SCIENCE: BIOLOGY
UNIT #4: DIVERSITY OF LIFE (4 WEEKS)

SYNOPSIS: Students compare the basis for evolutionary ideas beyond the fossil record and morphological comparisons, including molecular sequence data. The students examine the content of evolution and consider the merits and flaws of both sides of the argument. Students calculate the frequencies of genes in a population to determine if mechanisms of evolution are involved. Students analyze inherited characteristics of a species that has been displaced from its natural habitat to predict a possible new evolutionary pathway.

Enablers: Elementary - Evolution concepts include the relationship between organisms and the environment, parent and offspring, and an introduction to the fossil record and extinction. Middle school level - Concepts include biodiversity (as part of biomes) and speciation, further exploration of the fossil record and Earth history, changing environmental conditions (abiotic factors), natural selection and biological evolution.

STANDARDS

II. EVOLUTION

A. Mechanisms

6. The history of life on Earth is documented in the evolution of various species.
   a. present-day species descended from earlier, common ancestral species
   b. evolution is the descent with modification of different lineages from common ancestors
   c. recent molecular-sequence data as evidence for evolution generally, but not always, support earlier hypotheses regarding lineages of organisms based upon morphological comparisons
   d. modern ideas about evolution provide a natural explanation for the diversity of life on Earth as represented in the fossil record, in the similarities of existing species, and in modern molecular evidence
7. Modern theories are the synthesis of genetics and evolution, based on the historical perspectives of evolutionary theory. \

B. Diversity of Life

1. Speciation and biological classification are based on molecular evidence.
   a. modern ideas about evolution provide a natural explanation for the diversity of life on Earth as represented in the fossil record, in the similarities of existing species and in modern molecular evidence
   b. biological evolution explains the natural origins for the diversity of life
   c. present species descended from common ancestor
2. Variation of organisms within a species is due to population genetics and gene frequency.
   a. selection of individuals with a particular trait shifts to changing proportions of a trait in populations
   b. Hardy-Weinberg's laws are used to explain gene frequency patterns in a population
   c. populations evolve over time
   d. evolution is the consequence of the interactions of - -
      (1) the potential for a population to increase its numbers
      (2) the genetic variability of offspring due to mutation and recombination of genes
      (3) a finite supply of the resources required for life
      (4) the differential survival and reproduction of individuals with the specific phenotype
   e. technology allows access to real-time/authentic data to study population changes and growth in specific locations

LITERACY STANDARDS

RST.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

RST.10 By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

WHST.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

MOTIVATION	TEACHER NOTES
1. Teacher asks why it's important to track traits of organisms over time; students observe animal family tree interactive to see when and where new characteristics evolved. Teacher asks class to discuss the following statements – Evolution always moves from simple to complex *or* Evolution often favors the loss of complexity; small groups discuss one of the statements and list bullet points about their **discussion**. website - http://learn.genetics.utah.edu/content/variation/tracktraits/	1. **Discussion notes attached on page 7**
2. Students do a **web quest** to review the **geologic time scale**; students find answers to questions which are assigned and discuss with rest of class. Teacher shows video of Carl Sagan's – One Voice in a Cosmic Fugue part 2 about the development of life on the Cosmic Calendar and the Cambrian explosion. website - http://www.cotf.edu/ete/modules/msese/earthsysflr/geotime.html	2. **Geologic Time Scale Web quest attached on pages 8-9**
4. Teacher previews for students what the end of the unit authentic assessment will be and what students will be expected to do.	
5. Students write personal and academic goals	

TEACHING-LEARNING	TEACHER NOTES
1. Teacher introduces PPT "**Things You May Not Have Known about Evolution**"; students watch **PPT** to find reasons why a list of misconceptions is incorrect. (Students are divided into groups 1-7 and assigned to report on one misconception 1-7, then one 8-14. This arrangement will give each group time to write two responses.) Groups having the same two numbers meet and discuss answers; then groups jigsaw to report out and discuss all the misconceptions. (**II.A6; II.A6a,b**) **PPT website** – http://learn.genetics.utah.edu/content/variation/misconceptions	1. **Misconceptions: Things You May Not Have Known about Evolution attached on page 10**
2. Teacher shows video clip which shows how scientists know living things have changed over time; students write what evidence scientists have found and discuss. Teacher shows a video of the transitional fossils associated with whale evolution that help to explain "How We Know Evolution Happens"; students give specific examples of these fossils and explain why they are considered to be whale ancestors? (**II.A6; II.A6a,b,d**) (**II.B1a,c**) website - http://www.copernicusproject.ucr.edu/ssi/HSBiologyResources.htm (select video clip - Fossils and the Study of Evolution (3:30) video - http://www.pbs.org/wgbh/evolution/library/11/2/quicktime/e_s_3.html **-** How We Know Evolution Happens	
3. Teacher reminds students that according to the theory of evolution all things are related and asks how scientists would know that; students watch video PPT to make a list of four evidences and how they reveal similarities among species that result from common ancestry. (**II.A6; II.A6a,b,d**) (**II.B1a,c**) website – http://learn.genetics.utah.edu/content/variation/related/	

TEACHING-LEARNING	TEACHER NOTES

Teacher also shows a PPT Evolution at website; students take notes from teacher-selected frames. website - http://www.**copernicusproject.ucr**.edu/**ssi**/HSBiologyResources.htm

4. Teacher introduces activity: The; students take an imaginary fossil hunt. Following a script read by the teacher, students "find" (remove from envelope) paper "fossils" of some unknown creature, only a few at a time. Each time, they attempt to reconstruct the creature, and each time their interpretation tends to change as new pieces are "found". (**II.A6; II.A6a,b,d**) (**II.B1a,c**) activity website -http://www.indiana.edu/~ensiweb/lessons/gr.fs.fd.html)

5. Teacher explains Darwin's dilemma: The geologically-sudden appearance of dozens of major complex animal types in the fossil record without any trace of the gradual transitional steps Charles Darwin had predicted. Students watch a video which gives a description of the Cambrian explosion and traits of Cambrian life forms that existed hundreds millions years ago, which still amaze scientists today. Students discuss the issues presented in the video and consider the big question that the Cambrian Explosion poses - where does the massive increase in genetic information come from for the development of these new animal types? Students consider another possible view of the dilemma in video 2 by considering changes in protein structure. (**II.A6; II.A6a,b,d; II.B1a,c**)
video 1– 5Factors that Contribute to Gene Pool Changes Over Time from Discoverey Ed Streaming https://app.discoveryeducation.com/learn/videos/48129219-5daa-43e6-bcf2-03cd13f4b057?hasLocalHost=false (8:07)
video 2 - http://www.youtube.com/watch?v=h38Xi-Jz9yk (4:58)

6. Teacher explains that in recent decades Charles Darwin's explanation of evolution through natural selection has been challenged. Class does both parts of the activity A and B, with a follow-up class discussion for both A and B. (**II.A6; II.A6a,b,d; II.A7; II.B1a,c**)

A. Students watch a video to consider the evidence being used to explain the great diversity and complexity of life. Teacher discusses each video after viewing; students work in small groups to identify the key supporting points for each argument. Video title - Unlocking the Mystery of Life
video - http://www.youtube.com/watch?v=85q8y-z9Cyk – part 1(11:37) Explains Darwin's theory

B. In small groups students read one of **articles (attached);** compare findings and cite evidence in the article to support /contradict the theory; groups report out the information they found; teacher records arguments on chart paper as students highlight their own copy of the article and/or take notes. **(RST.9; RST.10; WHST.9)**

Class Discussion (see questions below.) Students analyze and critique the theory of Evolution by referring to the information presented in the videos/articles and through answering the following questions:

1. What factual information and statistical data is used to support its position? How convincing is the support?
2. What historical and / or societal references are used for support?
3. The Theory of Evolution is often on the defensive. Why do you think so?

After the class discussion each student assesses the usefulness of each source in answering the research question; integrates information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. **(WHST.8)**

TEACHER NOTES

6. Article -**Darwin's Theory -- A Theory In Crisis attached on page 11**
6. Article - **Darwin's Theory -- Slowly But Surely attached on pages 12-13**

7. Article – **Modern Evolutionary Synthesis attached on the page 14**

TEACHING-LEARNING	TEACHER NOTES
7. Teacher explains another evolution theory, **modern evolutionary synthesis**; students take notes. Students are reminded how the **irreducibly complex system** like the flagellum of a bacterial cell could not have evolved slowly, piece by piece and serves as a counter-example to evolution (students saw this presented in the T-L #6 video – part 2) (**II.A7**) 8. Teacher suggests students consider three questions about molecular sequence data and evolution; students copy the questions listed on 3 chart papers - What constitutes molecular evidence in terms of a look at origins for life? How does molecular evidence support evolution theory? What types of evidence has science gathered thus far?; students watch video of a lab experiment which demonstrates that a strain of yeast with a defective gene could use the human version of that gene to repair itself. Students discuss the possibility that we not only share a common genetic code with other organisms, but that we actually share specific genes, which is powerful evidence of our common ancestry. Students read and discuss article – The Common Genetic Code; students write comments to address the three questions; teacher records comments on chart papers as class discusses the questions. Students are encouraged to make comments related to the three questions as the unit work continues. (**II.Ac,d; II.B1a,b,c)** website – http://www.pbs.org/wgbh//evolution/library/04/4/l_044_02.html 9. Teacher introduces activity of the Darwinian approach to look at the morphology (form) of organisms and note more complex forms appear as time proceeds to the present. Students "take a trip" to the Greater Antilles to figure out how the *Anolis* lizards on the islands might have evolved. They identify patterns in biological data, such as morphological characters (physical features), habitat, and geographical distribution from which they form multiple evolutionary hypotheses to explain the patterns they observe. Students test their hypotheses using a provided phylogenetic tree/cladogram. (**II.A6; II.A6a,b,d**) Activity - Anolis Lizards of the Greater Antilles http://www.ucmp.berkeley.edu/education/lessons/anolis.html 10. Teacher discusses the investigation about evolution questions using online molecular databases; students are given three different animal species [available in the SWISS-PROT database] which they will be able to suggest which two species are most closely related, based on a comparison of the amino acid sequences of their beta hemoglobin. (**II.Ac,d; II.B1a)** website - http://www.indiana.edu/~ensiweb/lessons/p.tut.db.html 11. Teacher prepares students for the virtual activity for bacterial identification; students use science techniques used to identify different types of bacteria based on their DNA sequences. The techniques used in this lab are applicable in a wide variety of settings, including scientific research and forensic labs. (**II.Ac,d; II.B1a)** website – http://media.hhmi.org/biointeractive/vlabs/bacterial_id/index.html 12. Teacher discusses how "selection" changes proportions of a trait in populations; students take notes. Students watch audio PPT to understand the ingredients that drive evolution - variations, selection & time; students watch a video – "The Making of the Fittest, Got Lactase?" which describes how geneticists were able to date the origin of a mutation for lactose persistence by analyzing DNA. Class discusses how variations, selection and time were ingredients responsible for the co-evolution of lactose persistent genes within cultures of certain populations. (II.B2d, e) audio PPT - http://learn.genetics.utah.edu/index.html video – http://media.hhmi.org/fittest/Got_Lactase.html (14:52) 13. Teacher hands out cartoon- **Survival of the Sneakiest; in small groups students read cartoon and discuss how the content relates to biological fitness and sexual selection.**	12. Notes - **Changes to the Gene Pool: Microevolution attached on page 15**

TEACHING-LEARNING	TEACHER NOTES
Class shares ideas about the content presented. (II.B2a) cartoon: http://evolution.berkeley.edu/evolibrary/article/0_0_0/sneakermales_01 14. Teacher discusses **PPT** about **Hardy-Weinberg Principle**? and demonstrates sample problem; students take notes. Teacher emphasizes the list of conditions that cause evolution and explains that if all of these conditions are met at the same time, then there is no evolution occurring in a population. Teacher shows H-W Conditions animation to show how the conditions affect the population. (**II.B2a,b,c**) **PPT** - http://www.ursulinehs.org/powerpoint/Population_Genetics.ppt (intro HW frames 1-29) animation -http://nhscience.lonestar.edu/biol/hwe.html (this website also includes demo problems, sample problems, tutorial) 15. Teacher explains the activity - Population Genetics And Evolution and shows a video of a class doing the same activity students will do; students conduct the activity in three parts to study how the population can change. Class discusses the procedures for each part and what information students record. (**II.B2a,b,c**) Hardy-Weinberg video **-** http://www.pbs.org/wgbh/evolution/library/11/1/quicktime/e_m_2.html lab activity - http://www.education.com/study-help/article/laboratory-experiment-8-population-genetics/ (Note – students in the video used only 2 cards; but the lab says to use 4, like the number of genes contributed to gametes at the time of meiosis. But the activity does not take as long if students use 2 cards, and the data numbers will be smaller. Have students create a data table for each part of the activity.) 16. Video narrator shows students how to solve simple Hardy-Weinberg problems. He starts with a brief description of a gene pool and shows you how the formula is derived. He then shows you how to solve a couple of sample problems.Students watch video and follow each step and write what he is writing; teacher stops video after each step and asks questions. Students are given sample problems to solve. (**II.B2a,b,c**) video -http://www.youtube.com/watch?v=xPkOAnK20kw (11:08) sample problems, tutorial - http://nhscience.lonestar.edu/biol/hwe.html 17. Teacher can select one of the suggested activities regarding Hardy-Weinberg; students collect data and solve H-W problem which shows any changes in the population's gene frequencies. After completed, teacher asks - what does the Hardy-Weinberg Principle tells us about a population?; cla the p & q genes reveal and how the conditions impact the distribution and frequencies of the alleles. Goldfish Lab **-** http://evolution.about.com/od/teaching/a/hardy-weinberg-goldfish-lab.html **Fishy Frequencies activity - (attached**)	14. Notes – **Hardy-Weinberg Theorem attached on pages 16-19** 17. **Activity: Fishy Frequencies (attached on pages 20-22)**

TEACHER CLASSROOM ASSESSMENT	TEACHER NOTES
1. 2 pt. and 4 pt. response questions 2. Science Notebooks – includes students work on labs, activities, literacy standards 3. Quizzes 4. Out of class work – research	

TEACHER CLASSROOM ASSESSMENT	TEACHER NOTES
1. Unit Test	

AUTHENTIC ASSESSMENT	TEACHER NOTES

AUTHENTIC ASSESSMENT	TEACHER NOTES
1. An earthquake has struck in San Diego and the zoo has been destroyed. The animals have all escaped and are free to migrate outside the city limits and into the surrounding environment. A list of animals that have escaped is more than 650 species and subspecies; this list only includes animals that are very different from native species. The food and climate in California is different than the home of the animals. In order to survive the animal species must be able to adapt. Select an animal from the zoo's website and describe how this animal species will survive away from its natural habitat at the zoo and eventually establish a new evolutionary pathway. Describe characteristics this animal species already has which will enable it to get food, water, and mate(s); behave a certain way that protects it from climatic conditions, predators, and other species that compete for the same food and space; and have structural or functional modifications that will enhance how its body works. Explain how these features are of adaptive value to the species' survival. Describe at least five different types of adaptations (e.g., physical or structural, behavioral, physiological) and explain how these adaptations make it possible for this species to live in a different place and in a different way. Go to **San Diego Zoo – Wikipedia** for information about the animals. http://en.wikipedia.org/wiki/San_Diego_Zoo Go to exhibits and click on animals listed for information about each one. 2. Students evaluate their goals.	

In our ever-changing world, a naturally occurring genetic difference in an individual can become an **advantage** or a **fatal flaw** in the struggle for survival. Those who live to reproduce **pass their favorable genes to future generations**. Certain **characteristics become more or less prevalent over time** as the group as a whole evolves.

Exploring the animal family tree -- All animals alive on earth today are descended from a tiny, soft-bodied creature that lived in the sea over 600 million years ago. The descendants of this first animal have diversified and multiplied over millions of generations into a countless variety of species.

This simplified animal family tree (website visual) includes many of the more-recognizable animal groups (phyla), and it highlights several important events in animal evolution. The branch points represent single ancestral species that gave rise to multiple groups of descendants. The descendants share certain characteristics that were present in their common ancestor. Ancient traits that evolved near the base of the tree are shared by more animal phyla than are the traits that evolved closer to the tips of the branches.

Keep in mind that evolution is neither linear nor progressive. Look for traits that were lost in some groups, and traits that evolved more than once. Also note that even after hundreds of millions of years of evolution, many animals are still soft and squishy and live in the ocean.

MOTIVATION # 2 GEOLOGIC TIME SCALE - WEBQUEST

1. In order from oldest to present, what are the three eras of geologic time?
2. Which era do we live in?
3. When you were born, which era was it? (Answers may vary)
4. During which era did the first fish develop?
5. During which era did the first humans develop?
6. Which era is known as the "Age of the Dinosaur?"
7. Which era is known as the "Age of Mammals?"
8. Name the 11 (or 12) periods on the Geologic Time Scale, in order from oldest to present.

Paleozoic Era

9. When did the Paleozoic Era take place?
10. Where was Africa located during the Paleozoic Era?
11. Earth's greatest mass extinction (that we know about) took place at the end of the Paleozoic Era. What percent of Earth's species died off?

Mesozoic Era

12. Did cavemen live during the Mesozoic Era? Explain why or why not.
13. What did the South Pole look like during the Mesozoic Era? North Pole?
14. How did the Mesozoic end? List three hypotheses which may explain what happened at the end of the Mesozoic Era.
15. The three periods in the Mesozoic Era are the Cretaceous, Jurassic, and Triassic.

Choose one to answer questions 16,17,18.

Cretaceous Period

Jurassic Period

Triassic Period

16. **When** did this period take place?
17. Name five living things from this period. (your list can include plants, animals, or a combination of both)
18. **Where** have fossils from this period been found? (localities)

Cenozoic Era

19. Identify the time period covered by the Cenozoic.

20. Describe has happened during the Cenozoic in terms of
    a. Continents b. Climate c. Animals d. Humanity

Precambrian Eon

21. About how much of Earth's history took place during the Precambrian Eon?

22. From where and when do we find the earliest evidence of life on Earth?

23. How did life forms change before the end of the Precambrian Eon?

24. How did the atmosphere change before the end of the Precambrian?

TEACHING-LEARNING #1 MISCONCEPTIONS – THINGS YOU MAY NOT HAVE KNOWN ABOUT EVOLUTION

Use the following Website – http://learn.genetics.utah.edu/content/variation/misconceptions

Find reasons or evidence to prove that the following misconceptions are incorrect.

1. Evolution requires that you have to be the best to survive.

2. Evolution produces structures which are perfectly suited for their use.

3. Evolution produces completely new structures rather that modify existing structures.

4. Evolution is climbing the ladder to perfection.

5. Natural selection favors change.

6. Natural selection cannot eliminate harmful traits.

7. The genes of structures which organisms don't use will mutate and are eventually lost and the loss of the structure affects the organism's survival.

8. Evolution is a theory or a guess.

9. Evolution explains how life began.

10. Size is everything; more complex organisms have larger genomes.

11. Humans are the ultimate achievement of evolution.

12. Humans are more complex than mice.

13. Evolutionary change is linear.

Darwin's Theory of Evolution - A Theory In Crisis

Darwin's Theory of Evolution is a theory in crisis in light of the tremendous advances we've made in molecular biology, biochemistry and genetics over the past fifty years. We now know that there are in fact tens of thousands of **irreducibly complex systems** on the cellular level. Specified complexity pervades the microscopic biological world. Molecular biologist Michael Denton wrote, "Although the tiniest bacterial cells are incredibly small, weighing less than 10^{-12} grams, each is in effect a veritable micro-miniaturized factory containing thousands of exquisitely designed pieces of intricate molecular machinery, made up altogether of one hundred thousand million atoms, far more complicated than any machinery built by man and absolutely without parallel in the non-living world."

And we don't need a microscope to observe **irreducible complexity**. The eye, the ear and the heart are all examples of irreducible complexity, though they were not recognized as such in Darwin's day. Nevertheless, Darwin confessed, "To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree."

Darwin's Theory of Evolution - Slowly But Surely...

Darwin's Theory of Evolution is a slow gradual process. Darwin wrote, "…Natural selection acts only by taking advantage of slight successive variations; she can never take a great and sudden leap, but must advance by short and sure, though slow steps." Thus, Darwin conceded that, "If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down." Such a complex organ would be known as an "irreducibly complex system". An **irreducibly complex system** is one composed of multiple parts, all of which are necessary for the system to function. If even one part is missing, the entire system will fail to function. Every individual part is integral. Thus, such a system could not have evolved slowly, piece by piece. The **common mousetrap** is an everyday non-biological example of irreducible complexity. It is composed of five basic parts: a catch (to hold the bait), a powerful spring, a thin rod called "the hammer," a holding bar to secure the hammer in place, and a platform to mount the trap. If any one of these parts is missing, the mechanism will not work. Each individual part is integral. The mousetrap is irreducibly complex.

Of all these examples, the **flagellum** has been presented so often as a counter-example to evolution that it might well be considered the "poster child" of the modern anti-evolution movement. To anti-evolutionists, the high status of the flagellum reflects the supposed fact that it could not possibly have been produced by an evolutionary pathway.

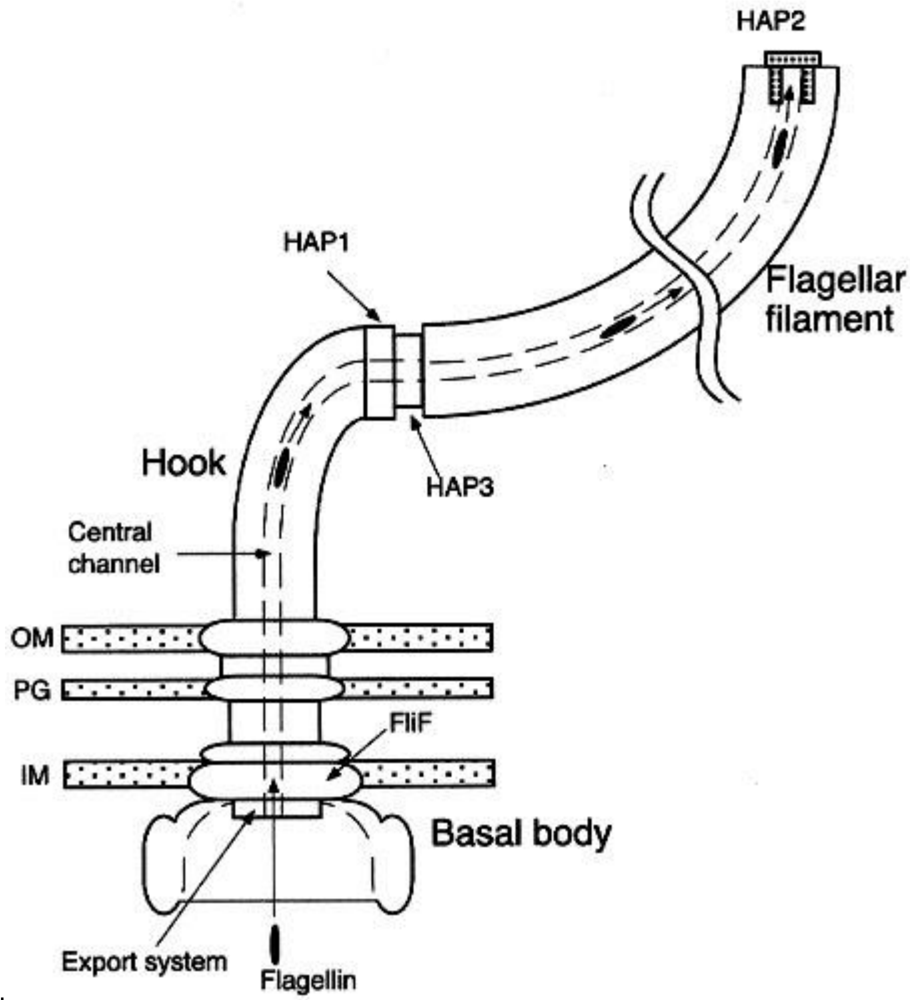


Figure 1: The eubacterial flagellum. The flagellum is an ion-powered rotary motor, anchored in the membranes surrounding the bacterial cell. This schematic diagram highlights the assembly process of the bacterial flagellar filament and the cap-filament complex. OM, outer membrane; PG, peptidoglycan layer; IM, cytoplasmic membrane (From Yonekura *et al* 2000).

TEACHING-LEARNING # 7: ARTICLE – MODERN EVOLUTIONARY SYNTHESIS

Modern Evolutionary Synthesis By Heather Scoville, About.com Guide

Definition:
The Theory of Evolution has itself evolved quite a bit since the time when Charles Darwin and Alfred Russel Wallace first came up with the theory. Much more data has been discovered and collected over the years that have only helped to enhance and sharpen the idea that species change over time.

The modern synthesis of the theory of evolution combines several different scientific disciplines and their overlapping findings. The original theory of evolution was based mostly upon the work of Naturalists. The modern synthesis has the benefit of many years of research in Genetics and Paleontology, among other various subjects under the Biology umbrella.

The actual modern synthesis is a collaboration of a large body of work from such celebrated scientists as J.B.S. Haldane, Ernst Mayr, and Theodosius Dobzhansky. While some current scientists assert that Evo-Devo is also a part of the modern synthesis, most agree it has so far played a very slight role in the overall synthesis.

While most of Darwin's ideas are still very much present in the modern evolutionary synthesis, there are some fundamental differences now that more data and new disciplines have been studied. This does not, in any way, take away from the importance of Darwin's contribution and, in fact, it only helps support most of the ideas Darwin put forth in his book *On the Origin of Species*. The three main differences between the original Theory of Evolution through Natural Selection proposed by Charles Darwin and the most current Modern Evolutionary Synthesis are as follows:

1. The modern synthesis recognizes several different possible mechanisms of evolution. Darwin's theory relied on natural selection as the only known mechanism. One of these different mechanisms, genetic drift, could even match the importance of natural selection in the overall view of evolution.
2. Modern synthesis asserts that characteristics are passed down from parents to offspring on parts of DNA called genes. Variation between individuals within a species is because of the presence of multiple alleles of a gene.
3. The modern synthesis of the Theory of Evolution hypothesizes that speciation is most likely due to the gradual accumulation of small changes or mutations at the gene level. In other words, microevolution leads to macroevolution.

Thanks to years of dedicated research by scientists across many disciplines, we now have a much better understanding of how evolution works and a more accurate picture of the change species undergo over a period of time. Even though different facets of evolutionary theory have changed, the fundamental ideas are still intact and just as relevant today as they were in the 1800s.

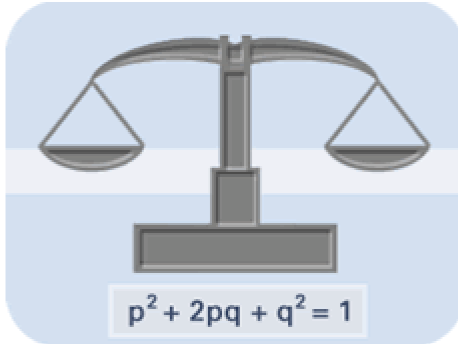
TEACHING-LEARNING # 12 NOTES - Changes to the Gene Pool: Microevolution

There can be many different forms of a gene. All of the versions of the genes in a population of a species are together called the gene pool. The gene pool does not always stay the same. Over generations, small changes in the amount of each type of gene can happen for a number of reasons.

- **Gene mutation**: An error during cell division can create a new type of gene. That new gene is a small part of the gene pool. It can be passed on to the next generation. If the new gene is useful, it might become a common part of the gene pool.
- **Gene flow:** if new individuals of the species move into or out of the region, it can affect the gene pool. For instance, the only people in North America were once Native Americans. Immigration from other parts of the world over the last several hundred years has changed the gene pool a lot.
- **Genetic drift:** The amount of each gene in a gene pool can change over time because of chance events. For instance, if a few individuals leave a population and establish a new one, by chance their gene pool may not have the same frequency of genes as in the population they left. For example, plants that get to islands as seeds stuck to the feet of birds or in their stomachs may not be typical of their species, but they become the gene pool on the island.
- **Natural selection**: Some genetic differences will improve the chance of survival of individuals that have them. For instance, hawks with large sharp talons may be more likely to survive than hawks with small talons. Since the surviving ones make the next generation, the genes for large talons are more likely to be passed on. Eventually, the gene pool shifts towards large talons.

Microevolution is changes in the gene pool of a population over time that result in changes to the varieties of individuals in a population. Examples of microevolution include bacteria that have become unaffected by antibiotics, or a change in a species' coloring or size. If the changes are over a very long time and are large enough that the population is no longer able to breed with other populations, it is considered a different species. This is called ***macroevolution***.

TEACHING-LEARNING #14 NOTES -HARDY-WEINBERG THEOREM



Hardy-Weinberg Theorem

The Hardy-Weinberg theorem is the principal that, in the absence of external pressures for change, the genetic makeup of an ideal population of randomly mating, sexually reproducing diploid organisms will remain the same, at what is called Hardy-Weinberg equilibrium.

Population genetics is the branch of genetics that studies the behavior of genes in populations. The two main subfields of population genetics are theoretical (or mathematical) population genetics, which uses formal analysis of the properties of ideal populations, and experimental population genetics, which examines the behavior of real genes in natural or laboratory populations.

Population genetics began as an attempt to extend Gregor Mendel's laws of inheritance to populations. In 1908 Godfrey H. Hardy, an English mathematician, and Wilhelm Weinberg, a German physician, each independently derived a description of the behavior of allele and genotype frequencies in an ideal population of randomly mating, sexually reproducing diploid organisms.

Their results, now termed the Hardy-Weinberg theorem, showed that the pattern of allele and genotype frequencies in such a population followed simple rules. They also showed that, in the absence of external pressures for change, the genetic makeup of a population will remain at an equilibrium.

Because evolution is change in a population over time, such a population is not evolving. Modern evolutionary theory is an outgrowth of the "New Synthesis" of R. A. Fisher, J. B. S. Haldane, and Sewell Wright, which was developed in the 1930's.

They examined the significance of various factors that cause evolution by examining the degree to which they cause deviations from the predictions of the Hardy-Weinberg theorem.

Predictions

The predictions of the Hardy-Weinberg theorem hold if the following assumptions are true:

1. The population is infinitely large.

2. There is no gene flow (movement of genes into or out of the population by migration of gametes or individuals).

3. There is no mutation (no new alleles are added to the population by mutation).

4. There is random mating (all genotypes have an equal chance of mating with all other genotypes).

5. All genotypes are equally fit (have an equal chance of surviving to reproduce).

Under this very restricted set of assumptions, the following two predictions are true:

1. Allele frequencies will not change from one generation to the next.

2. Genotype frequencies can be determined by a simple equation and will not change from one generation to the next.

The predictions of the Hardy-Weinberg theorem represent the working through of a simple set of algebraic equations and can be easily extended to more than two alleles of a gene. In fact, the results were so self-evident to the mathematician Hardy that he, at first, did not think the work was worth publishing.

If there are two alleles (A, a) for a gene present in the gene pool (all of the genes in all of the individuals of a population), let p = the frequency of the A allele andq= the frequency of the a allele.

As an example, if p = 0.4 (40 percent) and q = 0.6 (60 percent), then p + q = 1, since the two alleles are the only ones present, and the sum of the frequencies (or proportions) of all the alleles in a gene pool must equal one (or 100 percent).

The Hardy-Weinberg theorem states that at equilibrium the frequency of AA individuals will be p2 (equal to 0.16 in this example), the frequency of Aa individuals will be 2pq, or 0.48, and the frequency of aa individuals will be q2, or 0.36.

The basis of this equilibrium is that the individuals of one generation give rise to the next generation. Each diploid individual produces haploid gametes. An individual of genotype AA can make only a single type of gamete, carrying the A allele. Similarly, an individual of genotype aa can make only a gametes. An Aa individual, however, can make two types of gametes, A and a, with equal probability.

Each individual makes an equal contribution of gametes, as all individuals are equally fit, and there is random mating. Each AA individual will contribute twice as many A gametes as each Aa individual. The frequency of A gametes is equal to the frequency of A alleles in the gene pool of the parents.

The next generation is formed by gametes pairing at random (independent of the allele they carry). The likelihood of an egg joining with a sperm is the frequency of one multiplied by the frequency of the other.

AA individuals are formed when an A sperm joins an A egg; the likelihood of this occurrence is $p \times p = p2$
(that is, $0.4 \times 0.4 = 0.16$ in the first example). In the same fashion, the likelihood of forming an aa individual is
$q2 = 0.36$. The likelihood of an A egg joining an a sperm is pq, as is the likelihood of an a egg joining an A sperm; therefore, the total likelihood of forming an Aa individual is $2pq = 0.48$.

If one now calculates the allele frequencies (and hence the frequencies of the gamete types) for this generation, they are the same as before: The frequency of the Aallele is
$p = (2p2 + 2pq)/2$
(in the example $(0.32 + 0.48) \div 2 = 0.4$), and the frequency of the a allele is $q = (1 - p) = 0.6$. The population remains at equilibrium, and neither allele nor genotype frequencies change from one generation to the next.

The Real World

The Hardy-Weinberg theorem is a mathematical model of the behavior of ideal organisms in an ideal world. The real world, however, does not approximate these conditions very well. It is important to examine each of the five assumptions made in the model to understand their consequences and how closely they approximate the real world.

The first assumption is infinitely large population size, which can never be true in the real world, as all real populations are finite. In a small population, chance effects on mating success over many generations can alter allele frequencies. This effect is called genetic drift.

If the number of breeding adults is small enough, some genotypes will not get a chance to mate with one another, even if mate choice does not depend on genotype. As a result, the genotype ratios of the off spring would be different from those of the parents. In this case, however, the gene pool of the next generation is determined by those genotypes, and the change in allele frequencies is perpetuated.

If it goes on long enough, it is likely that some alleles will be lost from the population, because a rare allele has a greater chance of not being included. Once an allele is lost, it cannot be regained.

How long this process takes is a function of population size. In general, the number of generations it would take to lose an allele by drift is about equal to the number of individuals in the population.

Many natural populations are quite large (thousands of individuals), so that the effects of drift are not significant. Some populations, however, especially of endangered species, are very small: A number of plant species are so rare that they consist of a single population with less than one hundred individuals.

The second assumption is that there is no gene flow, or movement of genotypes into or out of the population. Individuals that leave a population do not contribute to the next generation.

If one genotype leaves more frequently than another, the allele frequencies will not equal those of the previous generation. If incoming individuals come from a population with different allele frequencies, they also alter the allele frequencies of the gene pool.

The third assumption concerns mutations. A mutation is a change in the deoxyribo nucleic acid (DNA) sequence of a gene—that is, the creation of a new allele. This process occurs in all natural populations, but new mutations for a particular gene occur in about 1 of 10,000 to 100,000 individuals per generation.

Therefore, mutations do not, in themselves, play much part in determining allele or genotype frequencies. Mutation, however, is the ultimate source of all new alleles and provides the variability on which evolution depends.

The fourth assumption is that there is random mating among all individuals. A common limitation on random mating in plants is inbreeding, the tendency to mate with a relative.

Because plants have a limited ability to move, and pollinators may not carry pollen very far, the plants in a population tend to mate with nearby individuals, which are often relatives. Such individuals tend to share alleles more often than the population at large.

The final assumption is that all genotypes are equally fit. Considerable debate has focused on the question of whether two alleles or genotypes are ever equally fit. Many alleles do confer differences in fitness; it is through these variations in fitness that natural selection operates. Newer techniques of molecular biology have revealed many differences in DNA sequences that appear to have no discernible effects on fitness.

As the cornerstone of population genetics, the Hardy-Weinberg theorem pervades evolutionary thinking. The advent of techniques to examine genetic variation in natural populations has been responsible for a great resurgence of interest in evolutionary questions. One can now test directly many of the central aspects of evolutionary theory.

In some cases, notably the discovery of the large amount of genetic variation in most natural populations, evolutionary biologists have been forced to reassess the significance of natural selection compared with other forces for evolutionary change.

Fishy Frequencies: A Hardy-Weinberg Population Genetics Simulation

Introduction:

Understanding natural selection can be confusing and difficult. People often think that animals consciously adapt to their environments - that the peppered moth can change its color, the giraffe can permanently stretch its neck, and the polar bear can turn itself white - all so that they can better survive in their environments.

In this lab you will use green and red m&m's to help further your understanding of natural selection and the role of genetics and gene frequencies in evolution.

Background: Facts about the "Fish"

- These little fish are the natural prey of the terrible fish-eating sharks - YOU!
- Fish come with two phenotypes – green and red:
  - green: this is a recessive trait (ff)
  - red: this is a dominant trait (F_)
- **In the first simulatio**n, you, the terrible fish-eating sharks, will randomly eat whatever color fish you first come in contact with. (There will be no selection.)
- **In the second simulatio**n, you will prefer to eat the green fish (these fish taste yummy and are easy to catch) you will eat ONLY green fish unless none are available in which case you resort to eating red fish in order to stay alive (the red fish taste salty, are sneaky and hard to catch).
- New fish are born every "year"; the birth rate equals the death rate. You simulate births by reaching into the pool of "spare fish" and selecting randomly.
- Since the green trait is recessive, the green fish are homozygous recessive (ff). Because the red trait is dominant, the red fish are either homozygous or heterozygous dominant (FF or Ff).

Hardy-Weinberg:

G. H. Hardy, an English mathematician, and W.R. Weinberg, a German physician, independently worked out the effects of random mating in successive generations on the frequencies of alleles in a population. This is important for biologists because it is the basis of hypothetical stability from which real change can be measured. This also allows you to figure out the frequency of genotypes from phenotypes.

You assume that in the total population of m&m's, you have the following genotypes, FF, Ff, and ff. You also assume that mating is random so that ff could mate with ff, Ff, or FF; or Ff could mate with ff, Ff, or FF, etc. In addition, you assume that for the green and red traits there are only two alleles in the population - F and f. If you counted all the alleles for these traits, the fraction of "f" alleles plus the fraction of "F" alleles would add up to 1.

The Hardy-Weinberg equation states that: $p^2 + 2pq + q^2 = 1$

This means that the fraction of pp (or FF) individuals plus the fraction of pq (or Ff) individuals plus the fraction of qq (ff) individuals equals 1. The pq is multiplied by 2 because there are two ways to get that combination.
You can get “F” from the male and “f” from the female OR “f” from the male and “F” from female.

If you know that you have 16% recessive fish (ff), then your qq or q 2 value is .16 and q = the square root of .16 or .4; thus the frequency of your f allele is .4 and since the sum of the f and F alleles must be 1, the frequency of your F allele must be .6 Using Hardy Weinberg, you can assume that in your population you have .36 FF (.6 x .6) and .48 Ff (2 x .4 x .6) as well as the original .16 ff that you counted.

Procedure 1: Without Selection

1. Get a random population of 10 fish from the "ocean."
2. Count green and red fish and record in your chart; you can calculate frequencies later.
3. Eat 3 fish, chosen randomly, without looking at the plate of fish
4. Add 3 fish from the "ocean." (One fish for each one that died). Be random. Do NOT use artificial selection.
5. Record the number of green and red fish.
6. Again eat 3 fish, randomly chosen.
7. Add 3 randomly selected fish, one for each death.
8. Count and record.
9. Repeat steps 6, 7, and 8 two more times.
10. Provide your results for the class. Fill in the class results on your chart.

Procedure 2: With Selection

1. Get a random population of 10 fish from the "ocean."
2. Count green and red fish and record in your chart; you can calculate frequencies later.
3. Eat 3 green fish; if you do not have 3 green fish, fill in the missing number by eating red fish.
4. Add 3 fish from the "ocean." (One fish for each one that died). Be random. Do NOT use artificial selection.
5. Record the number of green and red fish.
6. Again eat 3 fish, all green if possible.
7. Add 3 randomly selected fish, one for each death.
8. Count and record.
9. Repeat steps 6, 7, and 8 two more times.
10. Provide your results for the class. Fill in the class results on your chart.

FINALLY:

1. Fill in your data charts and calculate
2. Prepare a graph showing the frequency of the alleles in each generation
3. Answer the analysis questions.

Analysis:

1. Prepare one graph using both sets of class data (without selection AND with selection). On the "x" axis put generations 1-5 and on the "y" axis put frequency (0-1). Plot both the q and p for both sets of class data. Label lines clearly (without selection AND with selection).
2. In either simulation, did your allele frequencies stay approximately the same over time? If yes, which situation? What conditions would have to exist for the frequencies to stay the same over time?
3. Was your data different from the class data? How? Why is it important to collect class data?
4. With selection, what happens to the allele frequencies from generation 1 to generation 5?
5. What process is occurring when there is a change in allele frequencies over a long period of time?
6. What would happen if it were more advantageous to be heterozygous (Ff)? Would there still be homozygous fish? Explain.
7. In simulation 2, what happens to the recessive alleles over successive generations and why? Why don't the recessive alleles disappear from the population?
8. Explain what would happen if selective pressure changed and the recessive allele was selected FOR?
9. What happens if the sharks only eat very large fish that have already reproduced? What happens if they eat small green fish, before they have a chance to reproduce?
10. In what ways did these simulations represent real life? How were the simulations different from real life situations?

Remember to complete Discussion, Conclusion, and Reflection
Lab Grading Guidelines are at http://www.jdenuno.com/PDFfiles/LabGuide1.PDF

Table 1: Without Selection…Individual Results

Generation	Green	Red	q^2	q	p	P^2	2pq
1							
2							
3							
4							
5							

Table 2: Without Selection…Class Results

Generation	Green	Red	q^2	q	p	P^2	2pq
1							
2							
3							
4							
5							

Table 3: With Selection…Individual Results

Generation	Green	Red	q^2	q	p	P^2	2pq
1							
2							
3							
4							
5							

Table 4: With Selection…Class Results

Generation	Green	Red	q^2	q	p	P^2	2pq
1							
2							
3							
4							
5							

Remember: Determine proportions of Green and Red fish BEFORE you calculate p and q values