Detecting Genetic Conditions: Via Paper Karyotyping

Activity exploring human karyotypes, syndromes, and Mendelian genetics

Age
Grades 6-12

Content Areas
- Karyotypes
- Anomalies

Time
45 minutes

Objectives
- Students will become familiar with karyotypes and their role when diagnosing genetic disorders in individuals.
- Students will create a karyotype of a random individual and diagnose the disorder.
- Students will discuss genetic testing and the ethical issues that can arise.

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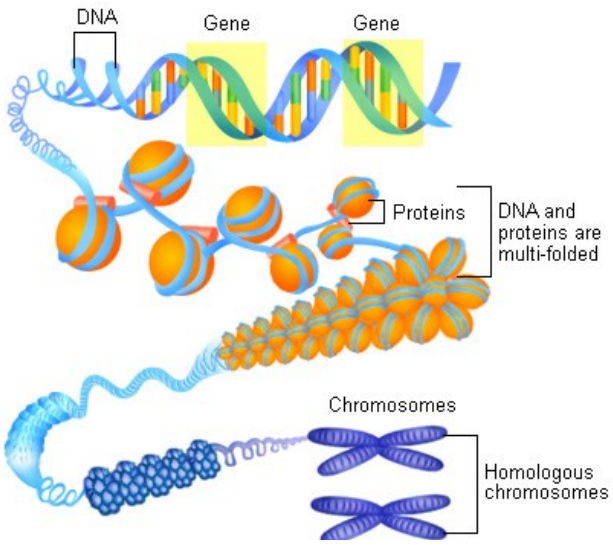
Background:

Occasionally, chromosomes can be lost or misplaced during the formation of gametes in meiosis or cell division in mitosis. Non-disjunctions (see glossary) or translocations that occur due to these changes can result in miscarriage or lack of fertilization. One in 150 live births that occur have some type of chromosomal abnormality (1). It is important to note that in most cases, these chromosomal abnormalities are not the result of genetic inheritance but are simply abnormal events in meiosis or mitosis.

Some abnormalities associated with chromosome structure and number can be visibly seen by a *karyotype* (see glossary). Karyotypes are used in genetic counseling for potential parents as well as for diagnosis when an anomaly is suspected. A person's biological sex is in most cases directly evident in their karyotype. Over 400,000 karyotype analyses are performed each year in the U.S and Canada (2).

In order to create a karyotype, chromosomes from a cell are stained and photographed in the metaphase of mitosis in order to visualize the replicated and condensed chromosomes under a microscope. The photograph is then enlarged and the homologous chromosomes are paired and arranged in order by size (except the sex chromosomes which are by convention displayed last). The tests are generally performed from a blood sample, but any tissue containing cells in the correct phase of mitosis can be used.



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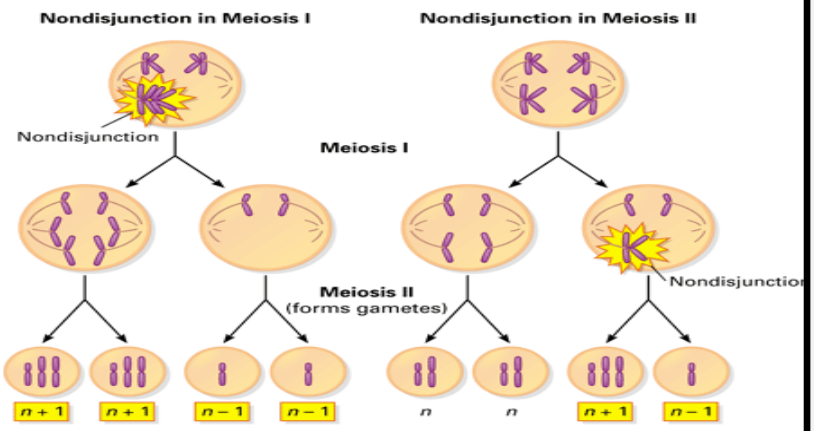

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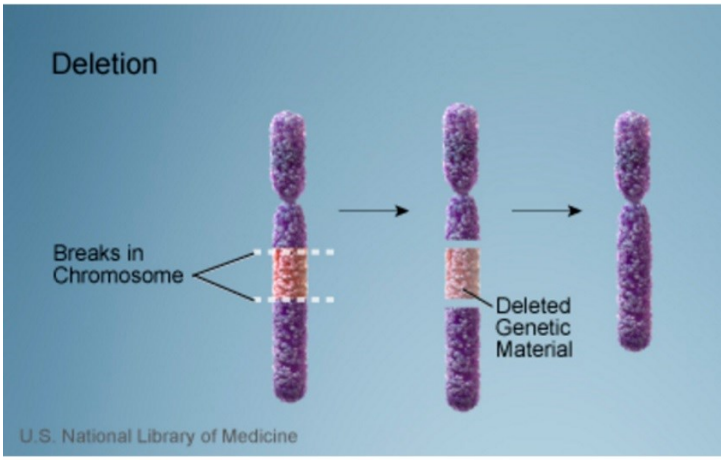

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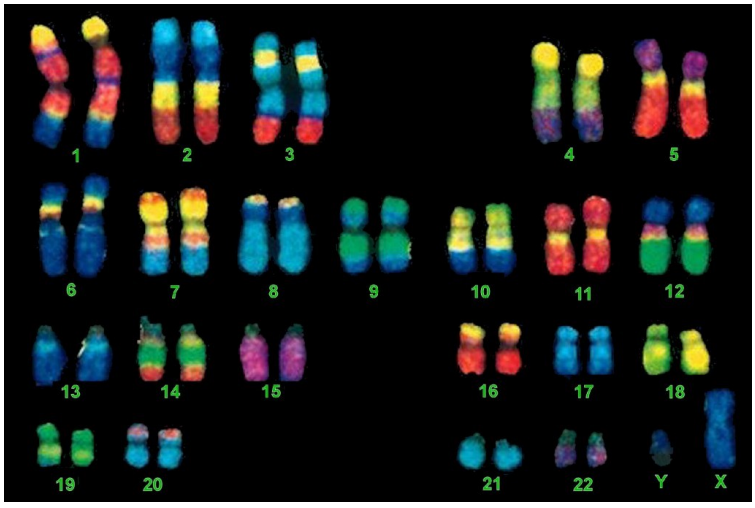

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Glossary

Autosomal Chromosomes: All chromosomes other than the sex chromosomes.

Chromatid: each of the two threadlike strands into which a chromosome divides longitudinally during cell division. Each contains a double helix of DNA.

Gene: A hereditary unit that is transferred from parent to offspring to help determine the characteristics of the offspring.

Genome: The complete set of genes present in an organism.

Karyotype: The number and visual appearance of chromosomes present in the nuclei of a cell.

Mosaicism: The condition of being composed of two or more genetically different types of cells.

Mutation: A change in the nucleotide sequence of an organism's DNA or in the DNA or RNA of a virus.

Nondisjunction: Failure of chromosomes to separate and move to opposite poles of the division spindle. It results in the loss or gain of a chromosome.

Sex Chromosomes: A chromosome responsible for determining the sex of an individual.

Sister chromatid: refers to either of the two identical copies (**chromatids**) formed by the replication of a single chromosome, with both copies joined together by a common centromere.

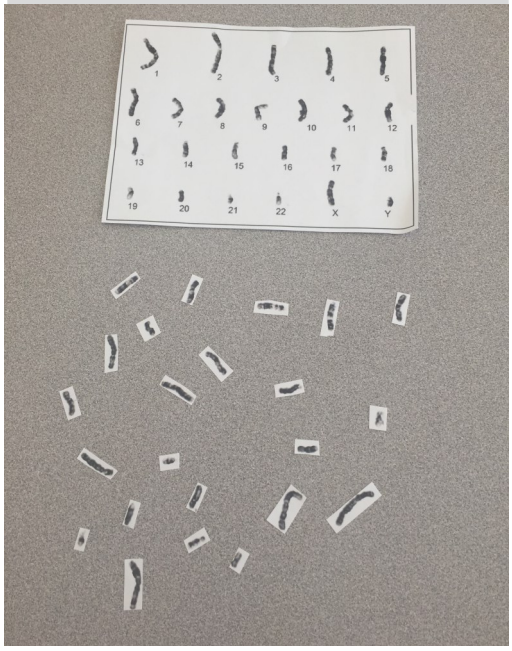
Translocation: An abbreviation in chromosome structure resulting from an attachment of a chromosomal fragment to a nonhomologous chromosome.

Trisomy: a condition in which an extra copy of a chromosome is present in the cell nuclei, causing developmental abnormalities.

(Reference #6)

Materials

- Glue/tape
- Scissors
- Incomplete karyotype worksheet



Directions:

1. Find a partner and take a plastic bag containing chromosomes from a karyotype with an unknown genetic disorder.

2. Using scissors, cut out all the chromosomes that are not labeled. Find its match on the karyotype skeleton labeled 1-23. (hint: Don't throw away extra chromosomes! They could be the key evidence for the presence of a genetic disorder!)

3. Continue step 2 until you and your partner are confident that all of the chromosomes are matched up. Proceed to glue or tape the pairs to the worksheet.

4. Observe the karyotype. Is there an extra chromosome where there shouldn't be? Is one arm of a chromosome noticeably shorter than the other one in its pair? Flip to the back of this document to find a list of common genetic disorders to identify the one in your worksheet.

1. **What chromosomal abnormality is displayed in the karyotype you received? How do you know?**

2. **How can you determine if your paper karyotype is male or female?**

3. What type of mutation occurs in this particular anomaly? Where in the genome does it occur?

Discussion Questions

1. In the paper karyotype activity, you were able to clearly see the chromosomal abnormalities, but other common disorders or illnesses such as migraines, obesity, and diabetes are thought to be genetically inherited to varying degrees. Why do you think the scientific community is unable to pinpoint a specific, universal genetic the cause of migraines, obesity, and diabetes in an affected karyotype?

2. A new company offers genetic testing and claims it can find out if you will get diabetes or high blood pressure for $1000. Does this sound like a good deal to you? Do you think this is a reliable test? Would you want to get tested?

3. What other factors can affect the potential of someone being predisposed to a genetic abnormality?

4. Assuming that you tested positive for a future serious health condition, do you feel that your health insurance company should have knowledge of this and be able to raise the rates of your health insurance based on these results? Why or why not?

List of Genetic Disorders

Klinefelter Syndrome (XXY)

What is it?	How do people get it?	What are the characteristics?	How is it diagnosed?	Treatments?
47, XXY is a genetic condition that is caused when a person has two X chromosomes and one Y chromosome. A typical male has one X and one Y chromosome and a typical female has two X chromosomes. Because a people with XXY have a Y chromosome, they are genetically considered males. However, a small proportion will develop as intersex (between male and female) or female.	caused by a nondisjunction A nondisjunction occurs during meiosis I or meiosis II in gametes with either too many or too few chromosomes. Klinefelter syndrome occurs in meiosis II where one pair of sister chromatids did not separate during anaphase II	primarily affects sexual development--testosterone levels are lower than normal as well as sexual organs do not fully develop. Puberty may be accelerated or halted. As adults, most all XXY males are infertile. Children and adults may be taller than average, with proportionally longer arms and legs. May have less-muscular bodies, wider, narrower shoulders, or minor to moderate learning disabilities.	Physical characteristics or most commonly, infertility via analysis of a person's karyotype. Can be diagnosed during a woman's pregnancy if amniotic fluid or placenta is tested for chromosomal abnormalities 75% of XXY individuals are never diagnosed.	Hormone treatments can be given if desired.

Edwards Syndrome

What is it?

Edwards syndrome occurs when an individual has an extra chromosome 18. A Trisomy 18 error occurs in about 1 out of every 2500 pregnancies in the United States and 1 in 6,000 live births.

How do people get it?

There are three types of Edwards Syndrome:
Nondisjunction (Trisomy 18), translocation, and mosaicism.

The most common cause is non-disjunction (95% of cases), where there is an error in cell division.

What are the characteristics?

Heart defects, kidney problems, small head, and severe developmental delays.

How is it diagnosed?

Diagnostic tests can be performed in utero during the first or second trimester of a pregnancy.

Karyotyping of the baby's DNA can be performed.

Treatments?

Although there is not a cure, each child has their own unique profile of how Trisomy 18 is affecting their developing body and organs.

All studies on survival rates show that there is a high mortality rate for children with Trisomy 18 before or shortly after birth.

Cri-du-chat

What is it?

Cri-du-cat Syndrome (5p minus) is a rare chromosomal condition that happens when a portion of small arm of chromosome 5 is missing.

How do people get it?

Deletion of the short (p) arm of chromosome 5.

Occurs in an estimate 1 in 20,000 newborns.

Studies show that larger deletions tend to result in more severe disabilities to the infants.

What are the characteristics?

Distinctive cry that resembles a cat (in infants), delayed intellectual development, slow or incomplete development of motor skills, small head size, diminished muscle tone, wide side eyes, a small jaw, etc.

How is it diagnosed?

Genetic tests such as amniocentesis can be performed before birth to diagnosis Cri-du-cat.

After birth, it can be diagnosed within the first few days.

Treatments?

Drug therapy, surgery, and rehabilitation may be utilized to manage the syndrome.

Turner Syndrome (XO)

What is it?	How do people get it?	What are the characteristics?	How is it diagnosed?	Treatments?
A genetic condition that results from a missing or incomplete X chromosome and only affects females.	Chromosome change where only one X chromosome is created. Turner Syndrome is not likely inherited; in fact, in most cases, a female with the syndrome will be the first and only person affected in the family.	short stature, infertility, heart defects, and delayed puberty.	A female with TS can be diagnosed in utero with an amniocentesis or at any point in their life using a karyotype.	Hormone therapy and ongoing medical care can be utilized to manage the disorder, specifically for growth and development.

Williams Syndrome

What is it?

Williams syndrome is a developmental disorder. It affects many functions of the body including intellectual ability, personality characteristics, distinct facial features, and problems with the heart and blood vessels.

How do people get it?

Caused by the deletion of genetic materials from regions 26 -28 of chromosome 7.

What are the characteristics?

Highly social personalities, an affinity for music, cardiovascular disease, attention deficit disorder, and broad foreheads.

Though they have difficulty with visual-spatial tasks, they excel at tasks that involve spoken language.

How is it diagnosed?

Detection of the gene deletion in the critical region of chromosome 7 that surrounds the elastin gene.

Treatments?

Early intervention programs and special education programs can provide individualized care and counseling for those with Williams Syndrome.

Diet modification and drug therapy can alleviate the symptoms of the cardiovascular problems that accompany the ailment.

Triple X Syndrome (XXX)

What is it?	How do people get it?	What are the characteristics?	How is it diagnosed?	Treatments?
Triple X syndrome is characterized by the presence of an additional X chromosome in each of a female's cells. It occurs in approximately 1 in 1,000 newborn girls, making it the most common female chromosomal abnormality.	It results from an extra copy of the X chromosome.	Typically no extreme physical features/ ailments that accompany XXX (tall stature). Associated with an increased risk of learning disabilities and a delay in speech and language skills. Behavioral and emotional difficulties are also a possibility.	Amniocentesis sampling is used during the prenatal period. After birth, a karyotype can be examined.	Early intervention therapies including psychological evaluations to support emotional development. If sexual development or fertility problems arise, hormone therapy is an option.

Resources

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6. "Chapter 12: Concept 12.2." *Chapter 12: Concept 12.2. Pearson Prentice Hall, n.d. Web. 21 June 2016.*

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12. Cereda, Anna, and John C Carey. "The Trisomy 18 Syndrome." Orphanet Journal of Rare Diseases 7 (2012): 81. PMC. Web. 15 Aug. 2015. PubMed citation.

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