Mystery of the Matching Marks

SYNOPSIS

When bullet marks from bullets at a crime scene match bullets fired from a suspect 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 telomere sequences.

This lesson is roughly equivalent to the climax phase of the activity that accompanies the WGBH NOVA production "**Judgment Day: Intelligent Design on Trial**" (first aired 13 November 2007). In that trial, testimony by Prof. Ken Miller includes the chromosome fusion evidence that this lesson explores. In that activity, several different lines of evidence for common ancestry are examined, and students experience the compelling effect of accumulating that evidence, seeing how multiple lines of evidence provide a high level of confidence in their conclusion: that humans and chimps share a common extinct ancestor.

PRINCIPAL CONCEPT

Modern apes and humans evolved from a common ancestor.

ASSOCIATED CONCEPTS

1. Evidence in the present can reveal events of the past.
2. Scientific explanations confirmed by different lines of evidence are stronger.
3. A hypothesis can be critically tested, and this can lead to support or weakening of the hypothesis
4. Multiple independent lines of evidence support the non-human ancestry of humans.

ASSESSABLE OBJECTIVES (Students will...)

1. recognize or describe two types of evidence that confirm the shared ancestry of humans and chimpanzees *(closely matched banding patterns of their chromosomes, and the presence of telomere DNA in middle of human chromosome 2).*
2. recognize how multiple lines of evidence strengthen scientific conclusions.
3. recognize that evidence for past events can be predicted and searched for, and this is valid science.

MATERIALS

Copy of Teacher Instructions (PDF version of this page)
PowerPoint presentation of this lesson: Part 1, Part 2, and Part 3.

TIME

Parts 1 and 2 (and possibly the short "searching" lab) takes about one 50-minute period. Part 3 requires at least 20' of the following period. Fits nicely into an 85' block period.

STUDENT HANDOUTS

Search for the Tell-Tale Telomeres (2-page handout, 1 per student or team)
Page 32 of the DNA file from the 2q13 region of our #2 chromosome (1 per student)
Graphic of the 23/24 chromosomes in 4 sets (human and 3 apes) (1 per team)
Review of the pre-search information (for use if DNA search is done on the second day); 1 per team or student.

TEACHING STRATEGIES & PREPARATION

Context:

This lesson would fit in your evolution unit, or as an extension/application of your chromosome genetics unit. Students should have already learned basic DNA structure, especially the nucleotide-pairing rule (A-T, G-C). It would also be helpful if they learned about the 5'-3' opposite orientation of the two side strands of DNA. It would be possible, with AP or even college prep biology, to use this lesson as an example of the process of science, but it might take some special preparation to familiarize students with some of the terminology and/or DNA concepts.

The PowerPoint presentation would be the easiest and smoothest way to present this lesson. Otherwise, there would be lots of overheads to prepare and keep organized. The PowerPoint guides 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. If you want to make overhead transparencies and present this lesson using your overhead, contact the **webmaster** for the **OH masters** and a **presentation script**.

Preparation:

Be sure to review the complete PowerPoint presentation (or prepare and sequence all transparencies.

[If you use the overhead, you will find, on the far right edge of the *human* karyotype transparency, a copy of the "extra chimp chromosome" that is also found on the *chimp* karyotype transparency. Cut off the vertical strip of transparency from the human karyotype that contains that copy. This is to be used to show how that chromosome, when inverted and moved alongside the upper part of our #2 chromosome, matches perfectly.]

Attach the 52 pages of DNA (from the 2q13 segment of our chromosome #2) end-to-end with tape. Roll it up or fan-fold it for easy unrolling (or unfolding) as it is taped and/or tacked up along a wall or two of your room (it's about 14 m or 16 yds). Install it before the lesson, so you can just point to it when appropriate. Be sure to run off enough copies of page 32 for each team to use, plus some extras in case a few get written on.

You should also have a map of your town/city/region, so that you can show the distance (about 18 km) that the entire DNA of chromosome #2 would be if printed out in the same scale as the 52 pages of DNA from the 2q13 region.

If possible, prepare **models** of two short chromosomes with their telomere DNA exposed at their ends. Try using a couple of long 1" ID black foam-plastic pipe insulation tubes (with strips of white tape or white paper wrapped around it to suggest the banding pattern), or two 1-meter lengths of plastic corrugated tubing, with the telomere sequences taped at their ends (use paper copies of the sequences supplied with this lesson). Use these to show that they can connect in only one way, and when you do, students can see why sequences change at the fusion point.

Run off copies of the student work sheet, at least one for each team, or one per student if you prefer. (Be sure to run off additional sets of these student work sheets for any additional periods.)
Run off sufficient copies of page 32 for all students (containing the fusion area in the 2q13 file of 52 pages).
Run off copies of the 4 chromosome sets (for 23/24 chromosomes), one sheet per team.

Background:

The Great Apes is a group of Primates that includes Orangutans, Gorillas, Chimpanzees and Humans. That's right! People have been biologically classified as essentially "hairless apes" for 250 years, based on their very similar anatomy and physiology. More recently, molecular biology has repeatedly confirmed our close biological relationship with the Great Apes, with nearly identical DNA and protein make-up.

In biology, "close biological relationship" implies common ancestry, something that many people refuse to accept, in spite of the strong evidence. So, in this activity, we will look at some additional evidence in chromosome banding patterns for that common ancestry, and test an idea about what may have happened to our chromosomes in our early pre-history that could either discount that evidence, or reinforce it. This is an excellent example of the "Fair Test" criterion that any successful scientific idea must pass.

What we will be looking for will be the possible existence of a DNA pattern in one of our chromosomes that could tell us if that chromosome was formed from two specific chromosomes that are found today in all the Great Apes. That DNA pattern is a particular repeating sequence of six bases: TTAGGG, called "tandem repeats." They are repeated 800 to 1600 times at the tip ends of all chromosomes in animals and plants. These tips are called "telomeres," and they seem to protect the functional parts of the chromosome, keeping them from getting damaged during replication. As a matter of fact, the telomeres are themselves shortened whenever a cell undergoes mitosis and cell division, so that older organisms have shorter telomeres than younger ones. They have been studied for helpful clues about aging and cancer, and help to explain why *embryonic* stem cells work better than *adult* stem cells.

In this activity, students will search the middle region in our #2 chromosome for the DNA evidence of those two telomeres that remain from their former existence as the ends of two shorter chromosomes in an early ancestor. In addition, students will increase their familiarity with Primates. their distinguishing traits and relationships, and our place in that group.

PROCEDURES
1. Show the PowerPoint, planning to read and interact with your students as it progresses.
If there is time (about 10 minutes), have students do the DNA search. Otherwise, do that the next day. If done the next day, you may want to go over the review sheet with them first, to bring them up to speed.
2. Search for the Tell-Tale Telomere
3. Show the follow-up (Part 3) of the PowerPoint, including the check-quiz at the end, then go over the check quiz key with your class so they can grade their papers while you discuss the questions, as necessary.
4. Show the extension ideas, and the interesting information about telomeres. If any students are interested in actually doing the search (or an extension search) on one of the online databases, refer to the "Chromosome Fusion" lesson for step-by-step instructions. You can print those out for each interested student. This could be a take-home extra-credit project.

ASSESSMENT
See Assessable Objectives for focus of assessment. If you create a test instrument that does this, please share with us at ENSI.
Answers to Student Handout Questions: "The Test: Search for the Tell-Tale Telomeres"
These are samples of what to expect; allow for slight variations that still convey the expected information.
1. 541
2. telomere
3. telomere (or "tip of a chromosome, specifically of a chromosome like a chimp's #2a)
4. C (common ancestor)
5. D (supports it)
6. Fusion of two short chromosomes to produce our #2
7. A (strengthens it)
8. We have a common ancestry (or, we are closely related)
9. B; Because our #2 clearly resulted from the fusion of 2 short ones - see #6
10. A (very closely)
11 (will vary; most likely "chimps")

EXTENSIONS & VARIATIONS

1. See the suggestions in the follow-up portion of the PowerPoint. They include a further test of our chromosome #2 origin, by searching for the former centromere region in the lower "q" arm, using an online database.

2. Our "**Chromosome Fusion**" lesson provides instructions for students to access and use professional online DNA databases for doing essentially what this "Mystery..." lesson does, as well as testing other hypotheses and answering other questions.

3. This "Mystery of the Matching Marks" lesson is roughly equivalent to the climax phase of the activity that accompanies the WGBH NOVA production "Judgment Day: Intelligent Design on Trial" (first aired 13 November 2007). In that trial, testimony by Prof. Ken Miller includes the chromosome fusion evidence that this lesson explores. In that activity, several different lines of evidence for common ancestry are examined, and students experience the compelling effect of accumulating that evidence, seeing how multiple lines of evidence provide a high level of confidence in their conclusion: that humans and chimps share a common extinct ancestor. The WGBH version, focusing on how confidence in scientific ideas builds with accumulated evidence, might be a useful alternative to the "Mystery..." lesson. It is available at **http://www.pbs.org/nova/id**.

ATTRIBUTIONS

Created by: Larry Flammer, 10 October 2007.