In this lecture topic:

- What is a species and how do new species arise?
- The importance of systematics?
- How can Mendelian genetics be use to explain natural selection in populations?
- Allele frequencies and evolution – Hardy Weinberg.
- Sources of variations in alleles

Darwin's five theories:

- No constancy of species
- Common ancestry
- Gradual changes
- Natural selection (microevolution)
- Multiplication of species
- All related to species

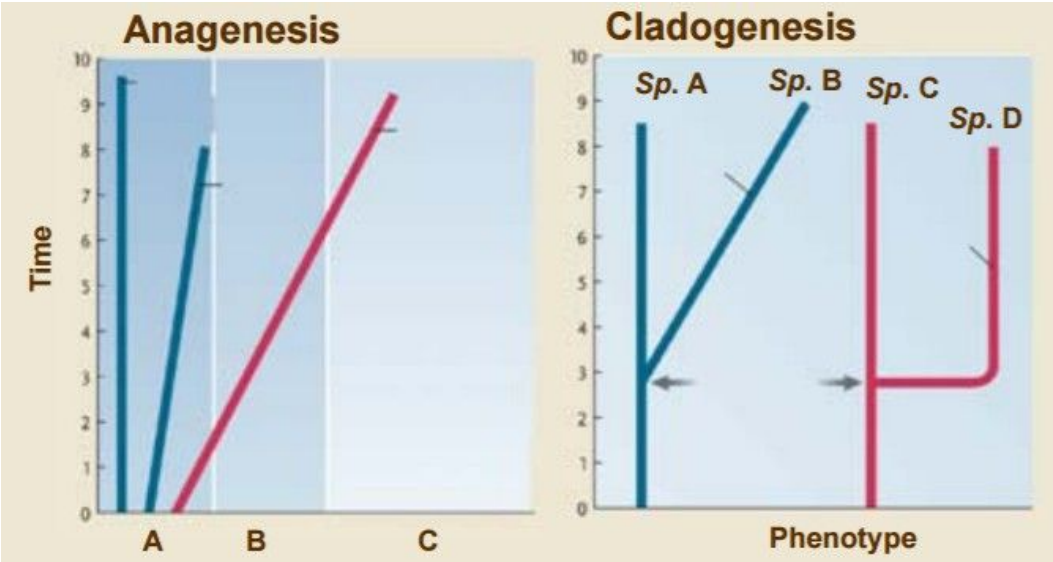
<u>Speciation:</u>

- **Biological species**
    - Species is a population of organisms capable of interbreeding and producing fertile offsprings → Mayer (1940s)
    - Isolating mechanisms
    - Not all biologists use this explanation
    - Ex. Agriculture Canada breed rapeseed for oil
        - Want to breed out the toxin → plant the rapeseed → come out with 2 leave and killed the plants with the toxin in it
        - The toxin level basically disappear due to this selective breeding → the product is very important and when Canada tried to sell it around the world they couldn't
        - Rapeseed is in the family of mustard → categorized as high toxins → cannot called this species of rapeseed
        - Go and change the name of the rapeseed → gave new name that it does not have this toxic element in it → called Canola oil
        - This plant can interbreed with the old plants
    - **Taxonomy**, the science that identifies, names, and classifies new species
    - Using Mayer's definition of two organisms producing a viable young, you cannot explain fossils and bacteria
    - Fossil cannot mate with each other → therefore don't know if they are same or different species
    - Bacteria does not mate with each other → divide by binary fission, so this definition cannot be put in place

- **Morphospecies**
    - A group is morphologically different that they are different species
        - Ex. the birds were in their own taxon and since birds are so dramatically different, they must be in a different group
        - Realize that bird are reptiles and they were not very unique from reptiles
    - Many field guides use the morphology to determine the species of bird → major way to distinguish birds
    - Variations in a species → how to deal with organism that can change colour in different season → can't use the morphology to determine the species
    - This definition is not very accurate and precise
- **Phylogenetic species**
    - A concept that seeks to delineate species as the smallest aggregate population that can be united by shared derived characters.
    - Using both morphological and genetic sequence data, scientists first construct an evolutionary tree for the organisms of interest
    - phylogenetic species comprises populations that share a recent evolutionary history

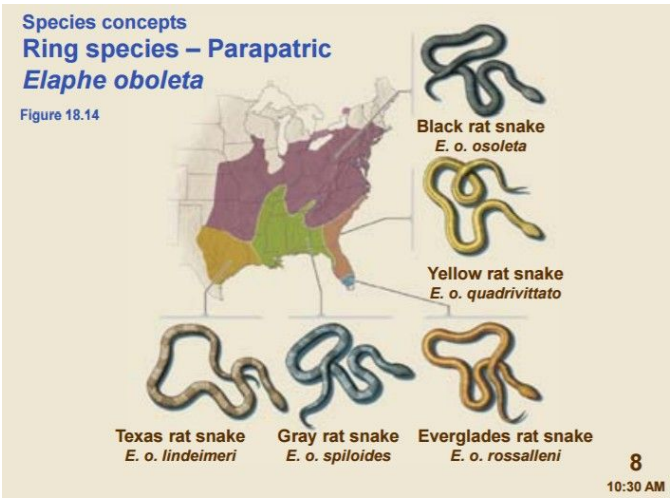
Rate of evolutionary change:

- **Anagenesis** → species slowly change its morphology → gradual transition line of the one species into another → one displaces the other species
    - Ex. the original horse is different looking to the modern horse
    - One replaces the other species through gradual slow change
- **Cladogenesis**
    - One group of organisms split into 2 groups → one group stays around and the other group is isolated and evolve on its own to become a new species
    - The groups are split and create a new species

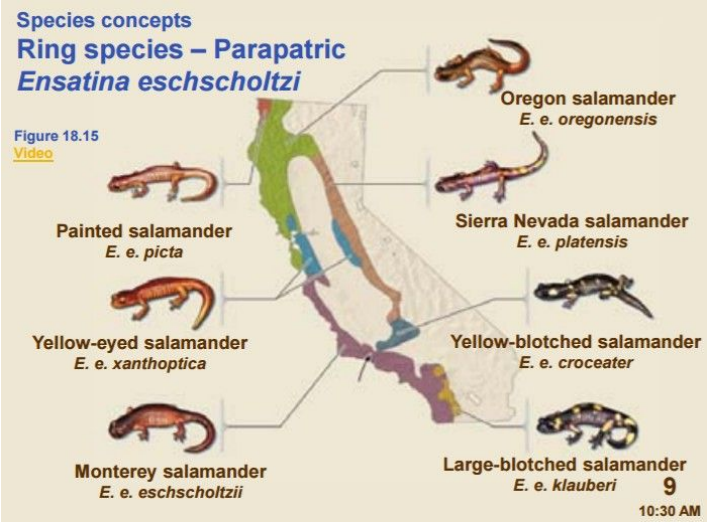


Parapatric:

- Example: The black snake in the middle of the black snake region is effectively reproductively isolated
- There is a region in which the 2 species of rat snakes (Black and the Texas) overlap each other → they can still potentially mate with each other and create hybrids
- 2 groups that separate from one species, but overlap with each other to create hybrids
- We need to identify this merging region of the 2 species → with old morphology, they recognize that the Black and Texas are different species
    - Now, the rat snake have subspecies and they all of their own ranges, but there is overlaps



- This is a species that is trying to divergent into 2 species, but they are not reproductively isolated from each other → where they overlap in their regions → example of misuse of Mayer's misuse of the species definition → so, subspecies is created
- **Subspecies** → Are local variants of a species
- **Parapatric** → Speciation between populations with adjacent geographic distributions.
    - Isolating the species and they are slowly changing into 2 species over time
    - Morphology is not enough to recognize different species
- Dogs are canis familiaris → ancestor of the dog is grey wolf (canis lupus)
    - Biological species concept say that they cannot mate with each other and that's why they are 2 species
    - Dogs can become wild and can mate with a wolf → not enough genetic difference between the 2 organisms
    - Change the names to both have canis lupus → grey wolf is canis lupus lupus and the dog is canis lupus familiaris
    - These 2 groups are going slowly becoming 2 different species → haven't completed it yet and give it the same genus and species name → use of subspecies describes this
- Another example:
    - Salamander on the top started moving downwards to the south → the salamander populations were isolated by the mountains
    - The salamanders on the right evolved to hide itself in the environment (cryptic), while the ones on the left evolved to have a bright red colour to imitate a poisonous animal (mimic)
    - The salamander finally meet each other and they created hybrids → become different than the both of the species → they cannot hide well and do not display a bright red color
    - Since hybrid is not viable, they will slowly become separate species
    - This is still Parapatric → still a connection between the groups
    - Example of Parapatric, anagenesis → heading towards a new species



- **Ring Species**
    - A species with a geographic distribution that forms a ring around uninhabitable terrain
- **Clinal Variation**
    - When a species is distributed over a large, environmentally diverse area, some traits may exhibit a **cline**, a pattern of smooth variation along a geographical gradient
    -

Second contact – Hybridization outcomes:

- Fusion of the populations
    - Ex. Polar bears and grizzly bears come back together
    - Polar bears and grizzly bears were isolated before, but now coming back together
    - Polar bears and grizzly bears create new one population
- Reinforcement
    - Hybrid is not viable → likely to become separate populations and different species
    - Ex. the salamanders above
- Hybrid zone formation
    - Hybrid region created in the overlaying of 2 subspecies → it does not seem like they will be different species
    - Big characteristics in bird population
    - Ex. Snakes
- Extinction of one population
    - One of the population can beat and survive more than the other population → one population died
- Creation of a new species

Allopatric speciation: The evolution of reproductive isolating mechanisms between two populations that are geographically separated → **gene flow** does not happen.

Allopatric Speciation - Vicariance:

- Physical thing to isolate 2 species
- Continental drift → the population is isolated from each other

Allopatric Speciation - Dispersal:

- Isolated in islands → changes the genes over time
- Animals caught in wind storms and stuck on an island
- A journey of the groups that separate the population
- Leading to the evolution of a **species cluster**, a group of closely related species recently descended from a common ancestor
- Ex. Galapagos

Example: Grylloblattid – Ice age vicariance

- A cricket → during the last ice age, the ice sheet did not get over the Yukon and the canadian mounties stick out from the ice and there were short summer seasons on the tops of these mountains
- Animals were living in the mountains → cricket altered metabolism to function in -10 degree C
- When the ice sheets moved out of the mountains, the cricket was so adapted to the cold that they cannot survive in the higher temperature → get isolated on the mountain tops
- Ice age isolated the crickets on the mountains → example of Vicariance

Sympatric speciation:

- 2 Groups of species are in one environment and stays as 2 species
- Ex. a bug modified a perfect sized beak to get to the germ core of the native plant species' seeds→ there is a introduction of a different plant species and they had a different sized seed
    - This same species of insects have 2 sources of food → the small sized beaked insects can eat the new small seeds and the normal sized beaked insect can eat the old plant seed
    - Happening in the same environment

Polyploidy:

- Containing more than two paired (homologous) sets of chromosomes
- **Autopolyploidy**
    - The genetic condition of having more than two sets of chromosomes from the same parent species.

    - Often results through an error in either mitosis or meiosis, when gametes spontaneously receive the same number of chromosomes as a somatic cell
    - Such gametes are called **unreduced gametes** because their chromosome number has not been halved.
- A tetraploid plant cannot produce fertile offspring by hybridizing with its diploid parents → therefore creating a new species → reproductively isolated from the original diploid population
- Fusion of a diploid gamete with a normal haploid gamete produces a triploid (3n) offspring, which is usually sterile because its odd number of chromosomes cannot segregate
- **Allopolyploidy**
    - The genetic condition of having two or more complete sets of chromosomes from different parent species
    - Two closely related species hybridize and subsequently form polyploid offspring
    - Hybrid offspring are sterile if the two parent species have diverged enough
    - If the hybrid's chromosome number is doubled, the chromosome complement of the gametes is also double → producing chromosomes that can pair during meiosis
    - Hybrids can then produce polyploid gametes and, through self-fertilization or fertilization with other double hybrids → creating new species
- Even when sterile, polyploids are often robust, growing larger than either parent species → grow larger crops
- A spontaneous doubling of chromosome number produces gametes with twice the original number of chromosomes, but the timing of doubling is different.
- **Autopolyploidy** → doubling occurs during a meiotic cell division that produces 2n gametes in the parent
- **Allopolyploidy** → the doubling occurs after a hybrid offspring is produced, when some of its cells are undergoing mitosis; meiosis in the polyploid hybrid then produces polyploid gamete
-

<u>Reproductive isolation:</u>Prezygotic isolation → which exert their effects before the production of a zygote (fertilized egg)

- **Habitat (Ecological)**
    - Living in the same geographical region may experience if they live in different habitats
    - Ex. because lions live in open grasslands and tigers in dense forests, the two species did not encounter one another and did not interbreed
- **Temporal**
    - One organism mate at different times

    - Ex. D. persimilis mates in the morning and D. pseudoobscura in the afternoon → fruit flies
- **Behaviour**
    - Results when the signals used by one species are not recognized by another
    - The proper male and the proper female meet and mate to each other
    - Ex. female birds rely on the song, colour, and displays of males to identify members of their own species
- **Mechanical**
    - Different reproductive parts → only work in one species
    - Ex. many plants have anatomical features that allow only certain pollinators, usually particular bird or insect species, to collect and distribute pollen
- **Gametic**
    - Animal eggs can recognize sperm → sperm and egg of the correct organism goes together
    - An incompatibility between the sperm of one species and the eggs of another, may prevent fertilization
    -

Postzygotic isolation → which operate after zygote formation

- Hybrid inviability
    - Don't survive because does not fit the environment
    - Hybrid individuals have two sets of developmental instructions, one from each parent species, which may not interact properly for the successful completion of embryonic development
    - Ex. domestic sheep and goats can mate and fertilize one another's ova, but the hybrid embryos always die before coming to term
- Hybrid sterility
    - Cannot reproduce
    - Such hybrids have zero fitness because they leave no descendants
    - Ex. the product of mating between a female horse and a male donkey
- Hybrid breakdown
    - They can breed with other hybrids and with both parental species.
    - However, the second generation (F2), produced by matings between hybrids (F1), or between F1 hybrids and either parental species, may exhibit reduced survival or fertility

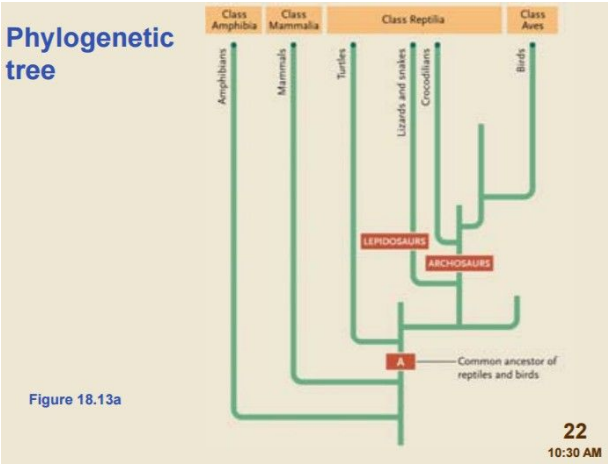
20th century: Modern biology

- Cellular respiration, ATP and mitochondria (1930-1950)
- Ecology (1940's)
- DNA is the genetic materials (1943)
- DNA structure (1953)
- Gene regulation (1961)
- Genetic code (1960's)
- Recombinant DNA experiments (1970's)
- Cloning of a mammal (1997)
- Human genome sequence (2000)

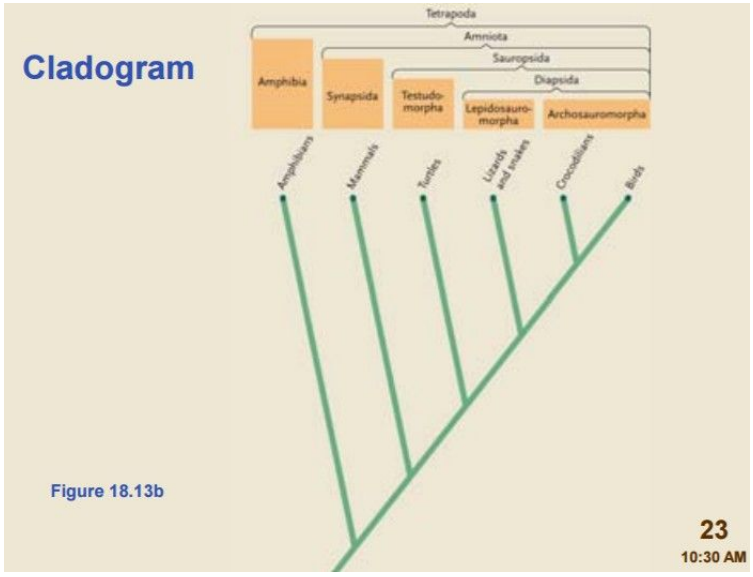
Cladistic (Phylogenetic):

Henning (1913-1976) → made to describe **insects**

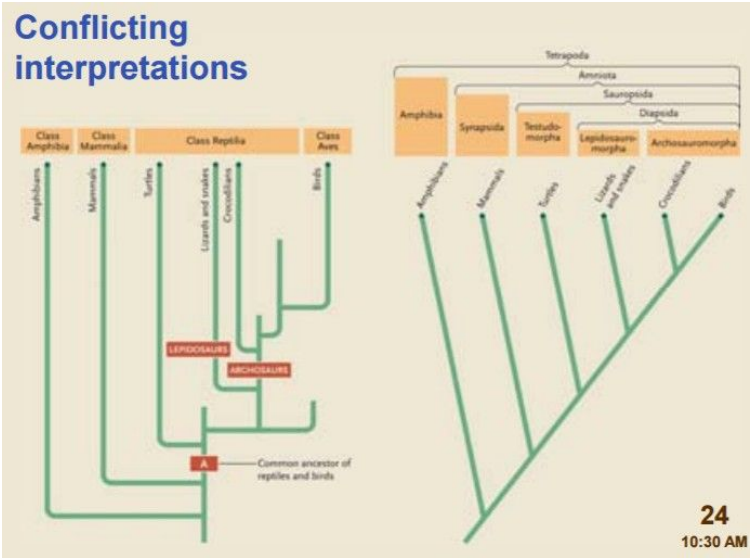
- Made new organization technique
- Cladistic (Phylogenetic)
- In this technique biologists try and find characters that have ancestral and derived conditions



- This is a evolutionary tree with Darwin's organization for the vertebrales → called a **phylogeny** → show the evolutionary history of a group of organisms → based upon similarities and differences in their physical or genetic characteristics.
- Shows the divergence of different organisms that became new species → classical way to view the world
- Some things extinct and disappear

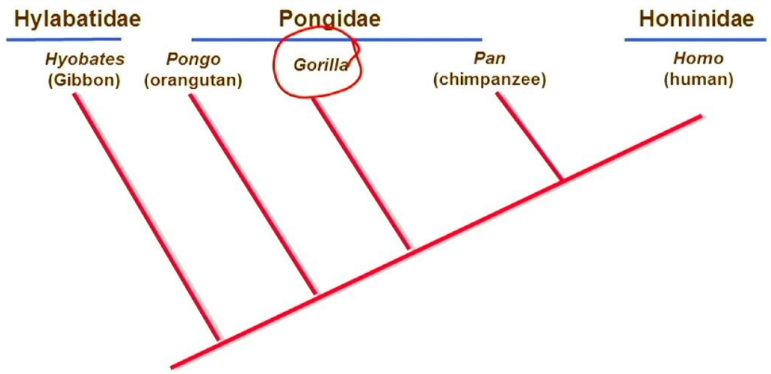


- A branching pattern with 2 branches
    - The original group will keep on moving and the creation of the new branches represents the creation of new species with a new innovative characteristic
    - There are folks all the way up
    - The characteristics of the birds should have all the characteristics of their descendents before → different labels on the top shows the groups
    - Basing on new innovative characteristics that arise and define the unique characteristics of the descendents of the characteristic
    - You have different sets of names → architecture of the cladogram is different because no bias of morphology



- Still feel that humans are most superior → humans have own family

- In molecular genetics, we see that the chimpanzee shares 99% of the DNA of a human and they are different than Gorilla → but we still classify humans in its own family



Evaluating Systematic Characters:

- Systematists often rely on phenotypic traits as indicators of genetic similarity or divergence
- Useful systematic characters must be genetically independent, reflecting different parts of organisms' genomes
- **Ancestral and Derived Characters**
    - Mosaic evolution refers to the reality that in all evolutionary lineages, some characters evolve slowly, while others evolve rapidly
    - **Ancestral characters** → A trait that was present in a distant common ancestor.
    - **Derived characters** → A new version of a trait found in the most recent common ancestor of a group.
        - Once a derived character is established, it usually persists in all of that species' descendants
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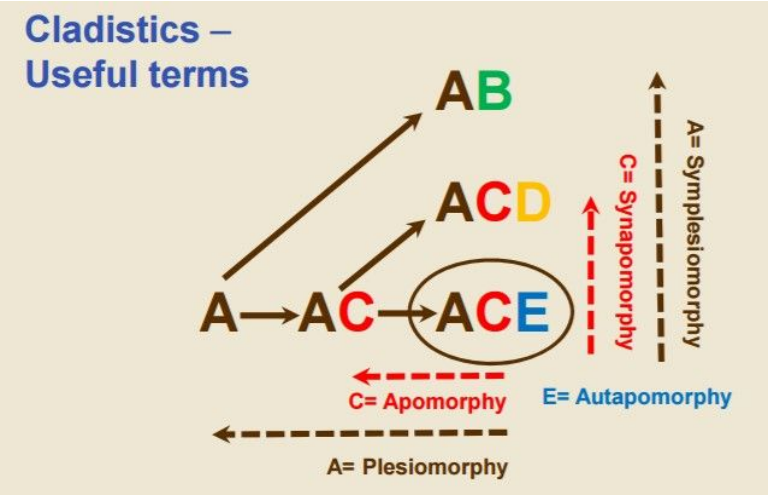
    - Systematists compare vertebrates with all animals lacking a vertebral column, they score the absence of a vertebral column as the ancestral condition
    - The presence of a backbone is a derived character.
    - Use outgroup comparison to distinguish ancestral from derived characters
    - Example:
        - Most modern butterflies have six walking legs, but some species in two families have four walking legs and two small, non walking legs
        - Shows that six walking legs is the prevalent condition, representing an **ancestral character**
        - Four walking legs is a derived character

Cladistics - Useful terms

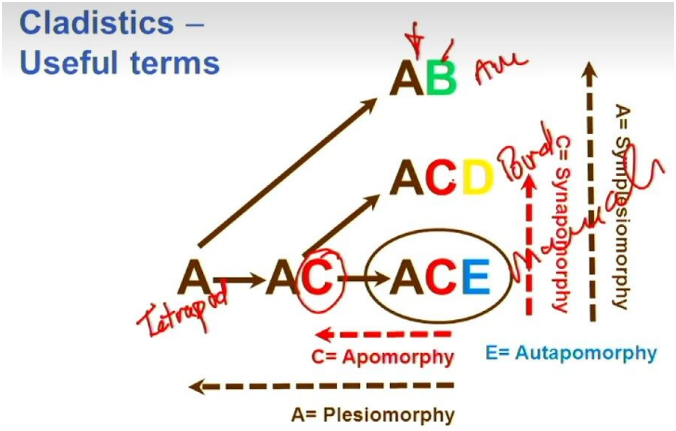
- Describing the characteristics → new, innovative characteristics → the original state is ancestral and the changed state is derived

- **Apomorphies**
    - Derived characters within a group (evolutionary lineage) → the changed state
    - What they got changed to
    - Unique to the level
- **Plesiomorphies**
    - primitive characters within a group → original state
    - The things that they were before
- **Synapomorphies**
    - Derived characters shared between groups → they must to shared the same change
    - If we believe that the first animals were diploblasts then a shared derived trait would be the triploblastic condition shared by many animal phyla - a synapomorphy shared by many different phyla
    - But if we are comparing phyla only one taxon has this trait making it an autapomorphy
    - The presence of mammary glands is a synapomorphy for mammals in relation to tetrapods but is a plesiomorphy for mammals in relation to one another
    - Possession by two or more organisms of a characteristic inherited exclusively from their common ancestor.
- **Symplesiomorphies**
    - Shared primitive characters that are shared between different groups
    - The diploblastic condition is a symplesiomorphy shared by all the other metazoans
- **Autapomorphy** is a distinctive feature, known as a derived trait, that is unique to a given taxon.
- **Character polarity** is the issue of the evolutionary history of a character

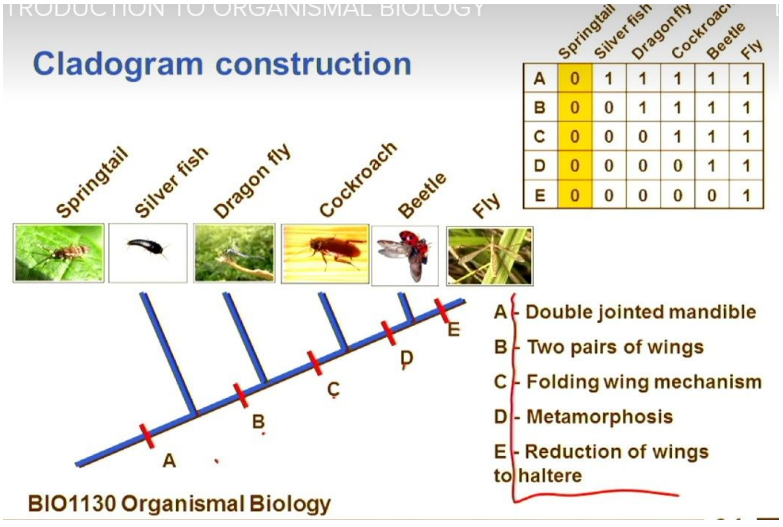
Example:



- The A is the plesiomorphy which is the original state (Tetrapod → has 4 limbs)
    - There has amphibian, birds and mammals
    - The amniotic egg (C) which is a new change and → shared by 2 groups, but doesn't hit the amphibian → see this inheritance
- This is the phylum chordata and they have an synapomorphy of having a notochord
    - When go to another group within the group, that is a new taxon name → so, that characteristic does not define the lower group
    - The apomorphies are unique and specific to the groups and not the groups within it



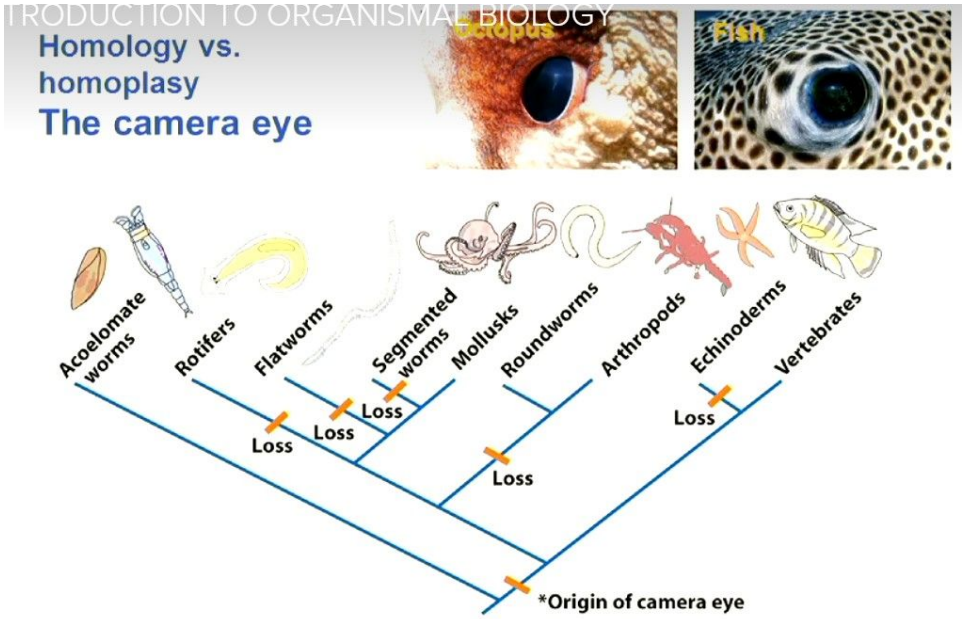
- Springtail is out group → score 0 for all of the characteristics and the organism is the closely related to the other ones too
- Silver fish is the apomorphic state



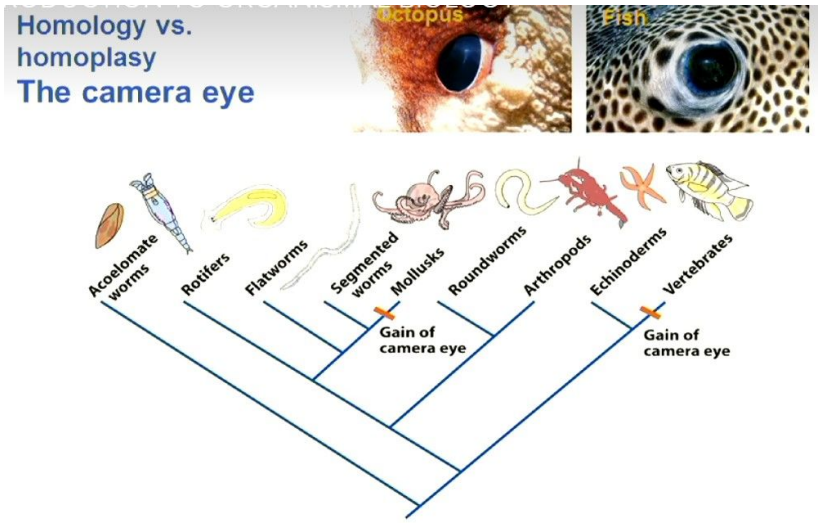
Cladistics:

- Criticized the inherent lack of clarity in classifications based on two distinct phenomena, branching evolution and morphological divergence
    - How can we tell why two groups or organisms are classified in the same higher taxon?
    - Ignores morphological divergence, producing phylogenetic hypotheses and classifications that reflect only the branching pattern of evolution.
- Place species that share derived characters in one group because they have a unique set of derived characters
- **Clade**
    - A monophyletic group of organisms that share homologous features derived from a common ancestor.
    - Unique derived characters → including hair, mammary glands, reduction of bones in the lower jaw, and a four-chambered heart
    - The ancestral characters of mammals do not distinguish them from other tetrapod vertebrates, so these traits are excluded from analysis
- **Cladogram** → portray strictly monophyletic groups and are usually constructed using the assumption of parsimony
    - Once a researcher identifies derived, homologous characters, constructing a cladogram is straightforward
    - Strictly cladistic classification parallels the pattern of branching evolution that produced the organisms included in the classification
- In our phylum the Chordata the first chordates didn't have jaws making the absence of jaws the initial ancestral, or primitive condition and their presence an advanced or derived trait
    - Jaws are found in fishes, amphibians, reptiles, birds and mammals making them a shared derived trait found in only a subset of the animals in the phylum
- As we score more and more characters – **ancestral 0 (-)** and **derived 1 (+)** there are some in the group that have almost all ancestral characters and their score will be low
- Others with lots of derived traits (sum of all those 1 scores) and high scores and are the ones farthest removed, most changed, evolved from the common ancestor
- The branching diagram that results is a cladogram and any one branch a **clade**

Parsimony - The KISS Principle

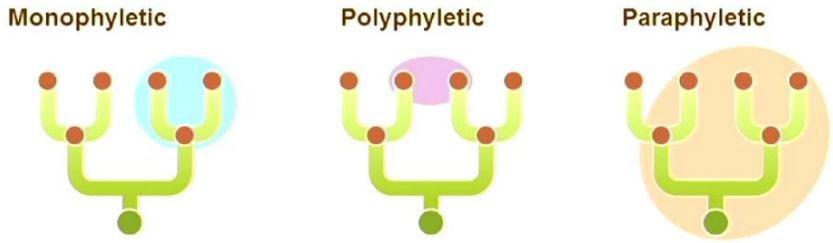


- You can say that 6 events used to explain that the camera eye has been evolved once



- Here we say that the gain of the camera eye evolved twice
- In Parsimony, it states to take the simplest one to explain
    - Many systematists also strive to create parsimonious phylogenetic hypotheses
    - According to the assumption of **parsimony** (also known as **Occam's Razor**), the simplest explanation of an issue is usually the most accurate

Anatomy of a Cladogram



- When converting the phylogenetic tree into a classification, Systematists use the **principle of monophyly**
    - They try to identify **monophyletic taxa**, those derived from a single ancestral species
    - **Monophyletic taxa** → A group of organisms that includes a single ancestral species and all of its descendants.
    - **Polyphyletic taxa** include species from separate evolutionary lineages
    - **Polyphyletic taxa** → A group of organisms that belong to different evolutionary lineages and do not share a recent common ancestor.
        - If based on the presence of wings, we placed bats, birds, pterosaurs, and insects in one taxonomic group (flying animals), it would be polyphyletic
    - A **paraphyletic taxon** → includes an ancestor and some, but not all, of its descendants
        - The traditional taxon class Reptilia is paraphyletic because it includes some obvious reptiles, such as turtles, lizards, dinosaurs, and crocodiles, but not other descendants, such as mammals and birds

- Monophyletic → what we want → one ancestor and know all the organisms there + how they relate to each other
- Paraphyletic → put birds in different groups → one group is not in the proper analysis → they are removed through misuse of analysis
- Polyphyletic → put 2 groups together and thinking they are related to each other → found out they are not
    - There is a common ancestor → Linnaeus thought worms were related to each other
- Hening gives us when you put the cladograms together and you found an organism that meets all of the citrea, you know they are the same species
    - Do it everything

Parallelism and Convergence Can Complicate the Scene

- There is a tendency among organisms living under the same conditions to develop similar body forms → called **parallel or convergent evolution**