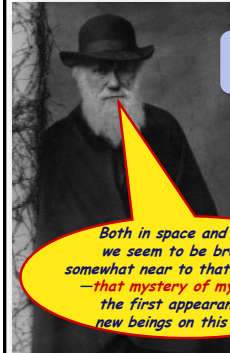


## Chapter 23

### The Origin of Species

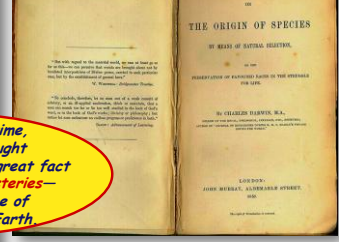


*“That mystery of mysteries...”*



Darwin never actually tackled how new species first 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**

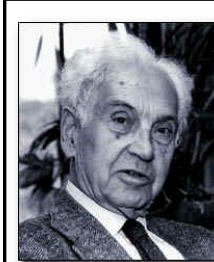
- ◆ defined by Ernst Mayr
- ◆ population whose members can interbreed & produce viable, fertile offspring
- ◆ reproductively compatible



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



Eastern Meadowlark Western Meadowlark



**“Evolution is so overwhelmingly established that it has become irrational to call it a theory.”**

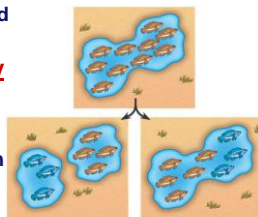
**Ernst Mayr**  
**What Evolution Is**  
**2001**

Professor Emeritus, Evolutionary Biology  
Harvard University  
(1904-2005)

### 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**



▪ **Types of Isolation**

- ◆ **allopatric**
  - geographic separation
- ◆ **sympatric**
  - still live in same area

### Pre-reproduction Barriers

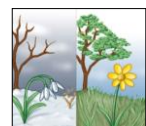
▪ **Obstacle to mating or to fertilization if mating occurs**



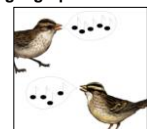
geographic isolation



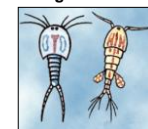
ecological isolation



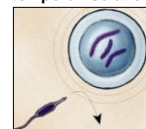
temporal isolation



behavioral isolation




mechanical isolation



gametic isolation

### Geographic Isolation

- Species occur in different areas
  - physical barrier
  - allopatric speciation**
    - "other country"



*A. harrisi*      *A. leucurus*

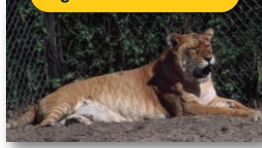
Harris's antelope squirrel inhabits the canyon's south rim (L). Just a few miles away on the north rim (R) lives the closely related white-tailed antelope squirrel.

### Ecological Isolation


- Species occur in same area, but occupy different habitats so rarely encounter each other

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

- lions in grasslands
- tigers in rainforest




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



### Temporal Isolation


- Species that breed during different times of day, different seasons, or different years cannot mix gametes
- 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


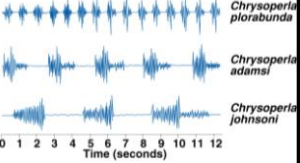


Blue footed boobies mate only after a courtship display unique to their species

sympatric speciation?


### Recognizing your own species...

courtship songs of sympatric species of lacewings





Time (seconds) 0 1 2 3 4 5 6 7 8 9 10 11 12

courtship display of Gray-Crowned Cranes, Kenya




firefly courtship displays



### Mechanical 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



sympatric speciation?

### 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!




Damselfly penises

### Gametic Isolation

sympatric speciation?

- 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 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.




sympatric speciation?

### 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

sympatric speciation?

- 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. 'Parents' 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

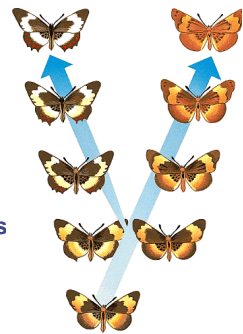


Niles Eldredge  
Curator  
American Museum  
of Natural History

### Gradualism

Gradual divergence over long spans of time

- assume that big changes occur as the accumulation of many small ones

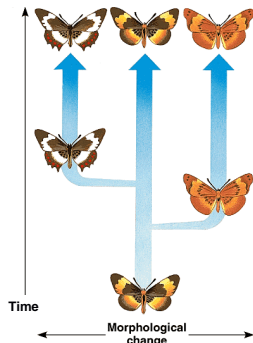


Morphological change  
(a) Gradualism model

### 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

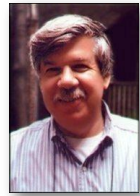


(b) Punctuated equilibrium model

### 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!

