Introduction to molecular biology: DNA

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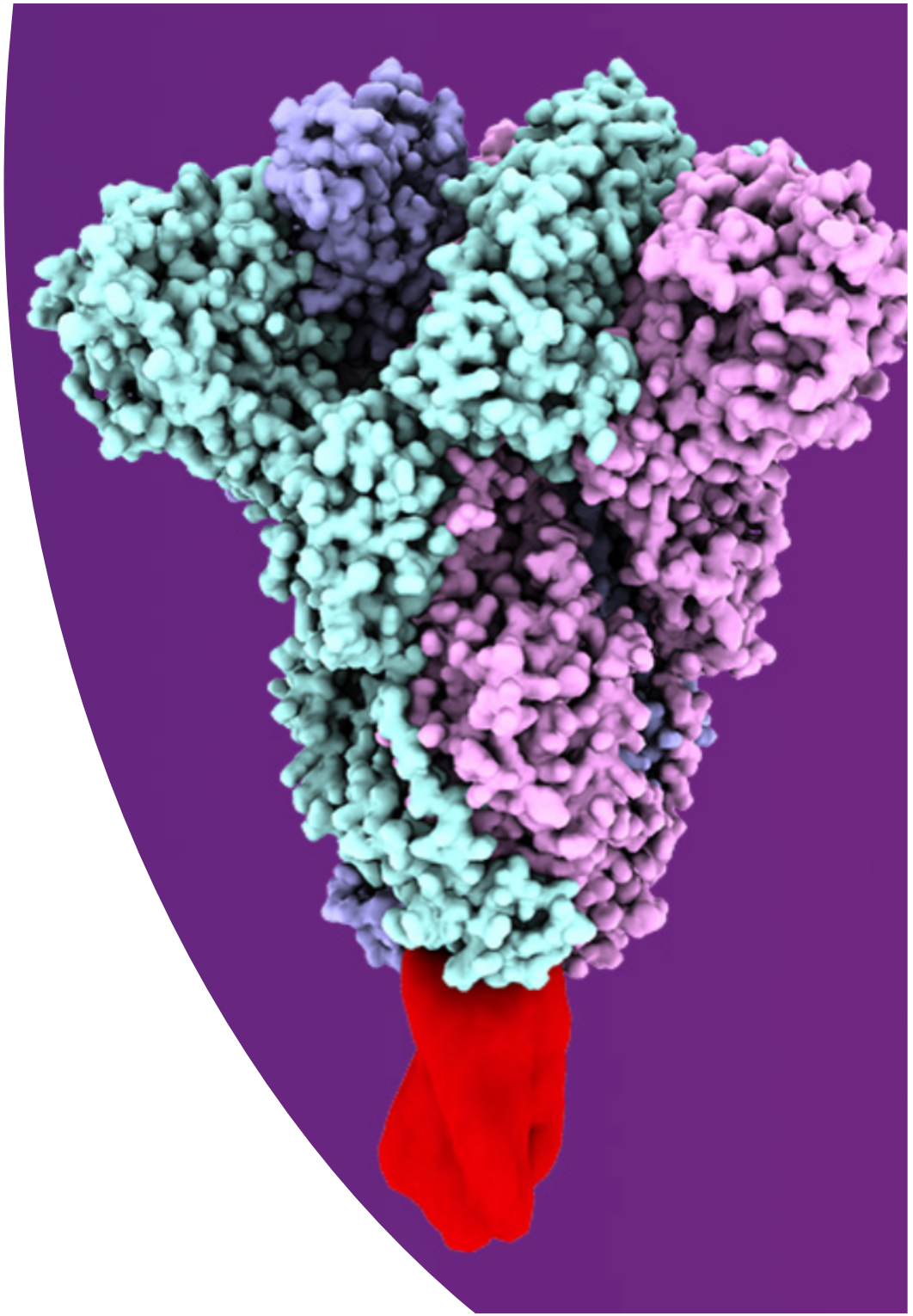
Molecular biology intro

- **Part 1:**

  nucleic acids (sequence, structure, biological role...)

- **Part 2 :**
  - genes and gene expression

- **Part 3:**
  - amino acids and proteins



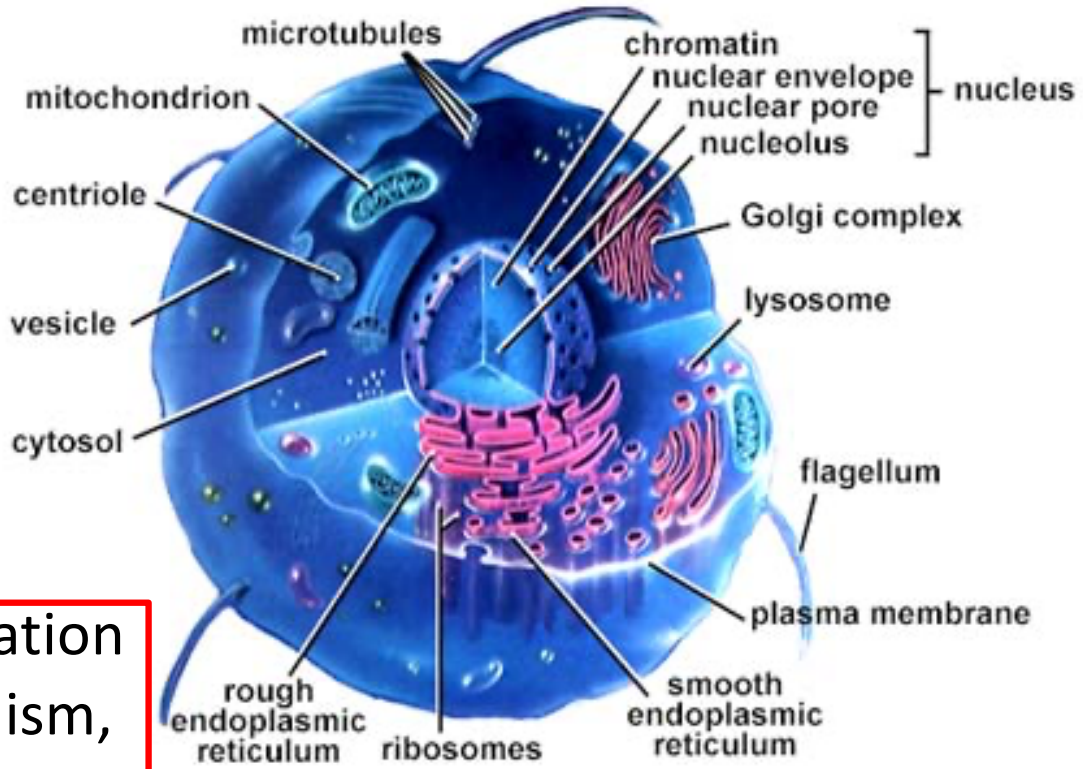
cell

- basic building blocks of all the living organisms → bio(macro)molecules → nucleic acids, proteins, carbohydrates, lipids

- two different cell types based on the structural organization:
  - **prokaryotic** cells (e.g. bacteria, archaea) – NO nucleus and cell organelles!
  - **eukaryotic** cells (e.g. plants, animals) – well defined nucleus and cell organelles (mitochondria, chloroplast…) → more complex system

common features of life forms

- mostly **C**arbon, **O**xygen, **N**itrogen and **H**ydrogen (and a little bit of sulphur, iron, magnesium, zinc…) combined into basic cellular ingredients:
  - nucleic acids (DNA, RNA)
  - proteins
  - carbohydrates (sugars)
  - lipids (fatty acids)
  - various small molecules

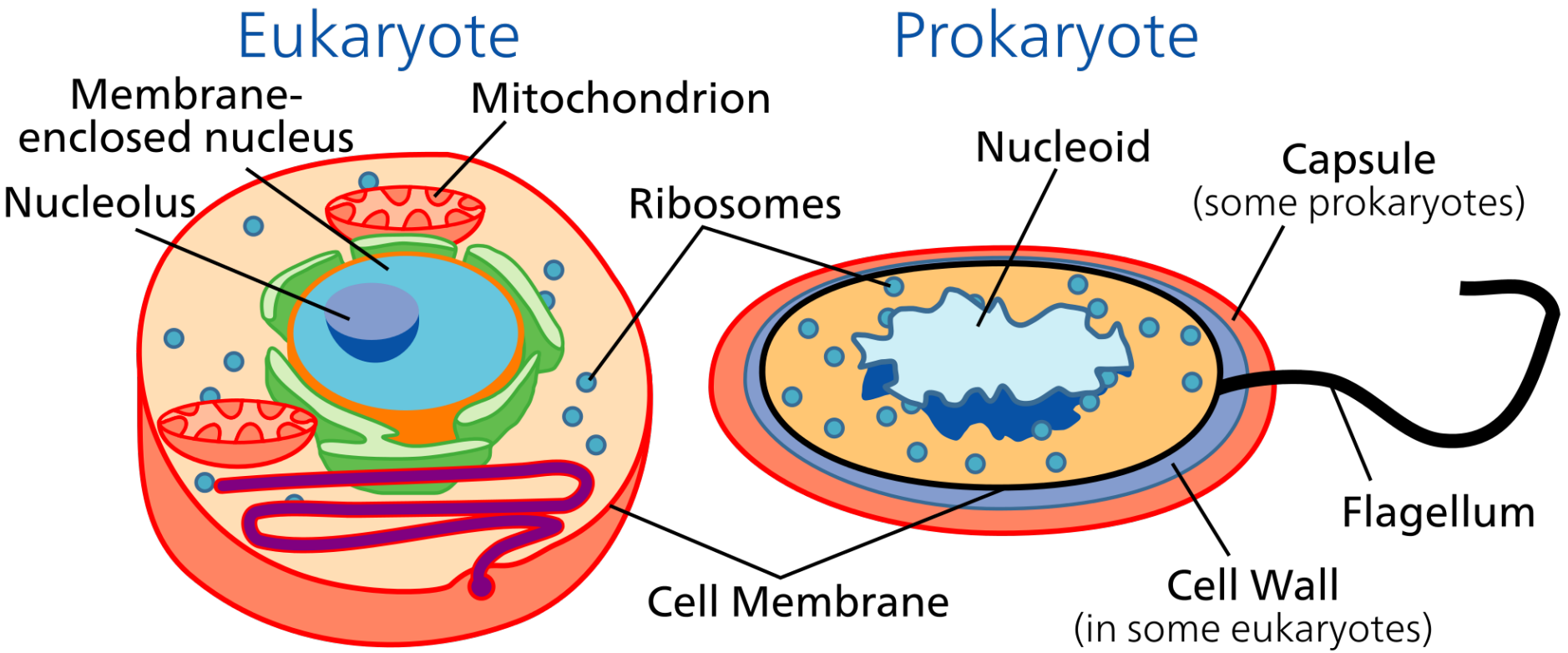


- Different roles for each type of biomolecules:

  DNA (RNA) → genetic information

  proteins → catalysis, metabolism, transport, structure, motion…

  lipids → membrane



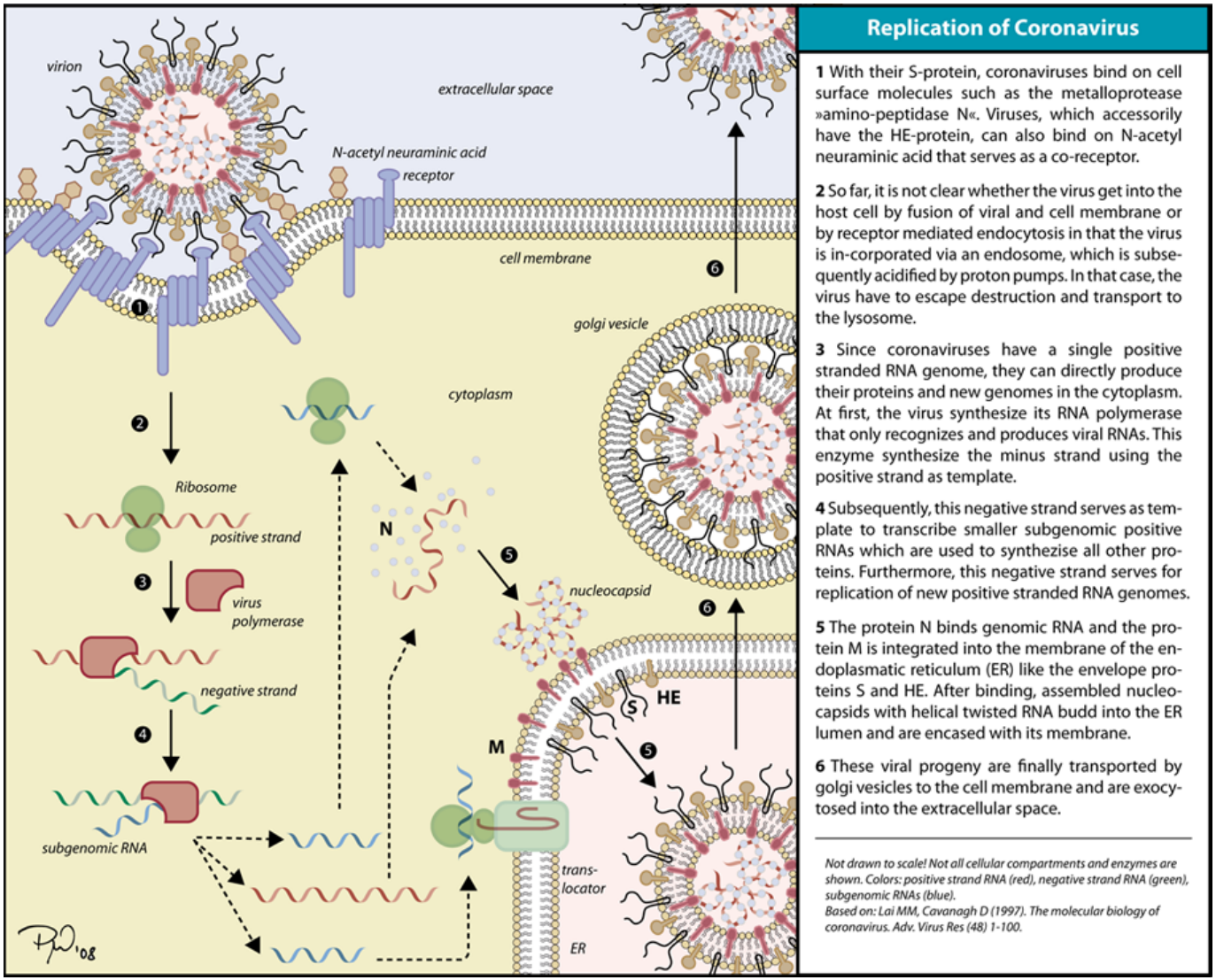
Common features:

- DNA genome
- Protein machines and catalysts
- Ribosomes (protein synthesis)
- ATP as (metabolic) energy source
- Lipid membranes

Distinct features:

- Chromosome structure
- Genome organisation
- Subcellular structures (organelles)
- Metabolic pathways

Coronavirus update: RNA virus



some useful links:

ONLINE TEXTBOOK ON CELL BIOLOGY:

http://www.nature.com/scitable/ebooks/essentials-of-cell-biology-14749010/contents

CELL BIOLOGY VIDEOS:

Quick review of eukaryote cell:

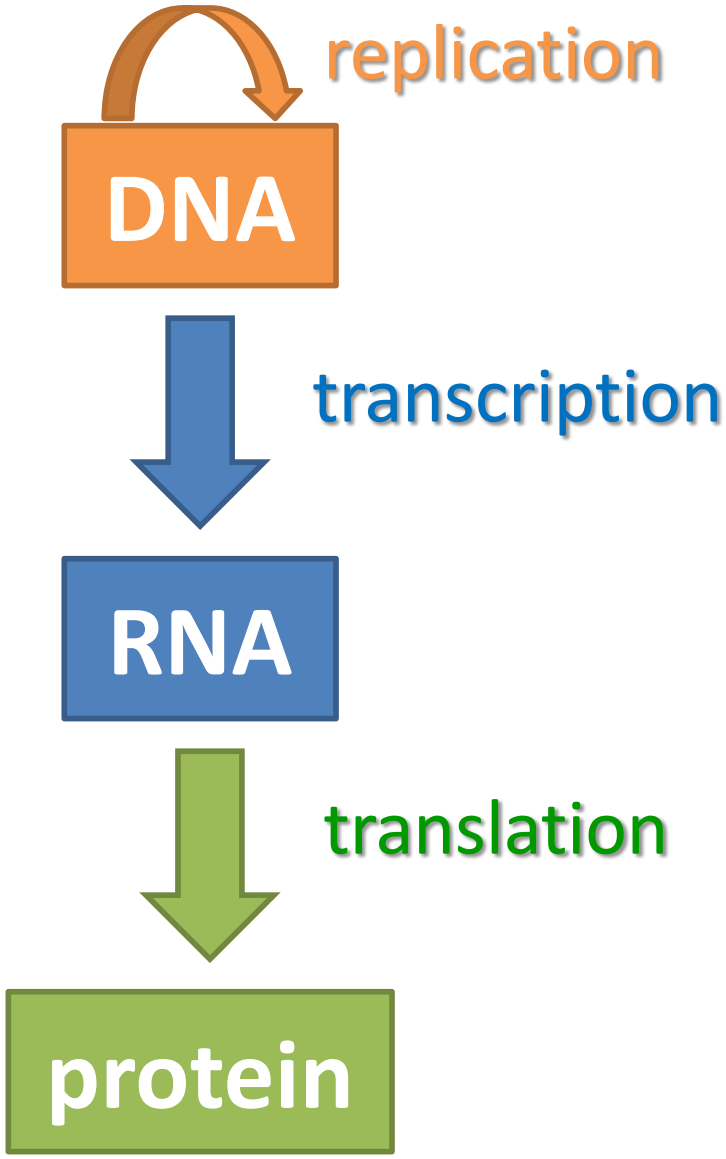
https://www.youtube.com/watch?v=vwAJ8ByQH2U

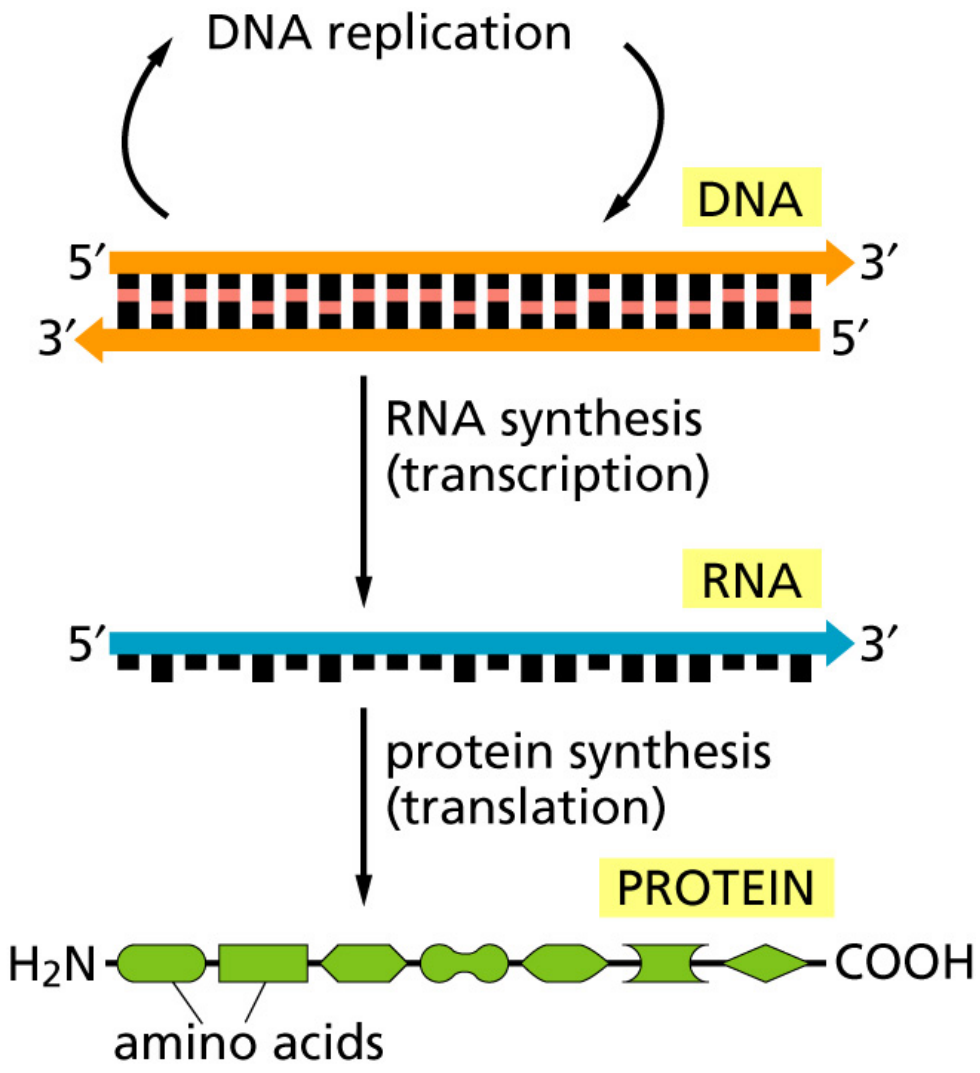
Prokaryote vs Eukaryote cells:

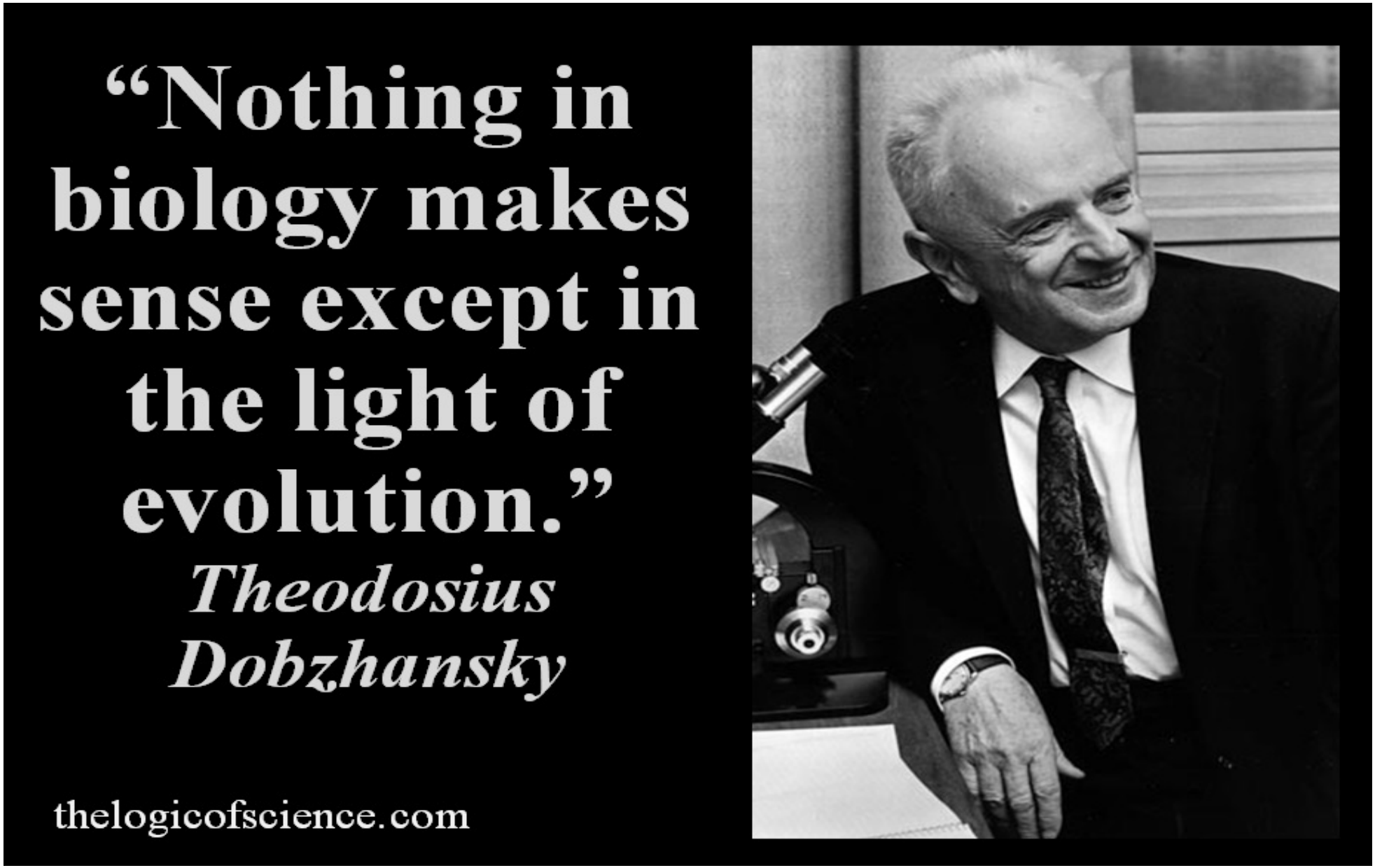
https://www.youtube.com/watch?v=zZtcMBTQaS4

central dogma of molecular biology

- link between these molecules:



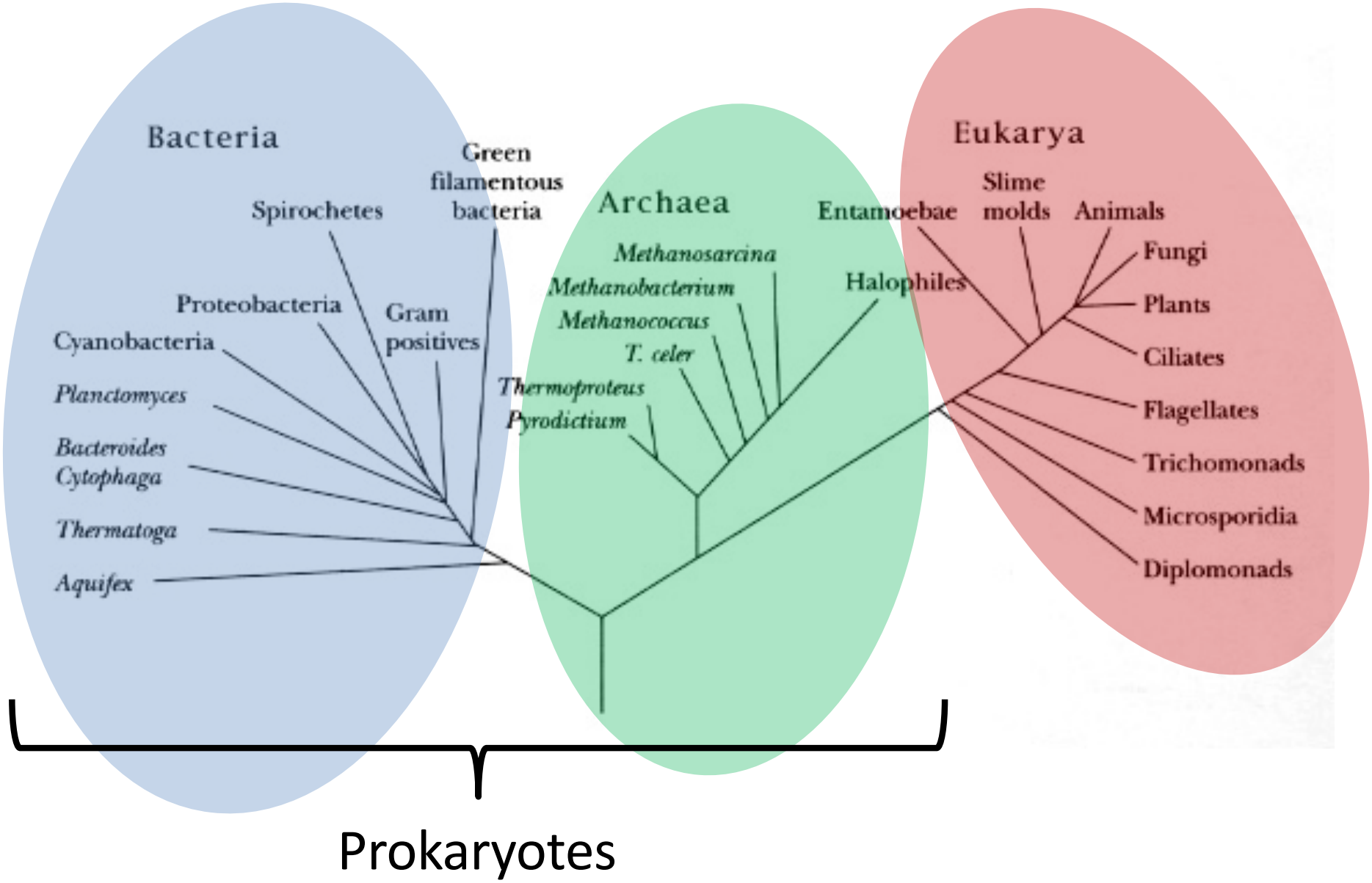




The American Biology Teacher, Vol. 35 No.3, Mar., 1973; (pp. 125-129) **DOI:** 10.2307/4444260

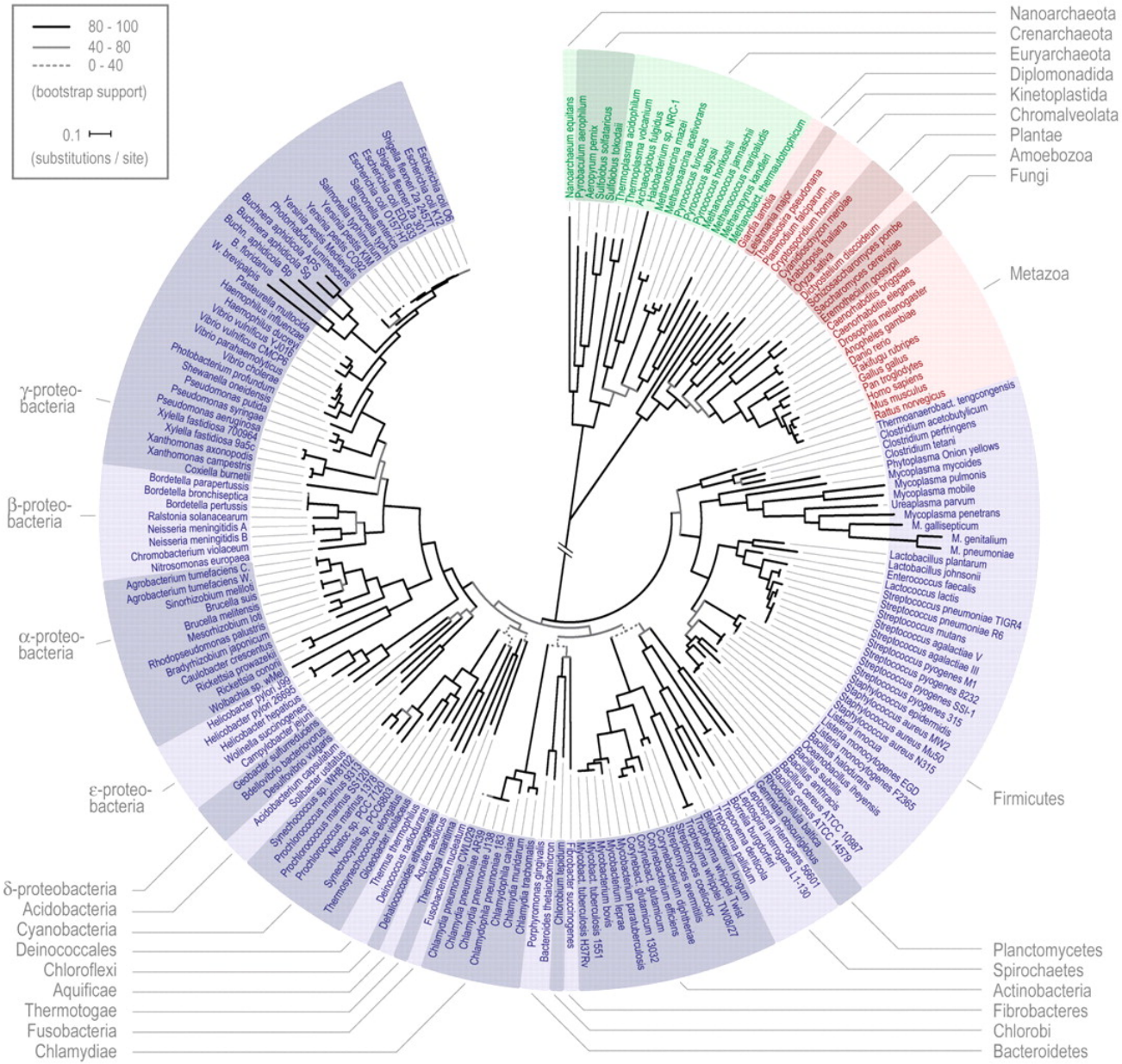
tree of life (3 domains)

domains → kingdoms → phylum → class → order → family → genus → species

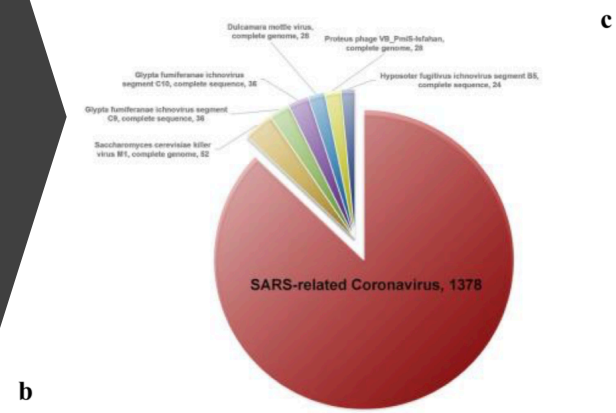


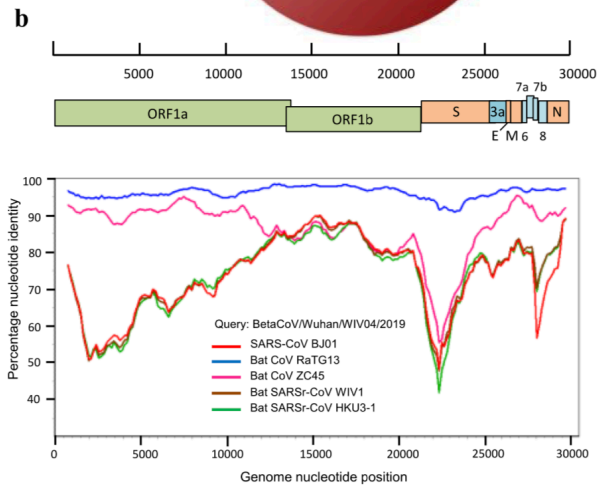
tree of life – high resolution

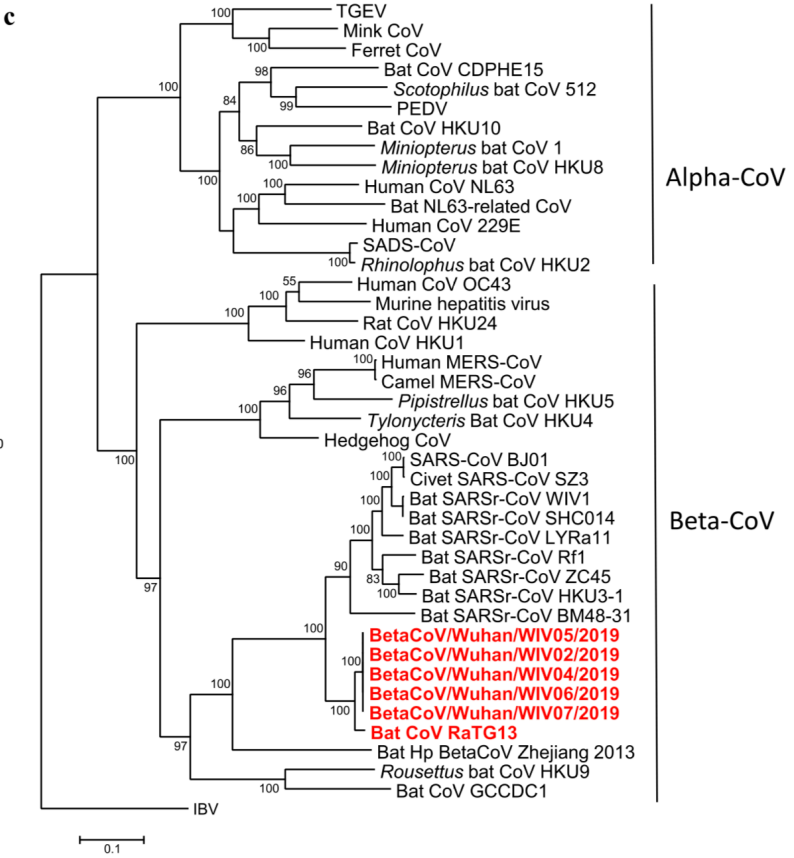
Ciccarelli et al., (2006). Toward Automatic Reconstruction of a Highly Resolved Tree of Life. *Science,* **311**:1283-1287



Coronavirus update: phylogenetics

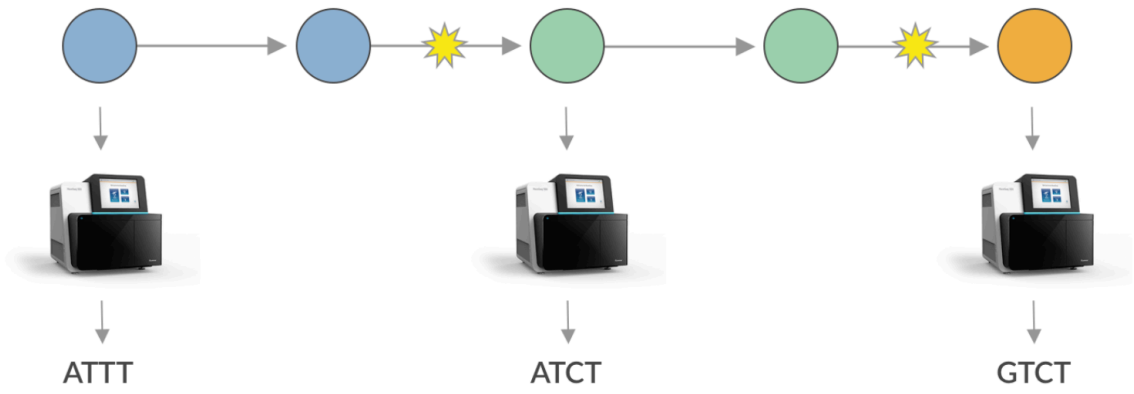


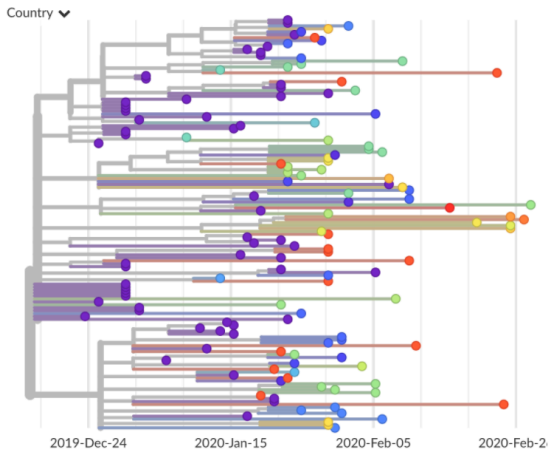


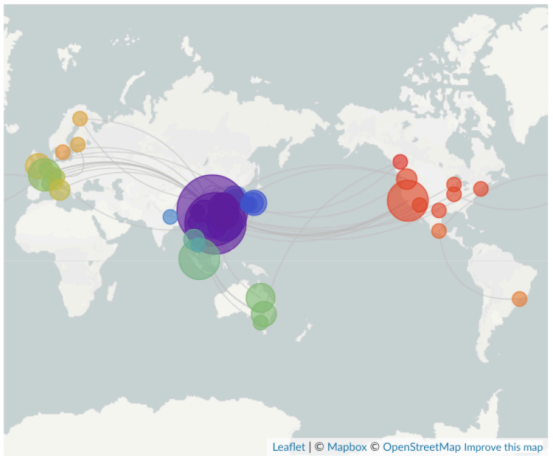


Zhou, P., Yang, XL., Wang, XG. *et al.* A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature* **579,** 270–273 (2020). https://doi.org/10.1038/s41586-020-2012-7

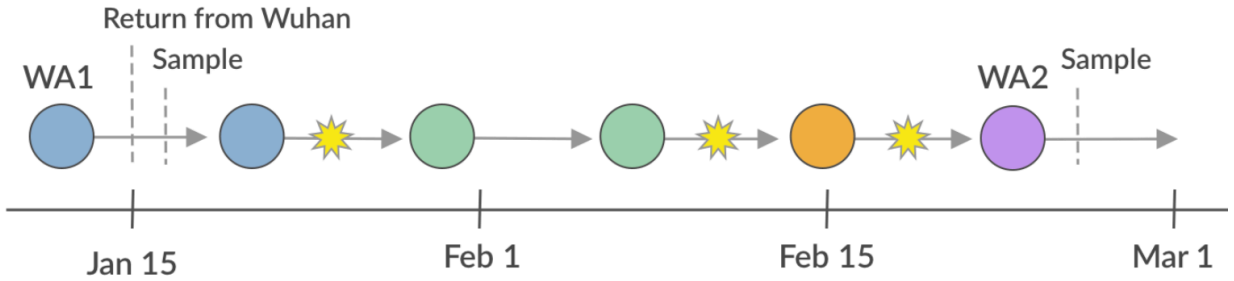
Coronavirus update: genome epidemiology





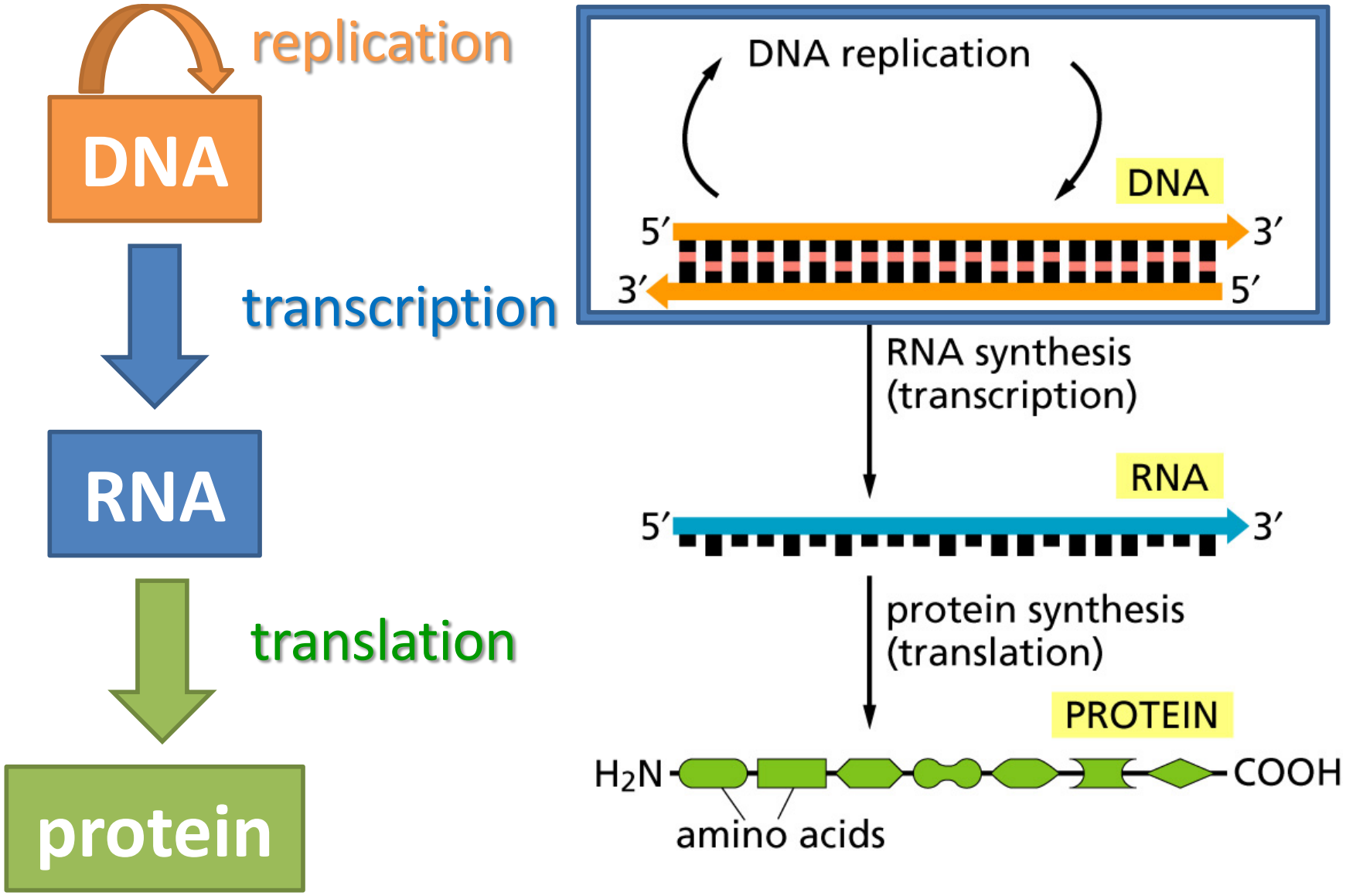


Trevor Bedford blog:
https://bedford.io/blog/ncov-cryptic-transmission/



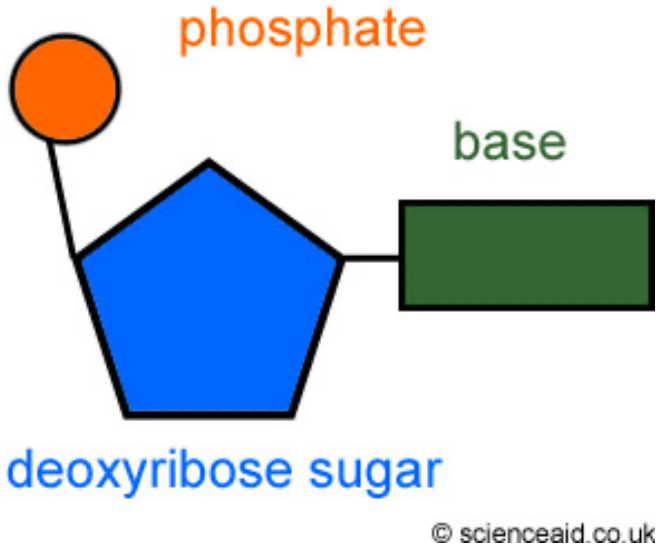
central dogma of molecular biology

- link between these molecules:



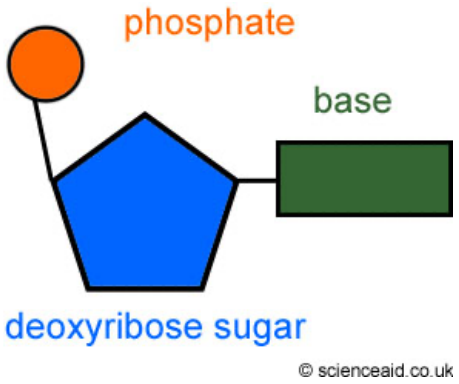
nucleic acids

- **d**eoxyribo**n**ucleic **a**cid (DNA) and ribo**n**ucleic **a**cid (RNA) → biopolymers of 4 different basic units – *nucleotides*

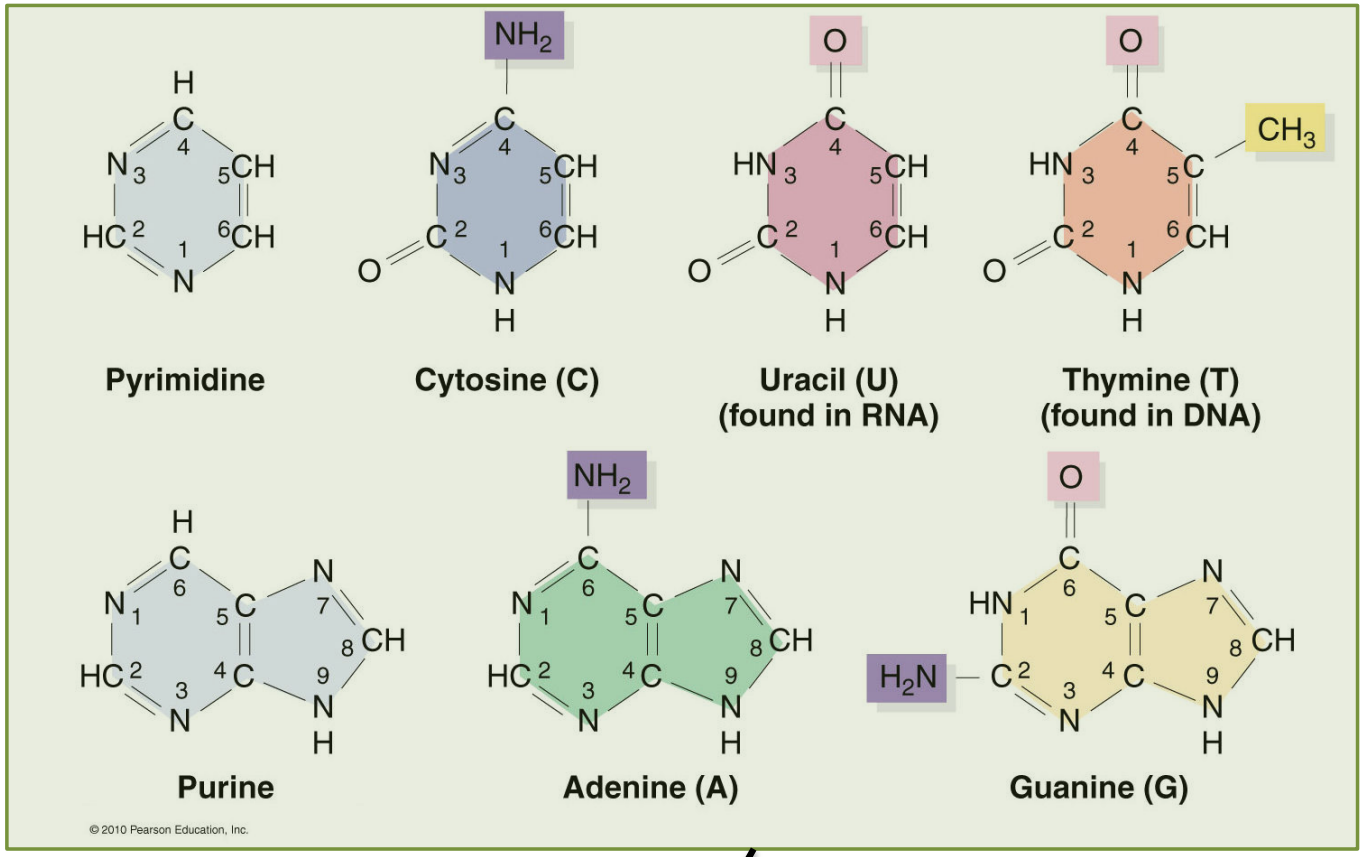


- nucleotide → nucleobase + pentose sugar (deoxyribose/ribose) + phosphate

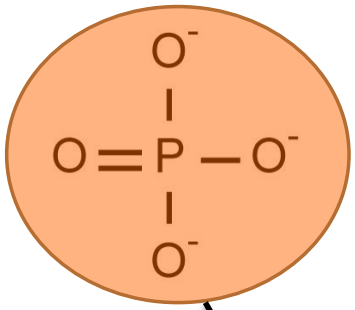
nucleotides

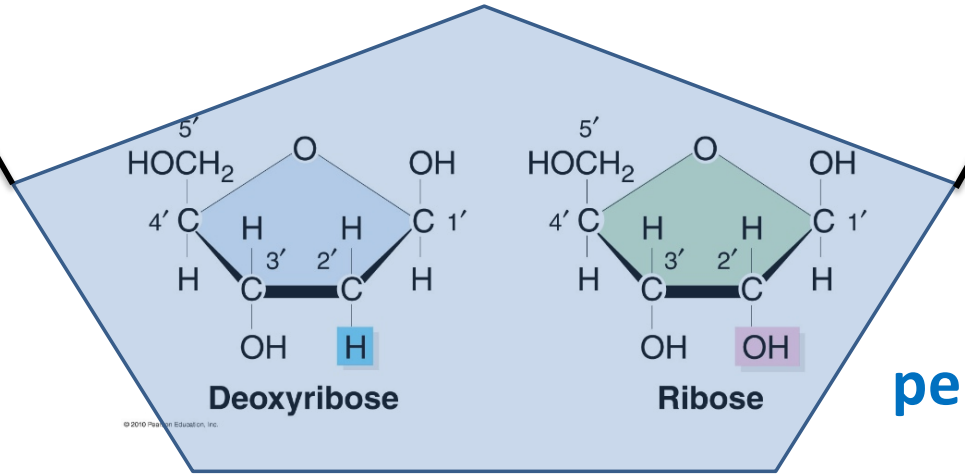


nucleobases

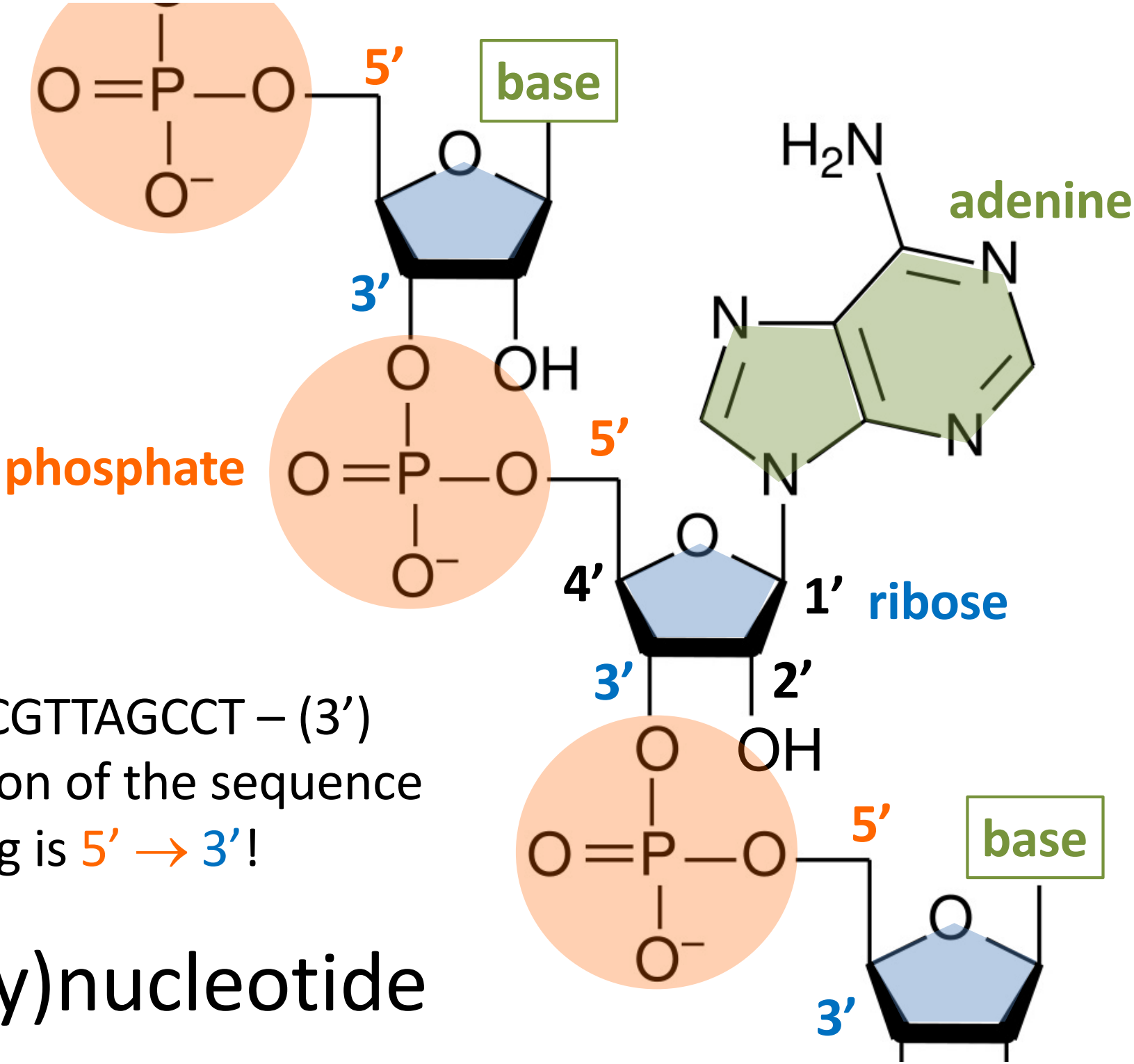


phosphate





pentose sugars

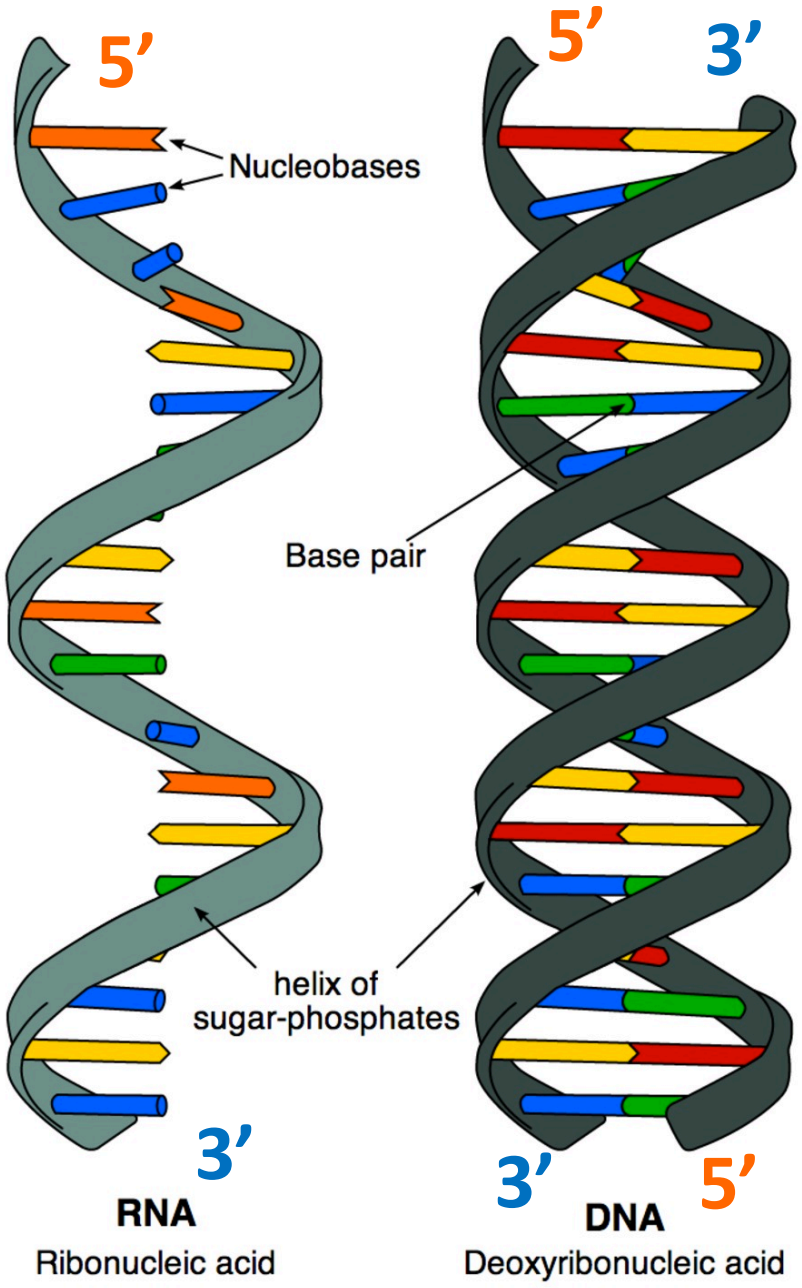


(5’) – CGTTAGCCT – (3’)
direction of the sequence
reading is 5’ → 3’!

(poly)nucleotide

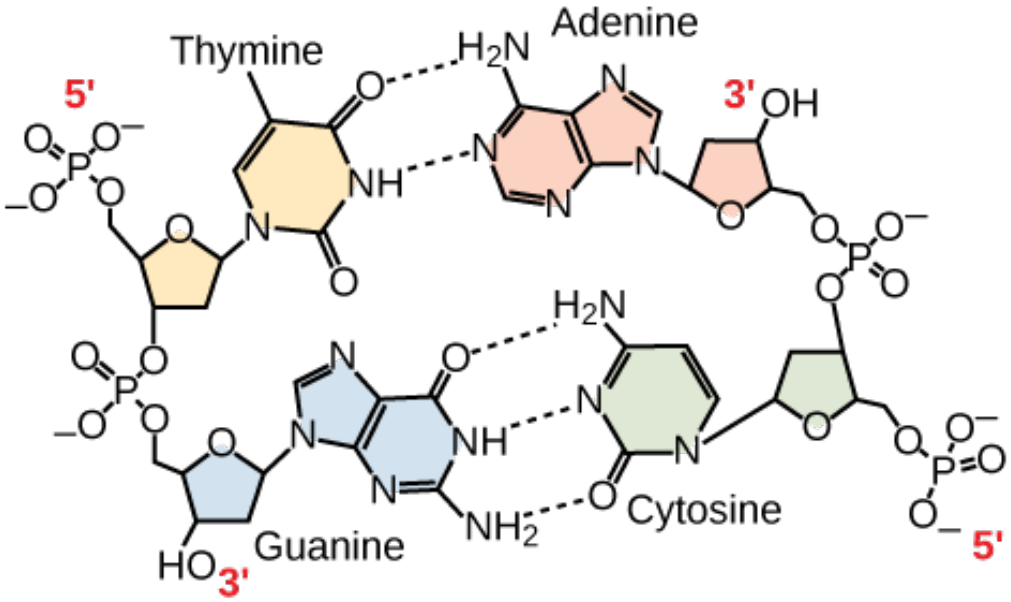
nucleotide polymers (strands)

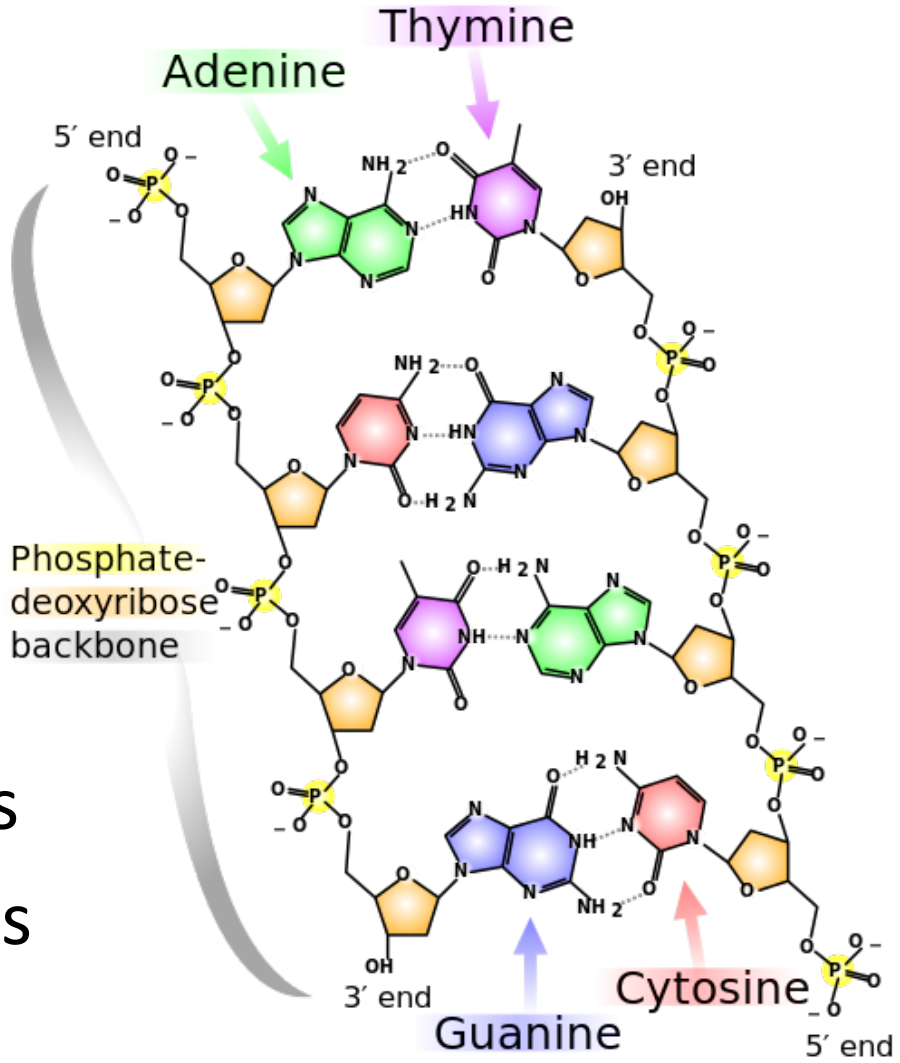
- RNA is usually a found as a single polynucleotide chain (strand)
- DNA forms double helix → 2 strands interacting through base pairing
- in DNA 5'→ 3' strand is called *sense* (coding strand), while the complementary chain is called *antisense* (3' → 5')
- only knowledge of sequence of one strand is required to retrieve the information



base pairing

- Watson-Crick base pairing in double helix (1953)



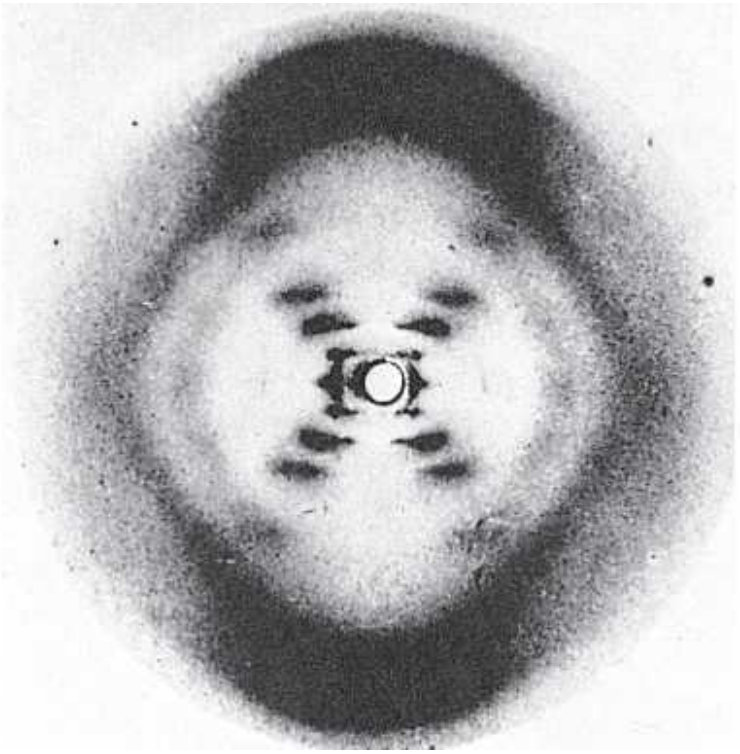


- AT pair → 2 hydrogen bonds
- CG pair → 3 hydrogen bonds

double helix history

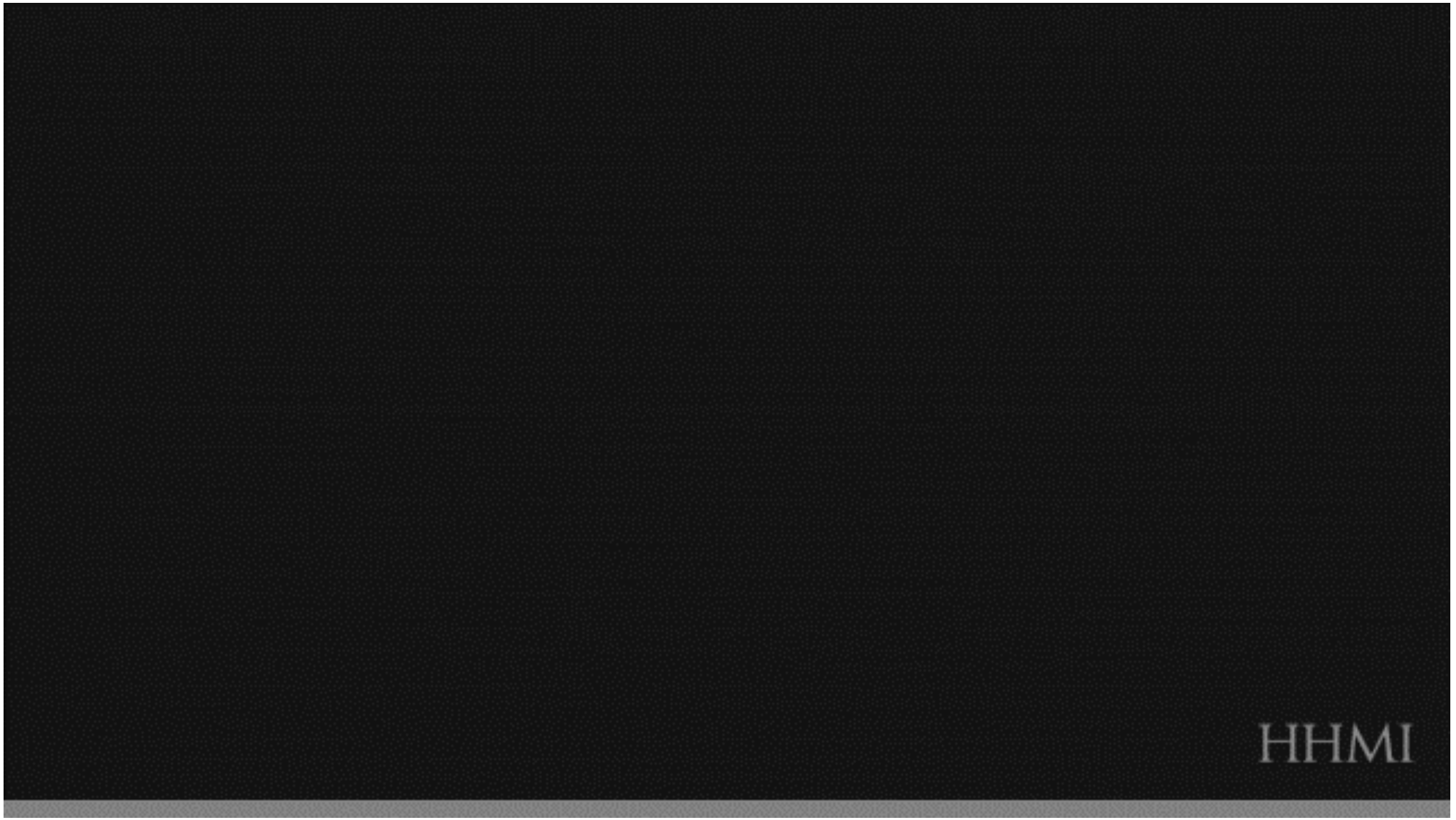
- competition & controversy
- James Watson & Francis Crick 1953 $\rightarrow$ Nobel prize in 1962 together with Maurice Wilkins (experimental verification)

Rosalind Franklin
(1920-1958)



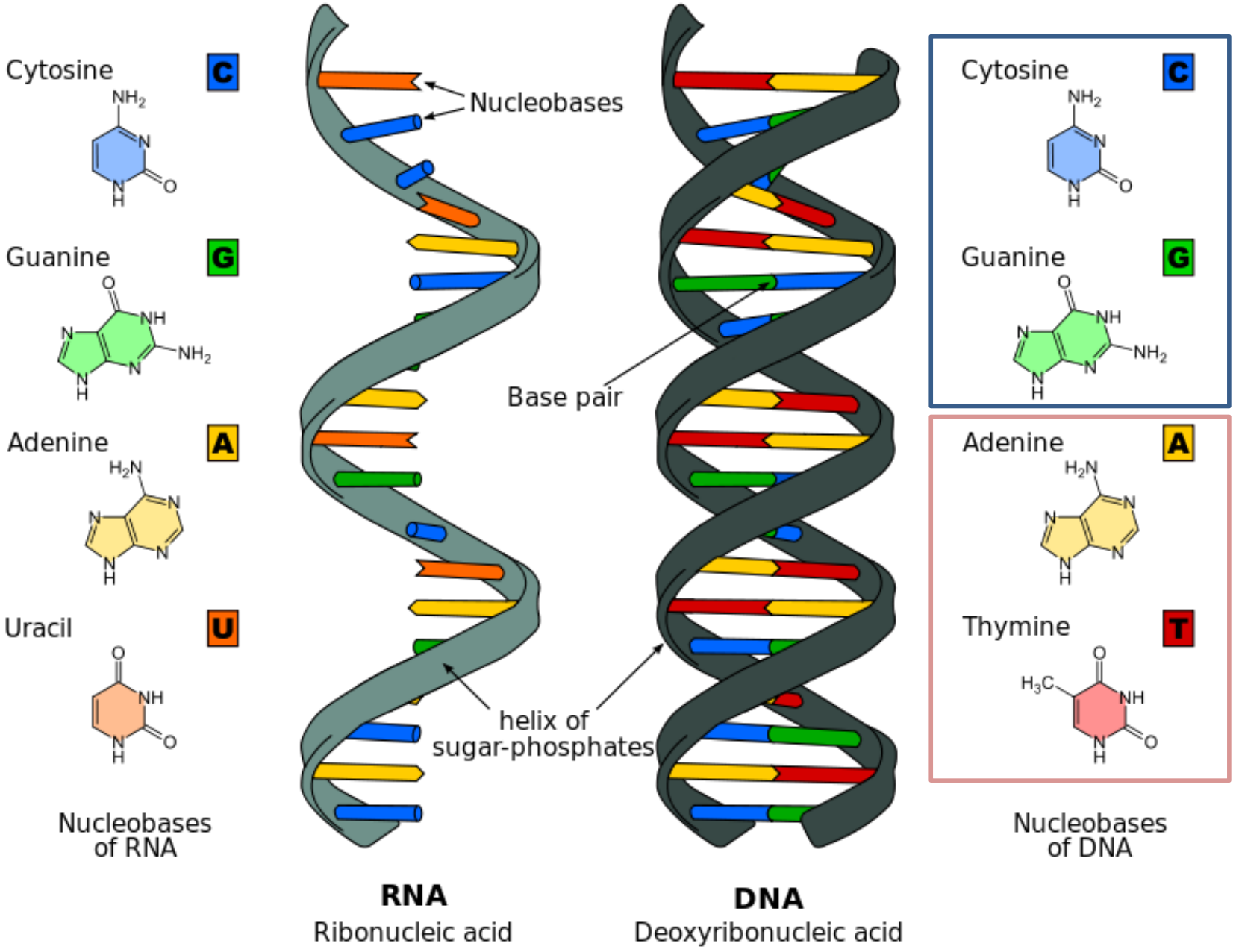
Famous Photo 51 of X-ray diffraction image of DNA crystals

double helix history

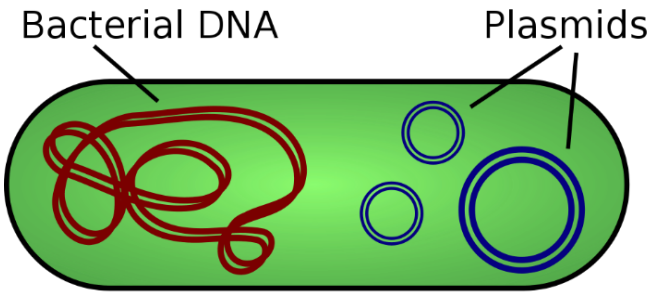


http://www.hhmi.org/biointeractive/watson-constructing-base-pair-models

in summary…

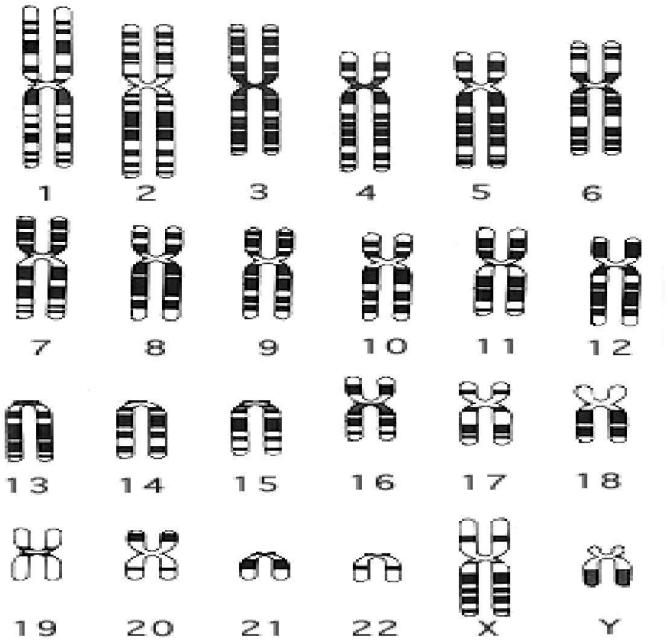

Cytosine
C
Guanine
G
Adenine
A
Uracil
U
Nucleobases of RNA
Nucleobases
Base pair
helix of sugar-phosphates
RNA
Ribonucleic acid
DNA
Deoxyribonucleic acid
Cytosine
C
Guanine
G
Adenine
A
Thymine
T
Nucleobases of DNA

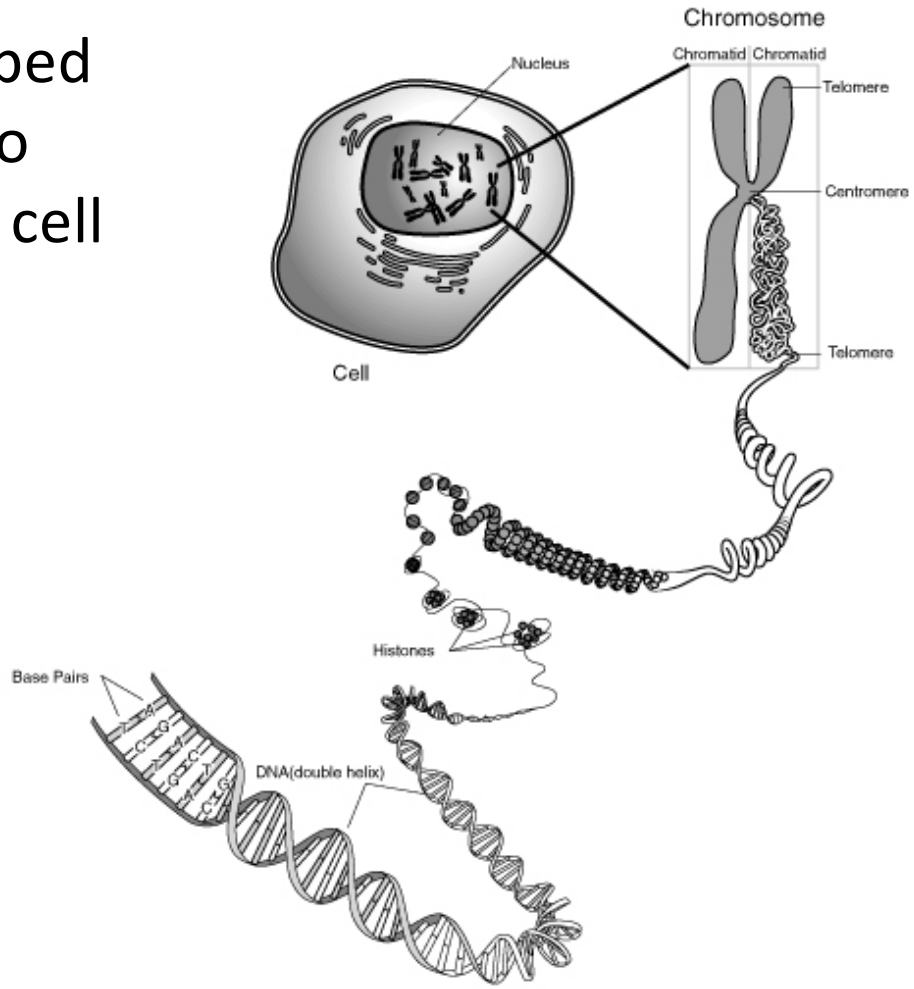
DNA in cells



- prokaryotes → circular DNA

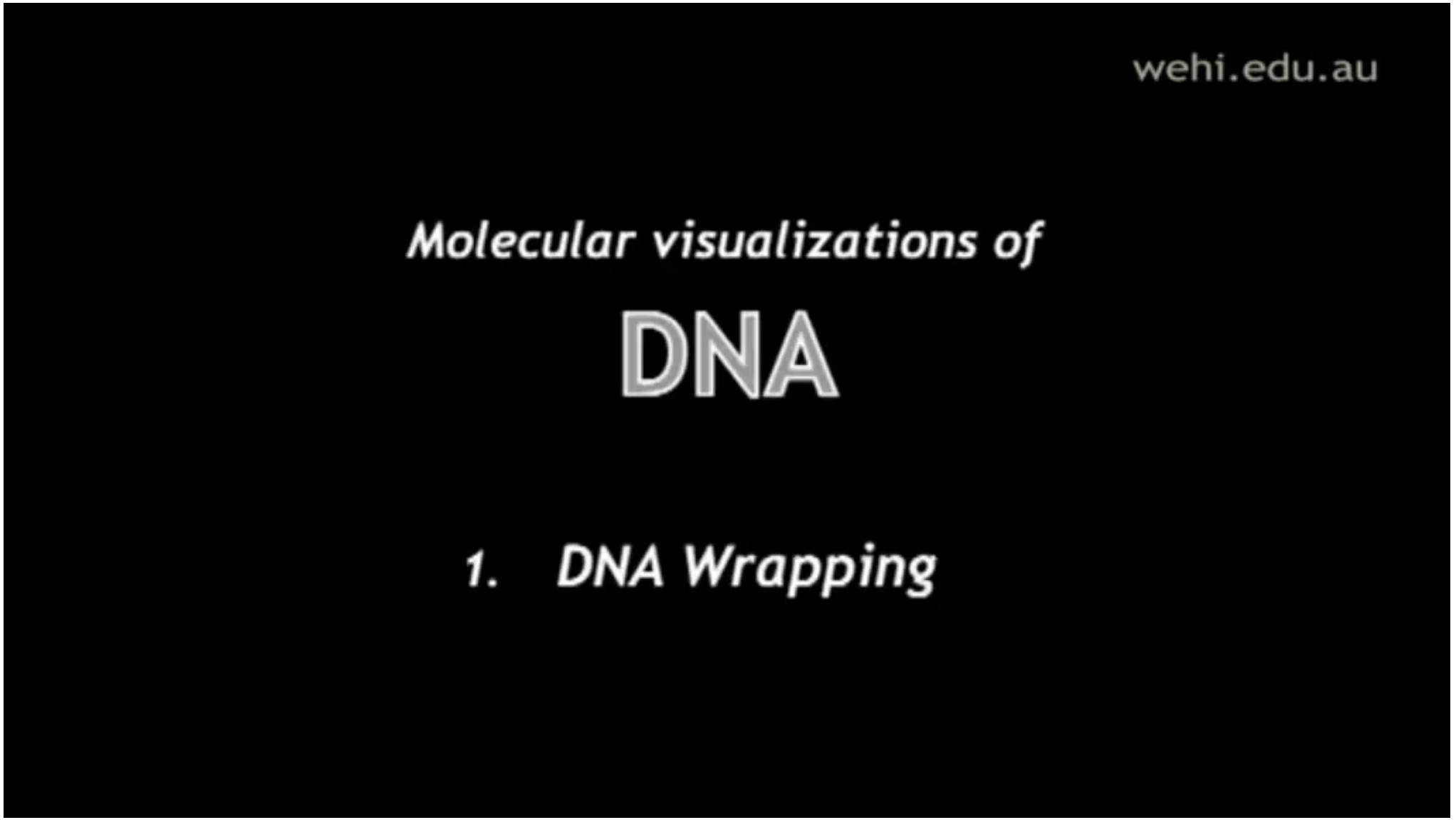
- eukaryotes → linear DNA wrapped around proteins and packed into chromosomes (enclosed within cell nucleus) → ~1.8 m





http://www.wehi.edu.au/education/wehitv/molecular_visualisations_of_dna/

DNA wrapping into chromosomes



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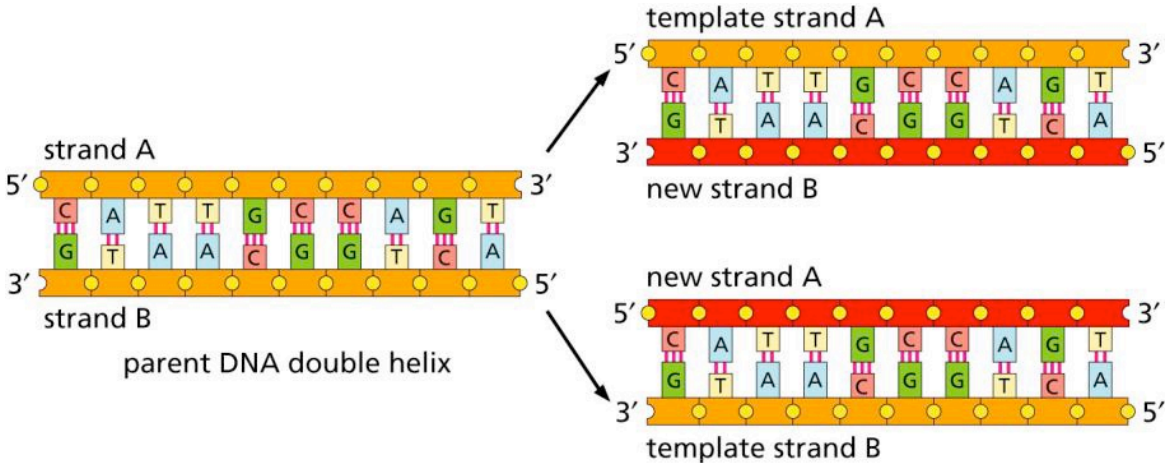
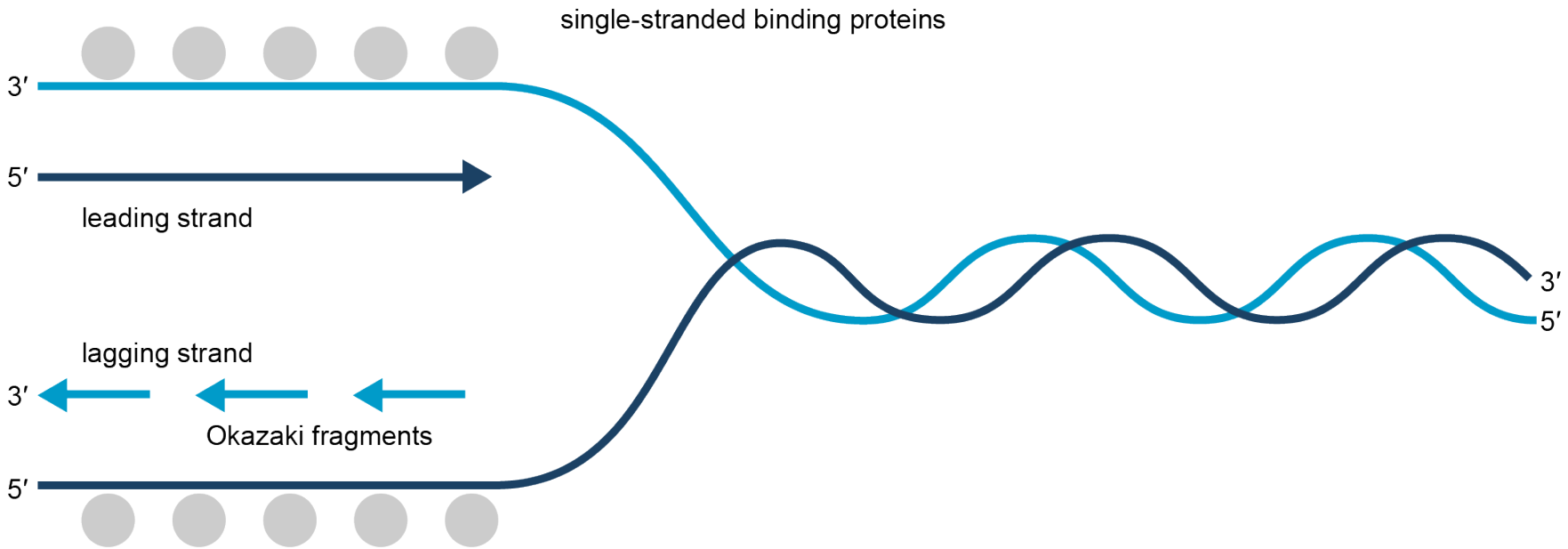


DNA replication

- cell division → duplication of genetic material → key to inheritance
- separation of the strands in double helix (helicase) → each strand serves as a template for a synthesis of the new complementary strand (DNA polymerase) → 2 new DNA chains
- proofreading → accuracy within 1 wrong base per billion!!

Basic steps of DNA replication

- initiation → unwinding of helix in AT rich areas – weaker H bonds
- elongation → DNA is always synthesized in the 5' to 3' direction (template is read in the 3’ to 5’ direction) → *leading* (5’ → 3’) and *lagging* strand (3’ → 5’)
- Okazaki fragments necessary as DNA always synthesized 5’ to 3’



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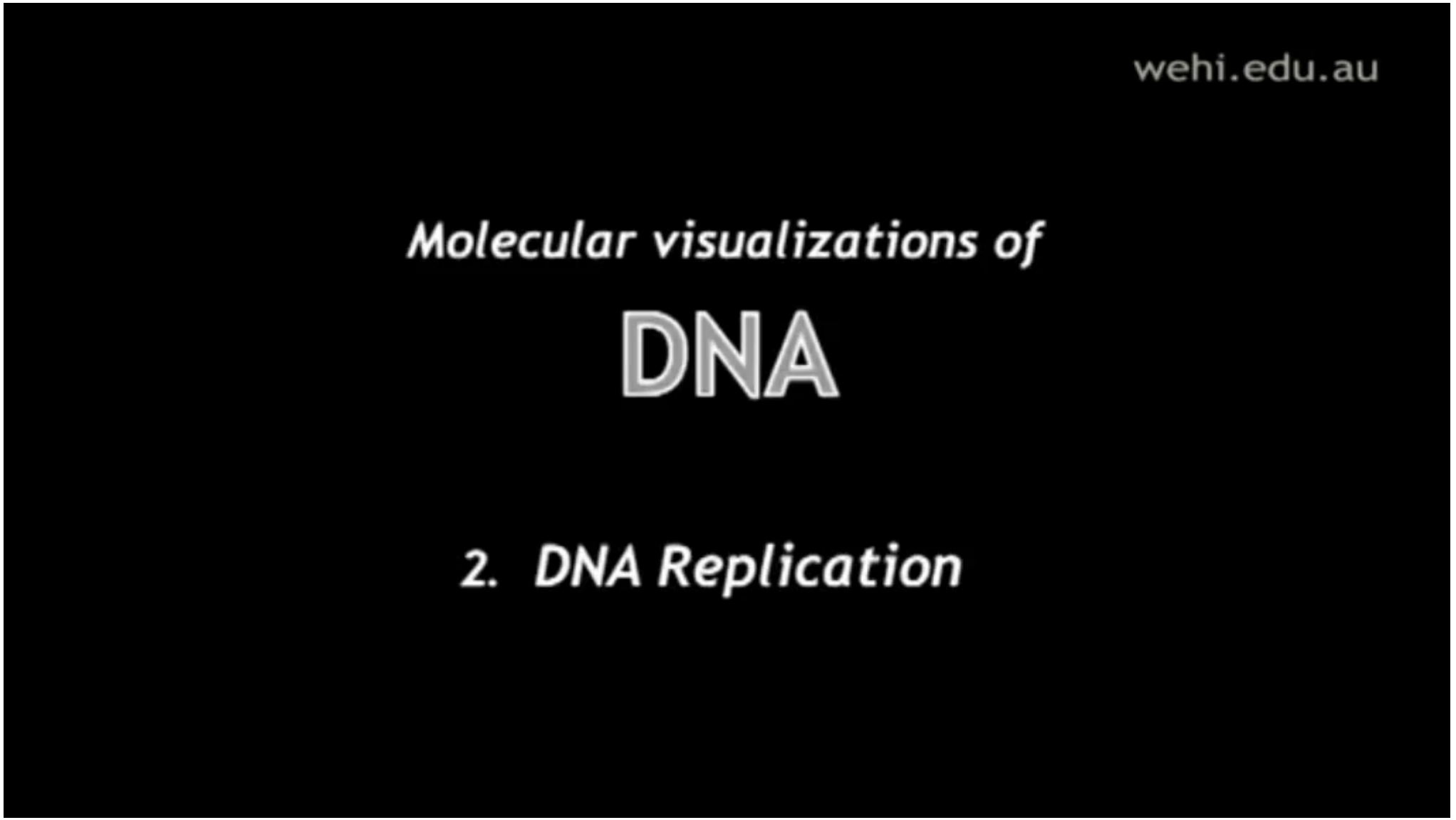
DNA replication



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Key learning outcomes

- Appreciate the differences between prokaryote and eukaryote cells and genomes
- Consider the role of evolution when investigating genomes and genes
- Have a broad understanding of the central dogma of molecular biology
- Understand how the structure of DNA and RNA gives rise to the genetic code and the central dogma
- Recognise the process of DNA replication and packaging

Refer to Week 1-2 Study Guide document