DNA

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What is DNA?

- **DNA is deoxyribonucleic acid.**
  - It is kept in the nucleus of a cell to protect it.
- **DNA = Instructions for making cellular proteins.**
  - Proteins are the functional molecules in an organism's cells.
    - *Proteins are like molecular machines.*
- **DNA tells a cell what ingredients it needs to make a protein.**
  - Those ingredients are also what give the protein its shape.
    - *The shape of the protein determines its function.*
  - The ingredients of proteins are amino acids.
    - *Amino acids are the building blocks of protein.*
    - *Just like a necklace can be made out of pearls, a protein is made out of amino acids.*

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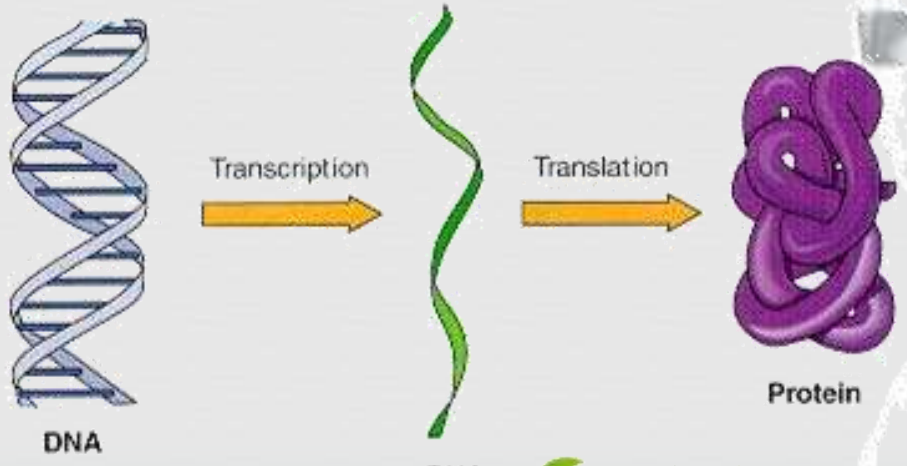
What is DNA?

- **Each section of DNA that codes for a specific protein is called a <u>gene.</u>**
  - A <u>gene</u> is just a length of DNA that codes for a protein.
    - *For example, the protein that gives your eyes its color is made from a specific stretch of DNA.*
  - Just like a sentence is a portion of a paragraph, a gene is just a portion of DNA.

- **DNA is responsible for the functions of all living things.**
  - Proteins are the molecules that make the cells of all living things work.
  - The information needed to create a protein is 'written' in DNA.
  - Without DNA, a cell could not create proteins.
    - *Without proteins, a cell could not function.*



Source: www.katiephd.com

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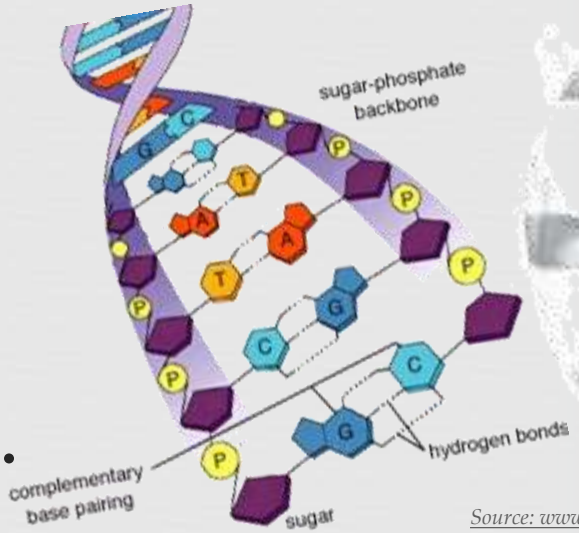
What is DNA made from?

- **DNA is made from 3 key ingredients**
  - 1. A nitrogen-based molecule (or base): there are four kinds of bases
    - *Adenine, Guanine, Cytosine, and Thymine*
    - *The order and combination of these bases in DNA determines how a protein is created by the cell*
  - 2. Sugar molecules
  - 3. Phosphate molecules

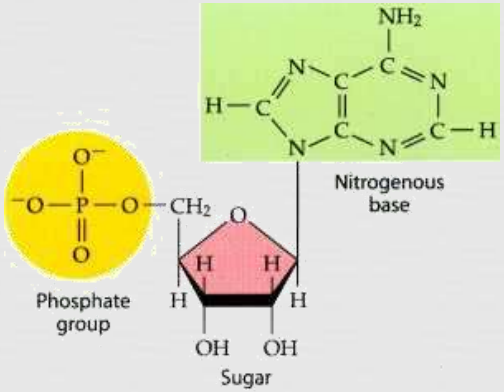


Source: www.mhhe.com

- **Sugar and phosphate together form the "skeleton" of the DNA molecule and hold the bases in place.**
  - Sugar and phosphate do not encode any information – they just hold the information in place.

Nucleotides

- **A <u>nucleotide</u> is a subunit (or building block) of DNA consisting of a base, a phosphate, and a ribose sugar.**



Bases

- **The bases in DNA are the molecules that actually create the code a cell reads in order to create a protein.**

- **There are 4 kinds of bases in DNA: guanine, cytosine, adenine, and thymine.**
  - The 4 bases are typically just abbreviated by their first letter: G, C, A, & T

- **The combinations of these four bases are what create the genetic code.**

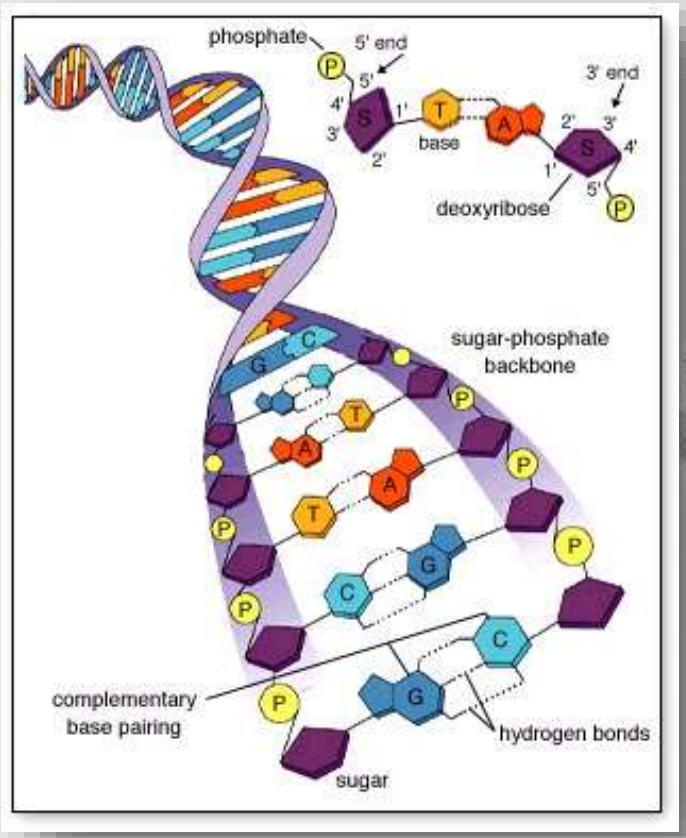
TTT phe	TCT ser	TAT tyr	TGT cys
TTC phe	TCC ser	TAC tyr	TGC cys
TTA leu	TCA ser	**TAA OCH**	**TGA OPA**
TTG leu	TCG ser	**TAG AMB**	TGG trp
CTT leu	CCT pro	CAT his	CGT arg
CTC leu	CCC pro	CAC his	CGC arg
CTA leu	CCA pro	CAA gln	CGA arg
CTG leu	CCG pro	CAG gln	CGG arg
ATT ile	ACT thr	AAT asn	AGT ser
ATC ile	ACC thr	AAC asn	AGC ser
ATA ile	ACA thr	AAA lys	AGA arg
ATG met	ACG thr	AAG lys	AGG arg
GTT val	GCT ala	GAT asp	GGT gly
GTC val	GCC ala	GAC asp	GGC gly
GTA val	GCA ala	GAA glu	GGA gly
GTG val	GCG ala	GAG glu	GGG gly

Image Source: chemistry.gravitywaves.com

Rules of DNA

- **<u>Rule #1:</u> DNA is formed of two sugar-phosphate chains on the outside and two bases on the inside.**
  - This closely resembles a ladder that twists.

- **<u>Rule #2:</u> Inside that ladder, A must always pair with T and G must always pair with C**
  - This occurs for two reasons:
    - *They wouldn't fit any other way.*
    - *A & T have two bonding sites; G and C have 3 bonding sites*
  - <u>G</u>reat <u>C</u>ombinations are <u>A</u>lways <u>T</u>ogether



Source: www.mhhe.com

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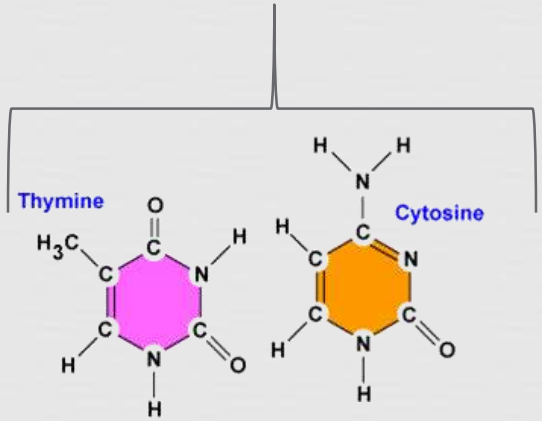
Too Big, Too Small, Just Right

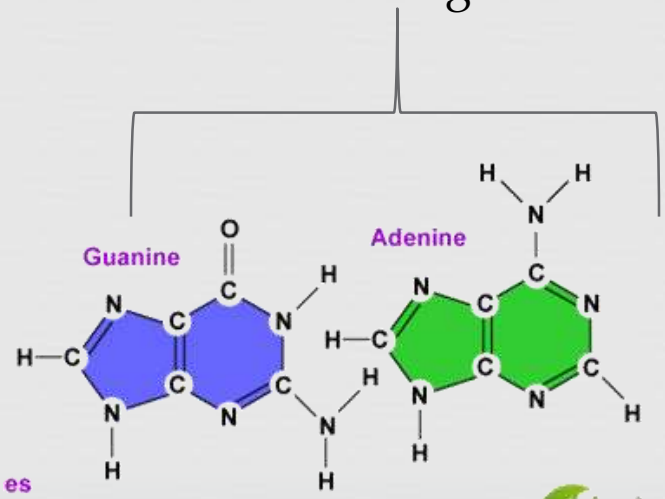
- **Thymine and Cytosine would be too small to fit inside the structure of DNA.**
  - These are the smallest of the 4 bases.

- **Guanine and Adenine would be too big to fit inside the structure of DNA.**

Too small



Too big



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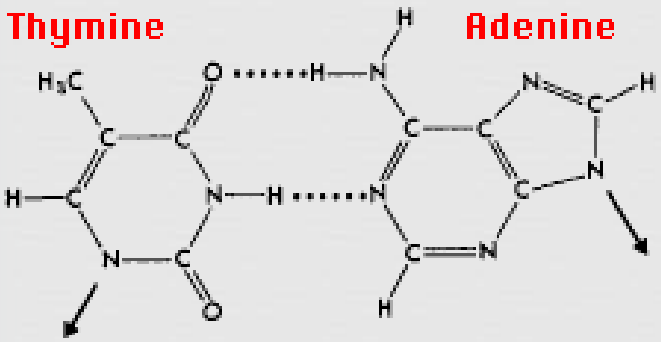
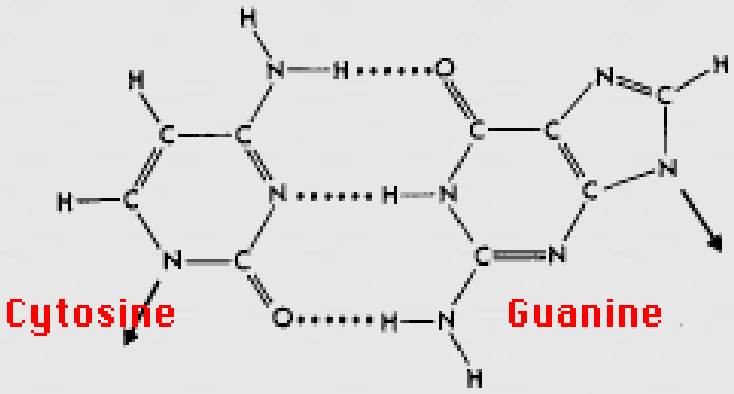
Base Bonding

- **C-G and T-A combinations are also necessary because of binding sites**
  - A and T have 2 binding sites (*AT=2*)
  - C and G have 3 binding sites (*GC=3*)
    - *They wouldn't match up any other way*





Rules of DNA

- **<u>Rule #3:</u> DNA is always read in a 5′ → 3′ direction**
  - 5′ and 3′ refer to how the carbon atoms in the sugar molecule are numbered.
  - DNA is always read from the 5th carbon atom to the 3rd carbon atom by the cell.
  - There is no up/down/ left/right in a cell – this is the only way to give the cell a sense of direction.

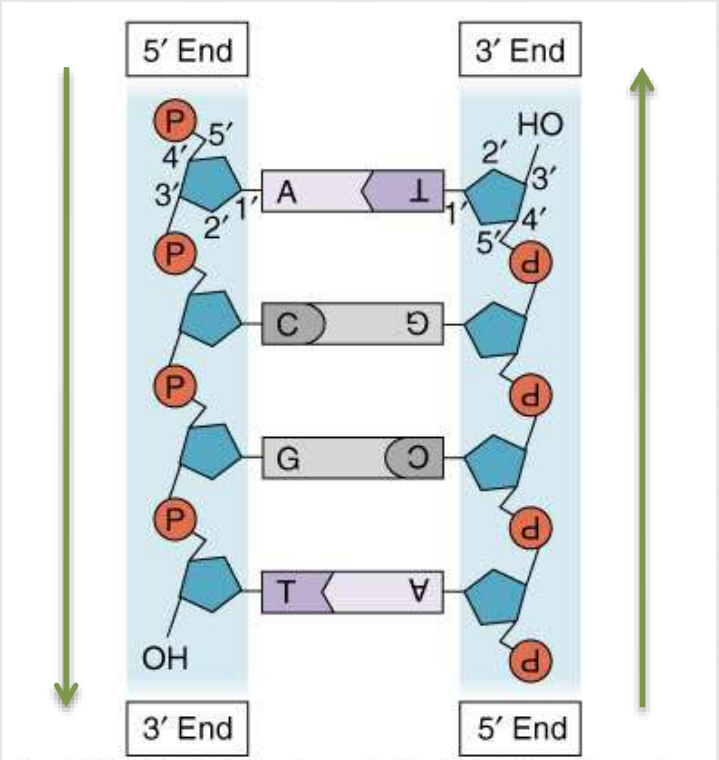


Image Source: celebrityhollywoodcool.blogspot.com

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How DNA Works

- **When the cell needs the information for making a protein, it will need to open up the DNA to read it.**
  - When DNA is in its "ladder" version, it is not able to be read.
  - The DNA must first be opened in order to read it.

- **The cell opens DNA using DNA Helicase**
  - DNA Helicase is a protein that opens DNA in the same way that your zipper tab opens a zipper.

- **Once DNA is opened, it can be duplicated.**
  - Each cell has only one copy of its directions.
  - It would be far too dangerous to risk damaging or losing the only source of information a cell has!
  - Because of this, a cell will make a copy of the DNA – mRNA.

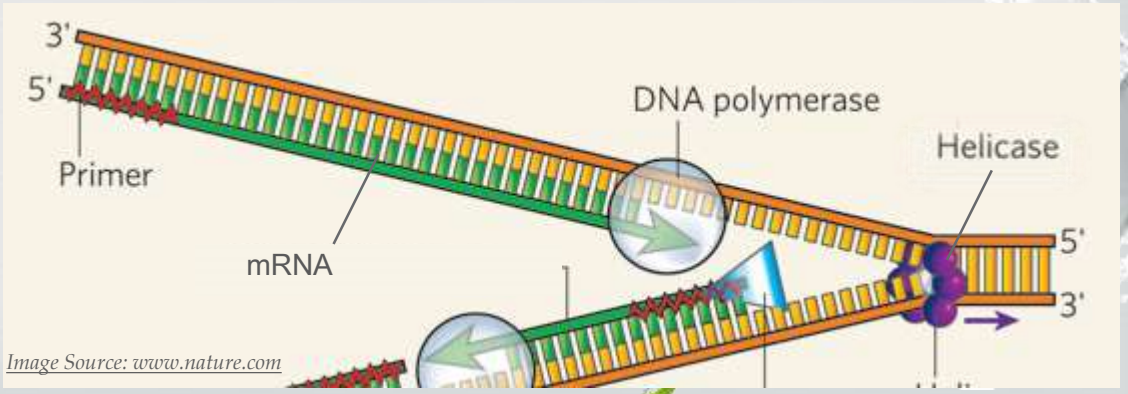
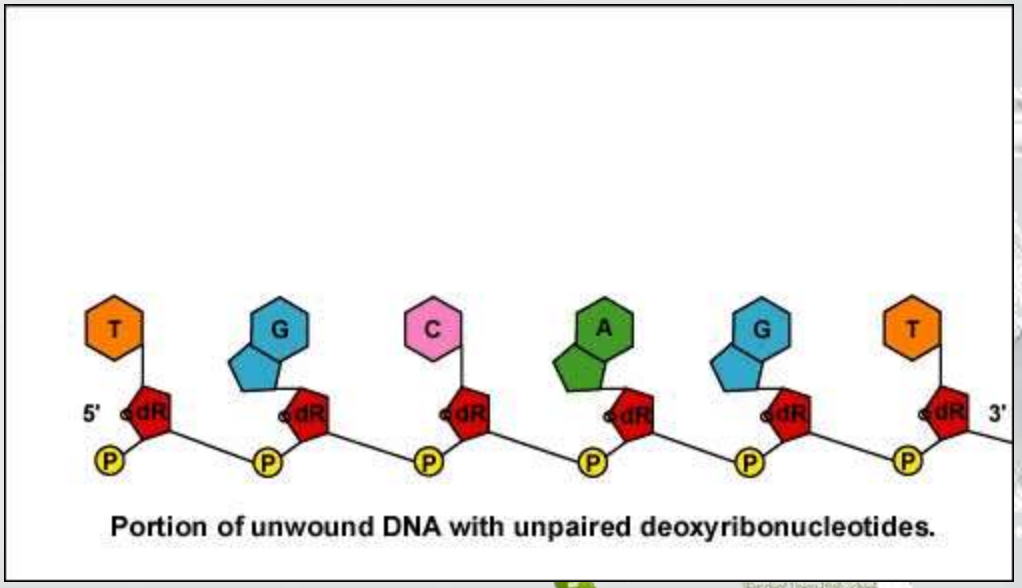


Image Source: www.nature.com

How DNA Works

- **<u>mRNA</u> is a copy of DNA**
  - mRNA is similar to DNA except that it is single stranded and uses Uracil (U) instead of Thymine (T)
    - *RNA is a more evolutionary-primitive version of genetic material.*
    - *Through natural selection, uracil was eventually replaced by thymine because uracil was more prone to mistakes and mutations.*

- **<u>Polymerase</u> is the protein that copies DNA and makes mRNA.**
  - Polymerase proteins read DNA in a 5→ 3 direction.
  - For every G, it puts a C.
  - For every C, it puts a G.
  - For every T, it puts an A.
  - For every A, it puts a U (because RNA uses U instead of T).



Portion of unwound DNA with unpaired deoxyribonucleotides.

Image Source: faculty.ccbcmd.edu

Transcription Animation

Step 1: Helicase opens and unwinds the DNA strand
Step 2: Polymerase adds a complementary base for each nucleotide
Step 3: The newly created mRNA strand goes to a ribosome to be read
Step 4: The DNA strand is closed and re-wound

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Transcription

- **The process in which DNA is read and copied so that a copy mRNA strand is created is called <u>transcription</u>.**
  - Analogy 1: Just a like a 'transcript' is a copy of a television program, transcription is the process in which DNA is copied.
  - Analogy 2: In medieval times, a 'scribe' recorded all the decisions of a king and copied them in a book.
    - *Polymerase is the 'scribe' for King DNA and makes copies in the form of mRNA.*

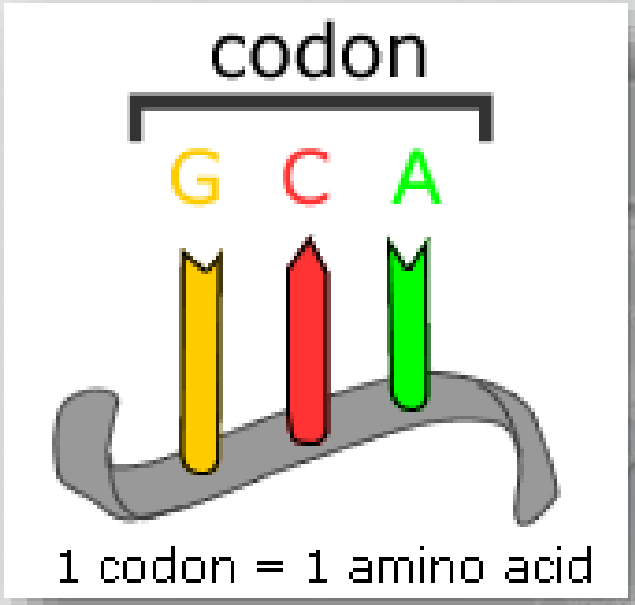
Image Source: [illegible]

Translation

- **After detaching from DNA, mRNA leaves the nucleus and travels to a ribosome.**
  - A ribosome is a protein factory.
    - *A ribosome is made out of rRNA.*
  - The mRNA is read by a ribosome in a 5 → 3 direction.

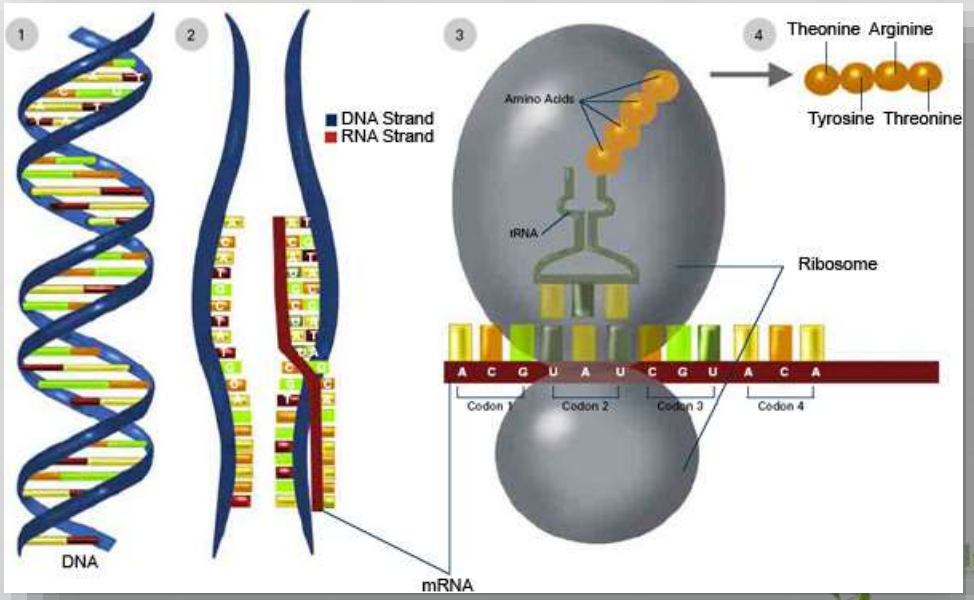
- **The bases in mRNA are read in groups of 3.**
  - Each group of 3 is called a codon.
  - Every codon (group of 3 bases) codes for a specific amino acid.
  - Amino acids are the building blocks of proteins.

- **The process of reading mRNA and creating proteins is called Translation.**



tRNA

- **A ribosome will read a codon in mRNA and tell tRNA what amino acids to bring to make a protein.**
  - tRNA will deliver the needed amino acid to the ribosome based on the codon being read.
    - *tRNA is the molecule that delivers amino acids.*



How tRNA 'knows'

- **tRNA 'knows' what amino acid to bring because it has the complementary RNA sequence.**
  - For example, if the codon is GCG, the tRNA carrying the correct amino acid will have the CGC codon.
  - Because it has the complementary RNA sequence, the tRNA will bond to the mRNA and then release its amino acid.
  - The ribosome will add this amino acid to the chain that forms the protein as the tRNA leaves.
  - The process will be repeated for the next codon.

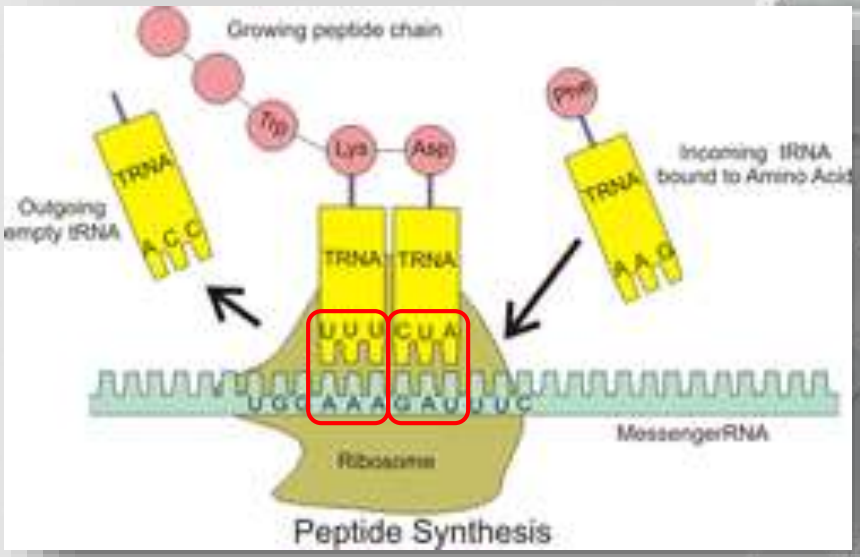
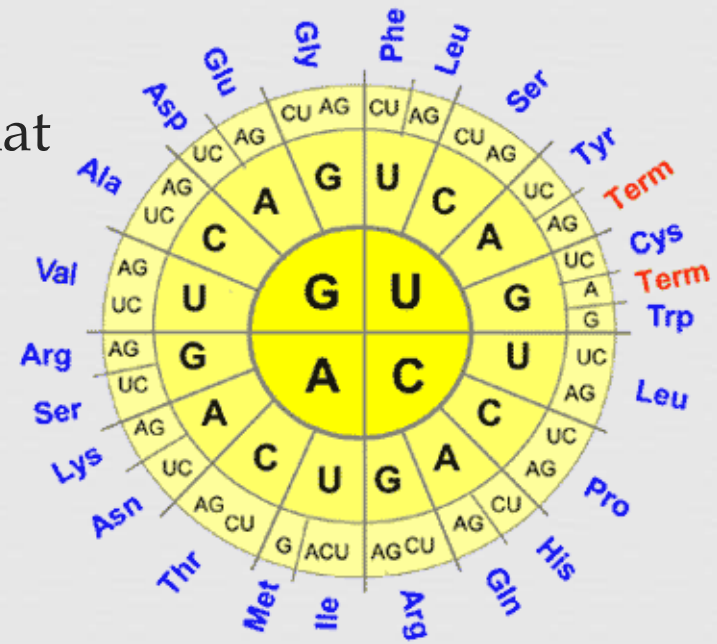


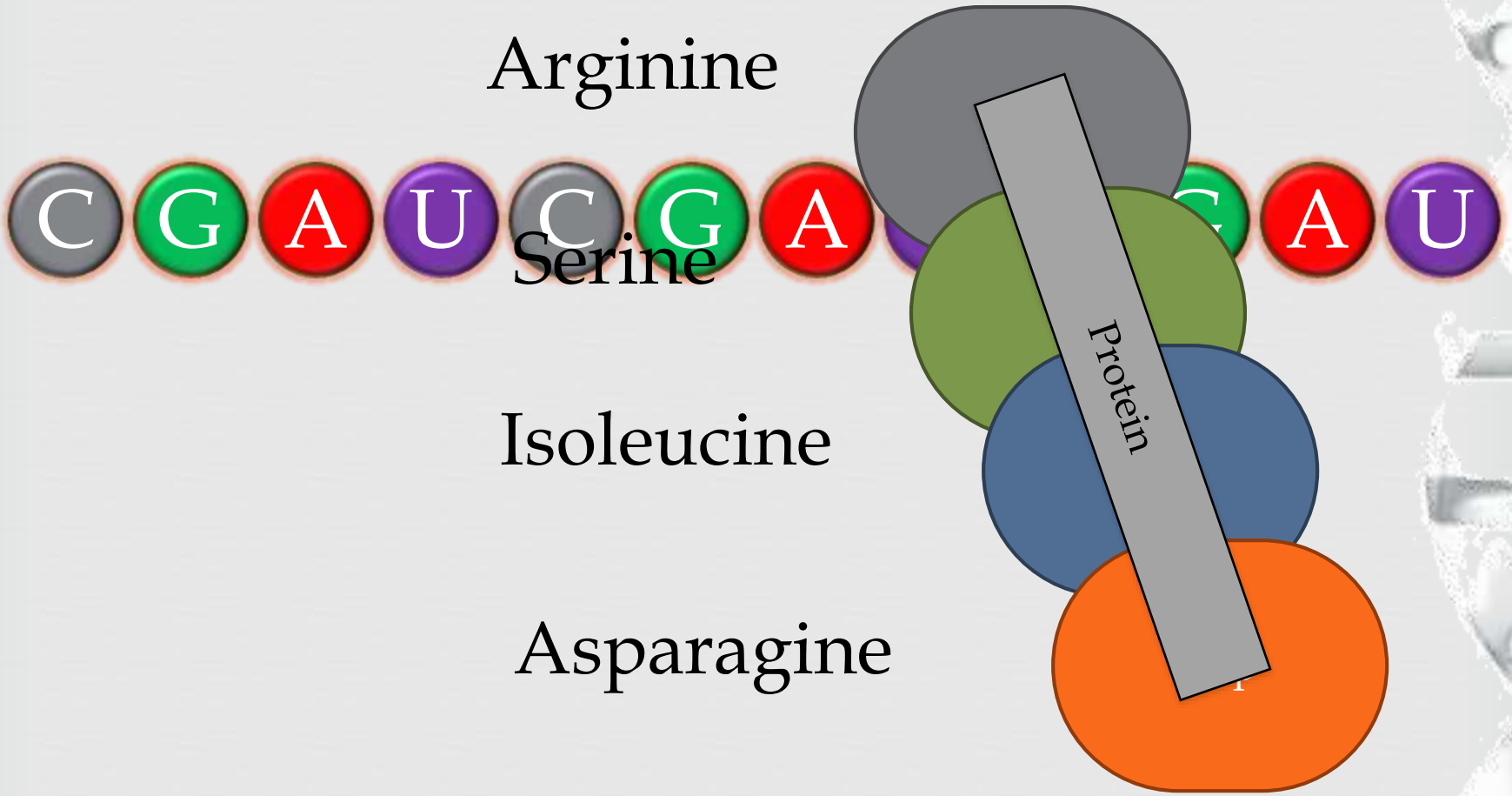
Image Source: en.wikipedia.org

Codons and Amino Acids

- **Every amino acid has at least one codon.**
  - If mRNA shows this codon to the ribosome, tRNA will deliver that amino acid.
  - Once delivered by tRNA, that amino acid will be added to the growing protein chain.
  - In this chart, you can see all of the codon combinations that code for each amino acid.
    - *E.g. CUU would be Leu, or Leucine.*
    - *UAC would be Tyrosibe.*

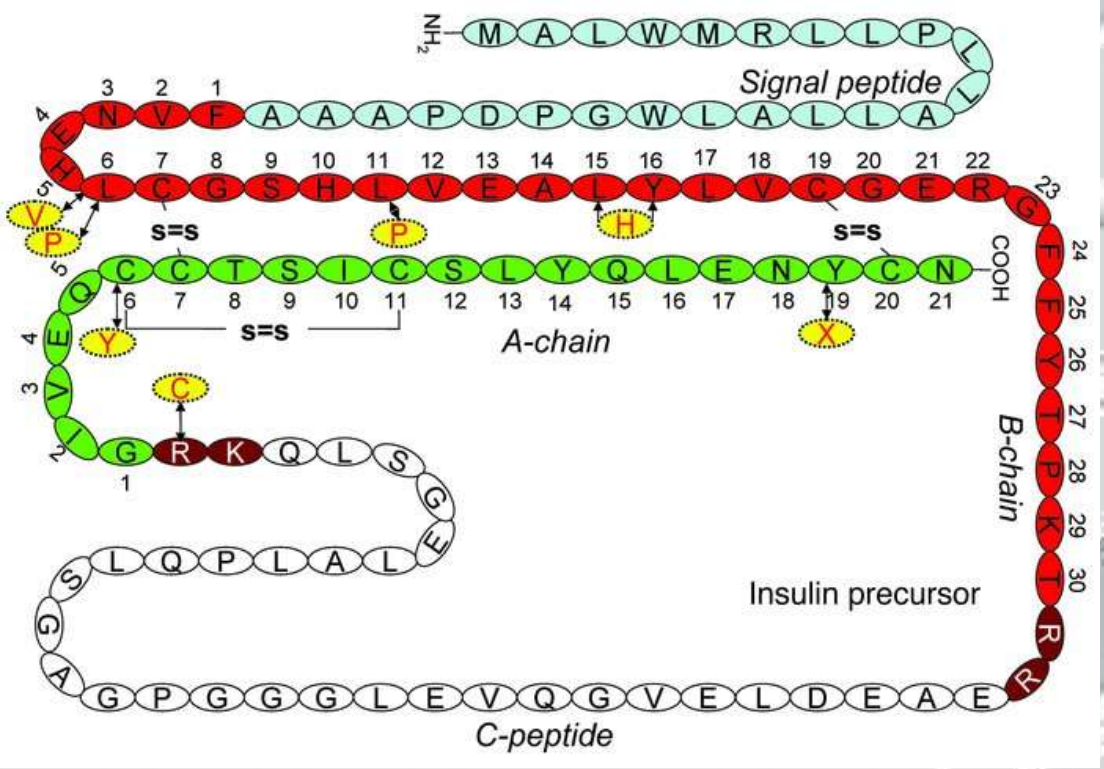


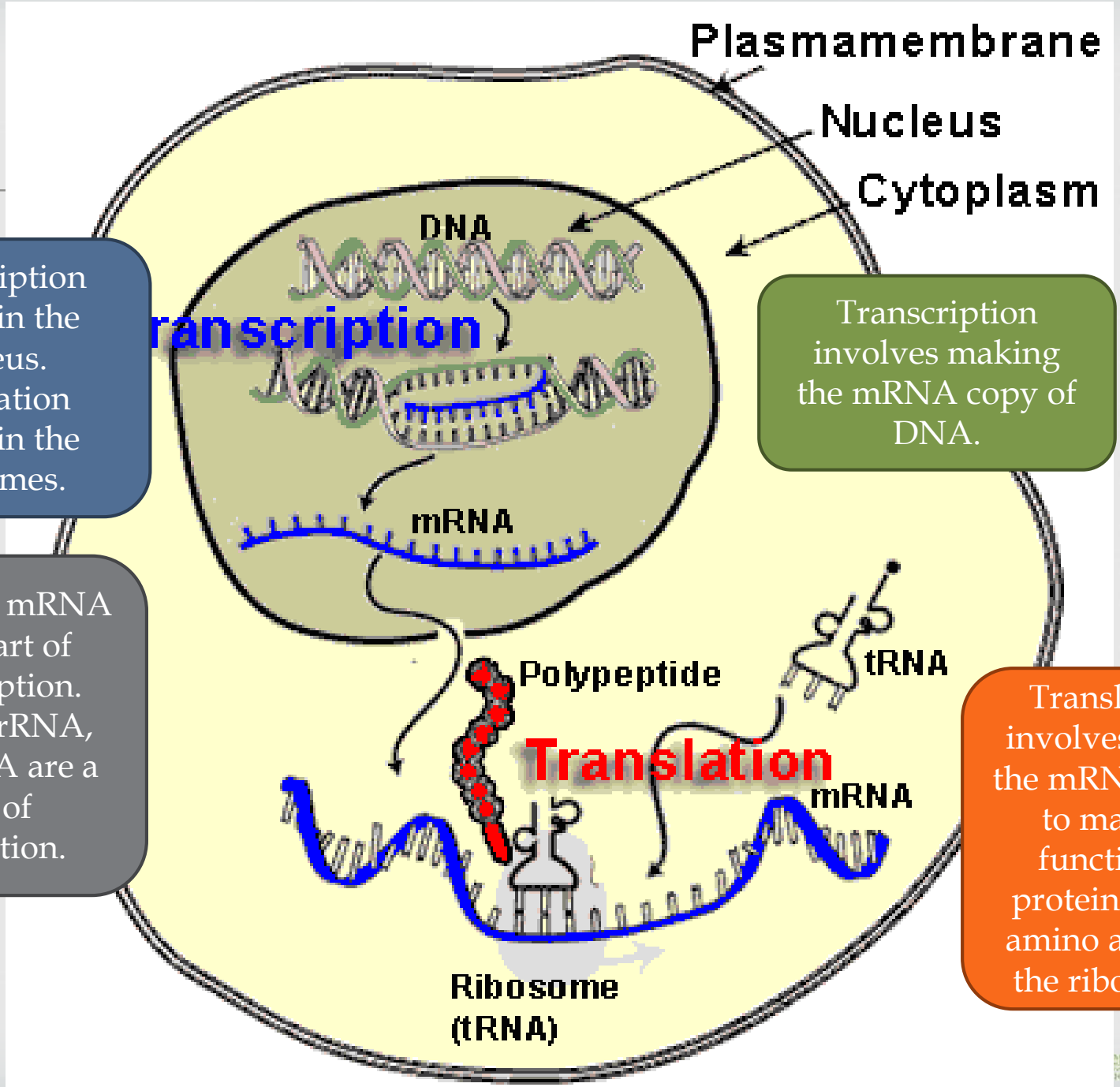
Translation Animation



Amino Acids → Proteins

- **A protein is a long string of amino acids.**
  - The type of amino acids in a protein, and their order, determine the function of the protein
    - *For example, insulin is shown here at the right*
    - *As you can see, it is simply a long chain of amino acids*





Transcription occurs in the nucleus. Translation occurs in the ribosomes.

Transcription involves making the mRNA copy of DNA.

DNA and mRNA are a part of transcription. mRNA, rRNA, and tRNA are a part of translation.

Translation involves using the mRNA copy to make a functional protein out of amino acids in the ribosome.

How to Make a Protein

- **To make a protein, a cell must undergo a few steps.**
  1. A mRNA copy of DNA must be made in a process called transcription.
     - *In transcription, helicase opens DNA so that polymerase can make a mRNA copy.*
     - *That copy will be made using complementary bases (e.g. T → A; G → C; A → U).*
  2. The mRNA copy travels out of the nucleus to the ribosomes to undergo translation.
     - *The ribosome reads the mRNA copy in groups of three bases (or codons).*
     - *For each codon, tRNA delivers the appropriate amino acid.*
  3. Each amino acid that is delivered by tRNA is assembled in a long chain.
     - *That chain of amino acids is what becomes the protein (or polypeptide).*

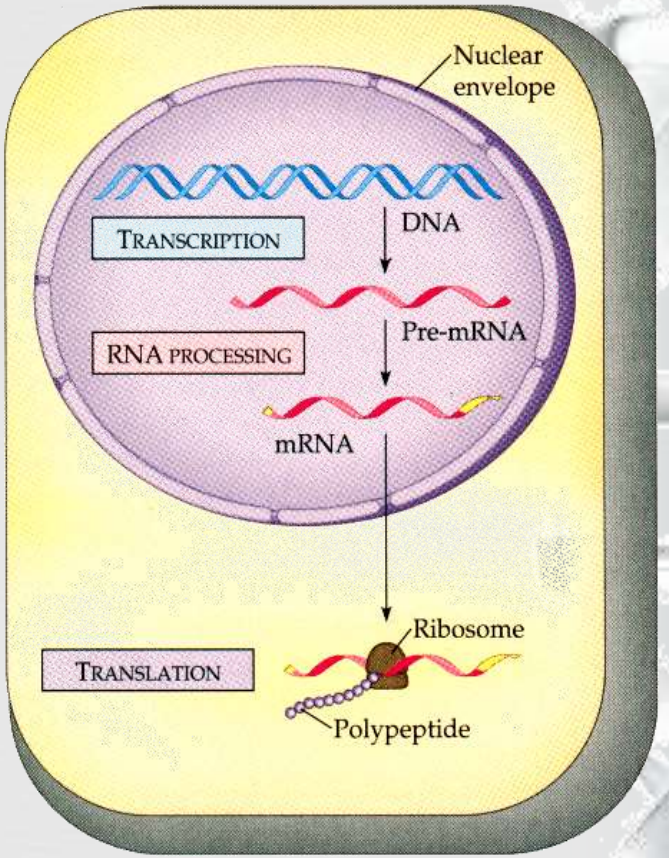


Image Source: godlessliberal.xanga.com

Why do we care about DNA?

- **In agriculture, DNA is everything!**
  - In order to change living species in order to domesticate them and make them productive, we had to change their DNA.
  - Prior to the mid-20th, no one knew what DNA was, but through selective breeding, we have been changing the DNA of species for 10,000 years.
  - Because we understand DNA today, these changes can occur much more efficiently and rapidly.

- **DNA is the future.**
  - Knowing how DNA works enables scientists to change DNA in a much more controlled manner.
  - As the world's population grows larger and resources available for agriculture grow scarcer, it will be more and more important to understand DNA and how to use it for production in order to produce enough food, fuel, and fiber to take care of the entire world.

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Why do we care about DNA?

- **DNA gives us options.**
  - By known how DNA works and how to change it, we can create more opportunities, including…
    - *Production of clean, renewable energy*
    - *Production of pharmaceuticals from plants, animals, and other organisms*
    - *Replacement of diseased or damaged organs (such as hearts or spinal cords)*
    - *And many more!*
  - The greater our understanding of DNA, the more potential we can create for society

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