Check your knowledge

Which of the following is the correct order of events?

1. Chromosomes line up at the metaphase plate.
2. Cell division is completed when the cytoplasmic components are physically separated.
3. The kinetochore becomes attached to each chromosome.
4. The sister chromatids separate.
5. The nucleus re-forms.
6. The nuclear envelope starts to breakdown into small vesicles.

Answer: 6, 3, 1, 4, 5, 2

CONCEPTS IN ACTION- This page of movies illustrates different aspects of mitosis. Watch the movie entitled "DIC microscopy of cell division in a newt lung cell" and identify the phases of mitosis.

Length and Control of the Cell Cycle

The length of the cell cycle varies greatly depending on the organism. Even within a multicellular organism, not all cells will divide at the same rate. In humans, the frequency of cell division ranges from embryonic cells that divide in just a few hours to cells like the neurons of the brain that never divide. There is also variation in the time that a cell spends in each phase of the cell cycle. When fast-dividing mammalian cells are grown in culture, outside the body under optimal growing conditions, the length of the cycle is approximately 24 hours. The timing of events in the cell cycle is controlled by mechanisms that are both internal and external to the cell.

Regulation at Internal Checkpoints

Daughter cells must be exact copies of the parent cell. Mistakes in the duplication or distribution of the chromosomes lead to mutations that will then be passed on to every new cell produced. To prevent a compromised cell from continuing to divide, there are internal control mechanisms or **cell cycle checkpoints** at which the cell cycle can be stopped until conditions are favorable. There are three checkpoints where cell division can be stopped; they occur near the end of G_1, at the G_2–M transition, and during metaphase (Figure 8.14).

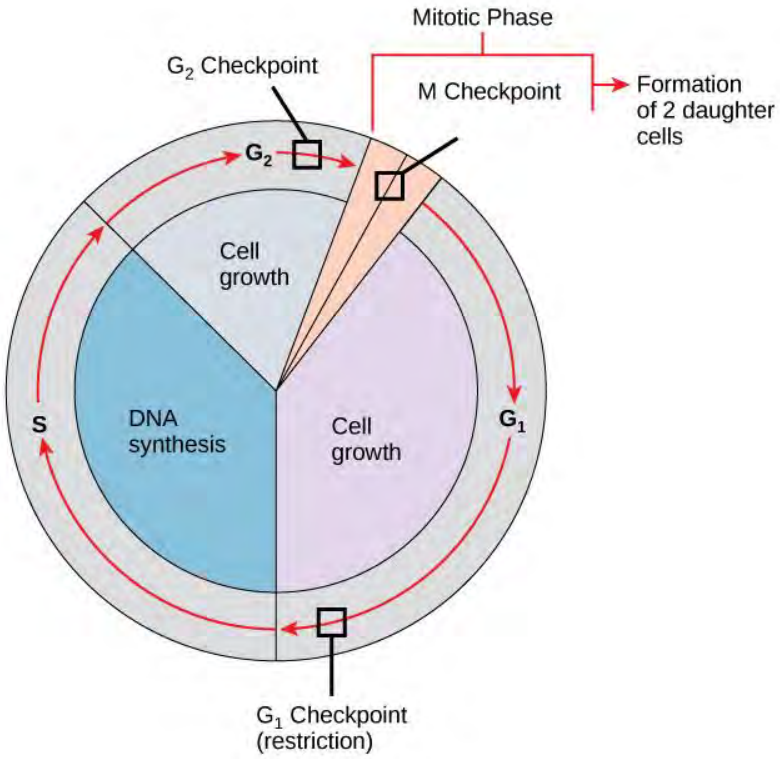

Figure 8.14 The cell cycle is controlled at three checkpoints. (credit: Fowler et al. / Concepts of Biology OpenStax)

The G_1 Checkpoint

The G_1 checkpoint determines whether all conditions are favorable for cell division to proceed. The G_1 checkpoint, also called the restriction point, is the point at which the cell irreversibly commits to the cell-division process. In addition to adequate protein reserves and cell size, there is a check for damage to the genomic DNA at the G_1 checkpoint. A cell that does not meet all the requirements will not enter the S phase.

The G_2 Checkpoint

The G_2 checkpoint prevents the cell from entering the mitotic phase if certain conditions are not met. As in the G_1 checkpoint, cell size and protein reserves are assessed. However, the most crucial role of the G_2 checkpoint is to ensure that all the chromosomes have been replicated and that the replicated DNA is not damaged.

The M Checkpoint

The M checkpoint occurs near the end of metaphase of mitosis. The M checkpoint is also known as the spindle checkpoint because it determines if all the sister chromatids are correctly attached to the microtubules that make up the mitotic spindle. Because the separation of the sister chromatids during anaphase is an irreversible step, the cycle will not proceed until each pair of sister chromatids is firmly anchored to spindle fibers arising from opposite poles of the cell.

CONCEPTS IN ACTION- Watch what occurs at the G_1, G_2, and M checkpoints by visiting this animation of the cell cycle.

CANCER CONNECTION: *The Implication of an Out of Control Cell Cycle*

Cancer is a collective name used to describe many different diseases caused by uncontrolled cell division. Despite the redundancy of the cell cycle, errors can occur. Proper replication of DNA during the S phase is monitored closely during the cell cycle checkpoints. However, even with the checkpoints, a small percentage of replication errors, called mutations, can occur and be passed on to the daughter cells. If one of these mutations occurs within a gene, a gene mutation occurs.

All cancers begin when a gene mutation gives rise to a faulty protein that is used during cell division. Even minor mistakes allow subsequent mistakes to occur more readily. Over and over, small, uncorrected errors are passed from parent cell to daughter cells. Eventually, the pace of the cell cycle speeds up as the effectiveness of the control and repair mechanisms decreases. Uncontrolled growth of the mutated cells outpaces the growth of normal cells in the area, and a tumor can result.

Inherited genetic abnormalities may cause loss of cell cycle control. Environmental factors, such as UV light or smoking, can also damage DNA and impact control of the cell cycle. Often, a combination of both genetic predisposition and environmental factors lead to cancer.

The process of a cell escaping its normal control system and becoming cancerous may happen throughout the body quite frequently. Fortunately, specific cells of the immune system are capable of recognizing cancerous cells and destroying them. However, in some instances, the cancerous cells remain undetected and continue to proliferate.

If the resulting tumor does not pose a threat to surrounding tissues, it is said to be benign and can usually be easily removed. A tumor becomes malignant, or cancerous, when it spreads beyond the tissue it originates in. The specific names of cancers reflect the tissues they arise in. For example, when the cancerous cells originate in white blood cells, important immune defense cells, the cancer is called leukemia.

Depending on the type and stage of cancer a person has, treatments vary. Traditional approaches, including surgery, radiation, chemotherapy, and hormonal therapy, aim to remove or kill rapidly dividing cancer cells, but these strategies have their limitations. Depending on a tumor's location surgeons may be unable to remove it. Radiation and chemotherapy are difficult, and it is often impossible to target only the cancer cells. The treatments inevitably destroy healthy tissue, as well. To address this, researchers are working on pharmaceuticals that can target specific proteins produced only in cancer-associated cells.