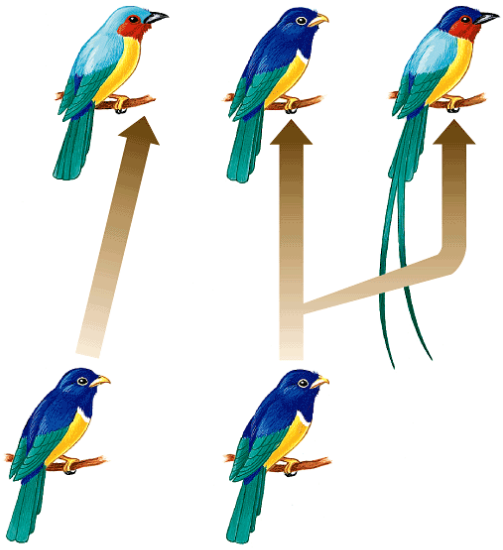
The Origin of Species Notes
AP Biology Mrs. Laux

The Evolutionary Theory must explain:

1. How adaptations evolve in populations
2. The origin of new species which results in biodiversity (speciation)

The fossil record provides evidence for 2 distinct patterns of speciation:

1. Anagenesis→(phyletic evolution)
   - -transformation of one entire species to another
   - -A→B
2. Cladogenesis→(branching evolution)
   - -budding of one or more new species out of a parent species that continues to exist
   - -new species usually comes from a small population that was isolated from original population and not permitted to interbreed
   - -ex: Darwin's finches
     - A→A
     - A→B



Remember→species are individuals that can interbreed, but cannot breed with members of other species

- -according to this, we cannot group organisms that reproduce asexually or fossils (extinct species)
- -in this case, grouped first by anatomical similarities

During speciation:

- Populations are separated→
- Gene flow is diminished→
- 2 separate populations adapt to own environmental conditions→ frequency of alleles changes in 2 separate populations due to natural selection, mutations, and genetic drift→

over time, 2 populations are so genetically different that they can no longer interbreed→
2 separate species

Why can't 2 new species interbreed? No gene flow between 2 species?

Reproductive barriers
- **-factors that impede 2 species from producing fertile offspring**
- **-reduce gene flow between populations**
- **-not always physical**

A. Prezygotic barriers
- **-mechanisms that prevent fertilization**
- **-no fertilization→no zygote→no viable offspring**

1. Habitat Isolation
- **-2 species in different habitats within same area do not encounter one another**
- **-may or may not be geographically isolated**
- **-ex: 2 species of garden snakes (*Thamnophis*) occur in same areas, but one lives on land and one in the water**
- **-seldom come in contact**

2. Temporal Isolation
- **-2 species mate or flower at different times of day or year**
- **-ex: brown trout (fall) and rainbow trout (spring) live in same stream**
- **-gametes have no opportunity to contact each other**

3. Behavioral Isolation
- **-one species does not recognize another species as mating partners because it does not perform correct courtship rituals, signals, songs, or release proper chemicals (scents, pheromones)**
- **-ex: fireflies**
  - **-males of each species blink lights in a characteristic pattern**
  - **-females differentiate between species by flashing patterns**
- **-ex: Gypsy moths**
  - **-females emit pheromones-only males of this species recognize this as a sexual attractant**
- **-ex: meadowlarks**
  - **-different species recognize each other via songs**

4. Mechanical Isolation
- **-anatomical incompatibility may prevent sperm transfer when closely related species attempt to mate**
- **-ex: dragonflies→use specific appendages to grasp onto females during copulation**
- **-other species, appendages don't grasp-bodies too thin**

-ex: plants pollinated by insects or other animals, floral anatomy is specific to a specific pollinator of one species
-hummingbird, bee

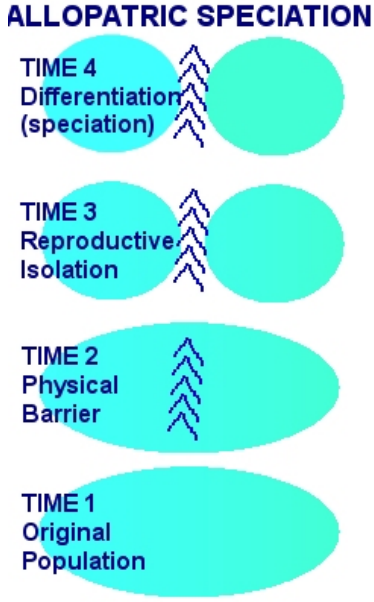
5. Gamete Isolation
-male gametes do not survive in environment of female gamete
-ex: internal fertilization→male sperm may not be able to survive inside female
-ex: external fertilization
-usually specific chemicals on egg attract sperm of same species
-no chemicals→no fertilization

B. Postzygotic barriers
-if fertilization does occur between members of 2 different species, offspring could not necessarily be viable and fertile
1. Hybrid inviability
-abortion of fetus at an embryonic stage
-ex; frogs-*Rana* sometimes interbreed, yet, offspring usually die before birth, those who do live, die very young
2. Reduced Hybrid Fertility (Hybrid Sterility)
-hybrids live and become functional, but are sterile
-gene flow is stopped because offspring cannot produce own offspring
-ex: mule
3. Hybrid breakdown
-when some species mate, F1 is viable and fertile, but when these hybrids mate with one another or parents, offspring of F2 will die or be sterile
-ex: cotton species
-F1→live, fertile
-F2→die or seeds produce weak, sterile plants

Speciation
-formation of new species
-occurs when 2 populations of the same species are isolated and gene flow between them is diminished
-each population can follow own environmental conditions
-2 ways in which speciation can occur

1. Allopatric Speciation-occurs when initial block to gene flow is a geographical barrier
-physically isolates the populations
-prevents interbreeding between populations
-geographical barriers:
-mountain ranges
-glaciers

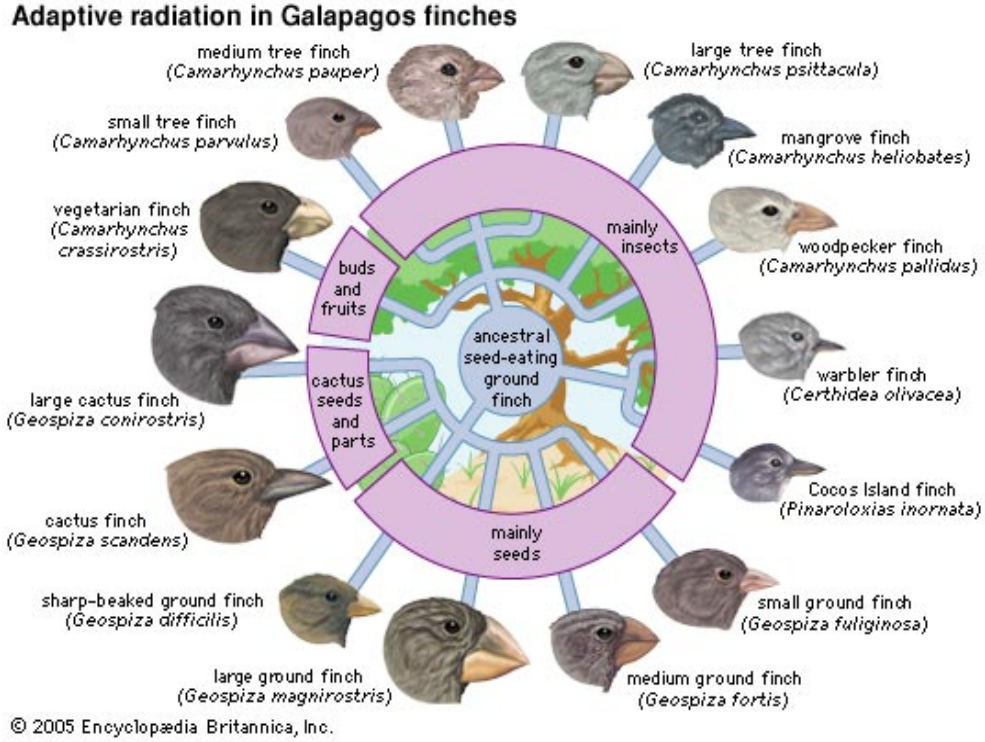
-land bridges
-subsidence of large lakes
-burned area with no food
-anything an organism may not survive a trip across



-gene frequency in 2 populations can diverge due to natural selection, mutation, or genetic drift
-if sufficient change occurs, interbreeding cannot occur even if barrier is removed→result→new species has formed
-ex: 2 different species of antelope squirrels in Grand Canyon
-White-tailed→smaller
-Harris' antelope squirrels→larger, black tail underneath
-cannot make it across canyon; therefore, geographic barrier resulted in allopatric speciation
-ex: 50,000 years ago-Death Valley in California was rainy with many lakes and rivers
-as rivers dried up over the years, there were left only small springs-that were isolated from one another
-result→pupfishes (*Cyprinodon*) that lived in lakes became isolated→developed new species of pupfishes in each spring
-world thought that all the species were originally from one species of pupfish that underwent allopatric speciation

Adaptive Radiation
-when many diverse species rapidly evolve from a single ancestor
-will occur when diverse geographical or ecological conditions are available for colonization
-ex: Darwin's finches (and all endemic Galapagos Island species)
-problem began with a single island, when some ancestral finches migrated

-isolation from original group could result in allopatric speciation
-as each finch adapted to new island and its place in it
-few individuals may have reached other islands, these may have also speciated
-it is possible, also, that new species could migrate back to original island and coexist with species of finch there
-especially if each has own niche- food, shelter, etc.
-this could occur several times leading to a number of species of finches, some of which coexist
-in each case the variants diverge from species as populations specialize to the new set of conditions on each island



Sympatric Speciation

-formation of new species within range of parent population
-reproductive isolation occurs without geographic isolation
-can occur quickly (in one generation) if a genetic change results in a reproductive barrier between mutants and the parent population

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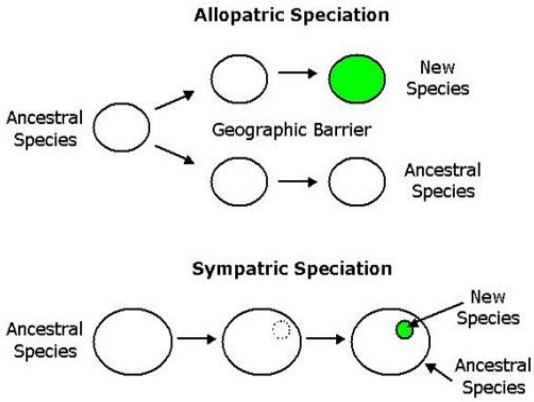


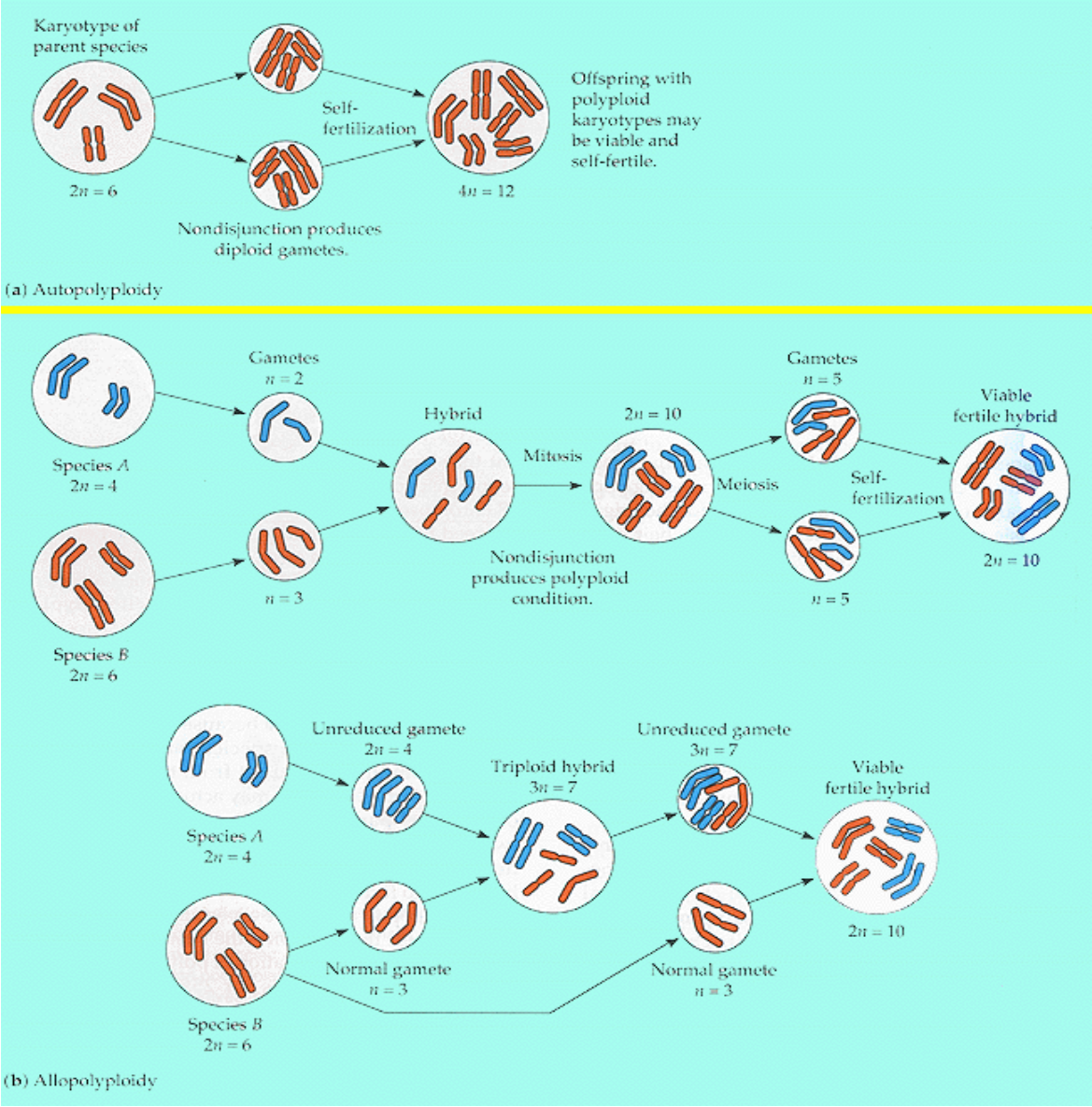
-can happen via:

1. Balanced Polymorphism

→maintenance of many different phenotypes in a population
-in some cases, specific colors or body structure may aid in camouflaging the prey from predators
-mating with individuals with different color patterns or body structure may result in offspring without the same phenotype-result, they may be eaten; therefore, some species of insects, birds, and other animals tend to mate within phenotypes-to produce genetically adapted offspring
-result→reduced gene flow between phenotypes and possible speciation
-ex: birds mating because of beak size

2. Polyploidy-

-possession of more than normal, 2 sets of chromosomes, found in diploid cells
-often occurs in plants (some animals)→result→3n, 4n offspring
-cause→nondisjunction of all chromosomes during meiosis
-will produce 2 viable diploid (2n) gametes and 2 sterile gametes with no chromosomes
-self-fertilization→4n
-cross with normal gamete→3n
-gametes for this individual (from meiosis) would automatically be 2n
-this would prevent mating with diploid individuals; therefore, speciation occurs in one generation
-discovered by Hugo de Vries (evening primrose)



3. Hybrid zone

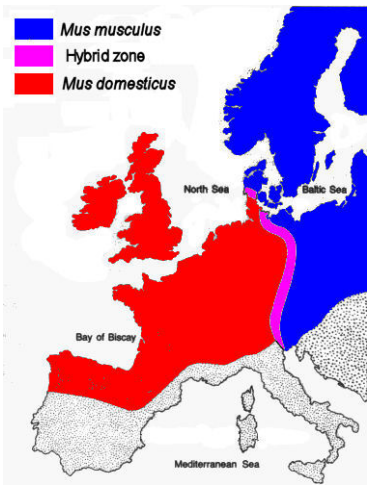
-when 2 individuals from 2 different species mate, 1 of 3 things can happen

a. they may interbreed freely

-merging of gene pools into a single gene pool

b. may not interbreed due to reproductive barriers

c. they may mate and produce progeny along a geographic barrier called the hybrid zone



-at times, species that diverged after becoming geographically isolated will interbreed later on where their geographical ranges overlap
-this overlap area→hybrid zone
-in this zone, there is a mixing of gene pools (alleles) between the 2 populations
-usually mix does not penetrate beyond hybrid zone
-this may allow hybrids to adapt to environment beyond range of either parent
-result→they may eventually diverge from parent populations
-ex: woodpeckers: red-shafted and yellow-shafted flickers
    -2 populations of flickers were isolated during ice age (diverged) and renewed contact a few centuries ago
    -they have established a hybrid zone from Alaska to Texas
    -this zone is not expanding and 2 species remain separate except for in this area

2 theories on how speciation occurs:
    -how species diverge over time
1. Phyletic gradualism
    -evolution occurs through gradual accumulation of small changes
    -speciation occurs over long periods of geologic time
    -paleontologists that support this argue that it is supported by the fossil record
    -not all life forms (species) would have been preserved; therefore, fossil record is more like snapshots of life that existed on the planet
    -shows incompleteness of the fossil record

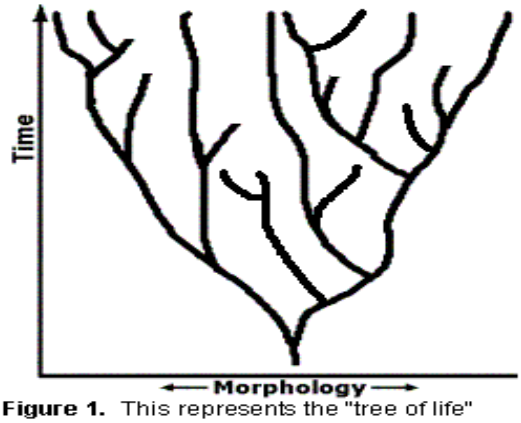


Figure 1. This represents the "tree of life" under Darwin's gradual theory of evolution where one species turns into another species through slow, smooth, gradual changes over long periods of geological time.

2. Punctuated Equilibrium

-contends that evolution consists of long periods of stasis-periods in which no evolution occurred-that are interrupted by geologically short periods of rapid evolution

-backers of this theory claim that this is proven by the fossil record, because rarely examples of "intermediate" forms of life

-few, if any, fossils are available from these short "bursts" of evolution

-feel that this is confirmed because the intermediates would have only been around for short periods of time; therefore, fewer opportunities for fossilization

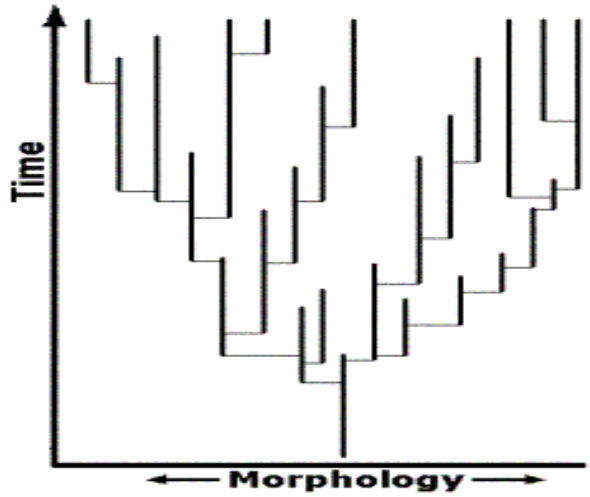


Figure 2. An evolutionary tree under a "punctuated equilibrium" model.[18] Most change in morphology (i.e. macroevolutionary change) takes place over geologically short time periods in small populations, such that transitional forms are unlikely to be fossilized.

Species Concepts and the Definition of "Species”

1) **Biological species concept**: Species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups (Mayr, 1940).

Biological species concept: A species is a reproductive community of populations (reproductively isolated from others) that occupies a specific niche in nature (Mayr, 1982).

Biological species concept: Species are the members in aggregate of a group of populations that breed or potentially interbreed with each other under natural conditions (Futuyma, 1986)

2) **Cladistic species concept**: A species is a set of organisms (an evolutionary lineage) between two branch points or between one branch point and an extinction event or a modern population (Ridley 1993).

3) **Cohesion species concept**: A species is the most inclusive group of organisms having the potential for genetic and/or demographic exchangeability. (Templeton, 1989)

4)**Competition species concept**: Species are the most extensive units in the natural economy such that reproductive competition occurs among their parts (Ghiselin, 1974).

5) **Ecological species concept**: A species is a set of organisms exploiting (or adapted to) a single niche (Ridley 1993).

Ecological species concept: A species is either 1) a lineage which occupies an adaptive zone minimally different from that of any other lineage in its range, and which evolves separately from all lineages outside its range, or 2) a closely-related set of lineages which occupy an adaptive zone minimally different from that of any other lineage in their range and which evolve separately from all other lineages outside their range (translation of Van Valen, 1975).

Ecological species concept: A species is a lineage or a closely related set of lineages, which occupies an adaptive zone minimally different from that of any other lineage in its range and which evolves separately from all lineages outside its range (Van Valen, 1976).

6) **Evolutionary species concept**: A species is a lineage (an ancestral-descendant sequence of populations) evolving separately from others and with its own unitary evolutionary roles and tendencies (Simpson, 1961).

Evolutionary species concept: A species is a single lineage of ancestor-descendant populations which maintain its identity from other such lineages and which has it own evolutionary tendencies and historical fate (Wiley, 1981).

Evolutionary species concept: A species is a population or group of populations that shares a common evolutionary fate through time (Templeton, 1989).

7) **Isolation species concept**: Species are systems of populations: the gene exchange between these systems is limited or prevented by a reproductive isolating mechanism or perhaps by a combination of several such mechanisms. (as defined by Dobzhansky 1970; in Templeton, 1989)

8) **Phenetic species concept**: A species is a set of organisms that look similar to each other and distinct from other sets (Ridley, 1993).

9) **Phylogenetic species concept**: A species is the smallest diagnosable cluster of individual organisms within which there is a parental pattern of ancestry and descent (Cracraft 1983).

Phylogenetic species concept: A species is an irreducible (basal) cluster of organisms, diagnosably distinct from other such clusters, and within which there is a parental pattern of ancestry and descent (Cracraft 1989).

10) **Recognition species concept**: A species is the most inclusive population of individual biparental organisms which share a common fertilization system. (as defined by Paterson, 1985; in Templeton, 1989).

11) **Typological species concept**: A species is a group of organisms conforming to a common morphological plan, emphasizing the species as an essentially static, non-variable assemblage. According to this concept the observed diversity of the universe reflects the existence of a limited number of underlying "universals" or types (*eidos* of Plato). Individuals do not stand in any special relation to each other, being merely expressions of the same type. Variation is the result of imperfect manifestations of the idea implicit in each species (Mayr 1969; Lincoln et al. 1982).

Everything we've talked about up to this point deals with microevolution
→definition→evolution in a single species
-the generation-to-generation change in a population's frequency of alleles or genotypes
-evolution on a small scale

Macroevolution→describes patterns of changes in groups of related species over broad periods of geologic time
-this pattern determines phylogeny→the evolutionary relationships among species and groups of species