Major events in the history of Biology: PreDarwinian biology

16th -18th century: The scientific revolution and the start of modern sciences

Douglas Adams (1952-2001)

- Author of Hitchhiker's guide to the galaxy
- Presented to scientists at a prestigious event and talked about science in terms of the four ages of sand/silica
- First- Telescope (1608): The first time silica was heated into glass to form lenses and the lenses were used to magnify distant objects
- Second- Microscope (1678): The lenses are used to look at small events, opened up the world to single celled organisms; cells have uniform structure thus cell theory. Microscope is used to look at and examine small things
- Third- Computer chip (1961): A little chip that is charged (state of 1) or not charged (stage of 0) when you start switching 1 and 0 together as a binary you are capable of coding. Example: Think about building something like the empire state building or any old building, there was no processor to do the calculations and all the math was done by hand
- Fourth- Fibre optics (1980s): Glass cables that can transfer information at a very high speed. This allowed scientists to share data through a long distance in order to collaborate. This broke down the isolation of scientists thus allowing them to share knowledge.

400 BCE-450: Greek and Roman ages

Hippocrates (460-370 BCE)

What was Hippocrates famous for (contributions)?

-He goes around in the Greek and Roman empires and follows practitioners and writes down and records their practices (what do they do with diseases, treatment, medicine…).

- There were dozens of authors writing in the book however he was the editor and assembled it all forming the Hippocratic corpus.

Aristotle (384- 322 BCE)

- Made contributions to geology, physics and general philosophy

What did he contribute to biology?

- First person to make a list about the complexity of organisms on the planet
- He took all of these lists and descriptions of organisms and ordered them from superior to inferior (most complex to simple)

- Scala Naturae (Ladder of life):
- Placed human species at the apex (top) because they are the closest to the gods, one trait that they have is live birth
- Followed by 4 legged organisms capable of giving live birth
- Live birth that does not have legs (whales)
- Organisms that lay eggs (reptiles, birds and amphibians)
- The cephalopods (squids, octopus)
- Arthropods (exoskeleton and crusty organisms) in the oceans
- Insects
- Mollusc (organisms inside clam shells)
- Jelly fish and sponges are placed around (on the sides)
- Higher plant: plant with seeds
- Lower plant: plant without seeds
- The bottom: Inanimate (non-living objects)

Theophrastus (371-287 BCE)

- Student of Aristotle
- Creates a set of books, 10 of these books are written and 9 of them have been copied since he wrote them (2300 years ago)
- He divides the books based on the flower structure
- He creates an organized list of plants and it turns out he gets them right
- Many of his classifications and sequences are still used today
- His work is famous and is printed countless times over the years

Why would plants be so important for these books to be copied over and over again?

- Medicinal purposes
- Food plants (explorers bring back as foods)
- Fibre
- Weaving
- Textile
- Construction

Some initial definitions about naming

Classification

- Aristotle and Theophrastus organized and catalogued the world around them
- Took a disorganized list that was be accumulated and put an order on them

Taxonomy

- They developed rules for them: Theophrastus had rules for the plants bade on the nature of flower parts and Aristotle based on how close the organisms were to humans
- These rules of classification are referred to as taxonomy
- When you apply an order to a set of objects its called a taxonomy
- E.g.) Dewey decimal system is the classification of library books

Types of Taxonomy

- **Folk**: Classifications of things that are not written down. In communities there was an individual (keeper of the knowledge) and organized the world around them in order to explain things. This information was passed through generations. The limitation to this was that the human mind is only capable of memorizing 500 names of objects. At most in 3 nested subdivisions (usually animate and inanimate things). Usually one country/ community will have a list and that list is "stolen" by another country or community and they add on to it. Ex) Eskimo's have around 45 words for ice because ice was important to their environment and thus distinguished the types of ice.
- **Artificial**: Aristotle and Theophrastus work is accredited to artificial taxonomy. They used arbitrary characteristics to group things. Dealing with a large amount of material that has been collected from a number of locations.
- Mechanical
- Natural (evolutionary)
- Cladistics (phylogenetic)

Essentialism

- The ancient Greeks believed all organism had a certain essence to them
- They believed the essence in an organism was passed down from one generation to the next and the essence never changes
- The origins of this essence is the god who created it

450-16th century: Medieval ages

Scala Naturae

- Instead of a bunch of gods at the top there is one individual GOD (is the supreme) and everything else is inferior
- After gods there is arch angels, everybody who ascended into heaven, humans on earth, things that fly in the air (birds), fishes, big animals roaming on the land, plants, inanimate objects and in the bottom there is Satan!
- In this time period there is still the scala naturae and essentialism, only difference is there is one all might god as opposed to several gods

Special Creation

Pattern:

- Species don't change
- Each species created on Oct, 23rd, 4004 BCE
- Species are not old
- Process: A designer of some sort
- Bishop usher went through the old testament and does a scholarly study to find out how much time has passed since creation to his present day (end of middle ages)

- The date he comes up with is Saturday, Oct, 23rd, 4004 BCE
- At that time it was 5600 years old thus making the world young
- How did it happen? Everything was put on earth on that day all at once by a designer of some sort

Europe

400-700 Early medieval age (dark ages):

- Everything is still in ruins (Rome)
- Have small communities and very little exchanges between them

1000-1300 High medieval ages:

- The cities are starting to get rebuilt
- Building of massive cathedrals
- Growing architecture, mathematics, libraries have reoccupied old works (ex. Aristotle's)

1300-1500 Late medieval ages:

- In 1347 3 or 4 people died from the plague (caused by fleas)
- The disease spread like crazy and it was catastrophic
- Everything that had been done to get back to commerce had to start all over again because 2/3 of the population was wiped out
- Ring around the rosy is a poem about the black plague

Why did the medieval ages last so long? It took 2-3 hundred years for people to be able to do things again, it than 3-4 hundred years for another collapse and it took another 3-4 hundred years to build it back up again. It takes 1100 years for European culture to establish. In 1492 Columbus discovered America thus ending the medieval ages and marks the start if European exploration

Byzantium and Islamic world (Golden age of Islam)

- All the Greek and Roman work was being translated and it was passed down to the Islamic world
- Al-Jahiz (781-869): He discovered the idea of natural selection
- Al-Dinwari (826-896): Took Theophrastus's book and expanded it even further to include plants from his area
- Avicenna (980-1037): He took the Hippocratic corpus and added the medical practices of the Islamic and Indian subcontinent
- Alhazen (980-1037): Tried to find a uniform way to find and observe things that are happening in the world. He came up with the 7-step scientific method in the year 1000
- Scientific Method:
- 1. Observation
- 2. Statement of problem
- 3. Formulation of hypothesis
- 4. Testing of hypothesis using experimentation
- 5. Analysis of experimental results
- 6. Interpretation of data and formulation of conclusion
- 7. Publication of findings

- Ibn al-Baitar (1197-1248): He created a pharmaceutical catalogue of plants that contains medicinal qualities, how to prepare it (boiled, paste, swallowed…), what dosage is needed and much more. This catalogue was translated into Latin and used throughout the 1700s. His work is still used today
- With the growth of the European world they conquered the Islamic cultures (crusades) and they steal all of the information from the Golden age and incorporate it into what they still retained from the Greek and Roman ages along with the medieval ages

16th -18th century: The scientific revolution and the start of modern sciences

- Everything can be explained with mathematics (calculus, linear algebra) and equations
- The development of physical sciences
- Essentialism was still accepted at this time

Copernicus (1473-1543)- earth is not the center of the universe

- In the old testament it is said that the earth is in the center and the sun and moon revolve around it
- He came up with the mathematics to prove that the earth revolved around the sun and this went against the old testament
- He wrote up all his theories and proofs into a book and told his colleagues to bring the book to him on his death bed and tells them to publish it
- You can not excommunicate someone who has died and their soul has left thus publishing his work and avoiding excommunication

Kepler (1571-1630)– planetary motion

Newton (1643-1727)– laws of motion, gravity and thermal conduction

Galileo (1561-1626)– further proof of earth revolving around the sub

- He got warning from the church saying he will be excommunicated if he keeps up with his theories
- He did end up getting excommunicated by the pope and was said to go to purgatory when he died
- In 1992 his excommunication was revoked because the catholic church acknowledged that the earth revolves around the sun

Boyle (1627-1691)– behaviour of gases

Pascal (1623-1662)– origins of calculus

Descartes (1596-1650)–geometry

Van Leeuwenhoek (1673)– first microscope,

- His microscope was constructed with a glass bead in the center and there is a structure where you place your specimen and move the lever to reach the glass

bead and look at it from the other side and the optic properties gives you an inverted image
- He did not tell anyone how to make them, the only way you can get one is to buy it from him
- What impact on biology? Ability to view microorganisms however he had no explanations for them

Andrea Vesalius (1542)-Anatomy
- His speciality was human anatomy
- He did dissections and created diagrams for the anatomy of the human body where he had carcases hanging on things and the anatomy is absolutely perfect

Harvey (1650's)– Anatomy and physiology
- Father of physiology
- He worked on blood, the heart, circulatory system, and valves in the heart

Linnaeus (1735) – Systema naturae
- He organized things into a hierarchical taxonomy
- Kingdom Phylum Class Order Family Genus Species
- Mnemonic: **K**ing **P**hilip **C**ame **O**ver **F**rom **G**ermany for **S**ex
- Phylum and family was not in his original classification
- He divided the kingdom Anamalia into 6 groups: Quadrapedia (4 legged creatures), aves (birds), pisces (fishes), isecta (crusty organisms), vermes (long and cylindrical with no legs)
- He believes humans are linked to the Quadrapedia and has the genus Homo (humans), Simia and Bradypus and than gives species names
- He has taken and created a set of characteristics organisms must have in order to belong to a group
- Autapomorphy: Characteristics that define a group

Fungi: Absorptive heterotroph, multicellular, eukaryotic
Plants: multicellular,

Example: Canadian Beaver
Kingdom: Animalia (heterotroph- no chloroplast, multicellular, eukaryotic and ingest/ digest through an internal chamber)
Phylum: Chordata (Notochord)
Class: Mammalia (Hair and mammary glands that create milk)
Order: Rodentia (continuously growing enamels (teeth))
Family: Castoridae (Gland that produces castor scents)
Genus: Castor (Canadian)
Species: Canadensis (beaver)

Binomen

- Two word nomenclature for all organisms: first word is a noun and is the genus (capitalized); the second word is an adjective and is the species (non-capitalized)
- Written in Latin and therefore it needs to be in italics (in a different language)

Changing thoughts on what living things are

Physicalists–with the exception of humans all living things are machines (Descartes, 17th century)

- All living things are basically machines of some sort: burning energy, movement
- Everything abided the laws of physics and chemistry
- If you can figure out how machines worked than you can see how living things worked (except humans)

Physical Science

- Dealing with the inanimate world (Example: expansion of gas is composed of thousands and millions of molecules which are identical to each other including behaviour; they are all in uniform with each other)
- Their findings applies against the whole universe (universal=laws)
- Based on mathematics, equations and numbers
- Equations that describe how things are carried out
- Once theory is disproven you have to throw the theory out

Vitalists – physical and chemical laws apply but living things have a vital force (essence)

- Agreed that physical and chemical laws were applied
- Explanation for how animals and plants (animate objects) functioned
- Essentialism (explained by more than a machine)
- At the time they didn't know what the essence was

Natural Science

- Dealing with animate objects (animate objects have a lot of variability and there is variation; animate objects don't do things in unison)
- Huge amount of variability in organisms (genetics)
- Need to sample more than 10% of the population to get an average or mean of some sort of response
- Only applies to the earth because information about life in the universe is unknown (not universal)
- No mathematics were applied
- Historic narrative (story) is how information is conveyed
- Inductive reasoning: Cant sample the whole living world and there is a lot of variation therefore you sample a small subset of that population hoping we understand how that works and assume that everything else will work that way (sub-sample and keep seeing it over and over again and think this is how it is all over the world).
- A single falsification does not negate the theory
- Example: There are multiple theories as to why giraffes have longer necks and those theories were food and sexual competition (head is used as a weapon to attack the other male). Biologists accept there are more than one theory.

Organicists (1930)– vital force replaced by genetic program and the importance of emergence (swarm behaviour)

- A recognition that genetics and certain features of certain organisms create a complexity which is not recognized
- Darwin uses a mechanism to explain the diversity of organisms using principals such as natural selection to explain the living world (creates a logically ordered set of statements and proofs as a narrative- accepted by both forms of sciences)
- Programing that the genetic code can do to turn biomolecules to information molecules and into molecules associate with the living processes

- **Emergence**: How something functions is more than the sum of its parts.
- Ex) when a protein folds there are properties there that wasn't initially there.
- Ex 2) Starling have no form of communication with each other, they come together and decide what they are going to do. From the perspective of the mathematical modeller, "flocking" is the collective motion of a large number of self-propelled entities and is a collective animal behaviour exhibited by many living beings such as birds, fish, bacteria, and insects. It is considered an emergent behaviour arising from simple rules that are followed by individuals and does not involve any central coordination.

Induction vs. Deduction

Deduction (from the general to the specific): All insects have wings and this animal is an insect. This animal has wings.

- Creates an equation that explains something
- Watch different things to see if the experiment holds
- Conclusions based on scientific experimentation, laws and principals
- Universal and keep confirming it with what you observe
- Cant make a rule until you have seen all the insects in existence

Induction: (from the specific to the general) This animal is an insect and it has wings therefore all insects have wings. (Many multiple observations!)

- Sample it as much as possible to see how it works (get the full understanding)
- Can make a rule based on seeing a large amount of insects

Physical Science	Natural Science
Inanimate objects	Animate objects
Physical and chemical laws	More than physical and chemical laws (Genetics)
Universal	Not Universal
Based on empirical observations	Based on historical narratives
Experimentation preferred method	Induction most used method
Single theory	Multiple theories
Single falsification enough to abandon a theory	Single falsification not necessary to abandon a theory

Anatomy of a scientific explanation (theory)

Two parts

–Pattern

–Mechanism or process

Questions to be asked

–What is happening? What is the mechanism behind the pattern that there is?

–How (proximate cause- creates an immediate event; direct effect of action taken)? Or Why (ultimate causes)?

- Example: proximate cause: I'm developing a drug, I look at the doses and find out this drug works; ultimate cause: trying to figure out the genetics of the drug and can you use genetic modification?

Proximate causes (Physical science-like biology)	**Ultimate causes (Natural science-like biology)**
Phenotype – morphology and behaviour Mechanical (predictable) Here and now Genes in action Experiments	Genotype - Genes and history Variable (probabilistic) Evolutionary past Changes in genetic programs Historical narratives

Scientific method

Some terms used in doing science

Theory and Fact:

- The general public believe a theory is incomplete and once its complete it will become a fact (however this is not the case for scientists)
- The most powerful explanations of anything that happens is a theory
- Natural science: Always leave ourselves open to an alternate explanation (never say it's a fact)
- Physical science: You have to destroy your theory as soon as it is known to be inapplicable in some way
- Biologists never state information as facts, instead they use theories
- Theory becomes stronger with the growth in observations

Hypothesis:

- Everything starts with a hypothesis: you look at something and understand it
- "If I do this, according to my explanation the following should happen"
- General public believe hypothesis is a feeling of how something happens (best guesses to how things work)

- For scientists hypothesis is the fundamental key to how everything is done because you study something and see a phenomena believing what you have is something of significance
- It's a logical prediction

Law
- Higher than a theory
- A theory becomes a law when it is universal
- Laws are present in physical sciences because they are universal
- In the natural sciences and biology there can not be laws because life outside the planet has not been discovered
- Only Mendel has a law in terms of biology because he has developed a mathematical mechanism on how items sort randomly

Prediction (logical vs. chronological):
- Chronological prediction is seen by non-scientists as a "I predict…" statement

Steps or stages
A question that needs to be answered
Gather information already known
Develop a hypothesis and test it
Interpret the results of the test
Retest
Publish results

Additional experimental components
Controls: A circumstance with no manipulation.
- Many of the phenomenon occurring in the natural world is extremely variable thus making it difficult for biologist's to have control

Control of variables:
- Make sure the two situations are similar as possible
- In biology this is difficult because for example you are testing a new drug and want to see the effects you can not easily find two identical organisms (e.g. mice) to test the drug on

Sampling error:
- There is no uniformity in biology
- You are never going to get the absolute exact value, only an approximation
- The more you sample, the more data points there will be to cluster around the true value
- Mathematical sampling means you collect as much data points as possible under uniform conditions and average that number out which yields the best approximation
- General rules in biology: take at least 10% of the population you are looking at

Repeat the test

Distribution of scientific facts

Journal selection

Manuscript preparation

Peer review

Revision

Publication

- Decide where you are going to publish your journal
- The most prestigious journals in which to publish your science is nature and science
- You pick a journal, write up a journal, show it to your lab group for feedback, and present it to the supervisor or colleagues resulting in several drafts. You finalize it, than mail it to the journal and the editor will receive it and go through it. The editor will find 3 names closely related to the research area and send them the article to read and comment on
- Identity is stripped off and is sent to a peer (blind peer review) and they determine if it is acceptable for publishing and revision
- Experts are looking to see if you prove what you are trying to prove and will ask questions which you must answer
- You have to pay for the journal to be published and it is usually funded by the research grant

Types of literature – what's the difference

Primary: The article that was written by the scientist who did the work.

- Every statement of fact has a reference in it (so you can look at the reference and read what the person is citing)

Secondary: An expert in the field summarizes what is said in an article or journal

- A person in the field can summarize all the literature from their colleagues to produce a review article
- This will be peer reviewed
- Every fact is still in citations
- The difference being the person who wrote it didn't do all the work

Tertiary: Science by scientists who have familiarity in the field but are not experts

- Lacking suitable references
- May have selected bibliography or list of articles at the end but there is nothing cited after every fact
- Example: the textbook. People are familiar with the field (such as educators) and

stay on top of the field so the textbook can be recent
- Not one author but other authors working on it (experts in the field reviewing the book)

Darwin's five theories – Natural selection
Natural selection – Industrial melanism

Peppered moth

Observation 1: Original museum collections had all white peppered moths and by 1900 traps collected 90% black.

- An observation was made that the moths were of a dark morph but in the early 1900s they were white
- Alleles have changed and this is a demonstration of natural selection (in a short period of time)

Question 1: Why did the moths shift from light to dark morphs?

Hypothesis 1: Fitness decreased when the moths that were more visible against the background colour of the trees.

- Fitness: The ability to survive and produce fertile offspring
- Fitness was affected: the moths who were able to blend in with the tree were less likely to be attacked by predators as opposed to the moths which are more visible to the background

Null hypothesis1: Fitness remains the same and is not affected by the background.

- There is no change in fitness and has nothing to do with the tree

Hypothesis 2: The bark colour of the trees has changed.

- The color of the tree has changed over time
- The color of the moth and tree are linked to each other in some way
- Some researchers: looked at the story of the moths and trees. They went across England and had color grades for the tree bark and scored the coloration and concluded that industrial activity changed the color of the tree bark.

Null hypothesis 2: The bark colour of the trees has not changed.

Experiment 1: Artificially rear light and dark morphs and place on tree and observe survival (fitness)

- They took dark and light moths put them in a tree that was dark, waited a period of time and trapped the moths (used black light since they are attracted to it) to see who came back

Experiment 2: Locate light and dark coloured trees.

- Went to a forest where there was no industrialization (no staining of the bark)

Result 1: Birds selected most visible moths

- If the null hypothesis is right than you should get 80% of both colors back
- If you get more black moths than white moths than the dark moths have some kind of advantage in the dark tree

Result 2: Dark trees showed same distribution as coal based industry

- They put out 100 white and 100 black moths and most of the white ones came back

Question: Do moths "rest" on backgrounds that match their colouration?

- This experiment was done in north America and the same results occurred
- Alternate experiment: If you take moths and put them in a drum with alternating black and white stripes, they preferably land on the color that matches them

Question: What impact would the clean air act, that reduced pollutant emissions have on the moth population morphs?

Question: What happens to other moths with light and dark colour morphs

Major events in the history of Biology: Darwinian thought

Georges-Louis Leclerc, Comte de Buffon (1707-1788)

- He is rich and affluent which allows him to travel over the world, as he travels around the world he notices there are certain types of animals that have a resemblances to each other but they are distinctively different
- He has an interest in cats and he notices that when you are near the equator or jungles you get a cat like organisms such as jaguars, panthers and more. In the grasslands of Africa you get other cat like animals including tigers and lions. There are all of these cat like organisms all over the world but with different characteristics and forms
- If you believe everything came at the same time (same day), what was the point of having cat like organisms? If you have one cat like organism why put variation on a theme as opposed to having only one cat?
- He starts to believe everything arrived at one time at one location (Garden of Eden) but as these organisms leave the garden and start to disperse around the world, the uniqueness/essence that made the original cat gets modified. A cat living in the jungle consuming different food, nourishment and inorganic materials thus altering its essence
- The farther you move away from the site where everything arose the farther and bigger the differences there is in the cats
- He believed there was one of everything to start with but as the original organism moved to different locations the environment modified its essence to create slightly different organisms
- He recognizes groups of organisms change with environment
- First bio geographer to realize there were variation in organisms and that was due to environment

Erasmus Darwin 1731-1802

- Translated Linnaeus's Systema naturae into English
- He wrote the Zoonomia (laws of organic life)
- He wrote the poem called: The temples of nature which gave us a sequence of change (everything did not arrive at once and everything changed over time)
- He was the grandfather of Charles Darwin

Georges Cuvier (1769-1832)

- Stones were being dug up which contained fossils
- He raises the question: if everything is put on the earth at the same time and nothing has changed how come there are all these other animals embedded in the stones
- He was the first person to reassembles all the bones of a fossil and recognizes that

the organism was not in existence (ex. Irish elk)
- He proposed the catastrophic theory: There were some organisms that originally arrived, disasters on the planet occurred and a whole bunch of these organisms died. These organisms can now be seen in what he calls a fossil.
- There have been organisms that have been extinct from Oct, 23rd, 4004 BCE
- Not only did organisms change over time but some have disappeared

Extinction
- Cuvier looks at organisms such as giant mammoths and dinosaurs
- Most interpretations at the time was that these creatures were mythical dragons and animals
- Cuvier believes that these animals are similar to animals that are still in existence but have gone extinct and therefore disappeared
- One of Cuvier's students will find a link to catastrophe (the catastrophe being Noah's flood). Everything arrived on Oct, 23rd, 4004 BCE and when the flood occurred Noah did not get everyone on the ark and the animals that did not get on the ark are the same animals found in fossils

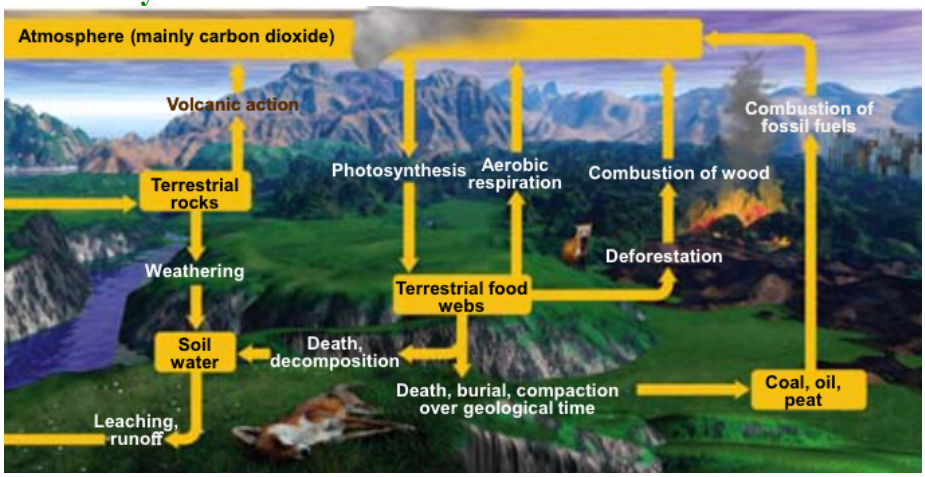
Charles Lyell (1797- 1875)

- Uniformitarian theory (over millions of years the earth's surface changes) of geological change
- Stratigraphy and the geological time scale
- He is interested in the layers of rock and he recognizes that there are certain compositions to rocks and they go through dramatic changes (move around the world- it is in the same sequence).
- Take all the layers and line them up and develop strata that occur in the rocks and these strata represent the changes in rock formation. The bigger changes represent the eons.
- He recognizes there are fossils in these strata and they are changing over time
- Lyell understands how sedimentary rock is formed and knows it takes thousands to millions of years to form, it is inconsistent to say that the earth is only 6000 years old. The earth is extremely old; there has been enough time for things like the extinction to occur. Catastrophic events were occurring slowly over a long period of time.

Rock Cycle
- The planet has the rocks from which it was formed (for example igneous) and there are rocks that have been built
- The original rocks are the molten rocks of the planet and the ones that have been added after words
-

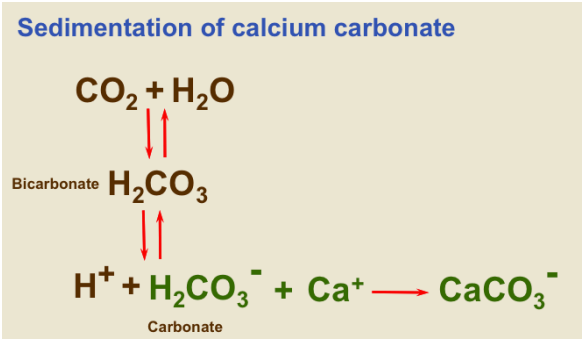
Plate Tectonics
- People at the time (Lyell) did not know about plate tectonics and only knew about things such as volcanoes

Carbon Cycle



- In the oceans there is an interface between the water and the air, the carbon dioxide in the air gets dissolved in the water
- There is a natural production of CO2 into the water
- Animals in the oceans are breathing out CO2 and releasing it

Sedimentation of calcium carbonate



- When you mix H2O with CO2 you get bicarbonate (carbonic acid) and the bicarbonate loses its proton and gets a negative charge it than attaches to any of the positively charged minerals that is present in the ocean
- When this bicarbonate ion combines with the positive charged mineral ion (Ca+) you get Carbonate salts (ex. CaCO3) and that molecule is insoluble and precipitates a solution which slowly falls to the bottom of the ocean
- There are billions of reactions happening and these minerals in the bottom of the ocean form together to create the fossilization of organisms found in the bottom
- Since this process takes a very long time Lyell recognizes that the earth must be extremely old

Continental Drift

- Pangaea was a large single landmass which over millions of years split apart into the continents we see today
- Scientists at the time did not know about continental drift but they did know something was going on
- Although continental drift was first proposed in 1910 it wasn't until the 1950s/1960s where it became scientific fact

- There is increasing evidence that our assumptions are in error (the planet is not young, location changes where things are) we recognize them as being explainable now but at the time they did not know about this
- What was the mechanism to explain all this?

Jean-Baptiste Lamarck (1744-1829)

- He was trying to find a mechanism behind how species changed over time
- His concept is transmutation of species and this means simply change (a change of the species).
- If you looked at complexity (low to high) over time everything starts of spontaneously as a small glob of life (infusarium) and it grows where it multiples over time. Over time this organism will change its appearance and become more complex and those changes will pass from one generation to the next. Another organism will start as an infusarium and change over time. If you kept doing this with multiple infusariums changing over time when you take a sampling through the diversity at any particular time you are going to find simple to complex organisms. Some organisms have been on the trajectory (graph= increasing slope) for a very long time and some have just started off on the trajectory.
- He believes in the concept of acquired traits as an organism uses some structure more frequently to the point where the structure changes it form and shape, that passes to the next generation. Traits in the trajectory get acquired and passed down to the next generation. Ex) The stretching of the neck in giraffes are passed down to the next generation
- Lamarck gets it wrong with the concept of acquired traits, what did he get wrong? He was talking about animals and animals have a set of cells in the embryo that are put aside which will later form together to become the gametes in the mature animal. Early on in development cells are divided into somatic cells and germ cells. Lamarck thought the somatic changes could pass to the next generation but what actually passes down is the material within the germ cells. The organisms with the unique characteristics did not acquire them from the somatic cells. The mechanism underlying sex (egg and sperm) is not known at this time. Lamarck presumes that somatic changes in an individual can be passed to the progeny of the individual not knowing the progeny is produced from a whole different set of cells (sperm and egg)

Essentialist explanation of change

- Transmutation (not Lamarck): Transmutation of change. This accommodates change by saying there is transmutation of the essence. Lamarck talks about change in species but here we are talking about the change in essence. (Lamarck talked about: the transmutation of species that change by environmental effects upon it)
- Transformation: Transformation of the essence means it changes slowly over time
- Finalism
- Environmental (this is Lamarck): Lamarck says it's an environmental transformation of the essence in other words interaction of the individual with the

environment.
- Another theory: An essence is naturally programmed to change over time however result is the same (infusarium changes over time)

Important stages in the history of Biology

19th century: Modern biology

- Wallace was a younger scientist who had been working in Indonesia and he had been observing changes in population over time in organisms
- What Darwin has come to conclusion is natural selection (favorable traits are passed down to the next generation)
- Wallace notices rather than focusing on individual changes (what Lamarck did), Darwin focused on the population of organisms and the variability of traits within the population
- Both recognized that within a population there are ranges of characteristics and some have an advantage they are more likely to reproduce and the characteristic will be passed down thus increasing the frequency of that characteristic within the population
- Darwin has been working on this for a long time and was hesitant to publish his work because his wife was an influential member of the church
- Darwin was married to Emma Wedgewood and she came from a wealthy who made china and fine dishware
- When Wallace realized the idea of natural selection he sent a communication to Darwin and asked for feedback, Darwin hands it over to Lyell
- Lyell got both Darwin and Wallace to present their findings on natural selection at the Linnean society of London
- Darwin has the most examples and proofs thus he is accredited to natural selection

Voyage of the HMS Beagle

- Darwin went to the Galapagos islands and noticed tortoise and finch species differed from island to island
- His findings will eventually lead him to the theory of natural selection
- He had 3000 pages of notes
- He is rich and affluent which means he did not have to work
- Lyell got him the job as a cabin boy on the boat and when he went, he took collecting materials with him (had the stuff shipped back to England)
- Darwin served as a naturalist
- Darwin becomes the single individual to make the biggest and most comprehensive collection of natural history from the south American continent ever in the history of the world
- He went on the beagle for 2-5 years
- He comes home and starts examining his collections for patterns

Lamarck vs. Darwin

- At the end of the beagle Darwin comes up with the concept that instead of the linear model of Lamarck you have organisms that change sufficiently to become 2 different types and those change again thus forming a branching patterns
- If you slice through in time you are going to see different compositions and things that are going to disappear (happening slowly over time)

Types of taxonomy

- Folk
- Artificial
- Mechanical
- **Natural (evolutionary):**
- Darwin suggests when we look at organisms and place them in the same taxon (everyone in the same family) they should be related to each other by the branching pattern and share the same evolutionary history
- Linnaeus took things on their visible similarities without understanding why however Darwin does this saying: things that are the same probably share the same ancestry and should be grouped together.
- Cladistics (Phylogenetic)

Darwin's five theories

- When you analyze origin of species there are 5 theories
- The last 3 are not accepted until heritability is discovered thus modern theory of evolution (all 5 become accepted)

1) No constancy of species

- Species have changed over time
- The change is driven by one of his other theories (natural selection)

Fossils:

- Fossil's out there, this builds onto Cuvier's comparative anatomy and other work done by people at the point of time.
- Fossilization is not an event that occurs frequently, its an event that appears under certain circumstances
- When living matter dies it doesn't fossilize (otherwise there would be billions of fossils)
- The whole way everything works is decomposition kicks in and everything gets recycled
- Only under unusual circumstances you get fossils and therefore really hard to find
- Some places fossils have been located: petrified woods, burgess shale, insects in amber and mammoth in permafrost
- Invertebrate fossils have now been found

- A criticism of Darwin's fossil's is the fossil record is poor or has gaps in it
- Soft-bodied animals (invertebrate) fossils were not identified at that time and that was a mystery for a very long time. In the last 30 years these fossils have been found in Canada
- The burgess shale: richest set of fossils of just soft bodied invertebrates
- Plate tectonics have shown us that these fossils can be found in parts of china (same fossils as burgess shale)
- Our understanding of plate tectonics (1960s) now tells us where we find fossils we can go to another best predicted location (make logical predictions)
- Fossil record has become much more robust and complete

Extinction:
- Things have disappeared over time thus the disappearance in his branching patterns

Transitional forms:
- A problem with fossils is that you don't get to see the transitional forms of organisms evolving from one form to another
-

Evolution of the horse:

- In collecting fossils of this group of animals, it became very clear in a linear sequence from the primitive ancestor to the modern day horse, all the intermediates could be found
- They identified in the intermediates that horses are able to become much better runners (changed in the shape of the leg), feed on the grasses that were becoming prevalent at the environment at that time (grass lands were becoming the dominant ecosystem)
- Since grass was becoming prevalent this organism needed to tap into the food resource and they also needed to be quick and agile in order to escape predators
- They had a number of digits which shortened down to a single digit
- The teeth become much more robust and the teeth enamel become much more stronger because the plants are responding to the horse thus developing silica and other necessities to be able to ingest the plants

Archaeopteryx lithographica
- This was a fossilized organism discovered after the time Darwin published his book and thus a big breakthrough
- It looks like a bird (feathers) and at the same time a reptile (tail, jaw with teeth in it)
- Transition between reptiles and bird
- This is an animal stuck halfway between thus filling in the missing gaps
- More bird transition fossils have been found to the point where we recognize a whole group of reptiles had feathers (not only unique to birds)

Puijila darwini

- It was found higher up in the artic of Canada
- They found a set of bones that gives us the transition from a land animal to the seals and aquatic animals we associate with fresh water environment

2) Common ancestry

- He proposes based on his branching patterns that there is a common ancestor to everything
- If you can figure it's way out their should be one organism that is the base of evolutionary history
- LUCA (lowest universal common ancestor) is the most recent organism from which all organisms now living on Earth have a common descent

Comparative anatomy

- Things that looked structurally similar to each other even if they functioned differently and indicating relativeness

Homology – Divergent evolution

- We have a structure for example a limb in a vertebrate that has exactly the same underlying structure (2 bones, single bone, wrist bone and digits) that has become highly modified to do different things
- When we look at the anatomy of a bat, bird, whale flipper, our own anatomy everyone has that same bone structure they just modified it to do something different (the structure has diverged different functions)
- We postulate that somewhere at the base of the branching there was some limb that consisted of single bone, double bone, wrist bone and digits
- Due to divergent evolution you would not want to group organisms based on flippers and fins because there are different structures underlying them
- You can easily say that flight evolved and wings have only evolved once. Instead of saying "I got a group of organisms that are united by bone structure you can organize them by the fact that they fly."
- Example: when the amphibians came up on land their jaw was resting on the ground and there was a bone that connected the jaw to the inner ear and that bone picked up low frequency vibrations (sense things that was walking towards them) over evolutionary time that structure was higher up and incorporated in the stapes.

Homoplasy (analogous) – Convergent evolution

- You got a group of organisms that are evolutionarily related to each other because I say flight is the evolutionary event that occurred and I'm going to have the taradactles, the birds and the bats because they all have flight. This grouping is artificial because when you start examining the structures of these wings you realize the 3 wings have something in common (bone structure) but those of the insects have no bone. You are seeing convergence because there are structures that are designed to carry out the same function (flight) but they don't represent the same sequence to get to that structure and that's what are problematic,

analogous or homoplastic structures. When you are doing evolutionary biology you have to decide whether these are convergent or divergent events in terms of what you are looking at. You end up with picking characteristics in a very suggestive manner. You can take the 3 vertebrate wings and say they are related to each other but when you look back at the branching pattern they don't share a common ancestor.

- Example: Mammals and fish and all kind of animal groups have this very stream line structure with fins and tail that propulsion even though they are not related to each other.
- Homoplastic structures: The wrist of a bat is the articulation point for the wing and the digits of the finger support the wing. If you look at a bird instead the digits have disappeared and there is a single digit remaining and we now have a whole new flight surface (feather instead of skin) that is suspended or attached. In contrast to the bat where the wings are attached to the digits, feathers are attached for the birds. If you look at pterosaur all the digits are there except their pinkie finger has elongated to a big wide structure and a flap a skin covering it. There are no similarities between these 3 species and what you notice is that somewhere farther back there is a common ancestor but there is no common ancestor for flight. When you break the vertebrates to groups something that united them can become a homoplastic character when you go to a lower level of taxonomy. Darwin has given us comparisons based on evolutionary based on observable structure.

Comparative embryology

- Many organisms follow a sequence or path in their development that is unique to other organisms as well
- In the animal world at the eight cell stage of an embryo there are one of two things that happen: 4 cells that divide in the middle and 4 cells that are on top and 4 cells are underneath
- For one group the 4 cells sit right on top and for the other group they shift and the cells sit in the grooves below them
- When 8 cells occur there are 2 ways for it to happen and they happened individually and there is a whole branching lineage that descents from that group
- This is a clue that there is a common ancestry

Vestigial structures

- Things that reflect functionality of organisms in the past that are not in use now
- Classic animals (mammals): Goosebumps- tell us we are related to animals that have hair, nictitating membrane- ancestors lived in a situation where they needed to protect their eyes from damage
- Is the appendix a vestigial structure? No it is not because it has been discovered that it plays into immunity and allergies. This little sac represents a reserve of material that makes sure the duct flora is kept in appropriate form and allergies are tied to ingested substances that create the allergens and the appendix is involved in that

Molecules

- A protein and if you have a protein that undergoes a change in sequence or composition and if you find that same change in a different group of ancestor there is a common ancestor
- A big molecule now is DNA and DNA sequencing thus demonstrating common ancestry

3) Gradual changes

- Changes are gradual
- Darwin did not know the mechanism behind change because at that time genes and inheritability had not been discovered

4) Multiplication of species

- When all of this works together you get new species and there is increasing diversity over time

5) Natural selection

- The underlying principal to all of this is: organisms that can reproduce more effectively have better fitness, their traits are passed down the next generation

Pasteur (1822-1895)

- He gives us that there is no spontaneous and that there is some kind of minimal germ that is the basis of all life (he has no idea of what its going to be)
- He does pasteurization to show that life becomes life (200 years ago)
- He gives us the germ theory

Cell theory

(Schleiden and Schwann – 1860)
–The basic unit of all organisms is the cell
–Individual cells have all the characteristics of life and
–All cell come from the division of other cells

- Schwann was working on animals and Schleiden worked on plants
- They took the microscopes that is in use in modern time and started to look at things and found a common universal structure in everything they looked at (plant, animal, fungus…). This became the fundamental germ that Pasteur was talking about and this is the smallest fundamental unit of life.

Mendel (1822-1884)

- Rediscovered 1900.
- Law of segregation of characters
- Law of independent assortment
- Mendel works as the same time as Darwin but he did not know about his works
- Mendel figured out inheritance and figures out the mathematics for it (laws)

- Meiosis and the relationship of heritable traits
- Worked with peas
- Packets on heritable information passed from one individual to the next and both parents contribute a packet and the off spring
- In Mendel's library there was a copy of the origin of species- he even added notes down the side but he did realise that it was the key to Darwin

Speciation and cladistics

- For speciation, read chapter 19 of the textbook!

Cladistics

- Willi Hennig found a brand new way to do taxonomy which is known as cladistics (Phylogenetic)
- Hennig says we shouldn't be making any statements about the quality of the characters we are looking at and should instead saying this is an original state for a character and its been modified to something else.
- Every characteristic has two states that it is in
- If you have more of the modified characters than another organism than you are probably further apart in your evolution and if you have many of the same characters you are probably closely related to each other

Phylogenetic tree

- A classic break down of an evolutionary tree is that of class amphibian, Mammalia, reptilian and aves

Cladogram

- When we look at a Cladogram there are only single pair of branches (events that occur)
- If everyone who has descendent or derived this characteristic is a tetrapod and share the new innovation with each other
- Another event comes along and that event is shared by all of the descendants (attached to the branch where that event occurred; branches to the right of it)
- Every little event finds a smaller and smaller subset
- A Cladogram consists of a series of perfectly nested groups as opposed to branches that go all over the place and you name the ends (phylogenetic tree), here you know each of the groups as you go on (Cladogram)

Conflicting interpretations

- One of the most famous conflicting trees is between the human Cladogram where humans are placed in their own group isolated from the chimpanzees. If you do enough scientific analysis humans fit into the same group as chimps and thus artificial taxonomies

Cladistics -Useful terms

Apomorphies: Derived characters within a group (evolutionary lineage)

- If you have a trait that has changed (polarizing the characters)
- Apomorphies define a new type of organism and everybody that descendants from the organism will have that trait and when they have that trait they are related to each other
- The more Apomorphies that you have the higher up in the tree you are
- Example: In amniote animals the switch between an egg with an amniote and an egg without an amniote, the amniote egg will be the apomorphy (new trait that makes its appearance).

Synapomorphies: Derived characters shared between groups

- A trait you share from a descendent from a common occurrence
- Example: In amniote animals, all the organisms that inheriate the egg are a group (amniotes) and when they inherit it, they have shared that derived trait and when you share that trait it's a synamorphy
- Inherited from the same ancestor, descendants from that ancestor are sharing the characteristic

Plesiomorphies: Primitive characters within a group

- Example: all those organisms that have the old trait (the egg without the amniote) has this characteristic that its ancient
- When we score a character between zero and one (have it or don't have it),

Symplesiomorphies: Shared primitive characters that are shared between groups