

Structure and Properties of DNA and Genes

Slide 2 DNA is the fundamental genetic material of all types of life. DNA is a completely informational molecule, in that it stores the information needed to produce the proteins and enzymes necessary for all of the metabolic pathways found in an organism. In this lesson, we will discuss some of the important structural and organizational features of DNA and the genes found in DNA, in order to better understand their role as the genetic material of life.

Slide 3 DNA is found in all living cells. A few specialized cell types, such as the red blood cells of animals, only contain DNA in the early stages of their development.

In prokaryotic organisms, DNA is found in an area of the cell called the nucleoid. In eukaryotic cells, it is bound by membranes in an organelle called the nucleus. In addition, certain eukaryotic organelles, such as the chloroplast and mitochondria, contain their own DNA.

Slide 4 Wherever DNA is found, its basic structure is the same. DNA is formed as a double-stranded molecule called a double helix. Essentially, a double helix is like a ladder that has been twisted around. The 'legs' of the DNA double helix are made up of a sugar-phosphate backbone. These backbones consist of alternating molecules of phosphate and sugar. In the case of DNA, the sugar is deoxyribose. The linkages connecting phosphates to sugars are covalent bonds called phosphodiester linkages. These covalent linkages make each individual strand of DNA very strong.

The 'rungs' of the DNA double helix are composed of nitrogenous bases. In DNA, there are four nitrogenous bases: adenine (A), cytosine (C), guanine (G), and thymine (T). Recall from our earlier lesson on macromolecules that the each nitrogenous base, together with a molecule of deoxyribose and a molecule of phosphate, makes up the fundamental subunit of DNA, called a nucleotide.

Slide 5 The opposing strands of a DNA molecule are held together by the hydrogen bonds that form between the nitrogenous bases of each strand. Remember that in DNA, A always pairs with T, and C always pairs with G, in a process called complementary base-pairing. The weakness of the hydrogen bonds makes it relatively simple to separate parts of the two strands of DNA, which is important in DNA replication, and in transcription of DNA into RNA. On the other hand, when taken together, the many hydrogen bonds in a DNA molecule combine to make the entire molecule a fairly stable structure, although the strands may still be separated, for example, by exposure to high heat.

Slide 6 Another important feature of DNA is that the two strands that make up the DNA double helix are antiparallel. That is to say that, while they are parallel to each other, the strands run in opposite directions. One strand of a DNA molecule runs in a 3' to 5' direction, while its opposing strand runs in the 5' to 3' direction. The directionality of the strands of DNA is determined by the molecules of deoxyribose that help make up the sugar phosphate backbones. For example, if you are moving along a strand of DNA and each phosphate group is followed immediately by the 5', or number five, carbon of deoxyribose, you are moving in the 5' to 3' direction. If the 3', or number three, carbon

of deoxyribose is encountered immediately after a phosphate group, you are traveling in the 3' to 5' direction. The antiparallel character of the DNA molecule has some important consequences in DNA replication, which we will cover in a future lesson.

Slide 7 Most of the information in DNA is stored in segments called genes. A gene is a specific sequence of nucleotides in a strand of DNA that codes for a specific polypeptide, or sequence of amino acids. Within a given molecule of double-stranded DNA, genes may reside on either of the two strands. Genes range in size from only a few hundred to several thousand consecutive nucleotides, depending on the size of the polypeptide that they code for.

Slide 8 Genes also are generally flanked by sequences of nucleotides that act to regulate their transcription, or, in other words, sequences that regulate how often genes are copied into RNA. In some cases, there are sequences that bind molecules that inhibit the transcription of DNA. In others, there are sequences of nucleotides that bind molecules that promote transcription. A common example, found in both prokaryotic and eukaryotic organisms, is the promoter region. The promoter serves to help bind an enzyme called RNA polymerase. The binding of RNA polymerase is necessary in order for transcription of the genes in DNA that code for proteins.

Slide 9 So how much DNA is in organisms, and how many genes do organisms require to successfully survive and reproduce? The amount of DNA found in organisms is quite variable. A relatively simple organism, such as the bacterium *Escherichia coli*, contains around 4.7 million base pairs of DNA. More complex organisms, on the other hand can contain more DNA by several orders of magnitude. Mammals, for instance, have on the order of three billion base pairs of DNA. Certain salamanders and plants may have up to 150 billion base-pairs of DNA. Stretch this DNA out straight and it would measure several meters in length! It's a pretty impressive packing job to get all of that DNA into a nucleus just one or two micrometers wide.

The number of genes in organisms follows a similar pattern to DNA - more complex organisms generally have more genes, although there are many exceptions to this rule. *E. coli*, for example has a little over four thousand genes, while single-celled yeast has around six thousand. Multicellular humans have somewhere between fifty and eighty thousand genes, while certain plants, such as rice, may have several thousand more.

Slide 10 As you can imagine, organizing the DNA in a cell can be a complicated endeavor. In order to accomplish this, DNA is packaged at several different levels. First, DNA in the cell is often wrapped around proteins called histones. Histone proteins help to organize DNA, and affect whether or not the DNA is available for replication or transcription. When DNA is associated with histone proteins it is referred to as chromatin. The individual units of DNA wrapped around histone cores are called nucleosomes. Nucleosomes, in turn, may be coiled and packaged together more and more tightly to form a chromosome, which is often visible under a light microscope.

In cells, DNA is packaged loosely for the majority of the time, so that it may be available for transcription, which will be discussed in the following lesson, or replication. Tightly packed chromosomes form and are visible mainly when a cell is dividing, such as during mitosis or meiosis.

