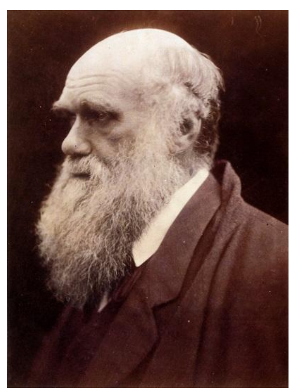
Evolution as a word has been used to refer to many things – from the process through which fictional creatures known as *Pokemon* reach a higher level; to the reincarnation of the same product so it can sell more.

In the context of Biology, however, we're all familiar with evolution because of the merits of one person: Charles Darwin.

On the Origin of Species: Natural Selection.

People of Darwin's time had this conventional view of Earth and its life. Concepts dating back to Aristotle, where species remain in fixed forms and Judeo-Christian culture enforcing literal interpretations of biblical creation in Genesis as life being created in its present-day form, was the prevailing notion.

Darwin's radical thinking, coming from a fascination with nature, and subsequently, a sea voyage, helped him frame his theory of evolution.



Darwin's experience with the voyage allowed him to form his notion of evolution: *"descent with modification*." Darwin isn't the first to propose evolution but his work provided a mechanism to explain the process.

In the process called natural selection, individuals with certain traits will survive and reproduce more than individuals who lack traits that fit into their living environment. Over generations, these traits accumulate and modify the organisms to better suit their specific ways of life in their environment. These accumulated traits and modifications are called adaptations.

Hence, because Darwin provided strong evidence for evolution or the idea that living species descended from ancestral species that are different from their present-day counterparts, his peers accepted the concept as a theory. A theory is a widely accepted explanation of a phenomenon that is broader than a hypothesis, is able to generate new hypotheses, and is backed by a large body of evidence.

Evidence for Evolution.

During Darwin's voyage, his observations indicated that geographic distribution or proximity is a better predictor of relationships among organisms than the similarity of environment. For example, plants and animals in temperate regions of South America resemble tropical species in the continent more than those temperate living species in Europe.

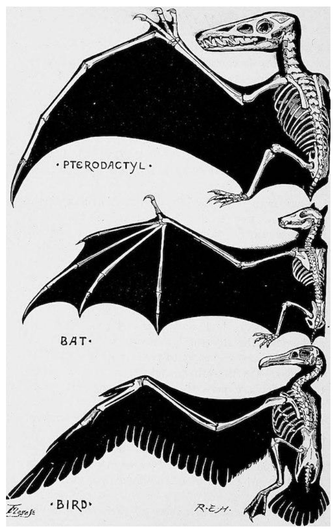
He was particularly intrigued by the organisms in Galapagos Islands, located 900 km towards the Pacific from South America, as most animal inhabitants are not found elsewhere in the world but resemble South American species.

In addition, he witnessed how an earthquake was able to lift Chile's coastline by a meter and this helped him refine ideas that natural forces affect the Earth's surface and, in turn, how life developed. This also helped explain how he was able to find fossils of marine snails high up on the Andes Mountain.

Fossils are remains of organisms that lived in the past. They allow us to document changes between past and present organisms and identify many species that have become extinct. Many fossils are found in fine-grained sedimentary rocks in layers atop another called strata.

Paleontologists, scientists who study fossils, gain access to very old fossils when erosion carves through the upper, younger stratum into the deeper, buried layers.

When fossils are found in the same layer/stratum, it can be assumed that they are found living in the same point in time and this can be confirmed through dating methods. Because these layers sort of chronicle the evolution over millions of years in the order in which fossils appear in the rock strata, this has been referred to as the fossil record and is one of the pieces of evidence for evolution.



Another evidence for evolution is the presence of anatomical structures that may have different functions but are structurally similar because they come from a common ancestor.

Similarity coming from this common ancestry is called homology and these features are called homologous structures. An example is the forelimbs of mammals. Comparing the limb of a human to that of a whale (that has become a flipper) or that of a bat (that has been modified for flight), the functions differ but when observed anatomically will have similarities.

This differs from analogous structures which are similar features that evolved independently for distantly related organisms. For example, the marsupial sugar glider from Australia is able to glide like the flying squirrel, a eutherian, because they modified their flap of skin tissues to allow gliding. Analogous structures come to be because of convergent evolution, the independent evolution of similar features in different lineages.

Some homologous structures turned into remnant structures that have become marginal or perhaps of no importance to the organism. Called vestigial structures or rudimentary structures, these features served important functions for the ancestors of the lineage. An example in the human body is the appendix. In ancestral species, diet is composed primarily of plant material hence the appendix then functioned as sites where symbiotic microorganisms would help digest cellulose from plant material.

Having proposed a mechanism for evolution, Darwin conceived the notion that artificial selection – selective breeding of domesticated plants and animals to get desirable traits in their offspring – was key to understanding change brought by evolution. By talking to farmers about livestock breeding, he learned two essential components of artificial selection: variation and heritability.

Variation, differences among individuals in the same group, allows breeders to select animals or plants with the most desirable combination of characters as breeding stock. Heritability, meanwhile, refers to the transmission of a trait from parent to offspring. Despite lacking underlying knowledge of genetics, breeders are already aware of the importance of heritability in artificial selection.

Evolution of Populations.

In his work, *The Origin of Species*, Darwin provided evidence that life on Earth evolved over time but he could not explain the cause of variation among individuals nor how these variations are passed from parent to offspring. It was only later when Gregor Mendel wrote a groundbreaking paper on inheritance in pea plants that the hereditary process needed to explain natural selection was discovered. However, the significance of Mendel's work was not recognized until it was rediscovered in 1900, where genetic understanding of evolution is based upon.

Genetic Variation.

You won't have trouble recognizing friends in a crowd (unless you have bad eyesight). This is because each person has a unique genome reflected as phenotypic variation, the inherited traits that are expressed in the individual such as the appearance which allows you to identify your friends.

Of course, not all variations in a population are heritable. The phenotype is a result of the combination of the genotype, the genetic makeup, and many influences from the environment. For instance, having done dental work to straighten your teeth will not pass your smile to your offspring. Only the genetic components are relevant to natural selection.

In sexually reproducing organisms, meiosis causes genetic variation since each cell undergoing meiosis has rearranged genetic information. When fertilization thus takes place, the result is a unique individual.

Mutation.

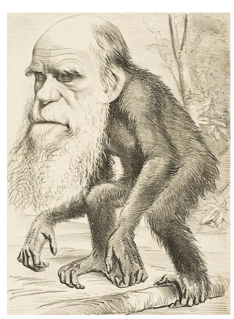
The mutation is the change in the genetic information encoded in DNA. Genetic information is stored in genes that can have different versions, structures referred to as alleles, that may affect the phenotype. When mutations of the gene occur, new alleles may form. Thus, the mutation is the ultimate source of genetic variation that serves as a raw ingredient for evolution. In eukaryotes, however, only mutations in cells that produce gametes can be passed and affect a population's genetic variability.

Mutations can have different effects and it is up to chance whether the mutation is beneficial or harmful. Mutation as small as a change in a single nucleotide in protein-coding genes may have a significant effect on the phenotype such as in the case of those with sickle-cell anemia.

Some mutations may allow individuals to improve their adaptations to their environment, as in the case of pests that develop insecticide resistance. Hence why we must be careful with the use of antibiotics, as most pathogens are also developing resistance. Mutations of the chromosomes, those that may alter, disrupt, or rearrange gene loci, are most certainly harmful. All these processes may have played major roles in the evolution of a population.

Misconceptions on Evolution.

A common misconception on evolution is that individual organisms evolve during their lifetime (some might even mistake it for metamorphosis where an individual will actually change in form as they grow). Although it is true that natural selection acts on individuals, the impact of natural selection becomes apparent in changes in a population of organisms over time.



Another common example of a misconception on evolution among people is that humans came from monkeys. To clarify this, imagine a family with two heirs--one is male and the other is female. In the case of our culture here in the country, the more frequent occurrence is that the male retains their last name while the female takes on her husband's name during the marriage.

Imagine the two lines many generations later. If the ancestor male heir retains their last name, throughout the generations they will still be related to the descendants of the female heir even if the female heir's lineage may have taken different last names throughout the same time span. Evolution is like that; there was a common ancestor between monkeys and humans; not that humans came from monkeys.

Mechanisms of Microevolution.

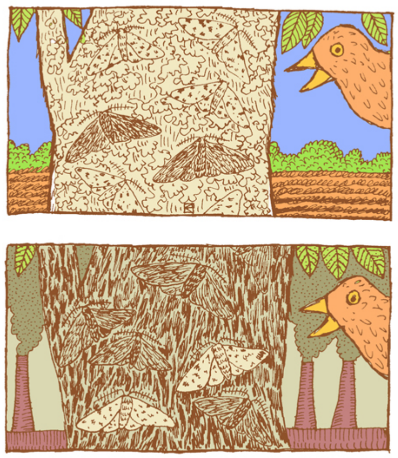
A population refers to a group of individuals of the same species that occupy the same area and can reproduce with each other. In studying evolution at the population level, biologists focus on the gene pool, which contains all copies of every allele at every locus in all members of the population. Genes that encode for specific traits can have alleles that allow it to manifest or not. These alleles vary in frequency in the population and when the frequency shifts over a number of generations, evolution occurs in its smallest scale called microevolution.

To understand how microevolution works, let's set up a population where evolution isn't occurring and thus the gene pool isn't changing. In this population, dominant alleles would over time become more frequent at the expense of recessive alleles.

The shuffling of alleles during sexual reproduction does not alter the genetic makeup of the population. In other words, unless an external factor causes the genetic makeup to change, the gene pool will remain constant. This condition is known as the Hardy-Weinberg equilibrium and for a population to be in this equilibrium, it must satisfy five main conditions:

1. The population must be large. Smaller populations are more prone to have their allele frequencies fluctuate due to chance events or encounters, depending on the magnitude of the event.
2. No gene flow between populations. When individuals move into or out of populations, they add or remove alleles which alter the gene pool. Think of animal hybrids as clear examples.
3. No mutations.
4. Random mating. As in the case of artificial selection if individuals mate preferentially, specific traits are favored and this modifies the gene pool.
5. No natural selection.

Deviations from the five conditions alter allele frequencies in a population. Three main causes of evolutionary change are natural selection, genetic drift, and gene flow. Natural selection has been discussed earlier and so we will focus on the remaining two forces.



Genetic drift refers to chance events that cause allele frequencies to fluctuate unpredictably. Two examples of events that lead to genetic drift are the bottleneck effect and the founder effect.

The bottleneck effect can be visualized when a catastrophe kills large numbers of individuals of a population. The remaining population will not have the same genetic makeup as the original population. Analogous to when shaking marbles through a bottleneck, only a few marbles will be able to escape. These living individuals may then have specific alleles, translating to higher allele frequency. Thus, the living population's genetic pool becomes skewed in favor of the increased allele.

Genetic drift also likely takes place when a few individuals colonize a new habitat referred to as the founder effect. This small group is not representative of the genetic makeup of the original population they left and may favor specific alleles. As such, what would otherwise be a low allele frequency in the larger population will become more frequent in this small population.

Gene flow causes change in a population's allele frequencies due to the migration of fertile individuals into or out of the population or when gametes, in the case of plant pollen or fungal spores, are transferred between populations. Gene flow tends to reduce differences between populations but it introduces new alleles into previously isolated populations.

Sexual Selection.

Darwin was the first to examine sexual selection, natural selection that favors individuals with certain traits fashioned for obtaining mates. Secondary sexual characteristics, noticeable differences not directly related to reproduction, manifest as sexual dimorphisms. These may come in the form of size difference; but can also include forms of adornment like horns, manes, and plumage with males usually being the showier sex, at least among vertebrates.

Sexual selection can be intrasexual or intersexual. When individuals of the same sex compete directly for mates, this refers to the former and is usually found in species where the winning individual acquires a harem of mates. The latter is the more common type of sexual selection wherein individuals of one sex (usually females) are choosy in selecting mates.

Concluding Words.

There are many things to be learned about evolution and the role it plays in shaping the diversity of life. Like a domino, factors, ranging from the smallest molecule in the DNA to external forces that help shape the planet, shape, and form how life exists and face these challenges.

As is the case of science, we build on the knowledge we have already gained; replacing obsolete information with better-supported ideas and notions but in doing so, we will always come into disagreements. Darwin did not specify that humans "evolved" in his work but anyone could arrive at the idea.

In his concluding lines in *The Origin of Species*, he stated gravity, in a subtle way that reflected the public mindset of his time, has already been accepted as a factual natural law of the universe. But when you compare it back to Isaac's time, such a concept has been referred to as "occult" and subversive of religion. As you might have noticed, evolution is an iffy subject for some groups of people.

When the prevailing notion of the time was that of an intelligent design, that a mastermind planned everything there is about life; Darwin helped break the mold and allowed further means to scrutinize the knowledge we have already obtained since then.

I will finish this text by sharing with you a passage from Richard Dawkins, a confirmed atheist, with the intent of sharing other perspectives on the nature of life than the preconceived notions we already have. In his work *The Blind Watchmaker*, Dawkins recounted when he tried to find a queen among a colony of army ants. He wrote the following:

"I never did glimpse the queen, but somewhere inside that boiling ball she was, the central data bank, the repository of the master DNA of the whole colony. Those gaping soldiers were prepared to die for the queen, not because they loved their mother, not because they had been drilled in the ideals of patriotism, but simply because their brains and their jaws were built by genes stamped from the master die carried in the queen herself. They behaved like brave soldiers, because they had inherited the genes of a long line of ancestral queens whose lives, and whose genes, had been saved by soldiers as brave as themselves."

Remember, knowledge is everywhere. How we handle, filter, and make use of that knowledge, which has become so much easier for us to grasp, ultimately rests on our hands.