



Themes in the Study of Life



What does it mean when something is “alive”?

■ The Seven Properties of Life:

◆ Contains highly-ordered structures

- Ex: The human eye, a cell’s chromosomes.

◆ Engages in energy processing

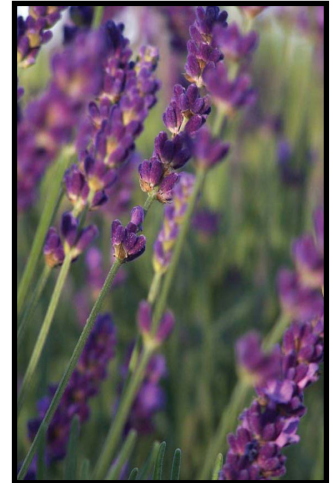
- Ex: Humans extract chemical energy from high-energy organic molecules in food in order to do biological work with

◆ Responds to the environment

- Ex: On a hot day, humans sweat to cool our bodies off if our temperature starts to rise.

◆ Engages in regulation

- Ex: Human maintaining a constant body temperature despite fluctuations in the outside environment



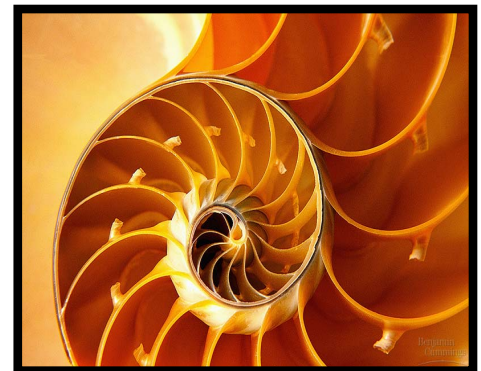
What does it mean when something is “alive”?

- ◆ **Evolutionary adaptations have evolved in the organism over many generations**
 - ◆ Ex: Organisms have traits that are best suited to their environments such as the aerodynamic shape of the wing of birds that allows it to fly.
 - ◆ **Adaptations** = traits that helps an organism **survive** and **reproduce**
 - ◆ These adaptations can be behavioral, anatomical, and biochemical/physiological.
- ◆ **Grows and develops**
 - ◆ Ex: Genes control the pattern and timing of development of all organisms
- ◆ **Reproduces**



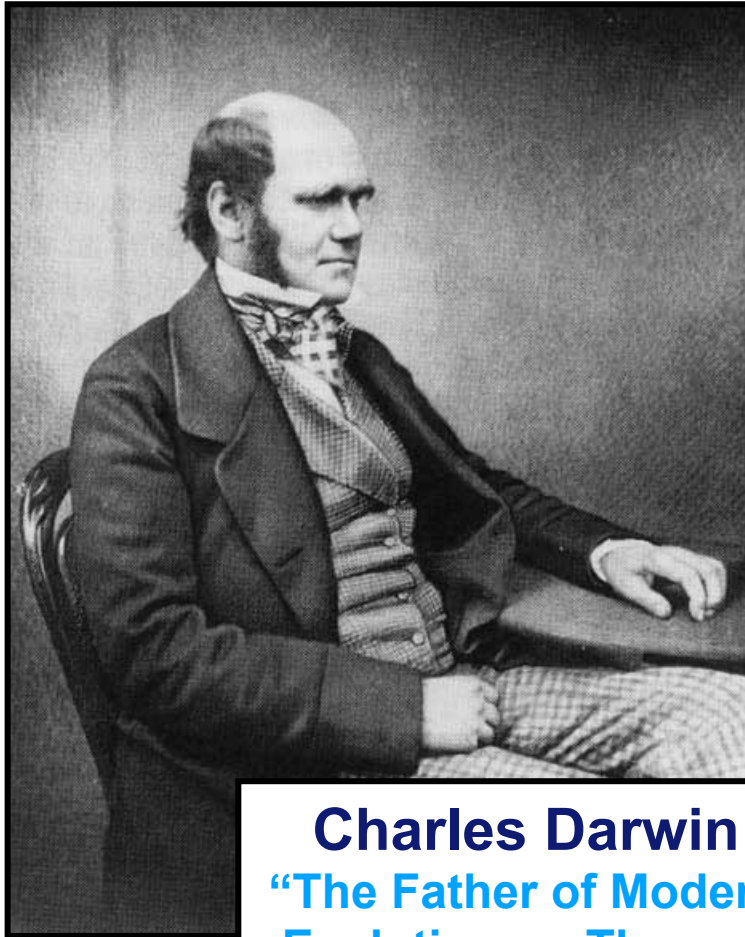
Certain themes connect key concepts in biology:

- Evolution accounts for the unity and diversity of life.
- New properties emerge at each level in the biological hierarchy.
- “Form Fits Function” - Structure and function are correlated at all levels of biological organization.
- Cells are an organism’s basic units of structure and function.
- The continuity of life is based on heritable information in the form of DNA being passed down generation by generation, life’s processes involving the expression and transmission of genetic information.
- Organisms interact with their environments, exchanging matter and energy, life requiring the transfer and transformation of energy and matter.
- From molecules to ecosystems, interactions are important in biological systems.
- Feedback mechanisms regulate biological systems.

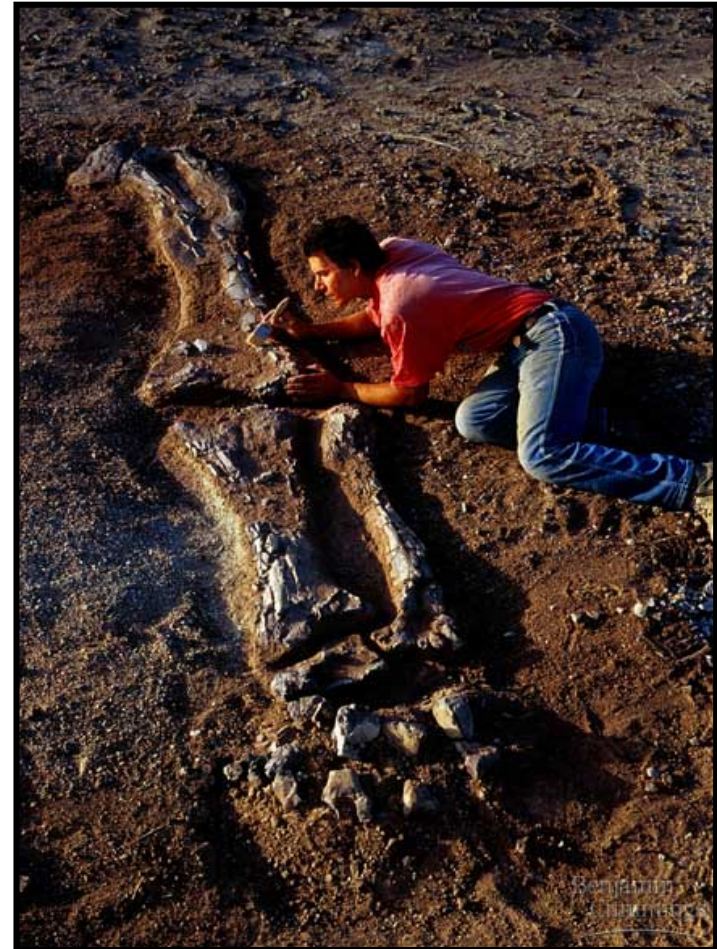


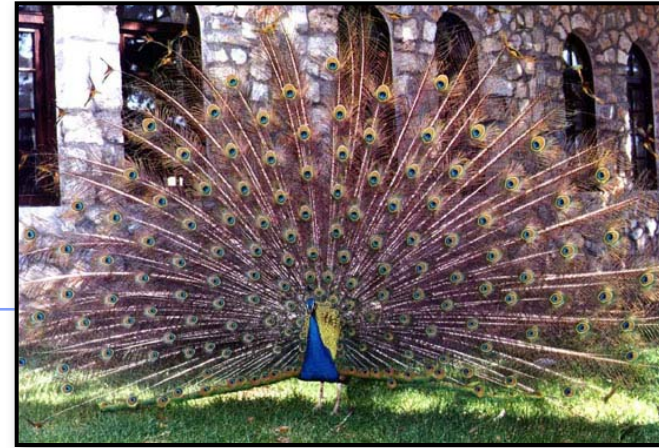
Evolution: The idea that organisms living on Earth today are the modified descendants of common ancestors.

- **Evolution is a core theme of biology.**



Charles Darwin
“The Father of Modern
Evolutionary Theory”





**"Nothing in biology
makes sense except in
the light of evolution."**

-- Theodosius Dobzhansky

March 1973

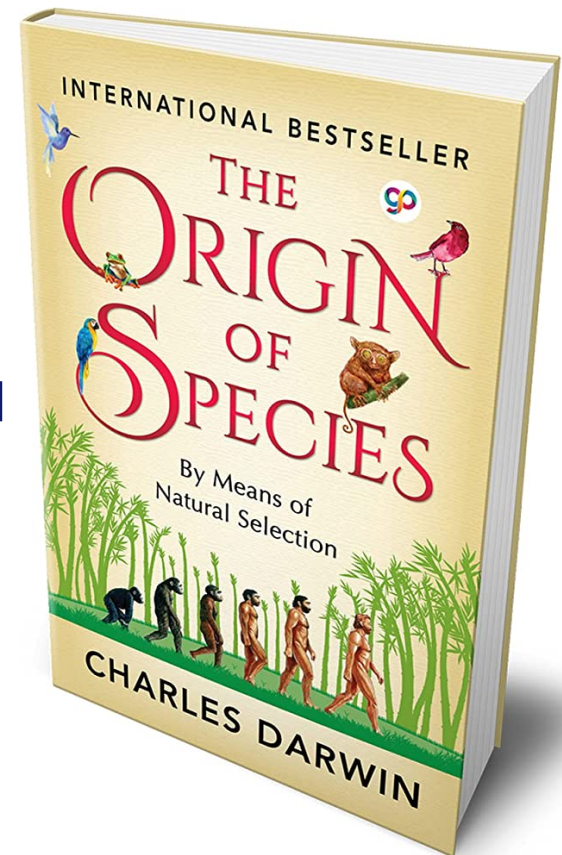
Geneticist, Columbia University

(1900-1975)

In 1859, Darwin Published his seminal work outlining his ideas on how organisms evolve.

In his book, On the Origin of Species by Means of Natural Selection he articulated (stated) two points:

1. Contemporary (current) species arose from a common ancestor
 - * This evolutionary history he referred to as “Descent with Modification”
2. He called the mechanism for this evolutionary modification (how it works) Natural Selection



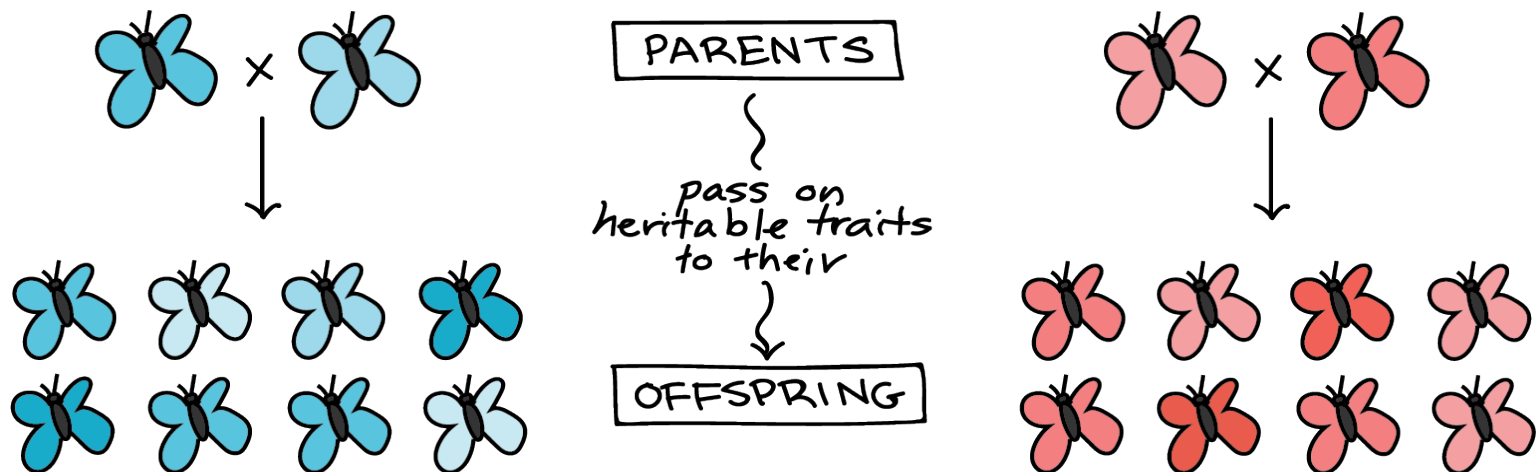
Darwin based his idea of Natural Selection, the mechanism he felt led to **Descent with Modification (Evolution)** on three key observations:

1. Heritable traits vary within a population.



From generation to generation, organisms of a species in a population will differ slightly from one another in their traits (*color, size, shape, behavior, abilities, etc*).

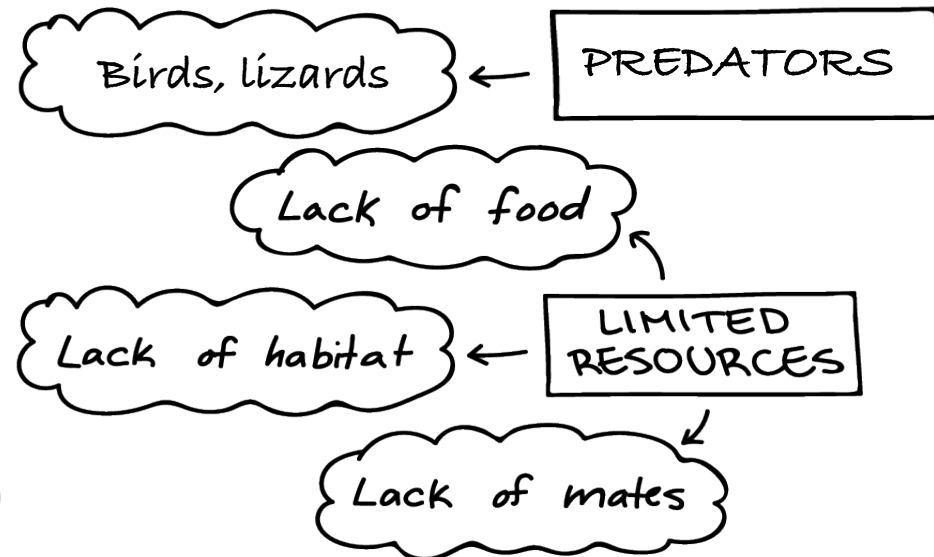
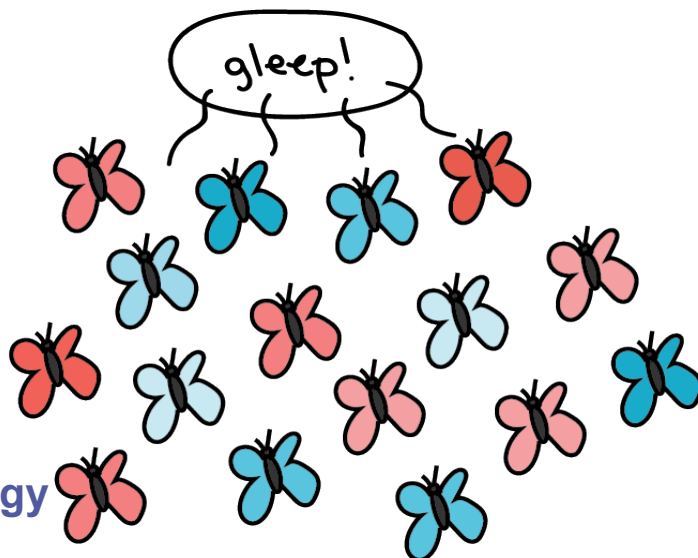
These traits are often heritable, meaning that these features are inherited or passed down from parent to offspring.



2. Since more offspring can be, and are, produced than the environment can support, competition exists for survival.



Organisms face numerous threats to their survival in the form of limited resources (water, mates, nutrients, space etc), predators, pathogens (organisms that use an organism's body as a source of resources to survive and reproduce, but in doing so make the host ill or cause it to die), natural disasters, etc.



...not all individuals will survive and reproduce.

3. Organisms seem to have traits or characteristics that are well suited for their environment.

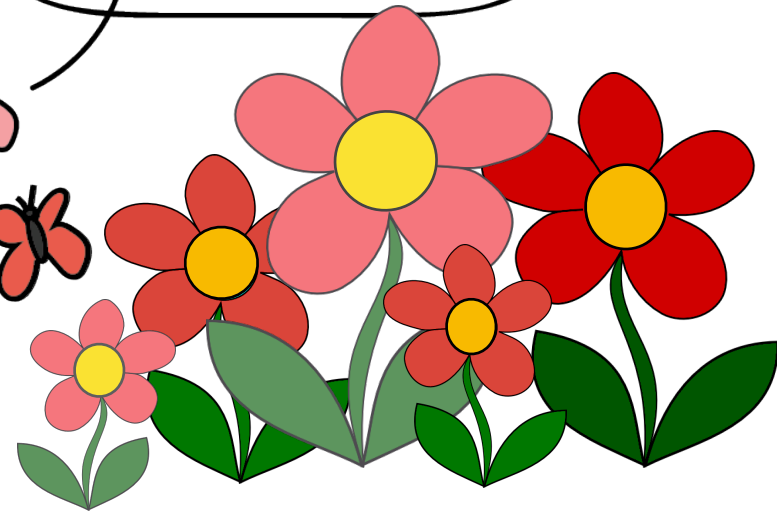
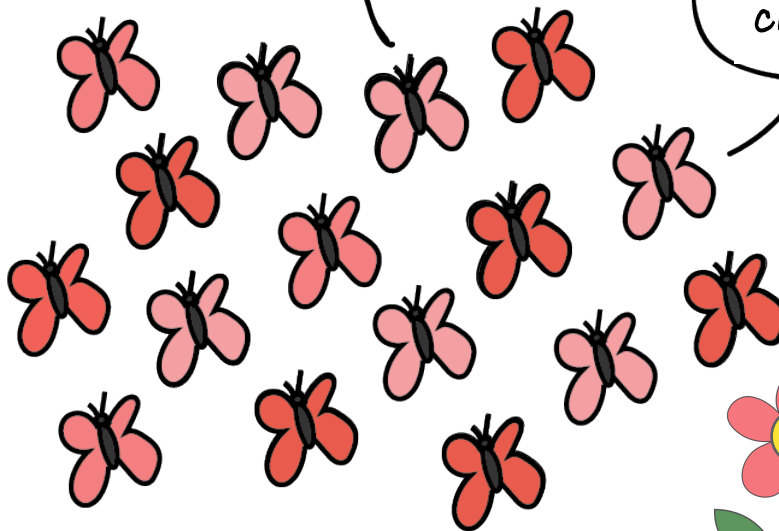
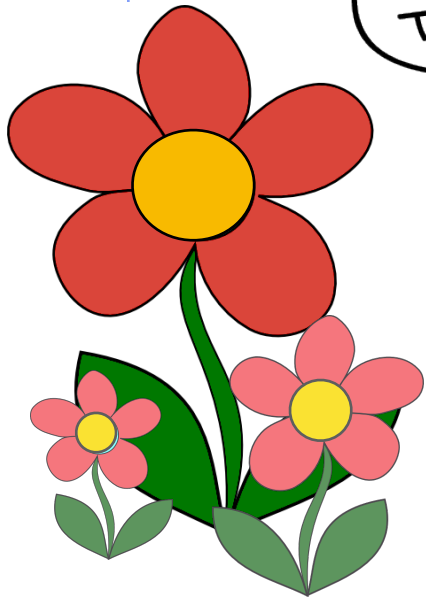


The features (called adaptations) organisms possess help them survive better and, thus, allow them to more successfully reproduce in their particular environment.



Hey, are you red?
That's pretty sweet!

Yes! We are nicely
camouflaged.

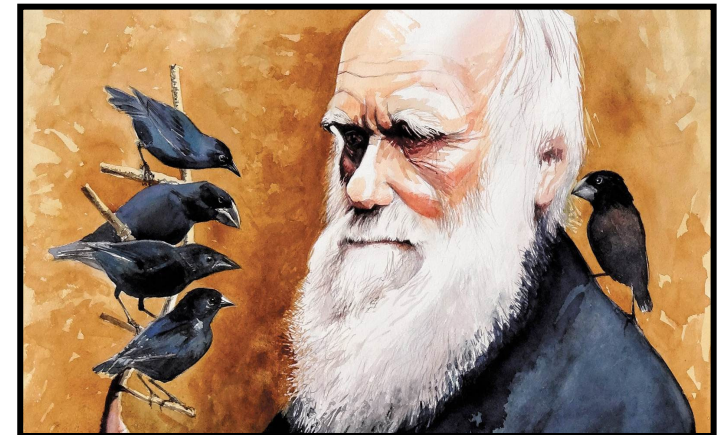


Darwin's Observations led him to Make the following Conclusions:

1. In a population, some individuals will have inherited more beneficial versions of traits that help them better survive and better reproduce in their particular environment.
2. On average, these individuals with more advantageous traits will produce more offspring than those with less beneficial versions of traits.
3. Because the helpful traits are heritable and organisms with these traits produce more offspring with these traits, the beneficial traits will tend to become more and more prevalent in a population as generations pass. Over many generations, this adaptation comes to make up a larger and larger fraction of the future population in that region!
4. The population on the whole, therefore, becomes better adapted to its environment, more individuals possess the inherited adaptation that helps them better survive and reproduce in that particular environment.

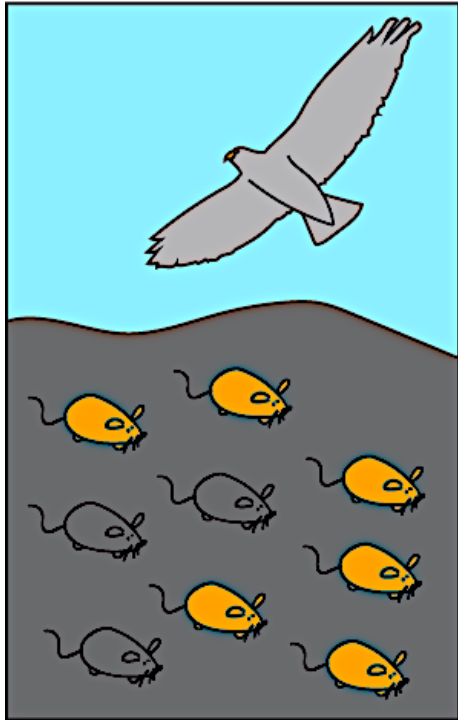
Evolutionary Mechanism: **Natural Selection**

- Evolutionary change is a product of the process of natural selection
- In **Natural Selection**, the environment's interaction with the traits of individual organisms influences which organisms survive and reproduce more successfully.
 - ◆ Therefore, Natural Selection leads to **modifications in the FREQUENCY of traits within a population over generations**, those that enhance survival and reproductive success becoming more common over time.
- Over time, species acquire **evolutionary adaptations**
 - ◆ Natural selection causes **populations** to become increasingly well-suited to their environments **over generations!**

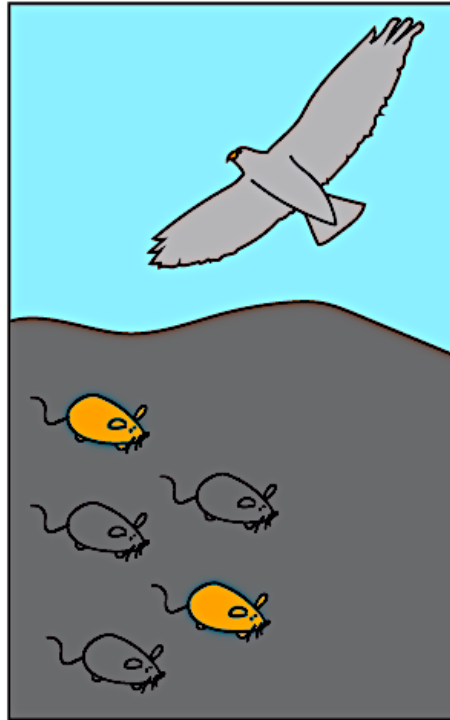


Example of Evolution by means of Natural Selection:

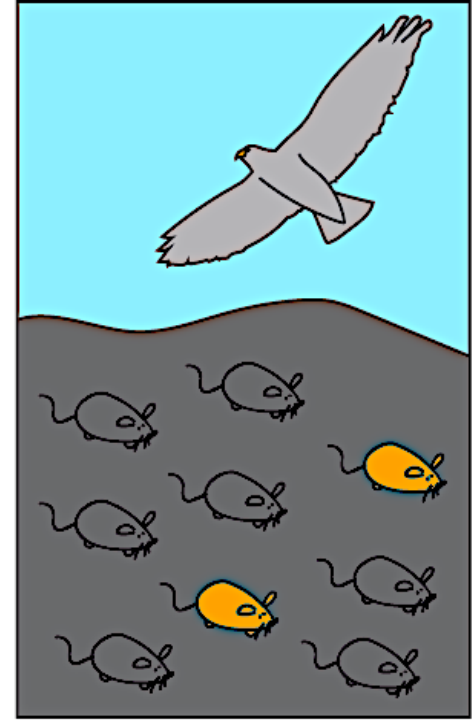
Given that coat color is an inheritable trait....



Some mice are eaten by birds



Mice reproduce, giving next generation



A population of mice has moved into a new area where the rocks are very dark. Due to natural genetic variation, some mice are black, while others are tan.

Tan mice are more visible to predatory birds than black mice. Thus, tan mice are eaten at higher frequency than black mice. Only the surviving mice reach reproductive age and leave offspring.

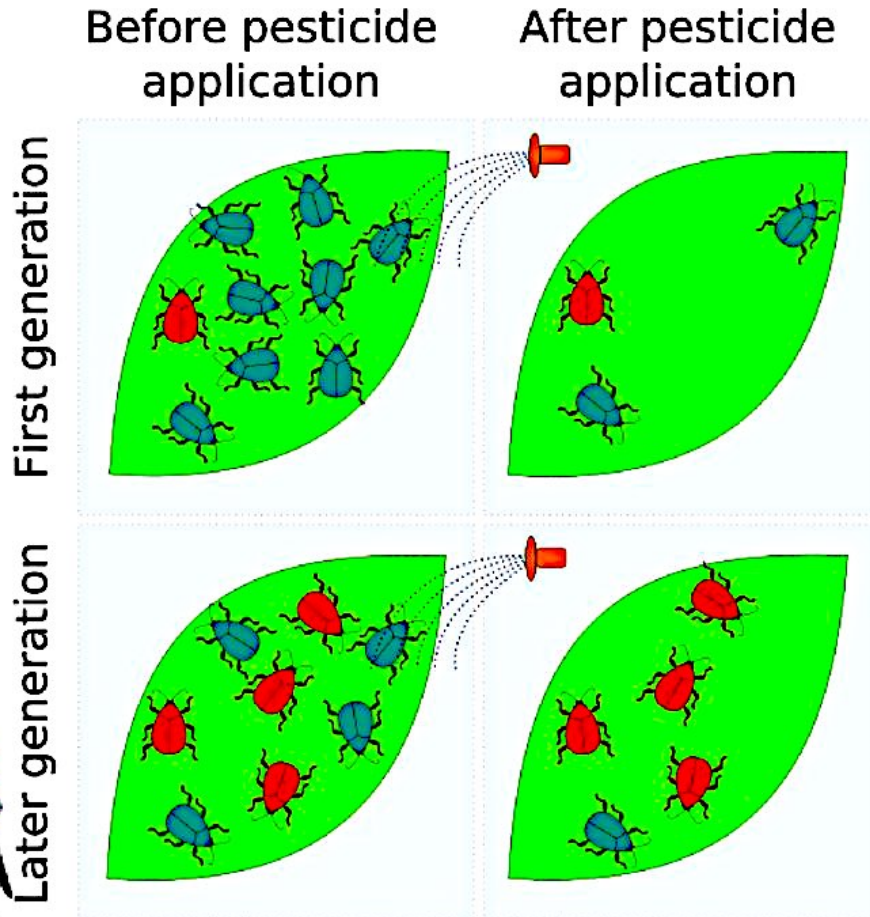
Because black mice had a higher chance of leaving offspring than tan mice, the next generation contains a higher fraction of black mice than the previous generation.

Example of Evolution by means of Natural Selection:

Given that resistance to pesticides in insects can be an inherited trait....

Natural Selection in Action:

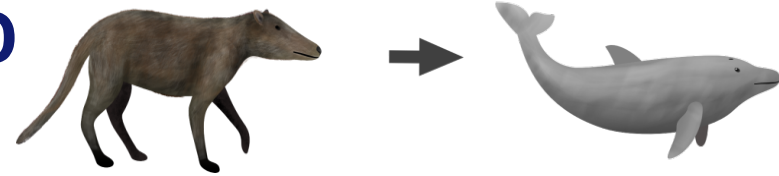
Pesticide Resistance.



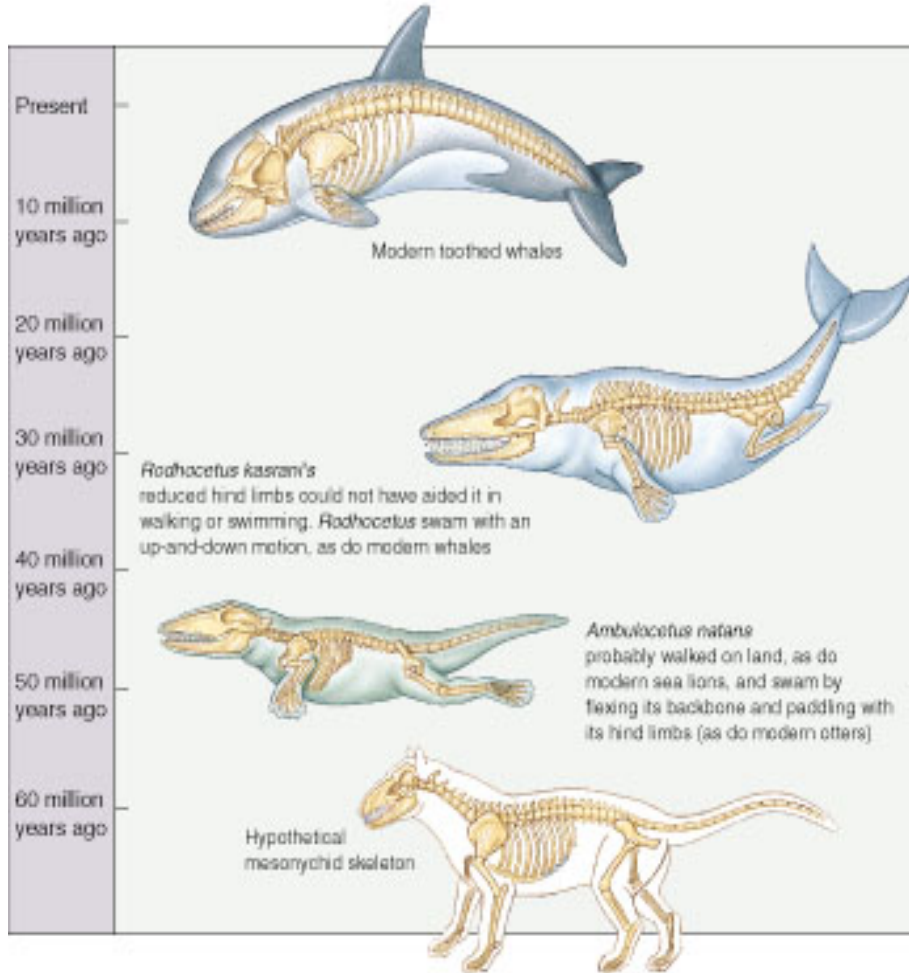
The insect population has evolved insecticide resistance.

If **by chance** there are a few insects in a population with a DNA mutation that allows them to live in the presence of an insecticide, they will survive to reproduce, passing their resistance genes down to future generations, **the insecticide becoming ineffective against the population of insects over time.**

DARWIN'S RATIONALE BEHIND THE THEORY OF EVOLUTION:



- Individuals who inherit traits that are advantageous have a higher probability of surviving and reproducing than those who do not possess such characteristics.



- Many generations later, the proportion of inherited traits in a population will have changed, with many more individuals having the advantageous traits.

ONLY THOSE TRAITS IN A POPULATION WHICH ARE INHERITED CAN CHANGE IN FREQUENCY DUE TO NATURAL SELECTION!!!

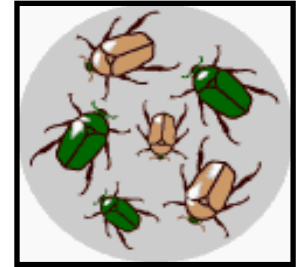
Example of Evolution by means of Natural Selection:

Given that beetle color is an inheritable trait....

Natural Selection in action...

1. There exists variation in traits.

For example, some beetles are **green** and others **gold**



2. There is differential reproduction.

Since the environment can't support unlimited population growth, not all individuals get to reproduce to their full potential.

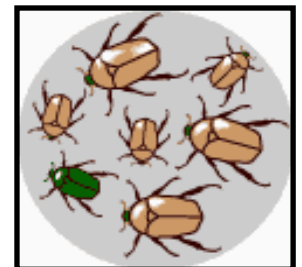


In this example, **green** beetles tend to get eaten by birds that hunt visually and so survive to reproduce **less** often than **gold** beetles.



3. There is heredity of the traits.

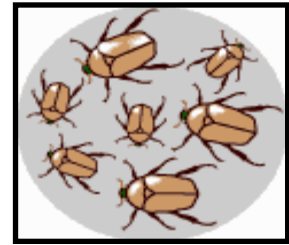
The surviving **gold** beetles have **gold** offspring because this trait has a **genetic basis**.



4. Over generations, adaptations spread through populations, which are said to have evolved

The more advantageous trait, **gold** color, becomes more common in the population over generations of time.

Gold coloration is an adaptation in this population.



Note: No version of a characteristic is inherently better than another! What is an adaptation may change over time if the environment changes.



If the beetles begin living on green grasses instead of straw-colored grasses, **green** will now be **SELECTED FOR** (instead of selected against) by natural selection.

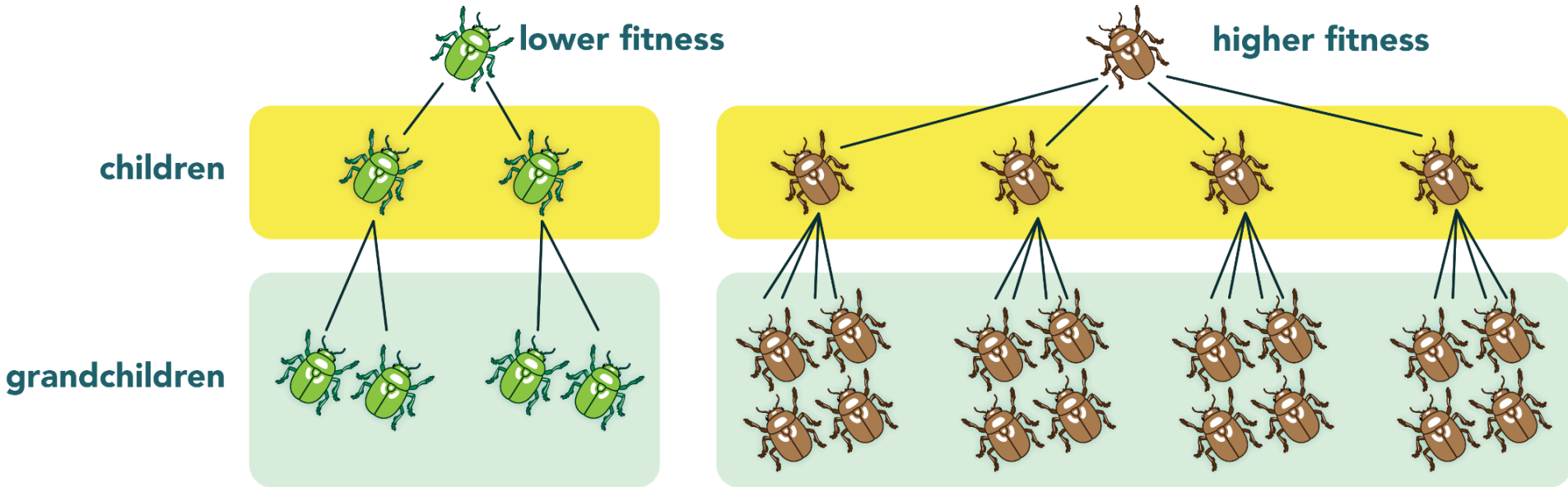
Green coloration will be the **adaptation** that spreads through the population over time while the frequency of gold coloration will dwindle.

If you have variation in INHERITABLE traits and DIFFERENTIAL reproduction, you will have evolution by natural selection as an outcome!

Differential Reproductive Success occurs because of variation in traits that affect survival time and ability to reproduce

EVOLUTION OCCURS BECAUSE OF THE UNEQUAL REPRODUCTIVE SUCCESS OF INDIVIDUALS THAT OVER TIME CAUSES THE POPULATION TO ADAPT TO ITS ENVIRONMENT!

Adaptation: Inherited characteristic of an organism that enhances its survival and reproductive success in specific environments.



(Biological) Fitness: how success an organism is at pass its genetic material to its offspring *(The more viable & fertile offspring an organism produces, the higher its relative biological fitness is compared to another)*

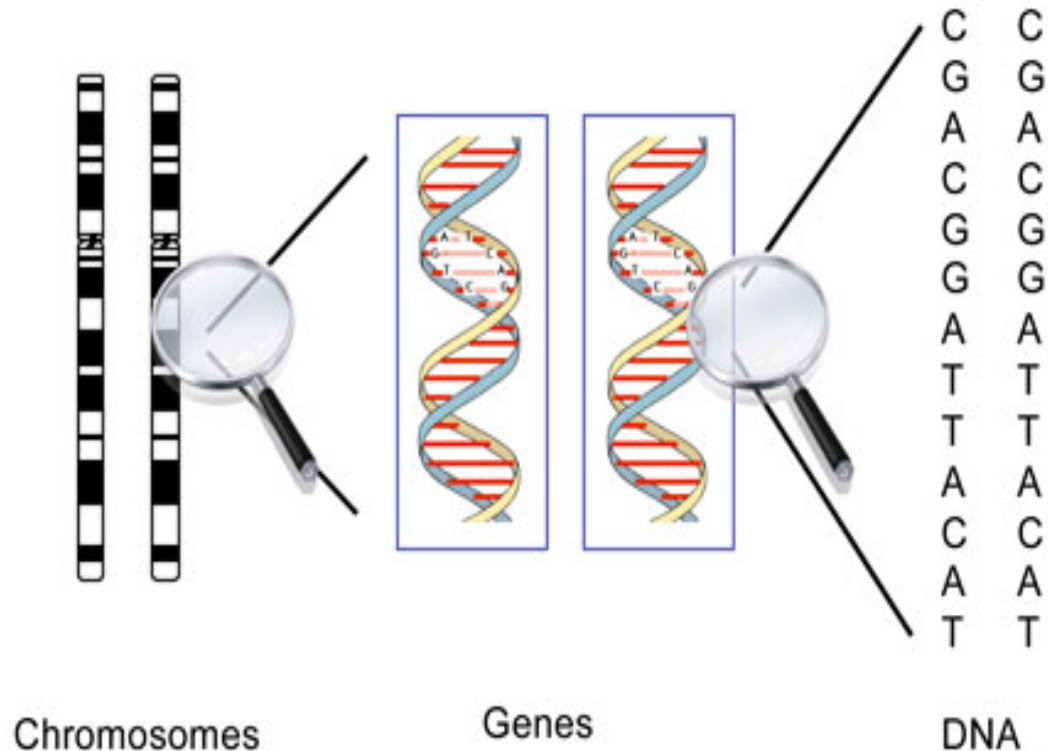
How is evolution Possible?

Evolution is descent with modification from a common ancestor, but exactly what has been modified that causes changes in traits for natural selection to act upon? **DNA**

DNA is made of smaller molecules called nucleotides (referred to as **A, T, G, C**), which are covalently bonded together in a certain orders (or sequence) to form large DNA molecules, often referred to as chromosomes.

The sequence of nucleotides encodes the instructional messages held in the DNA of an organism.

Genes = specific sections of DNA that contain hereditary information that the cell uses to make **RNA** or **protein** molecules from, which in turn give the cell certain traits.



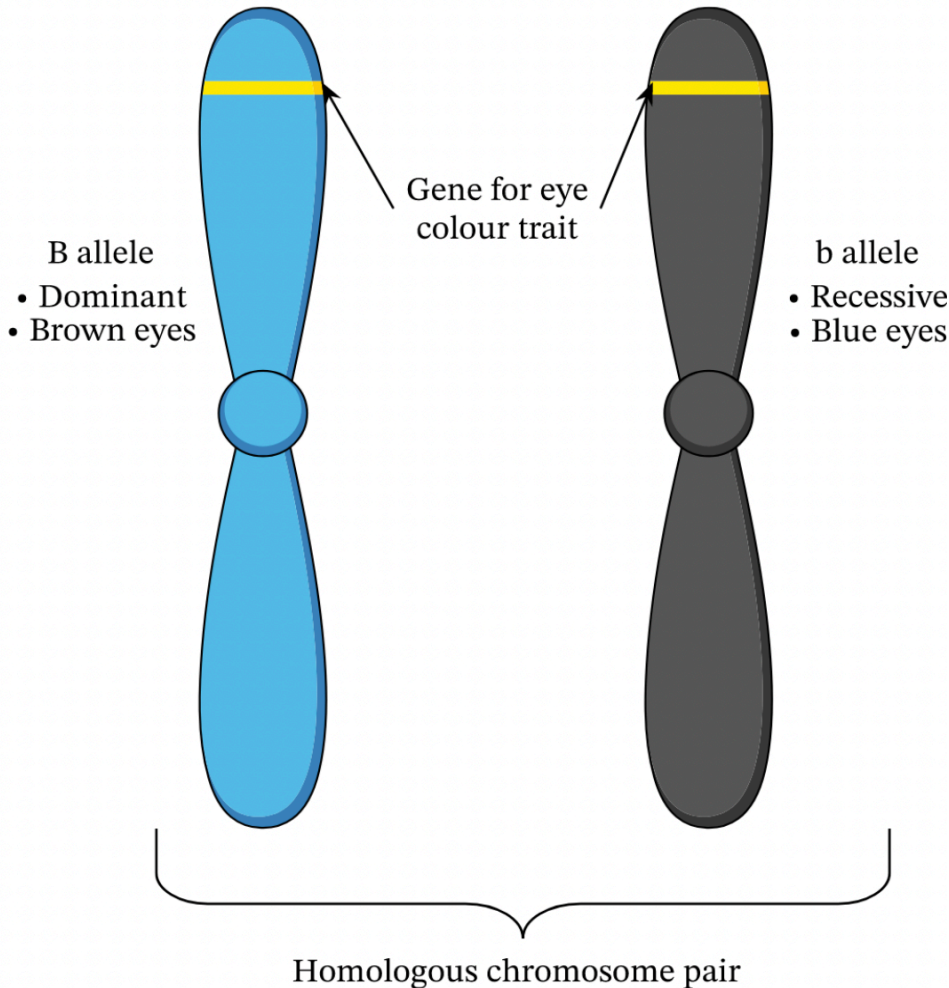
An Introduction to DNA in Humans

- One set of human DNA consists of 23 different molecules of DNA, each often referred to as a **chromosome**.
 - **In Humans, the chromosomes are named 1 through 22, the 23rd type referred to often as either the X or the Y.**
 - Almost all chromosomes contain 1000s to 100s of genes spread along their entire length.
 - Humans DNA contains between 20,000 - 25,000 genes in one set of chromosomes.
- Humans inherit one set of chromosomes from their biological father and one set from their biological mothers.
 - **In most human body cells, therefore, a cell contains 46 chromosomes in total, two of each type (*two chromosome 1s, two chromosome 2s, two chromosome 3s, two chromosome 4s etc*).**
 - This means have two copies of almost every gene, one copy inherited through the egg and one inherited through the sperm.
 - **The sequence of nucleotides in the two copies of the gene may be identical or may differ (*the two copies may be the same or two different alleles*)**
 - **Differences in versions of genes inherited may lead to differences in the versions of an RNA or protein made from the instructions in the gene and, thus, lead to variation in the behavior of the cell and organism.**

An Introduction to DNA in Humans

Chromosome from biological dad

Chromosome from biological mom



Genes (sections of DNA in our chromosomes) encode/contain the instructions a cell uses to make **RNA** and **Proteins** (two types of macromolecules).

- **The actions of RNA and proteins determine the characteristics of cells and thus organisms.**

How are the instructions in our genes used to make RNAs or Proteins?

- A **“RNA” gene in DNA** is copied into RNA. This **RNA** may have a particular function in the cell (Ex: tRNA, siRNA, snRNA, rRNA, miRNA etc..).
- A **“Protein” gene in DNA** is copied into an RNA known as **messenger RNA (mRNA)**. The instructions in the mRNA are then read by a structure called a **ribosome**, which uses the instructions encoded in the mRNA to build a **polypeptide** from smaller chemical building blocks called **amino acid**. Polypeptides fold to become **proteins**.

PROTEINS Help Determine the Traits of Organisms

mRNA: The Starting Point of Translation

DNA is transcribed into mRNA.

mRNA is translated into amino acids.

Each codon corresponds to one amino acid.

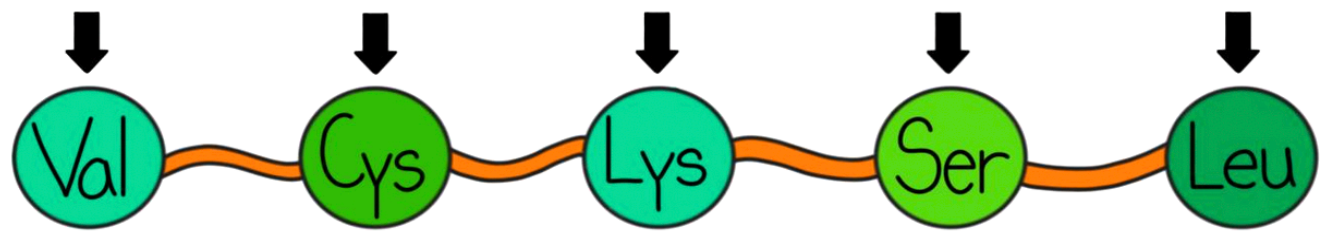
Amino acids form polypeptide chains.

Polypeptide chains fold into proteins.

Gene in the DNA (containing the instructions ribosomes use to build proteins)

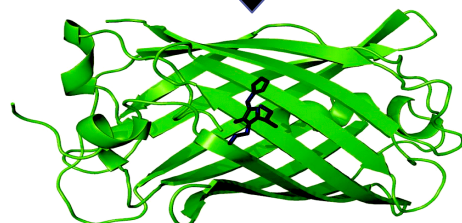


mRNA (containing the instructions ribosomes use to build proteins)



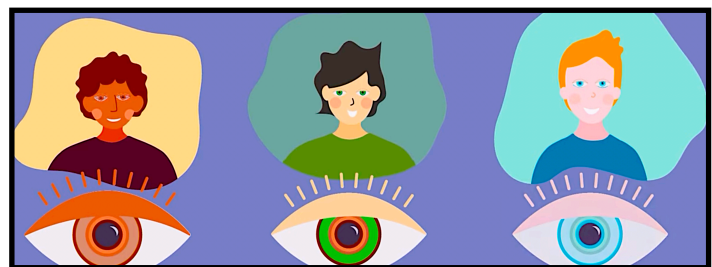
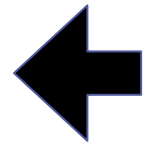
Amino Acid molecules are covalently bonded together into polypeptides.

Polypeptide



Protein

Trait
(a version of a character or characteristic)



How does evolution occur?

Because of DNA **MUTATIONS**, changes in the sequence of nucleotides or “letters” (**instructions**) in the DNA, a gene may exist as several different versions in a population of a species. **Each gene version is called an allele.**




Organisms that possess a different version of a gene (different alleles of that gene) might make slightly varying versions of RNA or Protein molecules, which then causes variations in the traits in the body and cells of the organism.

Evolution occurs when there is a change in the gene’s allelic frequency within a population over time - when some versions of the gene (certain alleles) for a particular character increase or decrease in frequency within a population.

Ex: The % of alleles for blue eyes in a POPULATION changes from 35% to 5% over several generations.

These genetic differences in DNA are heritable & can be passed on to the next generation—which is what really matters in evolution:

Long-term (trans-generational) change in the frequency of alleles for genes.

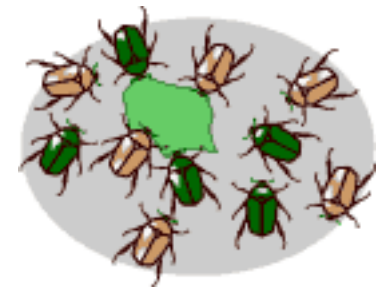
Gene in the DNA	Various traits (versions) for the character “Eye Color,” result from inheriting alternative versions (alleles) for the eye color gene.	
 Eye Color Gene	 Brown	 Blue

Which scenario illustrates “Descent with Modification”?

Descent with Modification? Scenario 1

Imagine a few months of temporary **drought** in which there are **fewer plants** for these beetles to eat.

All the beetles, including those that are slightly smaller and slightly bigger, have the **same chances of survival and reproduction despite the drought**, but because of **food restrictions**, the average **beetle size** in the population a few months later is still a **little smaller** than it was in the preceding generation of beetles.



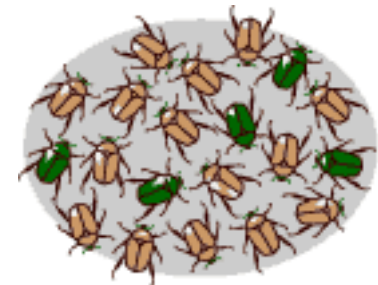
Beetles on a diet

Which scenario illustrates “Descent with Modification”?

Descent with Modification? Scenario 2

Most of the beetles in the population (say **90%**) have the **body color gene version (allele) for bright green coloration** and a few of them (**10%**) have a **body color gene version that makes them more brown.**

Some number of **generations later**, things have changed: **brown beetles** are more common than they used to be and **make up 70% of the population.**



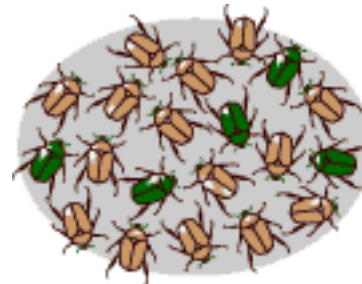
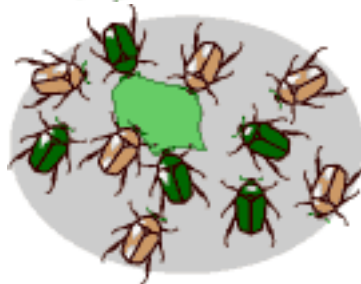
**Beetles of a
different color**

Which scenario illustrates “Descent with Modification”?

1. Smaller beetles due to temporary lack of food or...
2. A change in the amount of green and brown beetles in the population



OR



Beetles on a diet

Beetles of a different color

Which scenario illustrates “Descent with Modification”?

The difference in weight in example 1 came about because of environmental influences—the low food supply—not because of a change in the frequency of gene alleles (versions of the gene for beetle size) since all beetles, regardless of size, experienced the same reproductive success rates as prior to the drought in this scenario.

Because the smaller body size in this population was not genetically determined but is because of malnutrition across all beetles, this generation of smaller-bodied beetles will produce beetles that will grow to the same normal sizes again once they have a normal food supply. Therefore, example 1 is not evolution.

The changes in average color of the population in example 2 is definitely evolution. These two generations of the same population are genetically different. When it comes to the gene for beetle color, the frequencies of the allele for brown color and allele for green color in the population have changed due to natural selection (differential reproductive success of beetles with different coloration).

MISCONCEPTION!

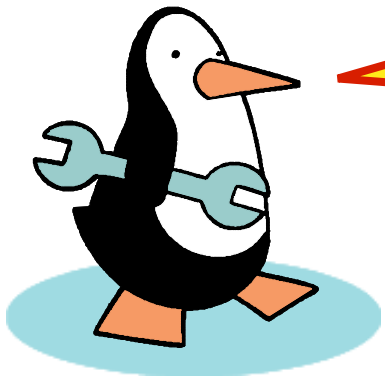
Though the effects of evolution are apparent by looking at an individual member of a species, individual organisms do NOT evolve in their lifetime!!!



Organisms don't adapt or evolve (not in an evolutionary sense); Organisms HAVE adaptations they inherited.

Populations (groups of organisms of the same species in a given region) evolve!!!

Evolution occurs when the frequencies of alleles of genes in a population change, which causes the average characteristics among organisms in a population to change over time.



MISCONCEPTION!

Evolution is **NOT**
GOAL-DIRECTED!

No population chooses
to evolve one way
versus another.

Evolution is a **consequence**
of individuals exhibiting variations in inheritable traits that
influence their lifetime reproductive success rates
(**their relative biological fitness**)
in a given environment.



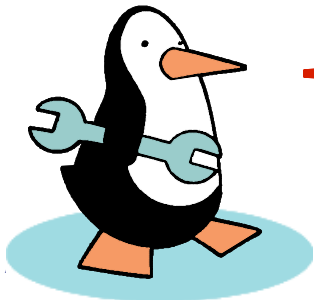
wrong



right

The species
that is able to survive long
enough to reproduce the most will
contribute more to the gene pool of the
next generation compared to one that
produces fewer or no offspring.

That's all...



Evolution explains unity & diversity

So we see both **UNITY**, since we descend from a common ancestor, and **DIVERSITY** since populations of species, in adapting to their environments, have experienced different random mutations and various modifications because of natural selection.

■ Unity

- ◆ *what do organisms have in common & why do similarities exist?*

- common biochemistry, anatomy, & physiology
- evolutionary relationships - connected through sharing a common ancestor that we inherited our DNA from



■ Diversity

- ◆ *why are there differences?*

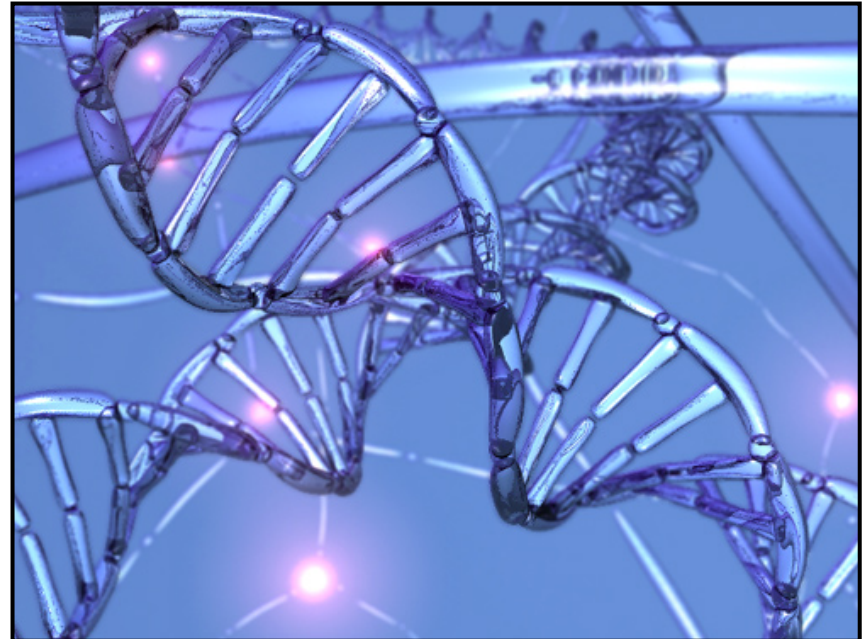
- natural selection **selects for or against** different versions of traits (that arise because of different mutations accumulating in DNA over time) in differing environments
- different adaptations allow different organisms to survive in different environments



Evolution explains unity & diversity

The best evidence of a common descent for all life is found in the universality of the genetic code.

ALL living organisms, from bacteria to humans, use nucleic acids in the form of DNA to store and transmit hereditary information.



Form fits function

- The alignment of **structure** & **function** is seen at all levels of biology (*These adaptations arose because of natural selection taking place over many generations*)

Wings are aerodynamic to create lift



Bones are hollow for light weight

Far reaching neurons send signals to muscles



Mitochondria have extensive surface area to make energy

Give it a try... “Form Fits Function”

The idea that form and function are related would be exemplified by which of the following examples?

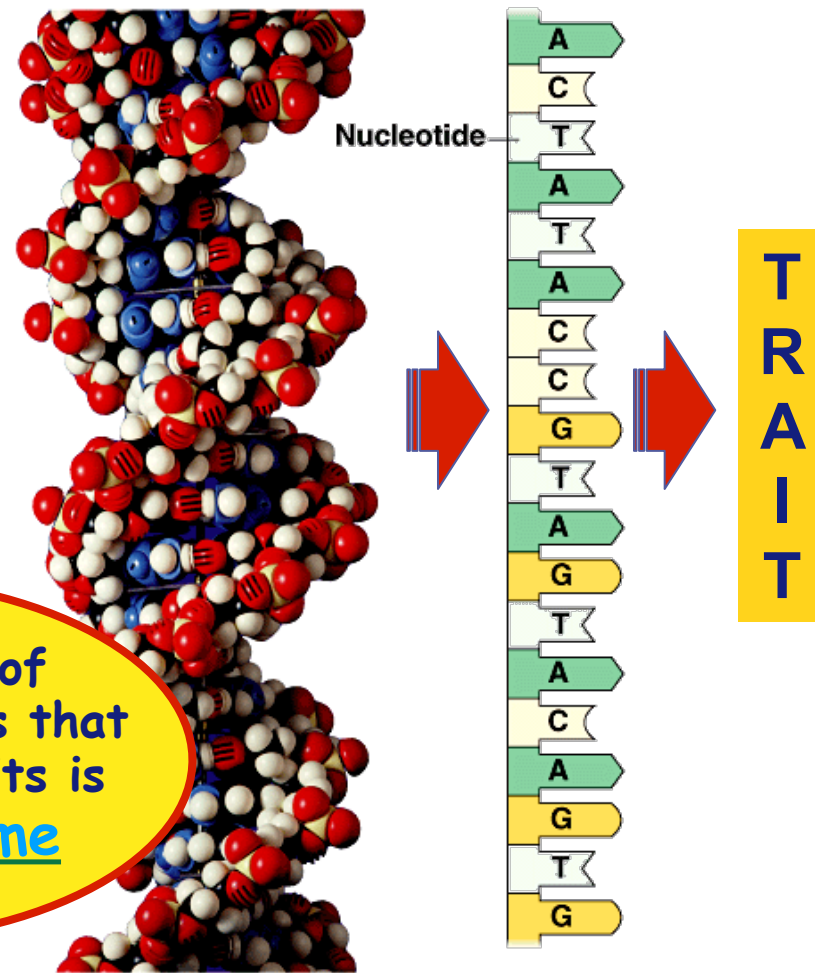
- A. Cells in the intestinal lining of vertebrates have many small projections that increase the surface area for absorption of nutrients.
- B. Plants that live in dry areas have large roots for absorbing water.
- C. Seeds that are dispersed by wind are very light.
- D. Fish that swim rapidly have bodies that are streamlined.
- E. All of the above.

Through natural selection, populations come to be dominated by adaptations, favorable characteristics that increase survivability and reproductive success.



Continuity & Change

- Continuity of life is based on heritable information in the form of DNA being passed down to each cell.
 - ◆ DNA – the genetic material – carries biological information from one generation to the next.
 - ◆ The blue print of an organism, it is only variations in the sequence of nucleotides (the building blocks of DNA) that reflect differences between organisms.



The entire set of genetic instructions that an organism inherits is called its genome

