DNA

- Structure and Function

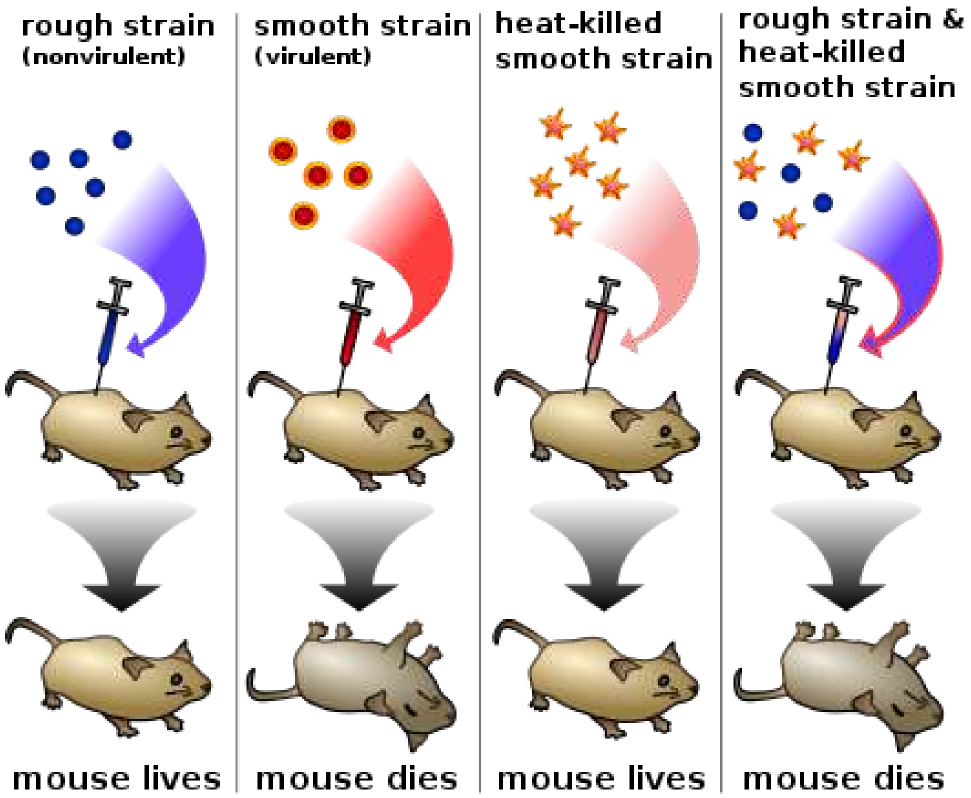
Learning Target

- I can describe the experiments of major scientists in determining both the structure of DNA and the Central Dogma.

DNA Pioneers

- Frederick Griffith, British scientist, 1928
- His guiding question was “How do certain bacteria cause pneumonia?”
- Designed experiments to figure this out using mice and two slightly different strains of bacteria

Griffith's Experiment



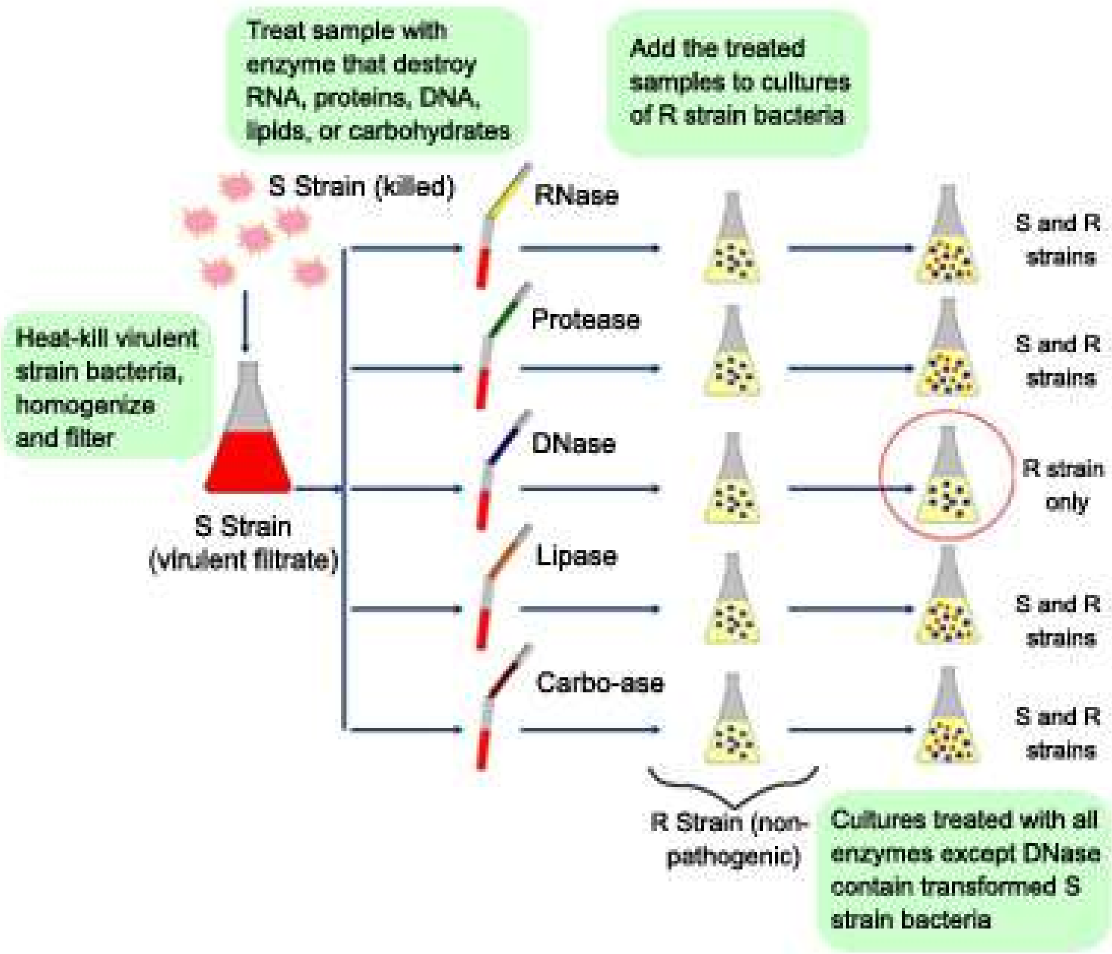
Griffith’s Experiment

- Griffith called the process of passing the disease causing trait to the harmless bacteria “ transformation”

DNA Pioneers

- Oswald Avery, Canadian biologist, 1944
- Decided to repeat Griffith's work
- Made extract from heat killed bacteria; then treated this with enzymes that could destroy some molecules. Transformation still occurred.
- Discovered that DNA stores and transmits genetic information from generation to generation

Oswald



Treat sample with enzyme that destroy RNA, proteins, DNA, lipids, or carbohydrates
Add the treated samples to cultures of R strain bacteria
S Strain (killed)
RNase
S and R strains
Heat-kill virulent strain bacteria, homogenize and filter
Protease
S and R strains
DNase
R strain only
S Strain (virulent filtrate)
Lipase
S and R strains
Carbo-ase
S and R strains
R Strain (non-pathogenic)
Cultures treated with all enzymes except DNase contain transformed S strain bacteria

DNA Pioneers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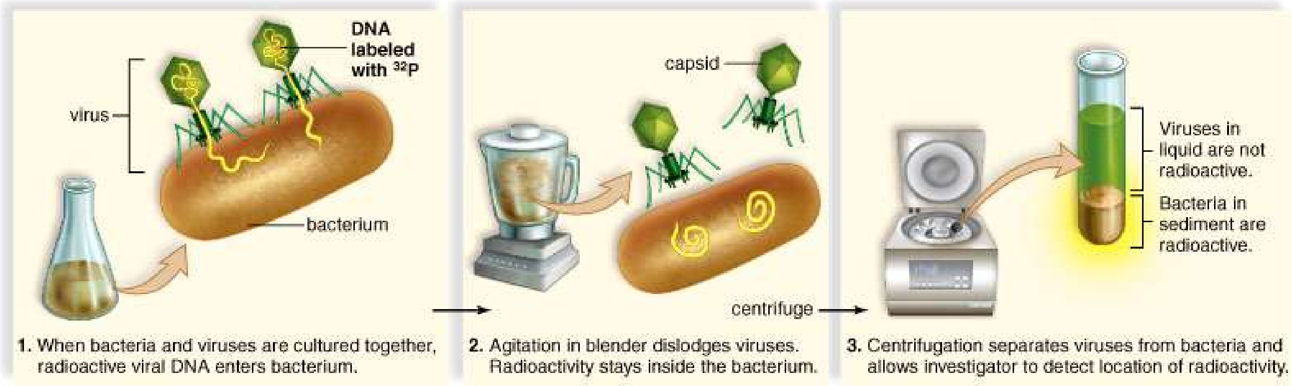
- Hershey-Chase
- Two American scientists: Alfred Hershey and Martha Chase
- Collaborated on studying viruses that infect living organisms
- Bacteriophage: type of virus that infects bacteria

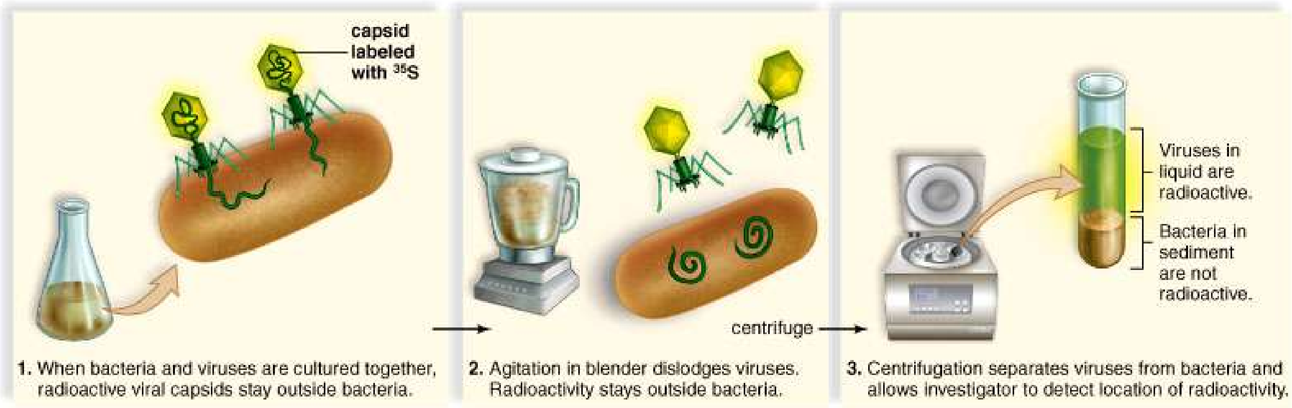
Hershey-Chase

- http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::535::535::/sites/dl/free/0072437316/120076/bio21.swf::Hershey%20and%20Chase%20Experiment

Hershey-Chase Experiments



a. Viral DNA is labeled (yellow).

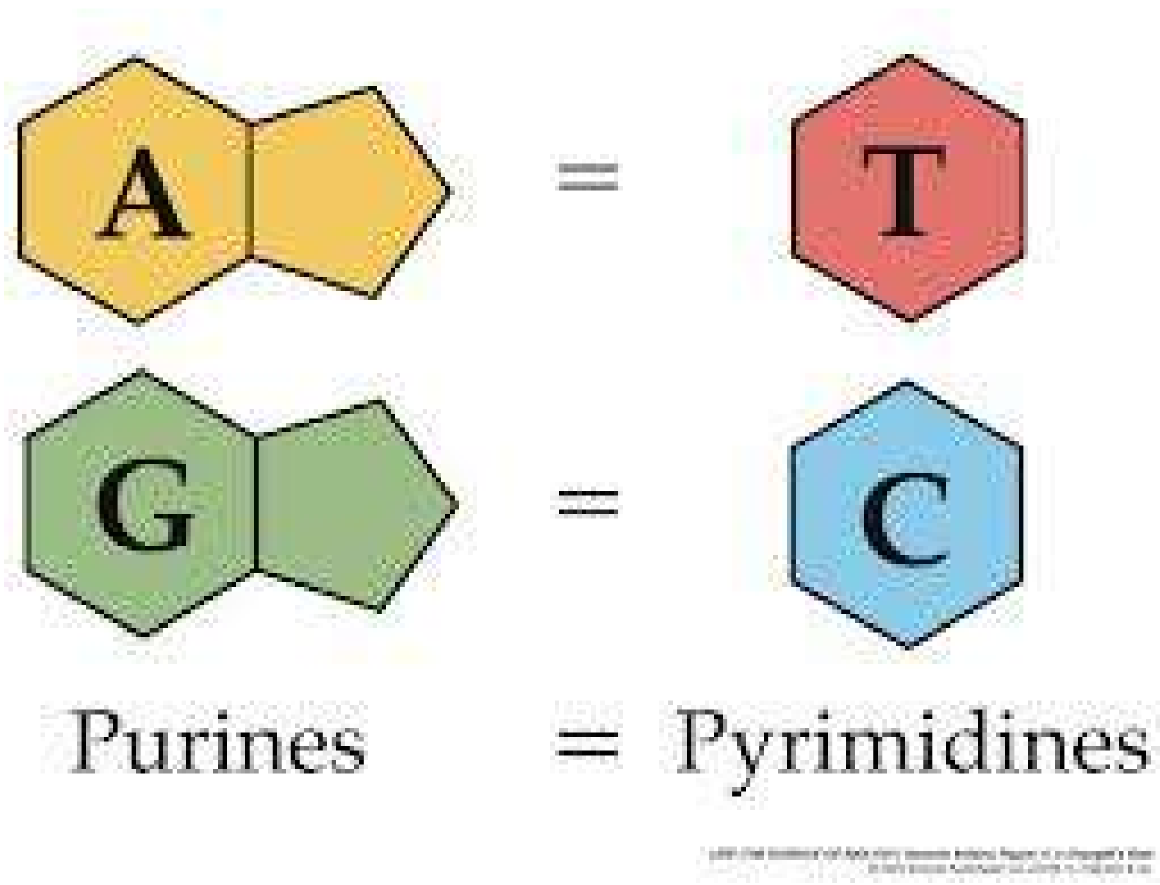


b. Viral capsid is labeled (yellow).

DNA Pioneers

- Erwin Chargaff, American biochemist
- Puzzled by relationship between DNA’s nucleotides
- Discovered that guanine and cytosine are nearly equal in any DNA sample; same went for adenine and thymine

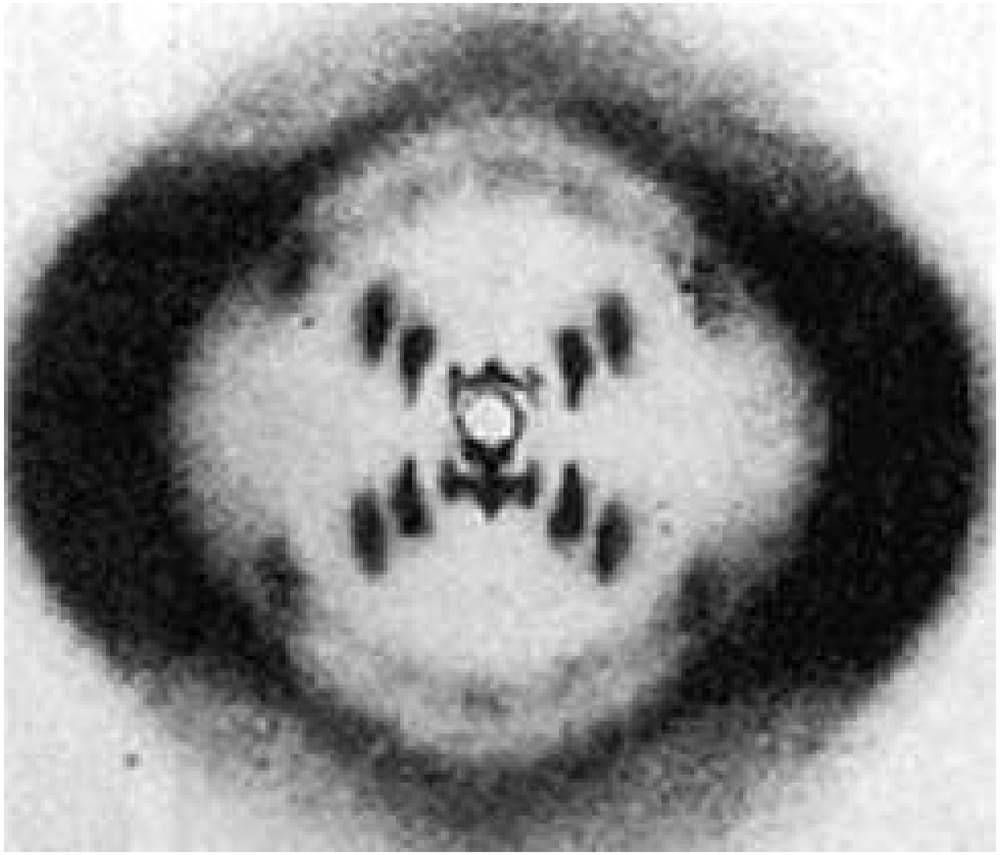
Chargaff's Rules



DNA Pioneers

- Rosalind Franklin,
- British scientist, 1952
- Studied DNA using xray diffraction
- Recorded DNA pattern
- Died of radiation cancer before she could have received Pulitzer Prize

Rosalind Franklin



Watson and Crick

- James Watson, American biologist
- Francis Crick, British physicist
- Used Franklin's xray diffraction (without her permission) to develop the double helix model of the structure of DNA

Learning Target

- I can describe the basic structure and function of DNA.

DNA Structure Video

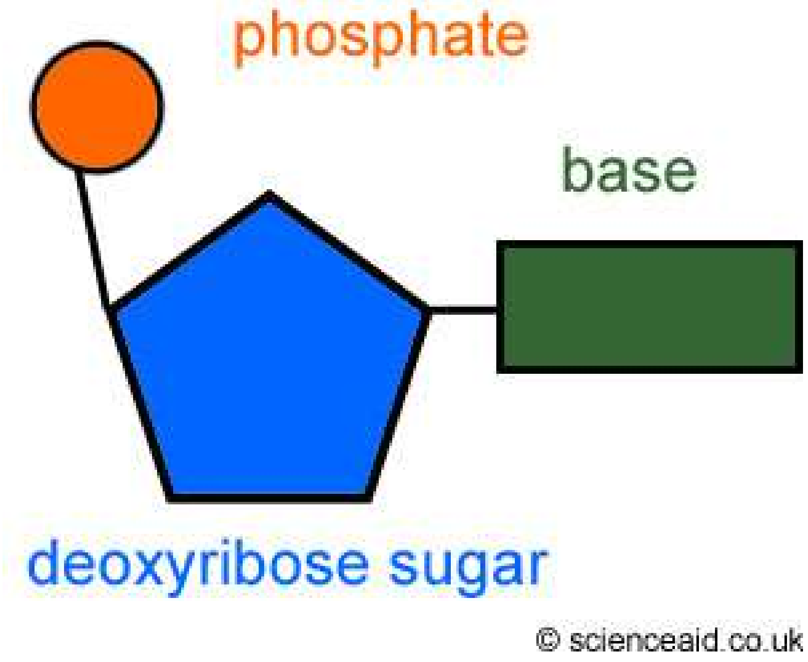
- http://www.youtube.com/watch?v=sf0YXnAFBs8

Structure & Function of DNA

- DNA is:
  - A complex polymer made of deoxyribonucleic acid
  - Nucleic Acids are made of nucleotides

Nucleotides

- Are made of
  - A simple sugar (Deoxyribose)
  - A phosphate group
  - A nitrogen base



DNA Structure

- Double Helix
  - Two strands twisted around each other
  - Resembles a winding staircase

DNA Structure

- Each side of the double helix is made of alternating sugar (deoxyribose) and phosphates
- Each strand is linked to the other by nitrogen bases

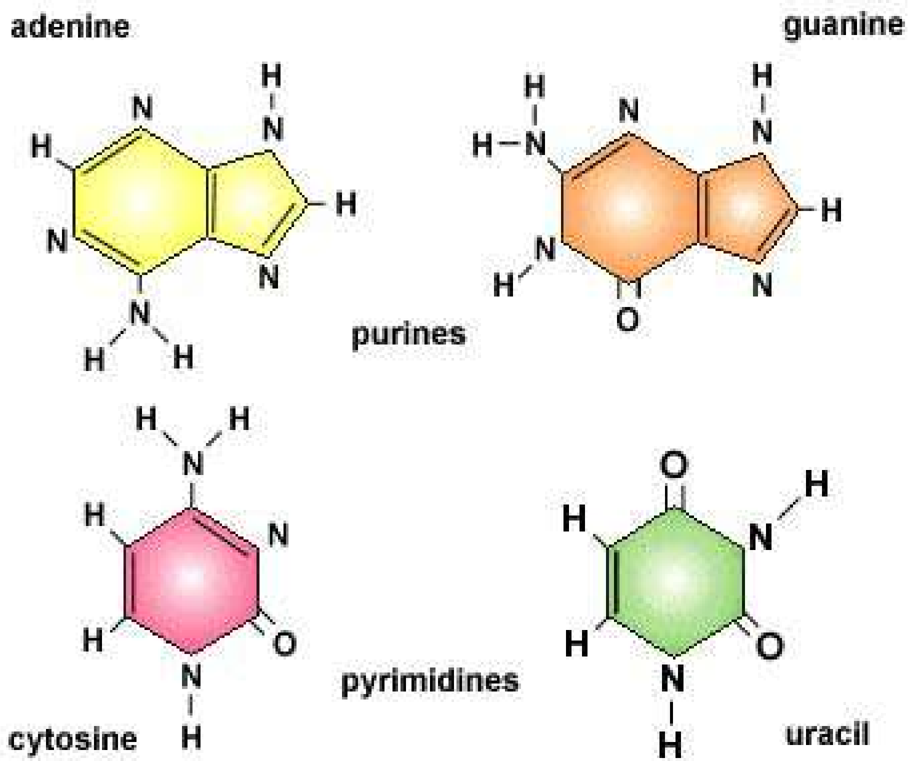
DNA Nitrogen Bases

- Four nitrogen bases make up the “stairs” of the DNA double helix
- Adenine
- Guanine
- Cytosine
- Thymine

DNA Nitrogen Bases

- Adenine and Guanine are purines
  - Made of two rings of carbon and nitrogen atoms
- Cytosine and Thymine are pyrimidines
  - Made of one carbon and nitrogen ring

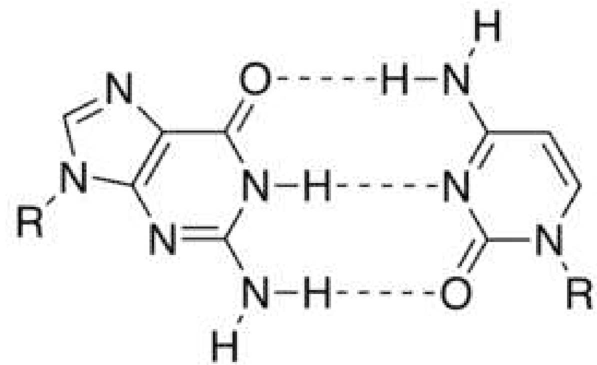
DNA Nitrogen Bases



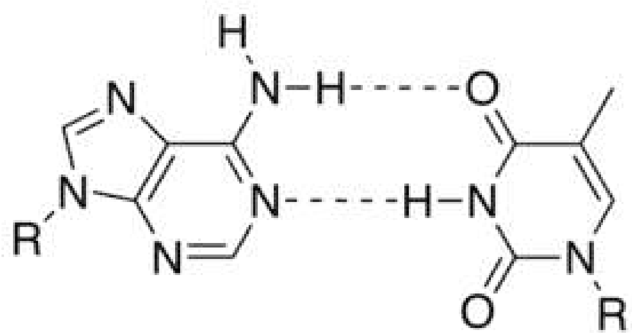
Base Pairing Rules

- One Purine must pair with one Pyrimidine
- The pairings are very specific; follow Chargaff’s Rules
- Adenine and Thymine always pair
- Cytosine and Guanine always pair
- A and T form two hydrogen bonds
- C and G form three hydrogen bonds

Base Pairing Rules



Guanine Cytosine



Adenine Thymine

DNA Replication

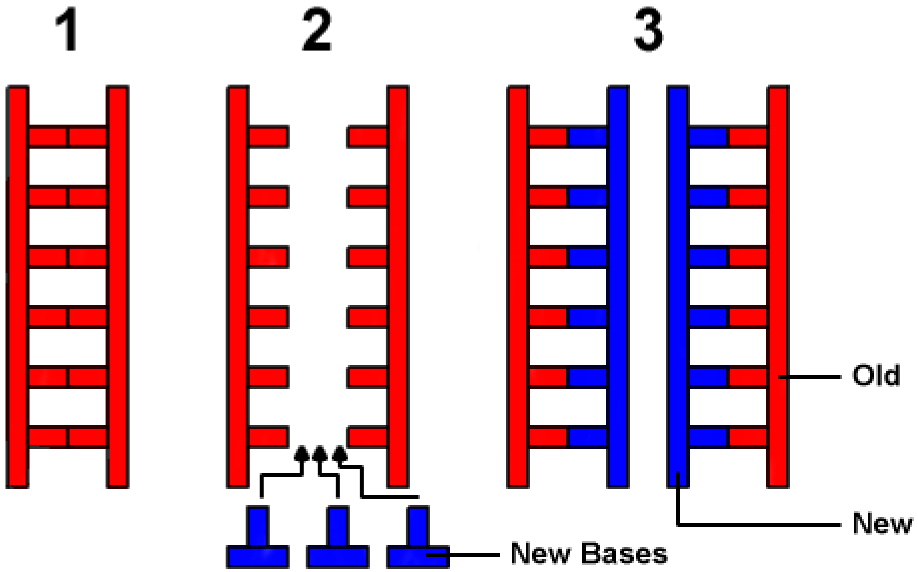
- The process of making a copy of DNA is called DNA replication
- Remember that DNA replication occurs during the “S” phase of interphase prior to the cell entering mitosis or meiosis

DNA Replication

- http://www.youtube.com/watch?v=zdDkiRw1PdU

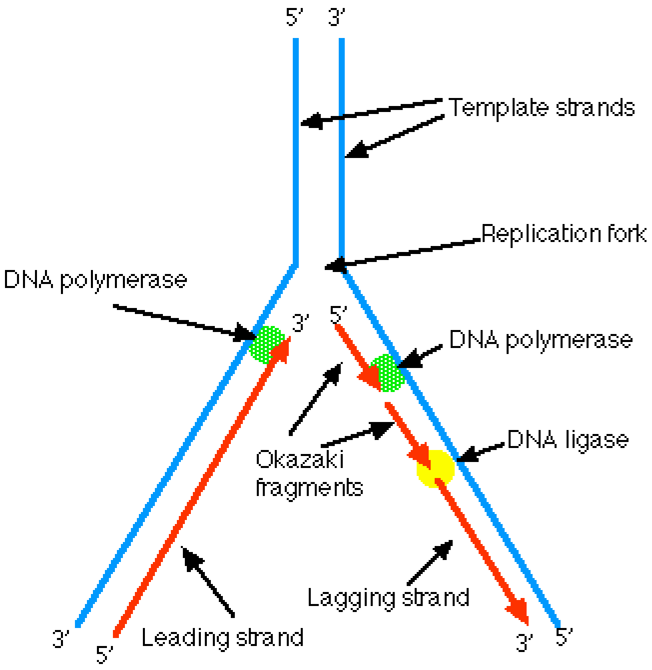
DNA Replication

- Replication is semi-conservative meaning that each new double helix consists of an old strand of DNA



DNA Replication—Step 1

- DNA helicases unwind double helix by breaking hydrogen bonds
- Proteins attach to each strand to hold them apart and prevent them from twisting back
- This area is called a replication fork



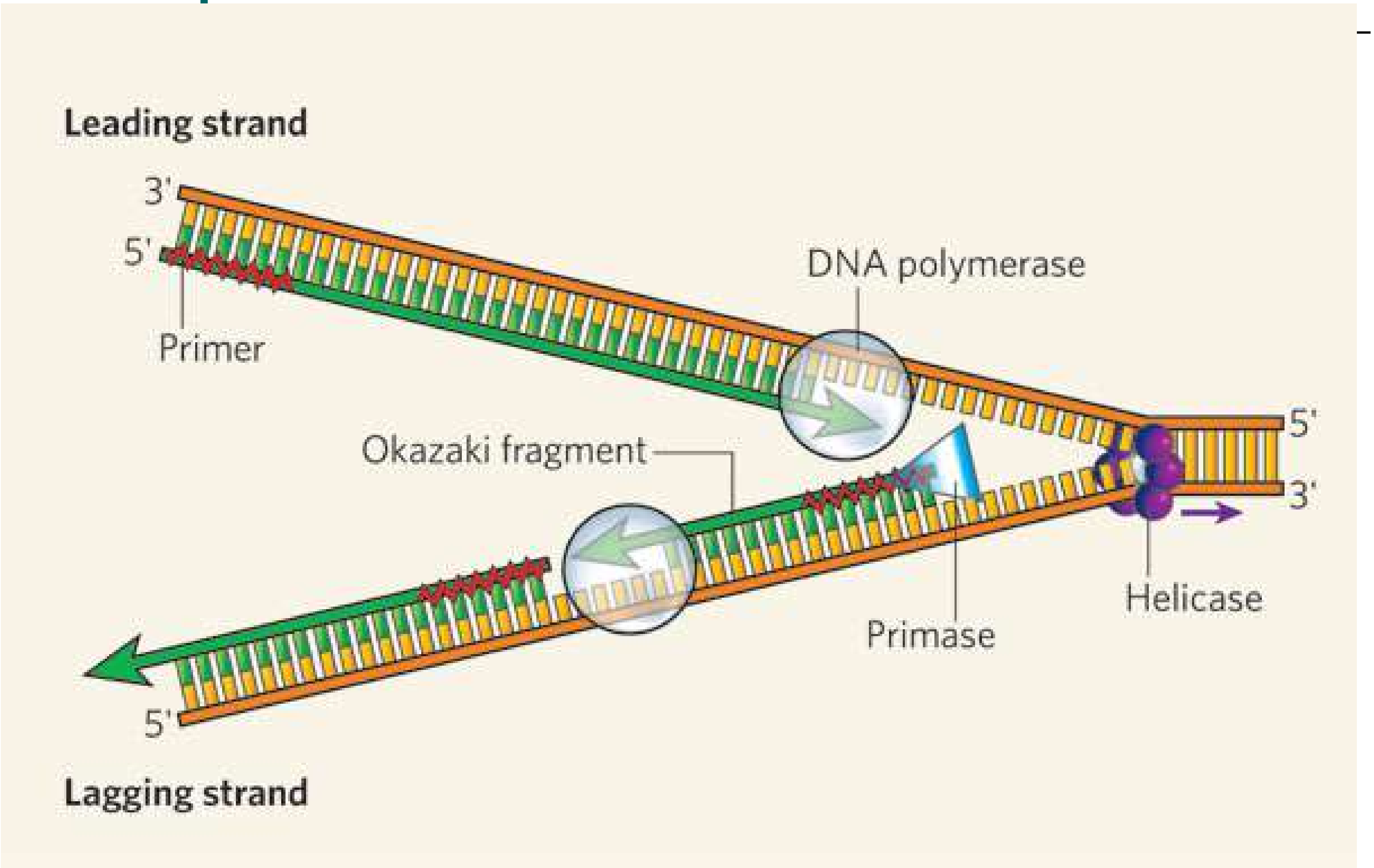
DNA Replication: Step 2

- Within the replication forks, DNA polymerase moves along each strand adding nucleotides to exposed nitrogen bases
- These are added according to base pairing rules
- As DNA polymerase moves along, two new double helices are formed

DNA Replication: Step 2

- The two strands are called the leading strand and the lagging strand.
- New nucleotides are always added in the 5′ to 3′ direction
- The leading strand goes very smoothly because it is in the 5′ to 3′ direction
- The lagging strand goes from the 3′ to 5′ direction
  - So its nucleotides are placed in small sections called Okazaki fragments. These are placed in the 5′ to 3′ direction

Step 2



Leading strand
3'
5'
Primer
DNA polymerase
5'
3'
Okazaki fragment
Helicase
Primase
5'
Lagging strand

DNA Replication: Step 3

- DNA polymerase remains attached until all the DNA is copied
- It detaches once replication is complete
- Two new DNA strands are made
- Each new double helix contains a new strand and an old strand
- The two new double helices are identical to each other.

DNA Replication: Step 4

- DNA polymerases can proofread and can back track a bit to correct any errors.
- Only 1 error per 1 billion nucleotides.

Learning Target

- I can describe the basic function and structure of mRNA, tRNA, amino acids and proteins.
- I can use codon charts to determine amino acid sequences of example polypeptides.

DNA to RNA to Proteins

- DNA, the genetic code, is made in the nucleus.
- DNA carries the instructions for making proteins.
- Proteins are made in ribosomes in the cytoplasm.
- How does this happen? RNA

DNA to RNA to Proteins

- RNA takes the genetic code from the nucleus to the ribosomes in a process called transcription.
- RNA differs from DNA in 3 ways:
  - It is a single strand (alpha helix)
  - It contains the sugar ribose
  - It has a different nitrogen base: uracil
    - Uracil replaces thymine

RNA

- Three types of RNA
  - mRNA-messenger RNA carries copies of protein instructions
  - rRNA-ribosomal RNA; on the ribosome
  - tRNA-transfer RNA; transfers each amino acid to the ribosome as specified by the genetic code

Transcription

- Transcription begins when RNA polymerase binds to DNA and separates the DNA strand
- RNA polymerase uses one strand of DNA as a template to make into one strand of RNA

Transcription

- The RNA polymerase (an enzyme) finds the promotor region on the DNA.
- Promotors signal where the enzyme should attach onto the DNA.

DNA Transcription

- DNA must be copied to messenger RNA (mRNA)
- mRNA goes from nucleus to the ribosomes in cytoplasm
- mRNA complements known as codons
  - Only 3 nucleotide “letters” long

- **Remember** RNA has uracil (U) instead of thymine (T)!

Transcription – Step I

A C G T A T C G C G T A

T G C A T A G C G C A T

Template DNA Strands

Transcription – Step II

A C G T A T C G C G T A

U G C A U A G C G C A U

Template DNA is Matched Up with Complementary mRNA Sequences

Transcription – Step III

A C G U A U C G C G U A

U G C A U A G C G C A U

mRNA leaves nucleus
and goes to ribosomes

A new complementary RNA strand is made (rRNA)

RNA Editing

- RNA needs to be edited.
- DNA has sequences of DNA not necessary for making proteins. These are called introns.
- The DNA sequences needed for transcription are called exons.
- Both are copied but the introns are cut out before leaving the nucleus.

Transcription Reminders

- The template strand is the DNA strand being copied
- The rRNA strand is the same as the DNA strand except U’s have replaced T’s

Genetic Code

- Different proteins have different functions
- It is estimated that each human cell has more than 30,000 genes
- Each gene is a code for making a specific protein

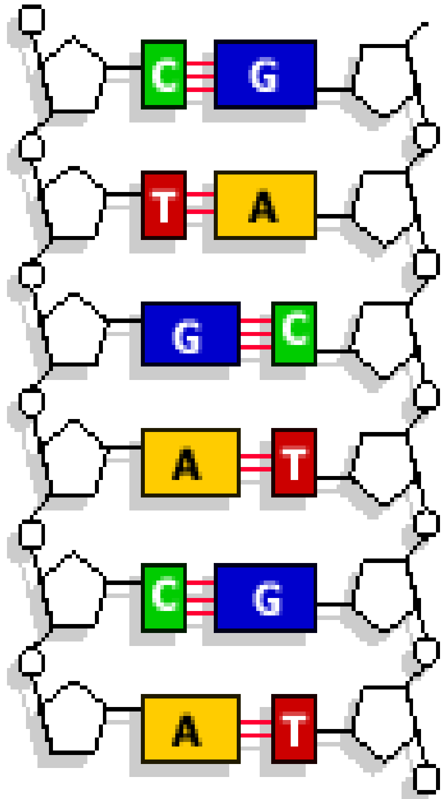
Genetic Code

- Sequences of nitrogen bases give the code for making a specific protein
- Proteins are made from 20 amino acids and DNA has only 4 nitrogen bases
- How do these small numbers make up the thousands of combinations to make a protein?

Genetic Code

- It takes sequences of three bases to provide the necessary combinations to make the proteins
- Each set of three nitrogen bases is called a codon (or triplet code)
- The order of nitrogen bases can determine the type and order of amino acids in a protein

Genetic Code



Genetic Code

- Sixty four codons are possible
- 60 are specific amino acids
- One is a start code
- Three are stop codes

FIRST LETTER	SECOND LETTER				THIRD LETTER
	U	C	A	G	
U	Phenylalanine	Serine	Tyrosine	Cysteine	U
	Phenylalanine	Serine	Tyrosine	Cysteine	C
	Leucine	Serine	Stop	Stop	A
	Leucine	Serine	Stop	Tryptophan	G
C	Leucine	Proline	Histidine	Arginine	U
	Leucine	Proline	Histidine	Arginine	C
	Leucine	Proline	Glutamine	Arginine	A
	Leucine	Proline	Glutamine	Arginine	G
A	Isoleucine	Threonine	Asparagine	Serine	U
	Isoleucine	Threonine	Asparagine	Serine	C
	Isoleucine	Threonine	Lysine	Arginine	A
	(Start) Methionine	Threonine	Lysine	Arginine	G
G	Valine	Alanine	Aspartate	Glycine	U
	Valine	Alanine	Aspartate	Glycine	C
	Valine	Alanine	Glutamate	Glycine	A
	Valine	Alanine	Glutamate	Glycine	G

Transcription is done…what now?

Now we have mature mRNA transcribed from the cell’s DNA. It is leaving the nucleus through a nuclear pore. Once in the cytoplasm, it finds a ribosome so that translation can begin.

We know how mRNA is made, but how do we “read” the code?

Protein Translation

- Modified genetic code is “translated” into proteins
- Codon code is specific, but redundant!
  - 20 amino acids
  - 64 triplet (codon) combinations

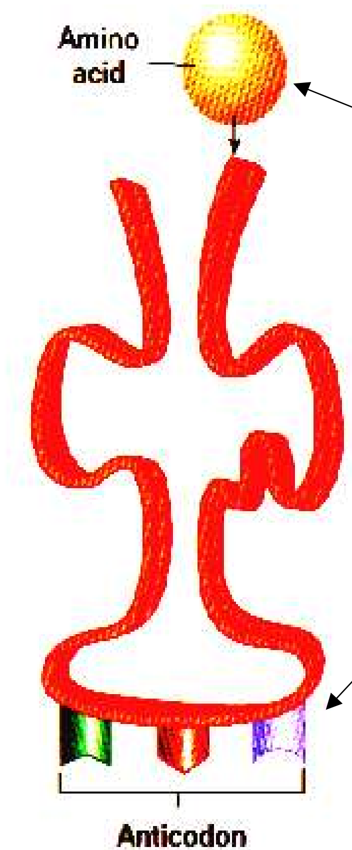
Protein Translation

- mRNA is transcribed in the nucleus; then enters the cytoplasm and attaches to a ribosome
- Translation begins at AUG (start codon)
- Each tRNA has an anticodon that is complementary to the codon on the mRNA

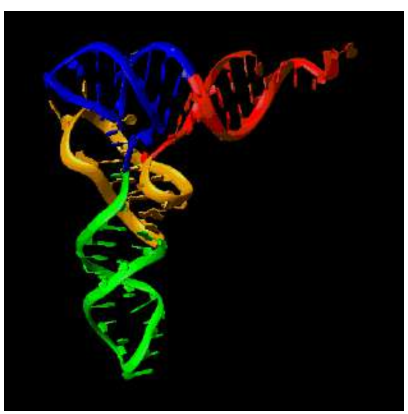
Protein Translation

- The ribosome positions the start codon (AUG) to attract its anticodon.
- This process continues until the strand is translated.
- The tRNA floats away from the ribosome to allow another to take its place.

tRNA



- Transfer RNA
- Bound to one amino acid on one end
- Anticodon on the other end complements mRNA codon



tRNA structure

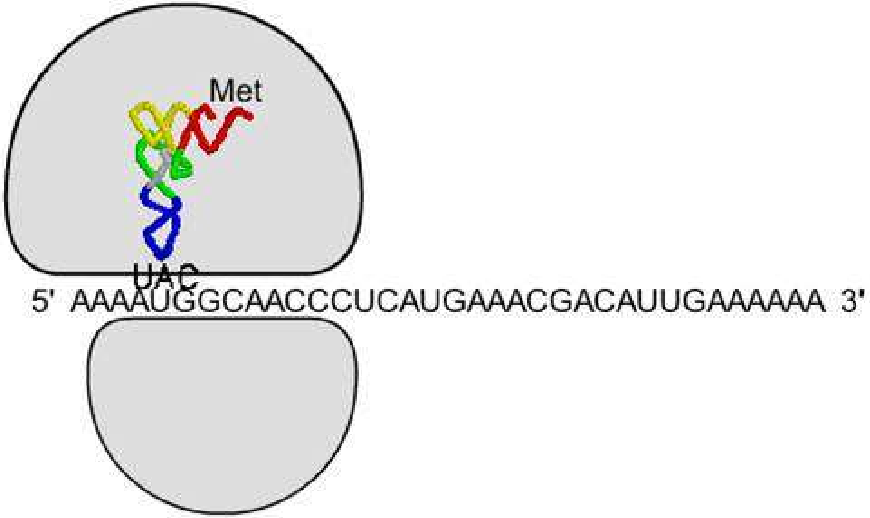
- 3-base code (triplet) is an “anticodon”
- Protein molecule
- Attached amino acid is carried from cytoplasm to ribosomes

tRNA Function

- Amino acids must be in the correct order for the protein to function correctly
- tRNA lines up amino acids using mRNA code

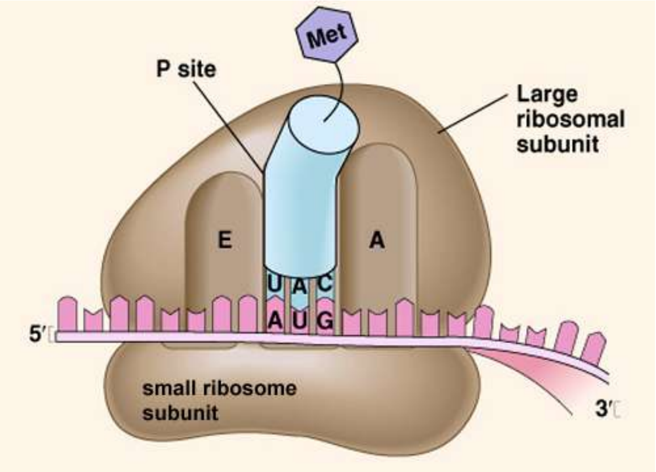
Translation

- Second stage of protein production
- mRNA is on a ribosome
- tRNA brings amino acids to the ribosome



Ribosomes

- 2 subunits, separate in cytoplasm until they join to begin translation
  - Large subunit
  - Small subunit
- Contain 3 binding sites
  - E
  - P
  - A



The Genetic Code

First position	Second position U		C		A		G		Third position
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U
	UUC	Phe	UCC	Ser	UAC	Tyr	UGC	Cys	C
	UUA	Leu	UCA	Ser	UAA	*Stop*	UGA	*Stop*	A
	UUG	Leu	UCG	Ser	UAG	*Stop*	UGG	Trp	G
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U
	CUC	Leu	CCC	Pro	CAC	His	CGC	Arg	C
	CUA	Leu	CCA	Pro	CAA	Gln	CGA	Arg	A
	CUG	Leu	CCG	Pro	CAG	Gln	CGG	Arg	G
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U
	AUC	Ile	ACC	Thr	AAC	Asn	AGC	Ser	C
	AUA	Ile	ACA	Thr	AAA	Lys	AGA	Arg	A
	AUG	Met	ACG	Thr	AAG	Lys	AGG	Arg	G
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly	U
	GUC	Val	GCC	Ala	GAC	Asp	GGC	Gly	C
	GUA	Val	GCA	Ala	GAA	Glu	GGA	Gly	A
	GUG	Val	GCG	Ala	GAG	Glu	GGG	Gly	G

ACGATACCCTGACGAGCGTTAGCTATCG

UGCUAUGGGACUG

First position	Second position: U		C		A		G		Third position
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U
	UUC	Phe	UCC	Ser	UAC	Tyr	UGC	Cys	C
	UUA	Leu	UCA	Ser	UAA	*Stop*	UGA	*Stop*	A
	UUG	Leu	UCG	Ser	UAG	*Stop*	UGG	Trp	G
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U
	CUC	Leu	CCC	Pro	CAC	His	CGC	Arg	C
	CUA	Leu	CCA	Pro	CAA	Gln	CGA	Arg	A
	CUG	Leu	CCG	Pro	CAG	Gln	CGG	Arg	G
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U
	AUC	Ile	ACC	Thr	AAC	Asn	AGC	Ser	C
	AUA	Ile	ACA	Thr	AAA	Lys	AGA	Arg	A
	AUG	Met	ACG	Thr	AAG	Lys	AGG	Arg	G
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly	U
	GUC	Val	GCC	Ala	GAC	Asp	GGC	Gly	C
	GUA	Val	GCA	Ala	GAA	Glu	GGA	Gly	A
	GUG	Val	GCG	Ala	GAG	Glu	GGG	Gly	G

Which codon codes for which amino acid?

- Genetic code- inventory of linkages between nucleotide triplets and the amino acids they code for
- A gene is a segment of RNA that brings about transcription of a segment of RNA

Transcription vs. Translation Review

Transcription	Translation
Process by which genetic information encoded in DNA is copied onto messenger RNA	Process by which information encoded in mRNA is used to assemble a protein at a ribosome
Occurs in the nucleus	Occurs on a Ribosome
DNA → mRNA	mRNA → protein