

Nucleic Acids

Slide 2 Nucleic acids are responsible for storing and transmitting the hereditary information of cells and organisms. There are two types of nucleic acids: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA, which is found in the nucleus of eukaryotic cells and the nucleoid of prokaryotic cells, contains the genetic information cells need to synthesize proteins. RNA is found throughout cells, and is required to translate the information of DNA into the actual amino acid sequences of proteins. As we know from a previous lesson, proteins, including structural proteins and enzymes, are absolutely essential to life.

Slide 3 Both DNA and RNA are polymers composed of repeating subunits, or monomers, called nucleotides. The genetic information that is stored in molecules of DNA or RNA is based on the sequence of these nucleotides, as we will see in a later lesson. Each nucleotide is composed of three parts: a phosphate group, a five carbon sugar, and a nitrogenous base. In nucleic acids, nucleotides are linked together through condensation reactions, resulting in covalent bonds between the phosphate groups and sugars of adjacent nucleotides. These covalent bonds are called phosphodiester linkages.

As you can see from the illustration, the repeating phosphate and sugar groups of nucleotides in nucleic acids form a fairly strong 'backbone' of the molecule. Now let's take a closer look at the nitrogenous bases that extend from each sugar molecule of the nucleotides in a nucleic acid.

Slide 4 There are five different nitrogenous bases found in nucleic acids. These are cytosine, thymine, uracil, adenine and guanine. Due to their single ring structure, cytosine, thymine and uracil are classified as pyrimidines. Adenine and guanine, on the other hand, consist of two fused rings, and so are classified as purines.

One of the important features of the nitrogenous bases of nucleic acids is that they are able to hydrogen bond with one another. Hydrogen bonding in nucleic acids occurs between the two strands of DNA molecules, or between DNA and RNA, or even within single strands of RNA that are folded back on themselves. Because hydrogen bonds are relatively weak, it is fairly easy to separate strands of DNA or to separate RNA from DNA. This is significant when DNA is replicated and when DNA is transcribed into RNA. Both of these topics will be covered in detail in future lessons.

When hydrogen bonding occurs between nitrogenous bases, purines always hydrogen bond with pyrimidines, and vice-versa. Purines do not hydrogen bond with other purines. Likewise, pyrimidines do not hydrogen bond with other pyrimidines. For instance, if you look at the illustration here of a double-stranded DNA molecule, you will see that cytosines and guanines hydrogen bond together to form a purine-pyrimidine combination, as do adenines and thymines. An easy way to remember this is that A (adenine) always bonds with T (thymine) or U (uracil), and C (cytosine) always bonds with G (guanine).

Slide 5 Now that you have a grasp on the structure of nucleotides, it is worth mentioning briefly that nucleotides are not just found as the monomers of nucleic acids. In fact, nucleotides, or versions of them, play many important roles for cells. For instance, ATP, the universal ‘energy currency’ of cells, is a modified molecule of adenine that carries three phosphate groups. Also, the cofactors NAD and NADP, which you will learn about when we cover respiration and photosynthesis, are both dinucleotides. In other words, each of these molecules contains two nucleotides.

In fact, these examples demonstrate an important concept in cellular chemistry. While cells may initially seem hopelessly complex, they actually use only a handful of metabolic pathways and molecules to perform the majority of their tasks. Many molecules are used for more than one purpose, and appear in different pathways. Keep this in mind when we cover respiration and photosynthesis in later lessons – these pathways will become more sensible as you see a few key players popping into the picture again and again.

Slide 6 As mentioned before, DNA and RNA have slightly different roles for cells. DNA stores the genetic information of cells, and RNA translates this information into the amino acid sequences of proteins. There are also important structural differences between DNA and RNA. First, DNA is a double-stranded molecule found in the shape of a double helix, while RNA is a single-stranded molecule. To help visualize the shape of the double helix of DNA, think of a ladder that has been twisted around. In this case, the legs or sides of the ladder are the sugar-phosphate backbone, while the rungs are the nitrogenous bases that are hydrogen-bonded to each other.

DNA also differs from RNA in its molecular make-up. The five carbon sugar of DNA is deoxyribose, while the sugar in RNA is ribose. What’s the difference? As the name would suggest, deoxyribose is a ribose with one oxygen missing. In this case, there is an oxygen missing from the 2’, or number 2, carbon of the five carbon sugar.

Last but not least, DNA and RNA differ slightly in the nitrogenous bases that they contain. Both DNA and RNA carry four nitrogenous bases – cytosine, guanine, adenine, and one other. In DNA, the fourth base is thymine. In RNA, the fourth base is uracil.

Slide 7 In addition to serving the immediate needs of cells by producing proteins, nucleic acids, particularly DNA, have great evolutionary significance. DNA is copied and passed from cell to cell and from parent to offspring, with extremely few changes. This process has to be exact – if it were not, changes in DNA would accumulate so rapidly that the genetic information stored in DNA would quickly become nonsense. Since DNA is so carefully passed from cell to cell - and has been since very early in the history of life on earth - the DNA of organisms is a lot like a history book. Comparing the DNA of different organisms can give us an informative look into their evolutionary history.