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### Friedrich Meischer 1870's – first to isolate DNA

Scientists believed that proteins carried the genetic information

20 different amino acids that make up proteins; DNA only 4 nucleotides: thought to be too simple to account for all variation both between & among the same species

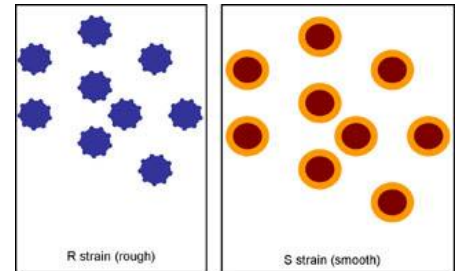
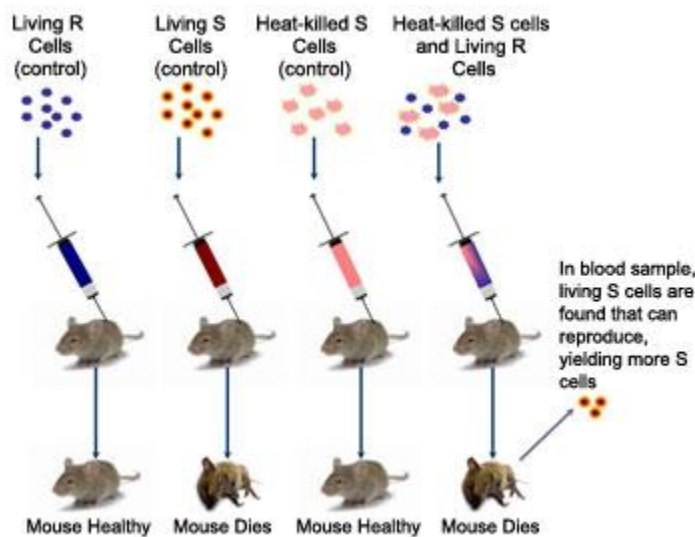
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### Frederick Griffith 1928 – discovered “transforming principle” – trying to create a vaccine for pneumonia

*Streptococcus pneumoniae*

(encapsulated/smooth: bad; non-encapsulated/rough: not harmful)

[http://www.visionlearning.com/library/module\\_viewer.php?mid=149](http://www.visionlearning.com/library/module_viewer.php?mid=149)



There may have been something still present in the non encapsulated bacteria that caused the infection even though the encapsulated bacteria were heat killed

The non encapsulated bacteria was alive & may have been able to acquire the ability to cause the infection even though the heat killed bacteria were dead the genetic material that can cause pneumonia may have still been functional & was passed on to the live bacteria that infected the mice

**Transformation:** incorporating extra cellular DNA into genome

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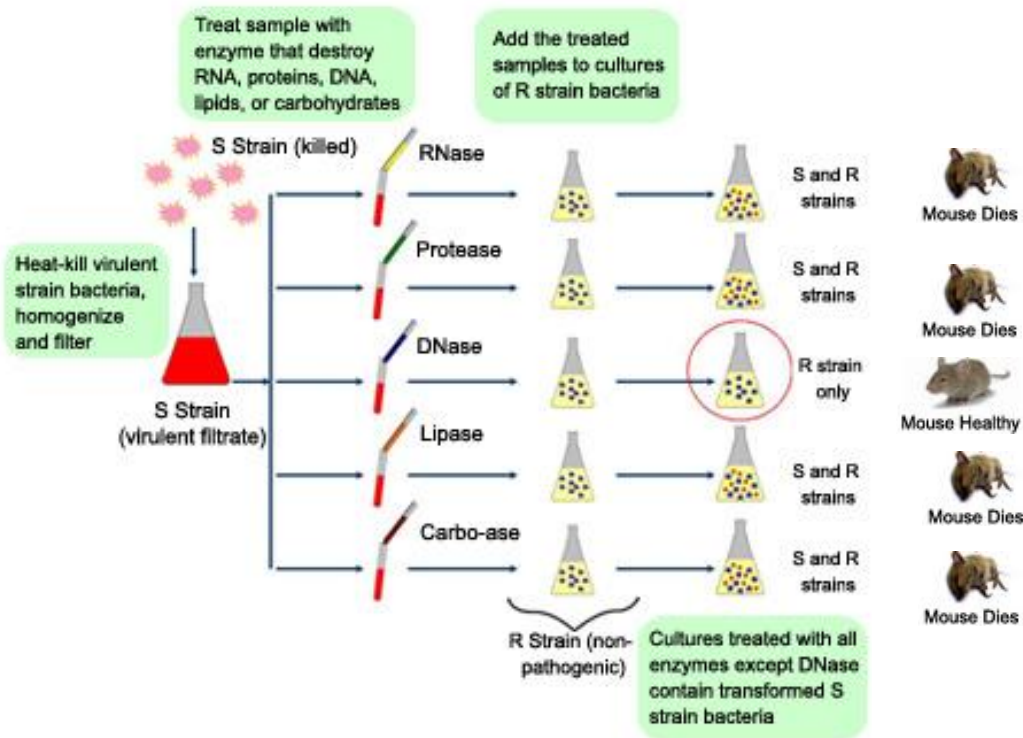
### Oswald Avery, Colin MacLeod, Maclyn McCarty 1944: prove DNA, not protein, is the transforming principle

One experiment:

Took heat killed encapsulated bacteria. Cut into five components: RNA, lipids, proteins, carbohydrates, DNA – looking for component that was the genetic information that caused bacteria to transform. Each of the components would have to be cultured with non encapsulated bacteria. Inject mice with each bacteria culture. Knowing what we know (DNA is the genetic material), only mice to get sick would be the ones who were injected with the bacteria that was cultured with DNA from the heat killed encapsulated bacteria.

More experiments:

[http://www.visionlearning.com/library/module\\_viewer.php?mid=149](http://www.visionlearning.com/library/module_viewer.php?mid=149)



The results confirm that DNA is the genetic material. And only when DNA is present, does the non encapsulated bacteria transform into the infectious encapsulated strain.

Scientists were still not convinced that DNA, not protein, was the genetic material...

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Alfred Hershey, Martha Chase 1952 – DNA became accepted as genetic material

Viruses: need a host to reproduce. Bacteriophage: bacteria eater; infects bacteria. Radioactive tracers are radioactive isotopes of certain elements whose pathways are easy to follow.

Protein coats of one virus culture were labeled with radioactive sulfur. DNA of other culture was labeled with radioactive phosphorus. (Sulfur is found in protein, not DNA; Phosphorus is found in DNA, not protein.)

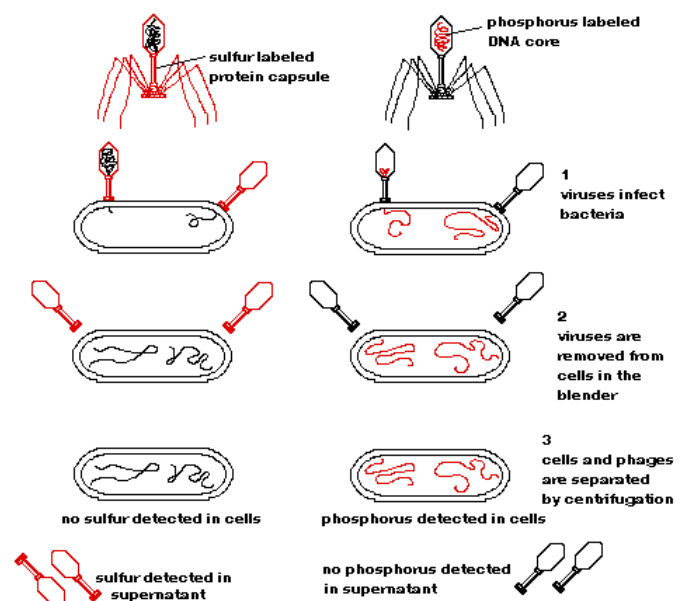
Labeled bacteriophages were mixed with bacteria. Radioactive sulfur had remained outside bacteria in protein of viral coats. Radioactive phosphorus was in the bacterium. The bacterium containing the viral DNA will produce compete viral particles that are identical to the original bacteriophage.

Conclusion: Radioactive phosphorus entered bacteriophages DNA. The genetic material is DNA, not protein.

DNA was finally widely accepted as genetic material

<http://www.bio.hbnu.edu.cn/wdsw/newindex/website/mit/digma/history2.html>

## The Hershey-Chase Blender Experiment



### P.A. Levene 1920's – DNA composition of 4 N bases & deoxyribose sugar.

Biochemist: DNA could be broken down into 4 nitrogen bases: thymine, adenine, cytosine, guanine; a 5-carbon sugar, and phosphate group.

Based on proportions, two deductions:

1. Each nitrogen base is attached to a sugar. That, in turn is attached to a phosphate – forms a single molecule which he called a nucleotide.
2. All four nitrogen bases must be present in equal quantities – seemed logical, but wrong. He thought they were clustered in groups of four & repeated in a string over & over. Dominated thinking for decades.

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### Erwin Chargoff 1947 – DNA is not equal for all species & ratio of bases varies among species

When the DNA of a species is sampled, the proportion of nitrogenous bases are the same within species. The proportion of nitrogenous bases varies among (different) species.

Source	Purines		Pyrimidines	
	A	G	C	T
Ox	29.0	21.2	21.2	28.7
Human	30.9	19.9	19.8	29.4
Wheat	27.3	22.7	22.8	27.1
E Coli	24.7	26.0	25.7	23.6
Sea urchin	32.8	17.7	17.3	32.1

Percent of guanine & cytosine is about the same as is adenine & thymine. And, cells from an individual species will always have the same proportion of bases. Individuals from other species have different ratios. So the variation in base composition could be the clue for the different genetic instructions in different species.

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### Rosiland Franklin, Maurice Wilkins early 1950's – X-ray crystallography of DNA

They crystallized a molecule of DNA. Then fired x-rays at that molecule. They captured the pattern of scattering of those x-rays on photographic film. It revealed that the molecular structure of DNA is helical: spiral staircase.

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### James Watson, Francis Crick 1953 – DNA molecule has the form of a double helix

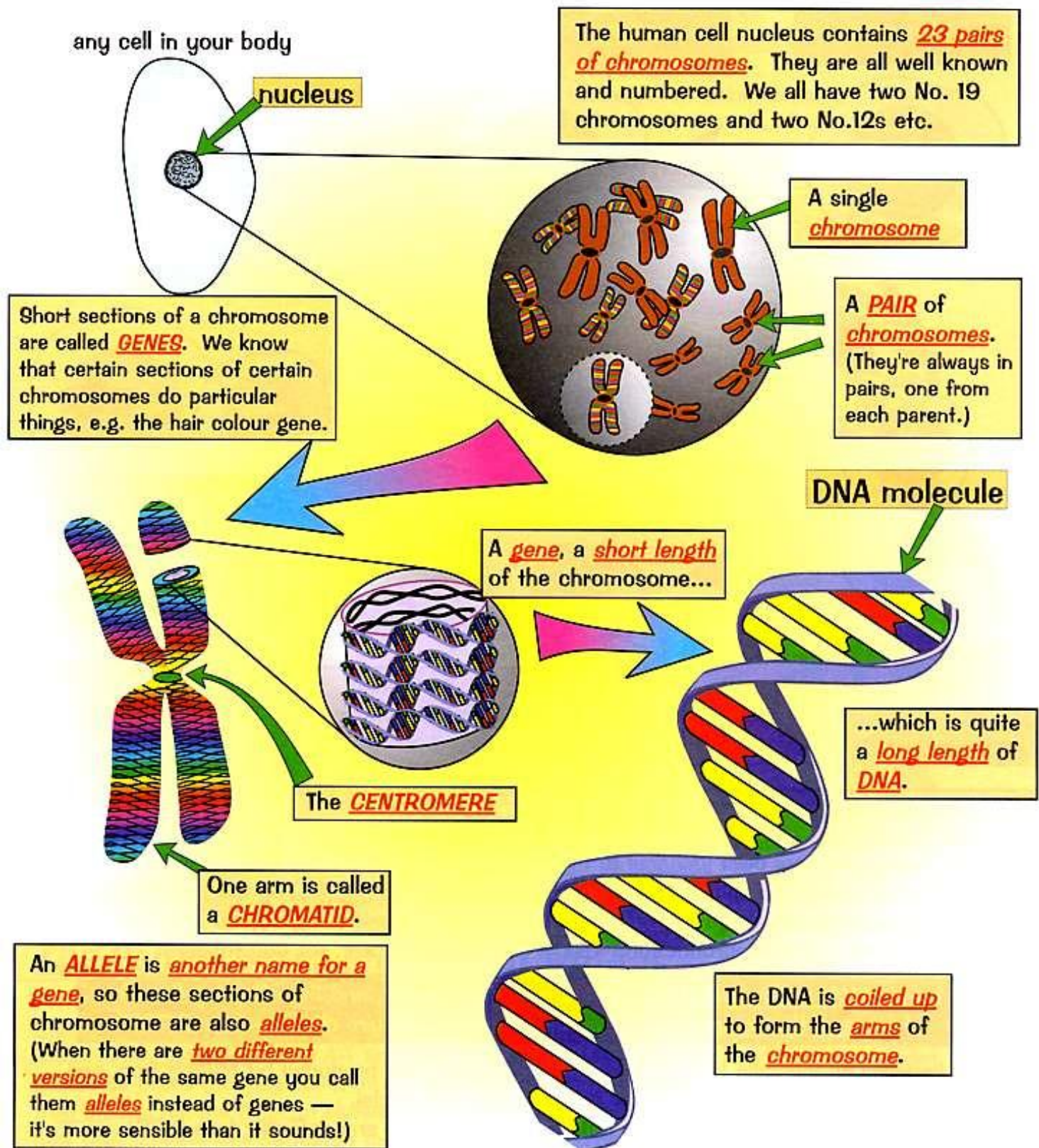
Proposed model after they had analyzed all the data from previous sources (especially Chargaff & Franklin/Wilkins). They measured the radius of the helix & they determined that the only way to maintain a consistent radius throughout the DNA was if the adenine paired with thymine & cytosine paired with guanine. Those pairings occupy the same radial space, no other linkages would work. This matched Chargoff's data: the percentages of thymine & adenine were about the same, as were the percentages of cytosine & guanine.

### Review:

- DNA is composed of a phosphate, a five carbon sugar called deoxyribose, and four kinds of nitrogen bases.
- Adenine & guanine are double ringed structures that belong to a group called purines.
- Thymine & cytosine belong to the pyrimidine group, & have only one ring.
- These components are arranged in units called nucleotides. Each nucleotide consists of a nitrogen base attached to a dextyribose & a phosphate.
- Each nucleotide has sites available for bonding with other nucleotides.
- Many nucleotides bonded together form a polynucleotide.
- The DNA molecule consists of two strands of nucleotides held together by the pairing of nitrogen bases. Adenine pairs with thymine & guanine with cytosine. The two strands are wound around a common axis forming a double helix
- There is no restriction of the order of bases in DNA, except that the proportion of bases must remain consistent within species.
- The sequence of portions in DNA strands between may be identical – two different species may form the same protein. However, the overall sequence between species will be different.
- 46% of the proteins in humans & E Coli are the same.



If you're going to get anywhere with this topic you definitely need to learn these confusing words and exactly what they mean. You have to make sure you know exactly what DNA is, what and where chromosomes are, and what and where a gene is. If you don't get that sorted out first, then anything else you read about them won't make a lot of sense to you — will it.



## Review: History of DNA discovery

- **Freidrich Miescher** (1868) found nuclear material to be  $\frac{1}{2}$  protein &  $\frac{1}{2}$  unknown substance 1890's, unknown nuclear substance named DNA
- **Walter Sutton** (1902) discovered DNA in chromosomes
- **Fredrick Griffith** (1928) working with *Streptococcus pneumoniae* conducted transformation experiments of virulent & nonvirulent bacterial strains
- **Levene** (1920's) determined 3 parts of a nucleotide
- **Hershey & Chase** (1952) used bacteriophages (viruses) to show that DNA, not protein, was the cell's hereditary material
- **Rosalind Franklin** (early 1950's) used x-rays to photograph DNA crystals
- **Erwin Chargraff** (1950's) determined that the amount of A=T and amount of C=G in DNA; called Chargaff's Rule
- **Watson & Crick** discovered double helix shape of DNA & built the 1st model – [TedED: James Watson on How He Discovered DNA](#) (20:15)

My DNA notes:

DNA (deoxyribonucleic acid) – stores & passes on genetic information from one generation to the next.

*\*We are all made of proteins – all are different, but similar – how are so many different kinds of proteins made?*

DNA “codes” for all those different proteins & passes that information to new cells & offspring – HOW?

Let's look at where we find DNA & its structure:

(because structure ALWAYS relates to function)

Chromosomes are made of: 1. **Protein** – histones  
& 2. **Nucleic Acids** – deoxyribose (5-C sugar), nitrogen base & phosphate group (phosphate +  $4O_2$ )

1953 – Watson & Crick discovered structure – twisted ladder – double helix (awarded Nobel prize)

→ Chromosomes are made of: DNA – the DNA contains the genes!

Sides: alternating deoxyribose sugar & phosphates

**\*\*notice sides run in opposite directions\*\***

(pentagon tip up refers to 5' end, flat bottom is 3')

Rungs: nitrogen bases – weakest part

2 kinds: **Purines** (double ringed) = adenine & guanine

**Pyrimidines** (single ringed) = cytosine & thymine

Each rung is made of one purine & one pyrimidine

**Adenine – Thymine (double bond)**

**Guanine – Cytosine (triple bond)**

Bases are bonded to sugar

\*Each sugar, phosphate & base = **nucleotide**

\*The order (sequence) of the bases determines the genes which determine the proteins made!

*Genetic Code = order of nitrogen bases (order is limitless! – this is why there is a wide variety of traits)*

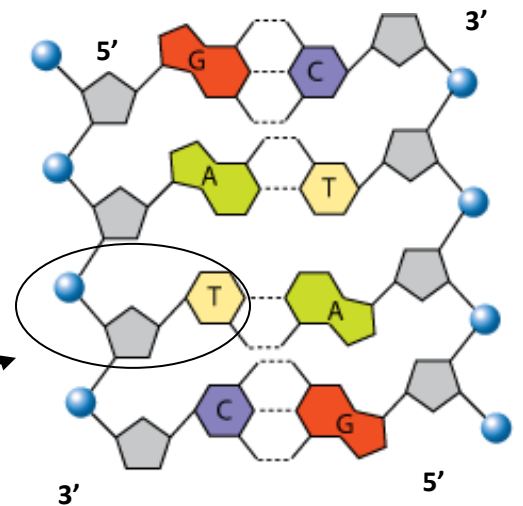
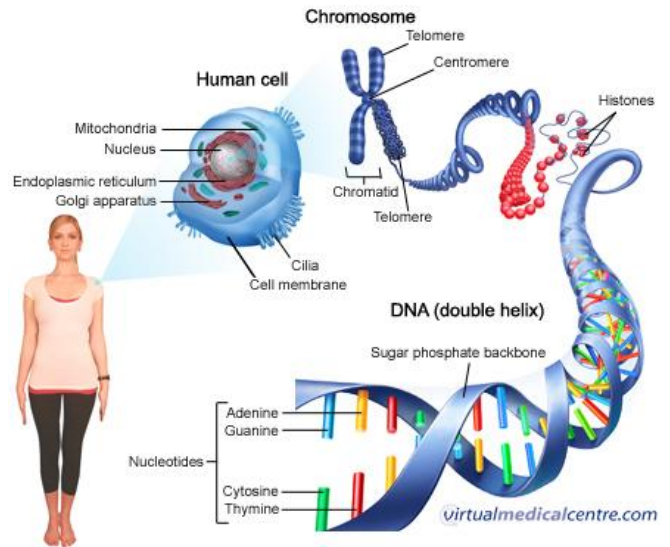
\*a DNA molecule may contain 3 billion base pairs

\*The more closely related two organisms are, the more alike their sequence of nucleotides

\*Human Genome project is working to determine the sequence for humans

→ Journey into DNA <http://www.pbs.org/wgbh/nova/genome/dna.html#>

→ Genetics Science Learning Center: <http://learn.genetics.utah.edu/> ([tour the basics](#) “What is DNA?”)



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**DNA Replication** – must duplicate (copy) during S phase of interphase during cell cycle before cell division

→ very fast & accurate

→ uses enzymes & ATP to complete the process

→ begins at special sites along DNA called origin of replication

1. DNA “unzips” & breaks at weak hydrogen bonds that connect bases – two strands open making a “replication fork”

- helicase: uncoils & unzips the DNA (& rewinds after replication)
- RNA primer – give new strand a starting point

2. Bases are exposed & matching nucleotides from the cytoplasm attach

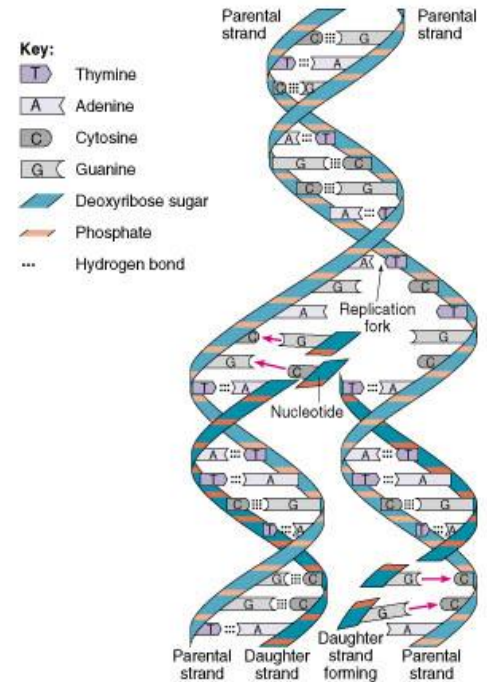
- DNA polymerase – adds corresponding nucleotides to exposed bases (& proofreads)

3. Strands are read in 3'→5' direction so copied in 5'→3' direction

→ leading strand (built toward replication fork) completed in one piece

→ lagging strand (built moving away from the replication fork) is made in sections called Okazaki fragments

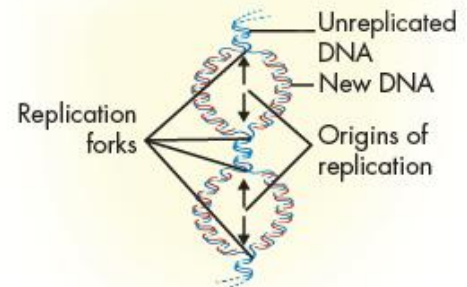
- ligase – binds fragments together



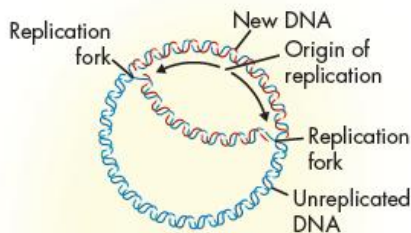
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\*\*replication is semi-conservative – new DNA consists of one old strand & one new strand

In eukaryotes: DNA very long & would take a long time if replication began at one end & ended at the other. Instead replication happens at multiple places.



**Eukaryotic DNA**



**Prokaryotic DNA**

In prokaryotes, replication occurs in the cytoplasm & DNA is much shorter & circular. Begins at one point & replicates in opposite directions:

Animations/ Visuals:

[DNA Replication Animation](#)

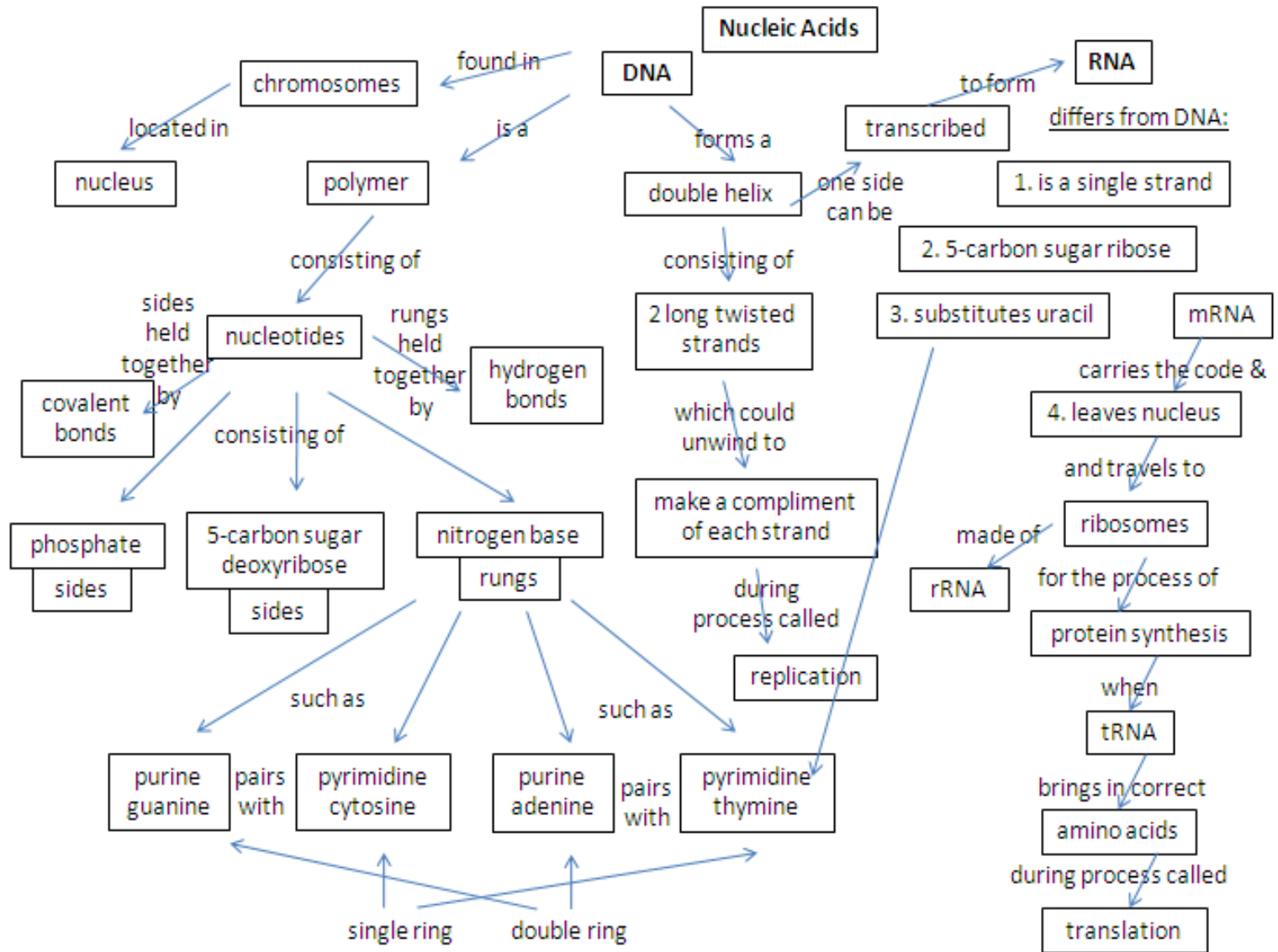
[Prokaryotic DNA Replication](#) (:31)

[Prokaryote vs. Eukaryote DNA Replication](#) (3:47)

→ DNA WORKSHOP ACTIVITY: [Build a DNA Molecule](#)

REVIEW SO FAR: [DNA Structure and Replication: Crash Course Biology #10](#) – [Kahn Academy link](#) **12:59** Hank introduces us to that wondrous molecule deoxyribonucleic acid - also known as DNA - and explains how it replicates itself in our cells.

## Nucleic Acid Concept Map



### DNA Structure & Function:

DNA Function	How DNA Structure is Adapted	Importance of the Function
Store Information	<b><i>Each strand of the double helix carries a sequence of bases, arranged something like letters in a four-letter alphabet.</i></b>	<b><i>The DNA that makes up genes controls development and characteristics of different kinds of organisms.</i></b>
Copy Information	<b><i>The base pairs can be copied when hydrogen bonds break and the strands pull apart.</i></b>	<b><i>Genetic information must be copied accurately with every cell division.</i></b>
Transmit Information	<b><i>When DNA is copied, the sequence of base pairs is copied, so genetic information can pass unchanged from one generation to the next.</i></b>	<b><i>Genetic information must pass from one generation to the next.</i></b>

## RNA NOTES

RNA – also a nucleic acid – Ribonucleic Acid

- involved in the manufacture of proteins
- DNA pattern is used to make RNA

### 4 Differences between DNA & RNA

1. RNA is **single stranded** – one half of the ladder – single chain of nucleotides
2. There is no thymine in RNA – **uracil** is found in its place (A-U)
3. Sugar molecule in RNA is **ribose** – has more oxygen than deoxyribose
4. RNA **can go outside of the nucleus**

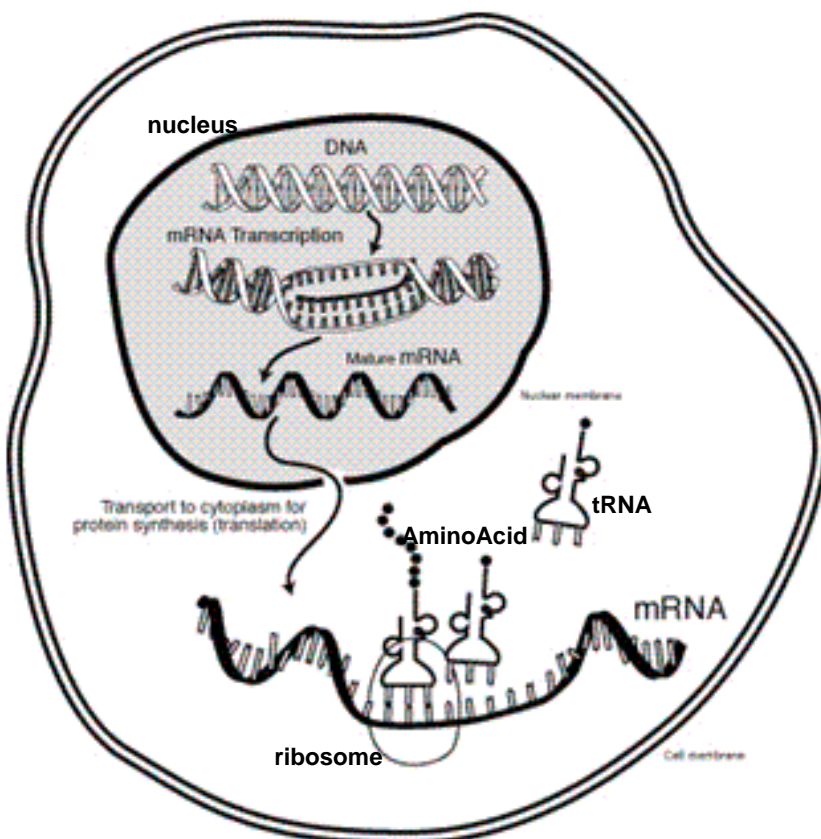
### 3 Types of RNA

1. Ribosomal RNA (rRNA) – makes up part of the ribosome
2. Messenger RNA (mRNA) – brings the code of DNA from the nucleus to the ribosome

\*ribosomes are where proteins are made

\*code (order of bases) gives the order in which amino acids must be linked to make a specific protein

3. Transfer RNA (tRNA) – picks up & carries amino acids to the messenger RNA on ribosomes



transcription  
animation:

<http://www.stolaf.edu/people/giannini/flashanimat/molgenetics/transcription.swf>

translation  
animation:

<http://www.stolaf.edu/people/giannini/flashanimat/molgenetics/translation.swf>



## SYNTHESIS NOTES

Proteins are made on the ribosomes.

DNA cannot leave the nucleus

SO: → messenger RNA makes a copy of DNA in nucleus (bases match up) – this is called *transcription*

→ the messenger RNA takes the copy to the ribosome

→ transfer RNA matches up with the messenger RNA at the ribosome to bring in the correct amino acids (this is called *translation*)

→ order of amino acids determines the protein

good overview of transcription & translation: <http://www.lew-port.com/10712041113402793/lib/10712041113402793/Animations/Protein%20Synthesis%20%20long.swf>

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**Transcription** – synthesis of RNA from a DNA template; RNA takes the info from DNA

- \*DNA unzips

- \*RNA matches with appropriate bases

- \*result is single strand of mRNA

- \*the mRNA moves on to the smaller unit portion of the ribosome

There are 20 amino acids

codon – each set of 3 nitrogen bases representing an amino acid – found on mRNA

- \*codons represent the same amino acids in all organisms

How do you know which amino acid is coded for by each codon? USE THE CHART!

Order of amino acids determines protein! – an infinite variety can be made.

**Translation** – the synthesis of protein on a template of mRNA – occurs on the ribosomes

tRNA – brings the correct amino acid to the ribosome to be assembled into a protein

- looks like a clover leaf with anticodon on loop at middle leaf & amino at stem

- binds to the larger subunit of ribosome

- **anticodons on tRNA** match with **codons on mRNA** to bring correct amino acid

3 Steps: 1. initiation – often the first codon on mRNA is AUG (codes for methionine)

2. elongation – enzyme joins amino acids & peptide bonds form between them

3. termination – UAA, UAG or UGA are the mRNA stop codon

SO:

If original DNA Strand is as follows, figure out what the mRNA, tRNA & amino acids are:

DNA: T A C T T A T C G A C C G T C G T T A T G A T T

mRNA: A U G A A U A G C U G G C A G C A A U A C U A A

tRNA: U A C U U A U C G A C C G U C G U U A U G A U U

Amino: methionine asparagine serine tryptophan glutamine glutamine tyrosine stop