PART

5

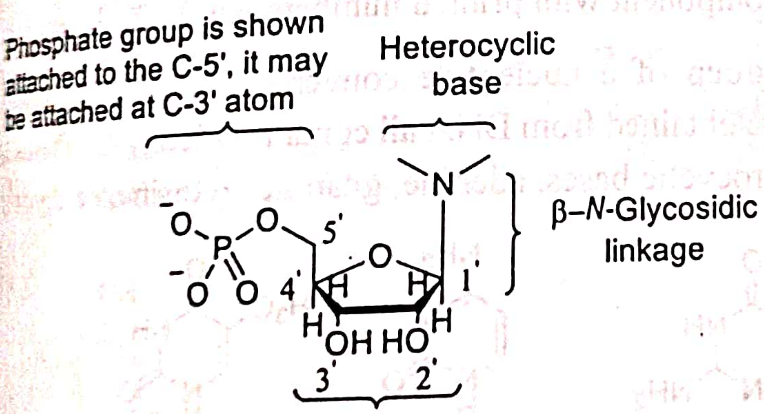
NUCLEIC ACIDS

Introduction:

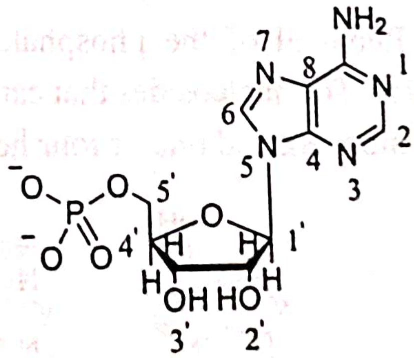
The nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), are, respectively, the molecules that preserve hereditary information and transcribe and translate it in a way that allows the synthesis of all the varied proteins of the cell. Much of our knowledge of how genetic information is preserved, how it is passed on to succeeding generations of the organism, and how it is transformed into the working parts of the cell has come from the study of nucleic acids. For these reasons, we shall focus our attention on the structures and properties of nucleic acids and of their components, *nucleotides* and *nucleosides*.

Nucleotides and Nucleosides:

Nucleic acids are linear polymers of monomeric units called *nucleotides*. Thus mild degradations of nucleic acids yield their monomeric unit, the nucleotides. A general formula for a nucleotide and the specific structure of one called adenosine 5'-phosphate (from RNA) are shown below:

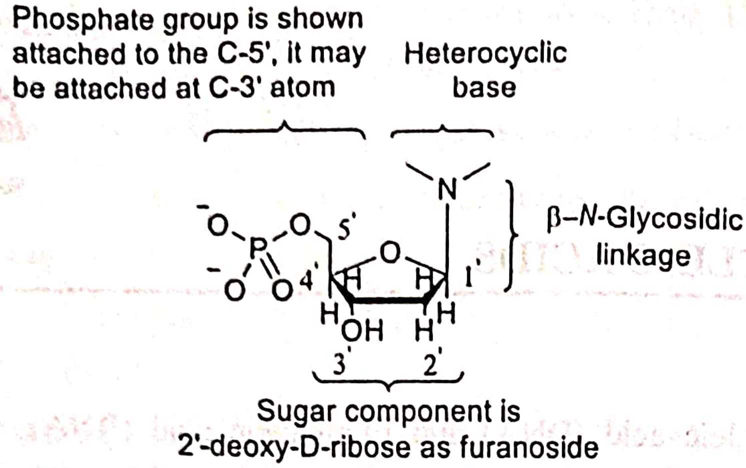


Sugar component is D-ribose as furanoside
General structure of a nucleotide from RNA

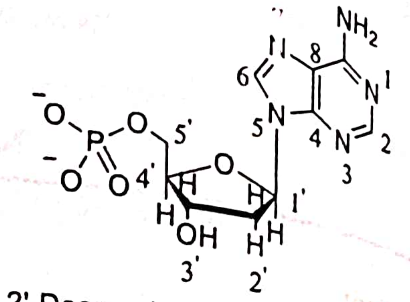


Adenosine 5'-phosphate, a typical nucleotide from RNA

Similarly, a general formula for a nucleotide and the specific structure of one called 2'-deoxyadenosine 5'-phosphate (from DNA) are shown below:



General structure of a nucleotide from DNA

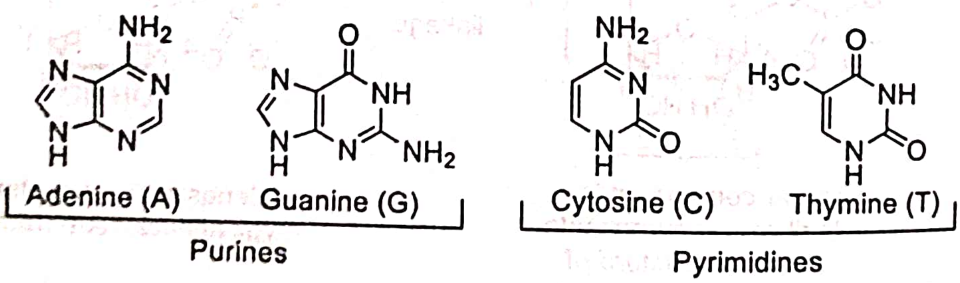

2'-Deoxyadenosine 5'-phosphate, a typical nucleotide from DNA

Complete hydrolysis of a nucleotide furnishes:

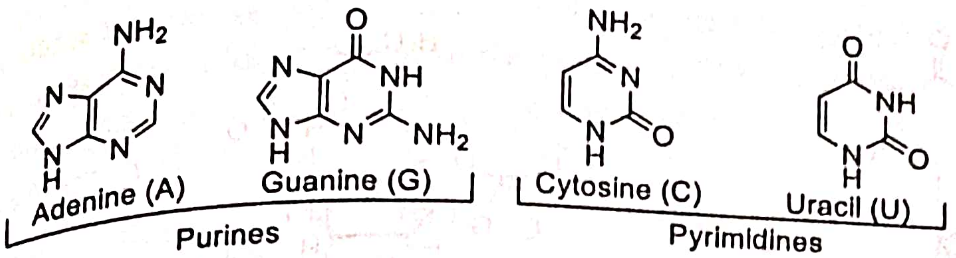
1. A heterocyclic base, either a purine or pyrimidine.
2. A five-carbon monosaccharide, either D-ribose or 2-deoxy-D-ribose.
3. A phosphate ion.

The central portion of the nucleotide is the monosaccharide, D-ribose or 2-deoxy-D-ribose and it is always present as a five-membered ring, that is, furanoside. The heterocyclic base of a nucleotide is attached through an *N*-glycoside linkage to C1' of D-ribose or 2-deoxy-D-ribose unit and this linkage is always β. The phosphate group of a nucleotide is present as a phosphate ester and it may be attached at C5'or C3'. In nucleotides, the carbon atoms of the monosaccharide portion are designated as their sugar component with primed numbers, i.e. 1', 2', 3', etc.

Removal of the phosphate group of a nucleotide converts it to a unit known as a *nucleoside*. The nucleosides that can be obtained from DNA all contain 2-deoxy-D-ribose as their sugar component and one of four heterocyclic bases, adenine, guanine, cytosine, or thymine:

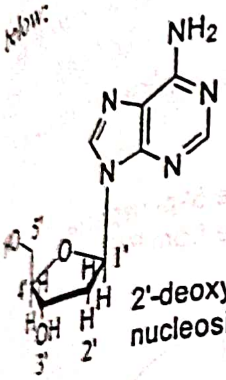


The nucleosides obtained from RNA contain D-ribose as their sugar unit and one of four heterocyclic bases, adenine, guanine, cytosine, or uracil:

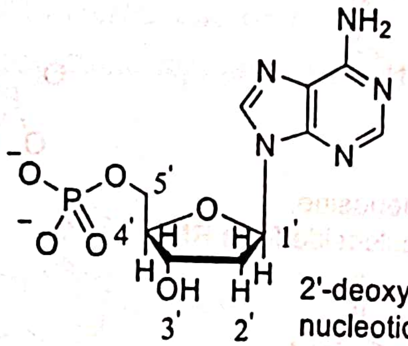


Notice that in an RNA nucleoside, uracil replaces thymine. The heterocyclic bases obtained from nucleosides are capable of existing in more than one tautomeric form. The forms that we have shown are the predominant forms that the bases assume when they are present in nucleic acids.

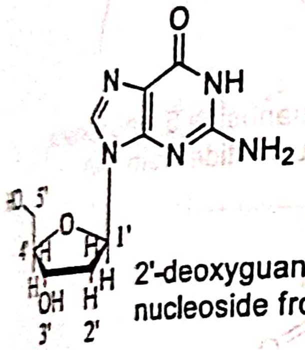
The names and structures of the nucleosides and nucleotides found in DNA are shown below:



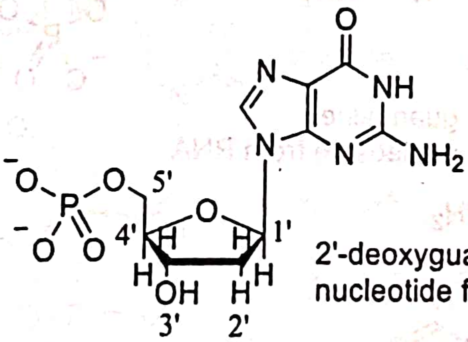
2'-deoxyadenosine, nucleoside from DNA



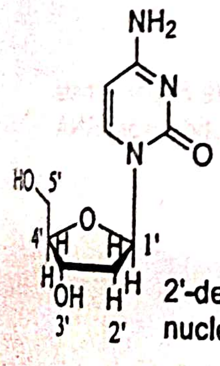
2'-deoxyadenosine 5'-phosphate, nucleotide from DNA



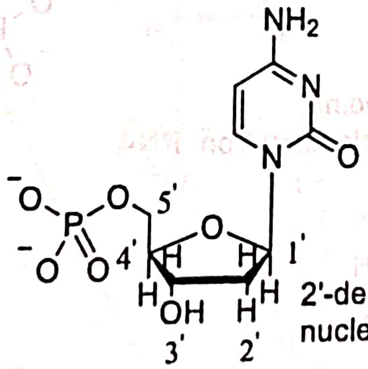
2'-deoxyguanosine, nucleoside from DNA



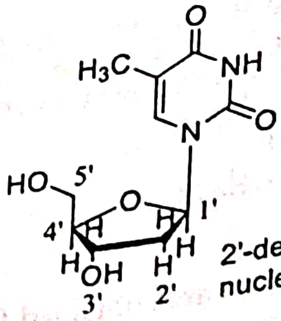
2'-deoxyguanosine 5'-phosphate, nucleotide from DNA



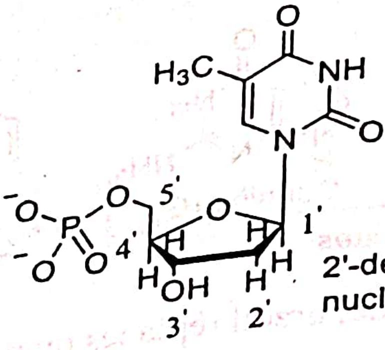
2'-deoxycytidine, nucleoside from DNA



2'-deoxycytidine 5'-phosphate, nucleotide from DNA

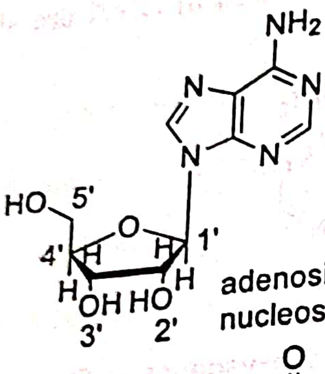


2'-deoxythymidine, nucleoside from DNA

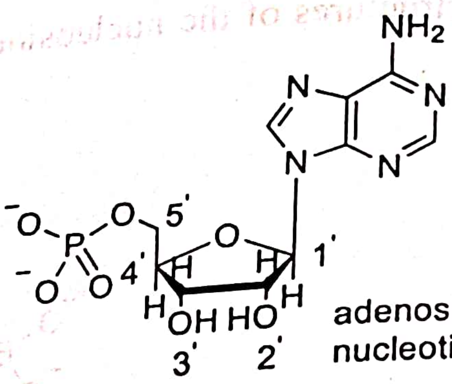


2'-deoxythymidine 5'-phosphate, nucleotide from DNA

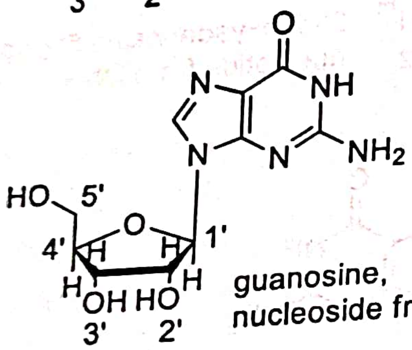
Similarly, the names and structures of the nucleosides and nucleotides found in RNA are shown below:



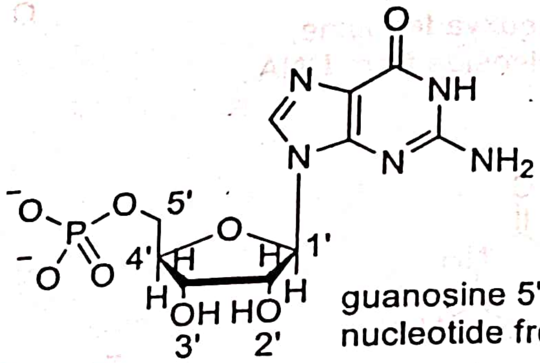
adenosine, nucleoside from RNA



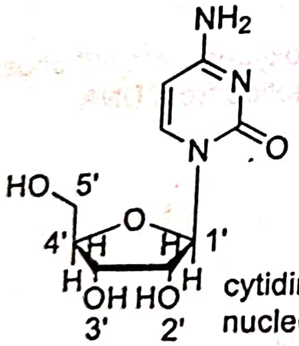
adenosine 5'-phosphate, nucleotide from RNA



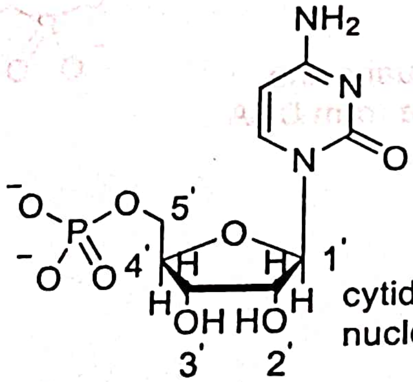
guanosine, nucleoside from RNA



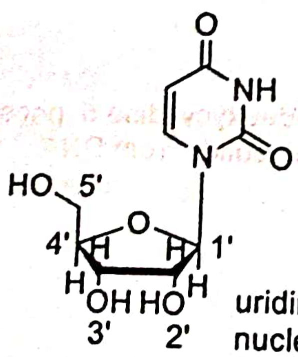
guanosine 5'-phosphate, nucleotide from rNA



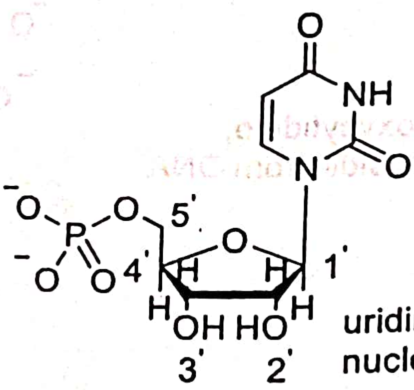
cytidine, nucleoside from RNA



cytidine 5'-phosphate, nucleotide from RNA



uridine, nucleoside from RNA



uridine 5'-phosphate, nucleotide from RNA

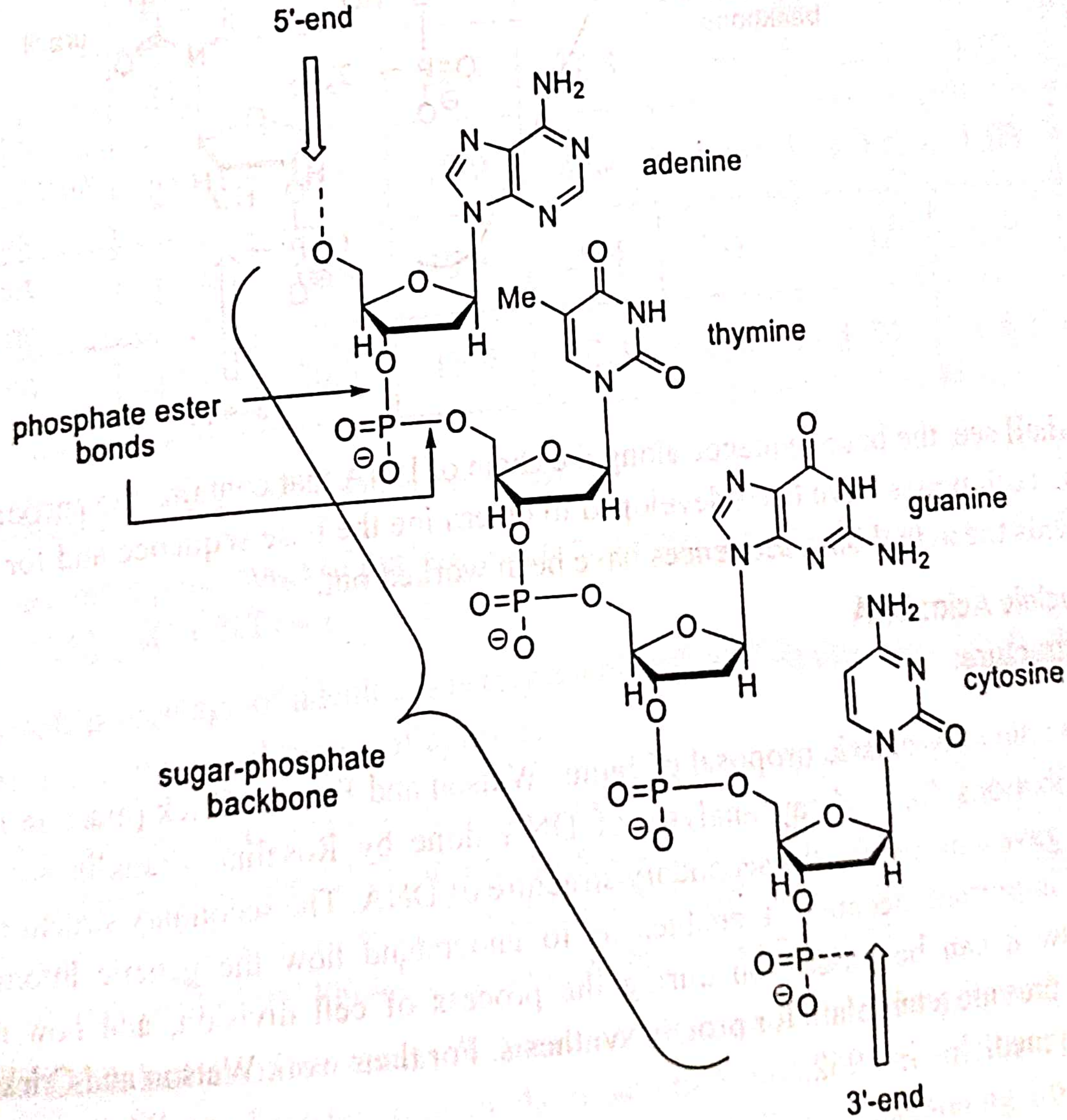
Nucleotides are named in several ways. Adenosine 5'-phosphate is sometimes called adenylic acid or 5'-adenylic acid in order to designate the position of the phosphate group, or simply adenosine monophosphate (AMP). Uridine 5'-phosphate is called uridylic acid, 5'-uridylic acid, or uridine monophosphate (UMP), and so on.

Deoxyribonucleic Acid: DNA

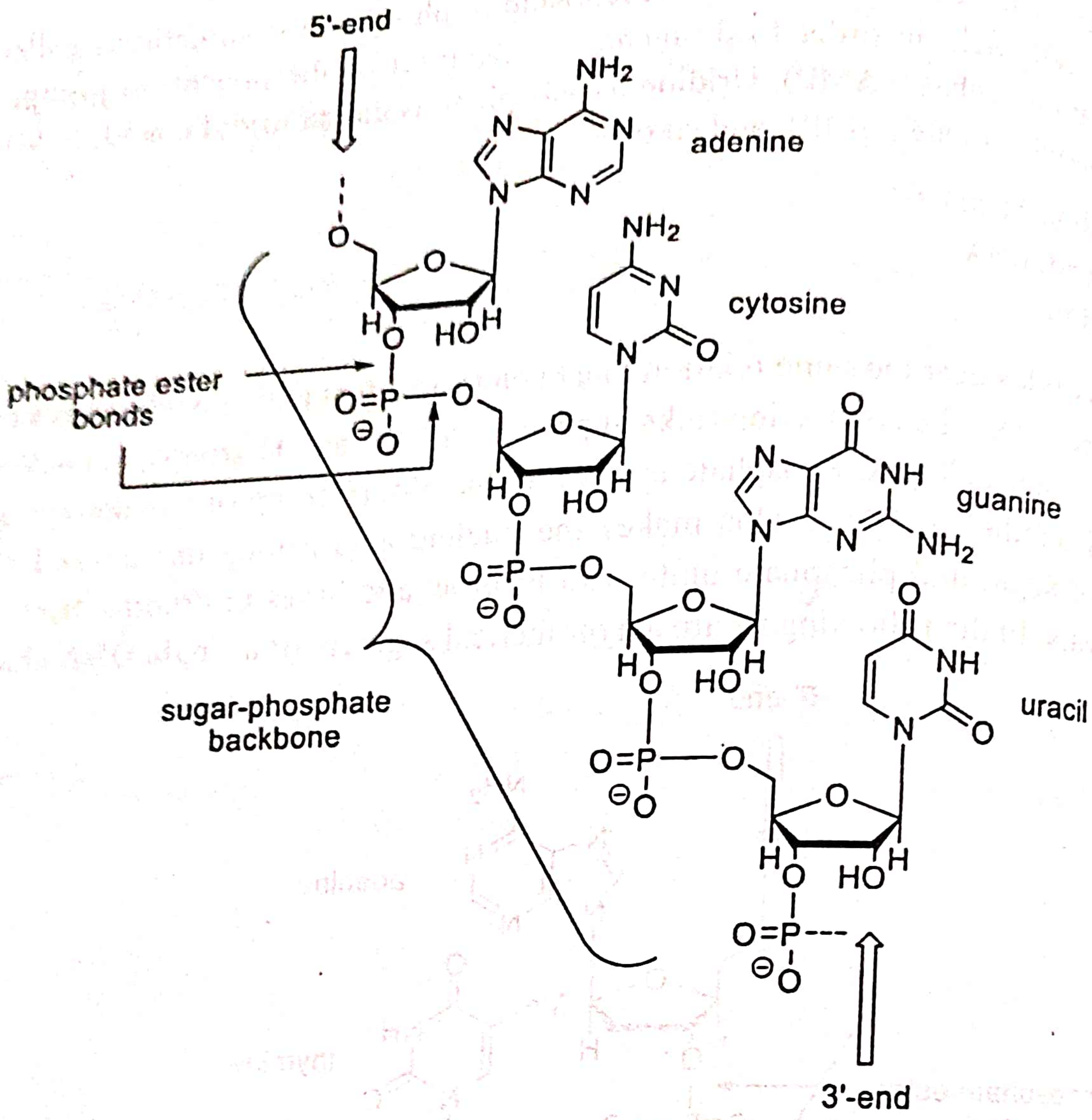
Ribonucleic Acid: RNA

Primary Structure:

Nucleotides bear the same relation to a nucleic acid that amino acids do to a protein; they are monomeric units. The connecting links in proteins are the amide groups; in nucleic acids they are phosphate ester linkages. Phosphate esters link the 3'-OH group of one deoxyribose with 5'-OH group of another in DNA. This makes the nucleic acid a long unbranched chain with a "backbone" of sugar and phosphate units with heterocyclic bases protruding from the chain at regular intervals. In the following figure a hypothetical segment of a single DNA chain is shown:



Similarly, a hypothetical segment of RNA chain is as shown below:



It is, as we shall see, the base sequence along the chain of DNA that contains the encoded genetic information. Techniques have been developed to determine the base sequence and for a number of nucleic acids the actual base sequences have been worked out.

Deoxyribonucleic Acid: DNA
Secondary Structure:

It was the now-classic proposal of James Watson and Francis Crick (made in 1953 with crucial contributions from X-ray analysis of DNA done by Rosalind Franklin and Maurice Wilkins) that gave a model for the secondary structure of DNA. The secondary structure of DNA is especially important because it enables us to understand how the genetic information is preserved, how it can be passed on during the process of cell division, and how it can be transcribed to provide a template for protein synthesis. For their work Watson and Crick won the Nobel Prize in medicine in 1962.