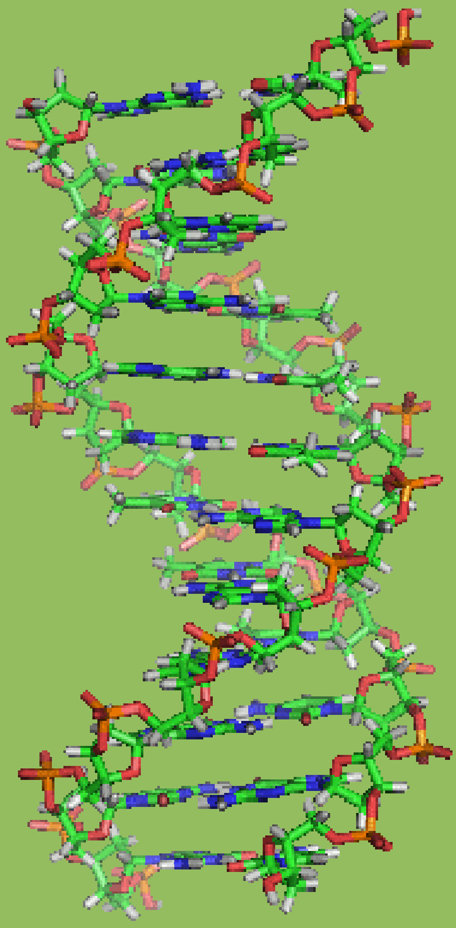
Forms and Phases of DNA & RNA



By Jonas Buchmann

Forms and Phases of DNA & RNA

- **Historical Outline & Discovery**
  - Overview
  - Griffith's Experiment
  - Hershey-Chase-Experiment

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  - H-Bonds
  - Alternative double-helical structures

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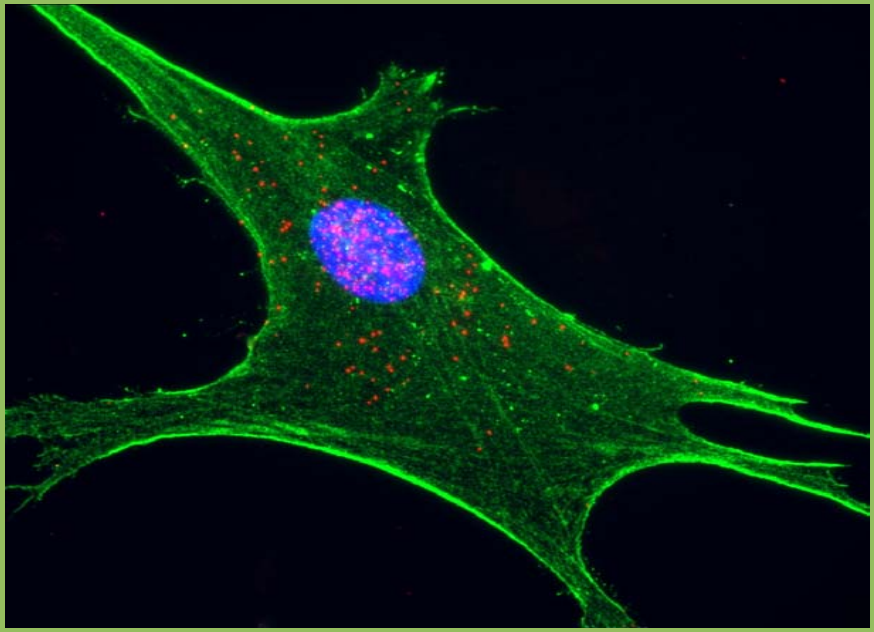
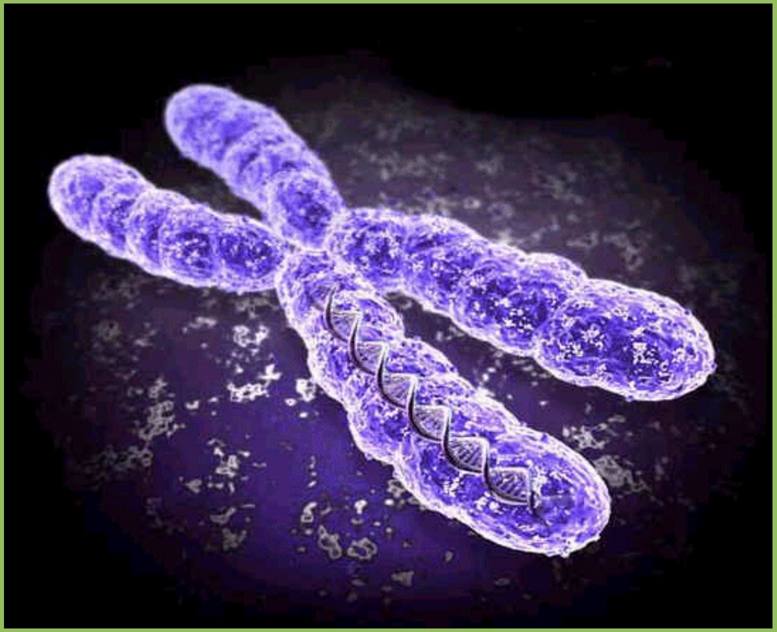
  - H-Bonds
  - Alternative double-helical structures
- **DNA Computing**

Historical Outline

- Isolation of DNA/RNA from Cell Nuclei
- Recognition Deoxyribose & Ribose
- Identification of the 4 Bases, Sugar & Phosphate Chain as structure
- Periodic Structure



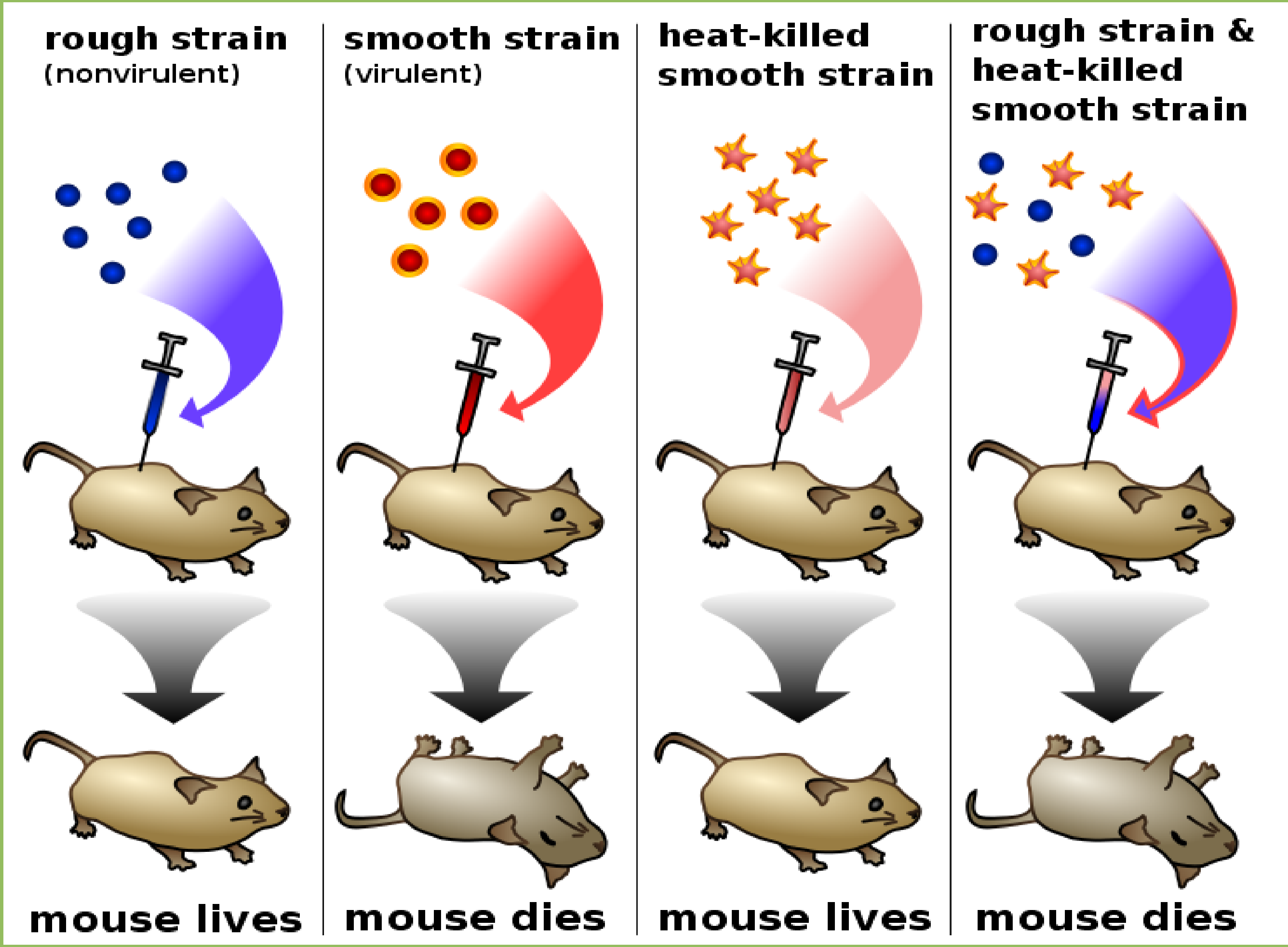


Historical Outline

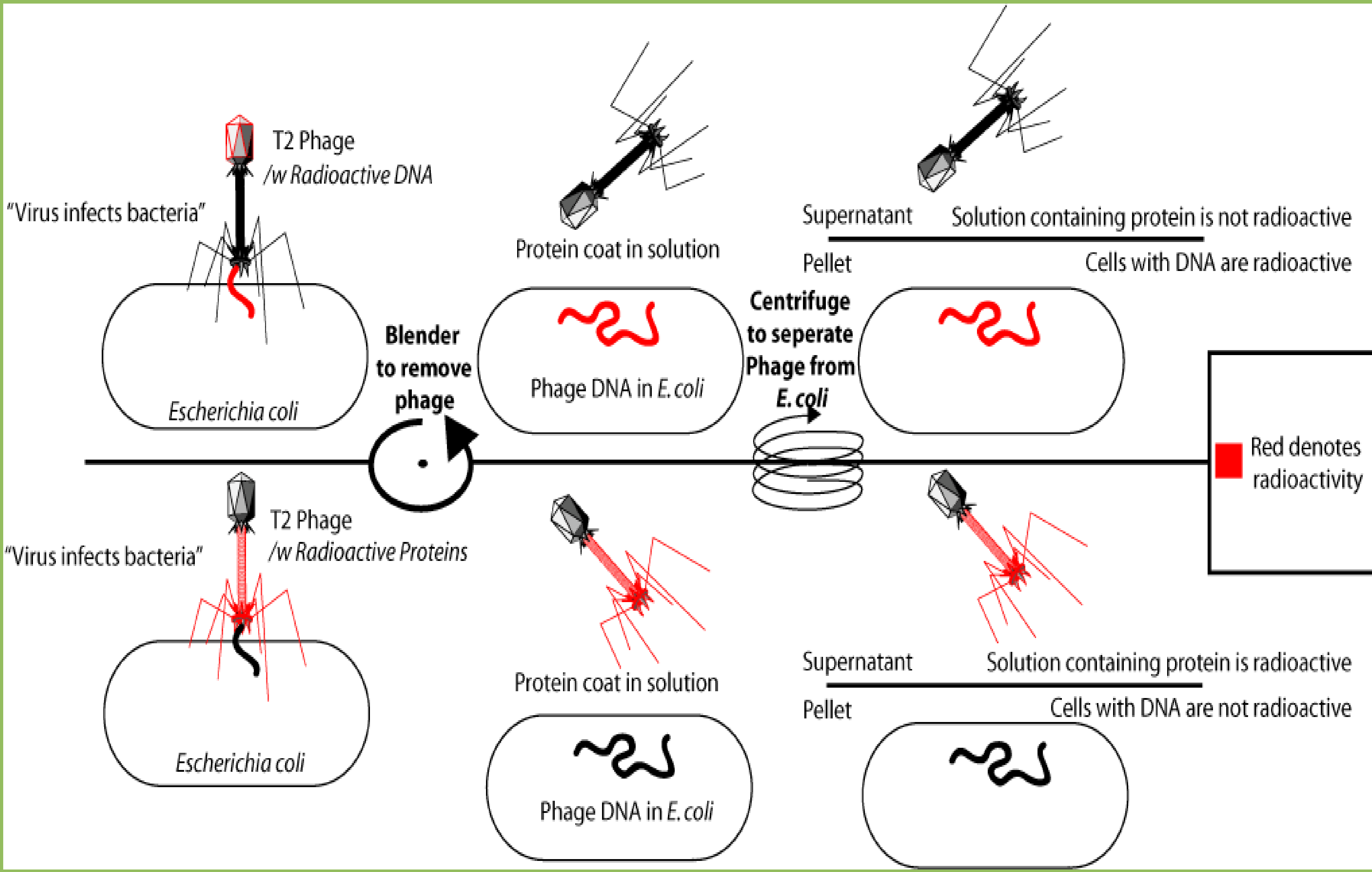
- Extraction
- Restriction to Chromosomes
- Transforming principle: **Griffiths Experiment**

- DNA is genetic material: **Hershey-Chase Experiment**

Griffith's Experiment

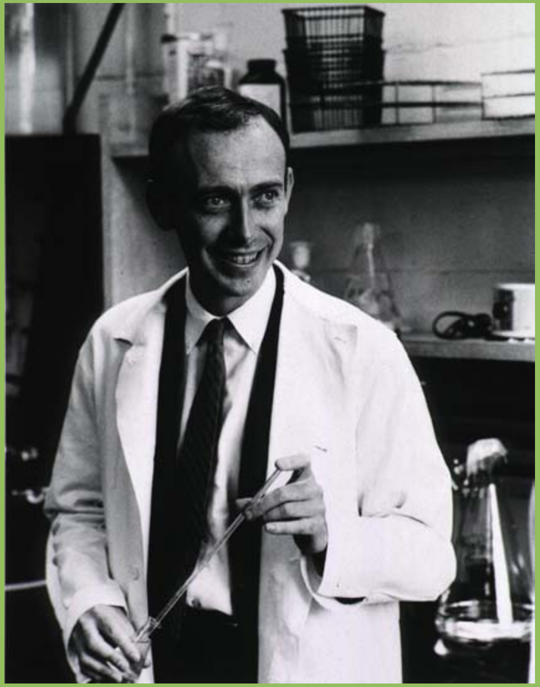


Hershey-Chase Experiment



Entering the Micro-World

- **So far mostly qualitative/macroscopic Experiments**
- **Discovery of (Alpha-)Helical structure in proteins**
- **Watson**



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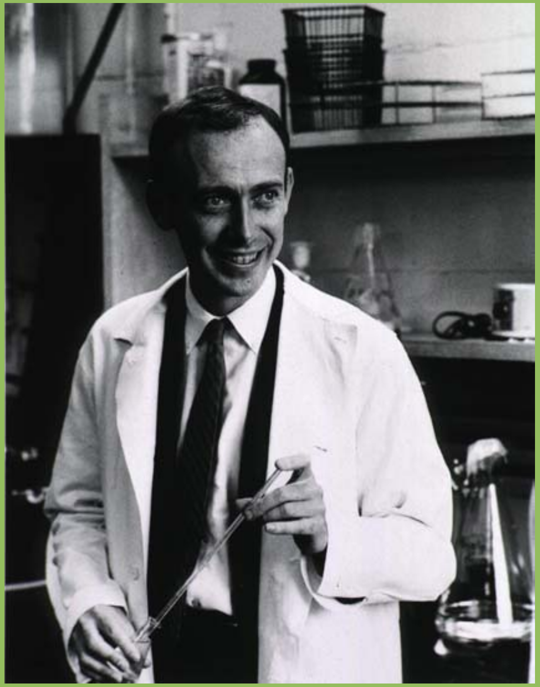
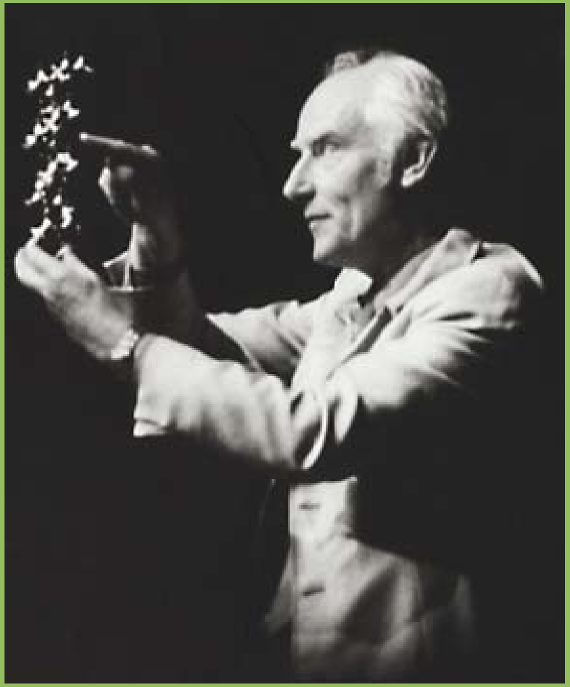
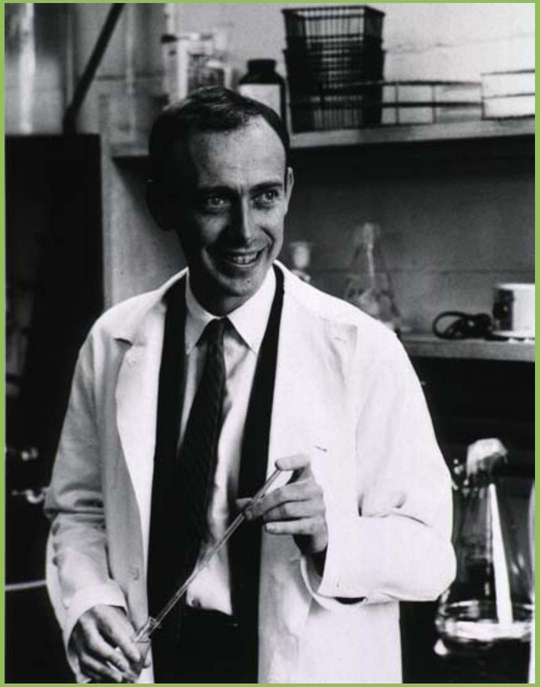
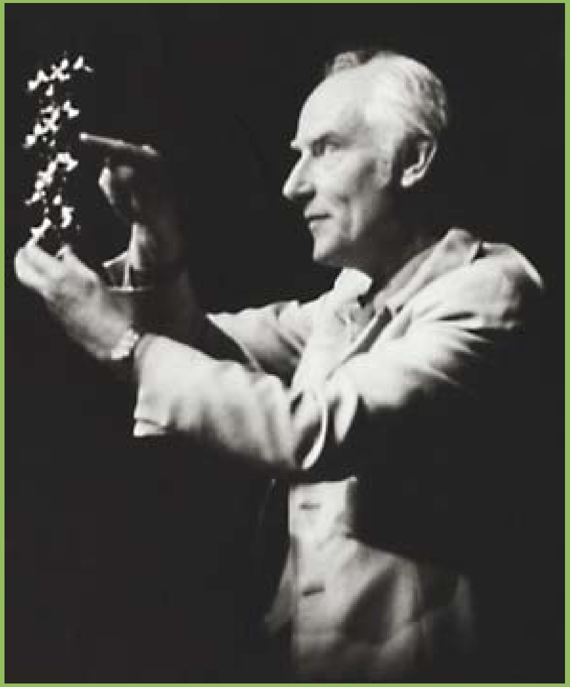




Entering the Micro-World

- **So far mostly qualitative/macroscopic Experiments**
- **Discovery of (Alpha-)Helical structure in proteins**
- **Watson & Crick and Rosalind Franklin**





Watson & Crick

- James Watson: „The instant I saw the picture my jaw fell open and my pulse began to race“

Watson & Crick

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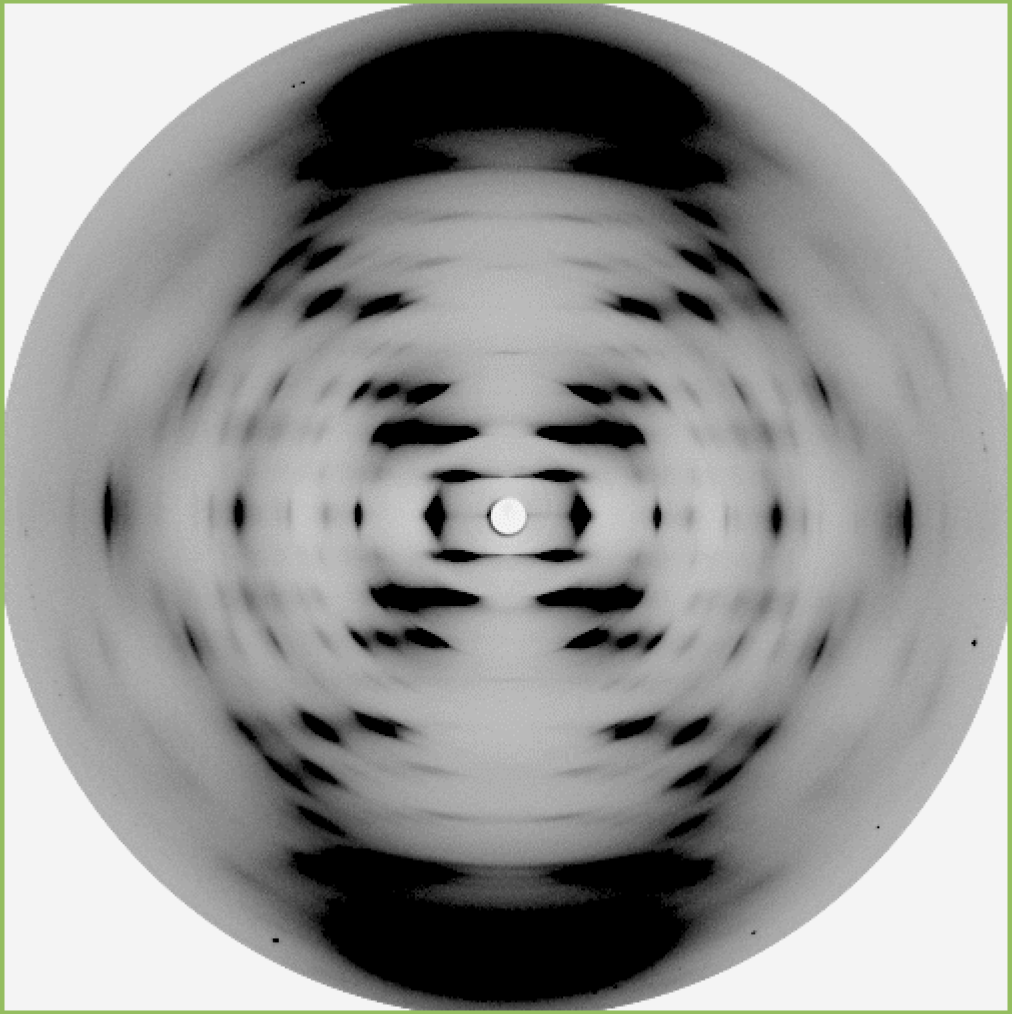
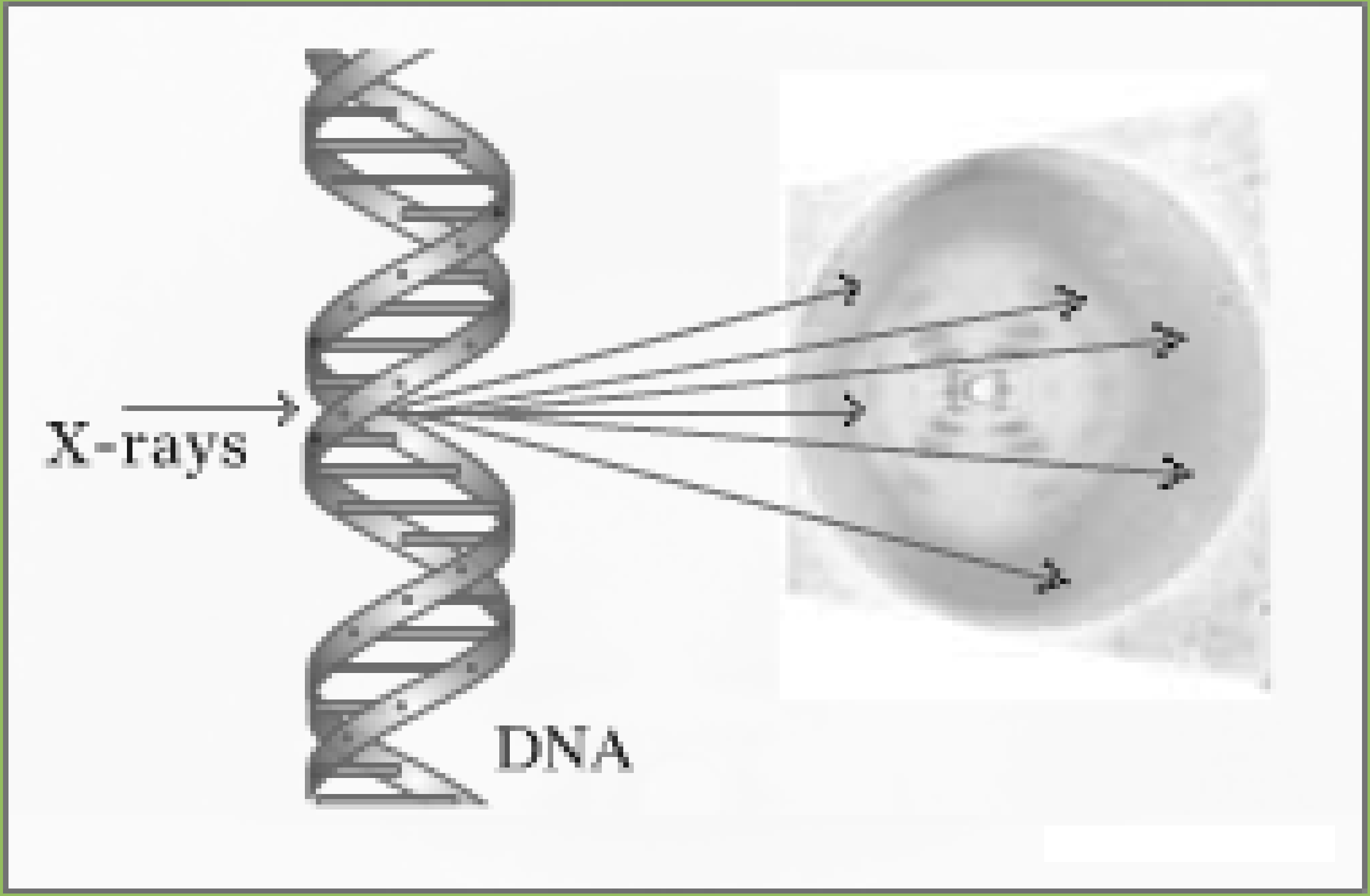


This picture actually shows all the important information about the double helix.

Watson & Crick: X-rays

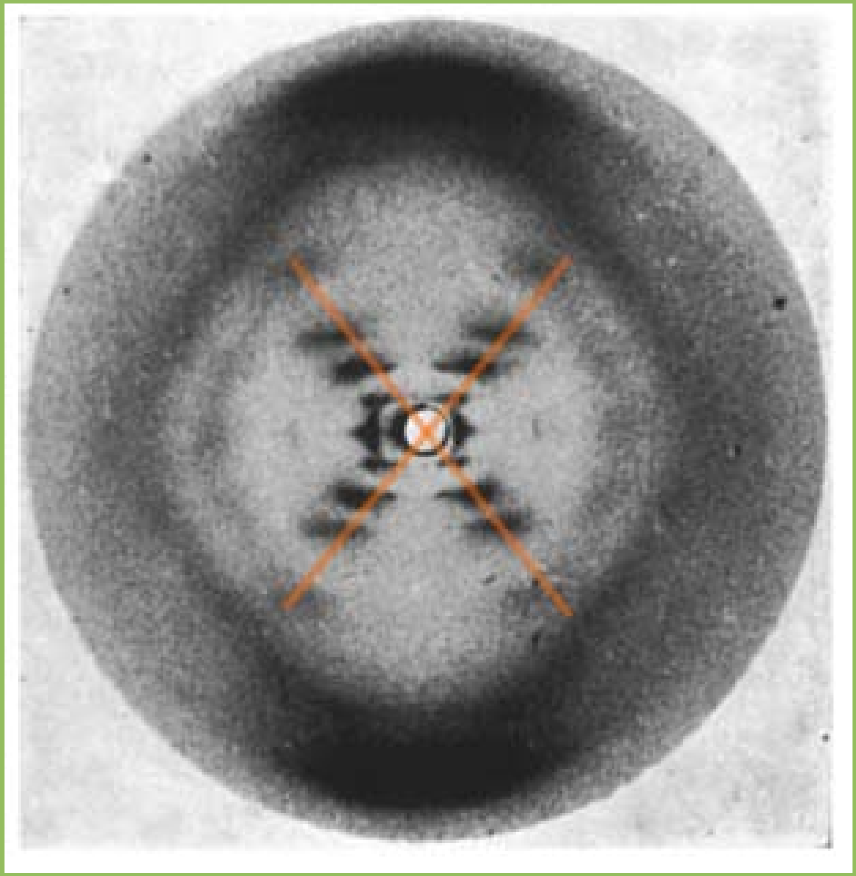


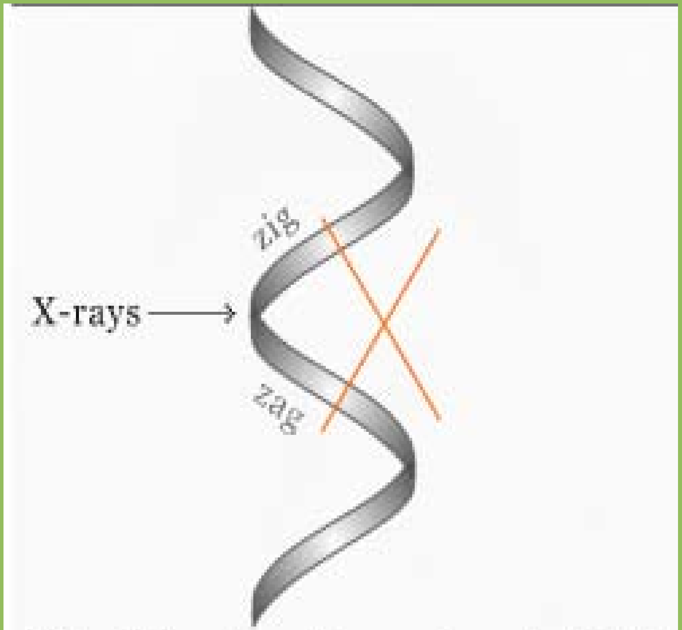
Franklin aimed X-rays at a vertically suspended fiber with thickness of a single hair.

That contained millions off „B“ or wet DNA from

Watson & Crick: The 'X'

- X-shaped Pattern is created when X-Ray move through helical shape
- Diffraction takes place at angles perpendicular to the helix

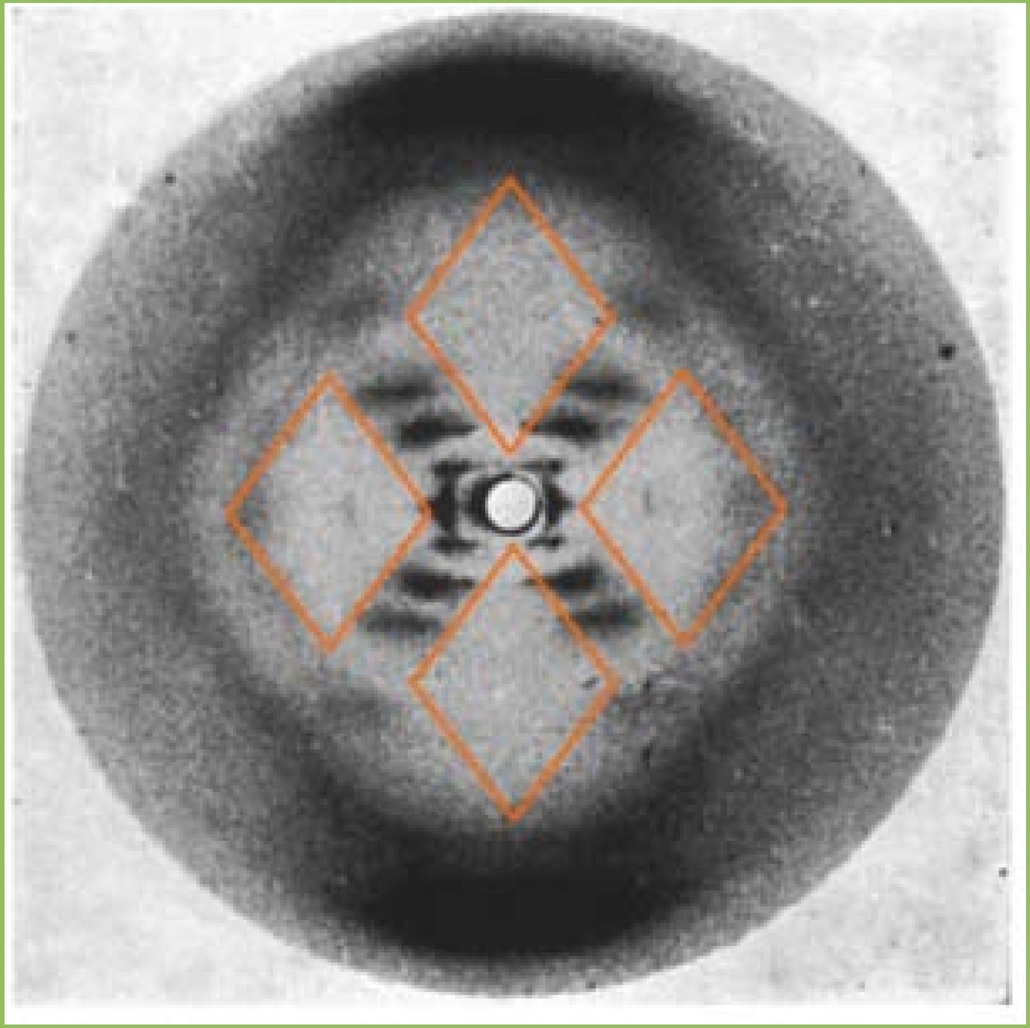




The diffraction of X-rays from the "zig" portions of the strand causes "zag" patterns on the resulting film—and vice versa.

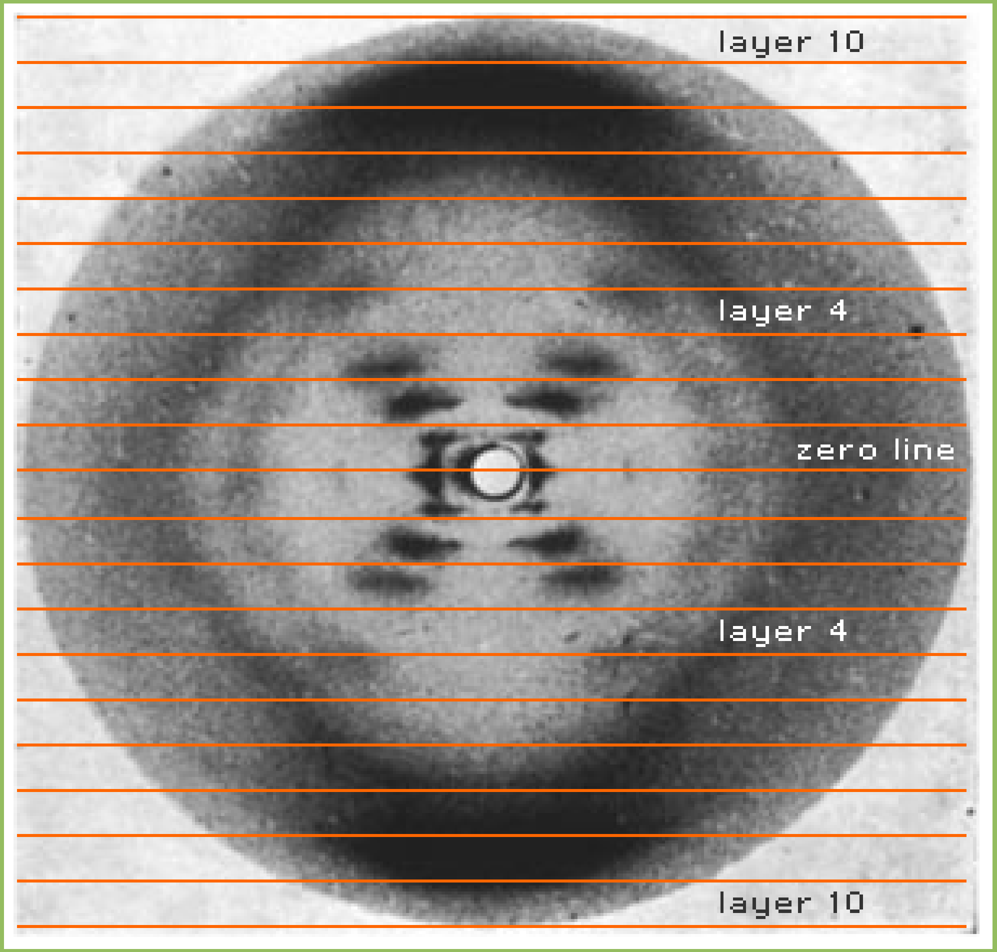
Watson & Crick: Diamonds

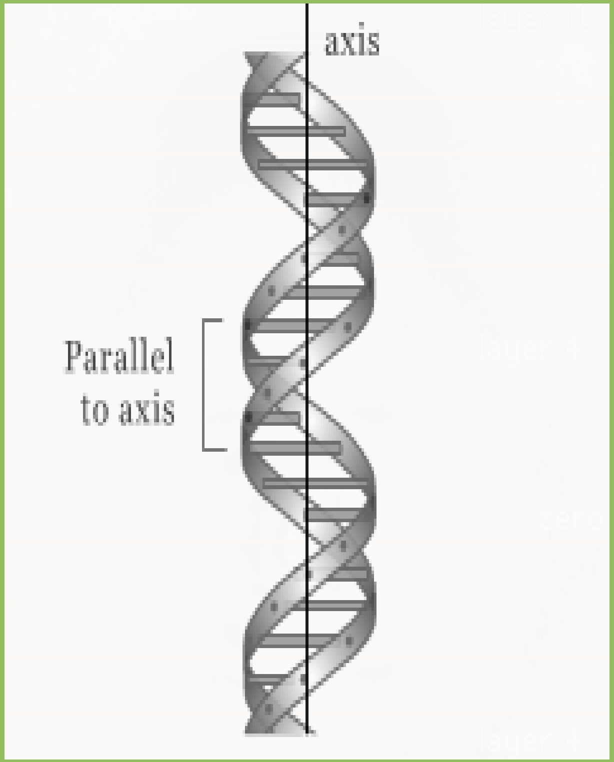
Four white diamond shapes indicate repeating pattern above and below the central 'X'



Smears

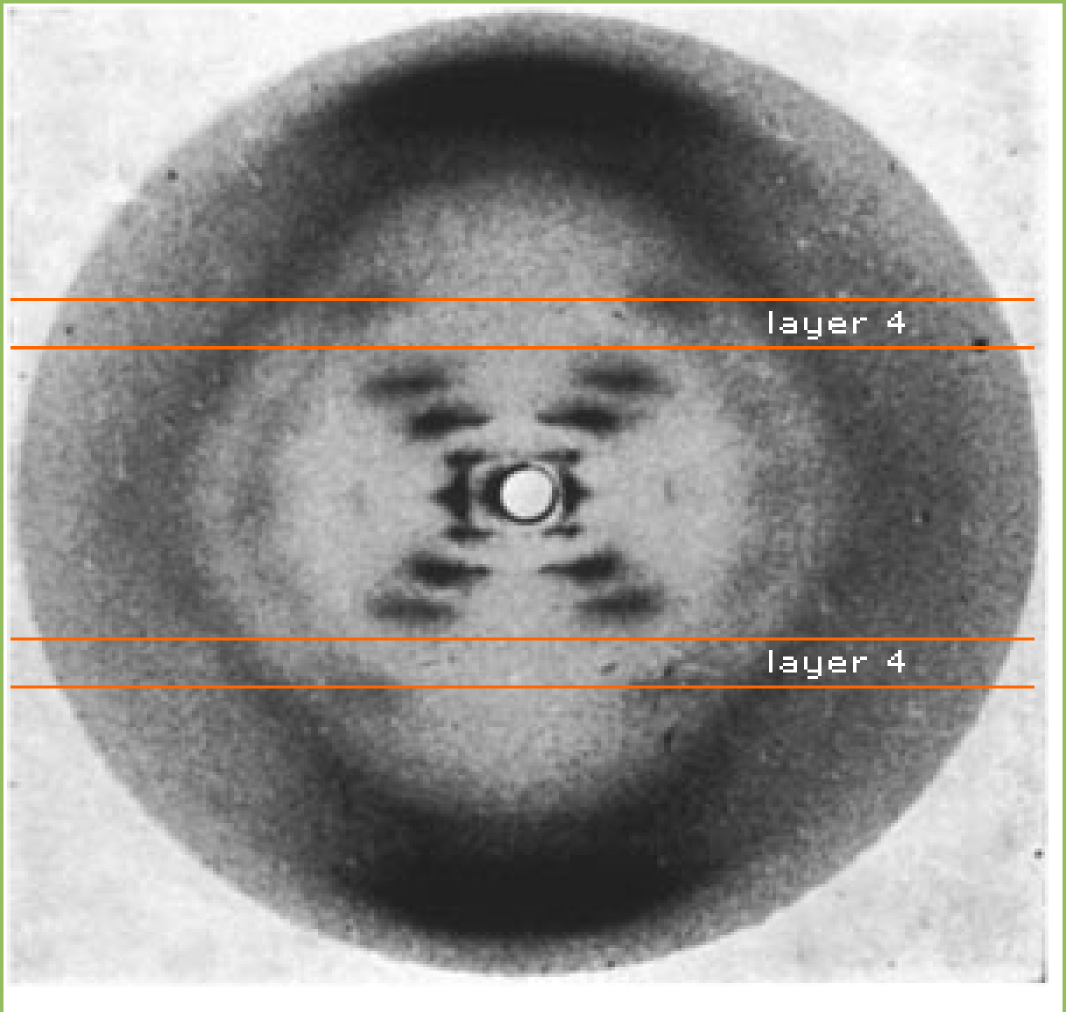
Blurry smears along some 'layer-lines' due to scatterings parallel to central axis of helix

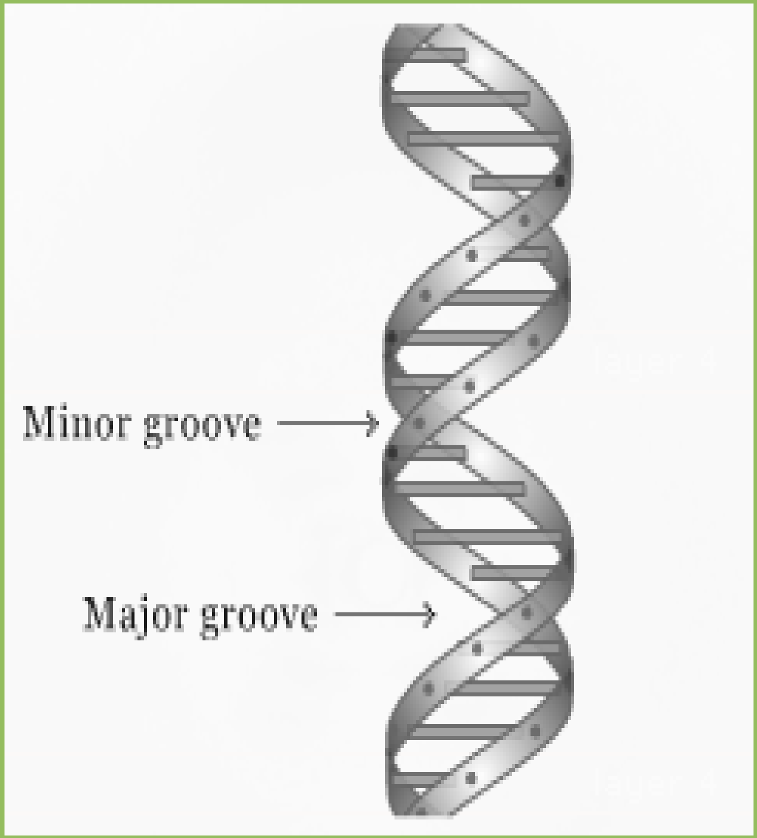




Missing Smears

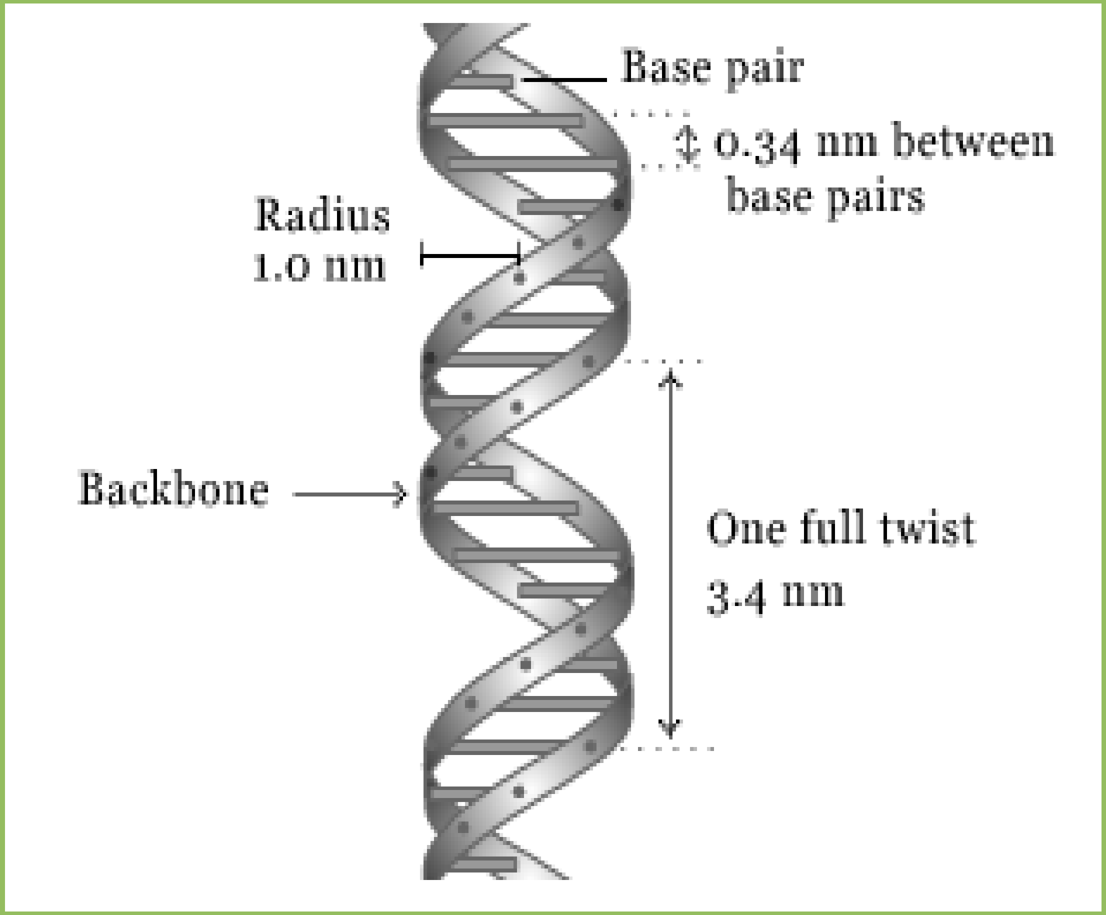
Layer 4 - Light spots are at crossing point of the two helix-strands: Cancel each other out





Watson & Crick: Measurements

From this image one can calculate the most important dimensions of DNA



Watson & Crick

Watson & Crick received the Nobel Price in Medicine 1962.
The Model they constructed was largely reconstructed from its original pieces in 1973 and was donated to the National Science Museum in London.

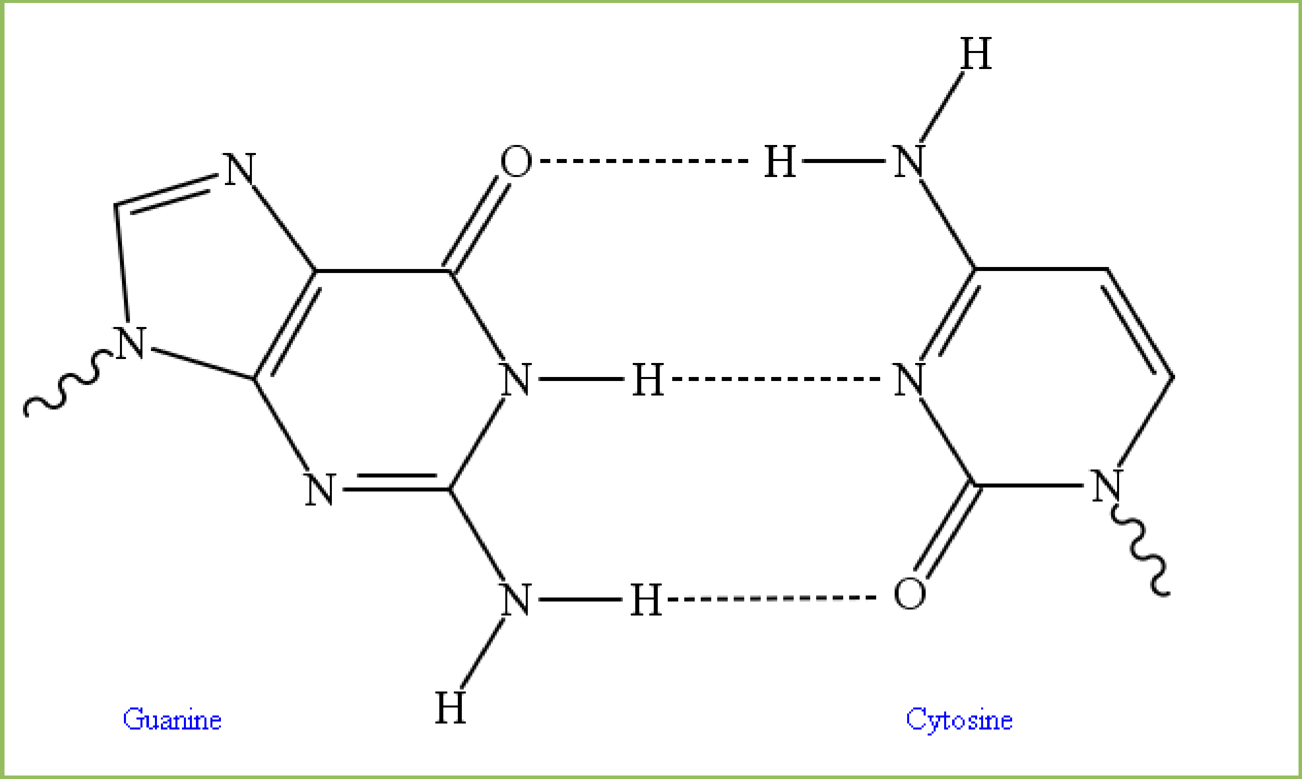
Base Pairing

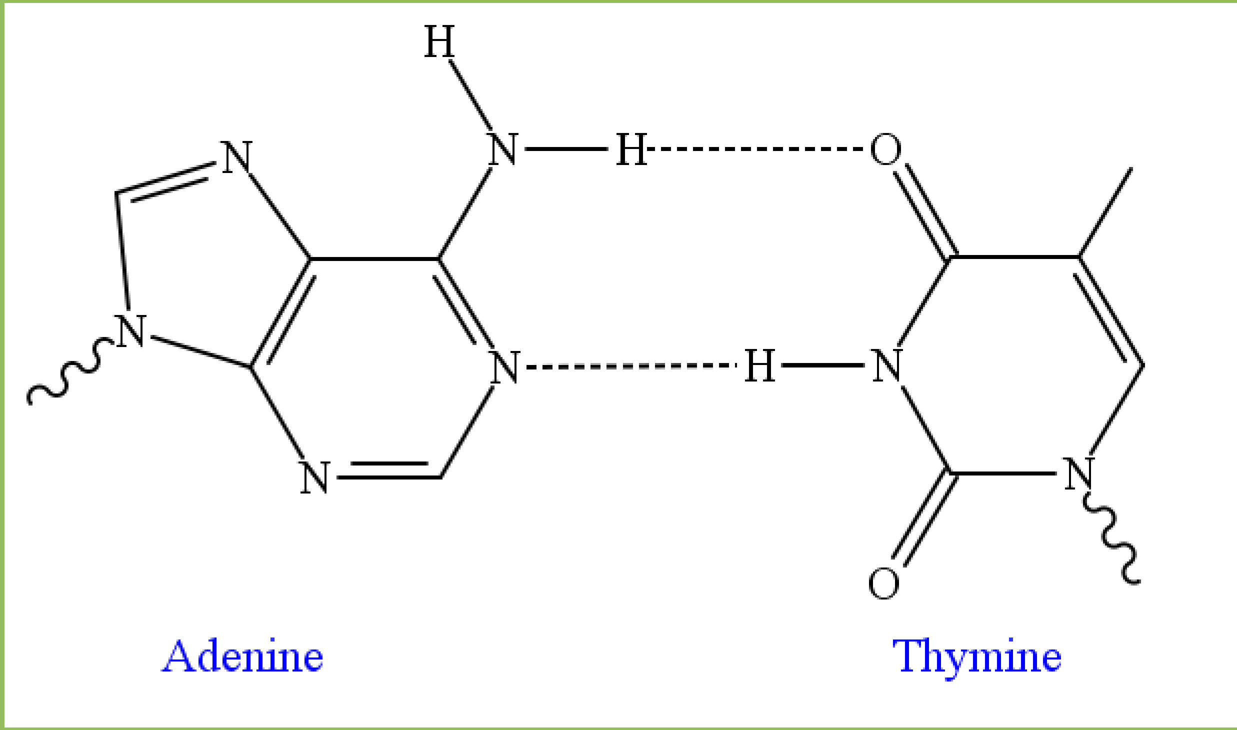
Each type of base forms a bond with just one type of base on the other strand: **'Complementary Base Pairing'**

Hydrogen Bonds

Adenine bonds only with **Thymine**

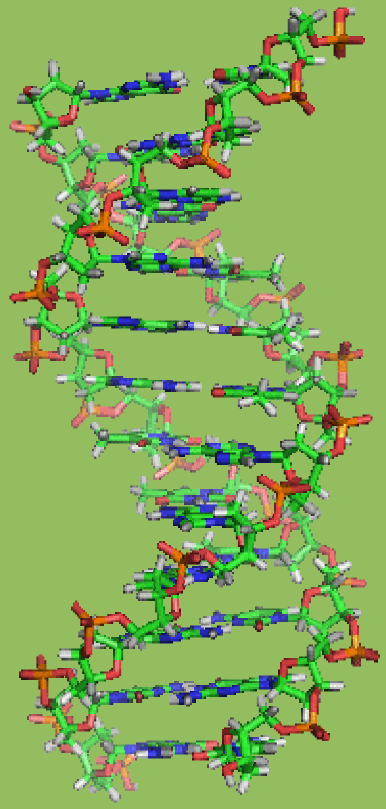
Guanine only with **Cytosine**


Guanine
Cytosine


Adenine
Thymine

Hydrogen Bonds

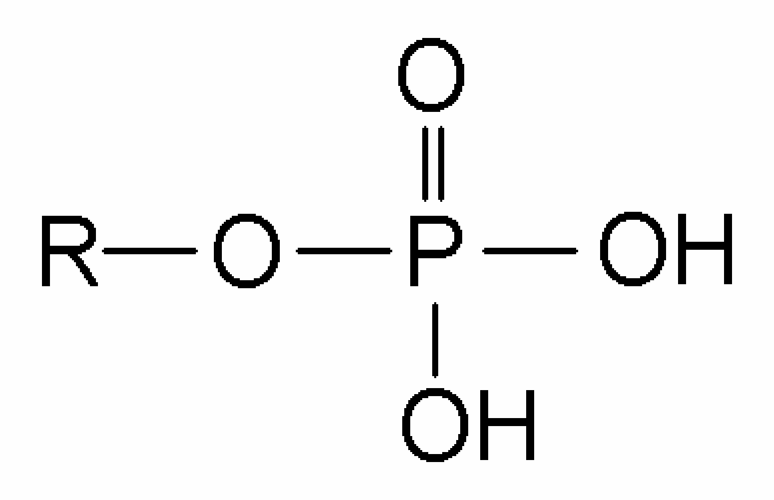
- Hydrogen bonds are not covalent
- Can be broken and rejoined easily
- duplicate sequence by 'zipping'



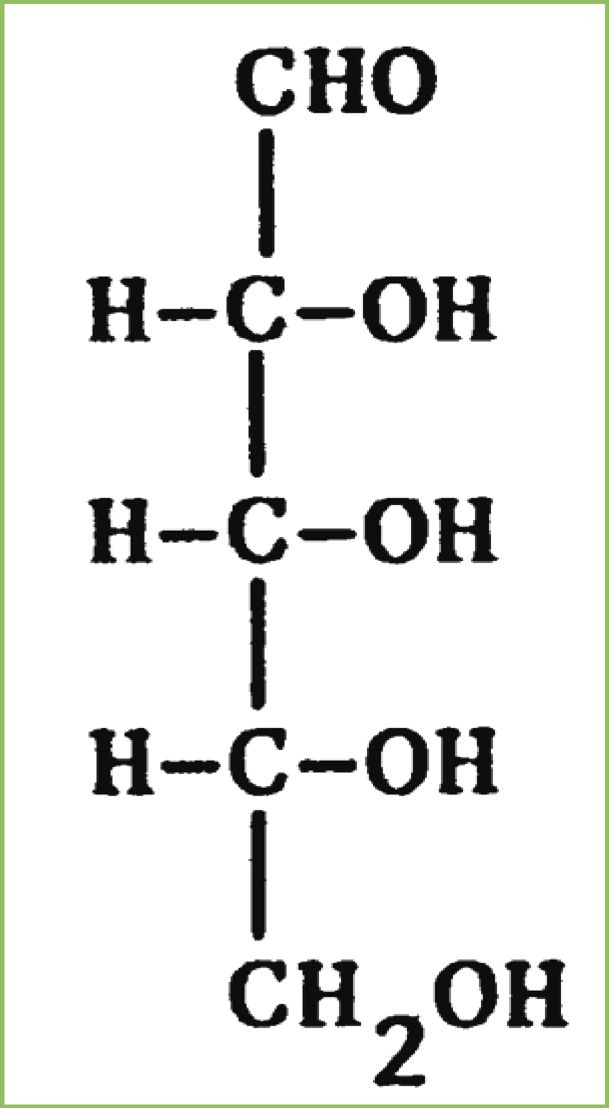
AT: 2 H-Bonds
GC: 3 H-Bonds (stronger than AT)

Backbone

Alternating Phosphate and Sugar residues create the backbone of the DNA strand.



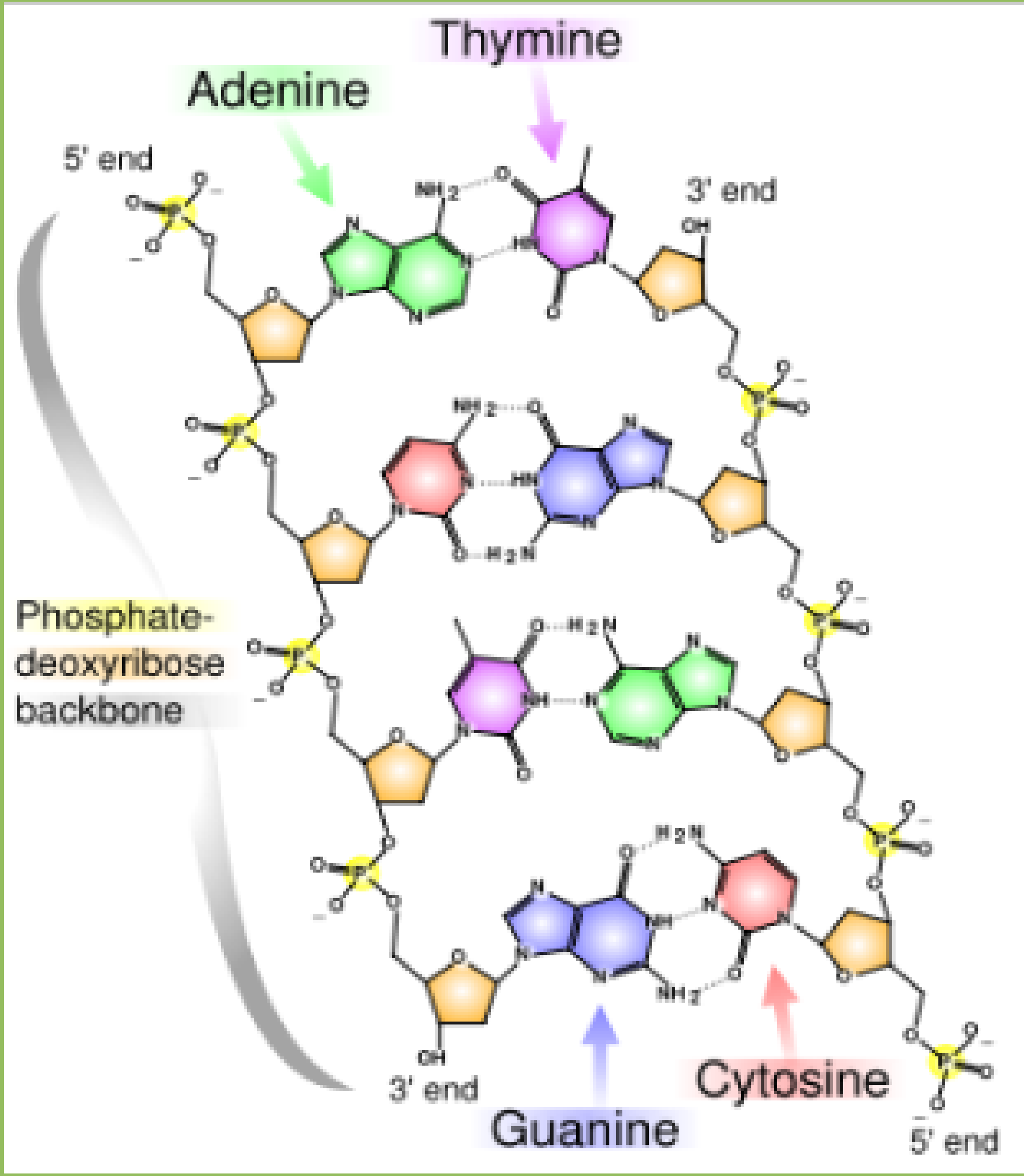
Phosphate



Pentose

Chemical Structure of DNA

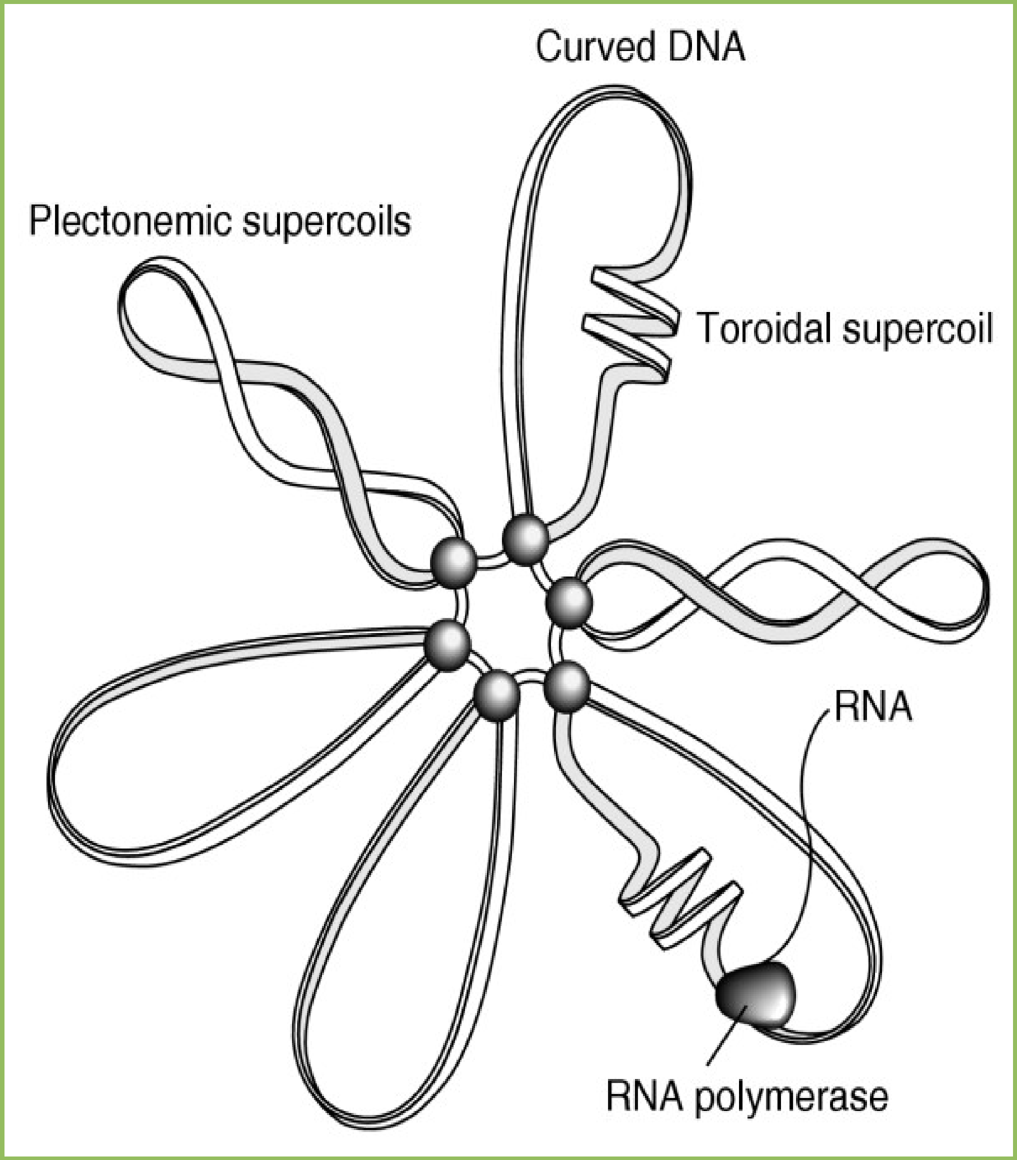
Finally we obtain the following general structure for DNA:



Supercoiling

Twisting of DNA like a rope
In direction of helix: **Positive Supercoiling**
In opposite direction: **Negative Supercoiling**
In nature mostly slight negative supercoiling

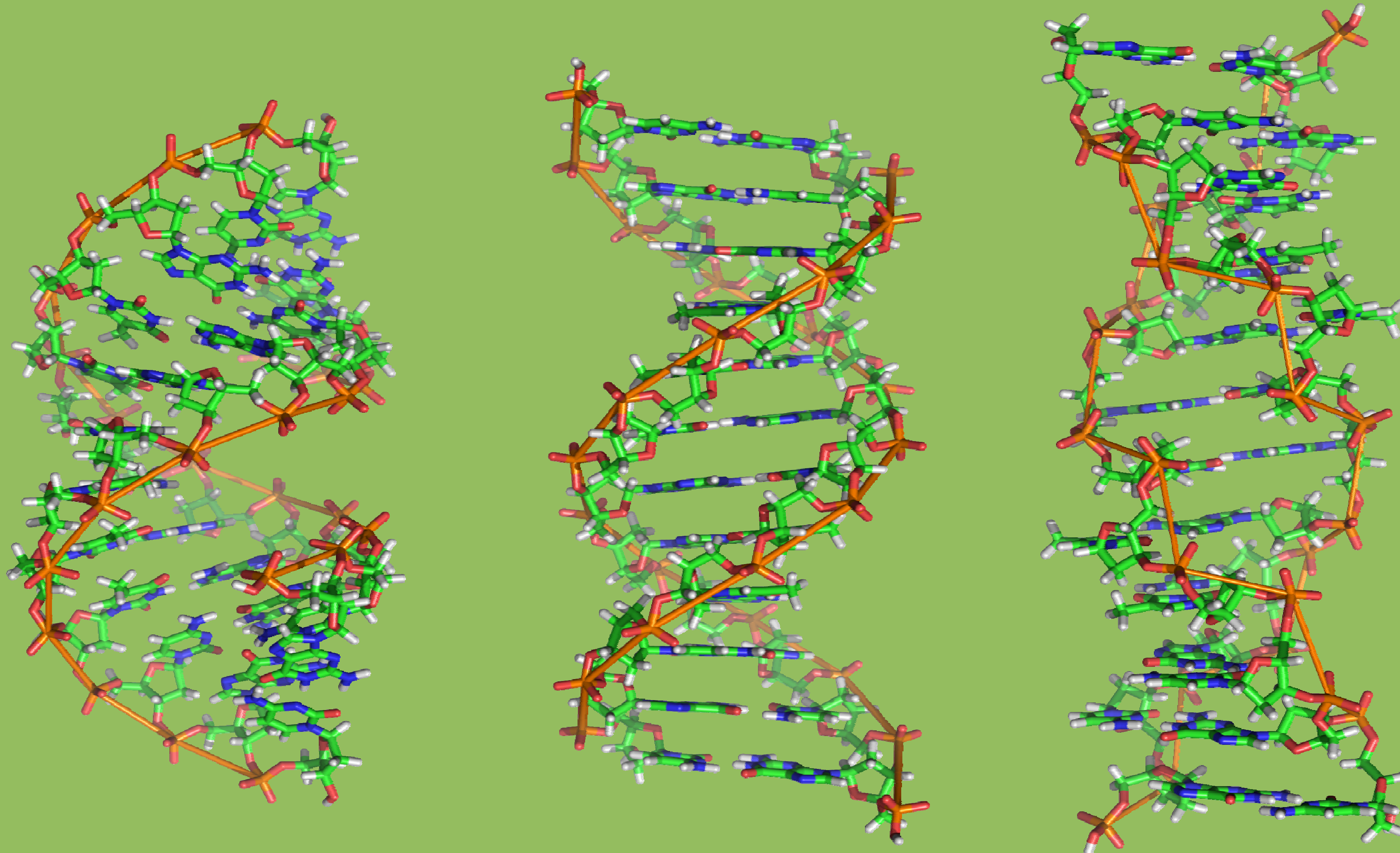
Close packing is energetically more favorable



Alternative double-helical structures

Several known conformations to date:
A-DNA
B-DNA
Z-DNA
others: C-, D-, E-, H-, L- and P-DNA

Alternative double-helical structures

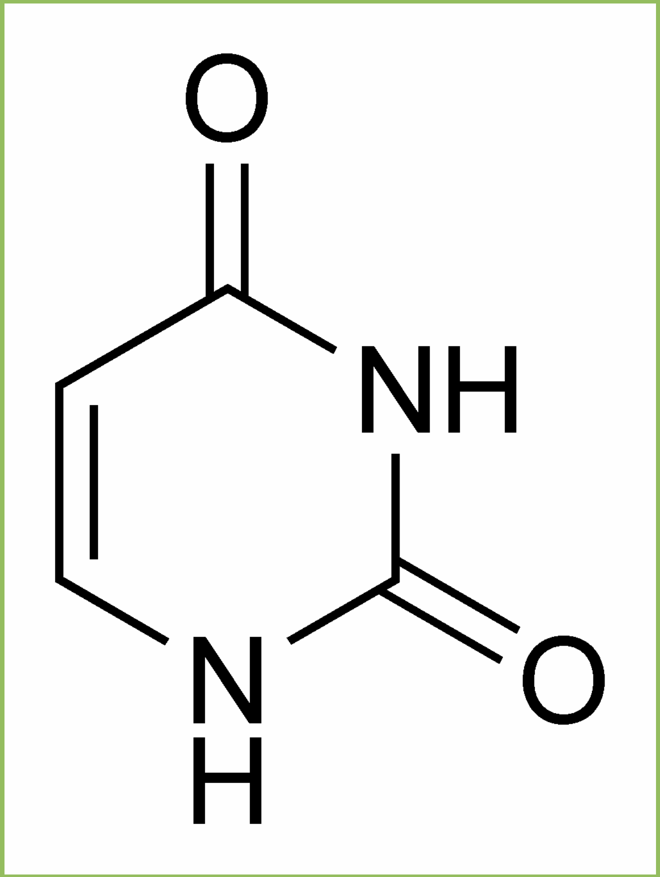


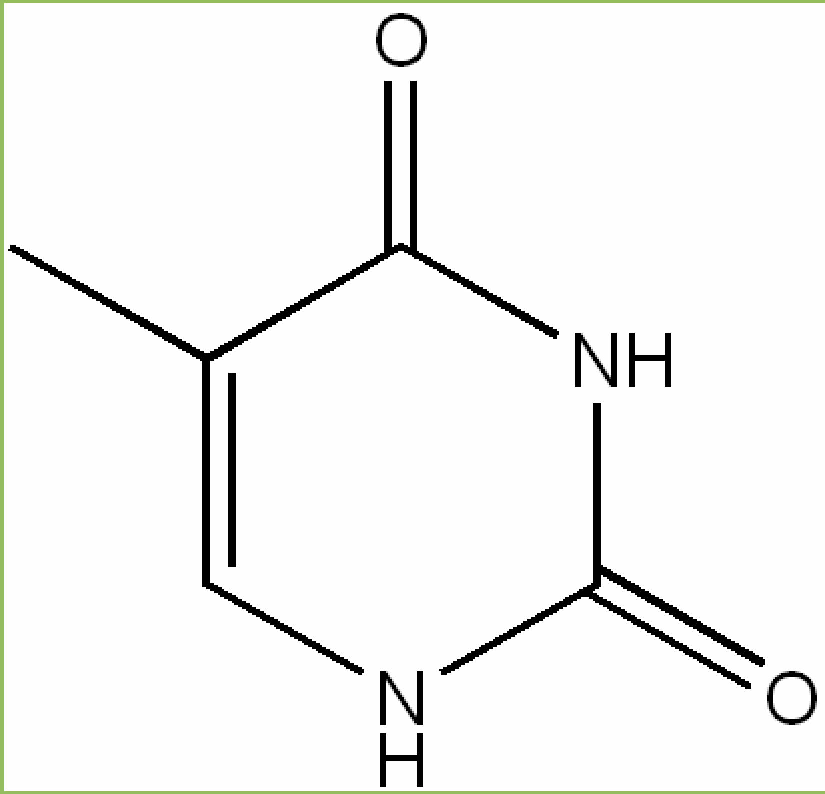
Alternative double-helical structures

Geometry attribute	A-form	B-form	Z-form
Helix sense	right-handed	right-handed	left-handed
Repeating unit	1 bp	1 bp	2 bp
Rotation/bp	33.6°	35.9°	60°/2
Mean bp/turn	10,7	10	12
Inclination of bp to axis	+19°	−1.2°	−9°
Rise/bp along axis	2.3 Å	3.32 Å	3.8 Å
Rise/turn of helix	24.6 Å	33.2 Å	45.6 Å
Mean propeller twist	+18°	+16°	0°
Glycosyl angle	anti	anti	pyrimidine: anti, purine: syn
Sugar pucker	C3'-endo	C2'-endo	C: C2'-endo, G: C2'-exo
Diameter	26 Å (2.6 nm)	20 Å (2.0 nm)	18 Å (1.8 nm)

Comparison with RNA

1. single-stranded (DNA: double stranded)
2. contains ribose (DNA: Deoxyribose)
3. Uracil instead of thymine





DNA Computing

Advantages:

Unique data structure
data density ~ 1000 Tbits per square inch
(100,000 times larger than hard drives)

Double strand nature (form RAID 1 array)

parallel operations

DNA-Computing: The Adleman experiment

Hamiltonian Path Problem:

Suppose that I live in LA, and need to visit four cities: Dallas, Chicago, Miami, and NY, with NY being my final destination. The airline I'm taking has a specific set of connecting flights that restrict which routes I can take (i.e. there is a flight from L.A. to Chicago, but no flight from Miami to Chicago). What should my itinerary be if I want to visit each city only once?

DNA-Computing: The Adleman experiment

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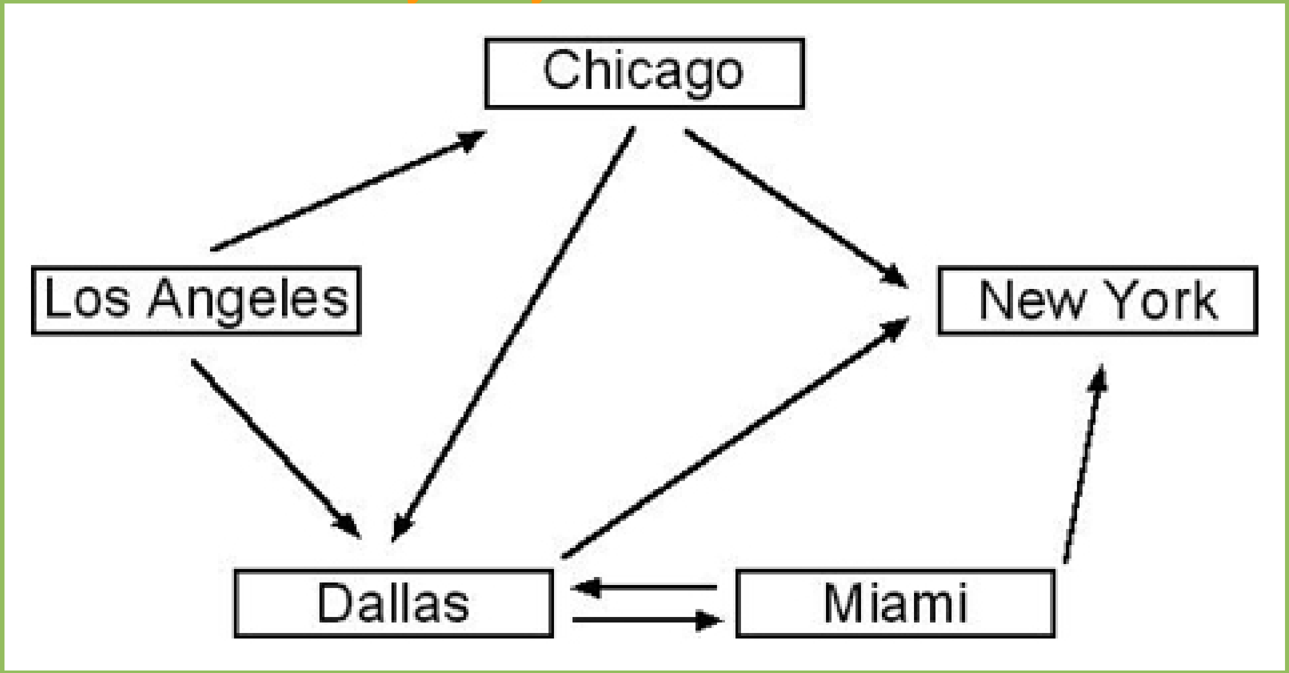


Obvious: only one solution

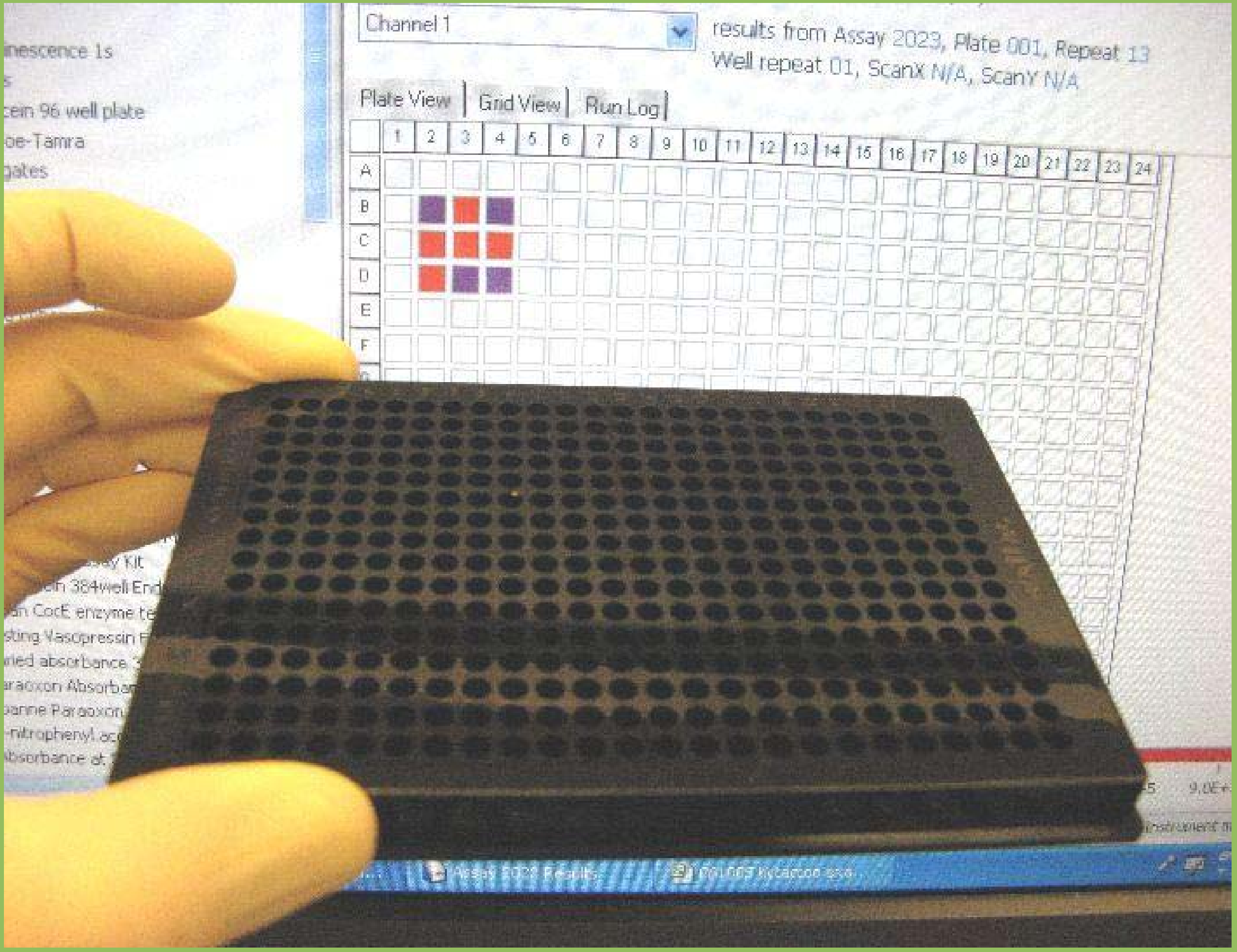
DNA-Computing: The Adleman experiment

Adleman's Solution:

1. Generate all possible routes.
2. Select itineraries that start with the proper city and end with the final city.
3. Select itineraries with the correct number of cities.
4. Select itineraries that contain each city only once.

Extensive solution of this problem:
http://arstechnica.com/reviews/2q00/dna/dna-1.html

DNA-Computing: Tic-Tac-Toe



http://technology.newscientist.com/article/dn10310-dna-computer-is-unbeatable-at-tictactoe.html

That's it!

Thank you for your patience.