CHROMOSOME CONNECTION ACTIVITY PACKET

SELF-CHECK QUESTIONS: Based on your reading of the **Background Information**, check your understanding at this point by answering the following questions:

1. If two different species have extensive identical chromosome banding patterns, they...
   A) must be related
   B) are probably related
   C) could be related, but not necessarily so
   D) are probably not related
   E) may or may not be related...no basis for judging this

2. If you found that two sets of chromosomes (one from species "X" and one from species "Y") showed a very close match (in the number of chromosomes and many identical banding patterns), it would be most reasonable to say that...
   A) one species evolved from the other
   B) both species evolved from a common ancestor relatively recently
   C) both species may be distantly related
   D) their chromosome similarities are only a striking coincidence

ACTIVITY

PART 1: Matching Bullet Marks

Imagine yourself as a scientist in training to become a CSI (Crime Scene Investigator). One of your tasks is to practice finding a match for bullets fired from the same gun. We know that bullets fired from the same gun have very similar markings caused by spiral grooves and imperfections inside the barrel of the gun.

Six guns were involved in a recent crime. Gun specialists fired each gun into a test chamber and retrieved the spent bullet from each gun. The bullet marks were photographed. You are shown photos of the scratch marks on those 6 bullets. You are then given a photo of the scratch marks on bullet (B) taken from that crime scene. Your job is to figure out which gun the crime scene bullet (B) was fired from.

1. Remove from your Chromosome Connection **Envelope** the strip of paper for Part 1, showing the bullet scratch pattern of bullet B, and the group of 6 other bullet scratch patterns (#1-6).
2. Place the B pattern next to each of the 6 patterns in turn. Which pattern matches the B pattern?

Return these two papers to the envelope when done.

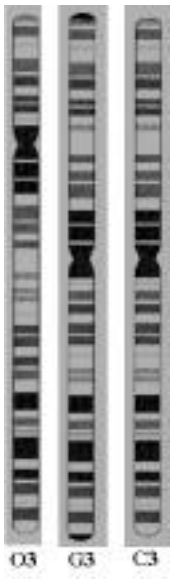
3. Since there is a perfect match, this tells you that these two bullets DID come from the SAME GUN...they both have a **common origin**.

PART 2: Identical Chromosomes?

Identical scratch patterns on bullets indicate they came from the same gun. The same principle applies when we look at chromosomes, the units of heredity found in each cell. **Identical chromosomes have a common origin. They are inherited from the same source: a common ancestor.**

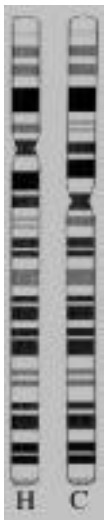
Chromosomes, when treated with a particular stain, reveal characteristic banding patterns, according to their molecular makeup. Where the chromosome proteins (histones) are tightly packed, they stain very darkly.

On the right are the detailed diagrams of chromosomes from three different animals which share many characteristics with humans. In fact, even these chromosomes are very similar to the human chromosome #3. You will find in your Chromosome Connection **Envelope** a strip of paper with the diagram of **human chromosome #3**. Place it next to each of the three chromosomes on the right. Is there a perfect match? If so, which one is it?



That's it!!! These two chromosomes **match perfectly**, band for band. Just as with the perfectly matching bullet scratch marks, this is taken as clear evidence that they must have had a **common origin**. Even though these chromosomes come from two different species, they both had to have a common ancestor. The perfectly matching chromosome is from a chimpanzee, so this tells us that humans and chimps must have descended from a fairly recent **common ancestor** that was neither human nor chimp.

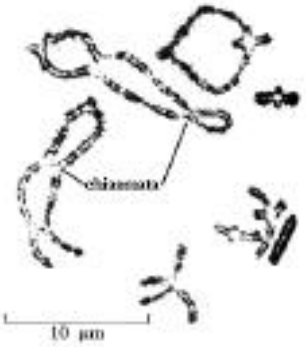
PART 3: Alike, but Different: Inversions



Sometimes similar chromosomes don't match perfectly. This is because even if humans and chimps once shared a common ancestor, they have both changed since that time, and it's reasonable to expect that their chromosomes have changed also. But even apparent differences can be more superficial than real.

On the right are two very similar human and chimp chromosomes: identical in both upper and lower regions, but apparently different near their centromere constrictions. In the Chromosome Connection **Envelope**, find the paper strip for part 3, showing just that centromere region. First, align that region so it matches the orientation in the **human** chromosome (H). Then, simply turn that segment upside down (rotate it 180°), and place it next to the **chimpanzee** chromosome (C) so that their centromere constrictions are at the same level. Identical, aren't they! You've just produced a pericentric (around the centromere) **INVERSION!**

Analysis suggests that this is exactly how the chimp chromosome was formed from the chimp/human ancestor. In fact, according to the authors of that study (Yunis and Prakash, 1982), the human chromosome #4 is considered as the ancestral type "because it's the only one from which the others [chimp, gorilla, and orangutan] can be derived by a single, but differing, pericentric inversion ..." That ancestral chromosome #4 has continued unchanged in humans. Scientists typically infer the simplest explanation from all the evidence, unless there are strong reasons to do otherwise.

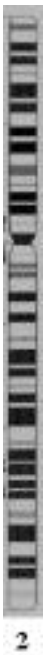


The tell-tale signs of inversion have been observed in many organisms. It is very common and normal, and typically occurs during meiosis (typical in sex cell production). During this process, chromosomes are seen in peculiar "crossing" configurations called "chiasmata", as shown here. Chromatids twist about each other, sometimes forming loops. These segments may break and reattach, reversed (inverted).

Many of the chromosomes in apes and humans are essentially identical except for their inversions. We know from numerous examples that inversions can occur (in humans and other animals) without affecting their fertility and normal development. Pericentric inversions are fairly common. See if you can find examples of inversions in other chromosomes shown in this lesson.

PART 4: Alike, but Different: Fission or Fusion?

In addition to inversions, chromosomes undergo other changes which can account for some of the differences seen in ape and human chromosomes. Sometimes, a chromosome will break apart, producing two shorter chromosomes from one longer one. This is called "**fission**". Other times, two short chromosomes will stick together, end to end, forming a single long chromosome where there were two before. This is called "**fusion**"



Humans have 23 pairs of chromosomes, chimps and the other apes have 24. Could this have happened as a result of an early ancestor chromosome splitting apart to produce the two smaller chromosomes (fission) we find in apes? Or, was there a common ancestor in which two smaller chromosomes linked together to make one, but only in the human line of descent? Let's see if we can find out. When we study the chromosomes carefully, we find that the long human chromosome #2 (shown at right) has banding patterns which look very similar to two shorter chromosomes found in apes (which we'll call "2p" and 2q").

In your Chromosome Connection **Envelope**, find the two "Part 4" strips, one marked "**#2p**" and the other marked "**#2q**". These are chimpanzee chromosomes. Be sure the blank paper at both ends of each chromosome are cut off. Now place them end to end, and align them next to the #2 human chromosome on the right. If they don't match, invert one or the other chromosomes, and/or exchange the "attachment" ends, until you get the combination which matches the human #2 chromosome. How would you describe that match comparison?
A) identical; B) very similar; C) somewhat similar; D) totally different.

Awesome! Detailed studies have shown that human chromosome #2 was most likely the result of the **fusion** of the two smaller chromosomes found in the common ancestor of chimps and humans (and still found in chimps). According to Yunis and Prakash (1982), the "... ancestral chromosome 2p [was probably] similar to that of orangutan and gorilla, with a pericentric inversion accounting for the chimpanzee 2p. The ancestral 2q, on the other hand, resembled that of gorilla and chimpanzee, and [the] human chromosome #2 can be explained [most simply] by fusion of a chimpanzee-like 2p and the ancestral 2q." This, in fact, is one of several indications that humans and chimps are more closely related to each other than either is to gorillas, and that orangutans are even more distantly related.

PART 5: How do the Other Apes Compare?

Not only do humans and chimps have very similar chromosomes, but (as you may have suspected by now) their chromosomes are also very similar to those of gorillas and orangutans.

From the Chromosome Connection **Envelope**, remove the paper showing 7 selected sets of chromosomes, with 4 chromosomes in each set. Each set consists of the corresponding chromosome from each of four species. In some cases, you may find that one chromosome in a set is significantly different from the other three. In other cases, all four are very similar, with none significantly different.

As you compare the chromosomes in each set, you can **ignore the dark-staining tip-ends** found on some chromosomes...they are composed of "heterochromatin", and are not considered as important differences. For each item below, if none of the sets show the specified difference, say "NONE of these"

1. Look for those sets in which the **fourth (O)** chromosome is significantly **different** from the other three. You might want to discuss your selections with a partner. **Record** the numbers of those sets.

2. Now look for those sets set in which the **third (G)** chromosome is clearly **different** from the other three. **Record** the number (or numbers) selected.

3. Finally, look for those sets in which the **1st** or **2nd chromosome (H or C)** is significantly **different** from the others. **Record** the number (or numbers) selected.

When you have answered 1-3 above, check with your teacher for the numbers most would choose. As a matter of fact, detailed analysis of **all** the chromosomes from these four species reveals that the H and C chromosomes are most alike (13 virtually identical), the G chromosomes are next most like H (9 virtually identical to H), and the O chromosomes are least like the others (8 virtually identical to H).

The **H** chromosomes are human, the **C** chromosomes are chimpanzee, the **G** chromosomes are gorilla, and the **O** chromosomes are orangutan.

CHECK QUESTIONS

3. How would you now compare the chromosomes (generally) of these four organisms (H, C, G & O)?
   A) identical
   B) very similar
   C) somewhat similar
   D) mostly different
   E) totally different

4. Based on the above observation (and the background information), what would be the most logical assumption about the relationship between these four organisms?
   A) they are members of the same species
   B) they all evolved from a common ancestor relatively recently
   C) they are most likely distantly related
   D) no basis for an assumed relationship...could be related or totally unrelated

NEW INFORMATION: Species C, G, and O are all in different genera which, based on anatomy, have all been traditionally classified in the **same taxonomic family:** the **pongids** (great apes), while humans have been placed in the **hominid** family**.** However, when we compare the full sets of chromosomes for all 4 species, we find that 1) all four species are very similar, and 2) the chimp set is more like the human set than either is like the other apes.

CHECK QUESTION

5. Given this information, should apes and humans all be placed in the same classification family? A) yes; B) no

PART 6: Chromosome Analysis and Degree of Similarity

Let's see what the scientists say. All the differences in the chromosomes from these four animals were recorded, counted and analyzed in great detail by the scientists doing this study, and from these data, it was possible to create a diagram, showing the likely sequence of steps in the evolution of these species relative to each other, and how closely related they are. In the diagram below (based on a similar one by Yunis and Prashak, 1982), the branching points and lengths of each branch are based on the types and relative numbers of chromosome differences between the four species.

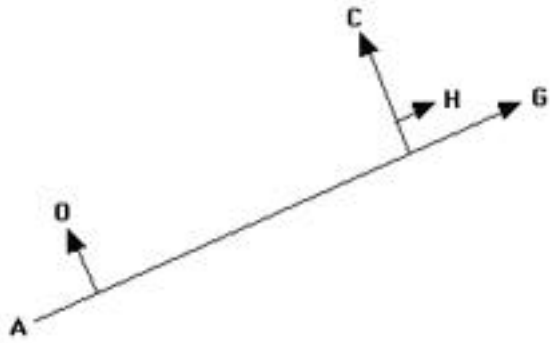
A = an extinct primate, common ancestor to great apes and humans

O = orangutan

H = humans

C = chimpanzees

G = gorilla



CONCLUSIONS

Traditionally, based mostly on anatomy, all **humans** and all **apes** have been placed in the same superfamily: the **hominoids**. Humans (all modern and fossil humans) have been placed in their own **family** (the **hominids**), while the great apes (chimps, gorillas, and orangutans) have been grouped in their own **family** (the **pongids**).

However, extensive "...biomolecular studies demonstrate unequivocally that the living African pongids - Gorilla (*Gorilla*) and the chimpanzee (*Pan*) - are actually more closely related to people than either is to the living Asian pongid, the orangutan (*Pongo*)." (Klein 1999). Reflecting the growing evidence (in fact **M**ultiple **I**ndependent **L**ines of **E**vidence), it has been proposed that **all apes and humans** be placed into the **same family** (the hominids), and that **humans even be placed in the same subfamily as the great apes** (orangutans, gorillas, and chimpanzees):. The **Chromosome Connection** provides evidence which clearly supports that thinking.

Multiple Independent Lines of Evidence...

This pattern of similarity in ape and human chromosomes closely matches the patterns and inferred biological relationships based on anatomical and molecular comparisons. It is also consistent with their geography (orangutans in Southeast Asia; gorillas, chimps, and earliest hominids in Africa). Here we have an excellent example of one important criterion for how scientists select the "best" explanation: **M**ultiple **I**ndependent **L**ines of **E**vidence, all pointing to the same conclusion. With all these "MILEs", we have a very strong case that humans and apes have a close kinship, relatively recent common ancestors. Apes truly ARE our COUSINS!

WHEN FINISHED WITH THIS ACTIVITY, BE SURE TO RETURN ALL 7 ITEMS TO THE CHROMOSOME CONNECTION ENVELOPE

REFERENCES: See the list of REFERENCES in the BACKGROUND pages of this lesson.