

Proteins and Protein Synthesis: An Overview

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An understanding of the basic bioscience involved in protein synthesis adds insight into the genesis of little-understood diseases, such as Creutzfeldt-Jakob disease, that develop as a result of protein synthesis and/or genetic mutations. Because protein synthesis occurs at the cellular level and is critical to cell function, one must first understand basic cellular structure before studying protein synthesis. A review of cellular structure is therefore presented in the following paragraphs.

CELLULAR STRUCTURE

The two major cellular components—the nucleus and the cytoplasm (protoplasm of the cell outside the nucleus)¹—are separated from other portions of the cell by membranes: The nuclear membrane separates the nucleus from the cytoplasm, and the cell membrane separates the cytoplasm from the external environment.

The organelles, which are highly specialized structures found in the cytoplasm, are also lined by membranes, which are composed of lipids and proteins. The lipid portion of the organelle membrane inhibits movement of water and water-soluble substances across the membrane while the protein portion penetrates the lipid framework and allows for the movement of certain substances through the membrane. Comparing the organelle membrane with a child's toy aids in understanding how the membrane functions. The toy—a wooden box with a variety of shapes cut out of it—requires a child to match puzzle-

like objects with the cut-out shapes on the box in order to insert the shapes into the box. Much like the organelle membrane, the box is not penetrable unless the child matches the correctly shaped object with the same-shaped hole in the box. In the case of the membrane, the protein "hole" allows passage of substances that match its biochemical requirements.²

A list of the basic types of organelles follows:

- **Endoplasmic reticulum** — A network of tubular and flat vesicular structures that allow for intracytoplasmic transport and communication.
- **Ribosomes** — Organelles attached to the endoplasmic reticulum, which are the usual site of protein synthesis for proteins transported outside the cell, or organelles that free-float in the cytoplasm and are the usual site of protein synthesis for proteins used within the cell.
- **Golgi apparatus** — A multilayered, membrane-like structure that secretes lysosomes, secretory vesicles, and other cytoplasmic components.
- **Lysosomes** — Vesicular organelles formed by the Golgi apparatus that disperse throughout the cytoplasm and provide for intracytoplasmic digestion.
- **Peroxisomes** — Organelles similar to lysosomes, which contain oxidases and protect the cell from potentially poisonous substances.
- **Secretory vesicles** — Storage compartments for secreted substances.
- **Mitochondria** — A self-replicating structure that synthesizes adenosine triphosphate (ATP), which

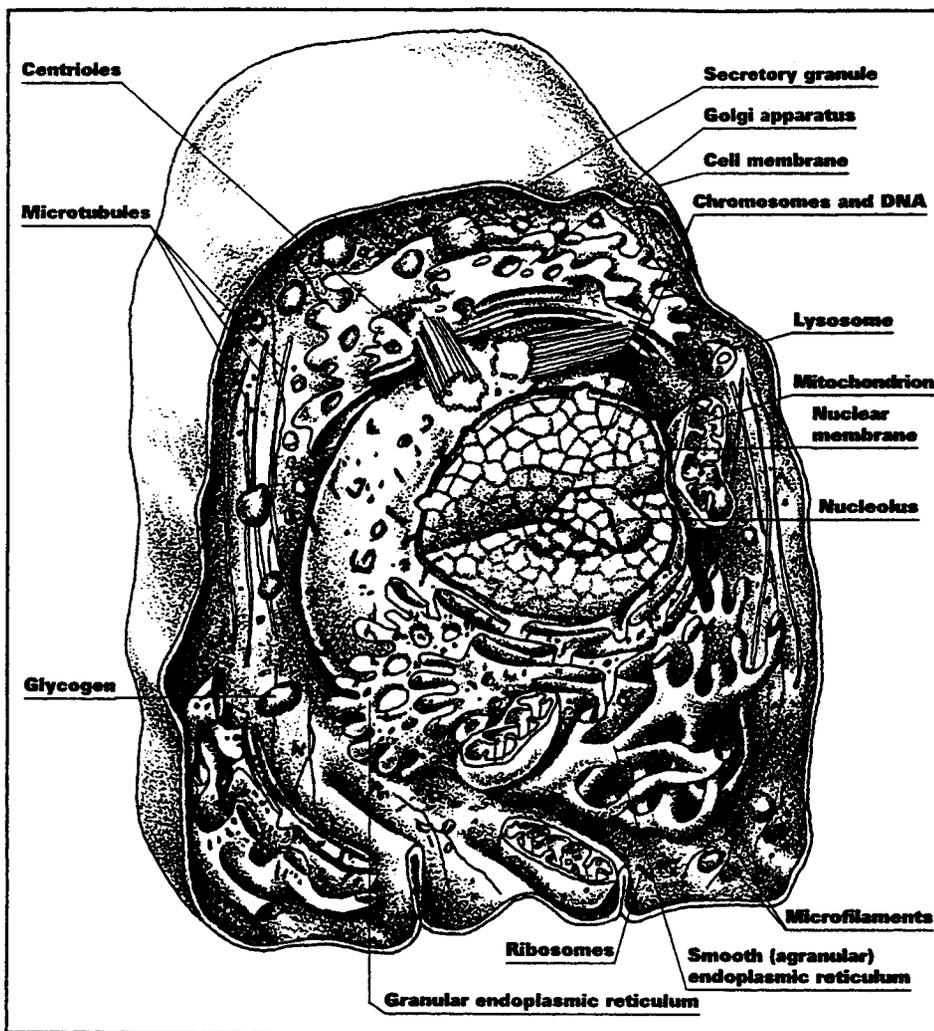


Figure 1—The two major components of a typical cell, the nucleus and the cytoplasm, are separated from other portions of the cell by membranes. The various organelles are highly specialized structures found within the cytoplasm.

diffuses throughout the cell and provides energy for cellular functions.

- **Tubules and Filaments** — Protein strands used to provide structure to cells and perform specific actions depending on cell type.
- **Nucleus** — The cell's control center, which has several substructures and contains large quantities of DNA.²

The basic components of a typical cell are depicted in Figure 1.

The cell's five primary substances—water, proteins, electrolytes, lipids, and carbohydrates—are referred to collectively as "protoplasm." Cells are made up

of 70% to 85% water, in which chemical reactions occur among various dissolved or suspended particles. Proteins, the second most abundant cellular substance, constitute 10% to 20% of the cell mass. Cellular electrolytes—particles that are charged electrically when dissociated in solution—include potassium, magnesium, phosphate, sulfate, and bicarbonate, as well as small quantities of calcium and sodium chloride. Lipids, substances soluble in fat solvents, occur mainly in the form of phospholipids and cholesterol. Carbohydrates, which play an essential role in cellular nutrition, are of

limited importance structurally.² The structure of the cell membrane, largely consisting of lipid and protein molecules, is depicted in Figure 2.

PROTEINS AND PROTEIN SYNTHESIS

Amino acids have been called the "building blocks" of protein. Cells are differentiated based on their protein structure, which regulates the type and rate of cellular chemical change (see Figure 3).² Hereditary information, passed from cell to cell through a set of amino acid sequences, determines the types of protein that a cell may produce. DNA within the nucleus contains a genetic code for sequencing amino acids. Base triplets form "code words" that ultimately determine the sequence of three amino acids. The code words are bound to the second strand of DNA's double-stranded structure.

While protein synthesis occurs in the cell's cytoplasm, DNA is confined to the nucleus. DNA code words must therefore be transcribed and transmitted for protein synthesis to occur. The transcription process requires a second type of nucleic acid—RNA—which contains triplet sequences called codons. The DNA double strand separates temporarily and one strand forms a template for the RNA strand. The RNA strand resembles the DNA template with two exceptions: Sugar deoxyribose is replaced with ribose, and the base thymine is replaced with uracil. The resulting nucleotides activate when two phosphate radicals are added, producing high-energy phosphate bonds derived from ATP molecules. The activated nucleotides are then assembled into a complex RNA molecule through enzymatic action and released into the nucleoplasm, where enzymes "edit" or remove unwanted sequences from the

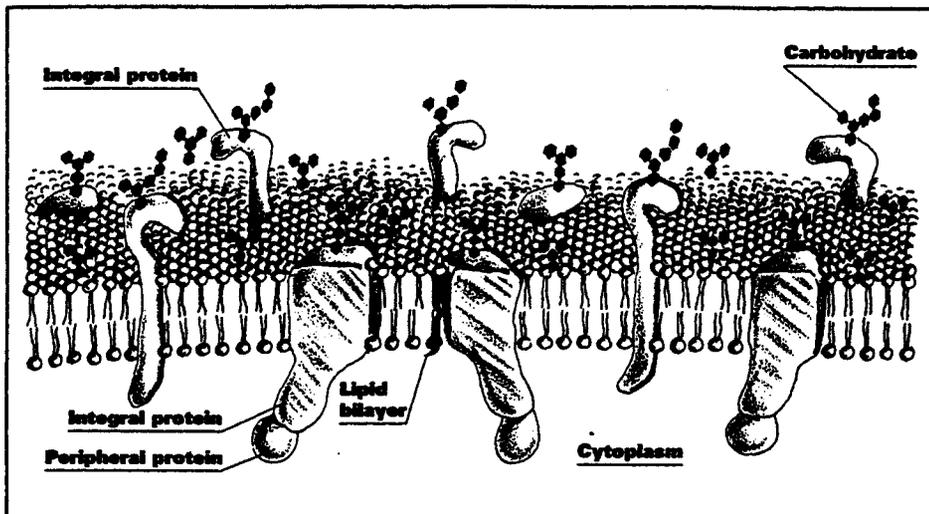


Figure 2—The structure of the cell membrane is largely comprised of a lipid bilayer interspersed with globular protein molecules.

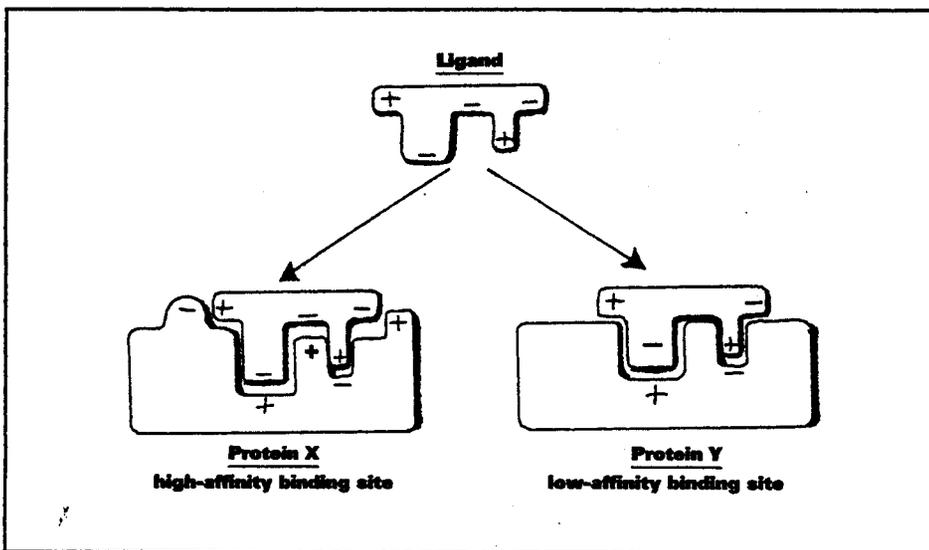


Figure 4—The synthesized protein selectively binds ions and molecules using a "lock-and-key" system. Scientists theorize that this process results in more complex ligands leading to the creation of large molecular structures. Ligand and protein binding-site interactions impact all cellular functions and regulation.

RNA strand. Edited strands are spliced to produce the final strand. The following three types of RNA may be produced:

- **Messenger RNA** — carries the genetic code to the cytoplasm and controls protein formation
- **Transfer RNA** — transports amino acids to ribosomes to be used in assembling the protein molecules
- **Ribosomal RNA** — forms with various proteins—the ribosomes—

where protein synthesis occurs.

Once the original code words are transcribed and transmitted from the DNA to the RNA, the codes align with amino acids to specify the type of protein that will be synthesized.² The resulting protein selectively binds ions and molecules (see Figure 4). The lock-and-key system used in a large hotel would be analogous to this process: The locks on each door are enough alike that a master

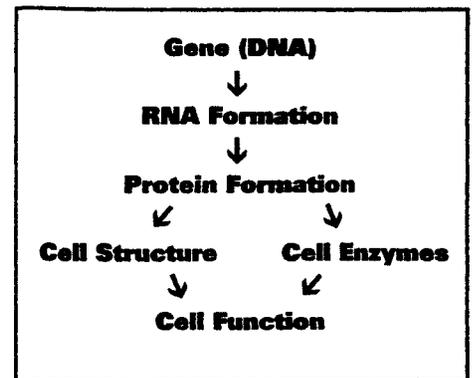


Figure 3—Protein synthesis as it relates to cellular function.

key may open them all; however, each lock is different enough that a minor change in a key will allow it to open only one door. The protein molecule has highly specific binding sites, which are determined by the following:

- Electrical charges
- Number and strength of electrical attractions
- Three-dimensional considerations

Essentially, all cellular function and regulation is determined by ligand and protein binding-site interactions (see Figure 4). While not fully understood, scientists believe that a ligand that has bound itself to one binding site may produce a more complex ligand that can be bound to another protein molecule.

These multimolecular interactions eventually result in large molecular structures. Protein's ability to bond specifically with other molecules also results in the development of intracellular and intercellular communicators, regulators, and modulators.

CONCLUSION

Protein synthesis, which is critical to healthy cell functioning, can be disrupted by carcinogens, other mutation processes, genetic failures, or prion replication. While surgery relieves the gross anatomical response, the disease process itself

occurs at the biochemical level. Please refer to the suggested reading list for more in-depth studies on protein synthesis. ▲

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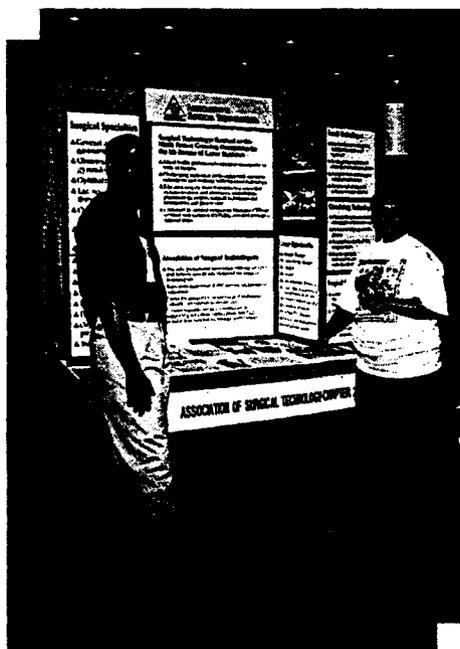
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AST Notes (cont'd from pg. 15)

- St. Claire Medical Center (located in Morehead, Kentucky), requires certification for employment in the CST position, assists in the recertification of all six CSTs, encourages the CST staff to teach surgical technology students who attend a nearby educational program, sends two CSTs to conference annually, and sends representatives to other educational programs throughout the year.
- Laura Mullin, RN, BS, CNOR (of Biddeford, Maine), actively promoted National Surgical Technologist Week, secured a pay increase for a staff of 10 surgical technologists while other area hospitals were not giving pay raises, and encouraged the surgical technologists to strive for acceptance and appreciation from co-workers.



TSgt George Clarke, CST, CSPDT, and Josie Ramirez, CST, represent AST and Chapter 299 at the Career Expo in Wichita Falls, Texas.

"TEXOMA SCRUBS" PARTICIPATE IN CAREER EXPO

Local high school students and current working adults were given an opportunity

to learn about surgical technology when Chapter 299 (the Texoma Scrubs) of Wichita Falls, Texas, recently exhibited AST's tabletop display at a career expo. Chapter President TSgt George Clarke, CST, CSPDT, coordinated the display, with the following chapter members also assisting at the booth: Josie Ramirez, CST, Elaine Vanderworth, CST, Bonnie Beavers, CST, Trish Duncan, CST, and Fran Burlison, CST.

George said he believed it was important for the chapter to be involved with the career expo. "We felt this was an opportunity to let the local community know that surgical technology is a profession and to give them an idea of the professional knowledge we must obtain," he said. The display also included information about AST and certification, as well as brochures from local colleges and vocational schools that offer surgical technology programs. ▲