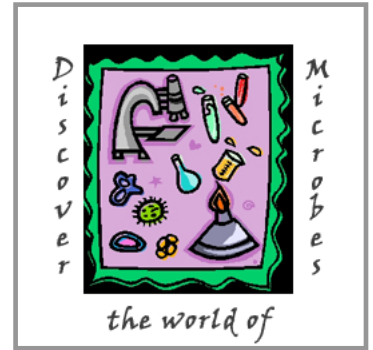


NABT 2006

Microbial Discovery Workshop

Friday, October 13 – Ballroom C
8:00am – 9:15am



The Tree of Life Revisited: Evolution and the World of Microbes

Facilitator: Mark Gallo, Niagara University, Niagara University, NY

Workshop Outline

- I. Introduction to ASM's Video Podcast Series and MicrobeWorld.org website**
- II. *Intimate Strangers* – Episodes 1, 2 and 3**

This video illustrates the universality of certain biological features and the diversity of all life forms can be explained the fact of a common ancestry. This ancient shared history can be traced in the DNA of present day organisms. Certain sequences are useful to show these relationships and surprising discoveries came about regarding the depth and breadth of microbial life forms, so much so that we have had to recreate the branch structure of the tree of life.
- III. Microbial Discovery Activity – Evolution of a DNA Sequence Over Time**

In this exercise the basic points made by Charles Darwin regarding evolution by natural selection will be simulated. A starting sequence will be replicated by others in order to simulate the generation of offspring and a population too large for the carrying capacity of the environment. Errors will arise in the sequence over time, which will simulate varying levels of fitness. Selection can then be applied to these offspring, thus satisfying the final component of Darwin's basic tenets. Computer programs that can create phylogenetic trees based on sequence similarity will also be demonstrated. After this activity, participants should have a better understanding of the basis for the three domain tree proposed by Woese and the value of DNA sequence in deciphering the relatedness of life forms on this planet.
- IV. Presentation of the Microbial Discovery on-line resources.**

Participants in this workshop will receive information on additional teaching resources available at the American Society for Microbiology website.

Did you use this activity in your classroom?
Please send questions/comments to:

American Society for Microbiology
Education Department
1752 N Street, NW
Washington, DC 20036
EducationResources@asmusa.org

An Educational Program of



**AMERICAN
SOCIETY FOR
MICROBIOLOGY**

Microbial Discovery Workshop - Sample Lesson Planning Guide

Teacher: _____

Standard: Content A, C, E, F, G

Benchmark(s):

Course/Subject:

Evolution of a DNA Sequence Over Time

Anticipatory Set

The Hook

(Excite and Engage Learner)

Students will engage in a game of spreading gossip, but the message is one of a string of A's, C's, G's and T's. They will then observe how much variation occurs in a sequence over time.

Review and Practice:

Individuals could be shown images or artifacts or objects related to the evolution of organisms on this earth. An excellent example can be seen in the family of mammals that include the present day horse. It would be instructive to relate how appearance (phenotype) is influenced by an underlying genetic make-up (genotype). Therefore it stands to reason that underlying changes in the DNA sequence could lead to changes in appearance of an organism. Divergence in a sequence in different organisms can also be followed if desired if multiple descendents are allowed. Students should review Darwin's tenets of natural selection.

Activate Prior Learning:

- Questioning
- Individual work
- Discussions
- Home work
- Group work
- Reciprocal teaching

Value of the Lesson:

The gene concept and mutations leading to variation in organisms are two concepts that are typically not tied together in a concrete manner; this exercise will make that connection.

Objective/Outcome:

Note that mutational events can get fixed into an organism's genetic code and can be passed on to future generations. Changes in a genome occur in a cumulative manner and that the changes are independent events. Multiple lineages can arise over time with different sequence variations.

Microbial Discovery Workshop - Sample Lesson Planning Guide

Instructional Delivery: Process

<p>Teacher Processes: Teacher will hand out instruction sheet describing how the student is responsible for the replication of one's genome. Other student will be offspring, with the possible inclusion of errors occurring during the replication phase. Later the message will be translated into a "protein" through use of a codon chart. Teacher will display the various sequences generated and allow the students to see how errors can become fixed into a population. If desired the teacher can enhance the lesson by placing the derived sequences into a computer and using a bioinformatics tool (CLUSTALW) to draw a phylogenetic tree of the sequences. Then one could test the robustness of this tool by comparing the known history of the sequences with the one predicted by the computer.</p>	<p>Activities:</p> <ul style="list-style-type: none"> • Mini lecture • Discussion • Thinking skills <ul style="list-style-type: none"> • Analyzing • Synthesizing • Evaluating • Sequencing • Classifying • Generalizing • Prioritizing • Cause-effect • Inferring • Hypothesizing • Planning • Decision making • Divergent thinking skills <ul style="list-style-type: none"> • Fluency • Flexibility • Elaboration • Simulations • Performance (oral, written, visual) • Research • Problem Based
<p>Student Process/Procedures: Student will read sequence to another student to mimic the replication process; the new student is an offspring of the first one. They in turn will repeat the procedure by reading the sequence to another student, thus creating another generation.</p> <p>After all generations are complete the student will translate one's own DNA sequence into amino acid sequence using supplied codon chart. Each amino acid sequence will then be compared.</p> <p>Once the basic manipulations are understood by the student's teacher will introduce other criteria so that the simulation more closely follows the conditions necessary for natural selection.</p>	
<p>Guided Practice (Check for understanding):</p>	<ul style="list-style-type: none"> • Cooperative Learning <ul style="list-style-type: none"> • Jig saw • Walk about • Para phrase • Academic controversy • Graphic Organizers <ul style="list-style-type: none"> • Classification grid • Sequence chart • Flow chart • Graphs • Demonstration • Manipulations

Microbial Discovery Workshop - Sample Lesson Planning Guide

Summary/Closure:

Clearly articulate (student/teacher):

What was learned? How will it be applied?

Student will see that errors in replication can lead to variation in future generations. These changes can continue to accumulate over time. Variation in DNA sequence is responsible for variation in amino acid sequence and in either case can be applied to our knowledge regarding an important component of evolutionary thought. Such variation is sufficient to account for the diversity in DNA or protein sequences that we see in all organisms.

Assessment and Evaluation of Lesson:

Learner will be asked to describe in own words how this relates to Darwin's theory of natural selection. The student will also be asked to describe what components of natural selection are illustrated and how it compares to Darwin's basic tenets.

- | | |
|---------------------|---------------|
| • Oral Presentation | • Performance |
| • Rubric | assignment |
| • Exhibition | • Observation |
| • Tests | • Checklist |
| • Project | |
| • Demonstration | |

Homework:

Read information regarding Darwin's theory on evolution. Student should also view additional information regarding the power of natural selection. Two interesting topics include the writings of Richard Dawkins and "methinks 'tis like a weasel" algorithm.

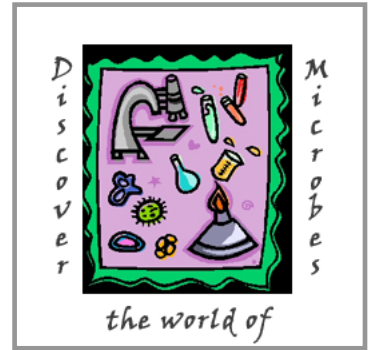
Technology-Utilization:

A podcast will be used to introduce the topic. Various historical references will be used to understand Darwin's theory of evolution. Additional sources of information will be explored, including the model of mutation accumulation known as Mueller's ratchet. The results from the class activity can be run through a CLUSTAL server to see the power of the predictive nature of modern bioinformatics tools. The "Methinks 'tis like a weasel" algorithm is typically run as a java applet on remote servers however the program is available for download and the students can explore the effects of changing the parameters such as population size and mutation rate.

Materials:

- | | |
|------------------|-------------|
| • Podcast | • Handouts |
| • Text | • Equipment |
| • Supplementary | • Computers |
| • Worksheets | • Software |
| • CLUSTAL server | • Other |

Microbial Discovery Activity



Evolution of a DNA Sequence Over Time

Abstract

One of the basic requirements of evolution is variation in a population upon which selection can act. One of the sources of variation is mutation in DNA. These changes may or may not be reflected in the ensuing amino acid sequence of a protein. This exercise explores the additive effects of mutation on an amino acid sequence over several generations. The activity is also useful in that it addresses several of the components of Darwin's theory of evolution through natural selection.

Intended Audience

K-4	
5-8	
9-12	X

Learning Objectives

At completion of this exercise, the student will:

- Understand that variation in a sequence can be generated through mutation.
- See that successive rounds of mutation lead to further variation in a sequence
- Identify that sequences that are most closely related in a temporal sense will share the highest degree of similarity
- Become familiar with the degeneracy in the amino acid code and how it may mask underlying changes in the DNA sequence.
- Be able to use clustering programs to perform an analysis of similarity
- Recognize sequence similarity in organisms may indicate underlying evolutionary relatedness

Necessary Student Background

Learner should be familiar with Darwin's theory of evolution by natural selection. Students should also understand that DNA is the hereditary and informational molecule and that information for the synthesis of proteins is encoded in the DNA.

Keywords

theory, evolution, natural selection, artificial selection, extant, extinct, neutral mutation, silent mutation, codon, CLUSTAL, dendrogram



General Information

Author

Mark Gallo, Ph.D.

Associate Professor of Biology

Niagara University, NY

mgallo@niagara.edu

National Science Education Standards Addressed

Standard A: Science as Inquiry - Students will analyze evidence regarding the process of natural selection and reflect upon this simulation and how it relates to present knowledge and thinking on evolution.

Standard C: Life Science - In completion of this activity, students will discover more about the structure and function of DNA, an integral part of life science. Students will also learn about DNA on a molecular basis, as the molecule responsible for heredity. Students will complete activities in which they discuss that DNA provides genetic continuity between generations. This activity explores at a molecular level many of the key points for natural selection as the driving force for evolution.

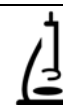
Standard E: Science and Technology – Addition of the CLUSTAL analysis will provide an opportunity for the learner for ways to see how important technology is to investigate scientific questions. Use of the mentioned algorithms that model the process of natural selection are also valuable means for students to design their own experiments and carry them out in a simulation.

Standard F: Science in Personal and Social Perspectives – The theory of evolution remains a topic of fervent discussion in the U.S. and is challenged by other groups using non-scientific means. This activity provides a clear, concise model of the events that lead to many of the steps necessary for evolution by natural selection.

Standard G: History and Nature of Science - The theory of evolution has been under societal attack by some groups since its inception. The polarization around this issue is the largest of its kind in the scientific community. Students will investigate some of the early arguments used to defend evolution and how the arguments have been strengthened in light of molecular biology.

Activity Specifications

Classroom setting	X
Requires special equipment	
Uses hands-on manipulatives	X
Requires mathematical skills	
Can be performed individually	
Requires group work	X
Requires more than one (45 min) class period	X
Appropriate for special needs student	X



Teacher Handout

Evolution of a DNA Sequence Over Time

Class Time

The activity requires two fifty-minute class periods. The first period will be needed to perform the first experiment and allow time for translation of the sequence and to display their individual results and explore the variations. The second period will be used for additional alterations of the activity so that it more closely models evolution by natural selection. Additional time would be necessary if one were interested in a more in-depth coverage of the bioinformatics tools available to predict the evolutionary relatedness of the sequences and to postulate the evolutionary steps necessary to lead to speciation.

Teacher Preparation Time

Minimal time needed to photocopy handouts.

Background

Darwin's Theory of Evolution by Natural Selection can be summarized as follows:

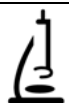
1. Phenotypic variation exists among individuals and the variation is heritable.
2. More individuals are produced each generation than can survive.
3. Those individuals with heritable traits better suited to the environment will survive.
4. When reproductive isolation occurs new species will form.

Most students will state that they have never seen evolutionary events or that evolution is not still occurring or that it takes a long time to see the results. It is argued by some that it doesn't occur at all and that the diversity of life forms that we see on the earth are due to an intelligent designer.

This lesson addresses each of the points of evolution by natural selection in a number of activities and hence builds upon the knowledge gained from the prior sections to assist the learner synthesize a comprehensive view.

It is important for the teacher to explain what is meant by the term theory in the biological community. A theory is an explanation of a phenomenon, it is a model that is supported by scientific evidence. It should be fortified by additional experimentation, may be useful in a predictive manner, and is falsifiable in which case it would be thrown out in favor of a new theory. Theories are large rule sets that explain a universal truth, such as the theory of gravity or the theory of relativity. The theory of evolution by natural selection has been under close scrutiny since its inception and it has never been falsified.

Students will also be introduced to the concept that DNA is replicated somewhat faithfully, and that it contains information to encode for the amino acids that make up proteins. Students will replicate and translate a sequence, and in the process they should be made aware of the fact that some DNA mutations have a dramatic effect on the protein sequence, others have a minimal effect (neutral mutations), and some appear to have no effect at all (silent mutations).



Materials and Equipment

Each student needs the following:

- Codon chart
- Student handout #1
- Student handout #2
- Student handout #3
- Figures handout

Methods

This activity is a derivative of the old telephone game. Instead of using a secret phrase you use a string of letters that the person must write down (replicate) onto a piece of paper. Then they read their string to another person who now becomes the scribe and writes down (replicates) what they can onto a piece of paper and so on until everyone in the room has written down (replicated) the secret code that they received from one other person.

Exercise 1: Mutation can occur and become fixed in a sequence. Sequence variation is heritable.

1. Print out the student handout #1 and the amino acid codon chart.
2. Place successive numbers onto the top of the student handout sheet.
3. Begin by reading the nucleic acid sequence to student number 1. Instruct that student to read to student 2, who will then read to student 3, and so on until every one has replicated the sequence.
4. Perform all of the replications first before allowing students to translate their sequence.

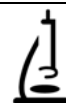
The secret code is a series of As, Cs, Gs, and Ts, the four nucleotide bases of DNA. You can reverse engineer the nucleic acid code to spell out a word in the single letter amino acid code. Just be aware that not all letters are represented: avoid B, J, O, U, X and Z.

Here is a sample:

AACATCGCGGGGGCACGCGCCTTTGCTCTCCTTAGC

Translate it yourself to see the amino acid sequence it contains using the codon chart (attached).

After everyone replicates and translates their sequence, have the students report out the results of their translation (the amino acid sequence) on the board in the same order that the sequences were received. See **Figure 1** in the **Appendix** for a representative sample of the results from this exercise. This initial experiment shows that it is possible to generate mutations and most students are amazed at how quickly the sequence "mutates" (or evolves) in a short time. Students will observe that cumulative mutations over time together with selection can lead to profound changes in the "genome" of this organism. These changes are reflected in a very valuable string of amino acids that are necessary for its survival. It is illustrative of Darwin's first point that there is variation in traits. However there are several limitations with this experiment to describe evolution by natural selection if taken alone. For starters each progenitor only leaves one offspring and hence point 2 is not met. This limitation can be reconciled in the following exercise.



Exercise 2: Each “organism” can produce numerous offspring. Every “organism” does not have equal selective fitness.

Darwin had noted not all offspring will have equal fitness in the environment. Therefore one could address that issue by performing the following exercise.

1. Print out student handout #2.
2. You read aloud the DNA sequence to all students in the class. Each student is an offspring that has replicated as faithfully as possible what you have spoken by writing down as many of the correct bases as possible.
3. Allow the students to place their particular amino acid sequences on display for all to see.
4. Apply a strict selective force so that only one sequence is fit and survives to re-populate. (Do not choose an amino acid sequence if there are two identical ones.)
5. Ask the student responsible for that particular amino acid sequence for their sheet so that you can use their DNA sequence as the starting point for populating the next generation.
6. Repeat steps 2 through 5 as many times as you see fit.

See **Figure 2** for an example of the outcome. The letters are there merely to represent eight different individuals participating in each round (generation).

The environment and hence the selective pressure is the teacher’s choice. However it is important that you explain to the student that although you are selecting one organism to survive at each generation you are not performing this action as a conscious effort of being a human. The process whereby humans intervene and selectively breed particular offspring while eliminating others is known as artificial selection. The end result of a higher percentage of organisms carrying a particular trait into the next generation is the same whether artificial or natural selection occurred.

The exercise has the organisms reproducing by asexual means. This is not a far-fetched view of the world as the majority of organisms increase in number through cell division.

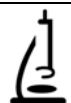
Exercise 3: Production of Isolated Lineages of Organisms

In the last exercise the student saw how variation in sequence can be used as a means to select for the one that is most fit for a particular condition. However oftentimes there is more than one survivor from one generation to the next, and they may be surviving in an environment that is independent of the others. This exercise is a way to produce multiple independent lineages that are an important component of speciation as noted in Darwin’s 4th point.

1. Print out Student handout #3.
2. Number sheets in the following manner: 1, 2A, 2H, 3A, 3D, 3E, 3H, 4A, 4B, 4C, 4D, 4E, 4F, 4G, 4H, then 5A through 5H and so on for as many student as you have in your class.
3. Read the sequence to individual 1, who in turn reads it to 2A and 2H.
4. Individual 2A reads their DNA product to 3A and 3D, whereas individual 2H reads their DNA sequence to 3E and 3H.
5. Individual 3A reads to 4A and 4B, 3D reads to 4C and 4D, 3E reads to 4E and 4F, and 3H reads to 4G and 4H.

(See **Figure 3** for my resulting scheme to create 8 lineages.)

This scheme is valuable for discussion of a number of points. For starters, there are no living (extant) common ancestors for many organisms alive on the earth today. They gave rise to these modern species and hence have gone extinct. (See **Figure 4**.)



One can trace the lineage of some organisms back to a common ancestor. (See **Figure 5**.) Students may be able to see the progression in sequence in a lineage over time. It may also be possible to detect common ancestors due to the continued shared sequence.

One can decide to use multiple sequence alignment programs to decipher the relatedness of the sequences. It is interesting to note the reliability of such programs. There are numerous free internet sites where one can input the class data. One such site is Biology WorkBench at the San Diego Supercomputer (<http://workbench.sdsc.edu>) where one can establish a free account and perform numerous analyses, with ClustalW being the one of interest for this activity. Another site is present at the European Bioinformatics Institute (<http://www.ebi.ac.uk/clustalw/>). And yet another is present at the Kyoto University Bioinformatics Center (<http://align.genome.jp/>). Numerous other sites are present, and the software is also available for download.

Microorganisms

None.

Safety Precautions

None.

Assessment

Students could be asked to explore the information and write an essay regarding the theory of evolution by natural selection as described by Darwin. After the activity it would be instructive for students to take their initial writing and then expand upon it to include how evolutionary thought has expanded over the years, with particular emphasis on molecular evolution. It is also possible to ask the students to perform a CLUSTAL analysis with the class data and submit a printout of the subsequent tree. They could describe their findings and note any discrepancies from expected relatedness based on the fact that the relationships were known.

Questions

1. Theodosius Dobzhansky, a geneticist whose work influenced 20th century research on evolutionary theory, said, "Nothing in biology makes sense, except in light of evolution." What do you think he meant by this quote?

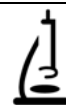
The common glue or thread of biological systems is that they all share a common origin and hence there as a particular universality in nature, but the simple rules of the theory of evolution as it pertains to natural selection has produced all the diversity of biological forms present today or in any time in the past.

2. What do the universal use of the DNA code and the triplet codon use for defining amino acid usage imply about the common origins of life?

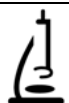
It is strong evidence for a common origin and hence the reason all organisms use the same code and codons. It is statistically impossible to reason it any other way.

3. Based on what you have seen as the scientific definition of a theory, can you think of other general theories in the sciences?

Planet rotation around the sun, our solar system is moving in the galaxy, earth and all the planets were all spun off during the beginning of our solar system. There are others.



4. How would you describe the difference in the way that others use the word theory?
Theory to the layperson means it is just someone's own idea, belief, feeling, with no need for any supporting valid scientific data.
5. What would you predict would be the benefit of a high mutation rate in an organism?
Large amount of variation of offspring that may help survivorship, especially in an uncertain world.
6. What would you predict would be the hazard of a high mutation rate in an organism?
High rate of amino acid sequence variation in proteins, many of which will work sub-optimally.
7. Do you think that this activity has a high or low error rate compared to your own DNA replication?
Extremely high rate compared to your DNA polymerase and other repair mechanisms.
8. Darwin used the phrase "descent with modification" to describe the process for the change in sequence over time leading to evolution. Do you feel that these exercises substantiate or refute his claim? Please explain your answer.
This exercise definitely supports Darwin's position. It was obvious that the sequences changed after a few "virtual" generations. It was also possible to predict which sequence was the progenitor of later sequences.



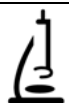
Supplementary Information

Possible Modifications:

One could decide to perform a comparison of the nucleic acid sequence and the amino acid sequence and evaluate the outcomes.

It is also possible to ask the students to perform a CLUSTAL analysis with the class data and submit a printout of the subsequent tree. They could describe their findings and note any discrepancies from expected relatedness based on the fact that the relationships were known.

Additional topics for expansion include discussion of Mueller's ratchet and its effect on sequence changes over time, the works and writings of Richard Dawkins on evolution and exploration of the "Methinks 'tis like a weasel" algorithm



Appendix

Figure 1. The Power of Mutations to Introduce Variation Over Time

Generation	DNA sequence	Amino Acid Sequence
1	AACATCGCGGGGGCACGCGCCTTTGCTCTCCTTAGC	NIAGARAFALLS
2	AACATCGCGGGCGGCACGCGGCTTTGCTCTCCTTAGC	NIAAARGFALLS
3	AACATCTCGGTGCCACGCGGCTTTCTCTCTATCTCT	NISVARGELSIS
4	AACATCTCGGTGGCACGCGGCTTTCTCTCTATCTCA	NISVARGELSIS
5	AACATCGTCGGCACGTCTTTTCTCTCTACTTCTGAC	NIVGTSFLSTSD
6	AACATCGTCGGCCTTCTCTCTCTACTTCTGAC	NIVGLLSLLL

Figure 2. The Power of Natural Selection

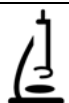
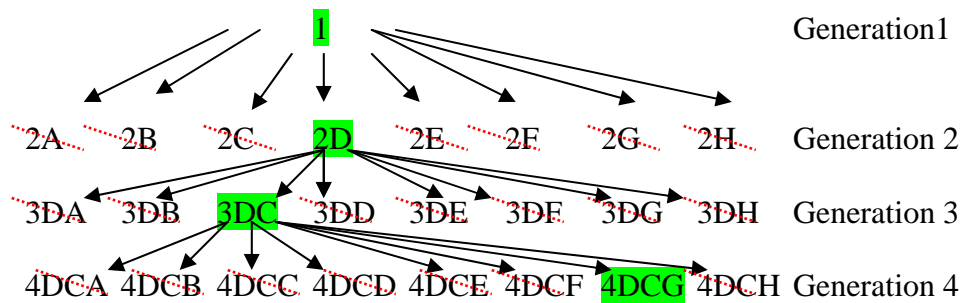


Figure 3. Scheme for Generation of Reproductive Isolation Leading to Speciation

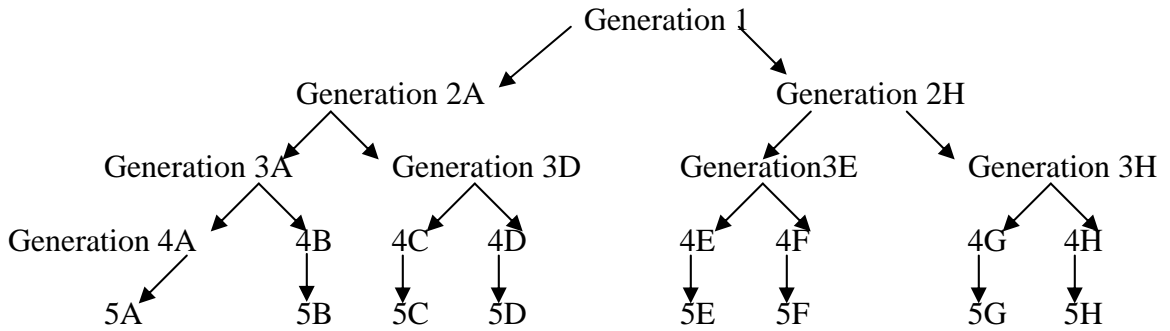


Figure 4. Scheme for Generation of Diversity in Present Day (Extant) Population

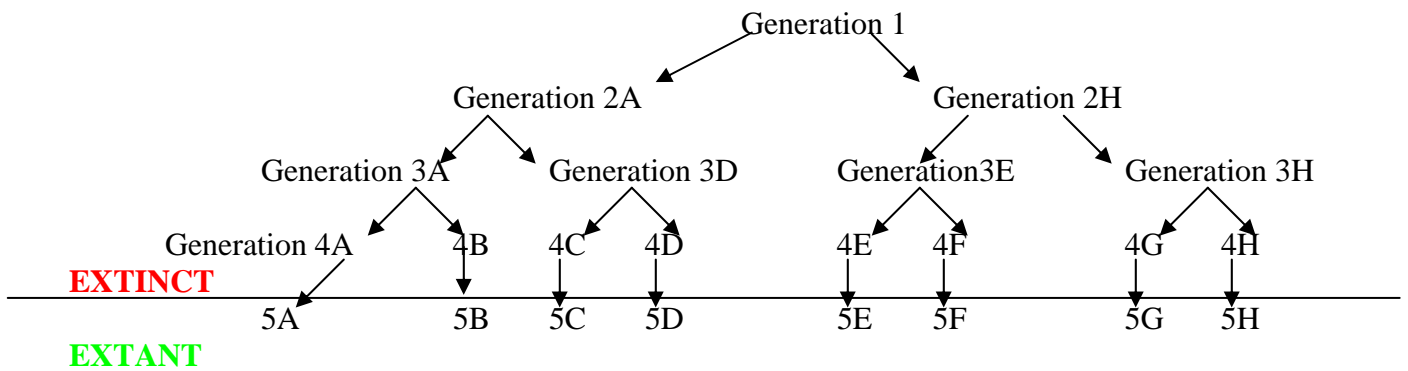
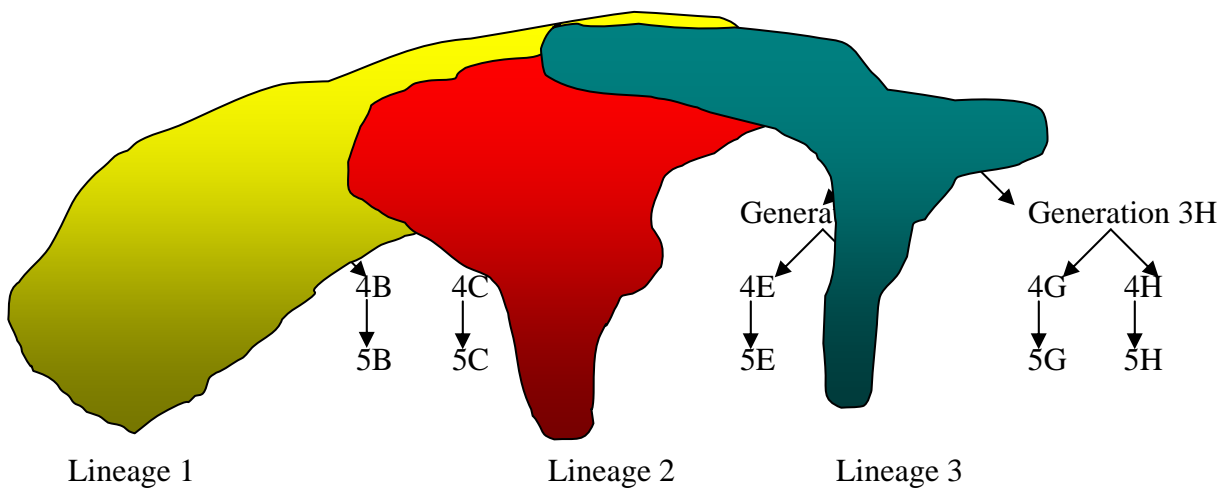
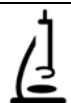


Figure 5. Following Lineages of Sequences Over Time



(Three of the eight possible lineages are outlined.)



Student Handouts

Evolution of a DNA Sequence Over Time

Student Name: _____

Introduction

One of the basic requirements of evolution is variation in a population upon which selection can act. One of the sources of variation is mutation in DNA. These changes may or may not be reflected in the ensuing amino acid sequence. This exercise explores the additive effects of mutation on an amino acid sequence over several generations. Each student becomes a replicator of a DNA sequence and as a result of their actions may add changes into the DNA sequence. The generational changes are noted as well as comparisons of sequence variation. The activity is also useful in that it addresses several of the components of Darwin's theory of evolution through natural selection.

Terms and Definitions

Theory – an explanation of a universal truth that is testable, such as the theory of gravity or the theory of relativity.

Evolution – a theory first expounded by Charles Darwin that the diversity of life arose on this planet through the process of natural selection.

Natural selection – selection by natural environmental forces.

Artificial selection – selection by humans.

Extant – organisms that are alive on the planet at the present time.

Extinct – organisms are no longer alive on the planet.

Neutral mutation – a mutation in the DNA and/or amino acid sequence that has no effect on the functionality/phenotype.

Silent mutation – a mutation in the DNA sequence that is not detected by a change in the amino acid sequence.

Codon – a collection of three nucleotide bases in a row that are used to encode for a particular amino acid.

Dendrogram – a tree diagram used to illustrate the relatedness of objects by clustering the arrangement of more similar objects.

Materials Checklist

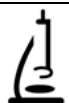
Codon chart (see attached)

Student handout #1 (this paperwork)

Student handout #2

Student handout #3

Figures handout



Evolution of a DNA Sequence Over Time - Student Handout #1

Name: _____

Exercise 1:

1. Please listen carefully and write down (“replicate”) as much of the sequence when it is spoken to you in the spaces below. Try to fill in as many of the spaces as possible. Guess if you are not sure.

DNA Sequence:

2. Read your sequence to the person with the next higher number when instructed to do so. Read it slow enough so that they can record it, but fast enough that they may make errors along the way.

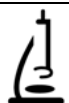
3. After all people have “replicated” the sequence use the accompanying chart to “translate” the DNA sequence into amino acids. Recognize that you translate the letters above in groups of three to give the appropriate amino acid. For instance if your first three letters above are AAC then that would encode the amino acid asparagine, designated by the letter N. Therefore you would write an N on the first space below. Continue translating the above sequence three letters at a time. If you have a TAA, TAG, or TGA that is a stop codon. Put a Star in that space and stop translating.

Amino Acid Sequence:

- - - - -

4. Write your translated product on the board next to your number when instructed to do so.

Please see Handout 2 for Additional Exercises.



Evolution of a DNA Sequence Over Time - Student Handout #2

Name: _____

Exercise #2.

Darwin had noted not all offspring will have equal fitness in the environment. Therefore one could address that issue by performing the following exercise.

1. Your teacher will read aloud a DNA sequence. Copy down as much of the DNA sequence as you can in an accurate fashion in the following space.

DNA sequence _ _ _ _ _

2. Translate your DNA sequence into amino acid sequence in the following space. Remember to begin reading from the left side, three bases at a time and use the codon chart to determine the single amino acid code.

Amino acid sequence _ _ _ _ _

3. Place your particular amino acid sequence on display for all to see.

4. The teacher will select one sequence to survive and re-populate.

5. If your particular amino acid sequence is chosen by the teacher then give her the DNA sequence so that she can use it to read aloud so that a future generation of variants will be produced with your sequence as a starting point.

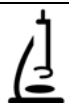
6. Repeat steps 2 through 5 as many times as the class allows. Use back of sheet to copy down the DNA sequence and then to translate to amino acid sequence.

The environment and hence the selective pressure is the teacher's choice. Please note that they will act as a source of natural selection.

Exercise 3: Production of Isolated Lineages of Organisms

In the last exercise you saw how variation in sequence can be used as a means to select for the one that is most fit for a particular condition. However oftentimes there is more than one survivor from one generation to the next, and they may be surviving in an environment that is independent of the others. This exercise is a way to produce multiple independent lineages that are an important component of speciation as noted in Darwin's 4th point.

See Student handout #3.



Evolution of a DNA Sequence Over Time - Student Handout #3

Name: _____

Exercise #3.

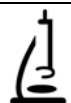
1. Listen for your combination number and letter to be called.
2. Please listen carefully and write down (“replicate”) as much of the sequence when it is spoken to you in the spaces below. Try to fill in as many of the spaces as possible. Guess if you are not sure.

DNA Sequence:

3. Individual 2A reads their DNA product to 3A and 3D, whereas individual 2H reads their DNA sequence to 3E and 3H.
4. Individual 3A reads to 4A and 4B, 3D reads to 4C and 4D, 3E reads to 4E and 4F, and 3H reads to 4G and 4H.
(See **Figure 3** for my resulting scheme to create 8 lineages.)
5. After all people have “replicated” the sequence use the accompanying chart to “translate” the DNA sequence into amino acids. Recognize that you translate the letters above in groups of three to give the appropriate amino acid. For instance, if your first three letters above are AAC then that would encode the amino acid asparagine, designated by the letter N. Therefore you would write an N on the first space below. Continue translating the above sequence three letters at a time. If you have a TAA, TAG, or TGA, that is a stop codon. Put a star (*) in that space and stop translating.

Amino Acid Sequence:

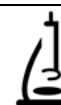
6. Write your translated product on the board next to your number when instructed to do so.



Amino Acid Codon Chart with Corresponding Single Letter Code.

Amino Acid	Single Letter Code	DNA codons
Alanine	A	GCT, GCC, GCA, GCG
Cysteine	C	TGT, TGC
Aspartic acid	D	GAT, GAC
Glutamic acid	E	GAA, GAG
Phenylalanine	F	TTT, TTC
Glycine	G	GGT, GGC, GGA, GGG
Histidine	H	CAT, CAC
Isoleucine	I	ATT, ATC, ATA
Lysine	K	AAA, AAG
Leucine	L	CTT, CTC, CTA, CTG, TTA, TTG
Methionine	M	ATG
Asparagine	N	AAT, AAC
Proline	P	CCT, CCC, CCA, CCG
Glutamine	Q	CAA, CAG
Arginine	R	CGT, CGC, CGA, CGG, AGA, AGG
Serine	S	TCT, TCC, TCA, TCG, AGT, AGC
Threonine	T	ACT, ACC, ACA, ACG
Valine	V	GTT, GTC, GTA, GTG
Tryptophan	W	TGG
Tyrosine	Y	TAT, TAC
Stop codons	*	TAA, TAG, TGA

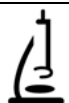
All 64 possible 3-letter combinations of the DNA coding units T, C, A and G are used either to encode one of these amino acids or as one of the three stop codons that signals the end of a sequence.



Evolution of a DNA Sequence Over Time - Student Handout #4

Extension Questions:

1. Theodosius Dobzhansky, a geneticist whose work influenced 20th century research on evolutionary theory, said, "Nothing in biology makes sense, except in light of evolution." What do you think he meant by this quote?
2. What do the universal use of the DNA code and the triplet codon use for defining amino acid usage imply about the common origins of life?
3. Based on what you have seen as the scientific definition of a theory, can you think of other general theories in the sciences?
4. How would you describe the difference in the way that others use the word theory?
5. What would you predict would be the benefit of a high mutation rate in an organism?
6. What would you predict would be the hazard of a high mutation rate in an organism?
7. Do you think that this activity has a high or low error rate compared to your own DNA replication?
8. Darwin used the phrase "descent with modification" to describe the process for the change in sequence over time leading to evolution. Do you feel that this exercise substantiates or refutes his claim? Please explain your answer.





M.D.A. Lesson Evaluation

American Society for Microbiology
1752 N. Street N.W.
Washington, D.C. 20036

Lesson Title:

Grade Level:

Course Title:

Teacher's Name:

Number of Students:

School District and Address:

Preparation

Yes

No

Notes:

Are the set-up procedures too complex for the purpose of the lesson?

Were the materials easy to acquire?

Did you have all applicable materials and equipment in your lab?

How much time did the lesson take to set up?

In class time?

Out of class time?

Lesson Design

Exceptional

Good

Poor

Unsatisfactory

Please rate the introductory activities.

Please rate the lesson/project

Please rate the experiment, in regards to student interest.

Handouts

Exceptional

Good

Poor

Unsatisfactory

Please rate the effectiveness of the teacher handout?

Please rate the effectiveness of the student handout?



M.D.A. Lesson Evaluation

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Washington, D.C. 20036

Assessment

Yes

No

Notes:

Can this lesson can be accomplished in the amount of time indicated by the author?

If no, how much time did the lesson take?

Are you planning any follow up activities?

If so, what assessments or reviews will you be using? (tests, essay, discussion, etc.)

How were the national science standards addressed in this lesson?

General

Yes

No

Was this lesson effective in conveying a particular concept/activity?

Would you teach this lesson again in future years?

Would you recommend this lesson to a friend?

How would you change this lesson if you were to teach it again?

Podcast

Yes

No

Was the podcast appropriate for the intended audience?

Was the podcast clearly linked to the lesson objectives?

Was the lesson enhanced by the use of the podcast?