
I told you man...
we shouldn't have come
to beach.
UV is not good for us...
http://biocomicals.blogspot.com

Mutations

Genotype changeability is due to:

- Mutations – changes in DNA sequence which are not directed and controlled by the cell.

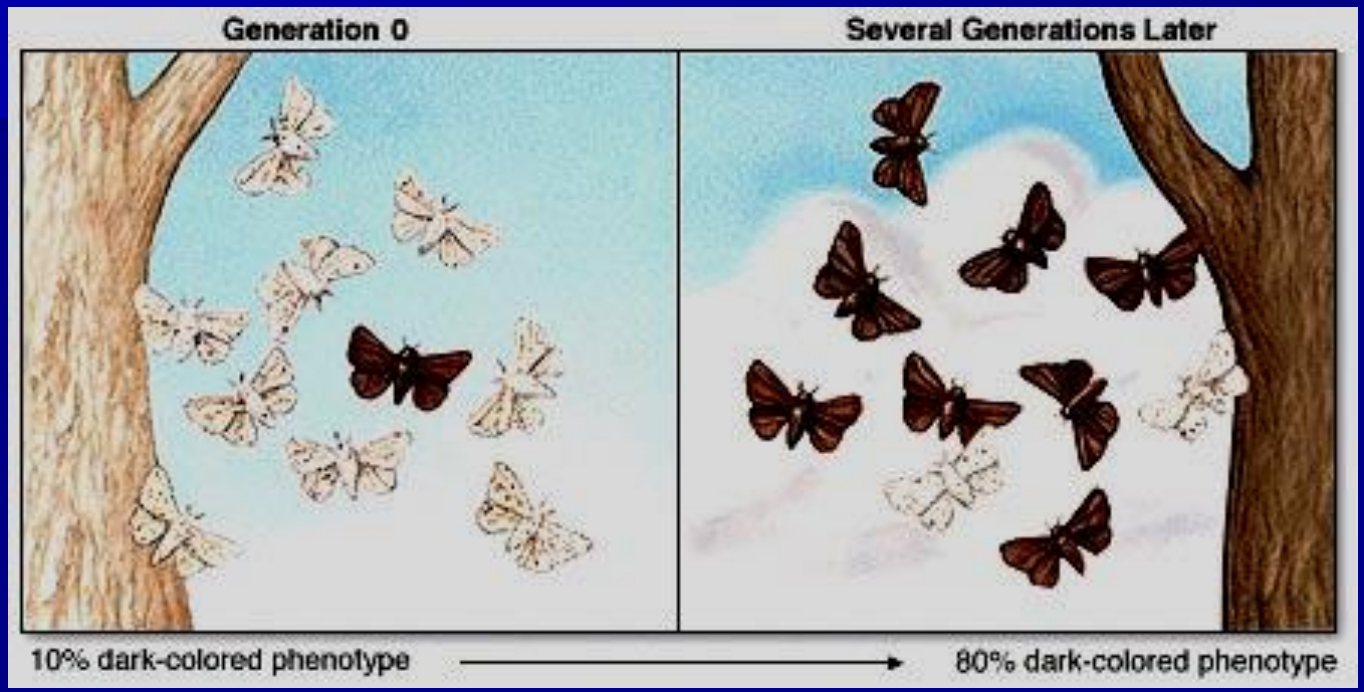
Just in case of sexual reproduction

- Variety of hybrids; result of chromosome segregation during meiotic Anaphase I and random gamete fusion; leads to new allelic combinations in the genotype.
- Recombination (meiotic crossingover) – leads to new allelic combination along the chromosomes.

Classification of mutation types

- By inheritance:
- Somatic (acquired) mutations – not usually transmitted to descendants.
- Germ line mutations (can be passed on to descendants).
- By effect on fitness:
- Harmful (deleterious) - decreases the fitness of the organism.
- Beneficial (advantageous) mutation increases the fitness of the organism.
- Neutral mutation has no harmful or beneficial effect; occur at a steady rate, forming the basis for the molecular clock; neutral mutations provide the basis for genetic drift .
- By effect on DNA structure:
- Small-scale mutations (point mutations); they affect a gene by changing one or a few nucleotides; they can be insertions, deletions or substitutions.
- Large-scale mutations – chromosome rearrangements (deletions, duplications, inversions, translocations) or numerical chromosome aberrations – aneuploidy and polyploidy.

- The natural selection decides if a mutation is beneficial or deleterious.
- The benefits of a particular mutation can be reconsidered if the environment is changed.



www.mhhe.com

Industrial Melanism A change occurred in a number of moth species populations in the late 1800's in industrialized areas of England and the United States. Prior to this period, moth populations were primarily composed of light colored moths with occasional mutant dark colored (melanic) moths. Over a number of generations, the populations changed such that the majority of moths were dark colored. This could be explained by a change in the bark of trees in the woods surrounding the industrial areas.

www.katiephd.com

Gene mutations

Gene mutations affect only one gene or more often a nucleotide in this gene. It is possible one nucleotide to be substituted by another (substitution). If one or more nucleotide is removed from the gene, it is a deletion. Insertion means one or more nucleotide to be added in the DNA strand.

Gene mutations have produced the alleles of genes, including, alas, the pathological ones.

https://www.singerinstruments.com/resource/what-are-genetic-mutation

- SUBSTITUTION:
  - One nitrogen base is replaced with another base

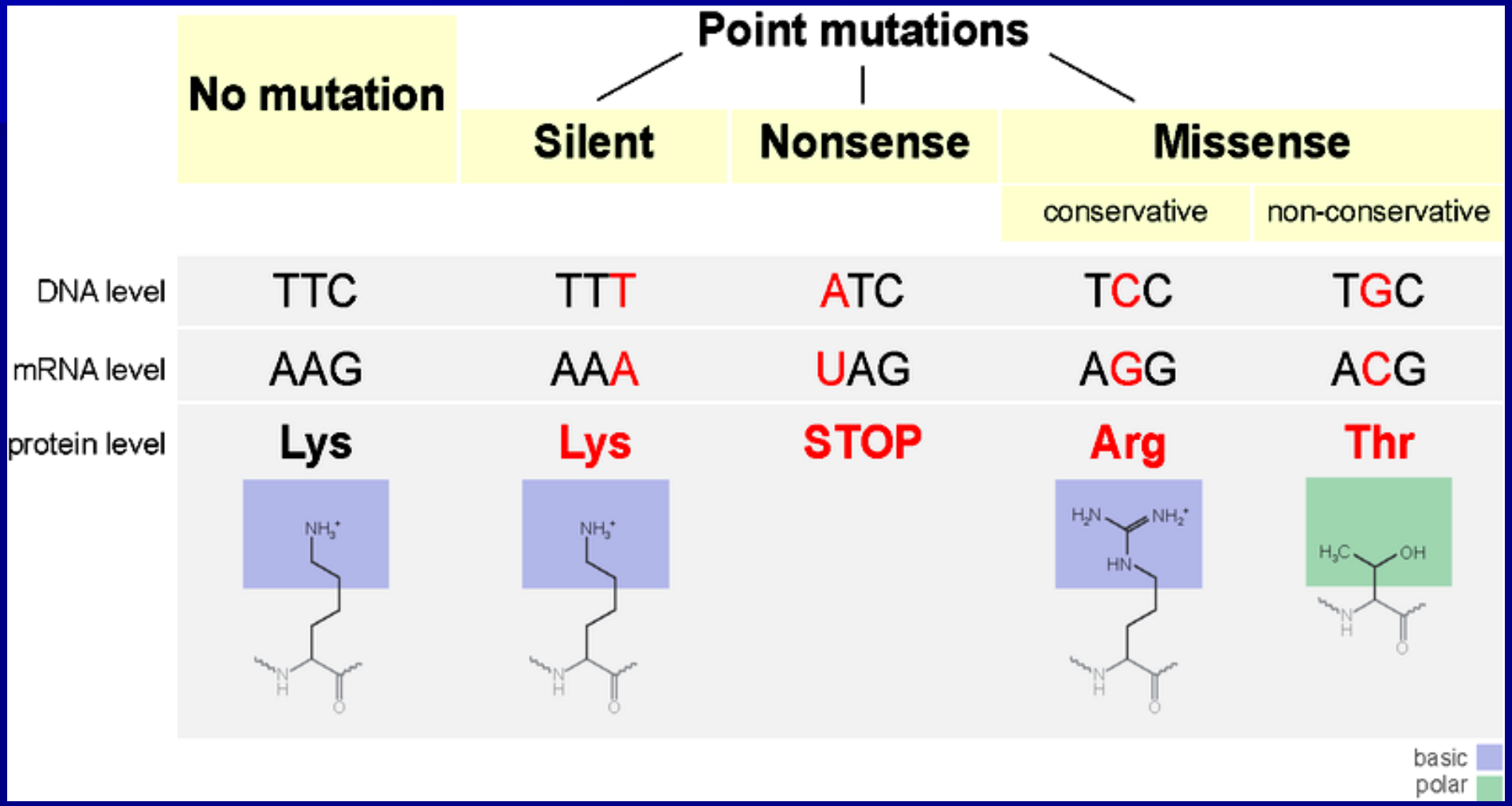
SAM MET BAT MAN

↓

SAM MET CAT MAN

  - Only one codon is affected. New gene may still make sense

Substitutions can have different effects on the protein



http://commons.wikimedia.org

Substitutions – impact on protein sequence

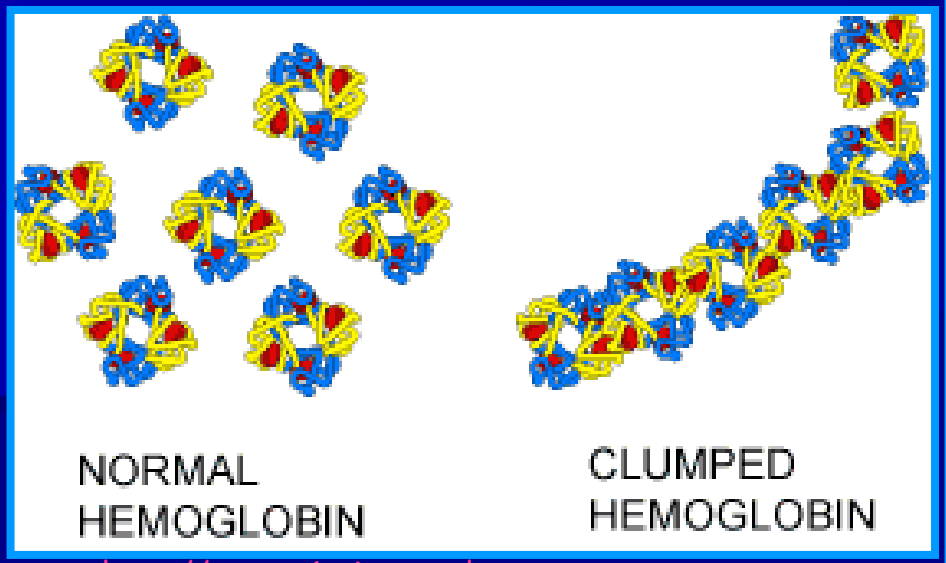
- Nonsense mutations - point mutations that result in a premature stop codon (nonsense codon).
- Missense mutations (nonsynonymous mutations) - a single nucleotide substitution turns one codon into another, encoded amino acid is different. If a hydrophilic amino acid is replaced by a hydrophobic one (or the opposite) the changes in protein conformation are more dramatic (sickle-cell anemia).
- Neutral mutations - the amino acid is replaced by a different, but chemically similar amino acid.
- Silent mutations (synonymous mutations) - do not change the amino acid sequence; they may occur in non coding regions or within codons but without amino acid change.

Cycle cell anemia

www.sicklecellinfo.net

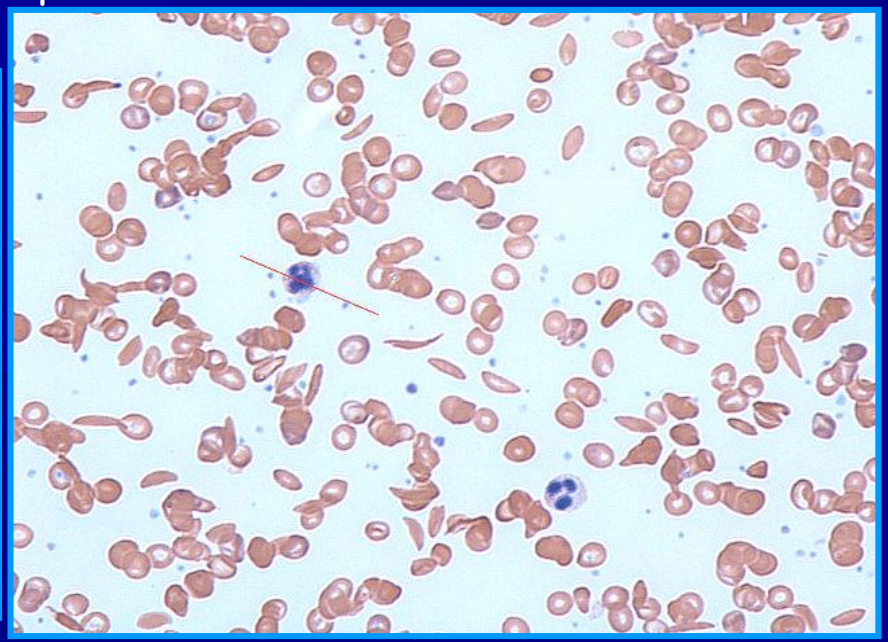
An example of a substitution, causing missense mutation, is the disease Cycle cell anemia. The reason for the disease is a substitution of a nucleotide in the gene for β-chain of the hemoglobin. This substitution causes changing of a codon for one amino acid to a codon for another. In this case one hydrophilic amino acid is displaced by hydrophobic which totally changes protein function. Hydrophobic amino acids try to avoid a contact with water. This wrong amino acid causes aggregation of hemoglobin molecules – individual molecules connect each other. It changes the shape of red blood cells to crescents.

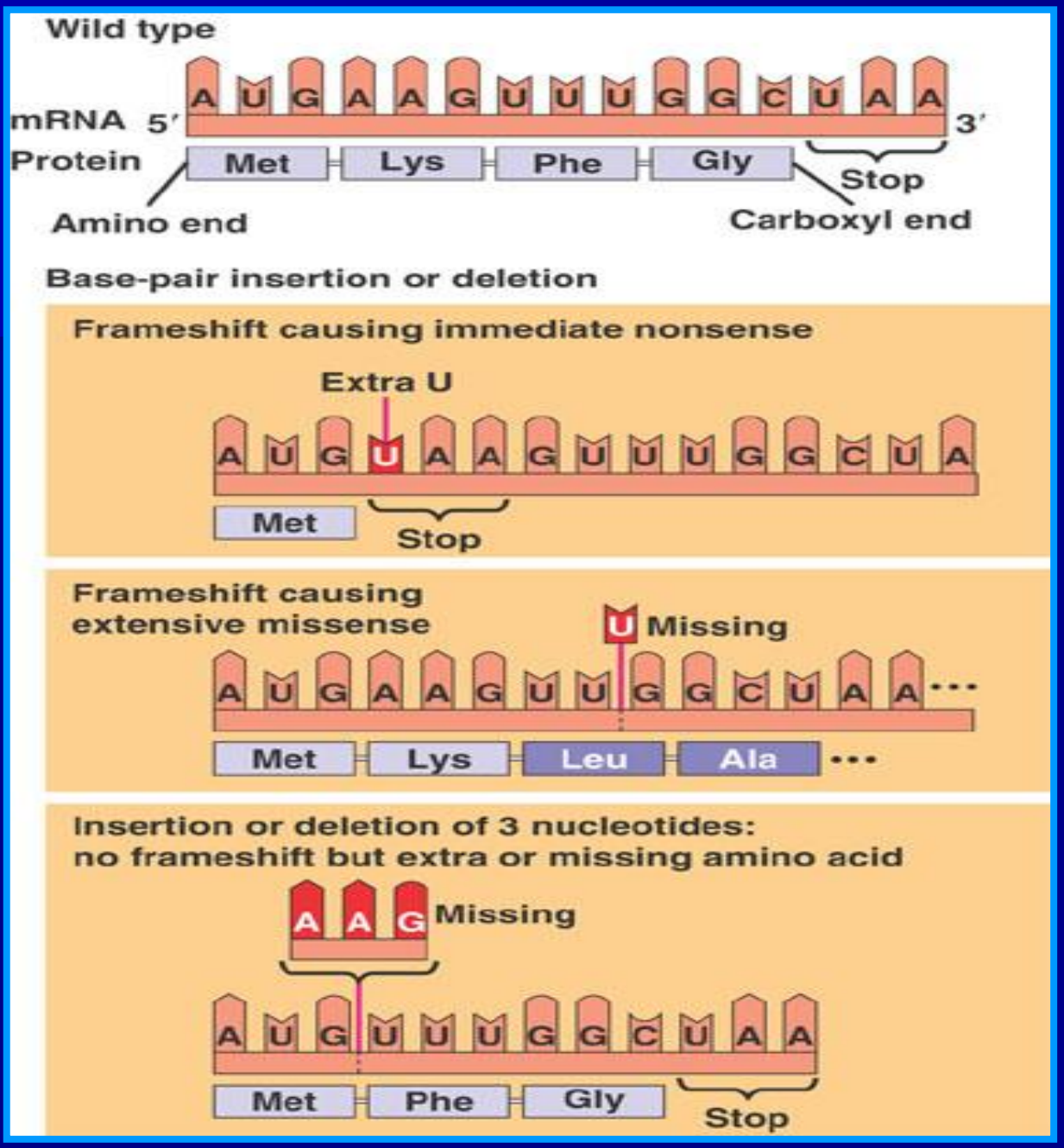
HEALTHHYPE.COM



http://evolution.berkeley.edu

http://course1.winona.edu





Frameshift mutation

It is a result of insertion or deletion of nucleotides. It disrupts the reading frame, because it changes nucleotide combinations after this insertion or deletion. The result of the frame shift is nonsense mutation, because stop codon appears very soon and protein synthesis ends. This shorter version of the protein is non-functional. Mutations like that are called loss of function, because the protein function is lost. Reading frame can adapt if the number of inserted or deleted nucleotides is evenly divisible by three.

www.mirror.co.uk

Dominant versus recessive

Recessive mutation

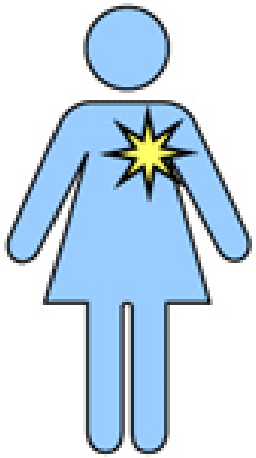
Recessive alleles are hidden in heterozygous. That's why two parents whith normal phenotype have an albino child.

Dominant mutation

To express dominant mutation is necessary to have only one mutant allele. This kind of dwarfism is dominant and lethal for homozygous. All of these dwarfs are heterozygous.

Germline versus somatic mutations

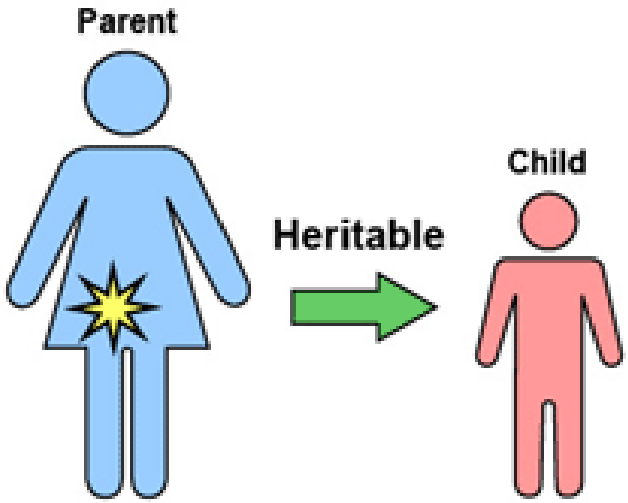
Somatic mutations
- Occur in ***nongermline*** tissues
- Cannot be inherited



Nonheritable

Mutation in tumor only
(for example, breast)

Germline mutations
- Present in egg or sperm
- Can be inherited
- Cause cancer family syndrome



Mutation in
egg or sperm

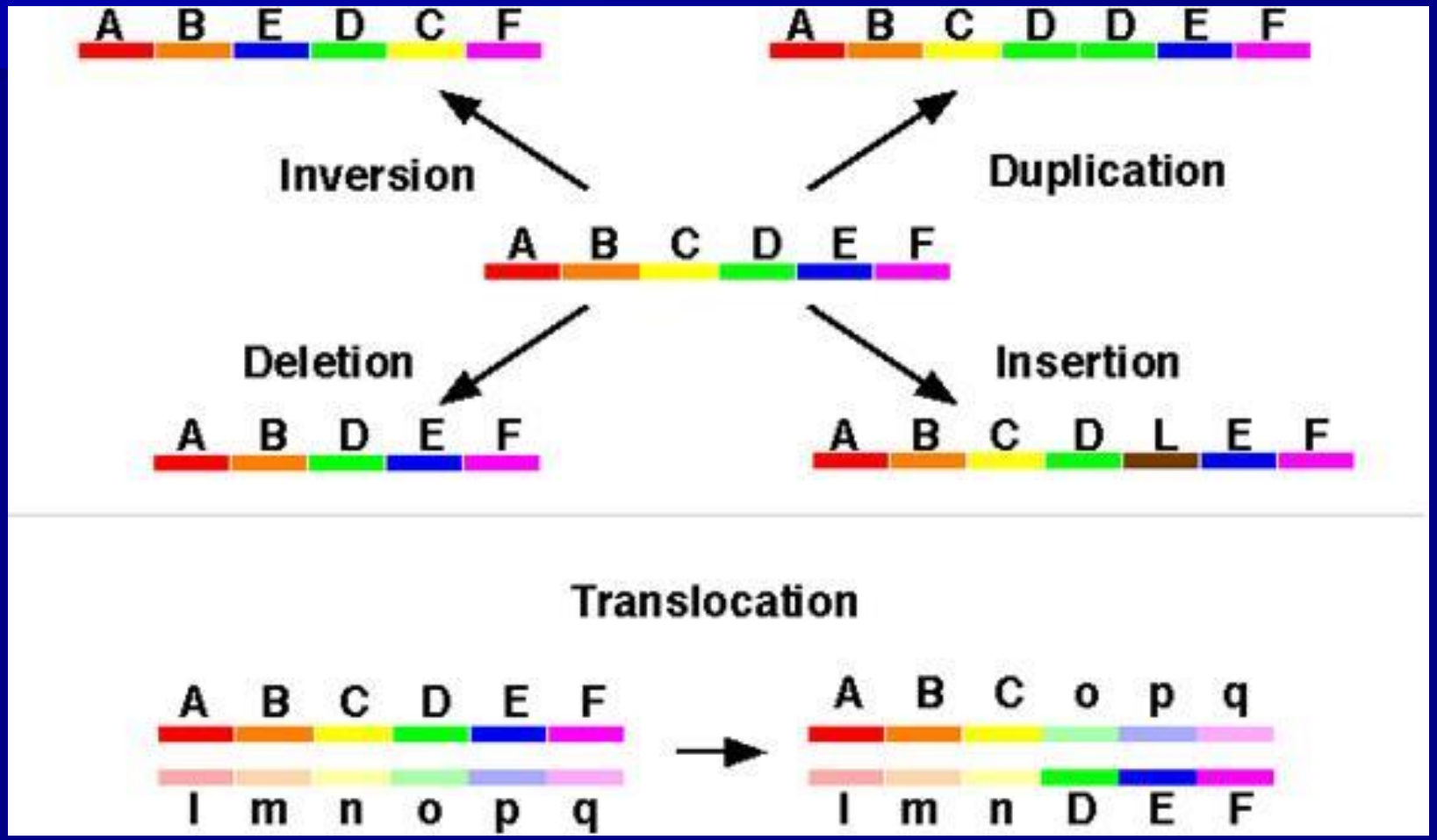
All cells
affected in
offspring

Adapted from the National Cancer Institute and the American Society of Clinical Oncology

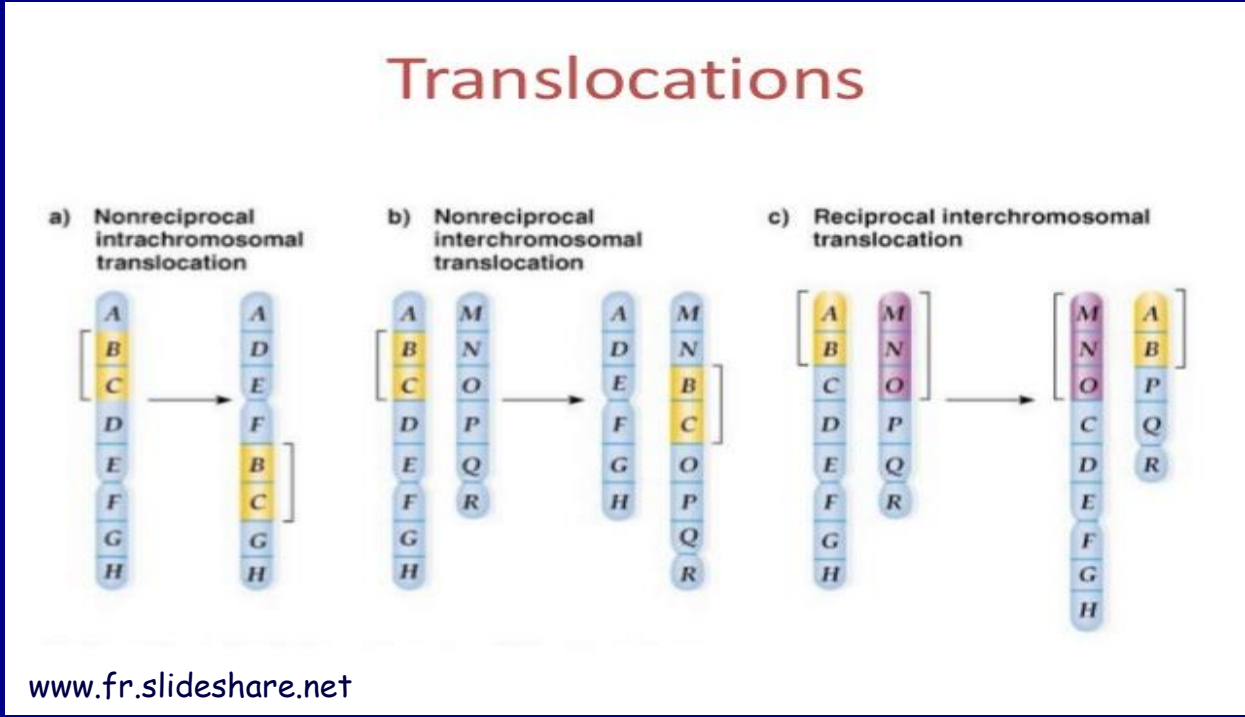
Chromosome aberrations

- Definition - any change in the normal structure or number of chromosomes.
- Two basic groups - numerical and structural.
- Numerical disorders – abnormal chromosome number.
- Structural aberrations - large DNA rearrangement; microscopically visible at metaphase.
- Inheritance
- If chromosome aberrations occur in the egg or sperm, they can be inherited, the anomaly is present in every cell of the new organism.
- Some aberrations can happen after conception, resulting in mosaicism (some cells carry the mutation and some do not).
- Chromosome aberrations can be inherited from a parent or "de novo" mutations. This is why chromosome studies are often performed on parents when a child is found to have an anomaly. If the parents do not possess the abnormality, it was not initially inherited; however it may be transmitted to subsequent generations.

Structural chromosome aberrations

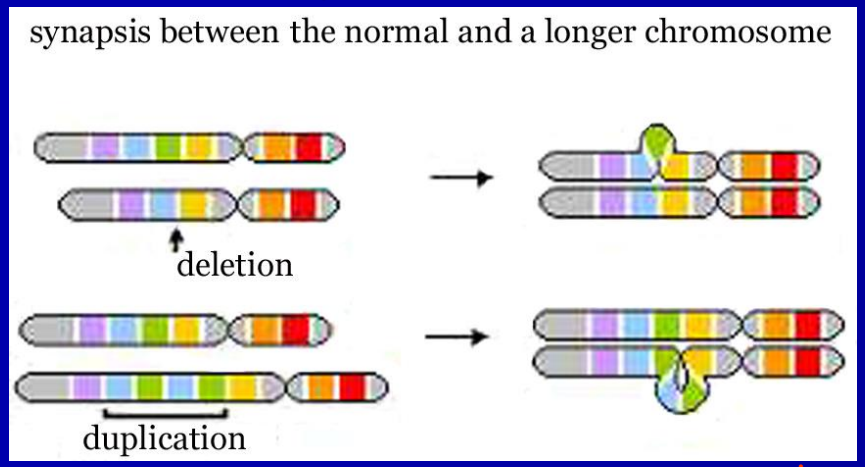


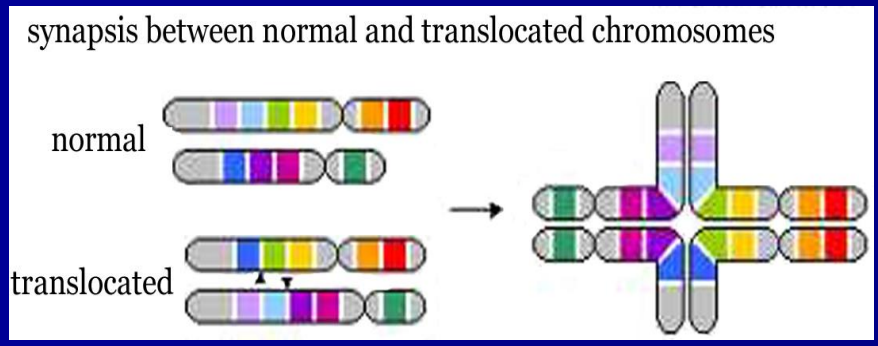
- If a fragment of a chromosome is lost, the mutation is called deletion.
- Duplication means presence of more than one copy of a piece of chromosome.
- Inversion happens if a fragment of a chromosome is cut out, rotated in 180 degrees and joined again to the same chromosome. If the cut fragment includes the centromere, inversion changes chromosomal structure.
- Translocation includes cutting out of a fragment and joining to non-homologous chromosome. Translocations can be reciprocal – if both of non-homologous chromosomes exchange fragments. Non-reciprocal translocation happens if only one chromosome transfers a fragment to non-homologous.

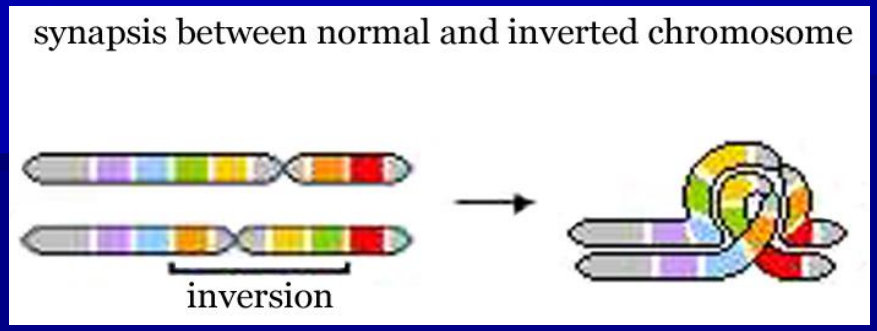


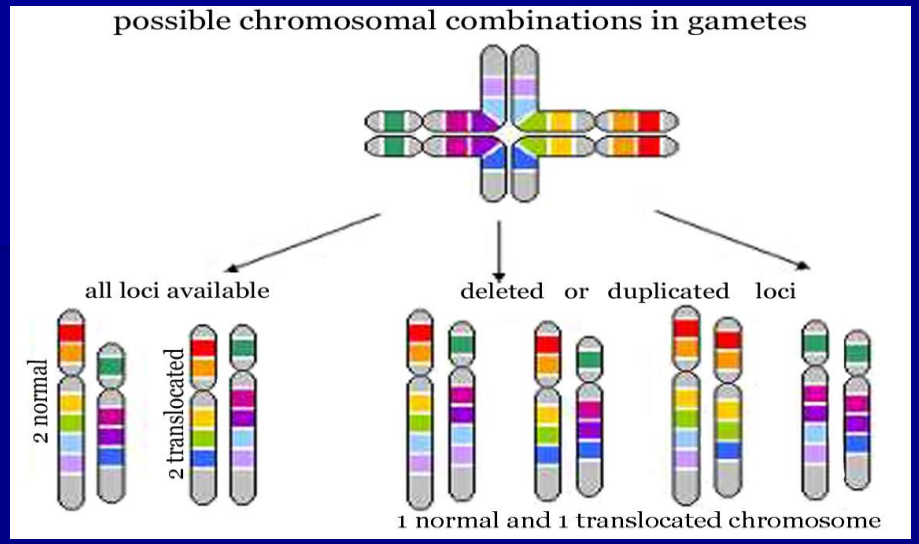
Meiotic problems after chromosome rearrangements

- Deletion or duplication forces one of the homologous chromosomes to form a loop in order to isolate chromosomal fragment which is missing for the other chromosome. Meiosis occurs because homologous exchange fragments and segregate.
- Segregation of the chromosomes is the main problem of inversions and translocations. Homologous chromosomes form this strange structures during meiosis (look at the pictures down). After crossing over segregation leads to appearance of chromosomes with two centromeres, fragments without centromere, chromosomes with missing or duplicated fragments. In this case meiosis can not produce functional gametes and the individuals, heterozygous for inversion or translocation, are infertile.









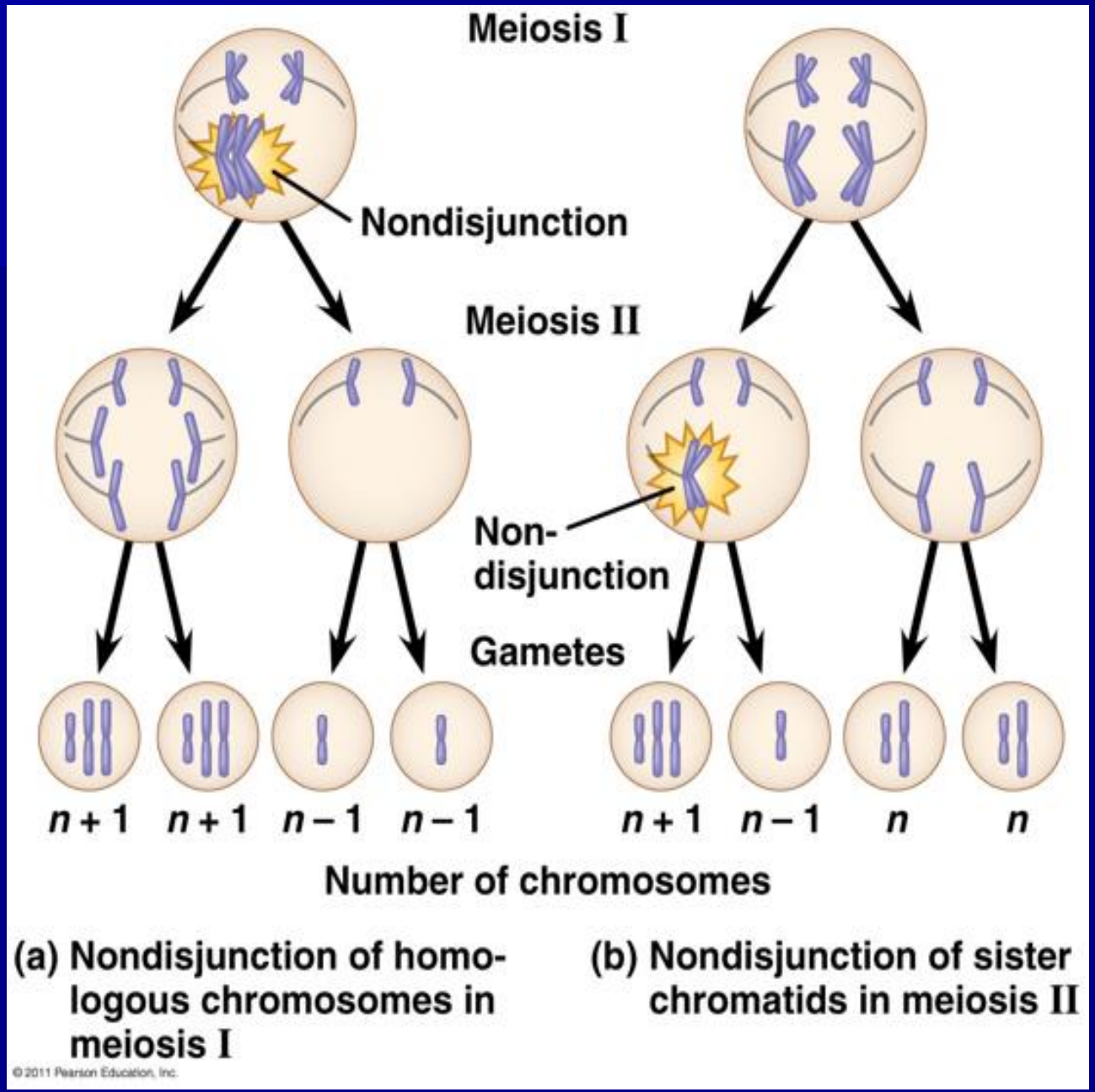
Numerical chromosome aberrations

- They are result of errors in chromosomal segregation during mitotic or meiotic anaphase, caused by dysfunction of the spindle or DNA associated proteins.

- Aneuploidy - any deviation from an exact multiple of the haploid number of chromosomes, whether fewer or more.
- Trisomy - one extra chromosome; monosomy - one less, than the normal.
- Examples: Down's syndrome (trisomy of chromosome 21), Edwards' syndrome (trisomy 18), Turner's syndrome (monosomy 45 XO).
- Phenotype effect of aneuploidies.

- Polyploidy - having one or more extra sets of chromosomes.
- Autopoliploidy - multiple chromosome sets derived from a single species; can arise from a spontaneous genome doubling (potato), or by fusion of 2n gametes. Bananas and apples can be found as autotriploids.
- Allopolyploidy – chromosomes derived from different species; result of multiplying the chromosome number in an interspecies F1 hybrid.

Chromosome nondisjunction during oocyte meiosis is the most frequent cause for human aneuploidy.



Anaphase lagging – another mechanism for aneuploidy

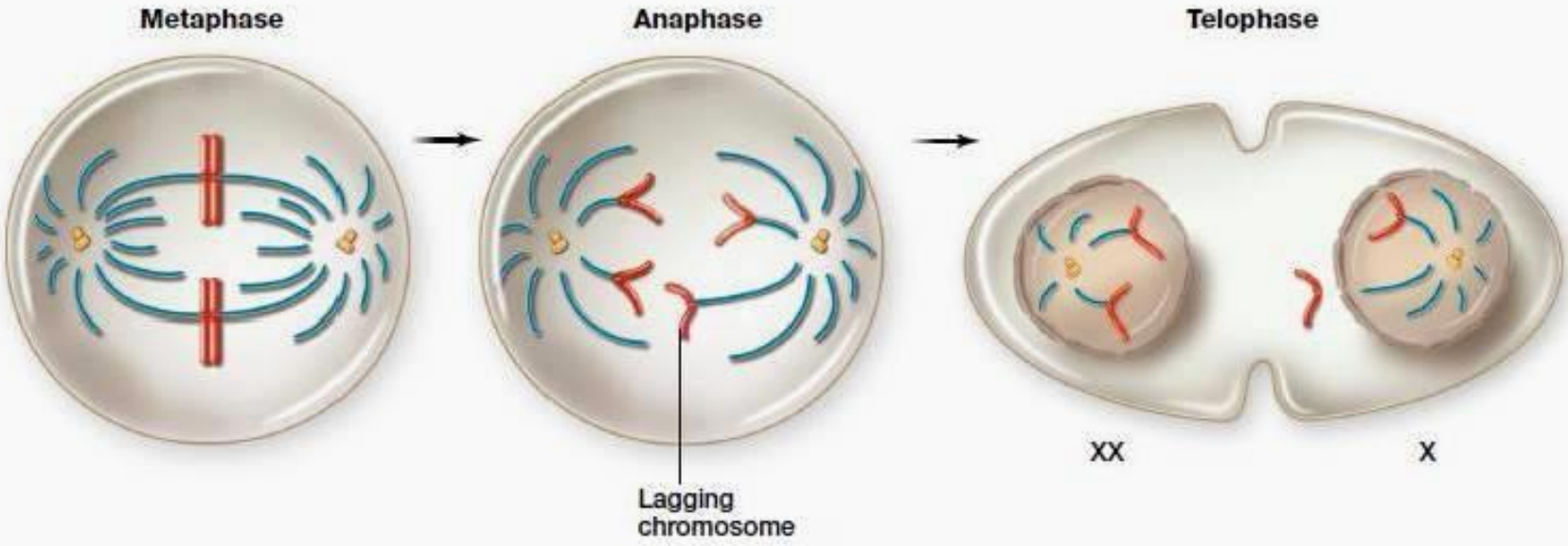
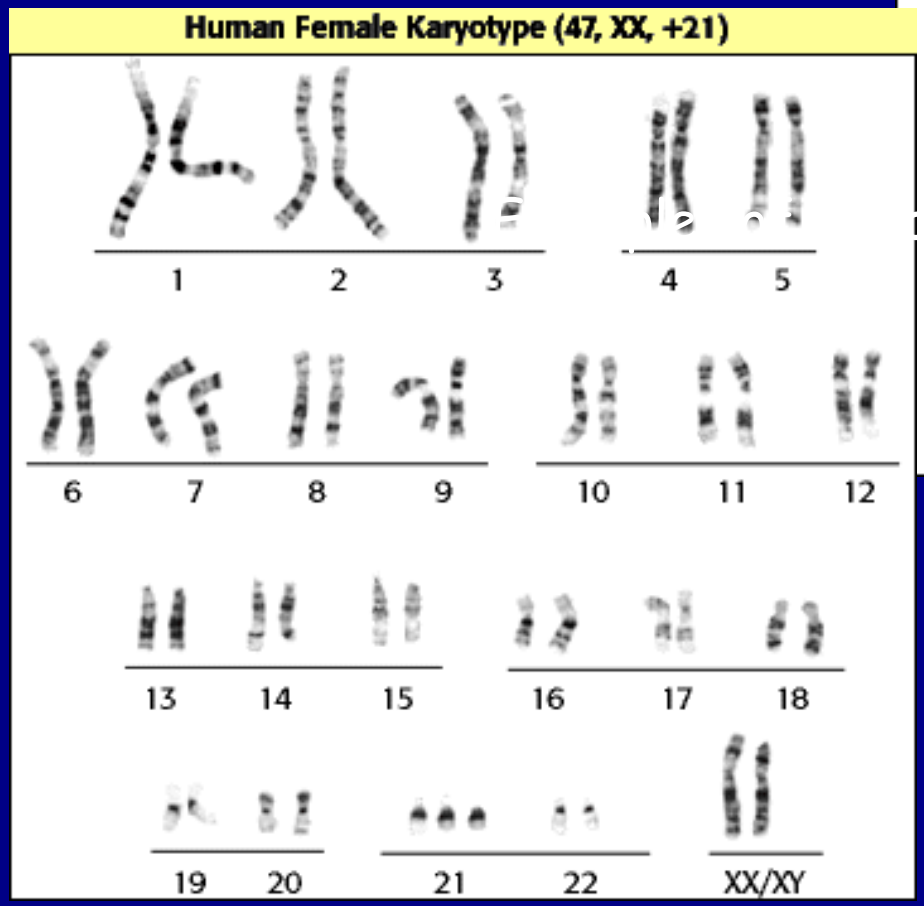
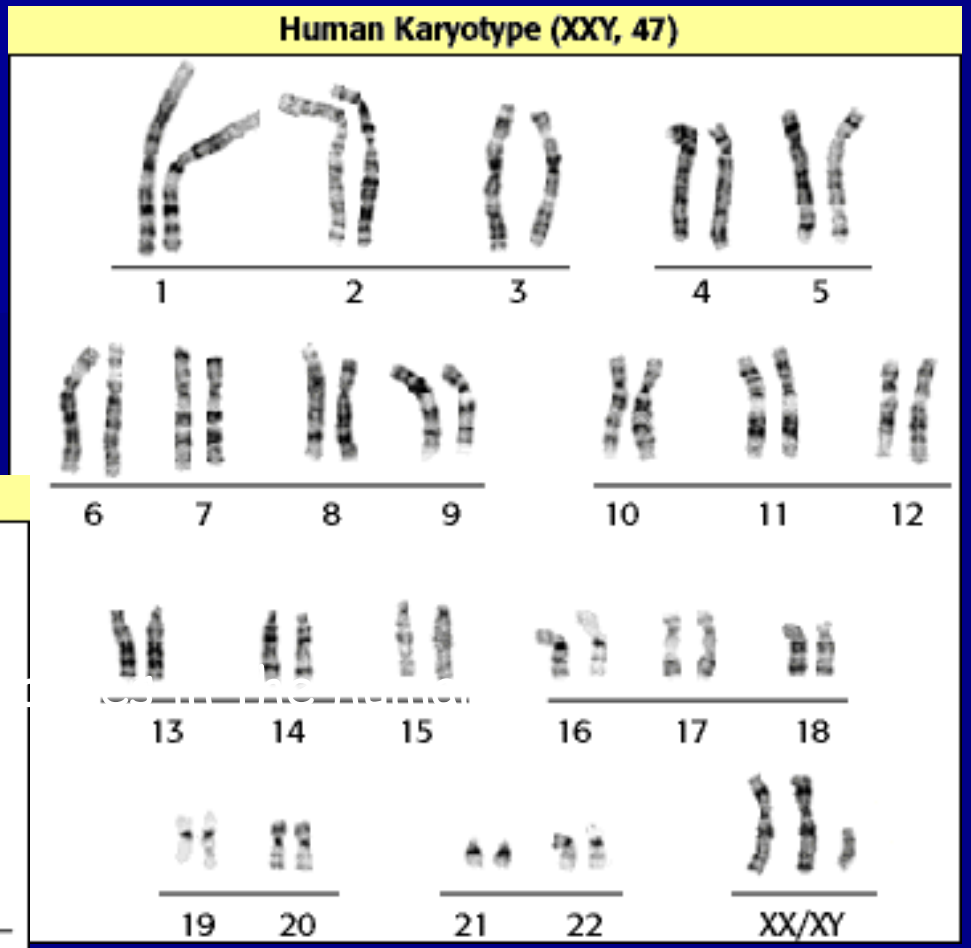


figure 8.36 Mitotic nondisjunction due to chromosome lagging. The lagging X chromosome is apparent during mitotic anaphase and fails to be within the reassembling nucleus during telophase, which results in one daughter cell being monosomy X.

http://mhanswers-auth.mhhe.com

Examples of trisomies in the human





www.biology.arizona.edu

https://www.thebestof.co.uk/local/epsom-and-ewell/community-hub/blog/view/lettings-director-cheryl-burn-to-run-london-marathon-to-raise-money-for-local-toddler-with-pataus-syndrome-personalagentuk/

https://medlineplus.gov/downsyndrome.html

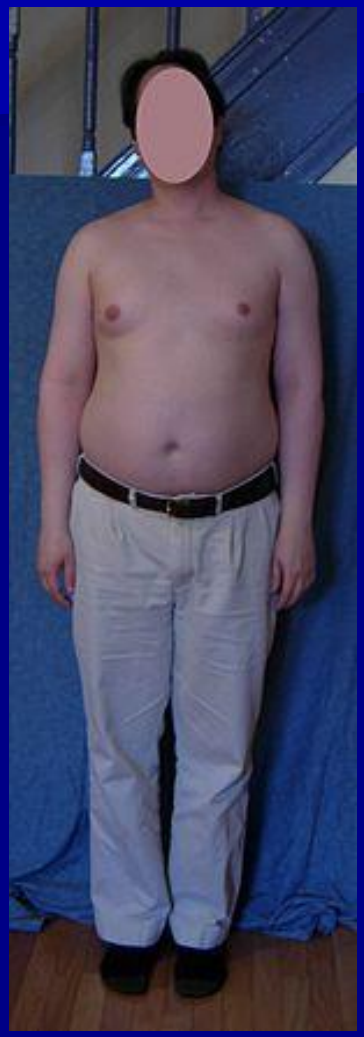
Down syndrome
(trisomy 21)

Patau syndrome (trisomy 13)

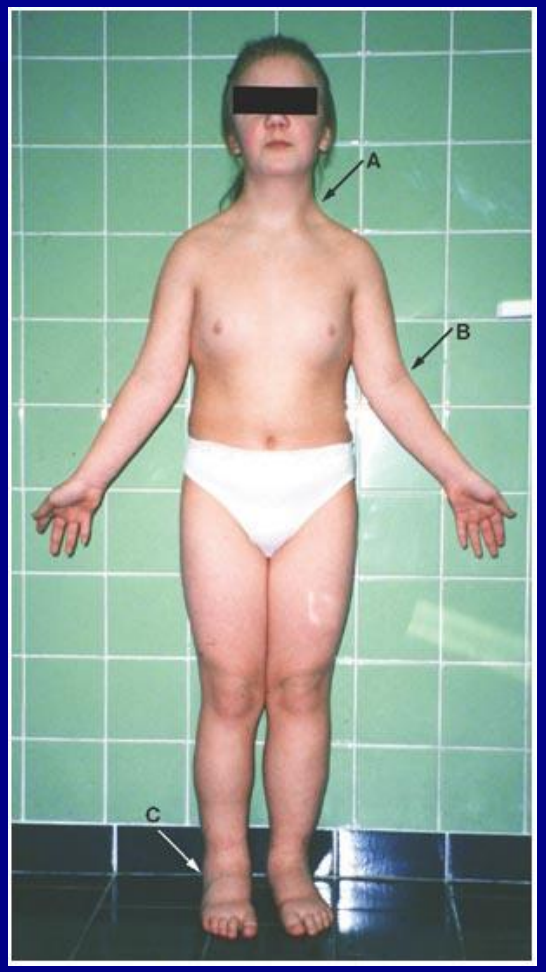
Edwards syndrome (trisomy 18)

https://www.gofundme.com/edwards-syndrome

Sex chromosome abnormalities helped to reveal the role of Y in sex determination



Klinefelter syndrome
47,XXY – male

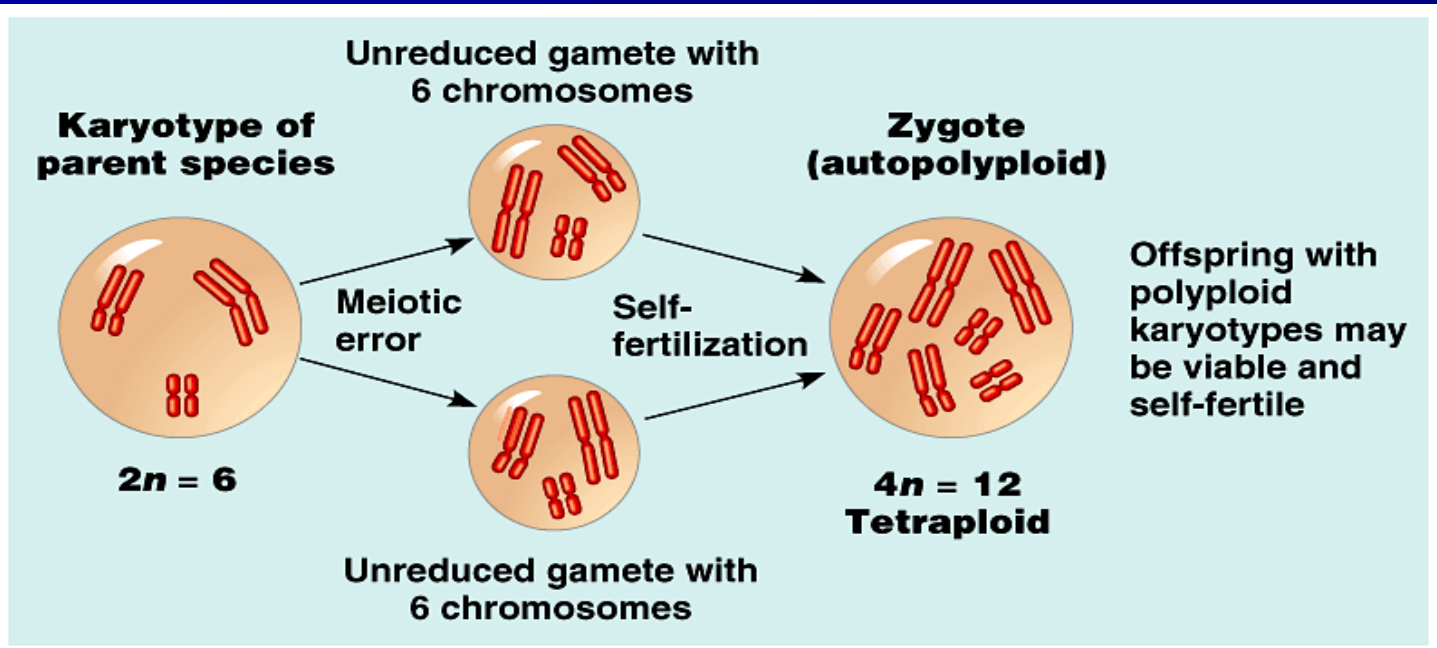


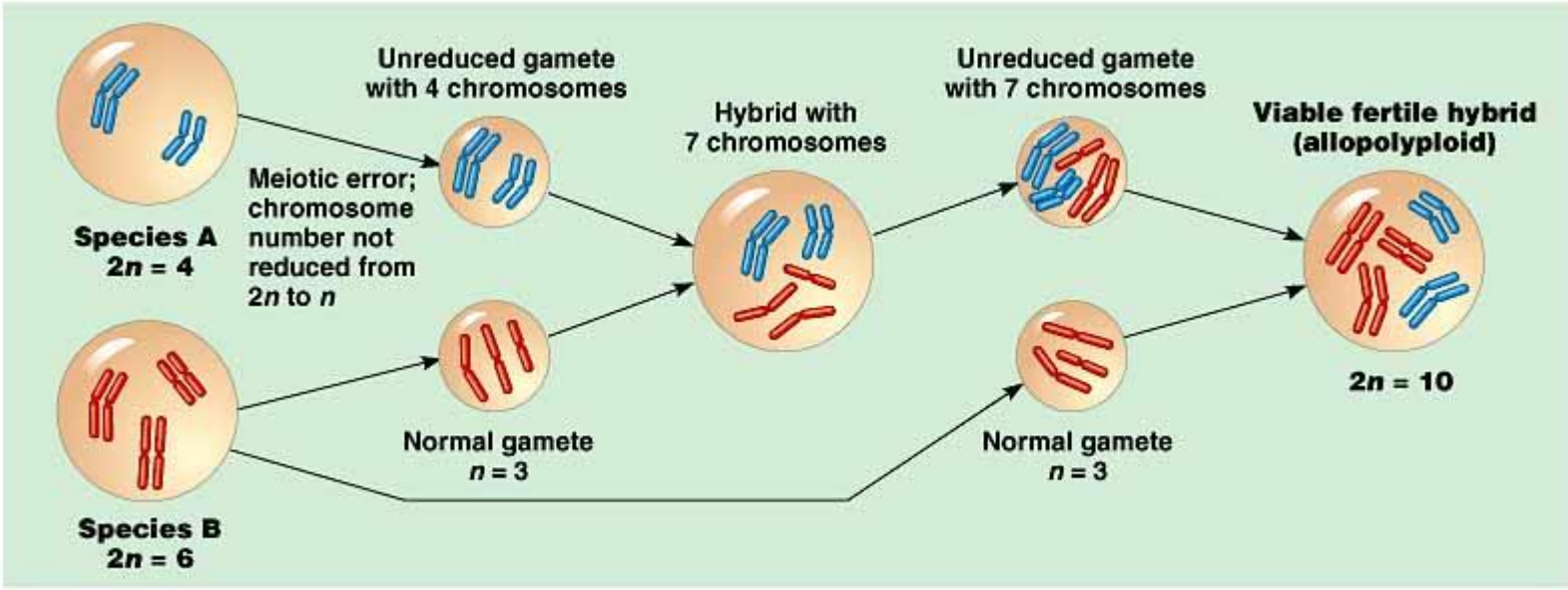
Turner syndrome
45,X0 – female

Why the polyploidy is more frequent in plants

- In plants there is no chromosomal sex determination; in animals, poliploidy disturbs the balance between genes located on autosomes and sex chromosomes.
- The polyploidy is related to meiotic problems; plants avoid them by asexual reproduction.
- Most of the agriculture plants are polyploid - potato, coffee, banana, peanut, tobacco, wheat, oats, sugarcane, plum, strawberry, clover , rye, turnip, dill, spinach, apple, radish, grapes, sugar beet, tea, watermelons, various forage grasses etc.

Auto- and allo-polyploidy

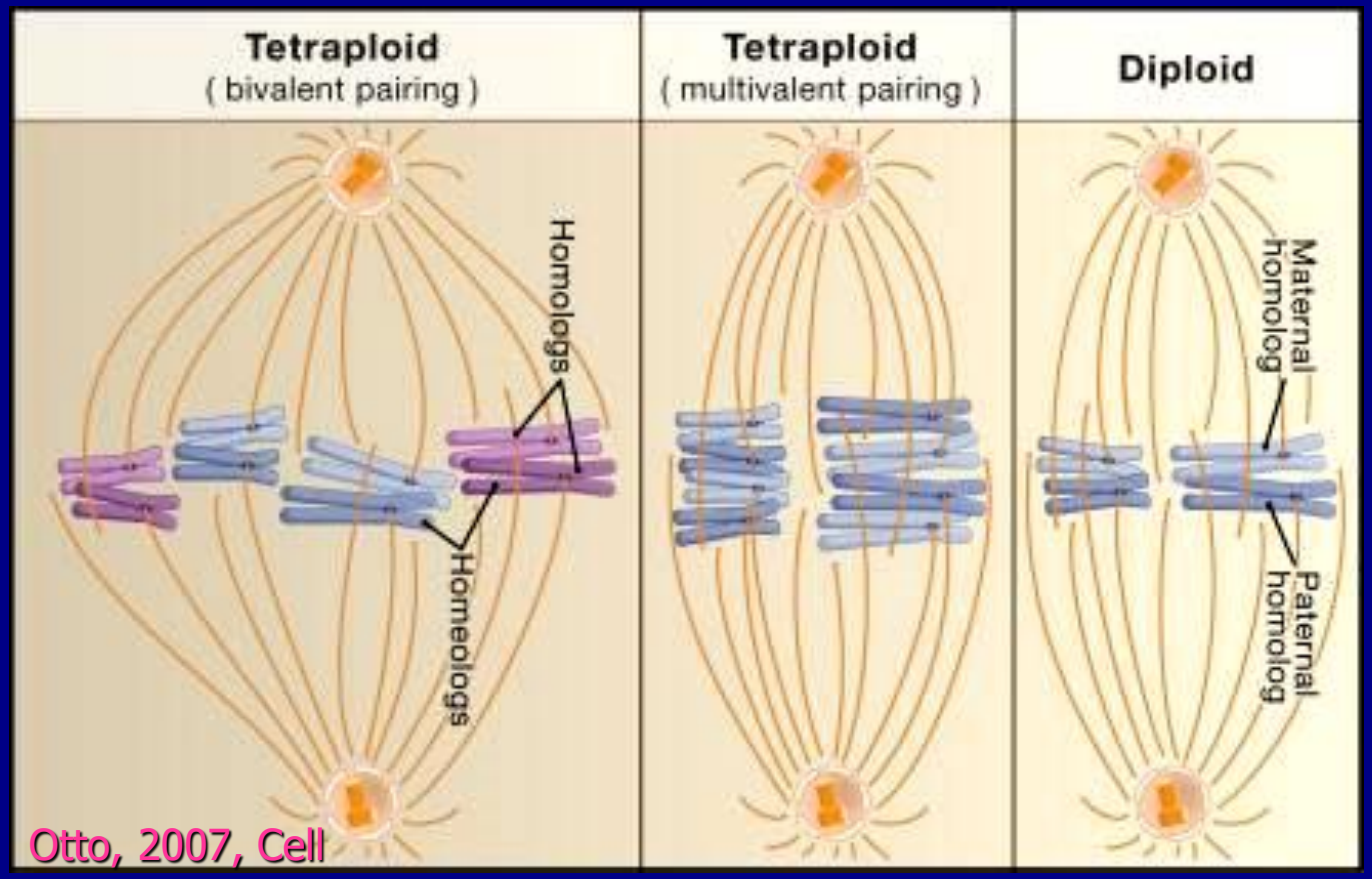




Polyploidy and meiosis

- Autotriploidy - the three homologous chromosomes can form trivalents as well as bivalents with univalents.
- Any region can pair, but only two chromosomes can pair in any one region.

allopolyploidy autopolyploidy



Otto, 2007, Cell

Polyploidy in animals

- 1/10 000 human newborns are tryploid (one of the gametes is diploid).Triploid babies die soon after birth.
- Some Annelida worms, insects with parthenogenetic reproduction, fishes and amphibians are polyploid.
- The animal for studying the effect of polyploydy in animals - ***Ambystoma*** (it can have chromosome number from n to 5n).

- The mammalian exception:
  Tympanoctomys barrerae (4n)

cricyt.edu.ar