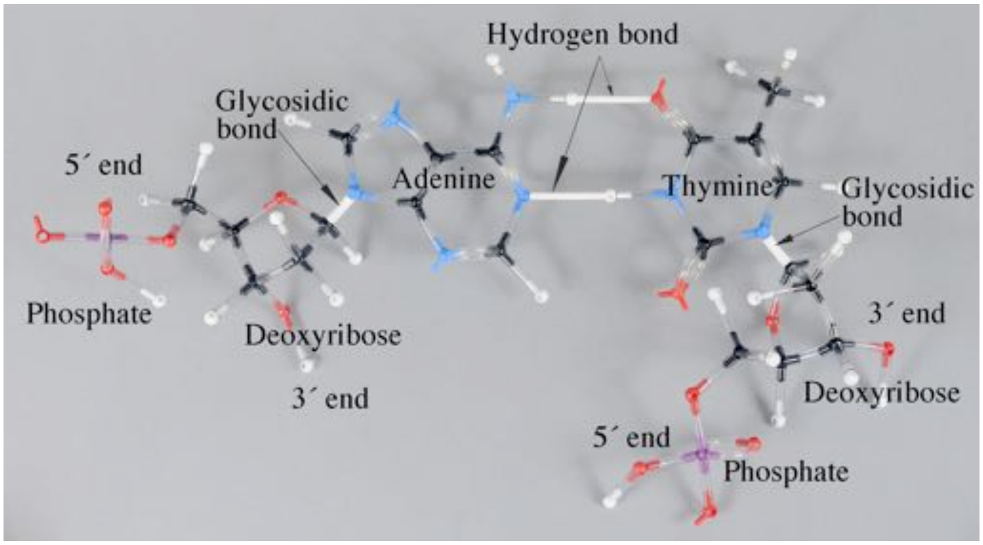
Super Models



Nucleotides
Molecular Model Kit

Ryler Enterprises, Inc.

Recommended for ages 10 - adult

Caution: Atom centers and vinyl tubing are a choking hazard. Do not eat or chew model parts.

Kit Contents:

60 white 1-peg hydrogen atom centers (1 spare)
16 blue 4-peg nitrogen atom centers (1 spare)
5 red 4-peg oxygen atom centers (1 spare)
25 red 2-peg oxygen atom centers (1 spare)
40 black 4-peg carbon atom centers (1 spare)
5 purple 5-peg phosphorus atom centers (1 spare)
6 white 2-peg hydrogen atom centers (1 spare)
128 clear, 1.25˝ bonds (2 spares)
30 clear, 4 cm bonds (2 spares)
6 white, 2˝ bonds (1 spare)
6 white, rigid 5 cm bonds (1 spare)
5 white, 0.87˝ bonds (1 spare)

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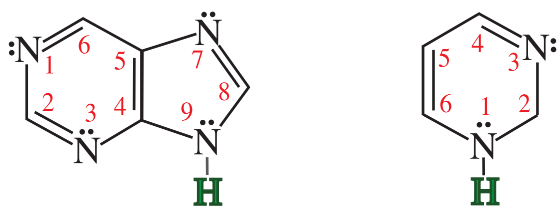
Nucleotides

General Information.

Nucleotides are the monomeric units which, when repeated many times, produce the extremely large biopolymers DNA and RNA. Nucleotides are composed of three parts; 1) a nitrogenous base; 2) a sugar; and 3) a phosphate ion.

There are two groups of nitrogen bearing bases (nucleobases) in nucleotides, purines and pyrimidines. Fig. 1 shows the basic structures found in all purines and pyrimidines, including the system for numbering the atoms in each.

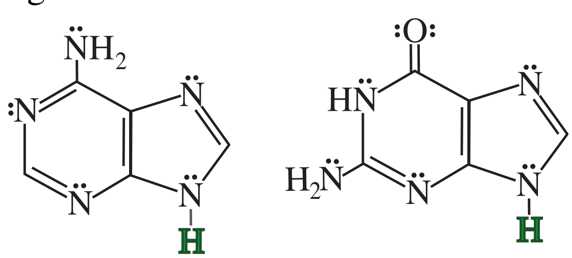


Purine numbering system

Pyrimidine numbering system

Fig. 1 Basic structures of purines and pyrimidines and the numbering systems.

The most common purines of DNA and RNA are adenine (A) and guanine (G). See Fig. 2.

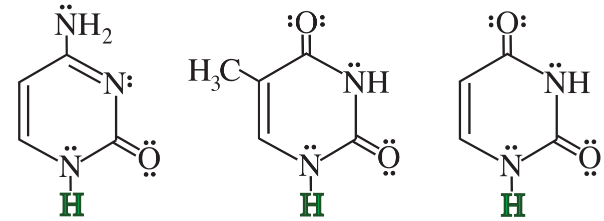


Adenine (A)

Guanine (G)

Fig. 2 Adenine and guanine.

The pyrimidine, cytosine (C), is found in DNA and RNA, while thymine (T) is found in DNA only, and uracil (U) is found in RNA exclusively, replacing thymine. See Fig. 3.



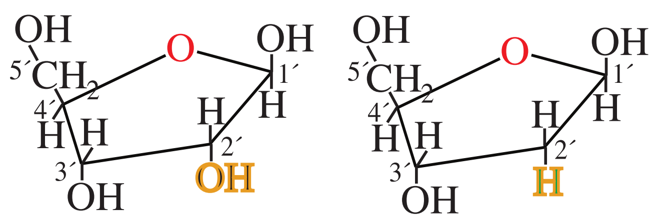
Cytosine (C)

Thymine (T)

Uracil (U)

Fig. 3 The pyrimidines, cytosine, thymine, and uracil.

The sugar of RNA is ribose, and in DNA the sugar is 2´-deoxyribose. The carbon atoms of both are indicated with prime (´) numbers in order to avoid conflict with the numbers of the nucleobases. The yellow –H and –OH emphasize the difference between ribose and deoxyribose. See Fig. 4.



Ribose

2´-Deoxyribose

Fig. 4 Comparing ribose and 2´-deoxyribose.

Carbon atoms form a tetrahedral shape (see Fig. 5) when they are bonded to four other atoms. The bonds in tetrahedral carbon are separated by angles of 109.5°.

Fig. 5 A tetrahedral carbon atom with 109.5° angles between all bonds.

The tetrahedral carbon atoms in the ribose and deoxyribose sugars of RNA and DNA respectively, are forced to have bond angles which are less than 109.5°. This condition raises the energy of the ring systems, and increased energy means less stability. In nature, the high energy of the sugar is reduced by rotating one of the carbon atoms out of the plane of the ring. In your sugar models, you can demonstrate the rotation by twisting the C2´ atom so that it is above the plane of the ring. Fig. 6 shows the C2´ of deoxyribose in an up position.

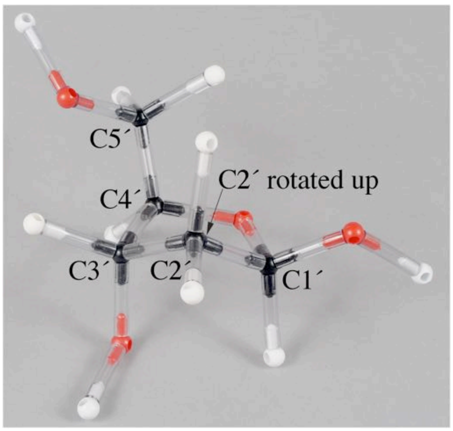


Fig. 6 C2´ of deoxyribose rotated up.

Fig. 7 shows a phosphate ion. Before bonding to a sugar molecule at C5´, the ion loses an oxygen and a hydrogen atom.

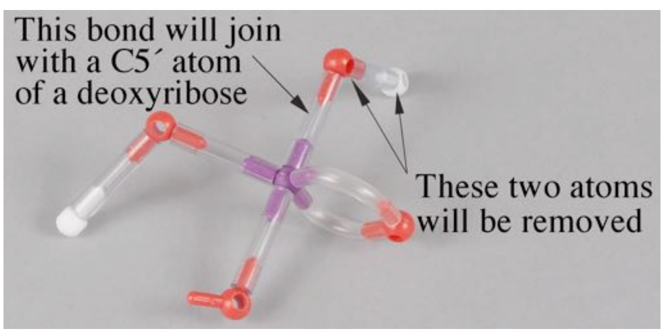


Fig. 7 A phosphate ion with a charge of 1-.

The molecule that results from bonding a nucleobase to carbon number one of ribose is called a ribonucleoside, and when a base is bonded to C1´ of deoxyribose, a deoxyriboside results.

Bonding a phosphate to a ribonucleoside at C5´ forms a ribonucleotide. A phosphate joined with a deoxyribonucleoside at its C5´ will make a deoxyribonucleotide.

The following two tables provide the naming conventions for the common DNA and RNA nucleobases, nucleosides, and nucleotides.

DNA

Primary Base Name	Nucleoside Name	Nucleotide Name (with one phosphate)
Adenine	deoxyandenosine	deoxyandenosine monophosphate (dAMP)
Guanine	deoxyguanosine	deoxyguanosine monophosphate (dGMP)
Cytosine	deoxycytidine	deoxycytidine monophosphate (dCMP)
Thymine	deoxythymidine	deoxythymidine monophosphate (dTMP)

RNA

Primary Base Name	Nucleoside Name	Nucleotide Name (with one phosphate)
Adenine	andenosine	andenosine monophosphate (AMP)
Guanine	guanosine	guanosine monophosphate (GMP)
Cytosine	cytidine	cytidine monophosphate (CMP)
Uracil	Uridine	uridine monophosphate (UMP)

DNA usually exists as a double stranded, elongated molecule called a double helix, or duplex, that is shaped like a ladder. The side pieces are made of alternating phosphate ions and deoxyribose molecules. The rungs are formed by hydrogen bonded bases. A single strand of the duplex is a long chain of nucleotides. In Fig. 8, two separate strands of DNA are displayed side by side. Notice that the strands are anti-parallel. That is they, they run in opposite directions with the 5´ end of the strand on the left being at the top, while the 5´ end of the strand on the right has its 5´ at the bottom. Notice also that the sugar molecules of each strand are pointing in different directions. The hydrogen atoms have been left out to insure clarity.

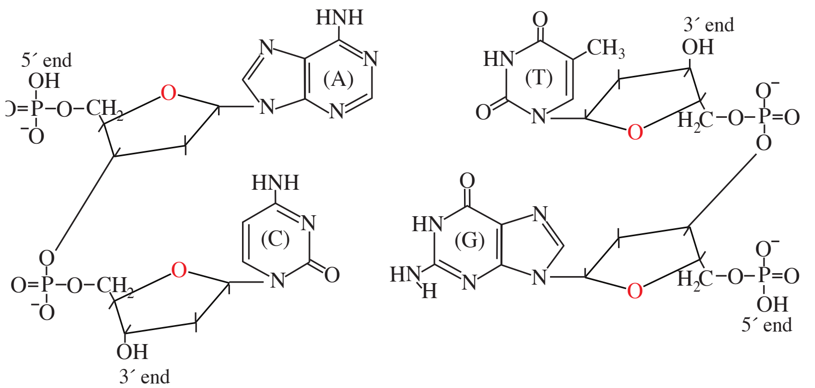


Fig. 8 Two strands of deoxyribonucleotides with opposite directionality, not bonded to each other.

The two strands are joined together with hydrogen bonds, three between C and G, and two between A and T, as shown in Fig. 9.

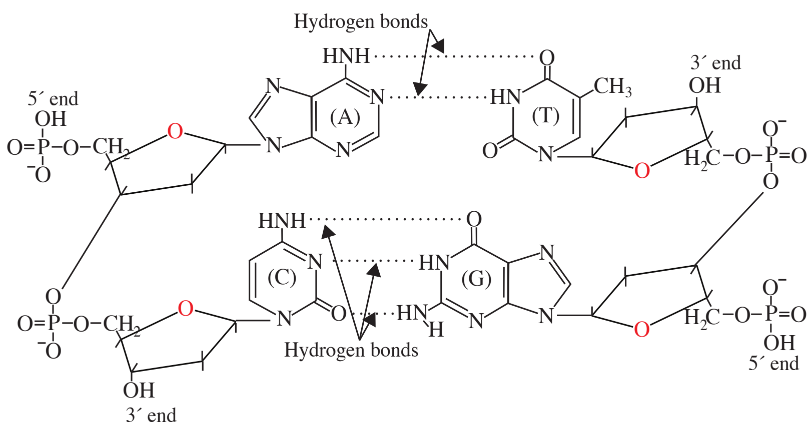


Fig. 9 Two strands of deoxyribonucleotides joined by hydrogen bonds.

The result of hydrogen bonding and twisting the DNA into a helix (spiral) is illustrated in Fig. 10. The form shown is the most common shape. Two other, less frequently observed shapes are A DNA, which also has a right handed twist, but it has a wider diameter, and Z DNA, which is twisted to the left, and it zigzags (hence its title “Z”).

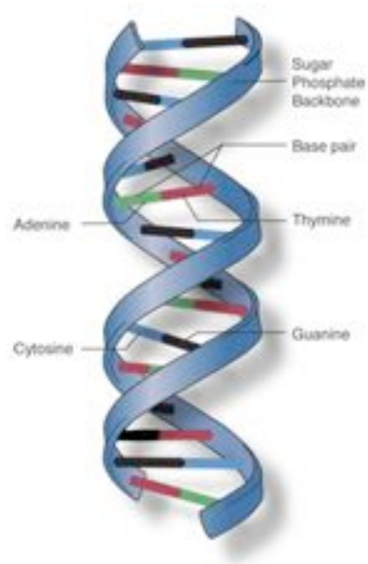


Fig. 10 The major form of DNA in all cell, the B DNA double helix.

There are about two dozen kinds of RNA molecules found in nature. What they all have in common is 1) they are long, single strands, 2) they are not as long as DNA, 3) they use the sugar ribose instead of deoxyribose, 4) they use uracil in place of the thymine base found in DNA.

It is not uncommon for RNA molecules to make a hairpin turn and have two or more sections of a strand bond according to the same rules as DNA. That is, A bonds to U (remember the T of DNA is replaced by U in RNA), and G bonds to C.

LABORATORY PROCEDURE

A. Make four 2´ deoxyribose molecules (refer back to Fig. 4). Use the two-peg oxygens for the sugars. Make sure that you know the numbering system used to identify each of the carbon atoms in the molecule.

B. Next make one of each of the following, adenine and guanine (see Fig. 2), and cytosine and thymine (see Fig. 3).

C. Remove the hydrogen atoms shown as green H's in the illustrations and the —OH's at C1´ from the sugars. Using short, white tubes bond the nucleobases to the deoxyribose sugars at C1´. When a different group of atoms is bonded at C1´ it is called a glycosidic bond.

As you make the glycosidic bond, make sure to use the correct peg on the nitrogen (blue) atom (in Fig. 1, atom number 1 for a pyrimidine, atom number 9 in a purine). The deoxyribose and the nucleobase should be in the same plane as you see in Fig. 11. If you have used the wrong peg on the nitrogen, you will see the arrangement of ribose and thymine in Fig. 12.

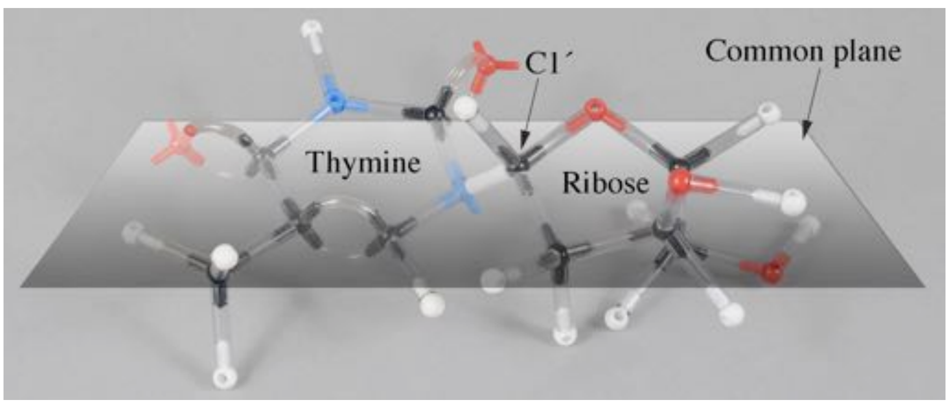


Fig. 11 Deoxyibose and the nucleobase, thymine in the same plane.

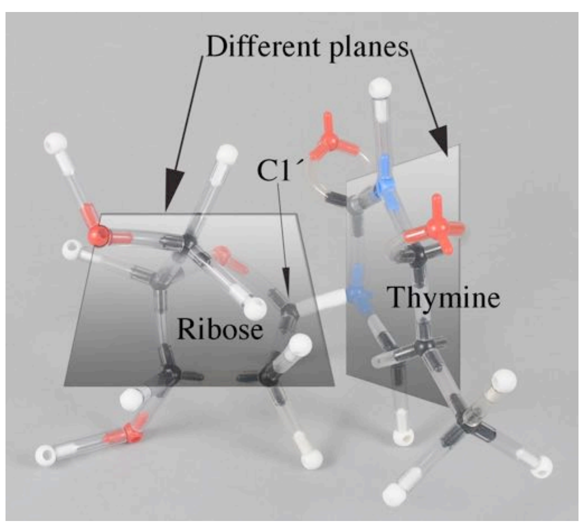


Fig. 12 Incorrect nitrogen peg was used: deoxyribose and thymine not in same plane.

You should now have four different deoxynucleosides. In order to get the oxygen of the sugar to point “up” or “down” as in Fig. 13, just twist the sugar to get the desired position.

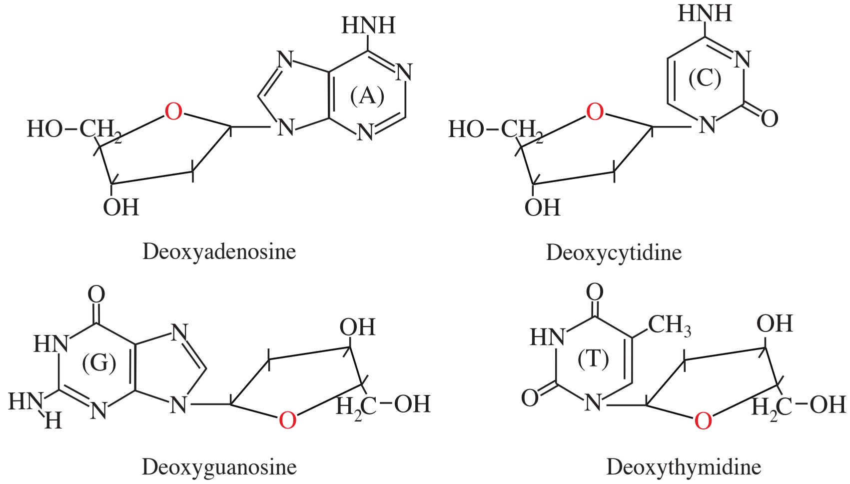


Fig. 13 The four completed deoxynucleosides.

D. Now bond phosphates (Fig. 7) to each of the sugars at their C5´ carbons. Do this by removing the —OH from the phosphate and the hydrogen along with its bond from the sugar and then attaching the open phosphate bond to the sugar . You now have four deoxyribonucleotides (see Fig. 14).

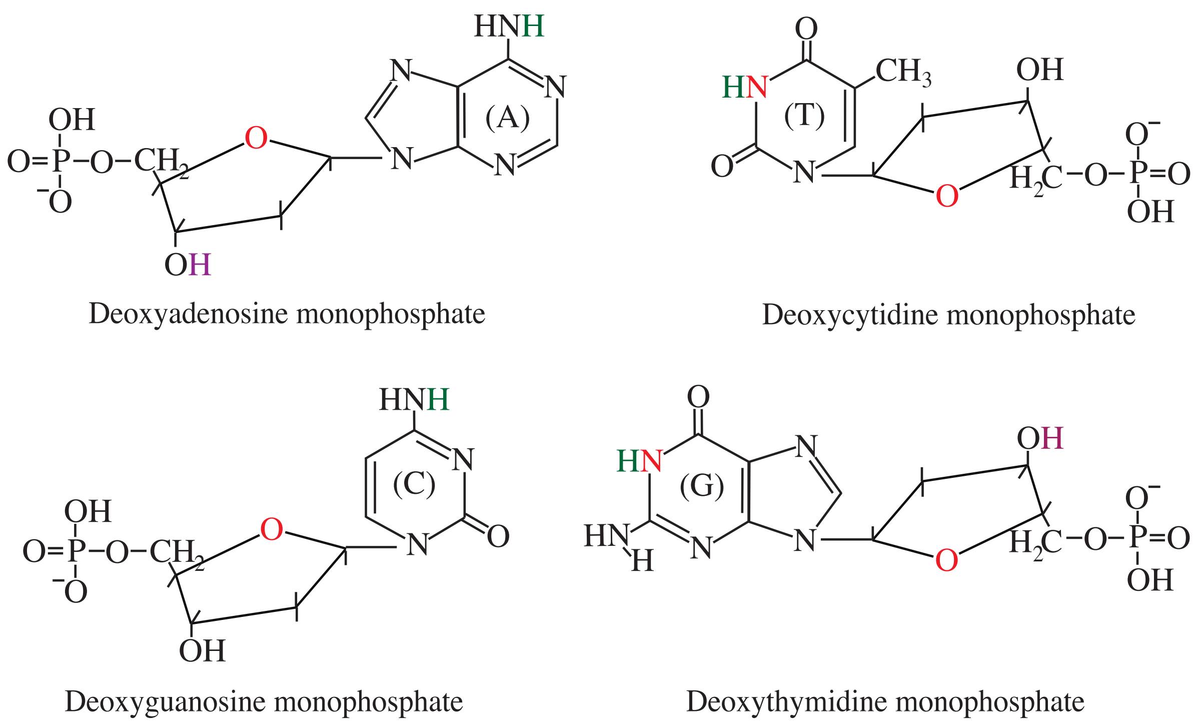


Fig. 14 Four deoxyribonucleotides.

E. Next, make a dinucleotide by removing the second —OH and bond from the phosphate on deoxyguanosine monophosphate, and remove the purple —H atom (not the bond) from deoxyadenosine monophosphate. Attach the unoccupied bond from the deoxyguanosine to the peg on the purple atom on the phosphate of deoxyguanosine. The result should look like Fig. 15.

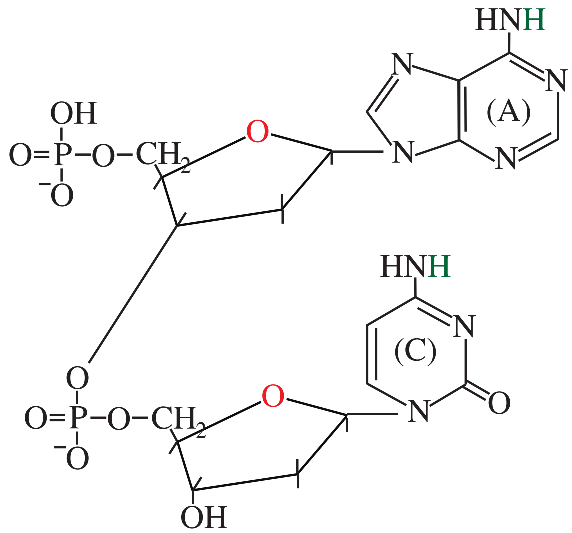


Fig. 15 A dinucleotide.

F. In a similar manner, make a second dinucleotide to look like Fig. 16.

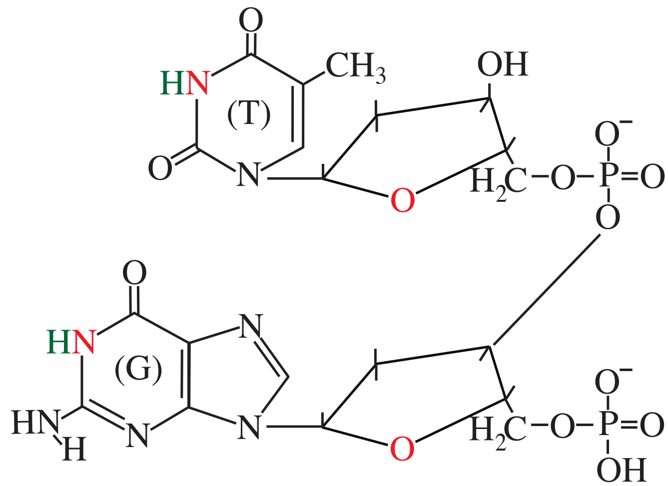


Fig. 16 A second dinucleotide.

G. The last step in making a molecular model of a small section of DNA is accomplished by making hydrogen bonds between the two dinucleotides that you just constructed.

Observe that in Fig. 14 there are four green —H atoms. Replace those atoms in your models with the two-peg, white hydrogen atoms. Also replace the two 4-peg nitrogen atoms colored red (N) in the diagram with blue, 3-peg nitrogen atoms. Use either the soft, white tubes or the rigid white tubes for the hydrogen bonds. In Fig. 17, the dotted lines represent hydrogen bonds. The bonding A-T is called a base pair, as is C-G. Therefore, you have just made a two base pair (bp) model of DNA.

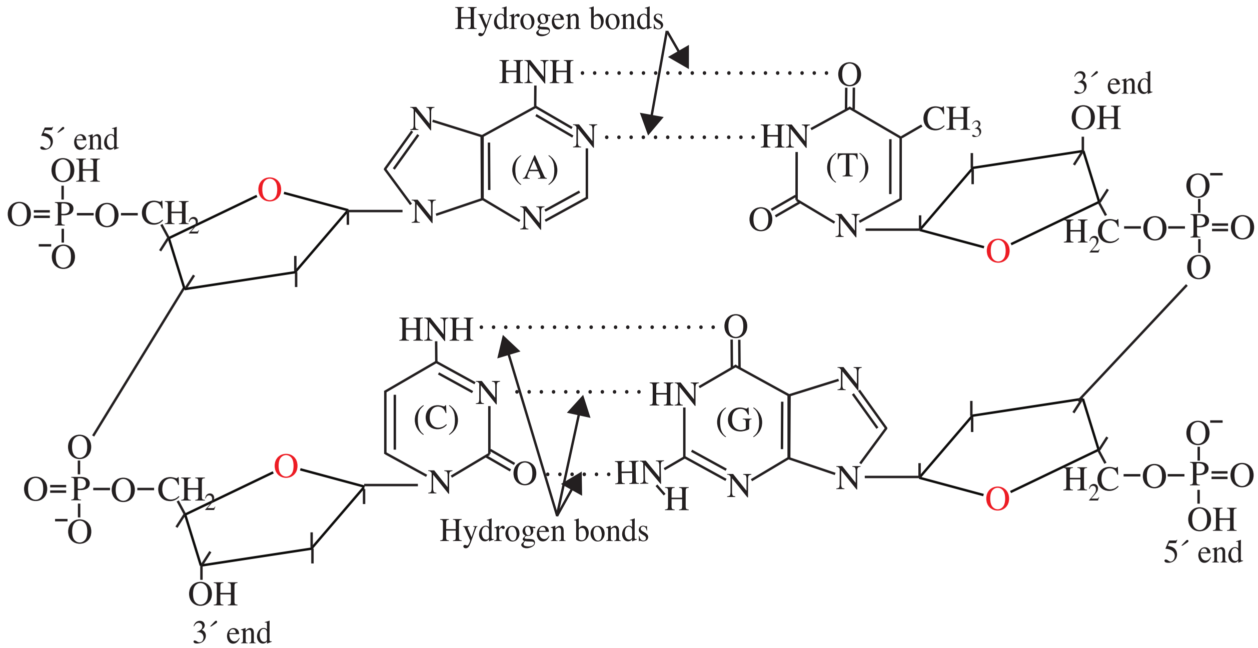


Fig. 17 A segment of DNA with two base pairs.

H. If time allows, a DNA-RNA bonding model can be made that would demonstrate transcription. For instance, if the dinucleotide on the right in Fig. 17 is to be made into RNA, remove the —CH_3 from the thymine, and replace the —H on C2´ of both deoxyribose sugars with —OH. The —OH should be on the same side as the —OH on C3´.

If RNA-RNA bonding is to be demonstrated, change the thymine as above, and then change the four sugars with —OH groups as explained above.

A tetraribonucleotide can be made by joining four RNA nucleotides with three phosphates.