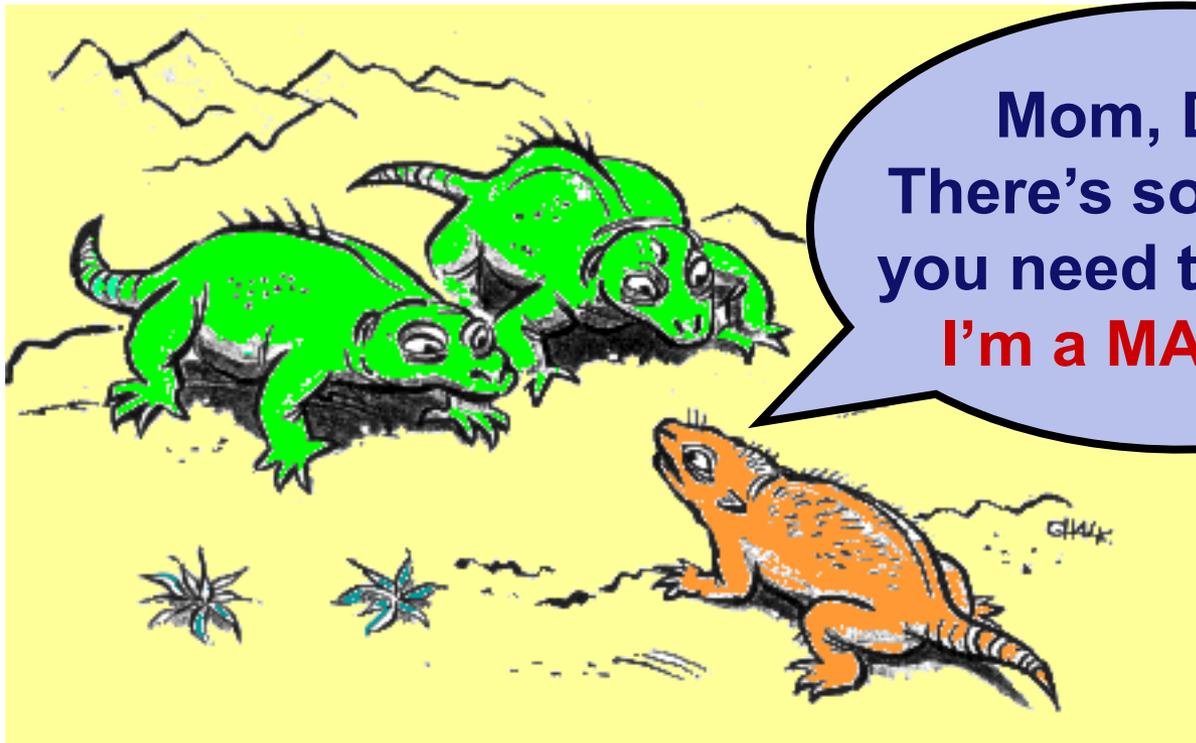
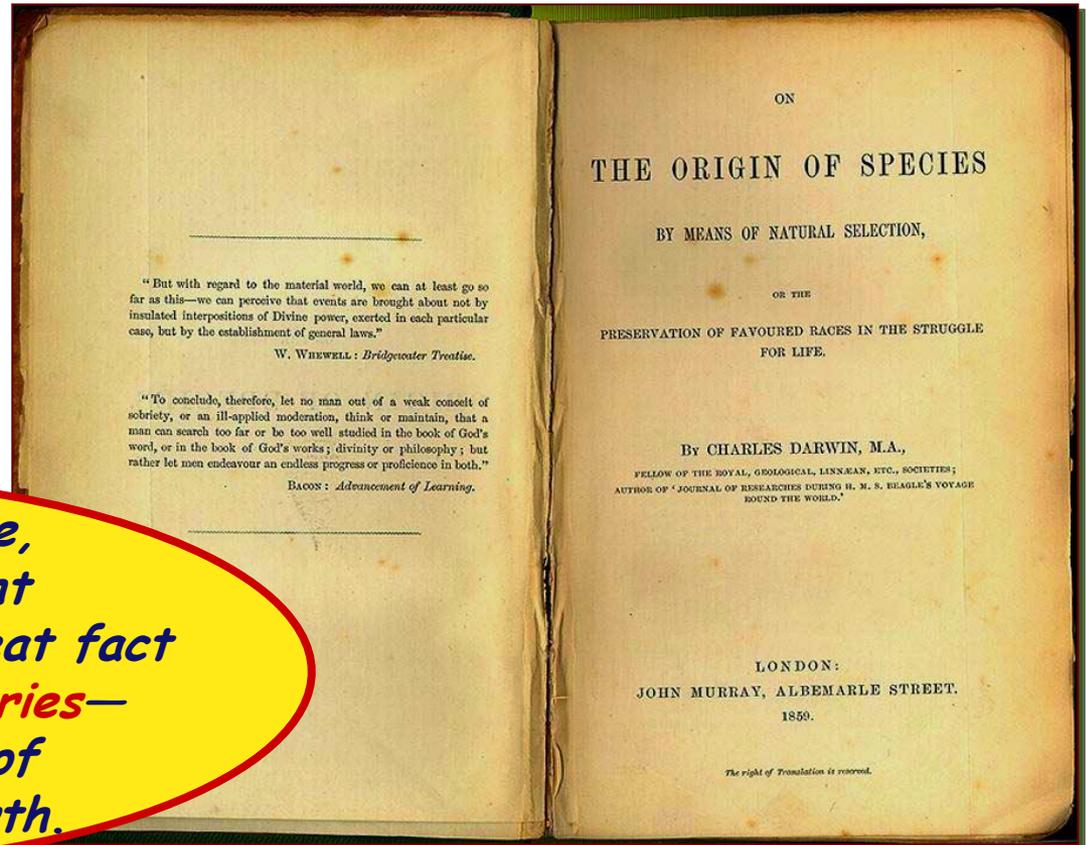
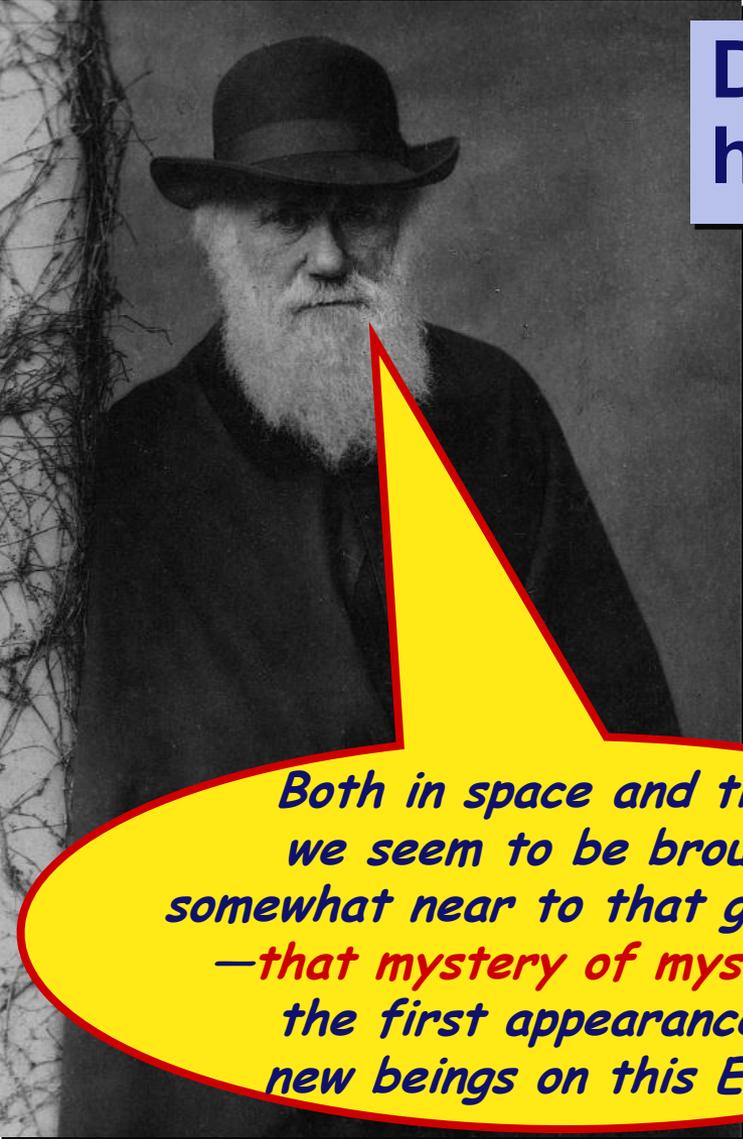


# The Origin of Species



**“That mystery of mysteries...”**

**Darwin never actually tackled how new species arose...**



**Both in space and time,  
we seem to be brought  
somewhat near to that great fact  
—that mystery of mysteries—  
the first appearance of  
new beings on this Earth.**

# So...what is a species?



## ■ Biological species concept

- ◆ defined by Ernst Mayr
- ◆ population whose members can interbreed & produce viable, fertile offspring
- ◆ reproductively compatible



**Distinct species:  
songs & behaviors are different  
enough to prevent interbreeding**



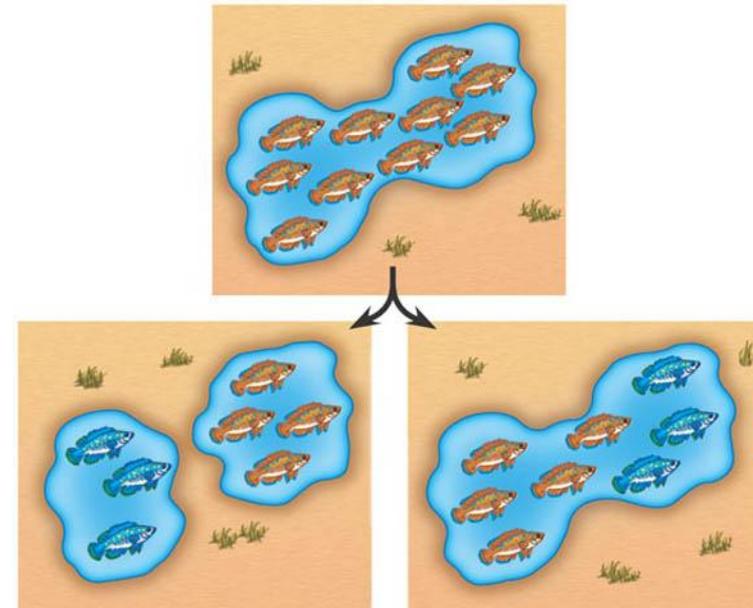
Eastern Meadowlark



Western Meadowlark

# How and why do new species originate?

- Species are created by a series of evolutionary processes
  - ◆ populations become **isolated**
    - geographically isolated
    - reproductively isolated
  - ◆ isolated populations **evolve independently**
- Isolation
  - ◆ **allopatric**
    - geographic separation
  - ◆ **sympatric**
    - still live in same area



(a) Allopatric speciation. A pop-

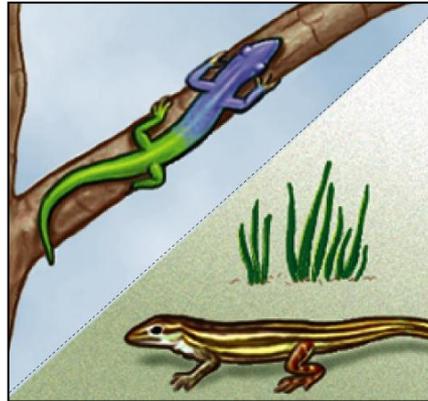
(b) Sympatric speciation. A

# PRE-reproduction barriers

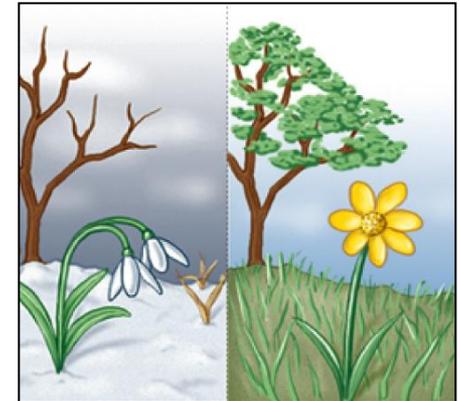
- Obstacle to mating or to fertilization if mating occurs



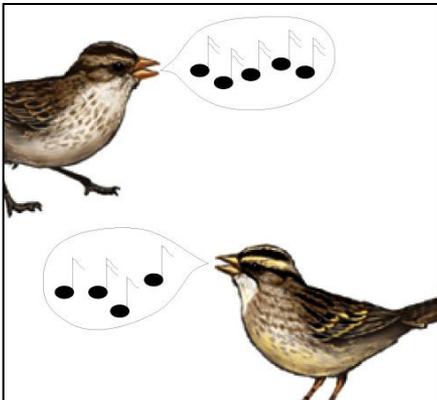
geographic isolation



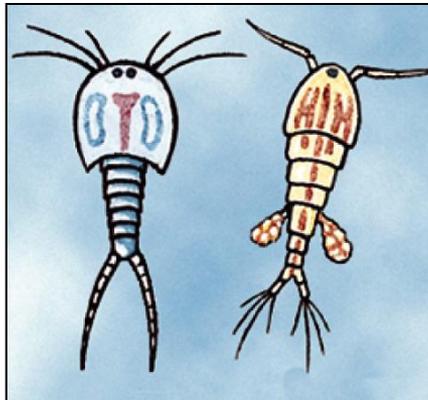
ecological isolation



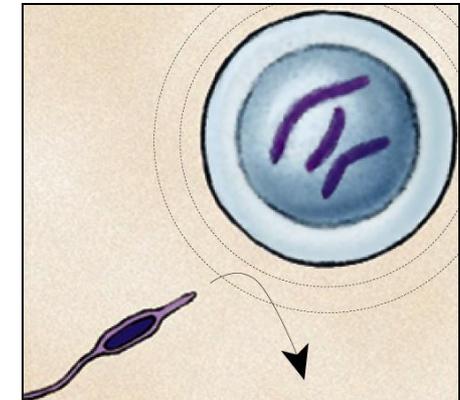
temporal isolation



behavioral isolation



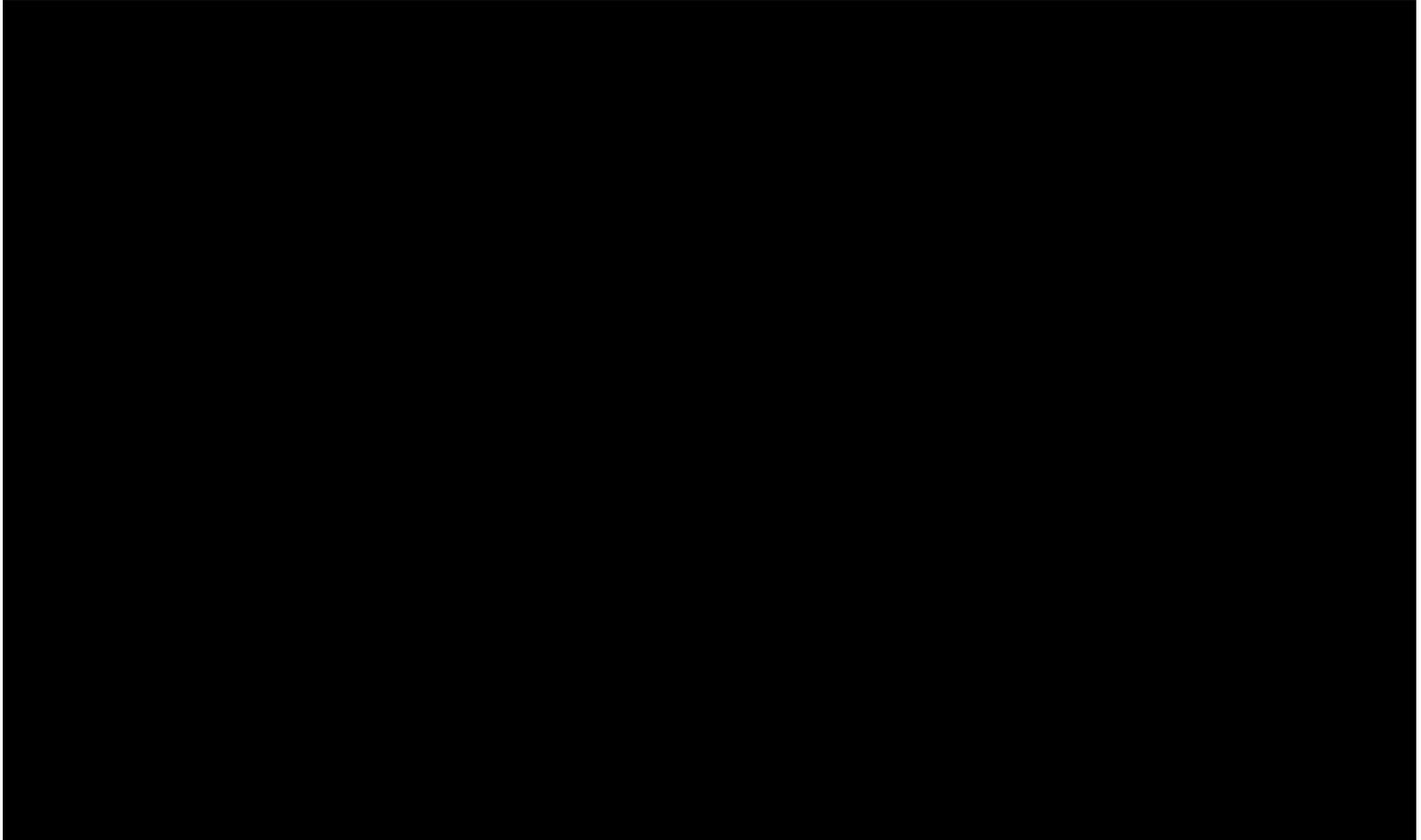
mechanical isolation



gametic isolation

# Speciation in Action

---



# Geographic isolation

- Species occur in different areas
  - ◆ physical barrier
  - ◆ allopatric speciation
    - “*other country*”



Harris's antelope squirrel inhabits the canyon's south rim (L). Just a few miles away on the north rim (R) lives the closely related white-tailed antelope squirrel



# Ecological isolation

- Species occur in same region, but occupy different habitats so rarely encounter each other
  - reproductively isolated

2 species of garter snake, *Thamnophis*, occur in same area, but one lives in water & other is terrestrial



lions & tigers could hybridize, but they live in different habitats:

- lions in grasslands
- tigers in rainforest



# Temporal isolation

- Species that breed during different times of day, different seasons, or different years cannot mix gametes
  - ◆ reproductive isolation
  - ◆ sympatric speciation
    - “*same country*”

Eastern spotted skunk (L) & western spotted skunk (R) overlap in range but eastern mates in late winter & western mates in late summer



# Behavioral isolation

- Unique behavioral patterns & rituals isolate species
  - ◆ identifies members of species
  - ◆ attract mates of same species □
    - courtship rituals, mating calls
    - reproductive isolation



Blue footed boobies mate only after a courtship display unique to their species



courtship  
Gray-Crowned

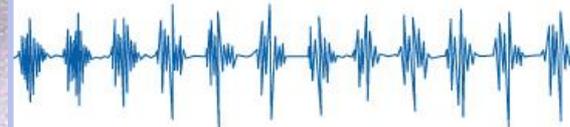
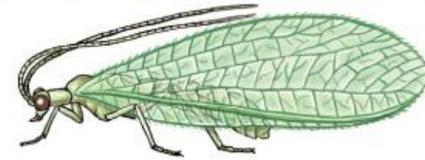


What can you say?

# Recognizing your own species



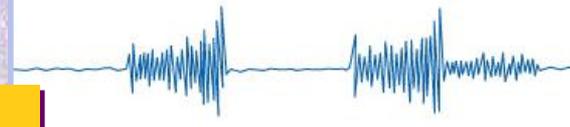
Relationship songs of sympatric species of lacewings



*Chrysoperla plorabunda*



*Chrysoperla adamsi*



*Chrysoperla johnsoni*

4 5 6 7 8 9 10 11 12  
Time (seconds)

AP firefly courtship displays

# Mechanical isolation

- Morphological differences can prevent successful mating
  - ◆ reproductive isolation

Even in closely related species of plants, the flowers often have distinct appearances that attract different pollinators. These 2 species of monkey flower differ greatly in shape & color, therefore cross-pollination does not happen.

## Plants



# Mechanical isolation

## Animals

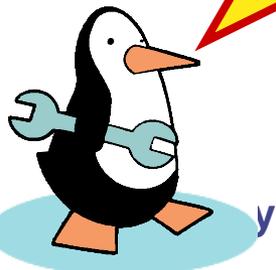
- For many insects, male & female sex organs of closely related species do not fit together, preventing sperm transfer
  - ◆ lack of “fit” between sexual organs: hard to imagine for us... but a big issue for insects with different shaped genitals!



I can't even imagine!



Damselfly penises



# Gametic isolation

- Sperm of one species may not be able to fertilize eggs of another species
  - ◆ mechanisms
    - **biochemical barrier** so sperm cannot penetrate egg
      - ◆ receptor recognition: lock & key between egg & sperm
    - **chemical incompatibility**
      - ◆ sperm cannot survive in female reproductive tract

Sea urchins release sperm & eggs into surrounding waters where they fuse & form zygotes. Gametes of different species— **red** & **purple** —are unable to fuse.

# POST-reproduction barriers

- Prevent **hybrid offspring** from developing into a viable, fertile adult
  - ◆ reduced hybrid viability
  - ◆ reduced hybrid fertility
  - ◆ hybrid breakdown



zebroid



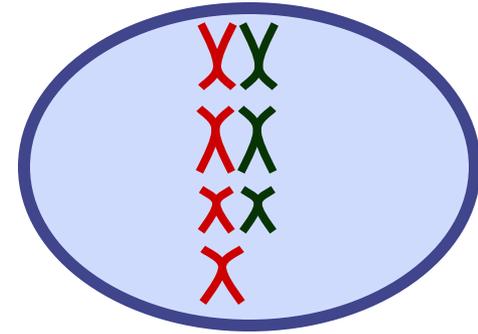
## Reduced hybrid viability

- Genes of different parent species may interact & impair the hybrid's development

Species of salamander genus, *Ensatina*, may interbreed, but most hybrids do not complete development & those that do are frail.



# Reduced hybrid fertility



- Even if hybrids are vigorous they may be sterile
  - ◆ chromosomes of parents may differ in number or structure & meiosis in hybrids may fail to produce normal gametes



Horses have 64 chromosomes (32 pairs)

Mules are vigorous, but sterile



Mules have 63 chromosomes!



Donkeys have 62 chromosomes (31 pairs)

## Hybrid breakdown

- Hybrids may be fertile & viable in first generation, but when they mate offspring are feeble or sterile



In strains of cultivated rice, hybrids are vigorous but plants in next generation are small & sterile.

On path to separate species.

# Rate of Speciation

- Current debate:

Does speciation happen gradually or rapidly

- ◆ Gradualism

- Charles Darwin
- Charles Lyell

- ◆ Punctuated equilibrium

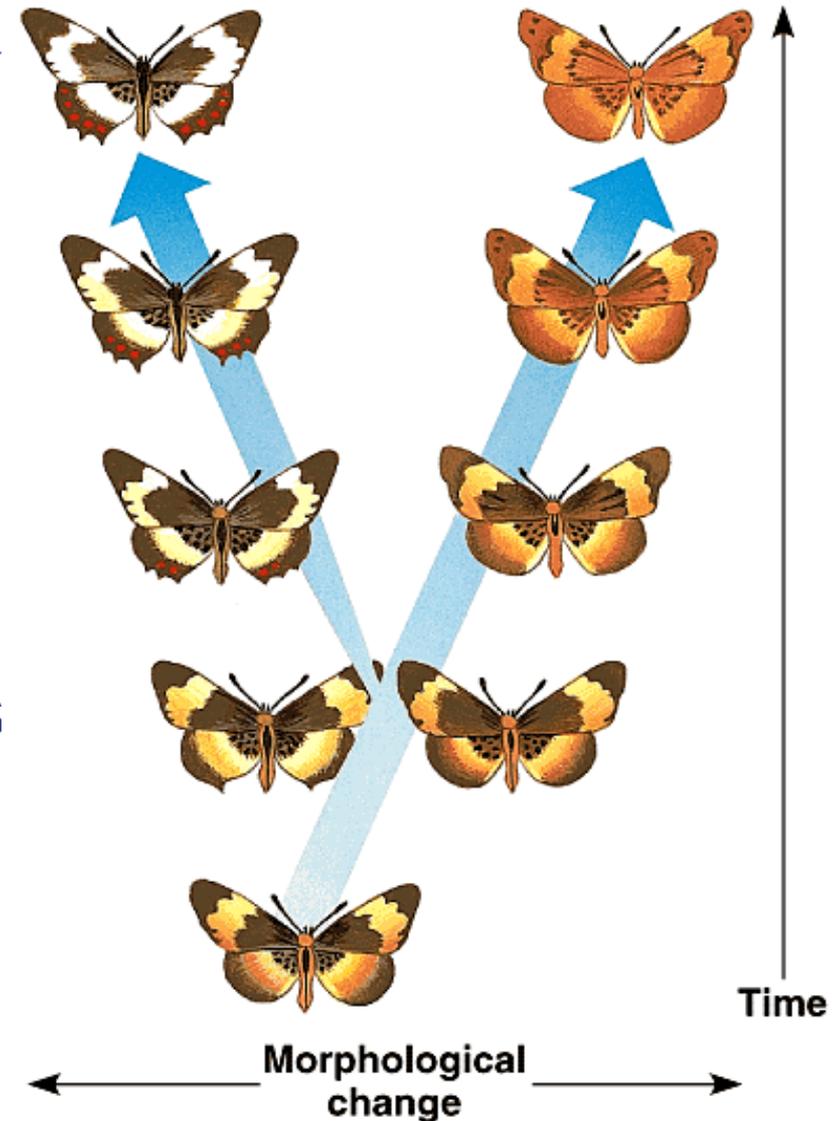
- Stephen Jay Gould
- Niles Eldredge



Niles Eldredge  
Curator

# Gradualism

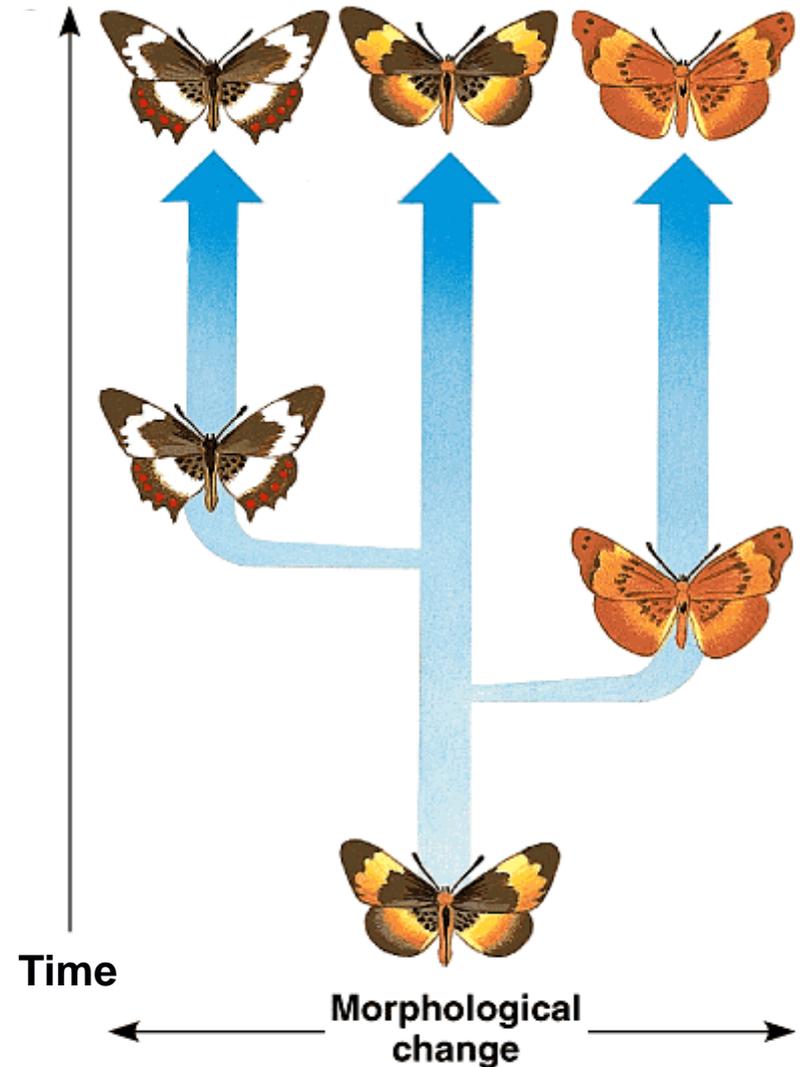
- Gradual divergence over long spans of time
  - ◆ assume that big changes occur as the accumulation of many small ones



(a) Gradualism model

# Punctuated Equilibrium

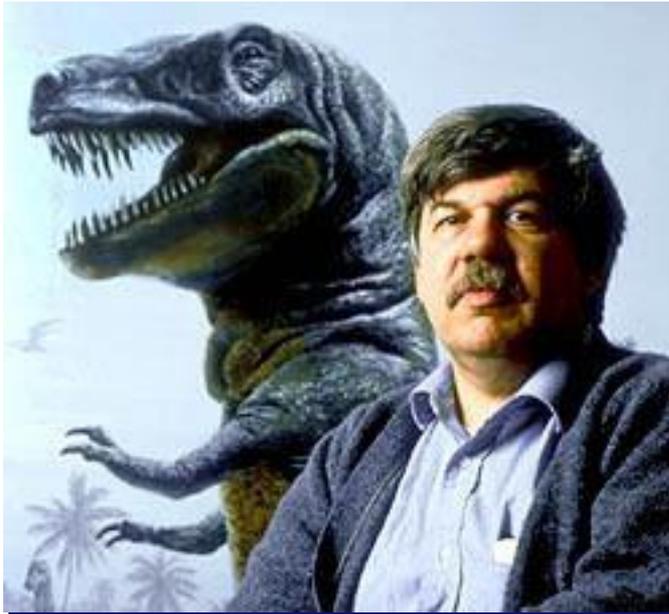
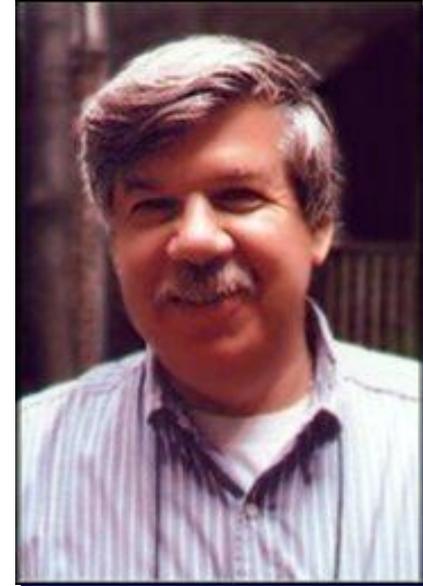
- Rate of speciation is not constant
  - ◆ rapid bursts of change
  - ◆ long periods of little or no change
  - ◆ species undergo rapid change when they 1<sup>st</sup> bud from parent population

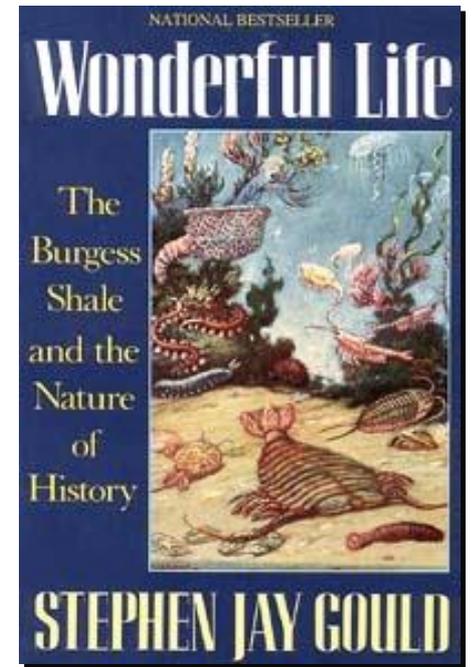
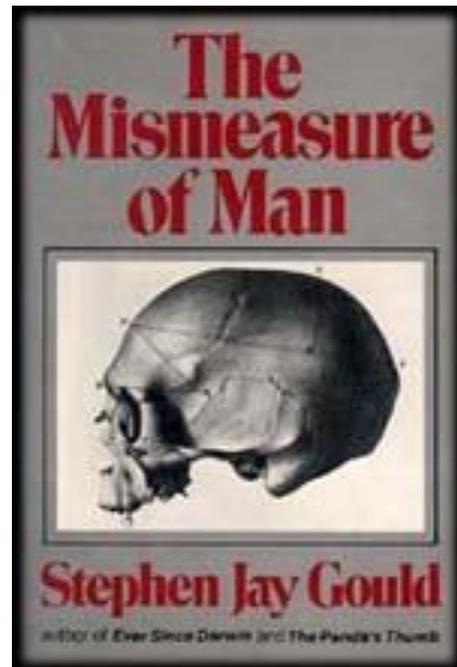
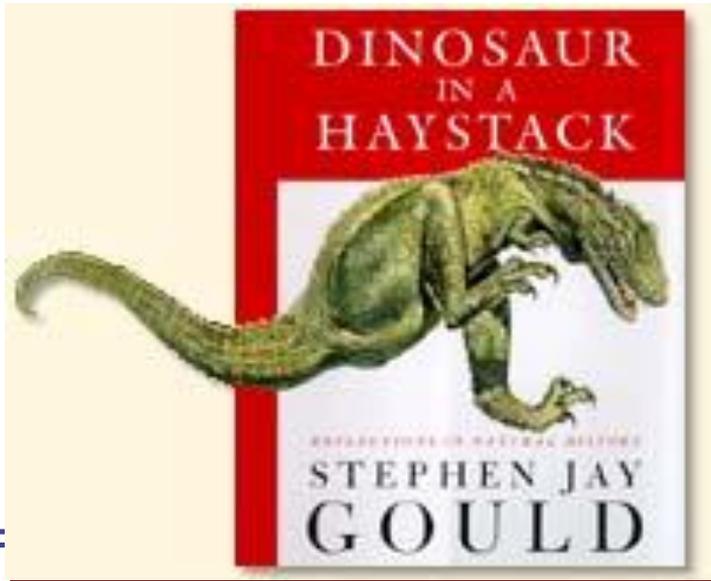
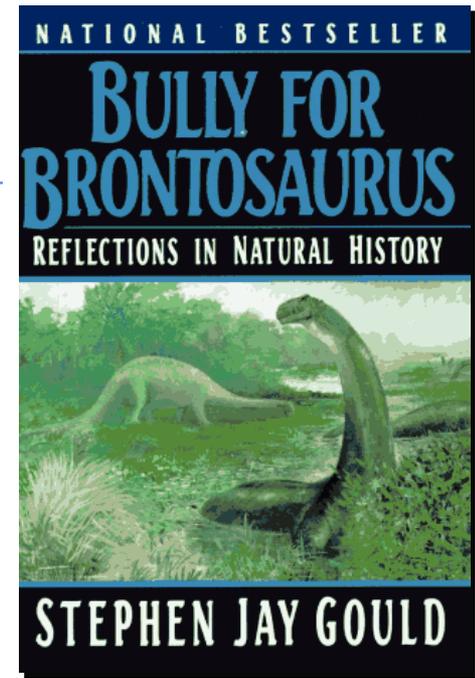
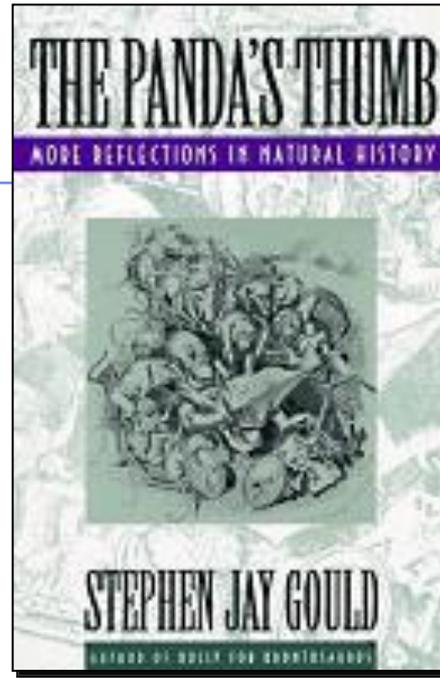
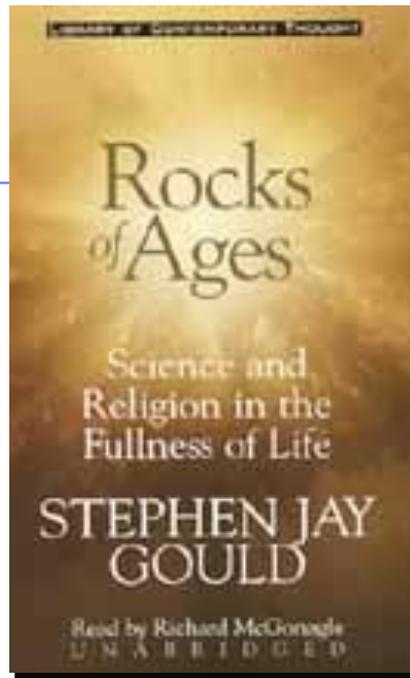
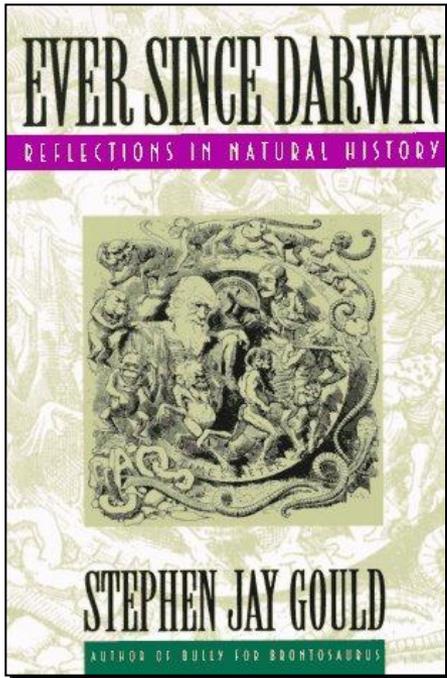


(b) Punctuated equilibrium model

# Stephen Jay Gould (1941-2002)

- **Harvard paleontologist & evolutionary biologist**
  - ◆ punctuated equilibrium
  - ◆ prolific author
    - popularized evolutionary thought



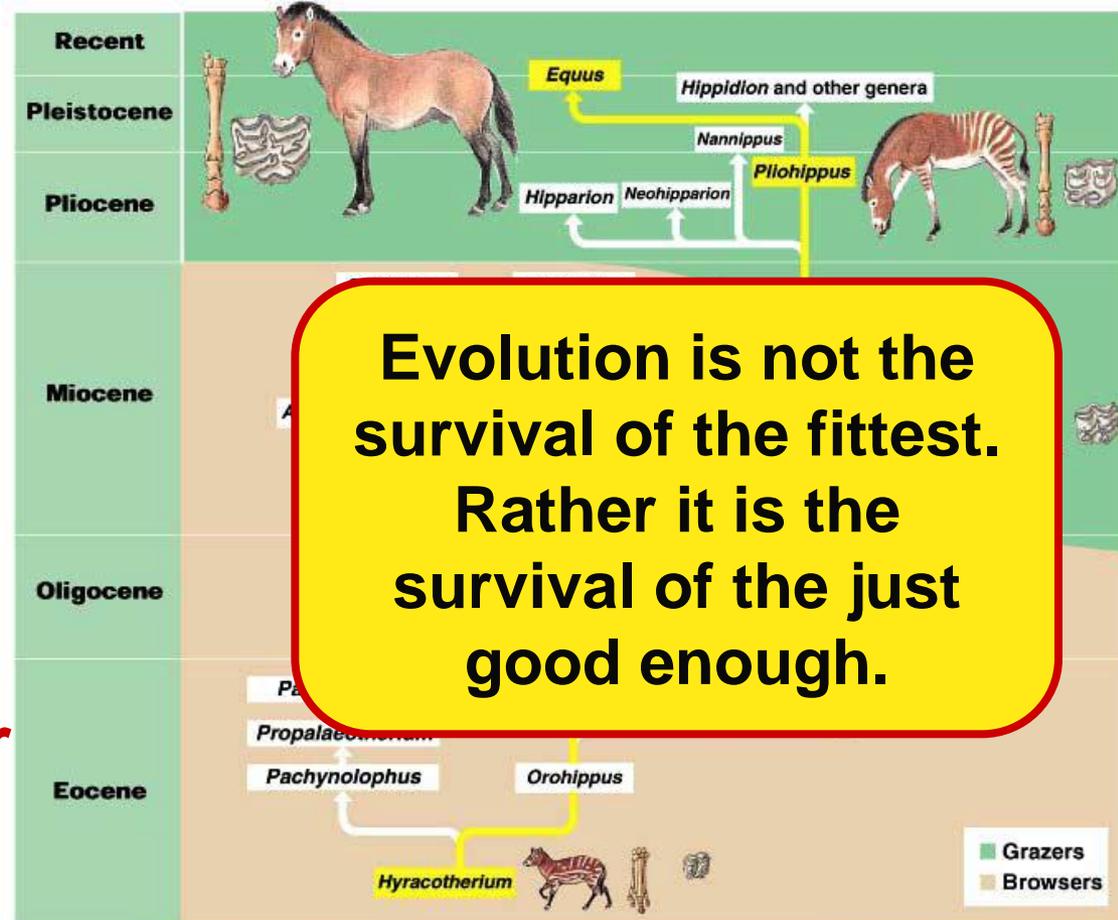


# Evolution is not goal-oriented

An evolutionary trend does not mean that evolution is goal-oriented.

Surviving species do not represent the peak of perfection. There is compromise & random chance involved as well

Remember that for humans as well!



# Any Questions??

