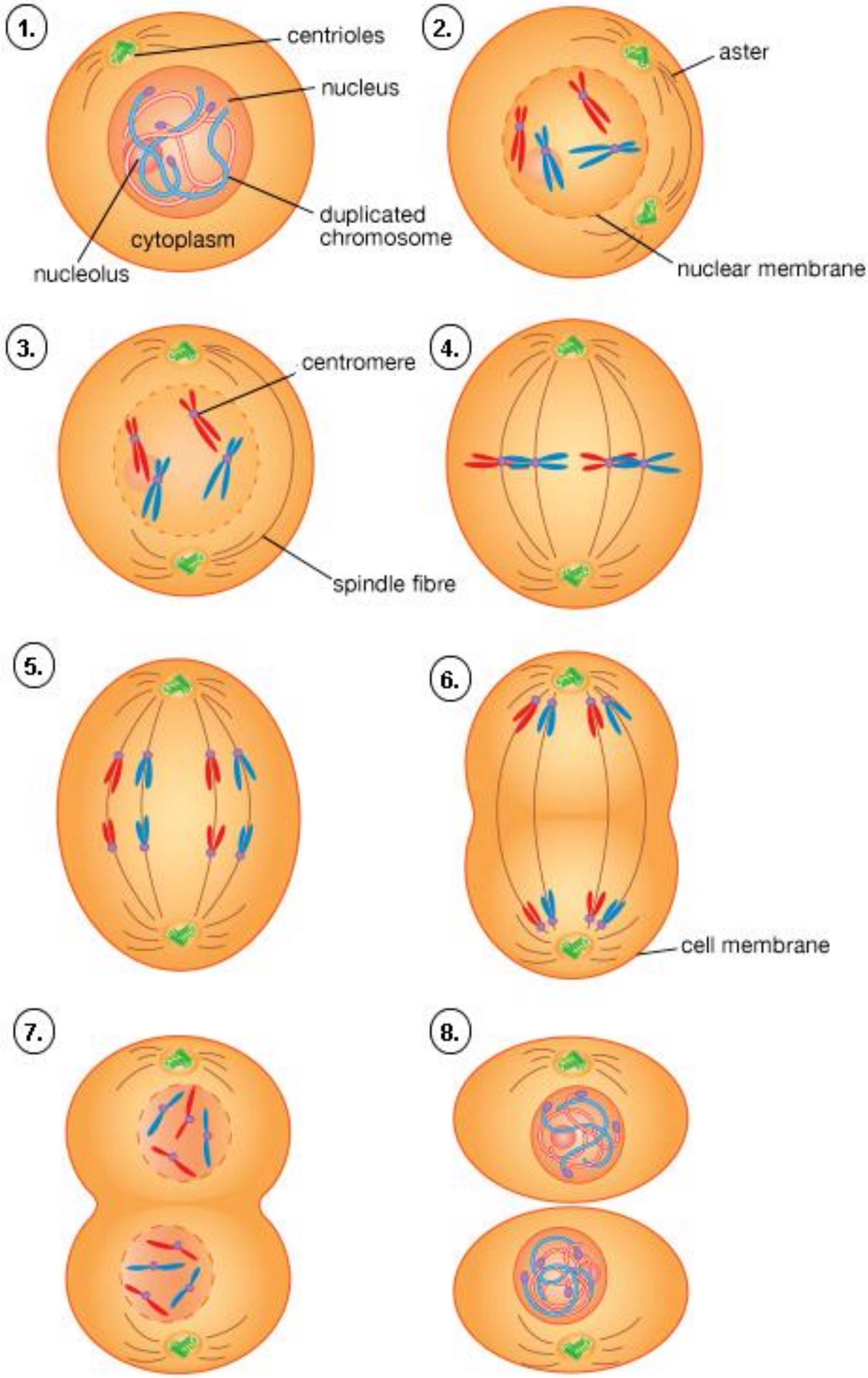
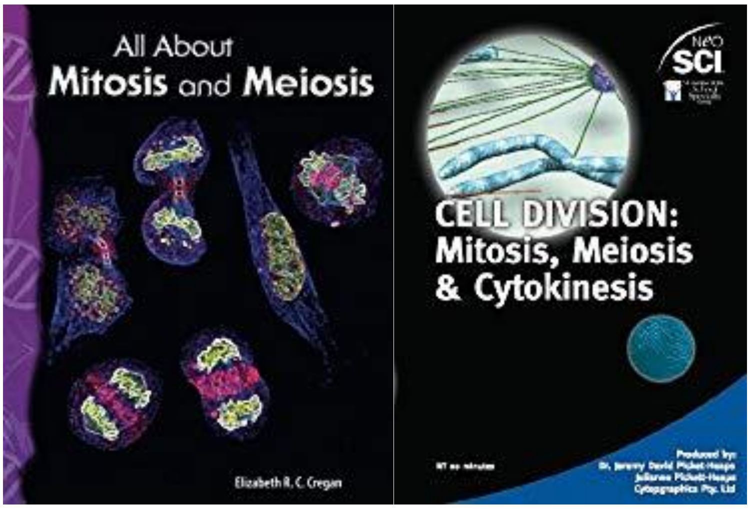

1.
centrioles
nucleus
duplicated chromosome
cytoplasm
nucleolus
2.
aster
nuclear membrane
3.
centromere
spindle fibre
4.
5.
6.
cell membrane
7.
8.

Organisms must be able to grow and reproduce. Prokaryotes, such as bacteria, duplicate deoxyribonucleic acid (DNA) and divide by splitting in two, a process called binary fission. Cells of eukaryotes, including those of animals, plants, fungi, and protists, divide by one of two methods: mitosis or meiosis.

Mitosis produces two cells, called daughter cells, with the same number of chromosomes as the parent cell, and is used to produce new somatic (body) cells in multicellular eukaryotes or new individuals in single-celled eukaryotes. In sexually reproducing organisms, cells that produce gametes (eggs or sperm) divide by meiosis, producing four cells, each with half the number of chromosomes possessed by the parent cell.

Chromosome Replication

All eukaryotic organisms are composed of cells containing chromosomes in the nucleus. Chromosomes are made of DNA and proteins. Most cells have two complete sets of chromosomes,which occur in pairs. The two chromosomes that make up a pair are homologous, and contain all the same loci (genes controlling the production of a specific type of product).



These chromosome pairs are usually referred to as homologous pairs. An individual chromosome from a homologous pair is sometimes called a homolog. For example, typical lily cells contain twelve pairs of homologous chromosomes, for a total of twenty-four chromosomes.

Cells that have two homologous chromosomes of each type are called diploid. Some cells, such as eggs and sperm, contain half the normal number of chromosomes (only one of each homolog) and are called haploid. Lily egg and sperm cells each contain twelve chromosomes.

DNA must replicate before mitosis or meiosis can occur. If daughter cells are to receive a full set of genetic information, a duplicate copy of DNA must be available. Before DNA replication occurs, each chromosome consists of a single long strand of DNA called a chromatid. After DNA replication, each chromosome consists of two chromatids, called sister chromatids.

The original chromatid acts as a template for making the second chromatid; the two are therefore identical. Sister chromatids are attached at a special region of the chromosome called the centro mere. When mitosis or meiosis starts, each chromosome in the cell consists of two sister chromatids.

Mitosis andmeiosis produce daughter cells with different characteristics. When a diploid cell undergoes mitosis, two identical diploid daughter cells are produced.

When a diploid cell undergoes meiosis, four unique haploid daughter cells are produced. It is important for gametes to be haploid, so that when an egg and sperm fuse, the diploid condition of the mature organism is restored.

Cellular Life Cycles

Mitosis and meiosis occur in the nuclear region of the cell, where all the cell's chromosomes are found. Nuclear control mechanisms begin cell division at the appropriate time.

Some cells rarely divide bymitosis in adult organisms, while other cells divide constantly, replacing old cells with new. Meiosis occurs in the nuclei of cells that produce gametes. These specialized cells occur in reproductive organs, such as flower parts in higher plants.

Cells, like organisms, are governed by life cycles. The life cycle of a cell is called the cell cycle. Cells spend most of their time in interphase. Interphase is divided into three stages: first gap (G1), synthesis (S), and second gap (G2).

During G1, the cell performs its normal functions and often grows in size. During the S stage, DNA replicates in preparation for cell division.During theG2 stage, the cell makes materials needed to produce the mitotic apparatus and for division of the cytoplasmic components of the cell.

At the end of interphase, the cell is ready to divide. Although each chromosome now consists of two sister chromatids, this is not apparent when viewed through a microscope. This is because all the chromosomes are in a highly relaxed state and simply appear as a diffuse material called chromatin.

Mitosis

Mitosis consists of five stages: prophase, prometaphase, metaphase, anaphase, and telophase. Although certain events identify each stage, mitosis is a continuous process, and each stage gradually passes into the next. Identification of the precise state is therefore difficult at times.

During prophase, the chromatin becomes more tightly coiled and condenses into chromosomes that are clearly visible under a microscope, the nucleolus disappears, and the spindle apparatus begins to form in the cytoplasm.

In prometaphase, the nuclear envelope breaks down, and the spindle apparatus is now able to invade the nuclear region. Some of the spindle fibers attach them selves to a region near the centromere of each chromosome called the kinetochore.

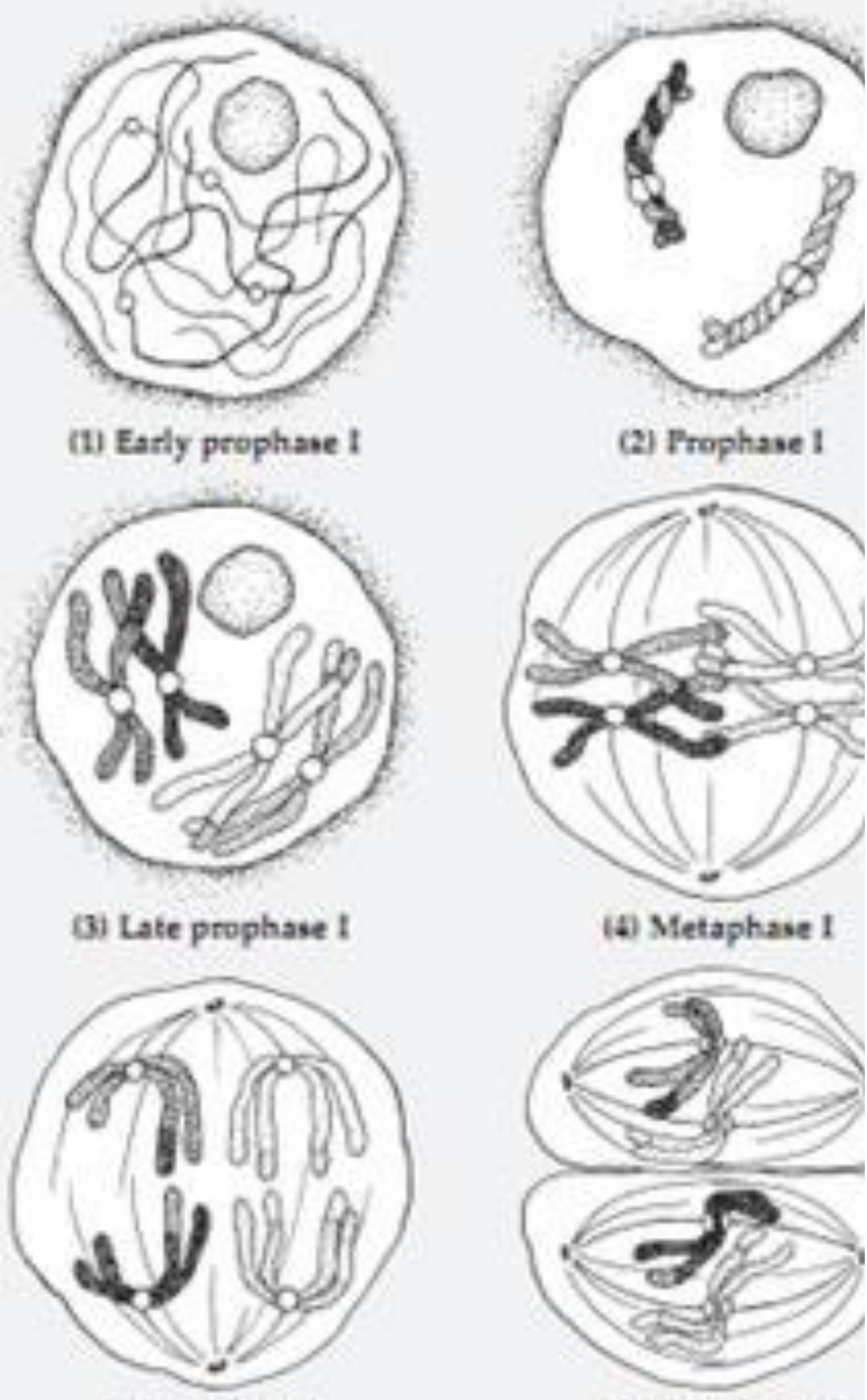
The spindle apparatus is the most obvious structure of the mitotic apparatus. The nuclear region of the cell has opposite poles, like the North and South Poles of the earth. Spindle fibers reach from pole to pole, penetrating the entire nuclear region.

During metaphase, the cell’s chromosomes align in a region called the metaphase plate, with the sister chromatids oriented toward opposite poles. The metaphase plate traverses the cell, much like the equator passes through the center of the earth. Sister chromatids separate during anaphase.

The sister chromatids of each chromosome split apart, and the spindle fibers pull each sister chromatid (now a separate chromosome) from each pair toward opposite poles, much as a rope-tow pulls a skier up a mountain. Telophase begins as sister chromatids reach opposite poles. Once the chromatids have reached opposite poles, the spindle apparatus falls apart, and the nuclear membrane re-forms. Mitosis is complete.

Meiosis

Meiosis: Selected Phases



Meiosis is a more complex process than mitosis and is divided into two major stages: meiosis I and meiosis II. As in mitosis, interphase precedes meiosis. Meiosis I consists of prophase I, metaphase I, anaphase I, and telophase I.

Meiosis II consists of prophase II, metaphase II, anaphase II, and telophase II. In some cells, an interphase II occurs between meiosis I and meiosis II, but no DNA replication occurs.

During prophase I, the chromosomes condense, the nuclear envelop falls apart, and the spindle apparatus begins to form. Homologous chromosomes come together to form tetrads (a tetrad consists of four chromatids, two sister chromatids for each chromosome). The arms of the sister chromatids of one homolog touch the armsof sister chromatids of the other homolog, the contact points being called chiasmata.

Each chiasma represents a place where the arms have the same loci, so called homologous regions. During this intimate contact, the chromosomes undergo crossover, in which the chromosomes break at the chiasmata and swap homologous pieces.

This process results in recombination (the shuffling of linked alleles, the different forms of genes, into new combinations), which results in increased variability in the off spring and the appearance of character combinations not present in either parent.

Tetrads align on the metaphase plate during metaphase I, and one spindle fiber attaches to the kinetochore of each chromosome. In anaphase I, instead of the sister chromatids separating, they remain attached at their centromeres, and the homologous chromosomes separate, each homolog from a tetrad moving toward opposite poles.

Telophase I begins as the homologs reach opposite poles, and similar to telophase of mitosis, the spindle apparatus falls apart, and a nuclear envelope re-forms around each of the two haploid nuclei. Because the number of chromosomes in each of the telophase I nucleus is half the number in the parent nucleus, meiosis I is sometimes called the reduction division.

Meiosis II is essentially the same as mitosis, dividing the two haploid nuclei formed in meiosis I. Prophase II, metaphase II, anaphase II, and telophase II are essentially identical to the stages of mitosis. Meiosis II begins with two haploid cells and ends with four haploid daughter cells.

Nuclear Division and Cytokinesis

Mitosis and meiosis result in the division of the nucleus. Nuclear division is nearly always coordinated with division of the cytoplasm. Cleaving of the cytoplasmto form new cells is called cytokinesis. Cytokinesis begins toward the middle or end of nuclear division and involves not just the division of the cytoplasm but also the organelles.

In plants, after nuclear division ends, a new cell wall must be formed between the daughter nuclei. The new cell wall begins when vesicles filled with cell wall material congregate where the metaphase plate was located, producing a structure called the cell plate.

When the cell plate is fully formed, cytokinesis is complete. Following cytokinesis, the cell returns to interphase. Mitotic daughter cells enlarge, reproduce organelles, and resume regular activities. Following meiosis, gametes may be modified or transported in the reproductive system.

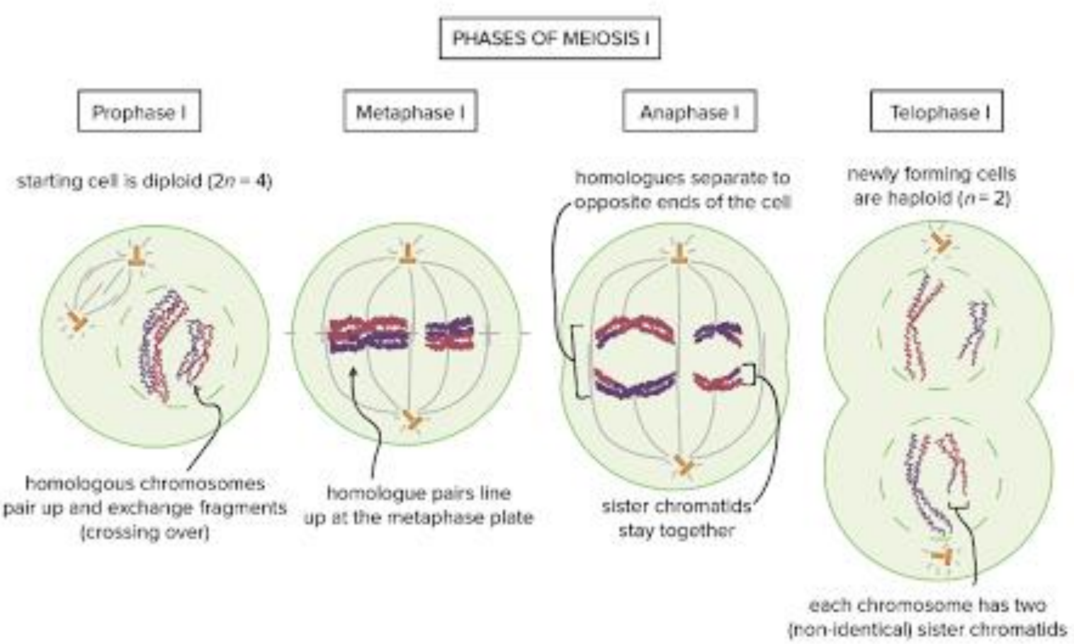
Alternation of Generations

Meiotic daughter cells continue development only if they fuse during fertilization. Mitosis and meiosis alternate during the life cycles of sexually reproducing organisms. The life-cycle stage following mitosis is diploid, and the stage following meiosis is haploid. This process is called alternation of generations.

In plants, the diploid state is referred to as the sporophyte generation, and the haploid stage as the gametophyte generation. In nonvascular plants, the gametophyte generation dominates the life cycle. In otherwords, the plants normally seen on the forest floor are made of haploid cells.

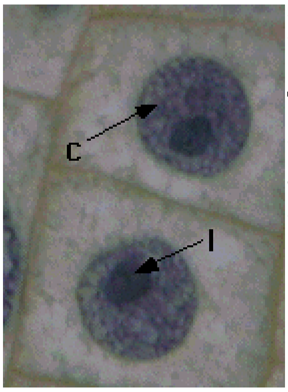
The sporophytes, which have diploid cells, are small and attached to the body of the gametophyte. In vascular plants, sporophytes are the large, multicellular individuals (such as trees and ferns), whereas gametophytes are very small and either are embedded in the sporophyte or are free-living, as are ferns.

The genetic variation introduced by sexual reproduction has a significant impact on the ability of species to survive and adapt to the environment. Alternation of generations allows sexual reproduction to occur, without changing the chromosome number characterizing the species.



Mitosis in Onion Root Tips.

Onion root tips are extremely popular for viewing the different phases of mitosis because the chromosomes are large and and very dark when stained. The images shown below were taken using a regular light microscope with an oil immersion lens at 1000X. Note that the actual magnification of the image will depend on the size of your monitor. The real size of a typical onion root tip cell is about .075mm (75 micrometers).

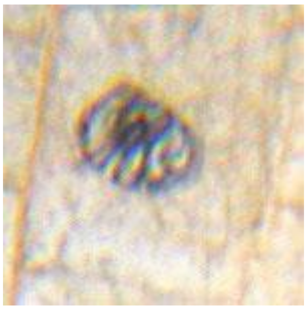


Interphase.

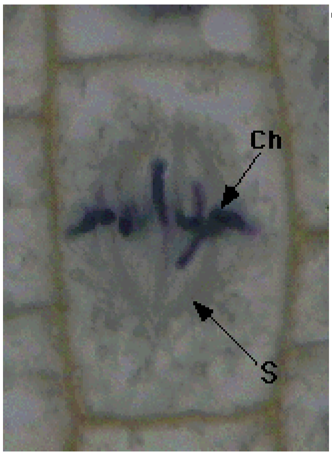
The two cells at the left are in interphase. The material inside the nucleus is largely chromatin(C) which consists of the chromosomes stretched out so that individual chromosomes are not visible. The dark structure(I) represents the nucleolus. Interphase cells typically have one or more nucleoli.

Prophase.

Observe the condensing chromosomes (dark regions) in the cell on the left below in early prophase. Note the cell on the right below with more prominent chromosomes and having lost the nuclear envelope.



Metaphase



This a very nice metaphase cell. Observe the chromosomes(Ch) at the equator of the spindle. The spindle(S) is highly visible. especially on the lower half of the cell.

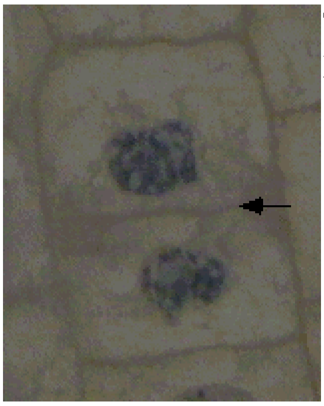
Anaphase

The cell to the left is a nice mid anaphase. If you closely compare the chromosomes with the metaphase cell, you can tell that the chromosomes are now unduplicated.

Telophase and Cytokinesis

The arrow is pointing to the spindle of this telophase cell. Also, there is a faint cell plate that may not show up on all monitors. In plant cells cytokinesis involves the formation of a cell plate. This is the start of the cell wall that will eventually divide the two new cells.

Late Telophase.



This image shows a late telophase cell near the left hand side of the image. Note that the cell plate goes almost all the way across the original cell and the reforming of the nuclear envelope.

Practice locating each of the stages of mitosis in the following slides of the onion root tip. Each picture contains at least one cell at each stage of mitosis (and some stages are represented by multiple cells).