CHAPTER 19
INTRODUCING EVOLUTION

Diversity Of Life
Section 19.1

- **Evolution** refers to the relative change in the characteristics of populations that occur over successive generations.

- **Adaptation** is a particular structure, physiology, or behavior that helps a organisms to survive and reproduce in a particular environment.

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There are many different adaptations within organisms on this planet. Examples include ; camouflage, a human’s thumb, an Eagle’s eyesight, etc. Adaptations help an organism survive and therefore that organism will have a better chance of passing on to its offspring the particular characteristic which was advantageous to its survival.

As well, changes in an organism’s environment can often determine whether an adaptation will or will not help an organism survive.

The Peppered Moth

The English peppered moth is an example of how characteristics can change in response to changes in an organism's environment.

- The peppered moth has two colors

1. Greyish – white with black dots
2. Black

- In 1848, estimates determined that there were many more greyish-white peppered moths (about 98%) than black ones (about 2%). In 1898, approximately 95% of the moths in Manchester, England were of the black color with only about 5% being greyish-white.

Industrial Melanism

- The reason for the change is due to a change in the moth's environment.
- Prior to the Industrial Revolution, the greyish-white moths were able to camouflage themselves against the light colored lichens on tree trunks while the black colored moths stood out and were eaten by predators.
- Once the Industrial Revolution began, air pollution from the factories killed the lichens and soot began to cover the tree trunks. As a result of this, the greyish-white moths were easily seen by predators and eaten while the black moths could camouflage themselves, survive and pass on their genes to their offspring.

Con't

- The difference between the two colors of peppered moth is a single gene. Before the Revolution, more greyish-white moths survived and thus passed on their form of the gene for color to the **gene pool.**

- Once the Revolution started, the black moths were able to survive and pass on their form of the gene. This occurred over a number of generations.

- In the 1950s, due to clean air legislation, lichens began to grow on trees again. This began to change the peppered moth once again. In 1959, 9 / 10 moths were black in color. In 1985, 5 / 10 were black and by 1989, only 3 / 10 were black.

- Based on the above example we can define evolution as ;
  - "Any shift in the gene pool of a population."

Natural Selection

- Natural selection is a process in which the characteristics of a population of organisms change because individuals with certain heritable traits survive specific environmental conditions and pass on their traits to their offspring. In order for natural selection to occur there must be diversity within a species.

- Because nature plays a role in selecting certain characteristics, we can say that the environment exerts a **selective pressure** on a population.

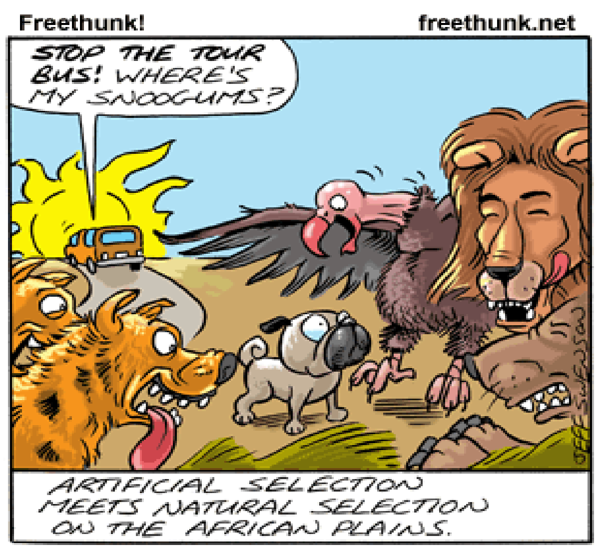
Natural selection does not grant organisms what they "need".

Artificial Selection

- Humans have the ability to artificially select organisms for certain traits. In the process of artificial selection, a breeder selects individuals to breed for the desired characteristic which he / she wishes to see in the next generation.

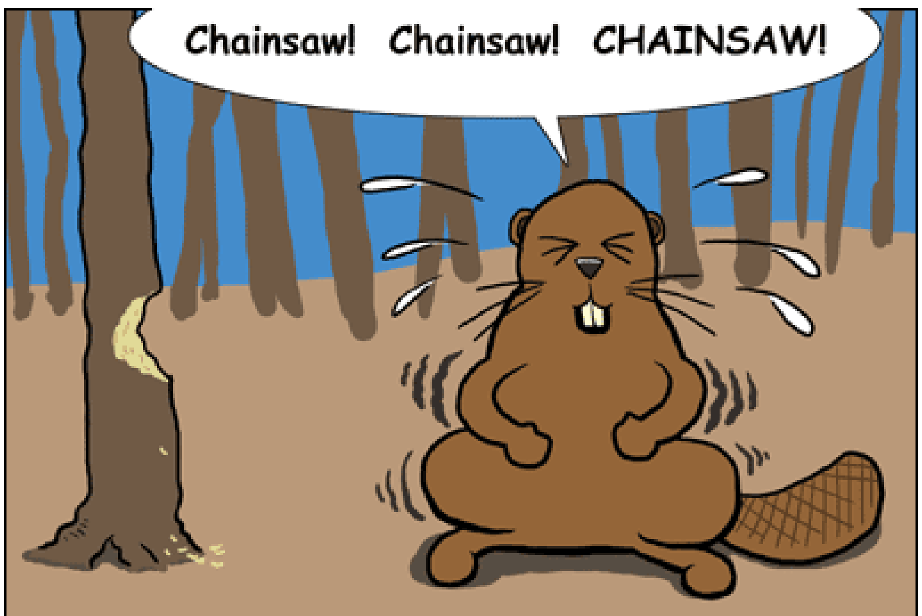
- As well, artificial selection can also produce characteristics which are not particularly desirable. Artificial selection is quite similar to the process of natural selection, however in artificial selection humans are playing the role of the environment by determining which traits are passed on from one generation to the next.

- In natural selection, "survival of the fittest" is the rule by which traits are passed on, however, in artificial selection this is not necessarily so



Natural Selection is Situational

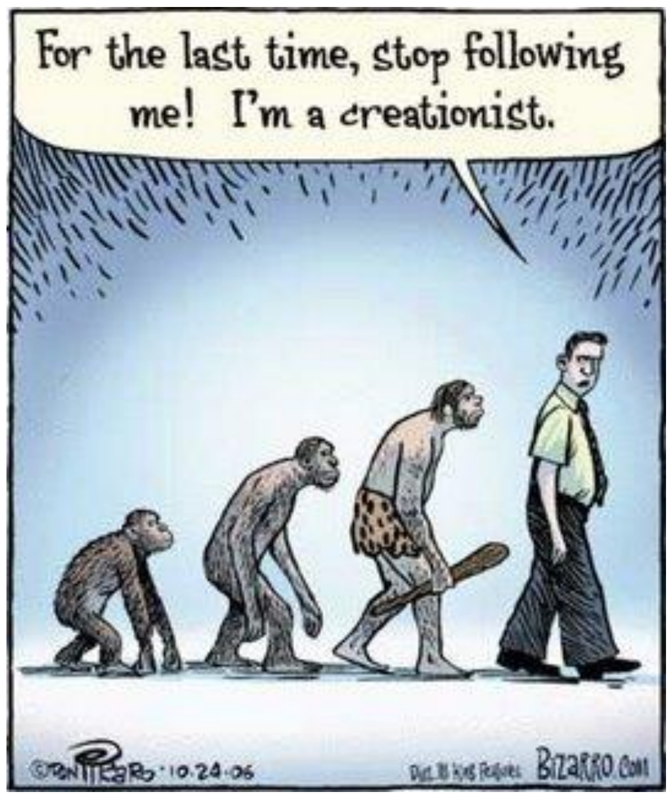
- Natural selection is considered to be situational.
- This means that adaptations which are beneficial to an organism in one situation may be useless or even detrimental in another situation.



Adaptation doesn't involve trying.

Developing The Theory Of Evolution Section 19.2

The work and ideas of many people has helped to shape our current understanding of evolution.



An Historical Context

- In ancient times, Greek philosophers believed that life gradually evolved.
- Other philosophers such as Aristotle did not support the idea of evolution and believed that all of the organisms that would ever exist were already created and would not change.

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- In the 19th century, new ideas began to emerge including:
  - Living things did change during the course of history.
  - Organisms which exist now may be different from the organisms which existed previously in history.
  - Populations of organisms probably even changed from one generation to the next.
  - Populations contain variations and populations can adapt to particular situations.
- The above ideas were contrary to the religious teachings of the time and were dismissed as hearsay.

Cuvier's Fossils

- **Paleontology** he study of fossils, provides important clues to help develop the theory of evolution.
- Georges Cuvier, a French scientist, is credited with developing the science of paleontology.
- Cuvier realized that the history of life on Earth was recorded in the layers of rocks which make up the Earth and these layers contained fossils.
- He also found that each of the rock layers, or strata, is characterized by a unique group of fossil species and the deeper the layer, the more dissimilar the organisms are from modern life.

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- He also recognized that the extinction of species was a common occurrence in Earth's history.
- Working layer by layer he found evidence that species appeared and disappeared over millions of years.
- Cuvier proposed the idea of **catastrophism** to explain the appearance and disappearance of species.
  - This idea suggests that catastrophes such as floods, diseases, or droughts had periodically destroyed species that were living in a particular region.
- Once species were destroyed in a geographical region the area would be repopulated by species from nearby unaffected areas.

Lamarck's Theory of Inheritance of Acquired Characteristics

- In 1809, Jean-Baptiste Lamarck published his theory of evolution.
- By comparing current species of animals with fossils he could see a "line of descent" which showed a series of fossils from older to more recent modern species.
- Lamarck proposed that microscopic organisms arose spontaneously from non-living sources.
  He also thought that species were initially primitive and began to increase in complexity over time until they achieved perfection. He believed that organisms would become better adapted to their environment over time

Con’t

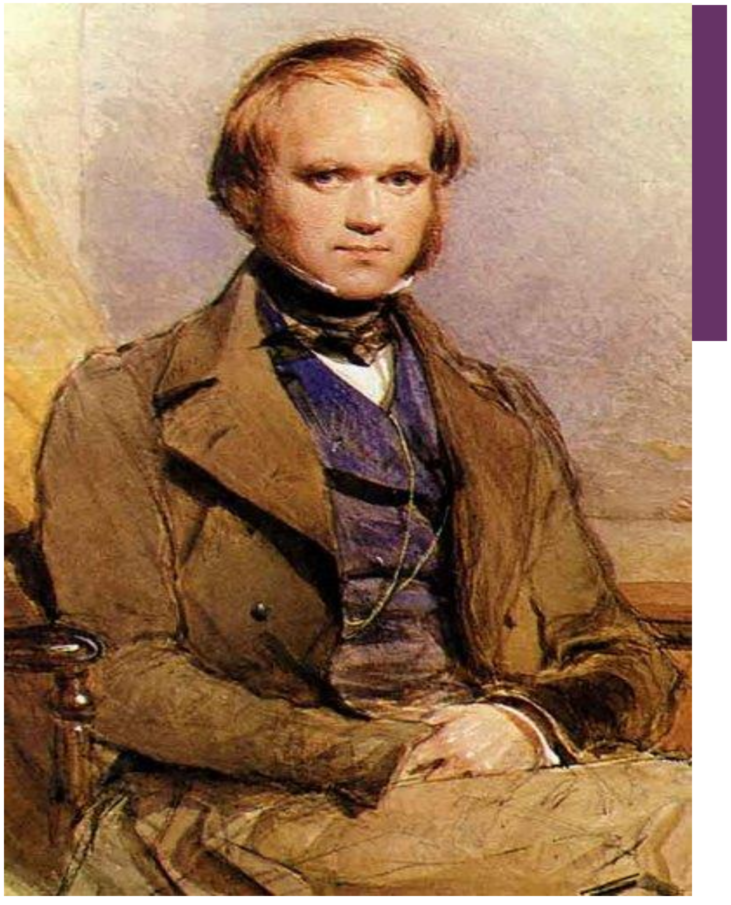
- Lamarck proposed the idea of “**Use and disuse”** This law states that if body parts were used extensively they would become larger and stronger. As well, if body parts were not used they would become smaller and weaker.

- He also proposed the idea of **“inheritance of acquired characteristics”**   This idea states that if an organism characteristics acquired during an organism’s lifetime could be passed on to its offspring.

- Although Lamarck’s theory of evolution is now known to be incorrect, his ideas provoked much thought and discussion.

- His ideas also influenced others such as Charles Darwin.

+ Darwin's Evidence



- In 1831, Charles Darwin began a 5 year voyage aboard a ship called the HMS Beagle. This voyage gave Darwin an opportunity to travel much of the world and explore the natural history of various locations.
- Darwin gathered thousands of biological specimens and made many important observations which led him to realize how life forms change over time and vary from place to place.

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- Darwin made several observations:
  - The flora and fauna of the different regions he visited were distinct from each other.
  - He also noted that lands that have similar climates seemed to have unrelated plants and animals.
  - He also found several important fossil remains and these fossils were related to living forms.

More about Darwin's Observations

- While in the Galapagos Islands, Darwin observed many new species which were unique to the Galapagos. However, there were differences in organisms from island to island.
- Observations of organisms such as tortoises and finches (birds) were a key to helping Darwin formulate his final theory of evolution. From his information on these two organisms Darwin demonstrated a mechanism for how new species could arise from ancestral ones in response to the local environment.
- Another important influence for Darwin was a book called ***Principles of Geology*** by Charles Lyell. Lyell's book expanded on the ideas of another geologist called James Hutton. Hutton had stated that the Earth's geological features were in a slow continuous cycle of change.
- As a result of reading this book, Darwin began to question the age of the Earth as proposed by biblical scholars who suggested that it was only 6000 years old. Darwin applied the idea of slow changes to geological features to populations of organisms.

Darwin's Theory of Evolution

- In 1838, Darwin read an article entitled ***Essay on the Principles of Populations*** which was written by Thomas Malthus.

- From this reading, Darwin came across the idea that; "plant and animal populations grew faster than their food supply and eventually a population is reduced by starvation, disease, or war." From this Darwin realized that individuals had to struggle to survive and only some individuals survive this struggle and produce offspring. The survivors could pass on their favorable traits to their offspring.

- From these ideas Darwin began to formulate his theory which he called **<u>Natural Selection</u>**.

- This theory can be summarized in the following statement:

- "Individuals that possess physical, behavioral, or other traits that help them to survive in the local environment are more likely to pass these traits on to offspring than those that do not have such advantageous traits."

- His ideas were presented in 1859 in a book entitled ***The Origin Of Species.*** Darwin was the first person to gather a number of facts related to evolution and present them cohesively, thus today we consider Charles Darwin to be the father of evolution.

+ Decent With Modification

- Darwin did not use the word "evolution" in his book, rather he used the idea of "descent with modification".
- The idea of descent with modification is based on two main ideas:
  - Present forms of life have arisen by descent and modification from an ancestral species.
  - The mechanism for modification is natural selection working continuously for long periods of time.
- Natural selection showed how populations of individual species became better adapted to their local environments.

Factors Governing Natural Selection

- The factors which govern the idea of natural selection include:

  1. Organisms produce more offspring than can survive, and therefore organisms compete for limited resources.

  2. Individuals of a population vary extensively and much of this variation is inheritable.

  3. Those individuals that are better suited to local environmental conditions survive to produce offspring.

- Processes for change are slow and gradual.

- Although we do consider Charles Darwin to be the father of evolution, the work of Lyell, Lamarck, and Cuvier also helped to shape our understanding of evolution.

Evidence of Evolution Section 19.3

- Evidence for this theory has come from:

1. The fossil record
2. The sciences of Genetics and Molecular Biology
3. The geographical distribution of organisms on Earth
4. Studies of the anatomy of animals
5. Studies of embryonic animals

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1. The fossil Record

- A fossil is made when organisms become buried in sediment which eventually converts itself into rock.

- From our study of sedimentary rocks which contain fossils scientists have created a fossil record of the history of life on Earth.

- This record shows the kinds of organisms that were alive in the past.

- Some fossils are similar to organisms which are alive today while others are different.

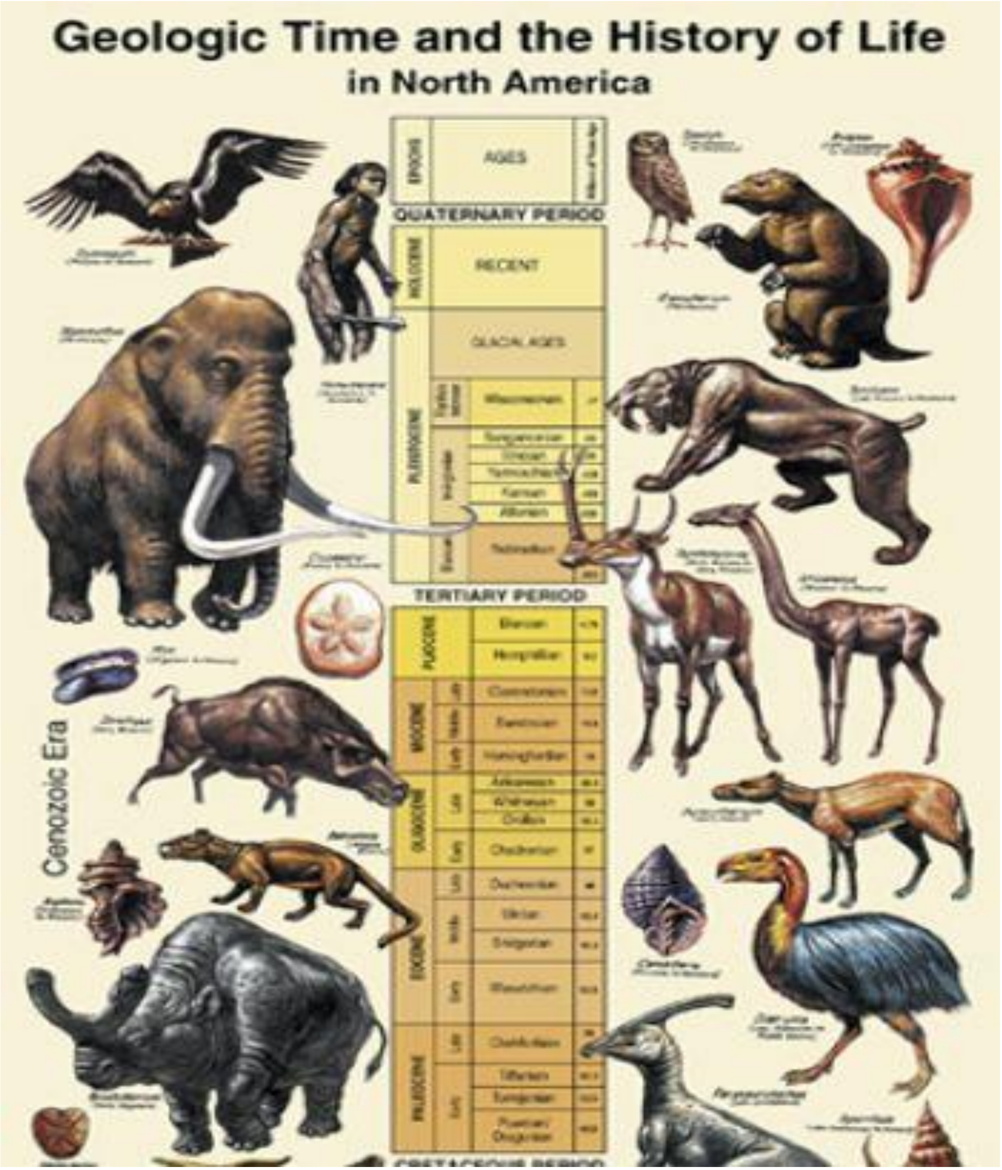
2. Fossil Study

- The study of fossils supports the idea that life has evolved over time.

- Scientists have created a geological time scale which shows when organisms appear in the fossil record.
  { See Fig. 19.10, P. 660 }

- Fossils appear in chronological order.
  - The oldest known fossils are stromatolites, rings of cyanobacteria, which lived around 3.8 billion years ago

Geological Time Scale



Fossil Recording

- All organisms do not appear in the fossil record simultaneously, this supports the idea that organisms have evolved from ancestral forms.

- We need to keep in mind that changes during evolution are slow and can take millions of years.

- An important discovery in the fossil record is **transitional fossils**. These fossils show intermediary links between groups of organisms and share characteristics common to the two separate groups.

- An example of a transitional fossil is Archaeopteryx, Fig. 19.13A, P. 661. This organism is an intermediary link between dinosaurs and birds.

Determining The Age Of Fossils

- There are two ways to age or date fossils :

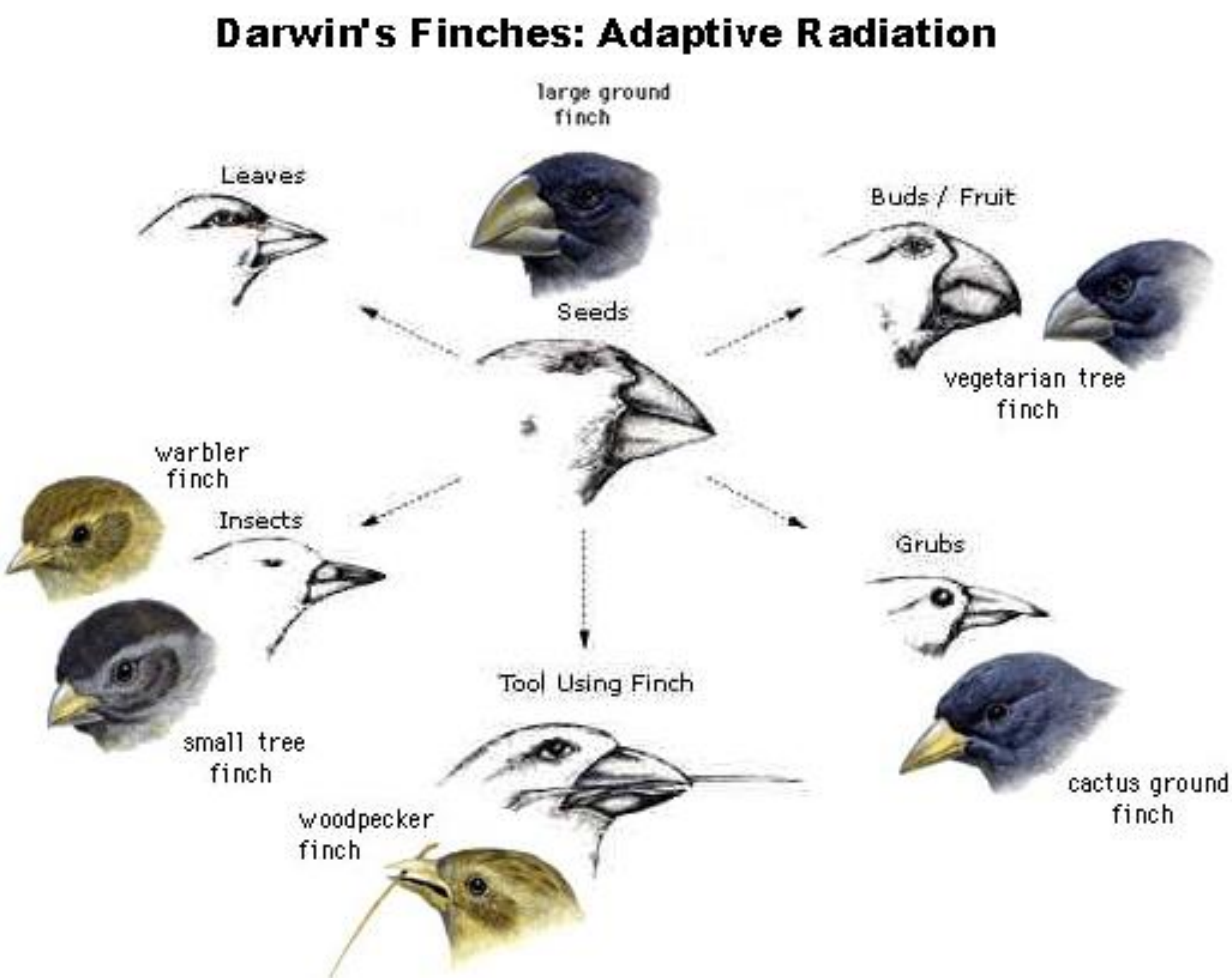
1. **Relative dating**
   - Relative dating ages a fossil due to its position in rock layers and therefore is only a rough estimate of a fossil's age. Fossils found in deeper rock layers are considered to be older than fossils found near the surface.
2. **Absolute dating**
   - Absolute aging is a much more accurate method of determining a fossil's age by using a technique called radioactive dating. Radioactive isotopes are chemicals which decay into another substance at a known rate called a **half-life**. Using the idea of half-life scientists are able to determine the age of a fossil.

- **Do Thinking Lab - Page 662 in textbook**

3. Geographical Distribution Of Species

- **Biogeography** is the study of the geographical distribution of species.
- Darwin's thinking was influenced by the distribution of organisms which he observed.
- This idea suggests that over time organisms adapt to the environment in which they live.
- Organisms which live on islands are a good example of how organisms will adapt to their surroundings.
- The Galapagos islands, islands of New Zealand, Madagascar (off the east coast of Africa) and the Canary islands (off the northwest coast of Africa) are all examples of environments where unique organisms have developed.

Darwin's Finches



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4. Anatomy

- Evidence for evolution can also come from studying the anatomy of various animals.

- Quite often, studies of anatomy reveal that a number of organisms have developed from a common ancestor.

- An example of such a study is the analysis of the forelimbs of a human, frog, bat, porpoise, and horse.

- The limbs of each of these organisms has the same basic arrangement of bones, yet they are modified into wings, arms, legs, and fins. Because these limbs each have a similar structure, we can say that they have

- evolved from a common ancestor. Such structures are called **homologous structures**.

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- An homologous structure may also be similar in function. Such structures are called **analogous** **structures**. An example of analogous structures is the limbs of the human, frog, and horse. Each of these structures has a similar function since they are all used for walking on land.
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- Organisms may also possess **vestigial structures**. These structures were once functional in the organism's ancestors, but do not have any current function. Examples of vestigial organs include ;
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- 1. The pelvic bones of Baleen whales.
- 2. The forelimbs of the Ostrich bird.
- 3. The appendix in humans.
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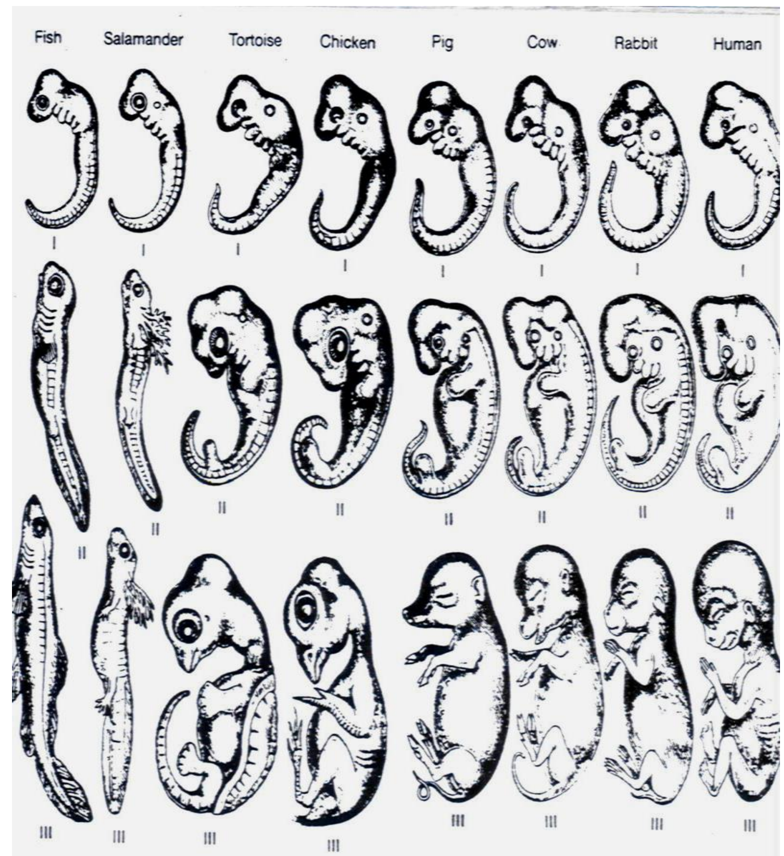
5. Embryology

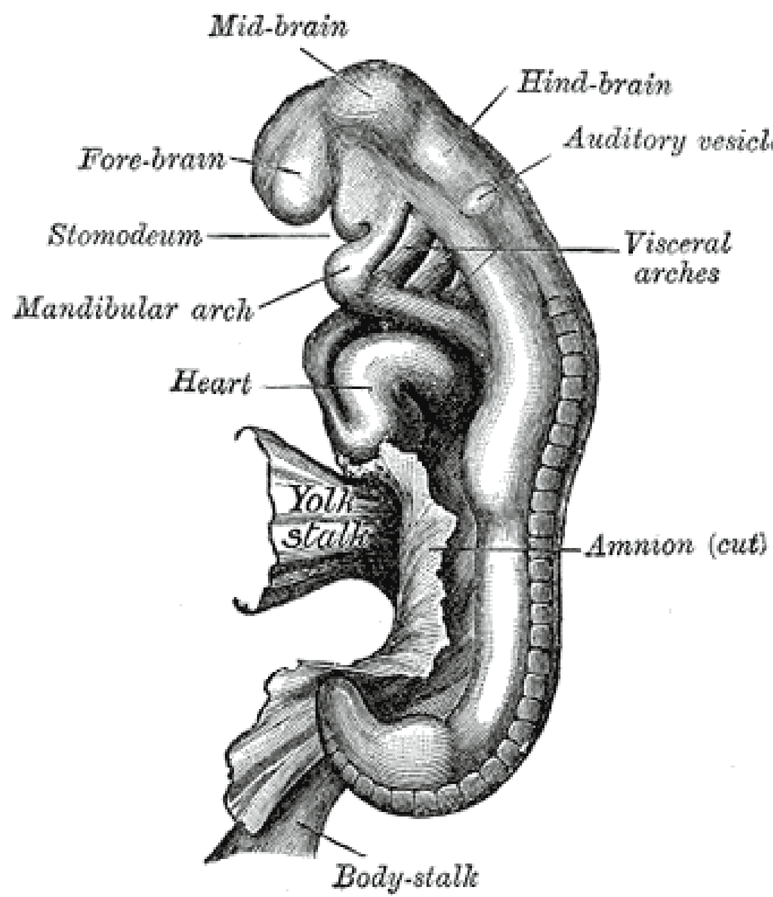
- Embryology is a branch of Biology which deals with the study of organism's embryos at different stages of development.
- When the embryos of different organisms are examined, similar stages of embryonic development are evident.



Embryo Example

- For example, using Fig. 19.17, P. 665, we can see that if we examine the embryos of fish, reptiles, birds, and mammals, there are stages when the embryos of each of these organisms have a tail and gill pouches. Later these structures are modified for certain uses.

- Similarities in the embryos of these organisms points to a common ancestral origin.



Heredity and Molecular Biology

Heredity

- When Darwin published his theories concerning evolution, the science of genetics had not yet been established.
- Today, we can use the knowledge which we have gained from this field to provide a large amount of evidence to support the theory of evolution.

Molecular Biology

- We can also provide evidence for evolution by studying the molecular structures which make up organisms.
- Two such molecules are DNA and proteins.
- We can determine how closely related two organisms are by comparing their DNA. If two species have similar patterns in their DNA, this similarity indicates that these sequences must have been inherited from a common ancestor.

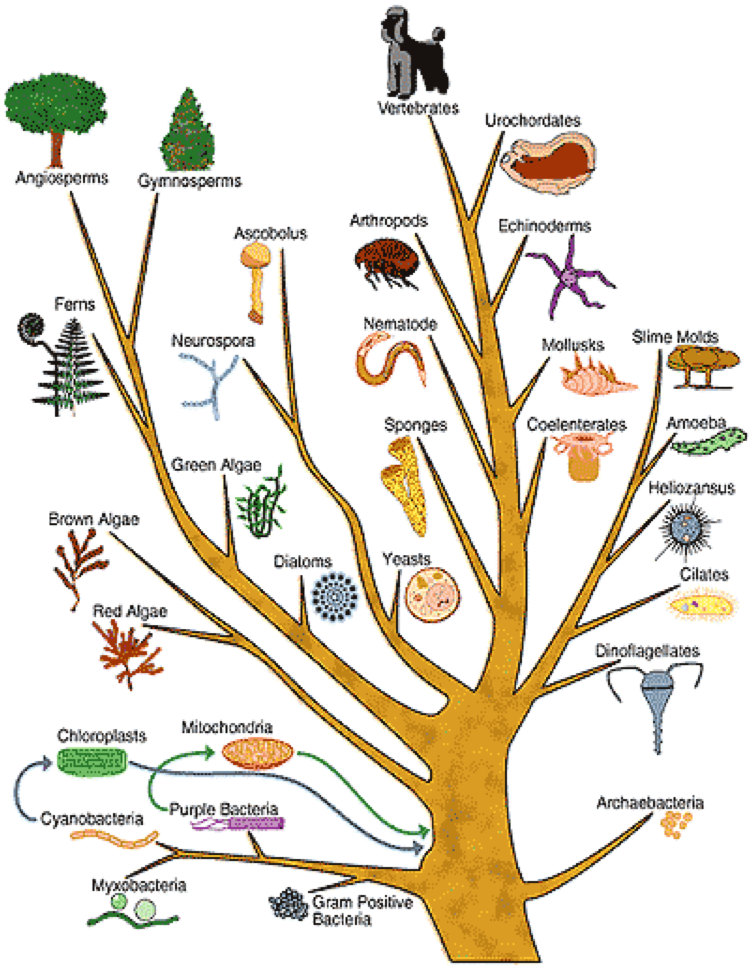
DNA Evidence…

- From DNA comparisons, scientists have determined a number of relationships between different organisms.
- Examples of organisms which have similar DNA patterns are:
  - Dogs and bears
  - Whales and dolphins
  - cows and deer
  - Humans and chimpanzees.

- The science of molecular biology has shown that all forms of life are related to the earliest organisms to some extent. This has allowed scientists to conclude that all life on Earth probably came from the same ancestor.

Con’t

- Although they may not look similar to each other, organisms will often have similar proteins, such as cytochrome c, which indicates relationships among otherwise dissimilar species.
- A diagram called a **phylogenetic tree** can be used to show what we call a pattern of descent.
- Using such a diagram, scientists can determine how certain molecules have changed over time and from this the evolutionary relationships among the organisms in which the changes have occurred.



Defining A Theory

- Evolution is considered to be a theory.
- The word theory implies that evolution is just a "guess" and not actual fact.
- However, the theory of evolution has a large amount of facts or data which can be used to back up what the theory is stating.
- Evidence such as homologous structures, DNA sequences, the fossil record, embryology, etc. are all pieces which help to form the puzzle which we call evolution.
- As a theory, evolution attempts to explain these facts and tie them together in a comprehensive way. Although there are those who refute the idea of evolution, the evidence for it presents a good scientific argument

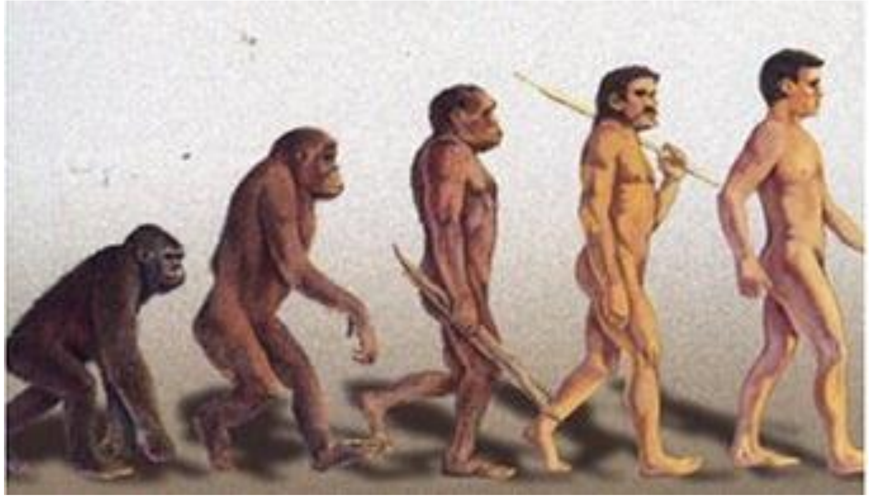
Chapter 20
Mechanisms for Evolution

Biology 3201

20.1 – Population Genetics

- Evolution can be divided into two levels

1. **Macro-evolution**
2. **Micro-evolution**



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Macroevolution vs. Microevolution

- Evolution on a large scale. It includes changes such as the evolution of new species from a common ancestor or the evolution of one species into two

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- Evolution on a smaller scale. This is evolution within a particular species. It is also the change in the gene frequencies of a population over time

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Heredity and Evolution

- Darwin's theory took a long time to gain acceptance because it was difficult to explain how traits were inherited

- Darwin's theory stated that new variants (variations) of a species arise in populations continuously. Some variants survive and produce more offspring while others die off

- However, the belief of the time was that characteristics which an individual obtained were blended as a result of an averaging of the characteristics from the organisms parents.

What was needed to get support?

- A way of explaining how variations arise by chance in populations
- Through the work of Gregor Mendel and others, the idea of natural selection gained support.
- In the 1930s, as the field of population genetics emerged, scientists showed that variations in a population could arise through changes called **mutations** in genes
- Since mutations can provide genetic variations within a population, evolution was now known to depend on both random genetic mutation and the mechanism of natural selection. This modern view of evolution is what we call **modern synthesis**

Population Genetics

- **<u>Population</u>** → a group of a single species which occupy a particular area.
- **<u>Gene pool</u>** → All of the genes in a population of organisms.
- Genetic variation can occur within a population or within an organism that makes up the population

Studying Populations

- Scientists use electrophoresis and polymerase chain reactions (PCR) to study variations in populations

- Population geneticists study the frequencies of alleles and genotypes in a population.
- By studying these frequencies they can determine any changes in the genetic variability of a population and thus determine if the population is undergoing micro-evolution.
- **Frequency** → number of occurrences of a particular allele in a population divided by the total number of alleles in a population.
- The frequencies of both alleles and genotypes within a population are called the populations **genetic structure**.

Section 20.2
Hardy-Weinberg Principle

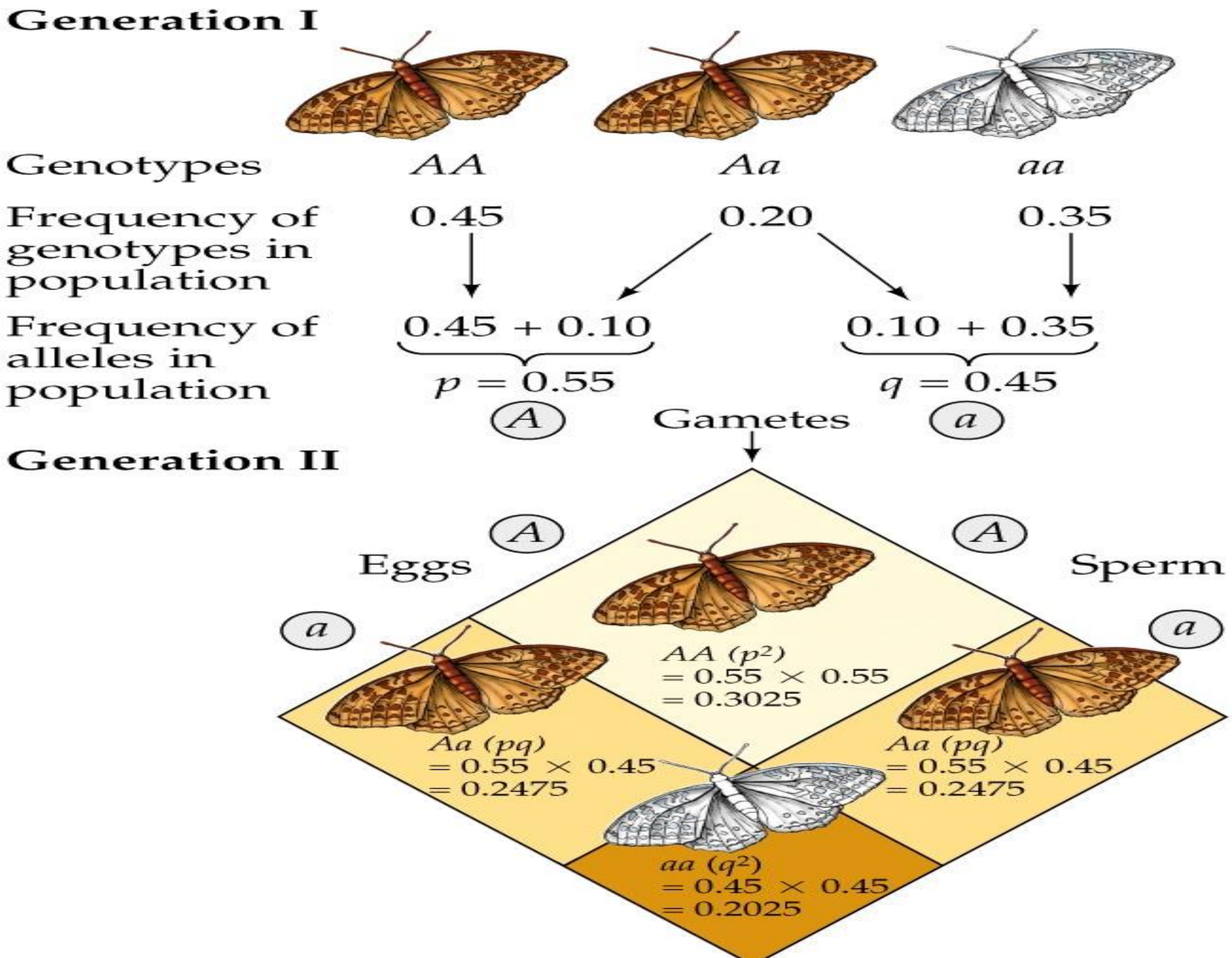
- In order for a population to undergo change it must have genetic variation

- One way to determine how a population does change over time is to develop a model of a population that does not change from one generation to the next and compare this hypothetical model to an actual population which does change. This is called the **<u>Hardy-Weinberg principle</u>**

The Principle - Mathematically

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

- **p** → frequency of a dominant allele
- **q** → frequency of a recessive allele
- **p^2** → frequency of individuals who are homozygous for the dominant allele. Example: AA
- **2pq** → frequency of individuals who are heterozygous for alleles. Example Aa
- **q^2** → frequency of individuals who are homozygous for the recessive allele. Example aa
- In the Hardy-Weinberg principle, **p + q = 1**
- **Read over the example on page 681 in textbook**


Generation I
Genotypes
AA
Aa
aa
Frequency of genotypes in population
0.45
0.20
0.35
Frequency of alleles in population
0.45 + 0.10
p = 0.55
0.10 + 0.35
q = 0.45
A
Gametes
a
Generation II
A
A
Eggs
Sperm
a
a
AA (p²)
= 0.55 × 0.55
= 0.3025
Aa (pq)
= 0.55 × 0.45
= 0.2475
Aa (pq)
= 0.55 × 0.45
= 0.2475
aa (q²)
= 0.45 × 0.45
= 0.2025

The Details

- The Hardy-Weinberg principle predicts the expected allele and genotype frequencies in an ideal population which is not subjected to selective pressure
- There are five conditions that MUST be met to maintain Hardy-Weinberg Equilibrium

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The 5 Conditions of Hardy-Weinberg

1. **Random mating** →Mating must be totally random i.e. Females cannot select male mates with a particular genotype

2. **No mutations** → There must be no mutations of alleles (genes) in the gene pool of a population.

3. **Isolation** → Populations must be isolated from each other so that there is no exchange of genetic material between them.

4. **Large population size** → Number of organisms in the population must be very large

5. **No natural selection** → There can be no advantage of one genotype over another due to the process of natural selection.

- Natural populations **cannot** meet all of the conditions above, therefore Hardy-Weinberg equilibrium can only be met in an artificial environment such as a laboratory

20.3 Mechanisms for Genetic Variation

- **Five mechanisms that can lead to microevolution**
  1. Mutation
  2. Genetic Drift
  3. Gene Flow
  4. Non-Random Mating
  5. Natural selection

Mutations I

- Mutations allow new alleles (genes) to form in a population and thus provides the variation needed for evolution to occur
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- When DNA mutates three things can occur to a body cell:
  1. It dies
  2. It malfunctions.
  3. It multiplies into a tumor.

The mutation disappears when the organism dies

Mutations II

- In a gamete cells mutations are passed on to subsequent generations. The inherited mutations may have favorable, unfavorable or neutral effects on a population.
- **Favorable mutations** provide a selective advantage and may result in certain individuals that are capable of producing a disproportionate number of offspring, thus increasing the frequency of that allele in a population.
- **Neutral or unfavorable mutations** can be a source of variation which ultimately help a population survive given the right circumstances.
- Any mutation which gives an organism an advantage will help it survive and produce offspring when other organisms without the mutation will tend to die off. This results in changes to populations, changing the gene pool of the population, thus resulting in change or evolution.

Genetic Drift I

- In a small population, the frequencies of particular alleles can be changed drastically by chance, this is called **genetic drift**.

- The smaller a sample size, the greater the chance of sampling error within a population.

- In population genetics, the sample size can greatly affect the gene pool of a population, the smaller the population, the less likely the parent gene pool will be reflected in the next generation, however, in a large population, there is a greater chance that the parent gene pool will be reflected in the next generation.

Genetic Drift II

- In any population, not all of the individuals in each generation will reproduce. This causes a shift in the allele frequencies in the next generation. With each subsequent generation, failure of all organisms to reproduce causes a further shift in allele frequencies.

- Shift in allele frequencies reduces the variability of a population, thus causing genetic drift.

- Although most populations are large enough to make the effects of genetic drift negligible, there are two situations which can cause genetic drift within these populations.
  1. **The Bottleneck Effect**
  2. **The Founder Effect**

Bottleneck Effect

- Natural disasters such as earthquakes, floods, etc. as well as human interferences such as over-hunting or habitat destruction can cause populations to be reduced in numbers to the point where they are almost extinct.
- Because most of the original population dies off, the surviving population no longer represents the gene pool of the original population.
- Thus, certain alleles will be over-represented while others will be under-represented

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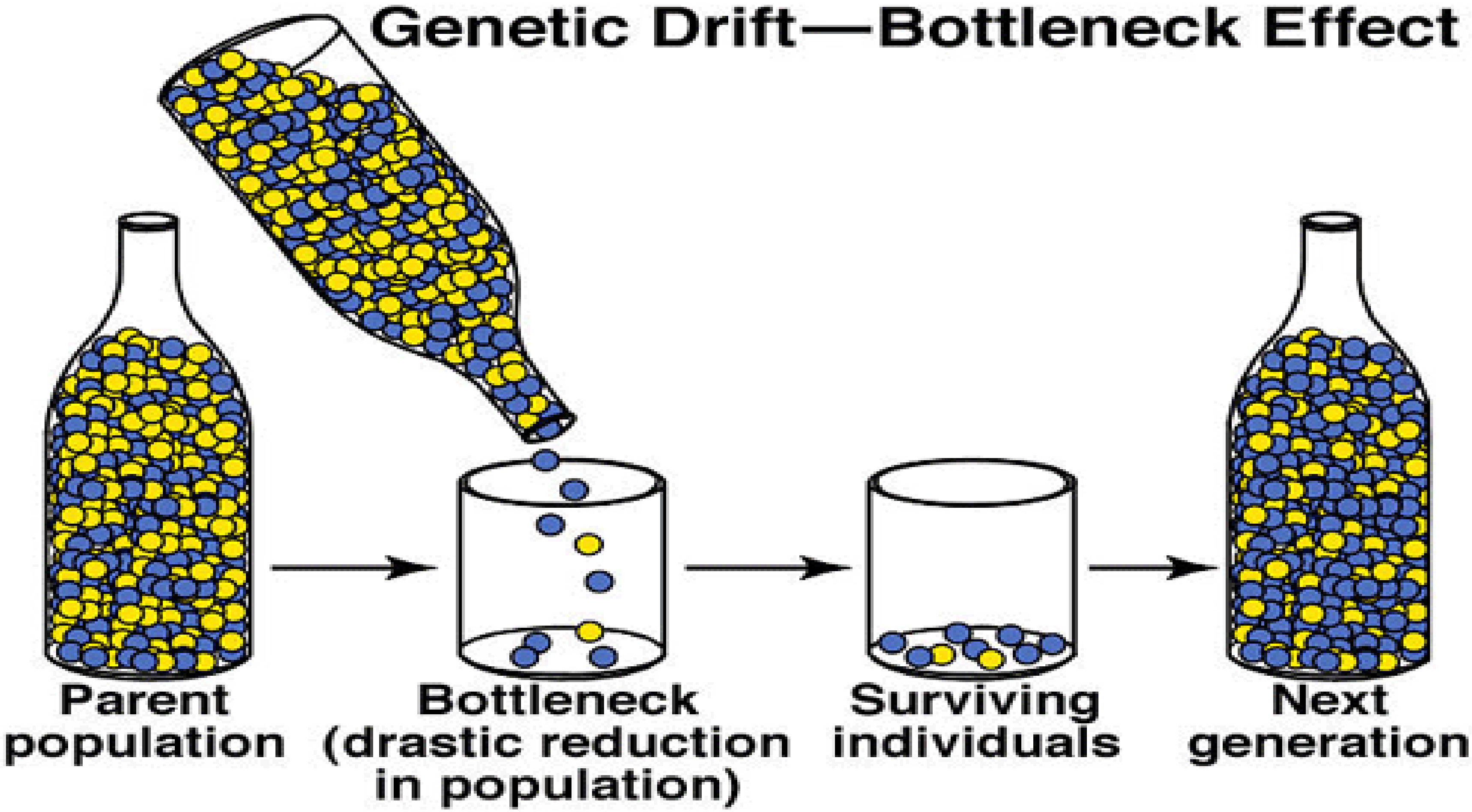
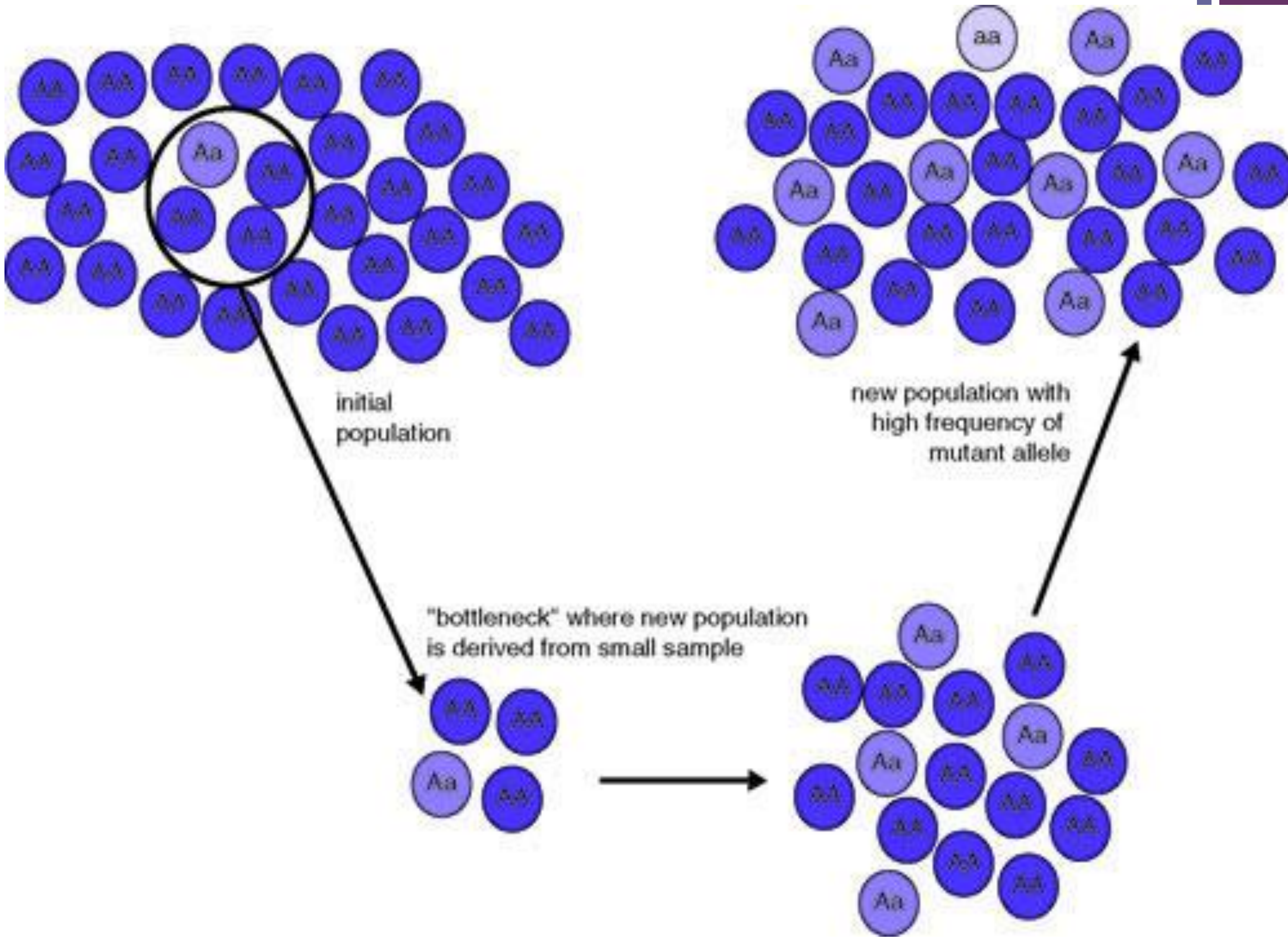

Genetic Drift—Bottleneck Effect
Parent population
Bottleneck (drastic reduction in population)
Surviving individuals
Next generation

Founder Effect

- This occurs when a small population of organisms colonize a new area.
- Due to the small size of the population, there is a good chance that all of the genes from the original parent population are not represented. Thus, any new population which is produced from this new, founder population will have an allele frequency which is different from the original population, this is the **founder effect**.
- As well, since the founding population is in a new environment which is different from that of the original population, different selective pressures will influence the gene pool of the population.
- The founder effect is important on islands and in other isolated habitats.



initial population
"bottleneck" where new population is derived from small sample
new population with high frequency of mutant allele

Gene Flow I

- To maintain its genetic equilibrium, the gene pool of a population would have to be completed isolated, however, this rarely occurs.

- Quite often new genes either move into or out of a population causing a change in the population's gene pool, this is called **gene flow**.

- Gene flow can reduce the genetic differences between populations.

Gene Flow II

- Over time, isolated populations can accumulate genetic differences due to the selective pressures of different environments.

- Gene flow between these different populations can reduce the differences between these two populations. Eventually, after extensive gene flow, two previously different populations may amalgamate into a single population with identical gene pools.

Non-random Mating I

- Random mating in a population will allow the population to maintain genetic equilibrium.

- However, not all organisms mate randomly, some take part in non-random mating.

- Two types of non-random mating are:
  1. Interbreeding
  2. Assortative mating

Non-random Mating II

- Interbreeding, mating between closely related partners, does not change allele frequencies in a population. It results in a more homozygous population.
- Assortative mating occurs when individuals choose partners which have a similar phenotype to themselves. This type of mating results in a decrease in the genetic diversity of a population.

Natural Selection

- Populations have a range of phenotypes and genotypes and some individuals will leave more offspring than others.
- If even a single allele gives a slight selective advantage to a population, the frequency of the allele in the population will increase from one generation to the next.
- Organisms which have the favorable allele will survive and reproduce and pass this allele on to their offspring.
- Thus, natural selection will cause a change in a population's gene frequencies. There are three ways for this to occur:
  1. **Stabilizing selection**
  2. **Directional selection**
  3. **Disruptive selection**

Natural Selection II

- **Stabilizing selection** favors an intermediate phenotype and actually acts against extreme variations of a phenotype. Thus, this type of selection reduces variation within a population so that the population will remain relatively constant.

- **Directional selection** favors the phenotypes at one extreme of a range over the other. This type of selection is common during times of environmental change or when a population migrates to a new habitat which has different environmental conditions. Global climate change can also cause directional selection in some populations.

- **Disruptive selection** occurs when the extremes of a phenotypic range are favored over the intermediate phenotypes. This can result in the intermediate phenotype being eliminated from a population.

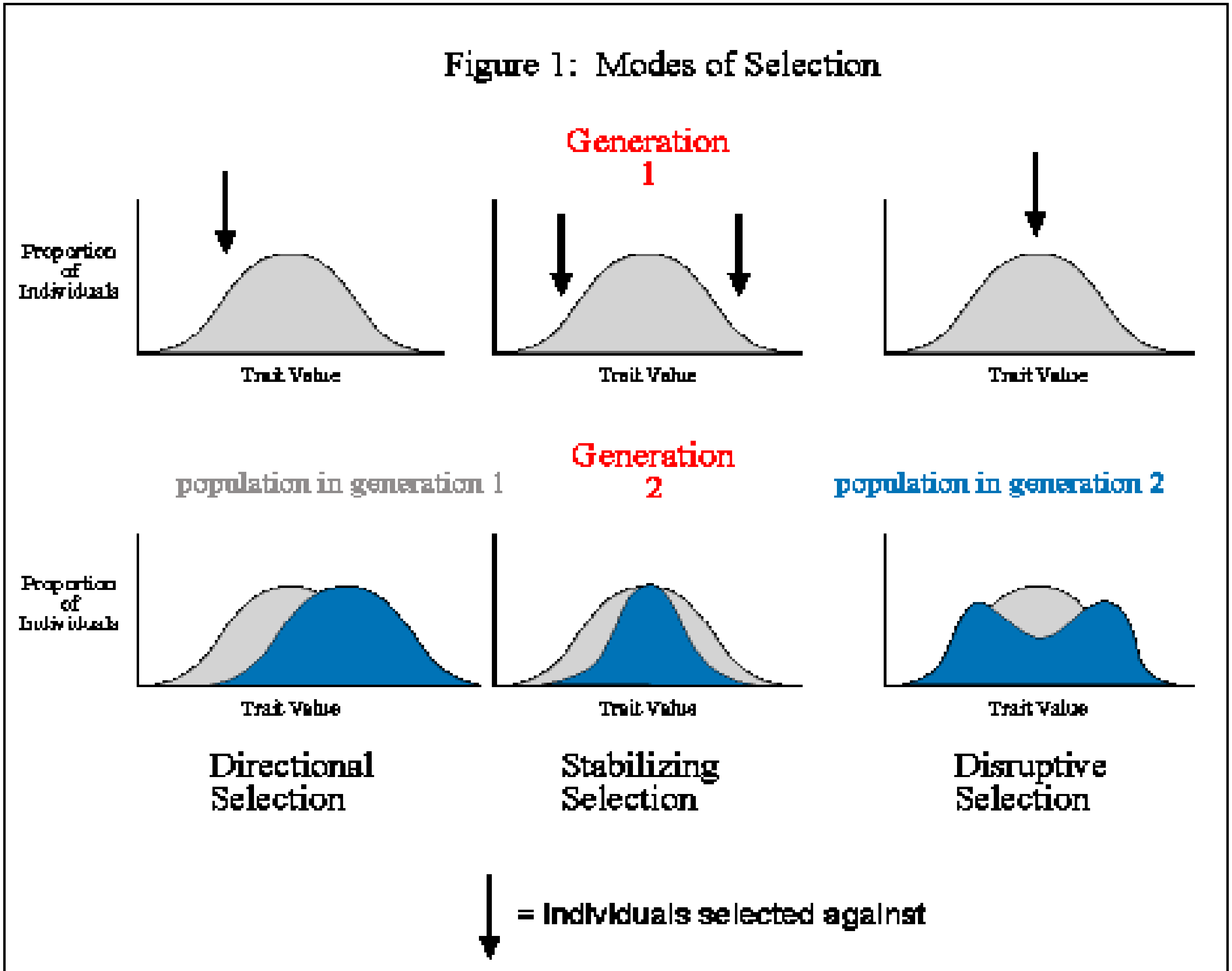


Figure 1: Modes of Selection

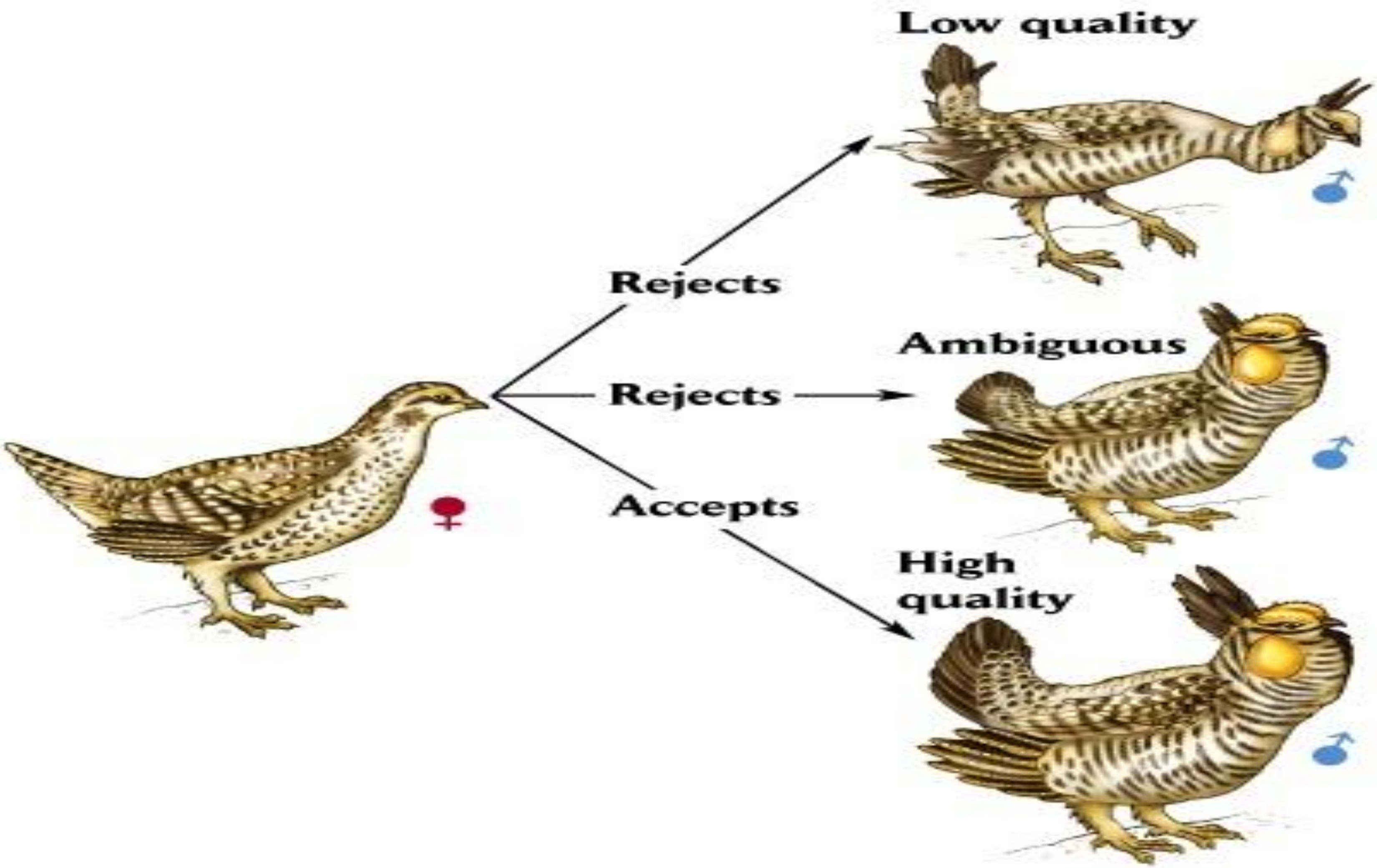
Sexual Selection I

- Sexual reproduction has evolved several times throughout the course of evolutionary history.
- Evolution has favored mutations that make a species' sperm smaller and eggs larger. Species tend to have many more sperm than eggs. Sperm tend to be mobile whereas eggs tend to be stationary.
- Evolution has also created a wide array of sexual behaviors and sexual attractants.

Sexual Selection II

- Males and females of many animal species have different physical characteristics. This difference between males and females is called **sexual dimorphism**.
- Differences in physical features, behaviors, etc. result in a type of selection which we call **sexual selection**.
- Sexual selection results in reproductive success allowing organisms to better survive and pass on their genetic material to the next generation.

Sexual Selection at work



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Chapter 21 Adaptation & S

Biology 3201

21.1 Adaptation

- Any trait that enhances an organisms fitness or increases it's chance of survival and probability of successful reproduction is called an **adaptation**.
- Adaptations arise from natural selection.
- Over a period of time, ***individual organisms*** become adapted to their immediate environment.
- Only those organisms that possess characteristics that enable them to survive are able to pass on these favorable adaptations to their offspring.

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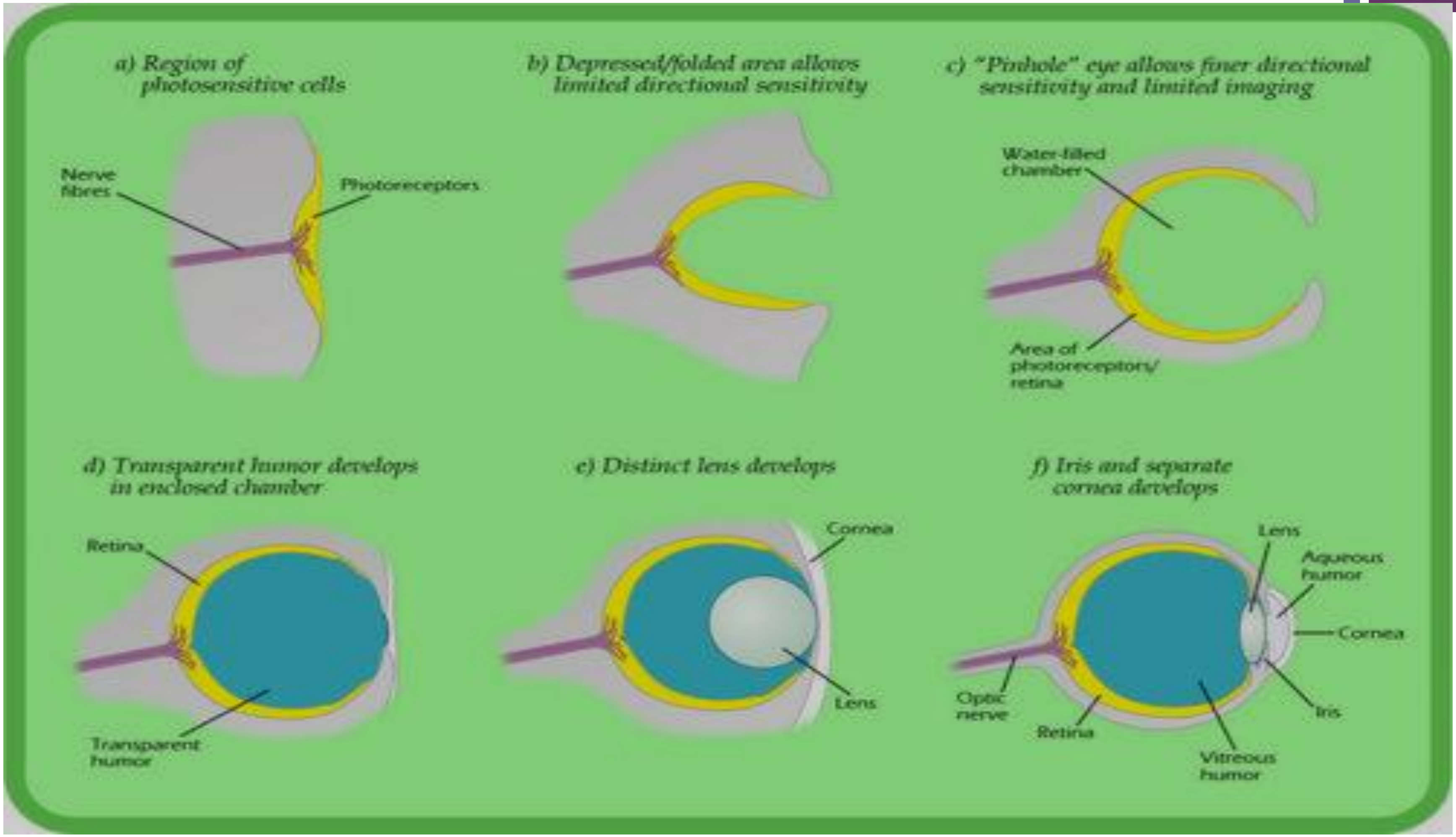
Evolution of Complex Adaptations

- Adaptations do not arise all at once. They evolve over time as a result of a series of small adaptive changes.

- An example of a complex adaptation is the evolution of the human eye from the eyes of lesser organisms. This complex form of the eye is a result of many years of developing in stages from a more simple eye.

- As the structural changes giving rise to more complex organs benefit organisms, these changes are then passed on to offspring

Evolution of the Human Eye

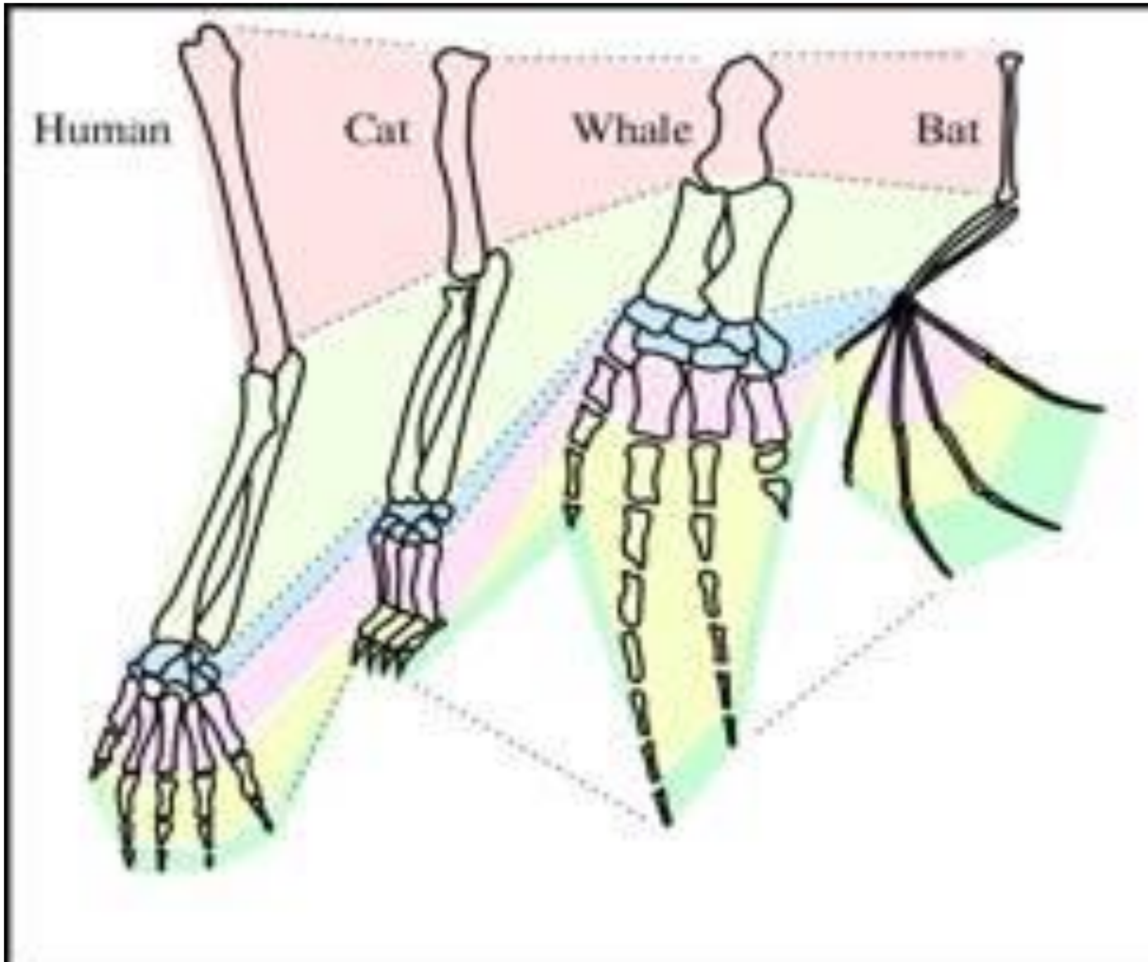


Changing Function of Adaptations

- Sometimes an adaptation which evolved for one function can have another use. This is called **exaptation**.

- **Example** Evolution of limbs and digits of terrestrial vertebrates.
  - Used by aquatic organisms to move around in their environment. These limbs were used to crawl, run, etc as the organisms moved onto land to live
  - Thus, what evolved as an adaptation for an aquatic existence eventually became useful for living on land.

Limb Evolution Illustrated



The limb bones of different mammals are clearly equivalent. We can "morph" one into another just by changing the sizes and proportions. Genetic mutations altering the gene-control proteins, the diffusible molecules, and the patterns of expression of the limb-development genes, are sufficient to make these changes in living things. One mutation occurs at a time, and the internal control mechanisms of embryo development integrate the body parts to form a working whole.

Types of Adaptations

- Three types of adaptations:
  1. Structural
  2. Physiological
  3. Behavioral

Structural Adaptations

- **Adaptations that affect the appearance, shape, or arrangement of particular physical features. Includes adaptations such as mimicry and cryptic coloration.**

- **Mimicry** allows one species to resemble another species or part of another species.
  - Ex: Syrphid Fly will often mimic a more harmful yellow-jacket wasp.

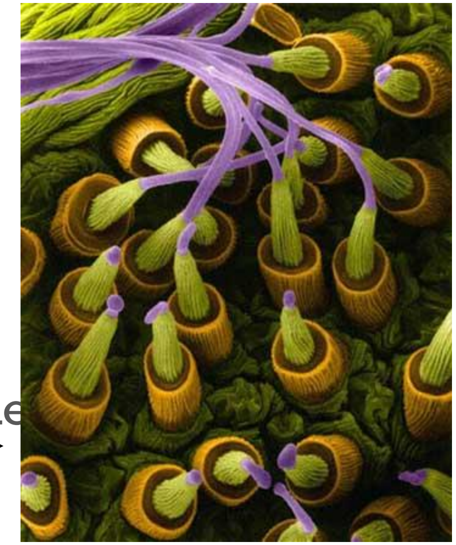
- **Cryptic colouration (camouflage)** allows prey to blend in with their environment. This is accomplished when an organism camouflages itself by shape or color.
  - Ex: A sea dragon resembling seaweed.

Mimicry and Cryptic Colouration

Physiological Adaptations

- Adaptations which are associated with particular functions in organisms.

- Examples:
  1. Enzymes needed for blood clotting.
  2. Proteins used for spider silk.
  3. Chemical defenses of plants.
  4. The ability of certain bacteria to withstand extreme



Behavioural Adaptations

- Adaptations which are associated with how organisms respond to their environment.

- Examples:
  1. Migration patterns.
  2. Courtship patterns.
  3. Foraging behaviors.
  4. Plant responses to light and gravity.

- These types of adaptation do not exist in isolation, they depend on one another.

Is Evolution Perfection??

- Although many people think that adaptation and natural selection tend to make an organism perfect, **this is not the case**.

- Adaptation and natural selection simply change an organ or organism in a way that improves the organisms chance of survival in its environment.

Why Evolution Is Not Perfect

1. Natural selection only edits variations that already exist in a population. Evolution has to make do with what is created; the new designs, although better than the old ones, are less than perfect.

2. Adaptations are often compromises of what an organism is ideally aiming to achieve.

3. Not all evolution is adaptive. Sometimes chance events can change the composition of a populations gene pool. Those organisms which survive a chance events do so randomly, not because they were better than other organisms.

- **The individuals that do survive are able to reproduce and pass on their genes to their offspring. Over time the population will change, hopefully for the better.**

21.2
How Species Form

- A species is a population that can interbreed and produce viable, fertile offspring.

- There are two pathways which lead to the formation of a new species
  1. **Transformation**
  2. **Divergence**

- **Transformation** is a process by which one species is transformed into another species as the result of accumulated changes over long periods of time.

- **Divergence** is the process in which one or more species arise from a parent species, but the parent species continues to exist.

- The formation of species, a process called **speciation**, is a continuous process.

Biological Barriers to Speciation

- In order for species to remain distinct they must remain reproductively isolated.
- Species which are reproductively isolated from each other are unable to interbreed, thus restricting the mixing of genetic information between species.
- Species are often isolated by particular types of barriers. Two main types of barriers include:
  1. Geographical barriers
  2. Biological barriers

Geographical Barriers

- Keep populations physically isolated from each other. Thus, the organisms from the populations are unable to interbreed with each other.

- Examples include:

- Rivers, mountains, oceans

Biological Barriers

- Keep species reproductively isolated from each other.

- Reproductive barriers fall into two broad categories:

  1. Pre-zygotic barriers
  2. Post-zygotic barriers

Pre-zygotic Barriers

- Pre-fertilization barriers, either impede mating between species or prevent fertilization of the egg if individuals from different species attempt to mate.

- Types of pre-zygotic barriers include:
  - Behavioural isolation – ex. Different mating calls
  - Habitat isolation – ex. Occupying different parts of a region
  - Temporal isolation – ex. Different mating seasons
  - Mechanical isolation – ex. Anatomical differences
  - Gametic isolation – ex. Egg and sperm not compatible

Post-zygotic barriers

- Post-fertilization barriers, prevent hybrid zygotes from developing into normal, fertile individuals.

- Types of post-zygotic barriers include:
  - Hybrid inviability – hybrid dies
  - Hybrid sterility – hybrid is unable to reproduce
  - Hybrid breakdown

Alternative Concepts of Species

- Historically, organisms have been classified into separate species based on measurable physical features, this is called the **morphological species concept**.

- Regardless of how species are defined, it is important to remember that speciation requires populations of organisms to remain genetically isolated from other species.

21.3 Patterns of Evolution

- Speciation is the process by which a single species becomes two or more species.

- There are two modes of speciation:
  1. Sympatric Speciation
  2. Allopatric Speciation

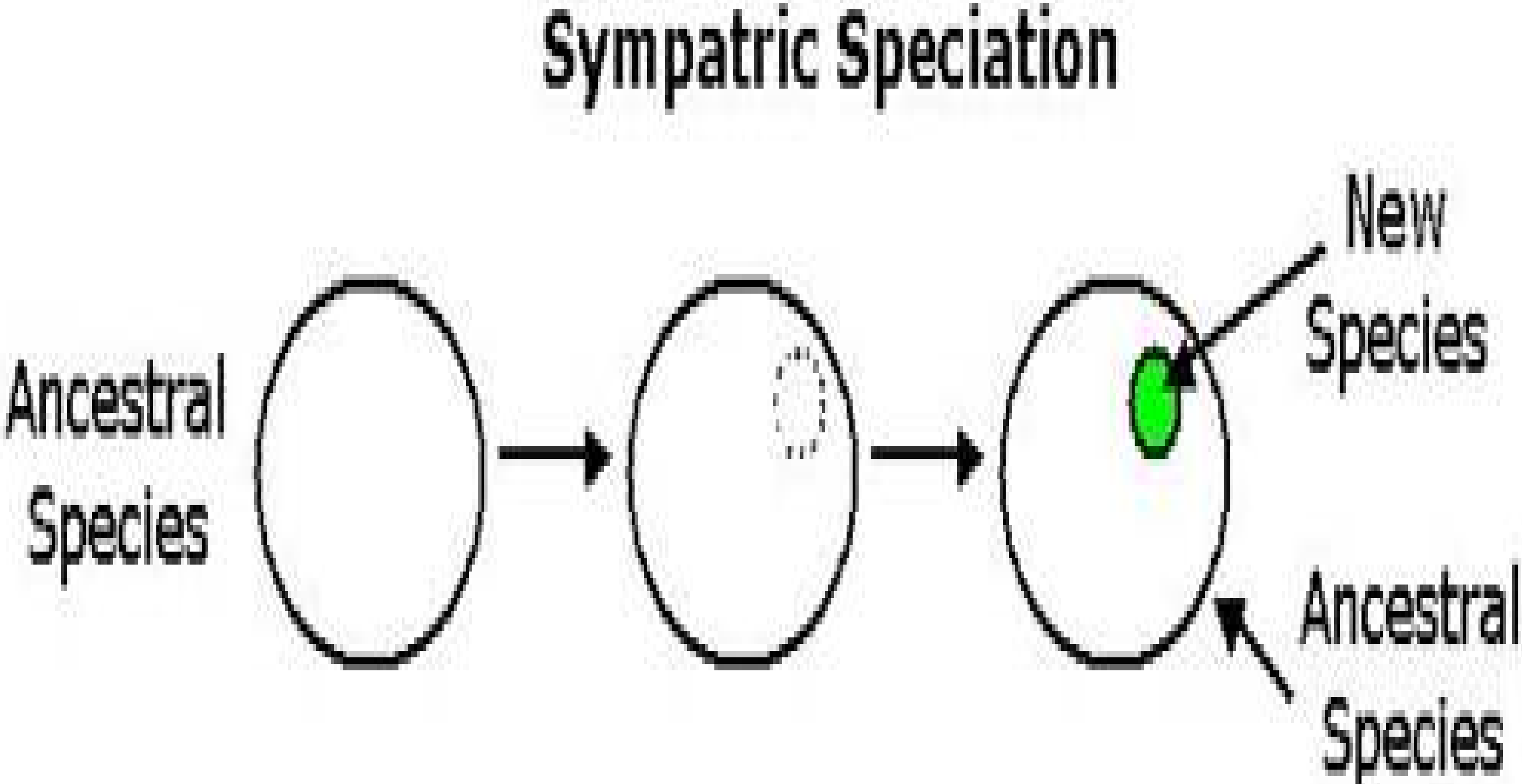
Sympatric Speciation I

- Occurs when populations become reproductively isolated from each other.
- This type of speciation is more common in plants than in animals.
- Two common ways in which sympatric speciation can occur are polyploidy and interbreeding.

Sympatric Speciation II

- Errors in cell division can result in cells which have extra sets of chromosomes, a condition called **polyploidy**. This is more common in plants than in animals, in fact, polyploidy is quite rare in animals. Any mating which occurs between a polyploid organism and a normal organism will result in sterile offspring. Since the new organisms are sterile and cannot successfully reproduce, they are considered to be a new species.

- Sometimes two species can **interbreed** to produce a sterile offspring. Eventually, the sterile hybrid organism can be transformed into a fertile species. This as well occurs most often in plant populations


Sympatric Speciation
Ancestral Species
New Species
Ancestral Species

Allopatric Speciation I

- Occurs when a population of organisms is split into two or more isolated groups by a geographical barrier.
- Over time, the gene pools of the two populations become so different that the two groups are unable to interbreed even if they are brought back together.
- The geographical isolation of a population does not have to be maintained forever for a species to be transformed, however, it must be maintained long enough for the populations to become reproductively incompatible before they are rejoined.

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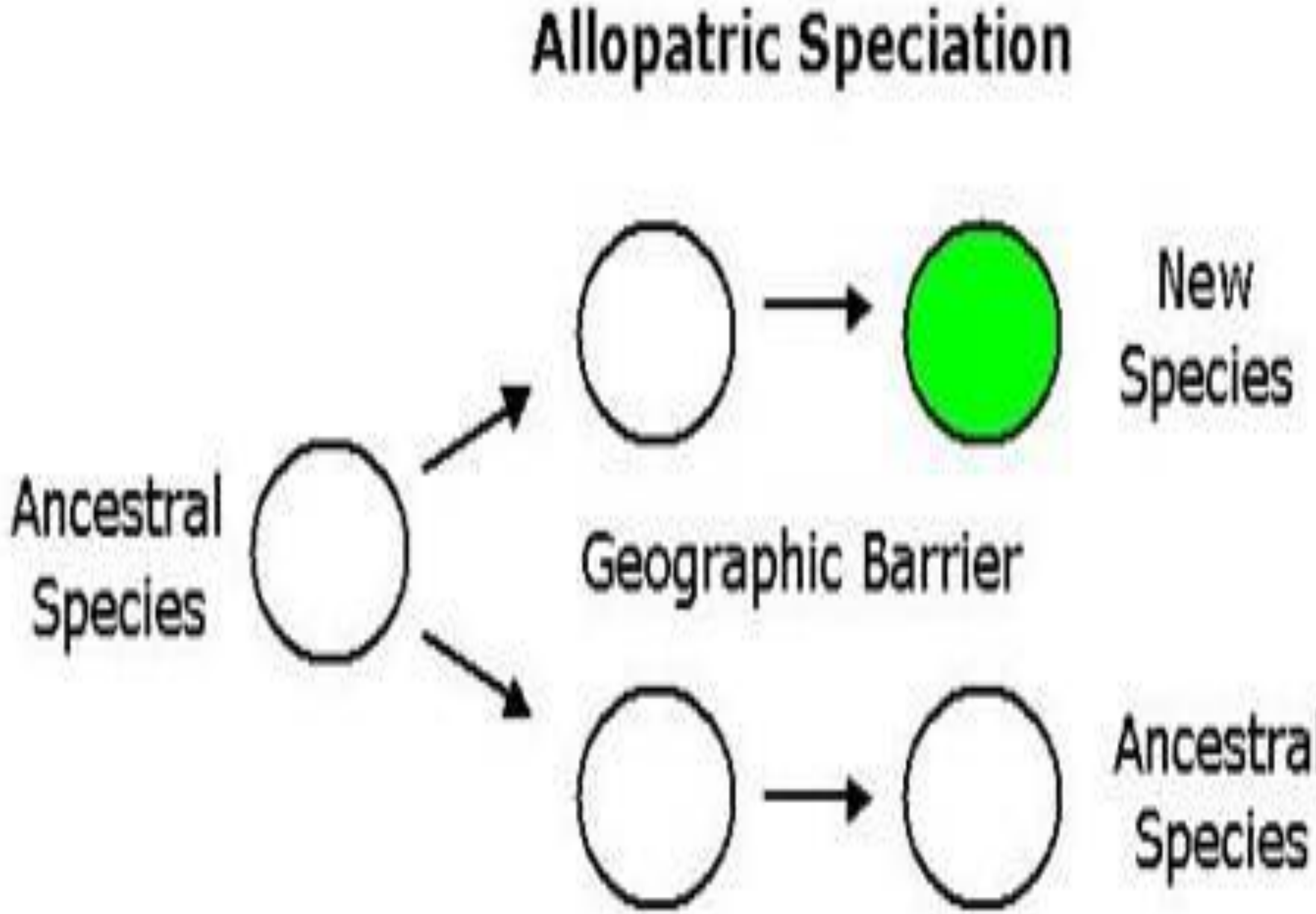
Allopatric Speciation II

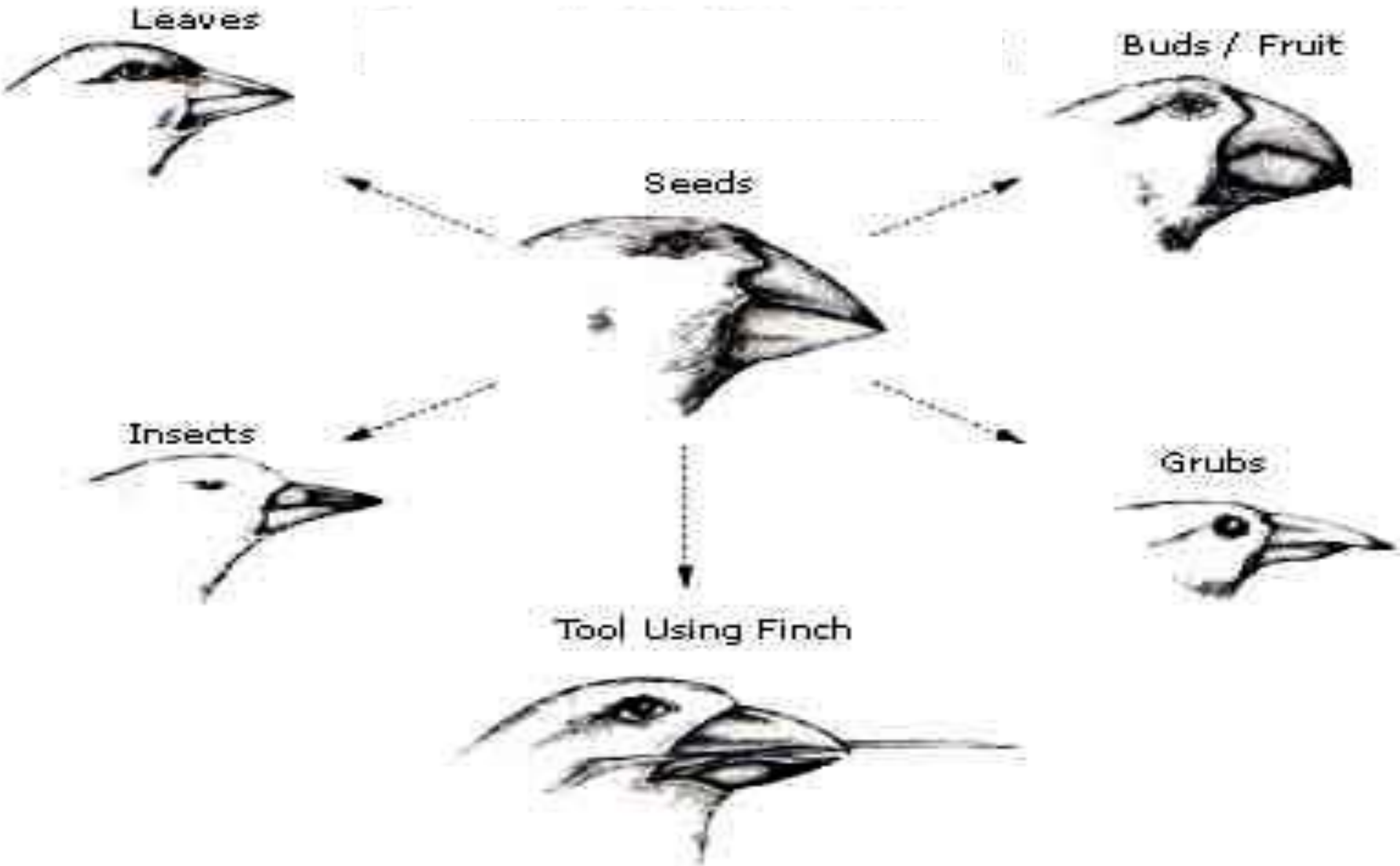
- The degree to which geographic isolation affects a population of organisms depends on the organisms ability to disperse in its environment.
- Generally, small populations that become isolated from the parent population are more likely to change enough to become a new species, especially those organisms which exist at the periphery of a parent population.
- Factors such as genetic drift, mutations, and natural selection will increase the chance of an isolated population forming into a new species.
- The finches of the Galapagos islands are an example of speciation.


Allopatric Speciation
New Species
Ancestral Species
Geographic Barrier
Ancestral Species

Adaptive Radiation I

- The diversification of a common ancestral species into a variety of species is called **adaptive radiation**.
- Darwin's finches are a good example of adaptive radiation.
- The first inhabited a single island. Eventually, the finches began to inhabit other neighboring islands. These islands had slightly different environments from each other and the selective pressures of the different environments resulted in different feeding habits and morphological differences for the finches.

Darwin's Finches & Adaptive Radiation



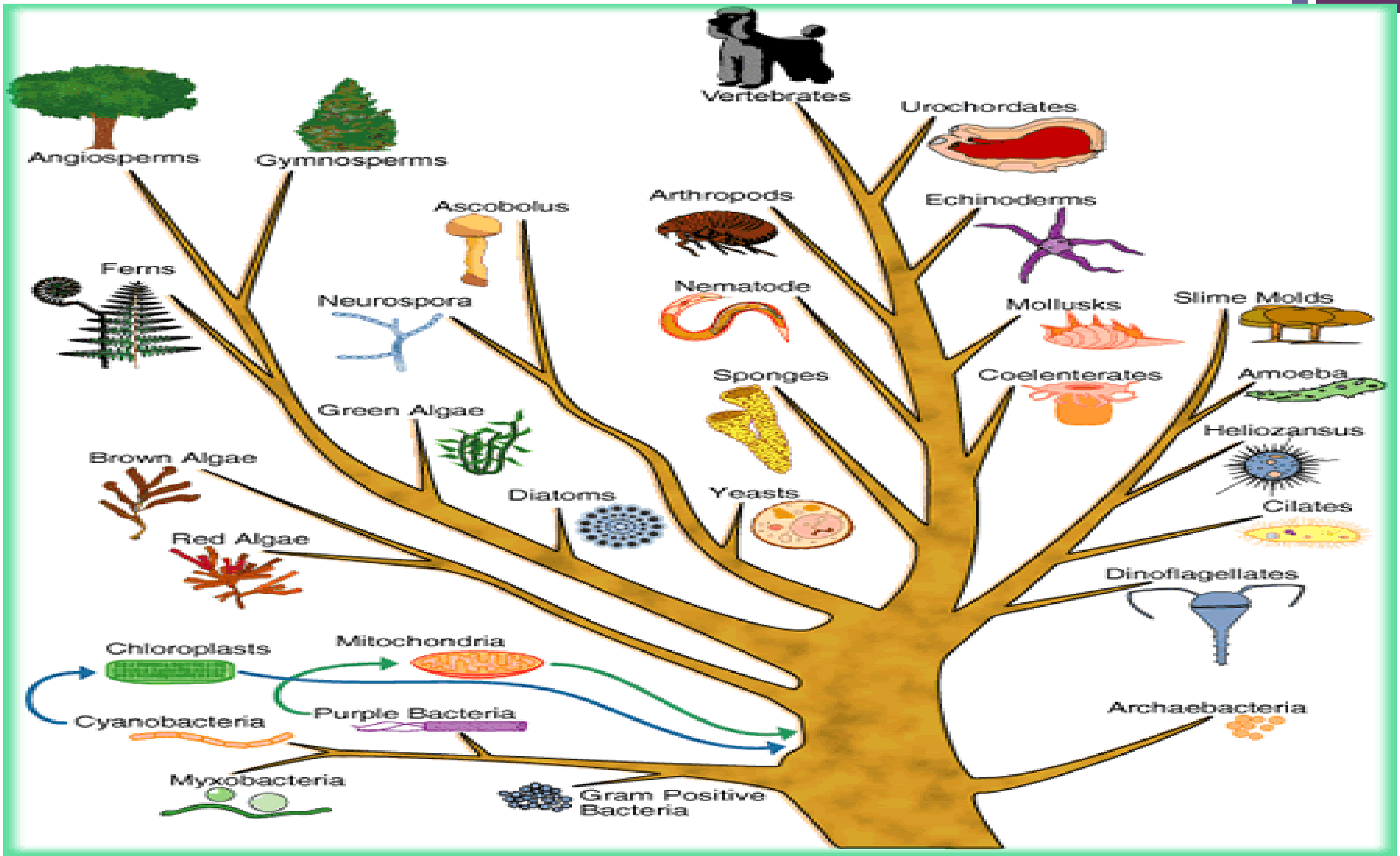
Adaptive Radiation II

- Islands are a great environment for studying speciation because they give organisms the opportunity to change in response to new environmental conditions.
- Each island has different physical characteristics which help the process of adaptive radiation to occur.
- Adaptive radiation can also occur after mass extinction events in the Earth's history.

Divergent & Convergent Evolution

- **Divergent evolution**
  - Pattern of evolution in which species that were once similar diverge or become increasingly different from each other
  - Divergent evolution occurs when populations change as they adapt to different environmental conditions.
- **Convergent evolution**
  - Two unrelated species develop similar traits after developing independently in similar environmental conditions.

Phylogenetic Tree shows Divergence



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Co-evolution

- Coevolution occurs when organisms are linked with other organisms and gradually evolve together.Predators and prey, pollinators and plants, and parasites and hosts all influence each others evolution.
- Many plants rely on insects and birds to spread their pollen, this causes the plants to change themselves in ways that will entice these organisms to come to the plants.
- Examples:
  - The constant threat of predators can cause prey species to evolve faster legs, stronger shells, better camouflage, more effective poisons, etc.
  - The struggle between parasites and hosts is another example of coevolution. Parasites such as bacteria, protozoa, fungi, algae, plants and animals consume their host in order to survive. Thus, the hosts must develop ways to defend themselves against the predator.

Co-evolution Examples

Pace of Evolution

- Two models attempt to explain the rate of evolutionary change
  - **Gradualism**
    - change occurs within a particular lineage at a slow and steady pace. According to this model, big changes occur from the accumulation of many small changes.
  - **Punctuated equilibrium**
    - evolutionary change consists of long periods of stasis (equilibrium) or no change interrupted by periods of rapid divergence or change.

21.4 Origins of Life on Earth

- Scientists have identified and classified around 1,400,000 species of life on Earth.
- It is estimated that there may be as many as 30,000,000 species of organisms on this planet.
- Because of this large variety of life, scientists are very interested in how life began on our planet in the first place.
- Science has proposed several theories and hypotheses concerning the origins of life on Earth. These are based on available evidence.

Chemical Evolution

- The most common scientific theory on the origin of life.
- Aleksander Oparin and John Haldane hypothesized that organic compounds, the building blocks of life could form spontaneously from the simple inorganic compounds present on Earth.
- **Oparin-Haldane theory**.
  - Early Earth had a reducing atmosphere which contained little or no oxygen, hydrogen, ammonia, methane gas, and water vapor.
  - These gases condensed to form pools on the Earth's surface which were called the **primordial soup**. Energy sources such as lightning and ultraviolet radiation caused the inorganic compounds in this "soup" to combine and form organic compounds. These organic compounds combined with each other and evolved over time to create an early form of life. From this early form of life, a common ancestor, all life evolved.

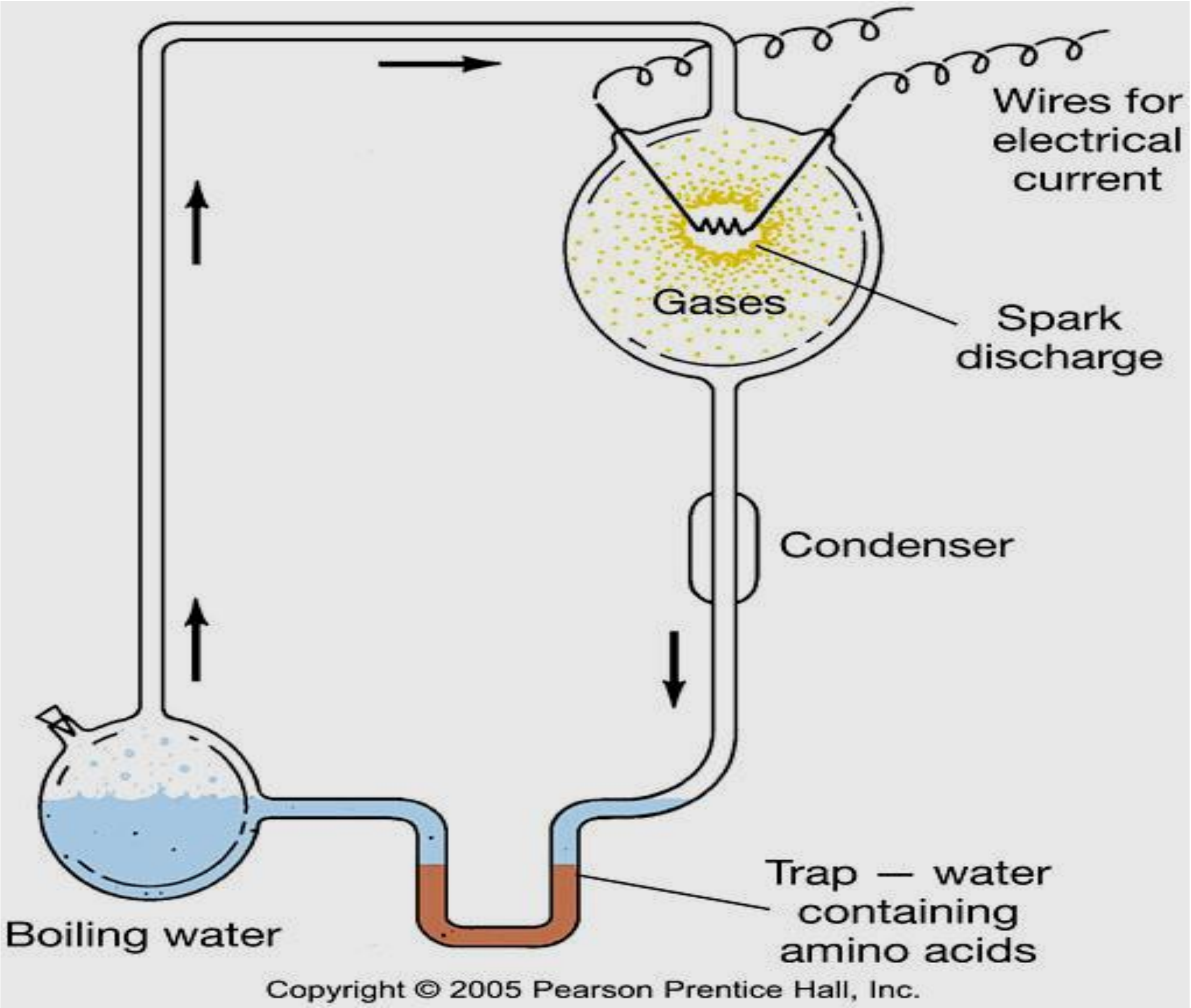
Stanley Miller's Experiment

- Stanley Miller performed an experiment to test the Oparin-Haldane theory. Miller created a system, (Fig. 21.21, P. 727) that contained an atmosphere similar to that of the early Earth.

- It contained methane, ammonia, hydrogen, and water vapuor. It also contained a source of energy in the form of electrical sparks to simulate lightning. After a week, Miller collected samples from the system which contained several organic compounds such as amino acids. Since organic compounds such as amino acids are the building blocks of living things, this showed that life could indeed have began in this manner.

- Further experiments such as Miller's have shown that organic molecules such as amino acids, nucleotides, and sugars (carbohydrates) can develop under these types of conditions.

The Set-up



Wires for electrical current
Gases
Spark discharge
Condenser
Boiling water
Trap — water containing amino acids
Copyright © 2005 Pearson Prentice Hall, Inc.

Molecules to Life?? How??

- Three ways that this could have occurred:
  1. Amino acids might have polymerized spontaneously to form a special kind of self- replicating protein.
  2. RNA might have self-replicated on its own.
  3. Both proteins and RNA might have developed at the same time inside some form of clay structure.

- The above ways resulted in some form of **protocell**. This protocell continued to evolve by the process of natural selection, becoming the first living cell from which all life developed

The Other Explanations

- **The Panspermia Theory**
  - Life originated elsewhere in the universe and migrated to our planet. This migration could have been performed by intelligent beings (aliens) or may have occurred by chance (meteorites)

- **The GAIA Theory**
  - proposed by Dr. James Lovelock, views the Earth as a living superorganism which is called Gaia. The Earth (Gaia) is maintained and regulated by the life which exists on its surface. It is the Earth's systems that keep themselves in balance by regulating the atmosphere and temperature of the planet. Life on the planet originated with chemical evolution, but once the planet became alive the Earth regulated the life on it.

More Explanations

- **The Intelligent Design Theory**
  - This theory suggests that life and the mechanisms which support it are too complex to have evolved by chance. Therefore, life must have been directed by some form of supernatural intelligence (eg. GOD).

Early Forms of Life

- Scientists believe that the first cell was a simple prokaryotic bacteria with no nucleus or organelles.
- The **heterotroph hypothesis** suggests that these first organisms were heterotrophs which could not make their own food. Therefore, they must have fed on the organic compounds in the primordial soup.
- Eventually most of the organic compounds became used up and therefore the bacteria which existed reverted to eating each other. However, as food became scarce, some of the bacteria began to manufacture their own food through the process of photosynthesis.

The First Bacteria

- The photosynthetic bacteria oxygen was produced as a waste material and began to accumulate in the atmosphere. The atmosphere eventually became an **oxidizing atmosphere**. As oxygen accumulated in the atmosphere, the first aerobic (oxygen-breathing) bacteria developed.

- The aerobic and anaerobic bacteria evolved by natural selection and eventually the first eukaryotic cells were formed, these cells contained a nucleus. Over billions of years of evolution, these cells became more advanced by forming internal organelles such as mitochondria, chloroplast. which performed specific jobs inside the organism.

+ Symbiogenesis

- Developed by the biologist Lynn Margulis
- Explains the development of eukaryotic cells.
- Development of a eukaryotic cell and its organelles could be a result of a process called **symbiogenesis**, the creation of new species through symbiosis.
- This theory is called **Serial Endosymbiosis Theory** (SET).

Serial Endosymbiosis

- Millions of years ago an anaerobic bacteria swallowed an aerobic bacteria. These bacteria then entered into a form of mutualistic relationship.
- The host anaerobic bacteria gained the benefit of being able to breathe oxygen while the guest aerobic bacteria obtained protection from a harsh environment.
- Over time, the guest bacteria developed into a mitochondria. Other swallowed bacteria developed into chloroplasts. As more organelles developed inside the bacteria, eventually a eukaryotic cell was formed

Endosymbiotic Hypothesis for the Origin of Mitochondria and Chloroplasts