

COMPARISON of HUMAN and CHIMPANZEE CHROMOSOMES

by
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Introduction:

Chromosomes are microscopic strands found in the nuclei of the cells of living things. As you may have learned in genetics, the codes for an organism's characteristics are located on that organism's chromosomes. Similarities of the characteristics in the members of a particular species (humans for example) are due to the similarities in the information on their chromosomes.

Similarities between members of different species might also be due to the similarities in the information on their chromosomes. Comparison of chromosomes is one of the ways currently being used to determine the evolutionary relationships between organisms of different species. Organisms get their chromosomes from their parents, and even further back in time, from their ancestors. The theory of evolution predicts that two species having a recent common ancestor should have chromosomes that are more similar than two species having a common ancestor further back in time. In other words, **species that are more closely related should have more similar chromosomes.**

It is possible to directly compare the chromosomes of two species of organisms. This is done by obtaining and staining a cell from a member of each of the two species. The chromosomes in the cells are located using a microscope. Then, a special camera that attaches to the microscope is used to take a picture. This picture is called a **karyotype**.

A karyotype for an animal like humans has two of each chromosome (except for males who have an X and a Y chromosome). When comparing the chromosomes from the two species, it is not necessary to use all of the chromosomes from the organism's cell. Instead, only one from each pair is used, since both chromosomes from the pair look alike. In examining the chromosomes, the length of the chromosome, the location of the centromere and the banding patterns are studied very closely. Then these chromosomal patterns from the two species are compared. The similarities and differences are carefully noted.

Earlier it was mentioned that organisms get their characteristics from the information on their chromosomes (which come from their ancestors). One way to determine how closely related two species are is to compare all of their characteristics. Humans are most similar in their characteristics to orangutans, gorillas and chimpanzees (the great apes). However, orangutans, chimpanzees and gorillas seem very similar to each other. Therefore, determining to which of these animals humans are most closely related is difficult. In making a determination of the relationships between very similar organisms, comparison of chromosomes is very helpful. The biologists that do such comparisons are called **evolutionary geneticists**.

In Part 1 of this activity, you will become familiar with the terminology used when geneticists closely examine chromosomes. Then, in Part 2, you will compare a set of human chromosomes to a set of chimpanzee chromosomes as an evolutionary geneticist would do.

Materials Needed:

Colored pencils Human and chimpanzee chromosome diagrams

Procedure:

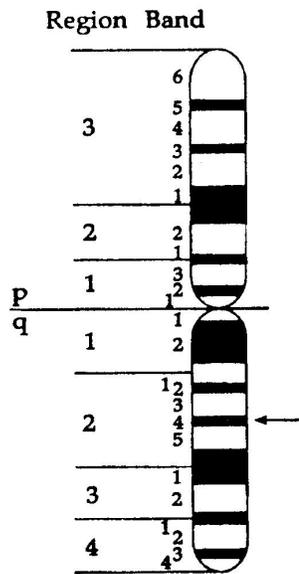


Figure 1
Human Chromosome #1

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

Part 1: Chromosome Anatomy

1A. When looking into the nucleus of a cell through a microscope, it is difficult even to see the chromosomes. It is impossible to distinguish one chromosome from another without staining. In the late 1960's and early 1970's, geneticists developed staining procedures that produce patterns of dark and light bands on each chromosome. In Figure 1, notice the detailed diagram (**karyogram**) of human chromosome #1 that shows these bands. This staining procedure uses a chemical called **Giemsa** so the **bands** produced are called G bands. Particular chromosomes of all humans absorb the stain in the same way. The stain produces band patterns that are unique for each of the 23 (24 in males) different chromosomes. For example, chromosome #1 for all humans has this same pattern of bands.

When chromosomes are stained with Giemsa, it is thought that the **dark** bands are where the chromosome proteins are **tightly** condensed, while the **light** bands are where the proteins are **less** condensed, and where the genes are more active.

ANSWER QUESTIONS #1-3 ON WORKSHEET

1B. Notice that the chromosome in Figure 1 has an area towards the middle that is narrowed. This is called the **centromere**. The centromere can be located in the center of the chromosome (as in Figure 1). It can also be located slightly to one side of the chromosome's center, near one end, or at the very end. **ANSWER QUESTION #4 ON WORKSHEET**

1C. Chromosome banding patterns and centromere location have been used as the basis for a system of identifying specific chromosome **regions** on each chromosome. Notice in Figure 1 that the centromere divides the chromosome into two **arms**. In this system, the short arm of each chromosome is designated the "**p**" arm. **ANSWER QUESTIONS #5-9 ON WORKSHEET**

1D. These banding and centromere markers allow the geneticist to clearly identify each of the different human chromosomes. The development of banding techniques and related methods has provided researchers with a powerful tool for chromosome studies and comparisons. Chromosome analysis has many important applications in the studies of genetics and evolution.

Part 2: Chromosome Comparisons

2A. Look over all of the pages of Figure 2. It shows a diagram of G banded human (left) and chimpanzee chromosomes side by side. For example, the chromosomes marked as #1 show human chromosome #1 next to chimpanzee chromosome #1. Notice that chromosome #2 has three chromosomes. We will discuss this unique feature later. In this part of the activity, you will be asked to examine the chromosomes closely in order to make some comparisons. **ANSWER QUESTIONS # 10-16 ON WORKSHEET**

2B. An **inversion** is a segment of a chromosome that is reversed in the order of the bands. It looks as if a piece of the chromosome had been cut out, inverted, and put back in the chromosome in reverse order. A **pericentric inversion** is an inversion that contains the centromere and has break points in both arms. **ANSWER QUESTIONS #17-25 ON WORKSHEET.**

WORKSHEET: COMPARISON OF HUMAN AND CHIMPANZEE CHROMOSOMES

PART 1: (READ PART 1A ON INFO SHEET)

- 1) How many bands are on the chromosome in Figure 1? _____
- 2) How many bands are there with a high concentration of tightly condensed proteins? _____
- 3) How many bands are there with less condensed proteins, more active genes? _____

READ PART 1B ON INFO SHEET

4) Now, using the chromosomes in Figure 2 as a guide. Draw chromosomes that show the other three types of centromere location in the space below. Label each drawing with its type of centromere location.

READ PART 1C ON INFO SHEET

- 5) What is the long arm designated? _____

Now, notice that each arm is subdivided into numbered regions beginning at the centromere and moving toward the ends.

- 6) How many regions on the chromosome are on the “p” arm? _____
- 7) How many regions on the chromosome are on the “q” arm? _____

Within each region, the bands are identified by numbers too.

- 8) How many bands does the third region on the “p” arm have? _____

In this manner, any region in the human karyotype can be identified by an “address” such as 1q2.4. The address consists of the chromosome number (1), the arm (q), the region (2), and the band (4).

- 9) Find this band (1q2.4) on the chromosome of Figure 1. What do you find pointing to this band? _____

READ PARTS 1C AND 2A ON INFO SHEET

PART 2:

10) There is one chromosome that is virtually identical in banding patterns and centromere location in the two species? What is its number? _____

11) There are seven chromosomes whose only difference is an additional dark band at the tip of one of the arms of the chimpanzee chromosome. Circle the extra bands on these chimpanzee chromosomes using **red** colored pencil. List the chromosome numbers here:

- 12) Chromosome #7 has an extra dark band at the tip of one arm of the chimpanzee chromosome too, but it also has another very slight difference. What is the other difference? _____

- 13) Circle the difference in #7 with **purple** colored pencil. Give the address of the band where this difference occurs. _____

- 14) Chromosome # 13 has a similar difference. Circle it in **orange** and describe the different feature. _____

- 15) Give the address of the band where this difference occurs. _____

16) There are three chromosomes that differ only in that there are two additional dark bands at the tips of the arms of the chimpanzee chromosome. Circle the extra bands on these chimpanzee chromosomes in **blue**. List the chromosome numbers here: _____

READ PART 2B ON INFO SHEET.

17) There are nine chromosomes that differ mostly in the presence of a pericentric inversion. Chromosome #5 is one of them. Find the section in chromosome #5 that is reversed between the two species. The segments that are inverted in these chromosomes vary in size. Designate the inverted section on all nine chromosomes by drawing a **green arrow** on both chromosomes that shows the inverted section. List the other eight chromosomes with pericentric inversions here: _____

18) As you were answering question 17 above you might have noticed that some of the chromosomes also had differences within the sections that were inverted. List these chromosomes here:

19) Describe the feature in the Y chromosome that is different between the two species. Circle the different feature in **brown**.

20) Overall, would you say that there are more similarities or more differences between the two sets of chromosomes? Give reasons for your answer.

21) In genetics you may have learned about a human condition called 'Down's Syndrome'. This condition is caused by an extra chromosome #21 in a person's cells. Recently, a baby chimpanzee in a zoo was born with characteristics similar to those found in humans with Down's Syndrome. When a karyotype prepared from the baby chimpanzee's chromosomes was examined, it was discovered that there was an extra chromosome #21 also. Is this evidence consistent with or contradictory to humans and chimpanzees being closely related? Explain why.

22) Examine both the chimpanzee and human chromosome #2. The left chromosome is human and the other two are from the chimpanzee. Assuming that chimpanzees and humans had a common ancestor approximately 5.5 million years ago, give two possible scientific explanations for why there are two chimpanzee and one human chromosomes here while there are only one of each of all of the other chromosomes. Your explanations must be based on physical evidence only, in order to be scientific.

23) Assuming the two species had a common ancestor, do you think this change occurred before or after the human line split from the ape lines? What is the physical evidence in the chromosomes that supports your conclusion?

24) Studies similar to this one were done where the chromosomes of humans were compared to gorillas and also to orangutans. It was found that there were more differences in both of these comparisons than there were in the human-chimpanzee comparison. What would this seem to indicate about which of these ape species is most closely related to humans? What is the physical evidence supporting your conclusion?

25) The chromosome comparisons in this study were done between regular chimpanzees and humans. There are actually two known species of chimpanzees. The most recently discovered of these two species is known as the Pygmy Chimpanzee or the Bonobo (*Pan paniscus*). The Bonobo is more like humans in its appearance and behavior than the regular chimpanzee (*Pan troglodytes*). Thus by appearances alone, it appears that the Bonobos are more closely related to humans than are the regular chimpanzees. If this is the case, what would you predict you would find if you did a chromosome comparison between Bonobo chimpanzees and humans? Give scientific reasons for your predictions.