Speciation:

What is it

How does it occur?

Where does it occur?

How long does it take to make a new species?

Can we observe speciation in real time and/or in the fossil record?

What is a species?

- **The Biological Species Concept**

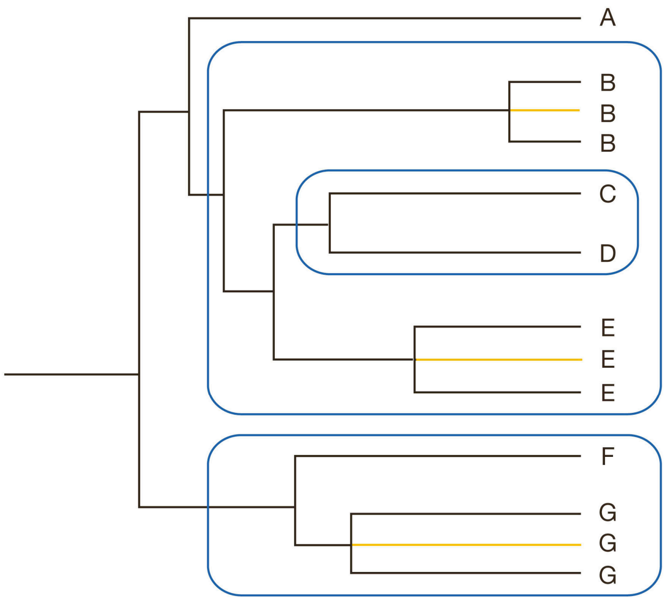
  Reproductive isolation is the centerpiece of the BSC. Reproductive isolation is the failure of populations to interbreed or to form viable or fertile hybrids

  "a species is an array of populations which are actually or potentially interbreeding, and which are reproductively isolated from other such arays under natural conditions."

  (Ernst Mayr)

The Phylogenetic Species Concept

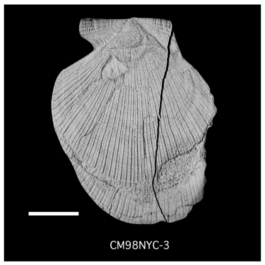
Monophyly is the centerpiece of the PSC. In other words, the populations of each species should share a common ancestor



The Morphospecies Concept

Morphological Species Concept: "a species is a diagnosable cluster of individuals within which there is a pattern of ancestry and descent, and beyond which there is not." (Eldredge and Cracraft, 1980).

- Morphological distinctiveness is the centerpiece of this concept



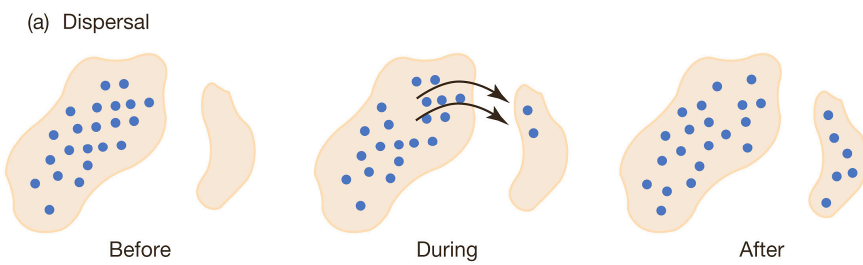
Mechanisms of Isolation

(The initial step in speciation is isolation)

- **Physical Isolation as a Barrier to Gene Flow**
  - Geographic isolation through dispersal and colonization
    - (New populations can become isolated from ancestral populations by dispersal into new territory)

  --Geographic isolation through vicariance (population physically split

  (Populations can become isolated from each other because a vicariance event makes the intervening territory uninhabitable)



Allopatric speciation

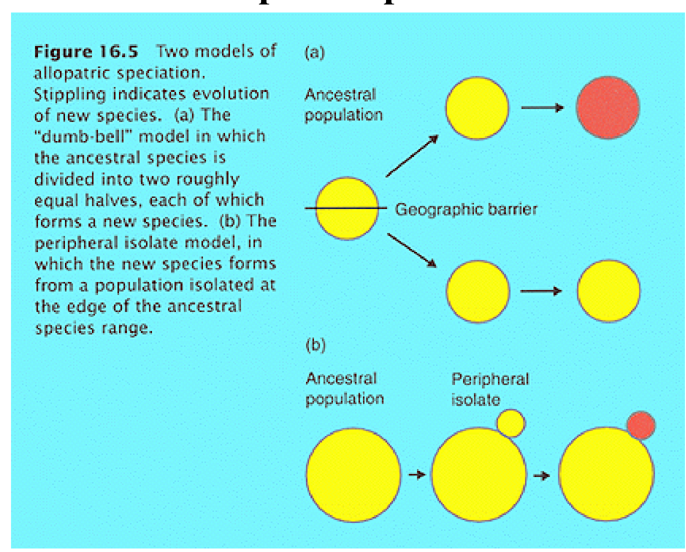
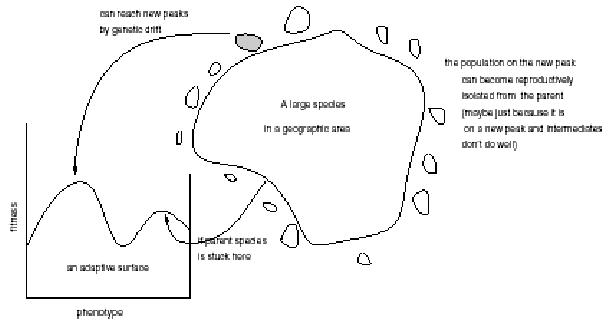
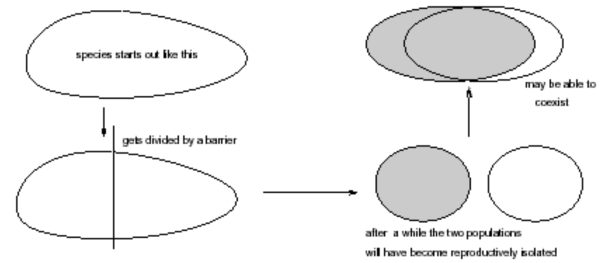


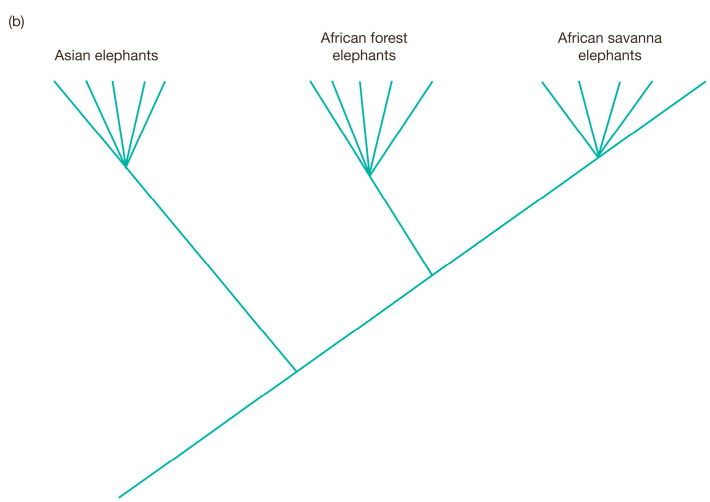
Figure 16.5 Two models of allopatric speciation. Stippling indicates evolution of new species. (a) The "dumb-bell" model in which the ancestral species is divided into two roughly equal halves, each of which forms a new species. (b) The peripheral isolate model, in which the new species forms from a population isolated at the edge of the ancestral species range.

Peripheral speciation (Ernst Mayr)



There are many other schemes for speciation
a commonly invoked one is allopatric speciation





Changes in Chromosomes as a Barrier to Gene Flow

- (Reproductive isolation resulting from polyploidy is an important mechanism of speciation in plants).

Genetic basis of Reproductive isolation

Main causes:

Chromosomal number or rearrangements (aneuploid gametes produces)

Allelic differences in one to many genes

Mechanisms of Divergence

- (Physical isolation sets the stage for speciation, but the critical next step is divergence of sister populations. Three mechanism are thought to be important for divergence).

Mechanisms of Divergence

- **Genetic Drift** (Drift is capable of producing rapid change in small populations, but it may not be an important mechanism of speciation).

  Natural Selection (Change is selection resulting from environmental change is undoubtedly an important mechanism for divergence).

  Sexual Selection (Sexual selection can lead to rapid differentiation of sister populations).

Secondary Contact

- (The third step in speciation is the re-establishment of contact between sister populations after they have diverged. This reunion is called secondary contact. Various outcomes are possible upon secondary contact).

Secondary Contact

- **Reinforcement** (Secondary contact may lead to selection for increased reproductive isolation, a process called reinforcement,
- **Hybridization** (Secondary contact may lead to hybridization and the fusion of divergent, sister populations).
- **Creation of New Species Through Hybridization** (Experimental studies of sunflowers, and other plants, confirm that possibility that new species can form from a hybridization event).
- **Hybrid Zones** (The fitness of hybrids affects the width of a hybrid zone and its fate).

Hybrid sterility

Many closely related species can produce viable hybrid offspring, but the hybrids experience reduced fertility or complete sterility.

A common cause of hybrid sterility is that the number of chromosomes differs in the parent species: produces diploid with chromosomes that can't pair and segregate properly at meiosis.

Horse: gametes have 32 chromosomes
Donkey: gametes have 31 chromosomes
Mules: 63 chromosomes in adult

How long does it take for reproductive isolation to evolve?

Does genetic divergence increase with time since restriction of gene flow?

Coyne and Orr (1989) investigated temporal pattern of the evolution of reproductive isolation

Punctuated Equilibrium

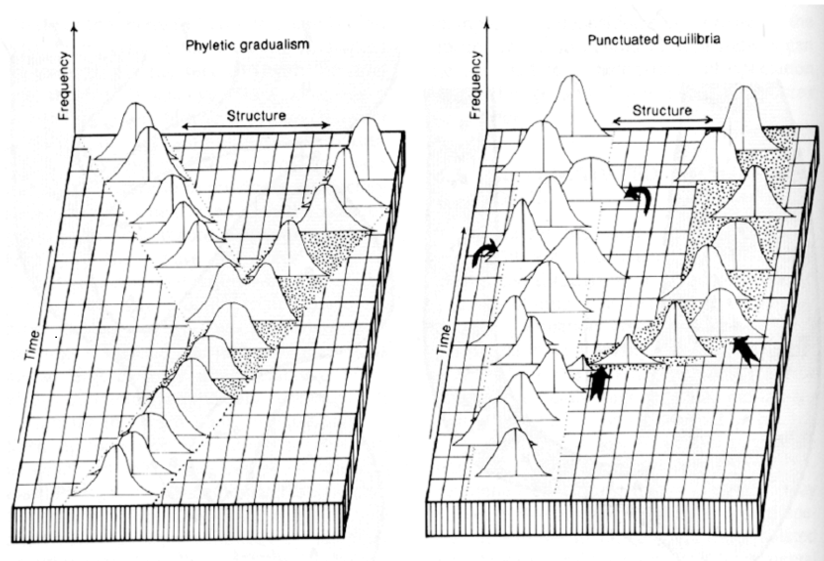
- Eldredge and Gould, 1971
- Controversial
- Used by Creationists
- Major concepts: stasis and rapid change:

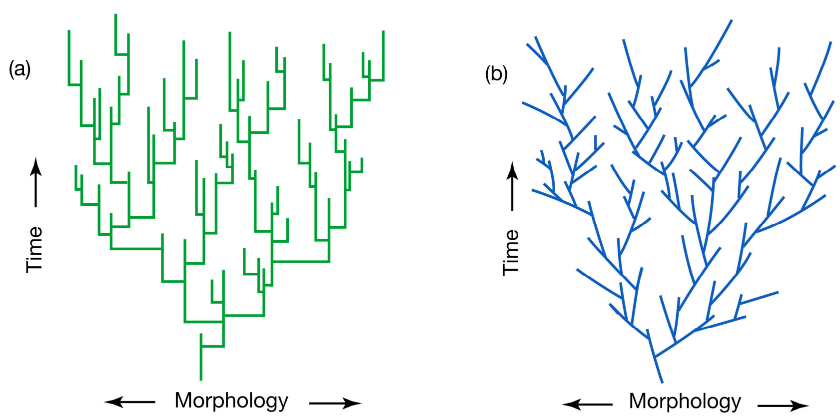
  most morphological change occurs during the speciation event itself

Punk Eek vs. Gradualism

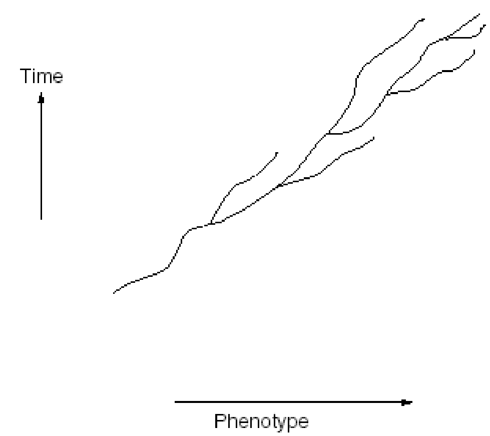
- Gradualism:
1. Rate of phenotypic change: low
2. Direction of phenotypic change:unidirectional
3. How do new species arise? Phyletic speciation in sympatry, and Allopatric speciation in small or large populations
4. Species are arbitrary subdivision of lineage continuum

- Punctuated Equilibrium
1. Rate of phenotypic change: high during speciation, low afterward
2. Direction of phenotypic change:oscillates around a mean
3. How do new species arise? Allopatric speciation in small populations
4. Species are real and discrete entities with beginnings and ends



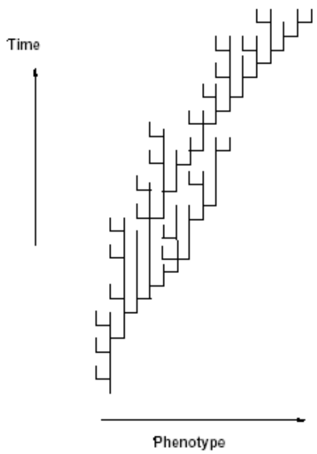


An adaptive trend according to gradualist neo-Darwinians



Selection is mostly occurring within species and not by species selection

An adaptive trend according to punctuated equilibrium



In this hypothetical diagram, 19 speciations leftwards, 21 rightwards

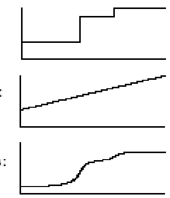
The debate over punctuated equilibrium

Issue 1: What are typical patterns of evolution

Punctuationists:

Traditional gradualists:

Gradualists these days:



Issue 2: Are new evolutionary forces needed to explain these?

Punctuationists: *Yes, species selection and peripheral speciation*

Gradualists: *No, can do the same with ordinary neo−Darwinian mechanisms*

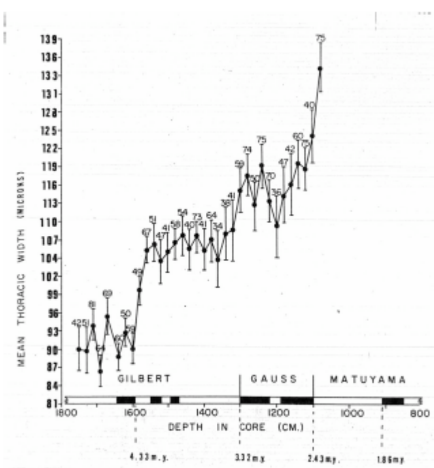
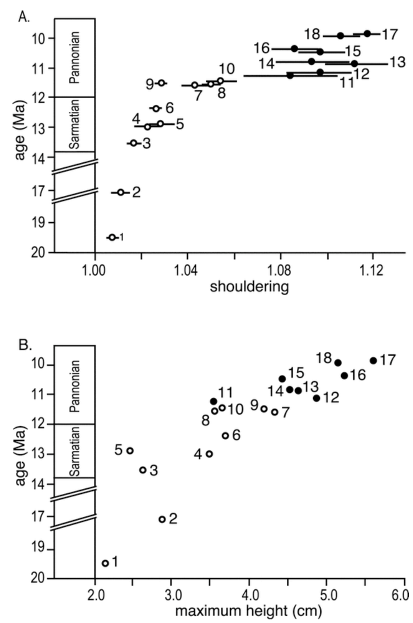


FIGURE 4. Mean thoracic width of *P. nema* vs. depth in core E14-8. Vertical lines through points indicate 95% confidence intervals for means. Numbers above lines indicate number of specimens in sample. Time line across bottom shows depth at which magnetic reversals occurred.



Adaptive Radiation

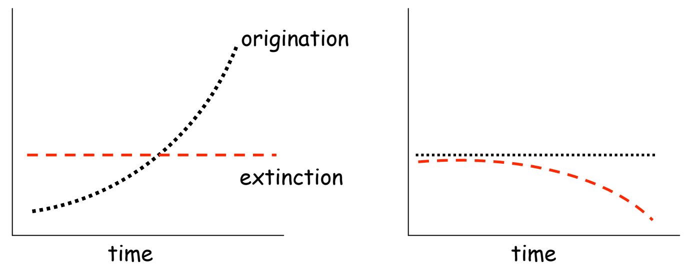
New inventions

New habitat

New unoccupied niches (extinctions h have occurred

Organismal diversity can be produced by either

- increased origination (speciation) rates *or*
- decreased extinction rates



Evolutionary rates

- Longevity of taxa through time
- Number of species produced through time
- Extinction rate of species/time
- Rate of change of some morphological unit (of phenotype), or of a protein
- Rate of change of genome or some part thereof

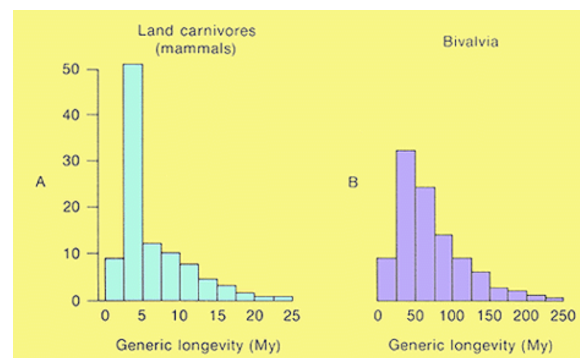


Table 15.1 Examples of the Estimated Average Durations of Species

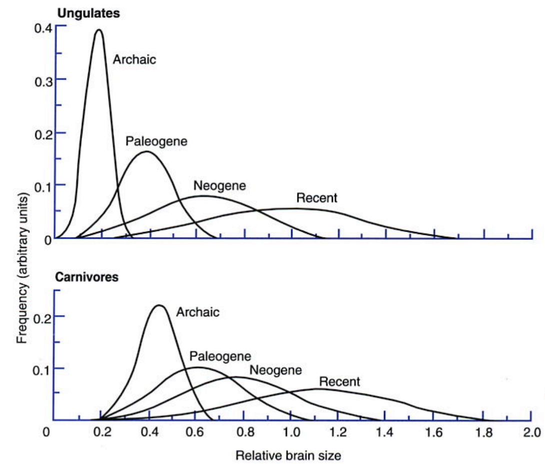
	Group	Duration (millions of years)
Protistans:	Foraminiferans	20–30
	Diatoms	25
Plants:	Bryophytes	20+
	Higher plants	8–20+
Animals:	Gastropods	10–13.5
	Ammonites	1–2, 6–15
	Trilobites	1+
	Beetles	2+
	Freshwater fishes	3
	Snakes	2+
	Mammals	1–2+

Three tempos of evolutionary rate:

- Bradylotelic - slow, living fossils
- Horotelic - average rates
- Tachytelic- very rapid -

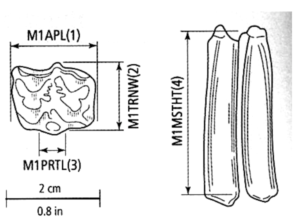
-- often seen after mass extinctions

distribution of relative brain size in predators and prey through the Cenozoic



How do we measure rates of evolutionary change?

How much change has occurred over this time interval?

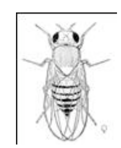


$$\frac{\ln x_2 - \ln x_1}{\Delta t} = r$$

Units are 'darwins'

Examples of rapidly formed species-tachytelic

- Faroe Island mouse 250 years



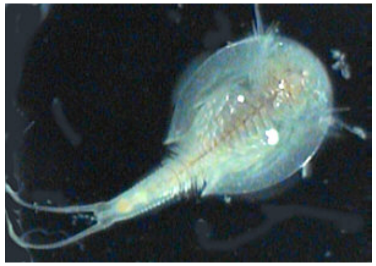
Drosophila paulistorum several years in a lab

Giant Primrose

virtually overnight

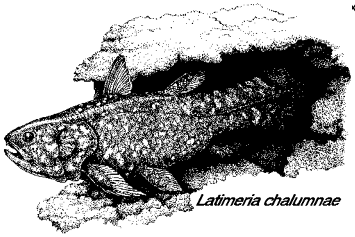
Cyclops dimorphus in

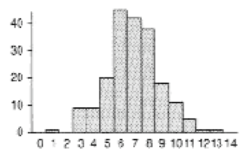
the Salton Sea less than 30 years



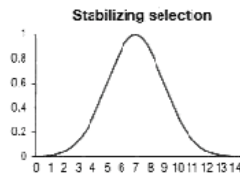
Examples of bradytelic - Living Fossils

Drawing (left) of Triassic (220 MYBP) & photograph (right) of modern specimens of tadpole shrimp, both of which are assigned to the same species (Triops cancriformis) (Notostraca: Crustacea), which xistence.





Distribution before selection



Fitness Function

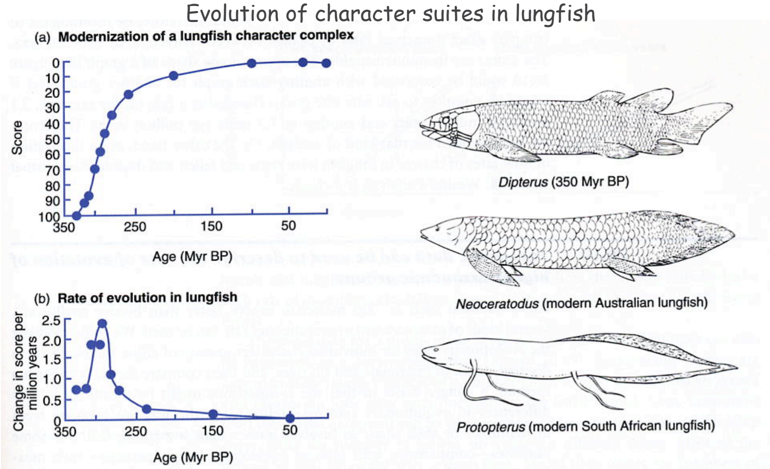
In living fossils evolutionary rate has changed:
Changes were "rapid" a long time ago

No change "recently"

These are considered 'living fossils'

- Horseshoe crabs
- Coelocanths
- Gingkos
- Amborella
- Tuataras
- Nautilus
- Horse tails

Examples of rapid change followed by slow change;
Evolution of character suites in lungfish



Are we entering a new age of extinction?

- Lots of bad data out there
- No doubt that there has substantial loss of birds and other endemics on islands
- Loss of species in high diversity areas hard to quantify
- Big problem - current standing biodiversity not known

But:

- Lots of signs that extinction rates are high
- Most caused by habitat disruption
- Trade-off mainly humans vs. biota - we need more food for 6 billion humans
- Forest loss major probable source of extinction
- Solutions are economic and political - and lots more good science needed