Cell cycle and Chromosomes

All cells are produced by divisions of pre-existing cells, growth and development of any organism depend in large part on multiplication, enlargement and differentiation of its cells beginning with the zygote.

Cell cycle

The cell cycle is the life history of a cell ,each cell capable of division passes through a cycle called interphase cycle or cell cycle which can be defined as a sequence of events happening from the one nuclear division to the beginning of the next.

The total time of the cell cycle in the animal cells varies with the species, maturation , tissue and many physical conditions like temperature, and the type of the cell. The cell cycle divided into 4 stages, G1,S and G2 phases forming the interphase and M phase forming the mitotic phase :-

1- G1 phase

Is the first gap or growth stage of the interphase begins immediately following the cell division, many events happen in this phase ;

* the nucleus and cytoplasm are enlarging, chromatin is fully extended not recognized as chromosomes under light microscope

* this time is considered the time of the active synthesis of RNA and protein and reactive all the metabolic pathways that slowed during the cell division.

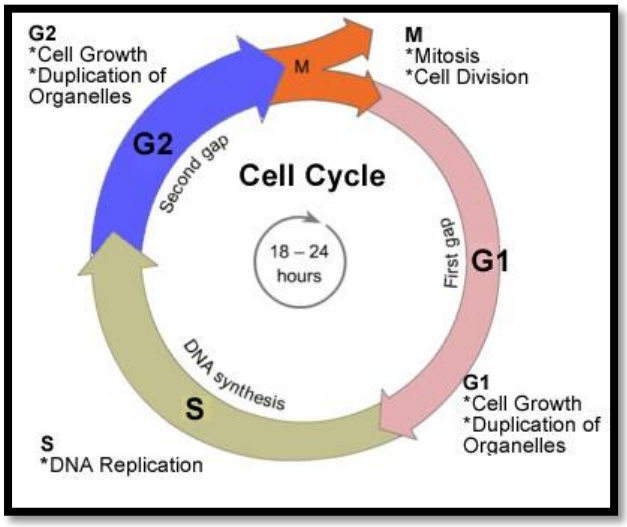
G1 is very variable in its duration; it may occupy 30-50% of the total time of the cell cycle or may lacking in rapidly dividing cells (e.g. those of early mammalian cells) because the rapid cell division just after fertilization, while the differentiated somatic cells that no longer divide (e.g. neurons) are arrested in the G1 stage which often referred to as G0 phase, type of these cells called postmitotic cells during

2- S phase

Called the synthetic phase, the events that happen; replication of DNA and synthesis of histones occur. DNA molecule of each chromosome becomes doubled in its amount, so that each chromosome will carry double set of the genes or two DNA molecules , at the end of this phase each chromosome is composed of two sister chromatids sharing one centromere, thus te cell retains the original diploid (2n) chromosome number but now has duplicate set of genes. Cells in early eukaryotic embryonic cells are completely locate in S phase because the short generation time have, and these cells have no G1 and G2 like the prokaryotic cells, this means that total genome DNA is replicated 100 times faster in early embryos than in late embryos or in adults tissues.

3- G2 phase

This is the second gap, or called the growth phase two, represent the less time of the cell cycle, new DNA is rapidly complexes with chromosomal proteins and synthesis of RNA and proteins continues, it may occupy 10-20% time of the cell cycle. At the end of this stage, the cell now is ready to inter the mitotic division or M phase.



The cell cycle in mature cell

Regulation of cell cycle

1- Regulation of the Cell Cycle by External Events

External factors can influence the cell cycle by inhibiting or initiating cell division. Unlike the life of organisms, which is a straight progression from birth to death, the life of a cell takes place in a cyclical pattern. Each cell is produced as part of its parent cell. When a daughter cell divides, it turns into two new cells, which would lead to the assumption that each cell is capable of being immortal as long as its descendants can continue to divide. However, all cells in the body only live as long as the organism lives. Some cells do live longer than others, but eventually all cells die when their vital functions cease. Most cells in the body exist in the state of interphase, the non-dividing stage of the cell life cycle. When this stage ends, cells move into the dividing part of their lives called mitosis.

Both the initiation and inhibition of cell division are triggered by events external to the cell when it is about to begin the replication process. An event may be as simple as the death of a nearby cell or as sweeping as the release of growth-promoting hormones, such as human growth hormone (HGH). A lack of HGH can inhibit cell division, resulting in dwarfism, whereas too much HGH can result in gigantism. Crowding of cells can also inhibit cell division. Another factor that can initiate cell division is the size of the cell; as a cell grows, it becomes inefficient due to its decreasing surface-to-volume ratio. The solution to this problem is to divide.

We can summarize the external events that can affect cell cycle regulation:

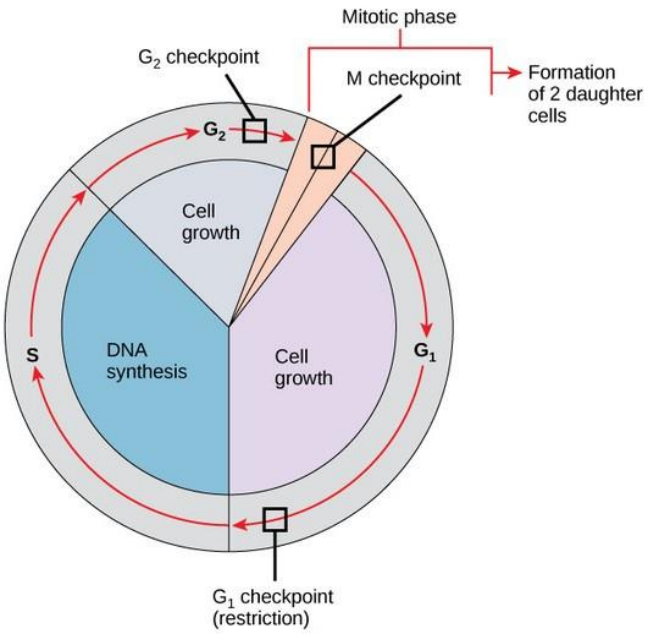
- The death of nearby cells and the presence or absence of certain hormones can impact the cell cycle.
- The release of growth-promoting hormones, such as HGH, can initiate cell division, and a lack of these hormones can inhibit cell division.

- Cell growth initiates cell division because cells must divide as the surface-to-volume ratio decreases; cell crowding inhibits cell division.
- Key conditions must be met before the cell can move into interphase.

2- Regulation of the Cell Cycle at Internal Checkpoints

The cell cycle is controlled by three internal checkpoints that evaluate the condition of the genetic information.

- Damage to DNA and other external factors are evaluated at the G1 checkpoint; called restriction point if conditions are inadequate, the cell will not be allowed to continue to the S phase of interphase.
- The G2 checkpoint ensures all of the chromosomes have been replicated and that the replicated DNA without mistakes or damage before cell enters mitosis.
- The M checkpoint occurs near the end of the metaphase stage of mitosis The M checkpoint is also known as the spindle checkpoint because it determines whether all the sister chromatids are correctly attached to the spindle microtubules before the cell enters the irreversible anaphase stage.



Internal Checkpoints during the Cell Cycle

Role of chromosomes in cell division

The prokaryotic genome typically exists in the form of a circular chromosome located in the cytoplasm. In eukaryotes, however, genetic material is housed in the nucleus and tightly packaged into linear chromosomes. Chromosomes are made up of a DNA-protein complex called chromatin that is organized into subunits called nucleosomes. The way in which eukaryotes compact and arrange their chromatin not only allows a large amount of DNA to fit in a small space, but it also helps regulate gene expression. Cells package their DNA not only to protect it, but also to regulate which genes are accessed and when. Cellular genes are therefore similar to valuable files stored in a file cabinet — but in this case, the cabinet's drawers are constantly opening and closing; various files are continually being located, pulled, and copied; and the original files are always returned to the correct location. Of course, just as file drawers help conserve space in an office, DNA packaging helps conserve space in cells. Packaging is the reason why the approximately two meters of human DNA can fit into a cell that is only a few micrometers wide. But how, exactly, is DNA compacted to fit within eukaryotic and prokaryotic cells? And what mechanisms do cells use to access this highly compacted genetic material? Cellular DNA is never bare and unaccompanied by other proteins. Rather, it always forms a complex with various protein partners that help package it into such a tiny space. This DNA-protein complex is called **chromatin,** where in the mass of protein and nucleic acid is nearly equal. Within cells, chromatin usually folds into characteristic formations called **chromosomes**. Each chromosome contains a single double-stranded piece of DNA along with the aforementioned packaging proteins. Eukaryotes typically possess multiple pairs of linear chromosomes, all of which are contained in the cellular

nucleus, and these chromosomes have characteristic and changeable forms. During cell division, for example, they become more tightly packed, and their condensed form can be visualized with a light microscope. This condensed form is approximately 10,000 times shorter than the linear DNA strand would be if it was devoid of proteins and pulled taut. However, when eukaryotic cells are not dividing — a stage called **interphase** — the chromatin within their chromosomes is less tightly packed. This looser configuration is important because it permits transcription to take place.

In contrast to eukaryotes, the DNA in prokaryotic cells is generally present in a single circular chromosome that is located in the cytoplasm. (Recall that prokaryotic cells do not possess a nucleus.) Prokaryotic chromosomes are less condensed than their eukaryotic counterparts and don't have easily identified features when viewed under a light microscope.

Chromosomes are the thread-like structure found in the nuclei of both animal and plant cells. They are made of protein and one molecule of deoxyribonucleic acid (DNA). In most organisms, one chromosome is inherited from the mother and the other is inherited from the father; to ensure that offspring carry traits from both parents. It's crucial that certain cells, like reproductive cells, have the correct number of chromosomes in order to function properly. Organisms grow by undergoing cell division to produce new cells and replace older The fundamental importance of chromosomes is that they contain DNA, It is important that chromosomes replicate properly so that each resulting cell has the correct amount of DNA after division, All human cells except for egg cells and sperm cells have 46 chromosomes, the *diploid* human number. Gametes (sex cells) have 23 chromosomes, the *haploid* human number; everyone is the product of the fusion of an egg cell and a sperm cell, and when these combine, the result is the normal amount of

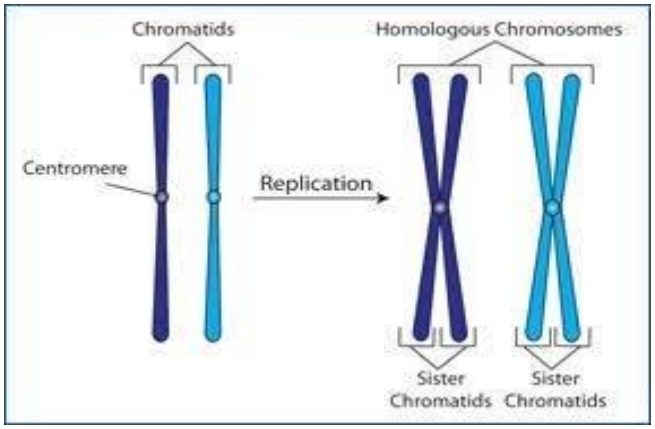
chromosomes, 46 paternal and maternal chromosomes are known as *homologous chromosomes*

Types of chromosomes

The term chromosome comes from the Greek words for color (chroma) and body (soma). Scientists gave this name to chromosomes because they are cell structures, or bodies, that are strongly stained by some colorful dyes used in research. Chromosomes are thread-like structures located inside the nucleus of animal and plant cells. Each chromosome is made of protein and a single molecule of deoxyribonucleic acid (DNA). Passed from parents to offspring, DNA contains the specific instructions that make each type of living creature unique.

Structure of chromosome

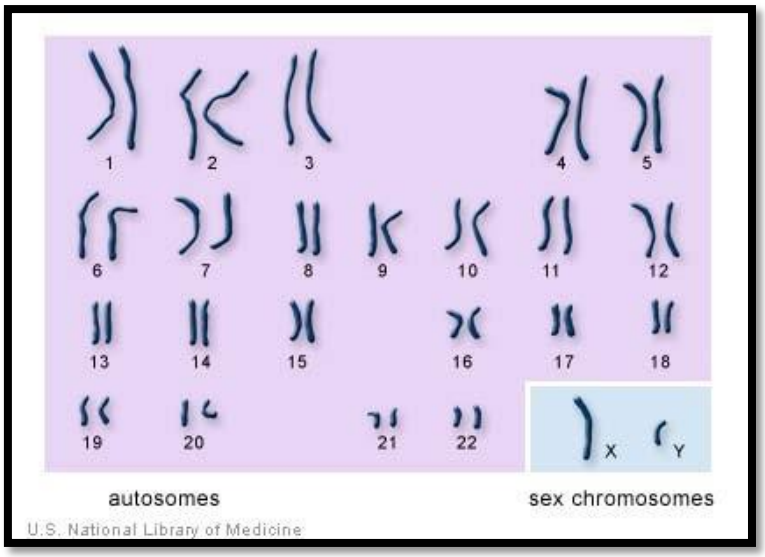
- In eukaryotic cells, chromosomes are composed of single molecule of DNA with many copies of five types of histones.
- Histones are proteins molecules and are rich in lysine and arginine residues, they are positively charged.
- During most of the cell's life cycle, chromosomes are elongated and cannot be observed under the microscope.
- During the S phase of the mitotic cell cycle the chromosomes are duplicated.
- At the beginning of mitosis the chromosomes are duplicated and they begin to condense into short structures which can be stained and observed easily under the light microscope.
- The attached, duplicated chromosomes are commonly called sister chromatids.
- The duplicated chromosomes are held together at the region of centromers.



Like all other eukaryotes, humans contain a fixed number of chromosomes within each of the nuclei in all their cells. There are essentially two types of chromosomes as characterized by karyotyping at the metaphase of cell division. These include:

Autosomes - There are 22 pairs of autosomes in humans.

Gonosomes or sex chromosomes - Humans contain two types of sex chromosomes including X and Y. While males have an X and a Y chromosome, females possess two X chromosomes.



Karyotype of the human genome

Each human cell thus contains 46 chromosomes in 23 pairs. The gametes or ovum produced by the female ovaries and the sperm produced by the male testicles, however, contain only 23 chromosomes. This ensures that when the egg and the sperm get fertilized to form a baby, it contains 23 pairs and restores the total chromosomal count to 46.

Males typically have two different kinds of **sex chromosomes** (XY), and are called the heterogametic **sex**. In humans, the presence of the Y **chromosome** is responsible for triggering male development; in the absence of the Y **chromosome**, the **fetus** will undergo female development. human fetus does not develop its external sexual organs until seven weeks after fertilization. The fetus appears to be sexually indifferent, looking neither like a male or a female. Over the next five weeks, the fetus begins producing hormones that cause its **sex** organs to grow into either male or female organs so, Men **determine** the sex of a baby depending on **whether** their sperm is carrying an X or Y chromosome. An X chromosome combines with the mother's X chromosome to make a baby **girl** (XX) and a Y chromosome will combine with the mother's to make a **boy** (XY).