Why don’t we call them the same species?

Santa Cruz Island
Why don’t we call them different species?

- Eastern milk snake (Lampropeltis triangulum triangulum)
- Red milk snake (Lampropeltis triangulum syspila)
- “Intergrade” form
- Scarlet kingsnake (Lampropeltis triangulum elapsoides)

Ernst Mayr (Harvard Univ.)
Biological Species Concept

Ernst Mayr ....
“...groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups.”

Individuals that cannot produce fertile offspring are termed reproductively isolated, and thus members of different species.

Species are based on interfertility, not physical similarity.

For example, the eastern and western meadowlarks may have similar shapes and coloration, but differences in song help prevent interbreeding between the two species.
On the other hand, humans have considerable diversity, but we all belong to the same species because of our capacity to interbreed.

The Process of Speciation

- Speciation is a two-part process:
  - identical populations must diverge
  - reproductive isolation must evolve to maintain the differences

- Reproductive isolation prevents populations evolved into different species from interbreeding, even if their ranges overlap.
The process of speciation is the process of reproductive isolation!

How do 2 populations become reproductively isolated?

- Reproductive barriers can be categorized as prezygotic or postzygotic, depending on whether they function before or after the formation of zygotes.
Reproductive isolating mechanisms

**Prezygotic Isolating Mechanisms**

- **Geographic isolation**: Species occur in different areas, which are often separated by a physical barrier such as a river or mountain range.
- **Ecological isolation**: Species occur in the same area, but they occupy different habitats and rarely encounter each other.
- **Temporal isolation**: Species reproduce in different seasons or at different times of the day.

**Postzygotic Isolating Mechanisms**

- **Behavioral isolation**: Species differ in their mating rituals.
- **Mechanical isolation**: Structural differences between species prevent mating.
- **Prevention of gamete fusion**: Gametes of one species function poorly with the gametes of another species or within the reproductive tract of another species.
- **Hybrid inviability or infertility**: Hybrid embryos do not develop properly, hybrid adults do not survive in nature or hybrid adults are sterile or have reduced fertility.
Geographic isolation

- It seems geographically separated populations are more likely to evolve substantial differences leading to speciation.

- This is called Allopatric speciation

Geographic Isolation
Prezygotic Isolating Mechanisms

- Prezygotic isolating mechanisms prevent the formation of zygotes.
  - Ecological isolation (Habitat isolation)
  - Temporal isolation
  - Behavioral isolation
  - Mechanical isolation
  - Prevention of gamete fusion

Habitat isolation

- Two species occur in the same general area, but utilize different portions of the environment and thus do not hybridize because they do not encounter each other.

- Can you think of an example?
Habitat isolation

Temporal isolation

- Two species that breed during different times of day, different seasons, or different years cannot mix gametes.
Temporal isolation

- Eastern spotted skunk (mate in late winter)
- Western spotted skunk (mate in late summer)

Behavioral isolation

- Many species, e.g. birds, differ in courtship rituals which tends to keep species distinct.
Behavioral isolation
Behavioral isolation

Closely related species may attempt to mate but fail because they are anatomically incompatible and transfer of sperm is not possible.

Mechanical isolation

- Closely related species may attempt to mate but fail because they are anatomically incompatible and transfer of sperm is not possible.
**Mechanical isolation**

![Diagram showing mechanical barriers](image)

**Gametic isolation**

- Gametic isolation occurs when gametes of two species do not form a zygote because of incompatibilities preventing fusion of sperms and eggs.
Oops! can’t get in.
Postzygotic Isolating Mechanisms

- Postzygotic barriers prevent the hybrid zygote from developing into a viable, fertile adult.
  - These barriers include
    - reduced hybrid viability,
    - reduced hybrid fertility
    - hybrid breakdown.
- **Reduced hybrid viability.** Genetic incompatibility between the two species may abort the development of the hybrid at some embryonic stage or produce frail offspring.

- This is true for the occasional hybrids between frogs in the genus *Rana*, which do not complete development and those that do are frail.
- **Reduced hybrid fertility.** Even if the hybrid offspring are vigorous, the hybrids may be infertile.
  - For example, while a mule, the hybrid product of mating between a horse and donkey, is a robust organism, it cannot mate with either horses or donkeys.
**Hybrid breakdown.** In some cases, first generation hybrids are viable and fertile.

However, when they mate with either parent species or with each other, the next generation are feeble or sterile.

For example, different cotton species can produce fertile hybrids, but breakdown occurs in the next generation when offspring of hybrids die as seeds or grow into weak and defective plants.

**Reproductive barriers** can occur before mating, between mating and fertilization, or after fertilization.
The biological species concept has limits when applied to species in nature

- Extinct species are separated into species based on morphology (fossils).
- There is high levels of hybridization among some species groups.
- It’s difficult to apply to species that do not occur together in nature.
- In addition, many species (e.g., bacteria) reproduce entirely asexually and are assigned to species based mainly on structural and biochemical characteristics.

No single definition of species may be universally applicable.
How do speciation get started?

How does a population diverge in the first place?

Geographic Isolation
Random changes may initiate reproductive isolation

- Given long enough periods of time, any two isolated populations will diverge due to genetic drift. If there is a chance divergence in reproductive mechanism, then it’s the start of reproductive isolation.

Allopatric speciation in the vials:
Females from populations raised on starch medium preferred males raised on starch medium over males raised on maltose medium after several generations of isolation.
Natural selection can enhance speciation

- Initially incomplete isolating mechanisms are reinforced by natural selection favoring the perfection of reproductive isolation.

- Hybrids are often selected against
  - a case of disruptive selection.

Reinforcement of reproductive isolation
Exercise: The likelihood of allopatric speciation increases when a population is both small and isolated. WHY?

Not all speciation are allopatric

- Geographic isolation (allopatric speciation) is not the only way to initiate speciation.

- Sympatric speciation -- instantaneous speciation through polyploidy
  - individual is born that is reproductively isolated from other members of species because of polyploidy - more than 2 sets of chromosomes.
- An individual can have more than two sets of chromosomes from a single species if a failure in meiosis results in a tetraploid \( (4n) \) individual.
- This mutant can only reproduce with itself (self-pollination) or with other tetraploids.

- Hugo de Vries produced a new primrose species, the tetraploid *Oenotheria gigas*, from the diploid *Oenothera lamarckiana*.
- The two species could not interbreed.
Many plants important for agriculture are the products of polyploidy.

For example, oats, cotton, potatoes, tobacco, and wheat.
All of the 500 or so endemic species of *Drosophila* in the Hawaiian archipelago descended from a common ancestor that reached Kauai over 5 million years ago.

The evolution of many diversely-adapted species from a common ancestor is called an adaptive radiation.
Multiple invasions and allopatric speciation can ignite an explosion of adaptive radiation

Adaptive radiation of Darwin’s finches
Geospiza fuliginosa
Geospiza fortis
Geospiza magnirostris
Geospiza scandens
Geospiza conirostris
Geospiza difficilis

Ground and cactus finches

Camarhynchus parvulus
Camarhynchus psittacula
Camarhynchus pauper
Cactospiza heliobates
Cactospiza pallida (woodpecker finch)
Platyspiza crassirostris

Tree finches

Vegetarian tree finch

Warbler finches
Adaptive radiation of cichlid fishes in Lake Victoria

- Fish eater
- Snail eater
- Algae scraper
- Second set of jaws
- Zooplankton eater
- Leaf eater
- Insect eater

Adaptive radiation is favored by periodic isolation events

- Glaciers link alpine zones into one continuous range.
- Mountain populations become isolated, permitting divergence and speciation.
- Alpine zones are reconnected. Separately evolved species come back into contact.

Glaciers recede → Glaciation
Periodic glaciation has favored the adaptive radiation in alpine buttercup, 14 species.

How fast does speciation occur?

- Darwin — Gradulism
  Infinitesimally small changes accumulating in a slow, steady way.
How fast does speciation occur?

- Fossil records show that the change of species are in stasis over enormous lengths of time (species undergo little change), then followed by abrupt occurrence of new structures, and many new species.

Punctuated equilibrium

Jay Gould and Niles Eldredge proposed

- *punctuated equilibrium*
  - Speciation normally proceeds in spurts, with long periods of little speciation in between.
Rate of Speciation

(a) Gradualism  (b) Punctuated equilibrium
Speciation and Extinction Through Time

- There have been 5 major mass extinctions interspersed within relatively consistent extinction patterns. However, biological diversity tends to rebound after mass extinctions.

[Graph showing number of families over millions of years with key extinctions marked]

Human impact the process of evolution

- Human alter environments
e.g., global warming

- Human decreased population sizes
  - increased genetic drift
  - increased extinction
Once upon a summer time,....
Exercise:

Why did the wren sing?

The wren heard the tape through its neural network, the perception of a song increased the sex hormone in the blood, which bind to the receptors in the brain, and triggered the production of songs.
Why did the wren sing?

The wren sang to defend a territory from other males and to attract females with which to reproduce.

Proximate reasons

- Neural pathway & hormone

Ultimate reasons

- Survival & reproduction
What is Behavior?

The way an organism respond actively to stimuli in its environment.

Generally, a behavior should increase the fitness of an individual. If not, natural selection will select against the behavior.

Exercise: nature-versus-nurture

Was the singing of a male wren an innate or learned behavior?
Early ethologists believe that behaviors are largely innate.

Frisch  Lorenz  Tinbergen

Egg-rolling behavior

(FAP)
Fixed action pattern (FAP)

- A sequence of behavioral acts that is essentially unchangeable and usually carried to completion once initiated.

- The FAP usually occurs in a series of actions the same way every time.

Oh, I hate the red bellies!
Innate Behaviors

- Behaviors that are developmentally fixed, usually based on preset pathways in the nervous system and thus are likely genetically programmed.

- The range of environmental differences among individuals does not appear to alter the behavior.

- Kinesis and taxis: the simplest mechanisms of movement.
  - Kinesis is a change in activity rate in response to a stimulus.
  - Taxis is an automatic, oriented movement to or away from a stimulus.
  - For example, phototaxis.
Evidence that behaviors have strong genetic bases.

Evidence 1—Identical twins
Identical human twins, separated at birth, develop behavioral similarities, even though they were raised in very different environments.
Evidence 2 – artificial selection
Behavioral traits pass from one generation to the next, thus are subject to selection.

Evidence 3  
hybrid behavior
Evidence 4 – Single gene defect

(a)

(b)

(c)

(d)
Certainly, behaviors have genetic basis. However, learning influences behavior

Learning occurs when animals alter their behaviors as a result of previous experience.

How does learning influence behavior?

- Associative learning
- Non-associative learning
**Associative learning (Conditioning)**

An association between two stimuli (classical conditioning), or between a stimulus and a response (operant conditioning) is developed.

**Classic Conditioning – associate two stimuli**
Pavlov and the poor dog

Operant Conditioning
- associate a stimulus & a response

OUCH!
Food-and-light or food-and-shock

Classic or operant conditioning?
If Willy is not going to touch a porcupine anymore, is it a classic or operant conditioning?