

BENG 100 Frontiers of Biomedical Engineering
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Chapter 5

SUMMARY

- Eukaryotic cells have lipid bilayer plasma membranes that separate their contents—including cytoplasm and organelles—from the extracellular environment.
- All cells utilize similar elements: the cytoskeleton is essential for determining cell shape; ribosomes, rER, and Golgi are essential for protein synthesis; mitochondria are involved in energy production; lysosomes are important for digestion of unwanted material; genetic information is encoded on chromosomal DNA in the nucleus.
- ECM is important for maintaining tissue structure, holding cells in position within tissues, and providing a mechanical/chemical support for cell function.
- Some membrane proteins allow cells to regulate transport of molecules between the internal and external environment; other membrane proteins allow the cell to adhere to other cells or to ECM; other membrane proteins serve as receptors for ligands and hormones.
- The cell cycle is an orderly sequence of events describing the life of a cell, from birth to division, with checkpoints that control critical cell transformations: the phases of the cell cycle are useful for describing cell activities.
- Stem cells are immature cells, which are capable of self-renewal and differentiation into more mature forms.
- Cell culture is one of the most important techniques of modern biology; it has also developed into an important tool for production by biomedical engineers.

KEY CONCEPTS AND DEFINITIONS

adhesion molecules - family of extracellular and cell surface glycoproteins involved in cell-cell and cell-matrix adhesion, recognition, activation and migration.

anaphase - stage in meiosis and mitosis in which sister chromatids are separated by the mitotic spindle fibers. The chromatids are pulled away from one another to opposite poles of the dividing cell, the nuclear membrane begins to reform and the cleavage furrow begins to constrict.

apoptosis - programmed cell death that enables the body to dispose of damaged, unwanted, or unneeded cells

asymmetrical division - division process of unipotent cells in which one of the two offspring maintains stem cell characteristics and the other differentiates and maintains a specific function

blastomere - cell formed by the division of a fertilized egg in which the G phase is absent, so replication occurs quickly, making up the blastula

centromere - region of a nuclear chromosome to which the spindle fibers attach to the kinetochore during cell division

chromatids - pair of replicated chromosomes produced during mitosis or meiosis. Separate during anaphase of meiosis II or mitosis when the centromeres divide and each becomes its own chromosome

cleavage furrow - constriction of the cell membrane during anaphase at the equator of the cell that marks the beginning of cytokinesis in animal cells. As the furrow deepens the cell divides

cotransporter – a secondary active transport system in which both the primary and secondary solute move in same direction across the membrane.

crisis - critical point in culture of tissues in which the cell must adapt to the culture environment or die

cytokinesis - division of the cytoplasm of a cell in which two daughter cells result

cytoskeleton - structural support of the cell composed of protein filaments that facilitate cell division, movement and shape; the protein filaments that compose the cytoskeleton also serve as tracks in which substances are transported within the cell

differentiation - changes in cell shape and physiology associated with the production of the mature cell types of a particular organ or tissue

DNA synthesis – process of copying a double stranded DNA strand prior to cell division resulting in two copies of the original DNA strand.

endoplasmic reticulum (rER) - extensive membranous network, continuous with the outer nuclear membrane and studded with ribosomes which give it a rough, or bumpy appearance

eukaryotic - cell that maintains distinct organelles, a cytoskeleton, and nucleus such as fungi, protozoa, plants and animals.

exchanger – a secondary active transport system in which the primary and secondary solute move in opposite directions across the membrane.

extracellular matrix (ECM) - any material produced by the cell and secreted into the surrounding medium, generally characterized as a three dimensional scaffold embedded in a gel containing proteins and filament fibers

G₀ phase - period of time in which the cell has completely exited the cell cycle

G₁ Phase - period of time representing the gap between mitosis (M phase) and DNA Synthesis (S phase)

glycosaminoglycans (GAGs) - long, unbranched polysaccharide molecules that are found on the cell membrane and help give various tissue desired structure

Golgi apparatus - organelle composed of stacks of separate intracellular membrane compartments which function to modify and package secreted and integral membrane proteins growth factors - serum protein that stimulates cell division when it binds to its cell surface receptor

hematopoietic stem cell - undifferentiated cell in the bone marrow that have the ability to both multiply and differentiate into specific blood cells

interphase - stage in the cell cycle between nuclear divisions in which chromosomes are extended and functionally active; the stage in which the cell does not actively do anything for mitosis or meiosis

integrins - largest family of adhesion molecules that mediate cell-cell, cell-extracellular matrix and cell-pathogen interactions by binding to various non integrin molecules

invariant asymmetrical division - mechanism of stem cell division in which a differentiated progenitor is produced as well as a constant number of stem cells

in vitro - biological or chemical work done in a test tube rather than in the organism itself

kinetochore - attachment point of the spindle fibers to the centromere on the sister chromatids during prometaphase in the cell cycle

lysosome - membrane enclosed vesicle consisting of hydrolytic enzymes used to breakdown cellular components and proteins found in the cytoplasm of eukaryotic cells

medium - any material on or in which experimental cell cultures grow; generally, these materials consist of a variety of nutrients or other compounds which yield desired results in the culture

meiosis I - first stage in the cell life cycle of gametes in which homologous chromosomes do not replicate but separate into two distinct daughter cells which further leads to meiosis II

meiosis II - second stage in the cell life cycle of gametes in which the daughter cells

produced in meiosis I undergo steps the same as mitosis, only with half the number of chromosomes

metaphase - stage of mitosis or meiosis in which the spindle fibers align the chromosomes in an equatorial plane in the cell

mitochondria - eukaryotic organelle that is the site of ATP synthesis via oxidative phosphorylation, the Krebs cycle and electron transport reactions

mitosis (M Phase) - see Chapter 3 Glossary

mitotic spindle - microtubule based structure present during mitosis in which the chromosomes attach and are separated toward opposite poles of the cell

necrosis - one of two types of cell death in which the cell swells and ruptures releasing its contents within the body and often causing an inflammatory response

nuclear membrane - also known as the nuclear envelope, a membrane system that surrounds the nucleus of eukaryotic cells. The membrane is perforated with pores that allow transport of genetic material, fluids and other important compounds

nucleus - membrane bound organelle containing the entire genetic material, genome, of eukaryotes

organelle - intracellular substructure having a specialized utility essential to proper cellular function

oxidative phosphorylation - process in which ATP is produced in conjunction with the mitochondrion from the breakdown of carbohydrates and fatty acids; see Chapter 4

peroxisome - organelle containing enzymes that catalyze the production and breakdown of hydrogen peroxide throughout the cell

pluripotent - property of a stem cell to develop into more than one type of differentiated cell
primary active transport – movement of molecules across a biological membrane that is driven by a chemical reaction, usually the hydrolysis of ATP
secondary active transport – movement of molecules across a biological membrane that is driven by the spontaneous movement of another molecule

progenitor - one of two types of cellular results from stem cell division which is characterized as the differentiated cell with a specific function

prokaryotic - primitive cells, such as bacteria, that lack cytoplasmic organelles, a cytoskeleton, and nuclear membrane which therefore leaves no distinct nucleus

prometaphase - phase of the cell cycle in which the nuclear membrane dissolves and the spindle fibers attach to the chromosomes kinetochore at the centromere

prophase - initial stage in cell division in which the chromosome condense and become visible in the nucleus and the cytoskeleton begins to form the mitotic spindle

ribosome - complex organelle composed of various proteins and ribosomal RNA that catalyzes the translation of messenger RNA into an amino acid sequence

selectins - family of adhesion molecules that recognize and interact with glycoproteins on the surface of other cells

smooth endoplasmic reticulum - extension of the endoplasmic reticulum responsible for lipid synthesis stem cell - cell produced early on after fertilization that is undifferentiated and maintains two defining characteristics: limitless self renewal and multilineage differentiation

S Phase - See DNA Synthesis

telomere - the ends of chromosomes that are necessary for replication and stability; the tip or end of the chromosome

telophase - final stage of mitosis or meiosis in which chromosomes uncoil, the mitotic spindle breaks down and cytokinesis occurs; nuclei also reform

transdifferentiation - conceptual theory that stem cells from one type of tissue may be able to differentiate into another type of tissue when environmental cues are altered

unipotent - property of cells that are only capable of developing into one type of cell or tissue

vector - in DNA cloning, the plasmid or phage chromosome used to carry the cloned DNA segment

QUESTIONS

1. Assume that you have a flask of cells in culture that, when viewed through a microscope, looks like the image in Figure 5.1b. How would you estimate the total number of cells in the flask?
2. Sodium bicarbonate is often used as the primary buffer system in cell culture medium. Why do you think that it is popular? How would you use bicarbonate to buffer the pH near 7.4?
3. Cell cultures are often used to investigate mechanisms of cell function in humans. Do you have any concerns about this practice?

4. The structure of prokaryotic cells is very different from that of animal cells, or eukaryotes. Compare these structural differences.
5. Describe the major differences between mitosis and meiosis.
6. The cells in your body are constantly proliferating. How is this important to growth of an organism and the repair of tissues?
7. Facilitated diffusion and active transport are two different mechanisms that the cells use to transport molecules into and out of the cell. Compare and contrast these two types of cellular transport.
8. Bobby has been culturing epithelial cells for experiments that he is performing in the laboratory. He has subcultured the cells many times, and has always fed the cells the proper medium. He recently ran an experiment and found that his cells are not growing the way that he previously observed. What are some reasons why these cells may not be acting as they did previously?