PERNYATAAN SANGKALAN

Evolution & Adaptation

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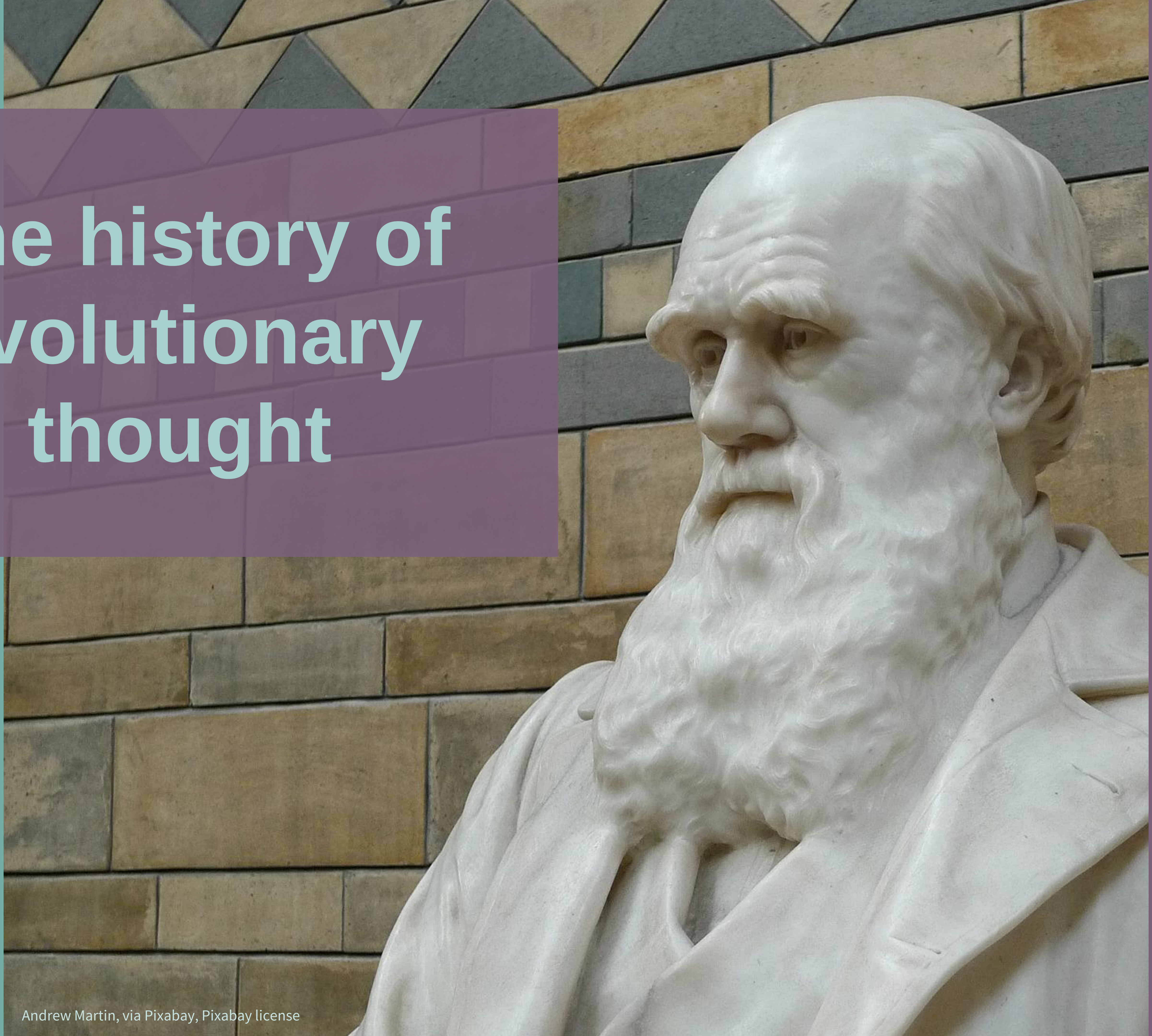
The history of evolutionary thought



01

The history of evolutionary thought

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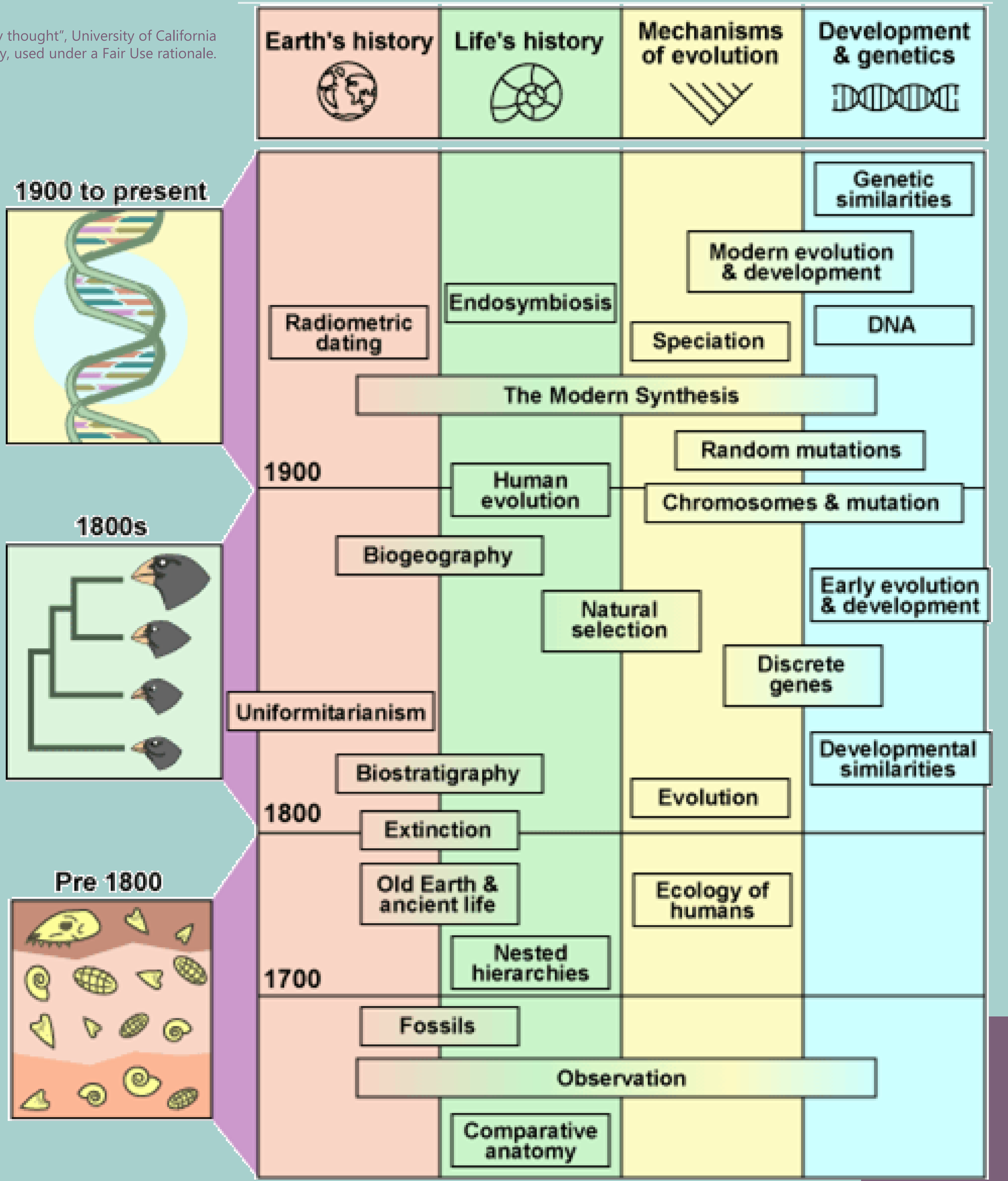

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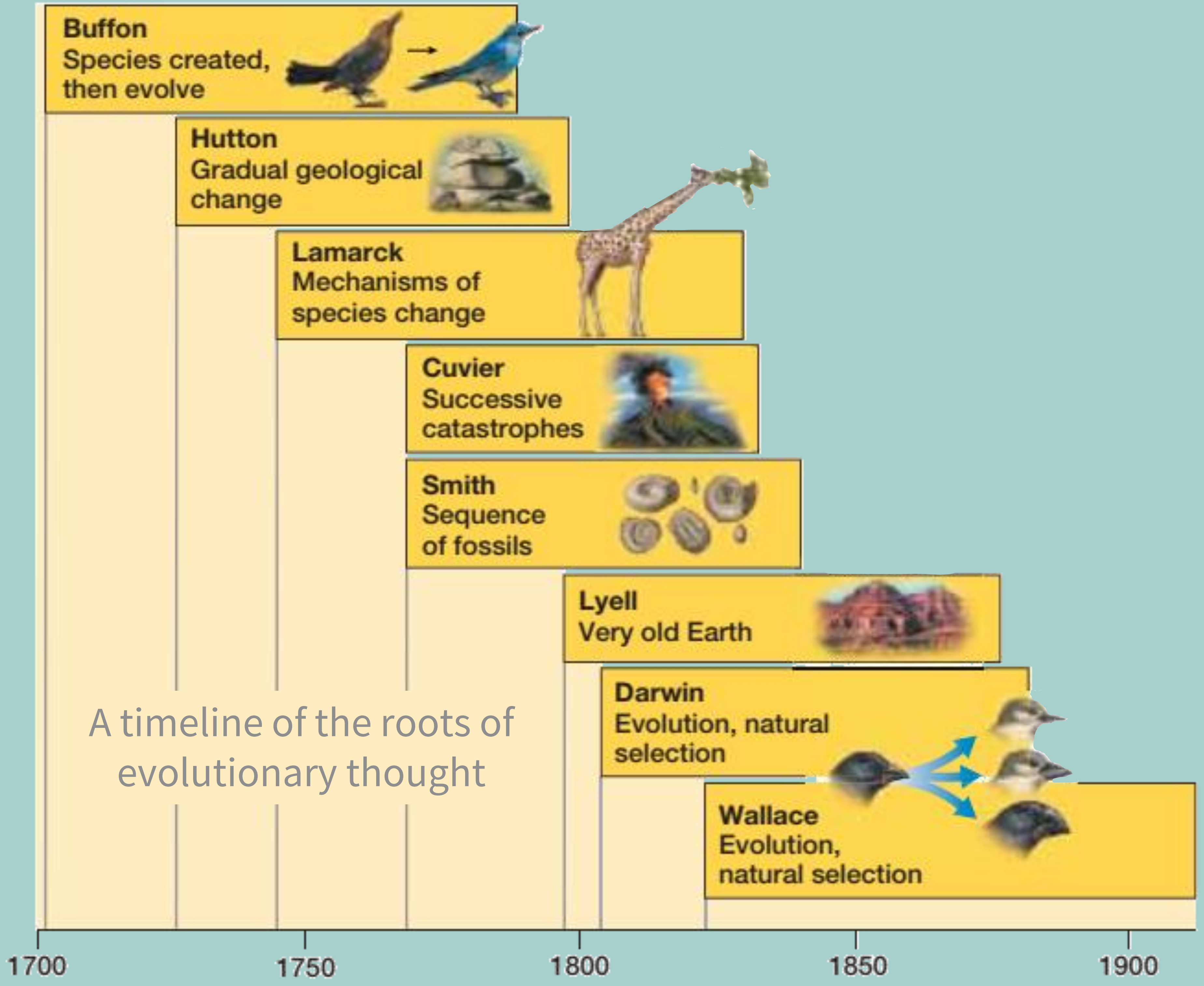
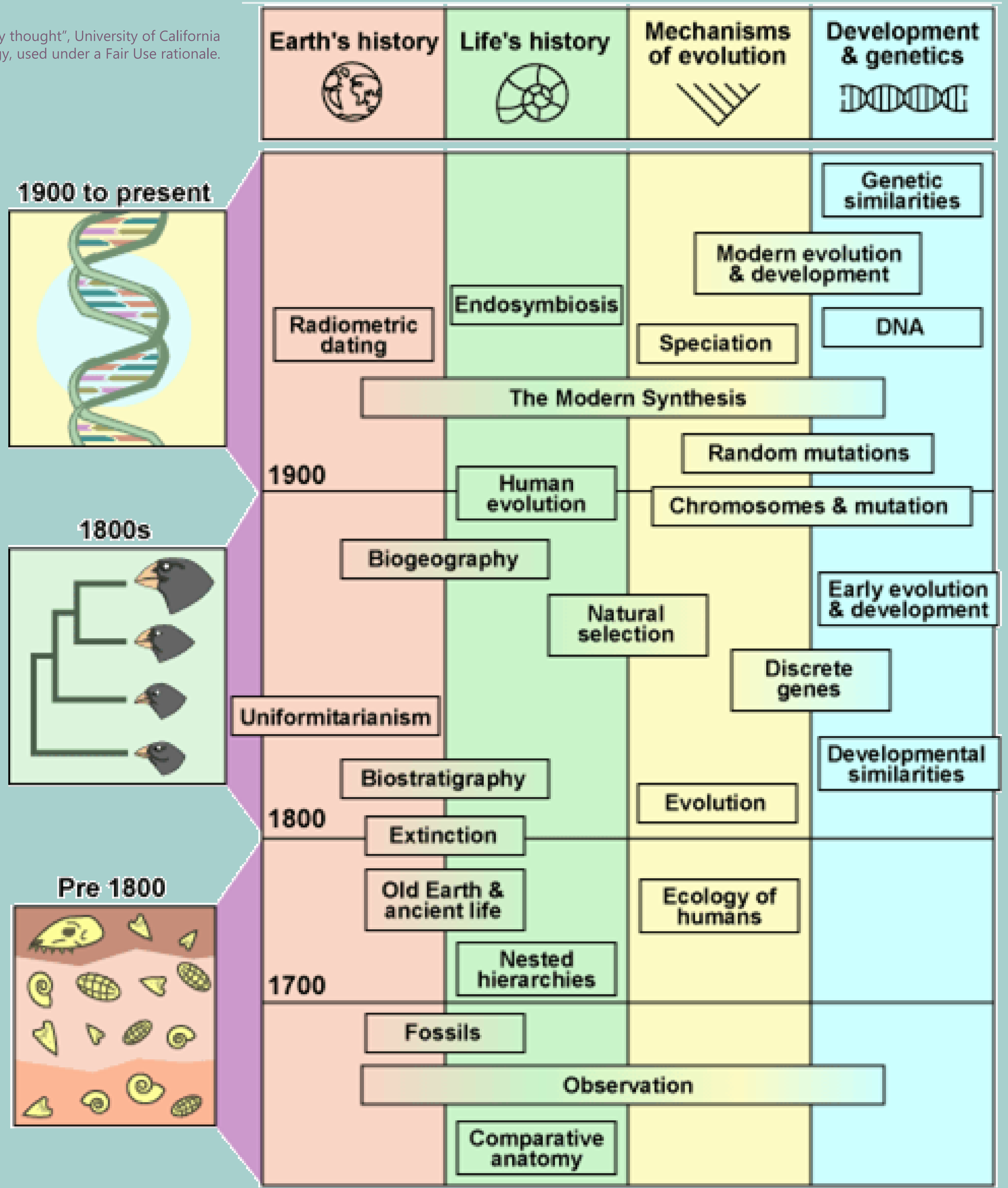


A timeline of the roots of evolutionary thought



[Fig. 15-2], Audesirk, used under a Fair Use rationale.

Processes and mechanisms of evolution

Graham Hobster, via Pixabay, Pixabay license

02

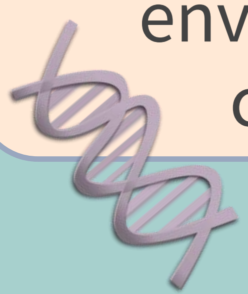
Evolution

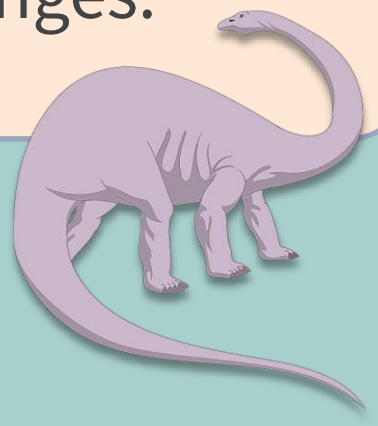
Evolution is "changes in the heritable traits of a population of organisms as successive generations replace one another." *)

*) National Academy of Sciences (c2021)

Two levels of evolution:

MICROEVOLUTION	MACROEVOLUTION
Short timescale (gene & population level). Small variations and environmental changes.	Longer timescale (species level and above). Larger environmental changes.





Both work on the same mechanisms:

1. natural selection;
2. genetic drift;
3. mutation;
4. gene flow/migration.

Microevolution

A change in the relative frequencies of alleles in a gene pool.

- Gene pool: the total genetic diversity found within a population (NIH-NHGRI c2021).

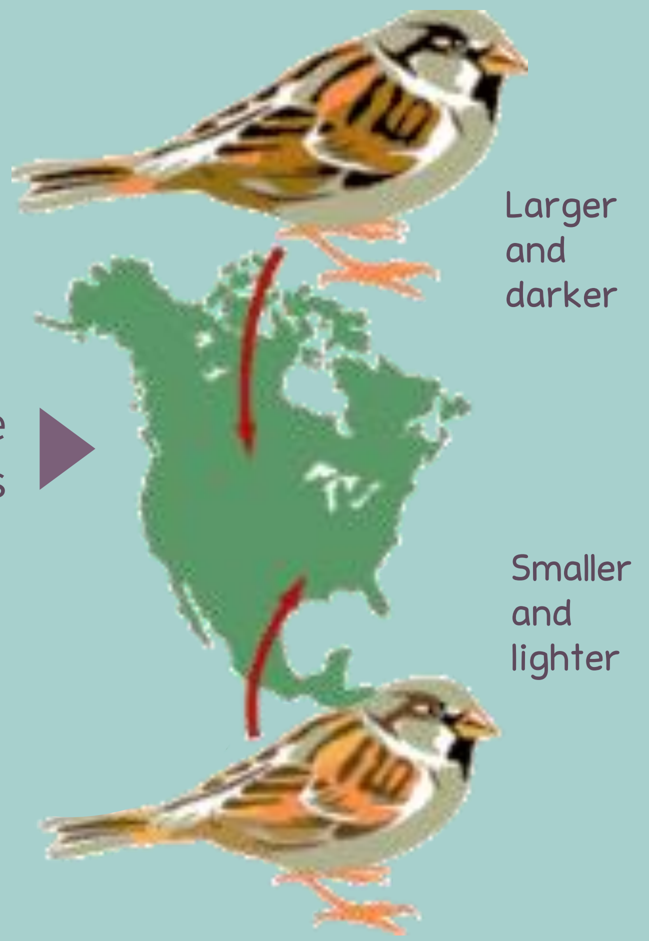
Can be observed over short periods of time.

- Does not result in a new species.

Examples:

- The resistance of target organisms to pesticides, herbicides, antibiotics.
- The body size of house sparrows in North America.
- The color change in the peppered moth, *Biston betularia*.

Microevolution of the size of house sparrows

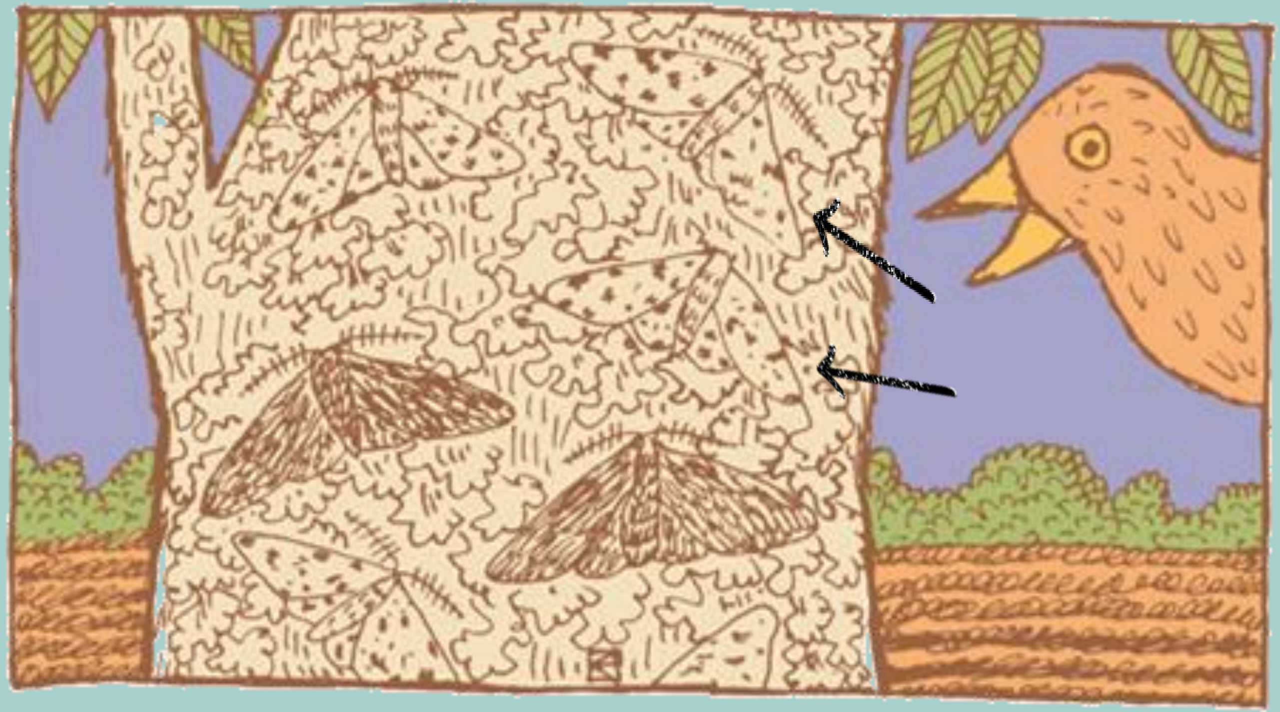


“Examples of microevolution”, University of California Museum of Paleontology, used under a Fair Use rationale.

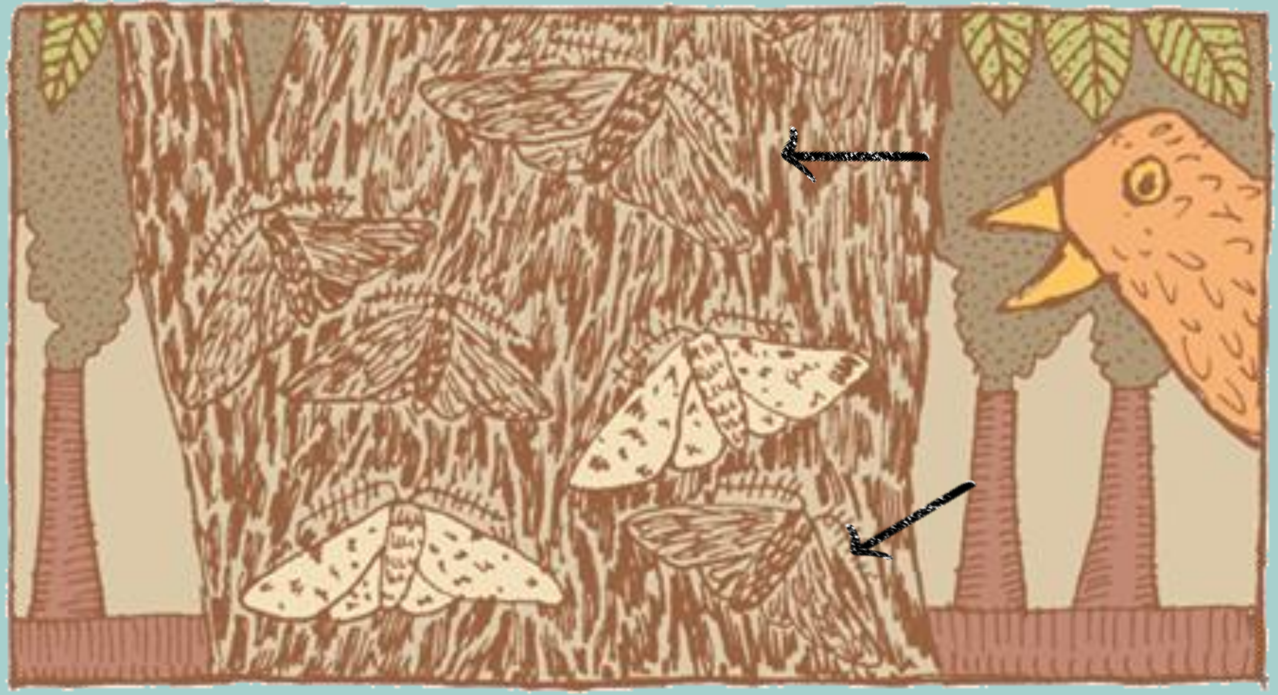
Microevolution in peppered moths *Biston betularia*

Natural variation in peppered moths' wing patterns: light and dark (*B. betularia* f. *typica* and f. *carbonaria*). ▼

▲ Initially, light-colored moths were more abundant (camouflaged against predator on light-colored trees and lichens).



▲ Before the Industrial Revolution, predation was higher on dark-colored moths; light-colored ones thrived.



▲ During the Industrial Revolution, predation was higher on light-colored moths; dark-colored ones thrived.

◀ Pollution caused by the 18th century Industrial Revolution in England.

Lichens died out; trees were blackened by soot.

Light-colored moths were now more visible and suffer a higher predation, die off; dark-colored ones flourished.

Now, with improved environment, light-colored peppered moths have again become common.

Macroevolution

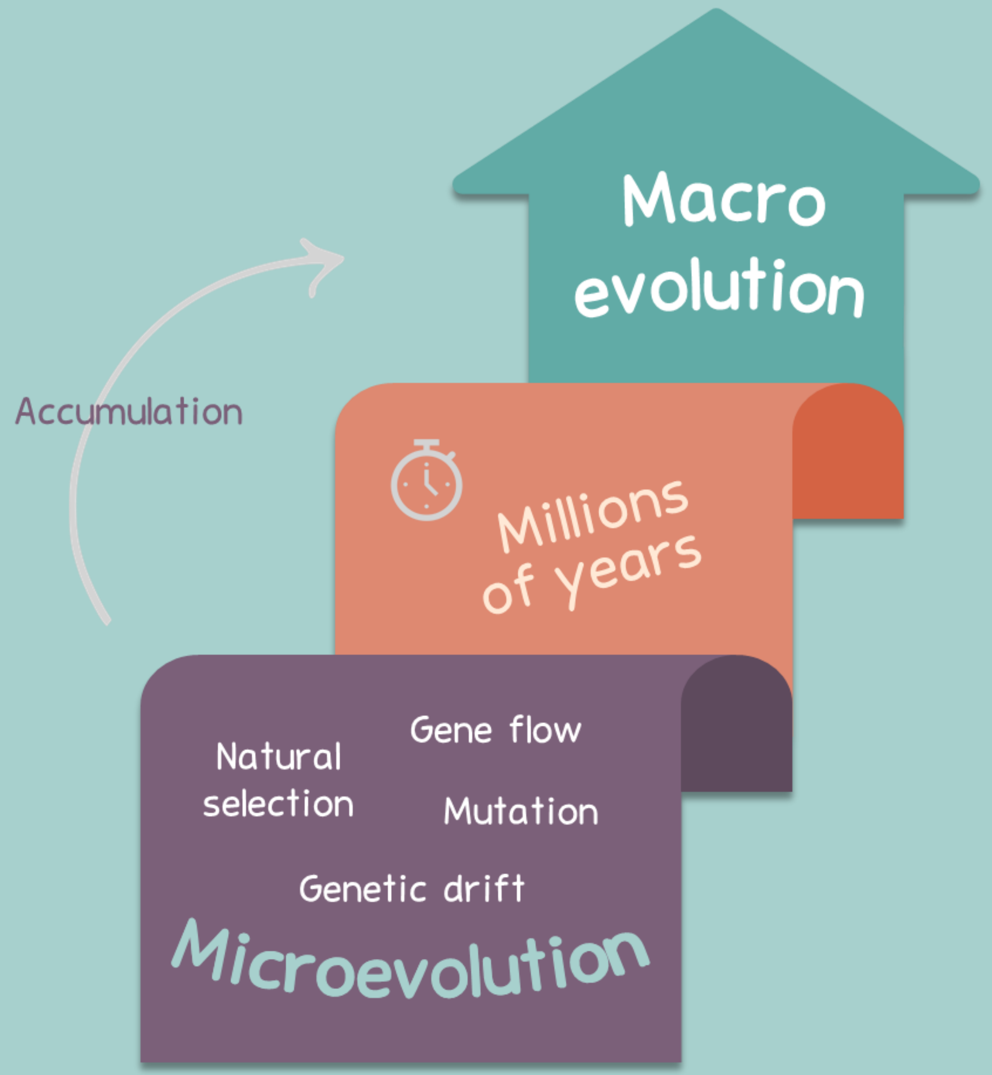


Diagram design by PresentationGO.com

The accumulation of changes in groups of related species over the course of millions of years.

Is observed through the reconstruction of the history of life using various evidence (geology, fossils, and living organisms).

Patterns: stasis, character change, speciation, extinction.

STASIS

Many lineages on the tree of life do not change much for a long time (can form a "living fossil").

CHARACTER CHANGE

Changes can occur quickly or slowly; in a single direction, or in reverse; within a single lineage or across several.

SPECIATION

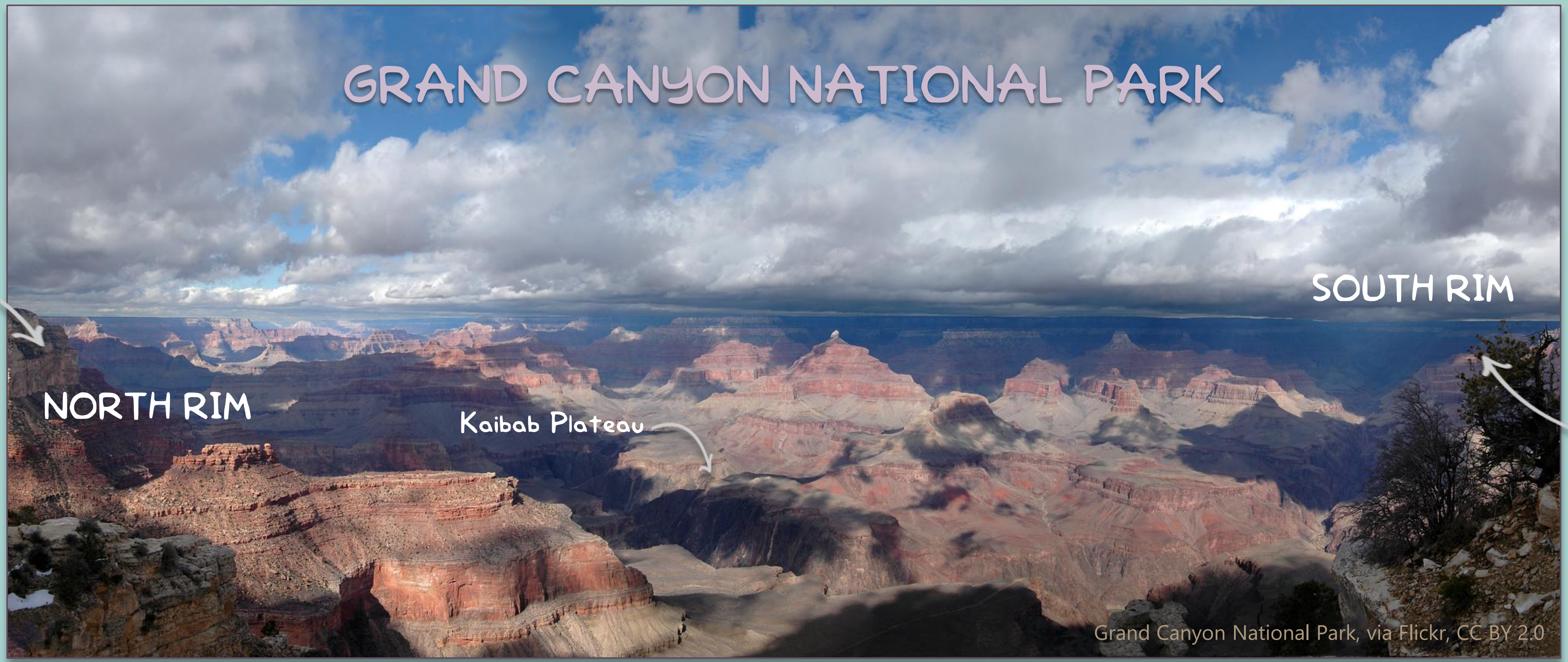
Patterns of lineage-splitting can be identified by constructing and examining a phylogeny.

EXTINCTION

Can be a frequent or rare event within a lineage; can occur simultaneously (mass extinction).

Macroevolution of Grand Canyon squirrels

Kaibab squirrel
Sciurus aberti kaibabensis



Abert's squirrel
Sciurus aberti

Evolution through geographic isolation during the period of the last Ice Age.

- Kaibab squirrel (found in the north rim) is a descendant and subspecies of Abert's squirrel (found in the south rim).
- Populations of Abert's squirrel during the warm climate were isolated in the north rim, around the area of Kaibab Plateau, eventually diverged genetically and formed the Kaibab squirrels.
- Other subspecies of the Abert's squirrels returned to the south rim after the climate cooled.

Mechanisms of evolution

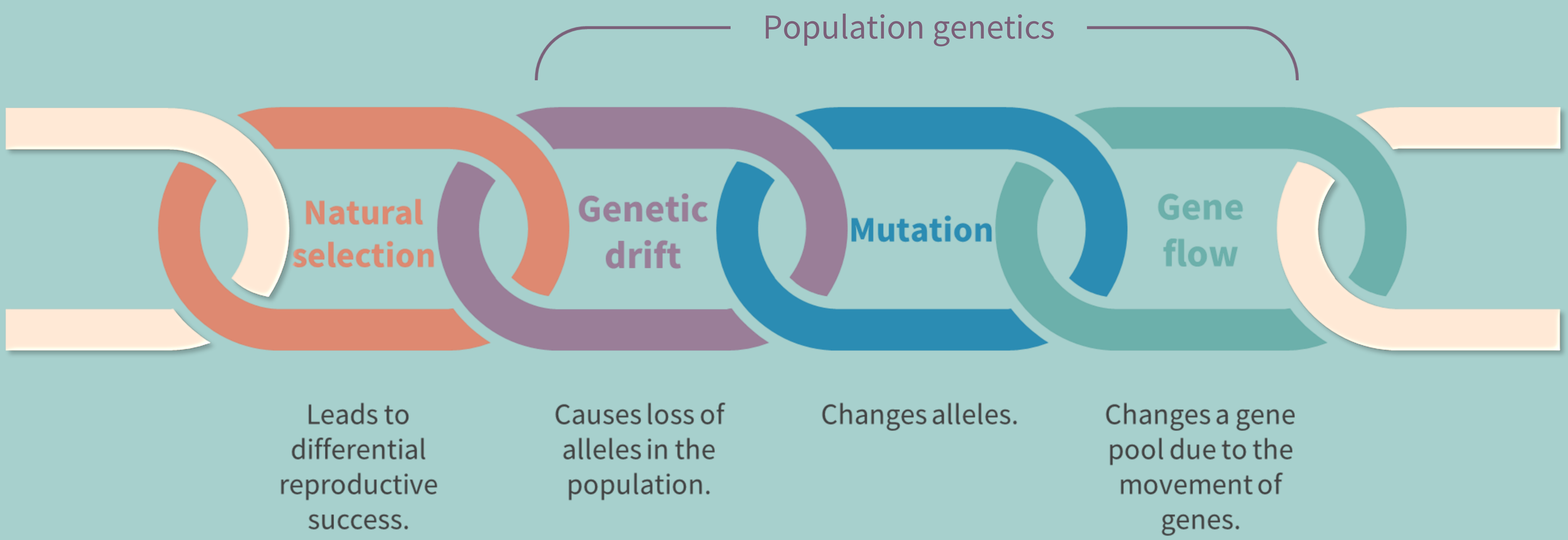
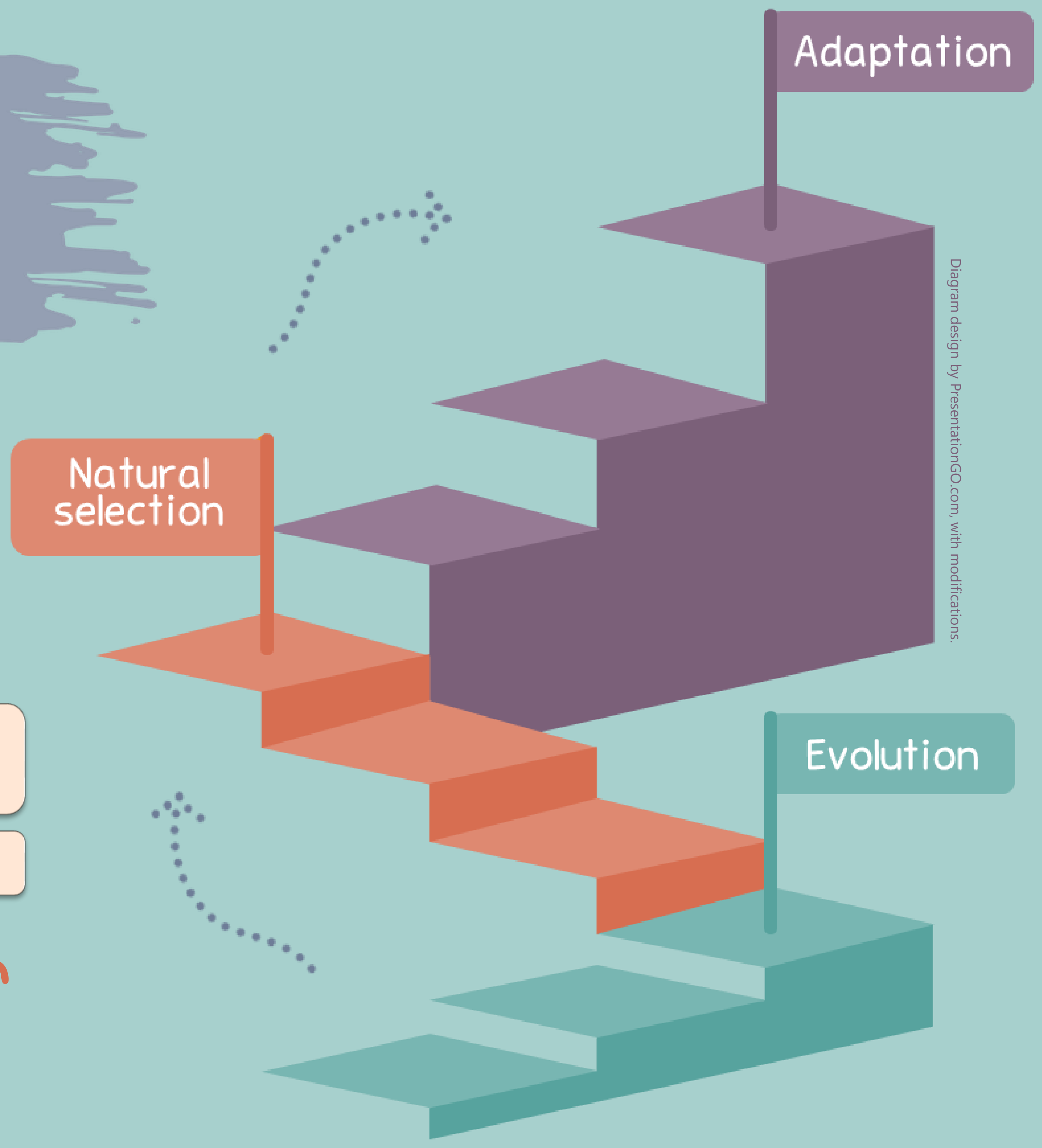


Diagram design “4-link chain” by PresentationGO.com, with modifications.

Evolution, natural selection, and adaptation

Natural selection and adaptations are part of the evolution of species.



A process in which living organisms adapt and change.

The key mechanism for evolution.

The mechanism

Adjustments organisms made in response to their environment to improve their chances at survival (= evolutionary adaptation).

An outcome of natural selection (gradual process).

A continuous process, does not have the final form.

Determines the rate of evolution.

The result

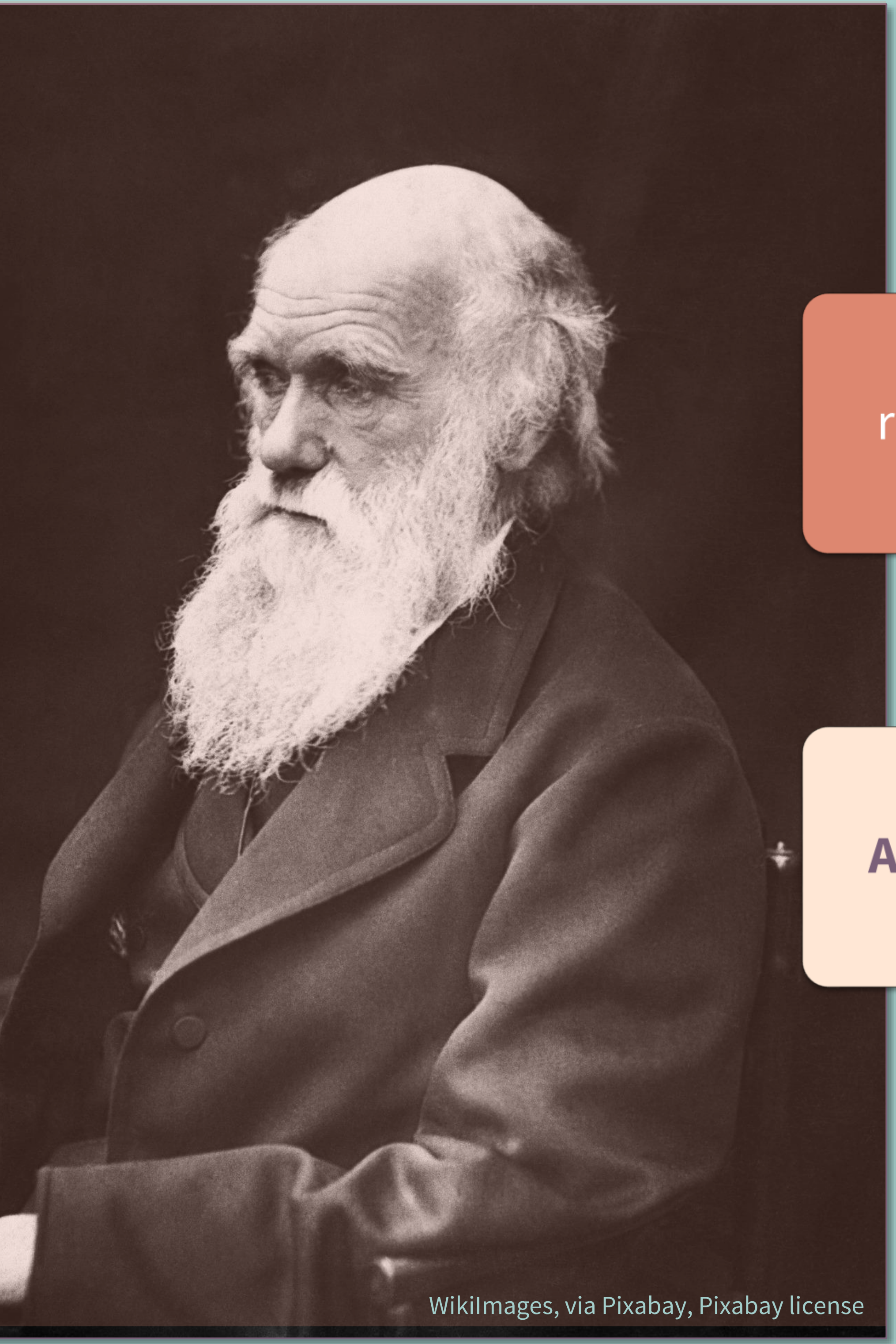
The change in species over time, from the ancestor to the modern form.

The process of constant adjustment of individual organism’s traits to changes in the environment.

Explains how the form and functioning of organisms is shaped by their environments.

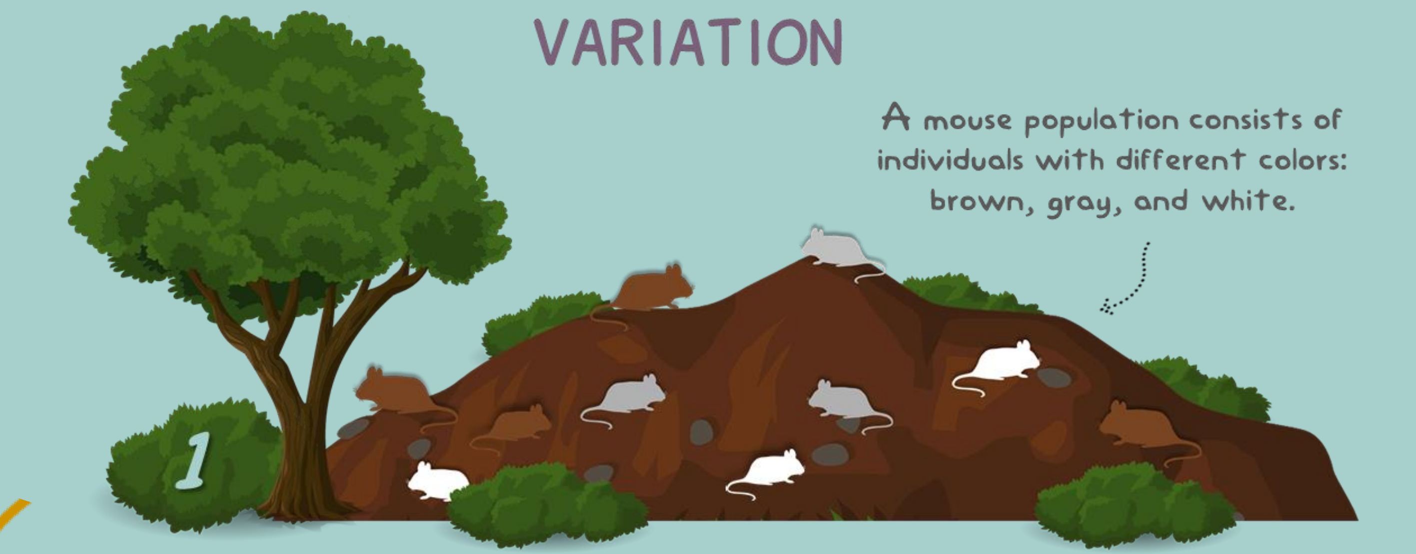
The event

Darwin’s concept of evolution by natural selection



1. High reproductive potential
2. Population size remains constant
3. Limited Resources
4. Competition
5. Populations show variation
6. Variation is heritable
7. Some traits enhance survival
8. **ADAPTATION**

Principles of evolution by natural selection



Due to genetic variation, individuals in populations naturally vary from one another in their characteristics.

High reproductive potential: many offspring are produced, but resources are limited. Offspring compete for survival.

Individuals with better traits for the environment ("the fittest") outcompete others, survive, and reproduce successfully, passing on their favorable traits to their offspring.

More offspring are produced inheriting the favorable traits; favorable traits accumulate in the population, as the better adapted individuals increase in proportion ("descent with modification" - Darwin).

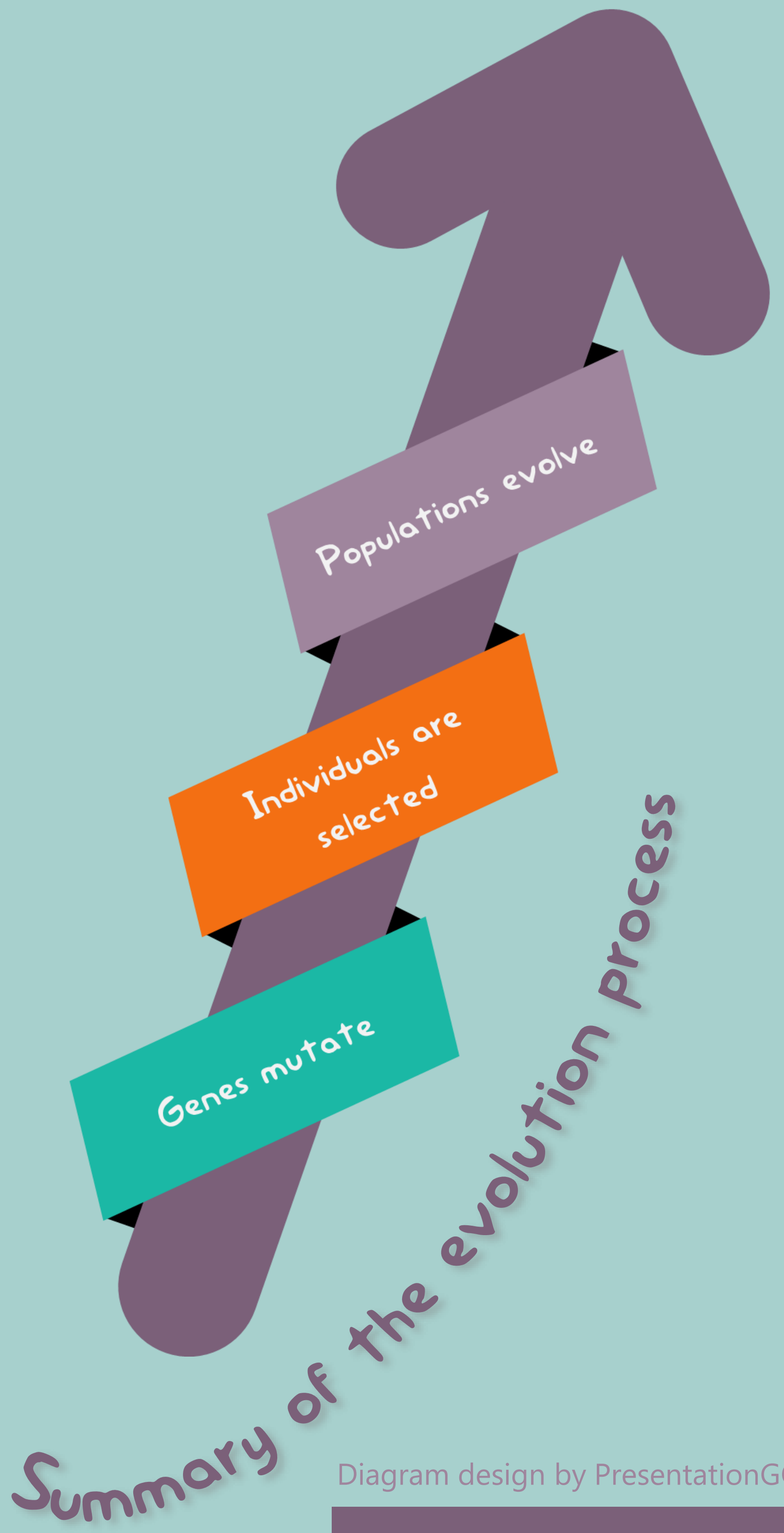
Figure is adapted from "Hooked on natural selection", University of California Museum of Paleontology's Understanding Evolution, and "Darwin, evolution, & natural selection", Khan Academy (SN Marliana, CC BY 4.0 /Vectors source: Pixabay, Pixabay license)

Populations are the units of evolution

Evolution by natural selection happens in populations.

Populations evolve because of their genetic variation.

In the variation, some individuals are better fit than others.



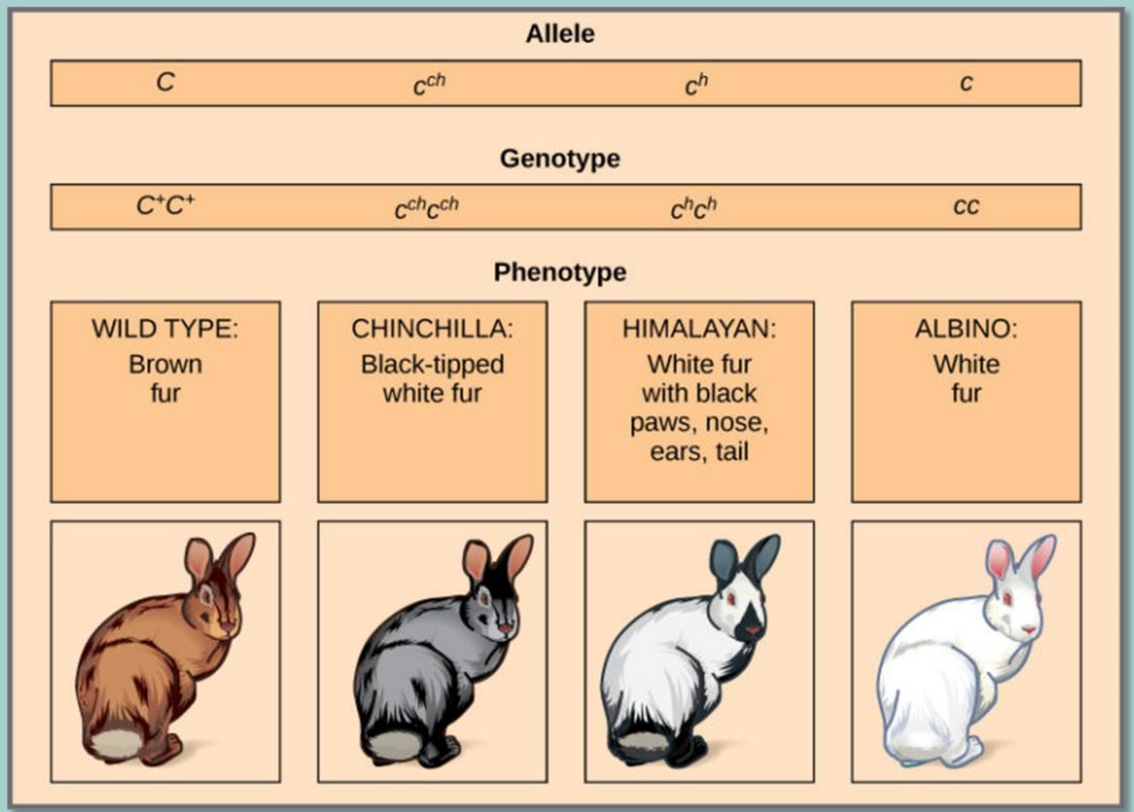
Variations & natural selection

Phenotypic variation may be caused by environment or genetic makeup, but only genetic changes result in evolutionary adaptation.

Genetic variation enhances variability in a gene pool; thus the more choice available for natural selection to work on.

Natural selection tends to reduce by decreasing the survival and fertility of the less-adapted organisms.

Allele level of dominance



Example of multiple alleles in a gene. The rabbit coat color (C) gene has four different alleles, each of which is dominant over the other allele(s) to their right in the picture.

Attached vs free earlobe

Handedness (left/right)

Fingerprints

"Neutral variation"

Some variations have no apparent advantage or disadvantage to fitness.

Types of selection

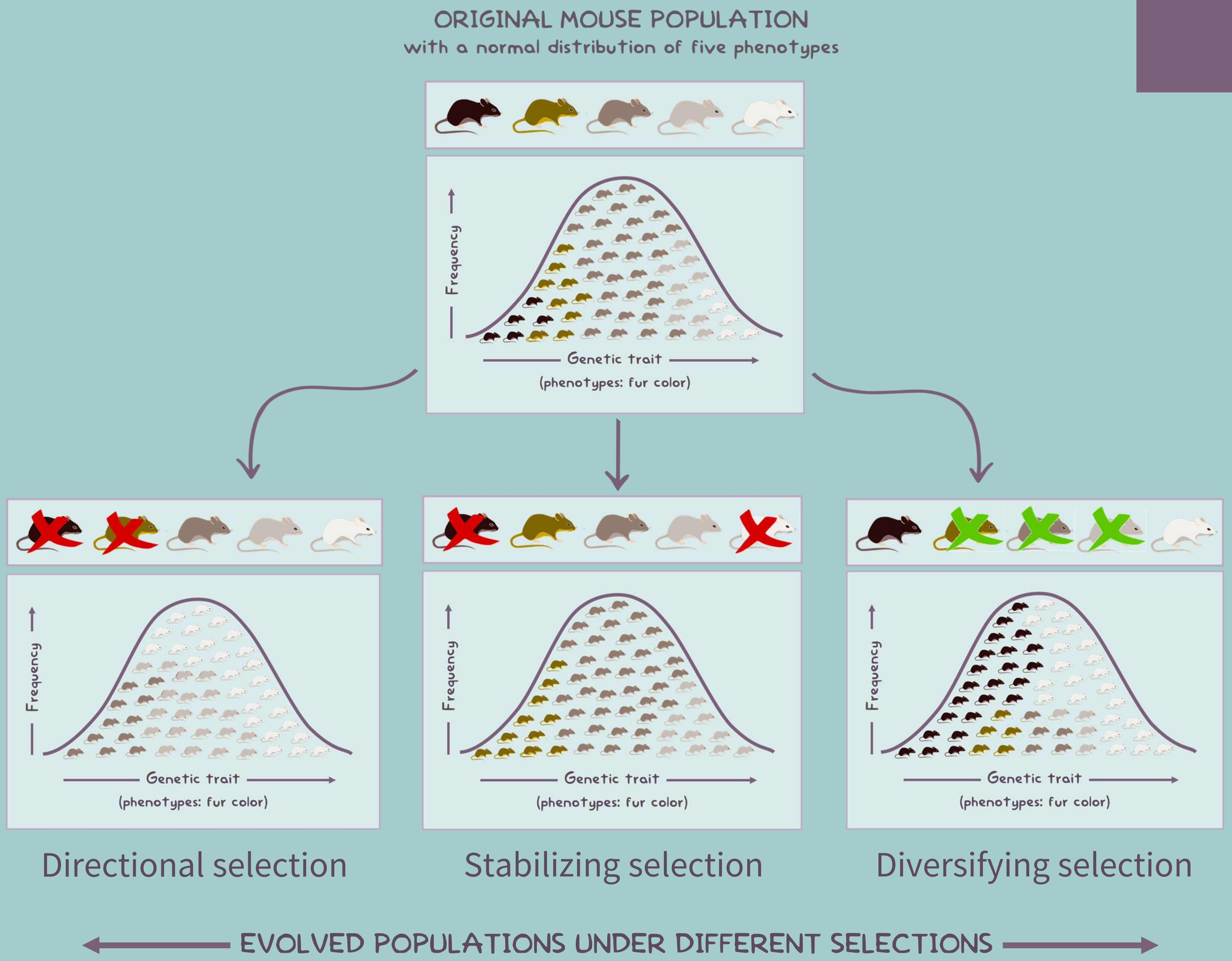
03

Types of selection

in natural selection

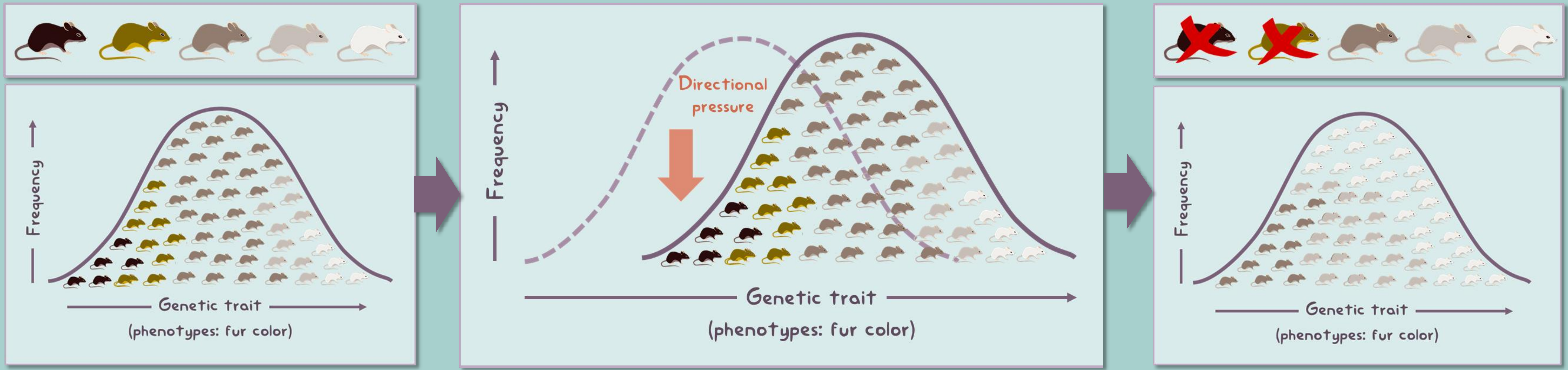
Selection:

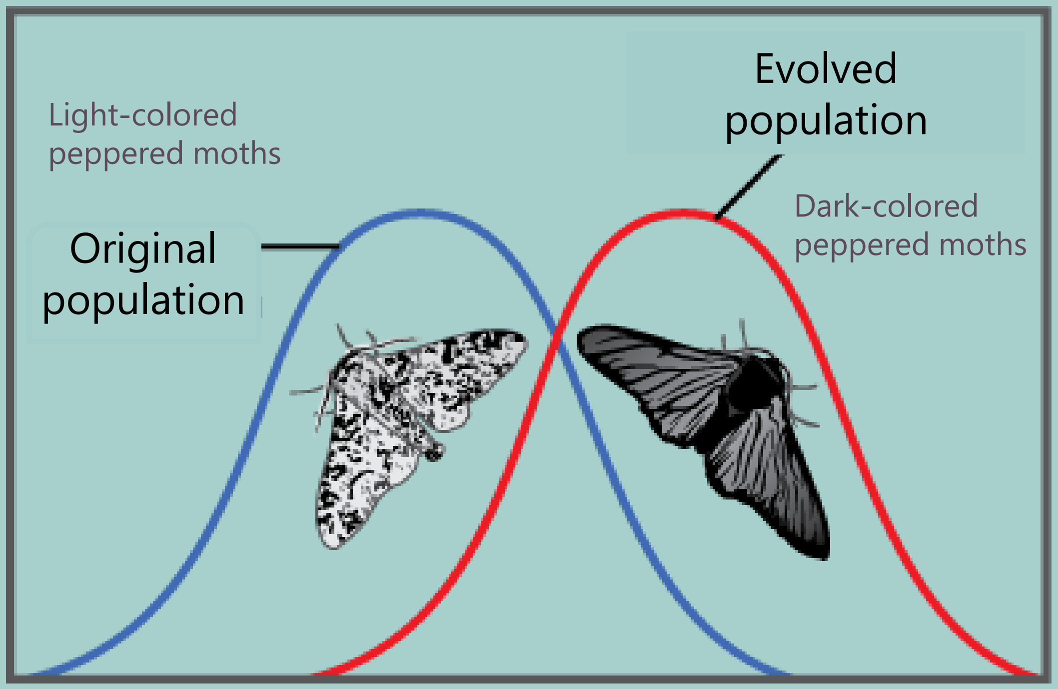
A "pressure" or process that causes evolutionary change in a population.



Adapted from “Types of selection”: BioNinja and CNX OpenStax. See References for the full credits.

Directional selection



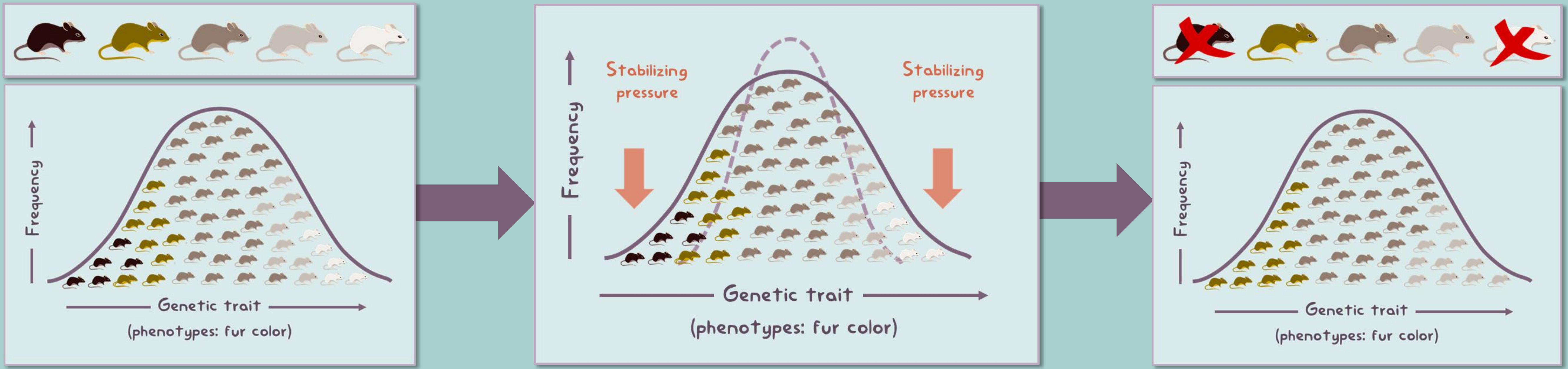


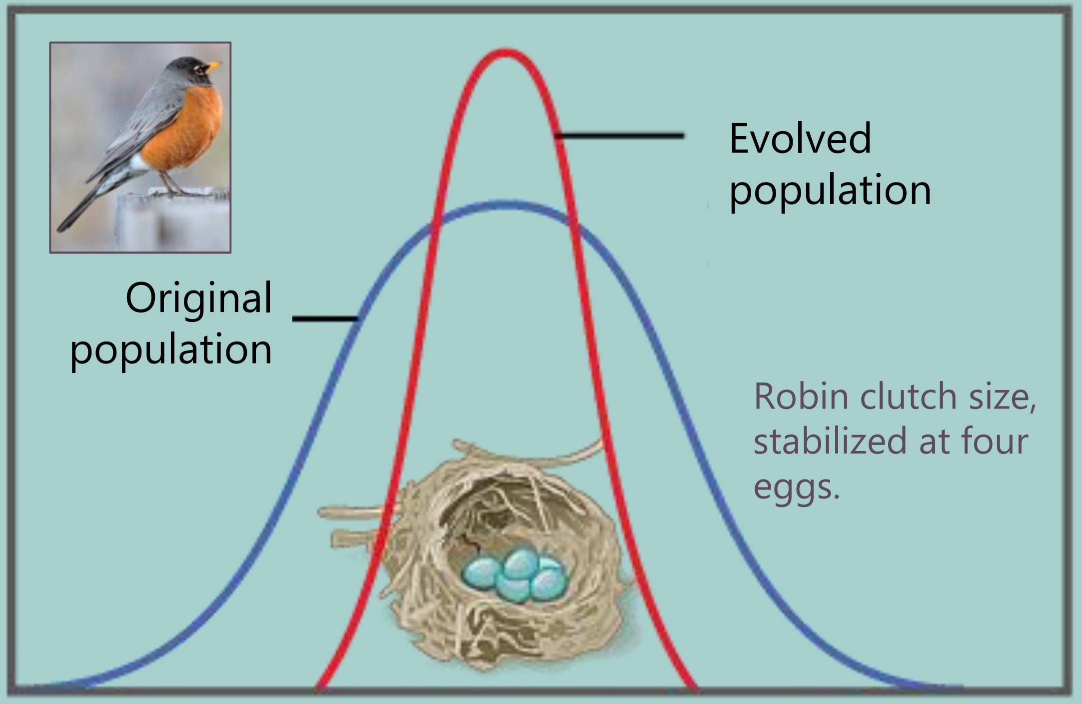
Directional selection favors phenotypes at one end of the spectrum, shifts the allele frequency distribution to the direction of the more advantageous trait.

Operates in response to gradual or sustained changes in environmental conditions; typically be followed by stabilizing selection.

Example: the shift in the individuals frequency of the peppered moths towards dark-colored ones during the Industrial Revolution period (selection pressure: air pollution).

Stabilizing selection



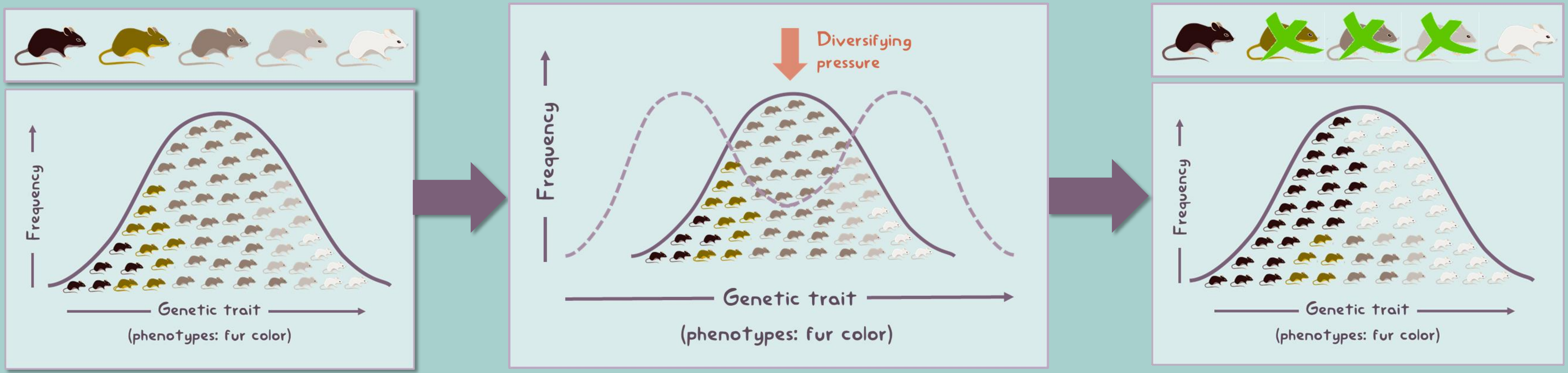


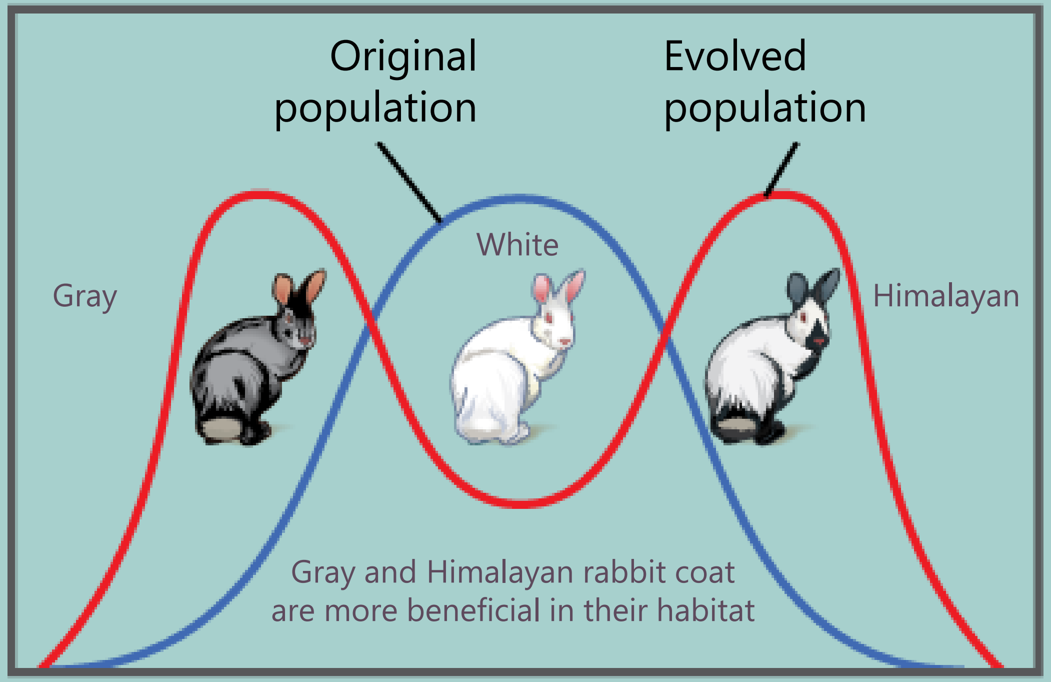
Stabilizing selection favors intermediate phenotypes; the allele frequency distribution narrows to the center (homogenous), removing extreme phenotypes at both ends of the spectrum.

Operates when environmental conditions are stable and competition is low.

Example: Robin clutch size. If too large, the chicks may be malnourished; if too small, there may be no viable offspring. Similar case with human birth weights (birthing complications vs risk of infant mortality).

Diversifying or disruptive selection





Diversifying selection favors extreme phenotypes over intermediate ones; the allele frequency distribution splits into a bimodal spread, shifting towards both ends of the spectrum; could lead to speciation.

Operates when fluctuating environmental conditions favor the presence of extreme phenotypes.

Example: A rabbit population with gray, white, and Himalayan phenotypes may experience diversifying selection towards the gray and Himalayan individuals, as they blend better to their rocky environment.

Sexual selection

The selection pressures on males (or females) to obtain matings.

- Females choose superior males to increase their fitness (better quality of offspring).

Results in sexual dimorphisms: males are often larger, with elaborate colors & adornments to attract females.

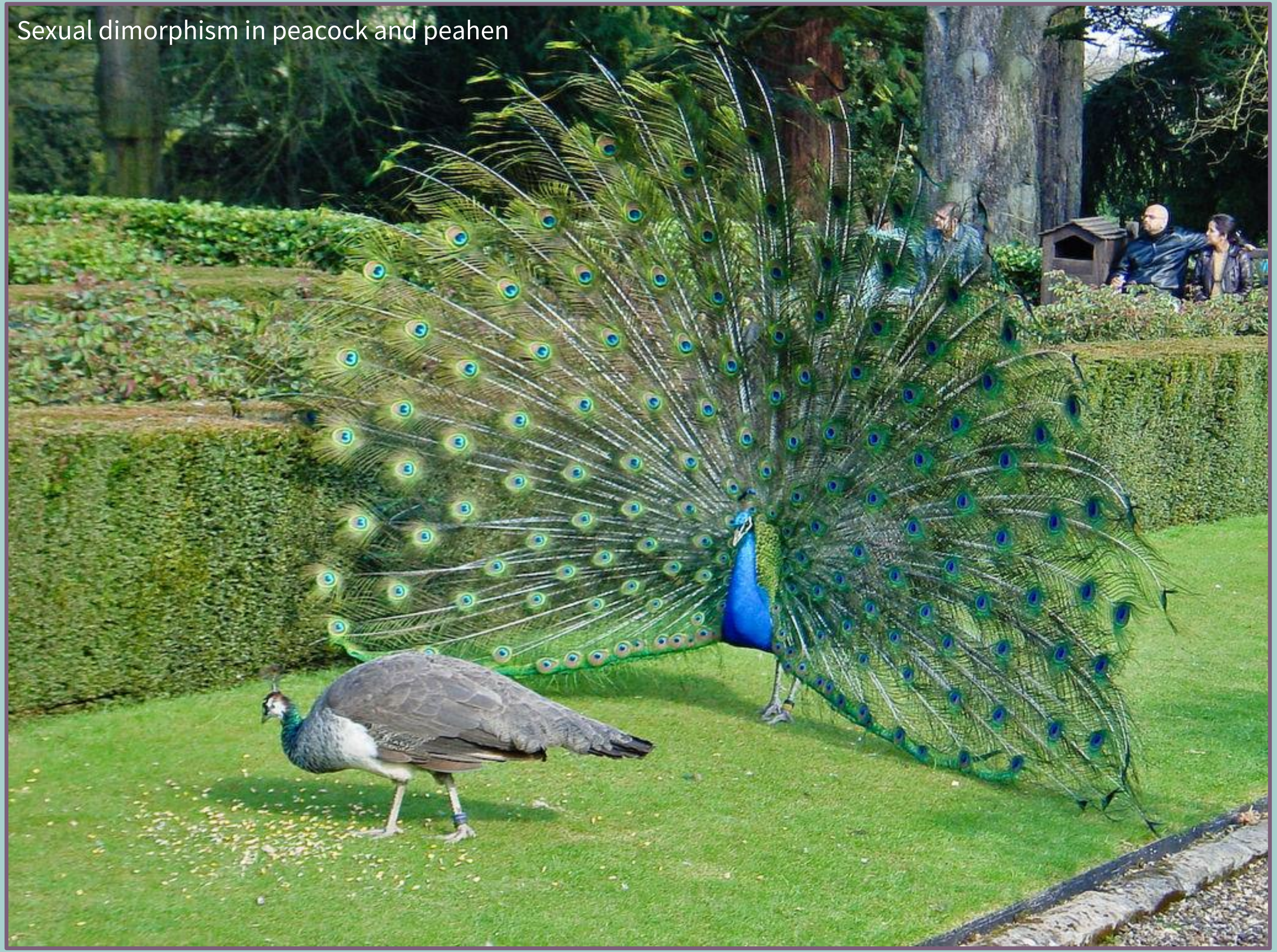
- These males receive the majority of the total matings, others receive none (because they are better at fighting off other males, or the females choose them).

“The handicap principle”: selected traits may carry risk towards survival, only the best males survive that risk.

- The characteristics may not benefit the likelihood of survival, but help to maximize the reproductive success.

Dimorphism in *Argiope appensa* male is smaller than female

Sexual dimorphism in lion and lioness



Sexual dimorphism in peacock and peahen

Frequency-dependent selection

The fitness of a genotype or phenotype in a population is related to its composition (“frequency”).

- **Positive selection**: the fitness of a phenotype or genotype increases as it becomes more common.
- **Negative selection**: the fitness of a phenotype or genotype decreases as it becomes more common (balancing selection).

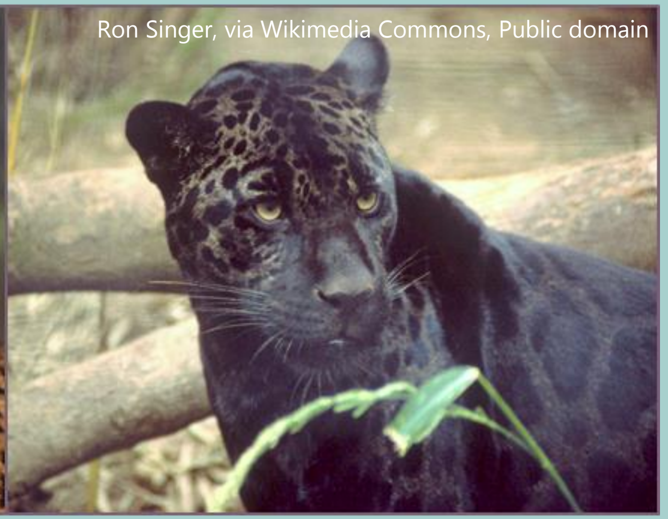
Usually the result of interactions between species, or between genotypes within species.

Results: polymorphic equilibria or dynamical chaos

- **Polymorphic equilibria**: a balance or equilibrium between morphs.
- **Dynamical chaos**: fitness of some individuals becomes very low at intermediate allele frequencies.

Müllerian mimicry among *Heliconius* species

Examples of phenotypic polymorphism: Grove snails Cepaea nemoralis (top); jaguar *Panthera onca* (middle); various flowering plants in the Mediterranean Basin (bottom).



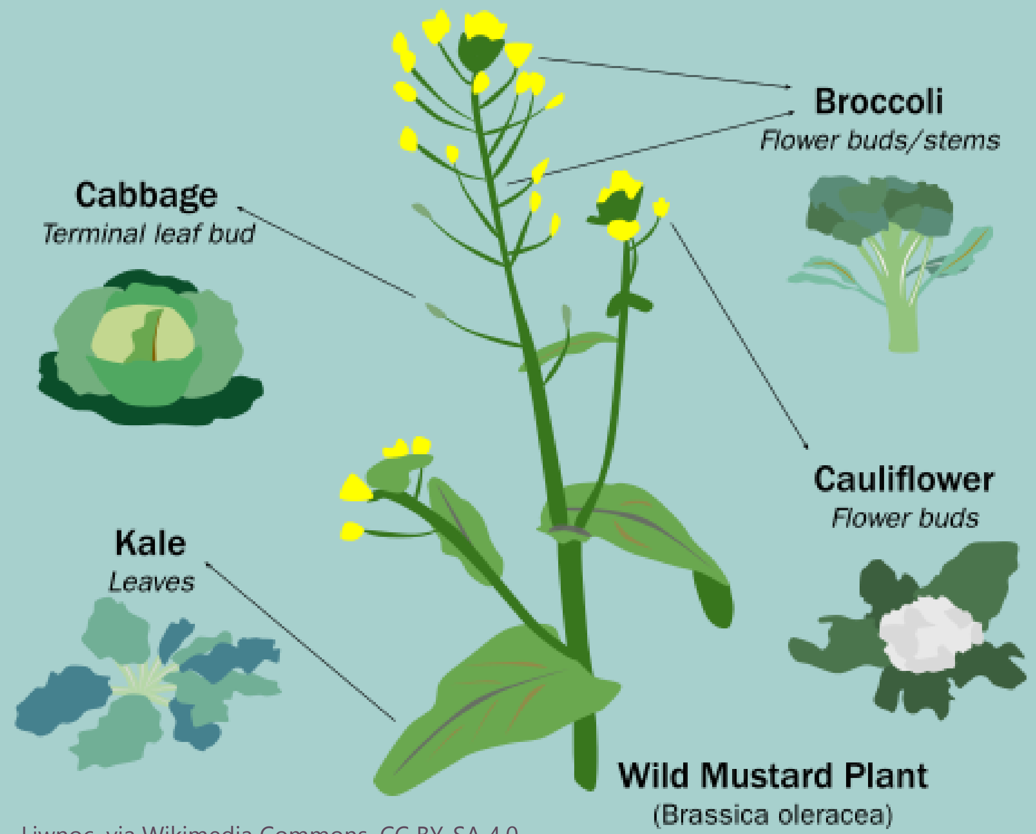
[Figure 1], Narbona et al. (2017), Plant Biology 20 Suppl 1. DOI: 10.1111/plb.12575, used under a Fair Use rationale

Natural vs artificial selection

Natural selection as the basic mechanism of evolution.

Artificial selection is when the role of the environment is performed by humans.

- Choosing organisms with specific characteristics and breed them.



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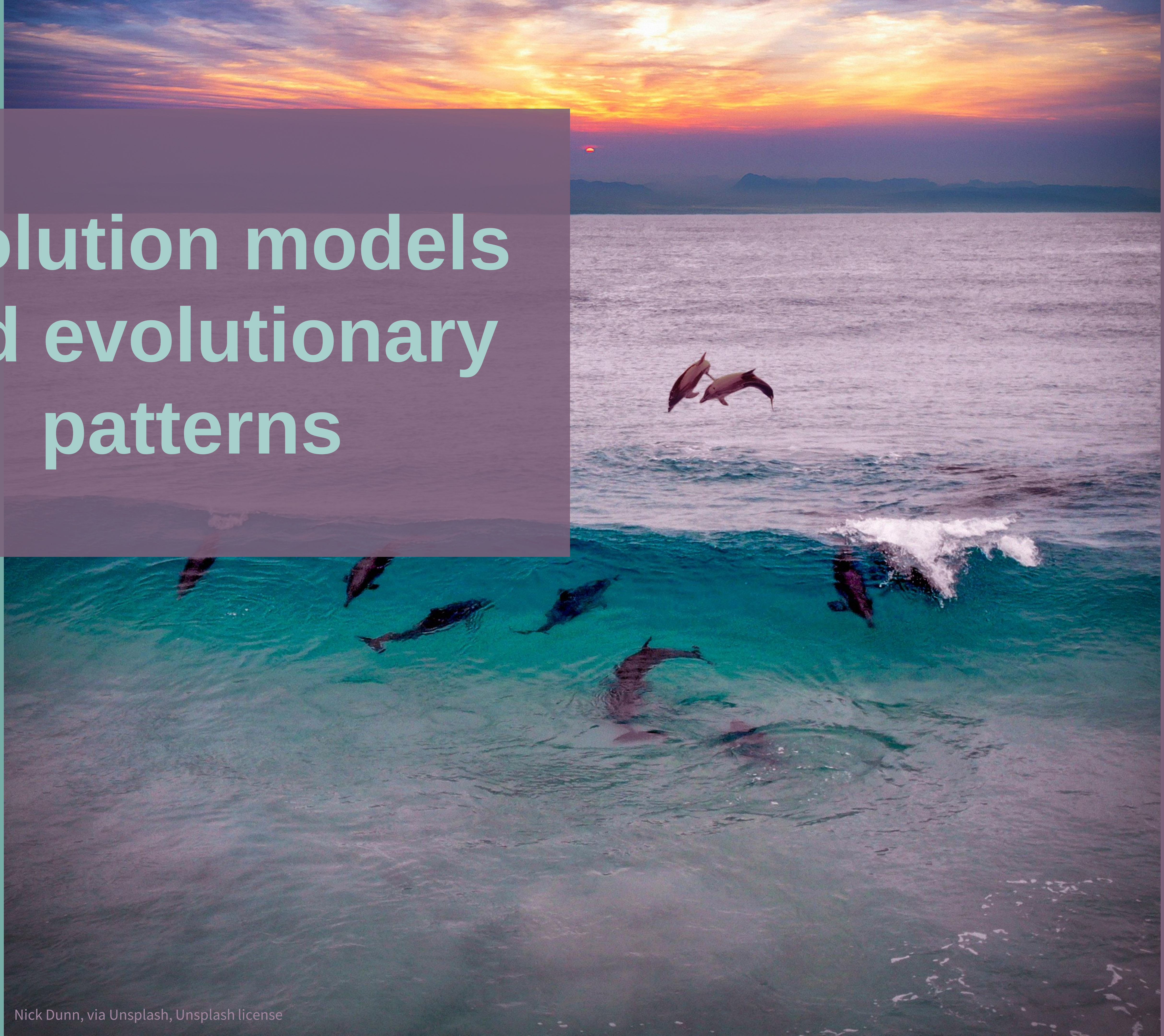
Evolution models and evolutionary patterns

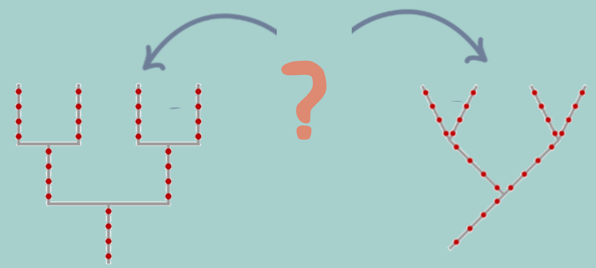


Nick Dunn, via Unsplash, Unsplash license

04

Models of evolution

Two contrasting hypotheses of how macro-evolution occurs: **gradually** or **in burst.**



Three models of evolution

1 Phyletic gradualism

The view: Most speciation is slow, uniform, by the steady and gradual transformation of whole lineages (anagenesis).

Evolution has a fairly constant rate; new species arise by the gradual transformation of ancestral species.

A suddenly appearing species with little signs of transitional forms in the fossil evidence is due to the incompleteness of the record.

3 Punctuated gradualism

A pattern that does not conform with either the gradualistic or the punctuational model of evolution.

A species lineage is in stasis over a significant duration; no speciation (lineage branching), and the transition is not rapid enough.

Speciation is not needed for a lineage to rapidly evolve from one equilibrium to another but may show rapid transitions between long-stable states.

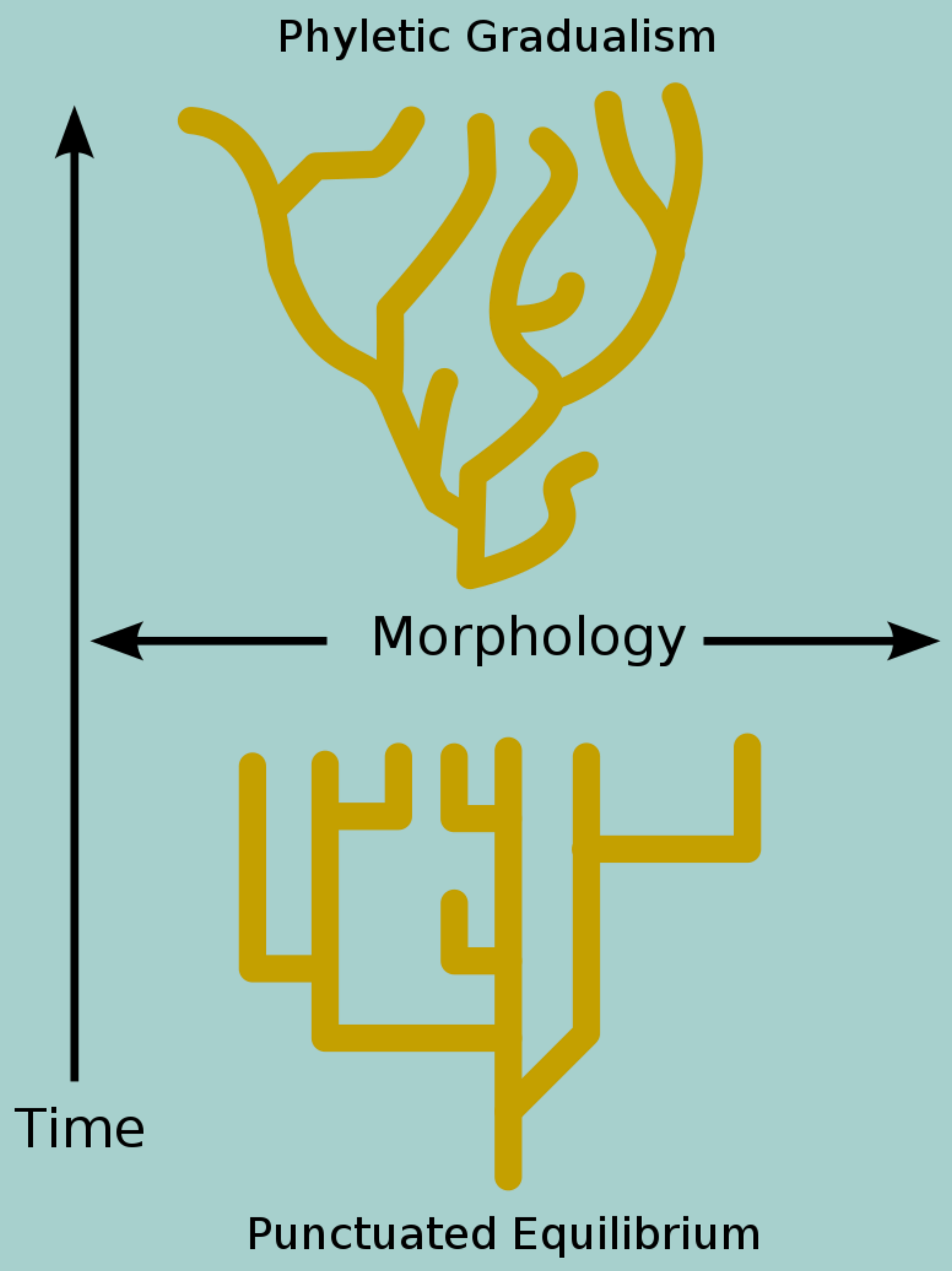
2 Punctuated equilibrium

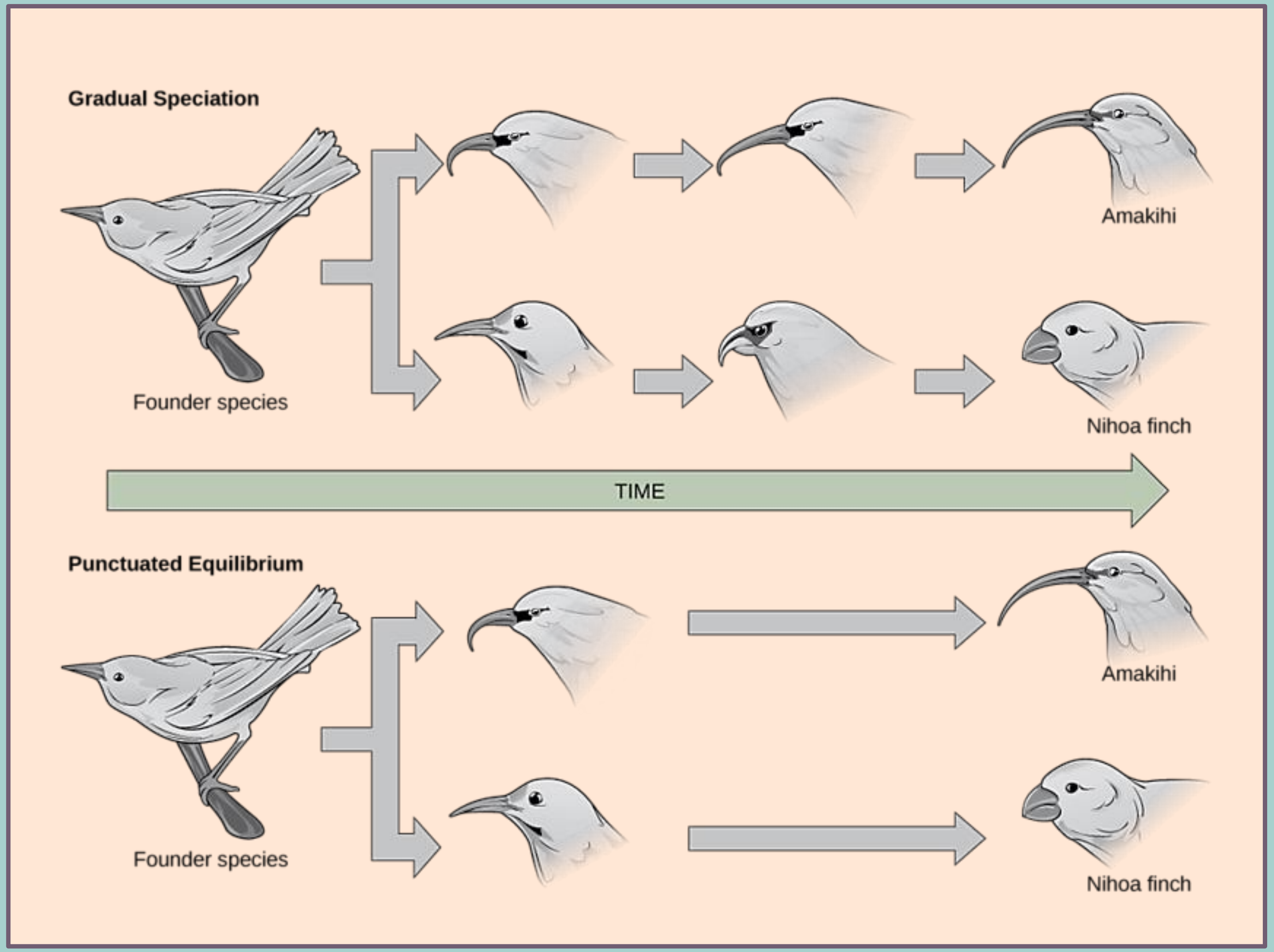
The view: Major evolutionary changes happen in localized, rare, rapid events of branching speciation (cladogenesis).

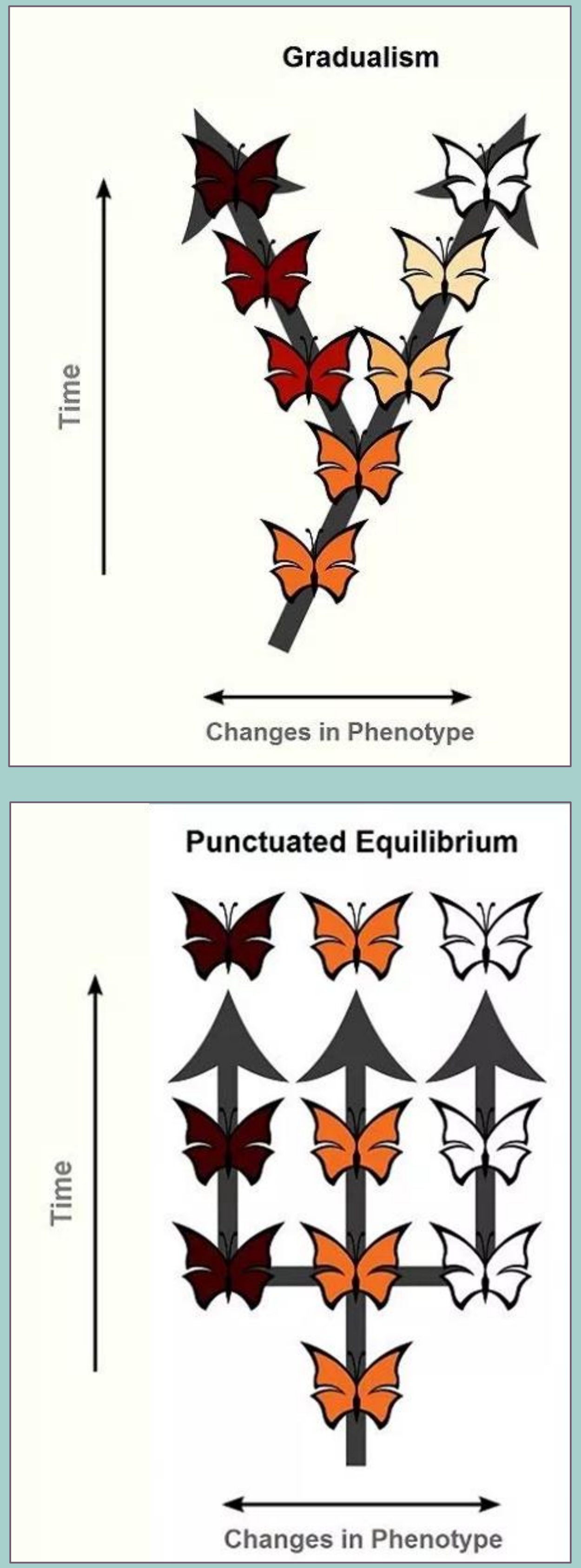
Evolution proceeds rapidly during speciation, but between speciation, the population remains relatively constant in a condition called **stasis**.

A species appears suddenly in a fossil record, persists for a period, then go extinct. No clear “line” between an ancestral species and a descendant species, unless splitting occurs.

Two main models of evolution







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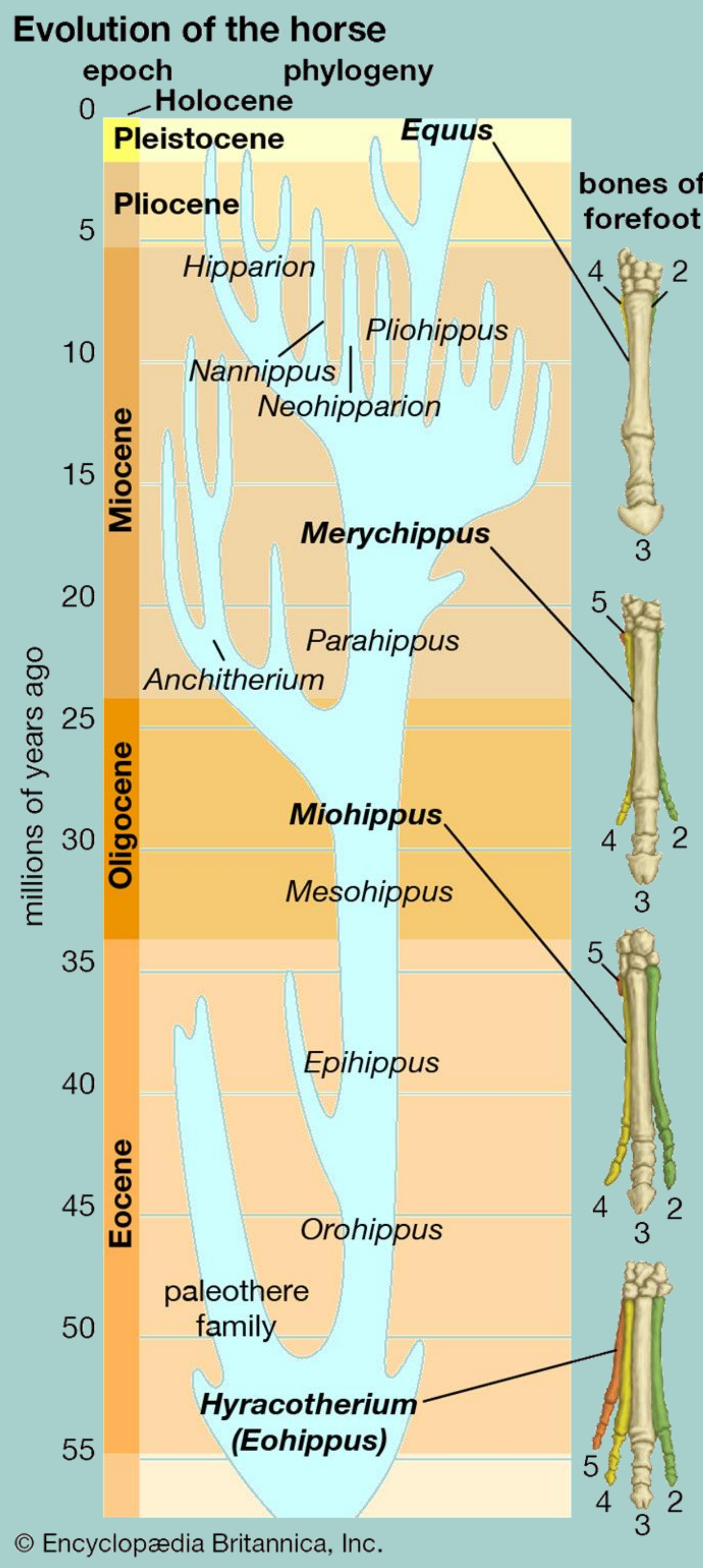
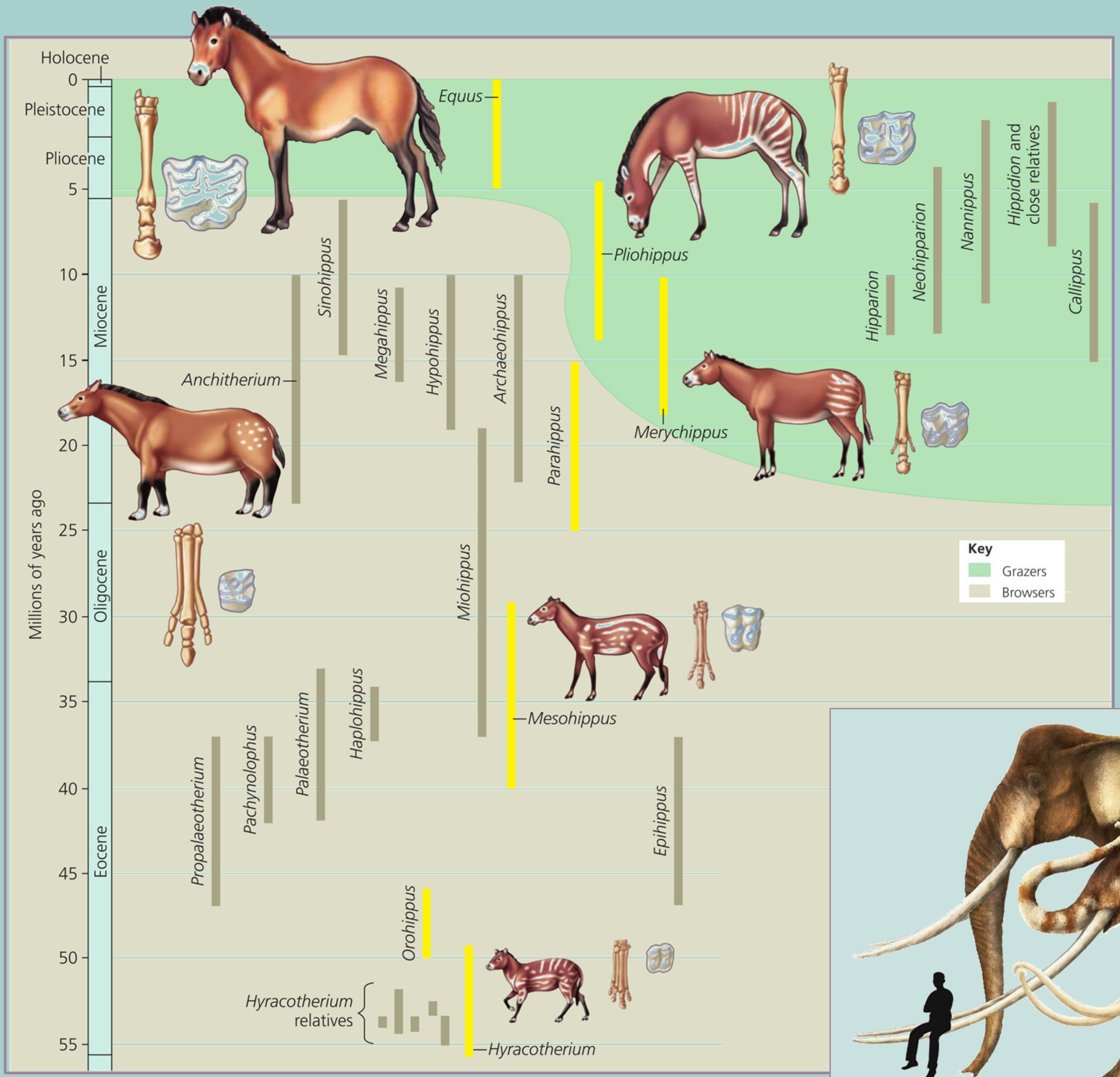
Biology Dictionary, used under a Fair Use rationale

Examples of evolutionary paths





“Figure 25.29. The evolution of horses”, Reece et al., 2019, Campbell Biology, Pearson, used under a Fair Use rationale

“Evolution of the horse”, Encyclopædia Britannica, used under a Fair Use rationale

- The evolution of horses based on the fossil records. The connection between the present-day horse *Equus* and its ancestor *Hyracotherium* (yellow lines) seems to show that the evolution progresses toward larger size, fewer toes, and grazing teeth (right image). However, this is just an illusion, as horses are only a small part, a surviving “twig”, in the complex horse’s evolutionary “bush” (left image).

  Despite often presented as an example of a punctuated equilibrium evolution, in fact, the evolutionary change of some characters of the horse lineage are formed through different paths. Some of the cheek tooth characters show a phyletic gradualism pattern, the foot mechanism shows a decidedly punctuated equilibria pattern, while size shows a mixture of the two types (Sonleitner 1987).

- The progression of elephants' ear size is said to be an example of gradualism in evolution.

Liam Elward/Phys.org, via Phys.org, free for educational use

Evolutionary patterns

Evolution has resulted in enormous variation in form and function.
At times, producing groups of organisms that are very different despite closely related, or vice versa.

Divergent evolution

Species once were similar (common ancestry), become increasingly different.

Happens when populations adapt to different environments.

Ancestor → New species, New species

Convergent evolution

Distantly related organisms (different ancestry) become increasingly similar.

Happens when unrelated species adapt to similar environments.

Parent species 1, Parent species 2 → New trait

Parallel evolution

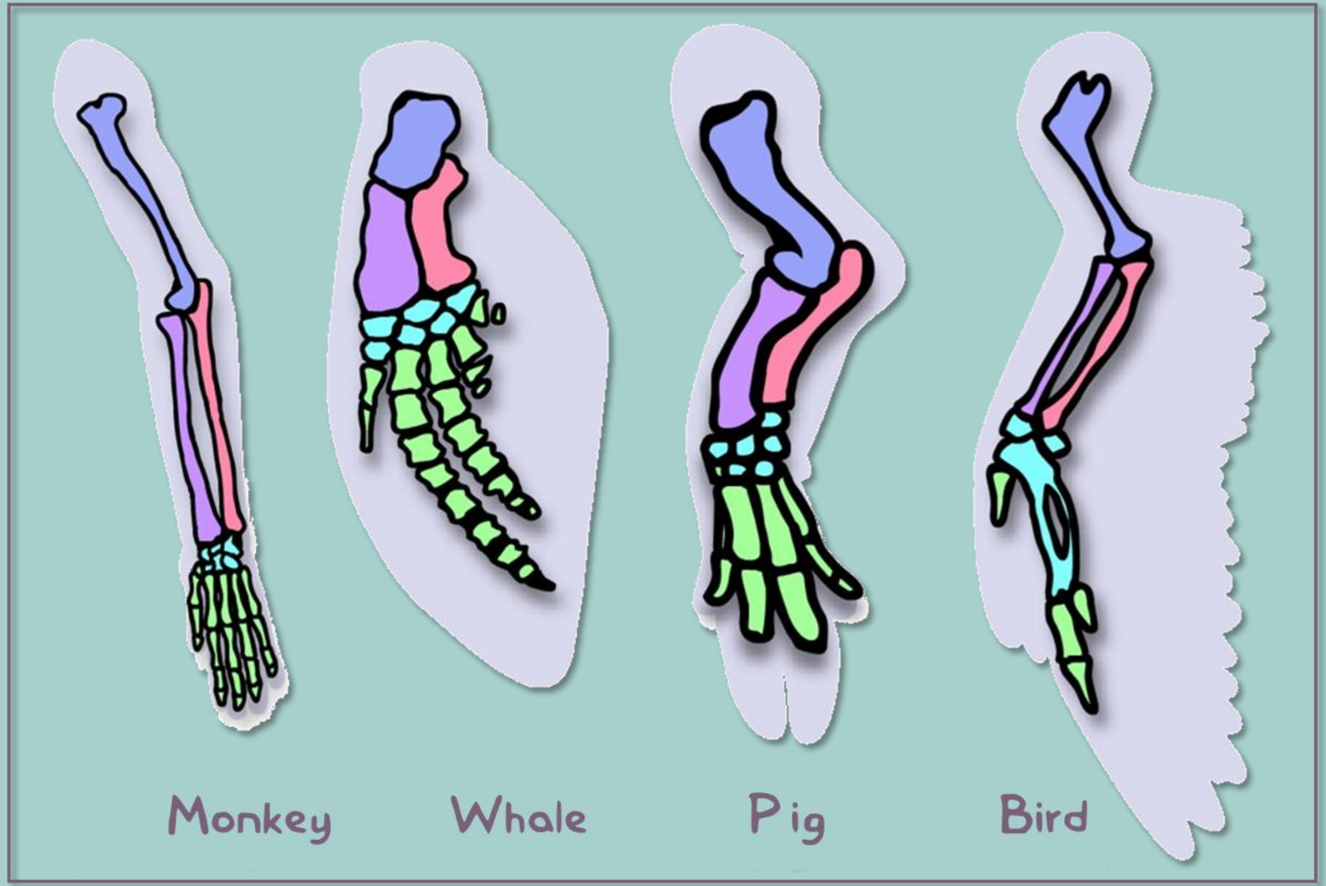
Divergent evolution

Related, interbreeding species ***diverge***, evolving different traits (evolutionary groups); become more dissimilar through time.

Primarily influenced by the change of abiotic factors (e.g. through migration) and biotic factors (e.g. predation, competition).

Species from a common ancestral origin evolve ***homologous structures*** (similar anatomical parts with different functions).

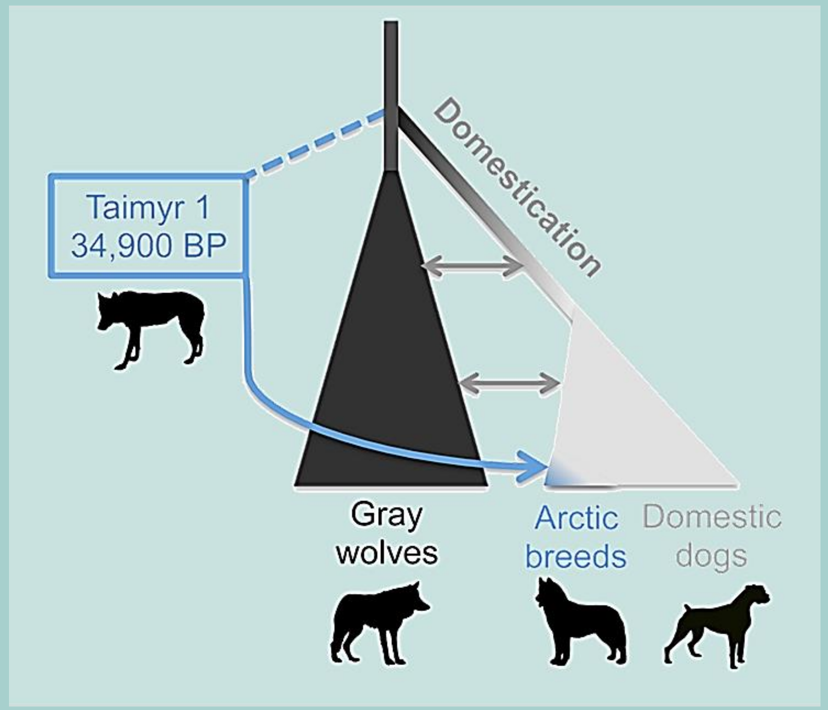
Example: Darwin's finches (adaptive radiation followed by divergent evolution); evolution of dogs.



Example of **homologous structures**: leaf modification in the pitcher plant, Venus flytrap, and cactus' spines (top); forelimbs of different vertebrate taxa are all derived from the same ancestral tetrapod structure (middle); modifications of two pairs of wings of ancestral insects: wings, halters, and elytra (bottom).

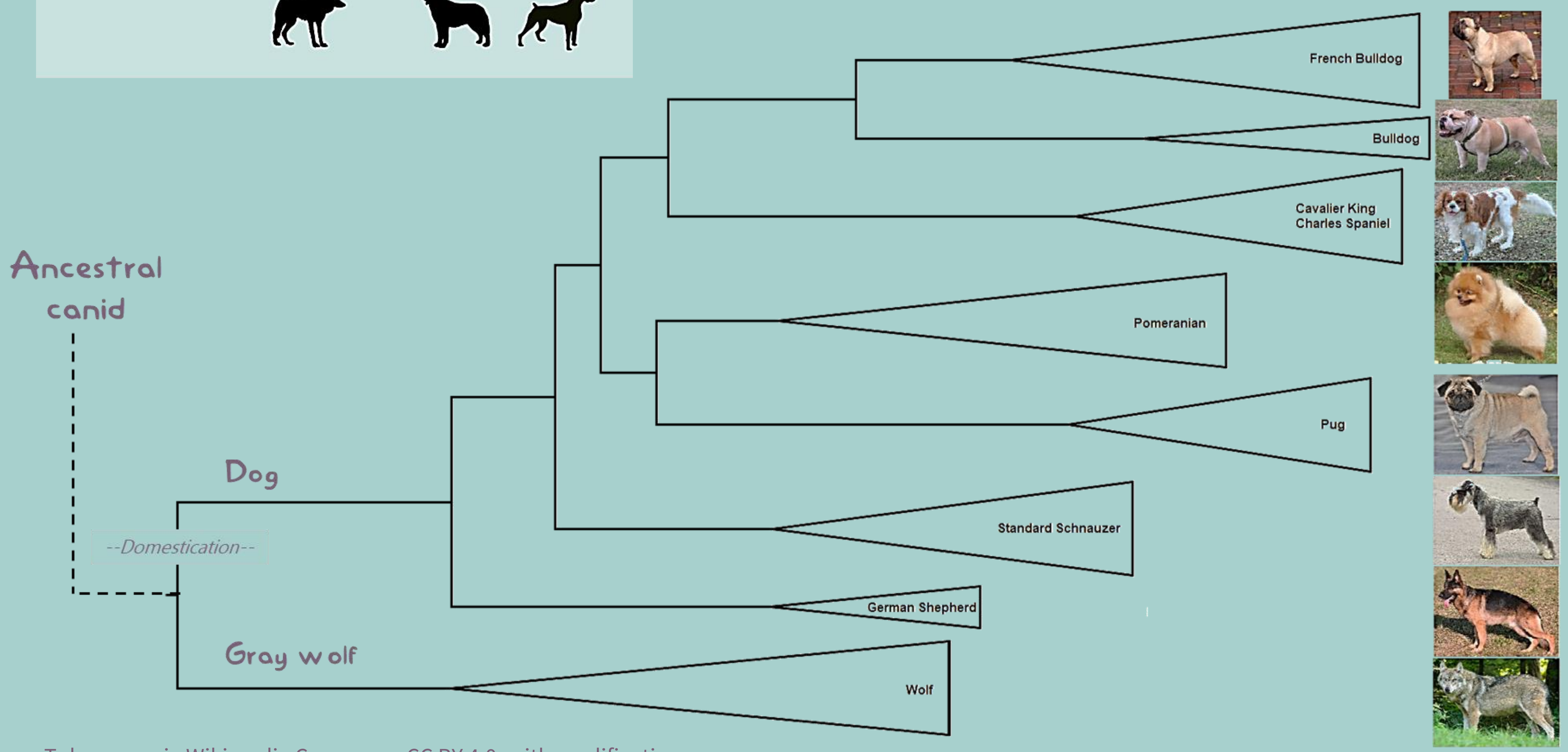
Divergent evolution examples

Skoglund et al. 2015. DOI: 10.1016/j.cub.2015.04.019.



The divergence of dog and the modern wolf from a shared ancestor. Here, the research find evidence of introgression from the archaic Taimyr wolf lineage into present-day Arctic dog breeds (e.g. Siberian husky), indicating that the ancestry of present-day dogs is derived from multiple regional wolf populations (Skoglund et al. 2015).

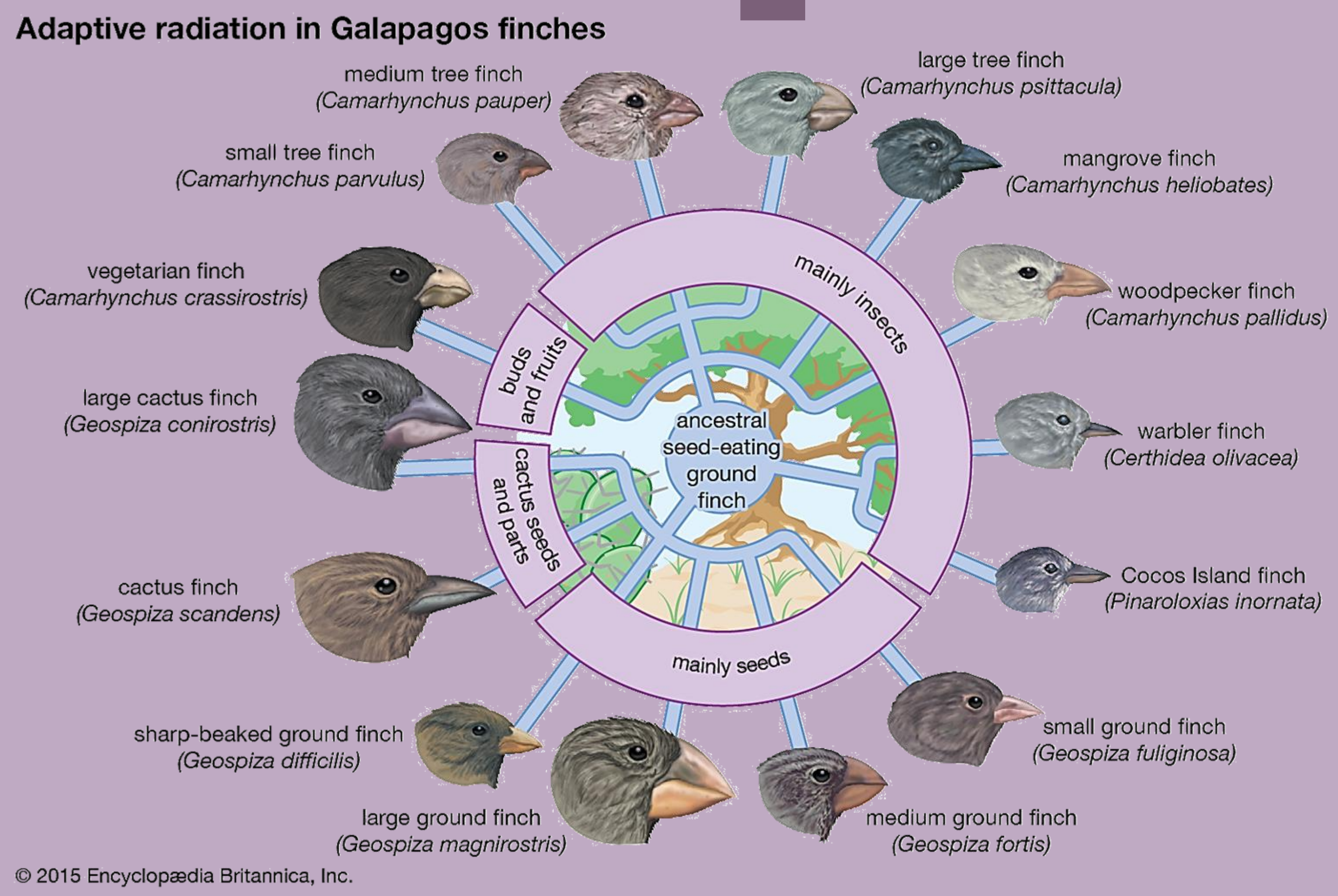
The phylogenetic tree of seven dog breeds *Canis lupus familiaris* rooted to wolf *Canis lupus*.



Tulumnes, via Wikimedia Commons, CC BY 4.0, with modifications.

Examples of species resulted from the divergent evolution of Darwin's finches: 1) *Geospiza magnirostris* (large seeds); 2) *Geospiza fortis* (smaller seeds); 3) *Certhidea fusca* (insects); 4) *Camarhynchus parvulus* (polyphagous, omnivorous).

Collage by Kiwi Rex, via Wikimedia Commons, CC BY-SA 4.0



"Adaptive radiation", Encyclopedia Britannica, used under a Fair Use rationale.

Convergent evolution

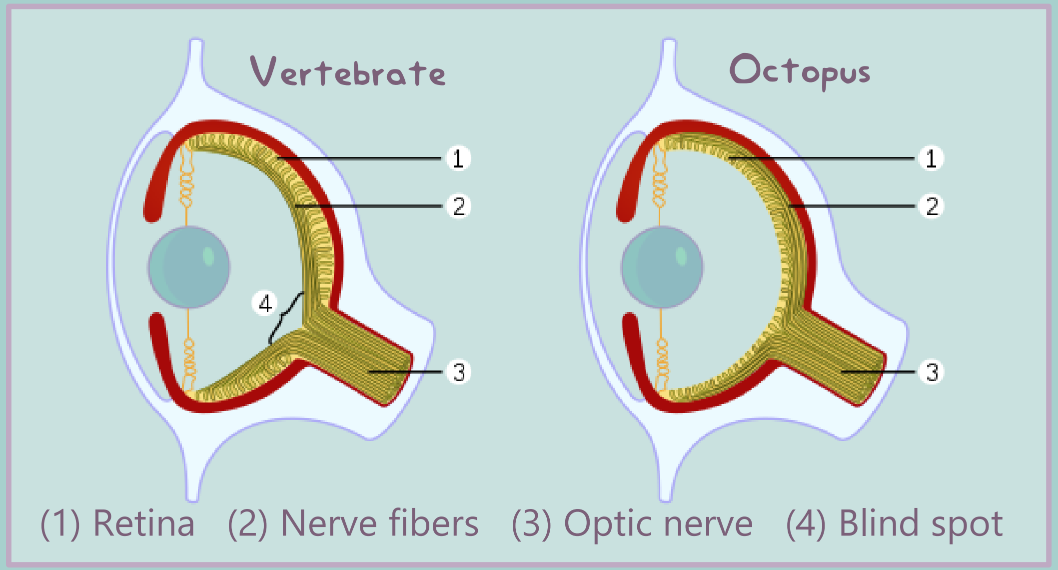
Distantly related species ***converge,*** evolving similar traits independently.

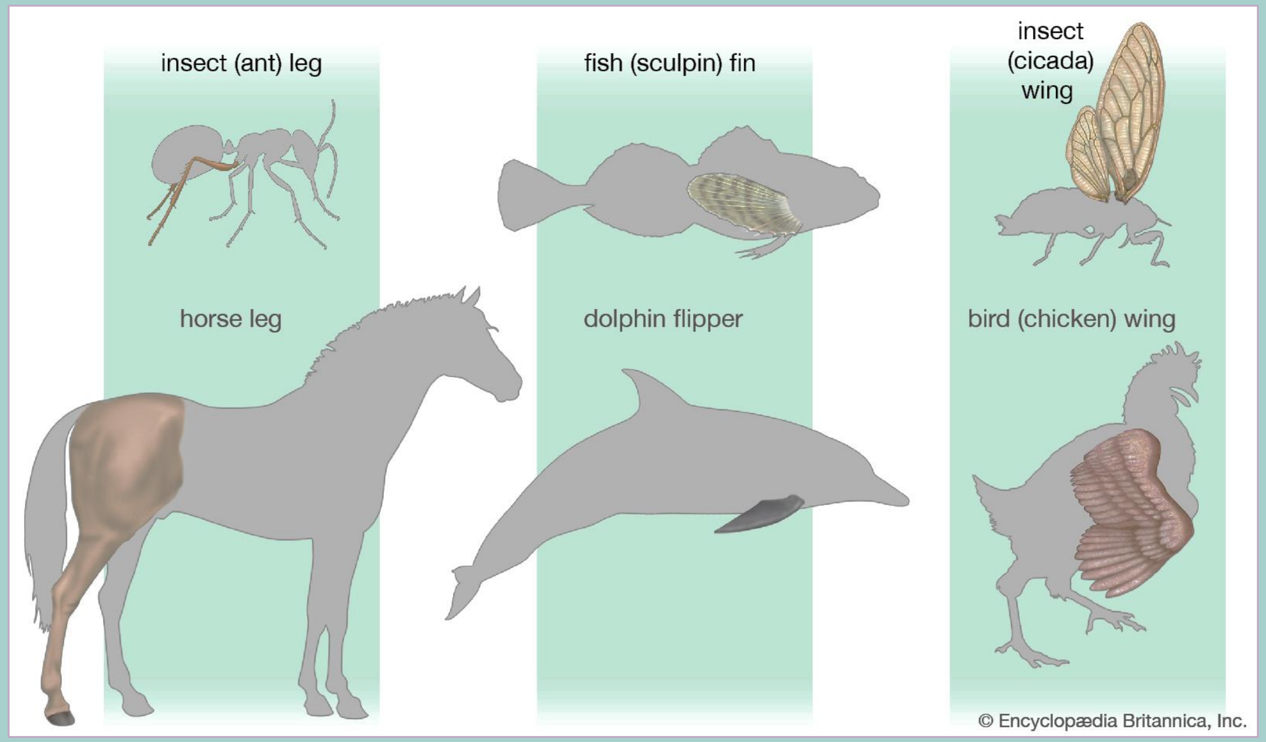
Populations are exposed to the same selective pressure that lead them into developing similar adaptive strategies (homoplasy).

Converging species evolve ***analogous structures*** (different embryonic origins, different anatomy, but have similar functions).

Example: wings in bats, insects, and birds; eyes of vertebrates and cephalopods; prickles, thorns, spines in plants.

Example of **analogous structures**: camera-type eyes of vertebrates and cephalopods (top), with a difference in the presence of a blind spot due to the routing of the nerve fibers (middle); various analogous structures in animals (bottom).





Convergent evolution examples

Myrmecophagy. A number of unrelated mammal species from different geographical regions have developed similar structures to support a myrmecophagy habit (feeding on insects, especially ants and termites): powerful fore claws and long, sticky tongues.

Streamlining. Various aquatic animals from different taxa have developed a streamlined body shape as an adaptation for life in water.

Tendrils. Snow pea *Pisum sativum* and *Passiflora* species have developed tendrils from different body parts in response to competition for light. *Passiflora* tendrils are stem tendrils developing from axillary buds. Tendrils in pea (legumes) are modified leaves produced by the vegetative meristem.

Parallel evolution

Unrelated species acquire similar characteristics (homoplasy) while evolving together at the same time in the same ecospace (Gabora 2013).

The criteria for defining convergent vs parallel evolution are often unclear (evolution is defined as parallel if the ancestors also shared a similarity in a particular trait, but how similar? How far back?).

The evolution is an adaptive response to the same environmental conditions (in convergent evolution, it is not always the case).

Example: the North American cactus and the African euphorbia; North American pronghorn and African antelope.

Parallel evolution of the North American cactus (top row) and the African euphorbias (bottom row) driven by the same hot arid habitats. Both adapt by evolving e.g. thick succulent stems and sharp quills (spines in cacti, thorns in euphorbias). ▼

▲ Parallel evolution of the American pronghorn (left) and the African true antelopes (examples are the blackbuck, middle; and the red-fronted gazelle, right), showing similar behavior and morphology, due to their adaptation to a similar niche and habitat (grassland and savanna).

Coevolution

Two or more species affect each other's evolution by exerting selection pressures on each other (reciprocal evolutionary changes).

Occurs when different species have close ecological interactions over a long time with one another, reciprocally changes one another's gene pool.

Can lead to very specialized relationships between species involved in the coevolutionary system.

Examples of coevolutionary systems: host and parasites, predators and prey, competitive, and mutualistic interactions.


Cheetah and Thompson's gazelle


Centropogon nigricans flower and *Anoura fistulata* bat


Centropogon umbrosus flower and *Eutoxeres condamini* bird


Brugmansia flower and *Ensifera ensifera*


Amegilla cingulata bee and *Acanthus ilicifolius* flower


Pseudomyrmex ant and bull thorn acacia


Yucca *Yucca whipplei* and yucca moth *Tegeticula maculate*

Misconceptions about evolution

05

Several misconceptions about evolution

Evolution explains the origin of life

Individuals evolve

Evolution does not tell us about how life first appeared on Earth; mostly deals with how life changed after its origin

Evolution is the change in genetic composition of a population over time, resulting from differential reproduction of individuals with certain alleles. Thus, an individual cannot evolve, a population does.

Several misconceptions about evolution

✕ Organisms evolve on purpose

✓ Natural selection works on variations already existing in a population; environment change is only a trigger. Evolution is not goal directed.

✕ Evolution = natural selection

✓ Natural selection is only one of the means of evolution. Others include mutation, migration, and genetic drift.

Several misconceptions about evolution

Evolution promotes the survival of species

Evolution produces perfect organisms

Evolution sometimes reduces fitness of individuals or populations, occasionally even lead to extinction. E.g.: accumulation of detrimental mutations, sexual selection ("the handicap principle")

Evolution produces a tree, NOT a ladder towards a better species. An organism's fitness is relative to its environment, which is usually changing. Gene flow and genetic drift may introduce bad alleles. Good alleles can be lost.

ADAPTATION

06

Adaptation

An inherited characteristic ("a change") that helps an organism to survive long enough to reproduce more successfully in its changing environment.

Are genetically-based and thus can be passed on from generation to generation; the result of evolution.

Can be **structural**, **behavioral,** and also **physiological**.

Types of adaptation

Structural or physical adaptations

Changes in the physical structure of a species over time to make it equipped (effective) to survive in a "new" environment.


Waldemar Brandt (top), Joe Lemm (bottom), Unsplash license

Behavioral adaptations

Changes in behavior of certain organisms or species as a strategy to survive in a "new" environment.


Tørrissen, via Wikimedia Commons, CC BY-SA 3.0 (top)
Michael Himbeault, via Flickr, CC BY 2.0 (bottom)

Physiological adaptations

An internal body process aiming at maintaining an equilibrium state under different environmental conditions.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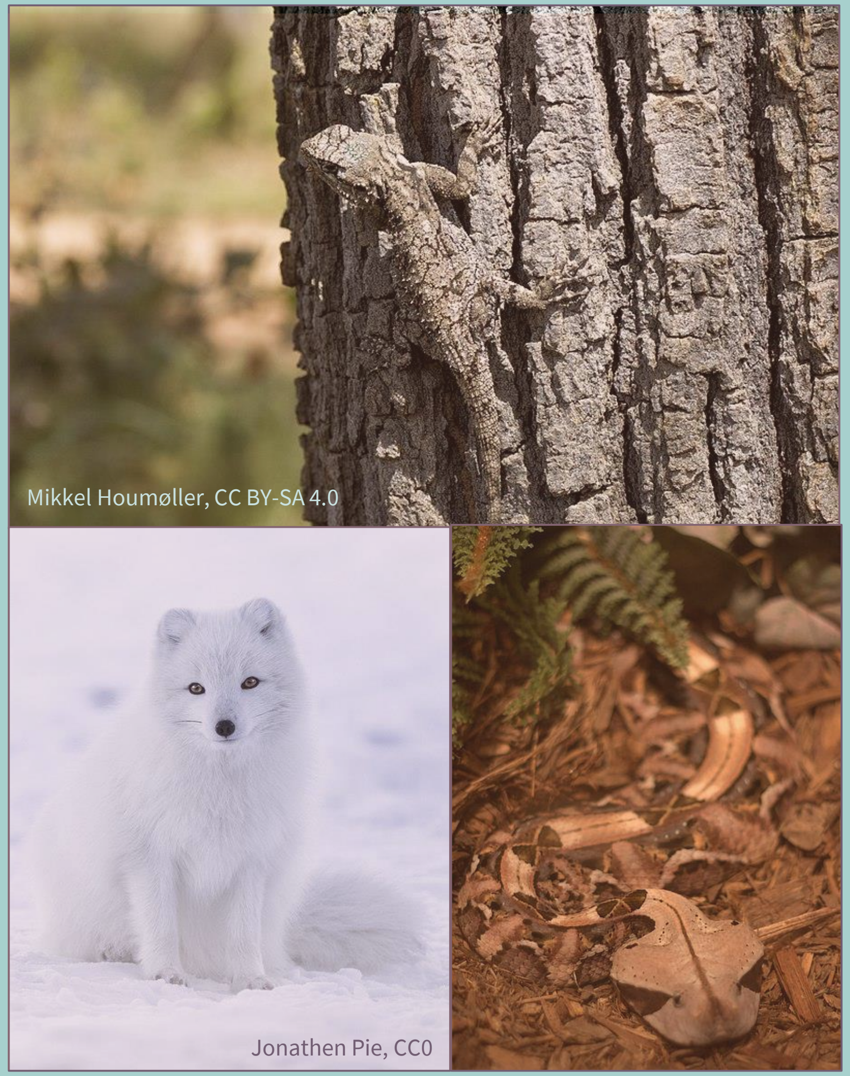
Physical adaptations in animals



Camouflage

Use of color to match the surroundings

Looking or sounding like another living organism

Mimicry

Body coverings & parts

Claws, beaks, feet, armor plates, skulls, teeth

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Behavioral adaptations in animals

Migration

Long-distance movement of animals on a seasonal basis

Hibernation/aestivation

A way to conserve energy to survive adverse conditions.

Anti-predatory

Actions that assist organisms to fight off predators

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Physiological adaptations in animals

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Chemical defense against predator

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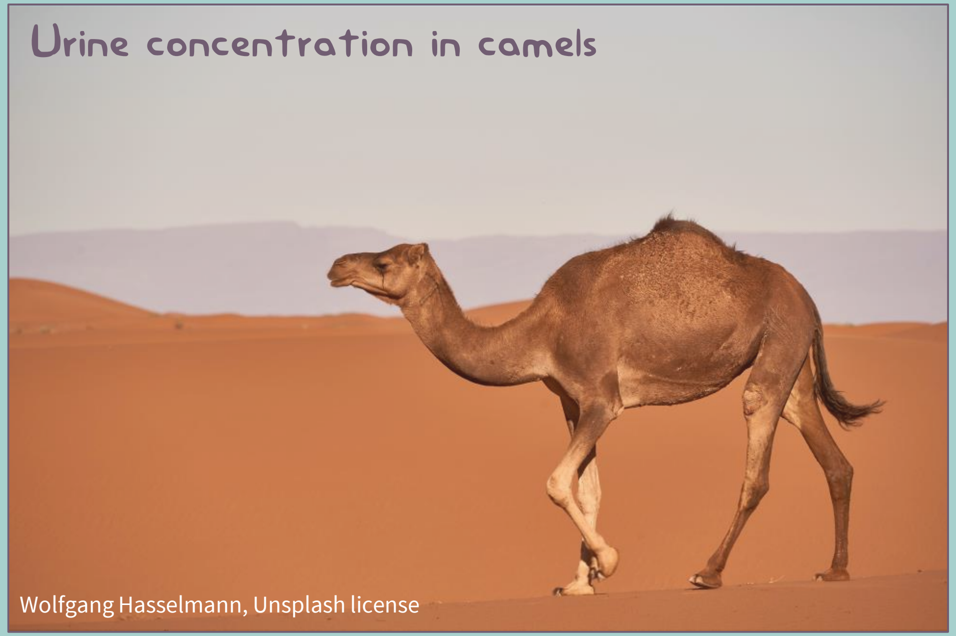

Wolfgang Hasselmann, Unsplash license

Physiological defense

James Gathany, Public Domain

Example in human

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Structural adaptations in plants


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Adaptations for reproduction

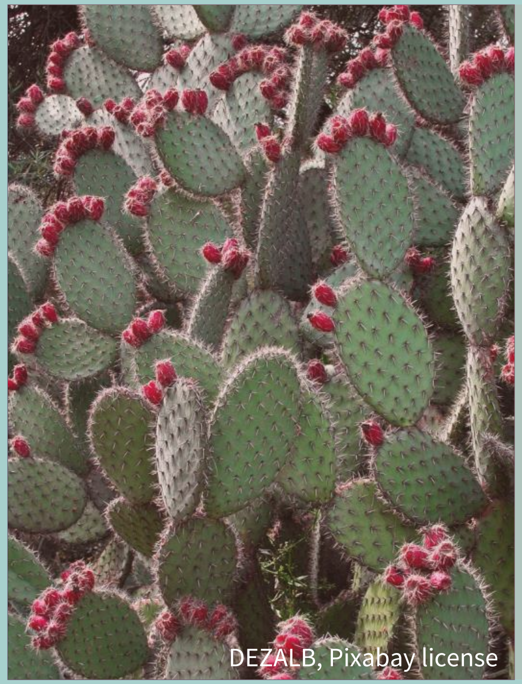
Brightly colored flowers with nectar attract pollinators (e.g. birds, insects). Sweet fruit attracts animals that spread seeds far away. Some seeds are shaped to catch the wind.

Adaptations for defense

Protecting from predators (different “thorns”, trichomes)

Adaptations to get food

Maximizing sun’s energy capture (leaves, stems).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Behavioral adaptations in plants


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Carnivorism

Carnivorous plants, such as Venus flytrap and *Nepenthes* can live in areas with poor soil, because they obtain their nutrients from the insects they eat.

Phototropism

Plant and sprouts grow towards the sun. Vines climb up trees to catch sunlight.

Geo-/gravitropism

Positive: grow down towards ground; negative: grow up against gravity.


Roberto Fiadone, via Wikimedia Commons, CC BY-SA 4.0


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Physiological adaptations in plants

Poison in black nightshade *Solanum nigrum*

Trichomes in stinging nettles *Urtica* spp.

Crypsis in *Mimosa pudica*

Idioblast in *Diefenbachia*

Trichomes in Cape sundew *Drosera capensis*

Full image credits at the end of the presentation

Summary

- Evolution describes changes in inherited traits of populations through successive generations
- Mechanisms of change in evolution include natural selection, mutation, genetic drift, and gene flow.
- Evolution works on the existing genetic variation in populations, resulting in adaptations.
- Adaptation is an inheritable change in organisms’ characteristics that helps them to survive long enough to reproduce more successfully.
- Natural selection can generate populations with better adaptations and fitness, but not perfect organisms.
- Evolution has no purpose, only the sum of the various driving forces.

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