Genetically Modified Everything
Seminar 1: Introduction to DNA
Disclaimer

This course does not provide any medical advice or suggestions and does not endorse any specific product or treatment.
Disclaimer #2

Today is going to be **hard** and there will be a lot of new terms and difficult pictures

It may bore some of you, you may hate me a bit

It will get better from here

Dan Promises
My Aims:

• Make DNA understandable

• Understand how DNA can be modified

• Look at interesting applications of genetic engineering in bacteria, plants, animals and humans

• Open an important discussion on the ethical considerations of genetic engineering
# Series Outline

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intro to DNA</td>
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<td>2</td>
<td>DNA through Generations and DNA Repair</td>
</tr>
<tr>
<td>3</td>
<td>GMOs - How we manipulate DNA</td>
</tr>
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<td>4</td>
<td>GMO Plants and Agriculture</td>
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<td>5</td>
<td>Genetic Engineering in Animals and Bacteria</td>
</tr>
<tr>
<td>6</td>
<td>Genetic Engineering in Humans</td>
</tr>
</tbody>
</table>
DNA

The Blueprint of Life
Where do we find DNA?

Your body contains approximately 37 trillion cells (37,000,000,000,000).

Each of your 37 trillion cells contains one nucleus.

Each Nucleus Contains 46 chromosomes.

Each Chromosome contains around 200 million individual DNA bases.
DNA is **INFORMATION**

<table>
<thead>
<tr>
<th>Language</th>
<th>Unit</th>
<th>Functional Unit</th>
<th>Functional System</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>Letters (A,B,C,D,...)</td>
<td>Words (Cat, Dog, Bologna)</td>
<td>Sentences/Books etc. “I feed my cat and dog bologna”</td>
</tr>
<tr>
<td>Binary Code</td>
<td>Zeros and Ones 01001</td>
<td>Script A=100001</td>
<td>Computer Program “Microsoft Word”</td>
</tr>
<tr>
<td>DNA</td>
<td>Base A,C,T,G</td>
<td>Gene “Actin”</td>
<td>Living Organisms i.e. You</td>
</tr>
</tbody>
</table>
DNA is contains INFORMATION

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**STORAGE LIMITS**

Estimates based on bacterial genetics suggest that digital DNA could one day rival or exceed today’s storage technology.

<table>
<thead>
<tr>
<th></th>
<th>Hard disk</th>
<th>Flash memory</th>
<th>Bacterial DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Read-write speed</strong></td>
<td>~3,000–5,000</td>
<td>~100</td>
<td>&lt;100</td>
</tr>
<tr>
<td>(μs per bit)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data retention</strong></td>
<td>&gt;10</td>
<td>&gt;10</td>
<td>&gt;100</td>
</tr>
<tr>
<td>(years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power usage</strong></td>
<td>~0.04</td>
<td>~0.01–0.04</td>
<td>&lt;10^{-10}</td>
</tr>
<tr>
<td>(watts per gigabyte)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data density</strong></td>
<td>~10^{13}</td>
<td>~10^{16}</td>
<td>~10^{19}</td>
</tr>
<tr>
<td>(bits per cm³)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

![Figure from Nature](https://www.nature.com)

Andy Extance, Nature 2016
The History of DNA
The History of DNA

- In 1865 Gregor Mendel Discovers Hereditary “Units”
- In 1869, Friedrich Meischer isolated a substance he referred to as “nuclein” later known to be DNA
- In 1948, Chargoff Discovers that the DNA of many species is all the same composition
The History of DNA

1942  Rosalind Franklin takes X-ray images that show the basic size and structure of DNA

1953  James Watson and Francis Crick Propose a structure of DNA based on the Franklin’s Results
## The History of DNA

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>The Human Genome Project is Proposed which aims to sequence (read) the entire human genetic code</td>
</tr>
<tr>
<td>2003</td>
<td>Human Genome Project Deemed Complete Showing Approximately 23,000 Genes within 3.3 BILLION bases (letters of DNA)</td>
</tr>
<tr>
<td>2019</td>
<td>Over half a million genomes have been sequenced. Evidence of genetically-engineered children has emerged</td>
</tr>
</tbody>
</table>
What is DNA
What is DNA

- DNA is a double helix
- It has a strong backbone that is **consistent**
- The inside of the helix is composed of the **variable** bases: A, C, T, G
- Both strands are the opposite of one another – they run **anti-parallel**
What is DNA

- The sugar phosphate backbone contains sugars (deoxyribose sugar) alternating with phosphate molecules.

- The bases (A,C,T,G) are nucleic acids.
What is DNA

Deoxyribose

Sugar

Base

Deoxyribo

Nucleic Acid

DeoxyriboNucleic Acid (DNA)
Summary

• There were a lot of confusing chemicals
• DNA is a double helix with a strong sugar-phosphate backbone
• Inside the backbone are the variable bases A,C,T,G
• A always pairs with T, C always pairs with G
DNA Structure

How does it store so much information
DNA Structure and Information Storage

DNA double helix (2-nm diameter)

“Beads on a string”

Linker

Nucleosome (10-nm diameter)

Histones

Tight helical fiber (30-nm diameter)

Supercoil (300-nm diameter)

Chromosome

700 nm
DNA Structure and Information Storage

• The DNA double helix is the simplest (unwound form of DNA)
• DNA wraps around histones to make nucleosomes
• A nucleosome contains 146 bases of DNA wrapped around 8 histone proteins
• A tight helical fibre of DNA/histone forms super-coil fibres
• Supercoil fibres bundle together to form chromosomes
How do we read DNA?
Central Dogma of Life
How do we read DNA?
Central Dogma of Life

One Gene Codes for One Protein
Transcription and Translation

- DNA
- RNA
- Replication
- Transcription
- Reverse transcription
- Translation
- PROTEIN
A gene is the functional unit of life

A gene is a unit of hereditary information

A gene is a segment of DNA that codes for a specific purpose

A gene is a segment of DNA that codes for a single protein (with exceptions)
Each gene is **transcribed** (copied) into RNA when needed.

The RNA is **translated** into protein.

Protein in the functional molecule of all cells.
Gene to Protein

One Gene

Transcription

Translation
During transcription, a protein called RNA polymerase copies the DNA sequence into an RNA sequence.

The RNA sequence is the opposite sequence with the exception that instead of T (thymine) you get U (uracil).

The gene is copied into from the start to the stop markers.
When a protein is needed, your cells will make RNA copies of the gene that codes for that protein.

For example, if you need to break down fat for energy, your body will transcribe the genes that help break down fat molecules.
The RNA molecules made during translation leave the nucleus so that they can be translated into protein.

In **translation**, a large complex called the **ribosome** converts 3 bases of the genetic code into one amino acid.

There are 20 amino acids, a string of amino acids makes a protein.

For example, an RNA molecule that is 300 bases long will make a protein with 100 amino acids.

The string of amino acids folds into a structure called a protein.
DNA Sequencing is the process of determining the precise order of nucleotides within a DNA molecule. It includes any method or technology that is used to determine the order of four bases—adenine, guanine, cytosine, and thymine—in a strand of DNA.
Currently the idea of a <$1000 genome is a reality

3rd Generation sequencing is soon to emerge

Massive amounts of genomic data are now available to scientists