

INTRODUCTION:

3 new species: All species are given genus name + species name, it is important to identify species so that we can categorize them, give them a status that we can use to protect them

- Pseudoloparis swirei (Mariano snailfish)
 - New species discovered 3000m under the sea, which is becoming a hot spot for finding new species
 - Dark environment, thus lots of observable adaptations
- Sciaphilia sugimotoi (New heterotrophic flower)
 - Symbiosis from fungus, heterotroph is thus different from other flowers.
- Pongo tapanuliensis (Tapanuli orangutan)
 - Different than other orangutan, knew that it existed, but only recently found out that it is very different, and deserves to be its own species (2007)
 - Has a different behaviour, call and critically endangered

His research profile: Flatfish (*Bothus mancus*)

- Live at the bottom of the ocean for portion of their lives, variety of sizes per species
- Fascinating factor: Have two eyes on only one side of the body
 - Larvae live in open water, undergo metamorphosis where one eye moves across the body, and dorsal fin also moves forward. Fish that once lived in open waters, will live close to the bottom.
 - Ability to change colour rapidly, move pigments through their epithelial cells, chameleons of the sea
 - Eyes sticking out lets them see their environment when their down on the sand, and allows them to react

Example of evolution: Cheetah, faster mammal on four legs

- Their success is not with speed, but acceleration, and the element of surprise in their hunt is what makes them successful. Can run out of breath quickly, can run fast but not for long

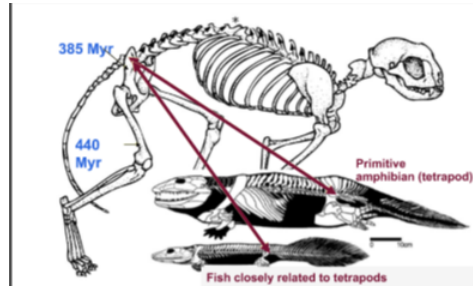
Overview:

1. Adaptations of vertebrates: locomotion organs (limbs/fins)

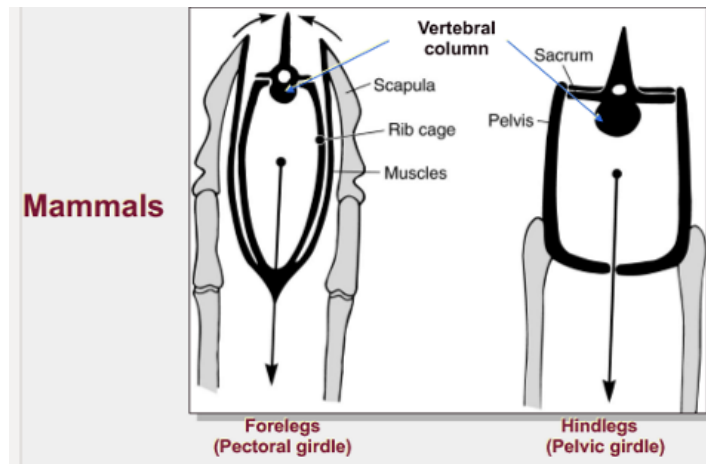
- Cheetahs did not evolve limbs (locomotion organs), even fish had paired fins that evolved into limbs as fish left the water. Limbs have since then evolved for purposes of stability, but still indicative of common ancestor. 440 million years ago

2. Adaptations of terrestrial tetrapods: pectoral girdle (scapula) detached from skull (allows evolution of a neck), pelvic girdle (pelvis) fused to vertebral column

- Pelvic girdle fused to the vertebral column: from primitive amphibians who first had a life outside water and needed support. 385 million years ago. Cheetah did not evolve this feature



- **Hind legs:** Femur attached to pelvic girdle, which is fused with the vertebral column, everything attached together allowing it to propel forward, hindlegs are **locked**
- **Front legs:** pectoral girdle (scapula) is not directly attached to the vertebral column, but instead **slides around the rib cage** in a muscle sling (proportion). Independent of the ribcage.
 - This gives **stability** to the abdominal cavity, internal organs are stable. Also gives stability to the head, **Shock absorption**, Scapula in the same line as forelegs extends **length of legs, making it more powerful: stride length**
 - Front legs provide **orientation** to the rest of the body, can detect slightest movements (head does not move)
- Note: scapula at the back of rib cage, while ours in on our back which gives as rotating arm movements for things like climbing (relevant for our ancestors), cheetahs front limbs only move in one axis



3. Adaptations of mammals: rotation of knees and elbows under body

- lizards/ salamanders have **sprawl posture**, femur parallel to ground allows walking out of water, and them just plopping down. **Limitation for size**, pushing the body up requires energy (ex: crocodile uses this, but they are just about the biggest organism for it, even they do not spend much time outside water, and when they are, they are not agile).
- Rotation of knee and elbow under body developed into limbs that are **pillars that support body**, lifts constraints associated with species size and made organisms **faster**

4. Adaptations of carnivorous: digitigrade

- Carnivores walk on their fingers, what does this do: **increase the length of the limb resulting in longer strides.** (65 million years)



- Exception = bears who are plantigrade (walk on palm)
- ****Unguligrade:** long limbs, walk on hooves (like nails), little muscle (light), which simply allow them to run fast. Difference for carnivores is that carnivores have paws for holding onto prey (more complex)

5. Adaptation of felines: retractable claws (25 myr)

6. Cheetah's claws are slightly different, they have **semi retractable claws**: maybe for getting better grip on ground for changing speed quickly when chasing prey (2.5 million years ago, also age of species). Thus the cheetah evolved semi retractable claws from a species that had retractable claws

Actually unique to cheetah: adaptation for speed (other than hindlimbs..)

- **Fur pigmentation**
- **Long and thin limbs**, especially in distal end (near end), gives them good stride length
- **Many fused bones** means little muscle (most muscle in thighs and elbows) makes them light, and very fast (light, slender muscular body)
- **Flexibility of spine** gives them higher stride length
- **Wide nostrils** gives them access to lots of air for high energy expenditure, and **heart and lungs have a very high functional capacity**

So what is a cheetah?

- Mammal with a few derived traits (evolution) that distinguish them from other felines

From genetic standpoint:

- Very low variability, almost 100% identical
- This makes them endangered as resilience of a species relies on genetic variability (ex: one disease will take out them all)
- How did it happen: bottleneck effect?
 - Event that reduced population to a small population who only have low variability themselves
 - Maybe one population from one island..?..

North American cheetah?

- Pronghorn: can run upto 95km/hours, but why, they are prey. Could be to escape predators: scientists found a predator that is now extinct: Miracinonyx (American cheetah) which shows the same skeletal structure as an animal that runs very fast (now extinct). Shows us that **fossils are the answer**
- Pronghorn can run fast as a result of **co-evolution** perhaps, ex: gazelle also runs fast due to selective pressures from cheetah, like an arms race
- **Note: American cheetah has no common ancestor to African cheetah, it is the same selective pressures that got them both to evolve the same traits independently**

CHAPTER 1: SCIENTIFIC METHOD

Science: intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experimentation

Biology: science of life

Scientific inquiry: diverse way if which scientists study natural world and propose explanations based on evidence derived from their work, Two approaches

- *Description based*: ex: **describing** nature, observing patterns to provide explanations, reinforce view of nature
- *Hypothesis based*: **explaining** nature, finding mechanisms of the natural world

Scientific method:

1. **Inductive reasoning: linked to descriptive based approach**
 - Make generalizations based on specific observations, from particular, to general
 - Ex: wake up, see blue sky (specific), say it will be a good day (general). See students going into classroom (specific), assume lecture (general)
 - Not very powerful, because general observation has a high probability of being incorrect. With science, inductive is never enough
 - Present heavily in media
2. **Deductive reasoning: linked to hypothesis based approach**
 - State hypothesis, and draw conclusions after experimentation and observation, going from general to particular
 - Ex: see blue sky, think it will be a good day (general), then check weather to confirm (testing). See kids going into the classroom, actually go into class and see the lecture screen. Left with closer result to truth

Example: case of dead fish in Gatineau

- Scientific inquiry begins with observations, hundred of dead fish in river July/August 2019, initial postulated cases: toxic spill (speculation, inductive reasoning)
- After proper necropsies of fish, cause of death was gas bubble disease, caused by overflow of the hydroelectric dam (gas gets out of solution, into bloodstream of fish)
- Does not mean all fish died like this, but demonstrated the process that came closest to the truth, compared to just a speculation

Scientific process: Scientific hypothesis must be verifiable, refutable, and reproducible (someone else must be able to replicate and produce same results)

1. Observation

2. From **hypothesis**, make a statement, must be testable

- NOTE: can never prove a hypothesis is the scientific truth, can only get close to the truth.
 - Hypothesis can be falsified, or not falsified
 - If hypothesis has survives multiple falsification attempts, it is a theory

3. **Prediction** must give a clear result (if, then...)

4. **Tests** are done

5. **Refute or not refute** hypothesis,

- If refuted: new hypothesis, if not refuted: needs to be continuously tested.

We have a contract between science and knowledge, consisting of 4 clauses. If one of these clauses is not respected, this is not science

1. **Initial skepticism:** asking honest questions on facts and hypothesis (tangible, real things), retests what has been found. Need to assess objectively, which helps refine the hypothesis as well.
2. **Realism:** world is older and exists independently from my perception of it, realm of ideas does not have priorities over the real world, need to stay objective, need to set religion, culture, societal ideologies aside
3. **Rationality:** scientists need to use logic, demonstration must be from coherent steps (scientific method).
 - **Parsimony:** methodological principle stating that acceptable theories are hypothetically the most economical in assumption (when given several explanation that list the same thing, scientists go with the least number of exceptions)\
 - EX: hear galloping in Ottawa, can assume its a horse, but it COULD be a Zebra, but in order for that to be true, we'd have to assume you are near a zoo
4. **Methodological Materialism:** all that is experimentally accessible in the real world is material or has material origin. Data cannot come from non-tangible things, like gods, extraterrestrial life...etc..
 - Ex: crop circles in 1970s, people thought it was from extraterrestrial life.
 - Parsimony hypothesis: humans did it, which was proven to be true

Example 1: Mimicry, in the case of Monarchs + Viceroy was once Batesian, now called Mullerian

- Monarchs are attracted to milkweed: milky substance is toxic to predator (blue jay), and bright colours of monarch indicate to predator that they should not eat it if they want to survive
- Bates found another species of butterfly that he thought was harmless, undergoing batesian mimicry:
 - where it has the same color pattern, but non toxic so the same predator does not eat it
- Concept was retested, and it was found that Viceroy (other species) is also toxic, thus this is case of Mullerian mimicry:
 - gives predators an even stronger message and advantages are given to both species

Example 2: Fur colouration of odd field mice

- Demonstration of rationality, causative hypothesis used (aims at defining how colour pattern evolves, the cause), deductive reasoning. Obeys 4 clauses between science and knowledge
 - Backstory: two populations, two colours. Beach = grey, in land = brown
1. Hypothesis: in this species, fur coloration patterns have evolved as camouflage in their native environments
 2. Prediction: if mice have a coloration that does not match their habitat, then they will be preyed on more heavily than the native, well matched mouse
 3. Test: plasticine mice are spray painted in brown/white colours, spread both colours in equal numbers in both habitats (have both control and experimental), count signs of attack
 4. Results: at beach, more brown were attacked, and other way around inland
 5. Hypothesis supported, not refuted

Example 3: Case study: introduction of fish in Gatineau Park: descriptive hypothesis

- Introduction of a species has an impact on fish biodiversity (more of an impact on smaller lakes), introduction of species for recreational fishing happens to increase value, sometimes piscivorous introductions are done, as piscivores are often fished recreationally
1. Observation: small lakes in which recreational fish species have been introduced do not have schools of small fish near the shore
 2. Hypothesis: introduction of piscivore fish species in small lakes would result in a decline in the number of smaller species (note: size of fish is often a defense in itself)
 3. Prediction: in small lakes from the same region, if lakes contain introduced piscivorous species, then they will have fewer smaller fish species than lakes without piscivores
 4. Testing: determine number of fish species in both types of lakes with sampling (comparative analysis of fish species diversity in both sample groups)
 - Sample area: in the park, introduction of piscivore species are in about 20 small lakes (experimental group), while there are still 25 lakes without the species (control)
 - Note: testing was redone the next summer to stay true to scientific method
 5. Results: lakes without introduced piscivorous fish species have significantly more (50%) small sized fish species than lakes with introduced piscivores
 - ** recommendation: no piscivorous species introduction for keeping biodiversity

Piscivorous species:

- Northern pike, smallmouth bass, largemouth bass

Indigenous, small sized species (minors in shallow water)

- Northern redbelly dace, banded killifish, blacknose shiner, fathead minnow, blackchin shiner
- Three spined stickleback: among first species to go because of flashy reproductive dance

CHAPTER 2: EVOLUTIONARY THINKING BEFORE DARWIN

Transformation in Antiquity : Anaximandre (610-546 BCE)

- First philosopher to write down his thoughts about the universe, sun, planets and origin of life
- Fascination with water (believed it was the central element of life), believed that as humans are dependent on parents, the human race relies on water. **Believes humans originated from water as fish embryo, and at puberty, fish attempted to explore the mainland (transformism)**
- “Animals are born from the sea by solar heat on water. They were first wrapped in spiny bark, as they aged they migrated on the mainland. When the bark burst, they survived briefly in their new lifestyle”.
- Looks at nature of material

Empedocles (483-423 BCE)

- All matter made of 4 elements, earth water air fire (elements are simple, eternal, and unalterable)
- Two major forces interact constantly on these elements: love (attraction or harmony), and strife hate (repulsion or discord). **The way these forces act on elements dictates the way life is made**

Democritus (460-360 BCE)

- Most scientific of greek philosophers, two realities: atoms and emptiness
 - Discovered atoms with logic (deduction), there has to be a smallest entity
- Matter: group of atoms in movement, atomic theory. **Intrinsic properties forces creation of shapes with atoms, until you get a viable shape that can create life**
- Humans and animals are born directly from dirt (**spontaneous generation**)

Conclusions of transformism: (a materialistic perspective)

1. Acts of creation are not due to gods, but the **innovative power of matter**
2. The origin of all things is **not teleological (has an ultimate goal)**, but is the result of chance (force acts of matter, happens to create life)

Classical Thinkers: Socrates (469-399 AD) + Plato (427-347 AD)

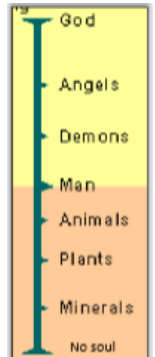
- Believed the more important questions are **not materialistic**, but linked to a search and an understand of the concepts of **beauty, kindness, justice, and sanity** (looking within to find life, not physical)
- Arguments about **logical, ethical and political questions** were more interesting than the truth, and nature is not useful in finding these answers.

Theory of Ideal Forms: Essentialism

- The visible, imperfect and changing realm which surrounds us is a **poor imitation of an Ideal World** (a permanent and perfect world of ideal forms that we possess at birth)
- EX: we have an ideal form of a chair when we are born, yet once we grow up and see environment/nature, we see that all these chairs are an imperfect view of an ideal form, creating confusion and illusion within us
- Look within yourself for the ideal forms. If you want to define beauty, or a species, just find it **within yourself**
- **Gods** are creative forces

Aristotle (384-322)

- It is important to define the **essence** of living beings, which is something he observed in nature
- Belief that **species are static**, and the morphological **variability is illusion and imperfection**
 - Ex: if he looked at a bunch of cats, he'll try and find the essence of a cat but variability between the cats are confusing to him
- Vitalist and perceives **multiple levels of souls** with cumulative effects:
 - Vegetal (grow + reproduce), Animate (move + grow + reproduce), Rational (think + move + grow + reproduce)
- Created **scale naturae** (great chain of natural beings), species are organised in a static and unchangeable hierarchy



The impact of Christianity: decline in the roman empire

- **God** becomes the measure of all things, concept of **scale naturae becomes metaphysical**, proclaiming the perfection of the Creator; species is fixed, new species found would just fit into the scala naturae

Fixity to Transformism

- 14th - 17th century, renaissance in europe: back to nature, and religion is progressively challenged
- 18th century, french revolution, **challenge of ordered systems, more open mindedness towards science**, richness is more widespread.
- Return towards observation of nature, and attempts to classify living organisms were done within the framework of the great chain of beings. Ex: french botanist proposed a ladder of his view on nature, some level of organisation (Bonnet: 1745)

Linnaeus (1707 - 1778)

- Swedish scientist, father of **taxonomy** (hierarchical classification with binomial nomenclature that we still used today, genus + species)
- Discovering each piece of ultimate puzzle: **Plan of Creation**, allowed for order in nature

- Excellent application of essentialism of Aristotle: not only did he find essence, but he classified it too

Buffon (1707-1788)

- Very noble, decided to devote his life to describing nature, and early in his career he saw: **all animals and life had one origin, age of planet is 75000 years old, it is very hot and cooling down** (all against religion)
- “Every family, from animals to plants has a common origin, all animals derive from one animal, which through time produced all animal species in existence today”
- **Censored** because religious conflict, so he abandoned ideas
- Became director of museum of natural history, which is what he liked better anyway

Lamarck (1774-1829)

- First **evolutionist**: species modify morphology through time, **environment determines morphology**, is factor of change (environmental determinism)
- 2 principles:
 - **Usage and non usage** (during lifetime, organ that is used a lot will get stronger and others will get weaker)
 - **Inheritance of acquired characteristics** (acquired characteristics will get passed down, ex: giraffe’s neck will stretch a few cm when getting food, offspring will have longer neck and the cycle continues)
- Gradual mechanism, adaptive. Involves **innate ability** (internal force) that makes something more complex.
- **Spontaneous generation is the explanation of the presence of simple organisms**. Not well received (religion)
- We know that this is not true: ex, tennis players have strong dominant arms, which is not seen specifically in their children
- **RECENT DISCOVERY: Epigenetics**, mechanisms like environment that modulate the expression of genes
 - Ex: Mice reacted to an odour as their parents did when they received a shock with that odour
 - Ex: WW2, period of starvation and women who were pregnant had kids who were predisposed to have diabetes and become obese.
 - Note: marginal process that is only transmissible over a few generations, and is potentially reversible

Cuvier (1769-1832)

- Colleague of Lamarck, interested in mammal **fossils**
- Established the science of **paleontology**, where the **older the stratum (layer of rocks), the more dissimilar its fossils are to current species**, from one layer to the next, species appear and disappear (deeper fossils = simple, upper strata = more complex fossils). **Fossils are different from living beings..**
- **Theory of correlation of parts (organs)**: organisms are harmonious, by finding one bone you can reconstruct the entire organism because of the harmony in morphology of living being (if you know your anatomy well), does this suggest common ancestry
- *Ex: Profound fossil in Cape Breton, first saw lower jaw, and a joint where it would join with the cranium, indicative that it is a carnivore.*
 - *Carnivores have a jaw joint level with lower jaw so that molars can provide scissoring motion for eating meat, while high jaw joints in herbivores so that all molars touch at the same time, jaw can maximize up and down / side to side for grinding (for cellulose)*
 - *Carnivore jaw joint is rounded, secure into curved area of cranium to make sure prey does not escape if alive in mouth*
 - *Ex humans: jaw of herbivores, our ancestors. With the implementation of tools and cooking, we introduced meat into our diet as well*
 - *Point?*
- He was a strong believer **fixity of species** (creationism), **extinction** (evolution as seen in his fossils), and **catastrophism**
- **Progressive creationism**: God once in a while puts a catastrophe that triggers extinction of a species, and then brings in more complex species, and here we are (Darwin first believed this)

Hutton (1728-1797) and Lyell (1797-1875)

- Hutton did not believe in catastrophism because he could not test it, he wanted to explain nature by nature
- **Geological changes are a result of slow and gradual continuous process**
- **Uniformitarianism**: laws of nature are **not affected by passage of time, present is key to past.** This means the **planet is more than 10 000 years old..**
- *Ex: Hoodoos: tent rocks, on top of each column of sand there is a rock. Rocks on top protect the bottom from eroding, which takes thousands of years to produce (seen in Himalayas).*
- *He found mini ones in Madagascar as well. Observing the smaller Hoodoos is a lot easier, yet it can also explain the big ones as well.*
- *Similar to Lyell: what we are able to observe now, can help us explain the past because no change.*

CHAPTER 3: CHARLES DARWIN (1809-1882) AND EVOLUTION

Voyage on the Beagle (1831)

Ship commissioned by British government to do cartography (map designing) of the coast of South America, Darwin became a naturalist of the voyage. Spends most of his time on land to sample fauna and flora and study South American geology

He was first a creationist, who believed in catastrophism

2 books impacted him:

- **William Paley : Theology or evidences of the existence and attributes of the deity**
 - Father of theology of nature, advocate for **harmony and design in nature being the indication of God's existence** (intelligent design). Complexity and harmony must signify higher power
- **Charles Lyell: Principles of Geology**
 - Sees fossils in Indies, experiences earthquake in Chile where he **saw the geography change around the coast**, and started to realise how often this happens and how much the land has changed

The distinct fauna of South America had Darwin thinking:

- Why do fauna and flora of Africa, Europe, Austria, and South America have **few species in common**? Why did God bother to make so many fauna?
- Why do the animals and plants of the **temperate zones of South America resemble the species living in the tropical zones of South America**, but not the species in temperate Europe (**Lamarckism**? Environment dictating morphology...) Darwin disappointed in Lamarck
- Why are the **mammal fossils** of South America **absent** from the current fauna (ex: Giant Sloth)? Why do these **fossils show resemblance with current species there** (ex: three-toed sloth)? ...Why are there species that are extinct?

Fauna of Galapagos are unique, yet show resemblance to species on the American continent.

- Ex: Galapagos Marine Iguana, similar to iguanas of South America. Galapagos Sea lion, closely related to California sea lion.

Evolution and Natural Selection

- 1837: Darwin mentions that species show resemblance because they share a **common ancestor**, not because of a common environment, **rejects Lamarck** (he said, descent of modification because he thought evolution referred to humans, and was different)
- **Rejects fixity**, materialistic view of life that is against religious dogma
- Begins **search for evolutionary mechanism**

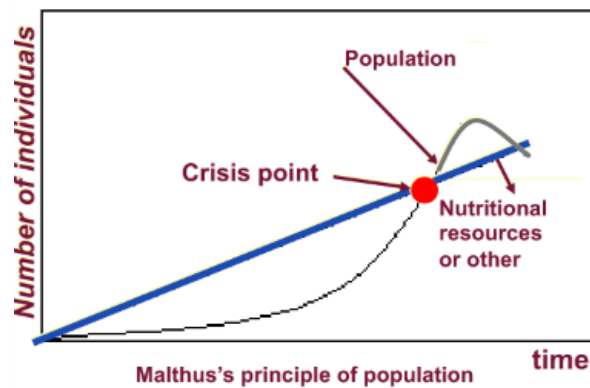
- Darwin's hypothesis with finches: finches share common morphological similarities because they share common ancestor, but **how did they evolve?** How did they come to the islands? Windstorm? Part of land broken? This is difficult to test

Darwin thought **fossils were essential in seeing gaps in morphological variability,**

- Ex: african elephant, dugong, rock hyrax all have distinct, unique features. This means there are morphological gaps in evolution when it comes to the evolution of the elephant
- In fact, 99% of species that have lived on earth are extinct... so we need fossils to see

Darwin read, “**An essay on the principle of population**”, by Malthus, which inspired him to formulate his famous theory of natural selection

- Malthus said: every human population has a tendency to increase geometrically, whereas the available resources to feed populations increase arithmetically.
- Point where there are too many people, we get a crisis that brings pop. back down again
 - **Crisis point separates winners and losers**
 - Darwin began to look at characteristics of winners, but in plants and animals



Observations

1. All species can produce **more offspring than their environment can sustain**, and **many of the offspring fail to survive and reproduce**. What makes winners?
 - Ex: spore clouds, maple trees, mola mola (ocean sunfish have millions of eggs only a few make it to adult)
2. Members of population often **vary in their inherited traits** (variability is not a flaw)

Inferences:

1. Individuals whose **inherited traits gives them a higher probability of survival and reproduction** in a given environment tend to leave **more offspring**
2. !!! From generation to generation, this **unequal capacity to survive and reproduce results in an accumulation of favorable traits in a population (Adaptations) !!!**

Wallace sent Darwin a letter to publish the ideas, they were working on the same thing, so 23 years after his voyage, he **published his views on evolution: “On the Origin of Species” (1859).**

- One chapter contains arguments against the theory from creationist colleagues (well written)
- Many have tried to refute, but unsuccessful..

Notions linked with natural selection:

1. Individuals do not evolve, **populations evolve** (you can't change your genome)
2. Only **hereditary traits are subject to natural selection**
3. Evolution needed **genetic variability**
4. Natural selection corresponds to **differential reproductive success within a population** from generation to generation
5. With time, natural selection enables individuals to become better **adapted** to their environment
6. Environmental factors vary in space and time, **selective forces are variable**
7. Traits in populations will change and can **modify species**

Valid mechanism because:

- Respects principle of **uniformity** (natural selection does not vary with passage of time)
- Results of natural selection are **visible** in nature
- Mechanism can be **verified** on current populations (ex: artificial selection)
- **Materialistic concept**, no need for divine interventions
 - Not random mechanism, enables individuals that are better adapted to their environment to be more abundant than those who are not (differential reproductive process)
 - Not a quest for perfection, not a directed process. Organisms only adapt to environment, no tendency towards ultimate morphology, ex: humans

Note: **artificial selection is finalized** because there is an **end goal**, can be obtained in a few generations (ex: wild mustard, dogs). Natural selection is not, because it can take a long time for changes to occur, no objective, just survival.

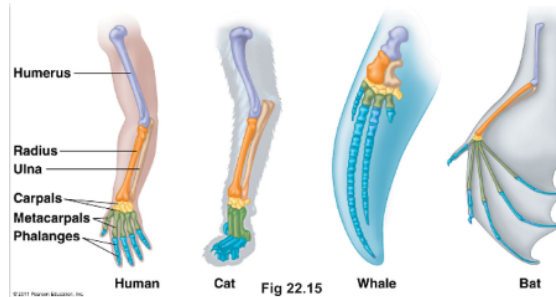
Examples:

8. **Peppered moth**: in both countryside and city, stay on surfaces in the daytime. When everything was **dark** (soot), dark moths were able to survive, and its population increased and became the majority. Opposite in the countryside, lighter moths are more abundant. Now with cleaner nature, black moths are rare everywhere
9. **Climate and medium ground finch**: there was a **drought** in 1977, population of adults went from 1200, to 80, selection favouring bigger **stronger beaks** to break available seeds. Availability of seeds is reduced, only abundant seeds were big hard seeds. Beak height has a genetic basis (most traits have either genetic, or environmental basis, ex height: is genetic, but also based on nutritional factors). Overall, population evolved to have bigger beaks
10. **Human altitude**: normal person, vs someone whose ancestors have originated in Tibet (adapted).
 - At over 2000m, partial pressure of O₂ is insufficient for normal saturation of hemoglobin, causes shortness of breath and altitude sickness (headache, digestive problems..etc..).
 - Physiological response (acclimatization): after a few days, the body compensates by increasing concentration of RBCs in blood, but that comes with serious health risks.
 - Person who lives there has the adaptation, he originated from the lowlands of asia, where there were some people who had the mutation that allows them to survive at high altitudes.

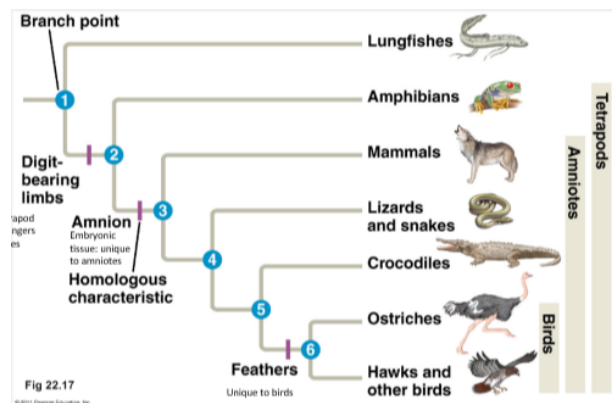
- High altitudes were independently colonized, examples:
 - **Andes**: higher alveolar surface in lungs, same hemoglobin concentration, but each molecule has higher oxygen capacity
 - **Qinghai Tibet plateau**: deeper breath, faster breathing cycle, larger pulmonary capacity and increased blood flow, lower hemoglobin concentration
 - Origin: Denisovan gene EPAS1 (cross breed between two species of human)
 - **Both able to compensate for partial pressures, but mutation is different**

Proof of Evolution: Homology

- Homologous structures, **resemblance between certain traits even if functions are different**
- Ex: Humorous of lots of animals:



- Can also look at **embryo**:
 - Ex: **post anal tail** in humans as a fetus, like many other animal's who end up developing more, but go away in humans
 - **Pharyngeal pouch**: pouch near head that disappear quickly in human fetus, but develop into gills for fish
- Homology can be visualised into **cladogram**, gives info about phylogeny, relationships between species, if they have common ancestors, or adapted separately



Proof of evolution: Fossils

- Ex: evolution of a horse, originated from a browser who ate leaves, did not rely on speed, and used camouflage. Horses today are adapted to speed with a more mobile foot, fewer number of bones, lighter, less muscle, stronger teeth and are no grassers, fossils show us this
 - Note: **not linear evolution**, like one trait after another, but diagram is instead branched. Linear shows an endpoint..
- Ex: Human evolution: classic evolution picture.. Wrong! Not linear, one species does not become the next, not one species that is evolving, but many with a common ancestor (ex: chimp). Note: humans did not get taller, height actually fluctuated.
- **Ex: Pakicetus**: fossil of it **fills the gap between whales today, and whales in the past which had four legs** (whales and hippos share a common ancestor).
- Filling the gaps:
 1. **Pakicetus**: It may even have toes (**digitigrade**: rapid predator?).
 2. **Rodhocetus** have a **pelvic fin**, thus mostly lived in the water
 3. **Dorudon** have very **little pelvic**,
 4. **Whales** have **pelvic girdle in flesh** where legs could have been



Proof of evolution: Vestigial structures : anatomic structure that has **lost almost all of its initial function**

Examples:

1. **in blue whale**: has reduced vestigial posterior limb, pelvis reduced to a floating pelvic bone under spine, suggests whales had ancestors with limbs
2. **Nictitating membrane** (third eyelid): small piece of flesh this is very important to birds/reptiles to provide protection, when flying, feeding...etc.. we don't need but we have a piece
3. **Appendix**: caecum is at the end of intestine and is a large sac in many herbivores important for cellulose digestion. Appendix in humans is like an unblown balloon that was once a large caecum

4. **Goosebumps + hair:** hair stands up from cold and fear from muscles attached because furry animals that have hair stand up have the tip of hair fold a little bit, forming a compact layer that imprisons a layer of air and keeps the body warm.
 - Human hair does not have this ability (too flimsy), but suggests that common ancestor may have had fully furry body
5. **Hiccups:** not optimal for humans, heritage from fish and amphibians
 - Contraction of diaphragm from pinch of phrenic nerve, epiglottis is shut
 - Phrenic nerve for respiration, emerges from 4th cervical vertebrae.. Why does it travel so long if it causes problems? Why can't it emerge closer to diaphragm?
 - Because we originated from fish who have respiratory tract at the throat, thus this is optimal for them. We don't have gills so our tract had to move downwards, so nerve followed + got longer
 - All mammals have the nerve, even giraffes (but they don't get hiccups)
 - Epiglottis: in larvae of amphibians, allows them to breathe through gills, or lungs, makes sure water does not get into lungs.

How to **refute** concept of evolution: discovery of a **fossil in the wrong place** in the geological archives

CHAPTER 4: GENETICS, NEO-DARWINISM, MODERN SYNTHESIS

Premedel perspective: Preformism, and the theory of blending inheritance

- **Preformist:** individuals form as **miniatures in sex cells**, growing by length (until 19th century)
- **Epigenesis:** start as 1 or 2 cells, **replicate** and **differentiate** into specialized cells/ tissue
- **Theory of blended inheritance:** both parents **participate equally in genetic makeup** of offspring. Problem: rapidly, all individuals will become **identical** or close to identical
- **Darwin's Pangenesis:** Theory of **gemmules** (hereditary particles) produced by body
 - When an **organ is used, it grows**, and the **more gemmule** it contains
 - Gemmules would be transported by blood from all parts of body, and collect into gametes
 - Thus gemmules would be particles associated with transmission of heredity
 - Refuted, through blood transfusion
- **Weismann's Theory:** he proposed that **only sex cells were responsible for heredity**, rest of organism was only structure doomed to disappear with death (your body is the carrier of genetic information)
 - Living being divided into two parts with distinct outcomes: **Germline, and soma, independent of each other**
 - Germline is unaffected by environmental influences, heredity is continuity of germline
 - Germline can influence phenotype, but soma has no influence on genotype.
 - **Natural selection is mechanism that can eventually change germline of population**
- *Example: Monkfish, light attracts prey.*
 - *Lanternfish only are female, male is a tiny parasite looking fish, attaches to a female, fusing themselves with the genital papilla, will lose all organs except for testicles and reproduce*

- Sometimes more than one attach (good for diversity)
- Extreme example that shows the independence of the soma and germ cells, soma can be greatly reduced as long as germline is passed down

Mendelian inheritance

- Used peas (variable, can crossbreed, cheap, short generation time, plenty of descendents, can self fertilize)
- Talked about 'hereditary factors', genes were unknown
- Each gene occupies a specific locus on given chromosome, which can have variants (alleles)
- All organisms inherit **two copies of a gene, each copy is an allele**, with a dominant allele, enzyme won't bother synthesizing for whatever trait. Note: **23 pairs of chromosomes in humans**
- **Law of uniformity of hybrids of the first generation:** if both alleles of a locus are different, the **dominant** allele determines appearance of the organism, while recessive allele has no notable difference in appearance EX: earlobes, free/ attached. Free is dominant
- **Law of segregation: two alleles for a heritable character segregate** during gamete formation and end up on different gametes, **haploid** gametes (cells are usually diploid, two homologous pairs of chromosomes) (meiosis)
- **Terms:**
 - Phenotype, genotype, homozygous, heterozygous
- **Law of independent assortment: each pair of alleles separates independently** from other pairs when gametes are formed.
 - This law is **not universal** because some traits are linked together, peas don't display this so Mendel was lucky

