NOTES – Ch 17: Genes and Variation

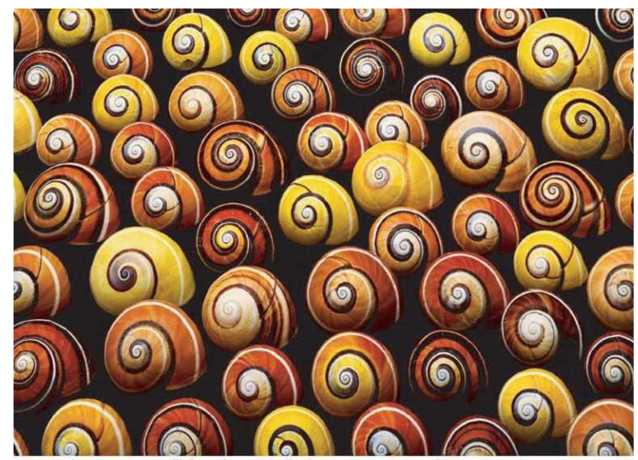
- Vocabulary
  - Fitness
  - Genetic Drift
  - Punctuated Equilibrium
  - Gene flow
  - Adaptive radiation
  - Divergent evolution
  - Convergent evolution
  - Gradualism

<u>17.1 – Genes & Variation</u>

- Darwin developed his theory of natural selection without knowing how heredity worked…or how variations arise
- **VARIATIONS are the <u>raw materials for natural selection</u>**
- All of the discoveries in genetics fit perfectly into evolutionary theory!

Genotype & Phenotype

- **GENOTYPE**: the particular combination of alleles an organism carries
- ***an organism's genotype, together with environmental conditions, produces its PHENOTYPE***
- **PHENOTYPE**: all physical, physiological, and behavioral characteristics of an organism (i.e. eye color, height)



Cuban tree snails (*Polymita picta*)

Natural Selection

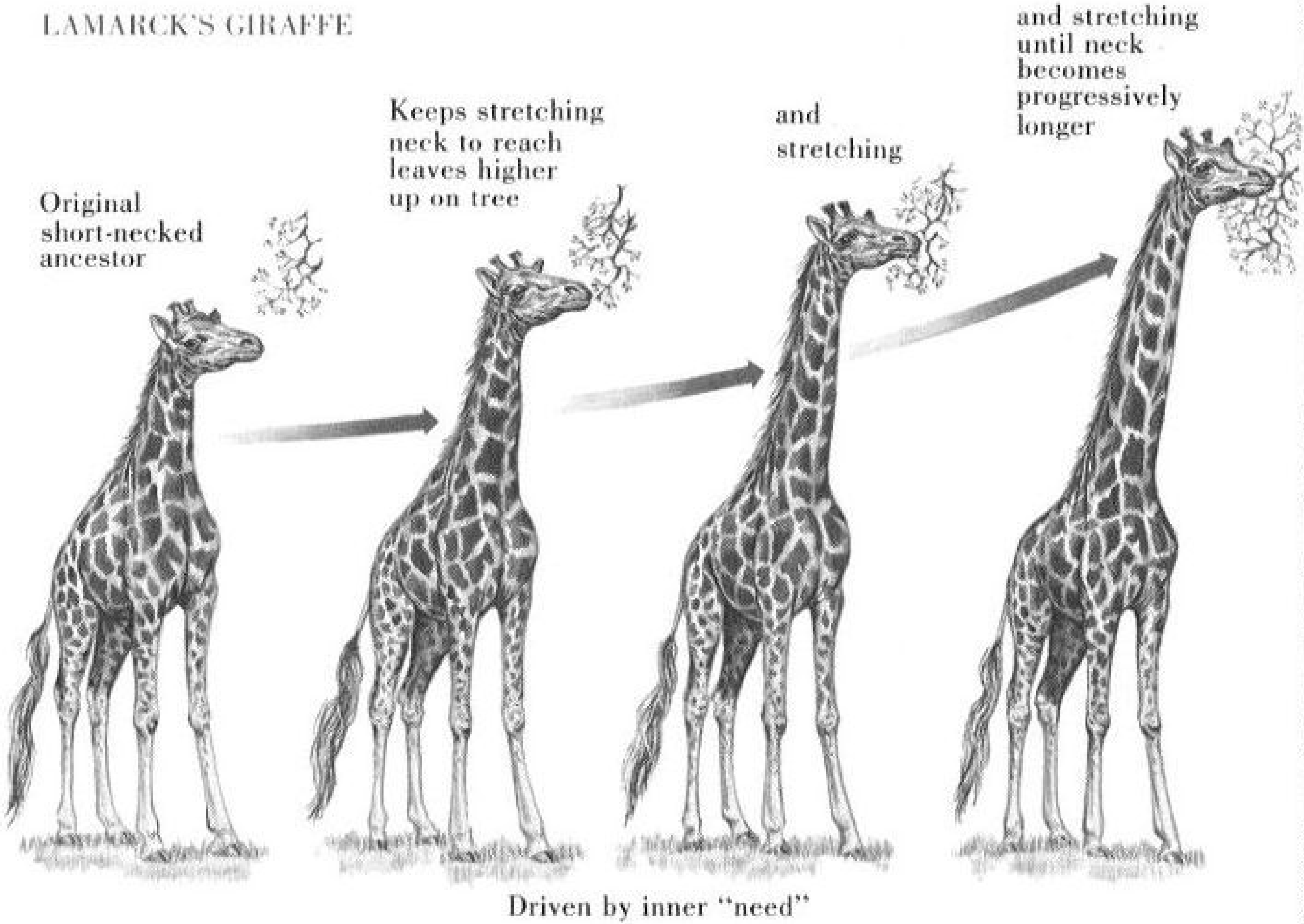
- **NATURAL SELECTION** acts directly on…

…PHENOTYPES!

- How does that work?...some individuals have phenotypes that are better suited to their environment…they survive & produce more offspring (higher fitness!)
- ***organisms with higher fitness pass more copies of their genes to the next generation!***

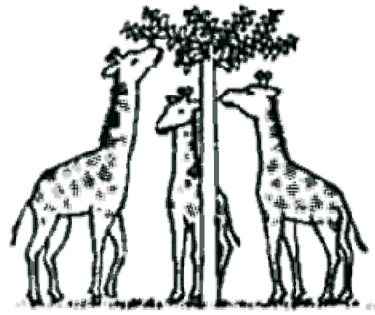
Do INDIVIDUALS evolve?

- NO!
- Individuals are born with a certain set of genes (and therefore phenotypes)
- If one or more of their phenotypes (i.e. tooth shape, flower color, etc.) are poorly adapted, they may be **unable** to **<u>survive and reproduce</u>**
- An individual CANNOT evolve a new phenotype in response to its environment


LAMARCK'S GIRAFFE
Original short-necked ancestor
Keeps stretching neck to reach leaves higher up on tree
and stretching
and stretching until neck becomes progressively longer
Driven by inner "need"

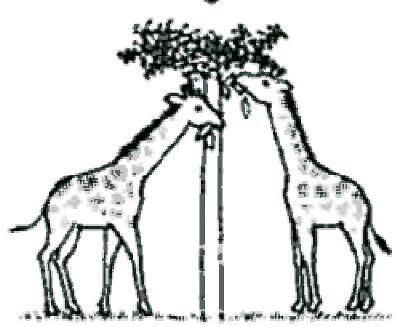
So, EVOLUTION acts on…

- ***POPULATIONS!***
- **POPULATION** = all members of a species that live in a particular area
- In a population, there exists a RANGE of phenotypes
- **NATURAL SELECTION** acts on this range of phenotypes ➔ the most "fit" are selected for **survival and reproduction**



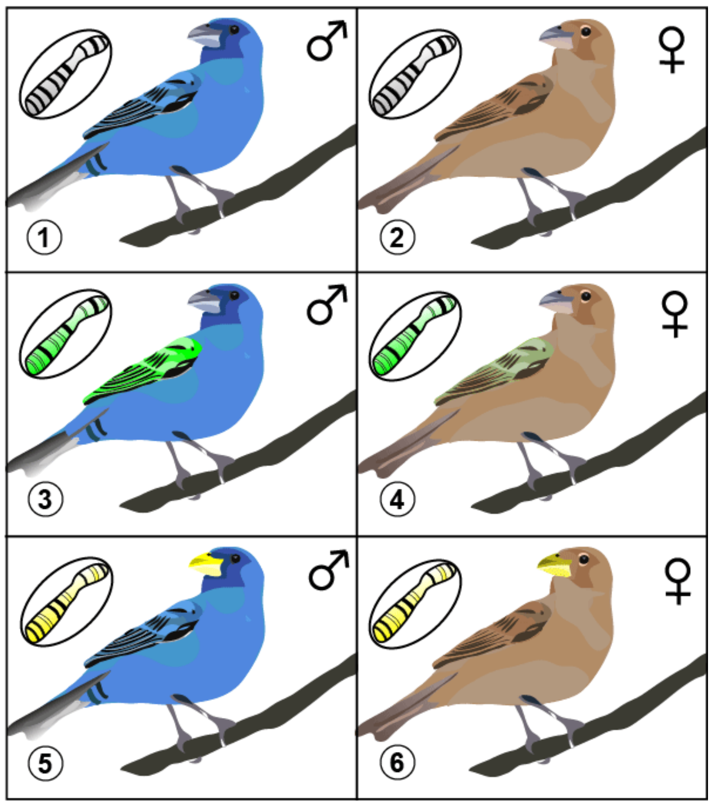
Originally the necks of giraffes were not long. Occasionally, however, some exceptional giraffes had necks just a bit longer than the average ones.

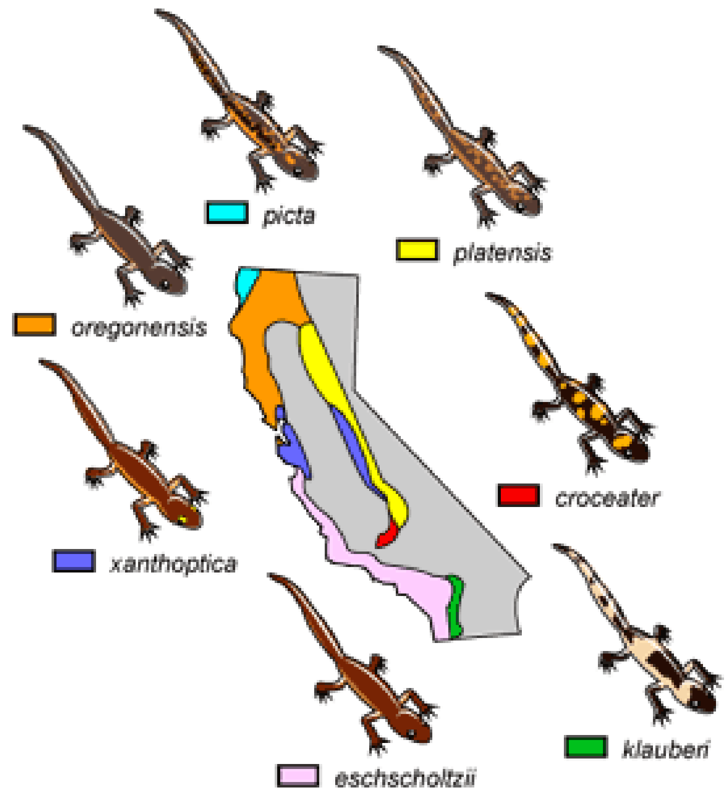
Those that had even a slightly longer neck survived by winning in the struggle for existence.



Generations and generations of those giraffes that had even a slightly longer neck than the others survived. That's what brought about today's long-necked giraffes.

17.2: Evolution as Genetic Change in Populations





Mechanisms of Evolution
(How evolution happens)

1) Natural Selection *(from Darwin)*
2) Mutations
3) Migration (Gene Flow)
4) Genetic Drift

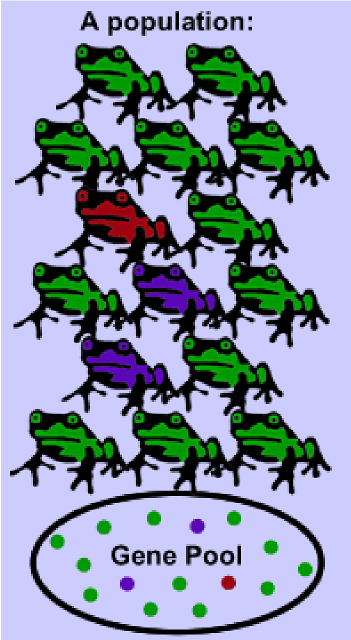
DEFINITIONS:

> SPECIES:

• group of organisms that breed with one another and produce fertile offspring.

> POPULATION:

• group of individuals of the same species that live in the same area.



> GENE POOL:

● combined genetic information of all members of a particular population.

> Relative (allele) frequency =

● the number of times that an allele occurs in a gene pool compared with the number of times other alleles occur

-Usually expressed as a %

<u>1) Mechanism of Evolution: NATURAL SELECTION</u>

- All organisms struggle for survival by competing for resources (especially in an overpopulated environment) so…

  ➔ <u>low levels of fitness</u> = <u>**die or leave few offspring**</u>

  ➔ <u>high levels of fitness</u> = <u>**survive and reproduce most successfully**</u>

1) <u>Mechanism of Evolution: Natural Selection</u>

- **<u>NATURAL SELECTION</u>: <u>survival of the fittest</u>**

  -Imagine that green beetles are easier for birds to spot (and hence, eat).

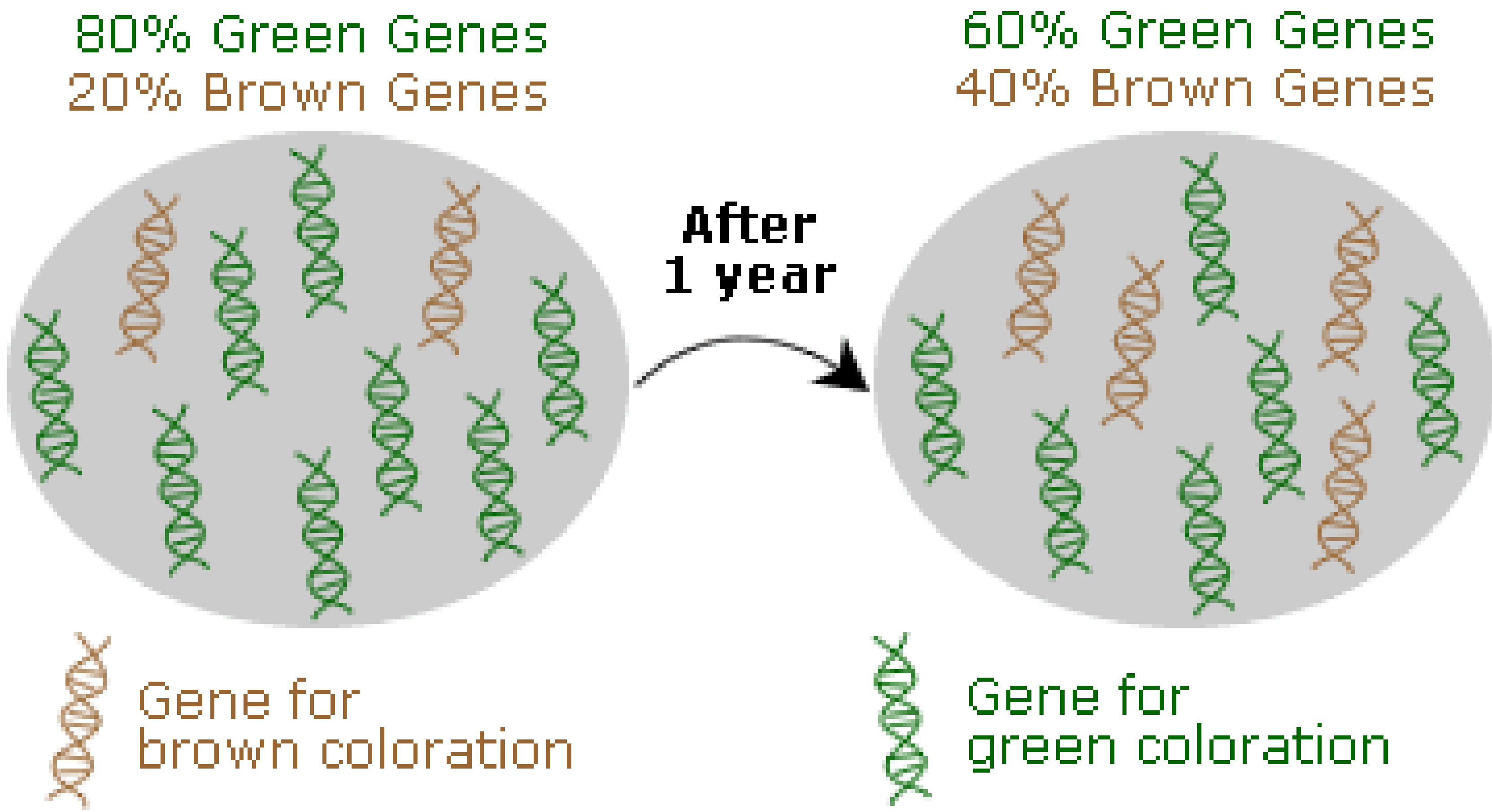
  ➔ Brown beetles are a little more likely to survive to produce offspring

  ➔ The brown beetles pass their genes for brown coloration on to their offspring

  ➔ Next generation: <u>brown beetles are more common than in the previous generation.</u>

What is Fitness?

- **<u>FITNESS</u>**: <u>how successful a particular genotype is at leaving offspring</u> in the next generation (relative to other genotypes)
  - -If brown beetles consistently leave more offspring than green beetles…
  - -The brown beetles have a **<u>greater fitness</u>** relative to the green beetles.

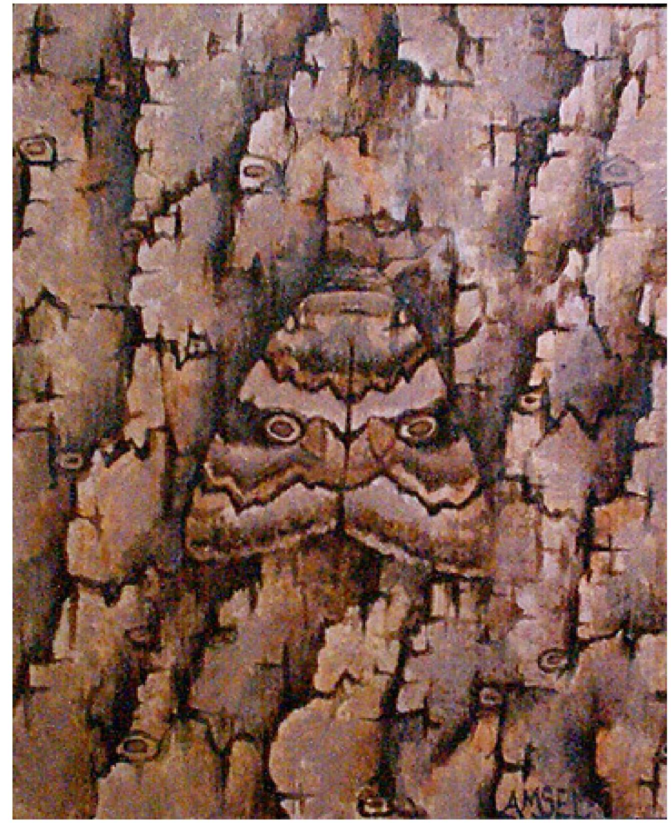

80% Green Genes
20% Brown Genes
After
1 year
60% Green Genes
40% Brown Genes
Gene for
brown coloration
Gene for
green coloration

Fitness is a relative thing

- A genotype's fitness depends on the **environment** in which the organism lives.

- The fittest genotype during an ice age, for example, is probably not the fittest genotype once the ice age is over.

FITNESS



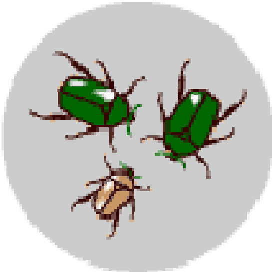
- The fittest individual is not necessarily the strongest, fastest, or biggest
- A genotype's fitness includes its **ability to survive, find a mate, produce offspring (leave** its **genes** in the next generation)

There cannot be <u>NATURAL SELECTION</u> without <u>GENETIC VARIATION</u> in the first place!

<u>**How do changes in appearance come about?**</u>

<u>**2) Mechanism for Evolution: MUTATION**</u>

- <u>**MUTATION**</u>: <u>change in the DNA sequence</u> that affects genetic information (random—not predictable)
  - -a <u>**mutation**</u> could cause parents with genes for bright green coloration to have offspring with a gene for brown coloration
  - -that would make the genes for brown beetles more frequent in the population.



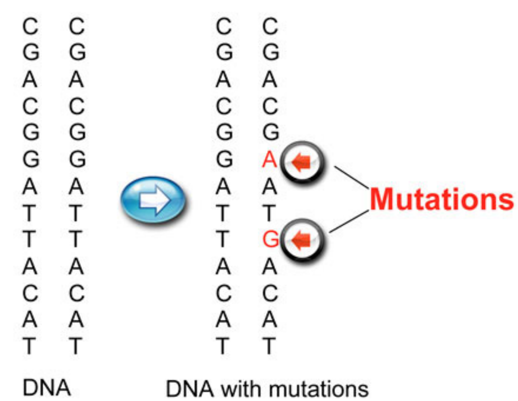
Sources of Genetic Variation - MUTATION

- Single mutation can have a large effect
- in many cases, evolutionary change is based on the accumulation of many mutations
  - ➔ can be beneficial, neutral, or harmful
  - ➔ mutations **do not** "try" to supply what the organism "needs."

Sources of Genetic Variation

- The individuals which happen to have the mutations giving them the **best adaptations** to the environment will be the ones that survive

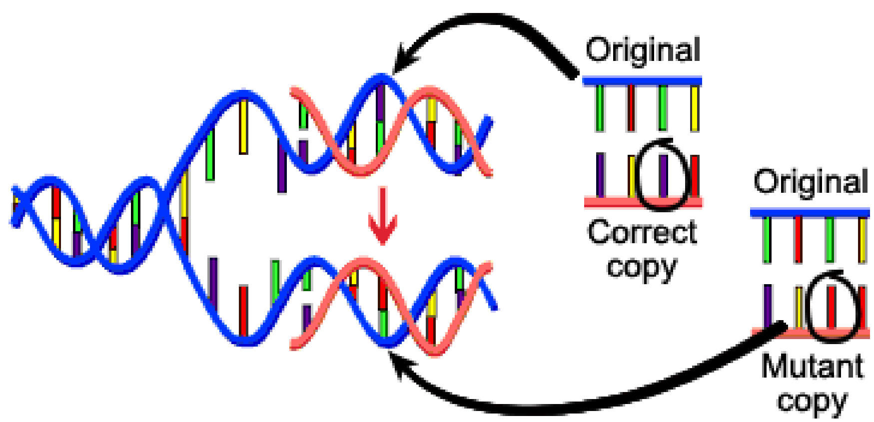
➔ hence the "good" mutations will be "passed down" to the next generation.



- **Not all mutations matter to <u>evolution</u>**
  - -All cells in our body contain DNA
  - -Mutations in non-reproductive cells won't be passed onto offspring

Causes of mutations:

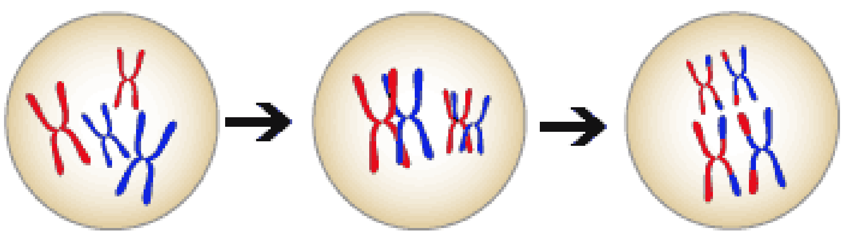
- <u>Mistake in copying DNA</u>
- <u>External sources—radiation, chemicals</u>



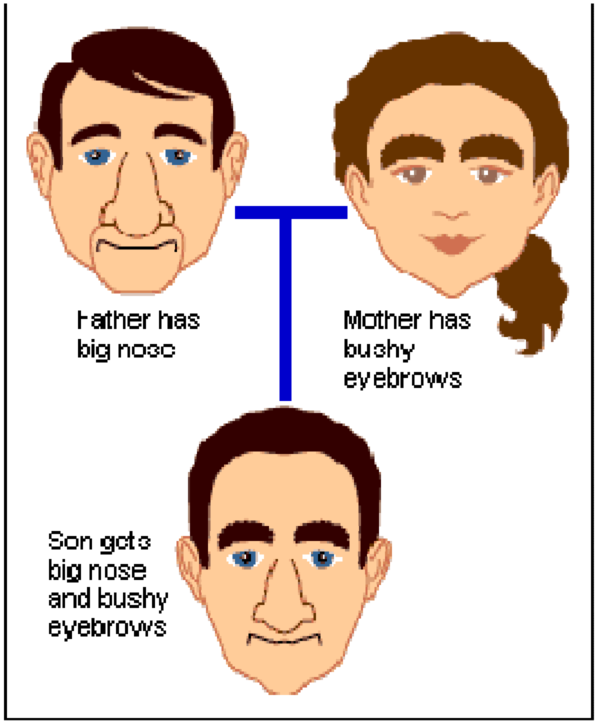
Sources of Genetic Variation

2) Gene shuffling: (How chromosomes line up in meiosis)

-Crossing over can occur

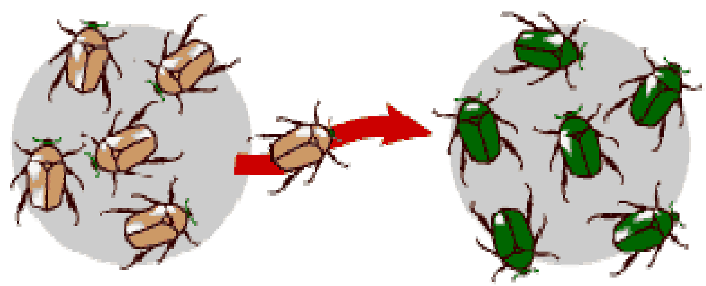


This shuffling is important for **EVOLUTION** because it can introduce new combinations of genes every generation.



3) Mechanism of Evolution: Migration (a.k.a. "GENE FLOW")

- Some individuals from a population of brown beetles might have joined a population of green beetles.
  - -would make the genes for brown beetles more frequent in the green beetle population.

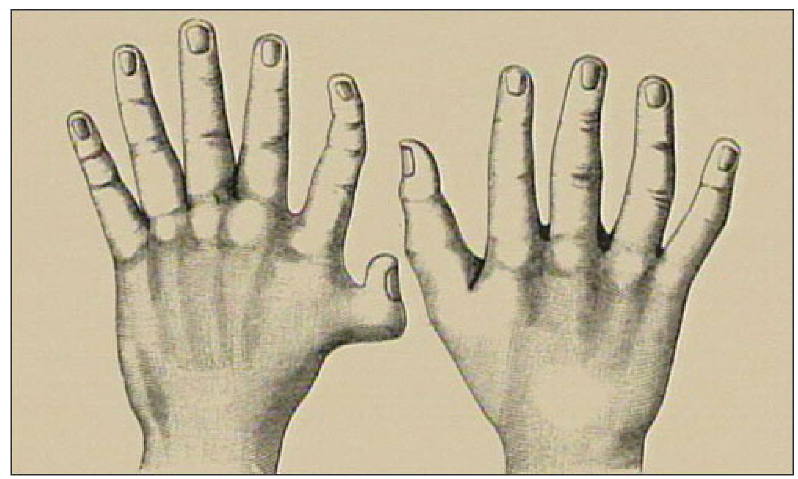


4) Mechanism for Evolution: GENETIC DRIFT

- In a population, an allele can become more or less common **by chance** (remember genetics and probability!)

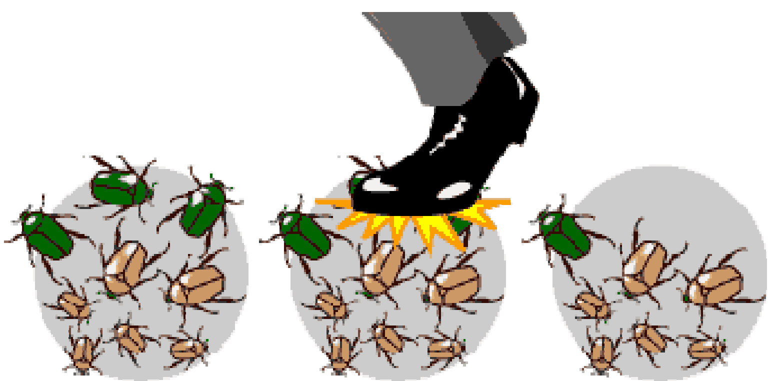
- **GENETIC DRIFT = The random change in the frequency of an allele** (gene)
  ➔ most effective with small populations

- SO…Gene pools can change without natural selection…
  an allele can become common in a population by chance alone.

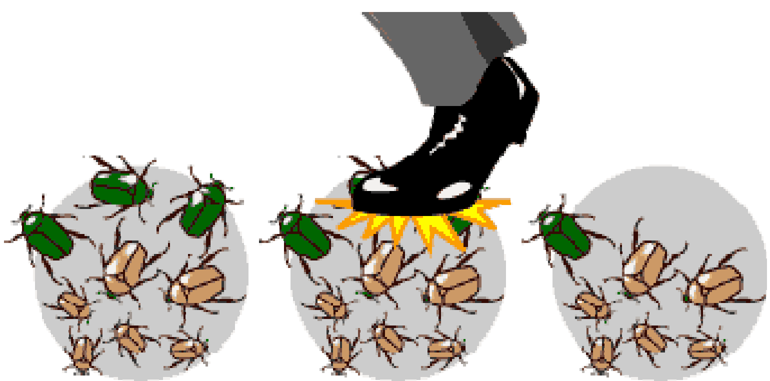


GENETIC DRIFT: example

- Imagine that a population of green and brown beetles
- Several green beetles were killed when someone stepped on them and therefore, they had no offspring.



- The next generation would have a few more brown beetles than the previous generation—but just by chance.
- **These chance changes from generation to generation are known as GENETIC DRIFT.**



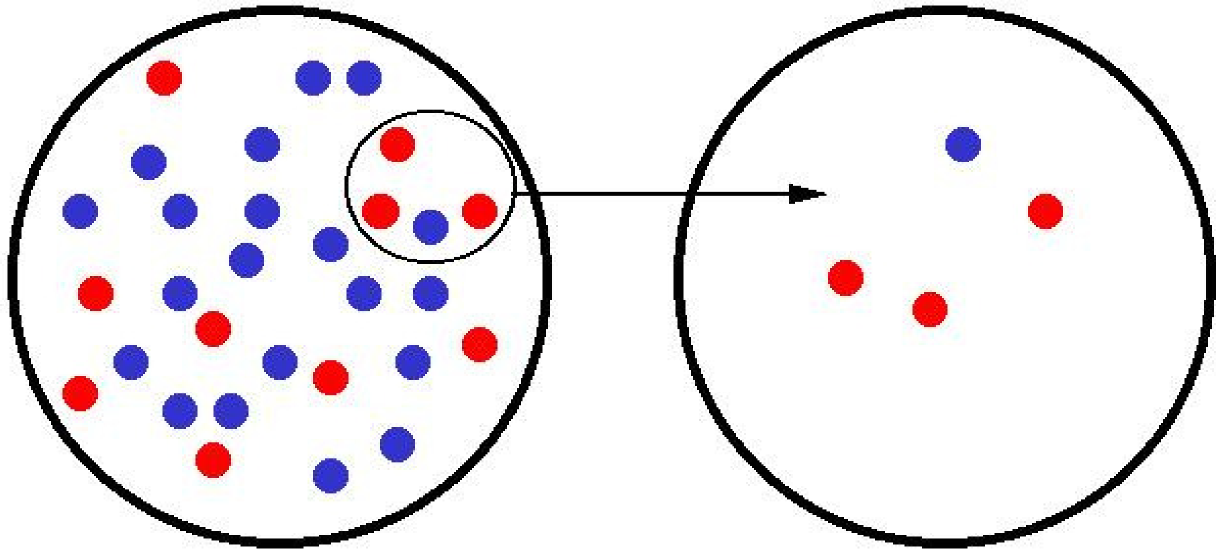
Genetic Drift Example: FOUNDER EFFECT

- A small group of individuals move to new habitat (the "founding" group)

- Their alleles and allele frequencies may be different that that of the original population

- So the new population that they found will have different allele frequencies than the original group… ***BY CHANCE!***

Founder effect

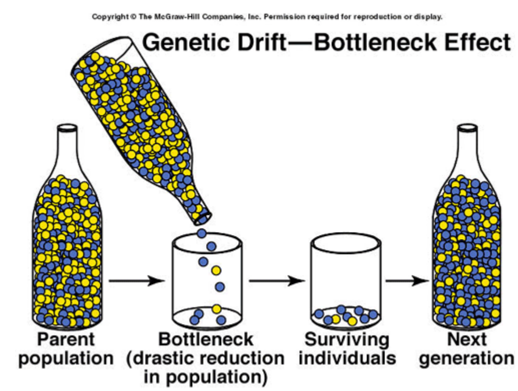


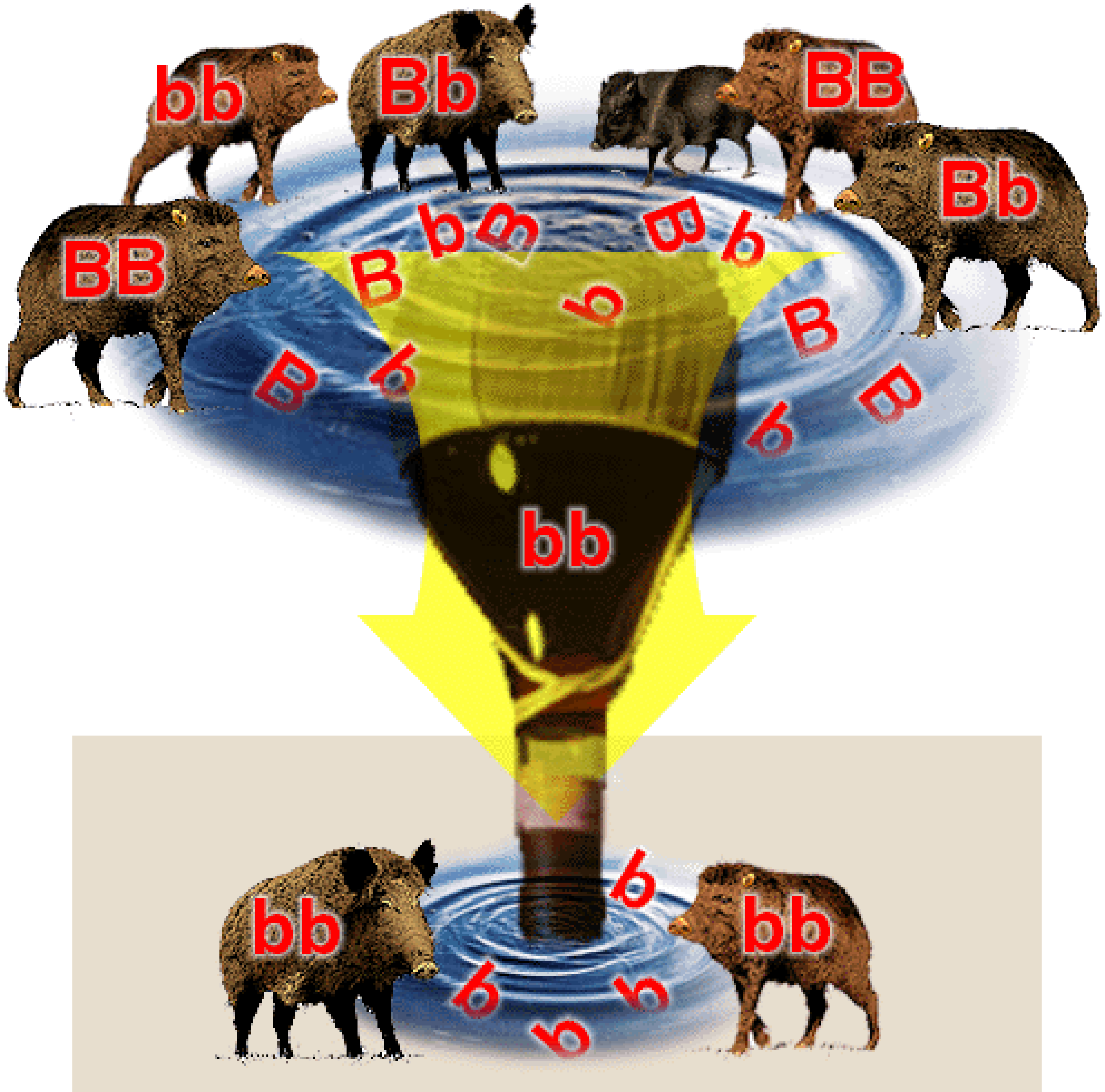
20 blue
10 red

1 blue
3 red

<u>Genetic Drift Example: BOTTLENECK EFFECT</u>

- a population experiences an event (storm, sickness, over hunted by humans) that causes it to decrease in # to just a few individuals
- the allele frequencies in the <u>few surviving individuals</u> may be different than the original population
- Example: <u>cheetahs</u>

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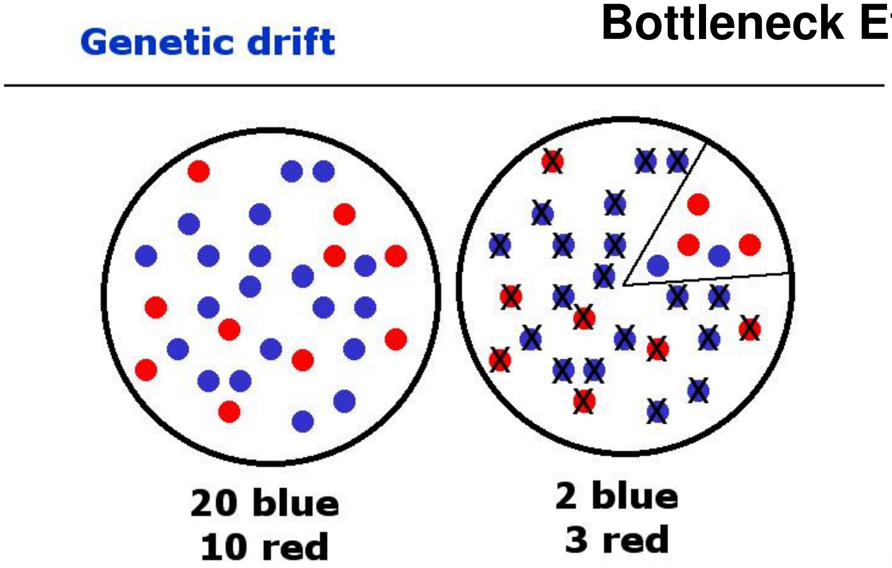
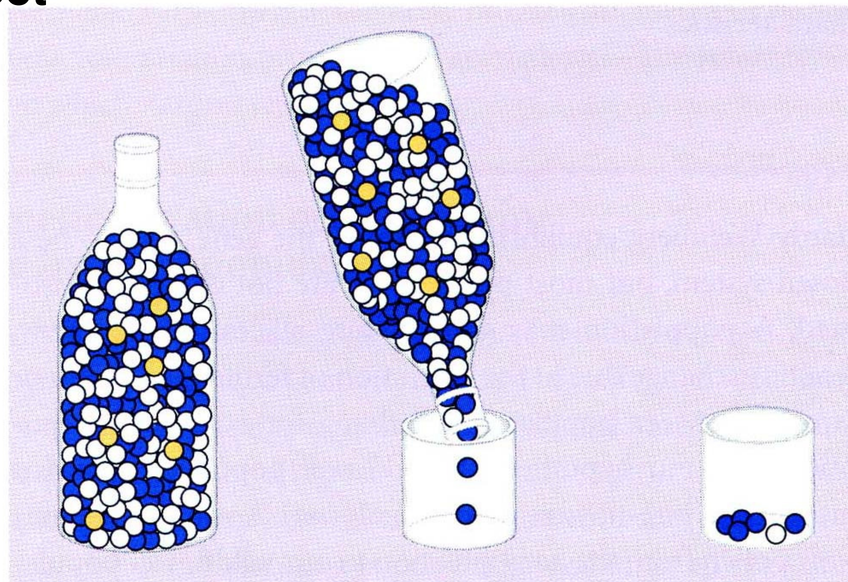
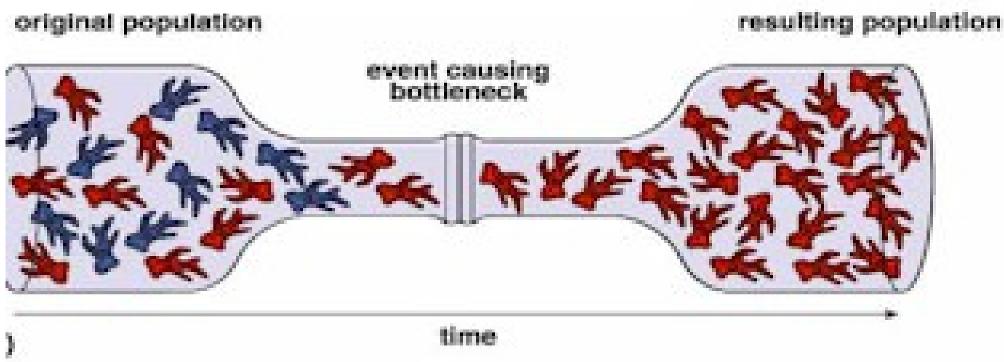
Bottleneck Effect







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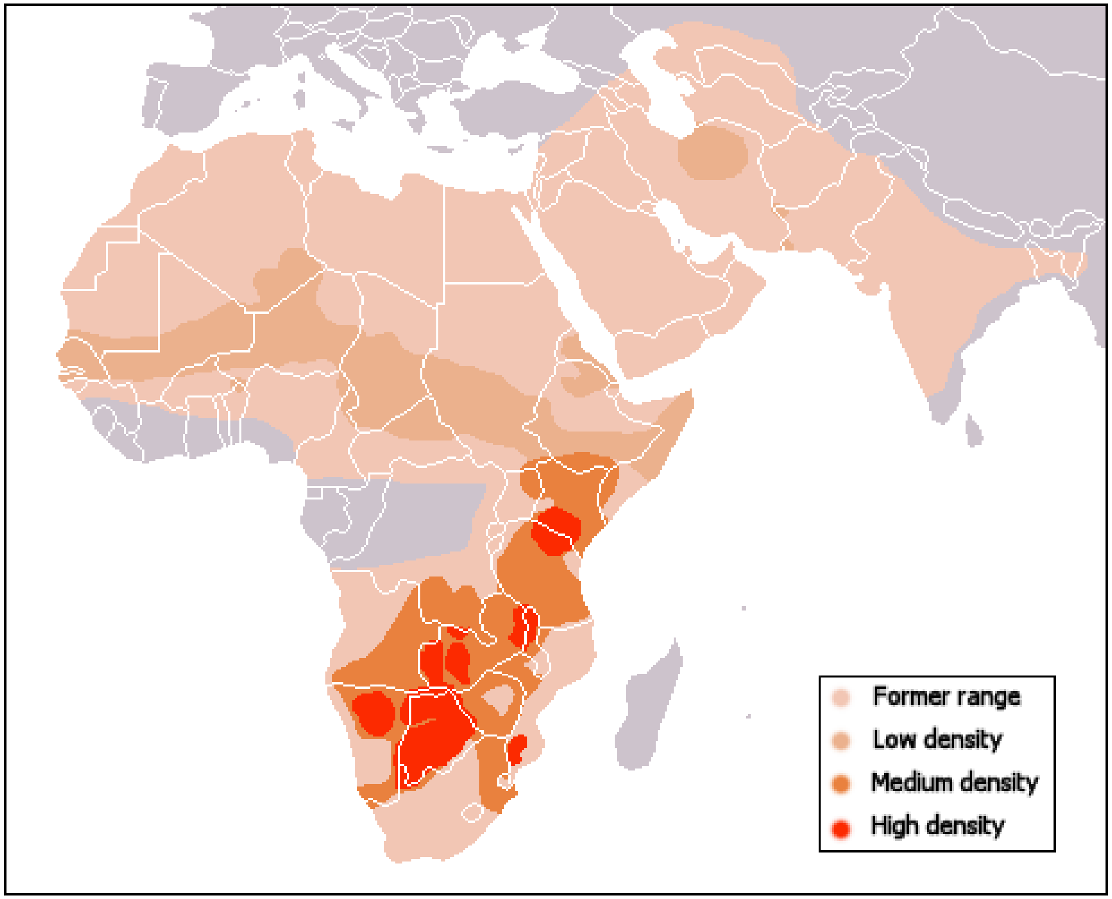
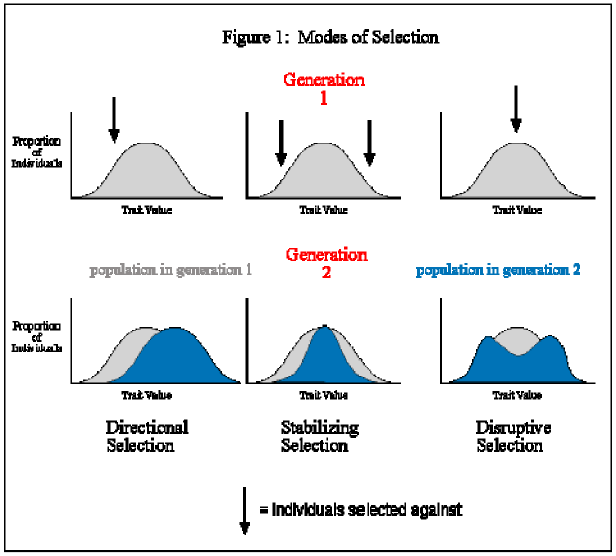

Former range
Low density
Medium density
High density

➔ ***Of all of the mechanisms covered, the "strongest" influence is that of NATURAL SELECTION…***

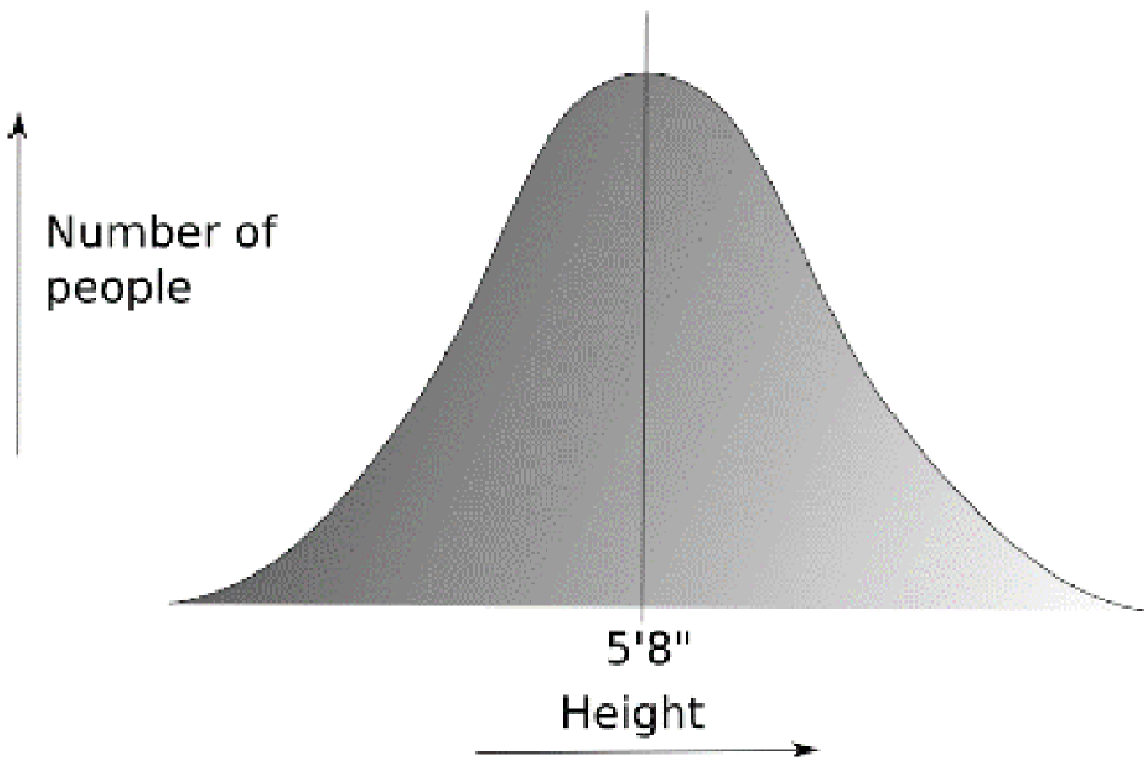
NATURAL SELECTION

- Natural selection on single gene traits can lead to changes in the allele frequency
  - -Ex: brown vs. green beetles
- **Natural selection on polygenic traits**—affects distribution of phenotypes in 3 ways
  1) **Directional Selection**
  2) **Stabilizing Selection**
  3) **Disruptive Selection**



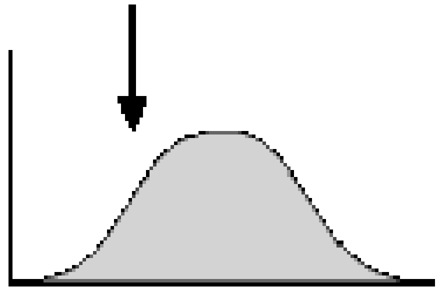
Modes of Selection:

- Imagine the range of phenotypes in a population are graphed into a distribution curve:

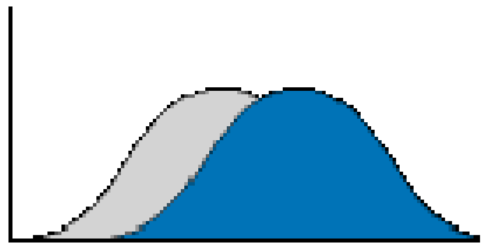


<u>1) DIRECTIONAL SELECTION:</u>

- If organisms at one end of the curve have <u>higher fitness</u> than organisms in the middle or at the other end of the curve
  - Finch beaks in the Galapagos
  - Result: specific beak size increased



population in generation



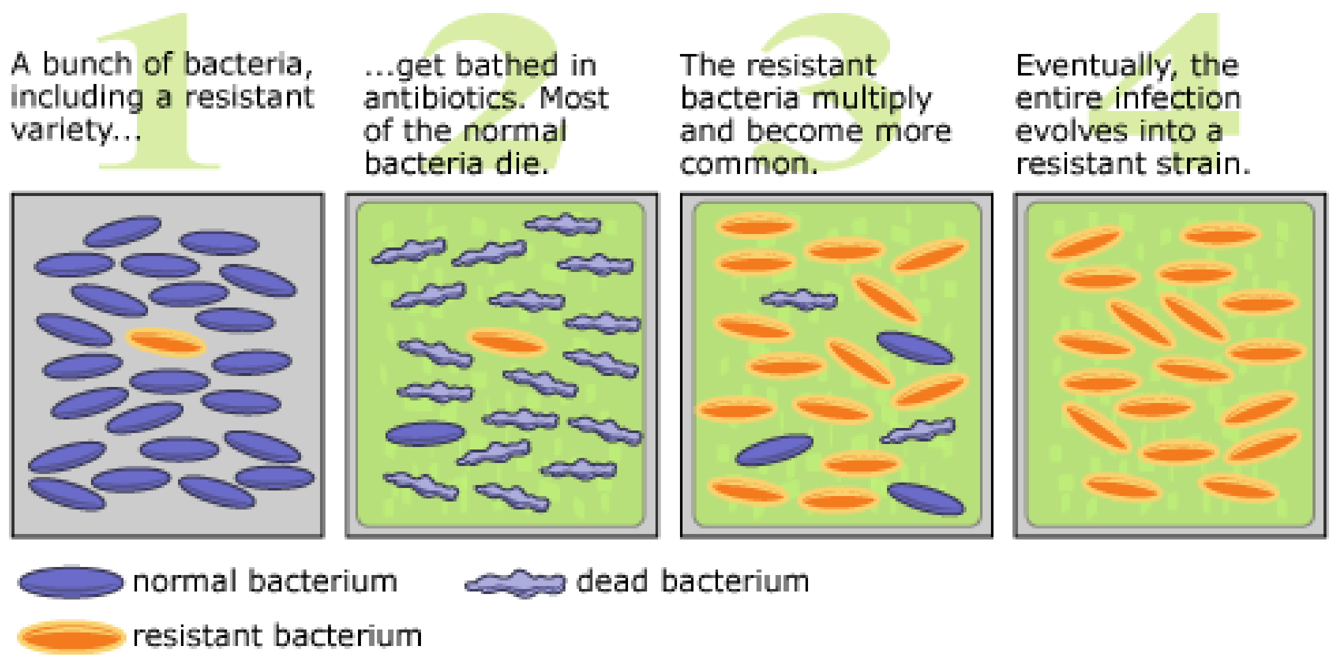
Directional
Selection

1) DIRECTIONAL SELECTION:

Examples:

-bacterial resistance to antibiotics

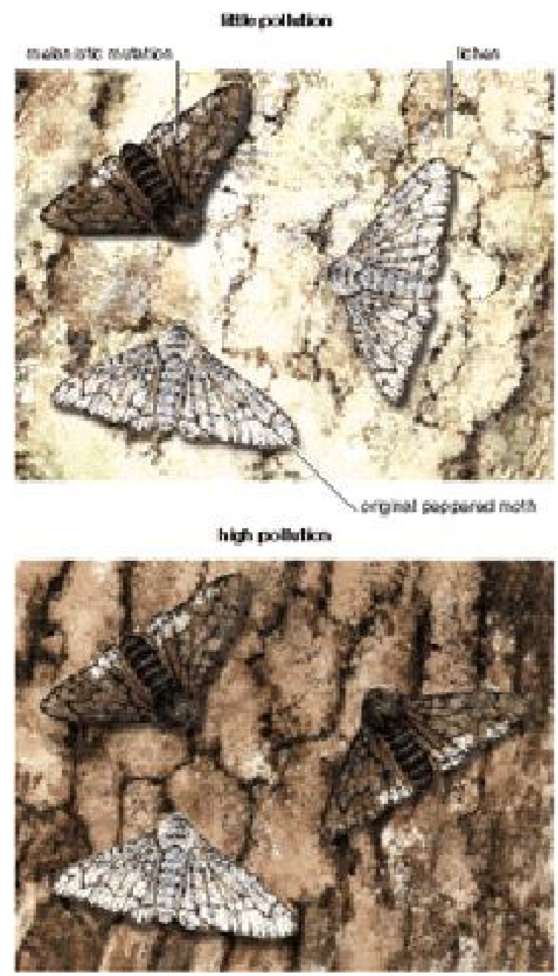
-peppered moth



<u>Peppered Moth example:</u>

- 100 years after the first dark moth was discovered in 1848, <u>90% of moths were dark</u>;

- the light variety continued to dominate in **unpolluted areas outside of London**.



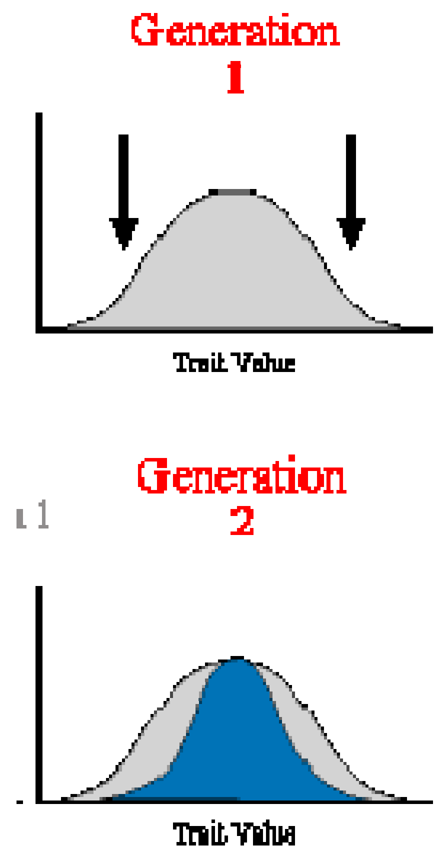
2) STABILIZING SELECTION:

- Individuals near center of curve have higher fitness that individuals at either end of the curve

  -Human baby birth weight

  ➔ Babies born vs. underweight less likely to survive

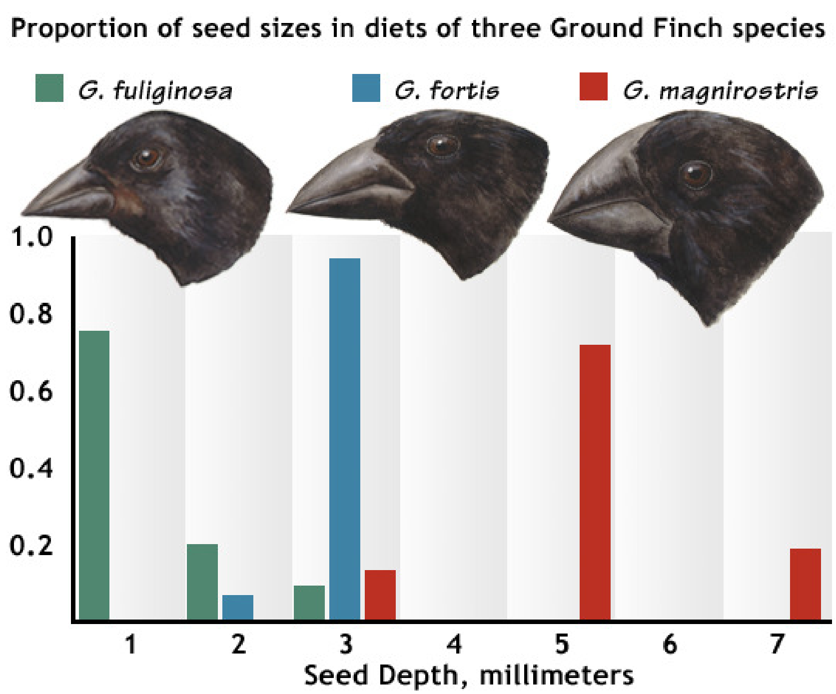
  ➔ Larger babies have a hard time being born (think size of birth canal)

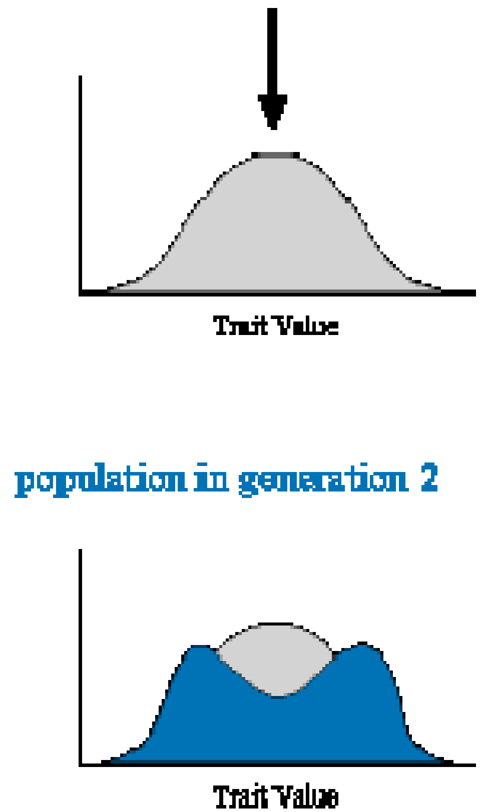


Stabilizing Selection

3) DISRUPTIVE SELECTION:

- Individuals at either end of the curve are more fit than those in the center
  - Intermediate type is **selected against**
- Ex: Bird beak size
  - if medium seed size becomes less common, birds that can eat the smallest and largest seeds will survive





Disruptive Selection

17.3 The Process of Speciation

Central Idea:

- **How does natural selection (and other mechanisms of evolution) lead to the formation of a new species?**

Speciation

- **<u>SPECIATION</u>**: **<u>formation of a new species</u>**

- *Remember:*
  - Species: a group of organisms that breed with one another and produce fertile offspring
    - *A population of individual organisms share a gene pool.*

- If a genetic change <u>increases</u> fitness, that allele will eventually be found in many members of the population

Speciation

- As new species evolve, populations become reproductively isolated from each other.
- When members of two populations **cannot** reproduce to produce fertile offspring = **reproductive isolation**
- At this point, species have **separate gene pools**
- Question: ***How does reproductive isolation develop?***

Kaibab Squirrel

Albert's Squirrel

<u>3 Kinds of Isolating Mechanisms:</u>

<u>1) Behavioral Isolation</u>

-Two populations are physically able to interbreed but have different courtship rituals or other types of behavior

<u>2) Geographic Isolation:</u>

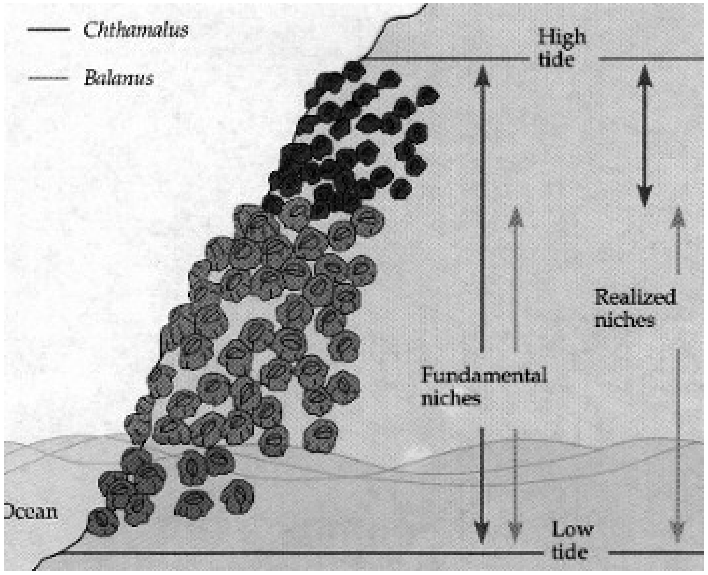
-Geographic barriers (<u>rivers, mountains, roads</u>) prevent genes from being exchanged, *including advantageous mutations and variations*

-BUT does not guarantee formation of a new species…WHY NOT?

<u>3) Temporal Isolation</u>

-Species reproduce at <u>different times</u> and therefore are unlikely to reproduce with each other

- What an organism eats and does (physical and biological conditions), and where it lives in its environment is a **NICHE**
- 2 species that occupy the same niche create **COMPETITION**
- Competition can lead to **EXTINCTION**



MACROEVOLUTION

Definition: **Large scale evolutionary changes** **that take place over** ***long periods of time.***

Six patterns of macroevolution

1. **Mass extinction**
2. **Adaptive radiation (a.k.a. divergent evolution)**
3. **Convergent evolution (analogous structures)**
4. **Coevolution**
5. **Gradualism**
6. **Punctuated equilibrium**

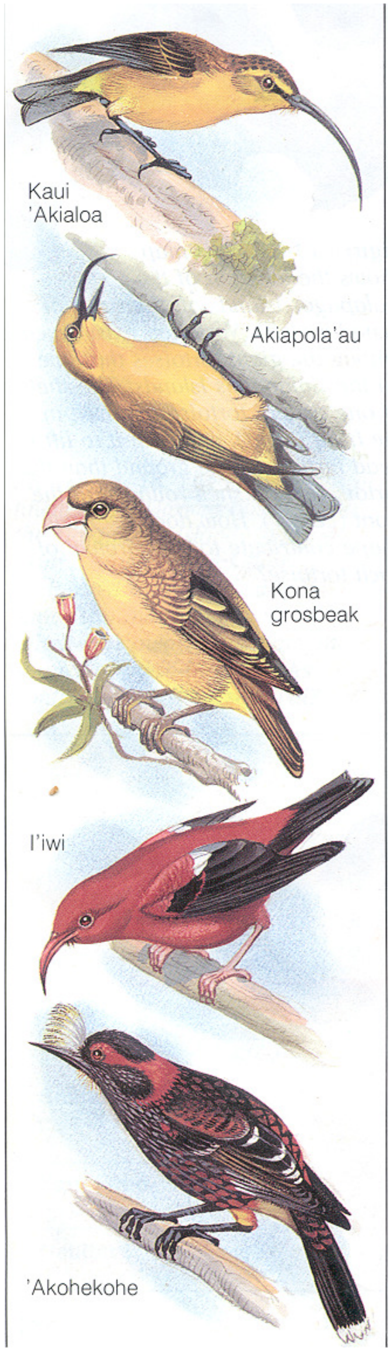
Adaptive Radiation

Process of one species giving rise to many species that live in different ways (niches)

A.K.A.: **DIVERGENT EVOLUTION**

EX: Darwin's finches!

Adaptive radiation in Galapagos finches

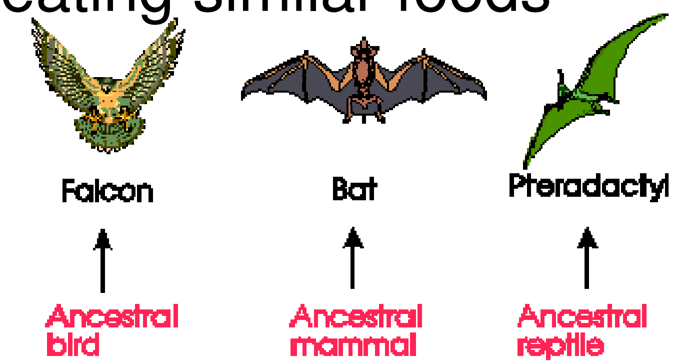


Organisms evolve a variety of characteristics that enable them to survive in different niches

Hawaiian Honeycreeper

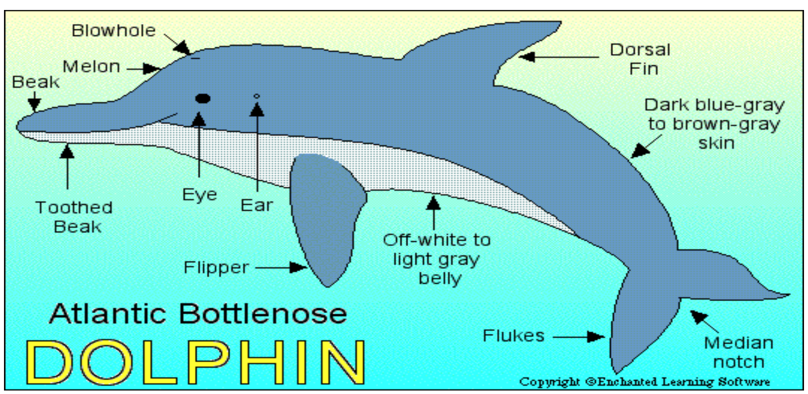
<u>CONVERGENT EVOLUTION:</u>

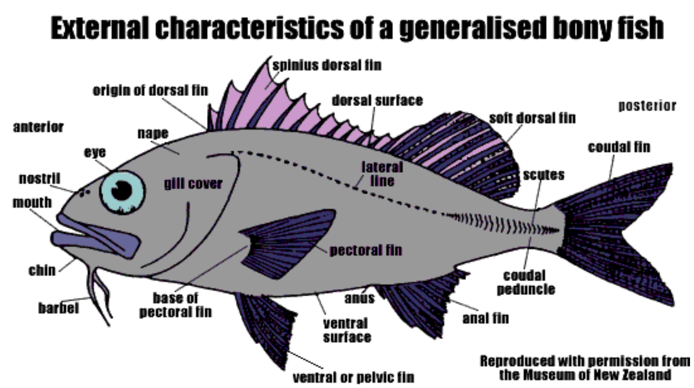
- Different organisms (unrelated) look similar ***because they live in <u>similar environments</u>***
- Different "raw material" for natural selection to work on, but…
  - Similar environmental demands
    - EX: moving through air, water, eating similar foods

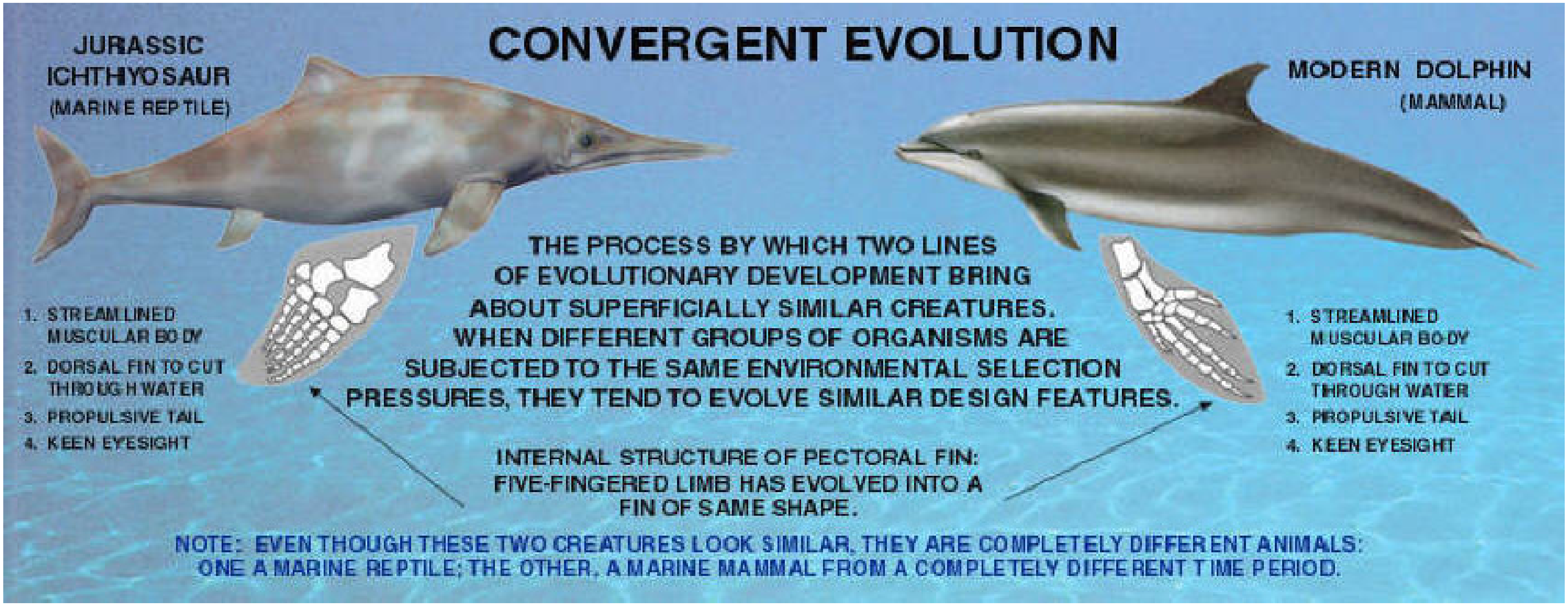


<u>CONVERGENT EVOLUTION:</u>

- Produces ***analogous structures*** like the **dolphin's fluke** and a **fish's tail fin**
  - Look and function similarly but do not share a common evolutionary history






CONVERGENT EVOLUTION
JURASSIC ICHTHYOSAUR (MARINE REPTILE)
MODERN DOLPHIN (MAMMAL)
1. STREAMLINED MUSCULAR BODY
2. DORSAL FIN TO CUT THROUGH WATER
3. PROPULSIVE TAIL
4. KEEN EYESIGHT
THE PROCESS BY WHICH TWO LINES OF EVOLUTIONARY DEVELOPMENT BRING ABOUT SUPERFICIALLY SIMILAR CREATURES. WHEN DIFFERENT GROUPS OF ORGANISMS ARE SUBJECTED TO THE SAME ENVIRONMENTAL SELECTION PRESSURES, THEY TEND TO EVOLVE SIMILAR DESIGN FEATURES.
1. STREAMLINED MUSCULAR BODY
2. DORSAL FIN TO CUT THROUGH WATER
3. PROPULSIVE TAIL
4. KEEN EYESIGHT
INTERNAL STRUCTURE OF PECTORAL FIN: FIVE-FINGERED LIMB HAS EVOLVED INTO A FIN OF SAME SHAPE.
NOTE: EVEN THOUGH THESE TWO CREATURES LOOK SIMILAR, THEY ARE COMPLETELY DIFFERENT ANIMALS: ONE A MARINE REPTILE; THE OTHER, A MARINE MAMMAL FROM A COMPLETELY DIFFERENT TIME PERIOD.

COEVOLUTION:

- 2 species exert an evolutionary influence on one another (and so, coevolve)

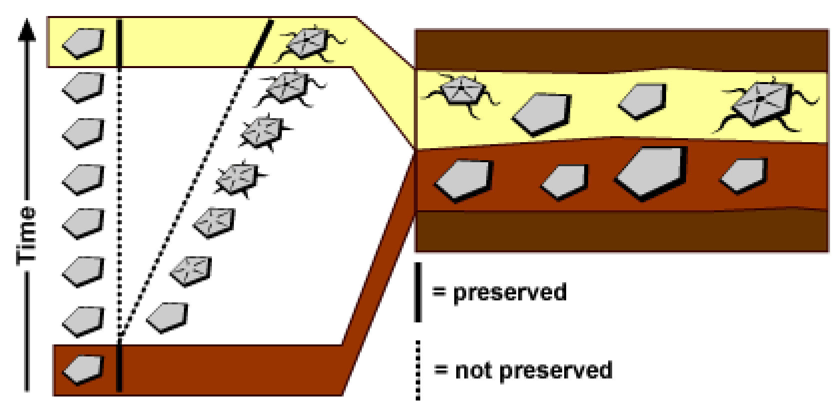
Examples:

-a parasite and its host

-a flowering plant and its pollinator insect or bird

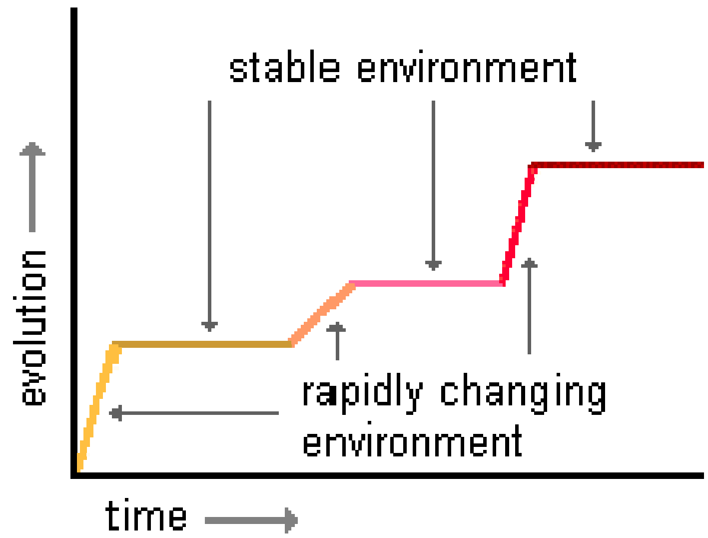
GRADUALISM: (Darwin's idea of evolution):

- Darwin thought evolution only took place over a LONG time
  - Hutton and Lyell's discussion of slow geologic change
- **GRADUALISM** = fossil record shows continuous, minor changes (evolution is slow and steady!)



Punctuated Equilibrium:

- Equilibrium—hardly any change
- Definition: A pattern of long stable periods interrupted by brief periods of rapid change



<u>Examples:</u>

**When the equilibrium is upset, change can occur in a short period of time

- EX: A small group of organisms migrate to a new environment
  - Organisms evolve <u>quickly</u> to fill available niches (Galapagos Finches)
- EX: A small population is cut off from its original population

Example of Punctuated Equilibrium:

- Life is going on smoothly for a population of mice.
- Then ***whoosh!***
- There is a flood which separates the population into two groups, one on one side of a river and one on the other side. (Geographic isolation → reproductive isolation!)

- **What could happen as a result?**

Gradualism vs. punctuated equilibrium:

- Biologists agree that either gradualism or punctuated equilibrium can results in speciation, <u>depending on the circumstances</u>