Gustavus Nobel Conference  
2013-14 Curriculum Materials

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Document Overview:

This series of 3 lessons explains how DNA sequences allude to hereditary relationships. This is a three part lesson modified from “Exploratorium 2007: The DNA Files Workshops” and from “ENSI: Mystery of the Matching Marks”.

Minnesota State Academic Science Standards:

BENCHMARK: 7.4.3.1.3 Inherited Characteristics

Distinguish between characteristics of organisms that are inherited and those acquired through environmental influences.

BENCHMARK: 7.4.3.1.1 Genes & Inheritance

Recognize that cells contain genes and that each gene carries a single unit of information that either alone, or with other genes, determines the inherited traits of an organism.

To some extend this BENCHMARK is touched upon: 7.4.3.2.4 Adaptations & Extinction

Recognize that extinction is a common event and it can occur when the environment changes and a population's ability to adapt is insufficient to allow its survival.

Objective: Students will be able to describe what happens to DNA sequences over millions of years as species diverge to differentiate conserved sequences from divergent ones and make the connection to common traits across species to use their ability of comparing patterns to detect similar patterns in chromosome banding across species

Type of Activity:

* Part 1: Students examine the process of mutations and their impact on evolution in a game which introduces them to the concept of conserved DNA sequences.
* Part 2: Students discover, using actual DNA sequences, that conserved DNA is very similar across species.
* Part 3: Students learn about karyotypes and that common banding patterns on chromosomes suggest common origin. They learn that chromosomes can fuse (stick together) and that there is evidence to suggest that this actually happened in the common ancestor of humans and chimps
  + (3 Powerpoints: teach as direct instruction or have students work in pairs as self-directed computer-based activity with teacher support). The PowerPoints guide everyone through the evidence and logic very nicely, and shows clearly what students should look for when they search for the tell-tale telomeres in the DNA sequence. After they have learned and discussed the material on powerpoints 1 and 2, they compare DNA sequences (human and ape), and see striking evidence for their common ancestry. Additional comparisons test (and confirm) the common ancestry hypothesis. Students find the “molecular fossil” of conserved DNA sequences in our cells. This engaging **inquiry** demonstrates the power of **multiple lines of evidence**.

Duration: Part 1: 20 mins, Part 2: 10 mins, Part 3: 85 mins

Connection to Nobel speakers: This activity develops a very basic understanding of DNA sequencing methodology allowing students to follow how Pääbo obtained his data.

Teacher Tips:

Prior to this activity, have students build an origami DNA Model.

**Part 1 Evolution and DNA sequence**

• In this activity, we are going to fast-forward the evolution of a piece of DNA by hand.

\*\*\*\*Pass out magnetic strips of DNA sequences and spinners, one each per

participant. (If magnetics strips are not available, use paper copies of DNA sequences, white out, and a pen to eliminate a base letter and replace it with another letter).

• We can talk about DNA in different ways. These DNA strips are a sequence of letters, A, C, T, and G. Those letters match up to the 4 colors we used when building our DNA models. Scientists use these four letters, A, C, T and G, instead of the colors, to represent the four different tiny molecules called nucleotides that make up the rungs of the ladder.

\*\*\*\*Show diagram of bases.

• Because A only pairs with T, and C only pairs with G, you only have to read half of the ladder to know what the other half says. So the DNA sequence strips you just

got look just like what scientists deal with every day; it’s just a string of letters.

• This is how this game works: You each start with the same sequence of letters representing the nucleotides. You are going to spin your spinner, like so (\*\*\*\*teacher demonstrates). Whatever letter it lands on, pick one of those from your sequence, and spin for another letter to replace it (\*\*\*\*teacher demonstrates). You have just created a mutation. Some of the letters are inside these black boxes. Any mutation in the black-boxed letters leads to death of the cell that has it. So, students (cells) who created a mutation in a black box will not be able to survive.

\*\*\*\*Let participants practice with their spinners briefly.

\*\*\*\*Give students 5 minutes to mutate their sequences, with a 10 second warning.

• Okay, stop. Now this much mutation would usually take millions of years for most

animals. But we fast-forwarded and did it in about five minutes. Who died along the way?

\*\*\*\*Point out that any mutations in the black-boxed letters led to death of the organisms that had them so they did not reproduce and left the genepool.

\*\*\*\*Have ‘survivor” participants bring their new sequences to the front and align them with one another in the genepool. Where do we see differences in the sequences? Where don’t we see any differences? Help students understand that the black-boxed letters are still all the same. Have students come up with ideas as to why. Help students understand that the rest of the letters have undergone some changes.

**Review**: What we see at the DNA level is the same thing we saw with whole organisms. Some things change, either because of chance, or because of natural selection. But because of natural selection, some things, like these letters in the black boxes, are important enough to be “protected”. They stay the same over time. This DNA in the boxes (that is important enough to stay the same over time) is called conserved DNA.

Concept: Conserved DNA sequences carry vital information for an organism and do not change over time or change very little.

Description of Activity: Paper lab, pair activity

Materials: Copies of colored gene sequences, copies of colored spinners, white out, scissors, pens, DNA sequences for part 2.

Extension and Follow-up Activity:

Part 2: **Which of these animals is most like the other?** (10 min.)

Educational Goal: have participants observe, using actual DNA sequences, that

conserved DNA is very similar across species.

• But we did the last activity backwards from how it’s done in the laboratory. Scientists

don’t know what letters of the DNA sequence are conserved before evolution happens. Scientists take the DNA from a bunch of different organisms and by comparing them they can figure out what must be important by seeing what gets protected.

• Now, you are all going to try it that way. Flip over your worksheets.

• There are two sequences here, Sequence A and Sequence B. Each row is an actual DNA sequence from a different animal. Draw a black box around a column every time the letters are identical for all the different species, like in the example. A dash means that that letter is missing. If there’s a dash, that DNA has not been conserved.

• Which sequence is more conserved (has changed the least) during evolution? Which

sequence do you think is more important?

• How many of you are surprised that there are sequences of DNA like this that we have that are almost identical to those in a chicken? Turns out, some DNA­ sequences are so important that every single living thing has it, from people to plants to bacteria.

Review: Conserved DNA is probably important for some function, when the sequence changes what happens to the function. Help students understand that the function is lost and that the cell can’t survive. If it is a reproductive cell, it may survive until after reproduction but the organism that forms from this cell will not survive. Have students think of something that can’t misform in THEIR bodies and have them speculate how the DNA sequence may be related to such a function.

Part 3: In part 3 students are asked to extend their concept of preserved DNA sequences to preserved DNA sequences on a chromosome. They are first introduced to the concept that chromosomes can be stained to create banding patterns. Where patterns match across organisms, evolution didn’t introduce any (or much) change and those sequences probably have the same origin.

This is a molecular probe into human evolution with a forensic flair. When bullet marks from bullets at a crime scene match bullets fired from a suspect’s gun, this provides compelling evidence of a *common origin* of the bullets - from the same gun. The same comparison of chromosome banding patterns of the chromosomes from humans and chimpanzees, likewise, offers compelling evidence of a common origin - a common ancestor. Furthermore, the existence of two shorter chromosomes in chimps that together closely match the long human chromosome #2 suggests the hypothesis that our #2 chromosome formed by the fusion of those two shorter chromosomes after we branched off from that common ancestor. Students test that hypothesis by searching for telomere DNA in the supposed fusion area of our #2 chromosome, and find it! This lesson includes a PowerPoint presentation that orchestrates the above series of experiences: background, preparation for the short lab, and follow-up. It also provides a somewhat more accessible version of the ENSI lesson: "Chromosome Fusion," where students actually search online DNA databases for the "molecular fossils" of telomere sequences.