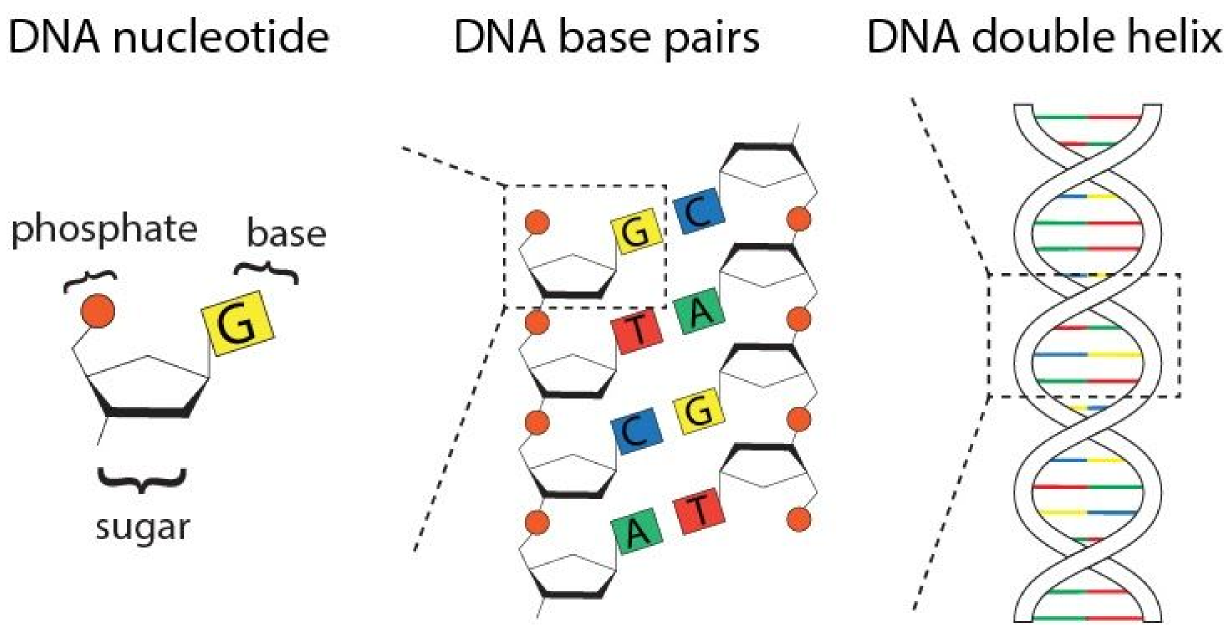
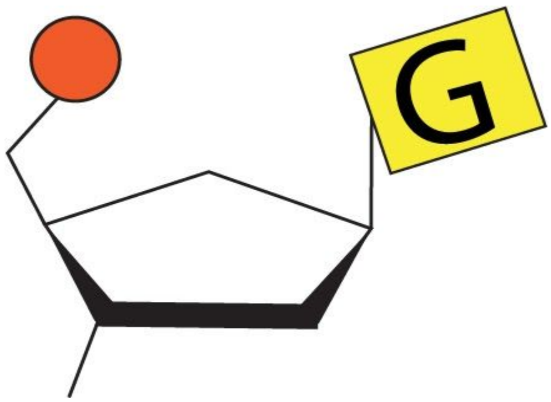
You've learned that our genes are stored in each of our cells in the form of molecules of DNA. DNA works so well at storing genetic information because it forms a "double-helix" structure with two strands of DNA twisting around each other. Each of these strands is a chain of linked up smaller molecules, DNA nucleotides, made from three parts, a sugar, a phosphate, and a base. The sugar and phosphate link up to the next nucleotide in the chain, while the base can be one of four different letters in the DNA alphabet, "A", "C", "G", and "T" (standing for adenine, cytidine, guanine, and thymine). The nucleotide bases in a strand of DNA can pair with bases on another strand, As pairing with Ts, Cs pairing with Gs, and vice versa. This "base-pairing" is what helps two strands of DNA come together to form a double helix, and is also how the proteins in our cells read the genetic information in DNA.

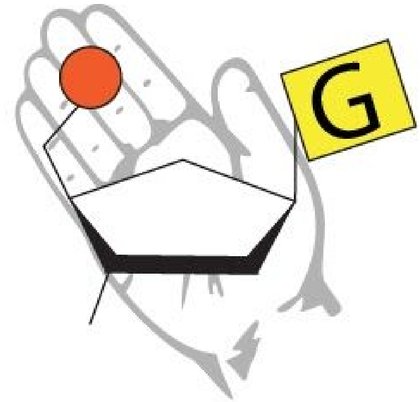


But there's another important property of DNA which determines how it forms a double helix: chirality. "Chirality" or handedness (the word chiral comes from the Greek word for hand), is a property many molecules have, particularly those found in living things, where a molecule and its reflection in the mirror are different. This might sound weird, but the same is true for parts of your body. No matter how you turn or flip your hands, you can't make one perfectly match the other: the thumbs will point in different directions, one will be palm up and the other palm down. However, if you hold up your right hand to a mirror, the reflection shows a left hand. Chiral molecules also have distinct left-handed and right-handed versions that are mirror images of each other.

Q1. *Here is a DNA nucleotide, as shown on the previous page. What would its mirror-image look like? Is this mirror image the same as the original nucleotide? Can you rotate one to make it perfectly overlap with the other?*



DNA nucleotides can be built in right-handed or left-handed forms. One way to visualize this is to picture a nucleotide resting in your hand, as shown to the right. You can see the sugar sitting in the palm of a right hand, with the phosphate touching the fingers and the base touching the thumb. If you rotate this nucleotide around, the relative position of the phosphate, sugar, and base never change, even if their direction does - just like the fingers, palm, and thumb stay in the same arrangement in your right hand, no matter how you turn it. This nucleotide is right-handed, or a D-DNA nucleotide (the D stands for dexter, or "right" in Latin). A left-handed nucleotide (L-DNA from the Latin word "laevus", or left), would not be able to fit in your right hand in the same way, no matter how you rotated it, but it would fit into your left hand (as you can see to the left).



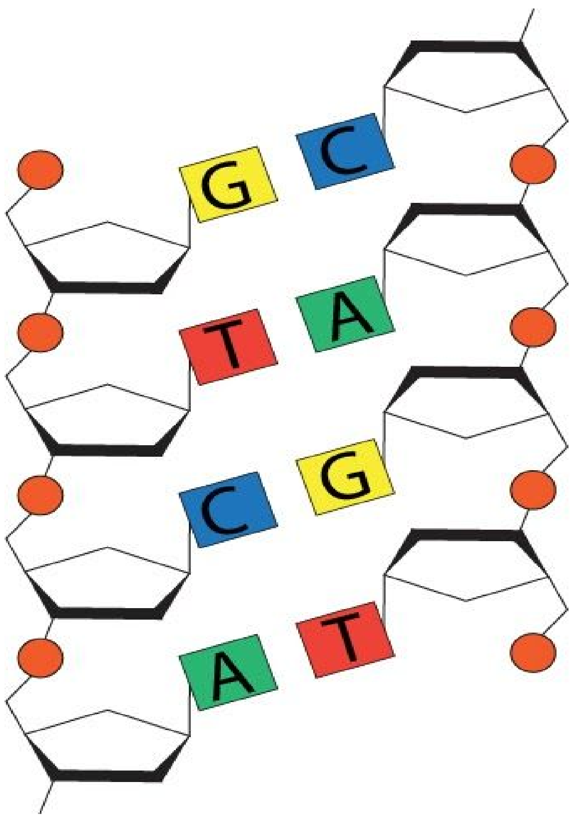
“right-handed” DNA nucleotide
(or D-DNA nucleotide)

“left-handed” DNA nucleotide
(or L-DNA nucleotide)

Although hands (or paws or hooves or flippers) come in left and right pairs, every living thing that scientists have found on Earth uses only right handed D-DNA. This is such an important feature of living things scientists have come up with a specific term for it, "homochirality", from the Greek words for "same" and "hand". Most chemical reactions that happen outside of living things, or inside a laboratory, will produce equal amounts of left-handed and right-handed molecules, so chemicals produced by living things are quite special and unique.

So why does life only use right-handed DNA? We can't find any left-handed L-DNA in living creatures to study, but we can make it in the lab and study it. Strands of L-DNA can base-pair with other strands of L-DNA, and form double helices, just like D-DNA. In fact, L-DNA behaves nearly identically to D-DNA.

Q2. *Here are two* D*-DNA strands, base paired together; lines have been added between the phosphates in each strand, and connecting each of the base pairs, showing the "ladder" structure that will twist into a double helix. Draw the same structure using* L*-DNA (use the* L*-DNA nucleotide structure shown previously as a reference), and add the same connecting lines. How are the two ladders for* D*-DNA and* L*-DNA related?*



Just like D-DNA and L-DNA nucleotides are mirror-images of each other, when two strands of DNA pair up together, the angle between the sugar and phosphates on the outside of the strands, and the bases on the inside, are different depending on whether it is D-DNA or L-DNA. These angles determine how the paired strands bend to form into a double-helix. You have been given a printed sheet of origami that can be folded into a double helix; some have been printed with D-DNA or L-DNA, and the different angles between paired nucleotides will determine how it is folded into a helix, mimicking what happens with real DNA. Answer the following questions and use the separate instructions to fold your origami double helix:

Q3. *Is the origami sheet you have been provided D-DNA or L-DNA? Use your answers to Q1 and Q2 to determine the answer.*

Once you've determined what type of DNA you have, follow the provided instructions to fold your origami helix. Remember that when making a fold in the paper, to always have the thick line on the outside of the fold, and the thin line on the inside. Once you have a helix, answer the following questions about it.

Q4. *A double helix can be chiral, just like smaller molecules. To determine the "handedness" of a helix, imagine it is a spiral staircase, and you are walking from the top to the bottom - as you move down these stairs, would you turning left or right? Whichever direction you need to turn as you move down a helix is the handedness.*

Q5. *Compare your helix with other students' - are all the helices the same handedness, or different? Compare the helix handedness of D-DNA and L-DNA - which handedness of DNA leads to a right-handed helix?*

Q6. *Carefully stretch out and cut one of the L-DNA helices in half, so that you have a single "strand" of L-DNA. Try to lay this strand onto a D-DNA helix, so that the bases in the L-DNA strand pair correctly to D-DNA. Is this possible without bending the L-DNA out of its original helical shape? Do you think an L-DNA and D-DNA strand could pair with each other?*

Q7. *Proteins in our cells bind to DNA to read and copy it. Proteins are made of amino acids, which like DNA nucleotides, are also chiral. Unlike DNA, amino acids found in living things are left-handed. Imagine your left hand is a protein: curl your hand and rest a D-DNA helix in it so that one edge is touching your palm and thumb, and the tips of your fingers are touching the other edge. Hold your hand in that position, remove the D-DNA helix, and try to place an L-DNA helix in the same position - can it fit, or do you* *have to move your fingers? Based on these results, would L-proteins in our cells be able to interact with L-DNA in the same way that they interact with D-DNA?*

Q8. *Imagine an organism that wasn't homochiral, and had equal mixtures of D-DNA and L-DNA nucleotides in its DNA strands. What problems would this cause? Would the organism be able to use this kind of DNA to store genetic information?*