Science MATTERS! ... IN CONNECTICUT

NIE ACTIVITY

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A Career in Chromosomes

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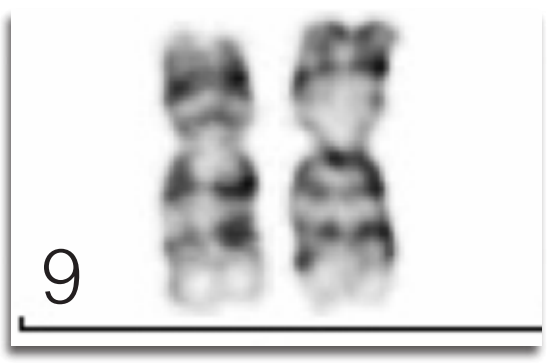


This inversion of chromosome 9 (on the right) is in high frequency in the human population.

Chromosomes, found in the nucleus of the cell, are complex structures made of strands of DNA tightly wound together with RNA and specialized proteins called histones. Human DNA is most closely related to the chimpanzee with ~98% shared DNA sequence. If so similar, why do chimpanzees have 24 pair of chromosomes and humans have only 23 pairs? How is it possible to look inside a cell to count the chromosomes? The answer to these questions, and many more, is the study of chromosomes, a science called **cytogenetics**.

A cytogenetic laboratory scientist harvests dividing cells from blood, bone marrow, and tissues at the **metaphase** stage of cell division when chromosomes are most condensed and visible. Cell membranes are swollen open with a salt solution and cells are fixed onto a glass slide. Chromosomes on the slide are lastly **G-banded**; treated with an enzyme to partly break away the proteins supporting the chromosomes and then immersed in a stain. G-banding will make a pattern of light and dark bands along each chromosome. Identification is based on three criteria which remain constant for a normal pair of chromosomes; relative size, **centromere** position, and G-band pattern. A chromosome analysis test result is a **karyotype**. The karyotype reports the chromosome count, sex chromosomes (XX female or XY male in humans), and any abnormalities in a standardized **nomenclature** such as 46,XX or 47,XY,+21.

A karyotype test is often normal; however, karyotypes may show an extra chromosome (trisomy), a chromosome loss (monosomy), or abnormalities in chromosome structure, all of which may be associated with health problems. Down Syndrome for example, results from trisomy of chromosome 21, a condition associated with intellectual disability and a characteristic facial appearance. Females with only one X chromosome have Turner Syndrome. Human and chimpanzee karyotypes appear G-band similar, however over evolutionary time, two separate chimp chromosomes fused together to form the human chromosome 2. Persons with a fusion of chromosomes 13,14,15, 21 or 22 have a Robertsonian translocation and are at risk for having children with a chromosome abnormality. Smaller chimp-human karyotype differences are a result of **inversions**, such as the chromosome 12 inversion. Inversions change the order of a piece of DNA, but do not usually result in a large gain or loss of DNA within a chromosome. For example, a chromosome 9 inversion occurs at high frequency in human populations but is not associated with disease. Other inversions can disrupt a gene or gene function at the chromosome break, for example an inversion on chromosome X is linked to deafness.

WORDS to know

Cytogenetics: the study of chromosomes

Centromere: each chromosome has a constriction point called the centromere, the location at which spindle fibers attach during mitosis. The centromere location on each chromosome gives the chromosome a characteristic shape and divides the chromosome into a long arm (q) and a short arm (p). Metacentric chromosomes have short and long arms of roughly equal length with the centromere in the middle. Submetacentric chromosomes have short and long arms of unequal length with the centromere more towards one end. Acrocentric chromosomes have a centromere very near to one end and have very small short arms.

G-banded: Giemsa banding (G-banding) is a technique used to produce the banding pattern on chromosomes useful for the identification of chromosomes. Chromosomes are treated with an enzyme to partially digest the proteins supporting the chromosome and then immersed in a stain.

Karyotype: Counting, pairing and ordering all the chromosomes of an individual or organism

Inversion: two breaks occur within one chromosome; the broken segment of DNA flips 180° (inverts) and reattaches to form a chromosome that is structurally out-of-order in sequence

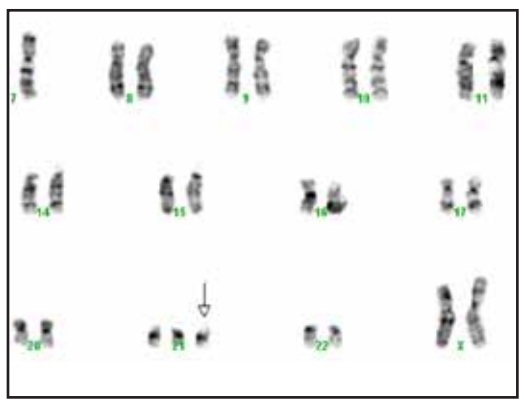
Metaphase: the second stage of cell division

Nomenclature: the devising or choosing of names for things, especially in a science or other discipline

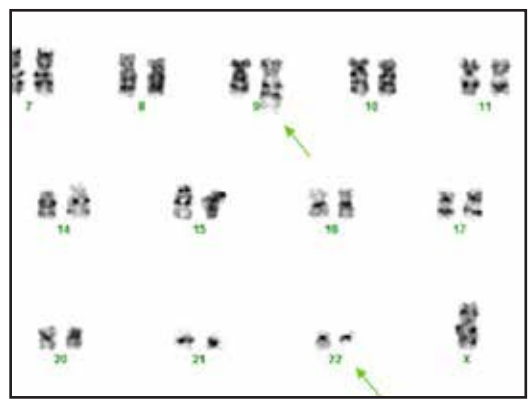
Translocation: the breakage, exchange and attachment of a piece of one chromosome with another chromosome. A translocation is balanced if no genetic material is gained or lost in the cell, whereas the translocation is unbalanced if there is a gain or loss of genetic material.

A **translocation** is defined as the exchange of DNA from different chromosomes. A person with a translocation between chromosome 9 at band q34 and chromosome 22 at band q11 will be diagnosed with leukemia, a type of cancer. Some translocations can be passed from parent to child. It is dependent on whether one or both chromosomes involved in the translocation is inherited from the parent that determines if the child will have clinical abnormalities. Other types of structural chromosome abnormalities can also occur including deletions, duplications, or the formation of chromosomes with two centromeres, for which the clinical outcome is dependent on the size and location of the chromosome region involved. Chromosomal differences in number and structure between species may lead to mating incompatibility and further evolutionary changes.

Clearly, cytogenetics has an important place in the study of evolution and human health. Despite advances with DNA sequencing, karyotyping is the only cost-effective method to identify balanced chromosome abnormalities and to provide a genome wide view in a single test.



Down Syndrome is a health condition resultant from three copies of chromosome 21 (Trisomy 21).



The translocation between chromosome 9 and chromosome 22 (arrowed) is diagnostic of leukemia. The bottom white part of chromosome 22 is moved to the bottom of chromosome 9 and a small piece of chromosome 9 is moved to the bottom of chromosome 22.

Meet the Scientist

I tried many high school and college job-shadows and internships including pharmacy dentistry, and various laboratories. Once introduced, I was hooked on chromosomes. Cytogenetics offers technically demanding procedures for a variety of tests on different sample types. In research and health care, every karyotype is a new puzzle. I don't do puzzles at home! I enjoy riding a Harley on the backroads or writing silly poems for friends and family.

SKILLS and KNOWLEDGE

Cytogenetic technologists are in high demand at hospitals, industries and varied research laboratories, including zoos. There are five cytogenetic technologist training programs in the country, with the first and the largest program at the University of Connecticut. Most technologists earned a bachelor's degree in a scientific discipline and received on-the-job training. Cytogenetic technologists typically have a good genetics knowledge, strong attention to detail, organization skills, and the ability to manipulate computers and precision instruments.

For Students and Teachers Making Curriculum Connections, see the following:

Connecticut State Department of Education (CSDE) - Common Core State Standards (CCSS): Mathematics

- CCSS.Math.Practice.MP1 Make sense of problems and persevere in solving them
- CCSS.Math.Practice.MP3 Construct viable arguments and critique the reasoning of others
- CCSS.Math.Practice.MP5 Use appropriate tools strategically

CSDE - Next Generation Science Standards: Scientific and Engineering Practices

- Asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using Mathematics and computational thinking; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information.

Hyperlinks:

Chromosome abnormalities: https://www.genome.gov/11508982/chromosome-abnormalities-fact-sheet/
Chimpanzee karyotype: https://www.coriell.org/0/images/karyotype/ag05253bs1k3.jpg
Inversions: https://www.youtube.com/watch?v=QXU7XojaEOs&list=PLHdemSStztKa79voJGhTkk7sinywEG9qz&index=9
Translocations: https://www.youtube.com/watch?v=MLDCJ2gUC84&index=5&list=PLHdemSStztKa79voJGhTkk7sinywEG9qz

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