GET1020 Notes

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1 Week 1 Lecture 1

Official Website for Darwin stuff

1.1 Evolution

Evolution is just **Change**, its not the "force" that drives change.
No direction; No tendecy to go from simple to complex.

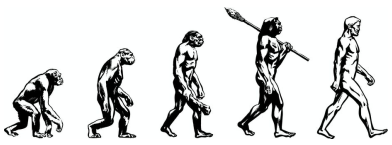

Figure 1: This graphic is false in that sense

There were many interpretations on how the world works. Christianity was prevalent in Charles Darwin's world, and stories like Adam & Eve, and Noah's Ark were popular.

1.2 Estimating the Age of the Earth? A Background History

James Usher (1650s) used the sacred text of their culture ie The Bible & other ancient sources to estimate the age of the Earth. His estimate came up to around **6000 years old** and became the most popular theory amongst people. This made its way into the Bible in the form of annotations, which convinced people that the Bible SAYS the world is 6000 years old, which is untrue.

Fossils? More Folklore explanations of where they came from. (Cyclops, Devil's Toenail etc) **Nicholas Steno (1667)** realised the similarity shark teeth to Tongue Stone fossils, but led to a question: How did a tooth of a shark end up in a rock? (And turn into rock?)

Steno reckoned that when sharks die, teeth fall down into the ground, sediments fall to sea and pile up on top of them, compressing them. Sediments washing out to sea create landforms in new areas, bringing the teeth inland. Lower Layers are older than higher layers, allowing for the dating of rocks (See Law of Original Horizontality and Law of Superposition)

Leonardo Da Vinci later realised fossils were not randomly scattered everywhere, but grouped together, resembling a **habitat**.

Robert Hooke's Micrographia (1665): popularized the Microscope, introducing organisms too small for the naked eye. He found "pores" in petrified wood under the microscop eand introduced the term "Cells" .

John Ray (1627 - 1705) catalouged different kinds of animals, **thought that animals being adapted**

so well to their environment proves God's divine design.

After John Ray, **Carl Linnaeus (1707 - 1778)**, also catalouged the living world. Species are clear cut and only come from pervious parents of the same species; Did not believe in Spontaneuous Generation of life. Also realised that there were far too many to fit in Noah's Ark.

He introduced binomial nomenclature, **Genus and Species**. *Eg) Homo Sapiens* For him, classification proved divine design. Also believed that "of all species originally formed by the Deity, there is no extinction". **Hierchical classification system introduced.**

Due to advancements in mining, discovery of Earth's hotter molten core, and that underground rock formations and structure are not straight/even.

Georges Buffon (1707 - 1788) also estimated the age of the Earth to be 75,000 years old through experimentation with cooling hot iron balls. Speculated that species can change a little to fit environments - but NOT to other species.

James Hutton (1726 -1797) discovered geological unconformity in Scotland. Instead of horizontal layers of sediments, it was vertical strips of sediments Rough band above vertical strips depict erosion, implying that they risen out from the sea. Sunk back down into the sea again, which causes the extra horizontal layers above the rough band. Yet again risen up above sea to be a cliff face.

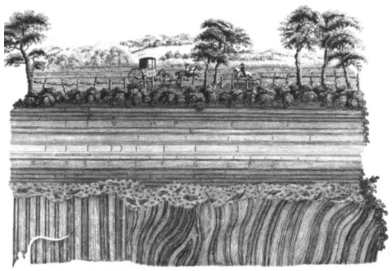

Figure 2: Geographical Unconformity

This would have taken an unimaginably long time to occur, which is compelling evidence of the true age of Earth. Hutton postulated that the world existed since forever, and that God wouldn't allow all dry land to be eroded away; There was a balance between erosion and creation of land.

NOTE: Though there were objections to these theories from the Church and people with religious reasons, the Bible had never been an object of veneration and read literally. The geologists and men of science who gave theories contradicting the Bible weren't against religion and were in fact religious, and people could accept and accomodate these new scientific ideas.

William Smith (1769 -1839) worked for companies that were digging networks of canals during the Industrial Revolution, in the form of expert surveying work. Looked carefully of what was found in the rocks.

Discovered that **type of fossils were specific to each layer/strata**, never found beyond their usual range.

Also that the order of the bed of rocks is the same everywhere these rocks were found. The lower layer and hence the lower fossils were lower than those in higher beds/layers. **Became possible to reconstruct the history of life.**

2 Week 1 Lecture 2

2.1 The concept of Extinction

In 1800, Anatomist **George Cuvier (1769 - 1832)** proposed an age of reptiles in the past. In 1808, published fossil characteristics at different strata on the Paris Basin, **no evidence of great flood but rather history of one era after another**. Environments had clearly changed in the past.

Cuvier found previously unknown types of mammals through skeletons. Through a skeleton on a Mastodon, he psostulated that **that species was extinct, which was considered irreligious**. However, being a large mammal, it was highly unlikely for it to have existed without human discovery.

Hence, the concept of extinction was established.

Jean-Baptiste de Lamarck (1744 - 1829) could not accept that livings things go extinct. Argued that rather than dying out, they **changed**. Tendency for organisms to become more complex → The **complexifying force**, and **Adaptive force** to fit their environment.

Lamarck that since living things gradually get more complex, he hypothesized that the presence of presence of primitive things today meant that life was still spontaneously springing to life at came into existence at different times.

Being immensely respected, Cuvier also obliterated Lamarck's reputation and labelled any theory of Evolution as unscientific.

2.2 The History of Earth

Mary Anning (1799 - 1847) found remarkable fossils at the seacliffs (Plesiosaur, Ichthyosaur which are sea reptiles). Also found fossil faeces, which showed what they ate. *(Eg Ichthyosaurs ate smaller Ichthyosaurs.)*

Dinosauria group named by **Richard Owen in 1942**. Crystal Palace Dinosaurs in 1854 was **reconstructed life-sized** and **put each group in their own geological era of time**. A first imagination of what dinosaurs look like.

This was the state of knowledge of history of life on Earth before Darwin, nothing related to Evolution.

Figure 3: Progressive Fossil Records: Primitive forms to Age of Reptiles to an Age of Mammals, though this looks like evolution at work, people at that time did not believe or think about evolution.

An explanation to this was clear-cut eras where living things were created then destroyed, process repeats.

Rev. William Buckland (1784 - 1856) kept a managerie of animals in his home and eat them. He realised marks in fossils turn out to be footprints of animals (through observing a tortoise in his kitchen)

At this point, human-like animals never appeared on any era of the history of life, as they realised that humans only came into the picture not too long ago. But otherwise, history of life on Earth was universally established at this point in time.

Louis Agassiz (1837 - 1873) proposed an **"Ice Age"**, as rock structures could have been made by the movement of gigantic glaciers.

Charles Lyell (1797 - 1875) argued against sudden revolutions, proposed slow gradual changes ***(See Temple of Serapis)***, and that geological changes likely occured throughout history at the same magnitude as it is today (Which other colleagues did not except). Ie there were **no great catastrophies, extinction was a normal process** all the time since **the world was changing and the animals weren't**.

Then where did the new species that replaced the old species come from? Lyell could not answer that. In fact, Lyell **hated the idea of evolution** and Lamarck's (who was now dead) theory of evolution, as he was **disturbed that humans were not separate and came from nature**.

Lyell then argued that history of life was not progressive but **circular**. Animals were created by some (not necessarily supernatural) means to suit new environments. He thus thought it was possible for previous animals to come again provided their environment returns. Through a correspondence to Lyell in 1836, **John Herschel** question if there were naturalistic means that animals were created? *Darwin ended up quoting this in the Origin of Species)*

Robert Chambers wrote **Vestiges of The Natural History of Creation** brought in the progressive nature of the UNIVERSE from simple to complex. **He put Man in the evolutionary sequence**, as the highest point that laws of nature have yet to obtain. At that point it was **unacceptable** to think that way, and this book was published **anonymously** due to its radical views, but became a bestseller nonetheless (partially due to its fiercely negative reviews, such as by **Adam Segwick**). This book ended up **converted more people to accept some kind of evolutionary views that any other existing book did**.

Darwin later wrote that though he didn't agree with this book, it did help prepare the public of similar views of living things changing over time.

3 Lecture 3: Darwin's early days

3.1 Shrewsbury, England (1809)

Darwin was born in the Mount House. His Father Dr Robert Darwin (1766 - 1848), Grandfather Erasmus Darwin (1731 - 1802) was famous themselves as physicians. His mother was Susannah Wedgwood Darwin (-1817) from the Josiah Wedgwood family.

Darwin was baptized at **The Parish Church of St. Chad's** as a child. You had to be a member of the State Church to access privileges, such as going to University or being an MP. However, his mother was more liberal (non-comformist) and attended **The Unitarian Chapel**. After she died, Darwin's sisters took him to the State Church.

3.2 Education

Darwin attended **Shrewsbury Grammar School**, where he did not excel. His father took him out of school early, sent to **University of Edinburgh (1825 - 1827)**, which was famous for medicine studies. His older brother Erasmus was also studying Medicine here, but ultimately didn't have a job as he had money.

Darwin did not enjoy his studies, commented his lecturer Alexander Monroe III's lectures as dull. Body dissection were needed, used old people, poor people who died on the streets, and criminals.

Burke and Hare killed people to obtain more bodies. Eventually got caught: Burke was executed, Hare got off as he ratted out his colleague. Burke was sent to anatomy school in Edinburgh for dissection, where his body still lies.

Darwin took electives on Natural History. Jameson, owner of the Edinburgh University's Natural History Museum took his students for an excursion, pointed out a rock that intruded into the surrounding rocks. James sneered that some people thought is was formed underwater, which Darwin found off-putting. **He decided he wouldn't study Geology**.

3.2.1 The Study of Marine Invertebrates

Darwin studied Marine Invertebrates; they were primitive, suggesting they were close to the beginning of life.

Darwin came under **Dr Robert Grant (1793 - 1874)**, gentleman, freethinker, **fierce Lamarkian** (Believed in evolutionary theories) expert on marine invertebrates. Walking along the beach collecting sea creatures, he burst out about Lamark's evolutionary theory: **first time someone openly spoke to Darwin about evolutionary theory**. Also introduced Darwin to **scientific jealousy and competition**: Darwin made discoveries on the microscope, which Grant considered disloyal for Darwin to publish (he later published it himself). **Darwin did not like that**.

Dr Grant studied lower orders of Marine Life: eg) Flustra or previously called 'zoophytes' (animal plants), now called Bryozoa.

Darwin's first scientific paper delivered to student scientific society **On the Ova of Flustra, 1827**.

3.2.2 Going to Cambridge (1828 - 1831)

Darwin did not like studying Medicine, did not like the sight of blood: he ran out of a lecture theatre during an exhibition operation on a child. Darwin's father proposed an alternative career path: **A clergyman**. *Interestingly, Darwin Sr and grandfather was a free thinker.*

Had to get a **BA degree** from Cambridge to become a Clergyman. Out of the 30 colleges, he went to **Christ's College**, a smaller, not as prestigious and academically-rigorous college, which suited him The universities were Quasi-religious: Darwin had to attend college chapel twice a day (sometimes having to read from the bible in front of the church), fellows were fellow Clergymen. Undergraduates had to enroll into 1 of 4 categories: Noblemen, Fellow Commoner, Normal Students and Sizars, and wore caps and gowns everywhere. There were only 2 hours worth of teaching/day. **It was also entirely male, students were not allowed to get involved with women**.

Darwin at that time was obsessed with shooting birds, had a shotgun in his room, which was a luxury and privilege for wealthy undergrads. Darwin deeply moved by fine art and organ music, but faded away over time. Darwin was also a terrible artist; his sister drew in his stead (Example given was beetles in a letter dated 30 June 1828)

Darwin became obsessed with collecting **beetles**, which was a craze among some undergrads. He would be going across the countryside to compete catching rare beetles.

Story of him finding 3 good beetles, one in each hand, he popped one into his mouth to catch the 3rd, which ended up being a Bombadier Beetle. It spat acid, making him lose all 3 beetles.

Darwin had a beetle collecting cabinet with 6 drawers.

Darwin took electives from **Rev. John Steven Henslow (1796 - 1861)** (who was married), Professor of Botany, 3 years in a row. Darwin attached himself to him, learned about science methodology. Darwin praised the pictures Henslow drew in his lectures and was a teacher's pet, laying out papers in the LTs. Known as **The Man who walks with Henslow**.

Darwin, with Henslow, found a rare plant, and was keen to impress his Professor. Tried and failed to pole vault across a ditch.

Also, they were collecting a rare toad called Natterjack, only needed one, but Darwin brought an entire hat of them.

Darwin also read excerpts from naturalist **Alexander von Humboldt's *Narrative of Travels to South America***. Humboldt discovered that at different altitudes, there are different plants that grow ('zones'). Combined Science and the romantic appreciation of the Natural World.

Rev. Adam Segwick (1785 - 1873), studied the oldest rocks known then. **His quotes greatly summarizes old ideology: The progressive development/successive forms of life was proof that God designed them.** Darwin learnt essential field geology on a field trip with Segwick.

Even without a Science degree/profession, Darwin had a considerable education in Science.

Interestingly, University gowns were derived when universities were medieval religious institutions, where monks wore robes.

1831: Darwin given his BA degree at Senate House. He was planned to study divinity, but **Henslow passed on Darwin's offer to travel on HMS Beagle**.

4 Lecture 4

4.1 Voyage on the H.M.S Beagle (1831 - 1936)

Offer from Royal Navy who invited Henslow to sail on a vayage as a naturalist. Due to career and married status, Henslow had to refuse. He recommended Darwin to go in his place, which he accepted gladly, though his father disapproved.

Darwin sailed without a notion of evolution, but rather natural history.

Captain Robert Fitzroy captained the ship employed a navigator and an artist to capture images.

H.M.S Beagle, His Majesty's Ship was small for 74 men to live on for 5 years, and had a state-of-the-art scientific library. Darwin stayed in the Poop cabin, and referred to the library daily.

The main purpose of the voyage was surveying and mapmaking, checking submerged rocks and making sure it was safe to travel. On the voyage, Darwin was mostly a geologist, then a biologist.

4.2 Journey around South America

Santiago, Cape de Verde islands, 385 miles off the west coast of Africa. Using Lyell's teachings, Darwin could find out the island's history and uplifting up from the sea through Geology.

Darwin realised that he should publish a book on his findings (currently about Geology).

While the ship was surveying, Darwin was mostly ashore studying the lands around the area.

Carried field notebooks and make notes (initial observations), which were used in his (more detailed) scientific diaries and letters. *One, the Red Notebook, had evolutionary speculations, but that was only written AFTER the voyage.*

Spent a lot of time with South American cowboys **Gauchos**, who were Spanish and hunted with weapons called **bola**. (Something like a projectile net) Darwin somehow caught his own horse with it.

Cliffs of Patagonia Multiple levels of Plateaus above sea level created by coastal erosion; At some point, the land had gone up multiple times Geological change taken place over long periods =¿ Darwin was just reaching Lyell's **Principles of Geology**, which supported this.

Extinct animals: Toxodon, Megatherium. Macaruchenia patachonia, who was extinct long ago, was related to llamas. **How and why is there a relationship between things in the past and things today?** Also Mylodon, extinct ground sloth, and extinct killer kangaroos in Australia, and Glyptodon, same family from Armadillo (only animal on Earth with the same bony plate).

Horses in America was introduced from Europe, but Darwin realised horses went extinct in America long ago, **despite the environment being perfect for them**. Lyell's book did not fit the evidence found here; if the environment was good, why weren't they created here?.

Curiously, the current living creatures were found only in areas where their related extinct ancestors were found.

Darwin discovered 2 species of a bird "Rhea", but so similar that Darwin shot and ate another species without realising: Distribution of species? **Why are they 2 species in the same area if they're so similar?**

Santa Cruz expedition, April-May 1834: Beach pebbles found far inland, land once under the sea, **proof of continental uplift**; could never have been made by a 40 day flood.

Myth: Darwin vs Fitzroy: Science vs Religion? False, Fitzroy was very scientifically minded, as seen from inviting Darwin, Beagle's library. Instead, **Darwin was laughed at for quoting the Bible**.

Fitzroy did convert after the voyage though.

Ship moved to **Tierra del Fuego**. **Fuegians (1832 and 1834)** very different people from Europeans. Wild and primitive existence in a cold part of the Earth, rumoured to have a peculiar diet: Cannibals during bad winters, whale livers? Darwin brought Fuegians to the voyage to act as a Christian missionary. When they returned though, they returned back into their primitive nature. **People who were like animals more than people, obscurred the lines between human and animal**.

1835, West Coast: Darwin experienced a minute-long earthquake followed by a tsunami at Concepcion. Noticed buildings at different angles got differently affected. Volcanic activity appeared around the same time. **Seashore gone up by one meter.** Comquimbo, Chile, displayed repeated crustal uplift. Going up into the Andes, Darwin found older and older seashells, and fossilized trees normally grown in swampy areas are ¿1000m above sea. **The land was clearly going upwards and side-to-side**.

Darwin speculated that the surface of the Earth was a crust floating on a liquid interior (Now Plate Tectonics).

Darwin found animals that lived in habitats different from those to which their group is adapted.

- A rattlesnake with no rattle
- Subterranean lizard with only front legs
- Burrowing rodent Tucu Tuco, seemed to be losing its eyes *(Then why do they have eyes?)*
- Flatworms (Normally sea creatures) on dry land
- Falkland island's goose that could not fly
- Galapagos lizard that feeds in the sea

On to the Galapagos.

5 Lecture 5

Darwin's dissecting microscope =¿ Has 1 lens

5.1 Galapagos Islands, 1835 and the finches

NOT the Eureka moment of Evolution!!!

Inhabited by **Giant Tortoises (Meaning of Galapagos)**, animals there showed no fear of man. (No humans on land, no land predators)

Marine Iguanas dissected, stomach contained only seaweed. Unexpected; No other lizard went into water to eat seaweed (Nothing to eat?) Darwin wrongly postulated that sharks were the iguanas only predators, when he flung them to the sea only for them to immediately swim back to shore. It was really because they were **Cold-blooded**. Only predators of these iguanas were snakes when they were babies.

Galapagos finches =¿ became the Symbol of Darwin's theory. Different species distinguishable from beaks. **MYTH:** Differently shaped beaks adapted to eat different food, example of adapting to environment. **Darwin had no clue about this.** Darwin did not label each finch by the particular island; some finches were on some islands and not others.

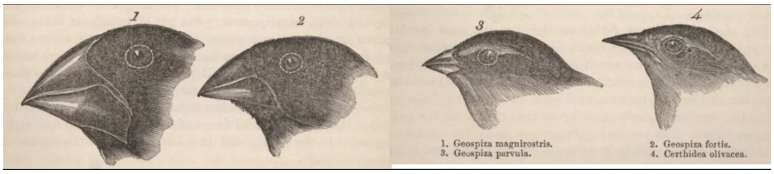

Figure 4: Types of Finches (13 types)

Darwin didnt know they were all finches. When he returned home, **John Gould, ornithologist**, examined his collection, told Darwin they were **all 13 species of finches, and they exist nowhere else**.

Darwin did notice, though, that Mockingbirds at the islands were different, but in the field, he wasn't sure whether they were species or varieties.

1836 (After the visit): Darwin wrote up ornithological notes for others to read, he **mentions the possibility of Evolution**.

Other than the birds, plants also had 'new species', confined in the Archipelago. The birds and plants look overwhelmingly similar to those in South America, despite the islands being 600 miles west from the coast.
Also, **did each finch only reach 1 island? Darwin reasoned they must have migrated within the islands,** adapting in the process.

5.2 Coral Atolls

Ring shaped islands in the Pacific made of coral rock. How tf did they form??

5.2.1 Lyell's theory

Coral can only grow on shallow water. Volcanic crater formed just beneath the surface, coral reefs grew on these submerged craters. Unlikely?

Darwin wanted to investigate these reefs.

5.2.2 Tahiti (Nov 1835)

Beagle neared the island of Tahiti, was like paradise to people (with beautiful topless girls).

Story of HMS Bounty 50 years ago

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H.M.S Bounty collected redfruit to the West Indies to grow for poor slaves as food.
Captain Bligh harsh disciplinarian; people mutinied, took ship by force, set him adrift in a boat.
Meanwhile, mutineers turned back to Tahiti to their girlfriends, sailed away with them to evade bei
Settled on Pitcairn island, which was wrongly charted and burned the Bounty.

20 years later, only children, women and 1 man remained alive. One girlfriend of 1 man died, led to
Today, their descendants still live on the island
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Christian Missionaries have been there for decades to "tame" the people there when Darwin arrived. Came under criticism from Europeans wanting to find beautiful girl paradise and were disappointed. **Darwin and Fitzroy approved to the missionaries, at South Africa, wrote joint letter in defence of the missionaries (Darwin's first intentional publication).**

Darwin climbed the peak of Tahiti (Mont Orohena), viewing the island and reef of Moorea (Eimeo). Having previous evidence of land subsiding/rising, and knowing corals grow around islands, postulated island next door, a volcanic mountain, subsided, leaving the coral reef around the island: A **Coral Atoll**. Coral reef grows upwards enough to compensate island going downwards.

Darwin speculated seafloor at that part of Pacific was gradually subsiding. Theory quickly won acceptance at home. But how to tell if his or Lyell's theory was correct? If volcanic rock within the atoll was not deep within the coral rocks (dead compressed coral): Darwin was wrong; if it is deep, then Darwin is right

1950s: Bikini Atoll, US atomic testing, did the drilling, 1 mile drilled of coral rock until volcanic rock was found. ***Darwin was right****.*

Map of Atolls in the world show they are closely distributed. *If that part of Pacific seafloor is subsiding, connected to South American coastline rising?*

5.3 Sydney, Australia

Already well-covered by naturalists here. Darwin was unimpressed with the people there (convicts).

5.4 St. Helena

Rocks there are part of the Earth's crust.

Plants and animals introduced wrecked the original environment and unique species.

11 July 1836: On a cliff, no wind, vastly different from the seabirds struggling against the wind over the sea: Winds hitting the sheer rock and creating an updraft.

5.5 Arriving Home

Darwin published the results of investigations: Volumes on:

- Fossil Mammals
- Fossil Shells
- Mammals

- Birds
- Fish
- Reptiles, Amphibians
- Insects
- Plants
- Funghi
- Marine Bryozoa
- And lots more were never published...

At that moment, he started to think how life might evolve.

6 Lecture 6, Oct 1836: The Beagle returns home

Darwin lived briefly in Cambridge in 1836 - 1837. (Cambridge was where his mentor Henslow was)

Darwin thought about getting married; Jotted down Pros and Cons LMAO. Not a sociable person, valued time a lot. This father advises him to get married, but to **"conceal carefully your doubts" (about religion)**.

6.1 Marriage

Jan 1839: Darwin married Emma Wedgwood (his cousin) and moved to London. Needs experts there to work on his mountain of collections. London was filthy, noisy and smoky.

1842: Darwins moved to Down south of London to the village of **Downe**. Bought a house: Downe house. Being wealthy, and receiving a dowry from his father-in-law, Darwin settled down. Already had 2 children by now. Will be his home and lab for the rest of his life. Darwin would walk everyday (Sand walk) which became a famous icon in his life.

6.2 Ideological Change

6.2.1 During the voyage - 1836

Rev. William Paley (1743 - 1805) (Represented as the antithesis of Darwin's theory) wrote the Natural Theology (how nature was created from God) (1802).

"The Position of the bones of Mastodon (?)" (Feb 1835), Darwin was still a creationist, but grappling with the problem of successive disappearances of species and unknown birth of new ones. Darwin heard about **apple trees grown from grafts on Chiloe (no seeds) and died at the same time (this was not true)**. Could this explain the deaths of the Mastodon?

At the end of the voyage, ornithological notes (June - July 1836), zoology of Archipelagoes seem to undermine the stability of species? Curious, even sceptical, but not yet convinced

6.2.2 Early 1837

Became fully convinced that life evolves (From a creationist to a **Transmutationist**)

3 main types of fact that convinced him:

1. Similarity between extinct and living creatures in the same place
    - Macaruchenia - Llama replacement?
    - Glyptodon - Armadillo replacement
2. Distribution of related living species and difficulties with determining species.
3. Relationship of Galapagos Islands species to those of nearby continent
    - Also, Finches and Mockingbirds were learnt to be species, NOT varieties

May 1837: Coral Formations paper

Groups of living beings peculiar to small spots are remnants of a large population, of a new one springing into existence.

6.2.3 Jan - June 1837: Red Notebook

1. Geographical Distribution: 2 Rheas descended from a common parent, but "at one blow" (or 'per saltum') =¿ Saltational Speciation
2. Distribution of species through Time and Space
3. Reproduction of individuals and species: Timer for species? When time is up, it will become extinct: but before it does, gives rise to a new species?

6.2.4 Notebook B

3 main questions.

1. How do species become adapted to a changing world? (Adaptation)
    - Variation from Sexual Reproduction
2. How do new species form? (Speciation)
    - Isolation?
3. How does the Hierarchy of Taxonomy Form? (Phylogeny)
    - Earlier mindset: Evidence of God's design
    - Descent from earlier types with irregular extinctions =¿ A tree of life?

6.2.5 Notebook C

Darwin thought about:

1. Hereditary transmission of form
2. Distribution of local and wide-ranging species
3. Distinction between affinity and analogy
    - Affinity = Similarity due to descent
    - Analogy = Similarity due to adaptations to similar envrionments
4. Relation between habit (behaviour) and structure
    - Eg Giraffe neck long start to grow????
    - Darwin felt behaviour first, then structure changes.

6.2.6 Notebook D

Main theme is reproduction: **What is the origin of adaptation?**

1. Why is the world not filled by one type?
2. Thomas Malthus' Malthusian Law of Population: Population Growth need to be prevented
    - **Natural Selection (Sept 1838)**:
    - Out of all offspring that get reproduced, all varying a little bit, only those with favourable characteristics survive.
    - Those that get unfavourable characteristics die.
3. Darwin's theories is NOT the influence of Economics despite popular belief.

6.2.7 Notebook E

Theory in its more or less, final form: **Evolution by Natural Selection**
"3 Principles will account for all":

1. Inheritance: Good characteristics expected to be passed on
2. Variation: All living things vary in every possible way
3. Population Growth-Competition-Selection: Inevitable result of large numbers of varying offspring

- Small Hereditary Variations
- Adaption is relative
- Adaptation is contingent on circumstances, variation is always there (Change/Stability based on local circumstances)

6.3 First Evolutionary Tree of Life sketch ever

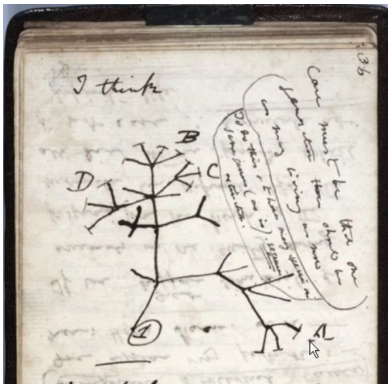

Figure 5: Famous Sketch, species A B C and D can vary, but all are related to one another

How recent is their common ancestor affects how similar things tends to be.

7 Lecture 7: Alfred Russell Wallace

Born in Kensington Cottage, Usk. Wasn't rich but wasn't poor either. Finished school at Hertford Grammar School (1838 - 1837). Moved to London in 1837, saw working class for the first time.

Surveying work (1837 - 1843): Railway lines was big business. Wallace's brother-in-law was a photographer.

Construction Business: Built Mechanics' Institute in Neath, later became a teacher in the **Collegiate School in Leicester (1844 - 1845)**. Met Henry Walter Bates, introduced Wallace to collecting beetles. Wallace was introduced to the **Vestiges of the Natural History of Creation** (See above). Wallace thought it was plausible.

Also heard of **phrenology**, reading shape of their brain by bumps on someone's head. Wallace had his head read twice. Also discovered **mesmerism**, believed living things have a magnetic fluid which can be manipulated, putting them into a trance (ie hyponotism). Was useful as there wasn't any anaesthetics back then. Also tried **Preno-mesmerism**.

Bates, in The Naturalist on the River Amazon (1863), Bates said that Wallace went to Brazil to 'solve the problem of the Origin of Species', which Wallace did NOT write in his letter, nor did he write about going to Brazil. Essentially rewrote history to make it sound like they were on the chase of the problem of evolution before Darwin published his book.

Bates and Wallace went to the Amazon (Apr 1848 - Oct 1852) to collect (butterfly) species. Ship burnt down (1852), species collection destroyed. **Wallace in 1853 (30 years old) after his return from the Amazon.**

7.1 To Singapore

Came to Southeast Asia to do more collecting, went to **Singapore (18 April 1854)**. Stayed in the London Hotel, now the Padang. Stayed at **St. Joseph's Church, Bukit Timah** with a French missionary. Singapore was rumoured to be infested with tigers (killing one person per day, which is untrue).

Concentrated collecting birds and insects. Skinned and stuffed birds etc, Wallace discovered and collected a lot of new species (birds, insect, mammals etc), but much narrower than what Darwin collected: **Wallace was a Commercial Collector: Selectively collect a range; Rather than for sale, Darwin was collecting for science.**

Asian Brown Flycatcher is the only Wallace specimen in Singapore. Sold to museum in Germany, exchanged specimens with Singapore. Caught in Malacca in 1862: but he wasn't in Malacca in 1862; caught by his friend, examined by him.

Punch holes on cloth with his gun to label his animals he collected. (Wallace Bee, for example).

His assistant, **Charles Allen**, not very helpful, Wallace was quite fed up; Wallace was a perfectionist. He chose to stay in Sarawak, worked for missionaries. Ultimately went to Singapore, became manager of the Perseverance Estate - now Geylang. He had 5 daughters, one married architect of Raffles Hotel.

Wallace's 2nd assistant, **Ali from Sarawak (1855 - 1862)**. Wallace trusted him completely.

Singapore 1856: Wallace sold 2 boxes of books for a young man, **George Rappa Jr.**. In 1859, Rappa became a partner of Philip Robinson, founder of Robinson & Co.

7.2 Sarawak Law Paper

Wallace's **Sarawak Law Paper, 1855** is NOT a theory of evolution, no mention of it: Living things has been created in a progressive order (old news). What's new is **new species that appear are similar to the ones that were there before**.

> "Every species has come into existence coincident both in space and time with a pre-existing closely allied species."

Wallace believed in evolution when he wrote this, but he kept it quiet; only suggestive to evolution. Though at the cutting edge of theoretical biological thinking back then, no one was interested. Darwin's reaction: Didn't get it, took it at face value "creation", didn't know he was hinting at evolution. "If he said evolution instead of creation, Darwin would have agreed."

The Wallace line in South-East Asia: Major biological fact in SEA that islands to the West have Asian species of animals; Islands to the East have Australian species, even though islands may be very close together. **Environment and Climate didn't seem to determine which species lived there, couldn't be explained.** *(Now know that this is due to Plate Tectonics, continental shift)*

8 Lecture 8
Why was Darwin so famous, but Wallace isn't?

Story has been changed from a positive rivalry VS current notion of being shabbily treated.

It is untrue that Wallace went to SEA to *"Solve the problem of the origin of species"*. (Evident from his 1856 paper ...many animals are provided with organs...which serve no material or physical purpose.")

8.1 The Ternate Essay

February 1856: Suffering from a tropical fever, Wallace had a new idea: Wrote essay outlining his new views.

Wallace to F. Bates (2 March 1858): Only comtemporary clue we have about his ideas *"...but I have lately worked out a theory which accounts for them naturally"* (referring to Tiger Beetles' camouflage)

Wallace's Ternate Essay *undisputed fact that varieties do frequently occur..*

Parent Species => Different varieties descended from parent => Only those that camouflaged in the new environment survives (Natural Selection; All other varieties are dead)

> "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..." (*Wallace's Ternate Essay*)

He writes up the **Ternate Essay** and sends it to **Charles Darwin**: The only man on Earth who already come up with the theory of Natural Selection. Wallace hoped that if Darwin found it sufficiently interesting, he would forward it to Charles Lyell. (Sending to Darwin was safe as Wallace knew that Darwin was an evolutionist).

Darwin forwarded it to Lyell as requested, and sent Wallace's essay for publication before he himself published his own **(People felt Wallace was 'robbed')**. Lyell couldn't be bothered. Conflicted about whos to publish, Darwin requested to send the letter to Joseph Hooker.

To avoid priority disputes, Hooker suggested for both essays read at the same scientific meeting by the Linnean Society. Charles Lyell and Joseph Hooker put forward the writings of both men (Both Wallace and Darwin weren't present at the meeting). Darwins' wasn't complete; but he wrote up a short essay about it.

Wallace was delighted to have his essay read to the Linnean Society he did not have access to

8.2 Conspiracy? Nope

Wallace sent the letter on 9 March 1858(?), Letter to Bates (sent 9 March) arrived on 3 June, but Darwin only claimed to receive it on 18 June?

Turns out Wallace posted on April mail steamer as he was replying to Darwin's letter from the March steamer.

8.3 The Origin of Species

Darwin's and Wallace's ideas have been published. **No reaction/scientific revolution. Simply too short/brief addressing such a huge issue.**

Darwin was persuaded to publish a overview of his ideas instead. In **1859**, 13 months of summarizing his 20 years of research made **The Origin of Species**. This book was extremely convincing and successfully convinced people. (None of this book came from Wallace)

Despite this, Darwin credited Wallace in the first page for having the same ideas, pushing both men into

fame and credit.

Wallace received a complimentary copy of the Origin of Species. Wallace seen points that he never thought of, felt that the book was incredibly convincing.

Wallace returned to England in 1862. 1869: Wallace published his own book of his travels.

8.4 A decade later...

After the **1870 meeting of the British Association for the Advancements of Science**, Wallace bemoaned to Darwin,

> "No opponents left who know anything of natural history, so that there are none of the good discussion we used to have"

Wallace went home, after being engaged and dumped, he **married Annie Mitten in 1866**. Had a radical change of his opinions about **Human Evolution**. Proposed for humans specifically, **an Overruling Intelligence must have been involved**. (ie God, even though he was not religious). Darwin was shocked, and this distanced Wallace from the scientific community, who now accepted Evolution and not Divine Intervention.

8.5 The Flat Earth Wager 1870 and other radical shit

Some flat-earth nutcase felt that the scientific community was conspiring against them, waged that no scientist could prove the Earth is round.

Wallace, once a surveyor and needed some money, took it up, and proved by means of looking at flags at a canal lining up perfectly in an inverting telescope. Wallace was given the winnings, but the nutcase spent the next 20 years hounding Wallace and prosecuting him.

The nutcase wrote to Wallace's wife threatening Wallace's life.

Wallace also duped into beliving in Ghosts (Spirit Photography), even believing the "ghost" in the photo was his mother when it didn't look remotely like her.

8.6 Wallace in 1913

Father of Biogeography? Not true; already exist before he started writing about the topic.

Greatest Field Biologist? No, Field Biologist is a modern term; he was a Naturalist.

Most famous scientist in the world when he died in 1913? Not exactly; he was the only one left from Darwin's age.

9 Lecture 9: What was he doing in 20 years?

Darwin only published his work in 1859, when he thought of the theory of evolution around 1839.

Darwin was wealthy; no pressure to publish his work to make a living.

9.1 Was Darwin afraid?

NO. Nothing that was written in his time mentioned him about Darwin delaying.

1958: James Huxley suggested fear of upsetting scientific colleagues contributed to the myth.

1974: Psychologist Howard Gruber's book Darwin of Man, advent of the delay. Darwin's 'dream' was dramatised by popular media. he did have a dream of getting hung, but he found it witty rather than being afraid.

In fact, long gestation periods were typical for Darwin's books:

- Inheritance Theory *Pangenesis* not published in 27 years in 1868.
- Observing orchids in 1830s, he only published a book in 1862 (30 years later)
- Psychological Development of his first child, published in 1877 (37 years later)
- Cross Fertilisation of plants in 1839, published 37 years later in 1876 (37 years)
- Significance of Earthworms realised in 1837, not published until 1881 (42 years)

All longer than the 20 years wait for the Origin of Species.

Darwin to **J. D. Hooker (11 Jan 1844) "...like confessing a murder..."** also popularized from media. In the same autobiography, "...all that I can say is that **I am ready to commit suicide**", also talked a lot about murder/death. *Using over-the-top language, similar to "Walao kms"*

Darwin to O. Salvin [1871], embarassed that O. Salvin helped him so much, he said **...I felt as if I had committed theft, arson or murder.....**

9.1.1 How Darwin treated secrets?

Darwin marked letters private, in a letter to Lyell "...but please repeat nothing..."

Nothing about evolution was marked private

9.1.2 Response from Vestiges

Did the hostile reaction from Vestiges frighten Darwin?

Darwin saw the Vestiges as amateurish, since it wasn't written by an expert, unlike Darwin's theory.

Richard Owen who received the Vestiges, wrote to the author, speaking of it positively.
"Secondary Causes": Laws of Nature happened after God and acted independently (ie God is the primary cause of "production of organised beings upon this planet").

9.2 What was he doing then?

Jan 1844: Sent *Volcanic Islands* for printing. Corrections in February.

1844: *1844 essay*: Rough draft of the spirit of Evolution. **Sent out to be commercially copied in good handwriting.** Became what is now known as **The Fair Copy**.

5th July 1844 Letter to his wife Emma: **"...I therefore write this, in case of my sudden death,..." to request to get it published.** VERY different from the commonly quoted "Don't publish this until I'm dead"

Nov 1845: To finish his South American Geology, then Zoology, then Species Work. **5 years from 1848 to 1852 doing species work**.

Finished *Geology* in 1846, expected *Zoology* to be finished by 1853. But there was one thing in the way:

9.2.1 Barnacles, aka *Cirripede: or Hairy Foot*

By Oct 1846, only barnacles really remained. Darwin was THE expert of marine invertebrates. Had a weird barnacle in the collection, was almost microscopic with no shell , which led him on to examine and dissect common forms.

People thought barnacles were a type of Mollusc. Turns out, there were **crustaceans**, especially obvious during certain stages of its life cycle:

1. Swim around, find suitable place to live
2. Glue heads to a rock/debris, forming shell plates
3. Reproduces through its long(est) penis to get to others vag

Darwin spent 8 years on this, became very experienced. By 1850, though Darwin was weary of barnacles, he didn't stop as by now, he had the obligation to complete his Barnacle project.

Darwin found that barnacles had **Structures that could adapt function to suit new conditions**, which was important for the evolutionary framework.

Owen's Nature of Limbs (1849): Presence of similar Backbones in organisms were **evidence of God's design plan**

Study of invertebrates led him to think about nature changing from bisexuality to unisexuality.

9.2.2 Unfinished Business

He only started species work from 1854 onwards, but there were still some major issues that Darwin has yet to solve.

1844:"Overlooked one problem: Tendency in beings descended from the same stock to diverge in character as they become modified." Solved in early 1850s: **Principle of Divergence**

Also: another difficulty - insect-communities cannot propogate their own kind Solved in November 1854: Only the queens passes the instincts on

10 Origin of Species, 6th Edition

Added last sentence to the book to defend himself, that this book was different: "I formerly spoke to very many naturalists on the subject of evolution, and never once met with any sympathetic agreement.

Implied he never bothered to keep it secret, unlike popular belief.

Darwin to a letter to **Asa Gray, 1857**: While he was working on other projects, he kept evolution in mind.

Darwin then recieved Wallace's letter and was surprised by it in 1858.

11 Lecture 10: The Main Event, the BOOK

Darwin grew his beard in 1862 hehexd.

11.1 About?

The book is about: Evolution by Natural Selection explains a wide range of phenomena that are otherwise inexplicable

The book is NOT about:

- The Origin of Life
- Does God exist?
- Is God ultimately behind nature? (**He strongly implies YES**)

11.1.1 How does he convince people?

- **Variation seen in Domestication**/Farming: Artificial Selection actually changes species.
  - *Eg) Pigeons have different breeds and were popular in Victorian Britain.*
  - *Eg2) Giovanni Stanchi (c. 1660) depiction of old watermelons*
  - *Eg3) Ancon Sheep*
  - *Eg4) Strawberries, farmed vs wild*
- Compares this to **Variations in Nature**, hence no clear distinction between species and varieties.
  - The tree of life makes sense of taxanomy; Creation cannot.
- **Struggle for existence**: geometrical population growth seldom happens because of checks (**Natural Selection** in play)
- **Sexual Selection**
  - Offspring has characteristics of those who managed to mate.
  - Females judge males whether to select them or not.
- **Geological Succession of Organic Beings**:
  - Species once extinct never reappear; succession of same families within same area explained.
- **Geographical Distribution**
  - Environments cannot explain Distribution:
  - *Eg) Amphibians do not live in oceanic islands even though the env is perfect for them. No way to get there: Ambiphibians' eggs killed on contact with salt.*
  - Animals and Plants have moved about and diversified from their ancestors, **limited by natural barriers**
- **Similarity between species**:
  - Embryology: Embryos show stark similarities between different species
  - Explained by evolution from a common ancestor
- **Vestigial Organs**: Why are they there without use?
  - Teeth in Embryos of whales, toothless as adults

- Toenails on flippers of manatees
- Wings on flightless birds
- Pelvis in whales, now without legs and without use

- **Homology**: Same structure in different species
  - Similar bone structure in animals, even for those who have no structural need for it

11.1.2 Difficulties on Theory/Answers to Objections

- **How could huge changes ever begin?**
  - By many tiny gradual steps and selection; Transitional forms all around us.
  - Proof from connection of throat to trachea, risking food entering lungs, similar to aquatic animals' swimbladder and gulping air to breathe
- **Organs seem to complicated and perfect, must have been designed?**
  - Many complexities of eyes appear in different species; every next generation is an improvement from the previous one as such improvements being advantages (Natural Selection again)
- **Why does a bee die after stinging?**
  - Ancestry; Characteristics/structures that were formerly useful persists due to inheritance
- **Imperfection of the Geological Record**
  - Fossil Record more fragmentary than we realise
  - Fossil Records are the accidental survival of remains in the past: Fast Forward to the present-How many still remain?
  - Occasional few who die near where sediments form such that it doesn't decompose

11.1.3 Does the natural world reveal evidence for a kind or benevolent design?

NO.

Laws of Nature is cruel "Struggle for existence": Eating each other, parasitic spiders etc etc....

Ernst Haeckel's tree of life from the Evolution of Man **mistakenly implies a direction or progress in Evolution**.

11.2 Changes to the Origin of Species over time

Historical sketch added to the third edition (1861)

At behest of Wallace, fifth edition (1869) first used Hebert Spencer's expression **Survival of the Fittest**

- Many now think this is misleading (No one chooses/selects who survives and who don't)
- Darwin though a better term would be "Natural Preservation"

11.3 The conclusion

> *"There is grandeur in this view of life, with several power, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved."*

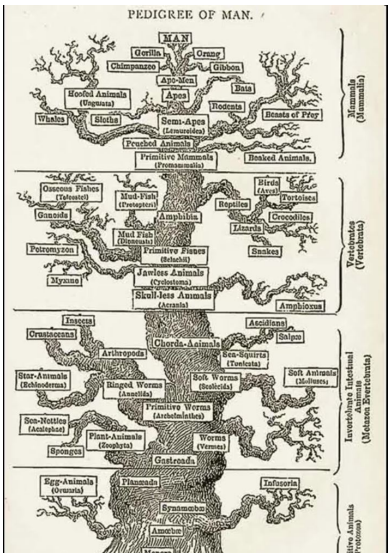

Figure 6: Mistaken Tree of Life, with Man at the top

12 Lecture 11: What happened after the publication?

Widely Reviewed in education periodicals, not generic newspaper; Wide range of reactions (correlated with their class, religion, education and ideologies)

Major Objections:

"God makes species, not Nature."

"We are separate from nature, we are not from other animals"

12.1 Reviews

Geologist Louis Agassiz rejected the Transmutation Theory outright.

Samuel Wilberforce review 1860 "...such a notion is absolutely incompatible... (with God and the spiritual condition of Man)"

Thomas Henry Huxley review 1860 Fair question for scientific discussion, religious or moral beliefs cannot decide whether a scientific claim is true or not. Helped Darwin write a review in a prestigious conservative newspaper.

"Darwin's bulldog?" Not true; Another myth

Clergyman Charles Kingsley accepted Darwin's theory, quoted in Origin of Species 2nd Edition 1860 "It is just as noble an idea that God created original forms that were capable of self-development, than to believe he had to create new species each time to fill the gaps"

Public Conference in **Oxford University Museum, 1860** Dispute of Bishop Samuel Wilberforce vs Thomas Henry Huxley. **Joseph Hooker** also claimed to smash the Bishop with his own words

Fleeming Jenkin's book review (1867) Swamping argument; "Inheritance" will be blended into the species after a while.

12.2 New Evidence Found

12.2.1 Mimicry

Henry Walter Bates in the Amazon collecting specimens published his own book, Naturalist of the River Amazons.

Discovery made (1861-3): Mimicry, nicer tasting butterflies often mimics appearance of bad-tasting butterfly species.

Close resemblance not from descent since not from same family, and only occurred in the same place where the other species existed. **Could only have been explained through Darwin's theory.**

12.2.2 Fossil Feather

1860: The oldest fossil feather found way below when birds were theorized to have existed. Found the fossil of **Archaeopteryx 1861 - 1863**, had wings but legs and arms are of equal length: similar to that of a running animal and had claws on wings.

Was like the "missing link" between birds and reptiles.

Only birds did not die out from the asteroid: birds are literally dinosaurs.

12.2.3 Asa Gray

Asa Gray reconciled Darwin's theories with his own religious views. God's active role is to choose which variations appear. Darwin thought it was nonsense, but was common thinking back then.

12.2.4 Gorillas

Paul Du Chaillu, Explorations and Adventures in Africa (1861) brought back Gorilla remains, looking remarkably human.

People descended from an ape? He was a fraud though, gorilla couldn't walk on 2 legs, and the cover page was plagiarised.

12.3 Richard Owen, 1857

Jealous of Darwin, dissected the brain of humans and apes and found a structure of human brains not found in ape brains (The Hippocampus is actually found in ape brains though)

Created a new subclass trying to separate humans from primates.

Huxley went to war with Owen (**The Great Hippocampus Question**)

12.4 Charles Lyell's new book

Geological Evidences of the Antiquity of Man (1863): Humans are a proper subject of scientific study.

Surveyed discoveries of early man, archaeological evidence in the Palaeolithic.

Charles Lyell was bothered that humans were related to primates, relunctant to accept, which disappointed Darwin.

12.5 T.H Huxley's new book

Man's place in Nature (1863): Man is clearly an animal, brains and skeletons more similar to chimpanzees and gorillas than they are to dogs.

12.6 Horse Evolution

Increased collection of fossil records showed the gradual evolution from small dogs to horses (1870s)

12.7 1869: 10 Years Later

Debate was generally over; Most of the International Scientific Community considered evolution as fact.

(As seen from change in phrasings from 3rd edition (1861) to 5th edition (1869))

But Natural Selection was not as widely accepted:

If Natural Selection is just Victorian social values applied to Nature, then why did so few accept it?

People believe it was reflected on what Darwin found in the capitalist society, and as a reflection of society: it should be consistent with what they already believe.

13 Lecture 12: Victorian Naturalism

Only natural laws and forces exist in nature, or can be detected in nature, or that a system of morality or religion having a purely natural basis.

In Britain: British ruling elite was alarmed at the **French Revolution** (ie if secular/anti-religious were to take charge). Britain became very conservative compared to the rest of Europe, to uphold the status quo to preserve the State Church.

Pierre-Simon Laplace (1749 - 1827) French astronomy wrote on astronomy presented to Napoleon. No mention of God in his work as His existence was irrelevant to his philosophy.

Jean-Baptiste Lamarck was an extremely radical figure in Britain.

The argument from Design. Others felt simply pointing out something was complicated doesn't mean it was God creation: but Britain believed otherwise. "Natural Theology (Find in the natural world, evidence for religion) vs Revealed Theology (From the Holy Book)"

Charles Babbage, the Ninth Bridgewater Treatise (1837) created a new invention: Calculating/difference engine. **Computer initially was a role of a human being**. Babbage was convinced a machine could replace Computers due to the regularity of their work. Had the point to undermine the idea of miracles/supernatural intervention in the natural world. Did a naturalistic attack using his computer: through displaying a seemingly non-random algorithm, people only believe what they see; Whatever they don't see, they call a miracle. **Perhaps there are higher laws of Nature not known to us, which phenomenons thus cannot be called miracles from God.**

John Pringle Nichol's Architecture of the heavens (1837) observed swirls in space (nebulas, galaxies), argued that this was the beginning of the solar system. Thus, suggested this was a **natural** way in which solar systems form.

13.1 Phrenology

Franz Joseph Gall came up with new scientific theory: Human mind could only interact with physical world through an instrument (The brain). The larger a part of the conduit was, the more we could interact with the world. (ie different parts of the brain did different things) Cuvier demolished Gall: he wasn't really accepted in the Scientific community. **Gall had the help of J. G. Spurzheim** outlining a new system. A damning review by a brain anatomist was written, which only garnered it more attention: introducing **Phrenology**.

Eg At the top of the head was the organ of veneration: Tendency to be religious. Above the ears: higher tendency to be a thief

13.2 George Combe

Phrenology eventually died out, but while it was popular, **George Combe** was convinced of Phrenology thorugh Spurzheim's lectures. Became a fulltime leader of the Phrenology movement, writing several books. He also becamee enthralled with Naturalistic philosophy. Combe was rather secular, and the Phrenology society was divided with those evangelical and those secular.

Combe's doctrine of natural laws 'The Constitution of Man' (1828): Man is as subject to natural laws as the rest of nature. His evangelical colleagues got fed up and quit the society. Incredible bestseller, but also extremely controversial: Antichrist, advocated a naturalistic view of the world where you didn't need to think about God. Combe argued that humans were constituted of 3 parts: each corresponding to one part of the natural world. **Analogy used:** Whether 'religious people' or 'thieves, liars etc' drown

depends on how well they take care of their 'ship (the natural world)', not how much they venerate God. You cannot ignore the natural world.

People long before Origin have been reading this book (about the philosophy of nature), sold much more.

Robert Chambers was a friend of Combe, in the Phrenology society as well. **Vestiges** borrows very heavily from Combe, although Combe did not believe in Evolution.

13.3 Biblical Scholarship

Analysis of the Bible by German Biblical scholars (Friedrich Schleiermacher, David Friedman Strauss, Ludwig Feuerbach) et al. New Testament written entirely in Greek, **studies and discoveries which shook people's faith**:

Eg A story of woman caught in adultery ('let ye who has no sin cast the first stone') did not appear in earlier copies. Original greek, writing style different from particular book that its in: That particular story inserted into book by another writer.

Shock in Conservative Britain: **Victorian Crisis of Faith** (Affected people differently from how much they revered the book)

The more liberal ones accepted nature, bible was meant to teach lessons etc. The more conservative ones didn't like this. So **Liberal Anglican theologicans began incorporating this historical scholarship into Christian doctrine in Essays and Reviews (1860)** Very controversial; inside the Church itself.

13.4 Origin of Species

For people who were exposed to Vestiges, Combe's doctrine etc radical ideas, wasn't too radical or different from what they were used to. **More easily accepted**.

13.5 Victorian Crisis of Faith

People were troubled about losing their Faith.

Thomas Henry Huxley (1869) found a respectable way to be non-religious. Described himself as 'Agnostic' - A 'not-knower', as 'Atheist' - 'a not-believer' was derogatory. Comes from **'Gnosis' - to know**. He put himself on morally high ground - No sufficient evidence either way to see if God exists. Elevate science/nature to be top-dog.

Darwin's wife was religious, but she was Unitarian: liberal end of the Christian spectrum. Didn't believe in Hell, adhered to brotherly love/forgiveness

Competition of Philosophies: Who has the moral high ground?

13.6 Science Professionalisation

Huxley and friends pushed for Science Professionalisation. **John Tyndall's Belfast Address (1874)** offended Conservative Belfast: Preached that God wasn't intervening, Laws of Nature are all you need to study. Often called a **Pantheist** - Everything is God; God is Nature.

Deist - Belief in God based on reason rather than revelation or the teaching of any specific religion

13.7 New movements arising amongst Religious Believers

Though there were a lot of events chipping away at faith, there were new religious movements that were up and coming.

Victorian Evangelism: Return to the core original Christian beliefs, strip away errors piling on over time. Adhere to literal meaning of the Bible.

13.8 How was Darwin so successful in Conservative Britain?

Used to new Radical Ideas.

Some had their faith chipped away; Some didn't let it trouble their Faith. Others thought it undermined the Bible.

It became widely accepted quickly. Irony that in the more Conservative past, there were less contesters of Evolution than the present?

Possibly, most were not Biblical literalists, did not feel they had to adhere rigidly to the text of the Bible.

14 Lecture 13: Botany

14.1 Darwin's Estate

14.1.1 The sand walk

Darwin walked everyday, thinking about concepts and ideas.

14.1.2 Game Hunting

Game hunters sneaking in illegally, put out lots of trap. In 1863, Emma and Darwin made an appeal against steel vermin traps

14.1.3 Orchids

Orchid Collecting was a major Victorian pastime. People felt its beauty were God's creation. Linnaeus (1758) knew of 100 species, by 1860, 6000 species were known.

14.1.4 Greenhouse

Amateur science, where Darwin conducted his botanical experiments. **Fertilisation of Orchids (1862)**: first of Darwin's book of supporting evidence of the theory of Natural Selection. But how could orchids be pollinated: pollinate themselves? Earlier theory: Self-Fertilisation, but Darwin believed they must have ways to vary: suggest sex "good effects of intercrossing".

Discovery that plants had different sexes happened 60 years before. Studied Early Purple Orchids (Orchis Mascula). Found pollen packets found on moths: **Co-evolution or co-adaptaion** (Friends with benefits) Moths drink nectar from different orchids, pollinating orchids.

Orchids bear 6000-18000 seeds per plant: Only a few make it. **Severe checks prevent orchids from reproducing too much. Any naturally occuring differences that allowed it to reproduce successfully were more likely to proliferate.** Flowers adapt to make it more likely for insects to pollinate them. (Eg Moths with probosces between 10-11 inches in Madagascar, seen from a long nectary of the *Angraecum sesquipedale*).

Wallace wrote about the predicted moth: As much confidence as "astronomers searched for Neptune". Moth discovered in 1903 (Xanthopan Morgani). Darwin convinced readers that **flowers had just the right structure to guide insects to receive pollen**, pioneered the science of pollination ecology.

Orchids too have vestigial structures. Darwin referenced to botanist **Alphonse de Candolle**, that structures were arranged in their proper places as they were descended from the same kind, not because of God's creation.

14.2 Reactions

Duke of Argyll, Reign of Law (1867) said Darwin sounded like a one was talking like a Creator did the work, unconvinced by Darwin's arguments that natural causes shaped orchids.

Darwin told **Botanist Asa Gray** after his review that "the Orchid book was a 'flank movement' on the 'enemies' of natural selection": Show how harmless his explanations were to do away with God: this is just how plants work. Praised Darwin for the explanations of structures and contributions to natural history.

14.3 Insectivorous Plants

First of Darwin's 3 books on the behaviour of plants: **Insectivorous Plants** (his shorteest book title). Structures of Sun-dews: Modified leaf which curls up around the fly. How? Darwin's experiments showed

the sun-dews leaf reacted to **nitrogen** which then released acid which dissolves and absorbs the object, similar to animals' digestive juices. Such plants grow in marshy areas, where there are little nutrients: get nutrients from insects.

Evolutionary history of Sun-dews speculated: **Absorption? Produce acidic juices for other reasons? Capture insects accidentally?** Different families of plants independently acquired the ability to digest insects!

How they adapted this process is explored in the book **¡TO READ?¿**

Do plants have 'nerves' or 'muscles'? Darwin conducted unusual experiments.

Utricularia, or bladderworts, suck in mosquito larvae through a vacuum: swift killer.

14.4 Climbing Plants

Published another book: **Climbing Plants** tendrils - modified leaves, climb up another plant. Twining plants make circling movements as they grow. Some repsond to stimuli: Light, gravity and touch. Climb to get more sun.

14.5 Different Forms of Flowers

His third book in Botany: Heterostyled flowers. Flowers of the same species but of different plants with styles and stamens , play critical role n ensuring cross-pollination, and preventing self-pollination. Different forms of flowers called **heterostyly**. Lythrum salicaria or Purple Loosestrife: 3 forms of flowers, not 3 species of plants!

14.6 Power of Movement of Plants

His fourth book: sensitivity to light and gravity. Some plants bend side-to-side as they grow.

15 Lecture 14: Books after the Origin of Species

15.1 The variations of animals and plants under domestication (1868)

Darwin's longest work. The only part of Darwin's previously planned "big book" which was printed, corresponds to the first two intended chapters.

Shows Artificial Selection. Polish fowl turned to normal chicken LMAO, artificially bred to change the shape of the skull. Selectively bred pigeons as well, had one origin: wild rock pigeon. **Selection explains Adaptation**.

Before genes/DNA, proposed **provisional hypothesis of pangenesis** ("whole birth"). Each cell in the body gave off "gemmules", passing on cell characteristics.

Darwin, Variation, pp. 5-6 and 10-11: Variations not favourable for the organism would be destroyed, favourable ones likelier to be preserved, "selected". **"Descent with Modification"**. What causes the variations? Darwin's analogy to **blocks of stone (Variation 2:431-2):** rocks beside a cliff, build a house, despite rocks having different/unique shapes; but you can explain by selecting, building a complex structure.

15.2 The Descent of Man (1871) and selection in relation to sex

Origin of Species didn't write much about human beings: more about the general process in Nature, and that it would make people **more relunctant to accept his views**. By 1871 he thought it was a good time

to bring out materials on this subject.

'Evolution' used for the first time.

Two topics: Evolution and Sexual Selection: Sexual differences between sexes. 3 main kinds of anatomical features:

- **Homologies:** Skeleton, nerves, method of sex, diseases are common among humans and animals, indicates descent from other primates.
- **Embryology:** Commons features of human embryos with animals indicate common ancestor (Gill slits, growth of blood vessels, hairy covering in 6th month, lanugo)
- **Vestigials Organs:** Moving ears/scalp, twitch skin, body hair, wisdom teeth, shortened caucum in the intestines (From past Herbivore Diet), Darwin Point, 3rd eyelid

Proposed that humans would (have been) classed as Quadrumana (Primates) based on characteristics, and its early progenitor must have been an asexual aquatic animal.

Sexual Selection: Human Races; believed that races were not adaptations to environments, but by natural, sexual selection. Slavery: people wanted to believe blacks had different origins from whites, a separate species. Darwin argued against. Evidence of sexual selection seen on feathers on birds used to find mates.

Caricatures circulated showing Darwin as a monkey.

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

Charles Bell claimed that human beings were endowed unique facial muscles to express emotions

Darwin showed that humans emotions and their expression were present to some degree in animals. **Main expressions are universal** in all races - all races descended from 'a single-parent stock' First time photographs were used in scientific works.

15.4 Expression of Emotions (1872)

Difference in mental functions, and concern for relatives between human and animal is one of degree, not kind.

Morality is a more refined development of instincts of other social animals. Controversial; Morality was considered sacred to what differentiated us from animals, including his wife.

Animals show emotions through different postures and expressions, same as humans. Photographs, some commissioned, some collected, described how people expressed different emotions. Expressions come from a common source, rather than gained independently.

16 Lecture 15: Darwin and Religion

Father and Grandfather were free-thinkers, his mother a very religious lady.

Standard View: Darwin lost his religious faith as a result of his daughter's death. **False: Gotten from the movie 'Creation'**, which gotten it From a remarkby historian **James Moore in 1982**, as conjecture.

Moore wrote a full statement of his theory in a book chapter in 1989: Annie's death was the key to Darwin's apostasy, due to:

- Proximity of Annie and religion
- Darwinw was still reading religious books in 1840s - 1850s

1991 Biogeography by Desmond and Moore further popularized the theory.

16.1 Thinking about Religion

As per his Autobiography and his 1838 Journal, after Darwin's return to Beagle, in 1836-9, started to think deeply about religion, conversion from 'orthodox' to 'doubts', which his father told him to conceal. **James Moore dismissed these dates as he thought it was incorrect.**

He didn't conceal his doubts. Emma's letters: hinted at giving up revelation in 1838. Biblical Scholarship by German and English scholars showed many things about the Bible's accuracy.

Reasons Darwin gave for his loss of faith: Evidence and Comparative Anthropology - took a universal view towards religious beliefs, rather than a local/Eurocentric one.

- False religions spreading
- No clear evidence for Bible's said miracles, especially after knowing more about fixed laws of Nature
- Writers of the Bible (people in general) then were ignorant and not credible
- Gospels not proven to be written simultaneuously to the events
- Differ in important details, especially for eye-witnesses
- The fact that those who do not believe would be punished: 'A damnable doctrine'

Darwin's disbelief of Christianity as a Divine revelation was so slow, he felt **no distress**: Contradiction of the Annie story

16.2 Why did Darwin stop attending Church?

Randal Keynes, Annie's Box (2001) introduced an extra element along the death of Annie: that he stopped going to Church, as per a Constable decades after Darwin's death. The Constable only came to Darwin's village years after Annie's death.

1879 letter to John Fordyce: Contradicted himself, calling himself both atheist and agnostic; not fully clear of the terms used.

Edward Aveling interview: An actual Atheist visited Darwin, where he admitted no evidence support Christianity, and that he never gave up Christianity until **40 years of age - how believable is this recollection?**

Darwin didn't talk about God enough in his books; some thought he was irreligious; He still took an active role in his town church, he and his butler being part of the Church Committee, and supported the

Village School, generous with donations. But Darwin reminded his readers not to overlook cruelty of Nature

Darwin's Burial in Westminster Abbey, 1882 - Darwin thought he would be buried in his town with his family. Stamp of approval of the Church by burying him in the most honoured place they have.

On his deathbed, Darwin converted back to Christianity? **Untrue, and no effect on anything whatsoever**

17 Lecture 16: Darwin's final days

Darwin's last book: **The formation of vegatable mould, through the action of worms, with observations on their habits (1881)** - Effects on Earthworms on the world. Worms spit worm castings out of their mouths, pushes up soil, burying stuff that worms could not do this to. Found that worms had no sight, smell, hearing, but had some intelligence. **Agriculture and landscapes caused by worms**.

Darwin's wormstone measure how quickly a stone sinks in the ground due to worm action.

17.1 Reactions to Darwin's death

Hundreds of Orbituaries published. 1885: Statue of Darwin at the Natural History Museum, London

17.2 Pangenesis (or against)

Recall: Gemmules were theorized by Darwin. **Francis Galton (1822 - 1911)** tested against pangenesis using Bunny blood transfusion, did their babies acquire those they got the blood from?

August Weissman: Germ Plasma theory (1896 - 1910), Inheritance only goes through germ cells (Sperm, egg), not body cells; no inheritance of acquired characteristics.

Gregor Mendel (1822 - 1884): [READ THE READING] Experiments of hybridity and inheritance using pea plants. Crossed pea plants, discovered 3:1 ratio; Some elements of ancestors still inside.
Mendel's Two Laws

- **Law of Segregation:** Individuals possess alleles for a trait, sex cells get one pair, offspring gets own pair, whichever is dominant will be expressed
- **Law of independent Assortment:** Different traits inherited independently of each other

Mendel's work overlooked at the time; Darwin himself got a 3:1 ratio. **Heredity was particulate, and inheritance can be explained through rules and ratios**.

Hugo de Vries 1889: Inheritance of specific traits comes in particles he calls "pangenes"

1900: Mendel rediscovered by Hugo de Vries, Carl Correns and Erich von Tschermak

de Vries' **mutation theory**: New forms of primroses appeared, called mutations; **New species appeared "at once"**, combined with Galton's statistics to create the Mutation Theory. Posed as an alternative theory to Darwin's theories?

1903: **Walter Sutton and Theodoe Boveri** suggested that chromosomes are Hereditary units; proved later to be incorrect.

Thomas Hunt Morgan sought to prove Mutation Theory using Fruit Flies.
1910: Showed genes are on chromosomes.
1915: Combined Mendel theories with Chromosome Theory of Inheritance.
Believed natural selection was minor; only eliminates the unfit.

Modern Synthesis (1936 - 1947): Mendelian genetics and Darwinian natural selection found to be compatible; part of the same thing.

1953: **Watason and Crick** discovered structure of DNA; contributed to advent of modern molecular genetics.

17.3 The age of the Earth (again)

Ernest Rutherford and radiometric dating led to discovery that Earth was about 4.5 Billion years.

Mystery of the Wallace Line solved: Surface of the planets moves.

Alfred Wegener (1880 - 1930): Theory of Continental Drift, but was ridiculed and despised as a fool.

Plate Tectonics 1950s - 1960s

- Palaeomagnetism
- Sea floor spreading shown by Magnetic striping

18 Lecture 17:

Wallace's lecture tour of USA, 1886-7 had no opposition to evolution.

18.1 Recent social movements opposing evolution

1925: **John Scopes' monkey trial**, a show trial, where a new law against teaching of human evolution in public schools was challenged as it was an imposition of religion doctrine into schools. (**See the Butler Act in 1925**) Scopes lost the trial, but there was international recognition of a dispute about evolution in education; People thought it was unfair to teach things to their children things they didn't believe in.

1970s: **Creationism** attempted to be introduced in American public schools; turned down.

1980s: **Creation-Science**, again an attempt to introduce a Biblical understanding of human origin in Science classroom. Also turned down.

1990s: **Intelligent Design** emerged which proports to be a scientific theory. Also overturned, same shit as creation-science, just replace the word. Same design argument from Rev. Paley's Natural Theology. **Irreducible Complexity** in **Michael Behe's Darwin's Black Box (1996)**: complicated biological structures could not have evolved in a gradual process.

Eugenics term by **Francis Galton in 1883**: Bad consequences for those believing in Evolution. Inspiration for racial stance of Nazis (but not the same thing)

Creation Museum (Kentucky, USA, 2007-) rejects all of modern science: **Young Earth Creationism**

18.2 Contradictions

Some phenomena today are more than 6000 years old:

- Radiometric dating
- Geology and Palaeontology
- Creatures alive: Old Tjikko in Sweden and King Clone in the Mojave Desert
- Dendrochronology (Dating of trees)
- Stalactites
- Coral Reefs, Atolls
- Ice Core Drilling
- Speed of Light: Star HE 1523-0901, is est. 13.2 Billion years old, and Cosmic microwave background radiation

19 Lecture 18: The Missing Link?

NO SUCH THING!

19.1 Darwin's time

No fossil record of humans-humans seem isolated, no traces connecting modern humans with pre-human ancestors.

Ernst Haeckel's **Paleontological tree of vertebrates** (1879) much more accurate representation than his previous Tree of Life.

19.2 The fossil trail begins

1856: **Skull cap found in Neader valley (Tal or Thal) of Germany**

1886: Next Neanderthal (another species of human) remains found. Could speak and made tools, more strong and robust body. Females seem to do as much hunting as males. Neanderthal interbred with humans. Not sure why they went extinct.

Homo Erectus: 1887: Eugene Dubois went to 'Indonesia', 1891: discovered a skull cap and femur (Sometimes called **Java Man**)

Homo Erectus had fire, made tools, colonised parts of the world; Europe, Middle East, all the way to Java

Piltdown Man: Fragments of skull and jawbone **supposedly** collected in 1912 from gravel put at Piltdown, East Sussex, England Ended up being fake, composite human skull; huge brain case, came before walking upright, which didn't really make sense.

Peking Man: (1923 - 1937) type of homo erectus, 500000 and 300000 years old.

Taung Child, South Africa, 1924, "Southern Ape of Africa", Australopithecus africanus, 3 and 2 million years old

Sir Arthur Keith, primate family tree in 1931

1960: Homo habilis (handyman) discovered in Olduvai Gorge, Tanzania, East Africa, 1.75 Million years old

1973: 'Lucy', an Australopithecus afarensis, in Ethiopia, 3.2 million years old

Made by Lucy's species was a fossil trackway (footprints) in Laetoli, Tanzania in 1976 - 1978, which was 3.6 milion years old.

Why did homonids start walking on two legs?

- Hunting theory
- See farther?
- Free the hands
- Aquatic Ape theory
- Trees theory

The latest Homonid discoveries: 2003 florensiensis went extinct when modern humans arrived on their islands 14000 years ago, 2010 Denisovans were interbred with humans as well

19.3 Out of Africa

Human 'races' are biological varieties, which are commonplace with all species. Darwin felt it was probable that Africa was formerly inhabited by extinct apes closely related to the gorilla and the chimpanzees, and they are most related to humans.

Migrations out of Africa showed that homo erectus was a hugely successful species

20 Lecture 19

Evolution happening today, evident from increasing disease resistance/DDT resistance increasing in mosquitoes.

20.1 The Cooking Ape Hypothesis by Richard Wrangham

Chimpanzee roasting marshmallows, human-like. What was it that made humans so different from other apes?

Eating meat and Hunting for it? Meat-eating arounds for millions of years as omnivores. On the other hand, eating living enzymes useless

- More calories
- Technical Skills
- Social Skills

20.2 Humans are biologically adapted for cooked food

Universal: Argued that not eating meat, but **cooking food, biologically adapted to eating cooked food**. Cooked food is a Universal human trait.

Need: In fact, no known case of long-term survival of eating raw food in the wild. **Alexander Selkirk** made fire to cook his food. **Lady in South America** survived on bananas, but bananas were from an abandoned plantation, and bananas were domesticated and artifically nutrient-rich.

Long-term 'raw-foodists' live only in cities. They get **chronic energy shortage and poor reproducitve performance**, as more body does more work to digest that food. About 50% women raw-foodists get amenorrhea: cease to menstruate, become infertile; happens during starvation, and is clearly unnatural. Also, modern supermarkets allow for any food you want despite limiting seasons, and they can still process food.

Guts: Instead, **human guts are disproportionately small, and molars are small**: adapted to low-fiber soft diets (and not uncooked meat).

Time: ¿ 200000 years ago, fire has been controlled, as seen from sites with hearths.

20.3 Other arguments for cooked food

More energy leads to More Reproduction: Humans 4 months quicker to concieve than chimpanzees

Protein denatured increases digestability. Raw eggs less protein intake than cooked eggs (Increase digestability by 44-78%).

Calories on labels do not take cooking into account; often quite meaningless.

Experiment on rats by giving softer food: Reduced cost of digestion, increased payout. Same with snakes: Cooking and Grinding food reduce cost of digestion by up to 23.4%.

Humans experience early weaning, can eat softer, more easily chewed food. On the other hand, chimps spend 4-7 hours a day chewing.

Via small guts and boost in energy, cooked food allows **brains to become bigger**. Possible for brains to become bigger.

Social Consequences? Females may stay behind to cook and take care of children while males hunt.

20.4 When did this happen?

Small molars guts found in **Homo Erectus** compared to ancestors: Signal of eating cooked, softer food.

Little meat from Australopithecines to **Raw meat in A./H. habilis (2.6M years ago)** to **Cooked Food in Homo Erectus (1.9M years ago)**

21 Lecture 20: Huamans looking the way they do

Professor Jared Diamond's Guns, Germs and Steel: People developed the way they did based on what was present in their environment.

21.1 Eurasian Colonization

Homo sapiens arose in Africa c. 200,000 years ago. Mitochondrial DNA passed on from the female mind - 'Mitochondrial Eve', all mit. DNAs stem from **one woman**. None of the other women's offsprings left descendants as long as hers did.

60,000 years ago: **Great Leap forward?** Striking difference in artifacts found, explosion of diversity. Reason unclear.

Some human beings left Africa around 100,000 years ago, spread around the world. Cave art found 44,000 years ago until recently. Cave art in Lascaux in France 16,000 years ago pre-date arrival of modern humans: **Neanderthals?**

21.2 The spread of farming

Writing only goes back 7000 years ago. Previous 200,00 years are considered **pre-historic**, living as hunter-gatherers. Begin domesticating plants 7000-8000 years ago, very different from wild plants, at the **Fertile Crescent** in the Middle East.

Jared Diamond theorized it was due to high number of plants which were easier to domesticate. Farming means more calories, more people, at the cost of having to stay at that location to farm, stuck to a very narrow diet, high effort to farm, living in their own filth, and disease spread more easily.

Suite of technology developed to farm better. People around the world **independently** learnt to grow plants.

Diamond theorized agriculture spread east west more easily (in place such as Eurasia, vs Africa) due to latitude.

21.3 Domestications of Wolves

First animal domesticated. (Darwin was the first to notice the pattern between domestication and natural selection)

Docile, friendly, tame ones were preserved, where violent ones killed.

Most aniimals though, have no temperament or are not suited to live on a farm.

Tame vs Domesticated?

21.4 Results of domestications

Specialists: Different jobs of different people.

Population Growth: Governments, taxes, armies started to exist.

Pyramids and Ziggurats could only exist if agriculture advanced.

21.5 Writing Systems etc

Cuneiform script from c. 4000 BCE. Oldest surviving love letter written in this form from a woman to a man.

Phoenician alphabet c. 1200-150 BCE, ancestor of the roman alphabet and english. Not pictographic

Spread rapidly and influenced each other, giving birth to other languages

Metallurgy also spread around the world.

Indo-European expansion from c. 6000 years ago, can trace by looking at languages used, from Ukraine to Europe and Central Asia.

Austronesian expansion from c. 1600 BCE from Taiwan to the Phillipines, SEA and Madagascar. Malay's and the Polynesian's ancestors.

By 1500CE there were very different societies in the world, resulting from what was available in different parts of the world.

21.6 Epidemic Diseases

Dense populations, and proximity to animals; there's always new people to infect. Natural selection of those with immunity, while the virus evolves.

Black Death: High fatality rate compared to wars etc.

21.7 Australia/China

No plants or animals in Australia that could be domesticated, other than macadamia nuts. Couldn't really develop from being hunter-gatherers.

Chinese ships didn't travel to Europe, it was the other way around. China was less subdivided by mountain ranges, united very early in its history.

21.8 Criticisms of Diamond's work

Not very polite criticisms, "Geographic Determinism" or "Academic porn"

22 Lecture 21L Evolution per se

Evolution does not:

- Solve 'problems'
- 'Shape' things
- 'Come up with ingenious solutions'
- 'Find ways to adapt living things'

Species do not compete, but individuals. Individuals do not evolve, but a population/lineage over generations.

22.1 4.5 Billion years ago

Simple organic molecules, single-cell organisms with DNA

22.2 2.5 Billion years later

Multicellular organisms appear, oxygen made by photosynthesizing cyanobacteria or blue-green algae as a waste product (by-product).
Stromatolites - Colonies of bacteria

22.3 2 Billion years later: 50 Million years ago

Jellyfish and Hydra appeared.
Sponges - very primitive/simple animals, no body symmetry, have a free swimming larvae form, hermaphrodites
Flatworms - Start similarly to free swimming sponge larvae, but can move, have sensors, bilateral symmetry, no eyes, but brains and stomach emerge

Ocean Sediments gradually accumulate: Round worms appeared, worms with shells evolved.
Shells without worm end sticking out: molluscs, clams, snails

Nautilus and Ammonites form. Octopus, squids, cuttlefish, argonauts too: they are molluscs who lost their shell
Argonauts form a shell while laying eggs, showing the similarities to the nautilus
Segmented worms, Crustaceans (segmented) and they gave rise to:

Insects, first creatures to walk on dry land due to a rigid exoskeleton
Sea Squirts, larval form has a simple notochord (Primitive ancestor of spinal cord). Collapses when taken out of water

Vertebrates form (Lancelets - which are 'pre-fish'), Cartilaginous Fish (No bones, has cartilage) and finally fish with true bone.
Fish like lungfish acquired first 'lungs' to help with poorly oxegenated water. Also, limb-like fins. Some evolved into...

Tiktaalik, 375 Million years ago. Stout, robust fins to skip from one muddy pond to another. First animal with a backbone to walk out of water. Bones in fin resemble hands today.

22.4 Tetrapods

Animals with 4 feet.

Amphibians, air-breathing, but are tied to water at some parts of their lives.

Next came Reptiles: waterproof skins, still lay eggs etc.
Snakes lost their legs; when burrowing underground, lost their sight and hearing as well. When some went back up above ground, the scales covering their eyeball became clear; Snakes cannot blink

Dinosaurs, covering of feathers. Birds are the only dinosaurs remaining

Mammal-like reptiles: Have eggs, but hair and warm-blooded. (Platypus, Echidna)
Milk produced out of milk glands in bellies. Milk evolved from (more nutritious) sweat.
Later, some mammals stopped laying eggs and kept it inside their bodies. Primates, like lemurs became monkeys and apes, and then Hominids and Humans etc

22.5 Flightless Birds

Galapagos Cormorant had no need to fly, as they swim around and catch fish; no longer able to fly. (Compared to a normal Cormorant)

23 Readings

23.1 Is Natural Selection the Mechanism Responsible for Evolution?

- Natural Selection confers survival advantage to those that best adapt to an environment, involves genes already present
- Natural Selection reduces biological diversity. In contrast, Darwinian Evolution speaks of its increase from simple organisms
- Species was (is?) defined as (in)ability of members to interbreed
-

23.2 Mini Science Encyclopedia by Ang Woon Chuan

- For evolution to take place, following need to happen:
    1. Mutation
    2. Natural Selection
    3. Separation of mutated (new) individuals from the others
    4. Length of Time, of millions of years
- Theory of Creation:
    1. Animals uniquely suited to their environment
    2. Living things havee in-buiilt mechanism to change within limits.