Name: _____ Date: _____ Period: _____

Unit 1, Part 1 Notes – Evolution Basics & Types of Natural Selection
AP Biology, 2018-2019

A. What is biology and what are the characteristics of life?

Biology is defined as the study of living things. The **characteristics of life** are the traits that must be shown to be considered a living thing (i.e. an "organism"). The characteristics of life agreed upon by biologists are given below.

- All living things are made of **cells.** Some organisms only have one cell (ex: bacteria) and some have many (ex: animals)
- All living things use **DNA** as their genetic code. DNA is a molecule found in cells. Its full name is deoxyribonucleic acid, and it contains the instructions for particular traits (ex: eye color, height). It is considered a "hereditary" molecule because it can be passed down to offspring.
- All living organisms **use energy** to fuel their cellular reactions. For example, humans eat energy-rich foods to power the reactions that occur within their muscles during exercise.
- All living things **grow and develop.** For example, a tiny seed sprouts and grows / develops into a mature tree.
- All living things **respond to their environment**. For example, deer run away when presented with a predator stimulus. **External stimuli** (ex: the deer / predator example above) are outside the organism's body, whereas **internal stimuli** are within the organism's body. For example, if a human's body temperature gets too high (i.e. an internal stimulus), the body responds by sweating.
- All living things maintain **homeostasis,** or stable internal conditions, within their bodies. For example, human body temperature, blood sugar level, and blood water level are all kept within a particular stable range.
- Groups of organisms (living things) change over generations. This process of gradual change within a group of organisms is called **evolution**. Individuals cannot evolve because they cannot change the traits that are determined by their DNA.

B. What is evolution?

1. **Evolution** is defined as a change over time in the frequency of particular traits within a population. In other words, evolution is a change in the amount of individuals displaying a particular inherited trait over several generations. For example, if a population of humans starts with 50% tall members and 50% short members but after several generations has 75% tall members and 25% short members, that population has evolved. Typically changes in the frequencies of traits within a population are related to changes in the environment. We will learn more about this later…

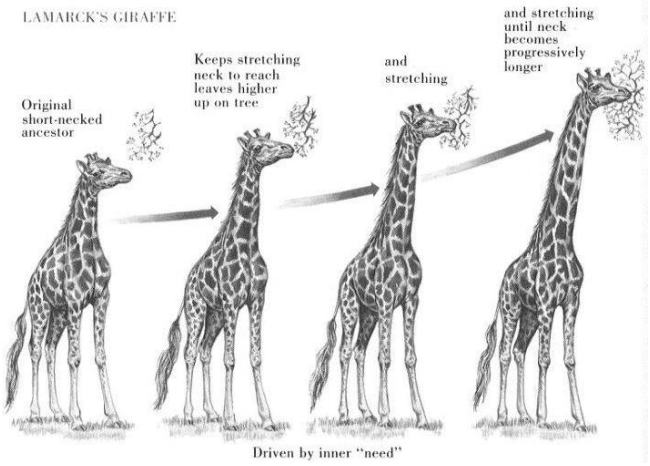
C. Which scientists helped develop our current understanding of evolution?

1. James Hutton
   a. He was the first scientists to propose that Earth is millions, not thousands, of years old. (Now we know that it is actually billions of years old!)
   b. He developed the theory of **gradualism.** The theory of gradualism states that profound (i.e. extreme) change is the cumulative result of slow but continuous processes (Note: his idea of gradualism was mostly theoretical; the first scientist to APPLY the theory of gradualism to real observable phenomena was Charles Lyell – see below)

2. Charles Lyell
   a. He was a geologist that developed the theory of **uniformitarianism,** which is based off of Hutton's theory of gradualism. Uniformitarianism argues that geological processes happened slowly and constantly to shape the Earth's surface in major ways (ex: erosion in the Colorado river eventually created the Grand Canyon)

Note: Hutton and Lyell's work gave rise to the question: If earth can change, why can't slow processes over long periods of time also produce changes in groups of living organisms?

3. Jean Baptiste Lamarck
   a. He was one of first scientists to suggest "life has changed over time."
   b. He developed the theory of **"Use and disuse",** which claims that body parts that get used become larger and stronger and unused parts become smaller.
   c. He also developed the theory of **"inheritance of acquired characteristics",** which claims that modifications acquired during the life of an organism can be passed to offspring.
   d. Lamarck used his two theories (use and disuse / inheritance of acquired characteristics) to explain why modern giraffes have long necks. He argued that ancient giraffes stretched their necks to reach food high in the trees, which resulted in permanent lengthening of their necks. They were able to pass these longer necks down to their babies. Over time, generations of giraffes stretched their necks more and more to reach higher food and passed these longer necks down, resulting in modern giraffes who have extremely long necks.



   e. Modern scientists argue that any "acquired characteristics" an organism gains during its lifetime as a result of its actions cannot be passed down to offspring because these traits are not controlled directly by the DNA that is passed from parents to offspring. For example, a man who lifts weights and gains more muscle mass will not have babies that have large muscles at birth (i.e. body builder babies!).

4. Thomas Malthus
   a. He proposed the idea that if resources are scarce, some organisms will not survive.

(Note: Information about the various scientists that contributed to the current understanding of evolution is NOT featured in the AP Biology curriculum, nor will it be assessed on our DBA or the unit test. However, it is important to be familiar with the idea that scientific theories often change over time as more data becomes available)

D. How did Charles Darwin incorporate the work of these scientists in his theory of evolution?

1. The Development of Darwin's Theory
   a. Darwin journeyed on a ship called the Beagle from 1831 to 1836 to the Galapagos Islands to observe organisms and spent years studying/writing after his return to develop his theory of evolution and its cause, natural selection.
   b. He wrote a book about his theory entitled *On the Origin of Species by Means of Natural Selection*, which was published 1859.
   c. At first his book and theory were rejected and ridiculed, but evidence for evolution has been/continues to be extensive.
   d. Evolution is considered by many modern scientists to be the "universal theory linking all biological concepts"

(Note: Information about the development of Darwin's theory of evolution is NOT featured in the AP Biology curriculum, nor will it be assessed on our DBA or the unit test.)

2. Darwin's Theory
   a. Darwin's theory of natural selection can be broken down into several parts.
      1. **There is variation in traits.** For example, some beetles are green and some beetles are brown (see series of images to the right)

2. **There is differential survival and reproduction**. In other words, because there are limited resources in the environment, not all organisms will be able to survive until reproductive age or reproduce to their full potential (i.e. have a lot of babies!). In this example, green beetles tend to get eaten by birds, so brown beetles are more likely to survive and reproduce.
3. **There is heredity**. Beetle color is a genetic trait, meaning it is controlled by DNA that is passed from parents to offspring. Therefore, the surviving brown beetles will have brown babies.

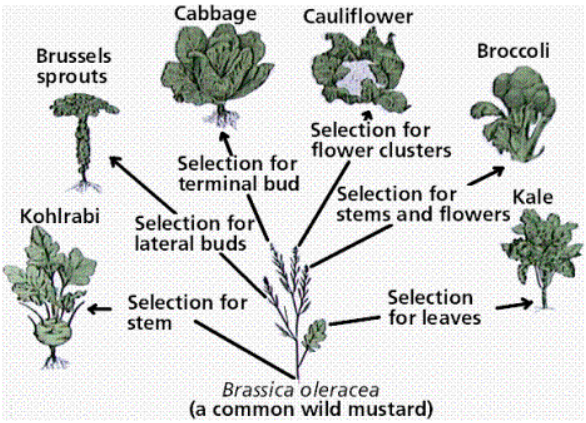
The end result of natural selection in this example is that the more advantageous trait, brown coloration, which allows the beetle to have more offspring, becomes more common in the population. If this process continues, eventually, all individuals in the population will be brown.

Several related vocabulary terms (including a condensed definition of natural selection) defined below.
-**Adaptations** are characteristics that helps an organism be more suited to its environment and thus better able to survive and reproduce. In other words, an adaptation is a genetic variation (an inherited trait) that provides an advantage to an organism in a particular environment. For example, brown beetle color is considered an adaptation in the environment described above. This may be because the ground is sandy and brown beetles are better able than green beetles to camouflage, so they are more likely to survive and reproduce. However, brown beetle color would not be an adaptation in a grassy environment because the birds will be better able to see the brown beetles than the green beetles. In summary, a trait that is considered an adaptation in one environment may not be an adaptation in another environment.
-**Natural Selection** occurs when individuals that are best suited to their environment survive and reproduce, resulting in inherited favorable/successful characteristics (i.e. adaptations) becoming more common in later generations. Remember, evolution is defined as a change over time in the frequency of particular traits within a population. Therefore, natural selection, or the environment "selecting" particular traits causes evolution.
-**Fitness** is defined as a measure of organism's reproductive success. In other words, an organism is considered fit when it can survive AND make a large reproductive contribution to the next generation (i.e. a greater number of offspring that carry its genes). Therefore, the old phrase "survival of the fittest," should really be "survival and reproduction of the fittest."
-It is VERY IMPORTANT to remember that **populations evolve, not individuals** (an individual cannot change his/her genes, however the frequency of a particular gene in the population can change over several generations)

3. Myths about evolution that are not supported by Darwin's theory and experimental evidence
   a. Evolution gives organisms the traits that they need. In reality, natural selection can only "select for" gene varieties that already exist; it cannot create entirely new traits out of thin air. The only thing that can create new gene varieties (ex: blue beetle color) for natural selection to act upon is a **mutation**. A mutation is a change in the DNA sequence that results in a change in the physical trait or **phenotype.**
   b. There is a set of "best traits" that will be favorable in any environment. In reality, a trait that is beneficial in one environment may be detrimental in another.
   c. Evolution is a "theory" so it's a "hunch" or "opinion." In reality, a scientific theory is supported by a large body of evidence. Check out the pieces of evidence to support evolution given below!

E. Evidence for Darwin's Theory of Evolution

1. Artificial Selection
   a. **Artificial selection** occurs when humans (not the environment) choose which organisms will reproduce based on their "useful traits" and encourage breeding among these organisms. This results in a higher percentage of organisms with useful traits in the next generation.
   b. For example, humans have bred Bassett hounds to be short and long for burrowing by selecting the shortest and longest male and female Bassett hounds to reproduce with one another. Additionally, humans bred varieties of a ~~wild~~



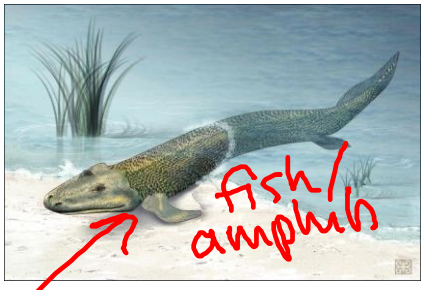
mustard plant with particular characteristics to create many varieties of vegetables (ex: Brussels sprouts, cabbage, broccoli). For example, farmers selected mustard plants with the largest leaves to reproduce for many generations to eventually produce the vegetable Kale (see image below).

c. Why is this considered evidence for evolution? – The success of artificial selection raises the question: If humans can select for higher percentages of certain traits in a population of organisms, then why can't nature/the environment do the same thing?

Image: Artificial Selection To Create Various Vegetables from A Wild Mustard Ancestor

2. The **fossil record** also shows changes in groups of organisms over time (AKA evolution!)

a. The fossil record has shown a sequence of changes in populations of organisms over time and allowed us to determine which types of organisms came first. The general sequence in the history of life deduced using the fossil record is given below.



i. Prokaryotes appear before eukaryotes. In other words, organisms containing cells without a nucleus appeared before cells with a nucleus.

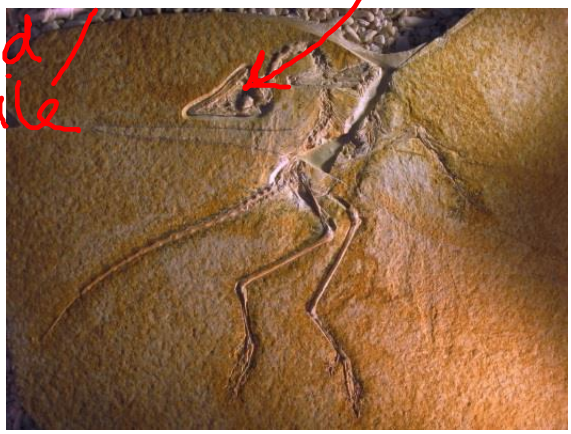
ii. Single celled organisms (ex: bacteria) appear before multicellular organisms (ex: animals).

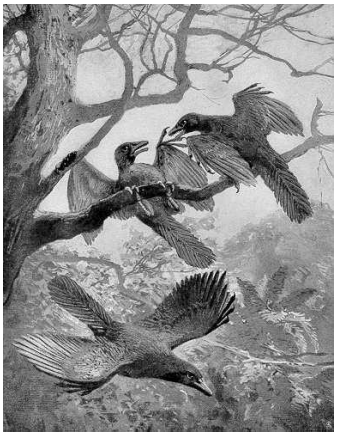
iii. Invertebrates (organisms without a backbone) appear before vertebrates (organisms with a backbone).

iv. The five main groups of vertebrates appeared in the following sequence: fish → amphibians → reptiles → birds → mammals.

b. In the fossil record, there are many **transitional fossils**, which are organisms with intermediate characteristics between two species. Transitional fossils are evidence of a change in the species from an ancestral form to a different modern form.

Example transitional fossils include *Tik taalik*, which has both fish and amphibian characteristics and represents a transition from aquatic ancestors to modern terrestrial forms (see an artists' rendering of this organism to the right), and *Archeopteryx*, which has both reptilian and avian (bird) characteristics and represents a transition from reptile ancestors to modern birds (see images given below of the actual fossil specimen and an artists' rendering of this organism).



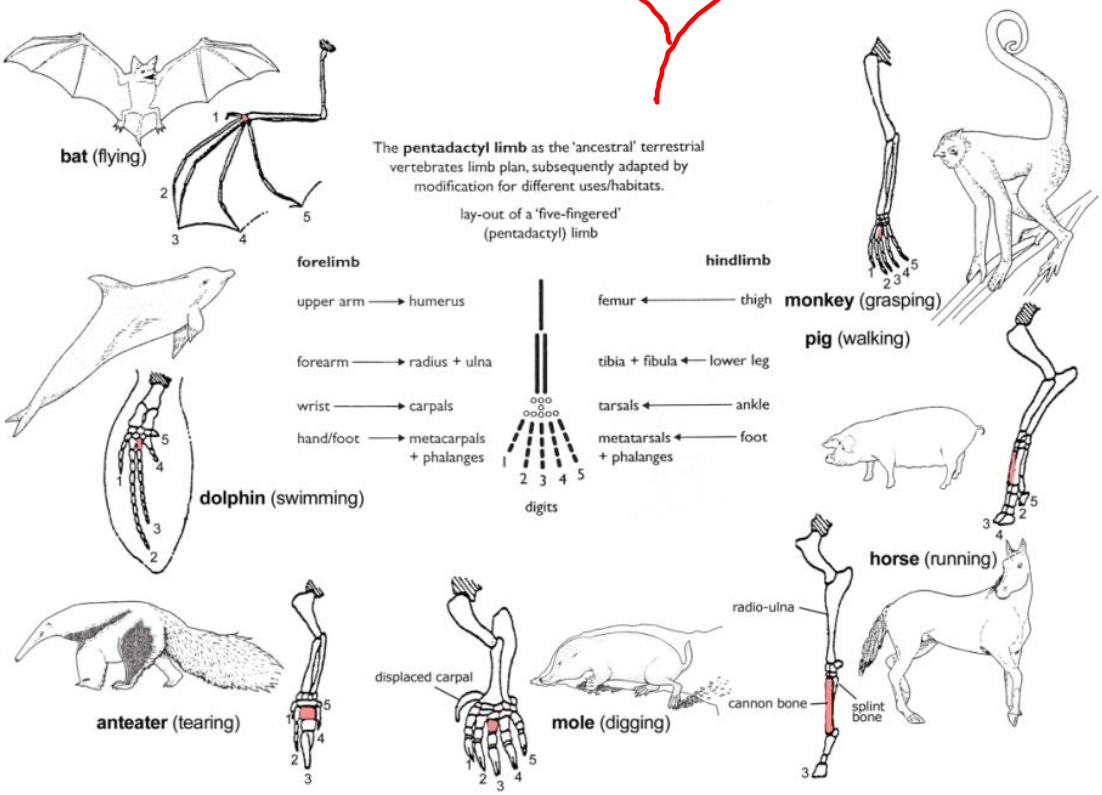


How do we determine the ages of fossils? Two methods are given below…

- **Relative dating** estimates the age of fossils based on their positions in layers of rocks, known as strata. Fossils found in lower strata were typically deposited first and are deemed to be older. By studying and comparing strata from all over the world we can learn which came first and which came next, but we need further evidence to ascertain the specific, or numerical, ages of fossils.
- **Absolute / Radiometric Dating** relies on the decay of radioactive atoms, such as uranium, potassium, rubidium and carbon within the fossil or rock surrounding the fossil. The percentage of "undecayed" vs. "decayed" atoms can tell you exactly how long ago an organism died.

3. **Comparative Anatomy** involves comparing the body parts of currently living species to determine their evolutionary relatedness.

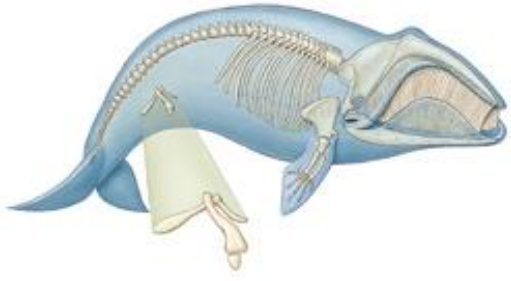
a. **Homologous structures** are body parts seen in different organisms that have a similar structure but not the same function as a result of different environments. These body parts are similar in structure because the organisms evolved from a common ancestor. For example, bat, dolphins, and monkeys all have the same forelimb bones because they evolved from a common mammalian ancestor (see image given on the next page). The bones have become different over time, however, because they are used for different purposes. For example, a bat's limb bones are thinner and lighter for flight, and a monkey's finger bones are modified for grasping objects. Homologous structures are considered evidence of **divergent evolution** which occurs when populations of an ancestral species branch apart / diverge from one another to become different species due to different environmental conditions.



b. **Analogous structures** are body parts seen in different organisms that have a similar structure because they have a similar function and environment. These body parts are not similar in structure due to common ancestry. For example, birds and butterflies have different ancestors but they both evolved wings for flight due to similar environmental requirements (see image given below). Analogous structures are considered evidence of **convergent evolution**, which occurs when unrelated species became more similar due to similar environments.

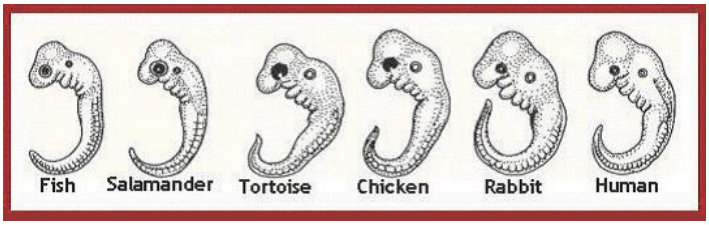
4. **Vestigial Organs**

a. Vestigial organs are remnants of structures that had functions in ancestors but are no longer essential or the function has changed. For example, whales evolved from a terrestrial ancestor with hind limbs. Their hind limbs once connected to a pelvic bone (i.e. hipbone). Once the terrestrial ancestor returned to the water, the hind limbs were lost and the pelvic bone became much smaller and disconnected



from any other bones. The presence of the whale pelvis is evidence that modern whales have changed / evolved from their ancestors (who presumably lived on land). The human tailbone and appendix are also examples of structures that are reduced in size and may have had a function in our ancestors but do not have a function today.

5. **Comparative Embryology**
   - **a.** Scientists have noted similar structures and developmental patterns in embryos of all vertebrates. For example, all vertebrate embryos have a tail and gill slits at some point in development (see image below). These similarities indicate that different vertebrate species may have had the same ancestor but became different due to different environments.
     Ex: Tail and gill slits found in all vertebrate embryos



6. **Molecular Biology**
   - **a.** DNA is found in all living organisms indicating that they share a common ancestor; various other molecules (ex: certain proteins) are also found in most living organisms
   - **b.** Scientists can compare DNA or protein sequences to determine how closely related organisms are to one another. Closely related species that shared a recent common ancestor have more similarities in their DNA or protein sequences than distantly related species that shared an ancient common ancestor. The picture below shows the protein sequences for Cytochrome C, a protein used in the process of cellular respiration for many organisms. Amino acids are the building blocks of proteins and are listed side-by-side for the various organisms included below. Note that humans and monkeys have more similarities in their protein sequences than humans and sharks, indicating that humans are more closely related to monkeys (and they share a more recent common ancestor than humans and sharks).

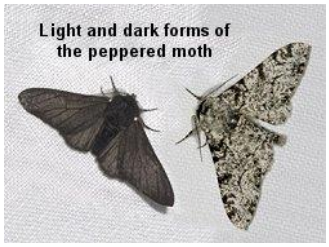
Cytochrome *c* Amino Acid Sequences

	Horse	Chicken	Tuna	Frog	Human	Shark	Turtle	Monkey	Rabbit
42	Gln	Gln	Gln	Gln	Gln	Gln	Gln	Gln	Gln
43	Ala	Ala	Ala	Ala	Ala	Ala	Ala	Ala	Ala
44	Pro	Glu	Glu	Ala	Pro	Gln	Glu	Pro	Tyr
46	Phe	Phe	Tyr	Phe	Tyr	Phe	Phe	Tyr	Pro
47	Thr	Ser	Ser	Ser	Ser	Ser	Ser	Ser	Ser
49	Thr	Thr	Thr	Thr	Thr	Thr	Thr	Thr	Thr
50	Asp	Asp	Asp	Asp	Ala	Asp	Asp	Ala	Asp
53	Lys	Lys	Lys	Lys	Lys	Lys	Lys	Lys	Lys
54	Asn	Asn	Ser	Asn	Asn	Ser	Asn	Asn	Asn
55	Lys	Lys	Lys	Lys	Lys	Lys	Lys	Lys	Lys
56	Gly	Gly	Gly	Gly	Gly	Gly	Gly	Gly	Gly
57	Ile	Ile	Ile	Ile	Ile	Ile	Ile	Ile	Ile
58	Thr	Thr	Val	Thr	Ile	Thr	Thr	Ile	Thr
60	Lys	Gly	Asn	Gly	Gly	Gln	Gly	Gly	Gly
61	Glu	Glu	Asn	Glu	Glu	Gln	Glu	Glu	Glu
62	Glu	Asp	Asp	Asp	Asp	Glu	Glu	Asp	Asp
63	Thr	Thr	Thr	Thr	Thr	Thr	Thr	Thr	Thr
64	Leu	Leu	Leu	Leu	Leu	Leu	Leu	Leu	Leu
65	Met	Met	Met	Met	Met	Arg	Met	Met	Met
66	Glu	Glu	Glu	Glu	Glu	Ile	Glu	Glu	Glu
100	Lys	Asp	Ser	Ser	Lys	Lys	Asp	Lys	Lys
101	Ala	Ala	Ala	Ala	Ala	Thr	Ala	Ala	Ala
102	Thr	Thr	Thr	Gly	Thr	Ala	Thr	Ala	Thr
103	Asn	Ser	Ser	Ser	Asn	Ala	Ser	Asn	Asn
104	Glu	Lys	—	Lys	Glu	Ser	Lys	Glu	Glu

7. Observable Evolution in Rapidly-Reproducing Species
   - **a.** The peppered moths in England are an example of observable evolution. There are two color variants in the peppered moth population, dark and light (pictured below). Initially, the light moths were more common in the population because they could camouflage with the light tree bark better and were less likely to be eaten by predators (i.e. birds). Over time, the frequency of dark moths increased as pollution and soot from the Industrial Revolution covered the trees and

allowed the dark moths to camouflage better. Once anti-pollution laws went into effect, the tree bark returned to its light color, and light moths again became more common.

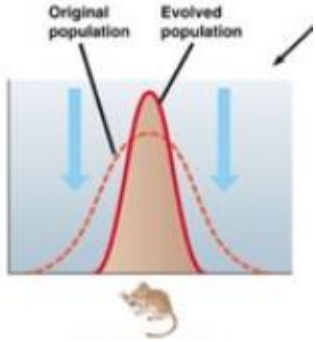
b. Another example of observable evolution is the evolution of antibiotic resistance in certain species of bacteria. We will investigate this example in class.



F. The Three Types of Natural Selection

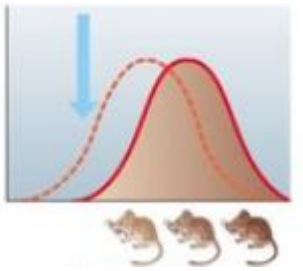
1. Stabilizing Selection

- Favors intermediate forms of a trait.
- Occurs in a stable environment
- Normal distribution "narrows".
- Example#1: Clutch size (# of eggs in a nest) may be a genetic trait in the mother Swiss Starling (a type of bird)
    - In nature, less than 4 or greater than 5 eggs presents a disadvantage ; 4-5 eggs (intermediate form of trait) results in the highest % survivorship in eggs, which means the gene form for 4-5 eggs in a clutch will become more common
- Example #2 (see image to the right): tan (not white or brown) mice blend into the sandy environment and are not eaten by predators; the tan mice survive and reproduce better, so tan becomes a more common trait in the next generation



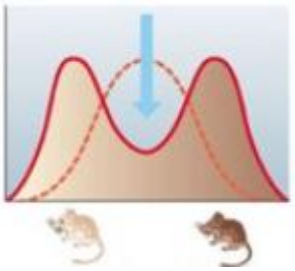
2. Directional Selection

- Favors ONE extreme form of a trait
- Example #1: Very large black bears survived periods of extreme cold better than medium sized or small bears, so large bears become more common during glacial periods
- Example #2 (see image to the right): white mice overheat in the summer months and may die; brown mice survive and reproduce better, so brown becomes a more common trait in the next generation.



3. Disruptive Selection

- Favors BOTH extreme forms of a trait
- Example #1: A population has individuals with either large beaks or small beaks, but few with the intermediate beak size (due to the difficulty of cracking either large or small seeds with a medium-sized beak)
- Example #2 (see image to the right): male white and brown mice perform more effective mating dances than tan mice and are more often chosen as mates, so white and brown become more common traits in the next generation



G. Sexual Selection

1. **Sexual selection** is a form of natural selection in which individuals with certain inherited characteristics are more likely than others to obtain mates.
    - Example #1: Physical traits that make a male seem more likely to produce healthy offspring (ex: large, colorful tail feathers in a male peacock) are more appealing to females. Therefore, females are more likely to choose males with these traits to reproduce, so we will see a higher percentage of these traits in the next generation, and they can become exaggerated over time. This type of sexual selection is called **female choice** or **intersexual selection** (selection between the sexes).

- Example #2: Physical traits that make a male better able to compete / fight with other males for access to females (ex: large antlers in elk) increase the likelihood of reproduction for that male. Therefore, we will see a higher percentage of these traits in the next generation, and they can become exaggerated over time. This type of sexual selection is called **male competition** or **intrasexual selection** (selection within one sex).

2. Sexual selection can cause **sexual dimorphism**, a difference between the two sexes in secondary sexual characteristics such as differences in size, color, ornamentation, and behavior. For example, male gorillas are often much larger than female gorillas because being large allows them to better compete with other males for access to females.

3. Sexual selection must be balanced with natural selection. Certain traits may make an organism more likely to reproduce but less likely to survive. For example, large, colorful tail feathers increase a male peacock's likelihood of reproducing but he has to survive long enough to reproduce to be considered "fit." Therefore, it is unlikely to see continued lengthening of male peacock tail feathers over future generations because males with these long feathers are more likely to be killed by predators before reaching reproductive age.

Notes Questions

For this notes packet, you do NOT need to do annotations because the questions below serve a similar purpose!

Vocabulary: Write the definition of each term below in your own words. Look it up from a second source if it doesn't make sense to you in the reading.

Evolution:

Adaptation:

Natural Selection:

Fitness:

Artificial Selection:

Transitional Fossils:

Homologous Structures:

Analogous Structures:

Vestigial Structures:

Practice Questions: *Answer the following questions thoroughly and accurately in complete sentences.*

1. Identify one problem with Lamarck's theory of use and disuse or his theory of the inheritance of acquired characteristics.

2. Why couldn't giraffes evolve in the way Lamarck claimed?

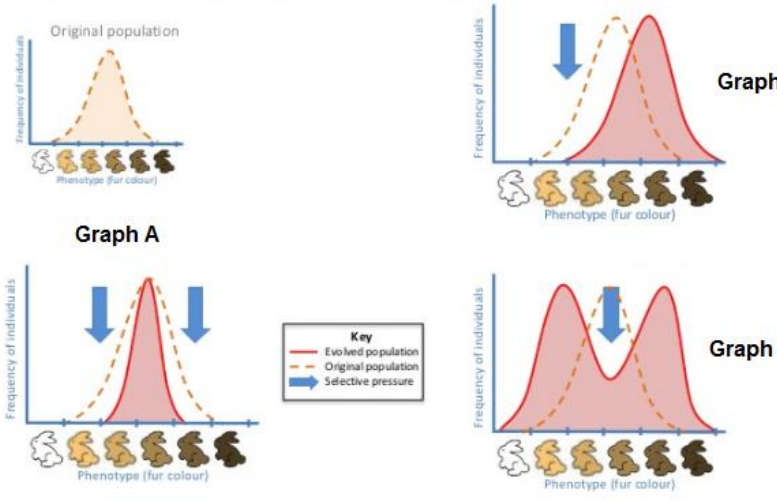
3. List the three essential parts of Darwin's theory of natural selection in your own words.

4. How is natural selection related to evolution?

5. How are mutations related to natural selection?

6. Explain why the following phrase is incomplete / incorrect: survival of the fittest.

7. Which of the following graphs (A,B, or C) best represents how a rabbit population will evolve after the population has been exposed to a predator that only eats light colored rabbits? Explain your choice.



8. Scientists noticed that over time, a population of birds evolved larger beaks. Describe one POSSIBLE environmental change that could have resulted in this trend.

9. Some individuals in a population of bacteria that infect humans (ex: strep throat bacteria) have a mutation that makes them resistant to antibiotics, the drugs used to kill bacteria in infected humans. The other members of the bacterial population do not have this mutation, and are easily killed by antibiotics. Initially, 10% of the bacterial population is antibiotic-resistant, while the other 90% is not resistant. How will the population of bacteria evolve over several generations if it is exposed to an antibiotic in its environment?

10. Explain how the fossilized species *Archaeopteryx* (i.e. a transitional fossil) provides evidence that modern birds may have evolved from ancient reptilian species.

11. Refer to the mouse coloration example in the notes. Explain what factor in the environment caused each type of selection and describe how the population change over time as a result?

	Factor in the environment that caused this selection?	**How did the population change?**
Stabilizing Selection		
Directional Selection		
Disruptive Selection		

12. How is intersexual selection different from intrasexual selection? Look up the meanings of “inter” and “intra” and use these in your response.

13. Why does sexual dimorphism occur? Use the term sexual selection in your response, and use the gorilla example from your notes.

14. Why might male peacock feathers stop evolving to be longer once they reach a particular length?

15. Explain why populations are the smallest units of life that can evolve (not organisms).

16. In **one sentence** for each, explain how each term contributes to natural selection.
    a. Variation among organisms

    b. Competition

    c. Adaptation

    d. Overproduction of offspring (more born than can survive)

    e. Limited environmental resources

    f. “Fitness”

17. In **one sentence** for each, explain how the following factors can affect the evolution of species:
    a. the environment

    b. mutations in genes

    c. fitness of organisms

    d. human activities

Self-Quiz - select questions from Campbell's Biology textbook. Use this resource as you see fit.

1. A trait is considered adaptive if it _____.
    a. arises by mutation
    b. contributes to fitness
    c. is passed to offspring
    d. occurs in fossils

2. _____ is the original source of all new alleles.
    a. mutation
    b. natural selection
    c. genetic drift
    d. evolution

3. Match modes of natural selection with their descriptions.

____ stabilizing a. eliminates extreme forms of a trait
____ directional b. eliminates midrange form of a trait
____ disruptive c. shifts allele frequency in one direction

4. In the early 1800s, biologist Jean-Baptiste Lamarck attempted to explain a mechanism for biological change. What mistake did Lamarck make (*now known as "acquired traits")*?
    a. He focused too much on external forces, failing to take into account internal mechanisms such as the effect of mutations.
    b. Lamarck incorrectly assumed species arose from periods of brief but intense catastrophes.
    c. He proposed that aspects of one's body can change due to use and disuse and that these changes are heritable.
    d. Lamarck tried to explain biological evolution as a function of chance – species changed over time but without discernable pattern due to the randomness of genetic change.

5. Which of these is not a vestigial structure found with the human anatomy?
    a. The coccyx of the pelvis
    b. The appendix
    c. The third molars
    d. The opposable thumb

6. Which of the following statements reflects aspects of Hutton and Lyell's ideas of gradualism that were incorporated into Darwin's theory of evolution?
    a. There is a struggle in populations for survival and reproduction.
    b. Natural selection acts on heritable variation.
    c. Small changes accumulated over cast spans of time can produce dramatic results.
    d. Homologous structures are found in organisms with a common ancestor.

7. Which of the following is *not* an observation or inference on which natural selection is based?
    a. There is heritable variable among individuals.
    b. Poorly adapted individuals never produce offspring.
    c. There is a struggle for limited resources, and only a fraction of offspring survive.
    d. Individuals whose characteristics are best suited to the environment generally leave more offpsing than those whose characteristics are less well-suited.
    e. Organisms interact with their own environments.

8. Analysis of forelimb anatomy of humans, bats, and whales shows that humans and bats have fairly similar skeletal structures, while whales have diverged considerably in the shapes and proportions of their bones. However, analysis of several genes in these species suggests that all three diverged from a common ancestor at about the same time .Which of the following is the best explanation for these data?
    a. Humans and bats evolved by natural selection, and whales evolved by Lamarckian mechanisms.
    b. Evolution of human and bat forelimbs was adaptive, but not for whales.
    c. Natural selection in an aquatic environment resulted in significant changes to whale forelimb anatomy.
    d. Genes mutate more rapidly in whales than in humans or bats.
    e. Whales are not properly defined as mammals.

9. In science, the term *theory* generally applies to an idea that
    a. Is a speculation lacking supportive observations or experiments.
    b. Attempts to explain many related phenomena.
    c. Is synonymous with what biologists mean by a hypothesis.
    d. Is considered a law of nature.
    e. All of the above.

10. Within a few weeks of treatment with the drug 3TC, a patient's HIV population consists entirely of 3TC-resistant viruses. How can this result best be explained?
    a. HIV has the ability to change its surface proteins and resist vaccines.
    b. The patient must have become reinfected with 3TC-resistant viruses.
    c. HIV began making drug-resistant versions of reverse transcriptase in response to the drug.
    d. A few drug-resistant viruses were present at the start of treatment, and natural selection increased their frequency.
    e. The drug caused the HIV RNA to change.

11. Which of the following pairs of structures is *least* likely to represent homology?
    a. The wings of a bat and the forelimbs of a human
    b. The hemoglobin of a baboon and that of a gorilla
    c. The mitochondria of a plant and those of an animal
    d. The wings of a bird and those of an insect
    e. The brain of a cat and that of a dog