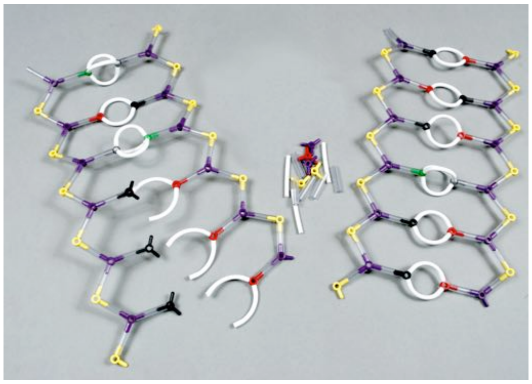
Super Models



Deoxyribonucleic Acid (DNA)

Molecular Model Kit

Recommended for ages 10-adult

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

Kit Contents:
25 purple 3-peg sugar (1 spare)
25 yellow 2-peg phosphate (1 spare)
9 red 3-peg adenine (1 spare)
9 black 3-peg thymine (1 spare)
5 green 4-peg cytosine (1 spare)
5 silver 4-peg guanine (1 spare)
75 clear, 1.25" covalent bonds (3 spares)
30 white, 2" hydrogen bonds (2 spares)

Related Kits:
Nucleic Acid Bases Molecular Model Kit
Nucleotides Molecular Model Kit

Replacement and Expansion Parts
Customized Kits

Phone: (806) 438-6865

E-Mail: etishler@rylerenterprises.com

Website: www.rylerenterprises.com

Address: 5701 1st Street, Lubbock, TX 79416

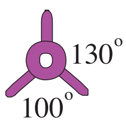
THE BASICS AND THE BEAUTY OF DNA

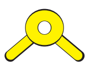
(A guide to understanding DNA)

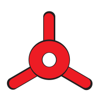
PART I: LEARNING THE PARTS OF DNA.

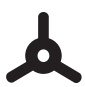
DNA is a double stranded **polymer** of **nucleotides**. A polymer is a long strand of repeating parts. In DNA, the repeating parts are called **nucleotides**. A nucleotide is made of a sugar called **deoxyribose**, a charged part (called an **ion**) of a molecule of **phosphate**, and one of the following **nitrogenous bases**: **adenine (A), thymine (T), cytosine (C), or guanine (G)**. They are called nitrogenous because they contain nitrogen.

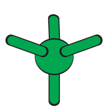
This kit supplies you with color-coded and bond parts as follows.

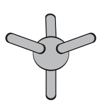
Sugar (deoxyribose) 

Phosphate ion, 

Adenine (A), 

Thymine (T), 

Cytosine (C), 

Guanine (G), 

Clear bond 

White (hydrogen) bond 

PART II: PUTTING THE PARTS TOGETHER.

EXERCISE I: IDENTIFYING THE PARTS OF DNA.

Without looking at the above diagrams, identify the parts that represent deoxyribose, phosphate, adenine, thymine, cytosine, and guanine.

EXERCISE II: MAKING A NUCLEOTIDE.

Assemble one nucleotide by placing a piece of clear tubing on the purple sugar-molecule peg that is at the top of the 130° angle farthest away from the other two pegs as pictured in Fig. 1. The tubing represents a chemical bond.

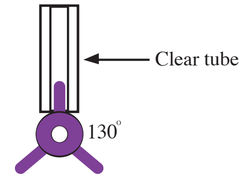


Fig. 1 Attaching a bond to deoxyribose.

Next, insert a peg of an adenine into the bond you just put on the sugar molecule. In order to complete the nucleotide, put clear-tubing bonds on the deoxyribose molecule pegs that are closest together, and place a yellow phosphate peg into either of these clear bonds. The phosphate is now on the **5´ carbon** of the nucleotide that you have just made (5´ is read five prime-the symbol ´ is called "prime"). The nucleotide is called a 5´ phosphate deoxyribonucleotide. This complicated name means that 1) the phosphate is bonded to the 5th carbon of the sugar molecule called deoxyribose, and 2) there is a nitrogenous base attached to the sugar-see Fig. 2. The use of the purple-three-peg-plastic piece simplifies the model building, so for now we cannot actually see the 5´carbon atom.

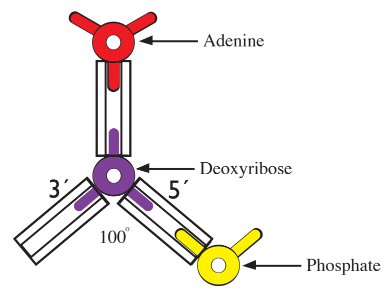


Fig. 2 A 5′ phosphate deoxyribonucleotide.

EXERCISE III: MAKING MORE NUCLEOTIDES.

Construct 23 more nucleotides from the remaining parts and clear plastic bonds. They will look similar to the nucleotide in Fig. 2, but in some there will be a different base in the place of adenine.

EXERCISE IV: MAKING A STRAND OF 12 NUCLEOTIDES.

Connect the yellow phosphate of one nucleotide to a 3′ bond on a sugar of another nucleotide. You have just made a dinucleotide which should resemble the one in Fig. 3.

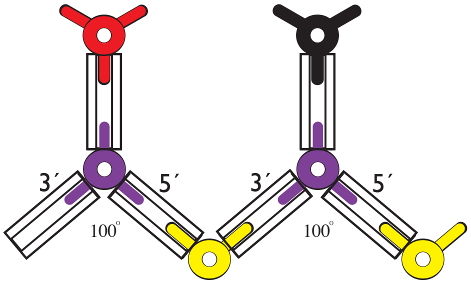


Fig. 3 A dinucleotide.

Continue to attach additional nucleotides to each other until you have a strand of 12. Your model should now closely resemble the five nucleotide chain shown in Fig. 4, but you may have a different order of bases.

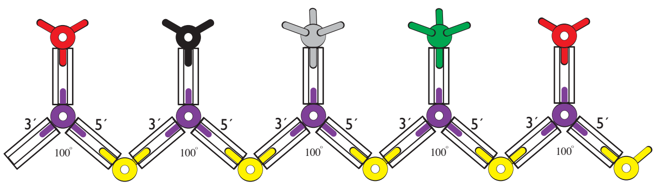


Fig. 4 A five nucleotide segment of a single strand of DNA.

EXERCISE V: MAKING A DOUBLE STRANDED DNA MOLECULE.

To complete a DNA molecule, you will now attach the remaining nucleotides to their partners (**complements**) on the strand of 12 nucleotides that you just made. Put **hydrogen bonds** (white tubes) on all of the unattached pegs of the base of the first nucleotide (on the **3′** end) of the chain. Do the same for all of the remaining bases of the single strand.

Connect the bases of all unattached nucleotides to the hydrogen bonds according to the following scheme: **Red is bonded to Black with two hydrogen bonds; Green is bonded to Silver with three hydrogen bonds.** The 5′ end of the just-added nucleotide should be on the left side. See in Fig. 5.

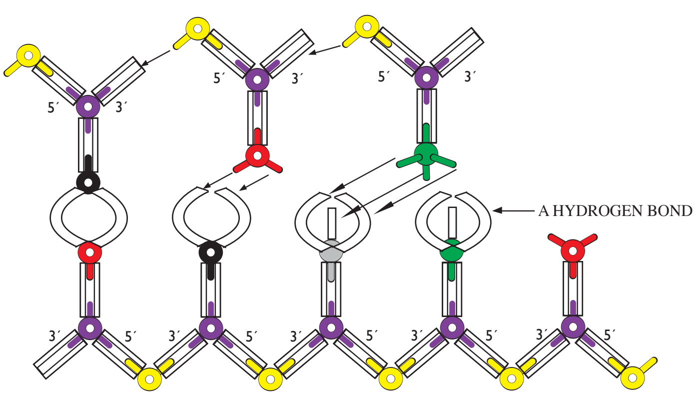


Fig. 5 Attaching complementary nucleotides to an original single strand of DNA.

Continue to attach nucleotide bases to their complements with hydrogen bonds as you just did. When you are finished adding the remaining 11 nucleotides, insert the phosphates into the clear tube bonds on the sugar next to each phosphate. The double stranded DNA you just made is called a **duplex**. Compare the diagram of a DNA duplex in Fig. 6 with your model. You do not have to have the same order of bases, but be sure that **RED IS BONDED TO BLACK, AND GREEN IS BONDED TO GREY.**

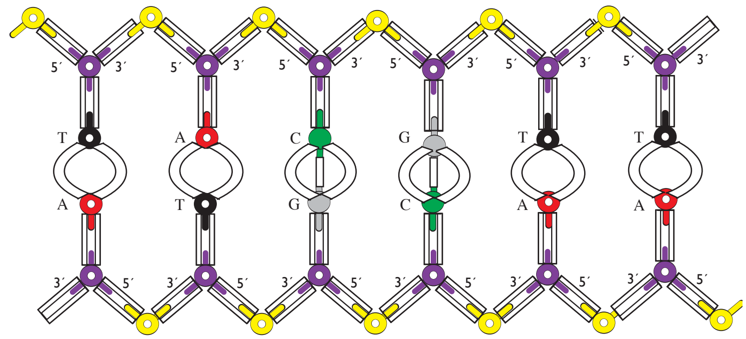


Fig. 6 A segment of a completed DNA molecule.

You have completed construction of a molecule of **DNA**. Look to the left side of Fig. 6; there is an A with a T above it. Since A (adenine) and T (thymine) are bases, this is called a **base pair**. There are 6 base pairs shown in the diagram as follows: A-T, T-A, G-C, C-G, A-T, and A-T. Your model should have a double strand with 12 base pairs. Make sure that you have obeyed the rules of DNA and paired an adenine (A) with a thymine (T), and paired a cytosine (C) with a guanine (G).

Notice that the two halves of the molecule run in opposite directions, that is the bottom half starts at 3´ on the left and proceeds to 5´ on the right. The top half is arranged with 5´ on the left and 3´ on the right.
This alignment is important to the functioning of the DNA molecule, and it is called an **antiparallel** arrangement.

Three features of DNA can be seen in the model. First, there are two kinds of bonds. The clear, thicker tubes represent strong-chemical bonds that can occur between almost any two types of atoms. The longer, white tubes are for hydrogen bonds that are weaker and involve the sharing of hydrogen atoms. Hydrogen bonds can easily be broken by heat, radiation or chemical agents. Second, there are two hydrogen bonds between A and T, while three hydrogen bonds occur between C and G. Organisms that live in hot springs have more C and G in their DNA, as you can imagine. And finally, the molecule resembles a ladder with the “rungs” represented by the bases and the “sidepieces” or "backbones" are made of alternating sugar-phosphate molecules (-s-p-s-p- and so on).

Congratulations! Now you are acquainted with the basics of DNA composition and structure.

PART III: MORE ABOUT DNA STRUCTURE.

The hydrogen bonding between the bases of the nucleotides forces the DNA takes on the form of a **helix** (spiral). Since DNA is made of two strands, we call the molecule a **double helix** (sometimes it is called a duplex). Below, in Fig. 7, there is a metal spring (not supplied) on the left and a portion of a DNA molecule on the right. A helix may be right-handed or left-handed. It is left-handed if, when seen from the top, it turns in a counter-clockwise direction. It is right-handed if, when seen from the top, it turns in a clockwise direction. Observe that the metal spring and the DNA double helix are right-handed. This form of DNA is called B-DNA, and it is one of several forms of the molecule.

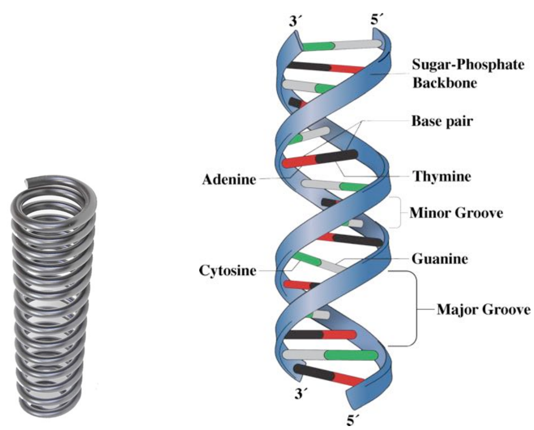


Fig. 7 A right-handed metal helix and a part of a right-handed DNA molecule.

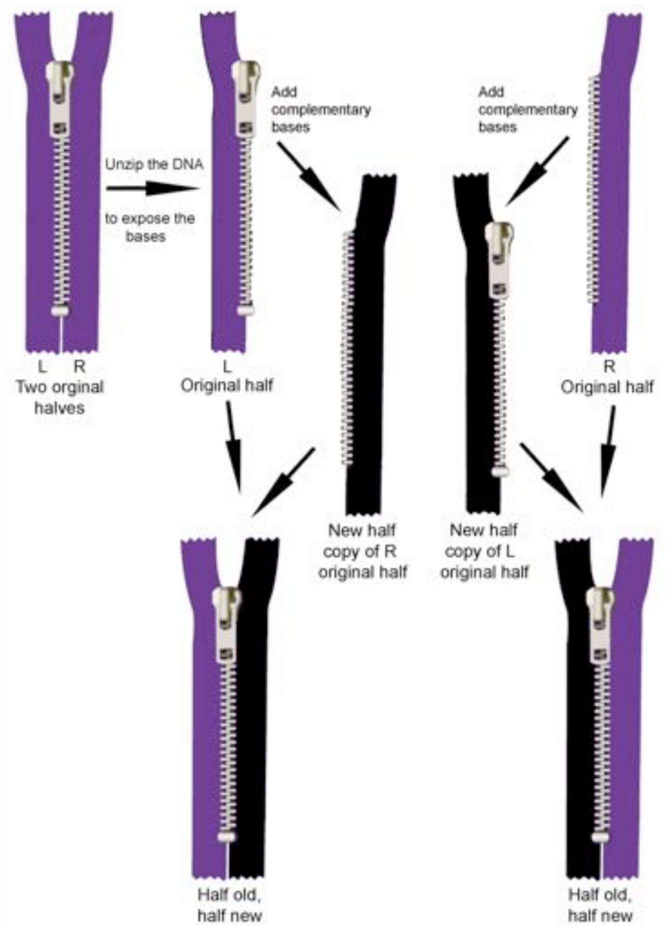
Two new features of DNA become obvious when you examine Fig. 7. One is the double helix which is similar to a spiral staircase, not a twisted ladder, and second, there are two sizes of grooves in the molecule. The larger is known as the **major groove**, while the smaller is called the **minor groove**.

In a living cell, DNA has two functions: 1) Make exact copies of itself prior to cell division or for other purposes, and 2) Control the development and the operation of the cell from its birth until its death.

This kit will be helpful in understanding the first of the two functions. A separate kit is available for studying the second function.

PART IV: REPLICATING A DNA MOLECULE.

Using zippers, we can see the overall plan for the steps used to make two exact copies of a DNA molecule.



STEP I: PREPARING 12 NUCLEOTIDES.

In order to show the duplicating (replicating) of a DNA molecule, you will need the following numbers and kinds of nucleotides.

Nucleotides with base-	Quantity
A	4
T	4
G	3
C	3

STEP II: UNZIPPING THE DNA.

Make a DNA model with the base order as in Fig. 8.

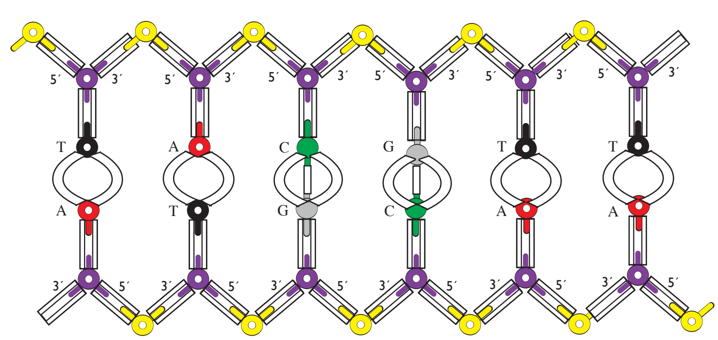


Fig. 8 A six base pair segment of DNA.

Starting from the right hand side of the molecule, separate the hydrogen bonds from the bases on the lower strand. In the actual cellular process, the bonds would be completely removed from both strands. But to save time, we only detach the tubes from one strand. As the two halves of the duplex separate, a space called the **replication fork** is formed. See Fig. 9.

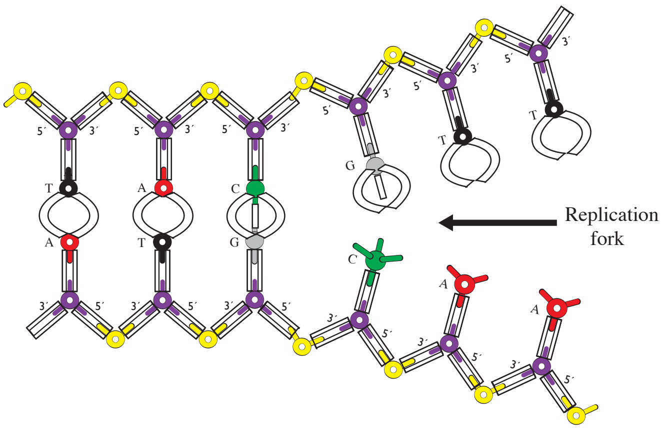


Fig. 9 Separating the duplex, forming a replication fork.

After complete separation, the model should look like the picture in Fig. 10.

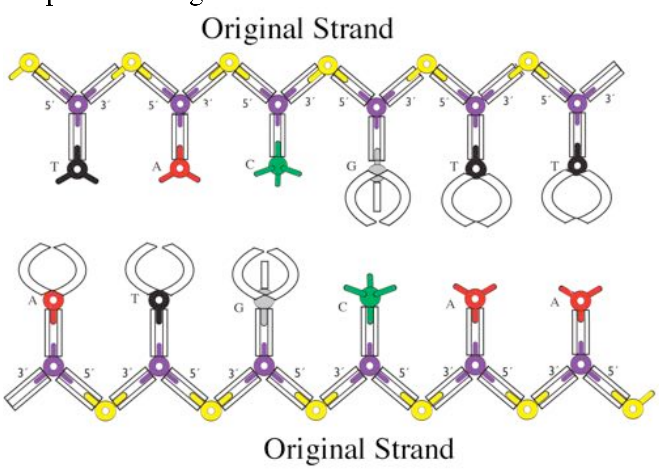


Fig. 10 Completely separated model.

STEP III: ADDING NUCLEOTIDES TO THE SEPARATED DNA STRANDS.

Now we face the problem of where to place the new nucleotides to be added to the old strands. The solution is related to 1) an energy requirement and 2) the availability of exposed bases on the original strands.

1) Building any complex structure from simpler parts, be it putting up a house, or making more DNA, uses energy. Constructing a house uses human and machine energy. Making DNA utilizes chemical energy.

   Every nucleotide to be added to the original DNA strand starts out as a sugar bonded to a base and to *three phosphates*. The three phosphates have high chemical energy that can power the building of a new strand of DNA.

   The three phosphates are always on the 5´ end of the sugar of any nucleotide. The placement of the phosphates, and the release of energy is illustrated in the next figure, Fig. 11.

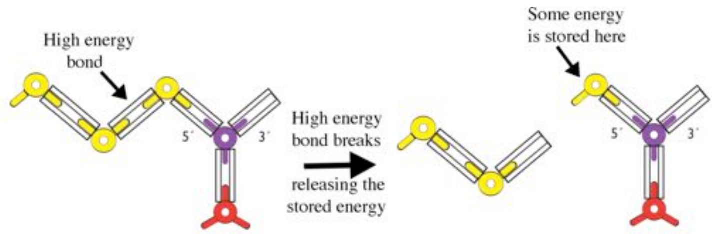


Fig. 11 Releasing the energy to form new DNA.

2) The placing of an new nucleotide is determined by the opening of the replication fork which exposes bases on the original DNA strand and by the position of a 3´ end of the strand. This is illustrated in the next diagram, Fig. 12.

Only the phosphate on the 5´ end of a nucleotide has enough energy to make more DNA. (Keep in mind that the phosphate is never found on the 3´ end of the sugar.

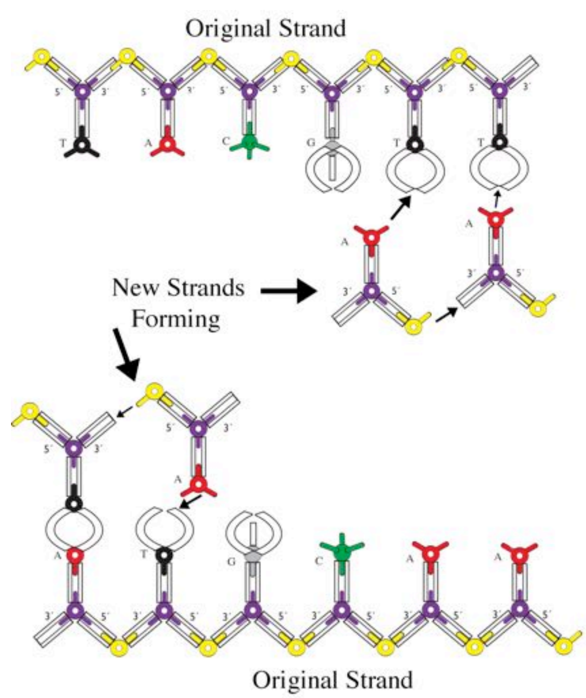


Fig. 12 Adding nucleotides to make two DNA molecules from one.

Notice that the bottom original strand and the top original strand add nucleotides in opposite directions. The process is complex and will not be investigated here.

PART V: A CLOSER LOOK AT THE CHEMISTRY OF DNA.

One can get a very good understanding of the form and function of DNA without a knowledge of the intimate details of the arrangement of the atoms that make up the molecule. This section may be skipped if it does not help in your understanding of DNA, but it might be of some interest to seeing deeper into the complexity of this important molecule of life.

Because we started by making nucleotides, we will look at illustrations of the linking of three parts that went into their structure.

First we have the sugar, deoxyribose, which has five carbon atoms. Four of the carbon atoms are understood to occur at the corners of a ring along with one oxygen. The elements in the diagram are oxygen (symbol O), hydrogen (symbol H), and carbon (symbol C), (The carbons are labeled with numbers that are marked with a prime symbol (´), Fig. 13. The sugar, ribose, has an oxygen atom bonded to the 2´ carbon. De (without) oxy (oxygen) ribose lacks that oxygen.

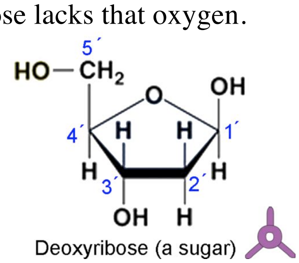


Fig. 13 Deoxyribose and the model part.

Next in making our model we bonded a base to the sugar. Fig. 14 is a molecular diagram of the base, adenine, which has its carbon atoms numbered. It should be clear now that we use prime markings on the numbers of the sugar to avoid confusion.

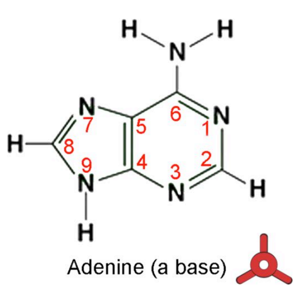


Fig. 14 Adenine and the model part.

At this time, it is not necessary for you to remember the numbering scheme of any molecular diagram, but keep in mind that if no atom is shown at a corner, a carbon atom is there.

Fig. 15 shows how the base is bonded to the sugar.

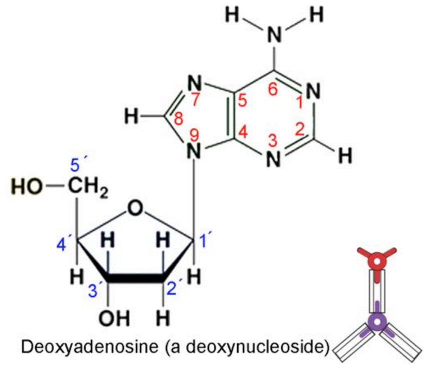


Fig. 15 Adenine bonded to deoxyribose and the model part.

To complete the nucleotide, we bond a phosphate ion (see Fig. 16) to the sugar. The P is the symbol for the element phosphorus. When in position, the phosphate defines the 5´ end of the nucleotide, as you can see in Fig. 17.

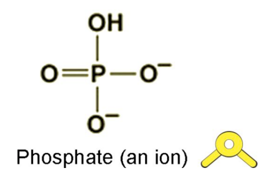


Fig. 16 A phosphate ion and the model part.

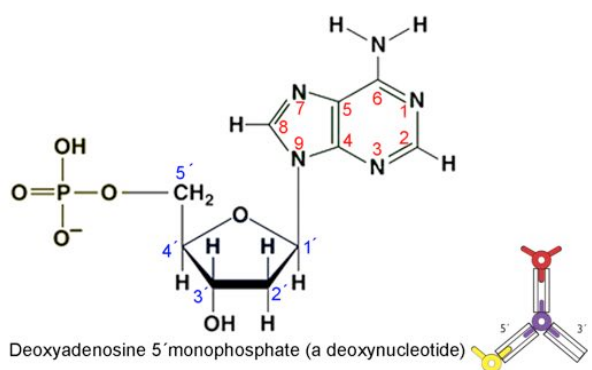


Fig. 17 A completed nucleotide and the model.

Fig. 18, below, has detailed molecular diagrams of the four bases of DNA.

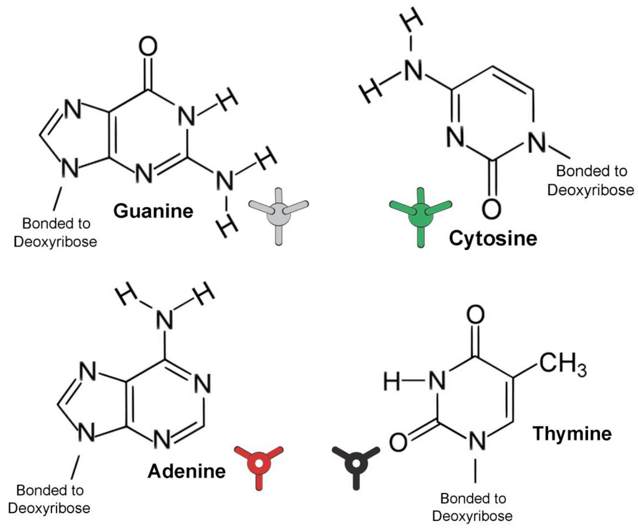


Fig. 18 The four nitrogenous bases of DNA.

Look again at Fig. 8, and review the meaning of the term base pair. There are three base pairs shown in a small section of DNA in Fig. 19. Observe how a hydrogen atom is shared between N and O, or between N and N atoms in a hydrogen bond.

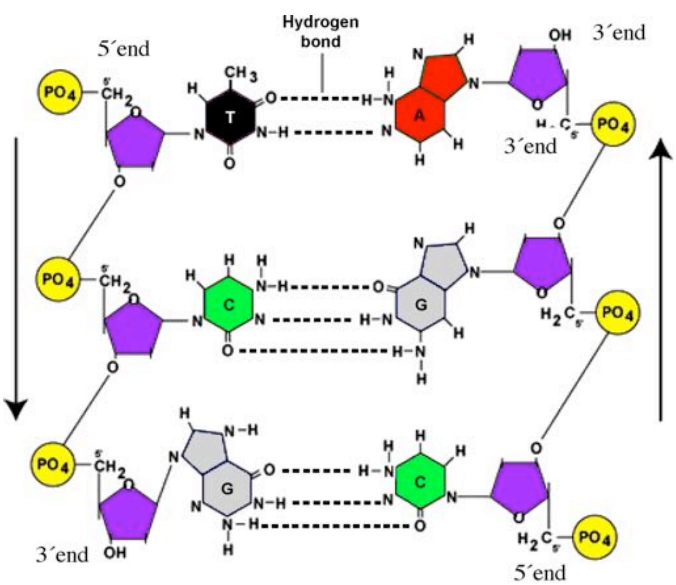


Fig. 19 Three base pairs, and 3´ and 5´ ends of the two halves of DNA.

ADDITIONAL INFORMATION

INTERESTING FACTS ABOUT THE HUMAN GENOME (THE TOTAL AMOUNT OF OUR DNA IN ONE BODY CELL):

Number of genes ~25,000.

Number of base pairs -3.2 billion.

DNA in protein coding sequences (these direct the cell to make proteins) -1.5%

DNA in **other useful sequences** (these make several types of special RNA molecules and control other sections of DNA) -3.5%

Number of pseudogenes (mutated genes that no longer function) >20,000.

DNA in repeated regions, similar to a word in a sentence being retyped thousands of times. One of them named *Alu* is present in over one million copies in each of our cells. Repeats play different roles in cells, some are helpful, some not. They have base pairs that have the same sequences. The average number of base pairs in a repeat is ~ 300. Amount of DNA repeats per cell ~50% of total.

ONLINE RESOURCES:

Many new terms are added in these videos, so you may want to watch them several times.

https://highered.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::535::535::/sites/dl/free/0072437316/120076/bio23.swf::How%20Nucleotides%20are%20Added%20in%20DNA%20Replication

http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::535::535::/sites/dl/free/0072437316/120076/micro04.swf::DNA%20Replication%20Fork

http://scienceprimer.com/dna-polymerase

https://www.youtube.com/watch?v=TNKWgcFPHqw

http://www.hhmi.org/biointeractive/dna-replication-basic-detail

TERMS TO INVESTIGATE FOR A FULLER UNDERSTANDING OF DNA:

Chromatin (euchromatin, heterochromatin)
DNA gyrase
DNA helicase
DNA ligase
DNA polymerase I
DNA polymerase III
Epigenetics
Histones
Mutation
Numbers of units (monomer, dimer, polymer)
Origin of replication
Replication (leading strand, lagging strand, Okazaki fragment, RNA primer)
Telomere (telomerase)

ASSESSMENT TO ACCOMPANY "**THE BASICS AND THE BEAUTY OF DNA**"

To find out what you know about DNA, and to find out how building the model increases your knowledge, choose the best answers to the following questions. **Prior to** assembly of the parts, place your answers in the blanks marked (before model), and **after** making the model, go through the questions again, and put your answers in the blanks marked (after model).

1. DNA is a long strand of repeating parts called ________(before model), ________(after model)
   a. nitrogenous bases
   b. deoxyribose
   c. nucleotides
   d. phosphate
   e. ribose

2. The sugar found in DNA is ________(before model), ________(after model)
   a. ribose
   b. adenine
   c. deoxyribose
   d. an ion
   e. glucose

3. The term "nitrogenous" means containing ________(before model), ________(after model)
   a. nitrogen
   b. neon
   c. a sugar
   d. nucleotides
   e. ions

4. Which of the following correctly lists the four bases of DNA? ________(before model), ________(after model)
   a. ribose, adenine, thymine, cytosine
   b. adenine, deoxyribose, phosphate, guanine
   c. adenine, guanine, cytosine, uracil
   d. guanine, cytosine, thymine, adenine
   e. cytosine, ribosine, thymine, guanine

5. In a nucleotide, the phosphate is bonded to ________(before model), ________(after model)
   a. a 1´ carbon atom
   b. a 2´ carbon atom
   c. a 3´ carbon atom
   d. a 4´ carbon atom
   e. a 5´ carbon atom

6. A nucleotide of DNA is composed of ________(before model), ________(after model)
   a. a nitrogenous base, deoxyribose, and a polymer
   b. ribose, a sugar, and phosphate
   c. ribose, phosphate, RNA, and a dinucleotide
   d. deoxyribose, phosphate, and sugar
   e. deoxyribose, phosphate, and a nitrogenous base

7. How many strands is a complete DNA molecule made from? ________(before model), ________(after model)

a. 1
b. 2
c. 3
d. 4
e. 5

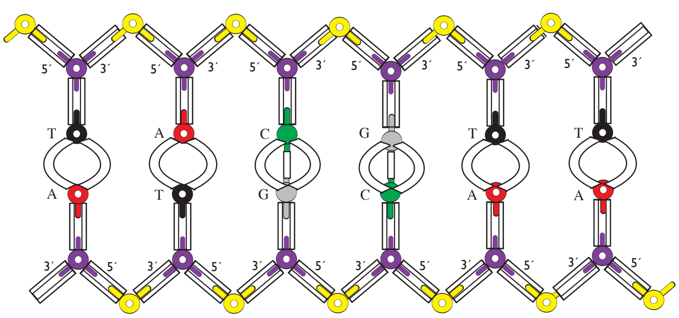
8. Which of the following is a correct complementary base pairing? ________(before model), ________(after model)

a. A-A
b. C-C
c. deoxyribose-deoxyribose
d. A-C
e. A-T

9. A complete DNA molecule looks like a ladder. What makes up the "side pieces" ("backbones") of the ladder? ________(before model), ________(after model)

a. nitrogenous bases
b. nitrogenous bases and phosphate
c. ribose and deoxyribose
d. sugar and phosphate
e. base pairs

10. How many base pairs are in this diagram? ________(before model), ________(after model)

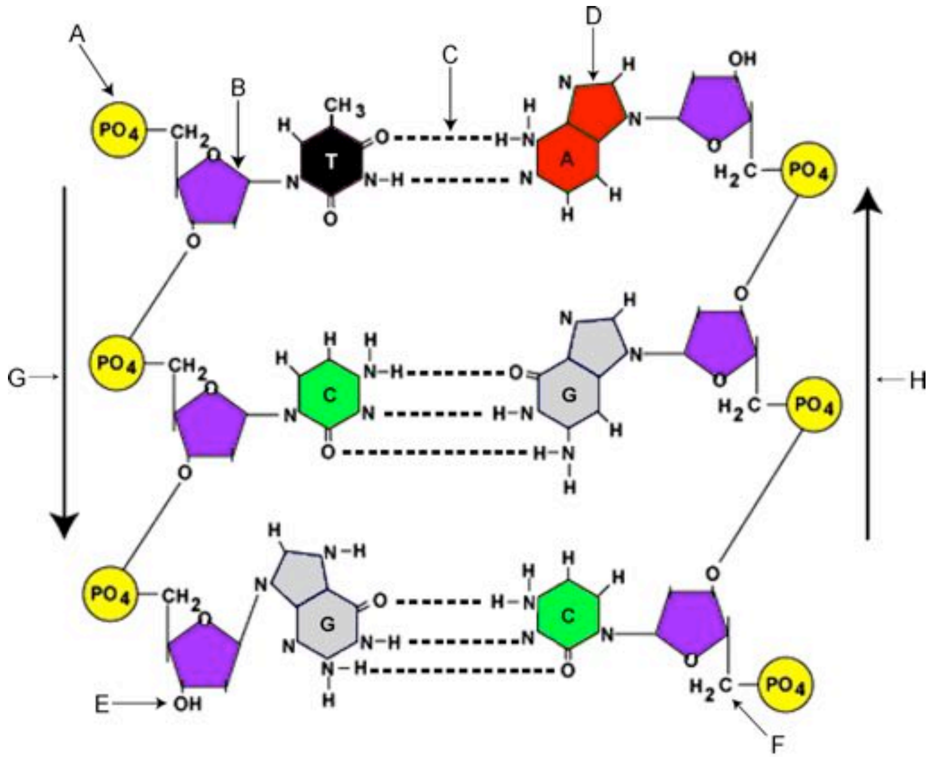


a. 2
b. 3
c. 4
d. 5
e. 6

11. What type of a bond connects two complementary bases together? ________(before model), ________(after model)

a. hydrogen
b. phosphate
c. deoxyribose
d. nucleotide
e. clear tube

The next seven questions are about the following diagram.



12. The letter A points to a ________(before model), ________(after model)

    a. ribose
    b. base
    c. hydrogen bond
    d. deoxyribose
    e. phosphate

13. B points to a ________(before model), ________(after model)

    a. ribose
    b. base
    c. hydrogen bond
    d. deoxyribose
    e. phosphate

14. C points to a ________(before model), ________(after model)

    a. ribose
    b. base
    c. hydrogen bond
    d. deoxyribose
    e. phosphate

15. D points to a ________(before model), ________(after model)

    a. ribose
    b. base
    c. hydrogen bond
    d. deoxyribose
    e. phosphate

16. To which end of the DNA molecule does E point? ________(before model), ________(after model)
   a. 1´
   b. 2´
   c. 3´
   d. 4´
   e. 5´

17. To which end of the DNA molecule does F point? ________(before model), ________(after model)
   a. 1´
   b. 2´
   c. 3´
   d. 4´
   e. 5´

18. The long arrows labeled G and H are pointing in opposite directions. Because of this arrangement, the two strands that make up DNA are said to be ________(before model), ________(after model)
   a. elongated
   b. antiparallel
   c. parallel
   d. twisted
   e. genetic

19. A replication fork occurs when the two strands of a DNA molecule are ________(before model), ________(after model)
   a. twisted
   b. parallel
   c. separated
   d. joined
   e. made 3´ prime

20. The energy to make a complex structure such as DNA is supplied by breaking bonds between ________(before model), ________(after model)
   a. sugars
   b. bases
   c. phosphates
   d. dinucleotides
   e. sugars and bases

ANSWERS TO ASSESSMENT QUESTIONS FOR
"THE BASICS AND THE BEAUTY OF DNA"

1. b. nucleotides
2. c. deoxyribose
3. a. nitrogen
4. d. guanine, cytosine, thymine, adenine
5. e. a 5´ carbon atom
6. e. deoxyribose, phosphate, and a nitrogenous base
7. b. 2
8. e. A-T
9. d. sugar and phosphate
10. e. 6
11. a. hydrogen
12. e. phosphate
13. d. deoxyribose
14. c. hydrogen bond
15. b. base
16. c. 3´
17. e. 5´
18. a. antiparallel
19. c. separated
20. c. phosphates