Teacher Guide

The discovery of the structure of DNA by James Watson and Francis Crick in 1953 was one of the most momentous scientific advances of the last century. This discovery has had far-reaching implications for modern molecular science and society. Students using the *Dynamic DNA Kit©* will explore the importance of this discovery through a study of **DNA STRUCTURE**, **FUNCTION** and **BIOINFORMATICS**.

Part 1 - DNA Structure: Nucleotides as Building Blocks of DNA

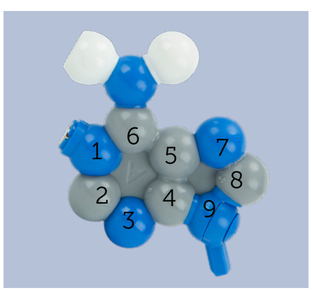
Note: The model is based on X-ray crystallographic structures and is built to scale (approximately 80,000,000 times actual size). For clarity in the model, hydrogen atoms are not shown except for the hydrogens forming the hydrogen bonds between the base pairs (shown in white) and the insertable hydrogen of the hydroxyl group on the 3' carbon of the sugar at the end of each DNA strand. The remaining colors used in the model are standard CPK colors and are as follows:

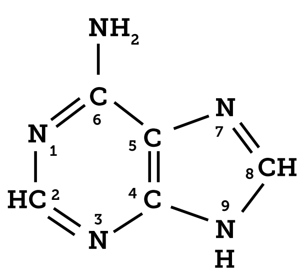
Carbon atoms: Grey	**Nitrogen atoms:** Blue
Oxygen atoms: Red	**Phosphorus atoms:** Orange

Engage with an exploration of the component parts of DNA nucleotides.
Compare, contrast and identify structures of the constituent parts.

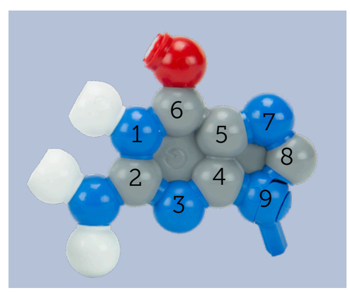
Nitrogenous Bases demonstrate variability with the purines: **adenine** and **guanine**, consisting of two fused rings and the pyrimidines: **cytosine** and **thymine**, consisting of a single ring.

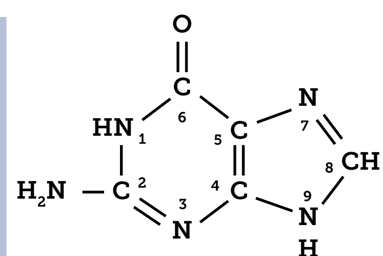
Purines





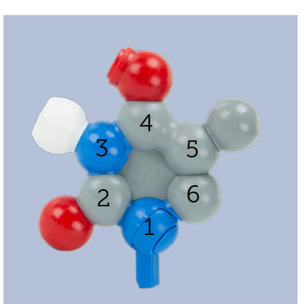
adenine (A)

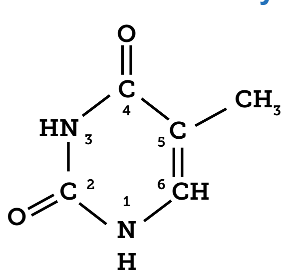




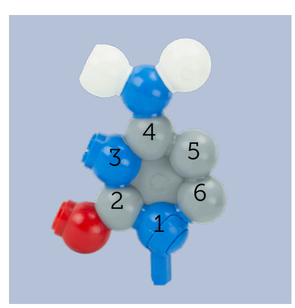
guanine (G)

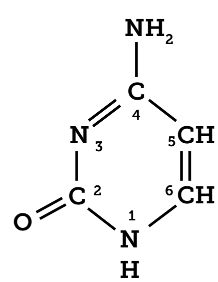
Pyrimidines





thymine (T)





cytosine (C)

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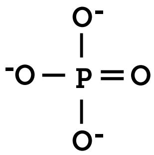
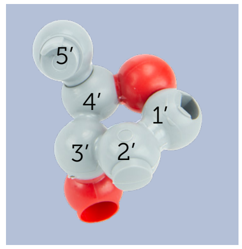
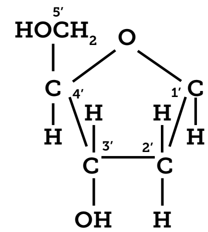
Phosphate (PO_4^{3-})



phosphate

Deoxyribose (5 carbon sugar forming a ring structure)



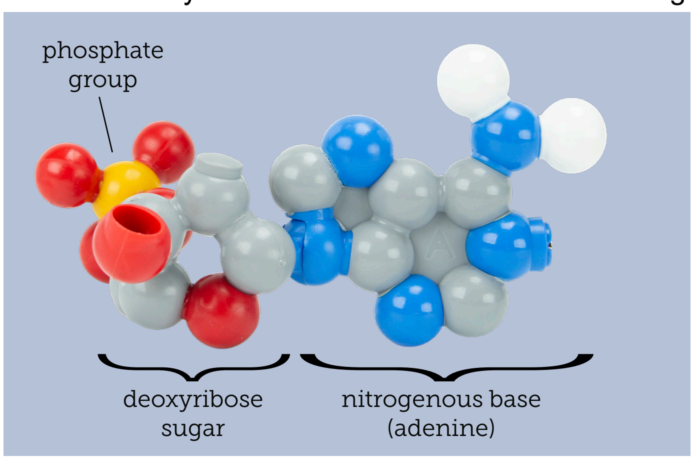


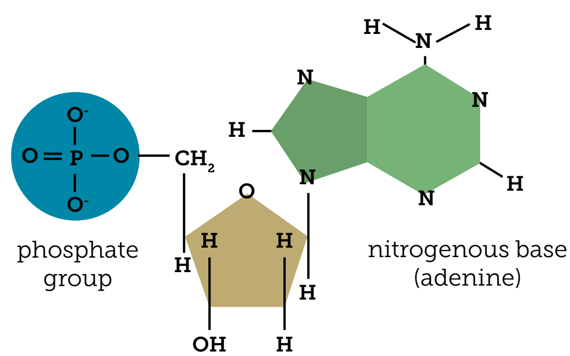
deoxyribose

Note: The polarity of a DNA strand (5’ → 3’) is determined by the order of the carbon atoms **within a single nucleotide**. The prime (‘) symbol distinquishes ribose carbons from nitrogonous base carbons.

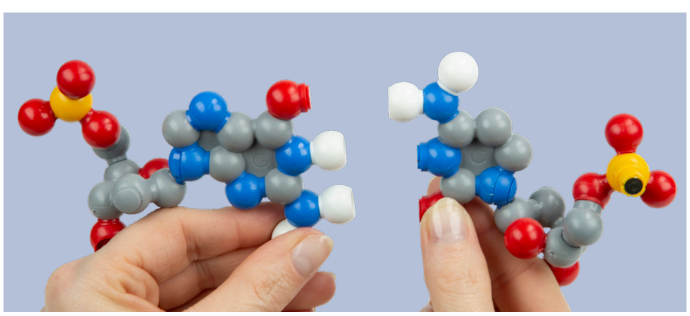
Note: Parts are shown without capped oxygen.

Join the constituent parts together using only the posts to form a **nucleotide.** Refer to the assembly instructions if you need directions. There are no magnet connections within a single base.

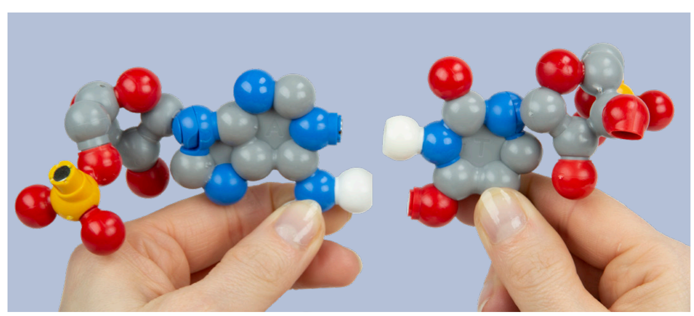




Base pair the complementary nucleotides, G with C and A with T, using the magnets to connect the hydrogen bonds. Ask your students how this base pairing explains **Chargaff’s rules**.



Three hydrogen bonds unite the G-C base pair.



Two hydrogen bonds unite the A-T base pair.

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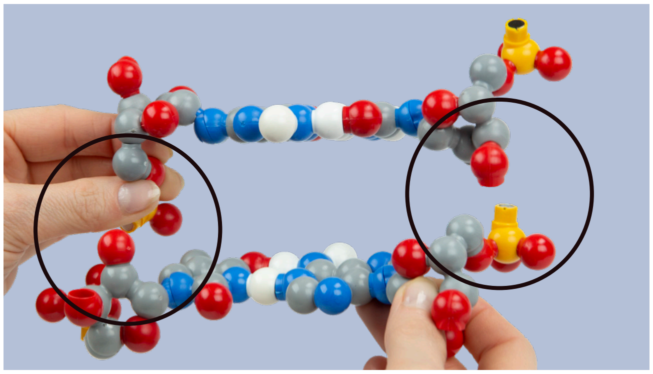
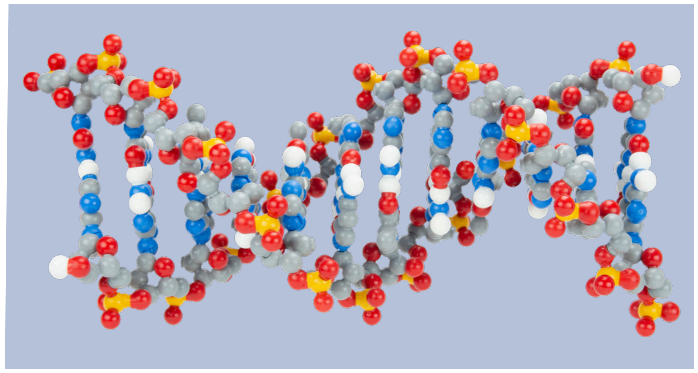
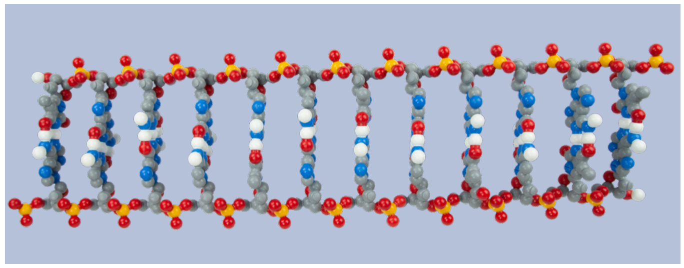


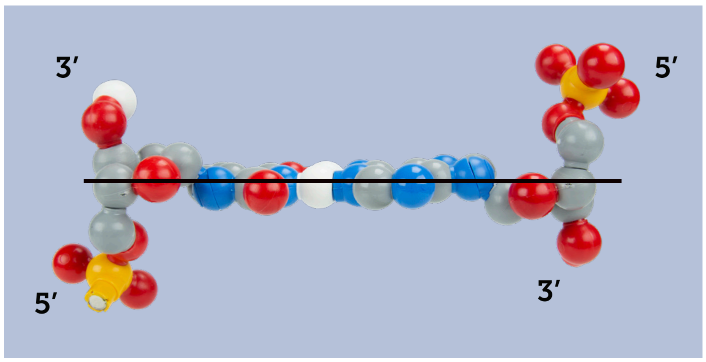


Assemble the base pairs to form a 12 base-pair double helix. You will need to set the DNA on a table and may wish to feed a metal rod through the middle. You'll need a rod to twist and untwist all 12 base pairs at the same time. We recommend you purchase a 24" long, 1/4" thick metal rod from your local home improvement store. Note that *Dynamic DNA* untwists into a flattened 2D ladder and transitions to the classic right handed, 3D double helix, demonstrating the dynamic nature of the molecule.



Non-standard base pairing can occur; however, these base pairs are not compatible with the double stranded helical structure of DNA for two reasons. First, base pairs formed with two purines or two pyrimidines will have a different diameter than the standard G – C and A – T base pairs. Second, when the non-standard hydrogen bonded base pairs form, the polarity of the strands of DNA will be parallel, not the anti-parallel structure consistent with DNA structure.

Have your students identify the component parts of the sides or backbone of the DNA model. Notice that the 5' phosphate of one strand is located opposite the 3' hydroxyl of the complementary strand. The two component strands are anti-parallel, with one strand oriented in the 5'- 3' direction and the other in the 3'- 5' direction. The opposite orientation of the two complementary strands has important implications for DNA replication and transcription.



Since the sequence of the nitrogen bases can change without changing the overall structure of the molecule, ask your students to propose how this may contribute to the function of DNA as an information storage molecule.

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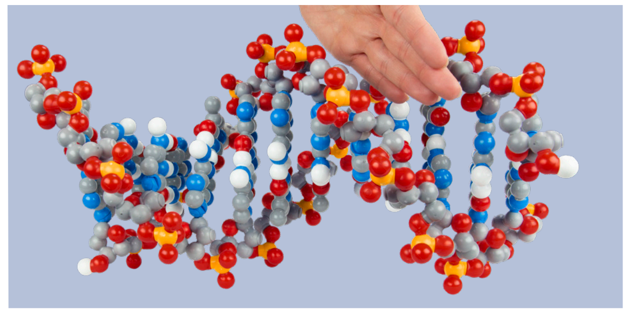
An important feature of the DNA double helix is that the two strands are twisted around each other, forming a major and a minor groove.

major groove

minor groove

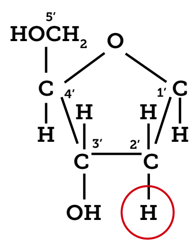


Conversion of DNA Structure to RNA Structure

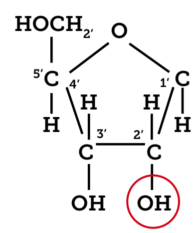
The *Dynamic DNA Kit©* can also be used to compare DNA and RNA structure.

To convert the deoxyribose sugar to ribose, add an oxygen to the 2' carbon of the sugar.

Ask your students, "What is the purpose of the extra oxygen in the RNA?"



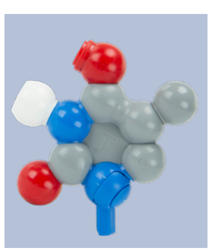
deoxyribose

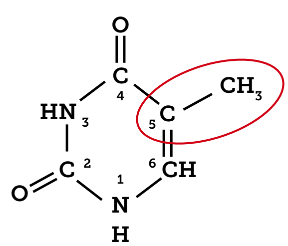


ribose

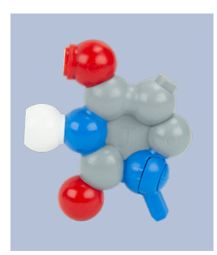
To convert the thymine to uracil remove the methyl group from the carbon in fifth position in the nitrogen ring of thymine.

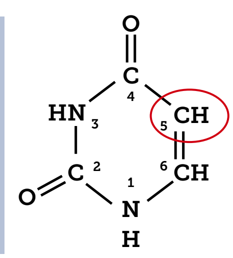
Ask your students, "Why uracil in RNA and thymine in DNA?"





thymine (T)





uracil (U)

Note: When making the uracil nucleotide, make sure to attach a ribose sugar, not a deoxyribose.

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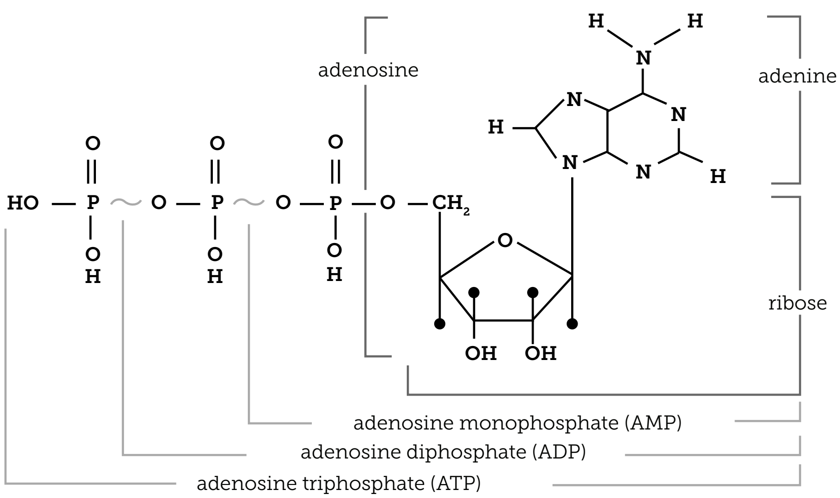
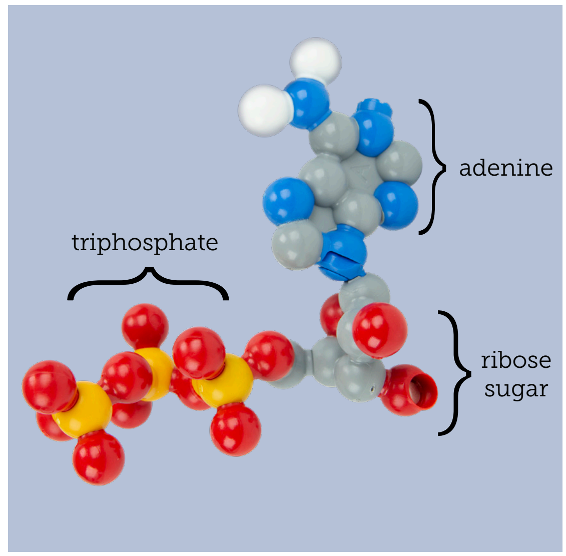
Modeling ATP

Adenosine-5'-triphosphate (ATP) is composed of **one adenine nitrogenous base**, **one ribose sugar** and **three phosphate groups**. ATP is the primary energy currency in biology.

Model AMP, ADP and ATP by adding phosphate groups to the adenine nucleotide phosphate group. Refer to the assembly instructions if you need directions.





Misconception Alert: The bonds between the phosphate groups of ATP are sometimes referred to as *high-energy* or *energy-rich* bonds. These terms can lead to a misconception that energy is released when the bond is broken. **All chemical bonds require energy to be broken and release energy when they form**.