Part3

University of Technology
Applied Sciences Department
Biotechnology Division

Genetics

2nd class

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The Genetic code

The genetic code is almost universal. It is the basis of the transmission of hereditary information by nucleic acids in all organisms. There are four bases in RNA (A,G,C and U), so there are 64 possible triplet codes. In theory only 22 codes are required: one for each of the 20 naturally occurring amino acids, with the addition of a start codon and a stop codon (to indicate the beginning and end of a protein sequence). Many amino acids have several codes, so that all 64 possible triplet codes are used. For example Arg and Ser each have 6 codons whereas Trp and Met have only one. No two amino acids have the same code but amino acids whose side-chains have similar physical or chemical properties tend to have similar codon sequences. This means that if the incorrect tRNA is selected during translation (owing to mispairing of a single base at the codon-anticodon interface) the miss incorporated amino acid will probably have similar properties to the intended tRNA molecule. Although the resultant protein will have one incorrect amino acid it stands a high probability of being functional. Organisms show "codon bias" and use certain codons for a particular amino acid more than others. For example, the codon usage in humans is different from that in bacteria; it can sometimes be difficult to express a human protein in bacteria because the relevant tRNA might be present at too low a concentration.

First base (5' end)	Middle base	Third base (3' end)			
		U	C	A	G
U	U	Phe	Phe	Leu	Leu
	C	Ser	Ser	Ser	Ser
	A	Tyr	Tyr	Stop	Stop
	G	Cys	Cys	Stop	Trp
C	U	Leu	Leu	Leu	Leu
	C	Pro	Pro	Pro	Pro
	A	His	His	Gln	Gln
	G	Arg	Arg	Arg	Arg
A	U	Ile	Ile	Ile	Met
	C	Thr	Thr	Thr	Thr
	A	Asn	Asn	Lys	Lys
	G	Ser	Ser	Arg	Arg
G	U	Val	Val	Val	Val
	C	Ala	Ala	Ala	Ala
	A	Asp	Asp	Glu	Glu
	G	Gly	Gly	Gly	Gly

Figure | The Genetic code – triplet codon assignments for the 20 amino acids. As well as coding for methionine, AUG is used as a start codon, initiating protein biosynthesis

An exercise in the use of the genetic code

One strand of genomic DNA (strand A, coding strand) contains the following sequence reading from 5′- to 3′-:

TCGTCGACGATGATCATCGGCTACTCGA

This strand will form the following duplex:

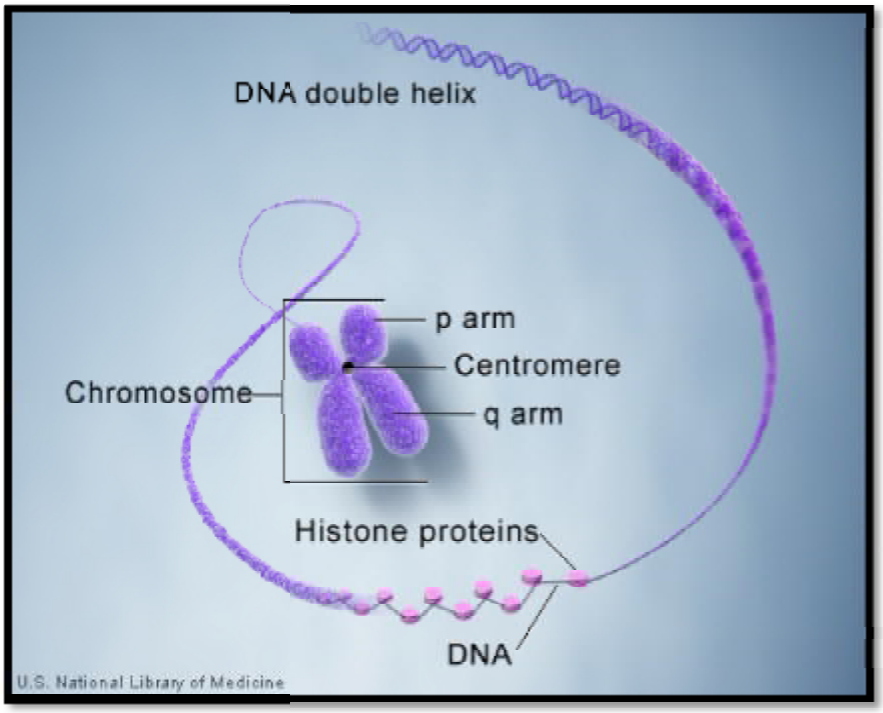
5′-TCGTCGACGATGATCATCGGCTACTCGA-3'
3′-AGCAGCTGCTACTAGTAGCCGATGAGCT-5'

The sequence of bases in the other strand of DNA (strand B) written 5′- to 3′- is therefore
TCGAGTAGCCGATGATCATCGTCGACGA
The sequence of bases in the mRNA transcribed from strand A of DNA written 5′- to 3′- is
UCGAGUAGCCGAUGAUCAUCGUCGACGA
The amino acid sequence coded by the above mRNA is
Ser-Ser-Ser-Arg-STOP
However, if DNA strand B is the coding strand the mRNA sequence will be:
UCGUCGACGAUGAUCAUCGGCUACUCGA
and the amino-acid sequence will be:
Ser-Ser-Thr-Arg-Ser-Ser-Gly-Cys-Ser-

What is a chromosome

In the nucleus of each cell, the DNA molecule is packaged into thread-like structures called chromosomes. Each chromosome is made up of DNA tightly coiled many times around proteins called histones that support its structure.

Chromosomes are not visible in the cell's nucleus—not even under a microscope—when the cell is not dividing. However, the DNA that makes up chromosomes becomes more tightly packed during cell division and is then visible under a microscope. Each chromosome has a constriction point called the centromere, which divides the chromosome into two sections, or "arms." The short arm of the chromosome is labeled the "p arm." The long arm of the chromosome is labeled the "q arm." The location of the centromere on each chromosome gives the chromosome its characteristic shape, and can be used to help describe the location of specific genes.

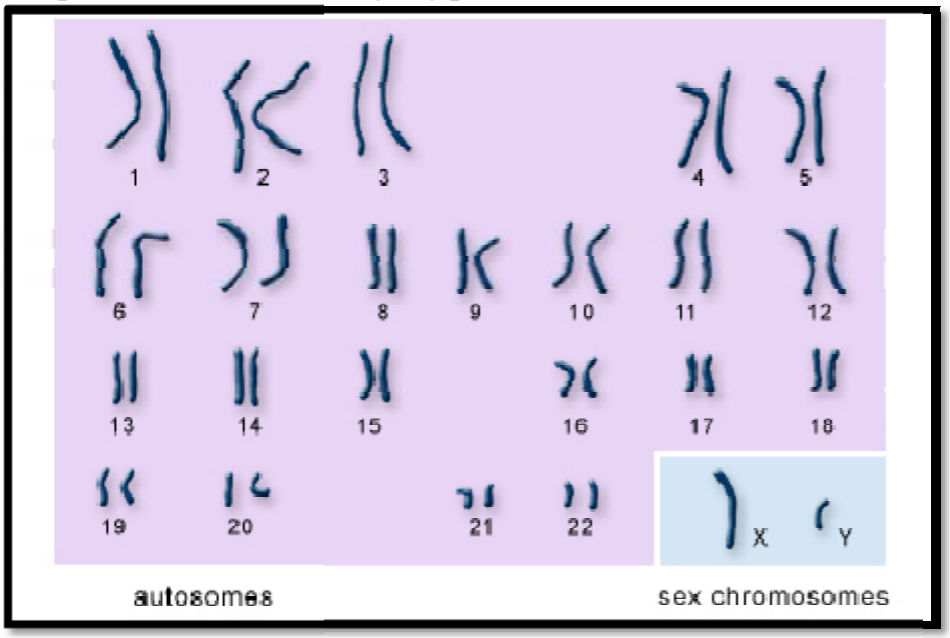


DNA and histone proteins are packaged into structures called chromosomes.

Human chromosomes

In humans, each cell normally contains 23 pairs of chromosomes, for a total of 46. Twenty-two of these pairs, called autosomes, look the same in both males and females. The 23rd pair, the sex chromosomes, differ between males and females. Females have two copies of the X chromosome, while males have one X and one Y chromosome.

The 22 autosomes are numbered by size. The other two chromosomes, X and Y, are the sex chromosomes. This picture of the human chromosomes lined up in pairs is called a karyotype.

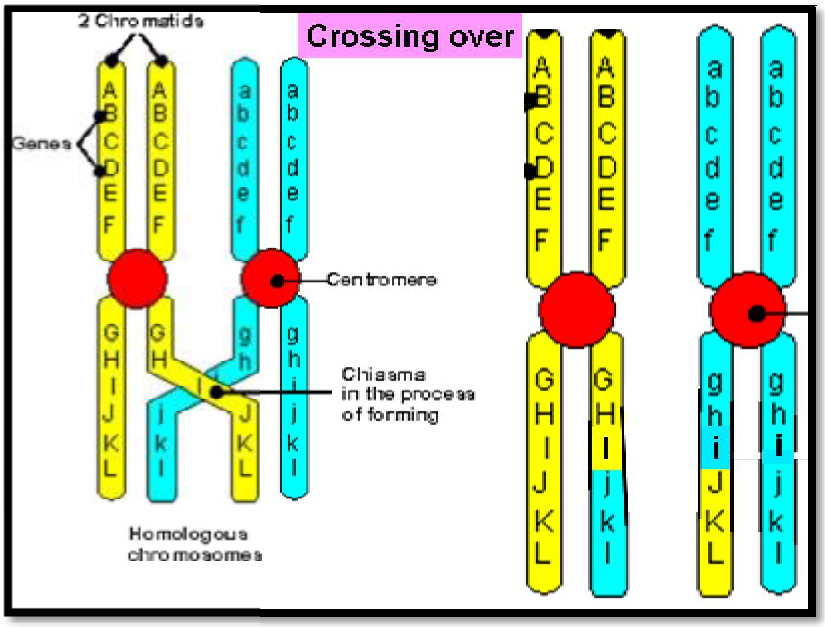


Chromosome Linkage

The location of two or more genes on the same chromosome so that they do not segregate independently during meiosis but tend to be transmitted together as a unit. The closer the loci of the genes, the more likely they are to be inherited as a group and associated with a specific trait, whereas the farther apart they are, the greater the chance that they will be separated by crossing over and carried on homologous chromosomes. The concept of linkage, which opposes the independent assortment theory of mendelian genetics, led to the foundation of the modern chromosome theory of genetics.

Crossing Over

Crossing over, process in genetics by which the two chromosomes of a homologous pair exchange equal segments with each other. Crossing over occurs in the first division of meiosis. At that stage each chromosome has replicated into two strands called sister chromatids. The two homologous chromosomes of a pair synapse, or come together. While the chromosomes are synapsed, breaks occur at corresponding points in two of the non-sister chromatids, i.e., in one chromatid of each chromosome. Since the chromosomes are homologous, breaks at corresponding points mean that the segments that are broken off contain corresponding genes, i.e., alleles. The broken sections are then exchanged between the chromosomes to form complete new units, and each new recombined chromosome of the pair can go to a different daughter sex cell. Crossing over results in recombination of genes found on the same chromosome, called linked genes, that would otherwise always be transmitted together. Because the frequency of crossing over between any two linked genes is proportional to the chromosomal distance between them, crossing over frequencies are used to construct genetic, or linkage, maps of genes on chromosomes. Mutations, temperature changes, and radiation all affect crossing over frequency. Under the microscope, a crossover has the appearance of an X and is called a chiasma.



Factors Affecting Crossing over

The following external factors can affect the frequency of crossing over:

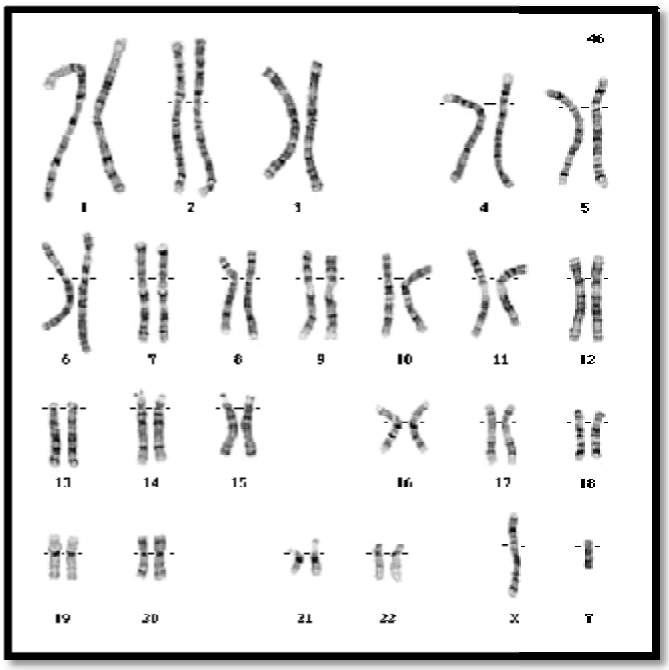
1. In ***Drosophila***, as maternal age increases, crossing over decreases.
2. Both low and high temperatures changed the frequency of crossing over.
3. The existence of crossing over factors has been shown in the cytoplasm of females. Consequently, females with reduced recombination frequencies can pass on this trait to their daughters.
4. Calcium and magnesium ions affect crossover frequency. Antibiotics such as mitomycin-***C*** and actinomycin-***D*** increase crossing over. Similarly ***X***-ray irradiation can increase crossover frequency in ***Drosophila*** females and induce it in males.
5. Heat and shock treatments also change rates of crossing over.

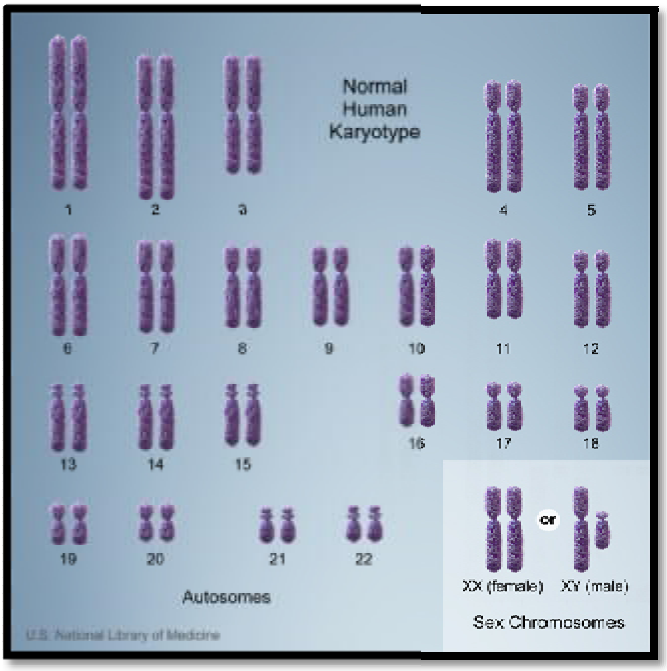
Variations in Chromosome Number & Structure

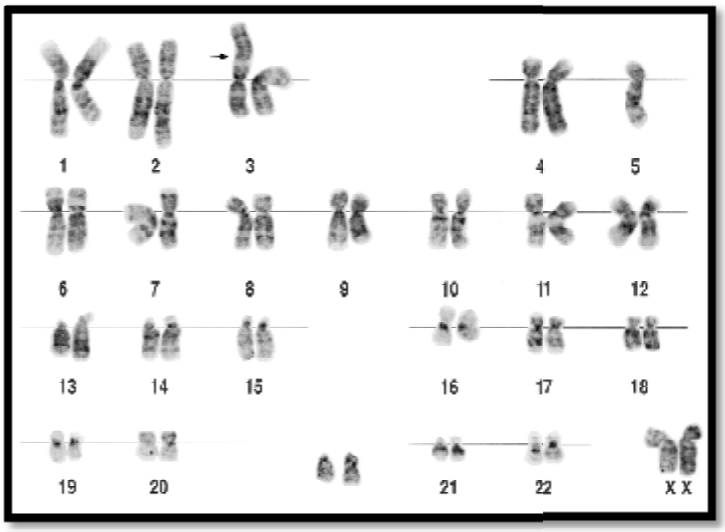
Normal number of chromosomes called ***euploid***; different number's called ***aneuploid.*** Types of aneuploidy

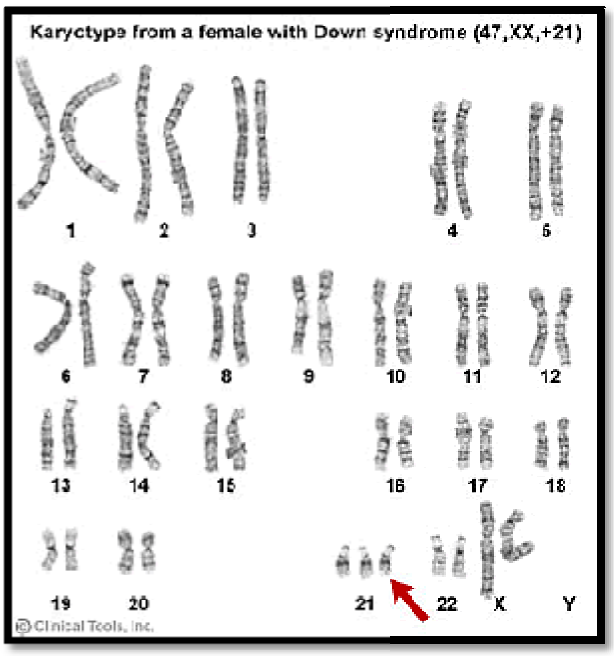
1. nullisomy—missing a pair of chromosomes so 2n-2
2. monosomy—missing 1 chromosome so 2n-1 (i.e. Turner XO female)
3. trisomy—an extra chromosome so 2n+1 (i.e. trisomy 21)
4. tetrasomy—2 extra chromosomes so 2n+2

Consequences of aneuploidy in meiosis often serious or fatal, especially in humans




Normal
Human
Karyotype
Autosomes
or
XX (female)
XY (male)
Sex Chromosomes
U.S. National Library of Medicine




Karyotype from a female with Down syndrome (47,XX,+21)
©Clinical Tools, Inc.

Variations in Chromosome Structure

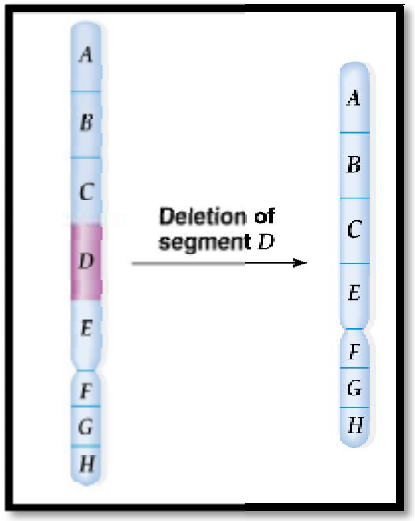
There are two primary ways in which the structure of chromosomes can be altered

1- The total amount of genetic information in the chromosome can change
   a- Decrease: Deficiencies/Deletions: loss of a chromosomal segment
   b- Increase: Duplications & Insertions: repetition of a chromosomal segment

2- The genetic material may remain the same, but its rearranged
   a- Inversions: A change in the direction of genetic material along a single chromosome
   b- Translocations: A segment of one chromosome becomes attracted to a nonhomollogous chromosome
      1- Simple translocations : One way transfer
      2- Reciprocal translocations: Two way transfer

Variations in Chromosome Structure: Deletions
part of a chromosome is missing. Deletions start with chromosomal breaks induced by:

- Heat or radiation (especially ionizing).
- Viruses.
- Chemicals.
- Transposable elements.
- Errors in recombination.



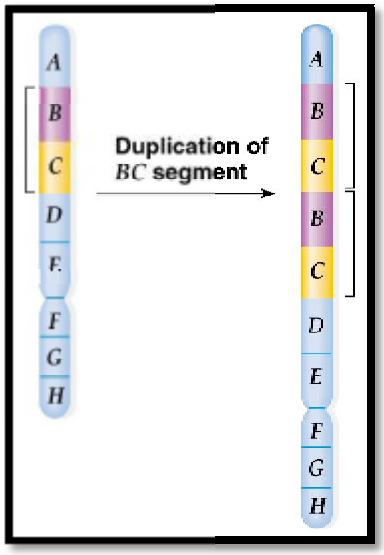
Deletions do not revert, because the DNA is gone (degraded)

The effect of a deletion depends on what was deleted.
– A deletion in one allele of a homozygous wild type organism may give a normal phenotype, while the same deletion in the wild-type allele of a heterozygote would produce a mutant phenotype.
– Deletion of the centromere results in an acentric chromosome that is ost, usually with serious or lethal consequences.
* No known living human has an entire autosome deleted from the genome.
Human disorders caused by large chromosomal deletions are generally seen in heterozygotes, since homozygotes usually die.

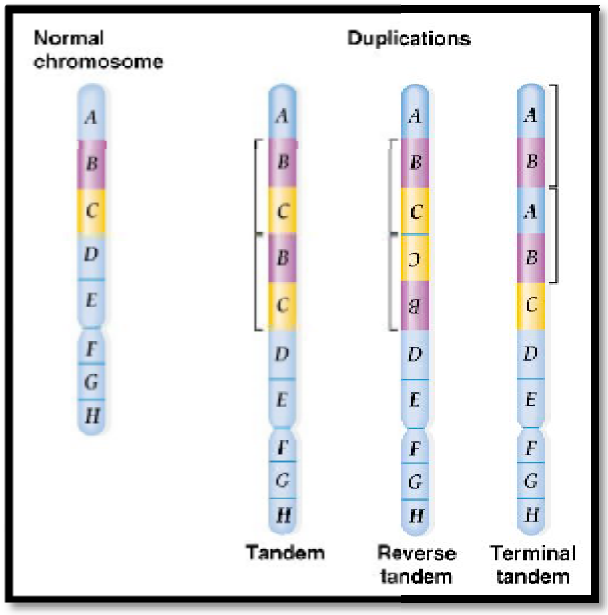
– The number of gene copies is important.
– Syndromes result from the loss of several to many genes.
– The deletion results in severe mental retardation and physical abnormalities.

Variations in Chromosome Structure: Duplications

Duplications result from doubling of chromosomal segments, and occur in a range of sizes and locations

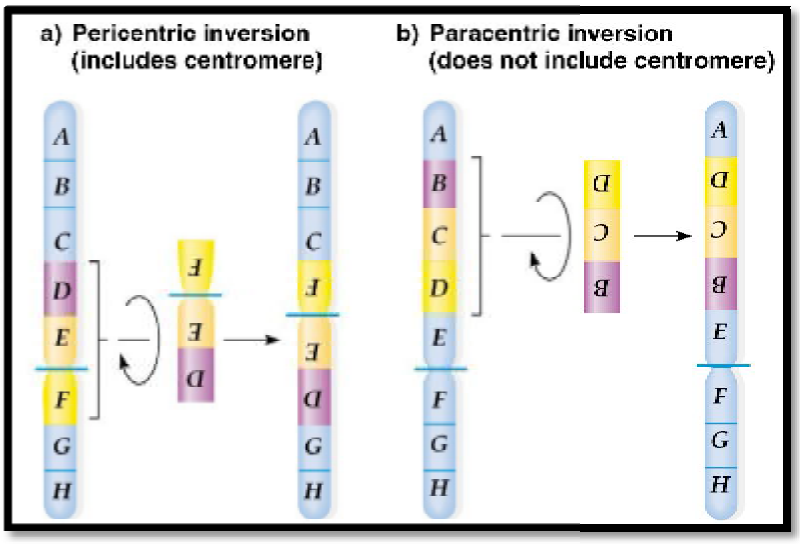


–Tandem duplications: are adjacent to each other.
–Reverse tandem duplications: result in genes arranged in the opposite order of the original.
– Terminal tandem duplication: is the tandem duplication at the end of a chromosome.



Variations in Chromosome Structure: Inversions

Inversion results when a chromosome segment excises and reintegrates oriented 180° from the original orientation.
There are two types as in figure.



- Linked genes are often inverted together.

– A homozygote will have normal meiosis. The effect in a heterozygote depends on whether crossing-over occurs.

- In an inversion, the total amount of genetic information stays the same, therefore, the great majority of inversions have no phenotypic consequences

- In rare cases, inversions can alter the phenotype of an individual

* Break point effect: The breaks leading to the inversion occur in a vital gene

* Position effect: A gene is repositioned in a way that alters its gene expression

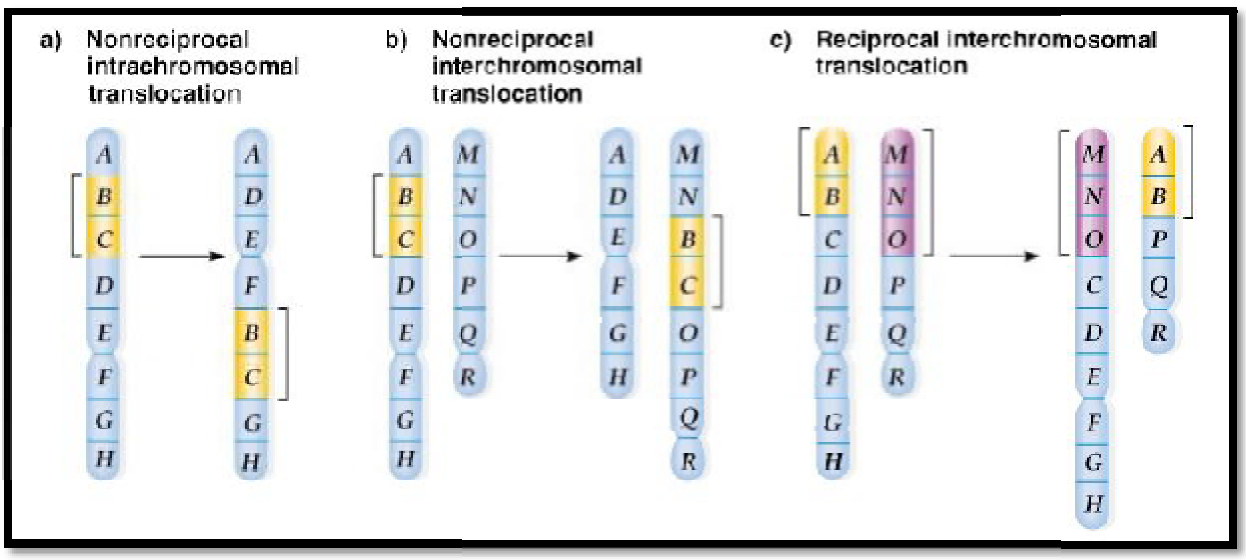
- About 2% of the human population carries inversions that are detectable with a light microscope, most of these individuals are phenotypically normal, However, a few an produce offspring with genetic abnormalities

Variations in Chromosome Structure: Translocations

A chromosomal translocation occurs when a segment of one chromosome becomes attached to another. There are two main types of medically important translocations:

1- Reciprocal (balanced) Translocations
2- Robertsonian (unbalanced) Translocations

Both types of translocations are capable of causing disease in humans.



In reciprocal translocations two non-homologous chromosomes exchange genetic material. Reciprocal translocations arise from two different mechanisms

1. Chromosomal breakage and DNA repair
2. Abnormal crossovers

Reciprocal translocations lead to a rearrangement of the genetic material not a change in the total amount. Thus, they are also called balanced translocations.

In Robertsonian Translocations the transfer of genetic material occurs in only one direction, it is associated with phenotypic abnormalities or even lethality. Example: Familial Down Syndrome in this condition, the majority of chromosome 21 is attached to chromosome 14. The individual would have three copies of genes found on a large segment of chromosome 21. Therefore, they exhibit the characteristics of Down syndrome.

This translocation occurs as follows:

– Breaks occur at the extreme ends of the short arms of two non-homologous acrocentric chromosomes

– The larger fragments fuse at their centromeic regions to form a single chromosome

– The small acrocentric fragments are subsequently lost.

This type of translocation is the most common type of chromosomal rearrangement in humans. Robertsonian translocations are confined to chromosomes 13, 14, 15, 21, the acrocentric chromosomes.

Mutation

Mutation is the alteration of DNA sequence, whether it be in a small way by the alteration of a single base pair, or whether it be a gross event such as the gain or loss of an entire chromosome. It may be caused through the action of damaging chemicals, or radiation, or through the errors inherent in the DNA replication and repair reactions. One consequence may be genetic disease. However, although in the short term mutation may seem to be a ***BAD THING***, in the long term it is essential to our existence. Without mutation there could be no change and without change life cannot evolve. If it had not been for mutation the world would still be covered in primeval.

In this course we are not going to consider the molecular events involved in mutation but instead will concentrate on the genetic consequences of mutation.

Somatic or germinal?

The first point to consider is where is the mutation occurring? Most of our cells are somatic cells and consequently most mutations are happening in somatic cells. New mutation is only of genetic consequence to the next generation if it occurs in a germ line cell so that it stands a chance of being inherited. That is not to say that somatic mutation is unimportant, cancer occurs as a direct consequence of somatic mutation and aging too may be caused at least in part by the accumulation of somatic mutations with time.

Different types of mutation occur at different frequencies:

type of mutation	Mechanism	frequency per cell division
point mutation	1. mistakes in DNA replication 2. DNA damage by chemical mutagens (or by radiation) and misrepair	~10^{-10} / basepair ~10^{-5} / gene ~0.5 / cell
submicroscopic deletion or insertion	1. unequal crossing over 2. Misalignment during DNA replication 3. insertion of mobile element 4. DNA damage by chemical mutagens (or by radiation) and misrepair	included in the above
microscopically visible deletion, translocation or inversion	1. unequal crossing over 2. DNA damage by chemical mutagens (or by radiation) and misrepair	6 x 10^{-4}
loss of a whole chromosome	missegregation at mitosis	1 in 100

Types of mutations

There are many different ways that DNA can be changed, resulting in different types of mutation. Here is a quick summary of a few of these:

a-Substitution

A substitution is a mutation that exchanges one base for another (i.e., a change in a single "chemical letter" such as switching an A to a G). Such a substitution could:

1. change a codon to one that encodes a different amino acid and cause a small change in the protein produced. For example, sickle cell anemia is caused by a substitution in the beta-hemoglobin gene, which alters a single amino acid in the protein produced.
2. change a codon to one that encodes the same amino acid and causes no change in the protein produced. These are called silent mutations.
3. change an amino-acid-coding codon to a single "stop" codon and cause an incomplete protein. This can have serious effects since the incomplete protein probably won't function.

b-Insertion

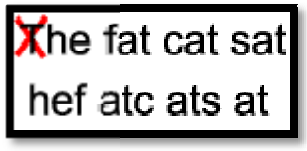
Insertions are mutations in which extra base pairs are inserted into a new place in the DNA.

c-Deletion

Deletions are mutations in which a section of DNA is lost, or deleted.

d-Frameshift

Since protein-coding DNA is divided into codons three bases long, insertions and deletions can alter a gene so that its message is no longer correctly parsed. These changes are called frameshifts.



For example, consider the sentence, "The fat cat sat." Each word represents a codon. If we delete the first letter and parse the sentence in the same way, it doesn't make sense.

In frameshifts, a similar error occurs at the DNA level, causing the codons to be parsed incorrectly. This usually generates truncated proteins that are as useless as "hef atc ats at" is uninformative.
There are other types of mutations as well, but this short list should give you an idea of the possibilities.

Oncogenes

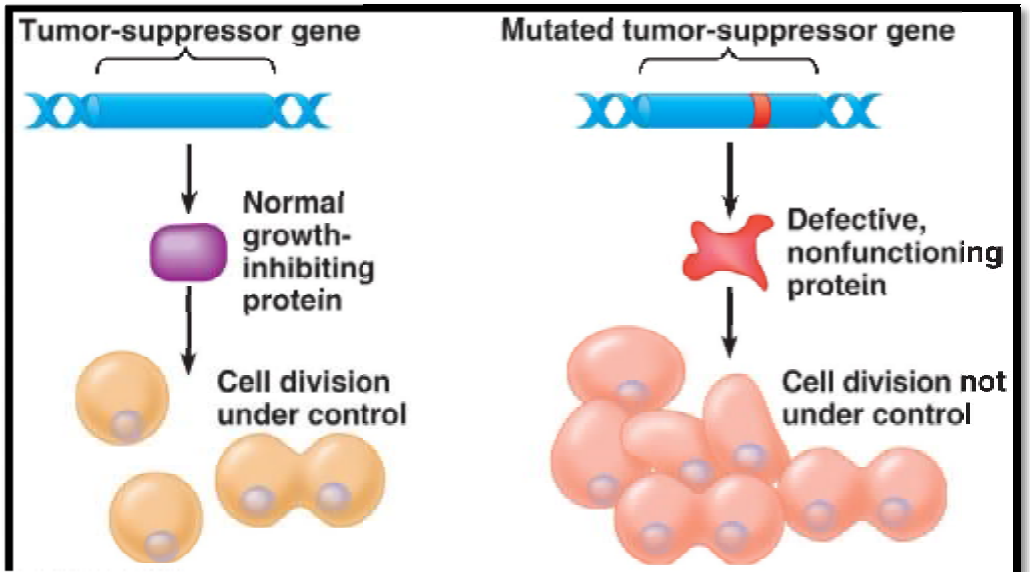
Oncogenes are proto-oncogenes that experienced mutation through several possible means. These include deletion and insertion mutations, increased transcription, point mutations, and gene amplification, among others. Viruses can also cause transformation of the proto-oncogene into an oncogene.

When these mutations occur, the result is often an increased activity in the affected proto-oncogenes. Cells often divide continually, causing it to increase in numbers, and in the growth of tumor size. There is also increased inhibition of apoptosis that regulate the death of cells naturally. When this happens, cells which are supposed to die, continue to stay in the body. These mechanisms are typical of how cancer develops inside the body.

Reactivation of proto-oncogenes that were turned off when their functions were completed, can also cause cancer formation later in life. And those that continue to perform increased activities than necessary may also contribute to the growth of cancer.

The Difference Between Proto-Oncogene and Oncogene Classes

Of the two gene classes, the proto-oncogenes are necessary for the proper development of a healthy body. Oncogenes, on the other hand, often promote negative effects inside the cells, thus leading to cancer formation.



Genetic disorders

The following is a list of genetic disorders causal type of mutation and the chromosome involved.

- P –Point mutation, or any insertion / deletion entirely inside one gene
- D – Deletion of a gene or genes
- C – Whole chromosome extra, missing, or both (see chromosomal aberrations)
- T – Trinucleotide repeat disorders: gene is extended in length

More common disorders

Disorder	Mutation	Chromosome
Angelman syndrome	DCP	15
Canavan disease		17p
Celiac disease		
Charcot–Marie–Tooth disease		
Color blindness	P	X
Cri du chat	D	5
Cystic fibrosis	P	7q
Down syndrome	C	21
Duchenne muscular dystrophy	D	Xp
Haemophilia	P	X
Klinefelter's syndrome	C	X
Neurofibromatosis		17q / 22q
Sickle-cell disease	P	11p

Angelman Syndrome
Is a rare disorder, having neurogenetic causes. The syndrome was first described in 1965 by Dr. Angelman. A syndrome is a based on group characteristics and manifest a specific condition. This syndrome can be described by an intellectual and evolutionary delay, difficulty to speak, sleep problems, erratic or jerky hand movement, uncontrolled laughter or just smiling and in general a perpetually happy appearance.

Canavan Disease
Is a genetic disorder which produces gradual damage to nerve cells of the brain. This disease belongs to the category of genetic disorders named leukodystrophies. Leukodystrophies' feature is myelin degeneration that is the phospholipid layer which protects nerve fibers.

Celiac Disease
Is a disorder which is autoimmune, affecting the small bowel, the persons belonging to all age categories, after infancy stage. Its symptoms can be diarrhea or fatigue, although these can be symptoms of other diseases too. Celiac disease is produced by a reaction to gluten, which is a gluten protein derived from wheat. The lining of the small intestine will become flat, which prevents the absorption of nutrients. The unique efficient treatment is a permanent gluten-free diet.

Charcot-Marie-Tooth Disease
Is a heterogeneous genetic disorder of nerves which is defined by touch sensation loss and loss of muscle tissue, especially in the legs and feet but also in the arms and hands as well, in the advanced phases of disease. Even if, for now, it can't be cured, this disorder is one of the most popular genetic neurological disorders. According to statistics, about 36 individuals among 100,000 are affected, by this disease.

Color Blindness
or deficiency to perceive colors can be of genetic nature, but can as well appear because of brain, eye, or nerve damage, or because of contact with some chemicals products. In 1798, the English chemist John Dalton studied this aspect for the first time, which is why it is sometimes called Daltonism.

Cri du Chat

Is a rare genetic disorder which approximately affects 1 in 20,000 to 50,000 live births. The disease is most common in the case of women. The disorder gets its name from the typical cry of babies born with this syndrome. The baby sounds like a kitten, because of problems with the nervous system and larynx. The good news is that about 1/3 of kids recover by the age of 2. Negative aspects of this disease may be:

- Feeding problems, because they can't suck and swallow well
- Low weight at birth and poor evolution
- Motor, cognitive, and speech delays
- Behavioral problems such as aggression, hyperactivity, and repetitive movements
- Uncommon facial traits that can change in time

Cystic Fibrosis

Is an inherited disorder which can affect the entire body, leading to gradual disability and death. The most common symptoms are difficulty breathing and not enough enzyme production in the pancreas. Low immune system and dense mucous production lead to frequent lung infections that are treated, but not always cured, sometimes by intravenous and oral antibiotics. Many other symptoms, like sinus infections, poor evolution, and diarrhea can be effects of this disorder in the case of other parts of the body. Sometimes, recurrent lung infections during infancy or childhood may be a sign of cystic fibrosis.

Down Syndrome

Is a chromosomal abnormality caused by abnormal cell division of chromosome 21. Three abnormal divisions can occur---Trisomy 21, an abnormality that occurs during sperm cell or egg cell development. Features problems related to cognitive ability, physical evolution, and facial traits.

Duchenne Muscular Dystrophy

Is a mortal disorder which is defined by rapid loss of muscle and gradual muscle weakness, as well as damaged muscular tissue, beginning in the pelvis, legs and then spreading over the entire lower body.

Hemophilia
is the name of some genetic disorders which mean the body's inability to control bleeding. The bleeding might be exterior, if the skin is broken by a cut, scrape, or it can be interior, into joints, muscles, or organs which are hollow. The result can be visible on the skin or subtle (e.g., brain bleeding).

Klinefelter Syndrome
Has the prime effect of abnormal testicular evolution, absence of secondary sex characteristics and decreased fertility.

Neurofibromatosis
includes different types of genetic disorder, which makes tumors develop along different nerves and besides that, may influence the evolution of tissues, which are not nervous, like skin and bones. The tumors may develop anywhere in or on the body.

Huntington's Disease
Is a single-gene genetic disease, affects the ability to talk, move and think. This inherited disorder is a result of a disease process that destroys cells in the brain. Huntington's disease is a certainty for everyone who inherits the mutated gene. Genetic testing for this incurable disease can determine if the mutated gene is present in the fetus or at any age.

Alzheimer's Disease (AD)
Is a multi-factorial genetic disease caused by mutations in multiple genes and environmental factors. Alzheimer's may be early onset, affecting people between the ages of 30 and 60, or it may be late onset, affecting individuals 60 years and older. Early-onset AD is rare, but only requires one of the mutated genes from a parent. Late-onset AD does not have the same genetic mutations as early-onset. Alzheimer's affects a person's thought processes, memory and language.

Breast Cancer
A multi-factorial disease may or may not be inherited. Two known genes associated with breast cancer are BRCA1 and BRCA2. Individuals with a mutated form of BRCA1 or BRCA2 are at a higher risk for developing breast cancer. Men and women can be affected or pass the mutation on to their children.

Mitochondrial Diseases

Mitochondrial genetic abnormalities affect the energy-giving part of cells. The mitochondria produce the energy to keep the body functioning. A mitochondrial abnormality can shut down the energy supply for any cell. This shut-down can be multi-system or specific to a particular group or groups of cells. The effects on muscle and nerve cells include muscle weakness, hearing loss, heart irregularities, difficulty with balance and diabetes.

Thalessemia

The hemoglobin in the blood is formed of chains of several globins. In the genetic disease called thalessemia, synthesis of one of these globin chains is reduced; the synthesis can also completely stop. Mutation is the cause behind thalessemia. Abnormal hemoglobin molecules are formed as a result of reduction in synthesis of globin chains. Thalessemia is an autosomal recessive blood disease, and it has originated in the Mediterranean region.

Sickle Cell Anemia

Sickle cell anemia, just like thalessemia, is autosomal recessive blood disease. In this genetic disease, red blood cells attain an abnormal shape; these cells become rigid and also attain a sickle-shape. The average life expectancy of patients with this disease is 48 years (females) and 42 years (males), respectively. This disease most commonly occurs in childhood. People from tropical and subtropical regions are more prone to sickle cell anemia. In this disease, the red blood cells become rigid and sticky. Blood vessels also are blocked by these cells; damage is caused to organs and infections occur.

DNA Recombination

DNA recombination refers to the process that a DNA segment moves from one DNA molecule to another DNA molecule. Involves the cutting and covalent joining of DNA sequences. It can occur between two different DNA molecules or between two regions of a single DNA molecule. The following three types are most commonly observed.

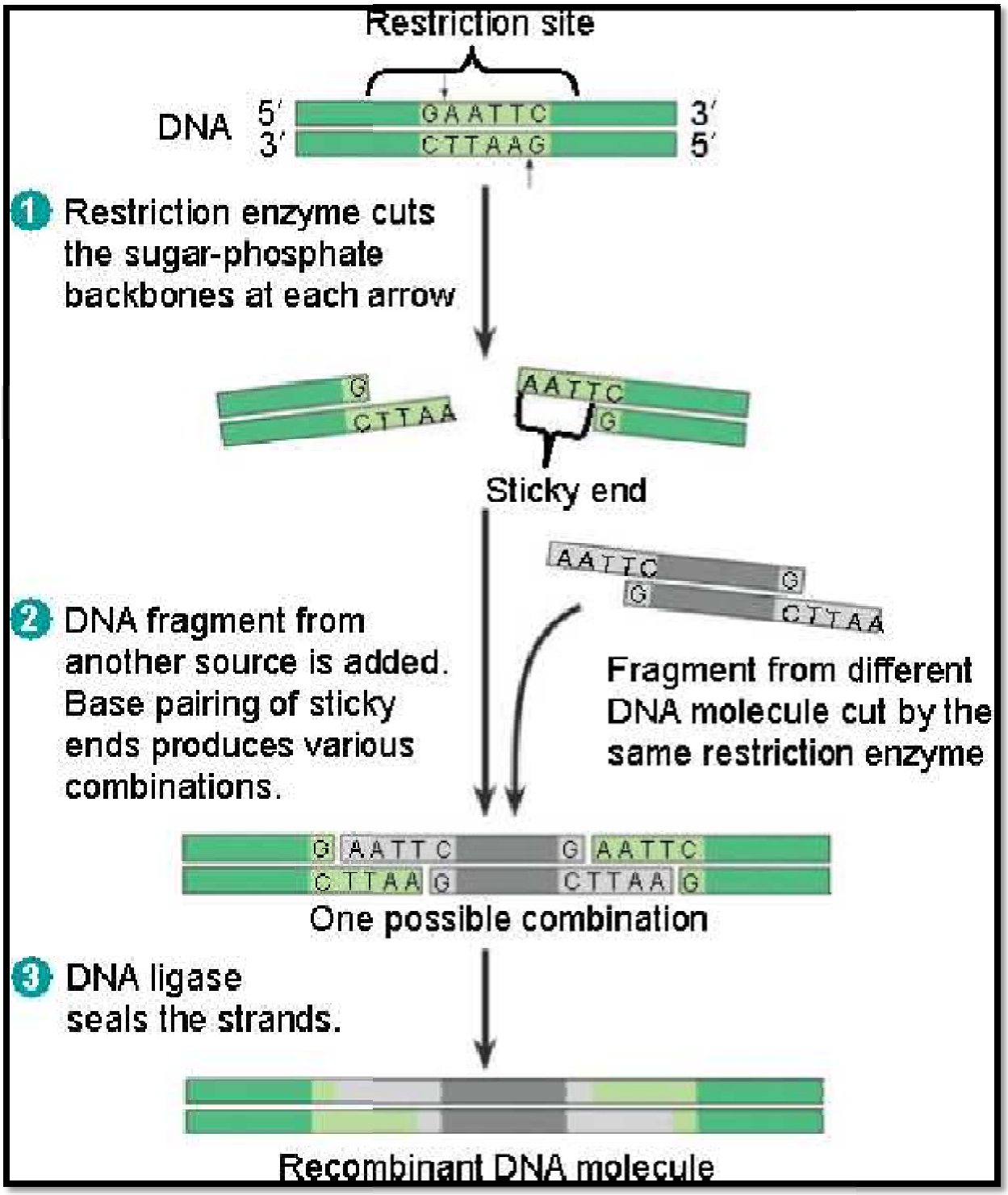
Homologous recombination
It occurs between two homologous DNA molecules, also called DNA crossover.

Site-specific recombination
It occurs at a specific DNA sequence which is present in both non-homologous DNA molecules that may have the recombination.

Transpositional recombination
A mobile element is inserted into a target DNA.
The homologous recombination often occurs during meiosis. Other types of recombination are not specifically related to cell division.

Recombination plays an important role in:
1) The process of introducing genetic variation by allowing genes to be reassorted into different combinations. For example, genetic recombination results in the exchange of genes between paired homologous chromosomes during meiosis.

2) Also, an important mechanism for repairing damaged DNA.
3) Recombination also is involved in rearrangements of specific DNA sequences that alter the expression and function of some genes during development and differentiation (for example immunoglobulins, the important antibodies of the immune system).
DNA molecules recombine by breaking and rejoining. In other words, phosphodiester bonds are broken and rejoined.



Application of Recombinant DNA Technology

Genetically Modified Plants

- Recombinant DNA technology is used is to genetically alter plants by adding or removing genes. Genes are often added to plants to increase the plant's resistance to bacterial or fungal infection, making herbicides less necessary, or to increase the sweetness of

fruit. Genes can also be subtracted to slow the process by which the fruit spoils or to modify the color of the flowers.

Transgenic Animals

- Another use of rDNA technology is to add an outside gene to the DNA of animals, creating a transgenic animal. These genes are added to the animal before it is born. Genes can be inserted into the animal to alter its protein content--for example, to produce a cow with low-lactose milk. Transgenic pigs might have organs that can be used for human transplantation. Creating disease-resistant animals is another possibility with rDNA technology.

Gene Therapy

- Gene therapy in humans is another possible use of rDNA technology. In this process, the gene is added to a virus and then inserted into human cells. Because viruses link up with the DNA strands of the host, the new gene is therefore expressed in the person. (In this type of therapy, the virus has been modified so it does not cause disease.) In cancer patients, genes can be inserted to correct abnormal genes, to introduce a "suicide gene" into the cancer cells or to increase the patient's immunity.

In-Uterus Gene Therapy

- Another way that rDNA technology can be used is in gene therapy on a fetus. The advantage to using gene therapy in uterus is that the fetus has a much higher stem cell count, making it easier to correct genetic abnormalities, such as cystic fibrosis. It may also be used in cases where the fetus is not making a certain protein or enzyme. In-uterus gene therapy is done by injecting a virus with the new DNA into the amniotic fluid, which the fetus then takes in by breathing.

Ethics of rDNA technology

Although rDNA technology provides many benefits and advantages, several ethical considerations and controversies are associated with this technology. Many people believe that altering human DNA is immoral and constitutes "playing God." In addition, because this is a fairly new technology, there are questions about the long-term health effects of consuming genetically altered plants and animals.

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