Science-1A Lecture: Week-13, Friday, November 5, 2021

DNA, Proteins and Enzymes, and Oxytocin

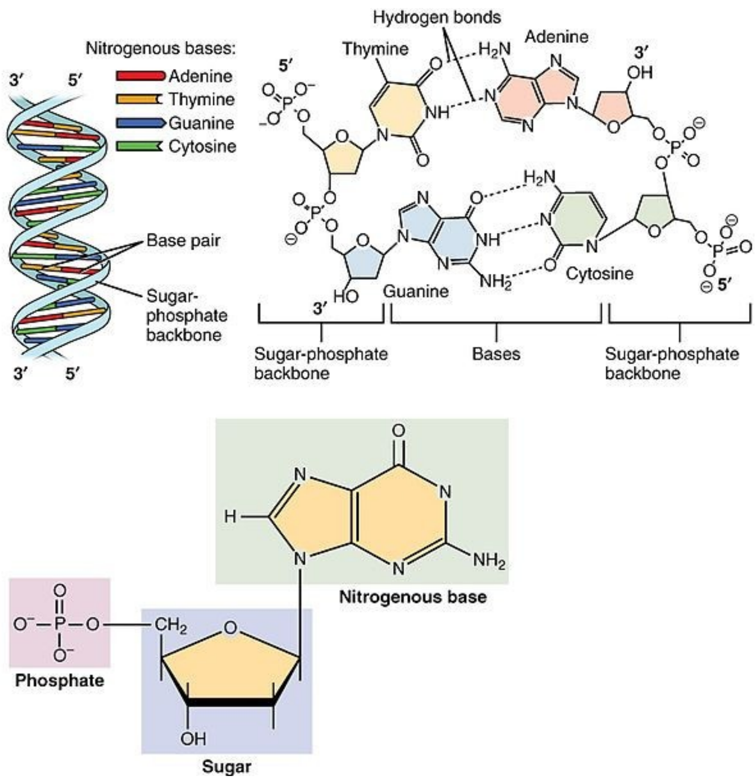
This lab is focused on understanding the basic outline of how life functions. **Read slowly, and carefully study the animations and diagrams.** It is worth understanding this magnificent mechanism developed by a billion years of evolution. The recipe books for all life on Earth – from microbes to humans – use the same process.

DNA Structure

The process to construct amino acid chains is directed by a pattern of molecule pairs in a long polymer called **deoxyribonucleic acid (DNA)**. DNA is like a recipe book where each of its tens of thousands of recipes (**genes**) describes how to make a particular polypeptide or protein. To allow replication during cell division and to reduce the chance for errors, DNA is composed of two strings of molecules joined together by hydrogen bonds and strengthened on the outside by a pair of phosphate backbones.

A small animation of 12 base pairs of DNA (a little over 1 full twist) is at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/DNA/DNA_animation.gif .
Hydrogen bonds which connect the two strands of its double-helix structure are not shown in this animation.

Its structure is explained in the diagram below at the right that was obtained with a slight modification (adding a 3') from *https://en.wikipedia.org/wiki/Nucleotide#/media/File:0322_DNA_Nucleotides.jpg* .



The basic components of DNA are the 4 **nitrogenous bases Adenine (A)**, **Cytosine (C)**, **Thymine (T)** and **Guanine (G)**. These are each connected to a deoxyribose sugar and a phosphate group to make **Deoxy...Monophosphate** versions. Those, in turn are paired by hydrogen bonds to make base pairs GC and TA which are stacked to construct DNA.

Two turns of the DNA double helix are shown in the upper-left of the figure at the right. **Nitrogenous base** pairs span between two sugar-phosphate ribbons with ends labeled 3' and 5' according to a traditional number scheme for the carbons of the sugars that make connections to the next or previous base pair. TA and GC pairs are shown as colored rods with mating ends shown in the small legend next to the double helix.

A similar color scheme is used in the molecular diagram in the upper-right of the figure which uses dashed lines to show the hydrogen bonds connecting each base pair, 2 for TA and 3 for GC.

Each base is connected to a 5-sided ribose sugar that is missing one oxygen making it a **deoxyribose** sugar.
Notice also that in the upper-right of the figure the oxygens in the sugar rings on the left side point upwards while those at the right point downwards. The connections to their respective phosphate chains are similarly inverted; the left side goes from 3' at the bottom to 5' at the top while the right side goes in the opposite direction.

At the bottom of the figure is shown in detail how a typical base (**Guanine**) is connected to a **Deoxyribose** sugar which in turn connects to a phosphate in the backbone. This combined molecule is called **Deoxyguanosine Monophosphate**.
Animations of the 4 monophosphate versions of the bases are at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/DNA/
The missing oxygen that makes the ribose sugar deoxyribose is apparent just above and to the right of the "r" in the word "Sugar". The –OH functional group closest to the "S" at the start of the word "Sugar" will lose its H and connect to the

phosphate backbone chain just below it (not shown). That connection is at the 3' carbon of the sugar whereas the phosphate shown in pink above it is connected to the 5' carbon.

Nature has cleverly chosen to put some double bonds in these 4 nitrogenous bases to make them flat so that they stack neatly when put together within the spiral double phosphate backbone of DNA. Either of the two base pairs is used as shown or flipped depending on whether it is on the 3'-5' side or the 5'-3' side.

An animation of the 2 layers shown in this figure, with hydrogen bonds shown in yellow, is at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/DNA/2-LayersOfDNA.gif
and with a slower rotation speed at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/DNA/2-LayersOfDNA-Slow.gif .

DNA Replication

The double helix structure allows replication. Its hydrogen bonds are unzipped into two nucleic acid chains, and molecular machines build a new opposite side onto each chain producing two identical copies or the original. This is possible since all G's must be matched to a C, all C's to G's, all T's to A's and all A's to T's. The speed of these microscopic processes is very fast since travel distances are tiny compared with the molecular speeds provided by thermal motion at body temperatures. This is shown in a marvelous short video entitled "DNA Replication - DNA Polymerase and Helicase Activity Animation" at
https://www.youtube.com/watch?v=v8gH404a3Gg .
It shows how the amazing enzymes called **helicase**, **dna polymerase**, and **lagging strand dna polymerase** rapidly perform this construction. You may want to watch it more than once to absorb it all. Notice that you can change the playback speed with the settings gear that appears at the lower right side when the mouse pointer hovers there.

You may have heard about a process called **polymerase chain reaction (PCR)** talked about in medical and crime shows. It is explained in the short video entitled "How does PCR work? The polymerase chain reaction explained" at
https://www.youtube.com/watch?v=3XPAp6dgl14 .
An interesting historical note about the discovery which made PCR practical was that bacteria in hot springs have a version of dna polymerase which operates at higher temperatures than that from most creatures. That high-temperature capability was key to the making PCR possible.

DNA to Messenger RNA (DNA Transcription)

DNA resides in the nucleus of a cell, but the manufacture of proteins from the information in DNA usually must occur in the protoplasm of the cell outside of the cell nucleus. Nature therefore copies gene information into a molecule called messenger RNA (mRNA) which is transported out of the nucleus into the protoplasm. This is described in the video entitled "DNA Transcription (Basic)" at
https://www.youtube.com/watch?v=5MfSYnItYvg .

mRNA to Proteins (RNA Translation)

After the mRNA has moved into the cell protoplasm, it is used by a very complicated molecular machine called a **ribosome** to read the mRNA and create the specified chain of amino acids. This is described in the video entitled "mRNA Translation (Advanced)" at
https://www.youtube.com/watch?v=TfYf_rPWUdY .

Summary Animations Leading to Cell Division

Finally, a 20-minute collection of animations shows this in greater detail including how chromosomes are formed and cell division happens. It is entitled "The Molecular Basis of Life" and is at
https://www.youtube.com/watch?v=fpHaxzroYxg .

DNA Coding to produce oxytocin

A specific example of how the oxytocin DNA code leads to the polypeptide oxytocin is described in the handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-13/DNAToProteins.pdf

The terms **protein**, **enzyme**, and **polypeptide** all refer to amino acid chains. Proteins are very long chains that fold up into complicated structures while polypeptides are simply short chains. Enzymes are proteins that catalyze biochemical reactions by having precise shapes that hold specific reactants in a manner that lowers their reaction energy barrier.

This Week-13 Friday Lecture is an extension of the Week-13 Lab and leads to an additional lab credit. To earn that credit, report that you have done the following:

1. Read this handout.

2. Watched the animation of a section of DNA at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/DNA/DNA_animation.gif

3. Watched the amazing 20-minute video summarizing DNA replication, protein creation, and cell division. It is at
https://www.youtube.com/watch?v=fpHaxzroYxg

4. Studied the handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-13/DNAToProteins.pdf
about how the DNA recipe for oxytocin is used to make the molecule oxytocin.

5. Watched the following 4 short animations:

DNA Replication - DNA Polymerase and Helicase Activity Animation (2 min 18 s)
https://www.youtube.com/watch?v=v8gH404a3Gg

How does PCR work? The polymerase chain reaction explained (2 min 15 s)
https://www.youtube.com/watch?v=3XPAp6dgl14

DNA Transcription (Basic) (1 min 52 s)
https://www.youtube.com/watch?v=5MfSYnItYvg

mRNA Translation (Advanced) (3 min 3 s)
https://www.youtube.com/watch?v=TfYf_rPWUdY