The human body is composed of hundreds of billions of cells. Other life forms also contain structures composed of numerous cells. For example, the small worm C. elegans contains only about a thousand cells. As we travel down the size scale, the number of cells decreases. Larger animals and plants also are composed of numerous cells. Holes and organs are formed by arrangements of numerous cells. The cell membrane is the basic structure of the cell. It is a selectively permeable membrane that controls the passage of substances into and out of the cell. The cell membrane contains proteins and lipids, and it is involved in many cellular processes, including signal transduction, transport, and cell adhesion. The cell wall is the outward extension of the cell membrane, and it provides support and protection to the cell. The nucleus is the control center of the cell, and it contains the cell's genetic material. The cytoplasm is the fluid that fills the cell and contains the organelles and other structures. The endoplasmic reticulum is a network of membranous sacs and channels that is involved in the synthesis and transport of proteins and lipids. The Golgi apparatus is a series of flattened sacs that is involved in the modification and packaging of proteins and lipids for secretion or transport within the cell. The lysosomes are membrane-bound sacs that contain enzymes that are involved in the breakdown of materials. The mitochondria are organelles that are involved in the production of energy for the cell. The chloroplasts are organelles that are involved in photosynthesis in plant cells. The plasma membrane is the outer boundary of the cell. It is a selectively permeable membrane that controls the passage of substances into and out of the cell.
The second category of cells is the eukaryotes, which compose all multicellular organisms, as well as some single-celled organisms like algae.

The cytoplasm is the liquid in which all the organelles float. The organelles are like little machines inside the cell that do different jobs. Some organelles make proteins, some store energy, some make fat, and so on. The organelles are surrounded by a membrane, which is made of a lipid bilayer. This is a double layer of lipids, which are molecules made of a hydrophilic (water-loving) head and a hydrophobic (water-hating) tail. The lipids are arranged so that the hydrophilic heads are on the outside, facing the water, and the hydrophobic tails are on the inside, facing each other.

The cell membrane is semipermeable, which means that it allows some substances to pass through it but not others. For example, water can pass through the membrane, but harmful chemicals cannot.

The cell membrane also contains proteins, which are long chains of amino acids. Some proteins are enzymes, which catalyze chemical reactions. Others are receptors, which bind to molecules that trigger cellular responses.

In addition to proteins, the cell membrane contains carbohydrates, which are molecules made of carbon, hydrogen, and oxygen. Carbohydrates are found on the surface of the cell membrane, where they bind to other molecules and help the cell recognize other cells. This is important because cells need to be able to communicate with each other.

The cell membrane is not only important for communication, but it also helps the cell maintain its shape and structure. It is like a flexible but strong boundary that allows the cell to grow and divide.

Finally, the cell membrane is involved in the exchange of materials between the cell and the surroundings. It allows nutrients to enter the cell and waste products to exit. It is through the cell membrane that the cell can communicate with its environment.

Examination of the cell membrane shows why the cell is the fundamental unit of life. The cell membrane is essential for the cell to function properly, and it is the cell membrane that ultimately reaches the interior of the cell, such as yeast and bacteria.
Protein Structure

Pushing against a strong plane wall, shifts the cell's cytoplasmic volume, making the cell more spherical. The cytoplasmic volume changes, affecting the cell's shape. This process is called cell expansion. The cell's plasma membrane is responsible for maintaining the cell's volume. If the plasma membrane is damaged, the cell will burst.

The plasma membrane is composed of lipids and proteins. Lipids are made up of fatty acids and glycerol. Proteins are made up of amino acids. The plasma membrane is semi-permeable, allowing certain substances to pass through while blocking others.

The plasma membrane is divided into two layers: the outer layer and the inner layer. The outer layer contains proteins that bind to the cytoplasmic membrane, while the inner layer contains proteins that bind to the extracellular matrix.

In summary, the plasma membrane is a vital component of the cell, playing a crucial role in maintaining the cell's volume and regulating the exchange of substances.
The number of molecules that can be built from carbon and the other elements is very large indeed. Biochemical systems, however, are likely to require a limited number of molecules that are made up of a relatively small number of distinct molecular building blocks. These are the amino acids, which are the building blocks of proteins. The four amino acids have been chemically joined with long chains of many other amino acids to form long chains of amino acids that are the building blocks of proteins.

The addition of a new amino acid to the polymer chain is a process called translation, which occurs on ribosomes in the cytoplasm of cells. The ribosomes read the genetic code stored in DNA and use it to assemble the amino acids into proteins. Each amino acid is attached to a tRNA molecule, which then binds to the correct position on the ribosome to form the growing protein chain.

The building blocks of proteins are called amino acids. The amino acids differ in their chemical structure, which determines their physical properties and the function of the protein they form. There are 20 different amino acids that are commonly found in proteins.

Amino acids are joined together by a peptide bond, which is formed when the amino group of one amino acid reacts with the carboxyl group of another amino acid. The resulting bond is a covalent bond that is very stable and is responsible for the long chains of amino acids that form proteins.

The structure of a protein is determined by the sequence of amino acids in the protein chain and the interactions between the amino acids. These interactions include hydrogen bonds, ionic interactions, and hydrophobic interactions. The three-dimensional structure of a protein is important for its function, as it determines how the protein interacts with other molecules and how it performs its biological role.

Proteins are essential for nearly every aspect of life, from the functioning of enzymes to the transport of nutrients in the body. They are involved in a wide range of processes, including metabolism, energy production, and cell communication.

In summary, proteins are an essential component of life, and their structure and function are determined by the specific sequence of amino acids that make up the protein chain. The study of proteins is crucial for understanding the basic mechanisms of life and for developing new treatments for diseases.
When proteins fold, they do not follow together like a string of beads. Instead, the protein folds into a compact, globular shape. The process involves the protein's amino acid sequence and the interactions between the amino acids. The final structure is determined by the secondary and tertiary structures formed by the protein's amino acids.

**Figure A-3**

- **Primary Structure**: The sequence of amino acids in a protein.
- **Secondary Structure**: Helices and sheets formed by hydrogen bonding between the amino acids.
- **Tertiary Structure**: The overall three-dimensional shape of the protein, formed by non-covalent interactions such as hydrogen bonds, ionic bonds, and Van der Waals forces.
- **Quaternary Structure**: The protein's functional form, resulting from the association of multiple subunits.

Each level of structure contributes to the protein's function and stability. The secondary and tertiary structures are critical for understanding protein function and interactions with other molecules.
Nucleic Acid Structure

The genetic information is stored in the nucleic acids DNA and RNA. DNA contains deoxyribose sugar and contains the four nitrogenous bases: adenine (A), cytosine (C), guanine (G), and thymine (T). Each DNA molecule is composed of two antiparallel strands that are held together by hydrogen bonds between complementary base pairs. RNA contains ribose sugar and contains the same nitrogenous bases, but thymine is replaced by uracil (U).

The nucleic acids are polymers of nucleotides, which consist of a pentose sugar, a phosphate group, and a nitrogenous base. The two strands of DNA are held together by hydrogen bonds between the complementary bases: adenine (A) pairs with thymine (T), and cytosine (C) pairs with guanine (G). These base pairs form a double helix, with the sugar-phosphate backbones on the outside and the bases on the inside.

The DNA molecule is double-stranded, with each strand consisting of repeating units of nucleotides. The sequence of nucleotides along the DNA strand is important because it determines the order of amino acids in a protein. Proteins are the building blocks of living organisms, and they are responsible for many functions, including structural support, enzyme catalysis, and signal transduction.

Understanding the structure of DNA is crucial for fields such as genetics, biochemistry, and molecular biology. The ability to manipulate DNA, such as by cloning or sequencing, has revolutionized medicine and biotechnology.

In summary, nucleic acids play a central role in the storage and transmission of genetic information. They are composed of nucleotides, which are held together by hydrogen bonds between complementary base pairs. The structure of DNA is crucial for the functioning of living organisms, and understanding it has led to many advances in science and medicine.
A piece of DNA containing four nucleotides.

Figure A-4

The chemistry of life
code, Camino’s invention was prophetic. Although he was wrong about the specific name of the protein, the main finding that messenger RNA was a replicon of the genetic message and that the information was stored in a cell’s RNA and transferred to protein is correct. The unique nature of messenger RNA (mRNA) was discovered when Robert Holley and his colleagues isolated and sequenced the first mRNA from a virus. In 1965, they reported that the mRNA was composed of a single strand of nucleotides, and that each nucleotide was connected to the next by a phosphodiester bond. This discovery provided the foundation for the modern understanding of gene expression and the molecular basis of life.

The large number of steps involved in expressing the information contained in DNA is a formidable challenge for biologists. The first step is the production of mRNA, a process that occurs in the cell nucleus. Once the mRNA is produced, it is transported to the cytoplasm, where it is translated into protein. The translation process takes place on the ribosomes, which are large complexes of RNA and protein. During translation, the mRNA is read by the ribosome, and the corresponding amino acids are assembled into a polypeptide chain. Once the polypeptide chain is complete, it is folded into a protein. The production of a protein from mRNA is a complex process that requires the coordinated action of many different enzymes and molecules. The study of gene expression and the molecular basis of life is a rapidly evolving field, and biologists are always exploring new ways to better understand how genes are controlled and how proteins are made.
GENE REGULATION

To begin transcription, the enzyme RNA polymerase recognizes the RNA promoter, a specific sequence of DNA that signals the start of transcription. This sequence is rich in purines and pyrimidines and is typically located about 30 to 45 base pairs upstream of the transcription start site. Once the RNA polymerase has bound to the promoter, it unwinds the DNA, creating a transient RNA-DNA hybrid that is used to synthesize the complementary strand of RNA.

Transcription then begins, with the RNA polymerase catalyzing the synthesis of RNA from the DNA template. The RNA polymerase continuously moves along the DNA, releasing the RNA strand as it goes. This process is highly efficient, and the RNA polymerase is able to synthesize long RNA molecules in a single pass.

As the RNA polymerase moves along the DNA, it encounters transcription factors that bind to specific DNA sequences. These transcription factors can either enhance or repress the transcription of the associated gene. For example, some transcription factors bind to enhancers, which are DNA sequences located far from the gene they regulate. These transcription factors can increase the rate of transcription by binding to the RNA polymerase and helping it move along the DNA.

The RNA polymerase then continues to move along the DNA, synthesizing the RNA transcript. Once the transcription has been completed, the RNA polymerase releases the RNA transcript and dissociates from the DNA. The RNA transcript can then be processed further, either by splicing out introns, adding a 5' cap, or adding a 3' poly-A tail, before being translated into a protein by the ribosome.
whether a single gene should be transcribed.

TRANSLATION
DNA replication begins at certain DNA sequences known as replication origins. DNA replication is the process by which a DNA molecule is copied to produce two identical DNA molecules. The process of DNA replication is critical for the survival and reproduction of organisms. It is a complex process that involves the coordinated action of several proteins and enzymes. DNA replication is a highly regulated process that occurs during the S phase of the cell cycle. DNA replication begins at specific locations on the DNA molecule known as replication origins. These origins are recognized by proteins that initiate the process of DNA replication. The replication origins are located at specific sequences of DNA that are recognized by the proteins involved in the replication process. The proteins that initiate DNA replication bind to the replication origins and recruit other proteins and enzymes that are necessary for the replication process. DNA replication is a highly coordinated process that is essential for the survival and reproduction of organisms.
complex, and therefore much less is known about it.

The replication of circular DNA appears to be much more
complex, and therefore much less is known about it.
The replication of plasmids also appears to be much more
complex, and therefore much less is known about the
plasmid DNA replication process. The replication of the
plasmid DNA involves a series of steps that are similar to
those involved in the replication of bacterial chromosome DNA.

The enzyme DNA polymerase is responsible for synthesizing
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During the replication process, the DNA polymerase enzyme
binds to the DNA template and begins to synthesize a new DNA
strand. The enzyme requires a primer, which is a short RNA
strand, to initiate the synthesis of the new DNA strand.

In prokaryotic cells, the RNA primer is synthesized by the
enzyme RNA polymerase. The RNA primers are then removed
by the enzyme DNA polymerase, and the DNA strands are
completed.

In eukaryotic cells, the RNA primers are removed by the
enzyme DNA ligase, which joins the DNA strands.

DNA replication is a complex process that involves a series of
steps. The steps include the unwinding of the DNA double helix,
the synthesis of new DNA strands, and the sealing of the DNA
strands.

The unwind complex of origin is the starting point for DNA
replication. The unwind complex is formed by the enzyme
DNA helicase, which unwinds the DNA double helix.

The unwound DNA is then used as a template for the
synthesis of new DNA strands by the enzyme DNA
polymerase. The enzyme DNA polymerase synthesizes new
DNA strands in the 5' to 3' direction, using the original DNA
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