Nucleic Acids

Introduction

This lesson focuses on the putting together the pieces and initiating the discussion of strands of DNA and RNA. Our main focus is to see where the pieces come from, how they connect to form a single nucleotide, then how those nucleotides will connect to each other. A main emphasis is simply on recognizing the pattern, the structure of the nucleic acids, and not on drawing out the carbon rings or where a nitrogen goes. Later, we'll talk about how strands come together, and how the base-pairs lead into the helix shape. There's some overlap since one naturally leads into the other.

Nucleic acids consist of a **5-carbon sugar**, a **base** (either a purine or pyrimidine), and a **phosphate**. It's the phosphate that connects one nucleic acid to another. We'll explore each of the three pieces discretely, then put them together.

The Sugar

All nucleic acids are built on a **5-carbon structure**, a pentose. There are 5 carbon positions. Each of these 5 positions does something quite reliably, regardless of the nucleic acid being built. Positions 1, 3, and 5 have an OH group when the sugar is on its own. Each of these positions allows for some bond to form, and the OH group will be replaced by something else.

The 1 position has an **OH** on it—this will be where the base goes.
The 3 position has an **OH** on it—this will be where the chain of nucleic acid will extend from.
The 5 position has an **OH** on it—this will be where the 3 position of the previous nucleic acid attaches to the 5 position of the next nucleic acid. The phosphate group goes on the 5 position; it will link via a **phosphodiester bond** between the 3 position of one and the 5 position of the other.

The ribose sugar, which **has an OH** group at the **2 position**, is used for **RNA** (ribose-nucleic-acid). If that position has had the OH removed, that is, if 2-De-oxyribose is the sugar, it's for DNA (deoxyribo-nucleic-acid). That alone determines whether the nucleic acid will be **RNA** (**OH** at the 2 position) or DNA (no OH at the 2 position).

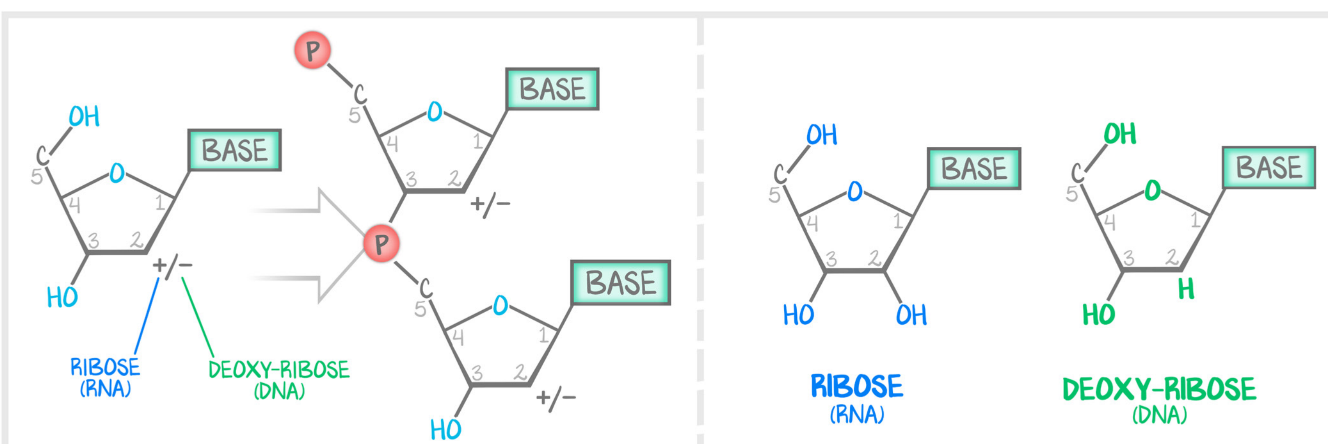

Figure 2.1: The Sugar
Pay attention to the 2 position. An OH group means ribose (RNA), and no OH group means deoxyribose (DNA).

The Base

The base is attached to the 5-carbon sugar at **position 1**. The base that binds will be either a purine or a pyrimidine.

Purine has two syllables. **Purines** have **two rings**. Purine nearly rhymes with "two rings." Learn the purines, and the pyrimidines will fall in place. It's ABSOLUTELY NOT necessary to attempt to undergrad biochem the structures. Knowing where to put the two lines for a double bond is futile and useless. Instead, focus on memorizing what matters.

First, look at the number of rings in the base. This separates purines (2-rings) from pyrimidines (1-ring).

Then look for an **amine group** (that means nitrogen) or not. The **purine** with an **amine** is **adenine**. The other purine is guanine.

The pyrimidines have one fewer ring than the purines because the second ring was "CUT" off. C-U-T, in that order, is a reminder of the three possible pyrimidines: Cytosine, Uracil, and Thymine. They're in that order because, like we organized the purine-with-the-amine first, cytosine is the pyrimidine-with-the-amine and is first. The step from the purine-with-the-amine (adenine) to the purine-without (guanine) was a deamination. So, too, is it a deamination to go from the pyrimidine-with-the-amine (cytosine) to the pyrimidine-without (uracil). Uracil to thymine is a methylation.

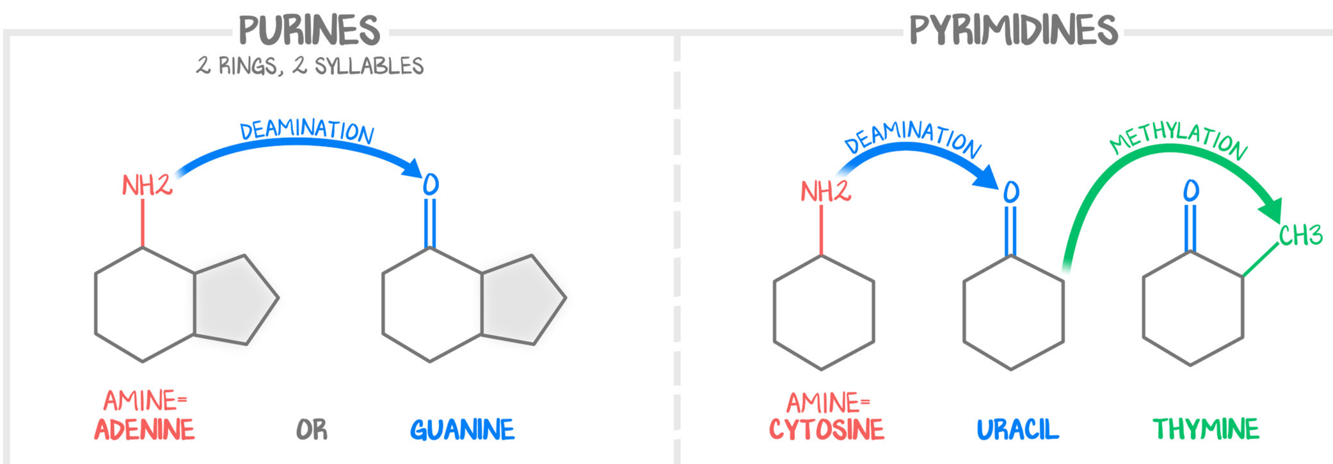

Figure 2.2: The Base
Purines have 2 rings (A and G). Pyrimidines take a CUT so have only one ring (C, U, T).

But the thing that makes this easier is that **deoxyribose** (DNA) can be only cytosine or thymine (amine-pyrimidine or not). **Ribose** (RNA) can be only cytosine or uracil (amine-pyrimidine or not). Both DNA and RNA can be only adenosine or guanine (amine-purine or not).

Remember that CUT is the pyrimidine, Uracil is for RNA, and AG are the other ones, and you can pretty much deduce it out.

The Phosphate Group

Phosphates form a high-energy bond. The more phosphates there are, the more energy there is. ATP, the source of energy in the body, is adenosine triphosphate (adenosine + three phosphates). These phosphate bonds store energy to be used later, and require specialized machinery to build (more on this in Metabolism). It takes only one phosphate to take a nucleoside to a nucleotide. It takes only **one phosphodiester bond** to link two nucleotides together. When analyzing the structure of a nucleic acid, look for the **phosphate group** at the **5 position**. It's either absent or present.

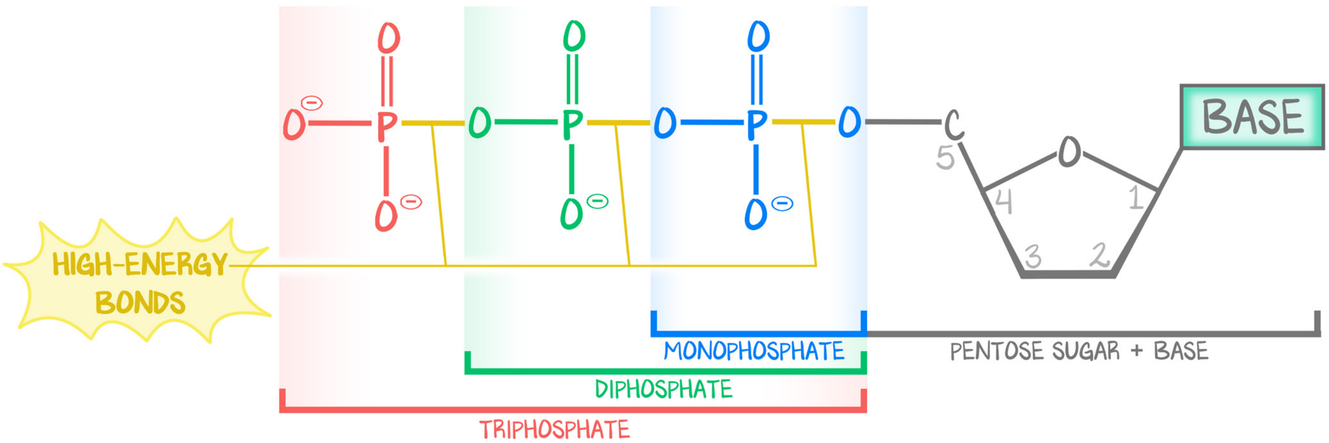

Figure 2.3: The Phosphate Group
The more phosphate bonds there are, the more high-energy bonds there are, the higher-energy the resulting molecule.

Nucleoside and Nucleotide

A **nucleoside** is a sugar with a base on it at carbon 1. A nucleoside can be either ribose (RNA, 2 position has an OH) or it can be deoxyribose (DNA, 2 position has no OH). A nucleoside has no phosphate on it; its 5-position carbon has the OH (hydroxyl) group.

A nucleo**s**ide is made before a nucleo**t**ide; s is one letter before t, and the only difference between a nucleoside and a nucleotide is the presence of one phosphate group at the 5 position (though nucleotides can have more than one phosphate, it helps the organizer to think about it from the perspective of nucleic acids, which follow the phosphodiester backbone, linking together nucleotides by a single phosphate group).

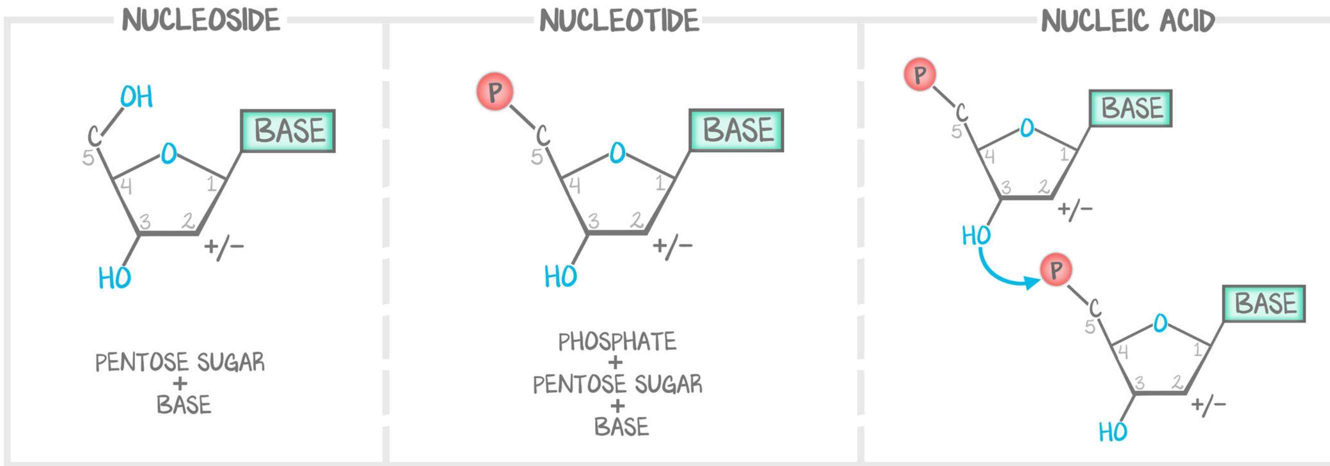

Figure 2.4: Nucleic Acid Chains
A nucleoside is a pentose and a base. Nucleotides are the pentose, base, and the phosphate group.

A **nucleotide** is a sugar with a base on it, a carbon, AND at least one phosphate at the 5 position. A nucleotide can be either ribose (RNA, 2 position has an OH) or it can be deoxyribose (DNA, 2 position has no OH). All nucleotides can come in a monophosphate (AMP), di-phosphate (ADP), or triphosphate (ATP) forms. In the examples given, Adenosine (A) was chosen, though it would be simple to replace it with G, C, U, or T.

Technically, if it's a deoxy form (DNA), a little d is added in front (dATP). The utility of this from this point forward is minimal. It was included for completeness and isn't a convention (or distinction) that matters in medicine.

Identifying What It Is by What It Looks Like

1. Identify the 5-carbon sugar, the base, and whether there's a phosphate. If phosphate, then tide; if no phosphate, then side.
2. Look at position 2. If OH then RNA, if no OH then DNA.
3. Look at the base. If there are two rings, it's a purine.
4. If there are two rings, and an amino group it's adenine; else it's guanine
5. If there's a one-ring base, it's a pyrimidine.
6. If there's a one-ring base + an amino group, it's cytosine.
7. If there's a one-ring base without an amino group, and it's RNA, it's uracil.
8. If there's a one-ring base without an amino group, and it's DNA, it's thymine.

Phosphodiester Bonds and Directionality

In English, we read left to right. We also write left to right. You're reading left to right now. It makes sense when the letters and the words are put down in the correct orientation. Consider the phrase *"you're reading left to right now . . . "* Any problem reading and comprehending that phrase? Probably not.

Now the same phrase again, with the letters being read right to left. *"won thgir ot tfel gnidaer er'uoY"* doesn't make a whole lot of sense, does it? And the word processor didn't like the phrase either. It doesn't mean anything to anyone.

Sequences of DNA are like chapters of our genetic code. They, like this lesson, are directional. It makes sense in only one direction. Now while multiple sequences can be layered on top of each other with the message changing depending on where you start and what is cut out—that's what the entire Transcription lessons are about—the code only makes sense in one direction.

Just as we read left to right in English, so too does DNA make sense only in the 5' to 3' direction. We start at the nucleotide with a free 5-carbon position, attached to a phosphate, then read from the 5 position forward towards the nucleotide with the free 3-carbon position, attached to a hydroxyl group. When written on an exam, unless prime is defined, the convention is 5' starts on the left, 3' ends on the right. 5' to 3', left to right. This means that each nucleic acid that's added to the sequence will attach its **incoming 5-carbon position** to a strand of nucleotides at the **3-carbon position** with a hydroxyl group. This attaching of the two nucleic acids is performed through a **phosphodiester bond**.

The phosphodiester bond is the backbone of a single strand of nuclear material. Each nucleotide is separated by a phosphodiester bond between the 3 position of one, and the 5 position of the other. Phospho (P) di-ester (2 O) comes from the phosphate group of the 5 position and the hydroxyl group of the 3 position.

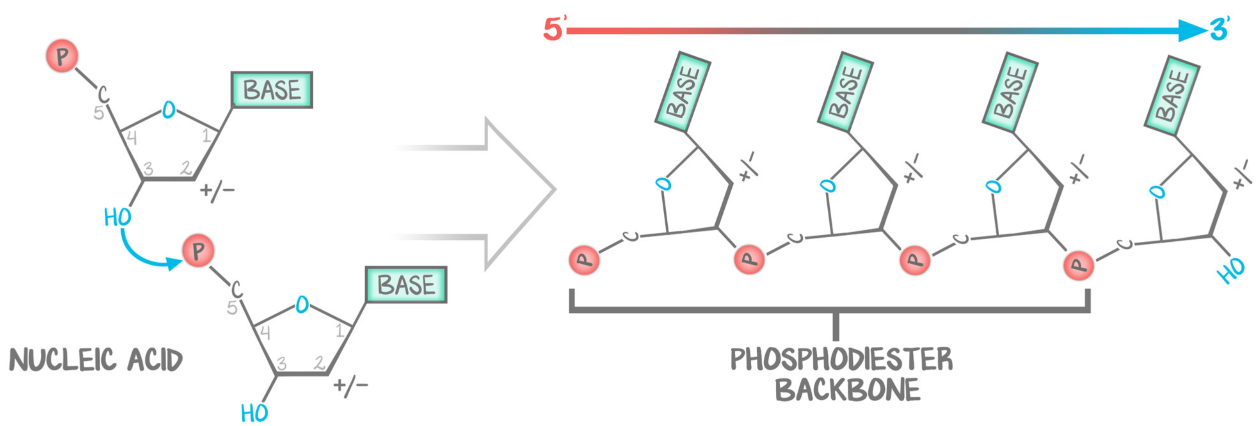

Figure 2.5: Nucleic Acids Linking Together
A phosphodiester bond is made by the bonding of the free 3-carbon OH end (the 3' end) of an elongating strand and the free 5-carbon phosphate (5') of an incoming nucleotide.