

➤ CELL DIVISION

• **MITOSIS**

- **chromosome number does not change (diploid to diploid)**
- **occurs in nearly all eukaryotic cells (& all cells of the human body at some point)**
- **two diploid daughter cells are produced with the same chromosome number and genetic make-up of the original mother cell which underwent mitosis.**

- **interphase** = the period in the cell cycle when the cell is not actually dividing; the cell is going about its day-to-day metabolic business and not undergoing mitosis or meiosis; **S phase** (DNA replication and chromosome duplication) occurs during interphase; **chromosomes are duplicated during S phase of interphase.**

- **S phase** = the period during interphase in which DNA replication and thus chromosome duplication occurs in eukaryotic cells; **chromosomes are duplicated during S phase of interphase.**

- **chromatin** = **DNA which is not condensed** into chromosomes is bound to protein; diffuse, long, fibers of DNA with proteins attached and the state of the DNA when the cell is not dividing. When the chromatin condenses (DNA “wraps” around itself and the proteins) during **prophase**, **chromosomes** are formed.

- **single chromosome** = a chromosome which has not been duplicated; the state of the chromosomes in a cell before S phase. **(in a stick drawing, ½ of an X)**

- **duplicated chromosome** = a chromosome which has been duplicated; the state of the chromosomes in a cell after S phase (sometime before mitosis or meiosis); **(in a stick drawing, a complete X)**

- **chromatid** = one half of a duplicated chromosome; looks like a single chromosome.

- **centromere** = a structure made of protein which holds the two halves of a duplicated chromosome together.

- **STAGES OF MITOSIS (after S phase of interphase)**

- **PROPHASE** = *the first stage of mitosis*
 - chromatin condenses to form duplicated chromosomes
 - the nuclear envelope breaks down (degenerates)
 - the spindle apparatus (made of microtubules) forms; the spindle attaches to the centromeres of the chromosomes and moves the chromosomes around during cell division.
 - crossing over does **not** occur during mitosis (more on this later)

- **METAPHASE** = *the second stage of mitosis.*
 - the mitotic spindle moves the duplicated chromosomes so that they are lined up at the cell equator (in the middle of the cell) equidistant from the two poles (opposite ends) of the cell.
NOTE: The centromeres of the chromosomes are lined up directly ON the equator (metaphase plate) of the cell in metaphase of mitosis.

- **ANAPHASE** = *the third stage of mitosis.*
 - centromeres of duplicated chromosomes divide and split
 - the mitotic spindle pulls the sister chromatids separate from each other as they move to opposite poles of the cell so that a complete set of daughter chromosomes is located at each of the two poles of the cell.

- **TELOPHASE** = *the fourth (and last) stage of mitosis.*
- duplicated chromosomes decondense back into chromatin
- the nuclear envelope begins to form around the chromosomes so that two separate daughter nuclei are created
- the mitotic spindle breaks down
- **At the end of telophase of mitosis, two daughter cells are produced each with the diploid (2N) number of chromosomes (same as the original, mother cell).**
- **In humans, a diploid cell has 46 chromosomes.**

- **haploid cell (N cell)** = in a sexually reproducing organism, a cell containing a single set of chromosomes: an N cell; a haploid cell has one half the number of chromosomes of a diploid cell of the same organism. Usually, the sperm and the egg are the only haploid cells.

- **diploid cell (2N cell)** = in a sexually reproducing organism, a cell containing a duplicate set of chromosomes; a 2N cell; a diploid cell has twice the number of chromosomes of a haploid cell of the same organism. Usually, the sperm and the egg are the only cells which are not haploid, that is, nearly all of the cells of the organism are diploid (except for the gametes).

- **gamete** = a sex cell; a haploid egg or sperm cell.

- **MEIOSIS**
- **a special type of cell division only seen in sexually reproducing organisms.**
- **cell division in which the chromosome number is halved. (46 to 23 in humans)**
- **the division of a single diploid cell into four haploid daughter cells.**
- **meiosis produces haploid gametes from diploid cells in the reproductive organs of the parents.**

- **INTERPHASE (before meiosis) = chromosomes are duplicated during S phase.**

- **NOTE: chromosomes are still duplicated before meiosis begins (just like mitosis).**

- **STAGES OF MEIOSIS (after S phase)**

- **MEIOSIS I = the first of two cell divisions that occurs during meiosis**

- **PROPHASE I = the first and longest stage of meiosis.**
- Prophase I is the longest stage of meiosis and the first stage of meiosis. **Begins with a single diploid (2N) cell containing duplicated chromosomes.**
- duplicated chromosomes condense from chromatin
- the nuclear envelope breaks down
- homologous chromosomes, each composed of two sister chromatids, pair up to form a tetrad. A tetrad has four chromatids.
- **homologous chromosomes** = the two chromosomes that make up a matched pair in a diploid cell. Homologous chromosomes are of the same length, centromere position, and staining pattern and possess genes for the same traits. One homologous chromosome (of each #, 1-23 in humans) is inherited from the organism's father, the other homologous chromosome (of each #, 1-23 in humans) is inherited from the organism's mother.
- **crossing over (or synapsis) occurs.** During crossing over, chromatids of homologous chromosomes exchange segments. The genetic information on each homologous chromosome is somewhat different than the information on the sister homologous chromosome that is attached to it by a centromere. Once crossing over is complete, the chromosomes that are formed are different than the original homologous chromosomes that formed the original tetrad.
- the spindle forms and begins moving homologous chromosomes toward the center of the cell

- ***METAPHASE I = the second stage of meiosis***
- the spindle moves the chromosome tetrads so that they are lined up at the cell equator (in the middle of the cell) equidistant from the two poles (opposite ends) of the cell. **During metaphase I, the homologous chromosomes have their centromeres next to and on each of the sides of the equator of the cell (that is, the centromeres of the homologous chromosomes are NOT on the equator).**
- ***ANAPHASE I = the third stage of meiosis***
- the spindle pulls the tetrads apart. **Centromeres do not divide and the sister chromatids that make up each doubled chromosome remain attached.** The spindle separates the pairs of homologous chromosomes from each other as they move to opposite poles of the cell.
- ***TELOPHASE I = the fourth stage of meiosis***
- the nuclear envelope only begins to reform around the chromosomes so that two separate daughter nuclei are created
- the mitotic spindle only begins to break down
- the chromosomes only begin to decondense back into chromatin after telophase I.
- **At the end of telophase I, two daughter cells are produced each with the haploid number of doubled chromosomes.**
- **In humans, at the end of telophase I, two cells are produced each with 23 duplicated chromosomes.**
- **CHROMOSOMES ARE NOT DUPLICATED. THERE IS NO S PHASE BETWEEN MEIOSIS I AND MEIOSIS II. THERE IS NO INTERPHASE BETWEEN MEIOSIS I AND MEIOSIS II.**
- ***MEIOSIS II = the second of two cell divisions that occurs during meiosis***
- ***PROPHASE II (chromosomes are already condensed after telophase I)***
- **Begins with two haploid (N) cells each containing duplicated chromosomes (23 duplicated in humans).**
- the nuclear envelope breaks down if it has reformed
- the spindle forms, if not already present, and begins moving chromosomes toward the center of the cell
- ***METAPHASE II***
- the spindle moves the duplicated chromosomes so that they are lined up at the cell equator (in the middle of the cell) equidistant from the two poles (opposite ends) of the cell **with their centromeres ON the equator of the cell.**
- ***ANAPHASE II***
- centromeres of duplicated chromosomes divide
- the spindle pulls the sister chromatids separate from each other as they move to opposite poles of the cell so that a haploid set of daughter chromosomes is located at each of the two poles of the cell
- ***TELOPHASE II***
- chromosomes decondense back into chromatin
- the nuclear envelope begins to form around the chromosomes so that two separate daughter nuclei are created
- the spindle breaks down

- **At the end of telophase, four daughter cells are produced each with the haploid number of single chromosomes.**
- **In humans, four haploid cells each with 23 single chromosomes are produced at the end of meiosis.**
- **genetic recombination** = the production, by crossing over, of chromosomes with gene combinations different from those in the original chromosomes. Genetic recombination occurs during meiosis in all organisms that perform sexual reproduction.

• **DNA REPLICATION**

- In virtually all organisms. **DNA (deoxyribonucleic acid)** is the genetic material that is inherited from one generation to the next.
- In a few viruses, **RNA (ribonucleic acid)** is the genetic material that is inherited from one generation of viruses to the next generation of viruses.
- **nucleotide** = a monomer of a nucleic acid (either DNA or RNA). Each nucleotide consists of a five carbon sugar (ribose or deoxyribose) covalently bonded to one of four different nitrogenous bases (a compound that contains nitrogen atoms) and a phosphate group. Nucleotides are the building blocks of DNA and RNA.
- **DNA** = the genetic material that organisms inherit from their parents; a double stranded helical molecule that consists of nucleotides linked together. The nucleotides that make up DNA are made of a **deoxyribose** sugar molecule attached to a phosphate group and a nitrogenous base. **The four nitrogenous bases in DNA are adenine (A), cytosine (C), guanine (G), and thymine (T).**
- **DNA polymerase** = the enzyme that assembles DNA nucleotides into the two strands of DNA.
- **RNA** = a type of nucleic acid consisting of nucleotides linked together. The nucleotides that make up RNA are made of a **ribose** sugar molecule attached to a phosphate group and a nitrogenous base. **The four nitrogenous bases in RNA are adenine (A), cytosine (C), guanine (G), and uracil (U).** RNA is usually a single stranded molecule and plays important roles in protein synthesis (translation).
- **sugar-phosphate backbone** = refers to the "sides of the ladder" in a molecule of DNA. The sugar (deoxyribose) and phosphate groups of each nucleotide in a strand of DNA are linked together with their nitrogenous bases (A, T, C, G) "sticking out" as the "rungs of the ladder".
- **complementary bases** = nitrogenous bases in nucleic acids that will form hydrogen bonds with each other. To form a double stranded DNA molecule, each of the bases will only form hydrogen bonds with other specific bases. **Adenine will only bond to Thymine (A to T) and Guanine will only bond to Cytosine (G to C).** Thus, one strand of DNA that had the sequence ATGCTCGTA would only bind to a complementary strand that had the sequence TACGAGCAT to form a double stranded DNA molecule.
- **DNA double helix** = refers to the three dimensional structure of DNA. The two strands of DNA are held together by **hydrogen bonds** and the two strands are wound around each other into a helical formation.
- **gene** = a discrete unit of hereditary information consisting of a specific nucleotide (base) sequence of DNA. Genes are made of DNA so they are found on the chromosomes in the nucleus of all eukaryotic cells.

➤ **CANCER**

- **mutation** = a change in the nucleotide sequence of DNA. If a mutation changes the sequence of DNA in a gene, then the mRNA and protein made from that gene will be different than it was before the mutation. Many mutations are harmful and lead to the synthesis of abnormal or non-functional proteins which could cause cell death or cancer. Rarely, a mutation occurs that is beneficial to an organism that allows it to make new proteins capable of new functions. These new "mutated" proteins may cause the organisms to show different traits and possibly have different abilities. This provides for part of the basis of evolution. Mutations can be caused by mutagens.
- **mutagen** = a chemical or physical agent that interacts with DNA to cause a mutation. The most common physical mutagen is high-energy radiation such as X-rays or Uv (ultraviolet) light. There are thousands of chemical mutagens such as benzene, cigarette smoke, some steroids, and alcohol. Some mutagens are also carcinogens. Additionally, an individual can be born with a mutation in a gene that makes them more susceptible to developing a particular disease.
- **carcinogen** = a chemical or physical agent that causes cells to become cancerous. Many carcinogens interact with DNA to cause mutations that lead to cancer. UV light from the sun and cigarette smoke are leading causes of skin and lung cancer worldwide.
- **proto-oncogene** = a normal gene whose protein product stimulates an increase in cell division; mutated proto-oncogenes become oncogenes. Oncogene proteins hyperstimulate mitosis.
- **tumor suppressor gene** = a normal gene whose protein product inhibits tumor growth and cell division; a mutated tumor suppressor gene can become inactivated which can facilitate tumor formation (inactivated tumor suppressor genes allow for more mitosis to occur).
- **growth factor** = a protein secreted by certain cells in the body that stimulates cell division. Growth factors regulate the cell cycle in cells. If the gene for a growth factor becomes mutated, the cell has the potential to become cancerous.
- **oncogene** = a cancer causing gene; oncogenes are often the genes for growth factors or related proteins that control the cell cycle.
- **cancer cell** = a cell that is not subject to normal cell-cycle control mechanisms. Cancer cells divide continuously, often killing the organism if unchecked. Cancer cells divide to form malignant tumors.
- **tumor** = an abnormal mass of cells that forms within otherwise normal tissue. **Not all tumors are cancerous (benign), only malignant tumors are cancerous.**
- **benign tumor** = an abnormal mass of cells that remains at its original site in the body and does not travel to other parts of the body.
- **malignant tumor** = an abnormal tissue mass of cells that can spread into neighboring tissue and to other parts of the body (metastasis); a cancerous tumor. Malignant tumor cells can be transported by the blood or lymph to other parts of the body.
- **metastasis** = the spread of cancer cells beyond their original site in the body by way of the circulatory or lymph vessels.

- **GENERAL TYPES OF CANCER**

- **carcinoma** = cancer that originates in the coverings or linings of the body, such as the skin, intestinal lining, or lungs.
- **sarcoma** = cancer that originates in the supportive tissues such as bone, muscle or cartilage.
- **leukemia** = cancer that originates in the blood forming tissues. Leukemia is characterized by an excessive production of white blood cells which causes an abnormally high number of white blood cells to show up in the blood when a white blood cell count is performed. Cancer of the bone marrow is a type of leukemia.
- **lymphoma** = cancer that originates from the lymph nodes or white blood cells.