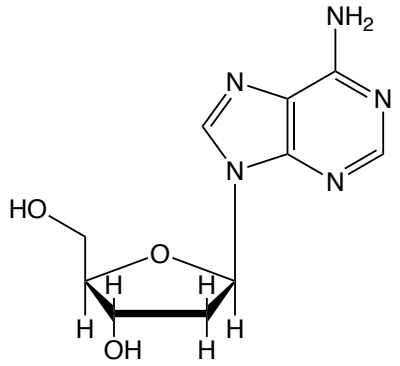
Nucleic acids

Information carriers of the cell

- Cells contain two types of chemically similar nucleic acids as principal **information-carrying** molecules:
    - **Deoxyribonucleic acid: DNA**
    - **Ribonucleic acid: RNA**
- **Most organisms have a DNA genome while some have RNA as their genetic material**
    - **Do you know of any examples?**

Nucleotides

Building blocks of nucleic acids



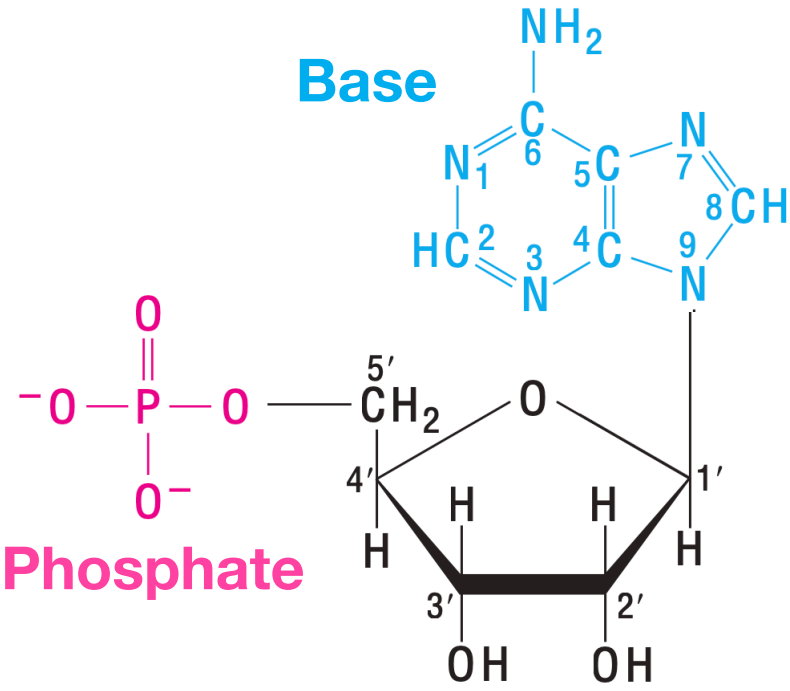
Nucleotides

Monomeric units of nucleic acids

The monomers from which DNA and RNA are built, called **nucleotides.**

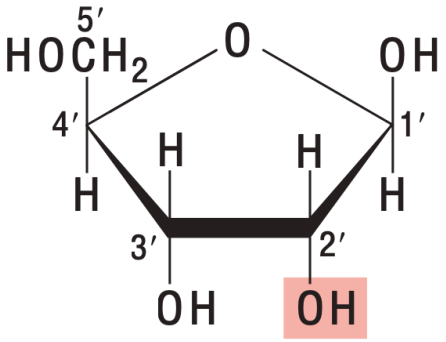
All have a common structure that has three characteristic components:

- a **pentose sugar** (a five-carbon sugar molecule)
- a **nitrogenous** (nitrogen-containing) base
- one or more **phosphates**

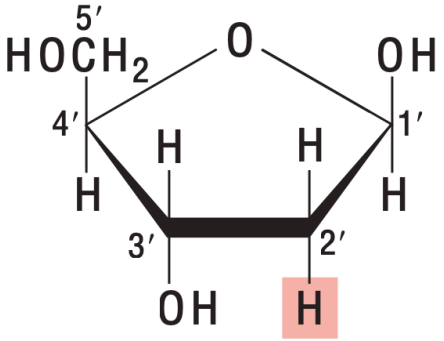


Pentose sugar

Identity of sugar determines whether it is DNA or RNA



Ribose

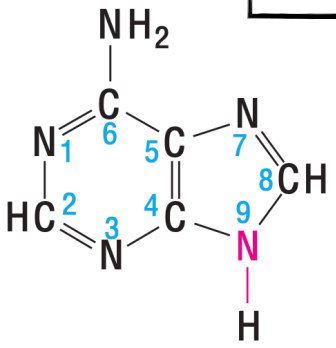


2-Deoxyribose

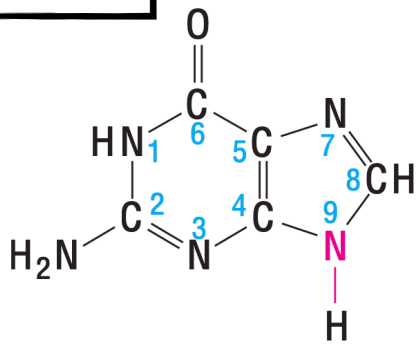
- In RNA, the pentose is ribose
- In DNA, it is deoxyribose.

Types of nucleobases

PURINES

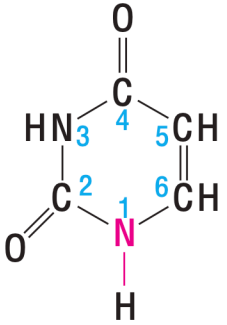


Adenine (A)

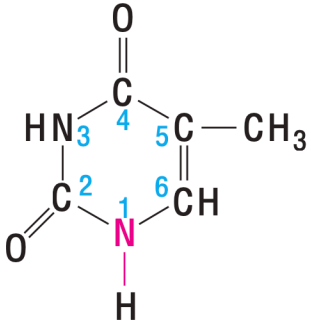


Guanine (G)

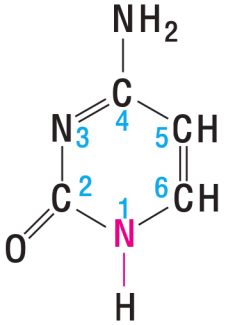
PYRIMIDINES



Uracil (U)



Thymine (T)



Cytosine (C)

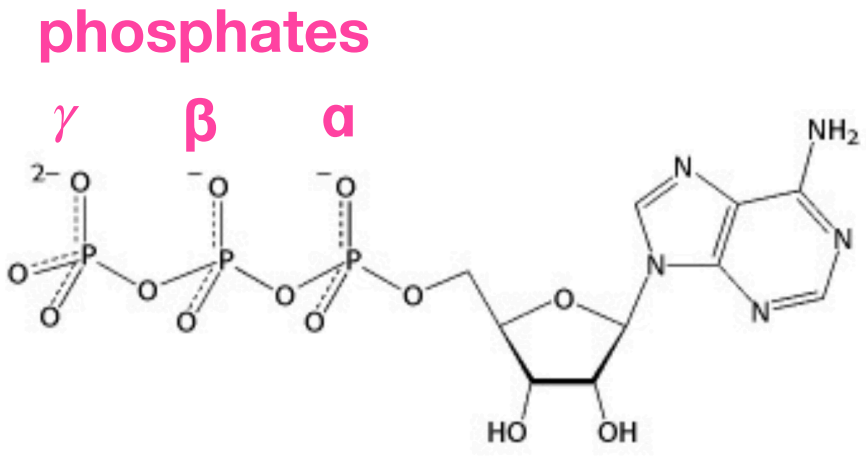
The **nitrogenous bases** are derivatives of two parent compounds, **pyrimidine and purine**.

- Adenine and guanine are purines, which contain a pair of fused rings
- Cytosine, thymine, and uracil are pyrimidines, which contain a single ring
- **Bases A, G, and C are found in both DNA and RNA; T is found only in DNA, and U is found only in RNA.**

Nucleosides and nucleotides

The molecule with a base and a sugar but without a phosphate group is called a **nucleoside**.

- **Nucleotides** are nucleosides that have one, two, or three phosphate groups esterified at the 5’ hydroxyl.
  - Nucleoside monophosphates (NMPs) have a single esterified phosphate
  - Nucleoside diphosphates (NDPs) contain a pyrophosphate group
  - Nucleoside triphosphates (NTPs) have a third phosphate



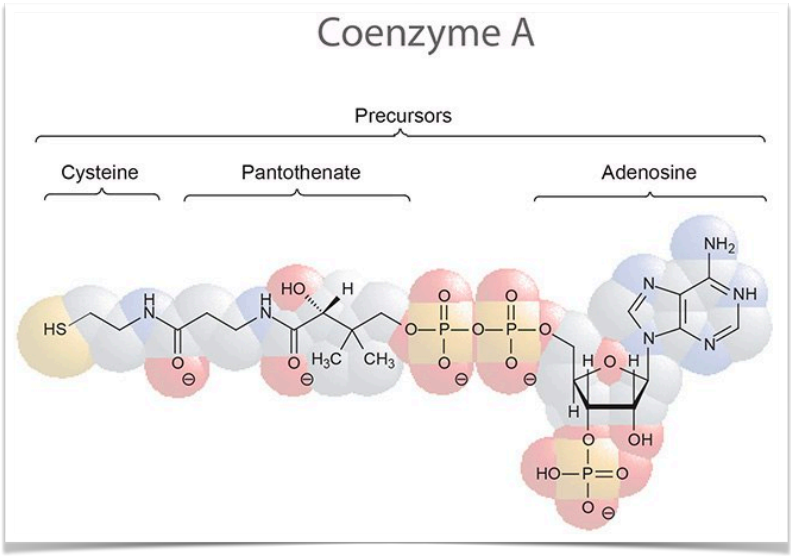
Terminology of Nucleosides and Nucleotides

		Bases			
		Purines		Pyrimidines	
		Adenine (A)	Guanine (G)	Cytosine (C)	Uracil (U) Thymine [T]
Nucleosides	in RNA	Adenosine	Guanosine	Cytidine	Uridine
	in DNA	Deoxyadenosine	Deoxyguanosine	Deoxycytidine	Deoxythymidine
Nucleotides	in RNA	Adenylate	Guanylate	Cytidylate	Uridylate
	in DNA	Deoxyadenylate	Deoxyguanylate	Deoxycytidylate	Deoxythymidylate
Nucleoside monophosphates		AMP	GMP	CMP	UMP
Nucleoside diphosphates		ADP	GDP	CDP	UDP
Nucleoside triphosphates		ATP	GTP	CTP	UTP
Deoxynucleoside mono-, di-, and triphosphates		dAMP, etc.			

Distinguish between dNTPs and NTPs: e.g. dAMP vs AMP

Diverse functions of nucleotides

- ATP is the most widely used biological energy carrier
- Metabolic regulators (cyclic AMP), GTP participates in intracellular signaling
- Activated intermediates in many biosyntheses: UDP-glucose
- Adenine nucleotides are components of the coenzymes, CoA, FAD and $NADP^+$.
- Nucleoside triphosphates are used in the synthesis of nucleic acids



The two fundamental conditions of life are:

1. Ability to self-replicate
2. Ability to catalyze chemical reactions

Nucleic acids are the basis for the ability to self-replicate

What are nucleic acids?

- Cells contain two types of chemically similar nucleic acids as principal **information-carrying** molecules:
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Genetic material

- Genetic material is responsible for inheritance and is passed from parent to offspring for all life on earth.
- To **preserve the integrity of this genetic information**, an organism's genome must be replicated with great accuracy with **minimal errors that introduce changes to the sequence**.
- A genome is organized into smaller, discrete units called **genes**

How did we know that nucleic acids are genetic material?

- In the first half of the twentieth century, Gregor Mendel's principles of genetic inheritance became widely accepted, but the chemical nature of the hereditary material remained unknown.
- Scientists knew that genes were located on chromosomes and that chromosomes consisted of DNA and proteins.
- At the time, **proteins seemed to be a better choice for the genetic material**, because chemical analyses had shown that proteins are more varied than DNA in chemical composition and physical properties.

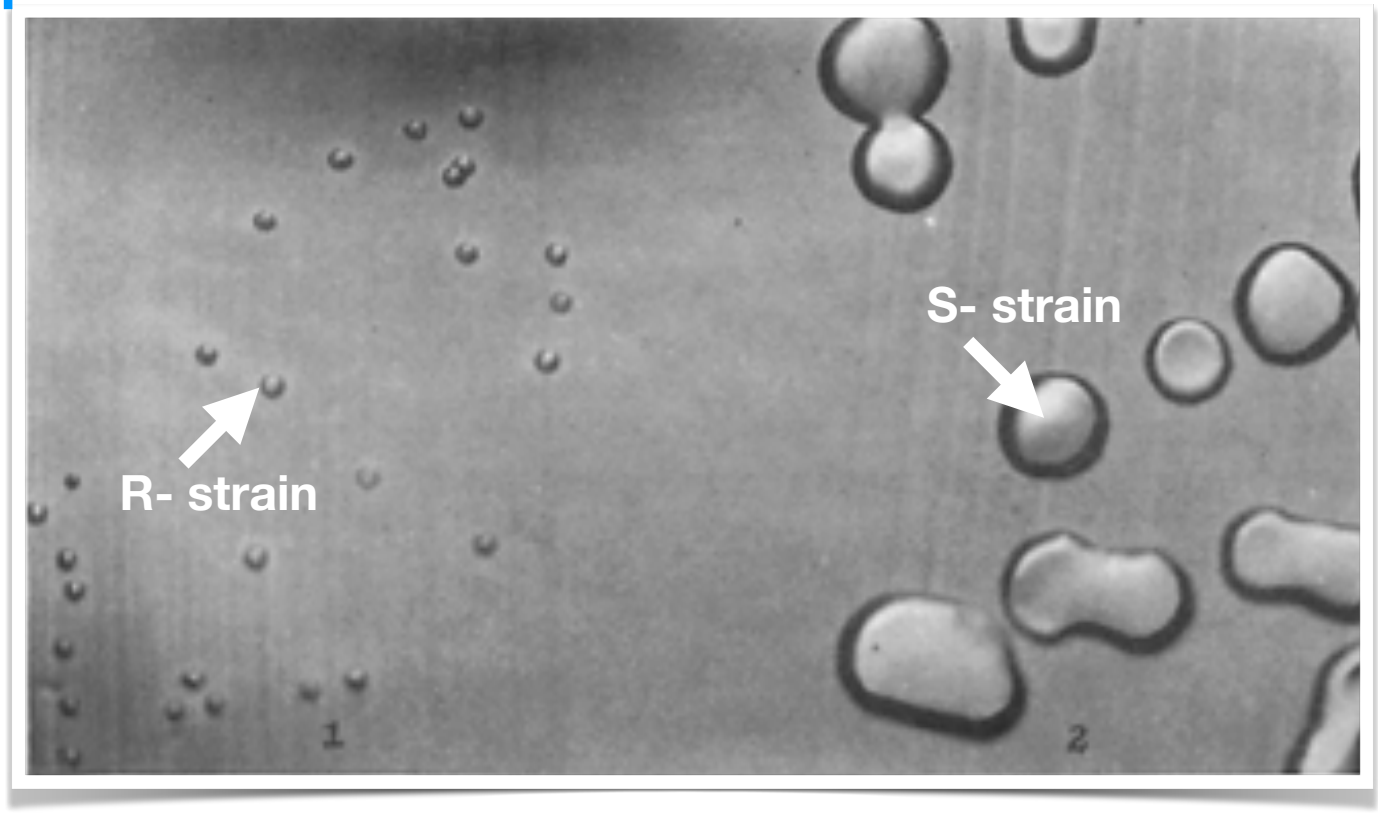
https://www.nature.com/scitable/topicpage/isolating-hereditary-material-frederick-griffith-oswald-avery-336/#

Griffith's experiment: 1928

"Transforming principle"

Strains of *Streptococcus pneumoniae*

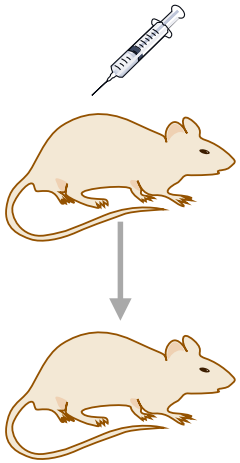
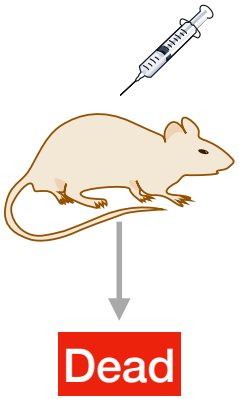
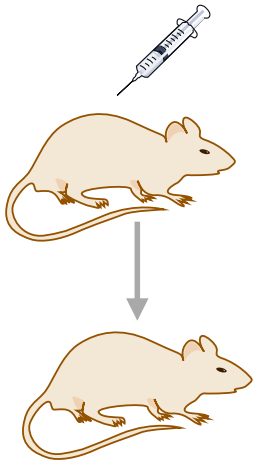
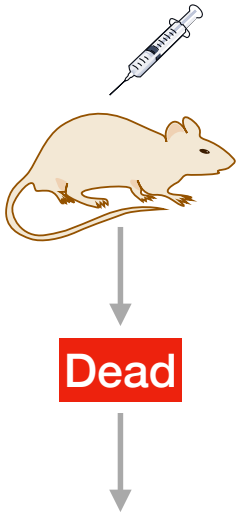
- **Rough (R) strain**
  non-virulent
- **Smooth (S) strain**
  virulent



Mice injected with the S strain died within a few days after injection, while mice injected with the R strain did not die.

Griffith's experiment: 1928

"Transforming principle"

Rough (R) strain *Streptococcus pneumoniae* (non-virulent)	Smooth (S) strain *Streptococcus pneumoniae* (virulent)	Smooth (S) strain *Streptococcus pneumoniae* heat-killed	Mixture of live rough strain with heat-killed smooth strain *Streptococcus pneumoniae*
			
	Dead		Dead

Frederick Griffith's demonstrated bacterial transformation and the presence of a molecular material that can transfer inherited characteristics such as virulence

Live bacteria isolated from hearts of dead mice were S strain

Bacteriologists believed that the “transforming principle” was protein