



Chemical Biology
 $DNA \rightleftharpoons RNA \rightleftharpoons Proteins$
 Molecular Engineering
Dr. Ron Rusay

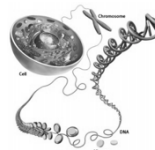
<https://www.youtube.com/watch?v=gG7uCskUOrA>



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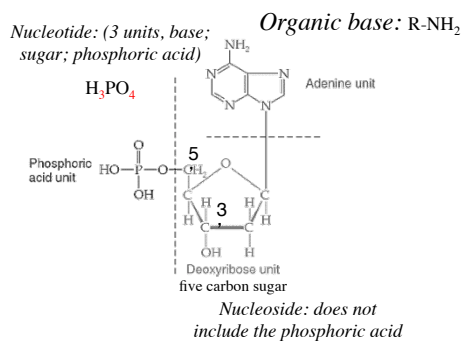
DNA & RNA: Nucleic Acids

- Store & carry genetic information.



- DNA (deoxyribonucleic acids) have molecular weights $\sim 6 \times 10^6$ to 16×10^6 daltons (amu) and are found inside the nucleus of the cell.
- RNA (ribonucleic acids) have molecular weights $\sim 20,000$ to $40,000$ amu and are found in the cytoplasm outside the nucleus of the cell.

Nucleic "Acids"



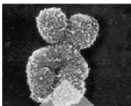
Nucleic Acids (DNA & RNA)

- DNA and RNA have different sugars (deoxyribose vs. ribose).
- There are only five bases found in DNA and RNA:
 - adenine (A),
 - guanine (G),
 - cytosine (C),
 - thymine (T found in DNA only), and
 - uracil (U found in RNA only).

Genetics & DNA



XX



Chromosome



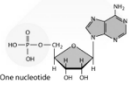
DNA double helix



Gene on a single strand of DNA

GGATATCCAAGC

Nucleotide sequence



One nucleotide



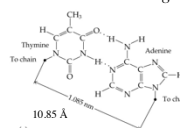
XY

DNA: Size, Shape & Self Assembly
http://www.umass.edu/microbio/chime/beta/pe_alpha/atlas/atlas.htm

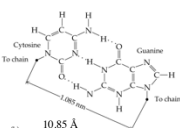
Views & Algorithms



(a)



(a)



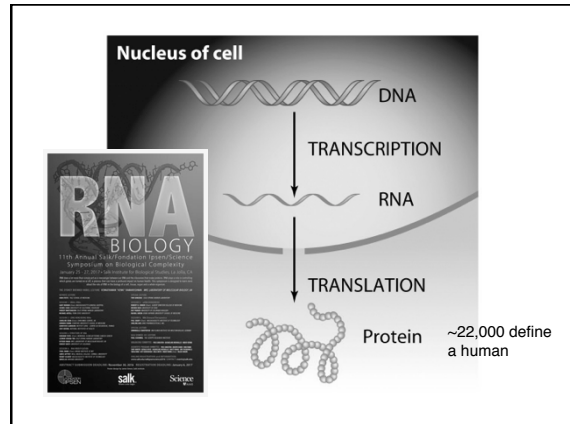
(b)



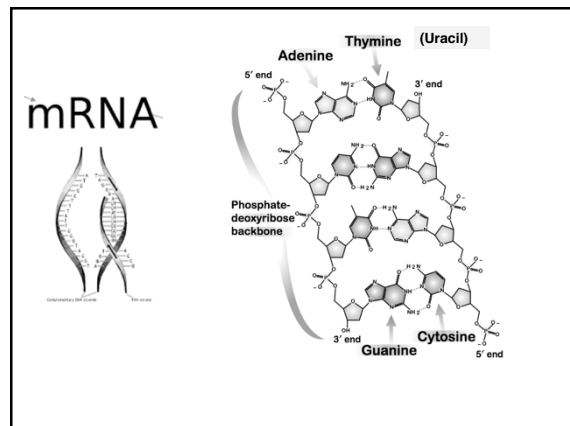
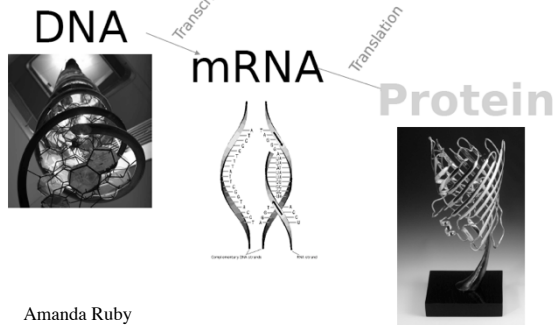
Protein Biosynthesis



<https://www.dnalc.org/resources/3d/09-how-much-dna-codes-for-protein.html>



Central Dogma



mRNA

Sense vs. Antisense strands

- **Sense strand** - the "other" strand, not transcribed.
- **Antisense strand** - the one mRNA attaches to, and is complementary to.
- mRNA is similar to the sense strand, except T→U.

Diagram labels: Elongation, RNA polymerase, RNA nucleotides, 3' end, Direction of transcription, Template strand of DNA, Newly made RNA.

DNA	Coding Strand (Codons)	5' >>> TTC >>> 3'
	Template Strand (Anti-codons)	3' <<< AAG <<< 5'
mRNA	Message (Codons)	5' >>> UUC >>> 3'
tRNA	Transfer (Anti-codons)	3' <<< AAG <<< 5'
Protein	Amino Acid	Amino >>> Phenylalanine >>> Carboxy

Antisense DNA from the left: GTAGGT...
mRNA: CAUCCA...

mRNA

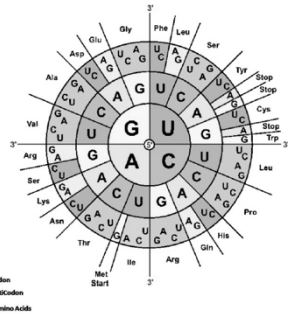
DNA	Coding Strand (Codons)	5' >>> TTC >>> 3'
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mRNA	Message (Codons)	5' >>> UUC >>> 3'
tRNA	Transfer (Anti-codons)	3' <<< AAG <<< 5'
Protein	Amino Acid	Amino >>> Phenylalanine >>> Carboxy

Coding Strand = Antisense strand: TTC
Anti-coding = Sense strand
mRNA: UUC

Protein Biosynthesis

Codons

- mRNA is translated in "chunks" of three, called **codons**
- The starting nucleotide is determined using bioinformatics to find the **reading frame**
- The genetic code is **degenerate** (similar, but not identical)



5' AUG CAA CCC GAC UCC AGC 3' → Codon
3' UAC GUU GGG CUG AGG UAG 5' → Anticodon
Met-Gln-Pro-Asp-Phe-Ser → Amino Acids

Protein Biosynthesis

Codon Chart

		Second Letter											
		U			C			A			G		
1st letter	U	UUU UUC UUA UUG	Phe Leu	UCU UCC UCA UCG	 Ser	UAU UAC UAA UAG	Tyr Stop Stop	UGU UGC UGA UGG	Cys Stop Trp	U C A G			
	C	CUU CUC CUA CUG	Leu	CCU CCC CCA CCG	Pro	CAU CAC CAA CAG	His Gln	CGU CGC CGA CGG	Arg	U C A G			
	A	AUU AUC AUA AUG	Ile Met	ACU ACC ACA ACG	Thr	AAU AAC AAA AAG	Asn Lys	AGU AGC AGA AGG	Ser Arg	U C A G			
	G	GUU GUC GUA GUG	Val	GCU GCC GCA GCG	Ala	GAU GAC GAA GAG	Asp Glu	GGU GGC GGA GGG	Gly	U C A G			
											3rd letter		

Central Dogma

DNA

Several nucleic acids linked together form DNA

Three nucleic acids in a row form a codon, which codes for different amino acids

Several consecutive codons form genes

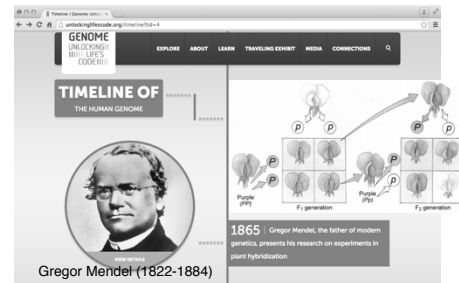
Genes code for a sequence of amino acids

Several amino acids linked together form proteins

~22,000 define a human

DNA: Genetics & Genomics Timelines

1865



<https://www2.edc.org/weblabs/Mendel/MendelMenu.html>

1953

DNA: Molecular Discovery

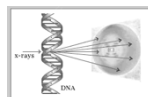
X-Ray Crystal Structure

<http://info.bio.cmu.edu/courses/03231/ProtStruc/ProtStruc.htm>

β-DNA: Rosalind Franklin



12 base sequence

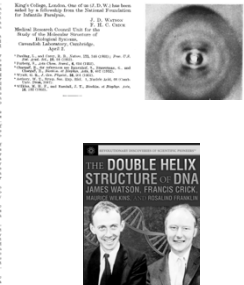


http://molvis.sdsc.edu/pdb/dna_b_form.pdb

April 25, 1953 NATURE

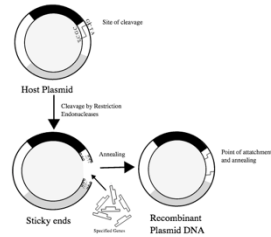
MOLECULAR STRUCTURE OF NUCLEIC ACIDS
A Structure for Desoxyribose Nucleic Acid
W. L. B. ...
The structure of the DNA molecule is a double helix, with the sugar-phosphate backbone forming the outer spiral and the nitrogenous bases forming the inner rungs. The structure is stabilized by hydrogen bonds between the bases, and the overall shape is maintained by the covalent bonds between the sugar and phosphate groups.

April 25, 1953 NATURE

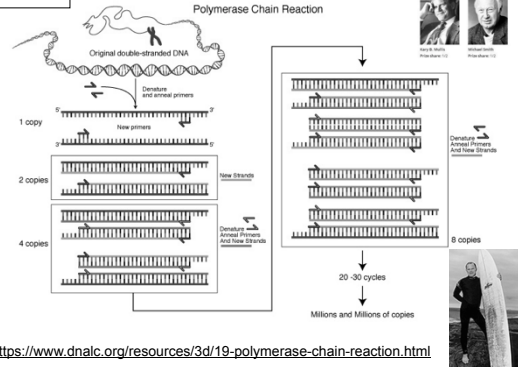


1975**Restriction Enzymes / Recombinant DNA**

Berg, Boyer, Cohen, and many others

<http://nar.oxfordjournals.org/content/early/2013/10/18/nar.gkt990.full>**1989****PCR: Polymerase Chain Reaction**
Kary Mullis, Cetus-Chiron-Roche, Emeryville
Polymerase Chain Reaction

The Nobel Prize in Chemistry 1993

<https://www.dnalc.org/resources/3d/19-polymerase-chain-reaction.html>

The Human Genome Project: Exploring our Molecular Selves.

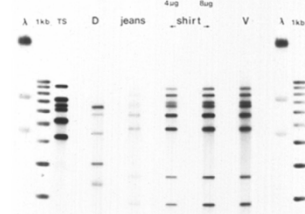
1994 FLAVR SAVR tomato

The FDA approved the sale of the first genetically modified food — the FLAVR SAVR tomato, deeming it as safe as conventionally-bred tomatoes.

The FDA's decision on the FLAVR SAVR tomato — marketed by Calgene, Inc. of Davis, California — marked the first time the agency evaluated a food that was genetically engineered. FLAVR SAVR tomatoes are modified to stay firm after harvest, so they can be left on the vine longer before shipping. The FDA decided the change in the tomatoes was not great enough to warrant mandated labeling describing the alteration.

Roger Salquist
Chairman
CEO
Calgene

Genes, Variation & Human History | The Future of Research & Medicine | How to Sequence a Genome | ELSI | Glossary

1995**Genetic Fingerprinting**

Blood on glove found on Simpson's property appeared to contain genetic markers of Simpson and both victims.

OJ Simpson and the bloody glove.

The Human Genome Project: Exploring our Molecular Selves.

1996

International strategy meeting on human genome sequencing
Mouse genetic map completed
Yeast genome sequenced
Archaea genome sequenced
Congress outlaws genetic discrimination in health insurance
280,000 expressed sequence tags (ESTs)
Human gene map created
Human DNA sequencing begins.

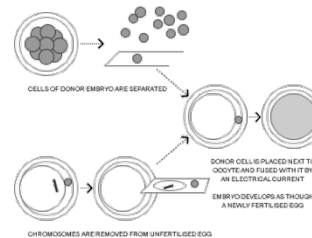
select the topic you would like to review

Genes, Variation & Human History | The Future of Research & Medicine | How to Sequence a Genome | ELSI | Glossary

<http://www.genome.gov/25019879>
<http://unlockinglifescode.org/timeline?tid=4>

1996**CLONING**

Hello Dolly!



2001

Golden Rice

<http://www.goldenrice.org/>







Hunan Study 2008

Golden Rice Paper 2012

Patents for Humanity Awards 2015

<http://news.sciencemag.org/asiapacific/2013/09/golden-rice-not-so-golden-tufts>



Transgenic Crops

Genetically Modified Organisms (GMOs)

WHAT IS THE FISH TRYING TO TELL US?

STOP GENETICALLY ENGINEERED FOODS!

Should your refrigerator be Condemned?

IA

+ = ?

Gene machine

Gene X + Gene for transposase

DNA inserted into plasmid using capsules that enable it to enter cells

Cell makes transposase enzyme from gene

The enzyme cuts out gene X and inserts it into a random spot in the genome

Gene for transposase breaks down after a few days

<http://www.greenpeace.org/international/Global/international/publications/agriculture/2013/458%20-%20Golden%20Illusion-GE-goldenrice.pdf>

<http://www.i-sis.org.uk/rice.php>

2015

Golden Rice

<http://www.goldenrice.org/>







Hunan Study 2008

WITHDRAWN July 2015

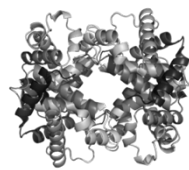
Patents for Humanity Awards 2015

<http://news.sciencemag.org/asiapacific/2013/09/golden-rice-not-so-golden-tufts>

A screenshot of the American Journal of Clinical Nutrition website. The top navigation bar includes links for HOME, CURRENT ISSUE, EMAIL ALERTS | ARCHIVES, SUBSCRIPTIONS, and SEARCH FOR ARTICLES. Below this is a copyright notice for 2012 American Society for Nutrition. The main content area features a large, bold, black text overlay that reads: "WITHDRAWN: For lack of evidence that all human participants provided full consent supported by Massachusetts Court (August 3, 2015)". The background of the website shows a search bar, a list of articles, and a sidebar with categories like "Feature", "Brief Report", "State of the Science", "This Article", and "Full Text".

2012 Genome Editing / CRISPR-Cas9

2016 Genome Editing / CRISPR-Cas9
Target
β-Thalassemia: Shortage of β-globin Protein

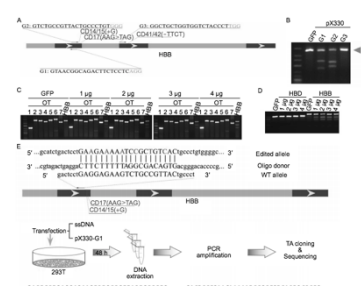


Normal β-globin

<https://www.dnalc.org/resources/3d/17-sickle-cell.html>

2016 Genome Editing / CRISPR-Cas9
β-Thalassemia / Human Embryo Research
<http://chemconnections.org/general/chem121/Gene%20Editing/Gene%20Editing%202015-0153.pdf>

CRISPR/Cas9-mediated gene editing in human trypsinogen alleles



RESEARCH ARTICLE

Protein & Cell

Genetic Fingerprinting

1985 500 nanograms
Amount of DNA needed for fingerprinting when the technique was first published in 1985. It corresponds to about one drop of blood or 100,000 cells.

2016 0.1 nanogram
The amount that, in some cases, suffices today. It corresponds to about 20 cells, a number that could be found in a fingerprint.

WHEN DNA IS LYING

- Forensics
- Paternity
- Military-ID
- Food
- Wine
- Anthropology
- Medical Diagnosis

<http://science.sciencemag.org/content/sci/351/6278/1133.full.pdf>

2016 5.3 x 10³¹ Megabases of DNA = 10²¹ Supercomputers

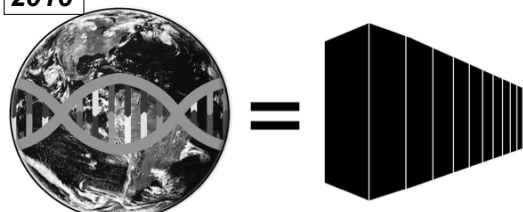


Fig 1. Storing the total amount of information encoded in DNA in the biosphere, 5.3 x 10³¹ megabases (Mb), would require approximately 10²¹ supercomputers with the average storage capacity of the world's four most powerful supercomputers.

<http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002168#pbio-1002168-g001>

Landmark HKE, Fergan DH, Cockell CS (2015) An Estimate of the Total DNA in the Biosphere. PLoS Biol 13(6): e1002168. doi:10.1371/journal.pbio.1002168

PLOS BIOLOGY

2016 Table 1. The total DNA content in the biosphere

	DNA amount (Mb)
Prokaryotes	1.6 (1.1) × 10 ³¹
Unicellular eukaryotes	1.3 (0.9) × 10 ²⁹
Fungi	1.7 (3.4) × 10 ²⁷
Animals	4.2 (1.5) × 10 ²⁹
Plants	3.6 (3.4) × 10 ³¹
Viruses	4.0 (3.4) × 10 ²⁹
Total	5.3 (3.6) × 10³¹

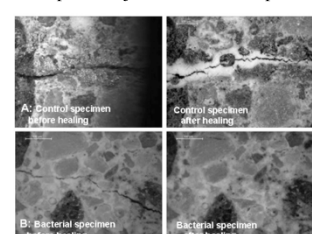
doi:10.1371/journal.pbio.1002168.t001

Landmark HKE, Fergan DH, Cockell CS (2015) An Estimate of the Total DNA in the Biosphere. PLoS Biol 13(6): e1002168. doi:10.1371/journal.pbio.1002168

<http://dx.doi.org/10.1371/journal.pbio.1002168>

PLOS BIOLOGY

2016 Bioengineering:
Structural Materials & Molecules
Bacteria & Yeast
Healing Concrete
<http://heronjournal.nl/56-12/1.pdf>



A: Control specimen before healing

Control specimen after healing

B: Bacterial specimen before healing

Bacterial specimen after healing

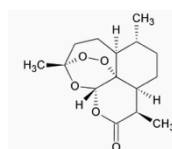
**2017-
2019**

Bioengineering:
Bacteria, Yeast & Chemical Synthesis

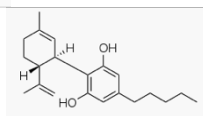
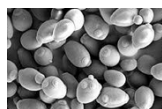
Brewer's Yeast
(*Saccharomyces cerevisiae*)



Chinese Wormwood
(*Artemisia annua*)



anti-malarial



cannabidiol (CBD)