Speciation

"New Species Can Emerge"

- **Darwin called the first appearance of new beings on earth the "mystery of mysteries".**
- The origin of species or **speciation** is central to evolutionary theory because the appearance of new species is the source of biological diversity.
  - *Evolutionary theory must explain how these new species come into existence.*
- **Speciation** explains both the unity (similarities) and the diversity (differences) of living organisms.

"Speciation"

- **Speciation** is a conceptual bridge between microevolution and macroevolution.
- **Microevolution** refers to the change in allele/gene frequencies in a population over time.
- **Macroevolution** refers to the broad pattern of evolution above the species level.
  - *here small changes have accumulated to the point where large noticeable changes have occurred in groups of organisms, for example the emergence of mammals or flowering plants.*

"Biological Species Concept"

- Before we begin to explore "how" species change we ought to first understand "what" a species is.
- The **biological species concept** defines a species as a group of populations whose members can interbreed in nature and produce viable, fertile offspring-but can not produce viable, fertile offspring with members of other such groups.
  - *gene flow (transfer of alleles) between populations tends to hold populations together genetically through the ongoing exchange of alleles.*
  - *in fact, removing gene flow plays a key role in the generation of new species as we will see shortly*

"Biological Species Concept"

Similarity between different species. The eastern meadowlark (*Sturnella magna,* left) and the western meadowlark (*Sturnella neglecta,* right) have similar body shapes and colorations. Nevertheless, they are distinct biological species because their songs and other behaviors are different enough to prevent interbreeding should they meet in the wild.

Defining a species is not always easy nor intuitive.

Diversity within a species. As diverse as we may be in appearance, all humans belong to a single biological species (*Homo sapiens*), defined by our capacity to interbreed.

"Biological Species Concept"

- **Do you see any limitations in defining species this way?**
- **Yes, of course.**
  - *bacteria- they are asexual*
  - *dinosaurs- they are dead*
  - *newly discovered organism- we have not yet and maybe never will be able to test its ability to reproduce with other organisms*
- **So what do biologists do in these cases?**
- **They use other definitions of species that are suitable for the circumstances.**

"Other Species Concepts"

- **When the biological species concepts falls short biologists use other definitions of species that are suitable for the circumstances.**

- Morphological Species Concept
  - *uses cell or body structures and features*
- Ecological Species Concept
  - *defines according to the niche it fills in an ecosystem*
- Phylogentic Species Concept
  - *uses morphology and molecular sequencing*

"Reproductive Isolation"

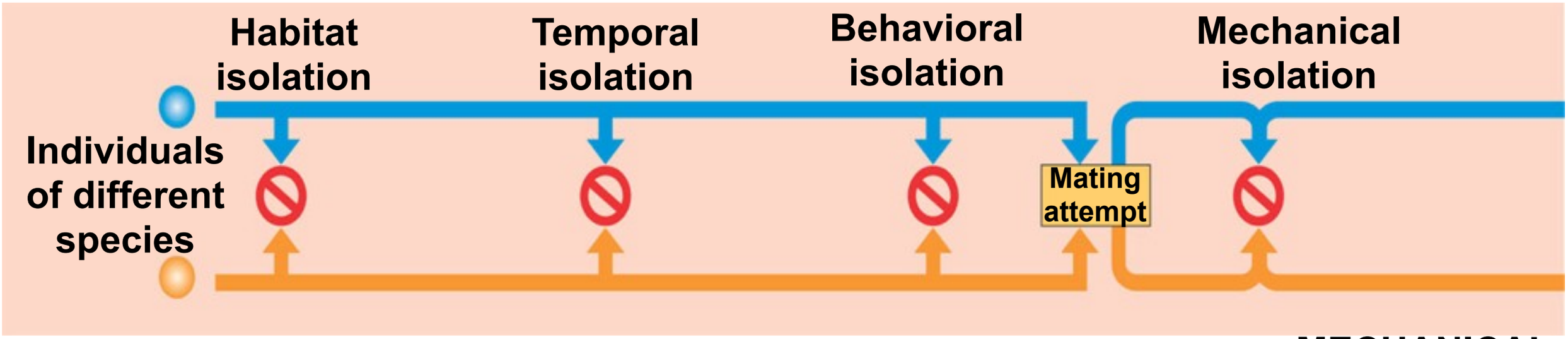
- Biological Species are defined by their reproductive compatibility, the formation of new species therefore relies on *reproductive isolation*.
- **Reproductive isolation-** existence of barriers that impede members of two species from interbreeding and producing viable, fertile offspring.
  - Such barriers block gene flow and prevent the formation of *hybrids*.
- **Hybrids-** offspring that result from interspecific matings.

"Reproductive Isolation"

- **Prezygotic Barriers-** Impede mating between species or hinder the fertilization of ova if members of different species attempt to mate
- **Postzygotic Barriers-** Often prevent the hybrid zygote from developing into a viable, fertile adult
- *sometimes a single barrier does not prevent gene flow but a combination of barriers usually will.*

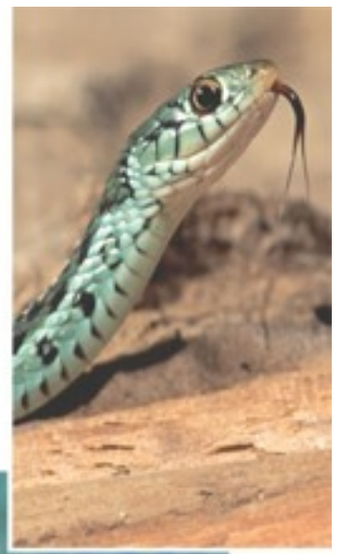
"Reproductive Isolation"

Prezygotic barriers impede mating or hinder fertilization if mating does occur



HABITAT ISOLATION

(b)



(a)

TEMPORAL ISOLATION

(d)

(c)

BEHAVIORAL ISOLATION

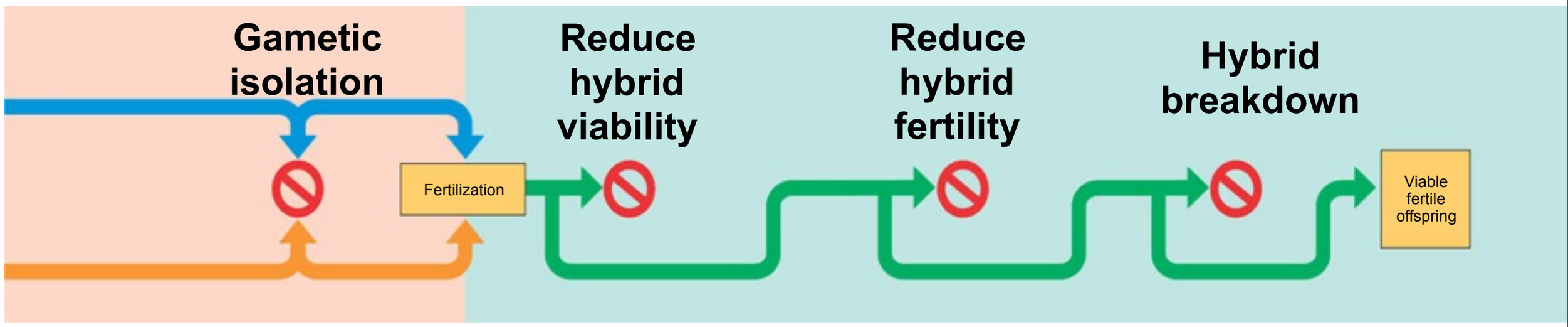
(e)

MECHANICAL ISOLATION

(g)

(f)

"Reproductive Isolation"



GAMETIC ISOLATION

REDUCED HYBRID VIABILITY

REDUCED HYBRID FERTILITY

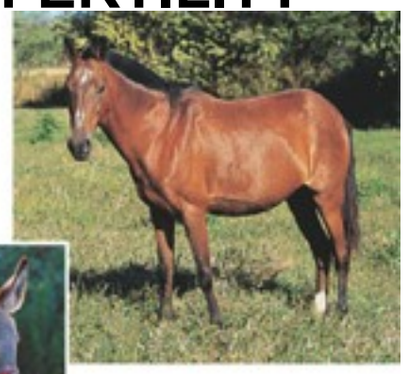
HYBRID BREAKDOWN

(h)

(i)

(j)

(k)



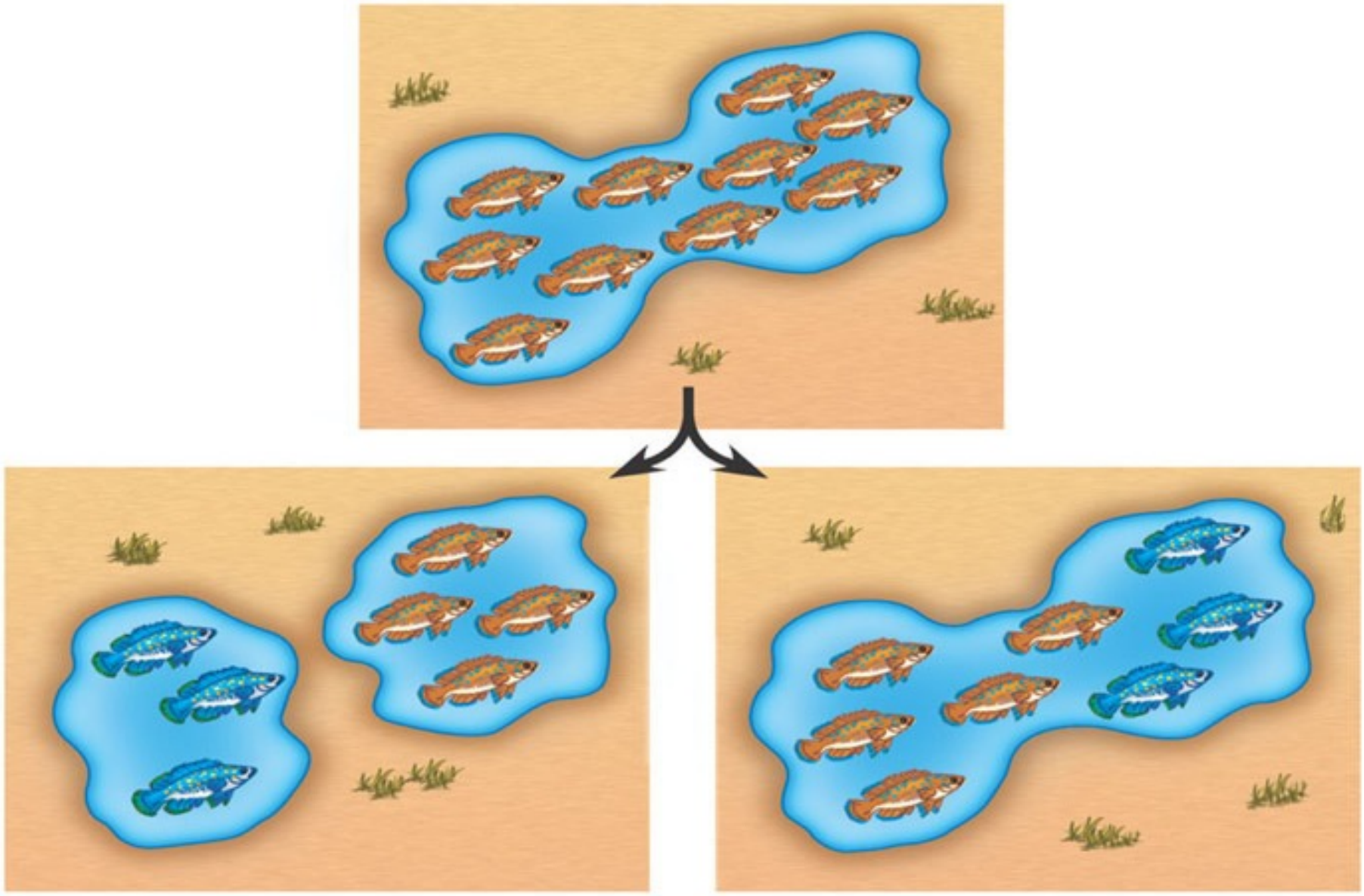
(l)

(m)

"Creating New Species"

- Speciation occurs in two main ways depending on how gene flow is interrupted.
- **Allopatric speciation-** gene flow is interrupted when a population is divided *geographically isolated* into two subpopulations
- **Sympatric speciation-** gene flow is interrupted not by geographical isolation but rather polyploidy, habitat differentiation or sexual selection. The population splits into subpopulations even though they remain geographically in contact.
  - *this form is less common and will not be discussed in MYP*

"Creating New Species"



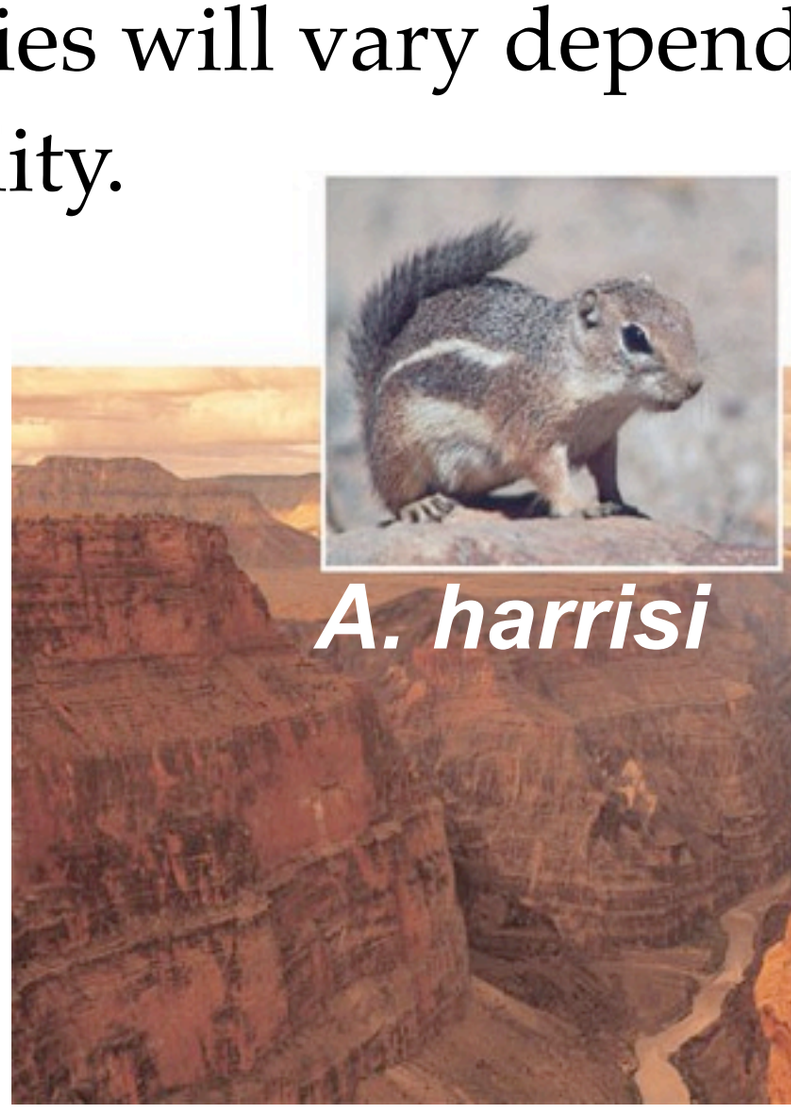
Allopatric speciation. A population forms a new species while geographically isolated from its parent population.

Sympatric speciation. A small population becomes a new species without geographic separation.

"Allopatric Speciation"

- "Physically" interrupted gene flow is the easiest and most common way to generate a new species.
- Obviously the degree of geographical isolation needed to create a new species will vary depending on the populations motility.

The grand canyon is enough to stop gene flow between chipmunks. Would it separate a population of birds? NO



"Allopatric Speciation"

- Once gene flow is interrupted, the two separate populations may diverge.
  - different mutations
  - natural and sexual selection
  - genetic drift
- With enough time any of one or combination of these factors can dramatically change the gene pools enough that if gene flow is reestablished the members of each subpopulation are longer able to produce viable, fertile offspring.

"Allopatric Speciation"

- A point of emphasis... geographical isolation by itself does not lead to reproductive isolation, reproductive isolation has to become *intrinsic* for speciation to take place.
  - females choose certain male traits
  - receptors on gametes no longer "fit"
  - organisms mate at different times of the year

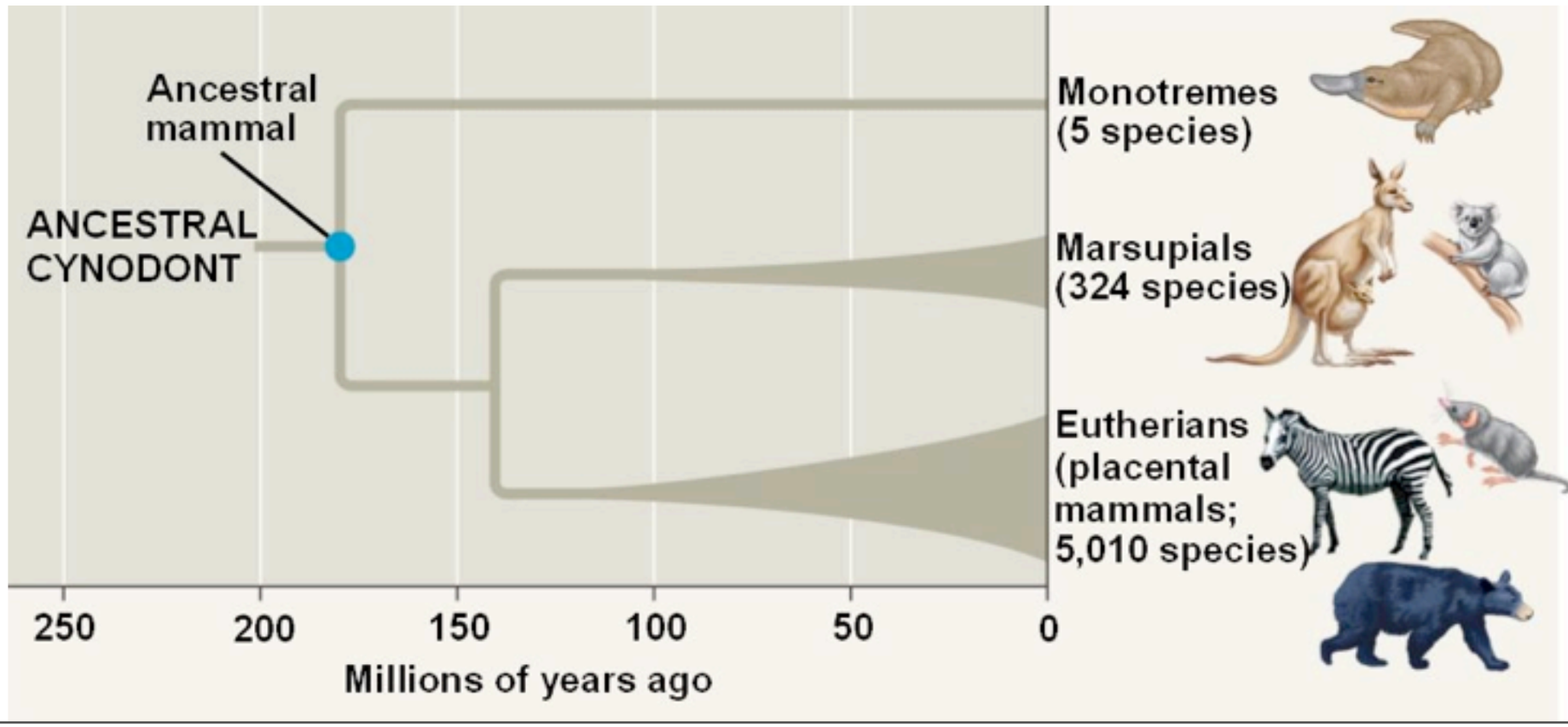
think of the reproductive isolating barriers we just looked a few slides back, geographic isolation has to lead to one or more of those in order for speciation to occur

"Adaptive Radiations"

- Sometimes we see explosions of many new species all at once.
- **Adaptive Radiation**- are periods of evolutionary change in which groups of organisms form many new species whose adaptations allow them to fill different ecological niches
  - these radiations have been documented on a large worldwide scale
  - these radiations have been documented on a small regional scale

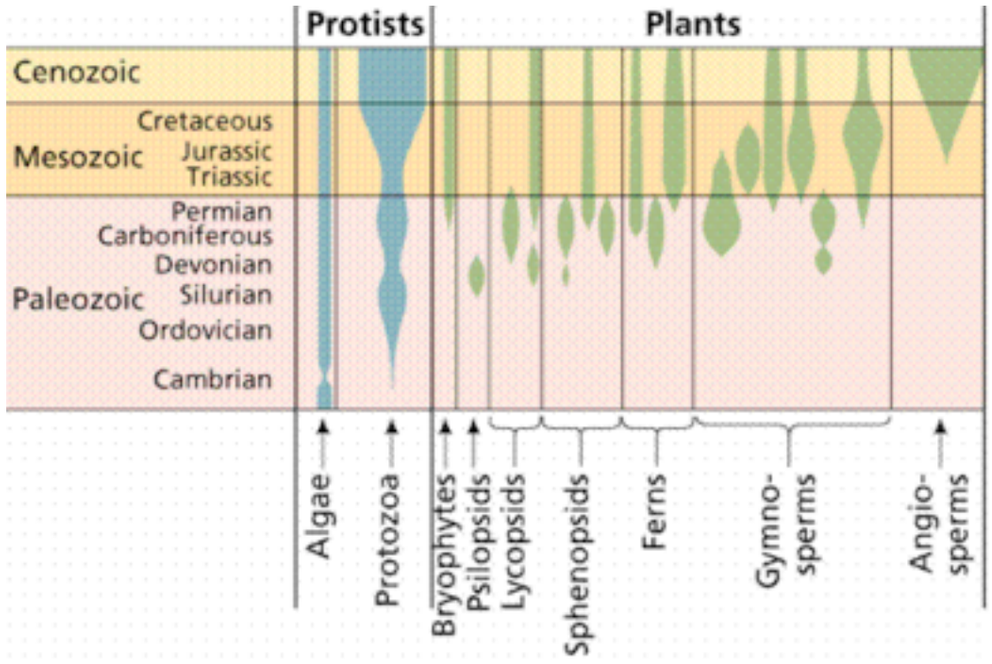
"Large, Worldwide Radiations"

- **Large scale adaptation radiations occurred after the big five mass extinctions.**
  - The number and diversity of mammals exploded after the dinosaurs went extinct.
    - *even though mammals first evolved 180 mya they lacked diversity and remained small*



"Large, Worldwide Radiations"

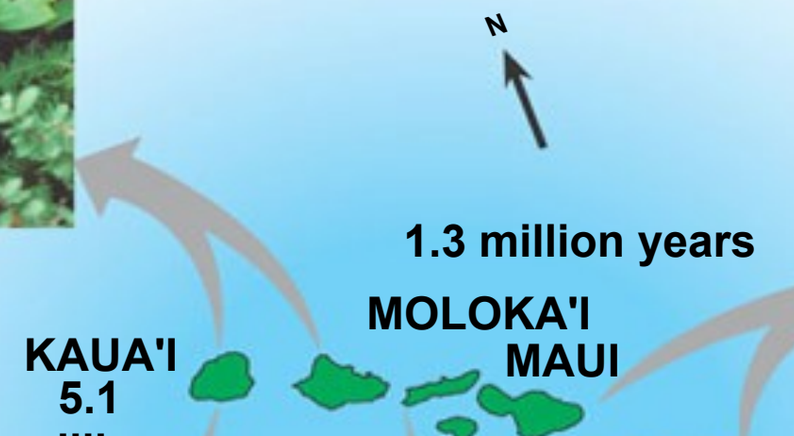
- **Large scale adaptation radiations often occurred after major evolutionary innovations.**
  - Radiations followed the rise of photosynthetic prokaryotes, evolution of large predators during the cambrian explosion and the colonization of land by plants.
  - *key adaptations allowed plants to explode and diversify on land which consequently led to the explosion of insect diversity that remains today*



"Small Regional Radiations"

These plants are part the "silversword" alliance. All these plants descended from a common ancestor "tarweed" that first arrived in Kaua'i from North America nearly 5 million years ago

Dubautia laxa



Argyroxiphium sandwicense

Dubautia waialealae

Dubautia scabra

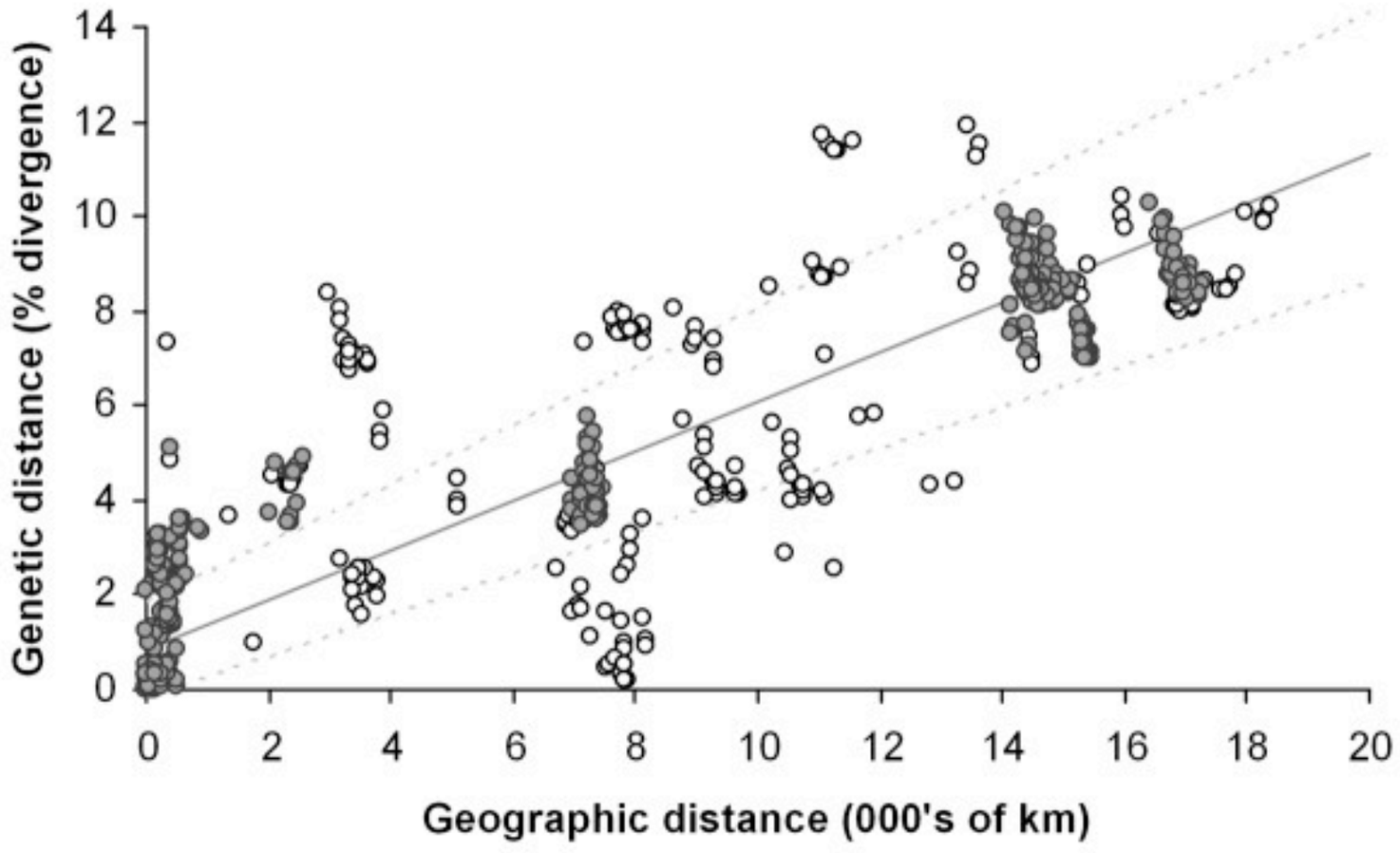
Dubautia linearis

"Small Regional Radiations"

- **Hawaiian Archipelago**
  - Tarweed seed/spores land on the first hawaiian island Kauai ~5 mya.
    - *little competition and abundant resources*
  - tarweed spreads, adapts & diversifies across Kauai and onto Oahu the next island formed in the chain
    - *this pattern continues with each successive island formed and with varying elevations and climate on each island the tarweed diversified into numerous and very different species*

"Evidence of Allopatric Speciation"

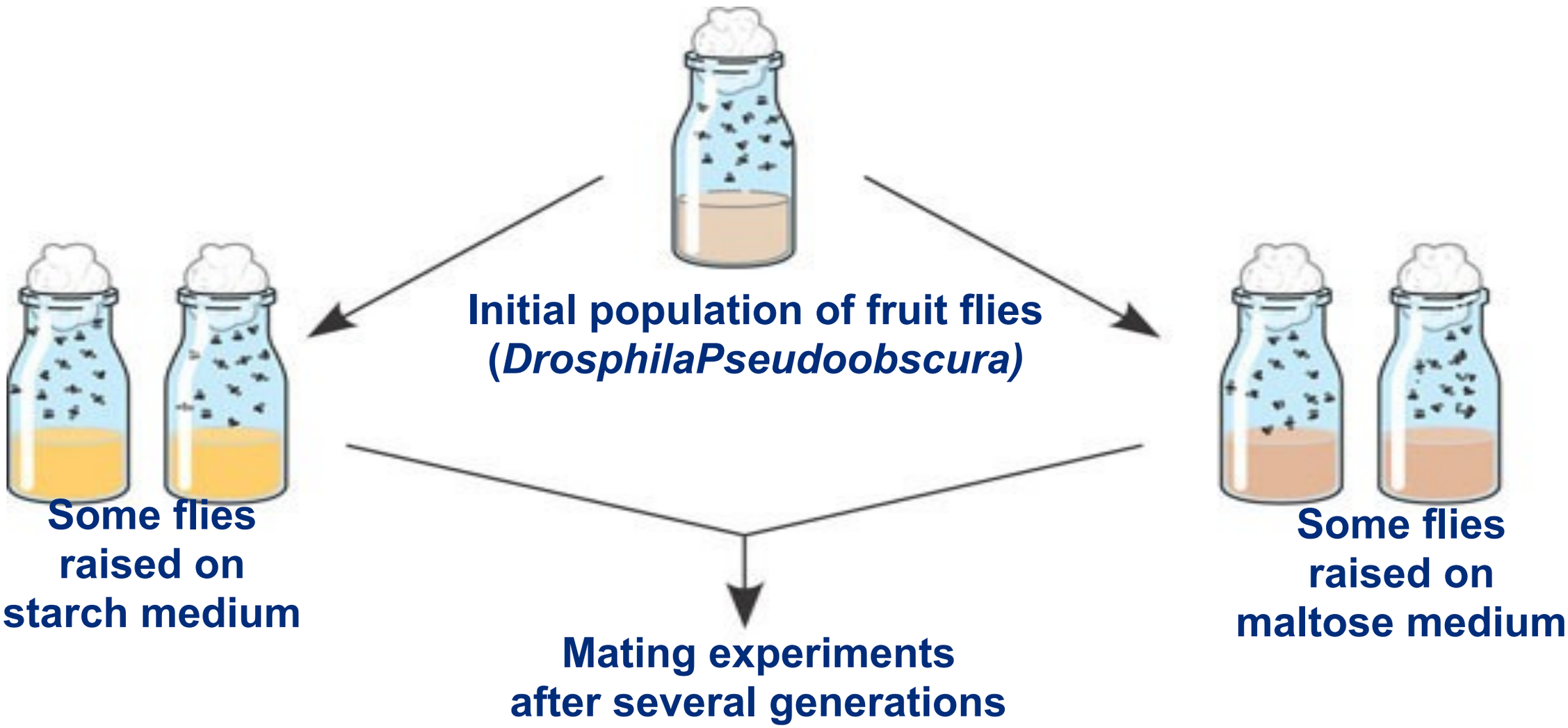
- Many studies, both in the field and in the lab, provide evidence for allopatric speciation.
  - in almost all cases the longer and farther two populations are apart the greater the likelihood intrinsic isolation will occur.



"Evidence of Allopatric Speciation"

EXPERIMENT

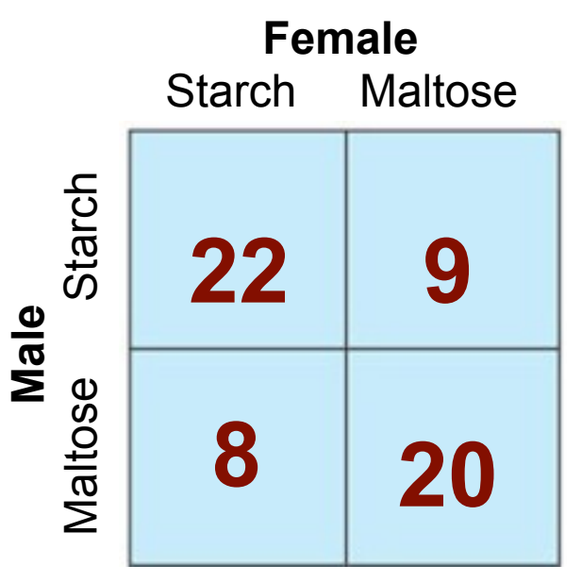
Diane Dodd, of Yale University, divided a fruit-fly population, raising some populations on a starch medium and others on a maltose medium. After many generations, natural selection resulted in divergent evolution: Populations raised on starch digested starch more efficiently, while those raised on maltose digested maltose more efficiently. Dodd then put flies from the same or different populations in mating cages and measured mating frequencies.

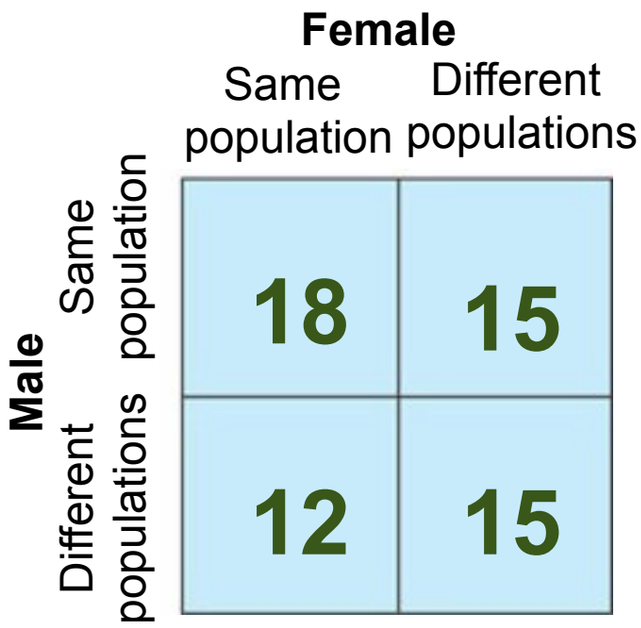


RESULTS

When flies from “starch populations” were mixed with flies from “maltose populations,”the flies tended to mate with like partners. In the control group, flies taken from different populations that were adapted to the same medium were about as likely to mate with each other as with flies from their own populations.

Mating frequencies in experimental group





Mating frequencies in control group

CONCLUSION

The strong preference of “starch flies” and “maltose flies” to mate with like-adapted flies, even if they were from different populations, indicates that a reproductive barrier is forming between the divergent populations of flies. The barrier is not absolute (some mating between starch flies and maltose flies did occur) but appears to be under way after several generations of divergence resulting from the separation of these allopatric populations into different environments.

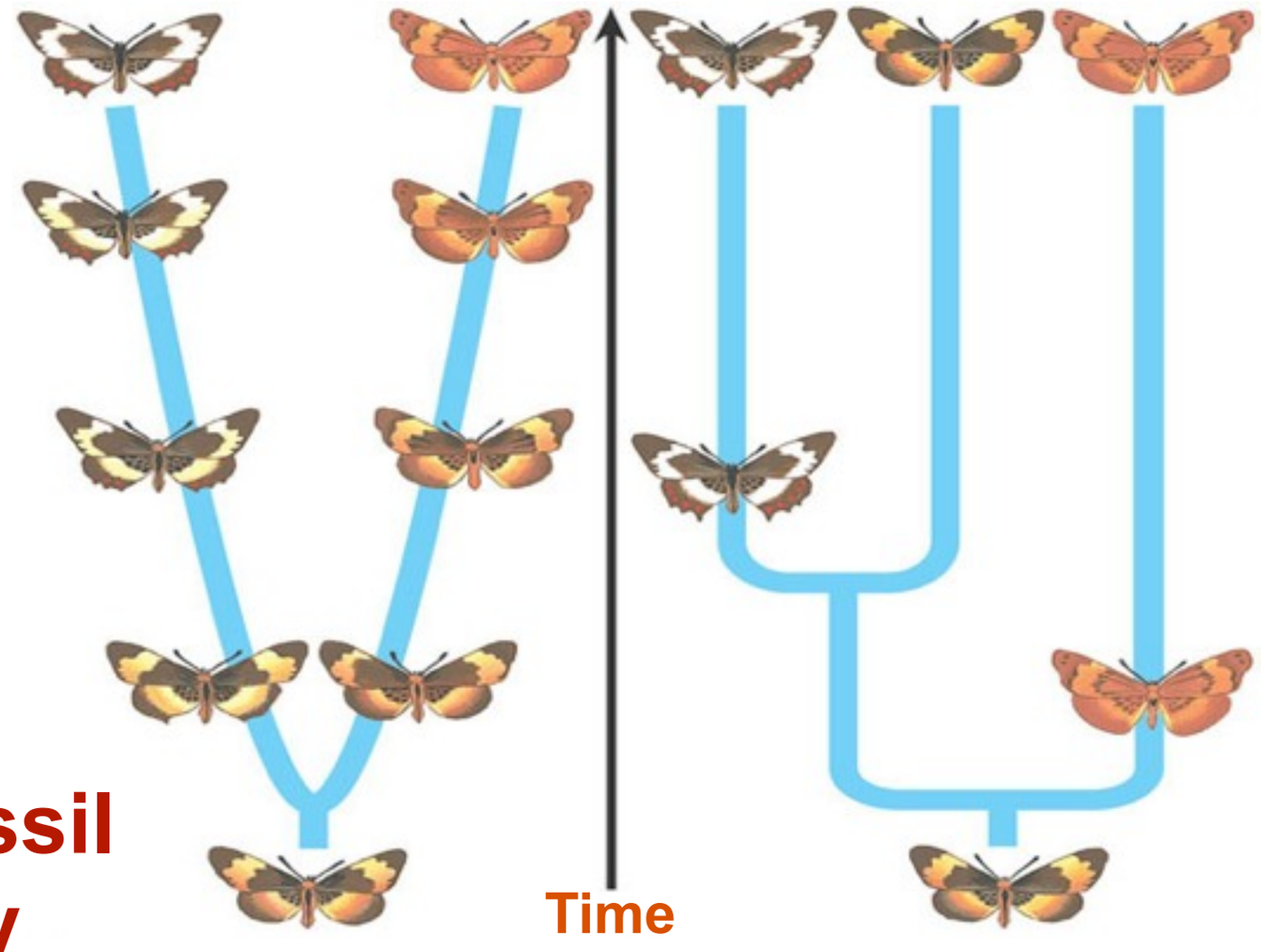
"The Rate of Speciation"

- The time it takes for geographical isolation to lead to reproductive isolation depends on a number a variables.
  - which genes mutate, the rate of mutations, extent of genetic drift, degree of environmental differences between the populations, generation times
- Intrinsic reproductive isolation leading to speciation may take thousands or millions of years or it may happen virtually "over night".

"The Rate of Speciation"

- Darwin described speciation as a gradual change over time.

Gradualism model. Species descended from a common ancestor gradually diverge more and more in their morphology as they acquire unique adaptations.

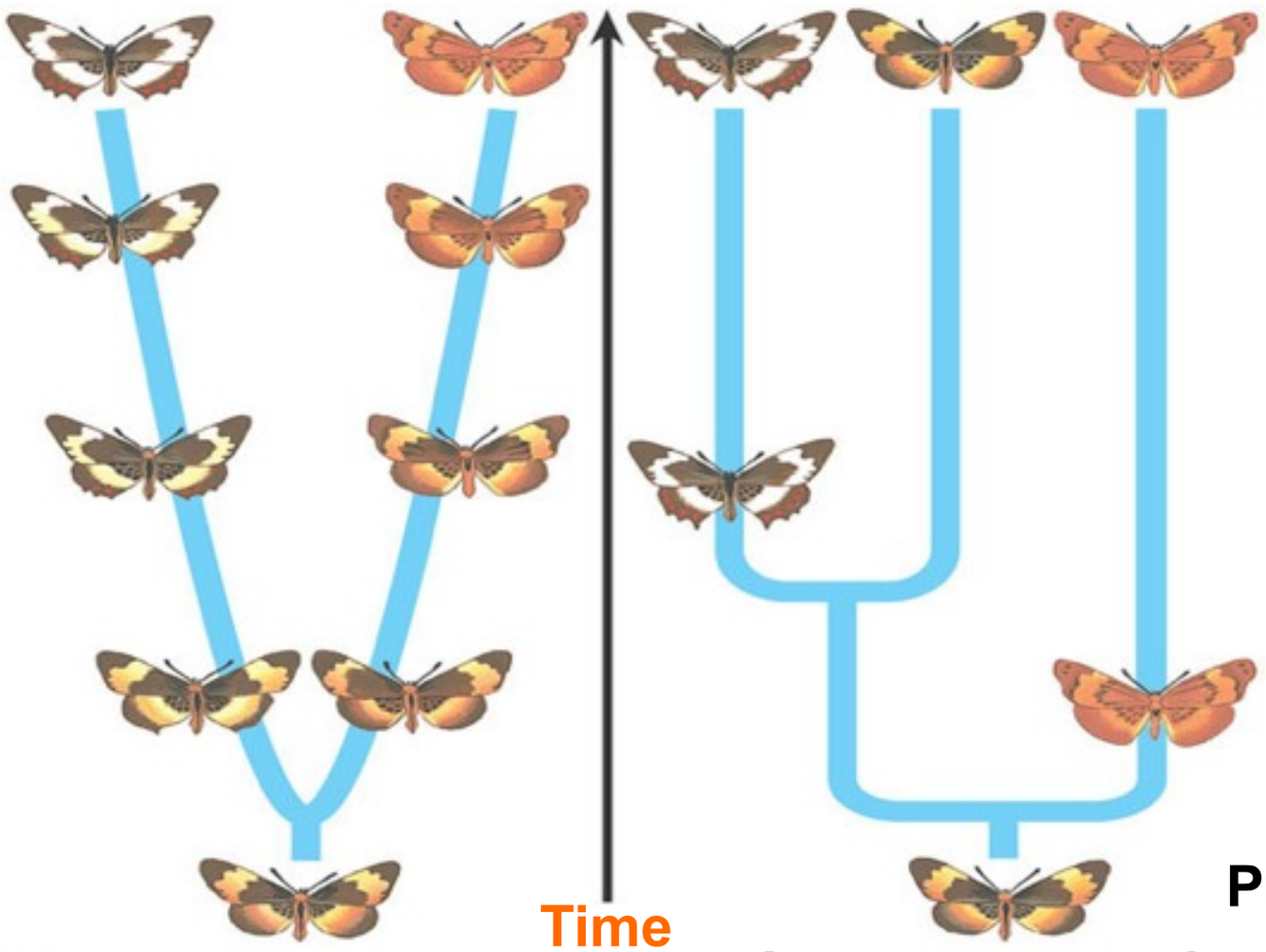


Punctuated equilibrium model.

However a lot of fossil evidence looks very different from this.

"The Rate of Speciation"

- Contemporary biologists Stephen Jay Gould and Niles Eldridge proposed a different view of speciation.



Many fossils appear similar for a long time, then exhibit abrupt changes in a short period of time followed by another period of stasis.

Punctuated equilibrium model.

A new species changes most as it buds from a parent species and then changes little for the rest of its existence.

Evolution is Not Goal Oriented

- Whether speciation occurs slowly and gradually or whether it occurs bursts, evolution has no end point in mind.
- Evolution "tinkers" with each organism making slight modifications some of which will be beneficial and others that are not.

Overtime this "tinkering" has lead to three key features in the natural world!

1. Organisms are well suited to their environments.

2. Organisms share many characteristics.

3. Organisms are remarkably diverse.