Cell Division

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Cell division is fundamental to all living organisms and required for growth and development. As an essential means of reproduction for all living things, cell division allows organisms to transfer their genetic material to their offspring. For a unicellular organism, cellular division generates a completely new organism. For multicellular organisms, cellular division produces new cells for the general development of the organism, as well as produces healthy cells to replace damaged cells from injury. Reproduction of multicellular organisms requires cell division to create reproductive cells. In order to divide, a cell first needs to duplicate and divide its genetic content into two daughter cells. This series of duplication and division is called the cell cycle. The details of the cell cycle vary from one organism to the next, but fundamental stages of cell division are universal. Cell cycle About 78% of a cell's life is spent in Interphase, growing and preparing itself for cell division. Interphase itself contains three subphases. Immediately after cell division, a newly-formed cell enters the Gap 1 or G1 portion of Interphase. During G1, cells actively grow and, in many cases, differentiate to perform specific functions. At this stage, the cell is sensitive to internal and external signals to determine whether to divide or not. Some cells, such as neurons do not proceed to cell division after differentiation and remain in G1 until they die. Once the cell meets criteria to proceed to cell division, it enters the synthesis or S stage of Interphase, during which the cell replicates its entire genome. Next, the cell enters the Gap 2 or G2 phase to synthesize all the necessary proteins for cell division. This is followed by the cell division phase. Types of Cell Division in Eukaryotes There are two types of cell division in eukaryotic cells-mitosis and meiosis. Somatic or non-reproductive cells produce daughter cells via mitotic division. Mitosis is the nuclear division and consists of five stages: prophase, prometaphase, metaphase, anaphase, and telophase During prophase, duplicated DNA molecules condense into tightly-packed chromosomes, while microtubules form spindles. The nuclear envelope dissolves in prometaphase. During metaphase, chromosomes that are connected to spindles line up along the equator of the cells. During anaphase, sister chromatids are pulled to opposite poles of the cell. Finally, during telophase, new nuclear envelopes are formed around both groups of chromosomes. After nuclear division is completed, cytoplasm around each nucleus separates from one another via cytokinesis, resulting in two identical daughter cells. The other type of eukaryotic cell division is called meiosis, which is specific to reproductive cells. Meiosis produces four daughter cells each with only half the genetic content of the parent cell. In this process the cell duplicates its DNA during Interphase and then completes two successive cell divisions splitting cells from two into four cells, respectively. These successive cell divisions are called meiosis I and meiosis II, both of which consist of all the stages from prophase to telophase. Exchange of genetic material between the sets of non-sister chromatids happens during prophase I in a process called crossing over. Homologous chromosome pairs are aligned along the equator of the cell during metaphase I and pulled away from each other during anaphase I. Haploid daughter nuclei are formed during telophase I. Cytokinesis commonly occurs before meiosis II, however, interphase almost never happens between the two successive divisions. Meiosis II is very similar to mitosis and separates sister chromatids. At the end of meiosis, four haploid daughter cells are formed. These cells daughter cells are called gametes and

form the sperm or egg cells. Regulation of Cell Division Cell division is tightly regulated externally and internally. External regulation assures the necessity of the division. For example, cells of the stomach lining divide frequently to meet the ongoing need for new cells to replace damaged cells. Similarly, injured tissues may experience higher rates of cell division to replace damaged cells but only for a certain period of time as long as the external signals to direct cell division are present. Internal regulation of cell division ensures the health of daughter cells. There are many checkpoints within phases of the cell cycle that regulate the transition of the cell from one phase to the next. For instance, quality control mechanisms let the cell proceed from G1 to S phase only if the DNA is intact and suitable for replication. Similarly, a checkpoint at G2 allows cells to proceed to mitosis (M phase) only if the DNA has been completely and accurately replicated. Also, a metaphase checkpoint assures that the chromosomes are attached to the spindles and aligned correctly before anaphase can start. A cell that fails at a checkpoint may be targeted for apoptosis if the cell is unable to correct the mistake. Some mutations allow cells to divide even when there is no signal directing cell division. For example, tumor-suppressor genes prevent cells from uncontrolled division and mutation in these genes relieves this inhibition. This aberrant cell division, if left unchecked, can cause tumor formation and in some cases lead to cancer. As one of the leading causes of death in the United States, cancer no doubt has a major impact on society. The lifetime risk of cancer increases with age as mutations in DNA accumulate over time, especially for breast, lung, prostate, and colon cancers1. Thus, ongoing research on cell division is essential for improving cancer detection, treatment, and eventually for prevention. In fact, current therapies to treat cancer take advantage of the knowledge of cell division mechanisms, such as targeting mechanisms involved in cell division. For example, platinum-drugs such as cisplatin bind to DNA and arrest DNA replication, while taxanes such as paclitaxel bind to microtubules and inhibit spindle disassembly thus arresting cell division2. An understanding of cell cycle and cell division mechanisms is also important to understand and develop treatments for conditions that affect nondividing cells. Currently, injuries to the nervous system or the heart can have debilitating effects since damaged neuron and muscle cells cannot be replaced. However, injury to the nervous tissue is associated with activation of cell cycle pathways in neurons and supporting glial cells. Interestingly, inhibition of these cell cycle pathways reduces the glial scar formation and secondary damage after injury. Therefore, understanding the regulation of cell cycle and cell division is imperative to understand the healthy and diseased conditions of all organ systems3. References Kennedy, BJ. Aging and Cancer. Oncology. 2000, Vol. 14, 12 (1731-40). Mahotra, V and Perry, MC. Classical Chemotherapy: Mechanisms, Toxicities and the Therapeutc Window. Cancer Biology & Therapy . 2003, Vol. 2, 1 (1-3). Byrnes, KR, et al. Cell cycle activation contributes to post-mitotic cell death and secondary damage after spinal cord injury. Brain. . 2007 , 130(Pt 11):2977-92

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