

# The Origin Of Species

Chapter 24

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- Objectives
  - Define and discuss the limitations of the four species concepts.
  - Describe and provide examples of prezygotic and postzygotic reproductive barriers.
  - Distinguish between and provide examples of allopatric and sympatric speciation.
  - Explain how polyploidy can cause reproductive isolation.
  - Define the term hybrid zone and describe three outcomes for hybrid zones over time.

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## Introduction

- Darwin explored the Galapagos Islands and discovered plants and animals found nowhere else on Earth
- The origin of new species, or speciation is at the focal point of evolutionary theory, because the appearance of new species is the source of biological diversity

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- Evolutionary theory must explain how new species originate in addition to how populations evolve
- Macroevolution refers to evolutionary change above the species level
  - Speciation is the bridge between microevolution (allele frequency changes within a population) and macroevolution

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### The Biological Species Concept



- Species is a Latin word meaning “kind” or “appearance”
  - The biological species concept defines a species as a population or group of populations whose members have the potential to interbreed in nature and produce viable, fertile offspring but are unable to produce viable fertile offspring with members of other populations
- Physical comparisons can be deceiving

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**(a) Similarity between different species**



**(b) Diversity within a species**

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## Reproductive Isolation



- Reproductive isolation is the existence of biological factors that impede members of two species from producing viable, fertile hybrids
  - It is a combination of various reproductive barriers
  - 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

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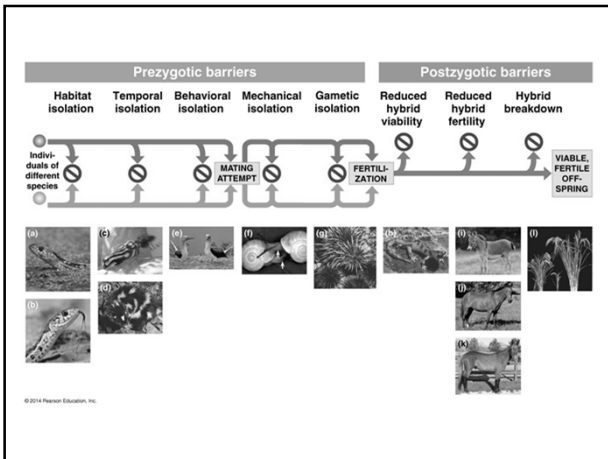
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## Limitations of the Biological Species Concept



- The biological species concept cannot be applied to
  - Asexual organisms
  - Fossils
  - Organisms about which little is known regarding their reproduction

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## Other Definitions of Species



- The morphological species concept
  - Characterizes a species in terms of its body shape, size, and other structural features
    - applies to sexual and asexual species but relies on subjective criteria
- The paleontological species concept
  - Focuses on morphologically discrete species known only from the fossil record
    - limited to only those features preserved during fossilization

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- The ecological species concept
  - Views a species in terms of its ecological niche
    - applies to sexual and asexual species and emphasizes the role of disruptive selection
- The phylogenetic species concept
  - Defines a species as a set of organisms with a unique genetic history
    - applies to sexual and asexual species, but it can be difficult to determine the degree of difference required for separate species

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## Mechanisms of Speciation



- Speciation can take place with or without geographic isolation
- Speciation can occur in two ways
  - Allopatric speciation
  - Sympatric speciation

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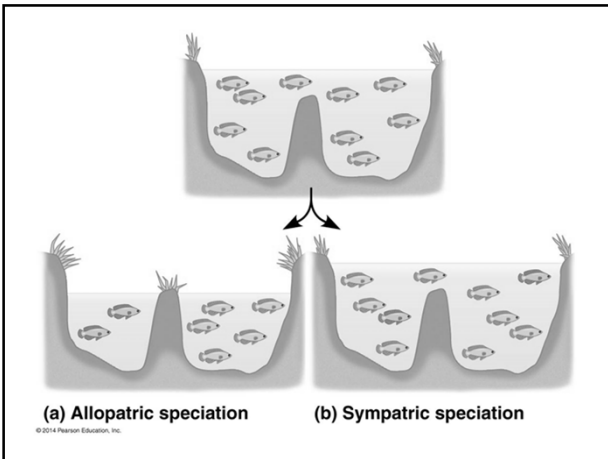
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### Allopatric (“Other Country”) Speciation

- In allopatric speciation gene flow is interrupted or reduced when a population is divided into two or more geographically isolated subpopulations
- Once geographic separation has occurred one or both populations may undergo evolutionary change during the period of separation

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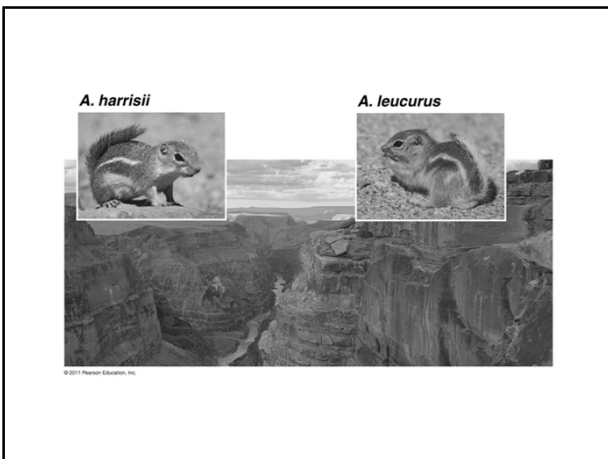
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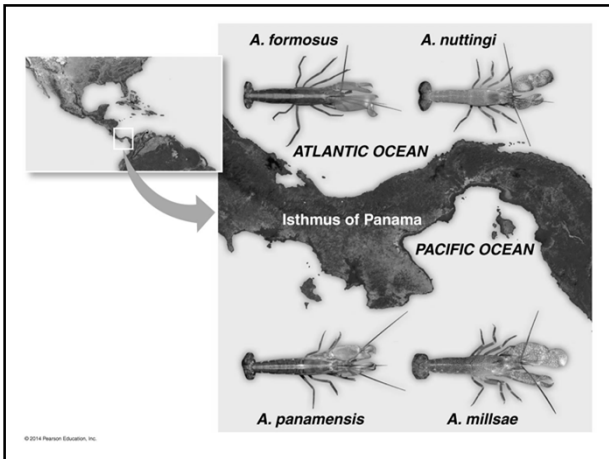
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- In order to determine if allopatric speciation has occurred reproductive isolation must have been established

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Experiment

Initial population of fruit flies (*Drosophila pseudoobscura*)

Some flies raised on starch medium      Some flies raised on maltose medium

Mating experiments after 40 generations

Results

|      |         | Female |         | Female              |                     |
|------|---------|--------|---------|---------------------|---------------------|
|      |         | Starch | Maltose | Starch population 1 | Starch population 2 |
| Male | Starch  | 22     | 9       | 18                  | 15                  |
|      | Maltose | 8      | 20      | 12                  | 15                  |

Number of matings in experimental group      Number of matings in control group

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## Sympatric (“Same Country”) Speciation



- In sympatric speciation, speciation takes place in geographically overlapping populations

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## Polyploidy



- Polyploidy is the presence of extra sets of chromosomes in cells due to accidents during cell division
  - Polyploidy has caused the evolution of some plant species

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- An autopolyploid is an individual that has more than two chromosome sets, all derived from a single species

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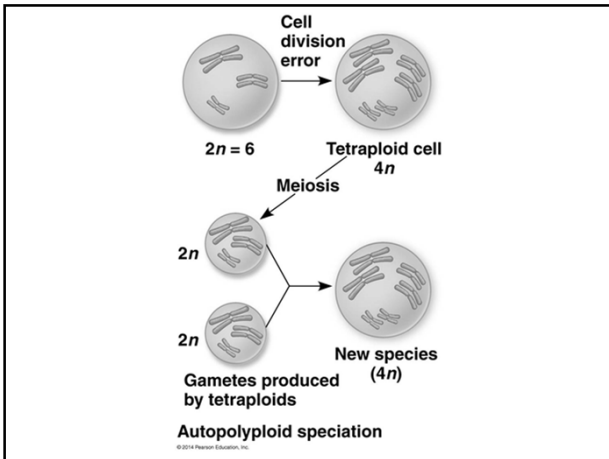
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• An allopolyploid is a species with multiple sets of chromosomes derived from different species

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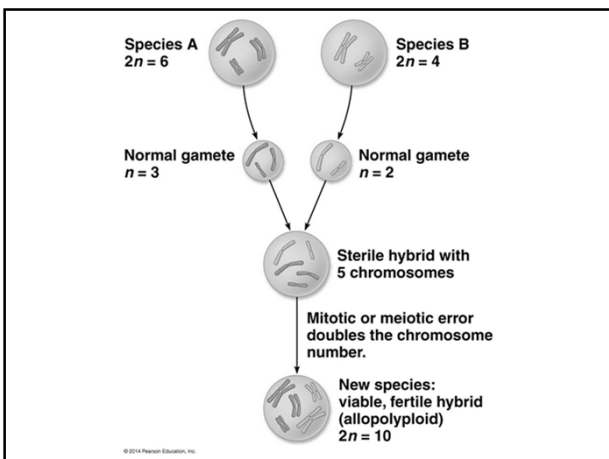
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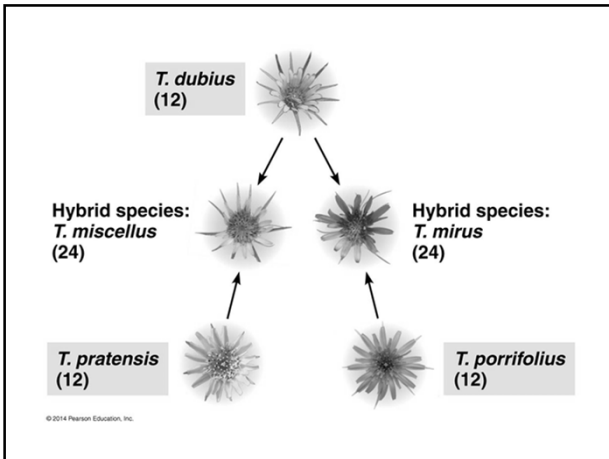


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- Many agriculturally important plants are polyploid including oats, potatoes, bananas, peanuts, barley, plums, apples, sugarcane, coffee, wheat and cotton

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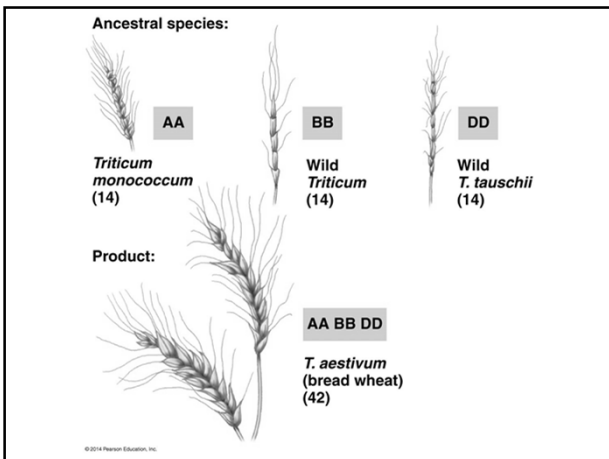
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## Habitat Differentiation and Sexual Selection



- Sympatric speciation can also result from the appearance of new ecological niches
  - In cichlid fish sympatric speciation has resulted from nonrandom mating due to sexual selection

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### Experiment

Normal light

Monochromatic orange light

*P. pundamilia*



*P. nyererei*



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## Allopatric and Sympatric Speciation: A Summary



- In allopatric speciation a new species forms while geographically isolated from its parent population
- In sympatric speciation the emergence of a reproductive barrier isolates a subset of a population without geographic separation from the parent species

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## Hybrid Zones

- A hybrid zone is a region in which members of different species mate and produce hybrids



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## Patterns Within Hybrid Zones

- A hybrid zone can occur in a single band where adjacent species meet
- Hybrids often have reduced fitness compared with parent species
- The distribution of hybrid zones can be more complex if parent species are found in multiple habitats within the same region



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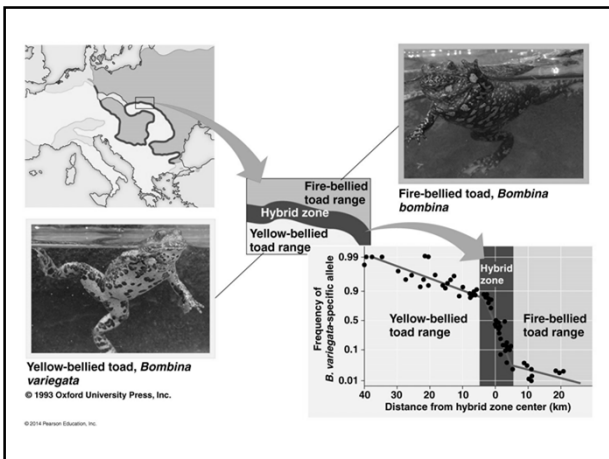
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## Hybrid Zones over Time



- When closely related species meet in a hybrid zone, there are three possible outcomes:
  - Strengthening of reproductive barriers
  - Weakening of reproductive barriers
  - Continued formation of hybrid individuals

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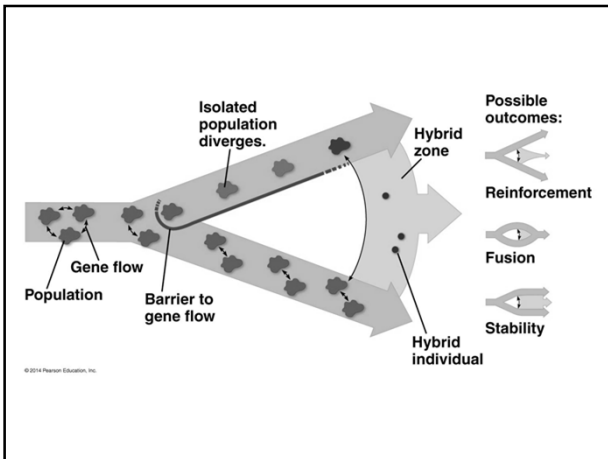
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## Reinforcement: Strengthening Reproductive Barriers



- The reinforcement of barriers occurs when hybrids are less fit than the parent species
  - Over time, the rate of hybridization decreases
- Where reinforcement occurs, reproductive barriers should be stronger for sympatric than allopatric species

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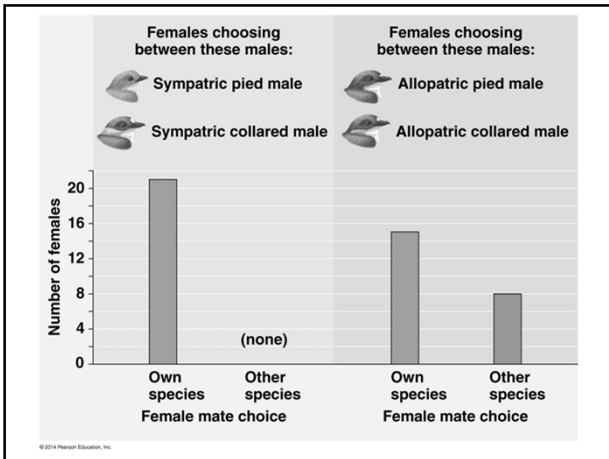
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### Fusion: Weakening Reproductive Barriers

- If hybrids are as fit as parents, there can be substantial gene flow between species
- If gene flow is great enough, the parent species can fuse into a single species

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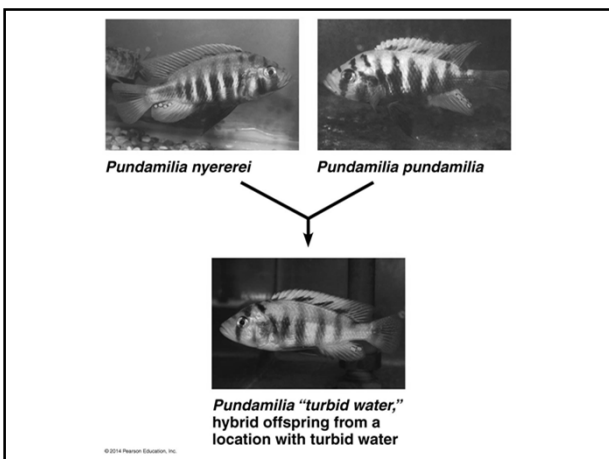
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## Stability: Continued Formation of Hybrid Individuals



- Extensive gene flow from outside the hybrid zone can overwhelm selection for increased reproductive isolation inside the hybrid zone
- In cases where hybrids have increased fitness, local extinctions of parent species within the hybrid zone can prevent the breakdown of reproductive barriers

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## The Tempo of Speciation



- The fossil record includes many episodes in which new species appear suddenly in a geologic stratum, persist essentially unchanged through several strata, and then apparently disappear
  - Niles Eldredge and Stephen Jay Gould coined the term punctuated equilibrium to describe these periods of apparent stasis punctuated by sudden change

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- The punctuated equilibrium model contrasts with a model of gradual change throughout a species' existence

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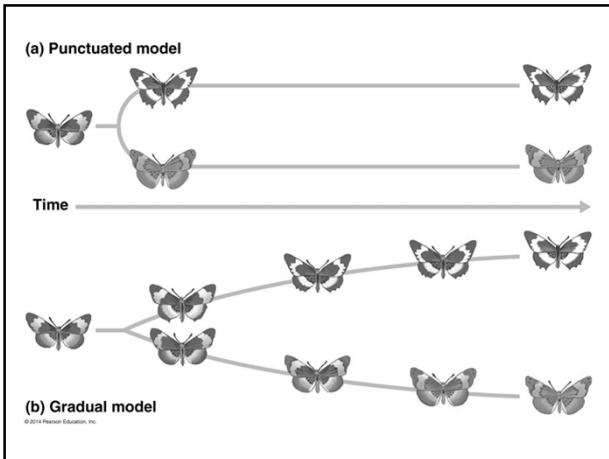
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## Speciation Rates



- The punctuated pattern in the fossil record and evidence from lab studies suggests that speciation can be rapid
  - The interval between speciation events can range from 4,000 years (some cichlids) to 40,000,000 years (some beetles), with an average of 6,500,000 years

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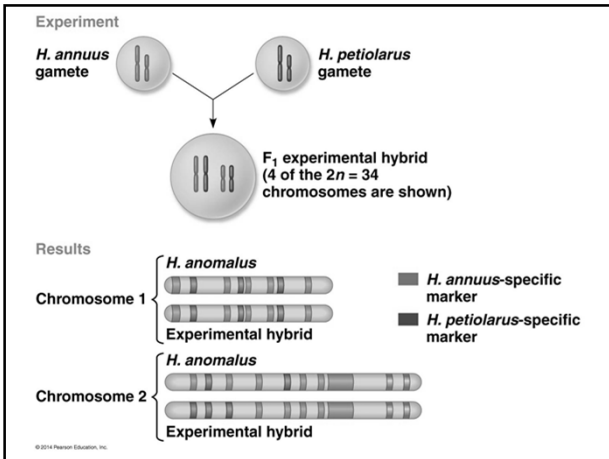
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### Studying the Genetics of Speciation

- The explosion of genomics is enabling researchers to identify specific genes involved in some cases of speciation
  - Depending on the species in question, speciation might require the change of only a single allele or many alleles

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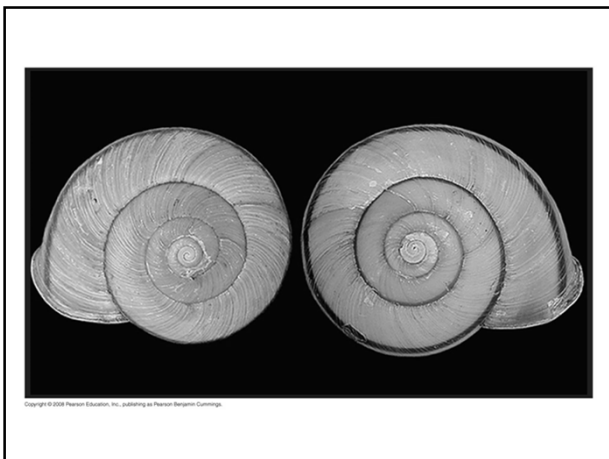
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(a) *Mimulus lewisii*



(b) *M. lewisii* with  
*M. cardinalis* allele



(c) *Mimulus cardinalis*



(d) *M. cardinalis* with  
*M. lewisii* allele

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