

CHROMOSOME FUSION Lesson: v3 (Evolution: Human Patterns, Science Processes)

SYNOPSIS:

The banding pattern of our long chromosome #2 closely matches the banding patterns of two shorter chromosomes found in apes. This suggests the likelihood that our #2 chromosome was formed by the head-to-head fusion (merging) of those two shorter chromosomes in an early human ancestor. To test that hypothesis, students search for evidence of this fusion in the DNA of chromosome #2, using online databases (or printouts of same) to seek the sequences typical of terminal DNA (telomeres). In the process, students see how patterns can reveal events of the past, thereby merging elements of both experimental and historical science. They discover the huge amount of DNA in a chromosome, get a sense of gene size and the number of pseudogenes, correlate visible chromosome bands and their contained DNA, and learn to use an accessible resource for further study and inquiry.

PRINCIPAL CONCEPT:

Modern apes and humans evolved from a common ancestor.

ASSOCIATED CONCEPTS:

1. The evidence that humans have evolved from non-humans is stronger than that for evolution within most other groups.
2. Many features of modern organisms reflect the structure of their ancestors in ways that are not adaptive.
3. Scientific explanations confirmed by different lines of evidence are stronger, more likely to be accurate.
4. DNA provides a useful record and diagnostic tool to study the ancestry of modern organisms.
5. Hypotheses about past events can be tested by looking for revealing patterns in the present.
6. Genes and pseudogenes are directly accessible on the internet for study and inquiry.

ASSESSABLE OBJECTIVES:

1. Given the likely fusion area sequence, students will recognize (correctly identify):
 - a) the telomere region from one original chromosome
 - b) the telomere region from the other original chromosome
 - c) the precise point of fusion (where the telomeres from two chromosomes meet head-to-head)
2. Students will correctly explain the significance of this fusion (in context with other indicators: molecular, banding patterns, fossil comparisons) in terms of biological relationship between apes and humans.
3. Students will demonstrate ability to navigate one of two websites to display the DNA sequence of a desired region in a selected chromosome.

MATERIALS:

Student Handouts (see below)

Teacher Instructions [Click here for this lesson in PDF format (3 pages)]

Likely responses to questions for each Part (available upon teacher request to **webmaster**)

TIME:

Two 45 minute class periods (or one period, with tightly structured, guided discussion by teacher).

STUDENT HANDOUTS: (Figures can be in plastic sleeves or laminated for annual reuse)

Chromosome Fusion: I. The Challenge; II. The Search [Click here to download this in PDF format (4 pp)]

Appropriate pages for **Part A**, **Part B**, **Part C**, and/or **Part D**. [Click here for all 4 Parts in PDF format (5 pp)]

Intro. Fig.: Hominoid Chromosomes: human, chimpanzee, gorilla, orangutan, comparisons, showing banding patterns (preferably used in a chromosome comparison lesson earlier)

Fig. 1: Chromosome #2, enlarged, comparing all four species

Fig. 2: Chromosome #2, from NCBI Map Viewer (for paper search)

Fig. 3: Chromosome #2, closeup of fusion region (for paper search)

Fig. 4: DNA Sequence in fusion region (for paper search)

Fig. 5: DNA structure, showing opposing 5' to 3' orientations of its two strands, and deoxyribose structure

TEACHING STRATEGY & PREPARATION:

1. This lesson could be used as an extension of chromosome comparisons in a genetics unit, or as an extension/application in a DNA unit. In either case, it serves especially well as a confirmation of the primate ancestry of humans indicated from the hominoid skulls lab, hemoglobin sequence comparisons, and/or a chromosome comparison lab, possibly in an evolution unit.
2. This lesson is most impressive and effective if the students have broadband access to the internet. Complete directions are provided. It could even be done as a homework assignment, required or extra credit. If online access is not available, the "Search" can be done using a printed copy (provided) of a tiny portion of the DNA in our chromosome #2 (Fig. 4). Be sure to have sufficient copies of the student instructions (**Challenge, and DNA Details**) plus copies of the appropriate "Search" page(s), depending on whether internet access is available, or not. If internet access *is* available, you have the option of using Parts A and B, or Part C, or all 3; your choice, depending on time available and which you think your students could handle best. Be sure to try all 3 parts (or Part D) yourself before doing this lesson, to help you decide which works best. Part C has two pages; best to print them back-to-back on one sheet/student. Part C would be easier to follow if student copies are printed in color (reflecting colors on website).
3. Provide sufficient copies of the **Figures** (one set per team, ideally placed back-to-back in plastic sleeves or laminated for easy re-use).
4. Overhead transparencies could be made of Figures 1-5 (plus the Intro Figure) to illustrate a classroom discussion of the process. If you intend to walk your class through the Challenge and DNA Details, you should also have overhead transparencies of the DNA diagram pages. Additional illustrations desired from specific DNA website pages will be emailed to you if you request them from the webmaster.

PROCEDURES:

1. INTRODUCTION (Read this to students):

When a bullet is suspected of being fired from a particular gun, its rifling marks can be compared to those on a known bullet fired from the suspected gun. If the bullet mark patterns match closely, this is strong evidence for their common origin (from the same gun). In like fashion, when the banding patterns of two chromosomes match closely, their common origin is strongly confirmed. Furthermore, similar DNA sequence patterns provide additional evidence for common origins. This lesson will allow you to further test the primate ancestry of humans.

[If you wish, obtain the bullet-comparison activity in "The Chromosome Connection" on the *Becoming Human* website (see list of Other Lessons below), and have your students do it.]

2. If students haven't seen (in an earlier lesson on chromosome comparisons) the page showing the banding patterns for *all* the chromosomes of humans and apes, be sure to show this to them (**Intro Figure**), either in a handout, or on your overhead projector. Tell them that these are banding pattern diagrams of the chromosomes from 4 different species of animals. Ask them what they see as particularly striking about the page... what stands out? [Hopefully, they will notice the strong similarities in banding patterns between the species]. Then point out that the first chromosome in each set is human, the second is from a chimp, the third is from a gorilla, and the fourth is from an orangutan.
3. Eventually, (if not mentioned by students) draw attention to our chromosome #2, where it matches a combination of two shorter chromosomes in the apes; (these apes have 24 pairs of chromosomes, while we have 23). At this point, students should read the **Chromosome Fusion Challenge**.

4. Students should be able to proceed largely on their own (working alone, in pairs, or small teams, as you prefer), following the directions given, using the figures provided, and answering questions in their notebooks or on a separate sheet of paper. In some classes, you might prefer to walk them through the lesson, at least through the **Challenge** and **DNA Details**, displaying the DNA sequences for discussion, then let them do the **Search** activity working in pairs at computers (or the paper version, Part D, if they have no internet access). Students should answer questions on the pages for the Part(s) of the Search on which they are working. This should be followed by guided class discussion of their answers.

ATTENTION: Sometimes, websites make changes. If you or your students find that the website pages don't seem to fit or respond to the descriptions in our directions, possibly, you (or clever students) can adapt to the changes and figure out how to accomplish the essential tasks critical to this lesson. ENSI has no control over the changes in other websites. In any case, let the ENSI webmaster know, and the directions will be revised to fit the changes and uploaded to the ENSI website. You will be notified when this has been done. A case in point: during the development of this lesson, the Sanger site made major changes to its pages, requiring major revisions to our directions. It does happen!

ASSESSMENT & EVALUATION:

[sample assessments, questions, are welcome; base these on the Assessable Objectives (above)]

EXTENSIONS & VARIATIONS:

A challenging extension would be for students to seek the DNA sequences at the ends of chromosomes, to confirm that they indeed show the same tandem repeats for telomeres as indicated in the existing lesson. In fact, if time allows, this could be an interesting "discovery" activity to *precede* this "Chromosome Fusion" lesson. The Sanger Genome Browser site (see Part C) would probably work best for doing this search. However, be forewarned that the downstream telomere (at the lower end of the q arm) lacks around 100-200,000 basepairs due to the lack of contigs for that tip end.

Experience with this lesson could encourage students to explore other lessons that utilize online DNA and protein analyzing programs, e.g., the "**Tutorial: Investigating Evolutionary Questions, Using Online Molecular Databases**", and "**Pseudogenes, Vitamin C & Common Ancestry.**" These programs will further enrich student understanding of evolution and the nature of science.

OTHER LESSONS: If not already studied, students should also work with the following lessons on this site, providing multiple independent lines of evidence deeply reinforcing the concept that humans and apes share a common ancestry:

- Comparison of Hominoid Chromosomes (should precede this Chromosome Fusion lesson).
- Chromosome Connection (at www.becominghuman.org > Learning Center > Lesson Plans)
- Hominoid Cranial Comparisons (Skulls Lab)
- Chronology Lab
- Molecular Sequences & Primate Evolution
- Footsteps in Time: the Laetoli Trackway

REFERENCES

"Comparison of the Human and Great Ape Chromosomes as Evidence for Common Ancestry" by Robert Williams, from *The Evolution Evidence Page* at <http://www.gate.net/~rwms/EvoEvidence.html>
You will find additional, very useful references on that page, particularly...

"Gene Content and Function of the Ancestral Chromosome Fusion Site in Human Chromosome 2q13-2q14.1 and Paralogous Regions" by Yuxin Fan, Tera Newman, Elena Linardopoulou, and Barbara Trask.
Genome Research, 2002 Nov., 12(11): 1663-72

ATTRIBUTIONS

This lesson was developed in July, 2005 by Larry Flammer, ENSI webmaster. It was inspired by the Evolution Evidence Page by Robert Williams (see References).

Many thanks to scientists Yuxin Fan and Barbara Trask (authors of referenced article) for their generous help in accessing the fusion regions online, and doing a Blast search.

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