## **Nucleotides in the PDB**

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**ASBMB Learning Objectives**

(<https://www.asbmb.org/education/core-concept-teaching-strategies/foundational-concepts/structure-function>)

1. Biological macromolecules are large and complex

* Students should be able to **describe the basic units of the macromolecules** and the types of linkages between them *(Introductory)*.

2. Structure is determined by several factors

* Students should be able to **recognize the repeating units in biological macromolecules** and be able to discuss the structural impacts of the covalent and noncovalent interactions involved *(Introductory)*.

### Nucleotides:

#### Role in biology:

Nucleotides are the building blocks of nucleic acids such as DNA and RNA. They can also act as the energy currency and/or signaling molecules in cells.

#### Chemical structure of Nucleotides:

While all nucleotides have a nitrogenous base, a sugar, and at least one phosphate group, nucleotides that form RNA have a ribose sugar while DNA nucleotides have a deoxyribose sugar.

When two additional phosphate groups are bound to them (i.e., the nucleotide has a total of 3 phosphate groups), forming and breaking the covalent linkage between the second and third phosphate group helps store and release energy in cells, respectively.

|  |  |
| --- | --- |
|  |  |
| Nucleotide A (Ribonucleotide) | Nucleotide DA (Deoxyribonucleotide) |

Each of the atoms in a base, sugar and phosphate groups are numbered following a specific convention.

* The base atoms are identified by the element symbol followed by a number - e.g., N1, C2
* The sugar atoms are identified by the element name, number, and a prime (‘) so that they are distinct from the base atom names - e.g., C1’, C2’
* The phosphate atom uses the element name and P followed by numbers for identification.

This numbering makes it easy to communicate the position where a linkage is formed or a modification is located. For example the deoxyribose sugar is called 2’-deoxy because the Oxygen linked to the C2’ atom in ribose is missing in the deoxy sugar (shown in the figure above). The phosphodiester bond between two nucleotides occurs due to a dehydration reaction between the 3’ hydroxyl and the phosphate group linked to the 5’ carbon in another nucleotide.

Did you know that the definitions, chemical formulae, and representative coordinates for all nucleotides are available in the [Chemical Component Dictionary](https://www.wwpdb.org/data/ccd) (maintained by the wwPDB)? You can search for these components or ligands using the [Ligand Expo](http://ligand-expo.rcsb.org/index.html) tool or directly from the [RCSB PDB](https://www.rcsb.org/) website.

### Explore:

* Explore the four common DNA nucleotides - [DA, DG, DC, DT](https://www.rcsb.org/search?request=%7B%22query%22%3A%7B%22type%22%3A%22group%22%2C%22logical_operator%22%3A%22and%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22logical_operator%22%3A%22and%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22terminal%22%2C%22service%22%3A%22text_chem%22%2C%22parameters%22%3A%7B%22attribute%22%3A%22rcsb_chem_comp_container_identifiers.comp_id%22%2C%22operator%22%3A%22in%22%2C%22negation%22%3Afalse%2C%22value%22%3A%5B%22dA%22%2C%22dt%22%2C%22dc%22%2C%22dg%22%5D%7D%7D%5D%2C%22logical_operator%22%3A%22and%22%7D%5D%2C%22label%22%3A%22text_chem%22%7D%5D%7D%2C%22return_type%22%3A%22mol_definition%22%2C%22request_options%22%3A%7B%22paginate%22%3A%7B%22start%22%3A0%2C%22rows%22%3A25%7D%2C%22scoring_strategy%22%3A%22combined%22%2C%22sort%22%3A%5B%7B%22sort_by%22%3A%22score%22%2C%22direction%22%3A%22desc%22%7D%5D%7D%2C%22request_info%22%3A%7B%22query_id%22%3A%229229853bce47884335b45643385af433%22%7D%7D). Note the D here denotes deoxy, for the deoxyribose sugar. Note: in the literature you may see these listed as dA, dG, dC, and dT.
* Explore the four common RNA nucleotides - [A, G, C, U](https://www.rcsb.org/search?request=%7B%22query%22%3A%7B%22type%22%3A%22group%22%2C%22logical_operator%22%3A%22and%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22logical_operator%22%3A%22and%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22terminal%22%2C%22service%22%3A%22text_chem%22%2C%22parameters%22%3A%7B%22attribute%22%3A%22rcsb_chem_comp_container_identifiers.comp_id%22%2C%22operator%22%3A%22in%22%2C%22negation%22%3Afalse%2C%22value%22%3A%5B%22A%22%2C%22U%22%2C%22C%22%2C%22G%22%5D%7D%7D%5D%2C%22logical_operator%22%3A%22and%22%7D%5D%2C%22label%22%3A%22text_chem%22%7D%5D%7D%2C%22return_type%22%3A%22mol_definition%22%2C%22request_options%22%3A%7B%22paginate%22%3A%7B%22start%22%3A0%2C%22rows%22%3A25%7D%2C%22scoring_strategy%22%3A%22combined%22%2C%22sort%22%3A%5B%7B%22sort_by%22%3A%22score%22%2C%22direction%22%3A%22desc%22%7D%5D%7D%2C%22request_info%22%3A%7B%22query_id%22%3A%22e1439f949357c1135b60fa6adac8a9bc%22%7D%7D). Note that these nucleotides have a ribose sugar.
* Besides these common nucleotides, PDB structures have many modified nucleotides that are either present in nature or designed. Explore all [DNA nucleotides](https://www.rcsb.org/search?request=%7B%22query%22%3A%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22terminal%22%2C%22service%22%3A%22text_chem%22%2C%22parameters%22%3A%7B%22attribute%22%3A%22chem_comp.type%22%2C%22value%22%3A%22DNA%20linking%22%2C%22operator%22%3A%22exact_match%22%7D%7D%5D%2C%22logical_operator%22%3A%22or%22%2C%22label%22%3A%22chem_comp.type%22%7D%5D%2C%22logical_operator%22%3A%22and%22%7D%5D%2C%22logical_operator%22%3A%22and%22%2C%22label%22%3A%22text_chem%22%7D%5D%2C%22logical_operator%22%3A%22and%22%7D%2C%22return_type%22%3A%22mol_definition%22%2C%22request_options%22%3A%7B%22paginate%22%3A%7B%22start%22%3A0%2C%22rows%22%3A25%7D%2C%22scoring_strategy%22%3A%22combined%22%2C%22sort%22%3A%5B%7B%22sort_by%22%3A%22score%22%2C%22direction%22%3A%22desc%22%7D%5D%7D%2C%22request_info%22%3A%7B%22query_id%22%3A%222b9f07c4b5251a2042ea47bc3c79111c%22%7D%7D) and [RNA nucleotides](https://www.rcsb.org/search?request=%7B%22query%22%3A%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22group%22%2C%22nodes%22%3A%5B%7B%22type%22%3A%22terminal%22%2C%22service%22%3A%22text_chem%22%2C%22parameters%22%3A%7B%22attribute%22%3A%22chem_comp.type%22%2C%22value%22%3A%22RNA%20linking%22%2C%22operator%22%3A%22exact_match%22%7D%7D%5D%2C%22logical_operator%22%3A%22or%22%2C%22label%22%3A%22chem_comp.type%22%7D%5D%2C%22logical_operator%22%3A%22and%22%7D%5D%2C%22logical_operator%22%3A%22and%22%2C%22label%22%3A%22text_chem%22%7D%5D%2C%22logical_operator%22%3A%22and%22%7D%2C%22return_type%22%3A%22mol_definition%22%2C%22request_options%22%3A%7B%22paginate%22%3A%7B%22start%22%3A0%2C%22rows%22%3A25%7D%2C%22scoring_strategy%22%3A%22combined%22%2C%22sort%22%3A%5B%7B%22sort_by%22%3A%22score%22%2C%22direction%22%3A%22desc%22%7D%5D%7D%2C%22request_info%22%3A%7B%22query_id%22%3A%2216c2f9f1052ba28e9f1996a97558bfeb%22%7D%7D) in PDB’s Chemical Component Dictionary to learn more.

### Examine:

To learn more about each nucleotide you can examine its Ligand summary page.

For example for [GT](https://www.rcsb.org/ligand/GTP), you can

* Examine the 2D and 3D structures of the molecule



* Access the complete chemical name, formula, and other chemical identifiers



* Download files, identify PDB entries where the molecule is present as part of a polymer, covalently bound, or interacting through non-covalent interactions.

 

* Find other ligands in the dictionary with the same or similar chemical properties.

 

* Where available, information about the molecule being a drug or nutraceutical and links to the DrugBank to access additional information.

