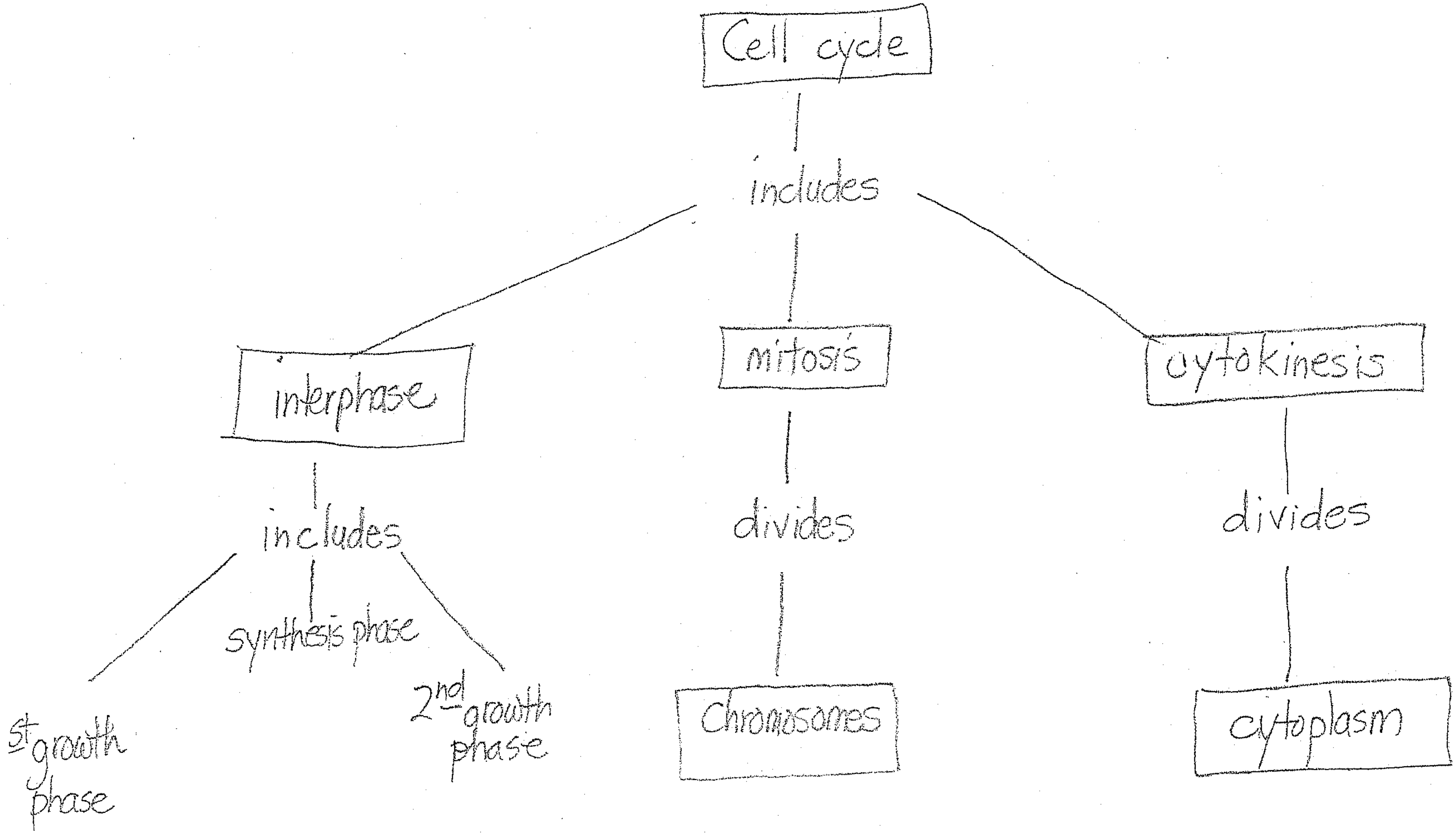
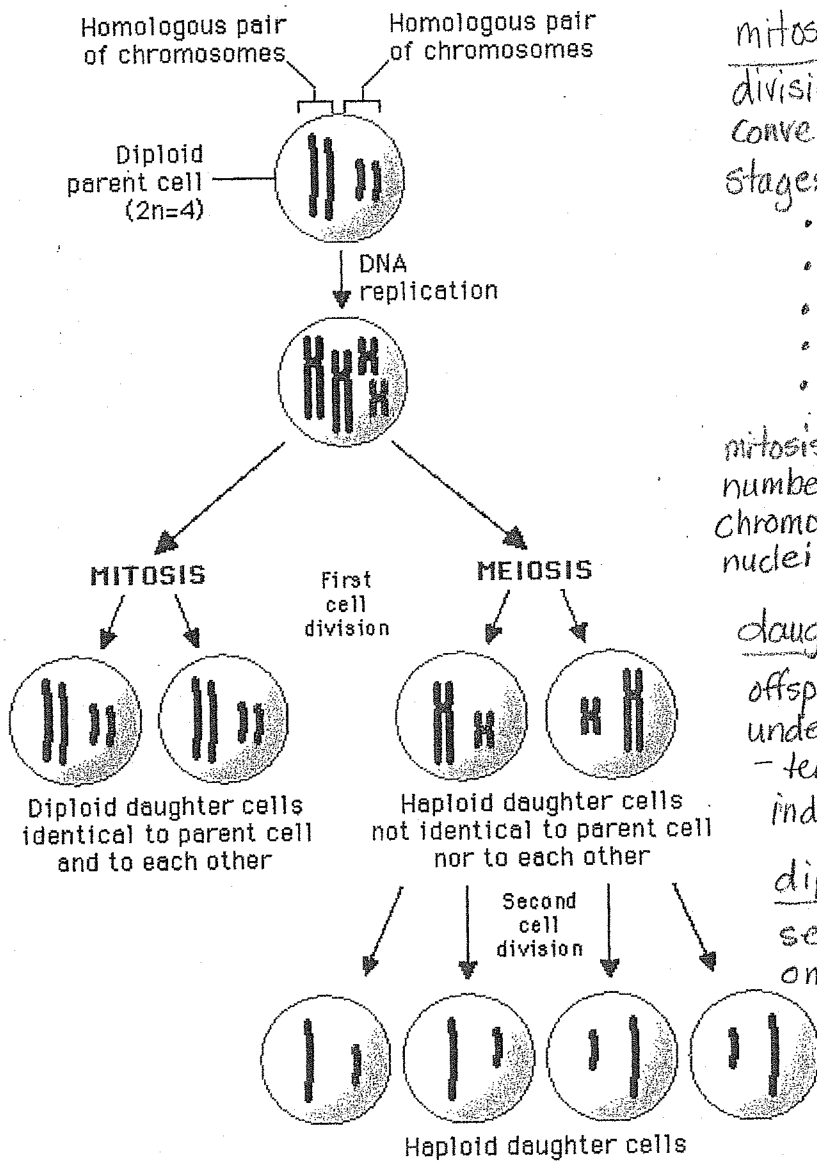

Cell cycle
includes
interphase
mitosis
cytokinesis
includes
divides
divides
synthesis phase
st growth phase
2nd growth phase
Chromosomes
cytoplasm

There are two kinds of cell division in eukaryotes. Mitosis is division involved in development of an adult organism from a single fertilized egg, in growth and repair of tissues, in regeneration of body parts, and in asexual reproduction. In mitosis, the parent cell produces two "daughter cells" that are genetically identical. (The term "daughter cell" is conventional, but does not indicate the sex of the offspring cell.) Mitosis can occur in both diploid (2*n*) and haploid (*n*) cells; a diploid cell is shown below.

In meiosis, diploid parent cells divide and produce the gametes or spores that give rise to new individuals. The parent cell produces four haploid daughter cells.



mitosis: process of nuclear division in eukaryotic cells conventionally divided into 5 stages -
- interphase
- prophase
- metaphase
- anaphase
- telophase

mitosis conserves chromosome number by equally allocating replicated chromosomes to ea of the daughter nuclei

daughter cell: cell that is the offspring of a cell that has undergone mitosis or meiosis - term "daughter" does not indicate sex of the cell

diploid: cell containing 2 sets of chromosomes (2n) one set inherited from ea parent

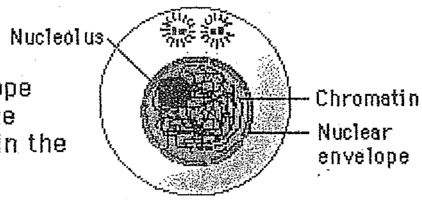
haploid: cell containing only 1 set of chromosomes

Prior to both mitosis and meiosis, the chromosomes in the nucleus are replicated. The nucleus then divides. Nuclear division is usually followed by division of the cytoplasm. In mitosis, there is one such division. Meiosis consists of two divisions; since the chromosomes have replicated only once, the four daughter cells have half as many chromosomes as the parent cell.

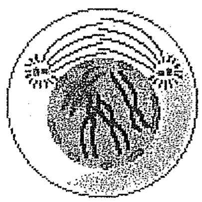
Observing Mitosis Using Prepared Slides
In your laboratory, you will study and sketch the events of cell division in either plant or animal cells, using a microscope slide of cells arrested at various stages in the process of division.

To help you identify which phase of the cycle a cell is in, let's go over the features to look for in each phase.

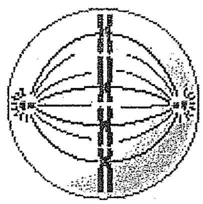
Interphase
The nucleolus and the nuclear envelope are distinct and the chromosomes are in the form of threadlike chromatin.



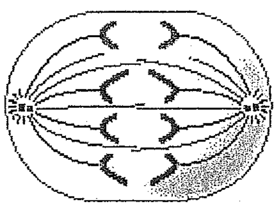
Prophase
The chromosomes appear condensed, and the nuclear envelope is not apparent.



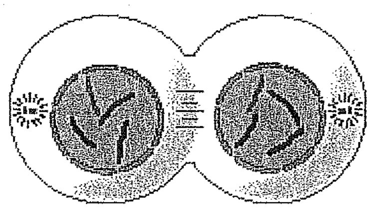
Metaphase
Thick, coiled chromosomes, each with two chromatids, are lined up on the metaphase plate.



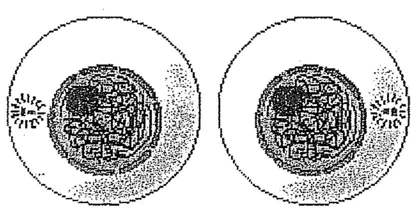
Anaphase
The chromatids of each chromosome have separated and are moving toward the poles.



Telophase
The chromosomes are at the poles, and are becoming more diffuse. The nuclear envelope is reforming. The cytoplasm may be dividing.



Cytokinesis
Division into two daughter cells is completed.



Chapter 14

To understand the process of reproduction and cell division, you have to get personally involved with the inhabitants of the eukaryotic cell's nucleus. Remember eukaryotic cells are those with true nuclei such as in plants, fungi, and animals.

The nucleus is the high rent district – the place where the hereditary materials of the cell are assembled into chromosomes, those tightly coiled molecular repositories of DNA. Remember DNA is the cell's blueprint, without which all construction on new cellular neighborhoods would come to a screeching halt. DNA molecules are extremely long, but in chromosomes. They are squished together and packed with a special kind of protein called *histone*. In fact – as unappetizing as it sounds – the long DNA molecules actually wind around globules of protein to form structures called chromatids. As the structures coil even more and thicken, they become the stars of the show, chromosomes. (And when a chromosome duplicates itself prior to division, the chromosome and its copy are called sister chromatids.)

You need to know about two other nucleic structures to understand the basics of cell division:

- The *nucleus* is the site of *ribosome* manufacture. Ribosomes are little duplexes made up of protein and ribonucleic subunits. The ribosomes are where amino acids are assembled into proteins.

- Nucleoplasm is another component of the nucleus. This appetizing mixture of water and the molecules is used in the construction of ribosomes, nucleic acids, and other nuclear material.

Cell Division

Cell division is the process by which new cells are formed to replace dead ones, repair damaged tissue, or allow organisms to grow. During cell division, two events occur that together replicate the old cell and pass on critical genetic information. These two events are *mitosis* and *cytokinesis*. Together, these events form the cell cycle. But first, the various nucleic structures vital to life and the continuation of life must form, grow in volume and get organized so that they can pack up and move into their new homes.

Control of cell division is a complex process. The size of the cell, availability of nutrients, attachment to a neighboring cell or membrane and the cell membrane receptors binding to growth factors (specific proteins found in body fluids) are all factors that regulate cell division.

All eukaryotic cells go through a basic life cycle, which, once begun, is continuous (and it is a good thing, or that cut or broken bone would never heal). Interphase, the stage between actual cell division, makes up the first three of four stages of the cell cycle, including the first gap phase (G_1), the synthesis state (S), and the second gap phase (G_2- see section on interphase).

Finally *mitosis* – the equal distribution of genetic information from a parent cell to two daughter cells' nuclei – occurs. This fourth part of the cell cycle is not part of interphase. Mitosis is followed by cytokinesis: a division of the cell's *cytoplasm*. Remember -cytoplasm is the fluid material cushioning the cell's nucleus and containing nutrients used to perform these cellular processes. Mitosis and cytokinesis usually happen in sequence.

Interphase

Division of genetic material would be impossible unless cell structures were created and organized for orderly cell division. This happen during interphase, which – as you might guess from its name – is the collection of processes that actually takes place between occurrences of cell division. The cell is not dividing during this, but instead, getting its house in order by engaging in the metabolic functions that make it unique. The nuclear membrane is intact, and individual chromosomes are not apparent during this period.

You might say that interphase is the time that the cell asserts its individuality. Activities such as nerve-cell transmission or glandular-cell secretion are the kinds of activities that take place during interphase. (*Note:* the existence of the 3 phases of interphase was discovered using radioactive thymidine.)The phases that together form interphase are as follows:

G_1 Phase (first gap): First during this stage, the cell grows in volume as it produces various cell components including tRNA, mRNA, ribosomes, and enzymes. This is typically the longest phase of the cell cycle. Some cells never leave it; they are said to be terminally differentiated. This phase immediately follows an occurrence of mitosis. It's when the cell is making the proteins and enzymes it needs to perform its unique functions. For example, a pancreas cell might be producing insulin for secretion, or a muscle cell might be learning how to contract so that movement can occur. Think of this phase as the cell's infancy and toddler period. Imagine a newborn's body building the bones and muscles necessary for mobility, unit one day the baby is actually able to get up and walk.

Note that during this initial portion of interphase, each chromosome is made up of just a single double-stranded piece of DNA and its associated protein. Also the cell's ability to switch from G_1 to S depends on its obtaining enough nutrients and the right combination of growth factors. These conditions control the cell's buildup of a very crucial protein, cyclin. Cyclin will combine with the enzyme cyclin-dependent kinase which regulates switching from G_1 and S and G_2 to mitosis. Later, the cell produces a different form of cyclin. Active cylcin-dependent kinase containing this molecule phosphorylates protein that switch the cell from G_2 to M and activate enzumes that destroy cyclin and deactivating the kinase complex itself, turning mitosis off.

S Phase: <u>This is when replication of chromosomes occurs</u>. During S phase, the cell puts the pedal to the metal for that key process – replication of DNA to prepare for distribution of genes to daughter cells. It is during this phase that the DNA within the cell nucleus replicates (copies exactly). Then the process is complete and there are 92 *chromatids (held together by centromeres*) arranged as twin threads, 2 per chromosome, in most human cells, where once there were just 46 chromosomes. Each of these chromatids becomes a new chromosome – identical to its parent – and each contains its own set of genes, which is different from the sets on other chromosomes. Histone proteins are also made during this period and cell centers and centrioles double. (Each chromosome has thousands of different genes, so all the genetic messages that make an organism unique are clear. You wouldn't want the message that gives you blue eyes to mix the one that creates your red hair.)

This replication process is how the parent cell ensures equal gene distribution between the 2 daughter cells.

G_2 Phase (second gap): During this phase, the cell is packing its bags and getting ready to hit the road for mitosis by synthesizing the spindle-fiber proteins needed to aid in the movement of chromosomes. Now the cell is all packed up and ready to hand off equal amounts of genetic material to its offspring. But there has to be a way to move the chromosomes from mother to daughters and then position them correctly in the new cells. So, in the organelles outside the nucleus, the cell organizes proteins into a series of fibers or microtubules, which – in the first phase of mitosis – form *spindles*. Think of these spindles as teeny people movers. In the next phase of the process, the spindles are arranged from pole to pole of the cell, helping to move chromosomes into place. Following the entire mitosis process – poof – the spindles will simply disappear.

Remember in this phase as the cell enters into mitosis each chromosome, which consists of 2 chromatids held together by the centromere, will condense and contains the diploid number of chromosomes.

Mitosis

After interphase is over, the cell has done all the growing and replicating it is going to do, and now it is time to prepare to vacate its cramped quarters and move its genetic riches into two daughter cells.

During mitosis, the cell is making final preparations for the impending split (division of nucleus and cytoplasm). Processes during mitosis ensure that genetic material is distributed equally. These processes take place in four stages. Remember, the cell cycle is a continuous process, with one stage flowing into another virtually seamlessly. But biologists have divided mitosis into the following stages to aid in their study.

- Prophase
- Metaphase
- Anaphase
- Telophase

Prophase

It is during this first stage of mitosis that the chromosomes become visible (not to the naked eye). Soon the thin, tangled threads of the chromatids coil and thicken to become chromosomes. Remember, each of these chromosomes carries identical genes on to their new residences.

At the same time the chromosomes are fattening up, the spindle fibers formed in interphase are doing what all good spindle fibers do – turning into actual spindles to help move the mobility challenged chromosomes to their final destinations. (The microtubules of the spindle fibers are formed from tubulin dimmers released by the disassembling of the cytoskeleton.) By this time, the centrioles (they are hanging on to the spindle fibers) have duplicated and moved to the poles of the cell, throwing off spindles like clotheslines running from one end of the cell to the other.

The other important event occurring is the disintegration of the nuclear membrane, giving the chromosomes free rein over the entire cell. (They are free to go anywhere they want, as long as they end up lined up exactly along the equatorial plane by the middle of the next stage.)

(*Prometaphase*: characterized by the disappearance of the nuclear envelope and the chromosomes kinetochores capture growing spindle fibers. Kinetochore fibers are spindle fibers which are attached to the kinetochore of the centriole)

Metaphase

By metaphase, the nucleus of the cell has completely disappeared, making it possible for the chromosomes to get to their pre-assigned positions. (There is no free reign here.)At first, they attach themselves at their beltlines to any old spindle around. But, pretty soon they move toward the center of the cell, until they form a perfect row along the equatorial plane. At this stage, there are still 46 of these guys and a total of 92 chromatids.

Anaphase

Now the chromatids part company, almost ready to start life on their own. But they are not ready to go too far – yet. This phase begins abruptly with the release of calcium ions into the cytoplasm. The chromosomes separate at their centers, and the chromatids move along their little spindle/people movers to the opposite poles. This event is sort of the "coming out" party for a chromosome. After this separation and movement, they are called daughter chromosomes. But they are not quite ready to move out– just yet.

Telophase

In this phase chromatin decondenses, each identical set of chromosomes gets its own nuclear membrane and set of nuclear bodies (nucleoli) and the division of cytoplasm occurs. Those microtubules that made up the spindles dissolve, meaning that the spindles disappear - just as if someone pulled in the clotheslines. Now <u>two identical daughter cells identical to the parent cell nucleus</u> are ready to move into their own digs.

Remember: mitosis occurs in diploid (pair of homologous chromosomes – 2 sets of chromosomes - in humans 46 or 23 pairs), haploid (one set of unpaired chromosomes – conatins ½ the diploid chromosome number) and tetraploid (typically in plants - four homologous chromosomes of each type) cells. The haploid number of chromosomes in a species is generally designated as N. (N=23 in humans, and 2N (diploid=46).

Cytokinesis

The last order of business is to give the new daughter nuclei suitable homes through ha process called *cytokinesis*.

In animals cells, the process begins with a mere indentation or furrow in the center of the cell. The furrow squeezes the cell membrane into the cytoplasm until two separate cells are formed. (imagine squeezing a ball of silly putty at the center until it becomes two balls of silly putty and you have got the idea.) This process is referred to as *cell cleavage*.

In plant cells, the process is slightly different because a rigid cell wall is involved, preventing the "silly putty" process of cell cleavage. Instead, a new cell wall forms at the center of the cell, with vesicles (small bags of necessary intercellular material) that join to form a double membrane called the cell plate. The plate eventually moves outward to marry the cell membrane. The cell plate then separates the two cells, and they move apart to become two new daughter cells.

Once cytokinesis is complete, the new cells move immediately into the G_1 stage of interphase. In complex organism, mitosis is the root of renewal and regeneration; it's used to heal wounds and regenerate parts of the body. In simple organism – fungus for example – it is the means of reproduction.

(In plant cells, cytokinesis occurs by the formation of the cell plate.)

Meiosis

Most human cells have 46 chromosomes for a reason, whereas sex cells have half that number – 23. Here's why: The most successful plants and animals have developed a method of shuffling and exchanging genetic information, constantly developing new combinations designed to function better in a changing environment. The process usually involves organisms that have two sets of genetic data, one from each parent.

Through sexual reproduction, a new individual is formed through the union of games (sex cells). But before the union of gametes can happen, the two sets of genetic information present in most cells must be reduced to one. Without this process, the zygote – the cell resulting from the union of two sex cells – would have four sets of chromosomes. Then the next generation, it would have eight, then 16 then 32 – well you get it – it would be a real mess. The resulting organisms would be unable to decode the genetic information, and the final result would be death.

So gametes (cells specialized for sexual reproduction in plants and animals - in animals, eggs in females and sperm in males) have what is known as the *haploid* number of chromosomes. The word comes from the Greek haplos, meaning single. So each gamete contains a single set of chromosomes – 23. When the two gametes unite, they combine their chromosomes (pairs) to reach the full complement of 46 in a normal diploid cell. Logically enough, diploid comes from the Greek diplos, meaning double.