Teacher's Answer Key

1. There are 24 bands all together. **Note:** On the "p" arm, region 1 has 3 bands; region 2 has 2 bands; and region 3 has 6 bands. On the "q" arm, region 1 has 2 bands; region 2 has 5 bands; region 3 has 2 bands; and region 4 has 4 bands.
2. There are 11 bands with a high concentration of tightly condensed proteins. (They are the dark bands.)
3. There are 13 bands with less condensed proteins. (They are the light bands.)
4. An example from Figure 2 of a chromosome with the centromere slightly to one side of center is #4. An example from Figure 2 of a chromosome with the centromere near the end is #18. An example from Figure 2 of a chromosome with the centromere on the end is #21.
5. The long arm is designated the "q" arm.
6. There are three regions on the "p" arm.
7. There are four regions on the "q" arm.
8. The third region of the "p" arm has six bands.
9. An arrow points to band 1q2.4 on the chromosome.
10. The chromosome that shows no differences is #3.
11. The seven chromosomes that differ only in an additional dark band at the tip of <u>one</u> of the arms of the chimp chromosome are: #6, 8, 10, 11, 14, 22, X.
12. The other difference in chromosome #7 is that one band in the "q" arm is slightly wider in the chimp.
13. The address of the above band is 7q31.1.
14. On the chimp chromosome there is an extra dark band that the human does not have.
15. 13q14.4 is the address of the additional band in the chimp chromosome #13.
16. The chromosomes that have two additional dark bands at the tips of the arms are #19, 20 and 21.
17. In addition to chromosome #5 discussed in the question, chromosomes #1, 4, 9, 12, 15, 16, 17, and 18 have pericentric inversions.
18. Of the chromosomes with pericentric inversions, chromosomes 1, 9, and 12 also have differences within the inverted section.
19. In the Y chromosome the "p" arms are homologous and much of the "q" arm is too. However, there are additional bands on the "q" arm of the human chromosome.

20. Obviously, there are many more similarities than differences when you look at the total number of bands, etc. <u>Additional note to the teacher</u>: According to Yunis' paper in *Science* (1980), there are more than 1200 bands that were compared. The differences noted in this activity are minor compared to the similarities. There is virtual homology in all of the non-heterochromatic bands (the light ones). Every band on the human chromosomes is also on the chimp chromosomes. There are also precise locations of the break-points in the inversions.

21. The extra chromosomes (#21) are homologous in chimp and humans; that is the chromosome lengths, banding patterns and centromere locations match. Since the bands indicate areas of greater or lesser protein condensations (and gene activity), this would seem to increase the likelihood that at least some of the genes on the two chromosomes are homologous also. While this is not direct evidence of homologous genes, the fact that the syndromes in two species are very similar too, lends a high degree of probability to this conclusion. This is an indication that the extra chromosome had very similar effect (through actions of genes) on both organisms. The evidence is consistent with humans and chimps being closely related.

22. It is clear that the two chimp chromosomes are homologous to the one human chromosome. Since we do not know how many chromosomes the common ancestor of 5.5 million years ago had, there are two possible explanations. The two chromosomes might have joined together to form the one human chromosome and the organism that this happened in is a human ancestor but not an ape ancestor. The other possibility is that in an ape ancestor one chromosome broke into two.

23. The change probably occurred after the human line split from the ape line since the apes have the same number of the chromosome #2 and the human is different. An additional note to the teacher: Orangutans, gorillas and chimps all have two chromosome #2 (actually they have four since we are only looking at half of the set here). Since humans are the only ones with one chromosome #2 and the apes all have two, a fusion of the two chromosomes in the human line most likely happened after the human line split from the apes. [See the diagram showing the **complete karyotypes** for humans, chimps, gorillas, and orangutans, with the corresponding chromosomes arranged side by side, in that order, from a photo provided by J.J. Yunis, and shown in his article in *Science* (1982), also available in Strickberger's *Evolution*, 1996, page 206; this is available in a separate pdf file at the end of the ENSI lesson.]

24. This data seems to indicate that humans are more closely related to chimpanzees than they are to gorillas and orangutans since there are fewer differences between humans and chimps than there are with the gorilla and orangutan [See pdf file of the **cladogram** from Yunis (1982)].

25. If Bonobos are more closely related to humans than regular chimpanzees, then there should be fewer differences between Bonobo and human chromosomes than there are between human and regular chimpanzee chromosomes. Additional note: perhaps just as intriguing would be to determine whether the differences between the two chimpanzees is greater than the difference between humans and either chimpanzee species!

Notes to teacher. The supplementary materials (References below) will help you understand better and will help you do a better job discussing these concepts with your students. I highly recommend reading them before doing the activity with your students. I also recommend doing this activity in two parts. Finish and discuss part one before going on to part two.

Note the enlarged human chromosome #1 at the end of these notes; use this to make an overhead transparency for class discussion. Also, note that the enlarged human and chimpanzee chromosomes to be copied for students to use in this lesson, are included as pdf files at the end of this ENSI lesson, along with a pdf file of the complete karyotypes for hominoids (humans and apes).

References:

Cummings, M.R. 1994. *Human Heredity*. St. Paul: West Publishing Co.
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Stein, P.L. and Rowe, B.M. 1993. *Physical Anthropology*. McGraw-Hill, Inc.
Strickberger, M.W. 1996. *Evolution*.. Boston: Jones and Bartlett Pub., esp. page 206.
Yunis, J.J. and O. Prakash. 1982. "The Origin of Man: A Chromosomal Pictorial Legacy." *Science*, vol. 215, pp. 1525-1529 (19 March 1982).
Yunis, J.J. and Dunham, K. 1980. "The Striking Resemblance of High-Resolution G-Banded Chromosomes of Man and Chimpanzee". *Science*, vol. 208, pp. 1145-1148 (6 June 1980).

Please feel free to call, write, or e-mail the author if you have any questions or comments on this activity. She welcomes your input.

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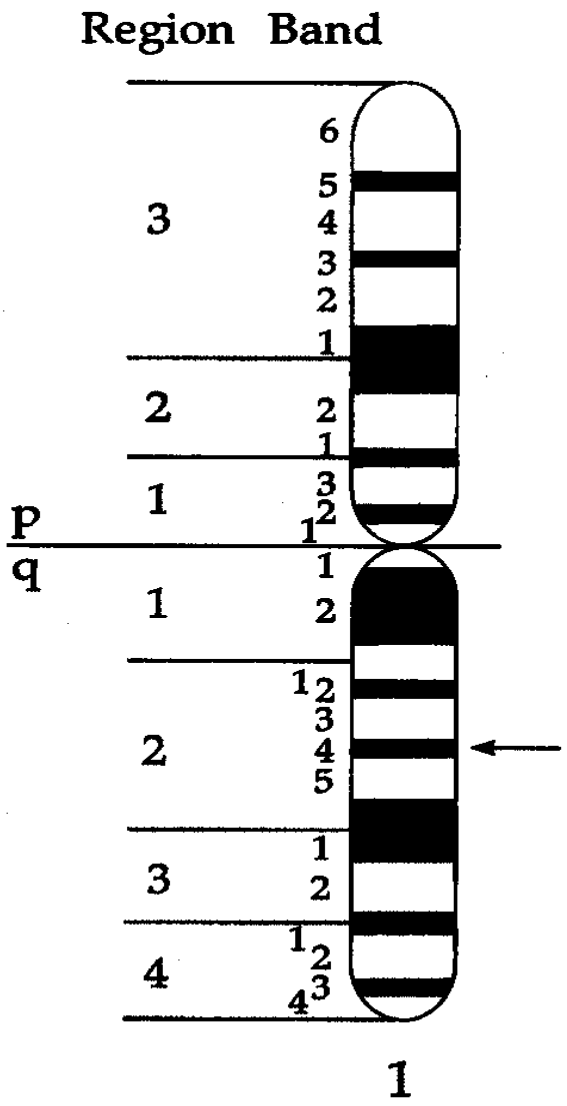

Figure 1.
Human Chromosome #1.
Transparency

Fig. 1 From *Human Heredity* by M.R. Cummings, 1994, St. Paul Publ. Co.