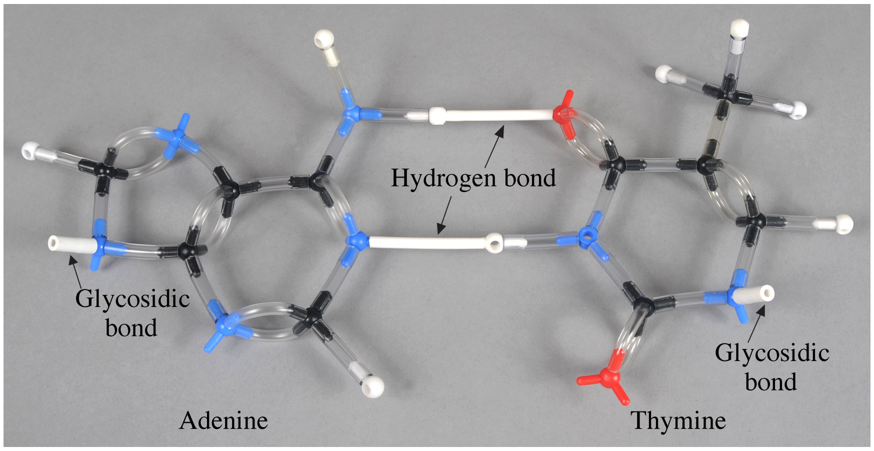
Super Models



Nucleic Acid Bases (nucleobases) 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:
20 black 4-peg carbon atom centers (1 spare)
13 white 1-peg hydrogen atom centers (1 spare)
6 white 2-peg hydrogen atom centers (1 spare)
16 blue 4-peg nitrogen atom centers (1 spare)
3 blue 3-peg nitrogen atom centers (1 spare)
5 red 4-peg oxygen atom centers (1 spare)
45 clear, 1.25″ bonds (2 spares)
30 clear, 4 cm bonds (2 spares)
7 white, 2″ bonds (2 spares)
5 white, 0.87″ bonds (1 spare)

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Nucleic Acids And Analogs

I. **General Information.**

In living cells, two types of nucleic acids can be found; deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). In viruses, one or the other will exist, but not both. Both kinds of nucleic acids are composed of long chains of building blocks known as nucleotides. A nucleotide in turn is made up of three smaller molecules; a sugar (ribose in RNA, deoxyribose in DNA), a phosphate ion, and a nucleobase, i.e. a nitrogenous base.

This kit is focused on the structures of the common nucleobases, which are adenine (A), guanine (G), cytosine (C), thymine (T), and uracil (U). A and G are larger molecules classified as purines. C, T, and U are the smaller pyrimidines.

A, G, C, and **T** are found in DNA, while A, G, C, and **U** are members of RNA molecules. **U** replaces T in RNA.

We also include information about the less common nucleobases which are important in the functions of all cells.

The table in Fig. 1 gives the naming convention for each individual nucleobase, the name of the nucleobase when it is bonded to a sugar molecule (resulting in a nucleoside), and the name of the nucleoside when it is bonded to one phosphate ion (resulting in a nucleotide).

Using adenine as an example, we show how it combines with the sugar ribose to form the nucleoside adenosine. Adenosine then joins with an inorganic phosphate ion to produce adenosine monophosphate, AMP. AMP is the nucleotide of RNA. See Fig. 2.

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)

Fig. 1 The naming of the nucleobases, the nucleobases bonded to a sugar, and nucleobases bonded to ribose which is bonded to one phosphate ion.

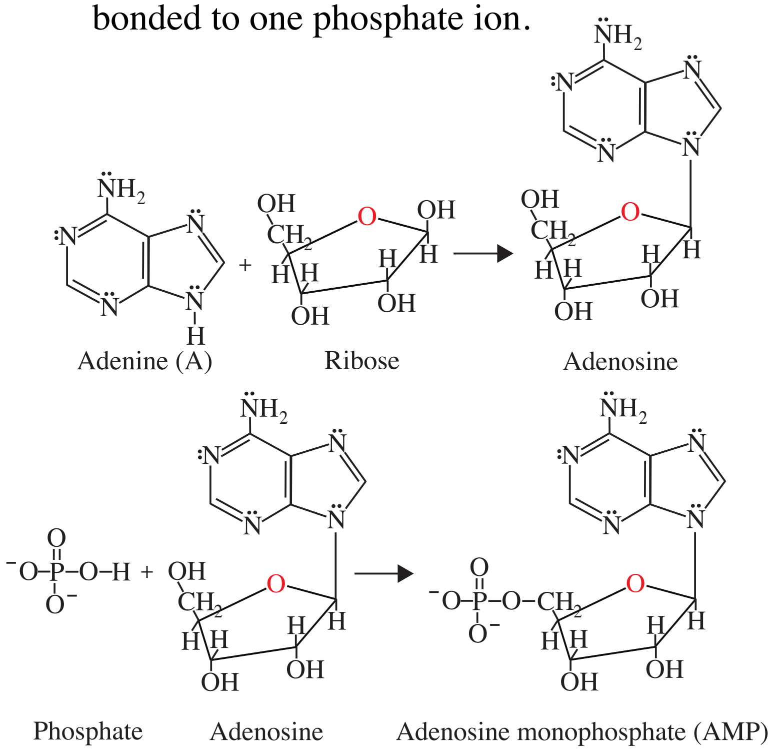
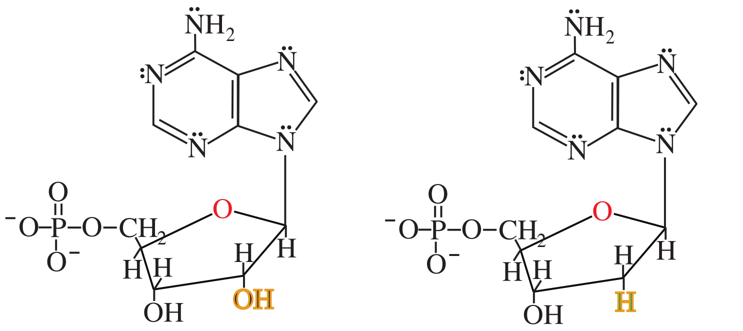


Fig. 2 Bonding adenine, ribose, and phosphate.

In Fig. 3, the difference between an adenine nucleotide of RNA and DNA are illustrated. Note that the ribose ring on the left has lost a gold colored oxygen to become the deoxyribose on the right.



Adenosine monophosphate (AMP) found in RNA

Deoxyadenosine monophosphate (dAMP) found in DNA

Fig. 3 The difference between AMP and dAMP.

II. **Biochemical symbolism.**

Build models of adenine, guanine, cytosine, and thymine, using the diagrams below as guides for the placement of bonds and atoms. Use the following color guide for the identification of the atom centers and bonds.

ATOM	COLOR
Carbon	Black
Hydrogen	White
Oxygen	Red
Nitrogen	Blue

BOND TYPE	COLOR	LENGTH
Single	Clear	1.25"
Double	Clear	4 cm
Hydrogen	White	2"
Glycosidic	White	.87"

Notice that when the models are finished, all the oxygen atoms have two pegs without tubes attached, and all the nitrogen atoms have one peg without a tube attached. Each of these pegs represents a pair of electrons (called a lone pair) which is not shared with another atom, but might be shared if a somewhat positive atom such as hydrogen contacts the pair. Place the long-thin-white tubes on the atoms that have dotted lines. The white tubes will be used to make these special connections (called hydrogen bonds) to hydrogen atoms. Note that hydrogen atoms can only be shared between oxygen–oxygen, oxygen–nitrogen, or nitrogen–nitrogen.

In some structural diagrams of molecules, atoms and/or bonds are omitted in order to simplify the diagram. It is understood that carbon atoms should have four bonds, nitrogen should have three, and oxygen should have two. Where two or more lines intersect but no atom is indicated in the drawing, insert a carbon atom. If the carbon doesn't have four bonds, add as many bonds and hydrogen atoms to get to the required number-four.

Examine Fig. 4, below. 1) How many of each of the following are in the diagram: carbon atoms; oxygen atoms; nitrogen atoms; single bonds; double bonds; lone pairs? 2) Are there any missing bonds, atoms and/or lone pairs? If you feel that some parts are missing or could be included, redraw the molecule in its complete form.

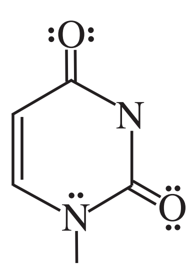


Fig. 4 Does this molecule have missing parts?

Answers: 1) carbon atoms–4; oxygen atoms–2; nitrogen atoms–2; single bonds–8; double bonds–3; lone pairs–6. Fig. 5 shows the complete structure with all of the atoms, bonds, and lone pairs.

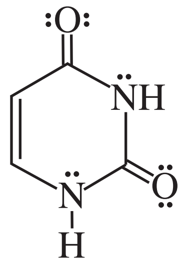


Fig. 5 Completed diagram of Fig. 1.

In some diagrams, structures are condensed by eliminating bonds as depicted in Fig. 6 where “a” is equivalent to “b,” and “c” is equivalent to “d.”

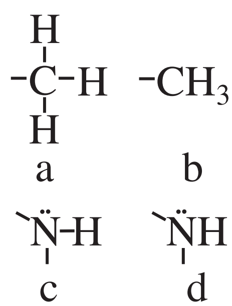


Fig. 6 Eliminating bonds in diagrams.

Use the long, and short, white tubes as follows. A dotted line connecting two bases together indicates the location of a hydrogen bond. Use the long, white tube for this bond.

Where the term “Deoxyribose” appears attached to an N, put a short-thick-white tube on the nitrogen atom center. Deoxyribose is the sugar found in the side chains of DNA molecules, and the bond between the sugar and the base is known as a glycosidic bond.

The short, clear tubes are for single bonds, and the long, clear tubes are for double bonds. To make a double bond, put two long, clear tubes on two of the pegs of each atom sharing the bonds as illustrated in Fig. 7.

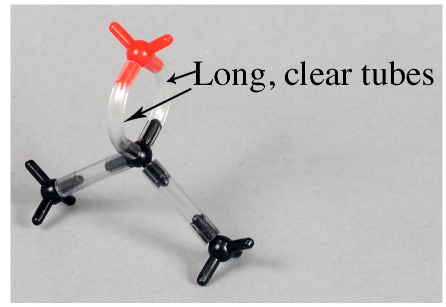
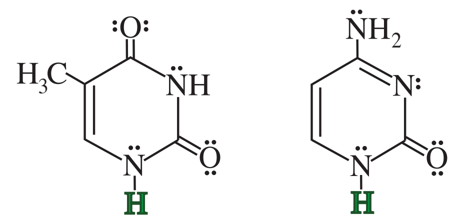


Fig. 7 A double bond.

When making a hydrogen bond, replace the single peg hydrogen atom with a two peg hydrogen atom. In the structures provided in these instructions, the hydrogen atom to be replaced is colored red (**–H**).

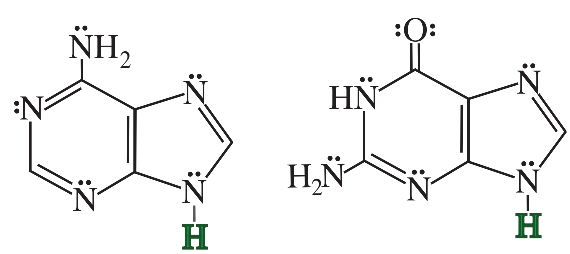
III. The standard nucleobases of DNA.

Assemble the DNA nucleobases using the diagrams in Fig. 8 and Fig. 9.



Thymine (T) Cytosine (C)

Fig. 8 The two pyrimidine nucleobases of DNA.



Adenine (A) Guanine (G)

Fig. 9. The two purine nucleobases of DNA.

The pyrimidine, uracil is illustrated in Fig. 10, below. Uracil is found in RNA where it takes the place of thymine. When the nucleobase, uracil bonds with the sugar, ribose, a riboside molecule called uridine is produced.

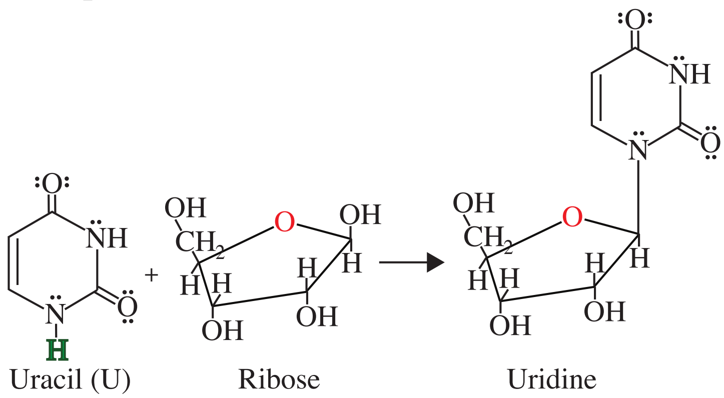


Fig. 10 The nucleobase, uracil, which is found in RNA.

IV. Joining the Bases.

You are almost ready to form base pairs using hydrogen bonds. First, make these modifications to the nucleobases.

1) Remove the hydrogen atoms that you see in Figs. 8 and 9 which are colored green in the diagrams, and as explained earlier, replace them with short, white tubes. These tubes represent the sugar, deoxyribose, in the case of DNA, and ribose in examples of RNA.

2) Replace the hydrogen atoms shown in red with white, two-peg hydrogen atoms.

3) Replace the four-peg nitrogen atom that is colored blue with a blue, three-peg nitrogen atom. See Fig. 11.

Adenosine and thymidine bond to each other to form a base pair (Fig. 11), and cytidine joins with guanosine (Fig. 12) in DNA. Use either the 5.5 cm long flexible, white tubes or the 5 cm more rigid, white tubes for hydrogen bonding. The bonding of A to T and G to C is called complementary base pairing.

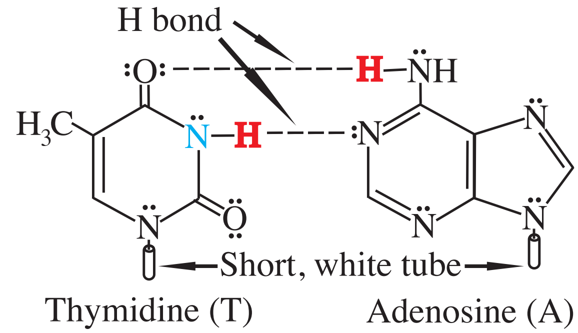


Fig. 11 Two hydrogen bonds joining A and T to form a base pair.

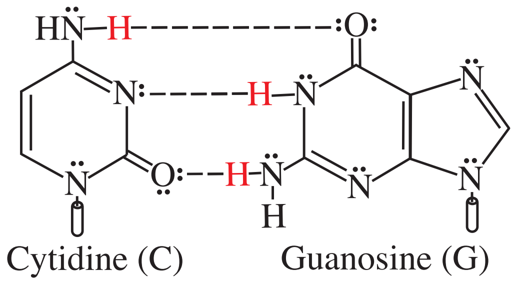


Fig. 12 Three hydrogen bonds joining C and G to form a base pair.

V. Analogs of the five common nucleobases.

First, let’s take a look at the numbering systems used for purines and pyrimidines, so that the numbers included in some names make sense. See Fig. 13.

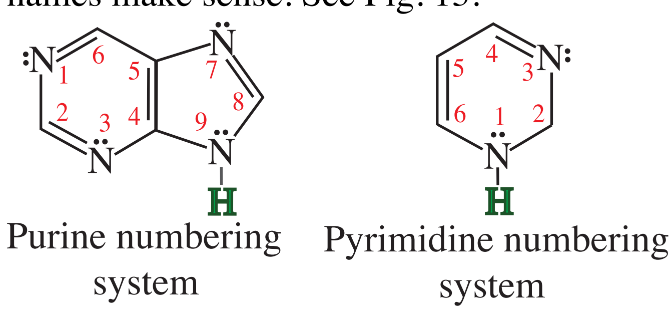
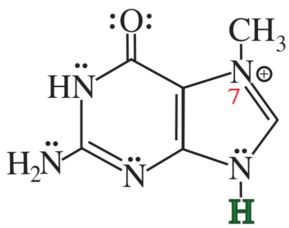


Fig. 13 Numbering atoms in the rings of purines and pyrimidines.

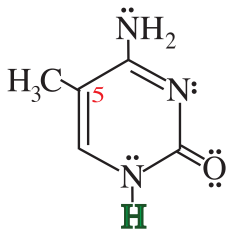
The analog nucleobases are modifications of the parent base already present in the completed strands of DNA or RNA.

Some nucleobases have a methyl group bonded to them. Guanine and cytosine are two examples, and their structures are illustrated below. A methyl group is shown separately. See Fig. 14.

A methyl group



7-Methylguanine (m^7G)

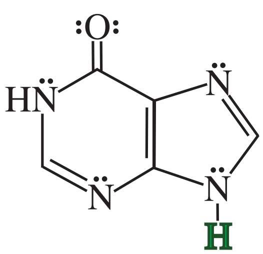


5-Methylcytosine (m^5C)

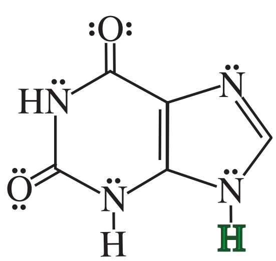
Fig. 14 Methylated guanine and cytosine.

These methylated nucleobases, as well as others, are important in the type of genetic control called epigenetics.

Hypoxanthine is a constituent of nucleic acids, most significantly in RNA. When hypoxanthine is metabolized, it is made into xanthine. Both of these are shown in Fig. 15.



Hypoxanthine

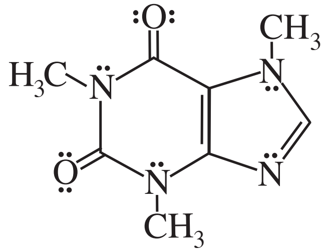


Xanthine

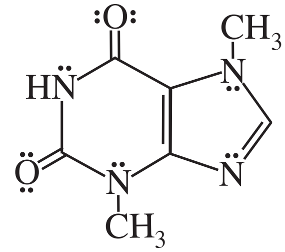
Fig. 15 Hypoxanthine and xanthine.

Xanthine, which can also be formed by the degradation of other purines, is made into the common stimulants, caffeine, theophylline, theobromine, and paraxanthine in many plant species. Theophylline is often used to treat asthma. Theobromine, which in Greek means food of the gods, is one of the major chemicals in chocolate. The four purines described above are not found in DNA or RNA.

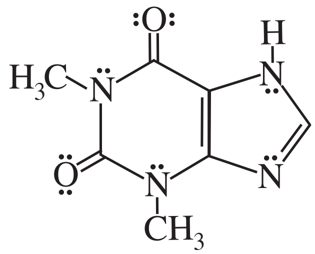
Fig. 16 shows the structures of caffeine and the products formed from it.



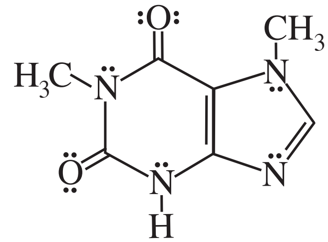
Caffeine



Theobromine



Theophylline

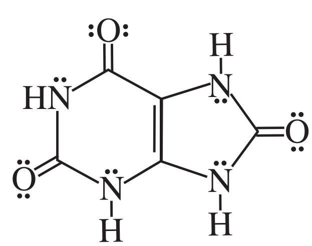


Paraxanthine

Fig. 16 Caffeine and its products.

In large enough quantities, all of the above chemicals are poisonous to humans. Depending on the size of the dog that ingests it, theobromine, even in fairly small amounts, can be life threatening.

Eventually, the purines in animals are converted to uric acid for excretion either in urine or feces. Unfortunately, in some humans uric acid will form crystals which deposit in joints (gout) or in the urinary system (kidney, ureter, or bladder) as solid stones. Birds, reptiles, and insects remove nitrogen waste from their bodies as uric acid. The structure of uric acid is given in Fig. 17.



Uric acid

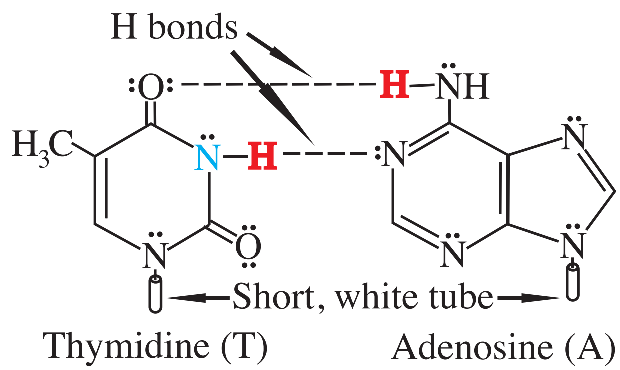
Fig. 17 Uric acid structure.

Student Assessment for Nucleic Acid Bases
Part I

Choose <u>either</u> the A-T base pair <u>or</u> the C-G base pair from the illustration below, and build a model including the hydrogen bonds and the short, white tubes to simulate sugar molecules.

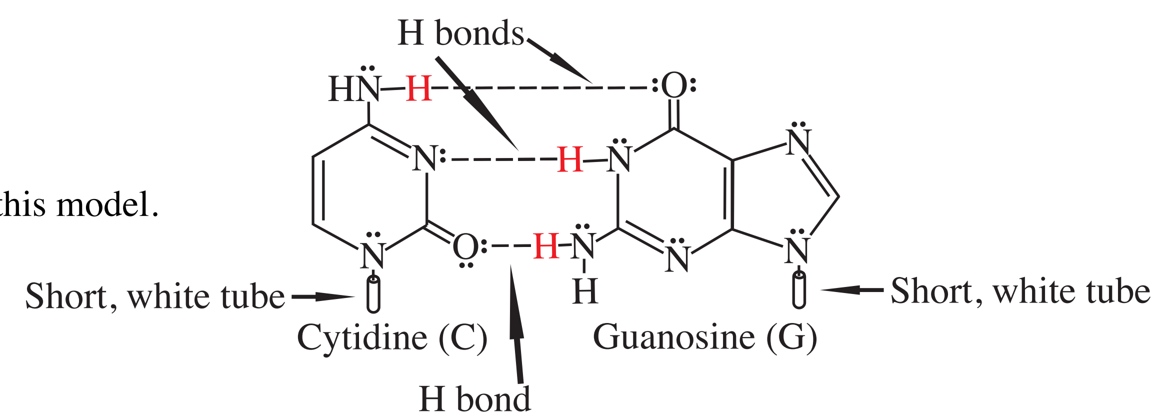
Show your model to your instructor to be checked.

This model. . .



Teacher's initials–____________

or this model.



Teacher's initials–____________

Student Assessment for Nucleic Acid Bases
Part II

Name________________________________ Date_________________
Class_____________________

_______ 1. In living cells, there are two types of nucleic acids They are
a. ATP and NAD.
b. DNA and NAD
c. RNA and NADP
d. DNA and RNA
e. MRI and CAT

_______ 2. DNA is composed of building blocks known as
a. acids
b. bases
c. nitrogen
d. nucleotides
e. riboses

_______ 3. RNA is composed of building blocks known as
a. acids
b. bases
c. nitrogen
d. nucleotides
e. riboses

_______ 4. The sugar found in DNA is
a. ribose
b. deoxyribose
c. glucose
d. sucrose
e. none of the above

_______ 5. The sugar found in RNA is
a. ribose
b. deoxyribose
c. glucose
d. sucrose
e. none of the above

_______ 6. Which of the following is not a nucleobase?
a. ribose
b. guanine
c. cytosine
d. thymine
e. uracil

________ 7. Which of the following is not found in DNA?
a. adenine
b. guanine
c. cytosine
d. thymine
e. uracil

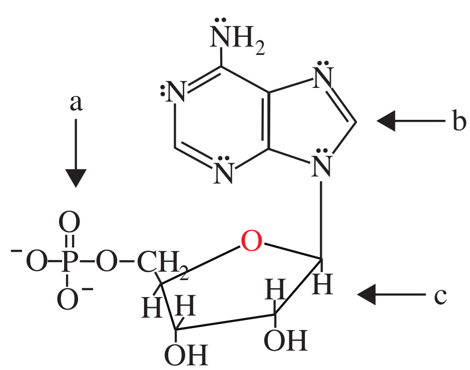
________ 8. Which of the following is not found in RNA?
a. adenine
b. guanine
c. cytosine
d. thymine
e. uracil

________ 9. Which of the following is not a list of parts of an RNA nucleotide?
a. adenine, ribose, phosphate
b. guanine, ribose, phosphate
c. cytosine, ribose, phosphate
d. thymine, ribose, phosphate
e. uracil, ribose, phosphate

________ 10. Which of the following is not a list of parts of a DNA nucleotide?
a. adenine, deoxyribose, phosphate
b. guanine, deoxyribose, phosphate
c. cytosine, deoxyribose, phosphate
d. thymine, deoxyribose, phosphate
e. uracil, deoxyribose, phosphate

________ 11. An RNA nucleoside does not contain
a. adenine
b. guanine
c. cytosine
d. thymine
e. phosphate

Questions 12 through 16 refer to the structure shown below.



________ 12. The letter “a” points to a(n)
a. acid
b. base
c. sugar
d. phosphate
e. ribose

________ 13. The letter “b” points to a(n)
a. acid
b. base
c. sugar
d. phosphate
e. deoxyribose

________ 14. The letter “c” points to a(n)
a. acid
b. base
c. sugar
d. phosphate
e. deoxyribose

________ 15. The letter “c” points to a(n)
a. acid
b. base
c. nucleolus
d. ribose
e. deoxyribose

________ 16. The entire molecule is called a(n)
a. nucleoside
b. nucleotide
c. nucleolus
d. DNA molecule
e. RNA molecule

________ 17. Which atom (element) is not in any of the nucleotides of DNA or RNA?
a. nitrogen
b. oxygen
c. hydrogen
d. carbon
e. sulfur

________ 18. Which of the following is a correct diagram for a hydrogen bond?
a. C-H- - - -C
b. C-H- - - -N
c. C-H- - - -O
d. O-H- - - -N
e. H- - - -H

_______ 19. Which of the following is a correct pairing of bases?

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

_______ 20. Which of the following is a purine base?

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