Chemical Biology
DNA ⇆ RNA ⇆ Proteins

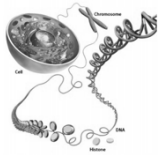
Molecular Engineering

Dr. Ron Rusay

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

DNA & RNA: Nucleic Acids

- Store & carry genetic information.

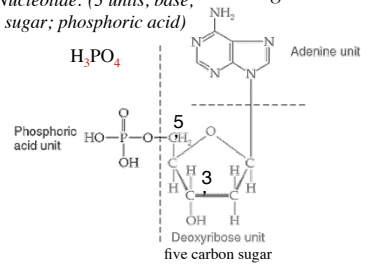


- DNA (deoxyribonucleic acids) have molecular weights ~ 6×10^6 to 16×10^6 daltons (amu) and are found inside the nucleus of the cell.
- RNA (ribonucleic acids) have molecular weights ~ 20,000 to 40,000 amu and are found in the cytoplasm outside the nucleus of the cell.

Nucleic "Acids"

Nucleotide: (3 units, base; sugar; phosphoric acid)

Organic base: R-NH_2



five carbon sugar

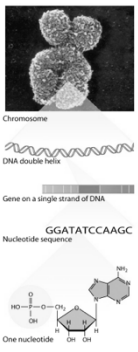
Nucleoside: does not include the phosphoric acid

Nucleic Acids (DNA & RNA)

- DNA and RNA have different sugars (dexoyribose 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

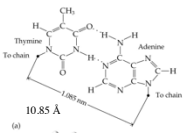


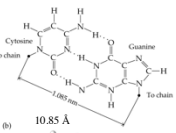
XY

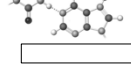
DNA: Size, Shape & Self Assembly

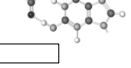
http://www.umass.edu/microbio/chime/beta/pg_alpha/atlas/atlas.htm

Views & Algorithms



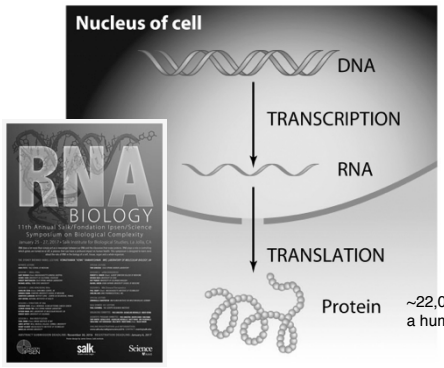






Protein Biosynthesis

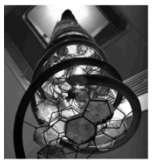
https://www.dnalc.org/resources/3d/09-how-much-dna-codes-for-protein.html



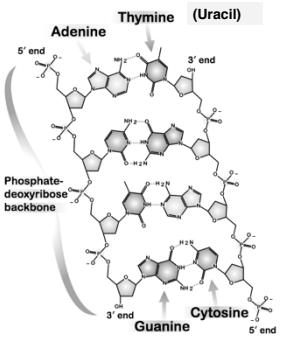
~22,000 define a human

Central Dogma

DNA → (Transcription) → mRNA → (Translation) → Protein

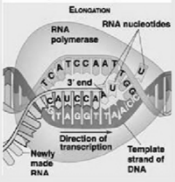


Amanda Ruby



Sense vs. Antisense strands

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



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

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

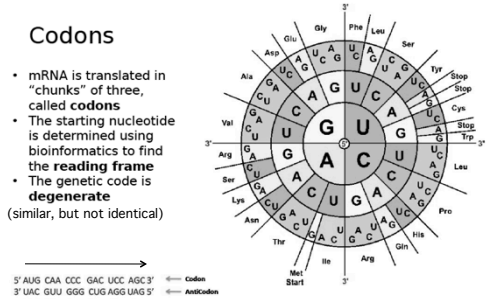
Coding Strand = Antisense strand: TTC
Anti-coding = Sense strand
mRNA: UUC

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)



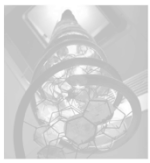
Protein Biosynthesis

Codon Chart

1st letter	2nd Letter: U	2nd Letter: C	2nd Letter: A	2nd Letter: G	3rd letter
U	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr UAA Stop UAG Stop	UGU Cys UGC Cys UGA Stop UGG Trp	U C A G
C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA Gln CAG Gln	CGU Arg CGC Arg CGA Arg CGG Arg	U C A G
A	AUU Ile AUC Ile AUA Ile AUG Met	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AGU Ser AGC Ser AGA Arg AGG Arg	U C A G
G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAU Asp GAC Asp GAA Glu GAG Glu	GGU Gly GGC Gly GGA Gly GGG Gly	U C A G

Central Dogma

DNA → RNA → Protein



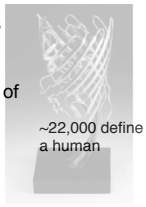
Several nucleic acids linked together form DNA

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

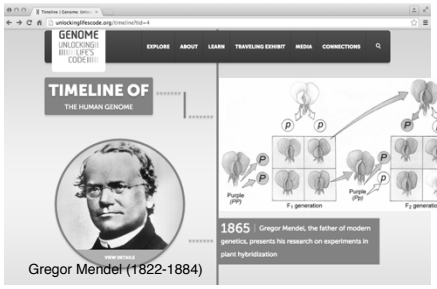
Several amino acids linked together form proteins



~22,000 define a human

1865 *DNA: Genetics & Genomics*

Timelines



Gregor Mendel (1822-1884)

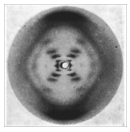
https://www2.edc.org/weblabs/Mendel/MendelMenu.html

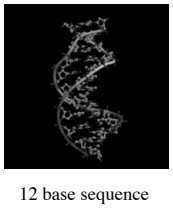
1953 *DNA: Molecular Discovery*

X-Ray Crystal Structure

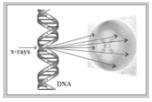
http://info.bio.cmu.edu/courses/03231/ProtStruc/ProtStruc.htm

β-DNA: Rosalind Franklin





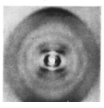
12 base sequence

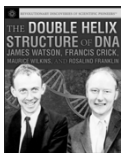


http://molvis.sdsc.edu/pdb/dna_b_form.pdb

MOLECULAR STRUCTURE OF NUCLEIC ACIDS

A Structure for Deoxyribose Nucleic Acid



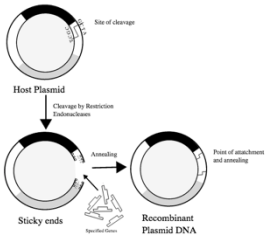


1975

Restriction Enzymes / Recombinant DNA

Berg, Boyer, Cohen, and many others

http://nar.oxfordjournals.org/content/early/2013/10/18/nar.gkt990.full



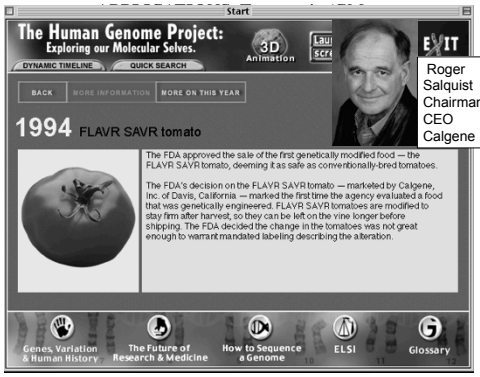
1989

PCR: Polymerase Chain Reaction

Kary Mullis, Cetus-Chiron-Roche, Emeryville

The Nobel Prize in Chemistry 1993

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



Roger Salquist
Chairman
CEO
Calgene

1995

Genetic Fingerprinting

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

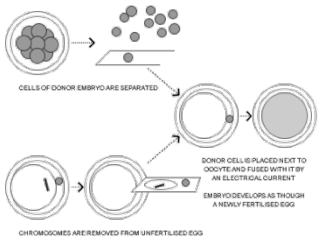
OJ Simpson and the bloody glove.

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

1996

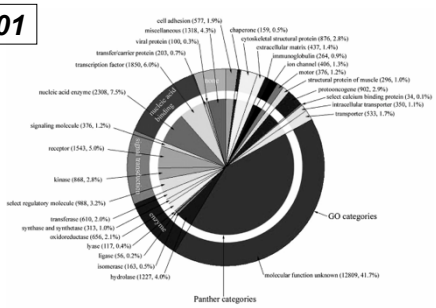
CLONING

Hello Dolly!



Human Genome: Distribution of the molecular functions of 26,383 human genes.

2001



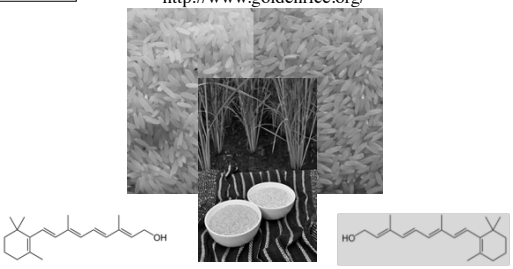
J. Craig Venter et al. Science 2001;291:1304-1351

Published by AAAS

2001

Golden Rice

http://www.goldenrice.org/



Hunan Study 2008

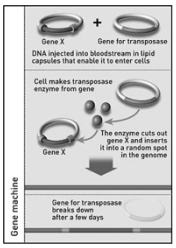
Golden Rice Paper 2012

Patents for Humanity Awards 2015

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

Transgenic Crops

Genetically Modified Organisms (GMOs)



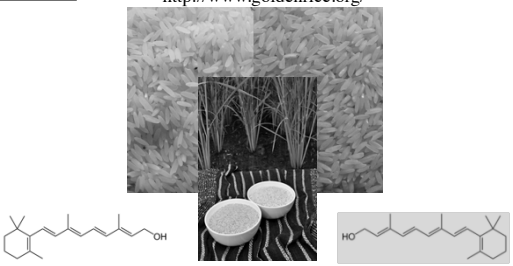
http://www.greenpeace.org/international/Global/international/publications/agriculture/2013/458%20-%20Golden%20Illusion-GE-goldenrice.pdf

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

The American Journal of CLINICAL NUTRITION

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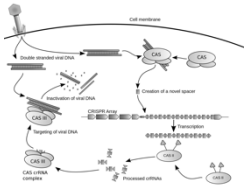
β-Carotene in Golden Rice is as good as β-carotene in oil at providing vitamin A to children[1,2,3,4]

WITHDRAWN:
For lack of evidence that all human participants provided full consent

supported
by Massachusettes Court (August 3, 2015)

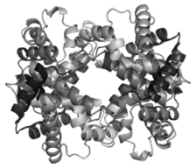
2012 Genome Editing / CRISPR-Cas9

https://www.youtube.com/watch?v=2pp17E4E-O8
https://www.youtube.com/watch?v=SuAxDVBt7kQ



2016

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



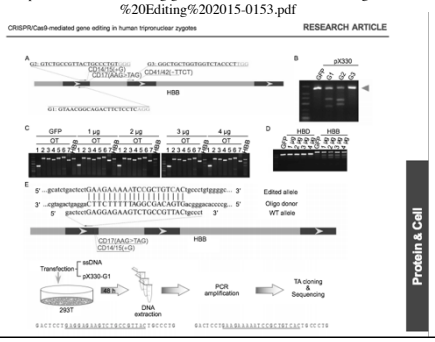
Normal β-globin

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



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.

WHEN DNA IS LYING

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.

2016

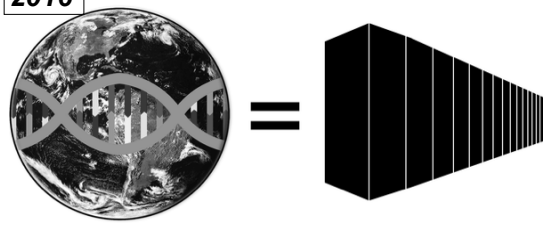
- Forensics
- Paternity
- Military-ID
- Food
- Wine
- Anthropology
- Medical Diagnosis

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

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

5.3×10^{31} Megabases of DNA = 10^{21} Supercomputers

2016



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

Landenmark HKE, Forgan 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://127.0.0.1:8081/plosbiology/article?id=info:doi/10.1371/journal.pbio.1002168

PLOS | BIOLOGY

2016

Table 1. The total DNA content in the biosphere

	DNA amount (Mb)
Prokaryotes	$1.6\ (1.1) \times 10^{31}$
Unicellular eukaryotes	$1.3\ (0.9) \times 10^{29}$
Fungi	$1.7\ (3.4) \times 10^{27}$
Animals	$4.2\ (1.5) \times 10^{29}$
Plants	$3.6\ (3.4) \times 10^{31}$
Viruses	$4.0\ (3.4) \times 10^{29}$
Total	$\mathbf{5.3\ (3.6) \times 10^{31}}$

doi:10.1371/journal.pbio.1002168.t001

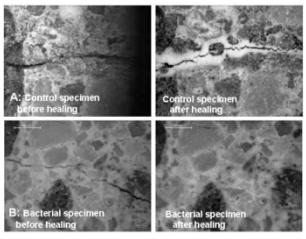
Landenmark HKE, Forgan DH, Cockell CS (2015) An Estimate of the Total DNA in the Biosphere. PLoS Biol 13(6): e1002168. doi:10.1371/journal.pbio.1002168
http://127.0.0.1:8081/plosbiology/article?id=info:doi/10.1371/journal.pbio.1002168

PLOS | BIOLOGY

2016

Bioengineering:
Structural Materials & Molecules
Bacteria & Yeast
Healing Concrete

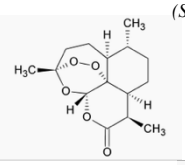
http://heronjournal.nl/56-12/1.pdf



2017-2019

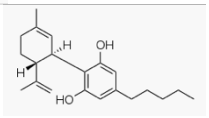
Bioengineering:
Bacteria, Yeast & Chemical Synthesis

Chinese Wormwood (Artemisia annua)



anti-malarial

Brewer's Yeast (Saccharomyces cerevisiae)



cannabadiol (CBD)