

Learning Unit	
Subject	Science
Title	Biological Evolution - Evolutionary Theories
Author	Ivone Gonçalves Carvalho
School	FORAVE – Associação para a Educação Tecnológica do Vale do Ave
Description of the unit	<p>In this unit, students are expected to:</p> <ul style="list-style-type: none"> ● Explain biological diversity based on models and theories accepted by the scientific community. ● Interpret concrete situations in the light of Lamarckism, Darwinism and from the Neo-Darwinist perspective. ● Explain biological diversity based on models and theories accepted by the scientific community.
Contents	<ul style="list-style-type: none"> ● Fixism ● Evolutionism ● Lamarck's evolutionary theory ● Law of use and disuse ● Law of inheritance of acquired characteristics ● Darwin's evolutionary theory ● Neo-Darwinism ● Mutations ● Genetic recombination
Learning Outcomes / Skills	<p>Students should be able to:</p> <ul style="list-style-type: none"> ● Understand the evolution of species over time. ● Understand the prevalence and elimination of mutations. ● Understand the role of the environment in biological evolution.
Target students/class	Secondary school (15 – 17 years old)
Prerequisites	<p>Students have a good knowledge of:</p> <ul style="list-style-type: none"> ● All living beings are made up of cells. ● Awareness of the biodiversity present in the Biosphere. ● Prokaryotic and eukaryotic cell anatomy. ● Scientific method.



Learning Unit	
Time expected	5 hours
Interdisciplinary links	Science ICT
Methodology	Group work Problem solving
Human Resources (internal and/or external)	Science teacher ICT teacher
Resources	Worksheets, PowerPoint, Videos, computer with Internet access
Lesson Plan	<p style="text-align: center;"><u>Lessons 1 and 2 (2 hours)</u></p> <p>Objectives Explain biological diversity based on models and theories accepted by the scientific community.</p> <p>Strategies</p> <ul style="list-style-type: none"> ● Discussion of the question on slide 2 of the PowerPoint multimedia presentation: Biological Evolution. ● Exploration of slides related to fixism and evolutionism in the multimedia presentation PowerPoint: Biological Evolution. ● Video exploration https://www.youtube.com/watch?v=x73bsC7WIsE <p>Pedagogical resources</p> <ul style="list-style-type: none"> ● PowerPoint: Biological evolution ● Video: https://www.youtube.com/watch?v=x73bsC7WIsE <p>Technological Resources</p> <ul style="list-style-type: none"> ● Computer ● Internet ● Multimedia projector <p style="text-align: center;"><u>Lessons 3 and 4 (2 hours)</u></p>



Learning Unit

Objectives

Interpret and explore concrete situations of Darwinism through the use of a virtual simulator.

Strategies

- Carrying out a practical activity: simulation of the evolution of a population of rabbits subject to various factors of evolution, over time, through the exploration of the interactive simulator “Natural Selection”, on the PhET platform.

Pedagogical resources

- Statement of the practical activity.
- Interactive simulator “Natural Selection”, from the PhET platform.

Technological Resources

- Computer
- Internet

Lesson 5 (1 hour)

Objectives

Explain biological diversity based on models and theories accepted by the scientific community.

Strategies

- Exploration of slides on neo-Darwinism from the PowerPoint multimedia presentation: Biological evolution.
- Worksheet and application of what was learnt.

Pedagogical resources

- PowerPoint: Biological evolution.
- Worksheet and application of what was learnt.

Technological Resources

- Computer
- Multimedia projector



Learning Unit	
21st Century Skills	<ul style="list-style-type: none"> - Critical thinking: students will critically analyse data related to evolutionary theories. - Problem solving: students will solve situations associated with natural selection by testing hypotheses defined by themselves. - Collaboration: they will collaborate in groups in the biology lesson. - Communication: students will communicate with each other by sharing ideas and solving problems. - Media and technological skills: students will have to manipulate a virtual simulator.
Assessment	<p>Summative Assessment:</p> <ul style="list-style-type: none"> ● Practical activity: simulation of the evolution of a population of rabbits subject to various evolutionary factors, over time, through the exploration of the interactive simulator “Natural Selection”, on the PhET platform. ● Participation, interest, commitment; capacity for synthesis and analysis. ● Formative Assessment: ● Verification and application of what was learnt.
Remarks	-



Biological Evolution





How can we explain the origin of biodiversity?

Did the species emerge as we know them today and remain unchanged over time, or are they the result of a slow and progressive change?

Fixism

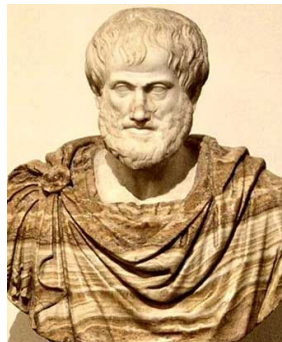
- Until the 19th century, fixism was the dominant conception to explain the origin of biodiversity.



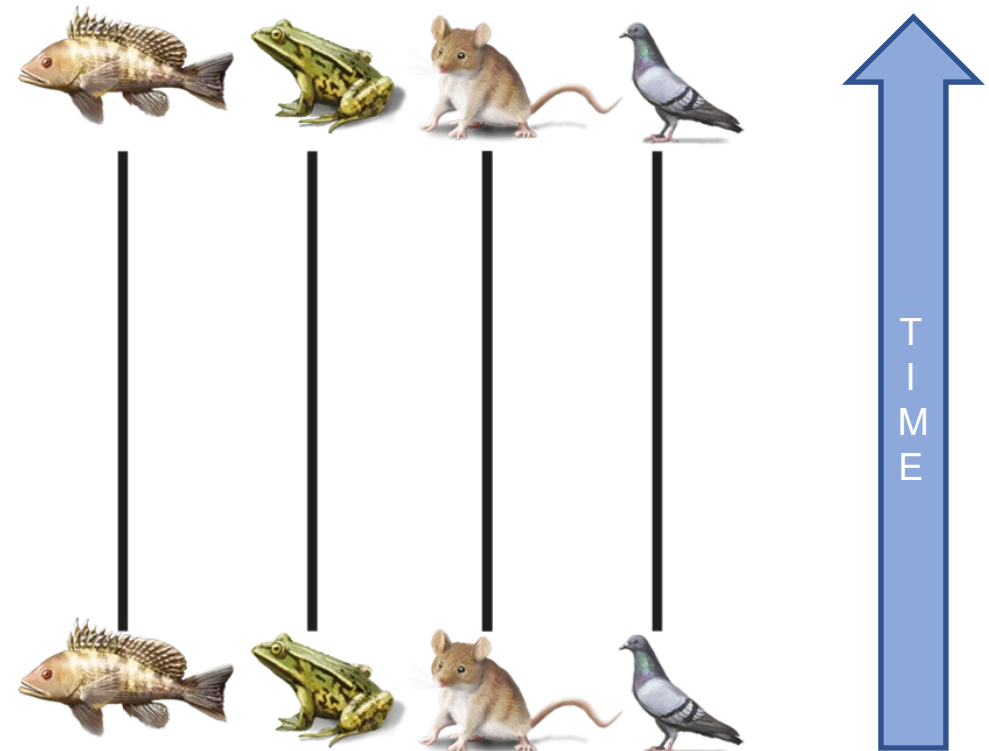
This conception argued that species remained unchanged since their creation, that is, they were fixed and immutable, therefore they did not undergo evolution.



Strongly influenced by religion and philosophy.



Aristotle



Fixism

- Within fixism, several theories are accepted to explain the origin of living beings. There are two that marked and define the principle of fixism: **Theory of Spontaneous Generation** and the **Principle of Creationism**.



The Theory of Spontaneous Generation postulated by Aristotle states that organisms arise spontaneously from non-living matter through the action of an active principle.



“... Compress a woman’s shirt, preferably a little dirty, into a vase with wheat. After 21 days, the yeast in female sweat transforms the grain into rats.”

Van Helmont (1648)

Fixism

- Within fixism, several theories are accepted to explain the origin of living beings, we highlight two that marked and define the principle of fixism: **Theory of Spontaneous Generation** and the **Principle of Creationism**.

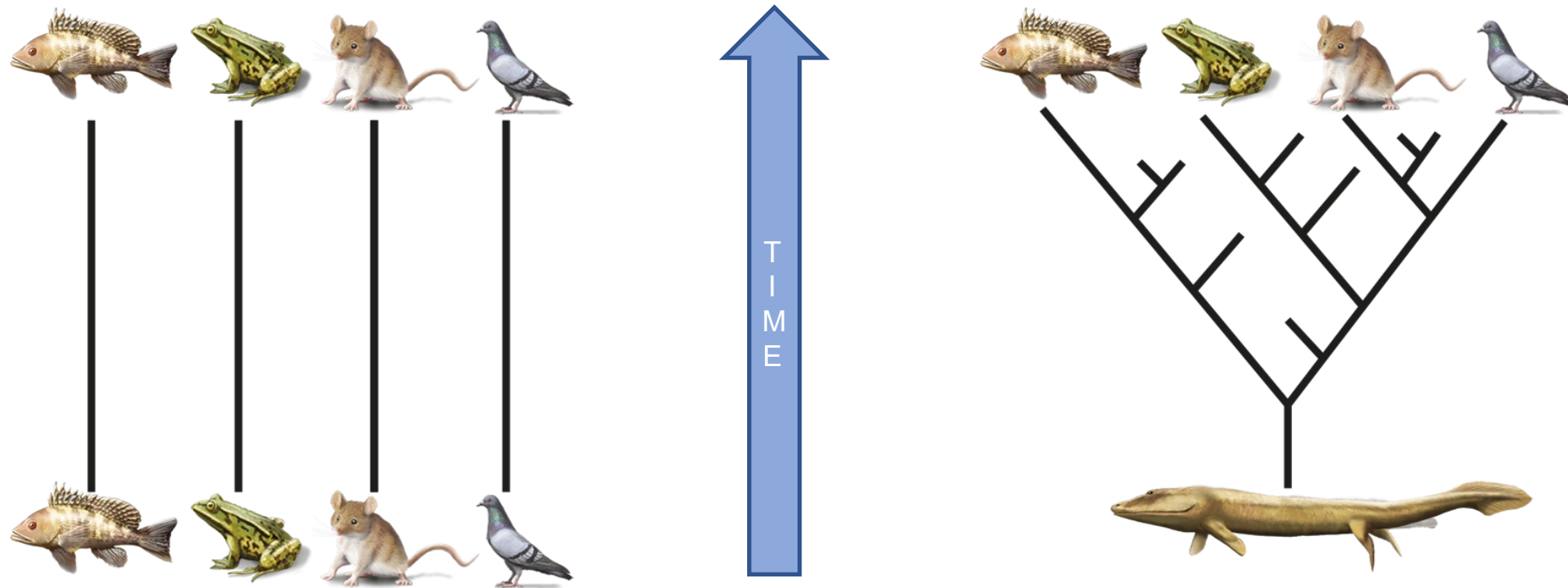


The Principle of Creationism or Creationism postulates that living beings were originated by divine creation, implying perfection and stability. After the first perfect species were created, they remained fixed over time. The imperfections that occur are sometimes due to the imperfection and corruption of the World.



Evolutionary theories

- From a vision of Nature that is immutable and governed by **fixed principles**...



... over the years, we move to a model that considers Nature **to be variable**.

Evolutionary theories

- In the middle of the 18th century, the first data and observations that began to emerge would call fixism into question. Geology was the science that contributed most to evolutionary ideas. The appearance of fossils of organisms very different from those of today shook up fixist ideas.



Evolutionary theories

- In an attempt to reconcile the data revealed by paleontological studies with fixist ideas, George Cuvier proposed the **Theory of Catastrophism**.



A succession of catastrophes occurred during Earth's history, leading to the destruction of living beings there. These areas would later be repopulated by living beings that migrated from other locations.



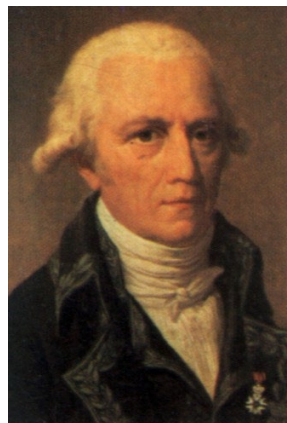
Cuvier

Evolutionary theories

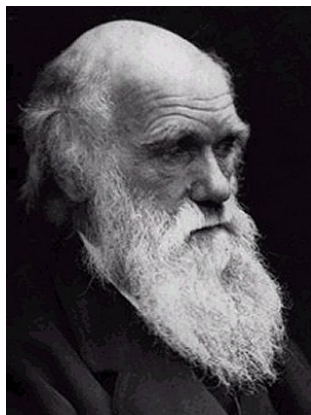
- At the beginning of the 19th century, **evolutionism** ended up imposing itself as a paradigm of the origin and diversity of species.



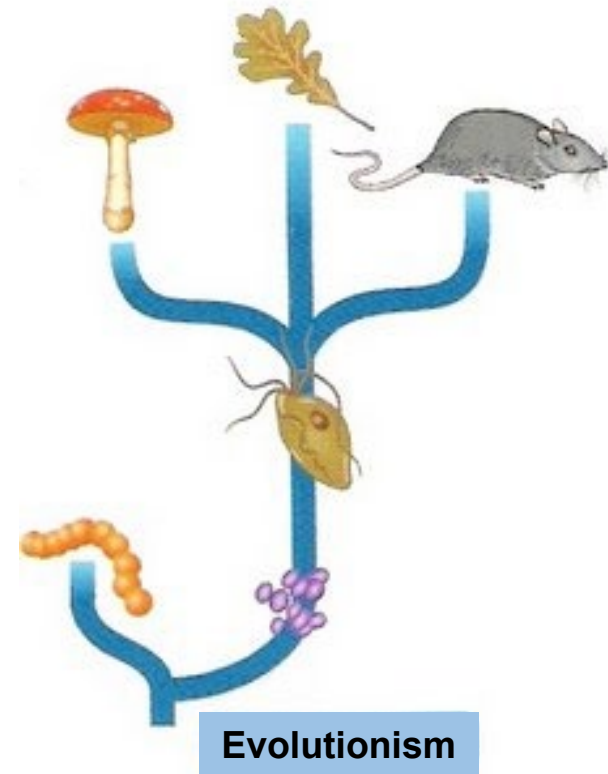
- ✓ It admits that species change slowly and progressively over time, giving rise to new species.
- ✓ **Species evolved** from other preexisting species (common ancestor).
- ✓ Important contribution from **Geology** (Paleontology and Stratigraphy).
- ✓ It caused an environment of great **controversy**.



Lamarck



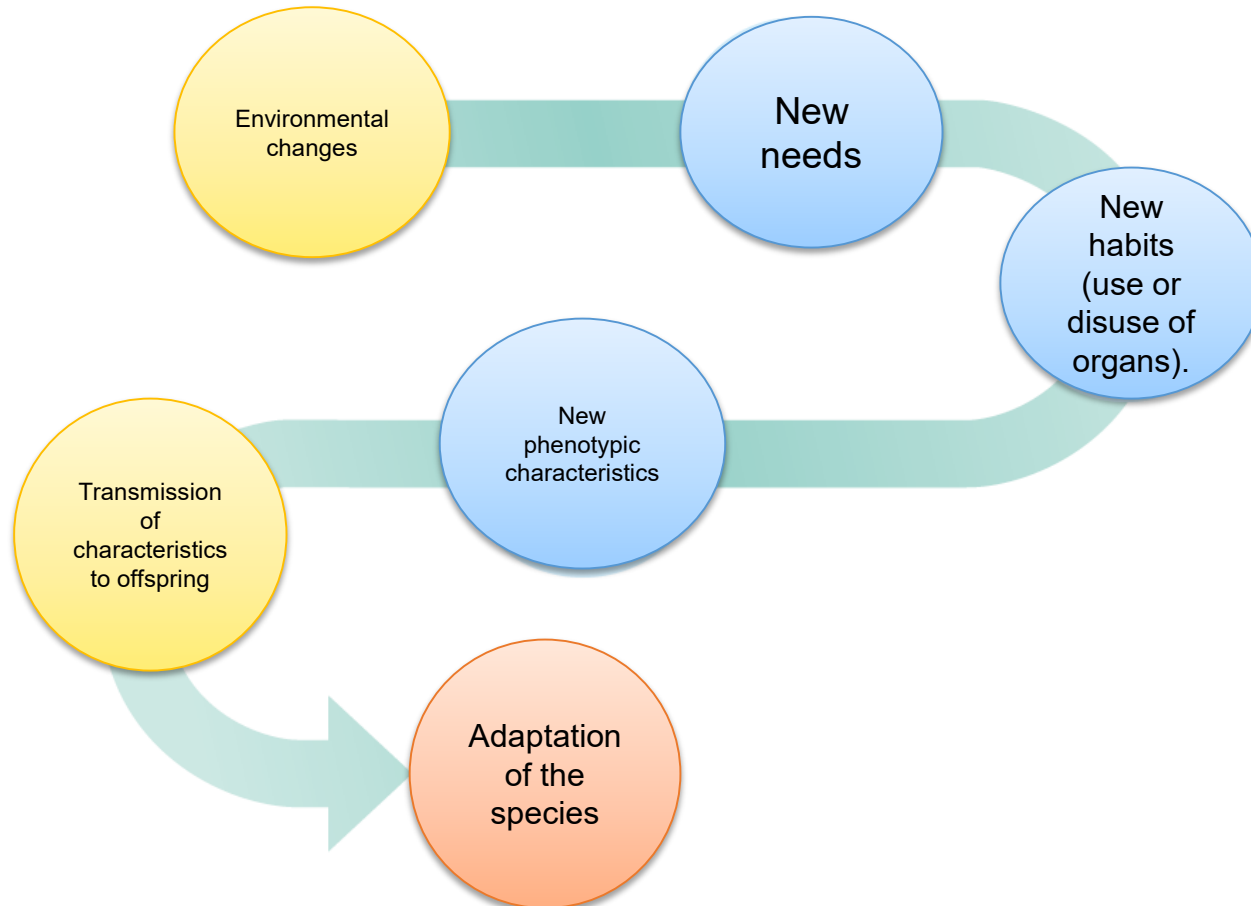
Darwin





Lamarck's evolutionary theory

- In 1809, Lamarck formulated an explanation of the mechanism by which species evolve over time.
- For Lamarckism, changes in the environment create in organisms the need to develop structures that allow them to adapt to new conditions.
- According to this conception, variations in organisms occur according to **the law of use and disuse** of organs and **the law of transmission of acquired characteristics**.



Lamarck's evolutionary theory

- **Law of use and disuse**

The continued use of a structure, an organ, or a faculty, leads to its development. The lack of use of a given structure or organ leads to its atrophy and, eventually, its disappearance.

- **Law of transmission of acquired characteristics**

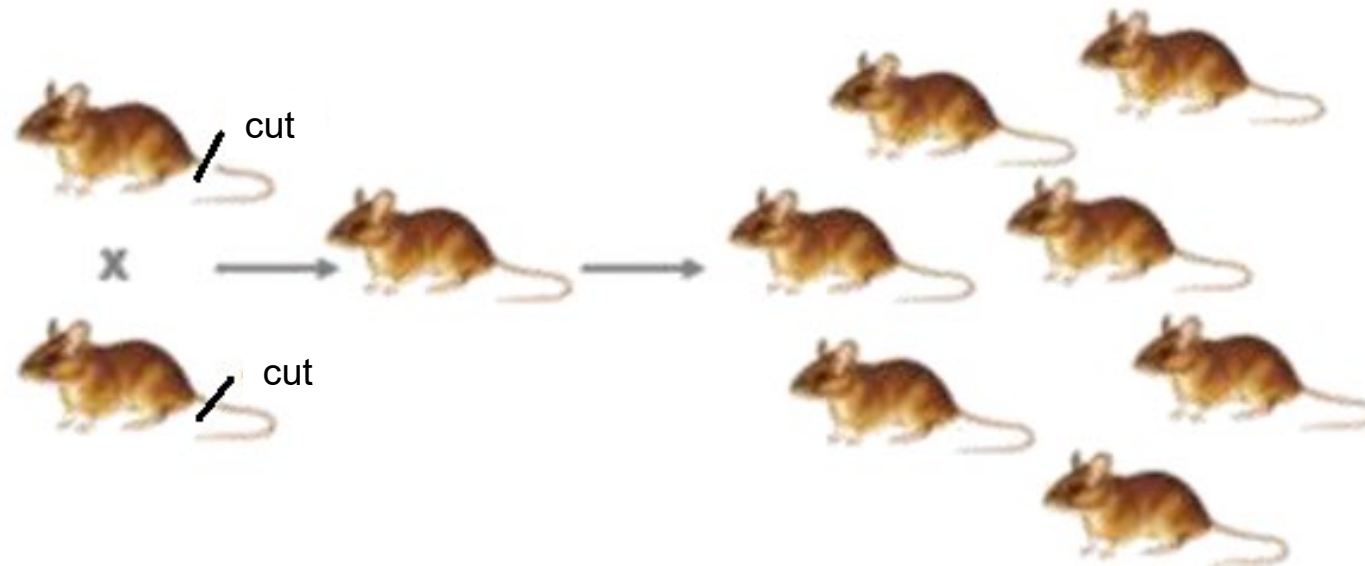
The characteristics developed by organisms, as a result of the use or disuse of an organ, are transmitted to their descendants.

Lamarck's evolutionary theory – reasons not to be accepted

- The law of use and disuse, although valid for some organs, such as muscles, did not explain all changes.
- The law of transmission of acquired characteristics is not valid. Atrophy or hypertrophy of a structure acquired during the life of a living being is not transmitted to offspring.



Virchow

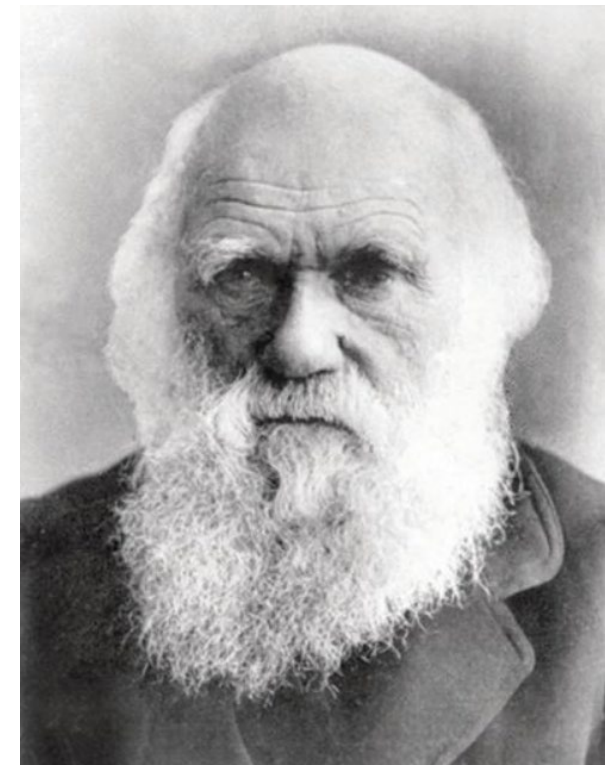


Darwin's evolutionary theory

- In 1831, **Charles Darwin** embarked on an expedition that would forever change the theory of evolution. It was during this trip aboard the HMS Beagle that Darwin, over the course of **five years**, collected most of the data that he would later use to **support his theory on the origin of species – Theory of Natural Selection.**



Map of Darwin's expedition aboard the Beagle.



Charles Darwin (1809-1882).

Darwin's evolutionary theory

- One of the places that most aroused Darwin's interest were the Galapagos Islands, an archipelago of volcanic islands located in the equatorial zone, close to the Equator.
 - ✓ Finches were important in explaining Darwin's theory because, although they lived on different islands and presented variations in the size, colour and shape of their beaks, they all showed a high similarity to each other, suggesting a **common origin – common ancestor**.



The conditions existing on each island, particularly the availability and variety of food, would have conditioned the evolution of these species and, therefore, presented variations, such as, for example, in the beak.

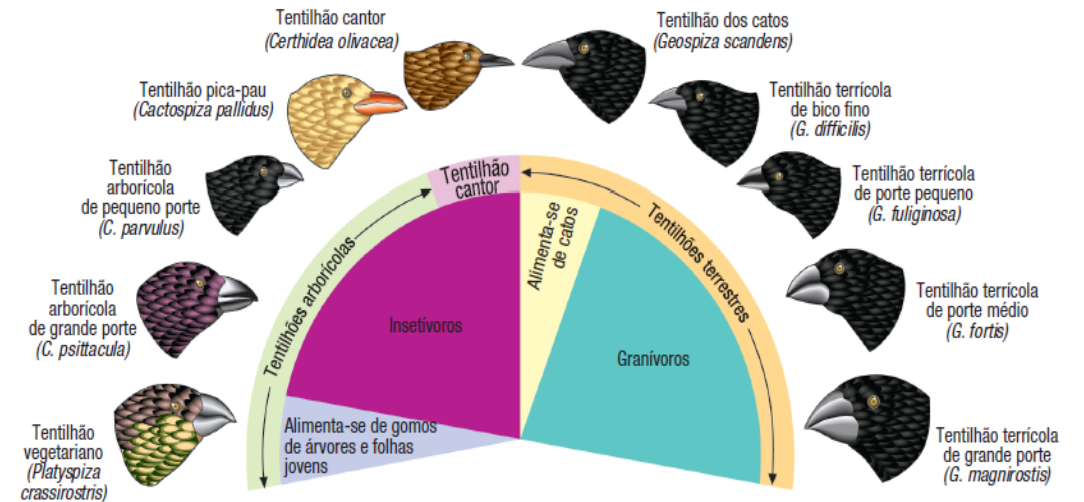
Darwin's evolutionary theory

- Foundations/studies that influenced Darwin:

- ✓ **Biogeography data** – data on the geographic distribution of different species (Darwin's finches, in the Galapagos).



Darwin found that, although the finches on each island differed in size, colour and shape of their beaks, they showed a remarkable similarity to each other, suggesting a **common origin**.



Darwin's evolutionary theory

- Foundations/studies that influenced Darwin:

- ✓ Geology data



During the trip Darwin had the opportunity to read Lyell's work, which profoundly influenced him. Lyell defended Uniformitarianism by admitting that the Earth underwent slow and gradual changes.

He also made observations of fossils: he found several fossils of marine animals in the Andes, thousands of meters above sea level (proving that the Earth undergoes slow and gradual transformations).



Darwin's evolutionary theory

- Foundations/studies that influenced Darwin:

✓ Demography data

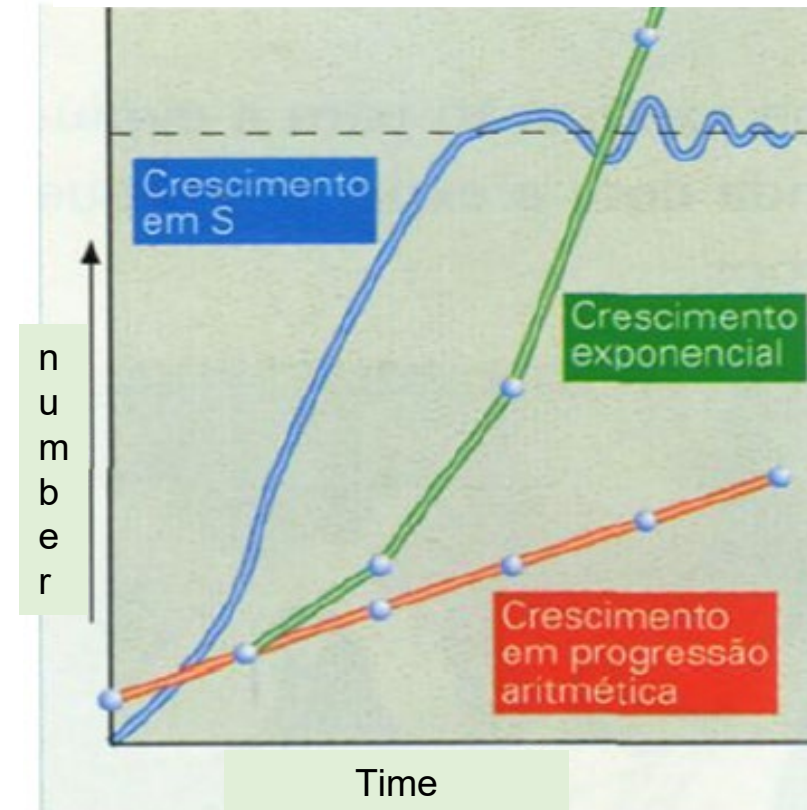


Studies by economist Thomas Malthus (defended by Darwin) stated that the size of the human population tends to grow exponentially, while resources are produced arithmetically.

Thus, given the competition for limited resources, predators and diseases, a large number of individuals die in the **fight for survival.**

Population = exponential growth

Food resources = growth in arithmetic progression



Darwin's evolutionary theory

- Foundations/studies that influenced Darwin:
 - ✓ Intraspecific variability



Darwin verifies that there is a wide variety of living beings and that there is variability within each species (beings with different characteristics/aspects) – existence of **intraspecific variability**.



Darwin's evolutionary theory

- Foundations/studies that influenced Darwin :

✓ Artificial selection



Darwin's experience as a pigeon breeder made him realize that it was possible, using controlled crossings, to select a set of desired characteristics. And that, after a few generations, animal populations had been subjected to artificial selection and would be different from the initial populations.



Darwin's evolutionary theory

- Fundamentações/estudos que influenciaram Darwin:

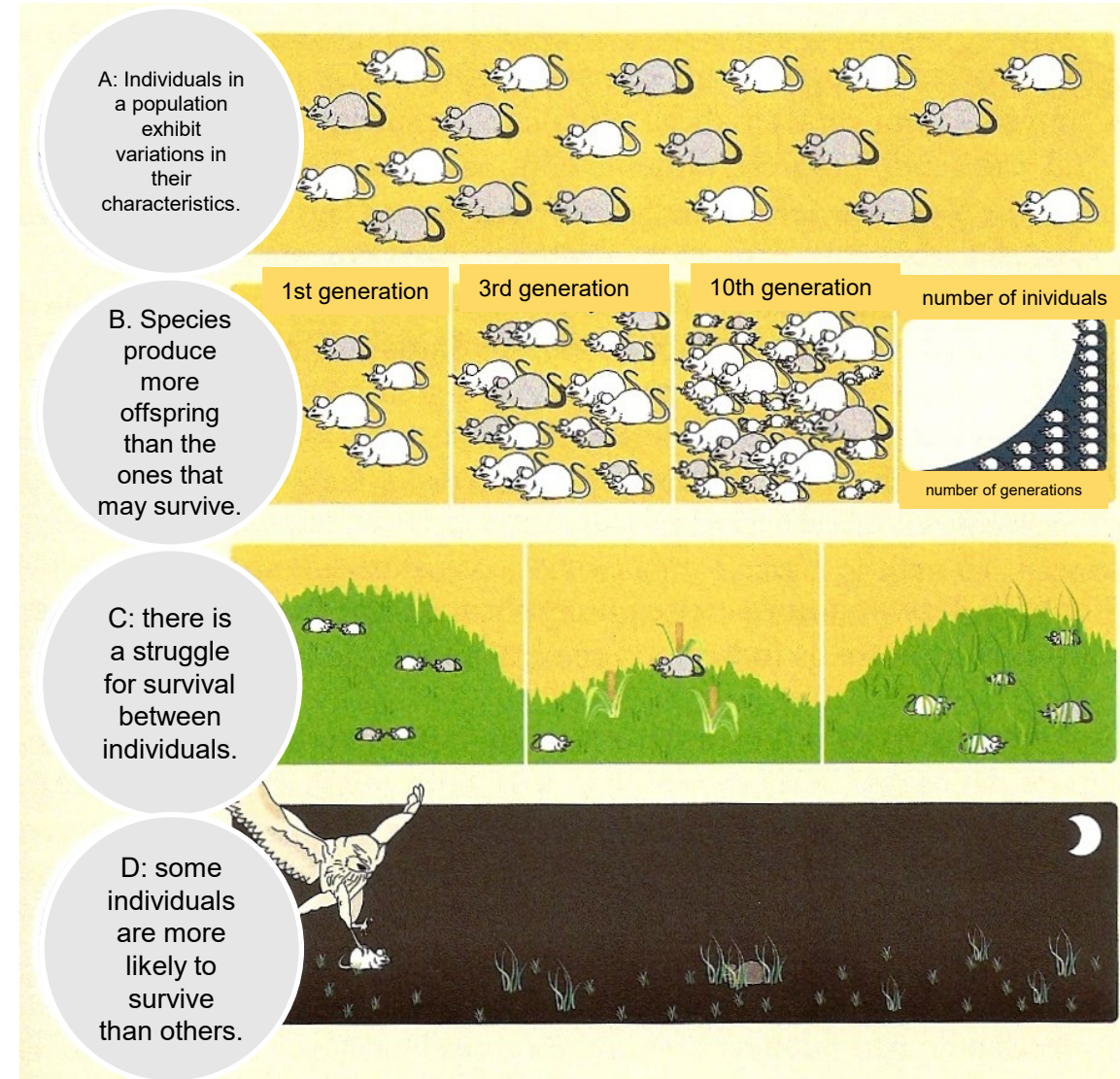
✓ Natural selection



Darwin admitted that, similar to what happens with animal breeders, Nature makes a selection of reproductive individuals, with the difference that it is **environmental factors that control this natural selection**.

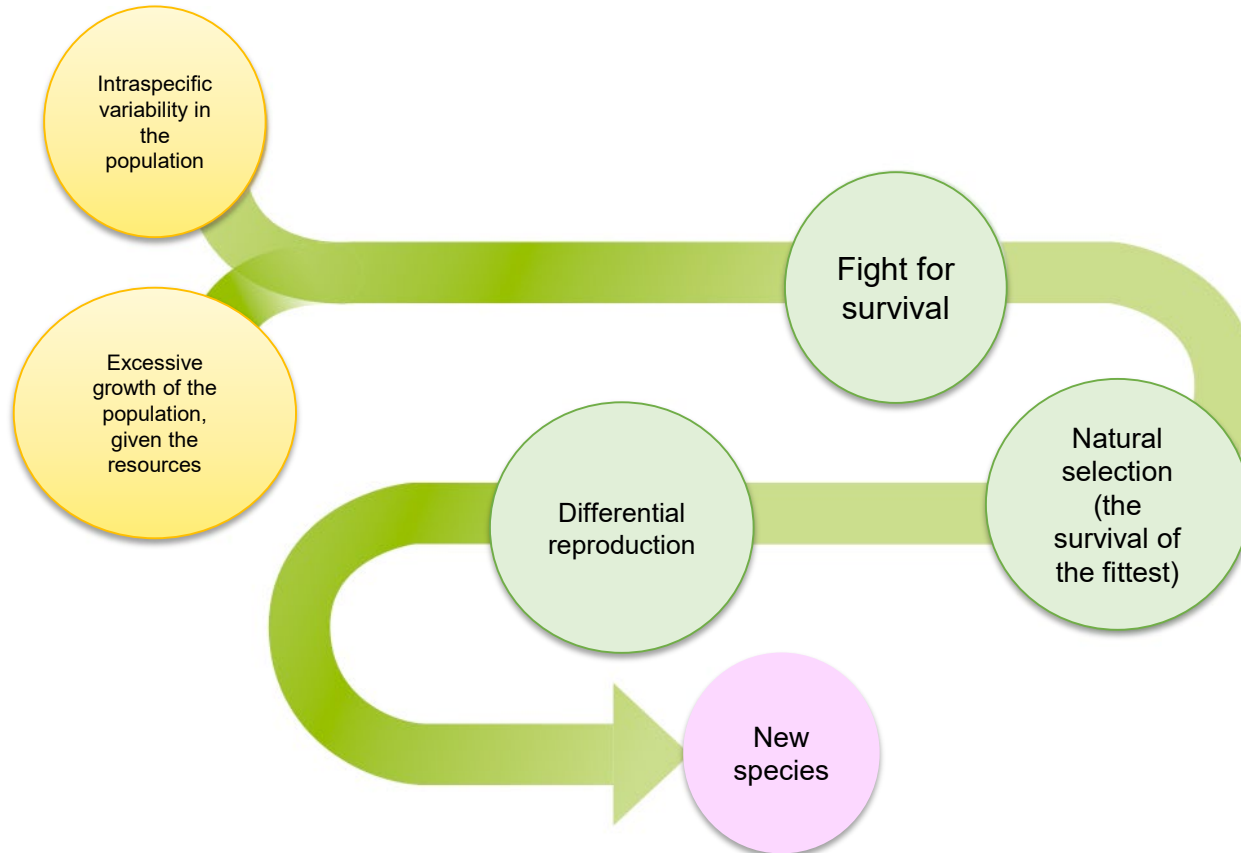


Process in which individuals with certain characteristics, which provide them with better adaptation to the environment in which they live, have higher survival and reproduction rates than other individuals without these characteristics.



Darwin's evolutionary theory

- The **theory of species evolution** proposed by Darwin is based on the following principles:
 - ✓ **Intraspecific variability;**
 - ✓ **Fight for survival;**
 - ✓ **Survival of the fittest (with advantageous characteristics);**
 - ✓ **Natural selection;**
 - ✓ **Differential reproduction (the fittest reproduce more).**

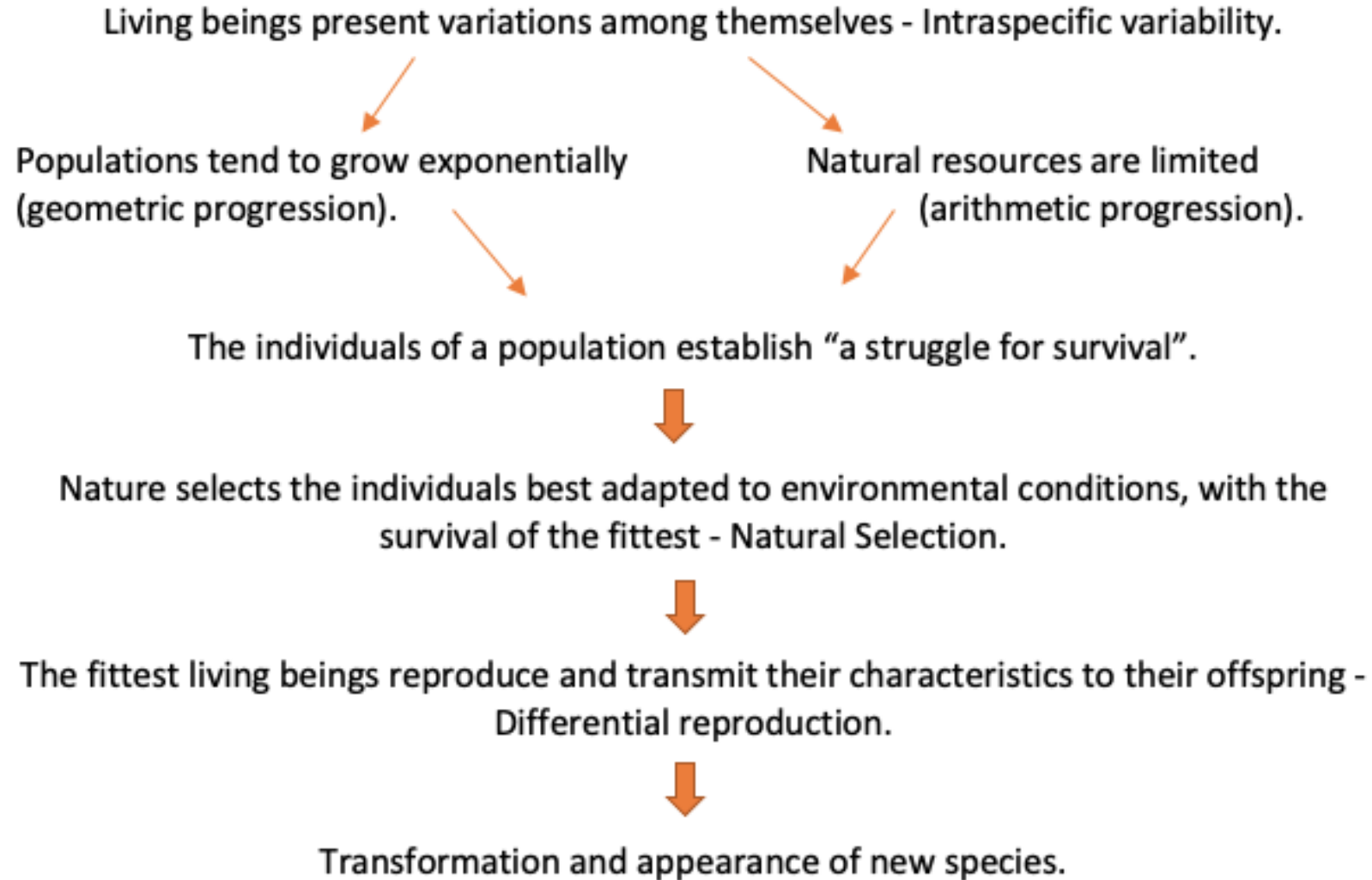


Darwin's evolutionary theory

- The evolution of giraffes according to Darwin.



Darwin's evolutionary theory

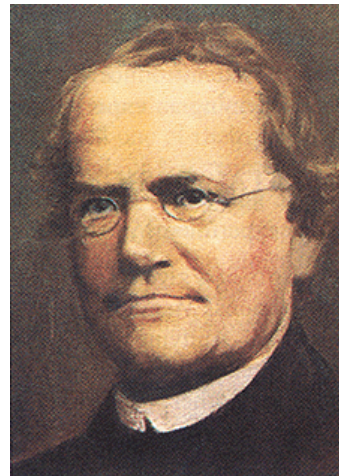


Darwin's evolutionary theory – what is not explained?

- Questions **not explained by Darwinism**
 - ✓ How do “natural variations” arise in individuals of a given species?
 - ✓ How are these variations transmitted to the next generation?



Although Darwin had a letter sent by **Mendel** on his desk, in which he presented his first ideas about heredity, he did not value them.



Comparison between Lamarck and Darwin's theories

Lamarck	Darwin
The environment creates needs that induce changes in the habits and forms of individuals.	The environment exerts natural selection that favours individuals with the most appropriate characteristics for a given environment and at a given time.
New characteristics are achieved through the repeated use or disuse of an organ or part of the body.	Within a population, certain individuals present characteristics that give them better adaptation in relation to others.
Acquired characteristics are passed on to descendants.	The fittest live longer, reproduce more and pass on their characteristics to their offspring.



Comparison between Lamarck and Darwin's theories

	Lamarckism	Darwinism
Middle role	Modifying agent	Selecting agent
Starting point	Homogeneous population	Population with intraspecific variability (heterogeneous)
Evolutionary unit	Individual	Population
Adaptation time	Short (faster because it acts on the individual)	Long (slower because it acts over generations)

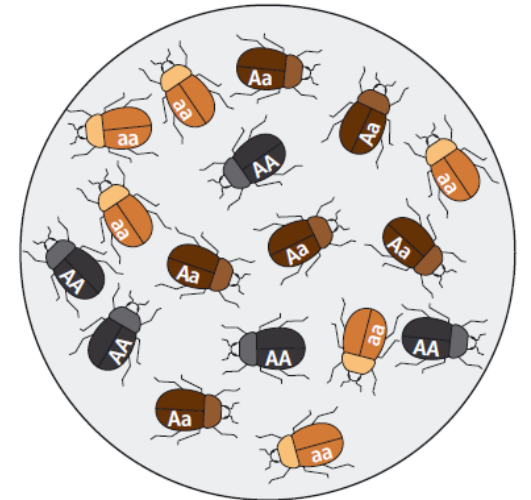


Neo-Darwinian theory of evolution

- In the 20th century, the synthesis of Darwinism with knowledge in **genetics** led to the development of a theory known as **neo-Darwinism**, or **synthetic theory of evolution**.
- According to **neo-Darwinism**, **intraspecific variability** is the result of:



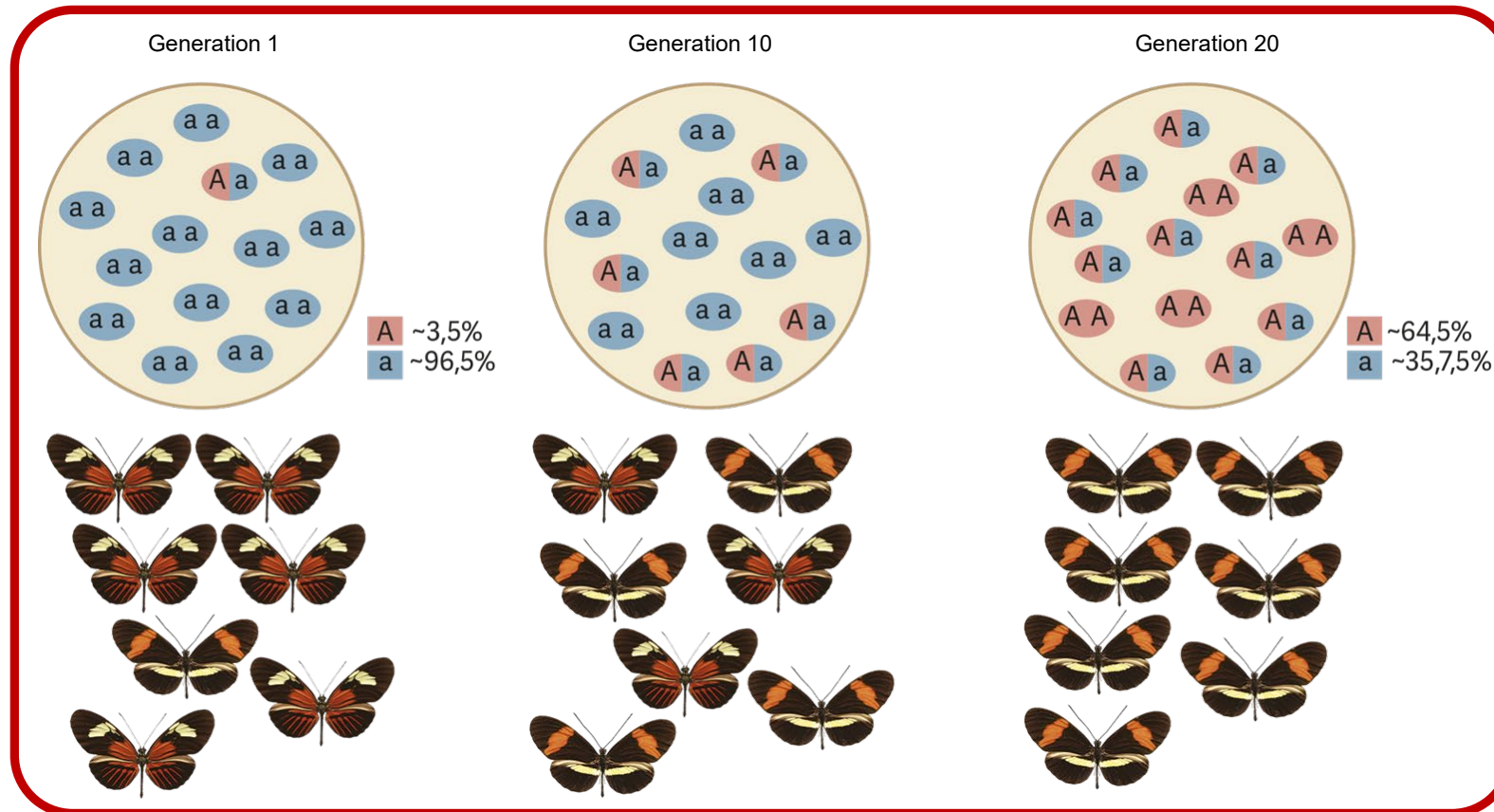
✓ **Genetic recombination** – resulting from **crossing-over** between homologous chromosomes and the **random separation of homologous chromosomes during meiosis**, which leads to the appearance of unique combinations of genes. The **random union of gametes during fertilization** also contributes to the appearance of individuals with unique characteristics in the population.



✓ **Mutations** – appearance of **new genes** that result in new characteristics.

Neo-Darwinian theory of evolution

According to neo-Darwinian theory, organisms in a population carry sets of genes. At a given moment, the totality of these genes constitutes the **genetic background** of the population.

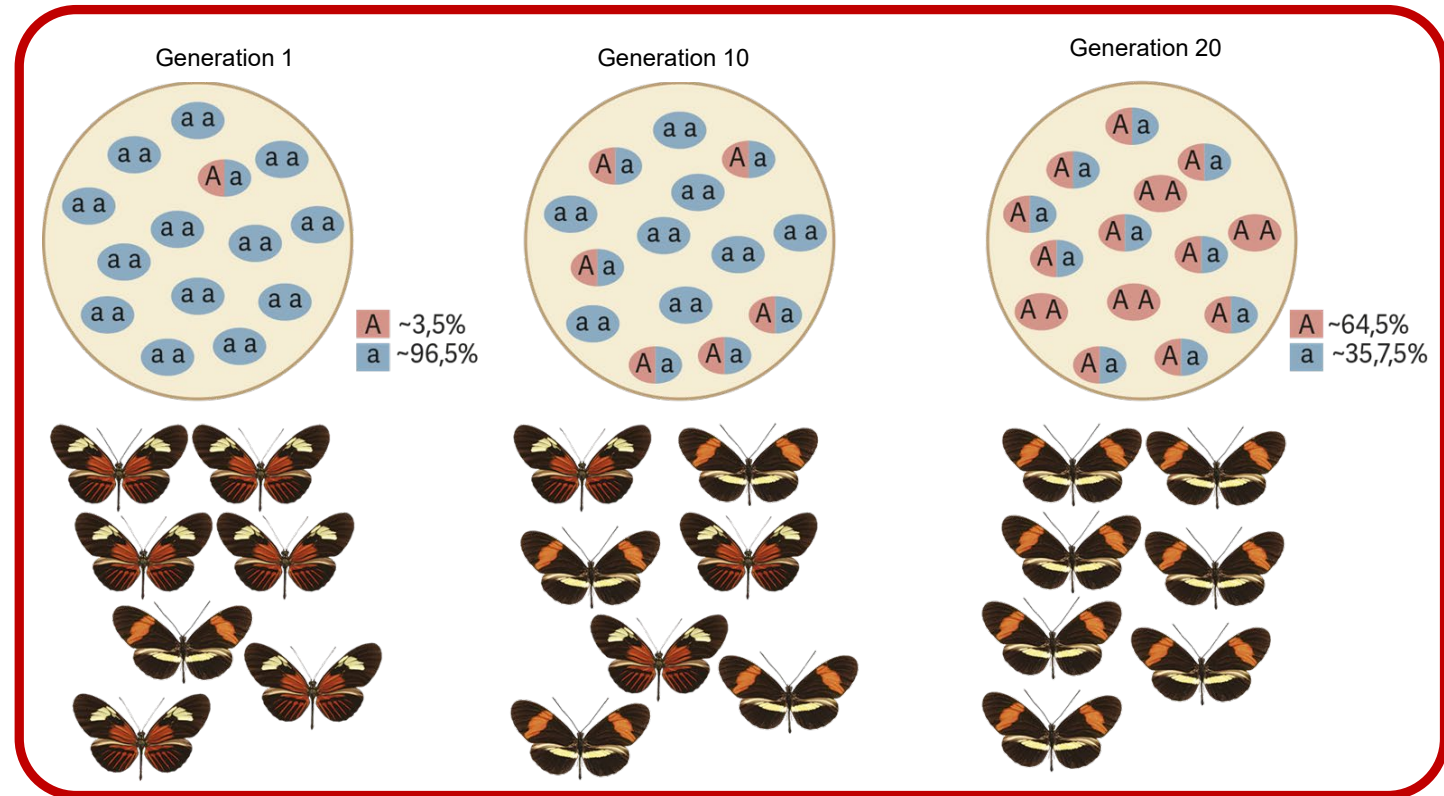


Neo-Darwinian theory of evolution

- Once **natural selection** acts on the individuals of a population, the fittest produce more offspring, resulting in greater passage to the following generations of genes that confer greater capacity for adaptation to the environment.



In this way, natural selection changes the genetic background of the population over generations, leading to the emergence of new species.



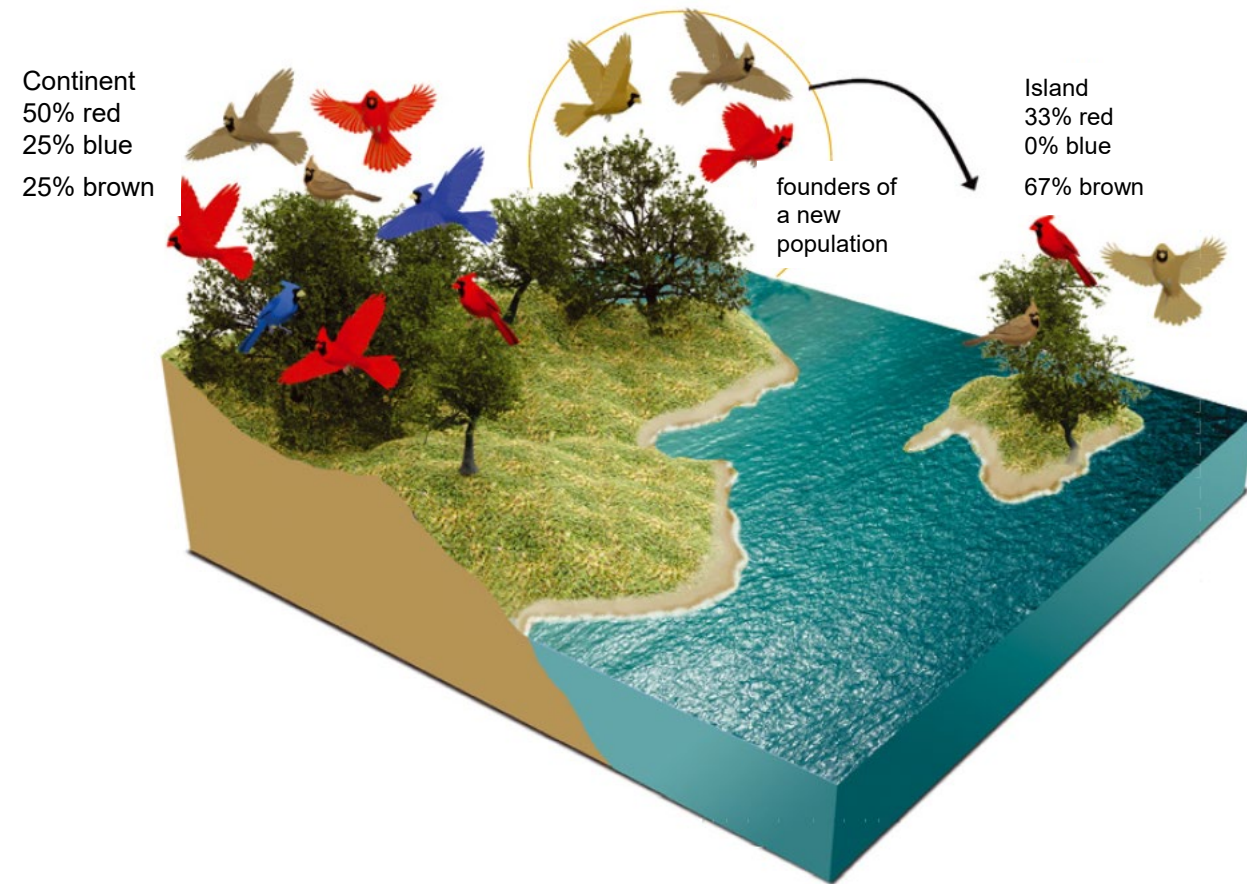
Neo-Darwinian theory of evolution

- In addition to others, there are two main mechanisms that **cause changes in the genetic background** of populations: **natural selection** (already analyzed in the previous slide) and **genetic drift**.



Genetic drift – variations in the genetic background of a population, which occur as a result of **random events**.

For example: when some individuals randomly isolate themselves from a large population, and establish a new population with a different genetic background comparing to the original population.



Biological Evolution



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Simulation of the evolution of a population of rabbits subject to different evolutionary factors

Introduction

This activity suggests the simulation of the evolution of a population of rabbits subject to various evolutionary factors over time.

Material

- Computer/tablet
- Interactive simulator «Natural Selection», from the PhET platform

PART A – Analysis of the simulation panel

PROCEDURE (part A)

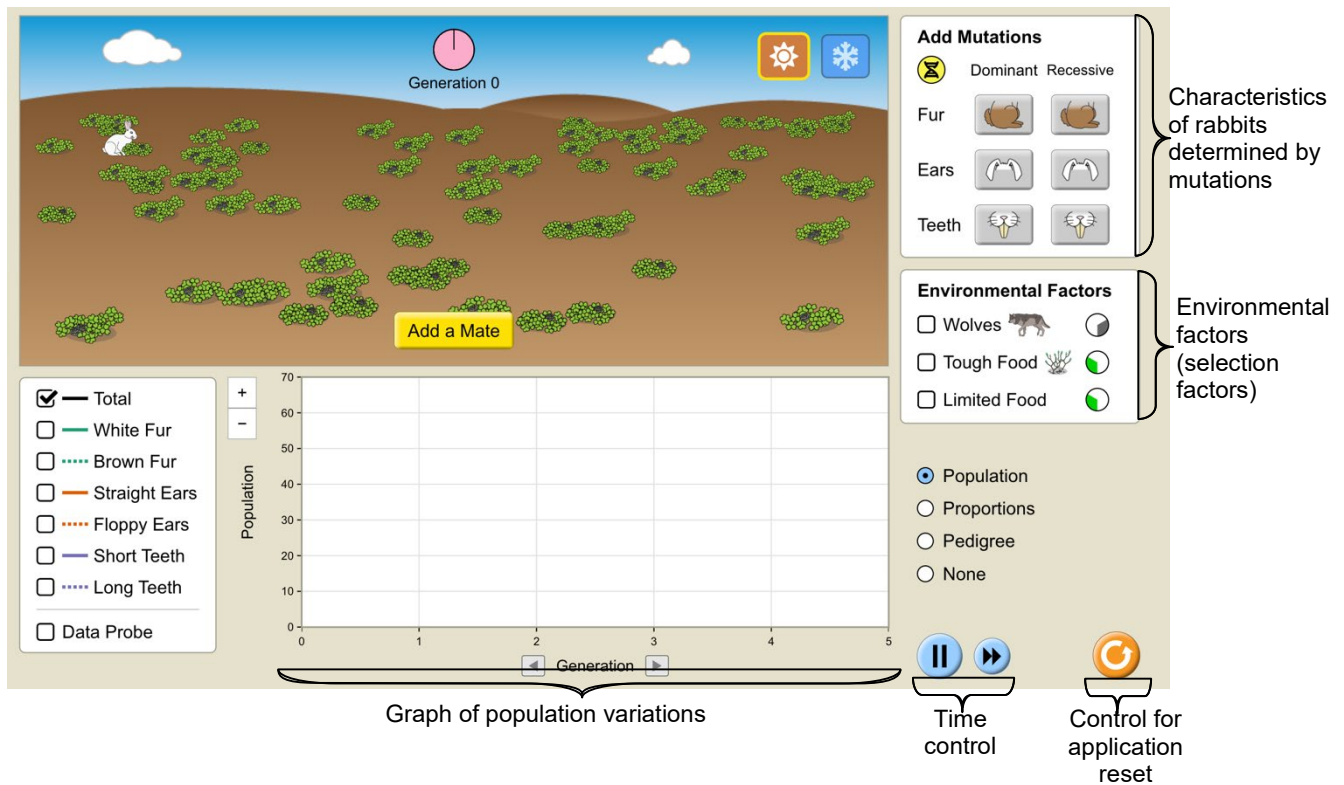
1. Access the “Natural Selection” simulator, through the link <https://phet.colorado.edu/en/simulations/natural-selection?>

This simulator allows the visualization of a rabbit population and its changes over generations when exposed to population control situations, limiting factors, such as the presence of predators and the amount of food available.

2. Click *Play*.

3. Click *Lab* and **explore** the simulation controls, in order to understand their meaning (Pic. 1).





Pic. 1 Simulation panel.

Note: The genotype is the gene responsible for a given characteristic while the phenotype refers to the observable characteristics of an organism or a population that result from the expression of the genotype, the influence of environmental factors and the possible interaction between the two.

DISCUSSION (part A)

1. **Indicate** the variables that you can control in the simulation.
2. How do brown rabbits emerge from light-coloured populations?
3. **Identify** the three mutations you can add to your rabbit population.

PART B – How is “fur colour” influenced by the existence of predators according to natural selection?

PROCEDURE 1 (part B)



2. **Set** the habitat to “warm climate”.



3. In the «Add mutations» area, **click** on the button corresponding to the trait «Brown fur», determined by a dominant allele.
4. **Click** “Add companion”.



DISCUSSION 2 (parte B)

1. **State** the predominant type of fur in the rabbit population, “white fur” or “brown fur”, over the three generations (suggestion: use the “Proportions (%)” option to access the data that supports your answer and write them down in table I).

Table I

Generations Phenotypes	Generati on 0	Generati on 1	Generati on 2	Generati on 3
% White fur				
% Brown fur				
Number of rabbits				

2. **Predict** what will happen to the proportions of white-furred rabbits and brown-furred rabbits, respectively, if a wolf-type predator appears.

PROCEDURE 2 (part B)



DISCUSSION 2 (part B)

1. **Complete** table II using the “Proportions (%)” option to access the data.

Table II

Generations Phenotypes	Generati on 4	Generatio n 5	Generatio n 6	Generati on 7



% White fur				
% Brown fur				
Number of rabbits				

2. **State**, showing evidence and justifying, whether the prediction you presented in the answer to question 2 of discussion 1 (part B) is correct.

3. **Comment** on the statement: *The “brown fur” character of rabbits is determined by an advantageous mutation in a hot environment dominated by wolves.*

4. **Identify** the independent variable in this study.

5. **Predict** the effect of a cooling climate on the habitat of the rabbit population.

PROCEDURE 3 (part B)



DISCUSSION 3 (part B)

1. **State**, justifying, whether the prediction you presented in the answer to question 5 of discussion 2 (part B) is correct.



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Verification and content application worksheet

1. Read the following sentence carefully: “The fish that live in the dark bottom of the oceans are blind”. **Explain** the existence of blind fish according to Lamarckian and Darwinian views.

2. Consider the following statements:

- A. “The grasshopper is green because it lives in the grass.”
- B. “The grasshopper lives in the grass because it is green.”

Identify, justifying, the statement attributed to Lamarck and the statement attributed to Darwin.

3. **Choose** the alternative to fill in the spaces, in order to obtain a correct statement.

3.1. According to _____, species are fixed and immutable entities, which emerged _____ from each other.

- A. [evolutionism] ... [over time].
- B. [evolutionism] ... [independently].
- C. [fixism] ... [independently].
- D. [fixism] ... [over time].

3.2. In relation to the theory of evolution, according to _____ the main force that promotes evolution is _____.

- A. [Lamarck] ... [natural selection].
- B. [Darwin] ... [mutation].
- C. [Lamarck] ... [differential reproduction].
- D. [Darwin] ... [natural selection].

4. Regarding biological evolution, **read** the following statements:

I. The giraffe evolved from ancestors with a short neck, which gradually developed due to the animal's effort to reach the leaves of taller trees.

II. The giraffe's ancestors had necks of varying lengths. After several generations, the group showed an increase in the number of individuals with longer necks, due to natural selection.

III. More adapted individuals leave a greater number of descendants compared to non-adapted individuals.

IV. The characteristics that develop through use are transmitted from generation to generation.

4.1. **Choose** the option that best classifies the previous statements.



- A. Statements I and III are in agreement with Lamarck and II and IV with Darwin.
- B. Statements I and IV are in agreement with Lamarck and II and III with Darwin.
- C. Statements I, II, III and IV are in agreement with Lamarck.
- D. Statements I, II, I II and IV are in agreement with Darwin.

5. Read the following texts carefully (A and B) and **say**, in accordance with evolutionary theories, to whom each text can be attributed.

Text A

If the intensity of rainfall in a region were to decrease, plants would, as a result, need to conserve water. After many years, as the region became more and more desert-like, the plants would pass on the water-saving traits they had acquired to their descendants. This is how plants typical of desert regions such as cacti, would have originated, as they were able to store large amounts of water.


Text B

In general, the more vigorous males, who are more adapted to their place in nature, leave a greater number of offspring. In many cases, however, victory will depend not on general strength, but on the fact that they possess certain special weapons, exclusive to men. A deer without antlers or a rooster without spurs would have little chance of leaving descendants.

Text A - _____

Text B - _____

6. The pictures below represent fundamental aspects of Darwin's theory. **Observe** them carefully.



A) Individuals in a population vary from one another.	B) Some individuals show better adaptation to the environment than others.	C) Less adaptable individuals have less chances of survival and reproduction.	D) Increases the reproductive success of the most adapted individuals, alternating the frequency of individuals in the population.
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6.1. Identify the factor that conditions the survival of individuals in the population in the picture.

6.2. State which mechanism Darwin was unable to explain in his theory of evolution. Identify the picture that represents it.

6.3. Describe, based on the pictures, how natural selection works in this case.

7. Choose the only statement that refers to fixist ideas.

- (A) Populations that inhabit a given environment evolve, adapting to changes in that environment.
- (B) Biodiversity is due to a supernatural act of creation.
- (C) Evolution can occur through mutations that significantly alter the phenotype of the mutants.
- (D) The changes produced in an organism throughout its life as a result of the use of an organ are transmitted to offspring.

8. “The most representative characteristics of whale skin, such as its great thickness, absence of hair, extremely soft skin and extraordinary regenerative capabilities, are much more adapted to the aquatic environment. Today, it is known that these characteristics resulted from the successive loss of several genes present in their terrestrial ancestors.”

Explain, according to the data and from a neo-Darwinist perspective, the current characteristics of whale skin.

