

Organic Molecules Functional Groups

Amines: Weak Organic Bases
Carbon Derivatives of Ammonia

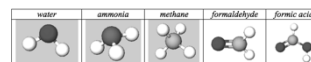
Dr. Ron Rusay



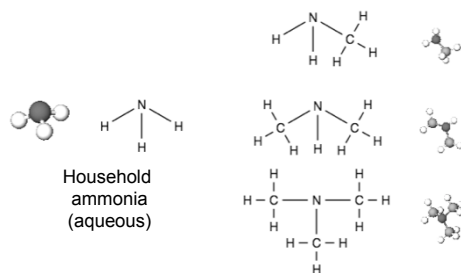
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Small Organic Molecules Common Functional Groups

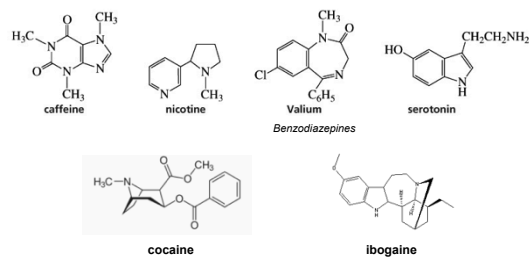
Name	General Formula
Alcohols	R-OH
Ethers	R-O-R'
Amines	R-NH ₂
Carboxylic Acids	R-C(=O)-OH



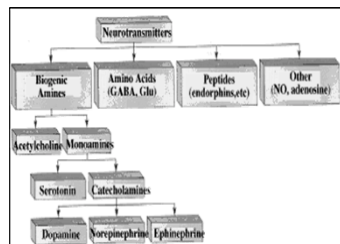
Small Organic Molecules Ammonia & Amines



Alkaloids: Naturally Occurring Bases Nitrogen Heterocycles



Amines & Neurotransmitters



<https://www.youtube.com/watch?v=YuJOhpNS0IY>



<http://www.coca-cola.co.uk/stories/caffeine-counter>
Caffeine: a natural insecticide, LD₅₀ = 150 mg/kg


<https://www.youtube.com/watch?v=OTVE5IPMKLg>

Coffee: The Greatest Addiction Ever (A testimonial?)



50% Chance of Death
Mass x 150mg
 e.g. to poison a 40kg human you need 13,500mg that's 90 cups of coffee.

Neurotransmitters



- Acetylcholine** is a very widely distributed excitatory neurotransmitter that triggers muscle contraction and regulates the secretion of certain hormones in the central nervous system. It is involved in wakefulness, alertness, anger, aggression, sexuality, and brain, among other things.
- Dopamine** is a neurotransmitter involved in controlling movement and plays a central role in brain's reward system and pleasure. It also regulates mood and is also related to a number of other functions.
- GABA (gamma-aminobutyric acid)** is an inhibitory neurotransmitter that is very widely distributed in the neurons of the cortex. GABA contributes to motor control, vision, and many other cortical functions.
- Glutamate** is a major excitatory neurotransmitter that is associated with learning and memory.
- Norepinephrine** is a neurotransmitter that is important for alertness, emotions, sleeping, dreaming, and learning. Norepinephrine is also related to a number of other functions.
- Serotonin** contributes to various functions, such as regulating body temperature, sleep, mood, appetite, and pain.

Alzheimer's disease is associated with a lack of acetylcholine in certain regions of the brain.

The loss of dopamine in certain parts of the brain causes the muscle rigidity typical of Parkinson's disease.

Some drugs that increase the level of GABA in the brain are used to treat anxiety and to calm the trembling of people suffering from Huntington's disease.

It is also thought to be associated with Alzheimer's disease, whose first symptoms include memory malfunctions.

Norepinephrine plays a role in mood disorders such as manic depression.

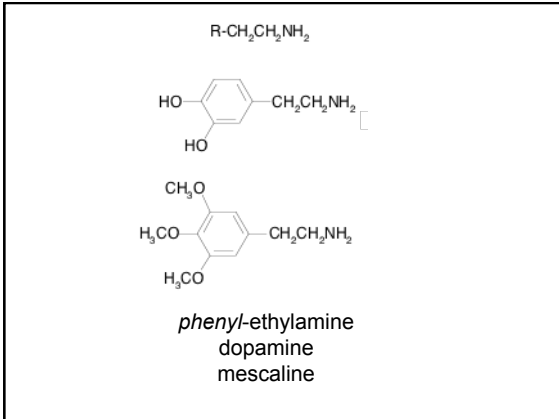
Depression, suicide, impulsive behaviour, and aggressiveness all appear to involve certain imbalances in serotonin.

ADENOSINE CAFFEINE

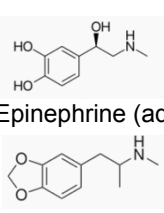
Major Neurotransmitters in the Body ^{1, 7, 8}

	Role in the body
Acetylcholine	A neurotransmitter used by spinal cord neurons to control muscles and by many neurons in the brain to regulate memory. In most instances, acetylcholine is excitatory.
Dopamine	The neurotransmitter that produces feelings of pleasure when released by the brain reward system. Dopamine has multiple functions depending on where in the brain it acts. It is usually inhibitory.
GABA (gamma-aminobutyric acid)	The major inhibitory neurotransmitter in the brain.
Glutamate	The most common excitatory neurotransmitter in the brain.
Glycine	A neurotransmitter used mainly by neurons in the spinal cord. It probably always acts as an inhibitory neurotransmitter.
Norepinephrine	Norepinephrine acts as a neurotransmitter and a hormone. In the peripheral nervous system, it is part of the fight-or-flight response. In the brain, it acts as a neurotransmitter regulating normal brain processes. Norepinephrine is usually excitatory, but is inhibitory in a few brain areas.
Serotonin	A neurotransmitter involved in many functions including mood, appetite, and sensory perception. In the spinal cord, serotonin is inhibitory in pain pathways.

<http://learn.genetics.utah.edu/content/addiction/reward/pathways.html>



F.D.A. Agrees to New Trials for Ecstasy as Relief for PTSD Patients (Nov. 2016)



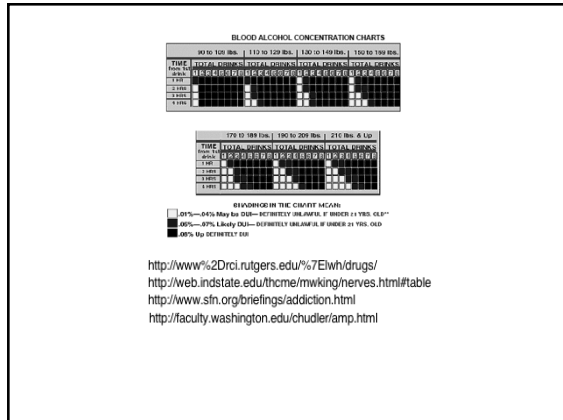
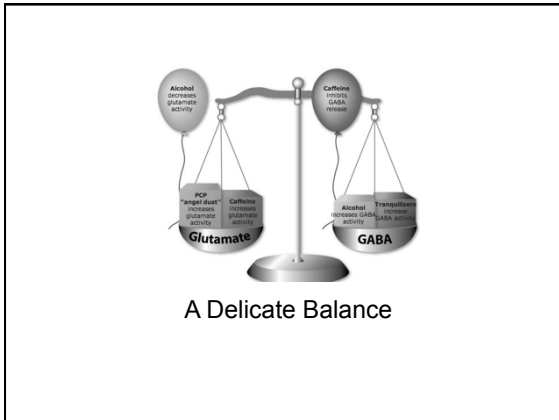
Epinephrine (adrenaline)

Ecstasy (mdma)

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<http://learn.genetics.utah.edu/content/addiction/reward/pathways.html>



Alprazolam

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<http://learn.genetics.utah.edu/content/addiction/reward/pathways.html>

Clinical Anxiety

How Does Xanax (Alprazolam) Work?

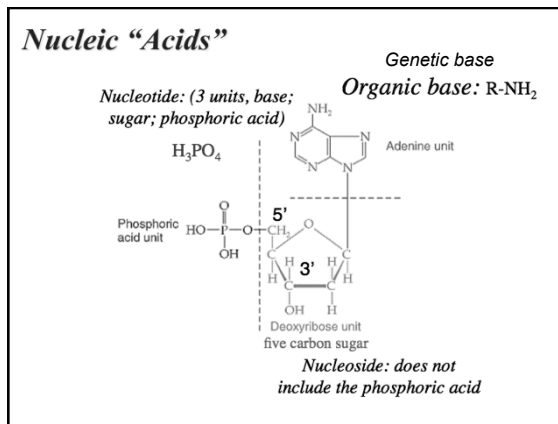
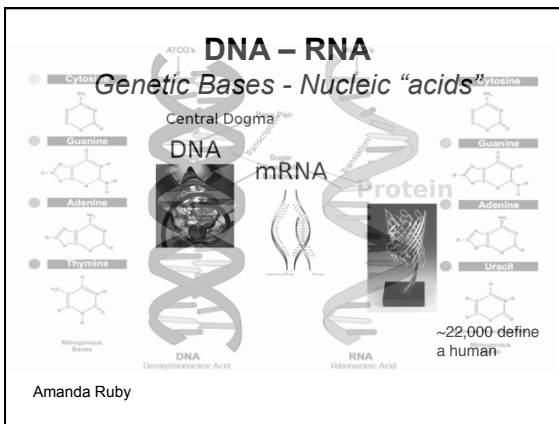
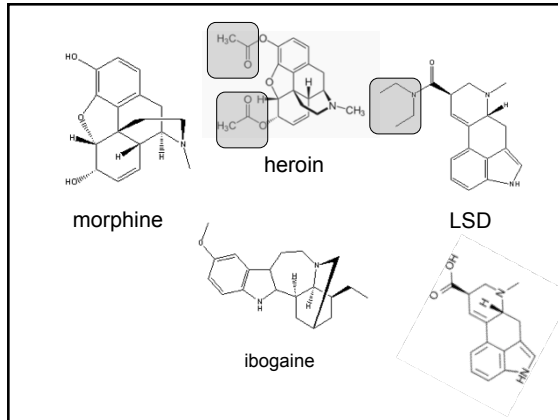
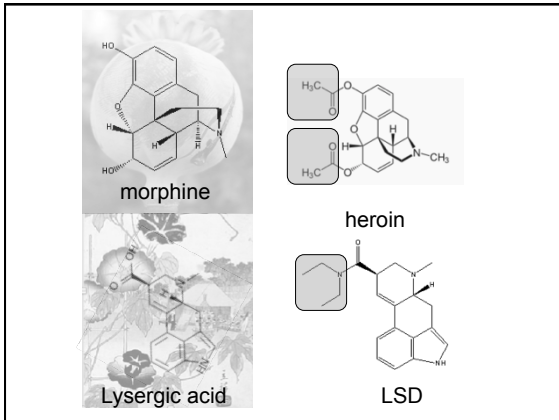
https://www.youtube.com/watch?v=Kq6oNcd3d-U&feature=push-u&attr_tag=LeRwov3XCoYuIxI4-6

Drug Uptake:
 Rank from slowest to fastest.
 a) injection; b) ingestion; c) inhalation; d) snorting

A) a<b<c<d B) c<a<d<b
 C) b<d<a<c D) d<b<c<a

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Genetic Bases in 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).

DNA & RNA: Nucleic Acids


- Store & carry genetic information.

- DNA (deoxyribonucleic acids) have molecular weights ~ 6 × 10⁶ to 16 × 10⁶ 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.

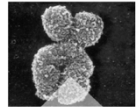
Genetics & DNA




XX



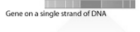
XY



Chromosome



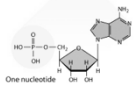
DNA double helix



Gene on a single strand of DNA

GGATATCCAAGC

Nucleotide sequence




One nucleotide

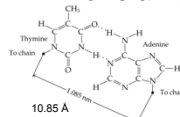
DNA: Size, Shape & Self Assembly

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

Views & Algorithms

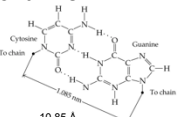


(a)



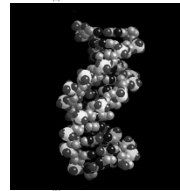
Thymine

10.85 Å




Adenine

10.85 Å



(b)

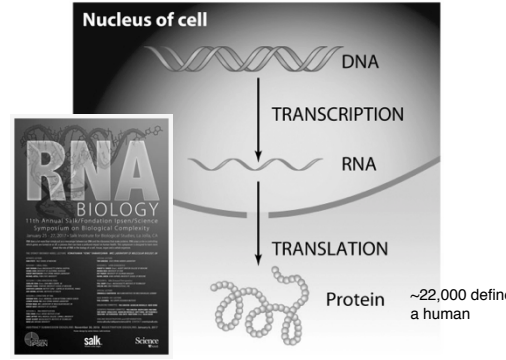
Protein Biosynthesis



PROTEIN SYNTHESIS

<http://chemconnections.org/general/movies/PROTEIN1.MOV>
<https://www.dnalc.org/resources/3d/09-how-much-dna-codes-for-protein.html>

Nucleus of cell



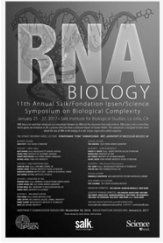
DNA

TRANSCRIPTION

RNA


TRANSLATION

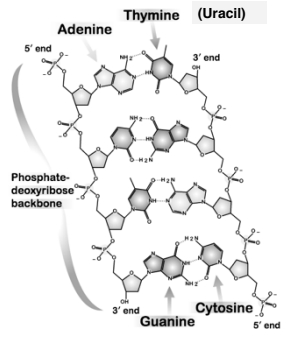
Protein ~22,000 define a human



RNA BIOLOGY
11th Annual Fall Meeting Special Issue
Symposium on Biological Complexity

mRNA





Adenine Thymine (Uracil)

5' end 3' end

Phosphate-deoxyribose backbone

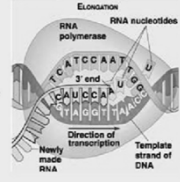
Cytosine Guanine

3' end 5' end

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.



RNA polymerase

RNA nucleotides

3' end 5' end


Direction of transcription

Heavily made RNA

Template strand of DNA

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

mRNA



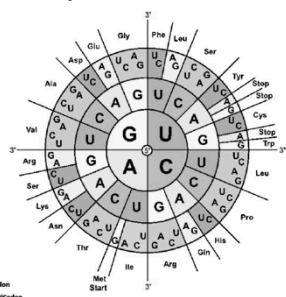
DNA	Coding Strand (Codons)	5' >>>-----TTC----->>> 3'
	Template Strand (Anti-codons)	3' <<<-----AAG-----<<< 5'
mRNA	Message (Codons)	5' >>>-----UUC----->>> 3'
tRNA	Transfer (Anti-codons)	3' <<< AAG <<< 5'
Protein	Amino Acid	Amino >>> Phenylalanine >>> Carboxy

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'
 3' UAC GUU GGG CUG AGG UAG 5'
 Met-Gln-Pro-Asp-Phe-Ser

← Codon
 ← AntiCodon
 ← Amino Acids

Protein Biosynthesis Codon Chart

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

Central Dogma

DNA → RNA → Protein

Several nucleic acids linked together form DNA

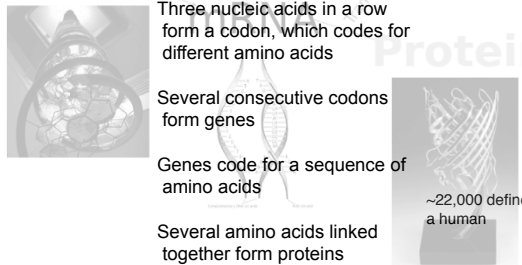
Three nucleic acids in a row form a codon, which codes for different amino acids

Several consecutive codons form genes

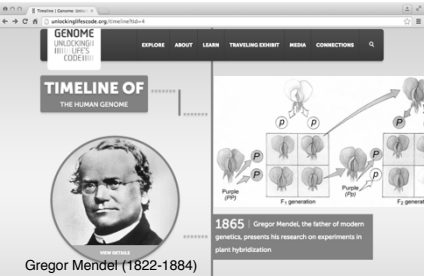
Genes code for a sequence of amino acids

Several amino acids linked together form proteins

~22,000 define a human



1865 DNA: Genetics & Genomics Timelines



Gregor Mendel (1822-1884)

1865: Gregor Mendel, the father of modern genetics, presents his research on experiments in plant hybridization

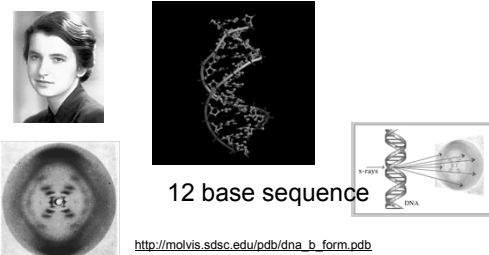
<https://www2.edc.org/weblabs/Mendel/MendelMenu.html>

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 Deoxyribonucleic Acid
 W. T. Watson and F. H. C. Crick

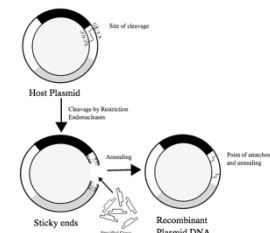
In a paper published in 1953, Watson and Crick proposed a model for the structure of deoxyribonucleic acid (DNA). The model is based on the following facts: (1) DNA is a long, thin, fibrous molecule; (2) it has a constant diameter of about 2 nm; (3) it is composed of two strands of equal length; (4) the strands are twisted around each other; (5) the strands are held together by hydrogen bonds between the nitrogenous bases. The model is a double helix, with the sugar-phosphate backbone on the outside and the nitrogenous bases on the inside. The bases are paired in a specific way: Adenine pairs with Thymine, and Guanine pairs with Cytosine. The model explains the stability and the ability of DNA to replicate itself.




1975

Restriction Enzymes / Recombinant DNA
 Berg, Boyer, Cohen, and many others

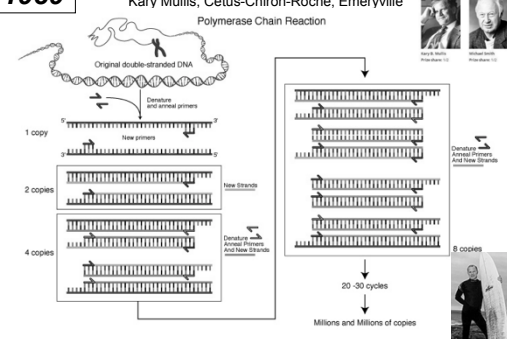
<http://nar.oxfordjournals.org/content/early/2013/10/18/nar.gkt990.full>



1989 **PCR: Polymerase Chain Reaction** The Nobel Prize in Chemistry 1993

Kary Mullis, Cetus-Chiron-Roche, Emeryville

Polymerase Chain Reaction



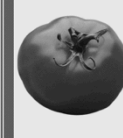
<https://www.dnalc.org/resources/3d/19-polymerase-chain-reaction.html>

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



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.

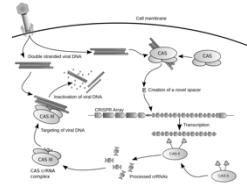
1996

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.

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

2012 Genome Editing / CRISPR-Cas9

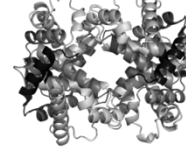
<https://www.youtube.com/watch?v=SuAxDVb7kQ>



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

2016 Genome Editing / CRISPR-Cas9
Target

β -Thalassemia: Shortage of β -globin Protein

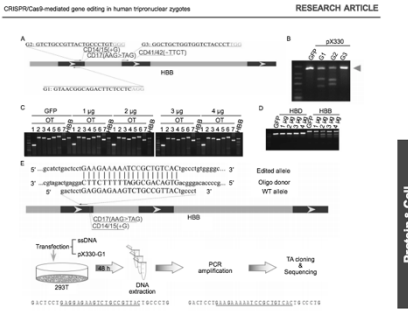


Normal β -globin

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

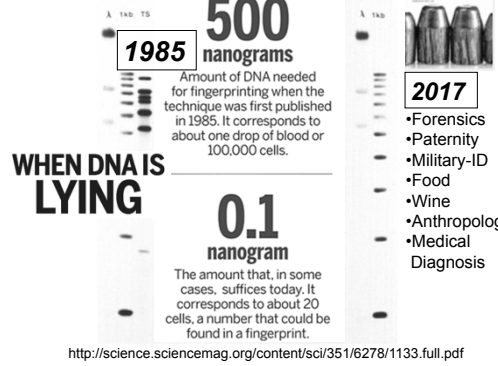
2016 Genome Editing / CRISPR-Cas9
 β -Thalassemia / Human Embryo Research

<http://chemconnections.org/general/chem121/Gene%20Editing/Gene%20Editing%202015-0153.pdf>



Protein & Cell

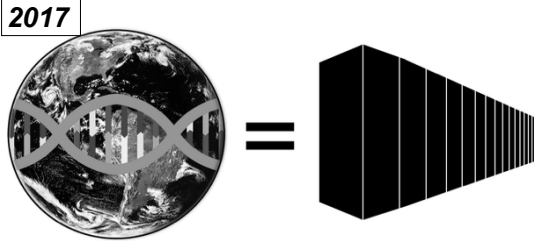
Genetic Fingerprinting



<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, 5.3×10^{31} 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



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

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) $\times 10^{26}$
Plants	3.6 (3.4) $\times 10^{21}$
Viruses	4.0 (3.4) $\times 10^{29}$
Total	5.3 (3.6) $\times 10^{31}$

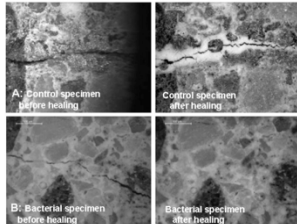
doi:10.1371/journal.pbio.1002168.t001

Landemark 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://dx.doi.org/10.1371/journal.pbio.1002168>

2017

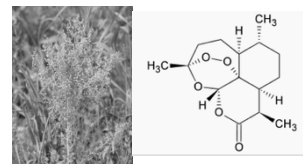
**Bioengineering:
Structural Materials & Molecules
Bacteria & Yeast
Healing Concrete**

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



2017

**Bioengineering: Artemisinin
Bacteria, Yeast & Chemical Synthesis
Chinese Wormwood (*Artemisia annua*)
& Malaria**



1989

PCR: Polymerase Chain Reaction
Kary Mullis, Cetus-Chiron-Roche, Emeryville

The Nobel Prize in Chemistry 1993

