Meeting Life's Challenges Part 1 Review

Why do species go extinct?

- **Short Answer- They were unable to meet life's challenges!**

Recall Living Organisms Must

- Obtain Nutrients
- Obtain & Conserve Water
- Eliminate Wastes
- Exchange Gases
- Sense & Respond to their environment
- Thermoregulate
- Defend themselves
- Reproduce

Why do species go extinct?

- **Long Answer- The environment changes, which in turn effects the species ability to meet one or more of life's challenges and as a group the species is unable to adapt in time to the new conditions.**

Environmental Changes & New Conditions

- Changing Climates
- Habitat Loss
- Being Out-Competed (by better adapted organisms)
- Over-Exploitation & Hunting

How have extant species made it this far?

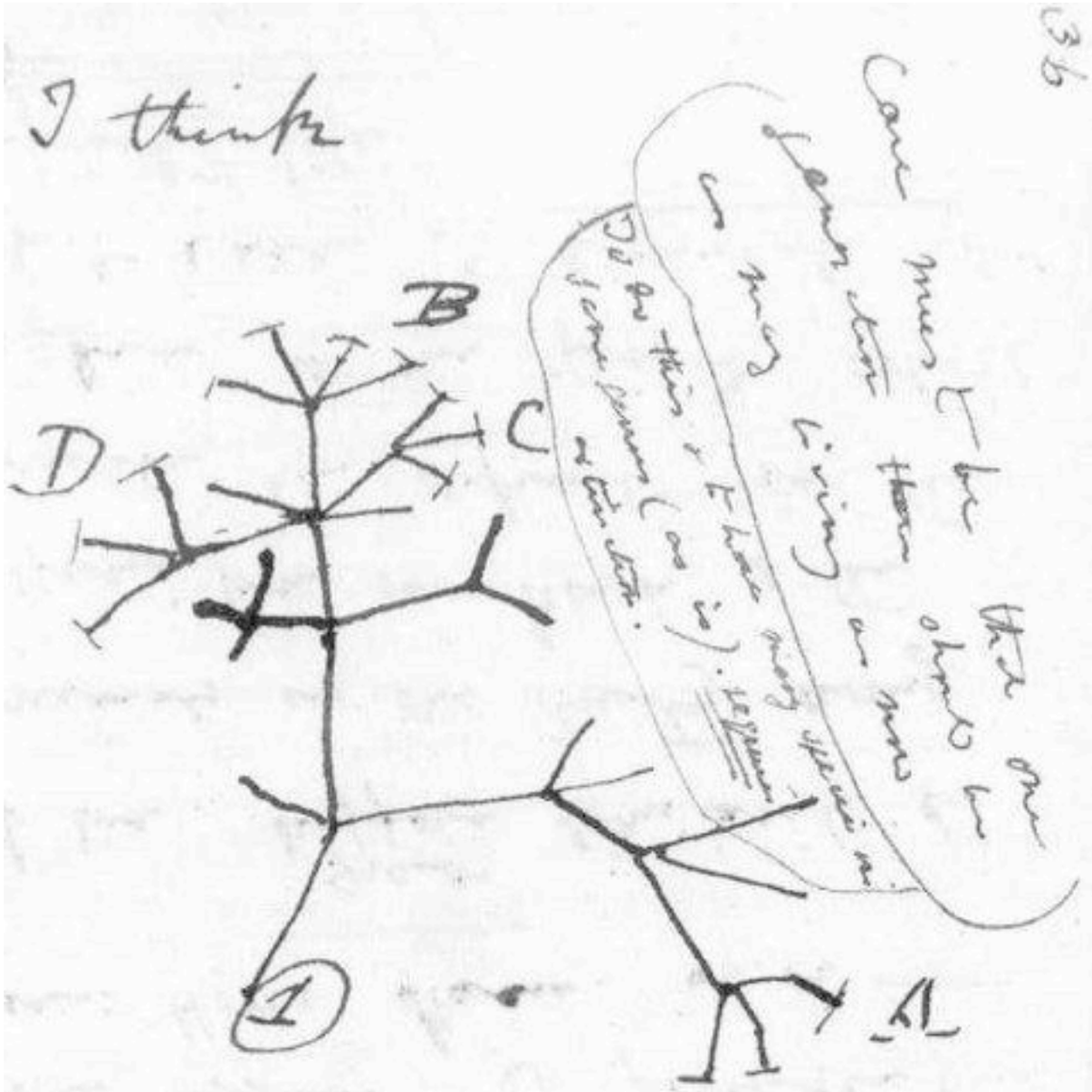
- **Long Answer- Descent with modification, the population (species) possessed enough variation that at least some organisms in the population were able to meet life's challenges in spite of the changing conditions. As a result these better adapted individuals left more offspring who were also more able to deal with the changing conditions. Over time (descent) a once rare trait in the population becomes more common (modification) and the population consequently is able to meet life's challenges and thus continues to survive through time.**
- **Short Answer- They adapted & Evolved**

How do species continue to meet life's challenges?

- **The population as a whole adapts and changes over time with the inevitable changing conditions...They Evolve!**

Origin of Species

- **Origin of Species beautifully illustrated life's**
  - **unity**
  - **diversity**
  - **relationships**



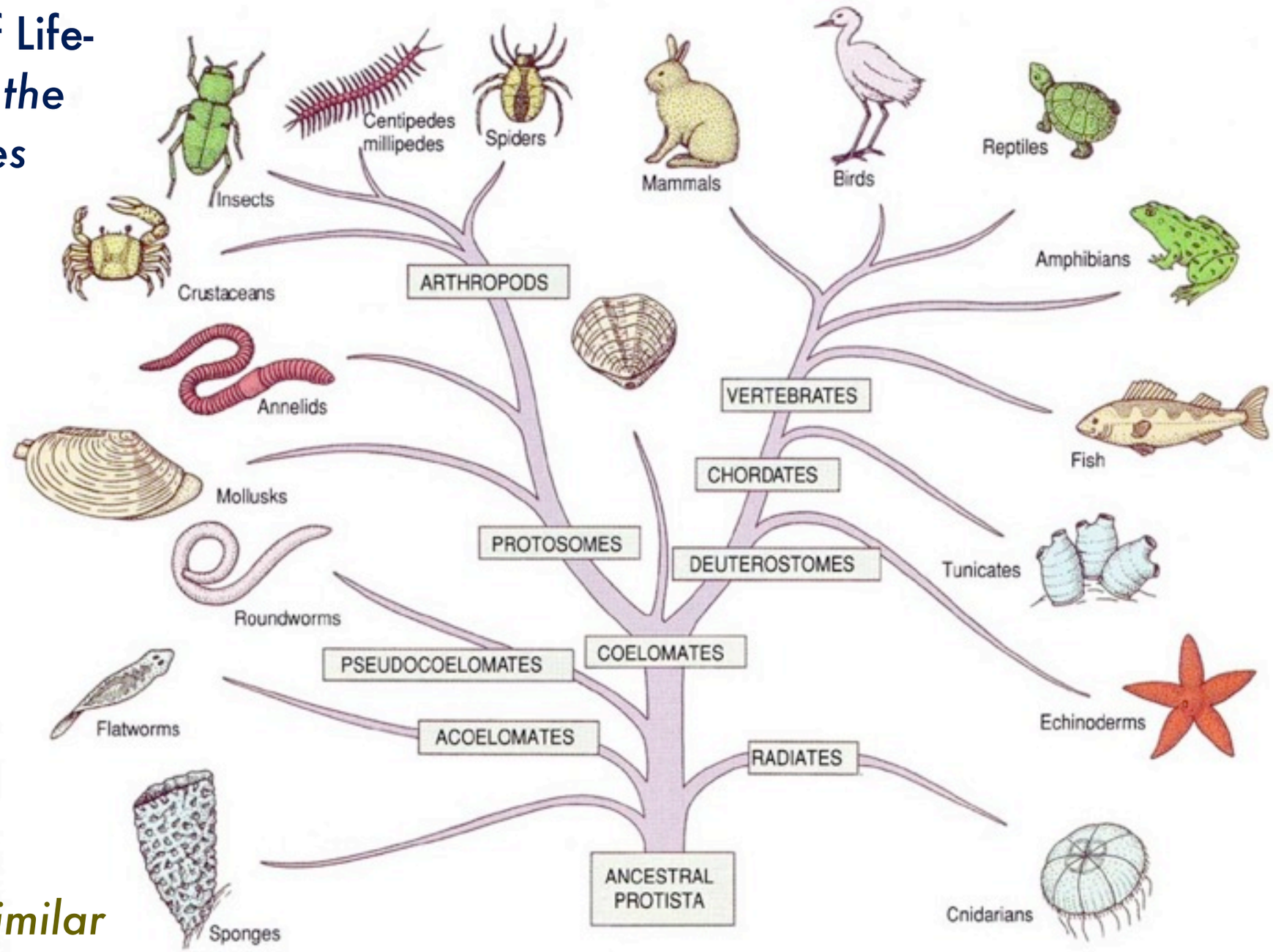
Darwin suggested that a "Tree" might best symbolize these ideas

Tree of Life

Diversity of Life- *is seen in the branches*

Forks- *represent common ancestors*

Relationships- *different structures are related to unique/different environments*



Relationships- *similar structures due to common ancestry and similar environments*

Unity of Life- *is seen in the trunk as single common ancestor*

Darwin's Argument

- **Variation exists among individuals in a population!**

Darwin's Argument

- **Populations produce more offspring than the environment can support, thus some will fail to survive and/or reproduce!**

Darwin's Argument

- **Individuals with inherited traits that give them a better chance of surviving and reproducing in a particular environment tend to leave more offspring!**

Darwin's Argument

- **The unequal ability of individuals to survive and reproduce will lead to accumulation of favorable traits and less favorable traits will diminish in the population over *time!**

*Darwin noted that if artificial selection could produce dramatic changes in a relatively short time frame then given enough time nature could fashion the same dramatic changes

Darwin's Mechanism

- **NATURAL SELECTION- differential reproductive success!**

- Beneficial traits are subject to the environment, a beneficial trait for one may be deleterious to another.
  (should the environment change so to might the beneficial traits)

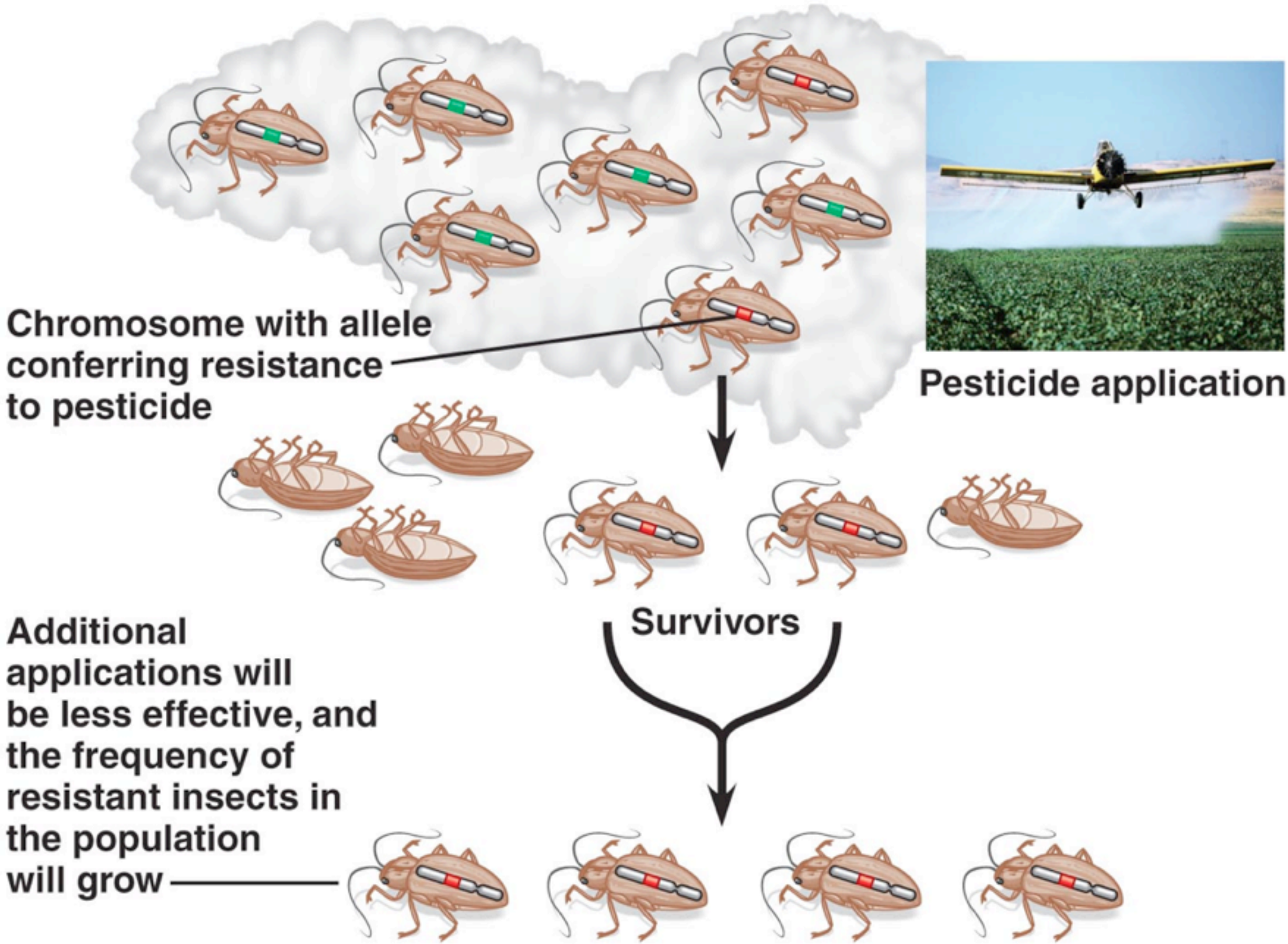
- Natural selections can only amplify or diminish the traits that differ in a population.
  (no variation = no selection)

- Populations evolve not individuals.

Evidence for Evolution

- **What does/can the theory of evolution explain?**
- **What observations does/can the theory of evolution support?**
  - **Pesticide Resistance**
  - **Fossil Record**
  - **Biogeography**
  - **Anatomical Observations**

*Pesticide Resistance

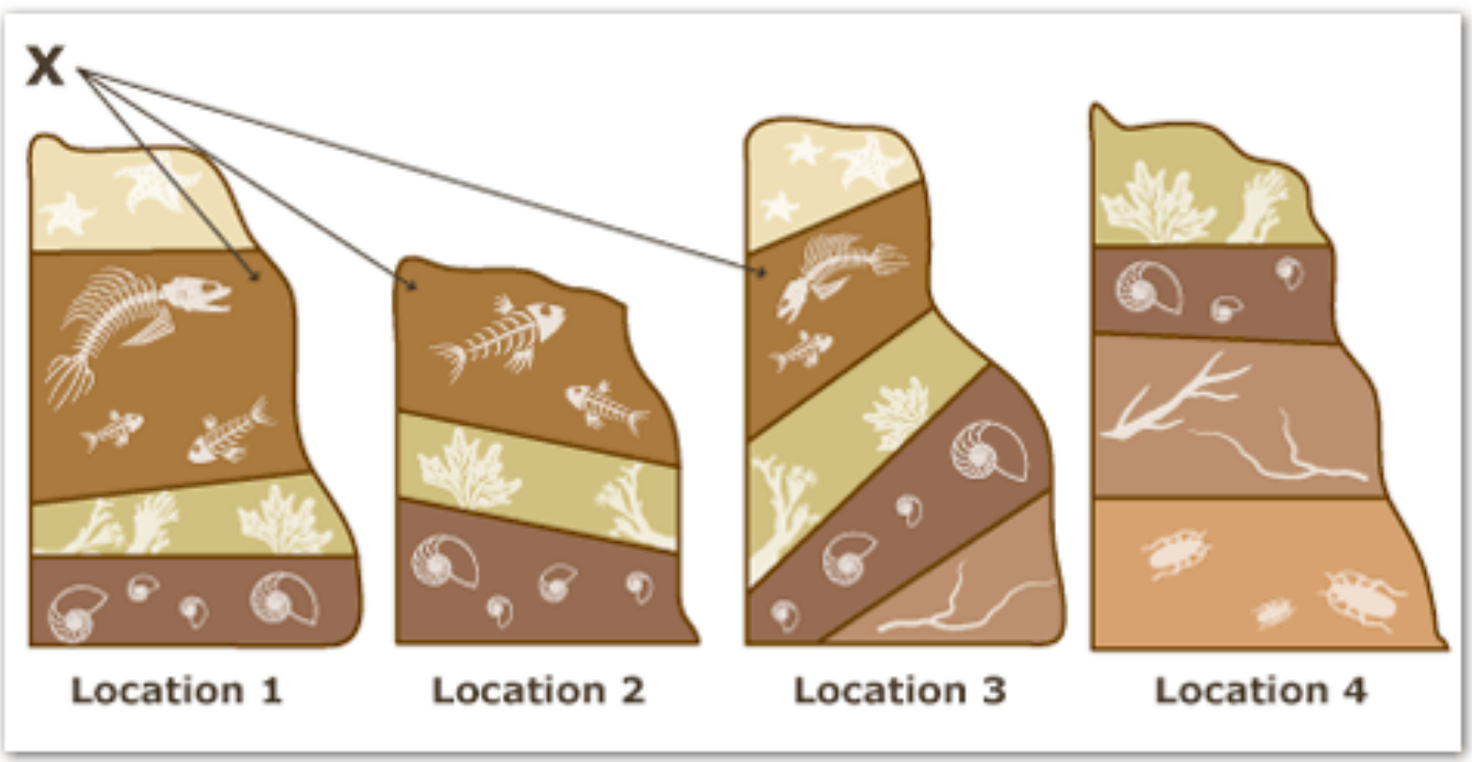


Fossil Record

- **Law of Superposition**

- **The lower the strata the older the rock**

- **General Pattern**

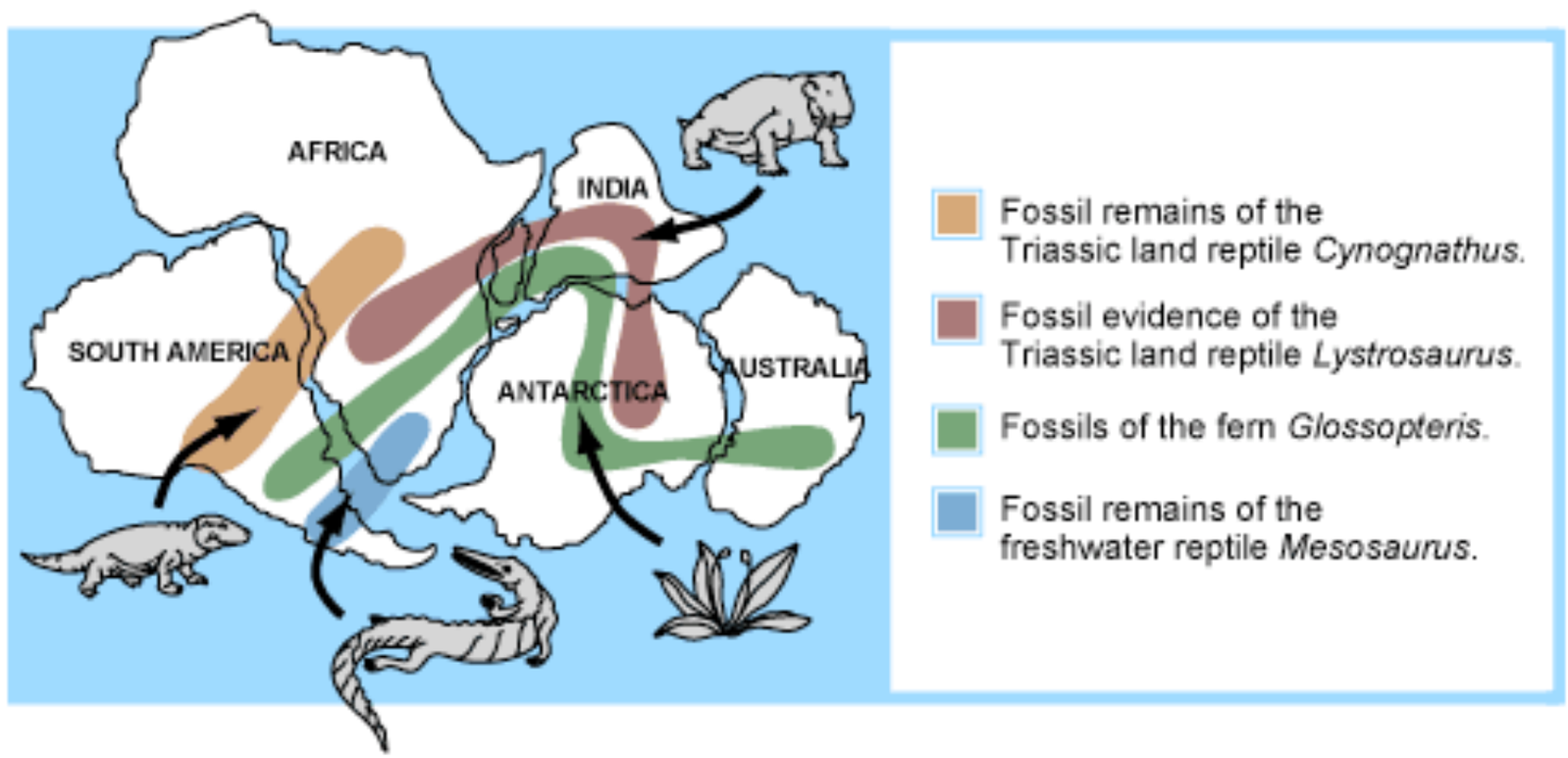


- **Shows a succession of forms**
- **Similar fossils in similar strata**
- **Older Strata, simpler organisms**
- **Newer Strata, more complex organisms**

Biogeography

- **Biogeography- is record of inheritance,**
  - **specifically the study of geographical distribution of species and how they got that way**

Global



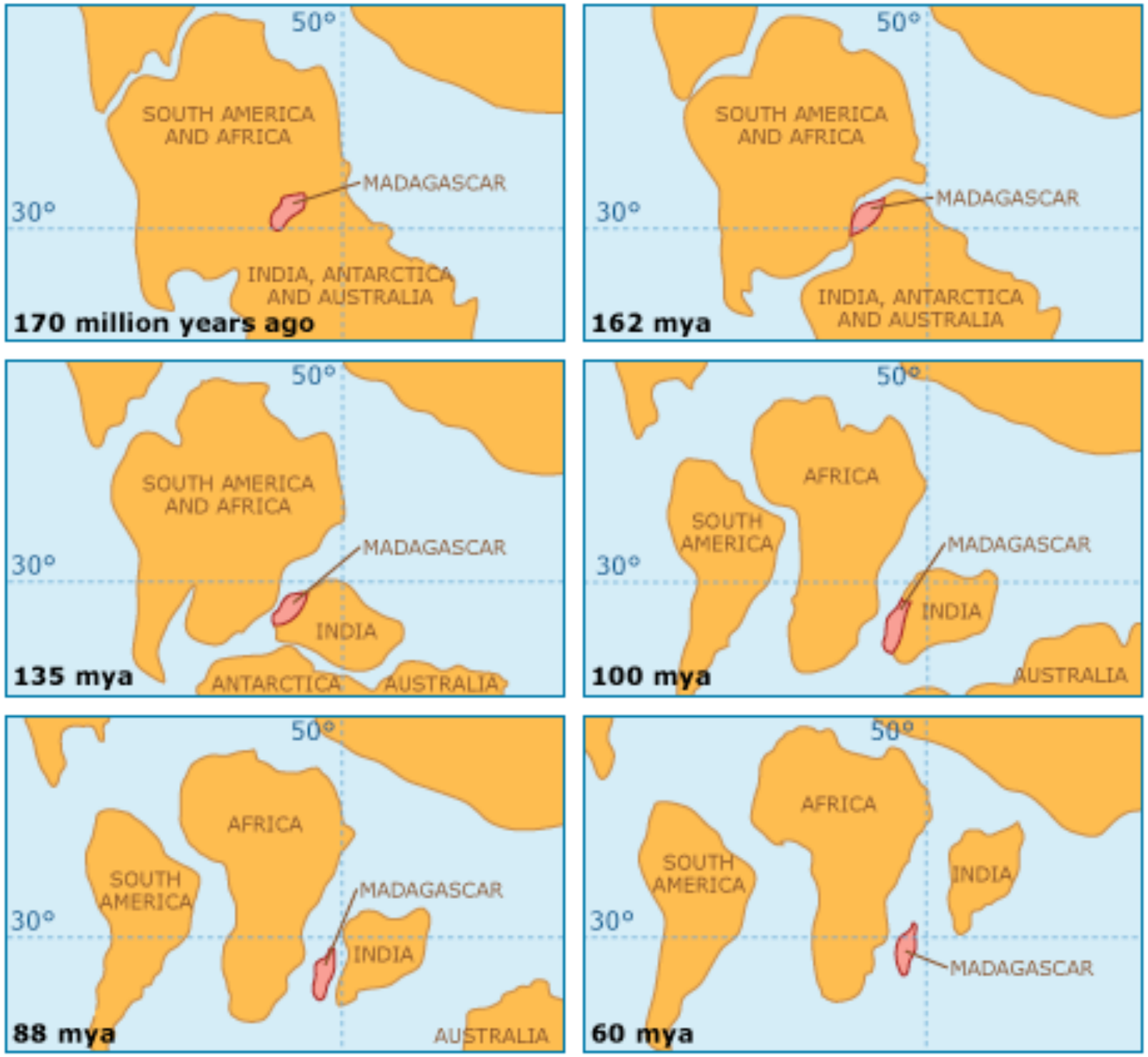
Wegener found that the distributions of fossils of several organisms supported his theory that the continents were once joined together.

Biogeography

Where did all of Madagascar's species come from?

Vicariance

species were there originally, and as land separated they moved with the land



Dispersal

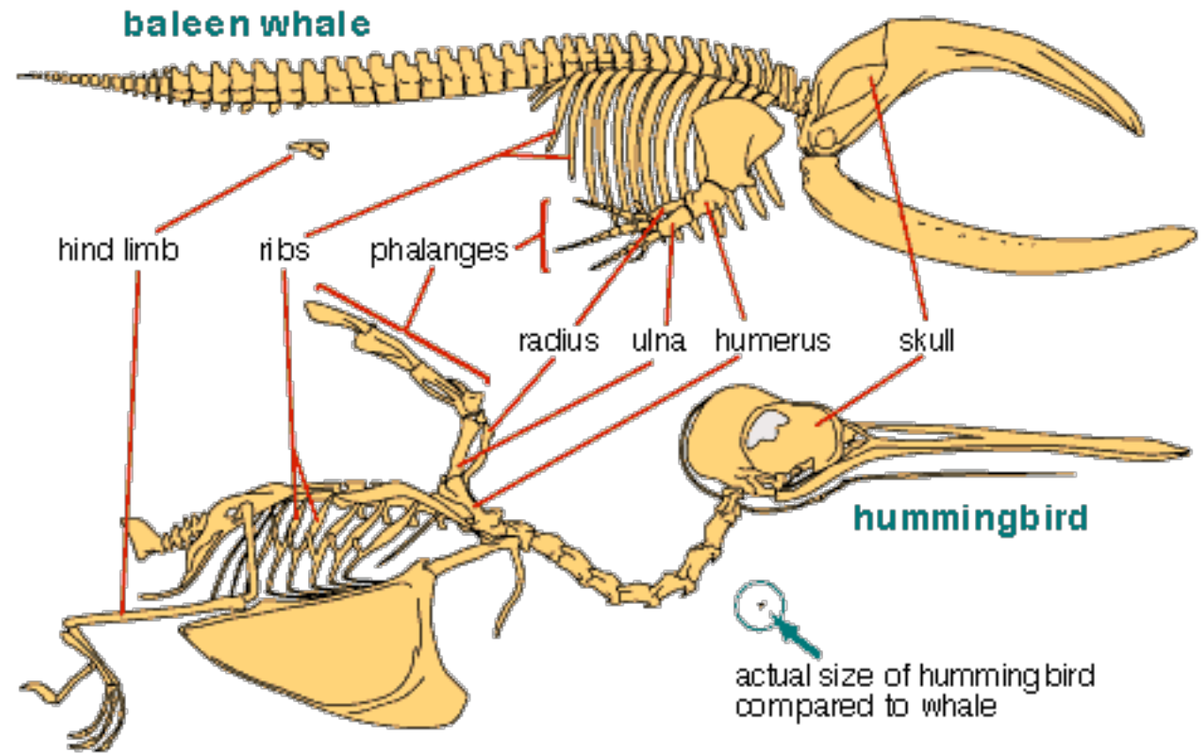
species traveled to the land after it moved

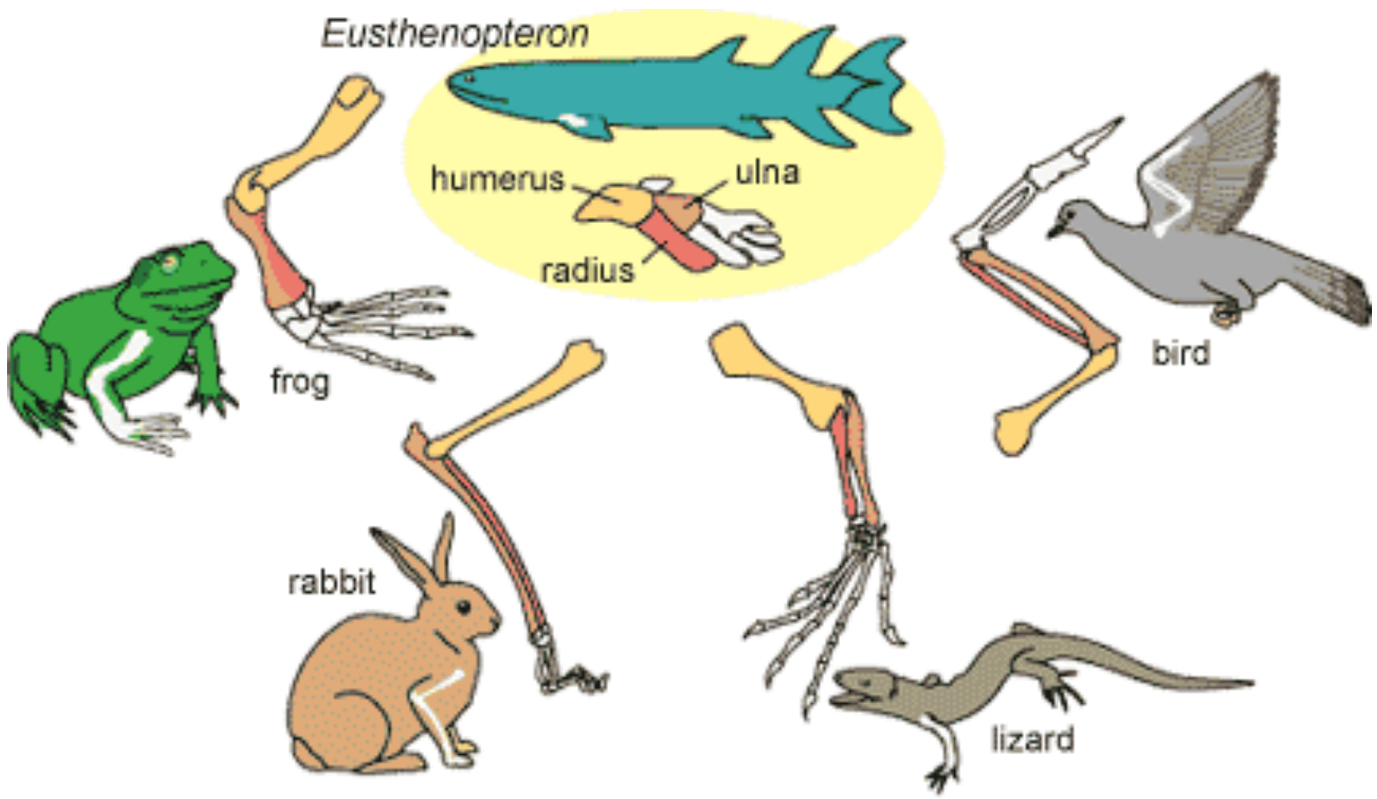
Homology

- **Homology- when related organisms will share certain traits due to common ancestry**
- ***(of course differences in traits are due to divergence as each species adapts to its own environment/challenges)***
  - **Anatomical**
    - **Vestigial Structures**
  - **Embryological**
  - **Cellular**
  - **Molecular**

Anatomical Homology

Although each skeleton appears very different nearly every bone in each has an equivalent in the other

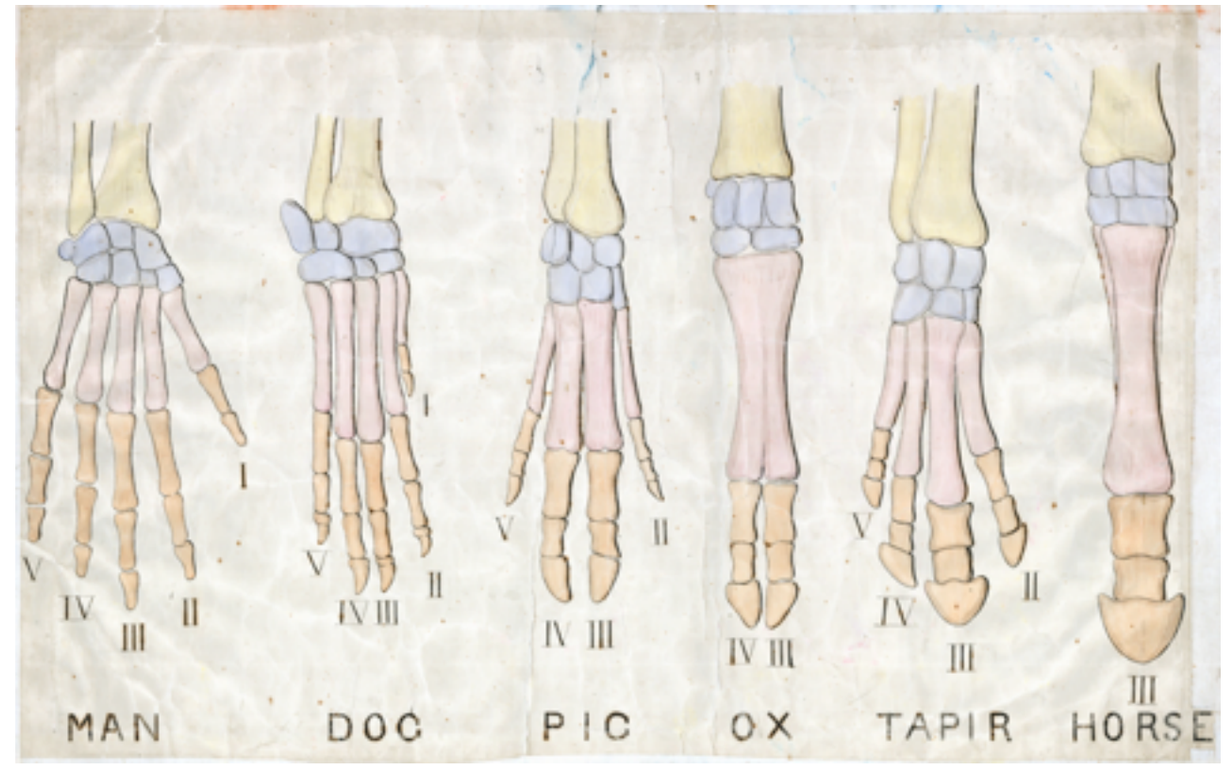




Classic example of tetrapod forelimbs, similar structures, dissimilar functions

Vestigial Structures

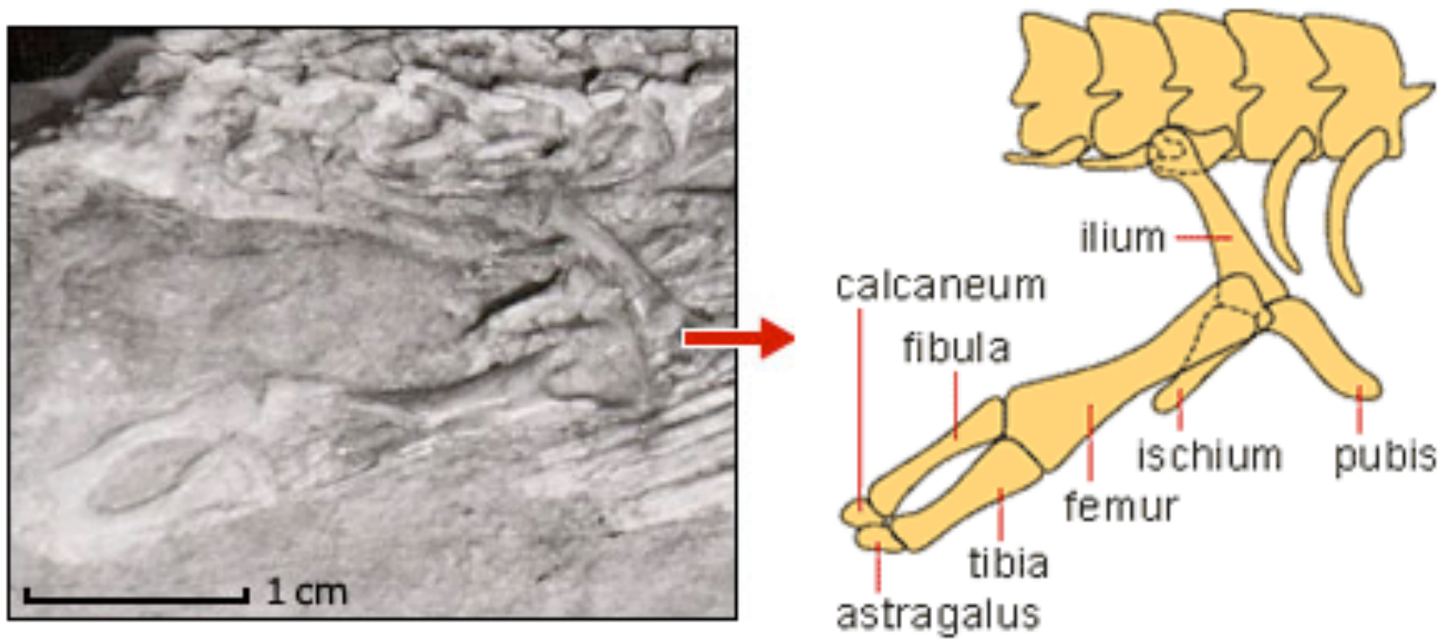
Structures inherited that over time become less functional



Embryological Homology

Snakes have legged ancestors.

Some species of living snakes have hind limb-buds as early embryos but rapidly lose the buds and develop into legless adults. The study of developmental stages of snakes, combined with fossil evidence of snakes with hind limbs, supports the hypothesis that snakes evolved from a limbed ancestor.

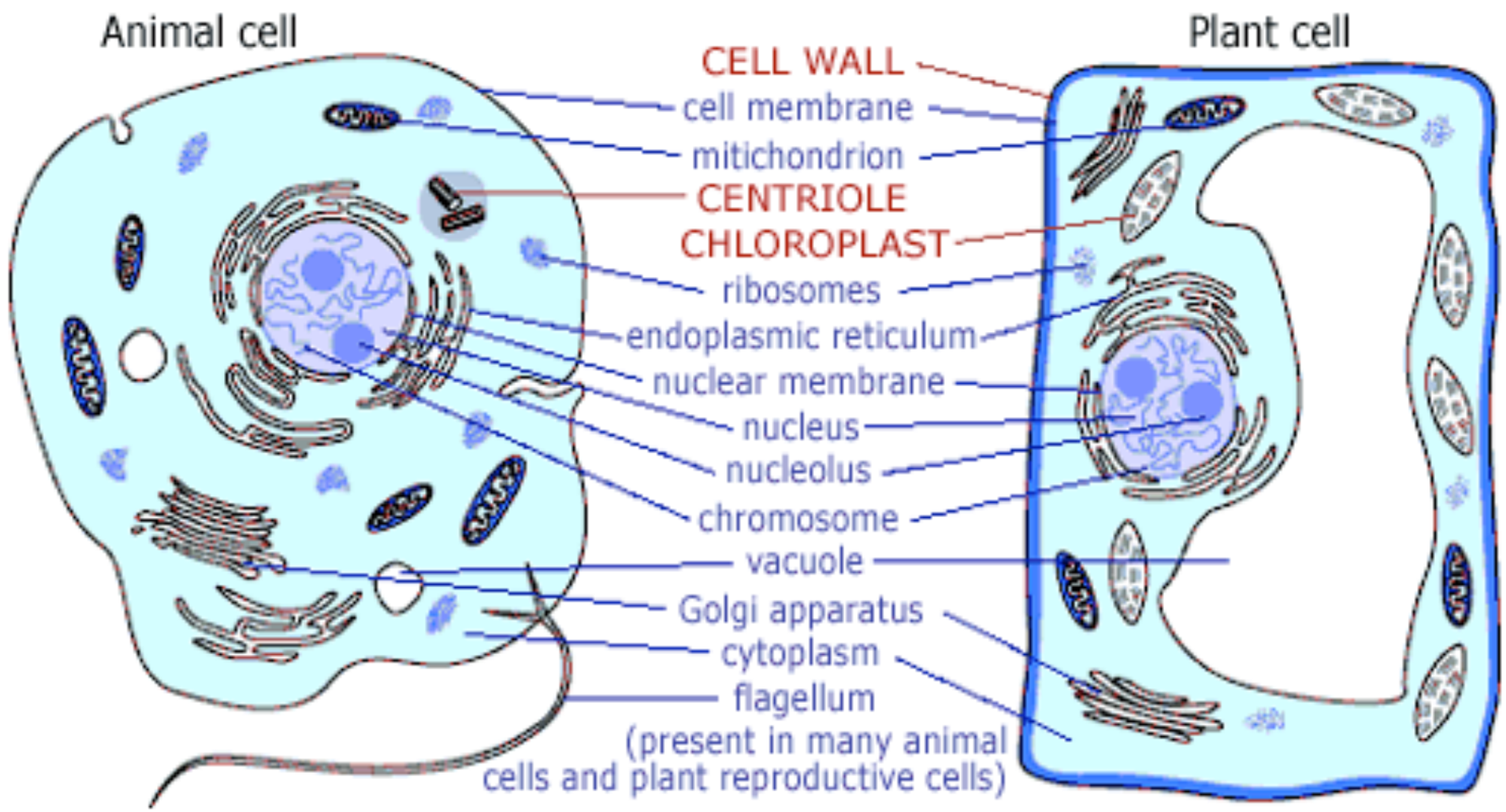


Above left, the Cretaceous snake *Pachyrhachis problematicus* clearly had small hindlimbs. The drawing at right shows a reconstruction of the pelvis and hindlimb of *Pachyrhachis*.

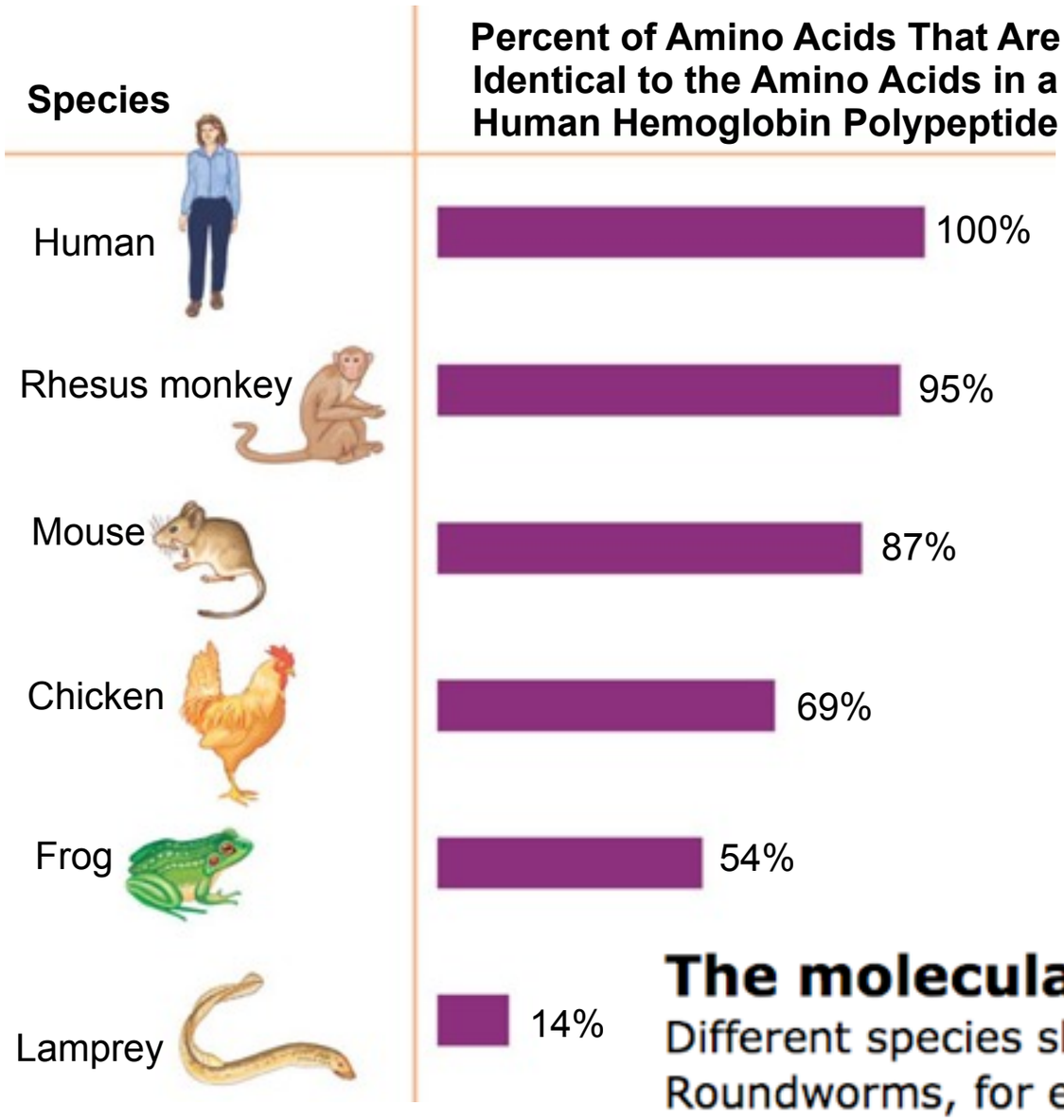
Cellular Homology

The cellular level

All organisms are made of cells, which consist of membranes filled with water containing genetic material, proteins, lipids, carbohydrates, salts and other substances. The cells of most living things use sugar for fuel while producing proteins as building blocks and messengers. Notice the similarity between the typical animal and plant cells pictured below — only three structures are unique to one or the other.



Molecular Homology

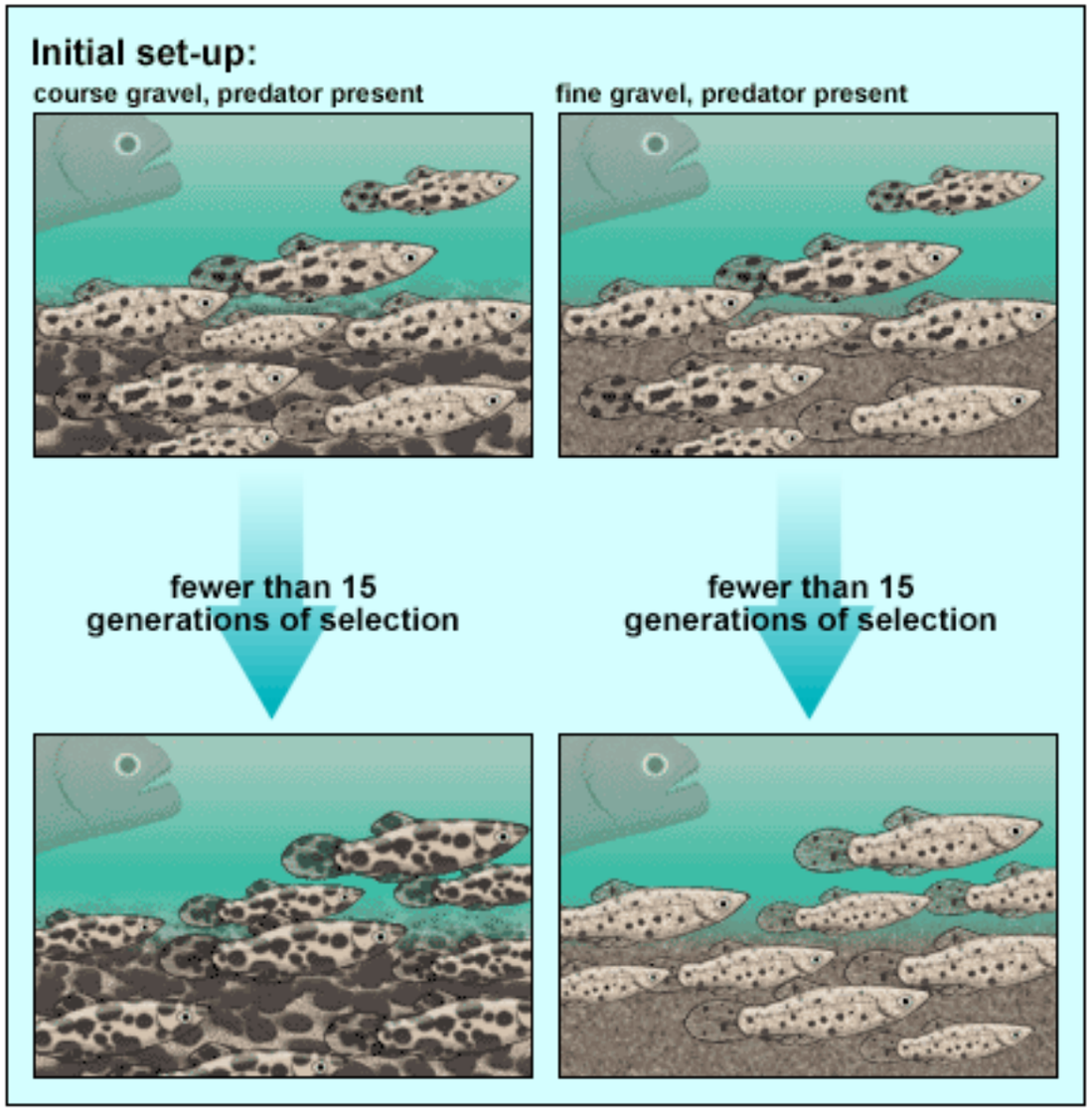


Biologists find homologies in amino acid sequences and nucleotide sequences of both DNA and RNA

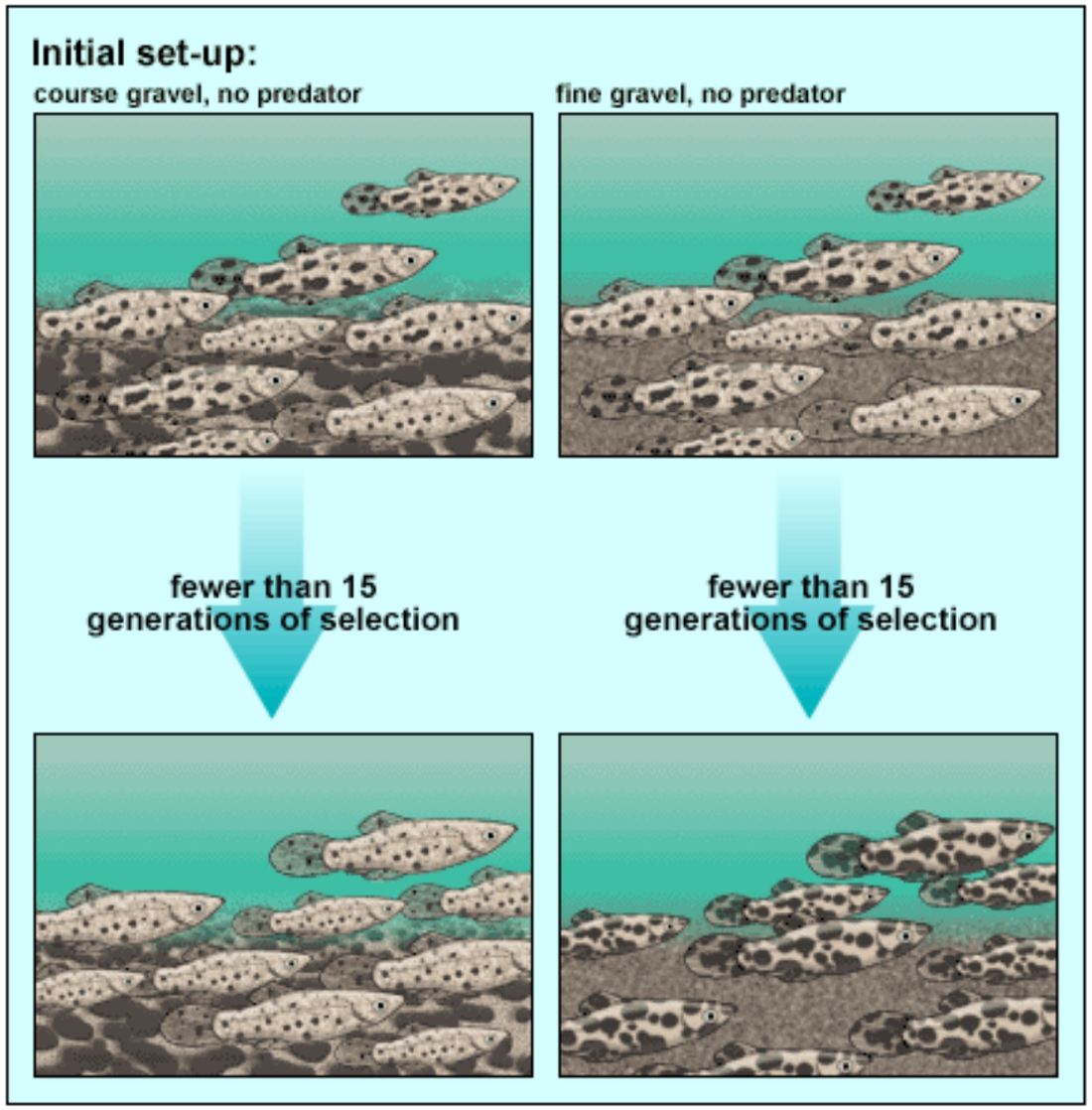
The molecular level

Different species share genetic homologies as well as anatomical ones. Roundworms, for example, share 25% of their genes with humans. These genes are slightly different in each species, but their striking similarites nevertheless reveal their common ancestry. In fact, the DNA code itself is a homology that links all life on Earth to a common ancestor. DNA and RNA possess a simple four-base code that provides the recipe for all living things. In some cases, if we were to transfer genetic material from the cell of one living thing to the cell of another, the recipient would follow the new instructions as if they were its own.

Natural Selection in Action



The predator serves as the strongest selective pressure, resulting in a population that blends with its surroundings to avoid being eaten



With predator removed sexual selection serves as the strongest pressure, resulting in a population with males standing out against their surroundings

What exactly is evolving?

- **The POPULATION as a whole adapts and changes over time with the inevitable changing conditions...POPULATIONS Evolve!**

- **The POPULATION is the smallest unit of evolution.**
  - **The Individual can change through growth and development but only populations evolve.**
  - **Traits effect the survival and reproductive success of individuals but the effects of natural selection are only seen in the larger group over time.**

Evolution

- **<u>Evolution</u> is simply a change in the gene (alleles) frequencies in a population over time!**
  - **3 Things can change gene frequencies**
    - ***Natural Selection**
    - **Genetic Drift**
    - **Gene Flow**

**Only natural selection results better adapted organisms*

Evolution- Ingredients

- **For evolution to occur we need at least two very important ingredients: time & variation.**
- **TIME**
  - **(in general) more time = greater changes**
  - **Darwin's mechanism was slow and gradual, it required vast tracks of time**
  - **Today we think "some" change might happen rapidly in bursts**
- **VARIATION**
  - **remember the force behind evolution is natural selection, the very word itself "selection " implies variation otherwise there is nothing to "select"**

Evolution- Variation

- **Individual variation occurs in all species.**
  - **some variation we can see- hair color**
  - **some variation we can see- blood groups**
- **Individual variation reflect genetic variation.**
  - **different phenotypes result from different genotypes**

When certain traits are favored over others it is in fact the genes, the "blueprints" for those traits that are being being favored. Thus GENES provide the raw material for evolution.

Variation in a Population

- **Biologists can quantify genetic variation at two levels.**
- **Gene Variability**
  - **measures variation among genes themselves**
- **Nucleotide Variability**
  - **measures variation among the nucleotides that make up the genes**

Variation Between Populations

- **Biologists can also quantify genetic variation between two different populations...** ***geographic variation.***
- **Differences are usually found**
  - **sometimes differences are purely random (genetic drift, discussed shortly)**
  - **other times the differences are likely a result of natural selection favoring certain traits over others**
    - **example- clines**

Sources of Variation

- **Recall: Evolution requires variation...**
- **BUT natural selection reduces variation in a population over time...**
- **THUS there must be mechanism(s) that generate(s) variation in a population otherwise populations would lose their ability to evolve**

SEX & MUTATIONS... Generate Variation!

Sex Sex Sex

- **Sexual Reproduction shuffles existing genes (alleles) deals them at random to produce unique individuals.**
- **The "shuffling mechanisms" include...**
  - ***Crossing Over***
  - ***Independent Assortment***
  - ***Random Fertilization***

Ultimately all the different genes that sex reshuffles originated in a population by way of a mutation.

Mutations...gotta have them!

- **Any and all new alleles (genes) arise from mutations.**
- **Mutations- are change in nucleotide sequence in an organisms DNA**
- **Mutations are random**
  - ***Only mutations that occur in gametes (sperm/eggs) can be inherited and passed generation after generation***
  - ***Somatic (body cells) mutations can not be inherited and thus die with the individual.***

Effects of Mutations

- **Mutations change nucleotide sequences, which in turn changes the protein product, which in turn alters the phenotype (trait).**
- **Most mutations are neutral or perhaps slightly harmful.**
- **On rare occasions a mutation results in a new trait that provides a selective advantage to the individual and should they reproduce to their offspring.**
  - **Over time this new gene becomes more common.**

Mutations

- **Mutations can occur in any number of ways.**
  - **Gene Mutations (small scale)**
    - *substituting one nucleotide for another*
    - *adding or deleting a nucleotide*
  - **Chromosomal Mutations (large scale)**
    - *rearranging chromosomal pieces (moving an entire gene or genes) in a genome*
    - *deleting or duplicating chromosomal pieces (deleting or duplicating an entire gene or genes) in a genome*
    - *disrupting an entire gene or genes at one time*

Evolution...Measured?

- **Can we determine objectively whether evolution is taking place in a population?**
  - **YES**
- **Can we quantify the rate or degree of evolution in a population?**
  - **YES**
- **Can a population not evolve?**
  - **YES**

Population Genetics

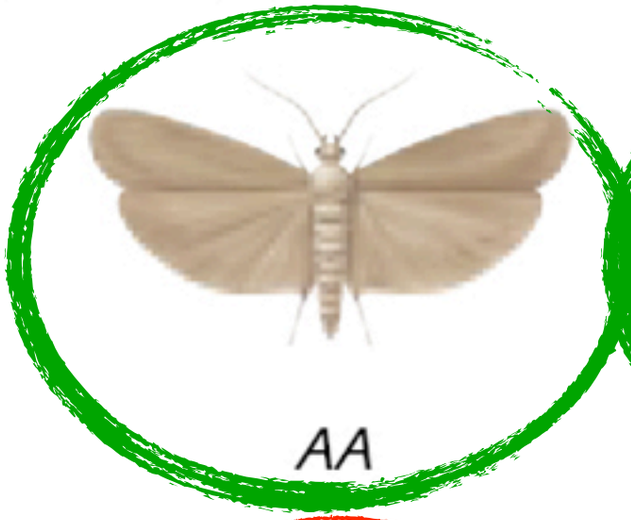
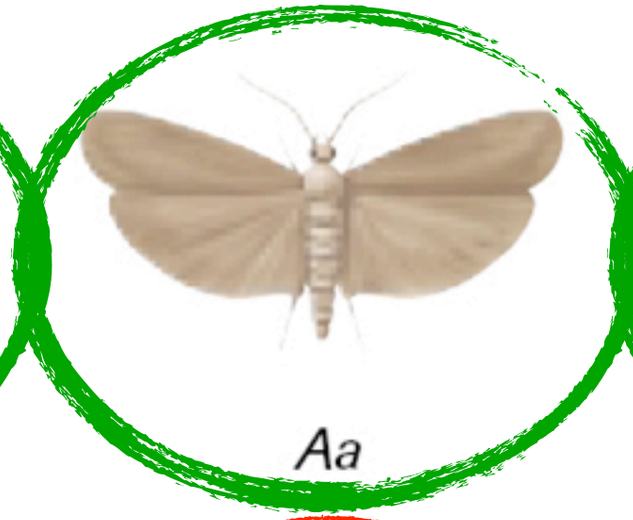
- **Recall: a *population* is a group of organisms of the same species, in the same general area that interbreed successfully.**
- **A *gene pool* represents all genes (alleles), at every locus in all members of a population.**
- **Recall: *evolution* is a change in gene (allele) frequencies in a population over time.**

Measuring Allele Frequency

- **To determine that evolution has occurred we must know the allele(s) frequency in a population at a point in time and compare it to the allele(s) frequency at a later time.**
- **This implies/requires that we can measure allele(s) frequencies...but HOW?**
  - *First we must the know the total number of individuals in a population*
  - *Next we must the know the frequency of a trait in a population.*
  - *Lastly we need to which alleles control the trait we are examining*

Genetic structure of parent population

which alleles control the trait

phenotypes			
genotypes	*AA*	*Aa*	*aa*
number of moths (total = 500)	320	160	20

population size *frequency of a trait in a population*

genotype frequencies	$\frac{320}{500} = 0.64\ AA$	$\frac{160}{500} = 0.32\ Aa$	$\frac{20}{500} = 0.04\ aa$
	$\times 2$		$\times 2$
number of alleles in gene pool (total = 1000)	640 *A*	160 *A*	160 *a*	40 *a*
allele frequencies	$\frac{800}{1000} = 0.8\ A$		$\frac{200}{1000} = 0.2\ a$
	p = frequency of A = 0.8		q = frequency of a = 0.2

Bingo!

Measuring Allele Frequency

- **To determine that the moth population is evolving we simply recalculate the allele(s) frequency in the population at a later time.**
  - **If we find that the frequency of A is no longer 0.8 or 80% and a is no longer 0.2 or 20% then the population <u>has evolved</u> because its <u>allele frequencies have changed</u>.**
  - **If we find that the frequency of A remains 0.8 or 80% and a remains 0.2 or 20% then the population <u>has not evolved</u> because its <u>allele frequencies have not changed</u>.**

Evolution…measured?

- **The fact of the matter is this... in real populations the allele/gene frequencies DO, in most cases, change over time**
- **Does this mean that allele/gene frequencies that do not change mean that the population is not evolving?**
  - **NO**
    - **The last example only measured one allele in the population, it is possible that an allele is not subject to selection pressures at some point in time.**

So what would a non-evolving population look like?

Non-Evolving Populations

- **A population not evolving would have to have ALL allele/gene frequencies remain constant over time in order for the gene pool itself to remain constant.**
  - **Keep in mind populations have hundreds to thousands of alleles/genes.**
  - **Is it likely or even possible that all allele/gene frequencies remain unchanged over time?...NO**
    - **Never the less we can still ask...Are there conditions where a populations' allele(s)/gene(s) would NOT change?**

Hardy-Weinberg Equilibrium

- **This principle describes a hypothetical non-evolving population**
- **In order for a population to maintain the Hardy-Weinberg equilibrium (not change) they must meet all 5 of the following conditions:**

Very large population	No genetic drift can occur.
No emigration of immigration	No gene flow can occur.
No mutations	No new alleles can be added to the gene pool.
Random mating	No sexual selection can occur.
No natural selection	All traits must equally aid in survival.

How likely is it that a population meets these conditions?

Not at all likely, close to impossible!

Hardy-Weinberg Equilibrium

- **This principle describes a hypothetical non-evolving population**
- **When gametes are donated randomly and matings are also random allele frequencies will not change and we can calculate genotypic frequencies from allele frequencies:**
  - **We can summarize the union of gametes in an algebraic equation**

$$(p+q)(p+q) = p^2 + 2pq + q^2 = 1$$

Solving Hardy-Weinberg Problems

- **Every Hardy-Weinberg problem is essentially the same, you will be given one (or more) of the 5 variables below, you will then use simple algebra to solve for the unknown.**

Know This

p = dominant allele

q = recessive allele

p^2 = AA genotype

2pq = Aa genotype

q^2 = aa genotype

Follow these steps

First- determine the unknown (which of the variables on the left do need to solve for)

Next- determine the known (which of the variables on the left do we have)

Last- using the equations on the right and simple algebra solve for the unknown

Use These

$$p^2 + 2pq + q^2 = 1$$

$$p + q = 1$$

Changing Gene Pools

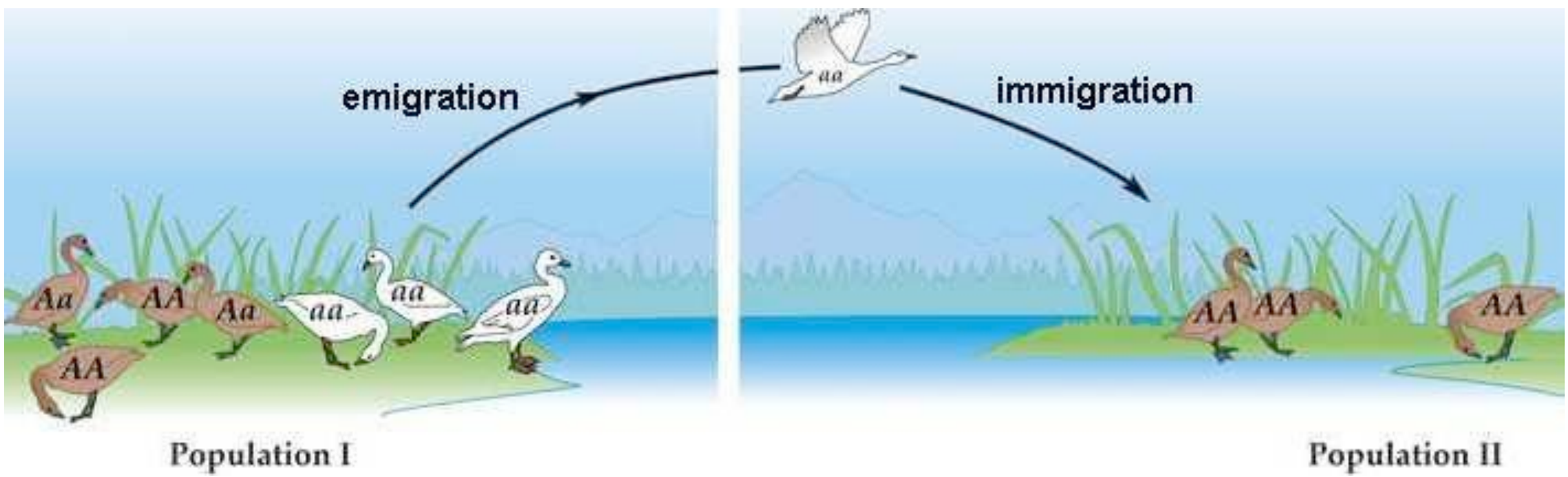
- **A deviation in any of the 5 Hardy-Weinberg conditions will change allele/gene frequencies.**
- **However three processes in particular change gene pools or cause evolution more than anything else.**
  - **Gene Flow**
  - **Genetic Drift**
  - **Natural Selection**

The smaller the population the greater there effect

Important Note...Natural selection is the only one that results in a population becoming more well adapted to its environment over time.

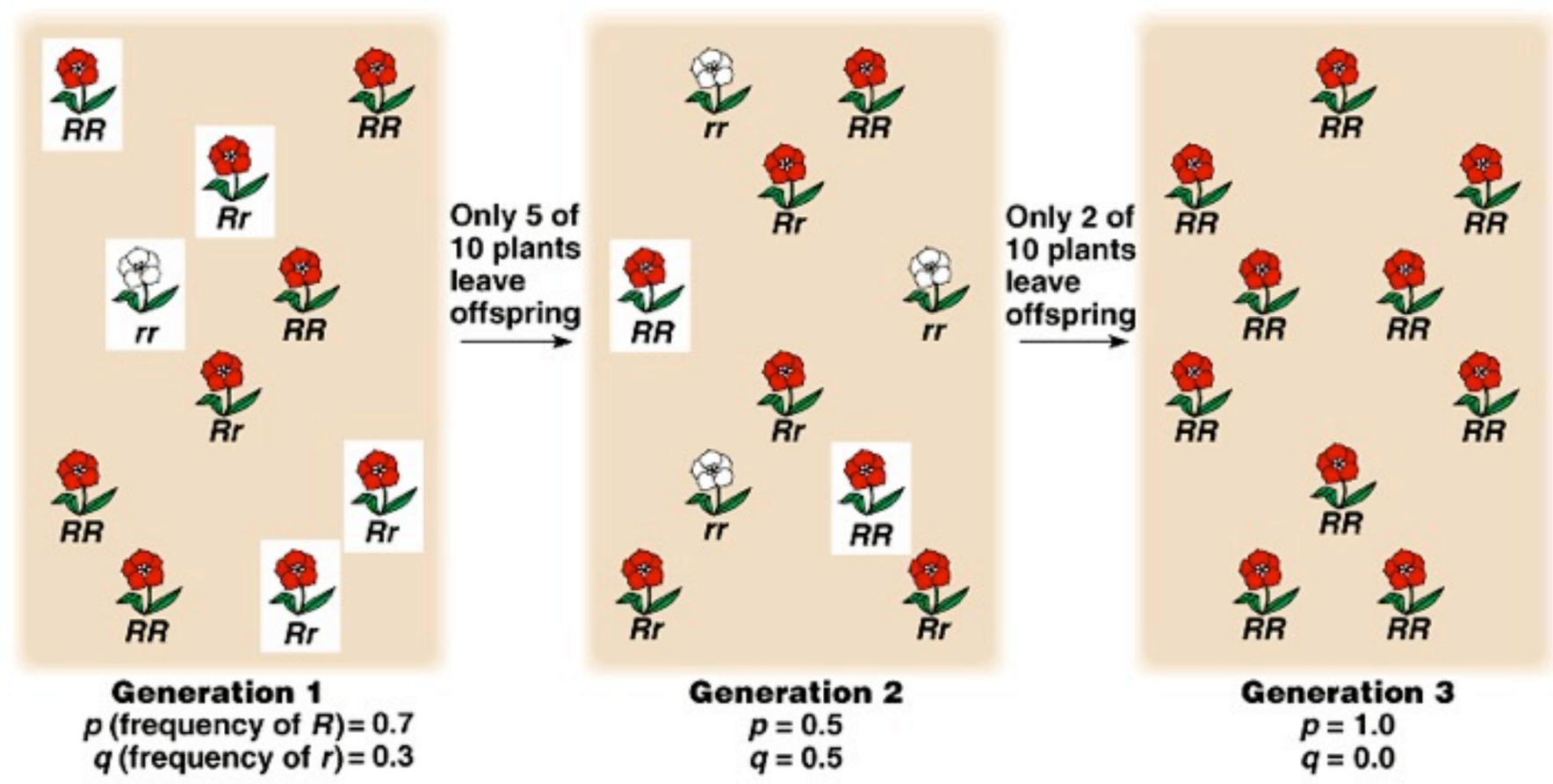
Gene Flow

- **Gene Flow- a population can gain or lose alleles/genes as a result of individual or gamete movement.**
- **Gene flow often reduces differences between populations, it can "melt" two populations into one.**



Genetic Drift

- **Genetic Drift- random and unpredictable fluctuations in allele/gene frequencies.**
  - **Genetic Drift will have a greater effect on smaller populations**
  - **Genetic Drift tends to reduce variation**
  - **Genetic Drift can "fix" (100% frequency) harmful alleles**



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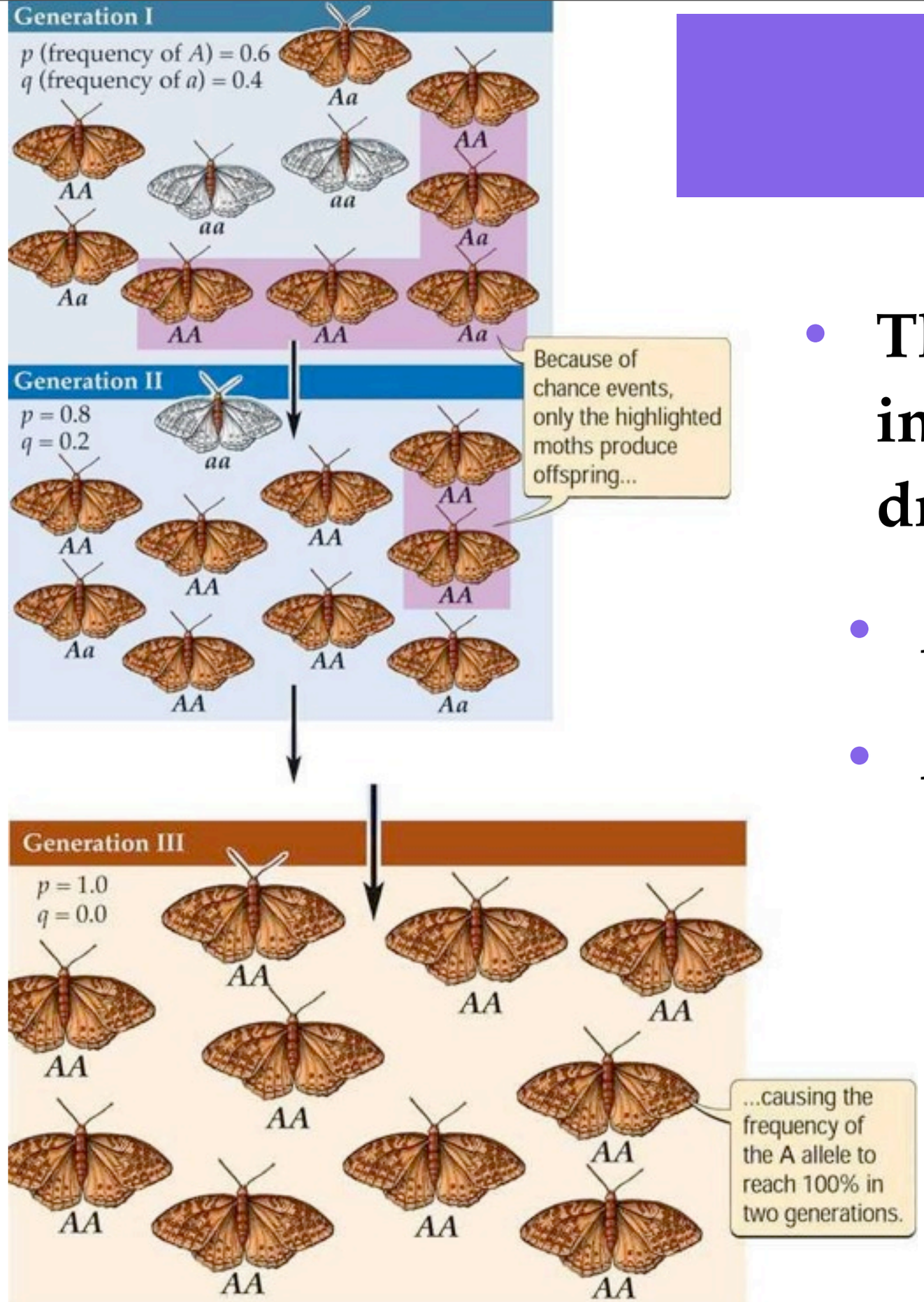
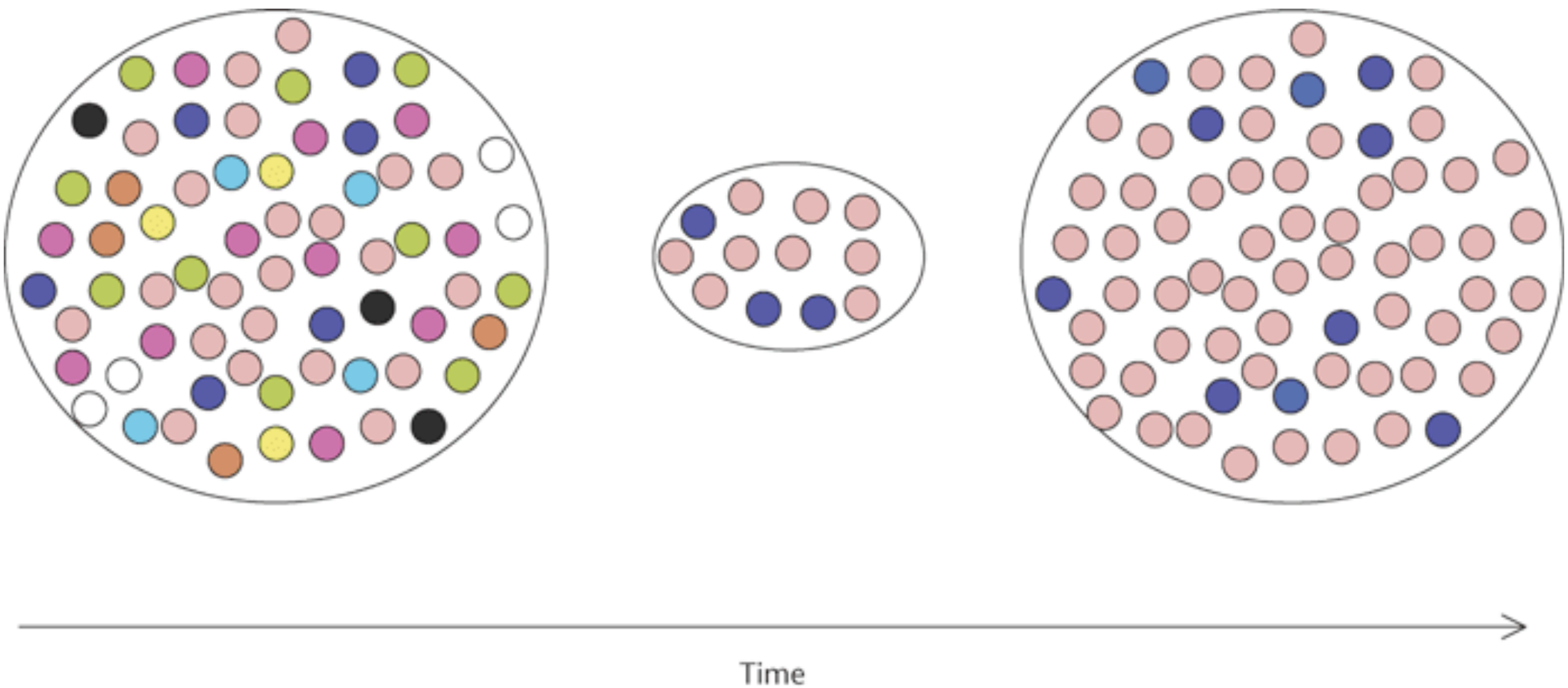
Genetic Drift



- **There are two events that increase the effect of genetic drift.**
  - **A bottleneck effect**
  - **A founder effect**

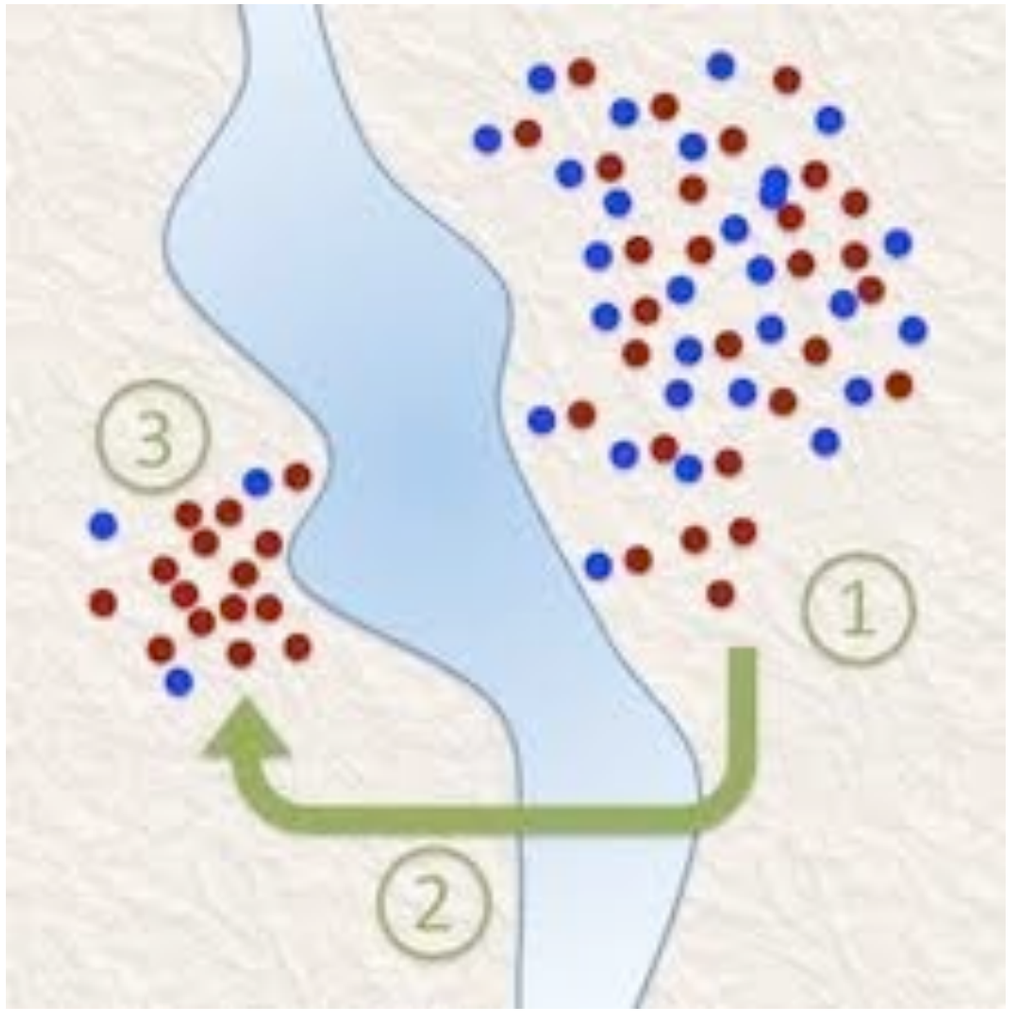
The Bottleneck Effect

- **Bottleneck Effect- can occur when there is large reduction in population size, the survivors may not reflect the composition of the original population.**
  - **can have a lasting effect on populations**



The Founder Effect

- **Founder Effect- when a small group leaves a larger population, establishes a new population that is not representative of the original .**

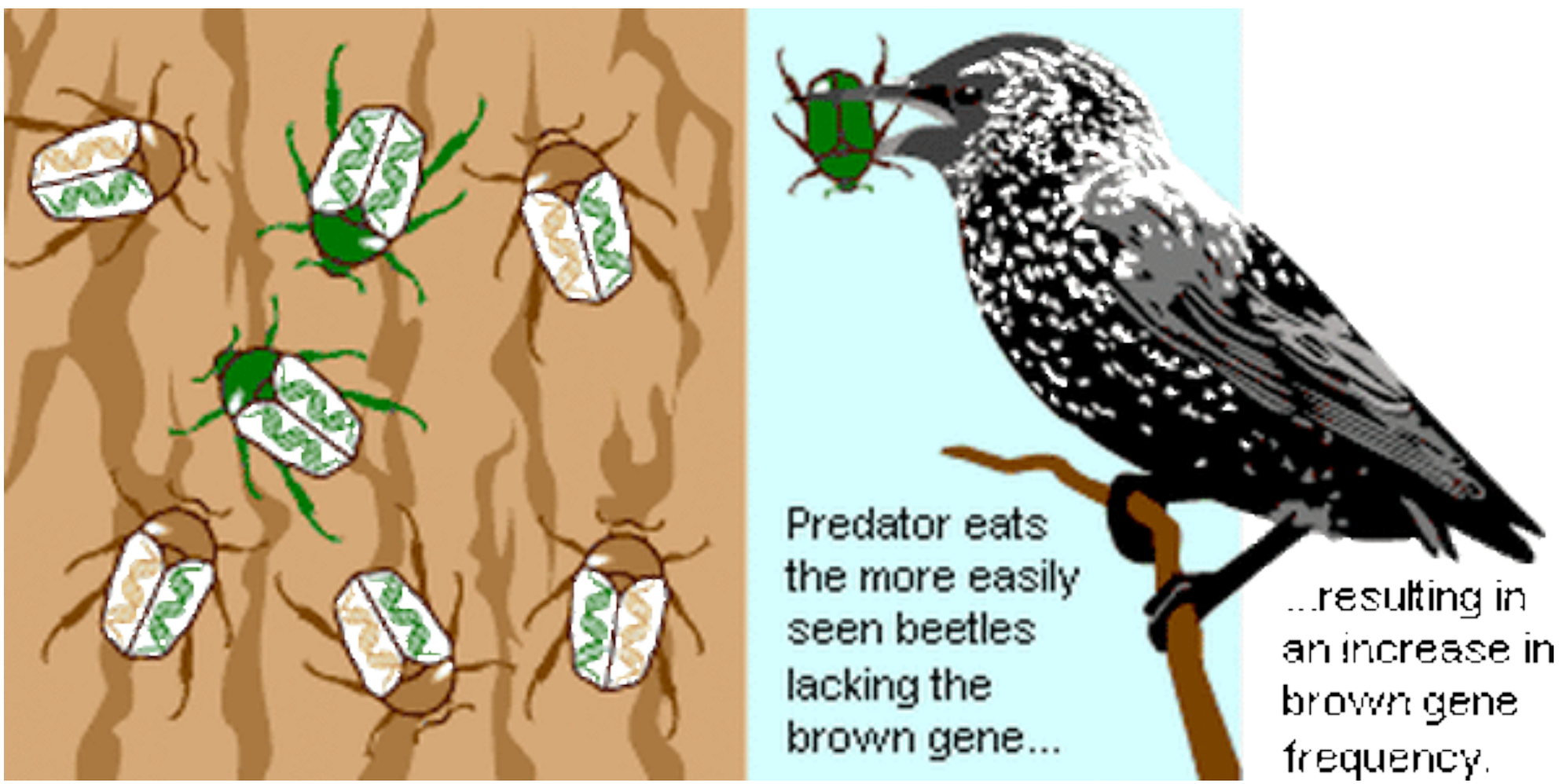


original population

new population

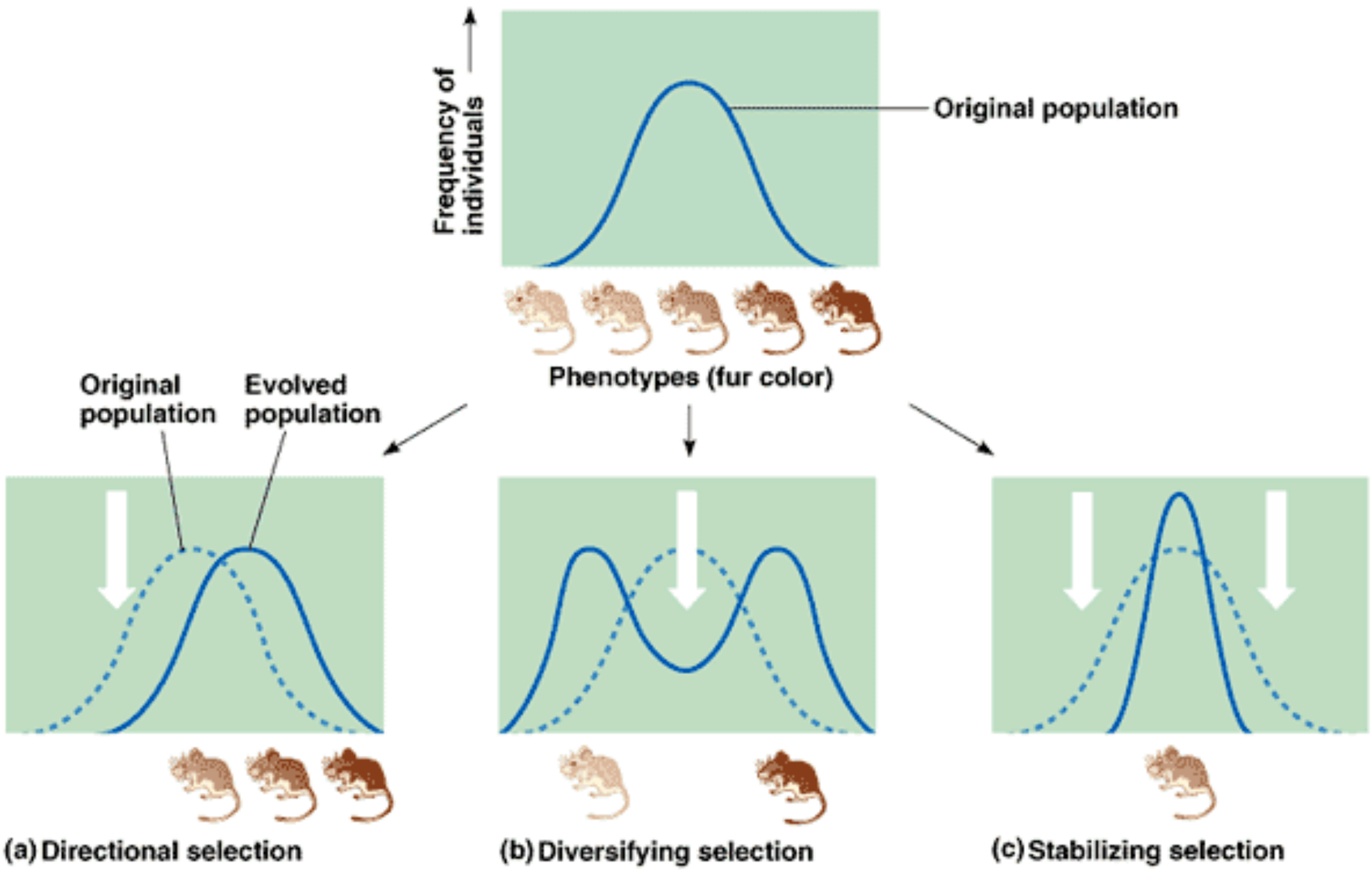
Natural Selection

- **Natural Selection- differential reproductive success.**
  - **Certain favorable traits become more frequent, non favorable traits become less frequent and the population becomes better suited to its environment over time.**



Natural Selection

- **Natural Selection- can alter frequency distribution of traits in 3 ways.**



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Conserving Variation

- **Recall...natural selection reduces variation in a population.**
- **Recall...sex and mutations generate variation in a population.**
- **There are also mechanisms that help to preserve, maintain or even restore variation in a population.**
  - **Diploidy**
  - **Balanced Selection**
    - **Heterozygote Advantage**
    - **Frequency-Dependent Selection**

Conserving Variation

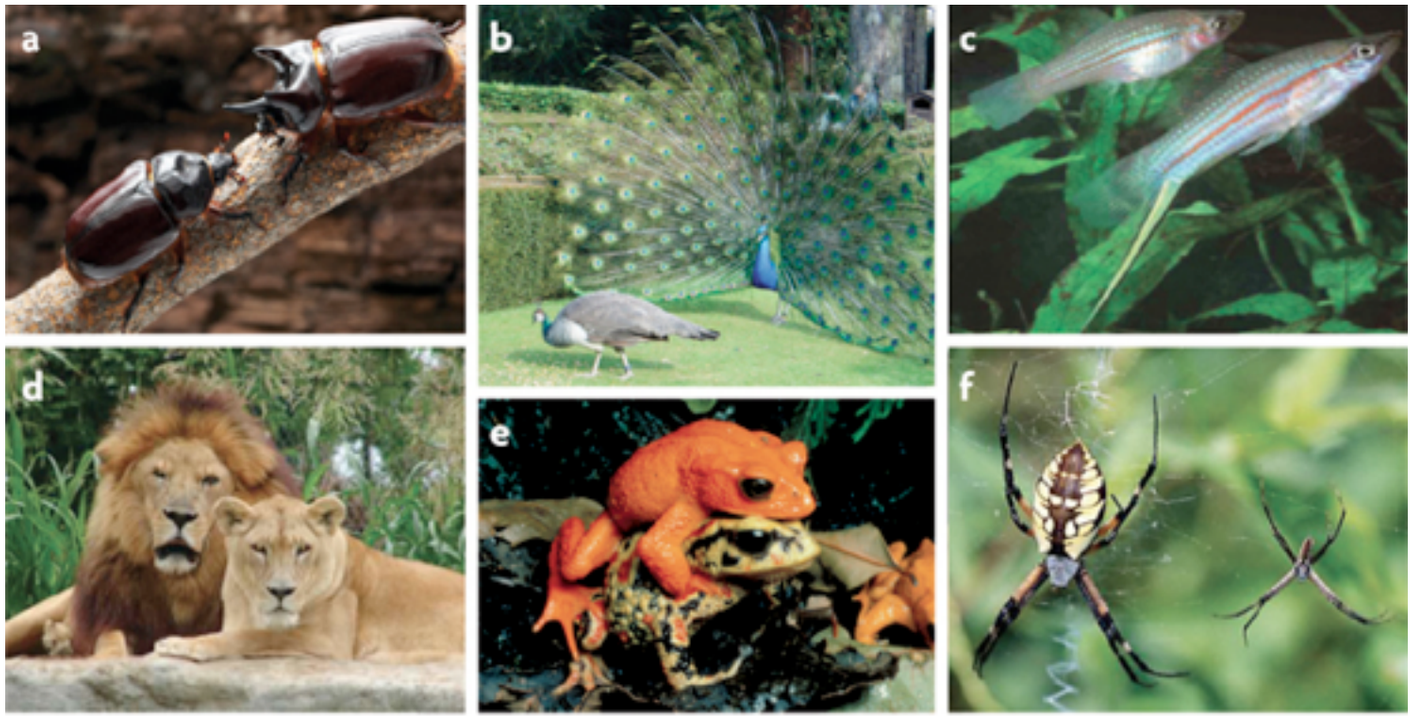
- **Diploidy- having two alleles to control a one trait.**
  - **Recall recessive phenotypes are only expressed when both recessive genes are present.**
  - **Thus recessive genes are often "masked" or hidden behind the dominant gene a heterozygous genotype.**
  - **As a result these recessive genes, even if maladaptive, can persist over time**

Conserving Variation

- **Balanced Selection- maintains two or more forms in a population**
  - **Frequency-Dependent Selection**
    - **As a phenotype becomes more common it is selected against, less common phenotypes are selected for thus over time the frequency of each oscillates back and forth and neither is eliminated, both persist in population.**
  - **Heterozygote Advantage**
    - **When the heterozygous phenotype is selected for, both dominant and recessive genes are maintained**
      - **Ex. Malaria story in Africa (see next slide)**

Sexual Selection

- ***Sexual Selection*- special type of natural selection where certain traits lead to certain individuals being more likely to mate.**
  - **Not only can sexual selection lead to adaptation but it can also result in sexual dimorphisms.**
  - ***Sexual Dimorphisms*- differences between secondary sex characters of males and females.**



Sexual Selection

- **Sexual selection works in two ways.**
  - ***Intrasexual Selection-*** **selection occurs within the same sex**
    - **ex. male fighting another male over right to reproduce**
  - ***Intersexual Selection-*** **mate choice, usually females select males**
    - **ex. females choose male mates based upon some trait(s) or behavior(s)**
    - **it is thought that these traits and behaviors represent good overall genetic quality**

Sexual Selection

- **Males and Females share the same biological imperative...reproduction or passing their genes into future generations.**
- **Their strategies for reproductive success can however be very different.**
  - **In general males have a "quantity" strategy and females employ a "quality" strategy.**
  - **This can be partly explained by their respective fecundity.**

Not so choosey Males...Quantity

- **In general males have greater fecundity than females.**
  - **their gametes are small and energetically inexpensive to make**
  - **they have numerous gametes in each copulation**
  - **theoretically males could produce thousands of offspring**
- **In general males do not bear or rear offspring**
- **In general males have more reproductive years**

Choosey Females...Quality

- **In general females have lower fecundity than males.**
  - **their gametes are large and energetically expensive to make**
  - **they have one or few gametes per copulation**
  - **practically females could produce fewer offspring**
- **In general females must bear and rear offspring**
- **In general females have less reproductive years**
  - **ex. menopause**

Evolutionary Fitness

- ***Fitness*- contribution an individual makes to the gene pool of the next generation relative to others.**
  - ***Relative Fitness*- contribution that a genotype makes to the gene pool of the next generation for same locus relative to others.**
  - **Be careful natural selection acts on phenotypes/traits not genotypes.**
    - **The organism as a "whole" is selected.**
  - **Thus the fitness of any one allele is dependent on the entire genetic make up of the organism and the environment at that point in time.**
    - **This can sometimes result in strange consequences...**

Evolutionary Fitness

- **Lastly sometimes alleles that do have no value or even slightly maladaptive can be perpetuated if the organism's overall fitness is high.**
  - **This explains have old useless DNA persists in a genome over time.**
- **It can go the other way as well... sometimes alleles that do have value are not perpetuated if the organism's overall fitness is low or by some accident dies suddenly.**

"The Perfect Organism"

- **No, Never, Not going to happen!**
- **Natural selection has never and will never fashion the perfect organism.**
  - **Selection can act on only existing variation.**
  - **Bad luck and changing environments**
  - **Can only work with what your given**
  - **Life is all about Trade-offs**

"The Perfect Organism"

- Natural selection has never and will never fashion the perfect organism.
- **Selection can act on only existing variation.**
  - **Organisms can not call upon mutations at will, they are random.**
  - **Organisms can not order a trait that they need.**

Adaptation doesn't involve trying.

Natural selection does not grant organisms what they "need".

"The Perfect Organism"

- Natural selection has never and will never fashion the perfect organism.
- **Bad luck and changing environments.**
  - **The natural events that move organisms from one place to another or result in "bottlenecks" is random.**
    - **Tsunami's kill indiscriminately whether an organism is well adapted or not.**
  - **Climate and environments are constantly changing as organisms become well suited for one another different one could emerge.**

"The Perfect Organism"

- Natural selection has never and will never fashion the perfect organism.
- **Can only work with what your given.**
  - **Organisms can throw away the traits given to them by their ancestors, instead they have modify what they have been given.**

Wings would certainly work better

"The Perfect Organism"

- Natural selection has never and will never fashion the perfect organism.
- **Life is all about Trade-offs.**
  - **Unit after unit we have seen examples of trade-offs or compromises**
  - **Consider ectothermy which is energetically cheap but a sudden or severe cold front could cost the organism its life.**

A few years ago we saw this first hand as iguana's died in great numbers from a severe cold front