elective for 3 years in a row

John Herschel's *Preliminary discourse* (1831): an overview of the science of the day - and a very whiggish history of science – it's all about progress. Herschel saw a law of continuity which meant that all parts of nature and science will be interconsistent.

- Showed Darwin that he had to collect a lot of small evidences to build up and present proper arguments

Rev. Adam Sedgwick (1785-1873), professor of geology: studied the most ancient rocks and fossils.

- Badly reviewed *Vestiges*: Thinks that successive forms of animal life are not derived in natural succession and come from a series of completely separate steps of creation that took place throughout history.

Alexander von Humboldt

- His book, *Narrative of Travels of South America*, also greatly influenced Darwin

He grew his beard in 1857.

H.M.S Beagle (1831-1836)

Charles Darwin went on the Beagle in place of Henslow (professor of botany). His father was initially against it but Darwin's uncle supported him.

Darwin went on the ship as a naturalist to explore the world. Captain Robert FitzRoy was initially against Darwin coming on the ship because of the shape of his nose. But they got closer afterwards (FitzRoy has a nasty temper). Most of the time was spent on land instead of on the sea (refer to reading notes). The voyage was a map chartering expedition and they had to survey coastlines (mostly on land). FitzRoy thought it was a good idea to hire a man to study the land as they were surveying the coastlines and sent an invitation to Cambridge.

Darwin was primarily a geologist on the voyage (both rocks and fossils)

When Darwin visited in the 1830s, South America had just been freed from Spanish and Portuguese rule. The interior was little known to the British so majority of their time was spent in South America. He primarily spoke Spanish throughout the voyage but was bad at it.

His field notebooks include:

- Correspondence
- diary
- Zoological diary
- Geological diary
- Specimen notebooks

ball
Gauchos are South American cowboys and Darwin learnt how to use a bola from them

Cliffs of Patagonia (coasts of South America) showed evidence of repeatedly being uplifted by geological forces

South America had a lot of fossils

First land touched by the voyage: Santiago, Cape de Verde islands. It was Darwin's first time seeing the tropics and seeing tropical plants and animals made him very excited.

Santa Cruz expedition: He realised 2 mountains were roughly parallel and that there were rolled stones on each side of the valley. FitzRoy commented that these rolled stones (evidence that the stones originated from seabed) could not have been formed within a 40-day flood.

He witnessed crustal uplift of 11 feet during the Santa Cruz expedition(?), section of Coquimbo, Chile(?), April-May 1834 and noticed a connection between this and the crustal uplift he witnessed in the mountains. He saw a connection between earthquakes and volcanoes in 1835. Walls the were // (parallel) to the movement of the land did not collapse. He realised earthquakes only shook in 1 direction.



Two fossils discovered by Darwin:

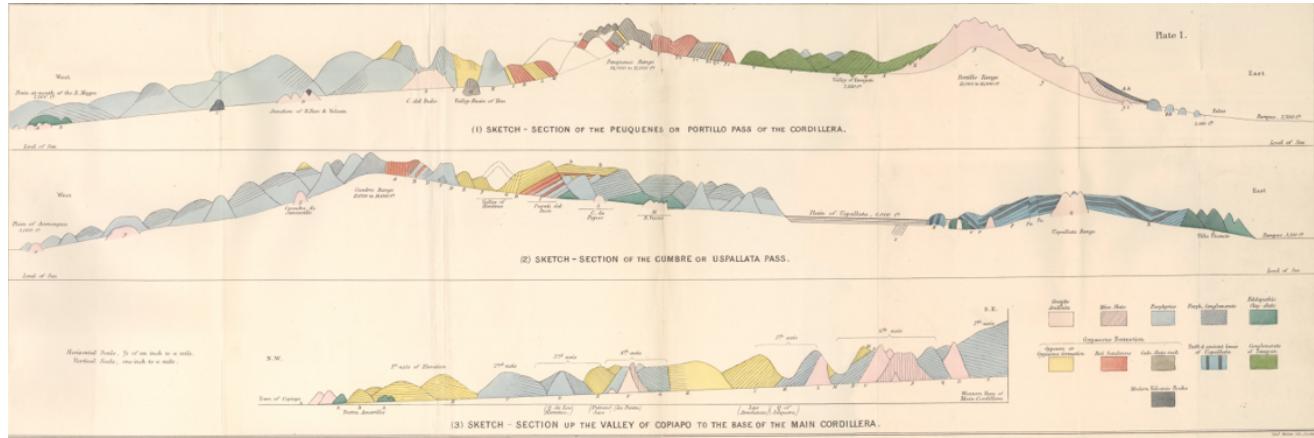
Giant extinct mammals: Toxodon & Macrauchenia, Megatherium & Glyptodon

Other extinct animals: Macrauchenia patachonica, Mylodon (extinct ground sloth)

Note: Darwin was laughed at by officers onboard the Beagle for quoting the bible. Also, in Darwin's time, extinction was well understood.

At Tierra del Fuego (The Land of Fire), FitzRoy brought Fuegians back to England to "civilise" them

Darwin's geological observations on South America (1846)

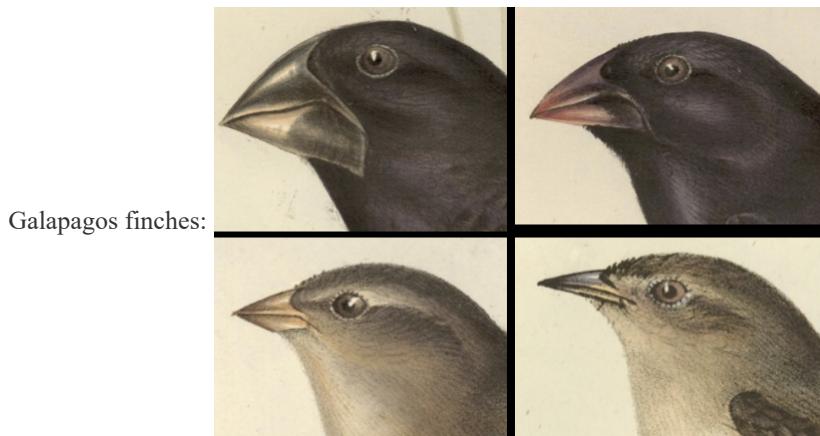


He found animals that lived in habitats different from those to which their group is adapted -- Similarity between extinct and living creatures in the same place, e.g. Glyptodon vs Armadillo. Darwin's idea was that species were separated by a barrier. Environments were the same but the species were living in different areas.

- Similarity between extinct and living creatures' locations. Relatives of the same family always found in the same place even though they existed in different eras (this was due to Lyell's cyclical Earth theory which made Darwin wonder why similar animals were always created in the same place in a new cycle and not elsewhere)
- Distribution of related living species. Realised that close relatives of living animals, although found in the same environment, lived in different places (this contradicts Lyell since Lyell proposed that animals were created to fit their environment so similar animals shouldn't exist in different places)

Darwin had a dissecting microscope but the magnification wasn't great.

Galapagos islands named after tortoises as they were the main animals on the islands.



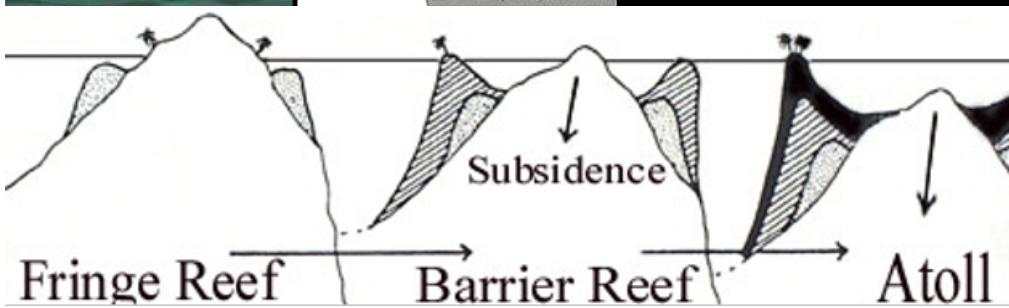
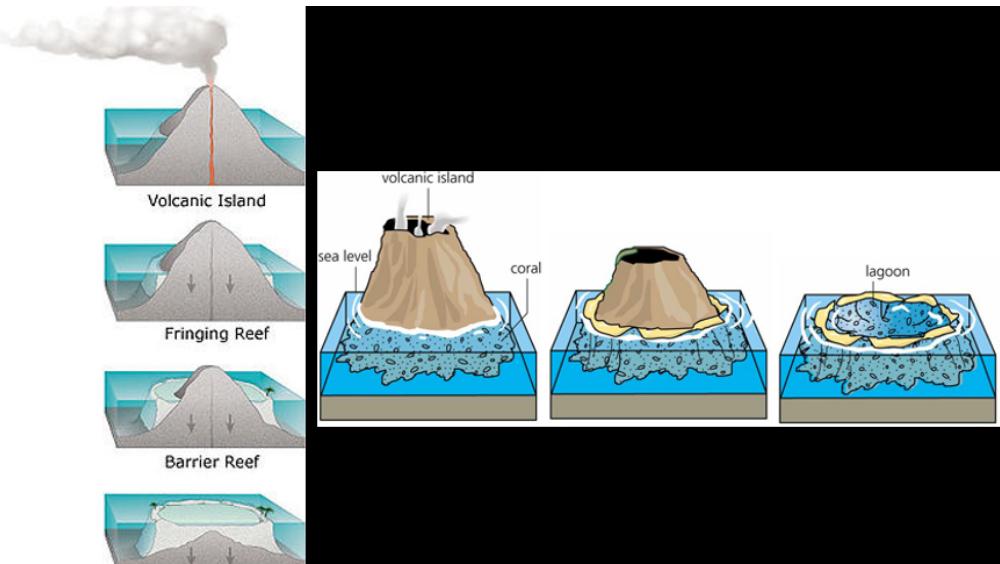
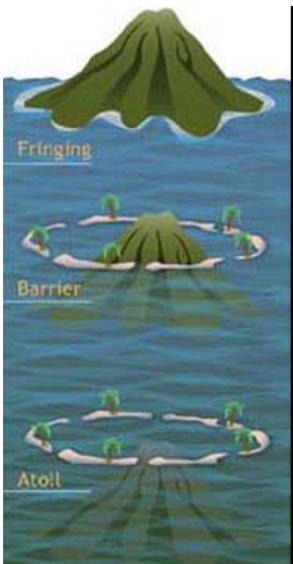
NOTE: finches were not the one that led Darwin to evolution. It was **mockingbirds**.

a person who studies or is an expert on birds.
Darwin gave the finches to John Gould (ornithologist) to study before he realised they were all finches. The first time Darwin thought evolution was true is in 1836, written in the ornithological notes.

Coral atolls formed around the land (sinking), instead of very very deep under the sea and grew out.

- Formation of coral atolls: Volcanic island, Fringing coral reef, Corals rise and volcano sinks, Left with coral atoll
- Darwin's theory on slow gradual change of the formation of Coral Atolls was so convincing that Lyell changed his views on the formation of atolls

An atoll is a ring-shaped coral reef, island, or series of islets. An atoll surrounds a body of water called a lagoon. Sometimes, atolls and lagoons protect a central island. Channels between islets connect a lagoon to the open ocean or sea. Atolls develop with underwater volcanoes, called seamounts.



Darwin and FizRoy wrote a letter containing remarks on the moral state of Tahiti South African Christian Recorder (1836), Darwin's first publication.

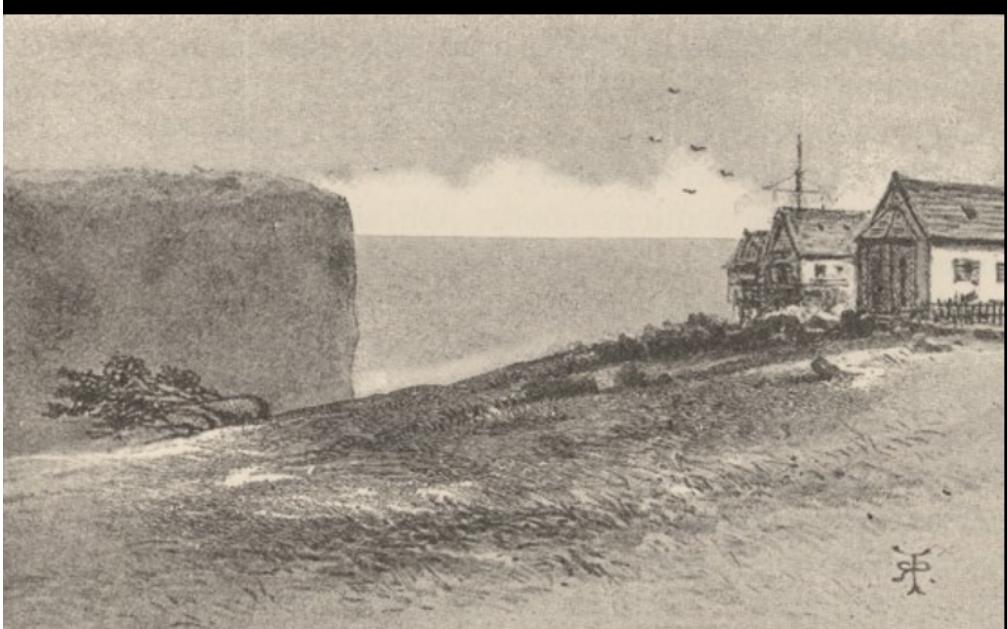
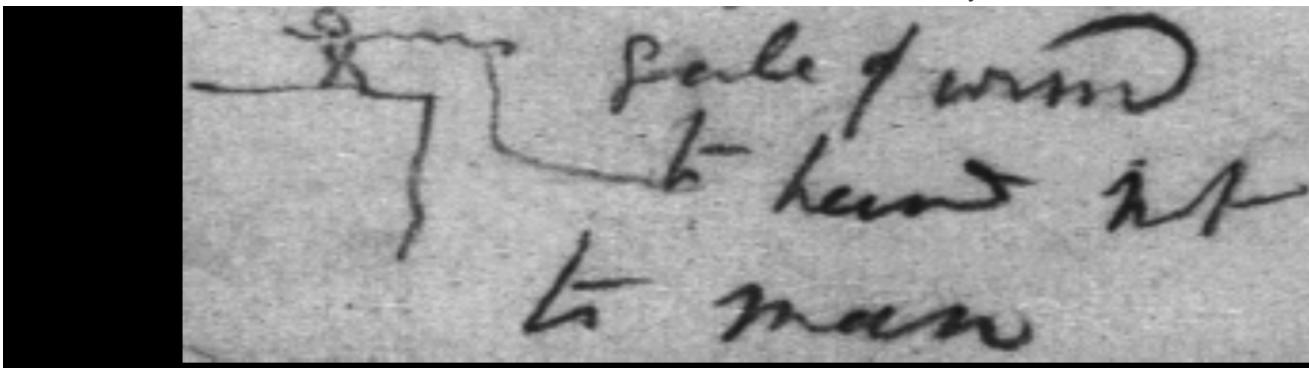
St

Helena,

11

July

1836:



Could not feel the wind when standing atop the brick(?) but could see the birds fighting against it. When arm is stretched out, could feel the wind.

After the voyage

Darwin married Emma Wedgwood (his cousin(?)) in 1839. In 1842, the Darwins moved to Down(e) south of London.

The astronomer John Herschel wrote to Lyell in 1836 about 'that mystery of mysteries, the replacement of extinct species by others'. Where did new species come from? What is their origin?

Darwin was still a creationist in Feb. 1835. He was grappling with the problem of successive disappearance of species- and unknown birth of new ones.

Ideas Darwin had before the Theory of Evolution:

1. Lifetime theory of extinction. Thought a species has an expiration date and will just go extinct when that date arrived
 - Heard about apple trees grown from the cut-off branches of trees in South America, Chiloe all dying together. Thought it was evidence of this theory since the new trees grown should be newly born and thus live longer than its "parent"
 - Had no evidence of anything that wiped the mastodons, believed the lifetime theory seemed to explain it
 2. Mockingbirds on Galapagos Islands 柱牙象
 - thought that the different environments of the Galapagos Islands is challenging the idea that species cannot change since the islands each hosted many different species of the same animal

In his 1836 (June-Jul) notes, he was curious and skeptical but not yet convinced. In early 1837, he became a transmutationist based on 3 facts

1. Similarity between extinct and living creatures in the same place

- Uncovering fossil mammals in South America. Similarities of fossils of extinct animals and current animals in South America

2. Distribution of related, living species

- Difficulties with determining species strikes Darwin. Rheas were 2 species not 1.
 - Two species of the same animal lived in the same environment by in distinctly different areas

3. Relationship of Galapagos islands species to those of nearby continent

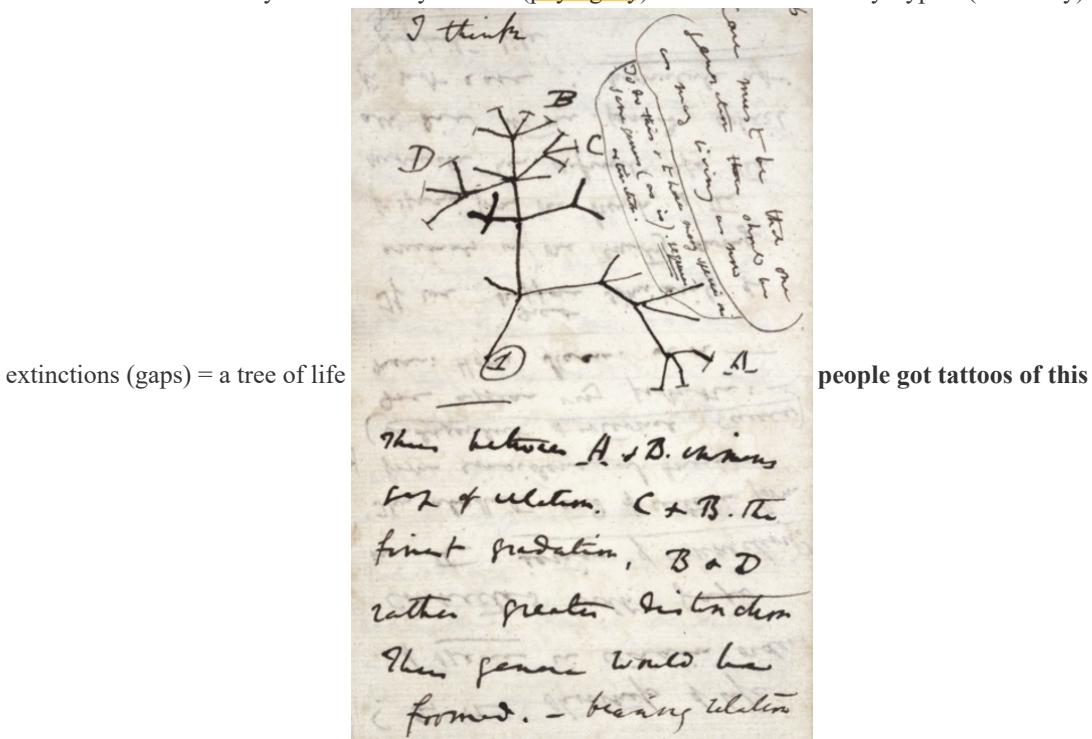
- Galapagos mockingbirds were 3 species, not just varieties
 - They all adapted to the different islands to become new species

Books/Papers

- **Coral formations paper** (May 1837): whether certain groups of living beings peculiar to small spots are the remnants of a former large population, or a new one springing into existence
 - **Red notebook** (Jan-Jun 1837): Geographical distribution, distribution of species through time and space, reproduction of individuals and species.
 - last notebook from the voyage of Beagle
 - this notebook showed that Darwin initially thought that a new species was immediately born from its parents, not gradualistic
 - **Notebook B:** 3 main questions
 1. How do species become adapted to a changing world? (adaptation)
 2. How do new species form? (speciation)

the history of the evolution of a species or group, especially in reference to lines of descent and relationships among broad groups of organisms.

- 3. How does the hierarchy of taxonomy form? (**phylogeny**). Descent from early types (similarity) with irregular

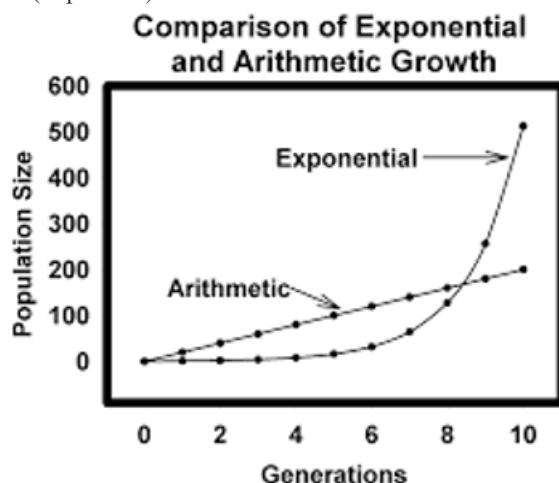


■ **Notebook C:**

1. Hereditary transmission of form (how living things pass on their traits)
2. Distribution of local & wide-ranging species (why some species only exist in some area of the world while others spread all over the world)
3. Distinction between affinity & analogy
 1. Affinity - similarity due to descent
 2. Analogy - similarity due to adaptations to similar environments
4. Relation between habit (behaviour) and structure. (which came first? woodpeckers' sharp beaks or their instinct to peck wood)

■ **Notebook D (main theme - reproduction):**

1. What is the theory of reproduction?
2. Why is the world not filled by one type?
3. Malthusian law of population (Darwin read a book by Thomas Malthus, is this the best possible world or not? Did not think the world gets better & better. Believed that population growth is exponential but food production is arithmetic - unable to keep up w population growth) (Darwin realised this doesn't happen which means they're being kept in check by something)
4. Darwin came up with Natural Selection (Sept 1838)



5. Was this the influence of economics?

■ **Notebook E (evolution by natural selection):**

1. 3 principles - inheritance, variation, competition-selection

2. Adaptation is relative - variation/differences are not formed w foresight that they will be needed (no goal). Adaptation is contingent on circumstances and variation is always there. Natural selection can cause change or stability (if already too good for its job aka crocodile)
3. End of notebook, but theory of evolution not done.

Alfred Russel Wallace

Parents: Mary Ann Wallce, Thomas Vere Wallace. Son of a gentleman (middle class)

Lived in Kensington Cottage, Usk and went to Hertford Free Grammar School (1828-1837). He studied similar subjects to Darwin.

Note: Wallace was not working class & was not forced to leave school early. He left school at the same age as other kids he just didn't attend uni.

Wallace then became a surveyor (1837-1843), working for his brother. He met Bates at Collegiate School in Leicester who introduced him to collecting beetles.

Henry Walter Bates: collector of beetles

Believed in phrenology (study of head shape and how it affects your personality, intelligence, etc) and mesmerism and performed mesmerism on his students

As a young man he was open to accept radical ideas and thus easily accepted Vestiges' ideas on evolution

Collectors often become experts.

Wallace went to the Amazon (April 1848 - October 1852). However, there was a fire onboard the ship in 1852 and though he managed to live, his collections didn't. On 18 April 1854, Wallace arrived in Singapore for the purpose of collecting species (he collected birds, mammals, insects & shells). He stayed at St Joseph's Church in Bukit Timah and witnessed the riots in the same year but did not know it was a riot.

- He went to the Amazon to collect and sell specimens NOT to investigate the origin of species/theory of evolution
- He took the Euxine, a first class ship, to Singapore
- Riots in Singapore in 1854 were between the Hokkiens and Teochews

He wrote about the riots in his publication - The Malay Archipelago, 1869

Tigers did not kill 1 person every day in Singapore

Wallace's mystery flycatcher - written found by Wallace however he was not in Malacca in 1862. It was actually found by someone else (I think his assistant?) but written by Wallace as he was the famous collector.

His assistant Charles Allen (Wallace didn't like him lmao) was not meticulous enough however he went to become a missionary in Malaysia and then returned to Singapore and became the manager of the Perseverance Estate- now Geylang and 1 of his daughters married the architect of Raffles Hotel.

His other assistant Ali from Sarawak (1855-1862) (Wallace liked him more).

George Rappa Junior was Wallace's agent who sold some books for him. He became a part of Philip Robinson, founder of Robinsons and Co.

Wallace went home from South East Asia in 1862 as a wealthy man

Wallace's name was accredited on the first page of Darwin's book as the only man who independently thought of the same theory

The **Wallace Line** is a faunal boundary **line** drawn in 1859 and named by English biologist Thomas Henry Huxley that separates the biogeographical realms of Asia and Wallacea, a transitional zone between Asia and Australia.

Wallace's love life

- Fell in love with a girl named Ms L. and went to her house every week to play chess with her father. She rejected Wallace :(((. His sister and mother advised him to give it more time and he spent the next year still playing chess with her father and asked her father and her for her hand in marriage and she agreed. He went over one day and she just vanished :((((((
- He marries Annie Mitten in 1866 on the rebound (is this the cousin???? or was it darwin's wife confuzzled)

Note: Wallace's papers never mentioned evolution explicitly but his private notebooks have.

Sarawak Law Paper (1855)

Believed to have outlined the theory of evolution except a 'mechanism' for how species change. However, people of the time did not see it as that. Phrases used:

- Living things have been "created" in a progressive order...
- Every species has come into existence coincident both in space and time with a pre-existing closely allied species.

But the paper never mentions evolution- new species are somehow created in this order

Wallace discovered the Wallace's Line

- Left side of line: all Asian species of animals, Right side of line: all Australian species of animals
- this is due to plate tectonic movements, plates from Australia and Asia in the past shifted very near to each other in the present

The Malay Archipelago (1869)

- Published by Wallace after travelling in South East Asia
- Published after going home
- Wallace became well known because of this book and also because his name was on the front page of Darwin's book

The flat Earth wager (1870)

an act of betting a sum of money on the outcome of an unpredictable event.

- Having been a surveyor, Wallace knew the Earth is not flat so he took up the wager due to financial difficulties (also, Lyell told him to go ahead). He successfully proved it but the dude refused to pay him and instead sued him and shit until he went bankrupt.
- He used a telescope to show that flags on a river will be slightly different heights due to the Earth being curved

Wallace is not the father of biogeography. It was already being studied long before him.

Wallace was not the greatest field biologist. He also never collected fish. He mostly collected or hired people to collect species to sell.

Wallace was not the most famous scientist in the world when he died in 1913

Later in life

Wallace had a change in opinion of natural selection in humans in 1869 after reading Lyell's publication after Lyell changed his mind too

- Thought that natural selection only applied to every other species and not humans
- thought that the existence of humans proved the presence of a God
- Darwin was very VERY sad about this

He got into spiritualism

- His evidence was when he went to a medium's reading and found a note written by a "ghost" because it wasn't the medium's handwriting
- Became antivax

Tour of USA (1886 - 1887)

Lecture tour where he gave talks on the theory of evolution he titled it Darwinism.

covering with notices.

There were no opponents of evolution who were placarding his lectures "we don't like evolution". However, decades later there were. Why was there no opposition? Modern opposition has not always been around.

Evolution has been an accepted fact in science since the 1870s. But ...

Scopes 'monkey trial' 1925 (from a small town in America) - They decided to test the new law in their state against the teaching of human evolution in public schools. Because they taught it was influenced by religion and that is not allowed in America.

The high school teacher, John Scopes, who stood for the trial lost but the international recognition that there were people who did not agree with evolution was enormous.

People thought it was not okay that children were taught things in school that they did not believe in. i.e. it is not okay that their parents' views were being contradicted by what is being taught in school.

Religious creationism

Creationism 1970s

Creation-Science 1980s - biblical understanding of the origin of human being into science classrooms in the USA.

Intelligent design 1990s

All the above were rejected because they were all religious. Thus, cannot be taught in US schools.

Intelligent design

Paley's argument - they look like they are designed so they must be designed.

"Irreducible complexity" - Main argument of Michael Behe's *Darwin's black box* (1996)

- There are biological structures that are so complicated that they could not have been formed a slow gradual process that Darwin proposed.

Some common objections

- Evolution is just a theory
 - In colloquial speech a theory is a conjecture or guess, in science a theory is an explanation whose predictions have been verified by experiments or other evidence
- Evolution is just chance
 - It's impossible that random chance could make the living world

Eugenics - Francis Galton coined the term in 1883. Inspired by evolution.

- Improve human breeds by selecting who to mate with, or;
- Sterilise people who were considered to be reproductively undesirable.

Creation Museum (Kentucky, USA, 2007-) - reject all modern science (e.g. reject age of the Earth)

- Young Earth creationism (Christian scientists who discovered this)
- The world only 6000 years old?
- Humans and dinosaurs lived simultaneously

- Also believed that before Adam and Eve sinned, the world was perfect. There was no death. The reason dinosaurs had sharp teeth was not to eat meat but to open coconuts..... uhhhh ok cool

Wallace VS Darwin

Wallace's aversion to adaptation (1856): "many animals are provided with organs and appendages which serve no material or physical purpose"

Note: Wallace did not travel to SEA with the intention to solve 'the problem of the origin of species'.

In Feb 1858 he was suffering from cabin fever when he had an idea of how species originate. He then wrote to Bates on 2 March 1858 - **I have lately worked out a theory which accounts for them naturally** (on the matching colour between tiger beetles and the sand etc.)

He went to an island called Ternate to get the skins of birds of paradise that were worth a lot of money

Wallace's Ternate Essay (Signed Feb 1858)

Sent to Darwin and Darwin was holy shookethed

He claimed that it is an "undisputed fact that varieties do frequently occur". "The *variety* would now have replaced the *species*...Such a variety *could not* return to the original form; for that form is an inferior one..."

Note: Darwin did not lie about when he received the essay, following the steam mailer's dates it's correct.

- When Darwin received the letter, he sent it to Lyell as Wallace had requested
- Lyell told Darwin to just post his own theory before Wallace but Darwin didn't want to because he thought it wasn't gentlemanly
- Darwin sent the letter to Joseph Hooker as well and he advised Darwin to share both theories together at a scientific meeting so there would be no priority in releasing the theories
- Wallace was very happy and immediately wrote a letter to his mother about his paper being read at a scientific meeting

Darwin's Origin of Species (1859)

Lyell's gradualism underlies *Origin*, long, slow action of small natural causes can accumulate to produce enormous changes...

Darwin condensed his theory down into 1 volume because Wallace told him it was already too long

- this greatly benefitted Darwin as no one wants to read some 10 - 50 volume theory
- contained such compelling evidence that the entire scientific community's view of evolution changed in 20 years
- By 1870, the entire scientific community completely accepted his theory of evolution

Some questions the book does not address:

- What is the origin of life?
- Does god exist?
- Is god ultimately behind nature? (he strongly implies yes)

- Variation seen in domestication:**

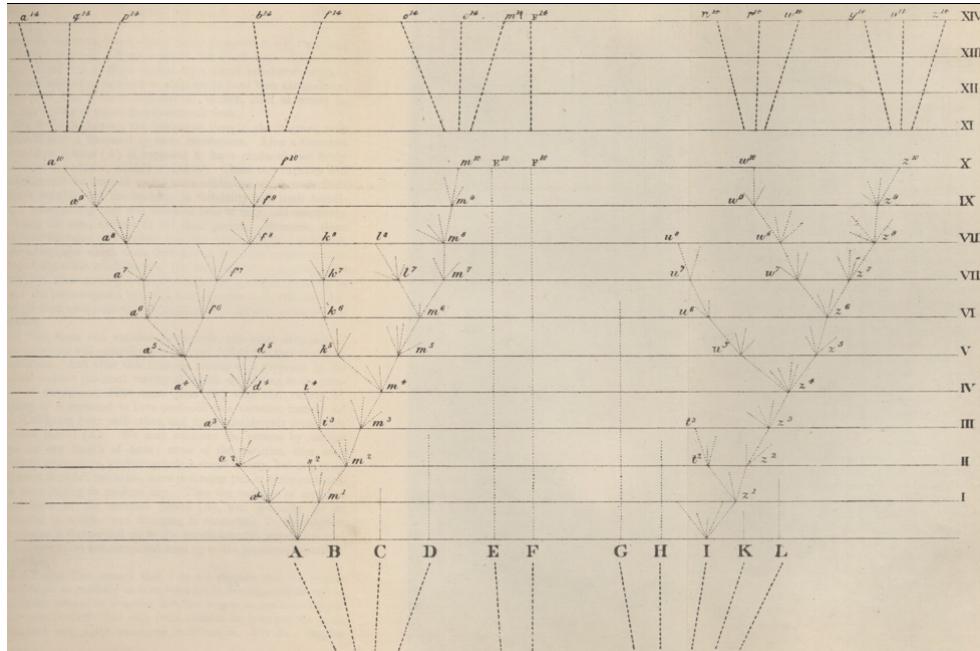
- Variations are ubiquitous
- Artificial selection* - this actually changes species now
- Breeds of domesticated animals and plants are analogous to new species.

- Variation in nature:**

- Plants and animals in nature vary just like domesticated ones

- There is no clear distinction between species and varieties. Why?

The tree of life makes sense of taxonomy. Creation cannot.



species (1859)

Diagram from origin of

The book is not about humans. It is about the general process of how living things change over time.

Darwin worked on this book for 20 years. Nothing from Wallace was put into this book. Wallace even wrote to Darwin after reading the book to praise it. After reading the *Origin of Species*, Wallace admitted that his theory was a lot more shallow than Darwin's as he didn't address sexual selection and other stuff.

Unfortunately, in the 1869 review of Lyell's *Principles*, Wallace thought natural selection could not explain Man. Instead: "an Overruling Intelligence." must have been involved. Darwin was saddled.

Hubert Spencer coined the term "Survival of the fittest". The 5th edition (1869) first used Herbert Spencer's expression "survival of the fittest". Darwin thought a better term would be "natural preservation"

Darwin kept pigeons as pets for his research and used artificial selection of genes through domestication as an analogy to explain his theory of natural selection

Sexual selection:

- Selection of male partners by females and the competition between male counterparts

Vestigial is the term for an organ not in use but still present due to inheritance from ancestors

- Shows leftover inherited stuff like teeth in embryos of toothless whales, wings on flightless birds, etc

Evidence of common ancestry:

- Homology (same parts in different species even though they don't need it)
- Embryology (why sometimes some parts develop in an embryo then disappears aka tails(?) in human embryos)
 - Embryos show similarities between different species
 - Only evolution from a common ancestor can explain these similarities
 - It shows left over inherited genes from ancestors which is no other way to explain their presence
- Rudimentary

Difficulties on his theory addressed by Darwin:

- Readers were impressed by his honesty and him addressing the holes in his theory

- How could huge changes ever begin? By many tiny gradual steps and selection. Many transitional forms (halfway from 1 species to another) are all around us
- Air breathing land animals' lungs originated from early ancestors of fish
- Some organs seem too complicated and perfect so that must be divine design?
- Why does a bee die after stinging? This mechanism did not start out as a sting, it's a compromise between whatever the hell it was last time and a modern day sting

Imperfection of the Geological Record (why did new species seemingly appear out of nowhere in the geological records)

- fossil record is even more disjointed than we thought
- there is a vast lapse of time between each layer as seen in the rate of deposition and erosion
- this explains the apparent sudden appearance of groups of species

Geological succession of organic beings:

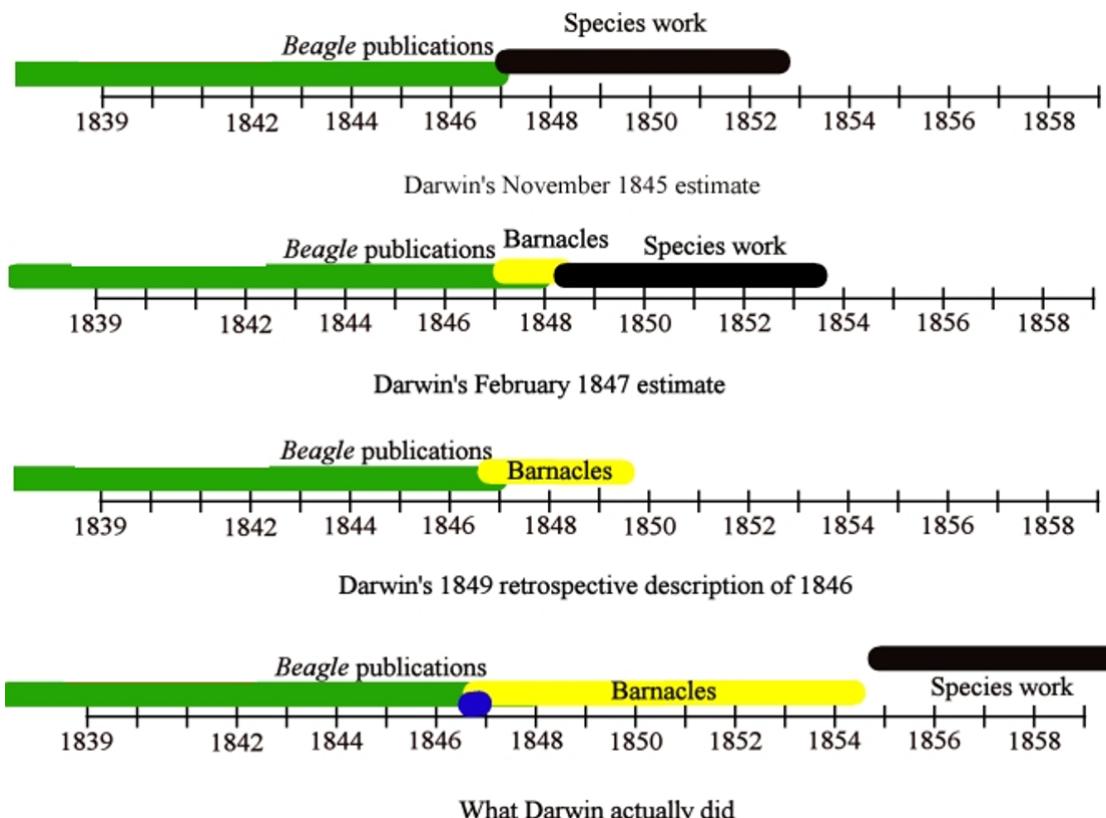
- Species once extinct never reappear.
- This explains why species of the same family all live within the same area

Geographical distribution

- Biogeography is the most compelling evidence for evolution
 - Environments cannot explain distribution of animals. Amphibians aren't found on oceanic islands despite the conditions there being ideal for them because they have no way to get there and weren't just magically created at the islands.
- Plants and animals have moved about, diversifying from their ancestors as they evolved but are still limited by natural barriers
- Only evolution explains the distribution

Darwin's delay

He didn't. He was just improving his theory and was working on other things beforehand.



In 1958, Julian Huxley suggested fear of upsetting scientific colleagues. In 1974, psychologist Howard Gruber's book *Darwin on Man* suggested that Darwin must have postponed because of fear.

'Proofs':

- His dream - a person was hung & came to life, then made jokes ..., changed hanging into his head cut off. But the gist is that it was not a scary/fear-inducing dream. Also, it was in third person so it wasn't him who was apparently dead.
- He said - "I gained much by my delay". But based on his word usage in other correspondence/papers showed that this word was to just mean time that elapsed not that he intentionally published it later. Also, he usually had long gestation periods for his books (not just the Origin of Species).
Gestation is the period of time between conception and birth.
- He wrote "like confessing a murder" in a letter to J.D. Hooker that species are not immutable. But he usually writes this way in his correspondence to others. When the letter was indeed to be kept secret, he marked them as "Private" or said "please repeat nothing..."

Things he was working on before finishing his theory on evolution:

- Writing the 1844 essay(?)
- Writing his paper on volcanoes
- Writing his paper on barnacles (spent 8 years on this)
- Working on his principle of divergence
- Working on why all insects seemingly didn't have a sex

He also told his theory to a lot of people before publishing & wrote in the 6th edition (1872) that he formerly spoke to very many naturalists on the subject of evolution, and never once met with any sympathetic agreement.

He was actually finishing up his writing for the voyage on the Beagle before starting the species work. In October 1846, barnacles remained. In May 1848, he wrote to his neighbour that "The Barnacles will put off my species book for a rather long period."

Note: Cirripede means hairy foot (scientific name for barnacle)

Barnacle



Transformation of a barnacle

1. Swims as a larvae
2. Glue head to solid object to form shell around its body
3. Shell/plates (homology w others, meaning same structure different species)
4. Feed with mouth extending out of shell
5. Grow w the world's largest penis to body size ratio

Two types of barnacles: Stalked and acorn barnacles

Barnacles are crustaceans

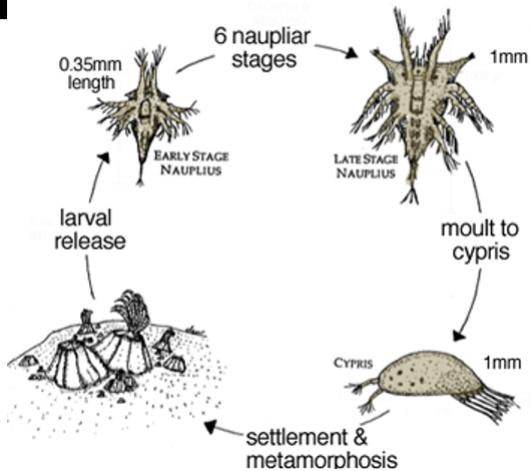
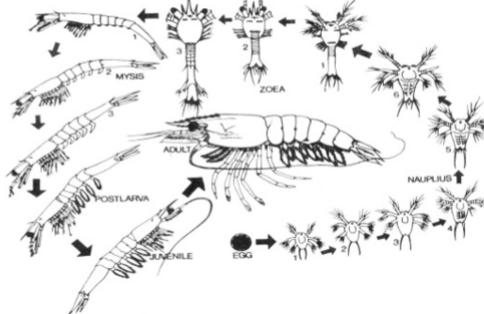
By 1850, he was sick of barnacles. He wrote them from 1847-1853. In 1851, he kind of suggested evolution by saying barnacles change from bisexual to unisexual.

"we have one curious illustration ... how gradually nature changes from one condition to the other,—in this case from bisexuality to unisexuality." Darwin, *A monograph on the sub-class Cirripedia, with figures of all the species. The Balanidae, (or sessile cirripedes); the Verrucidae*. 1851, p. 29.

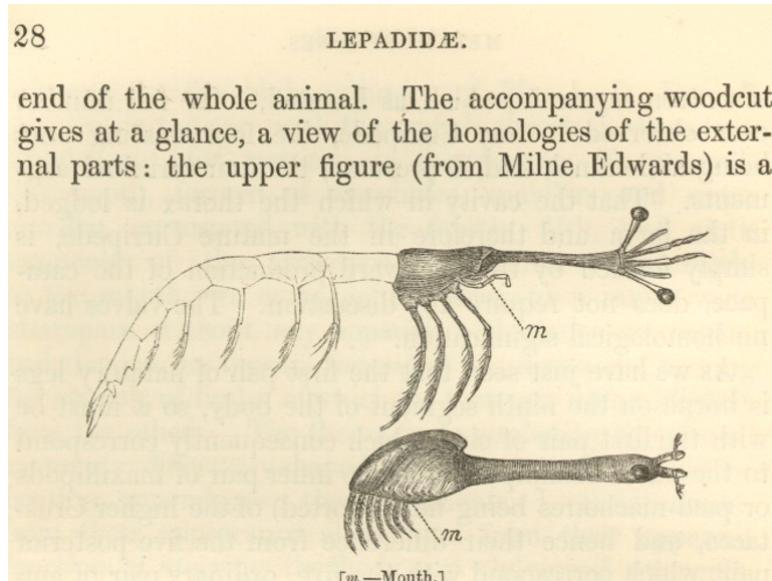
Crustacean vs Barnacles

Crustacean life cycle vs. Barnacle life cycle

Fig. 1. Life cycle of *P. monodon*



Their segmentation related to other crustaceans. These homologies showed how structures could adapt function to suit new conditions. A normal crustacean (top) compared with a barnacle (bottom)



Richard Owen (1849): Nature of limbs, archetypes. Thought that since every animal had specific limb types, it's evidence of divine design

Reception of the Origin of species

It was widely reviewed in educated periodicals, not the newspapers for the masses. There was a range of reactions. People's reactions tended to correlate with their class, religion, education, and ideological tendencies

Major objections:

- God makes species, not nature.
- We are separate from nature, we are not from other animals.
- *From:*
 - Geologist Louis Agassiz, 1860: consider the transmutation theory as a scientific mistake, untrue in its facts, unscientific in its method, and mischievous in its tendency (aka it was not only wrong, but dangerous)
 - [Samuel Wilberforce review 1860](#): incompatible not only with single expressions in the word of God [the Bible] but with the whole representation of that moral and spiritual condition of man which is its proper subject matter.

Support:

- From:

Thomas Henry Huxley 1860: This is a fair question for scientific discussion. Religious or moral beliefs cannot decide whether a scientific claim is true or not. Though he believed in evolution, he was not convinced by Darwin's theory of how it happens.

- Wrote for The Times (very conservative and religious newspaper) to review Darwin's book
- Also, he was never once called Darwin's bulldog.

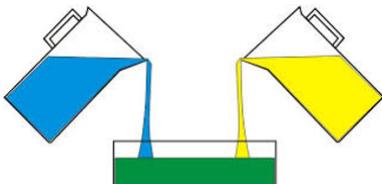
H.C. Watson: In a letter to Darwin - though he was the greatest revolutionist in natural history.

Charles Kingsley (2nd edition 1860): thought Darwin's theory went well with his religious beliefs. God could not have created so many species - he designed them to be able to evolve (capable of self-development).

- Charles Kingsley did not like this interpretation of animals autoevolving as quoted by Darwin in his book as it made it sound like God had to keep creating new species to fit their environment but he shouldn't have to because what he creates should be perfect.

Fleeming Jenkin's review in 1867: Blending Inheritance

- Basically if 2 random genes mixed and only the superior genes survived, would a European and a dark skinned islander's baby look more European over time? (he believed that Europeans were superior)
- Argument does not hold since the baby of someone with 6 fingers and someone with 5 fingers does not end up with 5.5 fingers



Asa Gray: also combined his religious theories with Darwin's theory that variations arise when useful. However, Darwin disagreed since there were many variations that were harmful.

Henry Walter Bates: *New evidence found:* The Naturalists on the river Amazon by Henry Walter Bates, Batesian mimicry. Species mimicking more dangerous variations to discourage predators from eating them. Argued this was evidence for Darwin's theory

Richard Owen (1857):

- jealous of Darwin, he wrote **anonymous** reviews to criticise Darwin's theory saying it's rubbish, and praised one of his own books. He also claimed to have found a difference between human and ape brains (challenged by Thomas Huxley).
- The Great Hippocampus Question.
- Kingsley wrote a book named the Water Babies to mock the question by naming it The Great Hippopotamus Test

Charles Lyell *Geological evidences of the antiquity of man* (1863): ancient times

- surveyed discoveries of early man, archaeological evidence, in the Palaeolithic (Pleistocene) (how long humans have been around).
- Wrote this because he really hated the idea of humans being related to primates and wanted to show he disliked the idea but was leaning towards support for Darwin.
- Said that humans are a proper subject of scientific study and shouldn't be excluded from the study of nature

T.H. Huxley's Man's place in nature (1863): Man is clearly an animal (not a plant or stone!) & Man is more similar to chimpanzees and gorillas than the latter are to dogs, for example.

By the 3rd edition (1861): The great majority of naturalists believe that species are immutable productions, and have been separately created

By the 5th edition (1869): Until recently the great majority of naturalists believed that species were immutable productions, and had been separately created.

By the 1870s most men of science had accepted evolution was a fact: i.e. common descent with modification but natural selection was still not accepted (Huxley didn't believe in natural selection)

Neanderthals are a different species of humans that have gone extinct

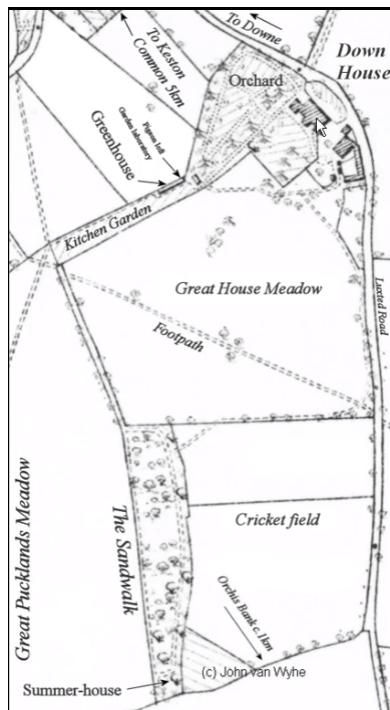
Fossil records of horses' ancestors: gradual change of the legs of horses was very convincing evidence of evolution

Wallace wrote a book: Darwinism (1889): Probably the second most influential book on evolution from Victorian times

Why did Darwin's theory spread so quickly and widely?

1. A lot of people mixed their religious beliefs into Darwin's theory. It wasn't a deal breaker to people's religions and they weaved it into their own theories
2. Around the time of the debates, a gorilla was brought back to the UK by Paul Du Chaillu for the first time and it was very humanlike and people thought this was evidence of evolution of humans (Chaillu spread false and exaggerated stories of gorillas being very fierce and scary and that's where the myth came from)

After the Origin of Species



The only publication Darwin did with his wife Emma (1863): An appeal (against steel vermin traps). Felt very strongly about animal welfare. A more humane trap should be invented

Some flowers only open at night and other flowers only grow in places where few people can see them. So people's reasons that they were there to please our eyes cannot be true.

Darwin's

greenhouse:



On the various contrivances by British and foreign orchids fertilised by insects, and on the good effects of intercrossing (1862) aka Fertilisation of Orchids (1862): is the first of Darwin's books of supporting evidence for the theory of evolution by natural selection. The only book with a picture on the cover.



His earlier theory: plant self-fertilisation. If plants continued fertilising themselves, they wouldn't vary. Then evolution would break down. So there must be a way for living things to combine with other species.

That's why Darwin's theory suggests sex. He then wrote to John Murray that he felt this book would support the Origin to show he worked hard for details.

Darwin calculated the some orchids bear 6k and 186k seeds per plant.



Darwin predicted that the long nectary ^ of the *Angraecum sesquipedale* (an orchid from Madagascar) must have moths with proboscis capable of extension to a length of between ten and eleven inches.

Wallaces' 1867 paper showed the 'predicted' moth. Two species became so coadapted to each other that they have a special relationship. In this case since the neck is so long, no other insect can come drink from them. Only one type of moth.

Instead of the orchid depending on any insect coming to drink from it and hopefully pollinates, only 1 type of insect is going to do the job by visiting another species of orchids.

Orchids all share the same blueprint (all descended from the same ancestor). They too have vestigial structures.

However, distinguished botanist Alphonse de Candolle said they were specially created and arranged in their proper places and were not remnants retained by inheritance.

Reaction towards Fertilisation of Orchids

Creationist's critique: Duke of Argyll's, Reign of law (1867). The language Darwin used of "purpose and intention" sounded like one was talking about a creator doing the work. Argyll was unconvinced by Darwin's arguments that only natural causes have shaped orchids.

Asa Gray: if the Orchid book came first, people would have praised Darwin rather than condemning him. Because it would show how clever the creator was.

Darwin told Gray the orchid book was a flank movement on the enemies of natural selection.

In 1874, Gray praised Darwin for finding the explanation

Why do some plants catch insects?

First of Darwin's 3 books on the behaviour of plants: Insectivorous plants

Common sun-dew: *Drosera rotundiflora*. Only substances with a lot of nitrogen made it react. Some substances excreted very similar to digestive fluids. A way for them to live in places with low nitrogen levels where other plants cannot live. (Colonise through adaptation)

Utricularia aka bladderworts is one of the swiftest insect killers (by opening the door inwards and sucking the plant in).

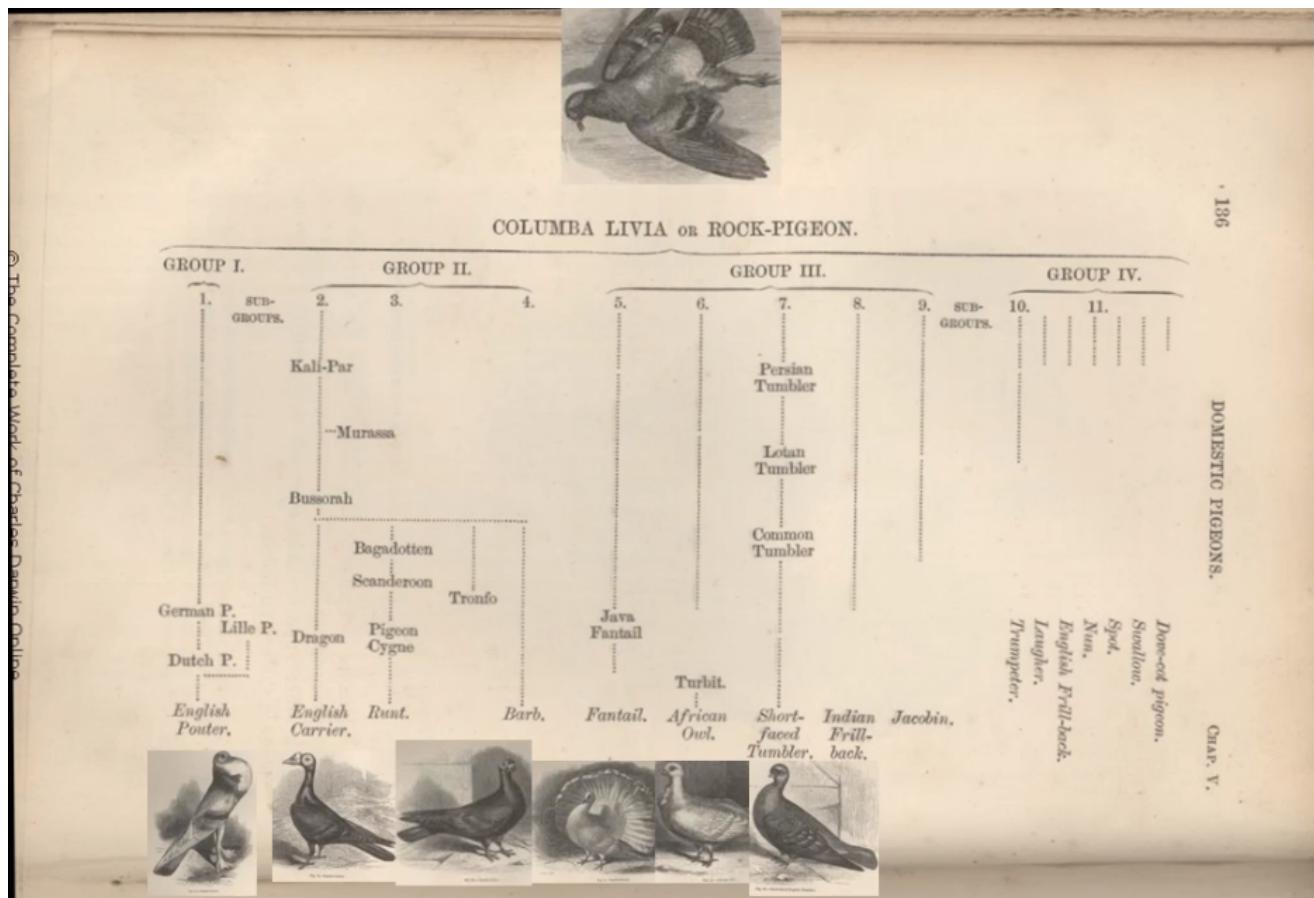
Climbing plants: spirally twine round a support. Initially he thought they made circling movements as they grow. In his experiments, he found they react to stimulants - light, gravity touch.

Different forms of flowers of plants of the same species: no little discovery of mine gave me so much pleasure as the making out the meaning of heterostyled flowers.

Other books

One of the most important books after the Origin of Species - The variation of animals and plants under domestication (1868): The only part of Darwin's big book on the Origin which was printed in his lifetime and corresponds to its first 2 intended chapters. This was his longest work and mentions artificial selection.

Polish fowl: extravagant headdress. Darwin used the different chickens to explain artificial selection (human selection)



Selection explains adaptation

The Descent of Man (1871)

From the reading: The sole object of this work is to consider, firstly, whether man, like every other species, is descended from some pre-existing form; secondly, the manner of his development; and thirdly, the value of the differences between the so-called races of man.

Descent is practically two books. One of it explains evolution of humans while the other one is about natural selection. The word evolution occurs here.

Three main kinds of anatomical features that indicate our descent from other primates.

1. Homologies

- Skeleton
- Nerves, blood, entrails, brain...
- Diseases spread between humans and other animals
- Same ailments, monkeys get drunk and smoke,

- Have sex and make babies the same way

2. Embryology (if there is no harm, there's no reason to change)

- man starts from egg like all other animals - not mini humans
- gill slits, growth of blood vessels
- hairy covering in 6th month, lanugo
- common features indicate common ancestor

3. Rudimentary (vestigial) organs

- muscles to twitch skin like horses, move scalp, move and direct the ears
- Darwin point (the vestigial leftover of the pointy part of the ear after folding inwards)
- third eyelid
- Wisdom teeth from shortened jaw
- Shortened caecum in the intestines, an adaptation to the change of diet from plant only diet to omnivore diet
- body hair

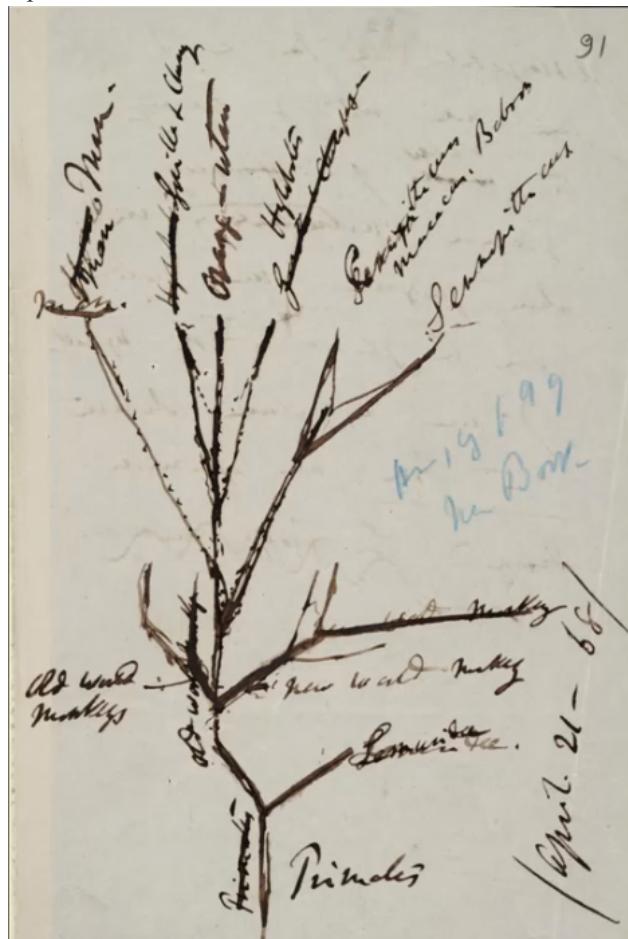
He thought that the human races are not the result of adaptation to different environments but the result of his theory - natural selection (the theory was very wrong)

In the decades before Darwin wrote his book there have been a lot of debate about the human races, mainly revolving around slavery in North & South America. People thought black Africans were a different species/were not humans.

He made his point about sexual selection with many different species - insects, fish, lizards and especially birds.

Argus pheasant: males use their feathers for courtship while females choose. But many thought it was not possible that these birds have the ability to appreciate the fine patterns. Nevertheless, Darwin thought the females do see the difference and choose the male of their liking.

Ape doesn't have tail. Also, Darwin **NEVER** said we come from monkeys



Old World (bottom left) means the monkey came from Africa and Asia, New world (beside Old World) means the monkey came from South America. Monkeys that can grab stuff with their tails come from South America.

The expression of the emotions in man and animals (1872)

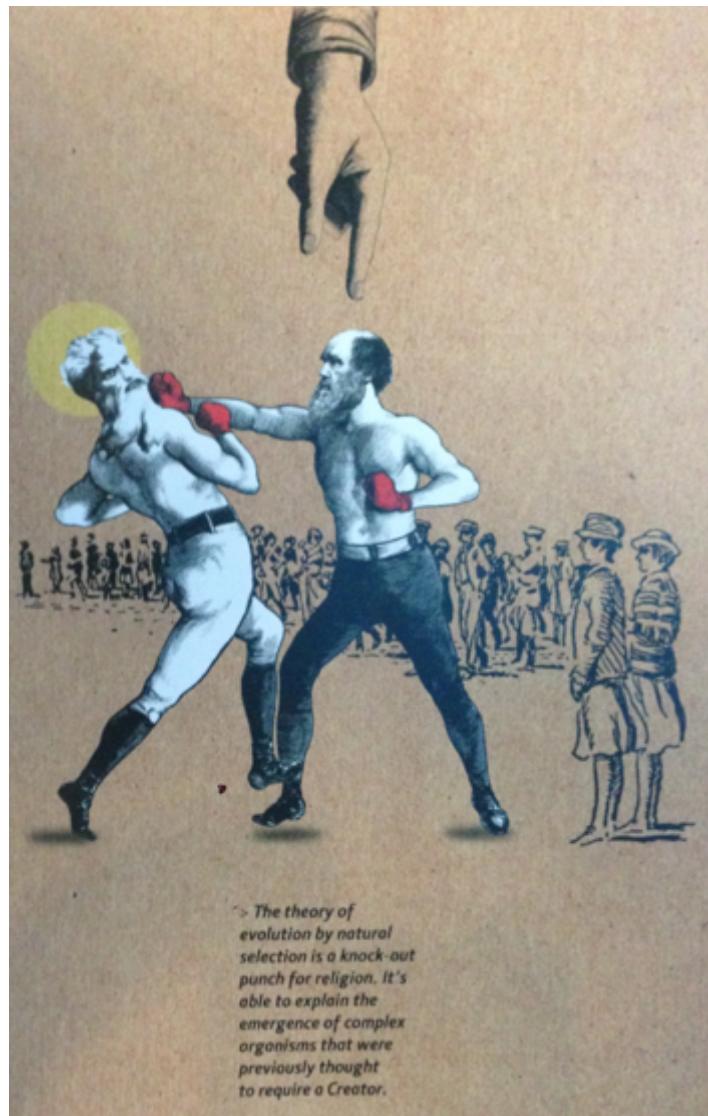
He wanted to put it in Descent of Man but it got too long.

Charles Bell (anatomist): humans beings were endowed with special muscles in our faces to express emotions.

Darwin showed that human emotions and their expressions were present to some degree in other animals.

- The differences in mental functions between humans and other animals is one of degree, not kind.
- Morality as a more refined development of instincts of other social animals (people were not happy about this because they thought it was the sacred thing that differentiated humans).
- Reciprocity and concern for the welfare of relatives

Darwin and Christianity



Movie: Creation (2009). Fake story (where he supposedly 'killed' God). In popular media, Darwin is portrayed as an anti-religious figure. His father and grandfather are atheists but his mother is religious. She brought him to church as a young boy

PAUL BETTANY JENNIFER CONNELLY

FAITH EVOLVES.

until she passed.



Darwin's daughter Annie died when she was 10 years old. That's when people thought he lost his faith. But for a century after Darwin's death this is not found in any of the literature on Darwin.

Nowhere in the millions of written words by Darwin that survive did he ever indicate that Annie's death had anything to do with his loss of faith.

- "I do not think that the religious sentiment was ever strongly developed in me." Darwin, *Autobiography*
 - In his *Autobiography*, Darwin reported that it was in 1836-9, after his return from the *Beagle* that he began to think deeply about religion. "During these two years I was led to think much about religion." In 1838, he wrote in his Journal: "*All September* read a good deal on many subject: thought much upon religion. Beginning of October ditto."

(62)

on the point of morality. I suppose it was the
 novelty of ~~such~~^{the} argument ~~as~~ ^{that} caused them.
 (i.e. 1836 & 1839)

But I had gradually come by this time to
 see the in the Old Testament, for its manifestly
 false history ~~as~~ ^{of} signs of the world, with the
 Town of Babel, the rainbow as a sign of peace,
 & for its attributing to God the feelings of a
 revengeful tyrant was no more to be tolerated
 than the sacred books of the Hindus, or the belief
 of my barbarian. The question then occurred
 were before my mind & could not be avoided,—
 is it unlikely that if God were now to make a
 revelation to a Hindu he would be inclined to

- In his *Autobiography* pg86: By further reflecting that the clearest evidence would be requisite to make any sane man believe in the miracles by which Christianity is supported,—that the more we know of the fixed laws of nature the more incredible do miracles become,—that the men at that time were ignorant and credulous to a degree almost incomprehensible by us,—that the Gospels **cannot be proved to have been written simultaneously with the events**,—that they **differ in many important details**, far too important as it seemed to me to be admitted as the usual inaccuracies of eye-witnesses;—by such reflections as these, which I give not as having the least novelty or value, but as they influenced me, *I gradually came to disbelieve in Christianity as a divine revelation.*

When did Darwin stop attending church?

Randal Keynes, Darwin's great great grandson. The constable started working at the church decades after Annie's death lmao. So there's actually no evidence that Annie's death triggered his loss of faith.

From Annie's box (2001), Randal Keynes: "After Annie's death, Charles set the Christian faith firmly behind him. He did not attend church services with the family; he walked with them to the church door, but left them to enter on their own and stood talking with the village constable or walked along the lanes around the parish."

He was a theist. Theist means he believes in one God. i.e. he believed there was a creator. However, in a letter to John Fordyce, he was being inconsistent by saying he is a theist but also saying he is agnostic (meaning he doesn't know if there is a God due to insufficient evidence).

'Agnostic' a term coined in 1869 by Huxley. (Remember, an atheist was a dirty word. No one would call themselves an atheist).

The Edward Aveling Interview, Aveling, 1883. *The religious views of Charles Darwin*

He was one of the few who actually very proudly called himself an atheist. At that lunch, Darwin also called the village priest to join them lolololol.

- Darwin: 'Why do you call yourselves atheists?'

- "Agnostic" is just "Atheist" in respectable language. Aveling replied, 'and "Atheist" is only "Agnostic" in aggressive language.
- Darwin: 'Why should you be so aggressive?' Is anything to be gained by forcing new ideas on people? Freethought is 'all very well' for the educated, but are ordinary people 'ripe for it?'

Darwin never wrote about religion in his publications. But he would remind his readers not to overlook the cruelty of nature - it's not what all the religious publications would paint nature; just flowers and sunshine.

When Darwin passed, he was given a state funeral and buried in Westminster Abbey (1882). Highest church in the land - the state church showed the highest form of approval and sanction that they could give to this man when he died by giving him a funeral in their most sacred church.

From the reading: To suggest, however, that his references to a Creator in the Origin of Species concealed a private atheism and were simply contrived to placate his audience would be an extreme interpretation. As he confided to the Harvard botanist Asa Gray in a letter of May 1860: "I had no intention to write atheistically....I can see no reason, why a man, or other animal, may not have been aboriginally produced by other laws; & that all these laws may have been expressly designed by an omniscient Creator, who foresaw every future event & consequence. But the more I think the more bewildered I become."

Common viewpoints by the 1870s-1890s

- God or a creator made the universe and the laws of nature which are so perfect that they need no further interference.
- Darwin's theory showed that biology too, like astronomy, chemistry, geology etc., was under the control of natural laws.
- Humans were descended from earlier forms like all other animals and plants. But perhaps God or a creator had then given humans something special?
- But evolution, like gravity or the roundness of the earth, was established in science.

Darwin's last book

Darwin's last book: *The formation of vegetable mould, through the action of worms, with observations on their habits* (1881). One can call it "Earthworms" or "Worms" for short.

The wormstone - used to measure how quickly it took for a stone to sink because of the worms.

[The 1885 unveiling of the statue of Darwin, at the Natural History Museum, London.](#)



UNVEILING THE STATUE OF THE LATE CHARLES DARWIN IN THE NATURAL HISTORY MUSEUM, SOUTH KENSINGTON

Pangenesis was Charles Darwin's hypothetical mechanism for heredity, in which he proposed that each part of the body continually emitted its own type of small organic particles called gemmules that aggregated in the gonads, contributing heritable information to the gametes.

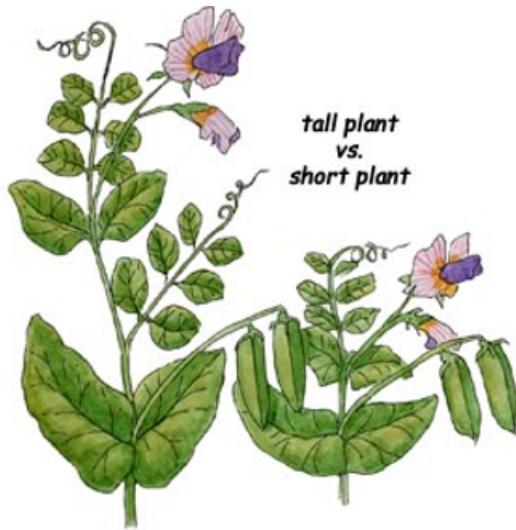
Genetics

- Darwin on genetics - pangenesis

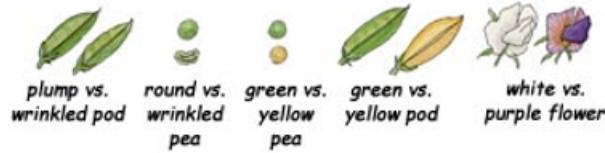
Francis Galton (1822-1911): against pangenesis. He wanted to test Darwin's theory by using bunnies. He transfused blood from some bunnies into other bunnies. E.g. brown bunnies into white bunnies. Then see if the baby given birth would be mixed. But they weren't. Then Darwin came out and said he never said it was in the blood (which is true but he also didn't directly address how)

August Weissman: germ plasm theory (1896-1910), inheritance (in a multi-cellular organism) only goes through germ cells (egg cells and sperm cells) not body cells. Which means no inheritance of acquired characteristics (what your textbooks incorrectly call 'Lamarckism')

- Gregor Mendel (1822-1884) [NOTE: he is not the founder of genetics~~~ He was not doing what even says he was doing although his studies were very influential]
 - 1843 began training as priest + Augustinian Abbey of St Thomas in Brno
 - 1851-1853 University of Vienna
 - 1856-1863 pea plants
 - Experiments on hybridity and inheritance in pea plants. Published 1865-1866



Traits that Mendel observed:



- 1867 became Abbot
- “Mendel’s two laws”:
 - Law of Segregation,
 - individual possesses a pair of ‘alleles’ (alternative versions of a gene) for a trait.
 - Sex cells get only one of the pair
 - Offspring thus gets its own pair
 - Whichever is *dominant* will be expressed, and;
 - Law of Independent Assortment
 - different traits are inherited independently of each other
- Hugo de Vries: In 1889, de Vries postulated that “inheritance of specific traits in organisms comes in particles” which he called "pangenes"
 - Mutation theory: new forms of primroses appeared (at once rather than slowly) – he called these mutations
 - Combined with Galton’s statistics he created a new theory for the origin of species: mutation theory
- 1903: Walter Sutton and Theodor Boveri suggested that chromosomes, which segregate or split in a Mendelian way, are hereditary units...
- Thomas Hunt Morgan: sought to prove Mutation Theory with his experiments breeding fruit flies.
 - 1910 He showed that genes are on chromosomes
 - 1915 He combined Mendel's theories with Chromosome Theory of Inheritance
 - He believed natural selection could only eliminate the unfit...
- Watson and Crick discover the structure of DNA, 1953. Their discovery contributed to the advent of modern molecular genetics

In 1990, Mendel was apparently re-discovered by Hugo de Vries, Carl Correns and Erich von Tschermak

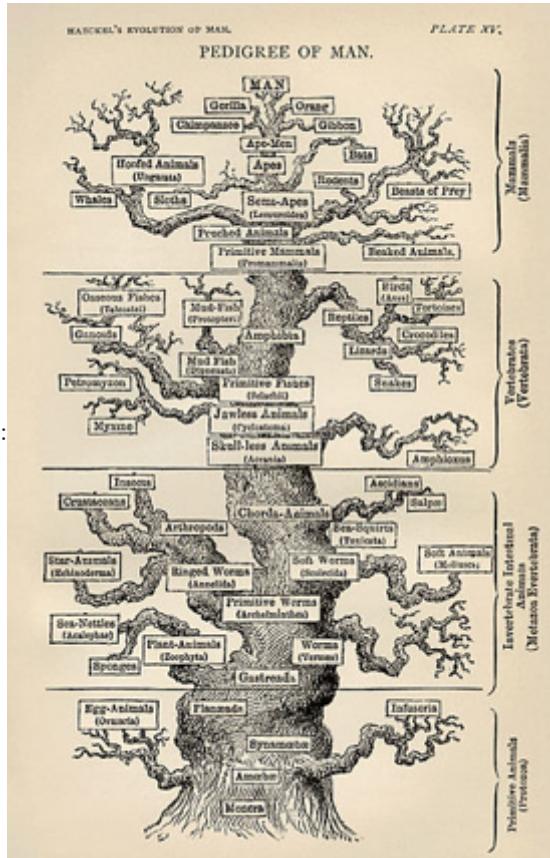
Missing Link?

Darwin and his predecessors had *no* fossil evidence of human origins. There seemed to be no traces of anything connecting modern humans with pre-human ancestors. And humans seemed so different from other species.

PLATE 117

PEDIGREE OF MAN.

Ernst Haeckel's Paleontological Tree of Vertebrates (1879):

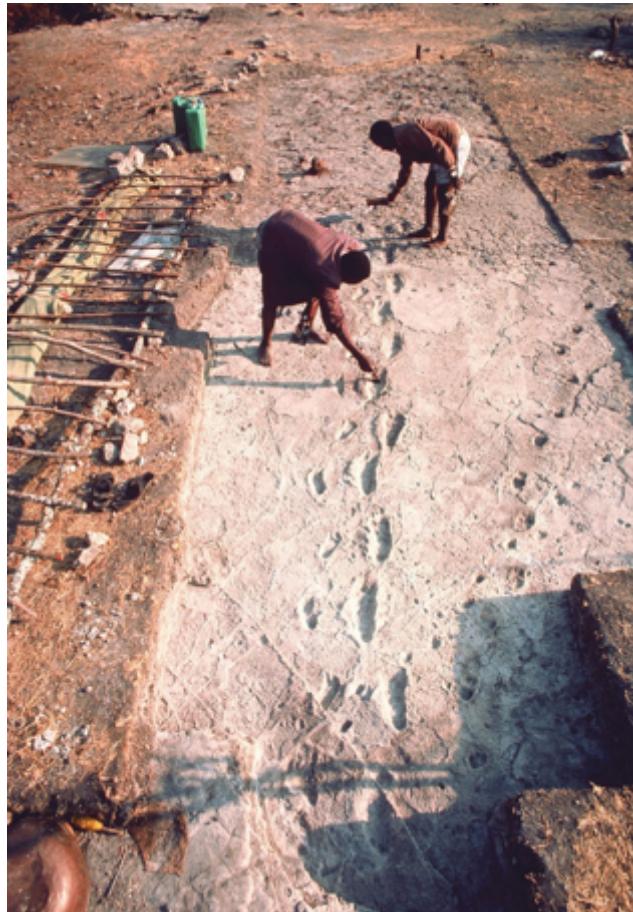


The Evolution of Man VI

PLATE

- 1856 a skull cap found in Neander valley (*Tal* or *Thal*) of Germany.
 - 1886 Next Neanderthal remains found. Neanderthals are bigger and stronger than us.
 - 1887 Eugene Dubois went to ‘Indonesia’. In 1891 he discovered a skull cap and femur (*Homo erectus* sometimes called Java Man are smaller than us but look similar)
 - 1912 Fragments of a skull and jawbone, **supposedly** collected from a gravel pit at Piltdown, East Sussex, England. It’s a fake!!! They put of an ape and an ancient human together.
 - 1923–1937 Peking Man. 500,000 and 300,000 years old; a type of homo erectus

- 1924 Taung, South Africa. 3 and 2 million years old; *Australopithecus africanus** = "southern ape of Africa", "Taung Child". Not a human, a different species altogether (a little human-ish but more ape-like than human)
- 1960 *Homo habilis*. 1.75 million years old; Olduvai Gorge, Tanzania, East Africa. *Homo habilis* = "handy-man"
- 1973 "Lucy". Found in Ethiopia in 1973- 3.2 million years old, *Australopithecus afarensis*
- 1976-1978 Laetoli, Tanzania. 3.6 million years old, footprints made by three *Australopithecus afarensis*



Note: Human beings did not come from chimpanzees. We share the same ancestor and from there we diverge. But they are the closest thing to human beings that are alive now.

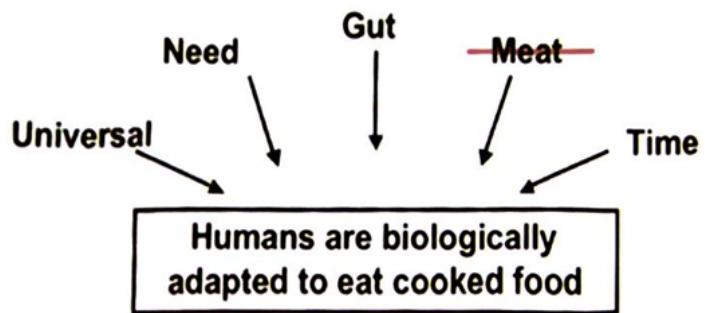
Why did hominids start walking on two legs?

- Hunting theory
- To see farther over new savannahs
- To free the hands
- Aquatic ape theory
- Trees theory

Homo floresiensis (nicknamed hobbits) & Denisovans - 40 thousand years ago, they died out. That was the same time modern humans reached those islands.

The Cooking ape hypothesis

How cooking made us human - Richard Wrangham



When did humans become biologically adapted to cooked food?

- Australopithecines ~ 5.6 - 1 mil years ago
- Homo erectus 1.8 - 1.9 mil years ago
- Homo heidelbergensis - 0.6 mil years ago

Molars and guts are small in homo erectus. Likely means they are eating cooked food.

Consequence of cooked food

- Early weaning (stop breastfeeding) of babies compared to chimpanzees. 2-3 years vs 4-5 years
- Amount of time spent chewing is much lesser for humans. < 1 hour / day vs 4 - 7 hours / day

Human intelligence

- tradeoff - guts and big brains (skulls got bigger). Huge amounts of energy needed to fuel the brain.
- Hence, it is possible for big brains to develop after eating cooked food.

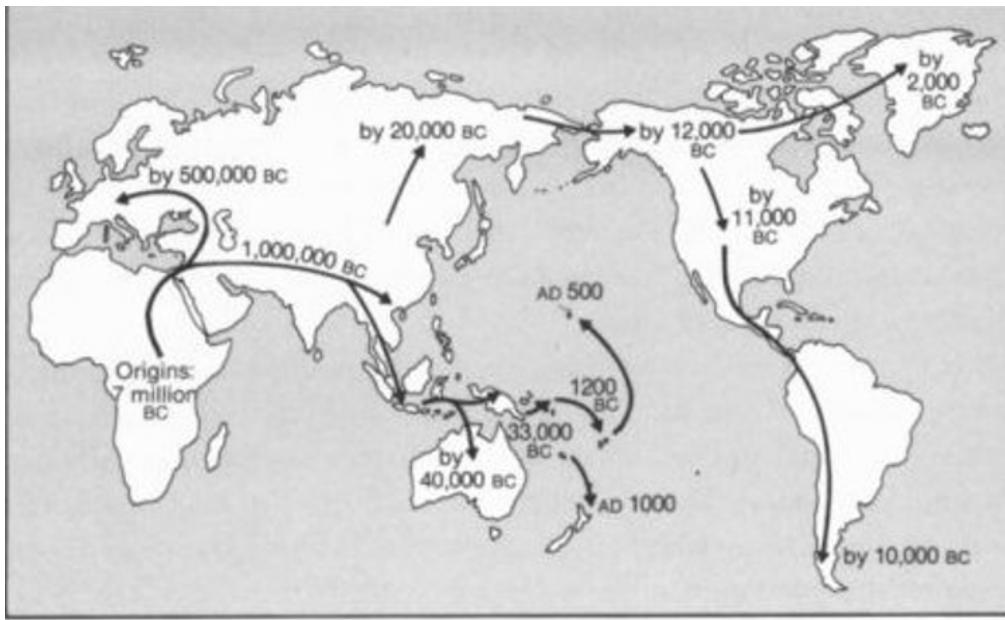
Summary

- Humans are biologically adapted to eating cooked food
- Cooking --> energy
- Since homo erectus ~ 1.8 - 1.9 million years ago
- Significance - anatomy, life-history, physiology, society

What happened after humans

Homo sapiens- anatomically modern humans (all of us) - arose in Africa c. 200,000 years ago

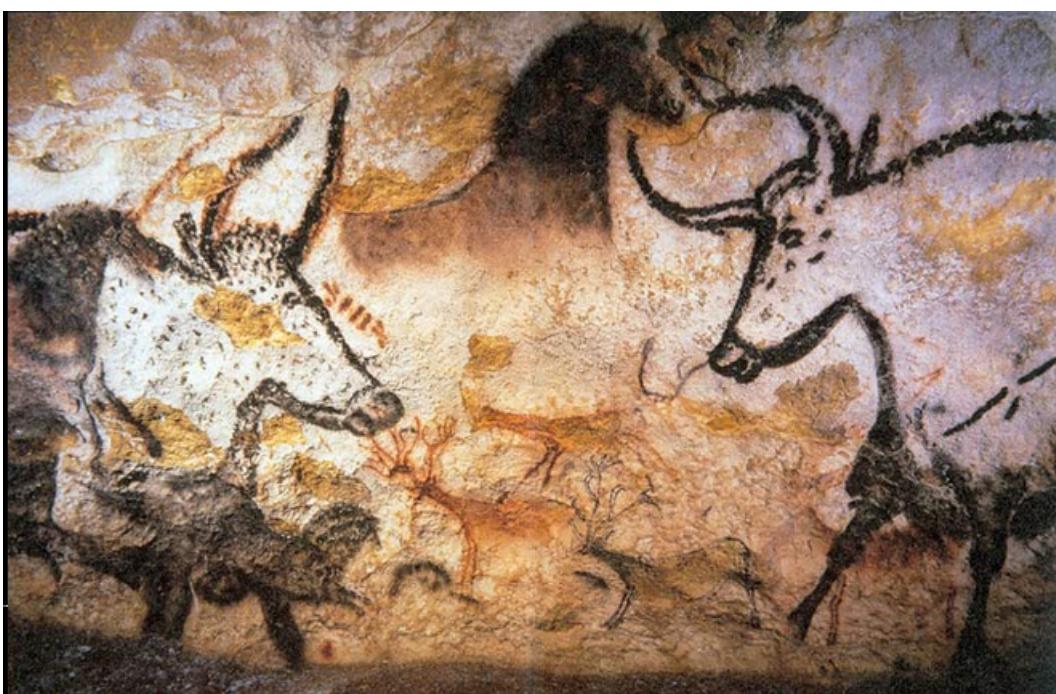
- 'Mitochondrial Eve'. Was not the first human female though the naming implies that. All human lives today are descended from her. It just so happens none of the descendants of the other women lived as long as we did.
- "all mitochondrial DNAs stem from one woman" and she probably lived around 200,000 years ago in Africa



Where modern humans (our species) moved to from Africa

Figure 1.1. The spread of humans around the world.

- Cave paintings from Lascaux in France. 16,000 years old



- We domesticated the wolf before any plants
- Found that it was easier to plant stuff along the same latitude than longitude since climate was mostly the same on the same latitude

Writing systems

- Cuneiform script from c. 4000 BCE
- The Phoenician alphabet, c. 1200–150 BCE. People who lived in the Mediterranean.
 - Ancestor of our alphabet (Roman alphabet). Not pictographic but alphabetic.
 - Based on sounds instead of things

Epidemic diseases

In hunter-gatherers, since the tribe is small, probability of disease is low. Also fatality rate is high since there's so few of them. Hunter-gatherers lived in cleaner environments than sedentary farmers because they often moved from place to place that weren't filled with humans excrements.

We live in such close proximity to animals. Once in a while, their diseases will spread to us.

- Smallpox, measles, influenza, typhus, bubonic plague...
- Dense populations & proximity to animals

The bubonic plague (black death) was the only disease that caused a dip in the human population. Incomparable to world wars and covid.

When old world people moved to the new world, they inadvertently passed the disease to people in the new world. And since the new world people has never experienced it, they were killed off.

Argument from design

- John Ray (1627-1705)
- Carl Linnaeus (1707-1778)
- Rev. William Paley (1743-1805): *Natural Theology, or evidences of the existence and attributes of the deity collected from the appearances of nature* (1802)
 - "There cannot be design without a designer"
 - The book linked science very closely to religion and how to relate science to the evidence of god
 - Analogy giving to support his stance was a watch in a meadow must have been placed there by someone. Similarly, stones in the meadow must've been placed there by a God (this view was already very old fashioned when he published it)

Natural theology vs revealed theology

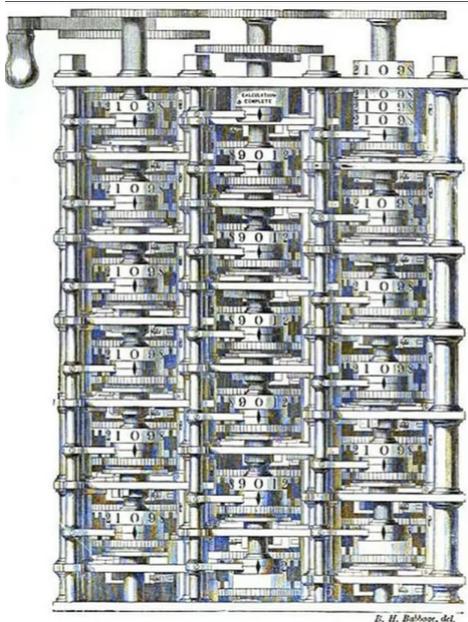
Victorian naturalism

- Naturalism: only natural laws & forces exist in nature/only natural laws & forces can be detected in nature/ a system of morality or religion having a purely natural basis.
- For some time associated with the French. Abolished the church and turned the church into palaces of reason. Claimed they worshipped reason instead of God.

Pierre-Simon Laplace (1749-1827) - French astronomer

- Laplace presented emperor Napoleon with a copy of astronomy & Napoleon supposedly said: "I see that there is no mention of God in your system of astronomy". He replied "Sire I have no need of that hypothesis" (i.e. denying existence of God)

Charles Babbage (friend of Darwin), The Ninth Bridgewater Treatise (1837) - actually wasn't part of the treatise but was written to mock the Treatise series. He was secular and came up with the calculating engine.



Used to play a 'trick' on his listeners: he would crank up the machine and let's say the number always went up by x then he would ask his listeners if it's true that the law of the machine designates the number increments by x . Then he would crank it again and the number goes up by $> x$. He's trying to tell his listeners that when those who believe in God see an anomaly they say that it is a miracle but it is not. They hastily assumed that it is a miracle but it is the law of nature that caused it.

John Pringle Nichol's *Architecture of heavens* (1837) - argument that nebulae were rotating (although there was no sun or planets). This was evidence of the process of planet formation. The formation of the solar system was an evolutionary process.

Franz Joseph Gall, physician. He thought there were 27 different parts (and size) of the brain that is responsible for a certain characteristic of a person.

J. G. Spurzheim, Gall's assistant wrote a book The physiognomical system (famous & controversial book on phrenology). He used Gall's name because Gall was famous and he was not.

George Combe (promoted phrenology & was very famous for it) - 'doctrine of natural laws'. Wrote the Constitution of Man (as in what constitutes man; what man is made of) and a lot of people were reading it; said to be the second book most people have after the bible. This book made Victorian society more secular and more prepared to accept scientific theories.

THE CONSTITUTION OF MAN—HIS SOUL, MIND,
AND BRAIN

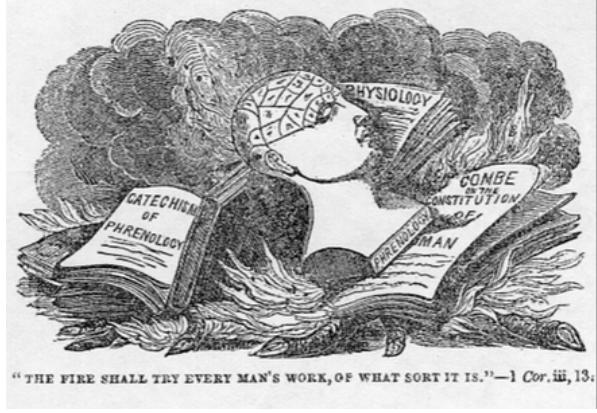
POPULAR PHRENOLOGY

TRIED BY THE WORD OF GOD,

AND

PROVED TO BE ANTICHRIST, AND INJURIOUS TO
INDIVIDUALS AND FAMILIES.

By PHILIP JONES.



Biblical scholarship

- Analysis of the Bible by German Biblical scholars such as Friedrich Schleiermacher (1768 - 1834), David Friedrich Strauss (1808 - 1874), Ludwig Feuerbach (1804 - 1872), et. al
 - Showed many new things about these documents.
 - Many authors were not contemporary, many inconsistencies.
 - E.g. story of a woman caught in adultery was not found in the oldest manuscripts of the bible. They realised that the writing style and vocabulary was very different.
- Ideas were taken to England by Samuel Taylor Coleridge & George Eliot's translations of Strauss' Life of Jesus (1846) & Feuerbach's Essence of Christianity (1854).

Victorian Crisis of Faith

A lot of people lost their faith

Huxley - the 'Agnostic' (1869). He was not a documented Christian. His explanation for agnostic was he didn't know for sure whether God exists or not; didn't have enough evidence to know 1 or the other i.e. dodging the question.

Science professionalisation

Science was not considered a profession. There were no jobs as a scientist. However, as time went on, more and more jobs came about and it was recognised as a profession.

John Tyndall's Belfast Address (1874) - very secular view. Religious sentiment should not be permitted to "intrude on the region of knowledge, over which it holds no command"

- Was he a pantheist? Someone who thinks nature is God. Possibly.

Some Victorian evangelists very strongly objected against secular views.

What is evolution

Evolution does not solve a problem

Evolution does not shape things. It is not a thing. It can't shape things. Yes, because of evolution things change over time. But there is no thing called evolution doing it.

Common misunderstanding: Species do not compete.

- But individuals do not evolve, only a population or lineage over generations.

3.5 Billion years ago

- Simple organic molecules
- Single celled organisms with DNA
 - All species now share this DNA

2.5 billion years ago

- Multicellular organisms appear
- Oxygen made by photosynthesizing cyanobacteria or blue-green algae
- Cyanobacteria
 - Capable of photosynthesis
 - Waste product: oxygen. Consistency of atmosphere of the planet changed. Oxygen was poison for the organisms alive back then.
- Stromatolites - colonies of bacteria



500 million years ago

- Jellyfish appeared
- Sponges – very primitive/simple animals

- Have a free swimming larval form
- No body symmetry
- Hermaphrodites that reproduce with eggs and sperm
- Flatworms (start very similar to free swimming sponge larvae)
 - Move with a front side, sensors
 - Bilateral symmetry
 - Organs emerge, brains, stomachs
- Ocean sediments gradually accumulate
 - Round worms appeared
 - Worms with shells evolved
 - Shells without worm end sticking out: molluscs
 - Clams
 - Snails
 - Octopus, squid, cuttlefish & argonauts- they are molluscs
 - Nautilus, distant cousin of ammonites
 - Segmented worms
 - Crustaceans
- Insects - The first creatures to walk on dry land, c. 400 million years ago
- Sea squirts
 - Their larval form has a simple **notochord**. They swim like tadpoles.
 - Eventually, vertebrates (**Lancelets**, pre-fish), Cartilaginous Fish, Bony Fish
 - Fish like lungfish acquired the first 'lungs' to help with poorly oxygenated water
 - Also limb-like fins
- Tiktaalik 375 million years ago
 - fins became more stout and robust to skid from one muddy pond to another. The first animal to have a backbone to walk out of the water.
 - similar to how mudskippers get out of water.
- Amphibians
- Reptiles (retain scales, fish body shape, lay eggs)
 - Snakes
 - Dinosaurs
 - Birds
- **Mammal-like reptiles**
 - Eggs, but hair and warm blooded - the platypus and echidna

The flightless cormorant of the Galapagos (there were flightless mega-ducks, geese and rails in Hawaii, flightless Moas in New Zealand etc.)



Some basic principles of evolution

- Every species comes about gradually. Every step has to be advantageous in its own terms- there is no mechanism for future needs.
- There is no such thing as evolving for ‘the good of the species’- only individuals live or die.
- Ancestry usually explains similarity.
- Isolation leads to difference ... Galapagos or any isolated place
- “Progress” is not inevitable, although of course:
 - Complex things can only come about after simpler ones. But sometimes more simple follows more complex.
 - Cave fish, crabs etc. have lost their complex eyes.
- New territory or niches opening up tend to draw in new species.
- Many things have happened again and again.
 - Big extinction events.
 - Explosions of diversity such as the Cambrian explosion.
 - Evolution of carnivores from herbivores- in fish, reptiles, dinosaurs, marsupial mammals, placental mammals... Aldabra tortoises perhaps...
- But life on earth has always been mostly microorganisms...