CELL GROWTH

Living things in most cases grow by producing more cells. There are two main reasons why living things grow:

a) The larger a cell gets, the more demands it places on its DNA.
b) As a cell gets bigger, it has more work moving enough nutrients (food) and wastes across its cell membrane.

The rates at which materials move through the cell membrane depend on the cell's surface area and the total area of its cell membrane. However, the rate at which food and oxygen are used up and formation of waste products depends on the cell's volume. As a cell grows, its internal volume increases faster than its surface area. That is, as a cell becomes bigger, its ratio of surface area to volume decreases. Before a cell gets too large, it divides, forming two "daughter" cells. Cell division is the process by which a cell divides into two new daughter cells.

Cellular Differentiation

A typical example of cellular differentiation is the development of a mammal (Fig. 1) below. The fertilized egg (zygote) differentiates into the blastocyst (early embryo) and this differentiates to the gastrula (late embryo). Later ectoderm, germ cells, mesoderm and endoderm all develop, form different cell types. Each type then differentiates into specialised cell, divides and form tissues. In developmental biology, cellular differentiation is the process by which a less specialised cell becomes a more specialised cell type. Differentiation occurs numerous times during the development of a multicellular organism as the organism changes from a single zygote to a complex system of tissues and cell types (Fig. 1). Differentiation is a common process in adults as well: adult stem cells divide and create fully-differentiated daughter cells during tissue repair and during normal cell turnover. Differentiation dramatically changes a cell's size, shape, membrane potential, metabolic activity, and responsiveness to signals. These changes are largely due to highly-controlled modifications in gene expression. With a few exceptions, cellular differentiation almost never involves a change in the DNA sequence itself. Thus, different cells can have very different physical characteristics despite having the same genome.

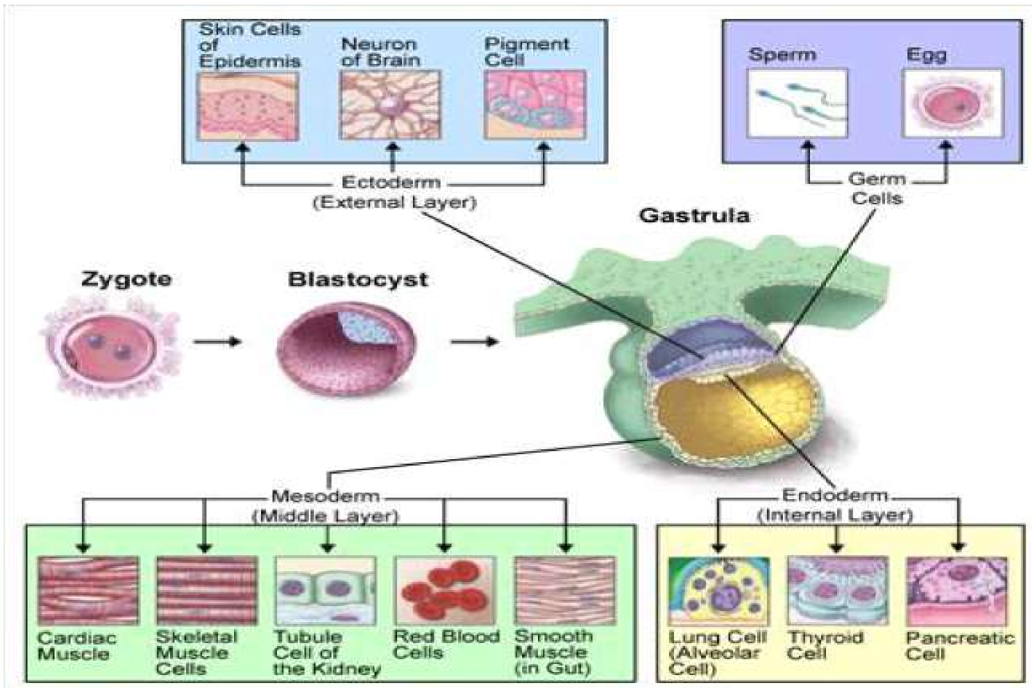

Figure 1: Cellular Differentiation

The center of the diagram shows the early steps in the development of a mammal. On the top and bottom are some of the fully-differentiated cell types that will eventually form in the adult.

Cell Turnover: In higher vertebrates (birds and mammals), adult body size is relatively constant as compared with its size of organs. Nevertheless, in many tissues, cell birth continues throughout their life - thus, for body and organ size to remain stable, cells must also die. Cell number is therefore proportional to the rate of cell proliferation and the rate of cell death.

Renewing Cells: Mitosis is the process that brings about the renewing of cells. In most adult tissues, cell turnover continues throughout the animal's lifespan. In some tissues, cell turnover is very slow, and cell proliferation occurs primarily after injury - e.g., liver, blood vessels. In some adult tissues, cell turnover is rapid and occurs via the stem cells e.g. skin epidermis.

Cell Number: In higher vertebrates cell birth continues throughout the life of an organism. However, if the body and organ size of the organism is to remain stable, cells must also die. Cell number is therefore proportional to the rate of cell proliferation and the rate of cell death. The processes of cell birth and cell death are termed cell turnover.

Cell Populations: Cell populations go through a type of exponential growth called doubling. Thus, each generation of cells should be twice as numerous as the previous generation. However, the number of generations only gives a maximum figure as not all cells survive in each generation. Cell divisions bring about population of cells. For example, during mitosis, a parent cell divides to give two daughter cells.

Types of Cell Division

For most of the constituents of the cell, growth is a steady, continuous process, interrupted only briefly at M phase when the nucleus and the cell divides to two. The process of cell division (e.g. mitosis), called cell cycle, has four major parts called phases. The first part, called G1 phase is marked by synthesis of various enzymes that are required for DNA replication. The second stage of the cell cycle is the S phase, where DNA replication produces two identical sets of chromosomes. The third part is the G2 phase where significant protein synthesis occurs. During this phase, it involves the production of microtubules, which are required during the process of division, called mitosis. The fourth stage, M phase, consists of nuclear division (karyokinesis) and cytoplasmic division (cytokinesis), accompanied by the formation of a new cell membrane. This is the physical division of "mother" and "daughter" cells. The M phase has been broken down into several distinct subphases, sequentially known as prophase, prometaphase, metaphase, anaphase and telophase leading to cytokinesis

Cell division is more complex in eukaryotes than in other organisms. Prokaryotic cells such as bacterial cells reproduce by binary fission, a process that includes DNA replication, chromosome segregation, and cytokinesis. Eukaryotic cell division either involves mitosis or a more complex process called meiosis. Mitosis and meiosis are sometimes called the two "nuclear division" processes. Binary fission is similar to eukaryotic cell division that involves mitosis. Both lead to the production of two daughter cells with the same number of chromosomes as the parental cell. Meiosis (a reduction division) is used for a special cell production process of diploid organisms. It produces four special daughter cells (gametes) each having half the normal cellular amount of DNA. A male and a female gamete can then combine to produce a fertilized cell now having normal amount of chromosomes.

A cell must copy its genetic information before cell division begins. Each daughter cell then gets a complete copy of that information after cell division. In most prokaryotes, the cell division is a simple matter of separating the contents of the cell into two parts. In eukaryotes, cell division occurs in two main stages, mitosis and cytokinesis. Mitosis is the division of the nucleus. Cytokinesis is the division of the cytoplasm. The cell cycle is a series of events cells go through as they grow and divide. During the cell cycle, a cell grows, prepares for division, and divides to form two daughter cells.

Comparison of the Three Types of Cell Division

The DNA content of a cell is duplicated at the start of the cell division process. Before DNA replication occurs, the DNA content of a cell can be represented as the amount **X** (the cell has **X** ribosomes). After the DNA replication process, the amount of DNA in the cell is 2**X** (multiplication: 2 x **X** = 2**X**). During binary fission and mitosis the duplicated DNA content of the reproducing parental cell is separated into two equal halves that are destined to end up in the two daughter cells. The final part of the cell duplication process is cell division, when daughter cells physically split from a parental cell. During meiosis, there are two cell division steps that together produce the four daughter cells. Meiosis is a cell division longer than either mitosis or binary fission. It is a deduction cell division in reproductive cells.

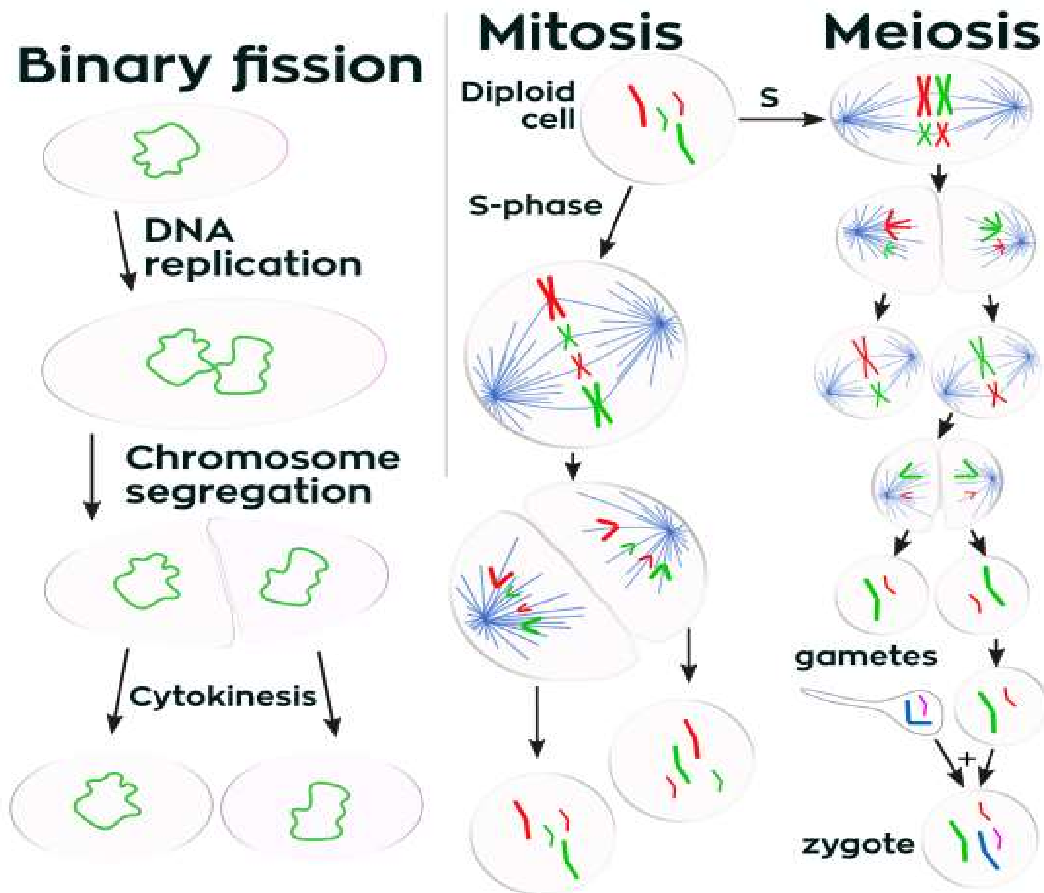

Figure 1: Various Types of Cell Division

After the completion of binary fission or cell reproduction involving mitosis, each daughter cell has the same amount of DNA (**X**) as what the parental cell had before it replicated its DNA. These two types of cell division produce two daughter cells that have the same number of chromosomes as the parental cell. After meiotic cell division four daughter cells are produced that have half the number of chromosomes that the parent cell originally had. This is often symbolised as N the haploid amount of DNA. Meiosis occurs in diploid organisms to produce haploid gametes. In a diploid organism such as the human organism, most cells of the body have the diploid amount of DNA, 2N. Using this notation for counting chromosomes we say that human somatic cells have 46 chromosomes (2N = 46) while human sperm and egg each has 23 chromosomes (N = 23). Humans have 23 distinct types of chromosomes, the 22 autosomes and the special category of sex chromosomes. There are two distinct sex chromosomes, the X chromosome and the Y chromosome. A diploid human cell of an individual human being has 46 chromosomes inherited from that person's father and the mother. That is, your body has two copies of human chromosome number 2, one from each of your parents.

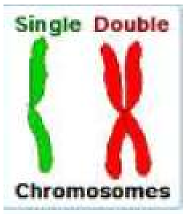

Figure 2: Chromosomes

During mitosis, immediately after DNA replication a human cell will have 46 "double chromosomes". In each double chromosome there are two copies of that chromosome's DNA molecule. During mitosis the double chromosomes are split to produce 92 "single chromosomes", half of which go into each daughter cell. During meiosis, the 46 chromosomes are reduced to half, 23 there are two chromosome separation steps which assure that each of the four daughter cells gets one copy of each of the 23 chromosomes.

Sexual Reproduction: In eukaryotes, e.g. in humans, meiosis occurs in sex organs (testes and ovaries) to produce gametes (sperm and egg cell). During sexual reproduction to produce a new human being (foetus), meiosis brings about genetic recombination events between sets of chromosomes. During this period, new combinations of genes in the chromosomes occur. In organisms with more than one set of chromosomes (humans) random mating produces homozygotes and heterozygotes.

Regulating the Cell Cycle

Normal cells divide and reproduce when the need arises. In a multicellular organism, cell growth and cell division are carefully controlled by certain factors. For instance, when an injury such as a cut in the skin occurs, cells at the edge of the cut divide rapidly. When the healing process is nearly complete, the rate of cell division slows down and then returns to normal.

Cause of Cells Division

Cells in a multicellular organism have different sizes, rates of growth and timing of cell division. Cells in a multicellular organisms divide to replace lost or damage cells and allow the organism to grow. Unicellular organisms divide to reproduce. Cells must divide for two main reasons:

a) Not enough DNA to provide the information a cell needs to survive
b) The surface area of a cell does not increase as fast as the volume of the cell.

Cellular Growth Disorders

A series of growth disorders can occur at the cellular level. A normal cell can become a cancer cell. Cancer is a disorder in which some of the body's cells lose the ability to control growth. Cancer cells do not respond to the signals that control the growth of normal cells. As a result, cancer cells divide uncontrollably. They form masses of cells called tumors, which can damage surrounding tissues. Cancer cells do not stop growing when they touch other cells. Instead, they continue to grow and divide until their supply of nutrients is used up. Cancer cells may break loose from tumors and spread throughout the body. Cancer cells can invade other cells (invasion) and spread to other locations of the body, a process that is called metastasis.