

CELL REPRODUCTION AND HEREDITY

genome (human) - is the total genetic information of the organism. It consist of the sum genetic information from the 46 chromosomes.

chromosome - is a structure consisting of DNA complexed with proteins that transmits genetic information from one generation to the next. This structure is made up of chromatin and is visible during mitosis.

chromatin - is a network of fibrils consisting of DNA and associated proteins observed within a nucleus that is not dividing (undergoing mitosis).

gene - is a unit of heredity found on a segment of a chromosome.

allele - is an alternative form of a gene. Alleles occur at the same locus on homologous chromosomes.

nucleic acid - is a polymer of nucleotides (adenine - thymine, guanine - cytosine). DNA and RNA are nucleic acids.

The Cellular Basis of Reproduction and Inheritance -

Life Cycle - The entire sequence of stages in the life of an organism, from the adults of one generation to the adults of the next.

Sexual reproduction involves passing traits from two parents to the next generation.

Asexual reproduction involves passing traits from only one parent to the next generation.

Cells arise only from preexisting cells

The principle (**Cell Theory**) was formulated in 1858 by German physician Rudof Virchow.

Cell division occurs in single-celled organisms when they reproduce and simple cell division is also involved in the growth and repair of multicellular forms.

Cell division functions to:

1. Maintains a favorable plasma membrane / volume ratio for the cell as a fertilized egg develops into an adult organism and
2. Allows specialization of cells to occur in multicellular organisms.

Cell division must provide a mechanism for distribution of DNA to the daughter cells, and for a division of the cytoplasm (continuity from generation to generation).

Bacteria reproduce by binary fission

Prokaryotic Chromosomes

The prokaryotic chromosome is a single long loop of DNA that is compacted into a nonmembrane bounded area called a nucleoid region. Packaging is minimal: The DNA is complexed with a few proteins and attached to the plasma membrane at one point.

Cell Division

Cell division in prokaryotes is by **binary fission**. Replication of DNA is followed by elongation of the cell so that the two chromosomes are separated before an ingrowth of the plasma membrane and formation of a cell wall separates the cytoplasm.

Eukaryotes have multiple chromosomes that are large and complex

Whereas a typical bacterium might have 3000 genes, human cells, for example, have 50,000 - 100,000. In multicellular plants and animals, the body cells (**somatic cells**) contain twice the number of chromosomes as the sex cells.

The full or **Diploid (2N)** number of chromosomes in somatic cells for humans is 46.

The **Haploid (1N)** number of chromosomes in sex cells for humans is 23.

Mitosis How Eukaryotic cells divide!

Mitosis is process in which a parent nucleus produces two daughter nuclei, each having the same number and kinds of chromosomes as the parent nucleus

Mitosis is divided into five phases for convenience of description.

These phases are as follows

Prophase chromosomes are visible. Two copies of each chromosome each is a chromatid which is connected to its duplicate at a single point, the centromere
Centrosomes begin moving apart. Spindle fibers form
Nuclear envelope is fragmenting end of prophase

Metaphase- mitotic spindle is fully formed with its poles at opposite ends of the cell
chromosomes are at the metaphase (middle) plate

Anaphase- the two sister chromatids of each duplicated chromosome separate (apart) at the centromere, giving rise to two daughter chromosomes
daughter chromosomes, each with a centromere and single chromatid, begin to move toward opposite poles.

Telophase- spindle disappears as new nuclear envelopes form around the daughter chromosomes.
two daughter nuclei appear at the two poles of the cell
chromatin fiber of each chromosome uncoils, and nucleoli reappear
the equal division of one nucleus into two genetically identical daughter nuclei is now finished

Cytokinesis - In animal cells, a cleavage furrow, which is an indentation of the membrane between the two daughter nuclei. The cytoplasm continues to separate till there are two independent cells.

Interphase- period of cell growth (G1 & G2) when the cell synthesizes new molecules and organelles.
The majority of the cell cycle is spent in interphase (not part of mitosis)

Cell density, chemical growth factors, and anchorage affect cell division

Control of Cell Cycle

Normal cells exhibit contact inhibition and stop dividing once they have made contact with other cells.

The total number of divisions for any particular human cell is usually a maximum of 50 to 100.

Cytoplasmic proteins, hormones, and nutrients are apparently involved in cell cycle control. Laboratory studies show that density-dependent inhibition of cell growth is controlled by the depletion of growth factor proteins in masses of crowded cells.

Crucial events in controlling the cycle apparently occur late in the G1 phase. If these do not happen, the cell will switch to a nondividing state (for example, nerve and muscle cells and many cells outside of meristematic regions in plants).

Cancer cells escape from normal control mechanisms

Cancer cells need little growth factor needed for cell division and do not exhibit the same cell cycle control that normal cells do.

Some cancer cells actually continually synthesize factors that keep them dividing.

Ionizing radiation therapy attempts to halt the spread of cancers by inhibiting their cell division cycles.

Chemotherapies depend on drugs that target various parts of the mitotic apparatus. These drugs are often products of other organisms (for example, taxol from the Pacific yew tree and a fungus that decomposes yew).

Review of the functions of mitosis: Growth, cell replacement, and asexual reproduction

Asexual versus Sexual Reproduction

Single-celled prokaryotes reproduce by fission. Single-celled eukaryotic protists reproduce by cell division that involves mitosis. Reproduction by binary fission and mitosis is termed **asexual reproduction**.

Although some multicellular forms do reproduce asexually, generally speaking, mitosis occurs during the growth and repair of tissues.

Multicellular forms usually carry on sexual reproduction, which requires sex cell (gamete) formation and fertilization.

Meiosis is a form of cell division that reduces the chromosome number from diploid to haploid and is involved in sex cell formation and sexual reproduction.

Chromosomes are matched in homologous pairs

Gamete formation and fusion are integral parts of **sexual reproduction**.

Meiosis

Chromosomes come in pairs called homologous chromosomes because they carry genes for the same traits.

Homologues share shape and genetic loci, but not necessarily genes.

In humans, 22 pairs, found in males and females, are **autosomes**.

Two other chromosomes are **sex chromosomes**.

In females, there are two X chromosomes; in males, an X and a Y.

Gametes have a single set of chromosomes

Each gamete (sperm or egg) contains one of each kind of chromosome. During meiosis, the chromosome number is reduced from the diploid (2N) number to the haploid (N) number, but in such a way that the daughter nuclei receive one of each kind of chromosome.

In both plant and animal life cycles, it is **fertilization** of the egg by the sperm that restores the chromosome number to the full diploid number in the zygote. **The fertilized sex cell soon undergoes mitosis to begin forming a new organism.**

Sexual life cycles involve the alternation between a diploid phase and a haploid phase.

An Overview of Meiosis

Meiosis require two nuclear divisions and produces four daughter cells, each has one of each kind of chromosome and therefore half the total number of chromosomes present in the mother cell nucleus.

Meiosis occurs only in diploid cells.

Like mitosis, meiosis is preceded by a single duplication of the chromosomes.

Again, the process is dynamic but may stop at certain phases for long periods of time.

The process includes two consecutive divisions (meiosis I and Meiosis II)

The halving of the chromosome number occurs in meiosis I.

Meiosis reduces the chromosome number from diploid to haploid

Meiosis I

Meiosis I is divided into the same four stages as mitosis.

1. Prophase I

During a process called **synapsis**, the duplicated chromosomes begin to pair with its homologue as they line up side by side. This close association assists **crossing-over** of genetic material between nonsister chromosomes of the **bivalent (tetrad)**. Then the homologous chromosomes begin to move apart but are held together by **chiasmata**. **Each homologous pair separates independently of all the other pairs.**

By rearranging genetic information, crossing over can make an important contribution to the genetic variability resulting from sexual reproduction.

2. Metaphase I

Bivalents are present at the equator during metaphase I. **The alignment is random and therefore any possible combination of chromosomes can occur in the daughter cells.**

3. Anaphase I

Homologous chromosomes separate during anaphase I. **This is the means by which the diploid number is reduced to the haploid number and also the reason why the daughter cells will receive one of each kind of chromosome.**

4. Telophase I & Interkinesis

Cytokinesis does not necessarily follow telophase I. However, there is a short period known as **interkinesis** before meiosis II begins. DNA does not replicate because the chromosomes are already duplicated.

Meiosis II

This second division of meiosis varies considerably from species to species but **it is essentially a mitotic like division in which the chromatids separate and become independent chromosomes.**

The four cells are not genetically identical to the mother cell because (1) they are haploid, and (2) crossing-over has resulted in different combinations of the genes on the daughter chromosomes. In other words, **genetic recombination** has occurred.

Meiosis in Humans

Meiosis is confined to **germ cells** that produce the gametes during **gametogenesis** and remain separate and distinct from the **somatic (body) cells**.

In female the germ cells are located in the ovaries where eggs are produced in a process called oogenesis. In males, the germ cells are located in the testes where sperm are produced in a process called spermatogenesis.

Oogenesis and Spermatogenesis

Complete oogenesis in females produces from each original cell only one egg and at least two nonfunctional polar bodies that disintegrate.

In males spermatogenesis results in four viable sperm from each original cell.

Review: A comparison of mitosis and meiosis

Comparison of Meiosis and Mitosis

Occurrence

Meiosis occurs only in cells that will eventually give rise to the gametes, but mitosis occurs in all types of cells in the body.

Process

Mitosis	Meiosis I	Meiosis II
Prophase No pairing of chromosomes	Pairing of homologous chromosomes	
Metaphase Diploid number duplicated of duplicated chromosomes at equator	Bivalents at equator	Haploid number of chromosomes at equator
Anaphase Chromatids separate	Homologous chromosomes separate	Chromatids separate
Telophase Two daughter nuclei are diploid	Daughter nuclei are haploid	Four daughter cells nuclei are haploid

The following are distinctive differences between mitosis and meiosis.

1. Chromosomes replicate their DNA once before both mitosis and meiosis. But chromosomes undergo only one division in mitosis and two divisions in meiosis.
2. Homologous chromosomes pair and undergo crossing-over during meiosis but not in mitosis.
3. Paired homologous chromosomes (bivalents) align at the equator of metaphase I in meiosis; individual chromosomes composed of two sister chromatids align at the equator in metaphase of mitosis.

Daughter Nuclei and Cells

The genetic consequence of mitosis and meiosis are quite different.

1. Four daughter cells are produced from a single cell that undergoes meiosis; mitosis results in two daughter cells.
2. The four daughter cells formed by meiosis are haploid; the daughter cells produced by mitosis have a chromosome number (2N) identical to their mother cell
3. The mitotic daughter cells are genetically identical to each other and to their parental cell. **Meiosis produces haploid daughter cells that differ genetically from each other and from the diploid mother cell due to crossing-over and independent alignment of bivalents at Anaphase I.**

Independent orientation of chromosomes in meiosis and random fertilization lead to varied offspring

Importance of Meiosis

Meiosis helps assure that the zygote will have a different combination of alleles than has either parent. As a result of independent assortment of chromosomes, the chromosomes are distributed to the gametes in various combinations. Given n chromosomes, there are 2^n ways that different combinations of the half-pairs can move to one pole.

A sexually reproducing population has a tremendous storehouse of variations, some of which may be advantageous for evolution, particularly when the environment is changing.

The two chromosomes in a homologous pair carry different genetic information

The fact that homologous chromosomes can bear different genetic information for the same traits at corresponding loci is what really makes gametes and therefore offspring different from one another.

Crossing over further increases genetic variability

Crossing over is the exchange of corresponding segments between two homologues.

This happens between chromatids within tetrads as homologues pair up closely during prophase I.

Crossing over produces new combinations of genes. Because crossing over can occur several times in variable locations among thousands of genes in each tetrad, the possibilities are much greater than calculated above. Essentially, two individual parents could never produce identical offspring from two separate fertilizations.