BIO 1130 Midterm 1 Review
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Introduction Chapter

Evolution and the Cheetahs

- The locomotion of cheetahs provide a good example of evolution
    - Very successful hunter with ~50% success rate
    - Catches prey with the element of surprise as they can accelerate to around 100 km/h in 2 seconds
    - Their prey (Thomson and Grant's gazelles) can reach 90 km/h
- Physiology
    - Pelvic girdle (pelvis) is fused to the vertebral column
        - Aids with propulsion when running
    - Pectoral girdle (scapula) is not directly attached to the vertebral column allowing it to slide against the rib cage
        - → Humans have a fixed scapula to their vertebral column which allows for a large range of motion
        - Increases propulsion, stride length, and helps with orientation
        - Rib cage sits in a sling of muscles for stability
    - The muscles in the neck/ shoulder/ chest area also keep the head and rib cage still while the cheetah is running so they are able to see their prey
    - Cheetahs can run very fast for only a short period of time whereas gazelles can run for longer extended periods of time at a slower speed but reach very quick peak speeds to escape predators
    - ✴ Evolutionary compromise
        - Due to the delicate anatomy and physiology of the body allowing the cheetah to run at such high speeds, they are unable to defend against prey against stronger predators as an injury would be detrimental
    - They have a prehensile tail used for balance
    - Many of these characteristics are also found in the prey of cheetahs but are modified for escaping predators
- Comparing modern limbs of mammals (cheetahs) to the fins of fish
    - Limbs emerged 440 million years ago
    - The pelvic girdle fused to the vertebral column 385 million years ago
        - Pelvic girdle found in primitive amphibians (tetrapods) to help support walking on land as air is less dense than water
    - Rotation of knees and elbows to bring limbs under the body to allow an erect posture for more efficient movement 220 million years ago
        - Fins → sprawled legs → knees and elbows tucked under the body; evolution based on energy required to move in environment
    - Most carnivores walk on their digits (digitigrade)

        - first fossil 65 million years old
        - The sole of the foot adds length to the leg which increases stride length; increasing speed
        - Deer have similar structure but walk on two “claws” (hoof)
    - All cats have retractable claws (25 million years)
        - Cheetahs have semi-retractable claws (2.5 million years)
            → Aids with traction while running and increases efficiency while hunting
    - The hind legs of a cheetah are the result of 440 million years of evolution
    - Adaptations of vertebrates in cheetahs
        - Locomotion organs (limbs/fins)
    - Adaptations of terrestrial tetrapods in cheetahs
        - Pectoral girdle (scapula) detached from the skull
        - Pelvic girdle (pelvis) fused to the vertebral column
            → Importance of detachment of scapula and evolution of neck movement
    - Adaptations of mammals in cheetahs
        - Rotation of the knees and elbows under the body (support and/or speed)
    - Adaptations of the order carnivores in the cheetahs
        - Walk on digits (digitigrade)
- Adaptations of cheetahs compared to other felines
    - Fur pigmentation
    - Long and thin limbs especially in the distal end to increase stride length
    - Lightweight, slender, and muscular body to increase speed
    - Flexibility of the spine for increased speed and stride length (can jump 6-7 m)
    - Wide nostrils, heart and lungs with high functional capacity
- What is a cheetah?
    - A mammal characterized by a few derived traits (evolutionary innovations) which distinguishes it from other felines
        - A result of 3,500 million years of evolution
        - Over 99% of its characteristics have evolved from species that are now extinct
        - Less than 1%of its features are uniques
            → So the cheetah is more the result of the history of its ancestors than of its own history
                → This applies to all living species including humans
- Importance of genetic variability
    - The royal cheetah is not a different species but a mutation therefore there is no genetic variability between any cheetahs
        - Due to the lack of genetic variability, the species is prone to being wiped out from disease which could not be combated by any/ many
        - This caused a population bottleneck effect after the species nearly went extinct

        - Genetic variability is important for explaining the theory of evolution
    - The american cheetah
        - We have antelope in the Americas which can run 95 km/h which is caused by a now extinct predator (american cheetah)
            → Convergent evolution; cats evolved fast speeds on different continents
            → American cheetah actually related to the puma

Chapter 1

<u>The Scientific Method</u>

- The Definition of Science
    - Science
        - The intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment
    - Biology
        - The science of how life works
    - Scientific Inquiry
        - The diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work
    - Two Approaches
        - Description-based (describing nature)
        - Hypothesis-based (explaining nature)
- The Scientific Method
    - Inductive reasoning
        - Linked to a descriptive based approach
        - Making a generalization often based on numerous specific observations
            → Particular to general/ observations to generalization
            → E.g. obs: this orange is sweet → gen: all oranges are sweet
    - Deductive reasoning
        - Linked to a hypothesis based approach
        - Involves stating a hypothesis and drawing conclusions (after experimentation and observation) from this hypothesis
            → General to particular
    - All scientific inquiry must start with one or multiple observations and subsequently the scientific method must be implemented
    - Scientific hypothesis must verifiable, refutable, and reproducible
        - From a hypothesis you can make a prediction
        - Predictions must be testable and give a clear result
            → If… then… statement
        - Hypothesis can be falsified or not falsified
        - We can never prove that a hypothesis is the scientific truth
        - If a hypothesis has survived multiple falsification attempts = theory

    - E.g. of the scientific process
        - Obs: this orange is sweet
        - Hyp: all oranges are sweet
        - Pred: If I taste all kinds of oranges, then they will always be sweet
        - Tests: tasting all kinds of different oranges
            → Travelled to Madagascar and tasted a very sour orange
        - Hypothesis is refuted/ falsified and a new hypothesis is formed: all oranges are sweet except those from Madagascar
        - If hypothesis was not refuted/ accepted, more tests are to be performed
- Contract between science and knowledge
    - Initial skepticism on facts
        - Asing honest questions on facts and hypothesis (tangible, real things) and always retest findings (there's always uncertainty)
            → E.g. Viceroy butterfly initially thought to be nontoxic until retested
    - Realism
        - Must ignore preconceived ideas and ideologies when performing experiments (the realm of ideas does not have priority over the real world)
    - Rationality
        - Logic: demonstrations from a scientist must be the result of coherent steps (evidence based)
            → Steps to arrive to a conclusion/ hypothesis
        - Parsimony: methodological principle which states that acceptable theories are hypothetically the most economical in assumptions
            → E.g. crop circles (most probable assumptions)
    - Methodological materialism
        - All that is experimentally accessible in the real world is material or has material origin (everything must be evidence based)
    - E.g. of mice fur colouration and introduction of fish in Gatineau park
✶ A valid scientific process needs to respect the clauses of the contract between the acquisition of knowledge and science
    - Breaking one of the clauses invalidates the contract because the acquisition of knowledge is not associated with an objective search for the scientific truth

Chapter 2 Evolutionary Thinking Before Darwin

<u>Transformism in Antiquity</u>

- Anaximander
    - First philosopher to <u>write</u> his thoughts
    - First to pose the idea that land species came from the water
        - Believed water is the central element of the universe
- Empedocles
    - All structures of the world (matter) are made up of four elements: earth, water, fire, air

        - These elements are simple, eternal, and unalterable
    - Believed two major forces interact constantly on these elements; love (attraction or harmony) and strife or hate (repulsion or discord)
        - Combination of the elements and forces which produced species
- Democritus
    - The most ”scientific” of the Greek philosophers
    - Believed in two realities: atoms and emptiness
        - Posed the idea through the idea of deduction
            → Continuously splitting matter into two until you reach atoms
            → Creatures are formed spontaneously through the interactions between atoms
    - Matter: group of atoms in movement. An atom cannot be created or destroyed (atomic theory)
    - There is an intrinsic property, a force of atoms that create shapes
- Conclusion
    - Acts of creation are not due to gods, but rather due to the innovative power of matter
    - The origin of all things is not teleological (namely, with an ultimate goal), but is the result of chance (random process)

<u>Classical Thinkers</u>

- Socrates and Plato
    - The materialistic approach of past philosophers gives way to more abstract questions and to the contemplation of the soul
        - The important questions are not materialistic, but rather linked to a search and an understanding of the concepts of beauty, kindness, justice, and sanity
    - Arguments about logical, ethical, and political questions are more interesting than the truth
    - The answers are not found in nature, but within the self
        - Thinking about questions from all sides
    - Theories of Ideal Forms (Essentialism)
        - The visible, imperfect, and changing realm which surrounds us is a poor imitation of an Ideal World (permanent and perfect that we possess at birth: the world of Ideal Forms)
        - The variation of forms is unimportant, only the quest to define and understand the Ideal Form is important
            → This philosophy will have a lasting impact on our perception of nature
    - Gods are the creative forces
        - Nature is very flawed therefore is confusing and imperfect
- Aristotle
    - Does not believe in the innate aspect of the world of ideal forms

        - Believed we acquired the ideal form after observing; not born with the essence of things
            → important in modern taxonomy (finding the essence of species)
        - It is important to describe the essence of living beings and this essence is observed in nature
    - Believed that species are static (unchangeable) and thus morphological variability is an illusion and imperfect
    - He is a vitalist and perceives multiple levels of souls with cumulative effects: vegetal (plants), animate (animals), rational (human)
        - Vegetative/ vegetal (plants; reproduce, grow)
        - Animated soul (animals; grow, reproduce, move)
        - Rational (humans;
    - Created the scala naturae (or great chain of beings)
        - Organization of species in a static/ unchangeable hierarchy
- Two visions of the Theory of Forms (Essentialism)
    - Plato → believed we are born with a view of preconceived idea of how things are supposed to be (ideal forms)
    - Aristotle → believed we learn the essence of things through observations

The Impact of Christianism

- With the decline of the Roman Empire, christianity became the main ideology of the western world resulting in the dark age for transformism (evolutionary thinking), with God becoming the measure of all things
    - The concept of scala naturae became purely metaphysical, proclaiming the perfection of the Creator
        - Belief that species are fixed and are a creation of God
        - Hierarchy of life (minerals; vegetation; animals; humanity; angels; God)
            → NO questioning tranformanism

<u>From Fixity of Species to Transformism</u>

- Renaissance in Europe (14th to 17th century)
    - Back to nature (great expeditions and discoveries)
    - Power of religion is progressively challenged
- French revolution (end of 18th century)
    - Challenge of ordered systems (monarchy) for an active pursuit of progress
    - More open-mindedness towards science
- During and after the Renaissance, there was a return towards experimentation and observation of nature
    - Attempts to classify living organisms were done within the framework of the Great Chain of Beings (Bonnet, 1745)
- Linnaeus
    - Father of modern taxonomy (Systema Naturae, 1758)
        - Hierarchical classification (still used today)
        - Binomial system of nomenclature

    - Didn't believe in evolution; believed in god
        - Discovering each piece of the ultimate puzzle (the Plan of Creation)
    - Inspired by Aristotle
        - Application of Aristotle's essentialism
- Buffon
    - Objective to describe nature
    - Proposed every creature had a common ancestor / origin
    - Believed the earth was much older than what the bible said (75,000 years old)
    - Believed in climate change; planet was once warmer
        - Tropical plant fossils in the north
    - The Faculty of Theology of the Sorbonne censored many of Buffon's theories because of conflicts with religious views
        - He then abandoned his evolutionary views and focused on describing nature
- Lamarck
    - First evolutionist who believed that species modify their morphology over time
    - Believed the environment was a factor of change (environmental determinism)
    - 2 principles
        - Principle of usage and non-usage (of organs) → use it or lose it (depends on environment)
            → Believed the environment impacted morphology which was then passed down
        - Principle of inheritance of acquired characteristics
            → Traits acquired during life are not transmitted therefore this principle was falsified
            → E.g. strong right-sided tennis players
    - Gradual mechanism, adaptive and involves an innate ability (internal force) of an organisms to become more complex (i.e., the static "ladder" or "chain" becomes an escalator)
    - Spontaneous generation
        - Explains the presence of simple organisms
    - His theories were not well received by his peers as it contradicted religious views
    - Problem with Lamarck's theory: Acquired traits cannot be inherited
        - E.g. bonsai tree
- Cuvier
    - Established science of paleontology
        - Older the stratum, the more dissimilar its fossils are to current species
        - From one layer to the next, species appear and disappear
    - Theory of correlation of parts (organs)
        - E.g. carnivores jaw joint in line with teeth for scissor cutting action
        - Cuvier was able to identify species through small portions of their skeleton

    - Cuvier was a creationiost and believed in the fixity of species, extinction, and catastrophism (extinction caused by God)
    - Progressive creationism
        - Notion that after each extinction, the species returned a bit more complex each time
- Hutton and Lyell (geologists)
    - Geological changes are the result of a slow, gradual and continuous process
        - Geology was less threatening to people's beliefs at the time
    - Principle of uniformity (uniformitarianism)
        - Laws of nature are not affected by the passage of time
        - Hutton didn't think it was possible that the earth was 10,000 y/o, thought it was much older and that the planet is changing through time
            → Wanted to explain nature by nature, not by the supernatural
            → Darwin was inspired by the Principle of uniformity and applied it to the biological world
    - "The present is the key to the past"
        - Studying the present to understand the past
    - Vision of the world: "with respect to human observation, this world has neither a beginning nor an end"
    - Lyell is the first to establish geology as a scientific discipline

Chapter 3 Charles Darwin and Evolution

<u>The Voyage of the Beagle</u>

- Leaves on the Beagle to do the cartography of the coast of South America
- Darwin quickly became the naturalist of the voyage
- He traveled the world and spent most of his time on land to sample the fauna and flora and to study South-American geology
- The trip was planned for two years but lasted five years.
- During the trip, two books had an impact on Darwin
    - William Paley (1743-1805): "Theology, or evidences of the existence and attributes of the deity"
        - Paley is the father of The Theology of Nature
            → Advocates that harmony and design in nature are indicators of the existence and the acts of God (today = intelligent design)
    - Charles Lyell : "Principles of Geology"
        - Darwin began his travels with religious beliefs, believing in the Great Flood and in Cuvier's catastrophism but his beliefs changed by the end of his trip and he was in total agreement with Lyell and Hutton's principle of uniformity
    - The fauna of south america made Darwin question why many environments around the world are so similar but house such different species

Evolution and Natural Selection

- Darwin was the first to come to the conclusion that species have similar traits because they share a common ancestor, not a common environment
    - E.g. Galapagos island finches
  - This rejects the fixity of species and accepts the concept of descent with modification (evolution)
  - Rejects Lamarck's evolutionary mechanism (environmental determinism)
- 99% of species that lived on Earth are extinct
  - Species have an existence, they go through a change in morphology, then go extinct
  - Most evolutionary branches finish in a dead-end (extinction)
- "An essay on the principle of population" by Thomas R. Malthus
  - Every human population has a tendency to increase geometrically, but the available resources increase arithmetically
  - The human population increases faster than its capacity to feed itself
    - Leads to chaos (crisis point; famine, sickness, war) and an eventual decrease in population size
- Darwin's first observation
  - All species can produce more offspring than their environment can sustain and many of these offspring fail to survive and reproduce
- Darwin's second observation
  - Members of a population often vary in their inherited traits
- From these observations we can make two inferences
  - Individuals whose inherited traits gives them a higher chance of surviving and reproducing in a given environment tend to leave more offspring
  - From generation to generation, this unequal capacity to survive and reproduce (differential reproductive success) leads to an accumulation of favourable traits in a population
    - This is NATURAL SELECTION (enables the emergence of adaptations)
- Important notions linked with natural selection
  - Individuals do not evolve, populations evolve
  - Only hereditary traits with variability can evolve
  - Individuals with traits that lead to higher survival and reproductive success are "fitter"
  - If a trait is well adapted to its environment, it confers to a higher relative fitness
  - Environmental factors vary in time and space
    - Selective forces are variable and a trait that increases fitness in a specific environment might lose this fitness in a changed environment
      → E.g. blue fish in a blue pond, light vs dark moth
      → Selective pressures can change
      → Genetic variability increases resiliency to change in selective pressure in the environment to prevent species extinction
  - Traits in populations may change and may modify the species

- Artificial selection
    - Can be finalized as there is a fixed goal
    - End result can be achieved in a few generations
- Natural selection
    - Never finalized
    - Can take a long time for changes to occur
- Humans and Altitude
    - At over 2,000 m, the partial pressure of O2 is insufficient for normal saturation of hemoglobin for a traveller in high altitudes causing shortness of breath and altitude sickness
    - Causes the body to have a physiological response (acclimatization)
        - Increases concentration of red blood cells in the blood
    - E.g. Qinghai–Tibet Plateau (3,500 m) and Andes
        - After 150 generations and 550 generations (respectively) the majority of the population settled in these areas have adaptations have the genetic traits allowing for survival and reproduction in high altitudes
            → Qinghai–Tibet Plateau: deeper breath, faster breathing cycle; larger pulmonary capacity and increased blood flow; lower hemoglobin concentration
            → Andes: higher alveolar surface in lungs, same hemoglobin concentration in blood but each molecule has a higher oxygen capacity
    - ✶ Mutations are FAVOURED not CAUSED by environments

<u>Proof of Evolution</u>

- Homology
    - Descent with modification theory (theory of evolution) explains the resemblance between certain traits even if the functions are different (homologous structures)
    - Homologous structures are a result of having a common ancestor
        - E.g. comparing bone structure between human arm, cat leg, whale fin, bat wing
        - E.g. post-anal tail in human and chick embryo which dissapear during development
            → All chordates have post-anal tails at some point in development
    - ✶ Life is organized as a tree
        - Phylogenetic tree shows relationships between species and organizes them based on homologous structures
        - Shows that many species from the same family lived at the same time
        - Linear evolution is far from reality
        - Species did not replace one another
            → E.g. evolution of a horse; can organize species in a tree based on size (field vs forest), toes, legs (running vs hiding), teeth (grazers vs browsers)

- Vestigial structures
    - Anatomic structure that has lost (almost) all its initial function
    - E.g. whale evolved from quadrupedal species which is evident based on the presence of a pelvic bone
    - E.g. nictitating membrane/ third eyelid, appendix, hiccups, and goosebumps and hair all provide evidence of evolution from a common ancestor which used these structures
        - We had vegetarian ancestors; rabbits and horses have large caecum, whereas our caecum is small (but functional) → the appendix is the remanence of a large caecum that we didn't need
        - Goosebumps and hair came from our ancestors who had lots of hair which they used to trap heat under their fur
            → We lost the density of our fur but we still have the reflexes for goosebumps
            → Also linked to emotion which increases appearance of size in animals when angry/ scared
        - The hiccups are a heritage from our fish and amphibian ancestors

Chapter 4

<u>Transmission of Traits (Inheritance): Pre-Mendel Perspectives</u>

- Performism and the Theory of Blending Inheritance
    - The theory of blending inheritance: universally accepted theory until the end of the 19th century
        - Both parents contribute equally in the genetic makeup of offspring
        - For each trait the child would show an intermediate value between the traits of its parents
            → This would cause all individuals to become identical/ very similar which is not consistent to what we observe
    - Darwin's Pangenesis
        - The theory of gemmules (hereditary particles) produced by each part of the body
        - When an organ is used, it grows and the more gemmules it contains and vice versa
        - The gemmules would be transported in the bloodstream from all parts of the body and assembled into gametes when they are formed
        - Gemmules would be the particles associated with the transmission of heredity
        - Francis Galton's experiment refuted Darwin's hypothesis
    - August Weismann's Theory
        - Proposed that only sex cells were responsible for heredity, whereas the rest of the organism was only a structure doomed to disappear with the death of the individual

- → Living beings are divided into two parts, with distinct outcomes: germline (gametes) and the soma (the remainder of the body)
- → The germline is impervious to environmental influences and heredity is simply the continuity of the germline
- → Thus, the germline and the environment can influence the phenotype, but the soma and the environment have no influence on the genotype
- → Natural selection is the only mechanism that can eventually modify the germline of a population
- → E.g. male monkfish fuses to female (shows that soma is first and foremost the receptacle of the germline)

✴ A chicken is the method by which an egg makes another egg