# DNA-based (nano)technologies


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DE LA RECHERCHE À L'INDUSTRIE cea

cnrs dépasser les frontières

SyMMES
SYSTÈMES MOLÉCULAIRES ET NANOMATÉRIAUX POUR L'ÉNERGIE ET LA SANTÉ

# Outline

***I. DNA molecular structure and properties***

*DNA and RNA chemical structures*
*Biological functions of nucleic acids*
*DNA (un)stability*
*DNA synthesis (chemical and PCR-based)*

***II. Design of new functionalities for DNA***

*Data storage with DNA*
*Introduction to biosensors & Aptamers*

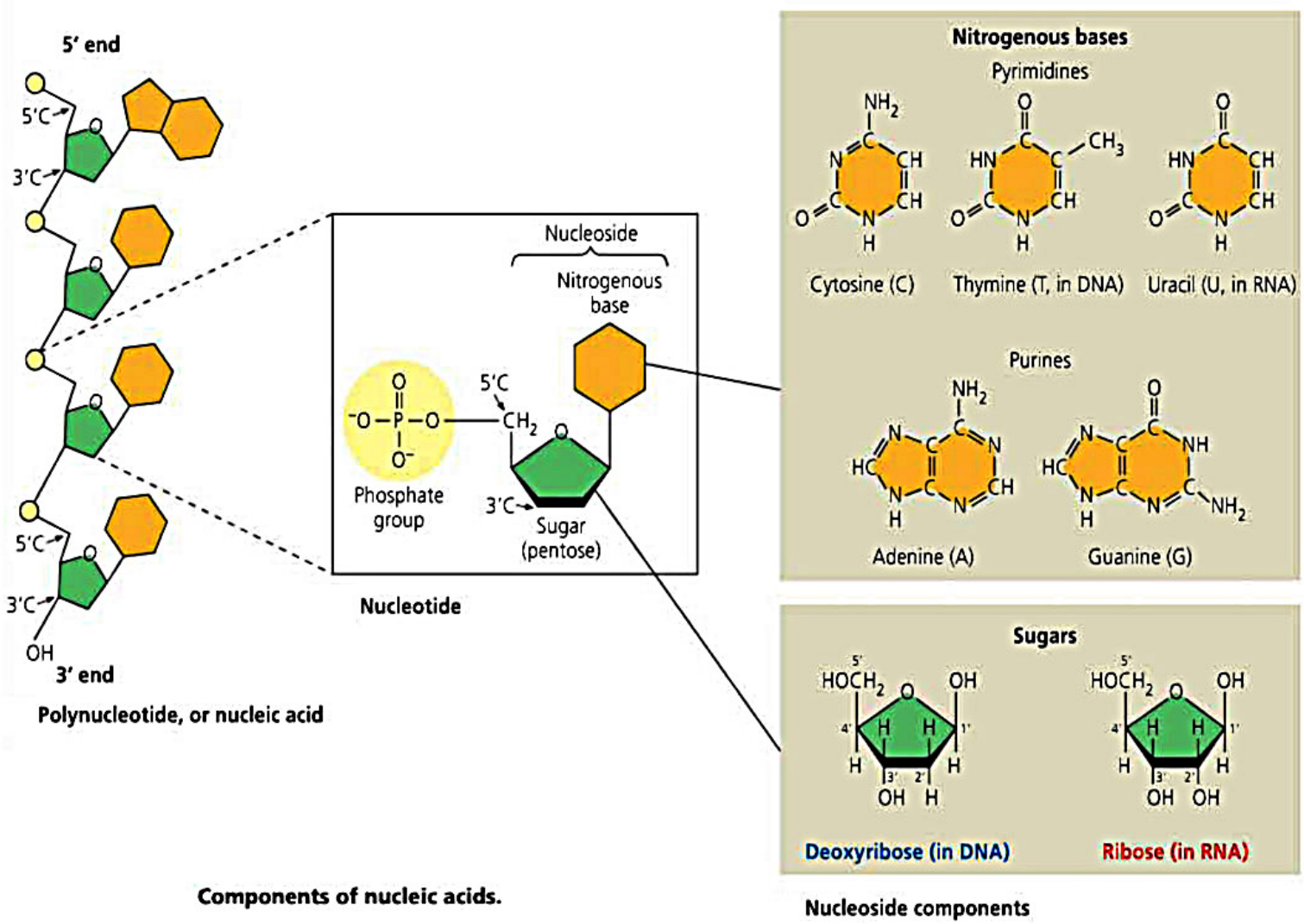
***III. DNA as a nanometric tunable object***

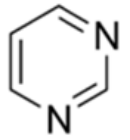
*Pionneer work*
*DNA origamis, structures & design*
*DNA based origamis for sensing*
*DNA bricks*
*DNA multi-enzyme catalysts*

***IV. DNA for nano-electronics***

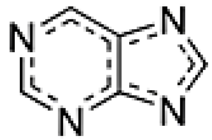
*DNA based nano-lithography*
*DNA based nano-wires*

# DNA, nucleosides and nucleotides



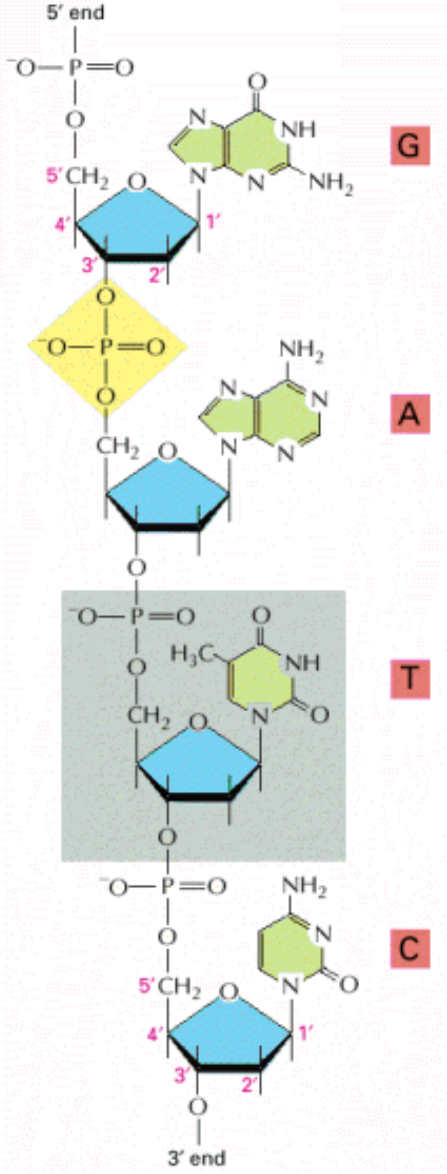



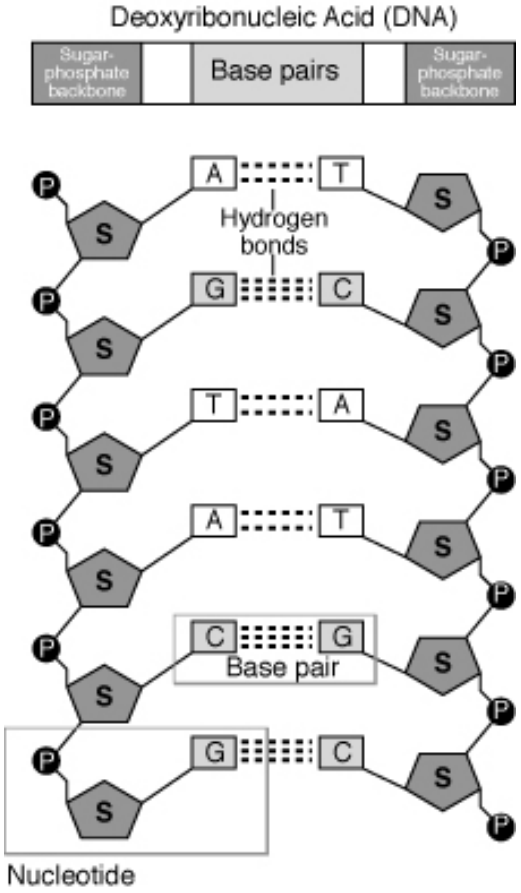
Pyrimidine

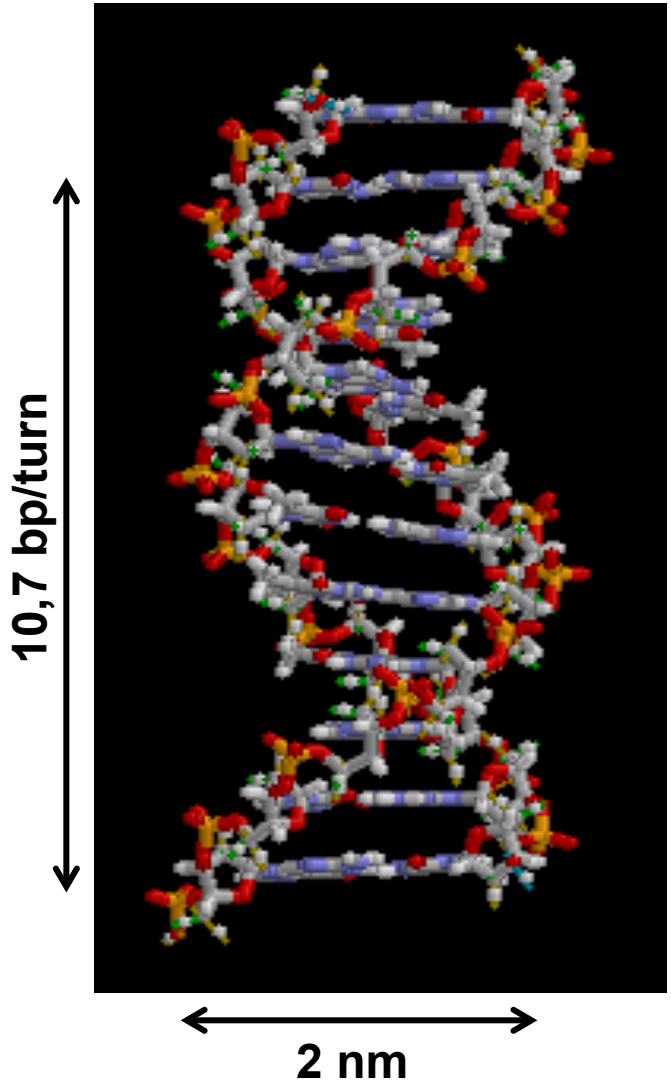


Purine

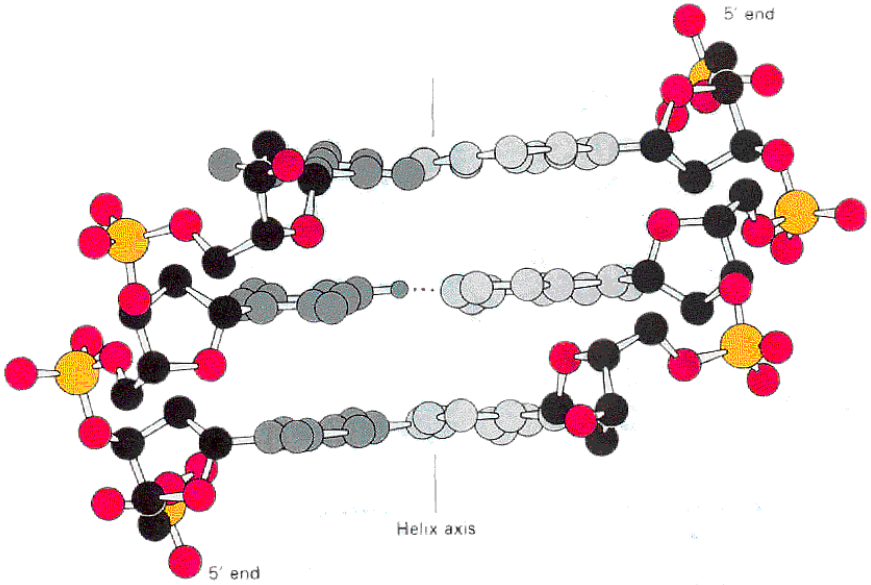
# *DNA self-assembling*

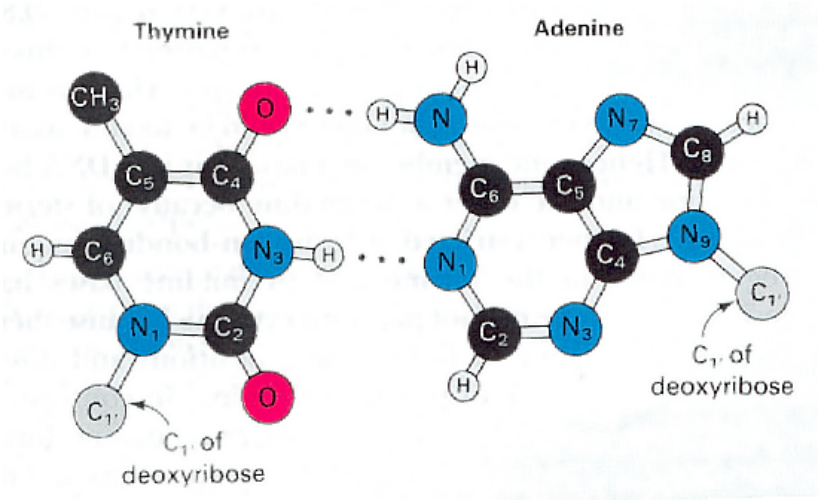


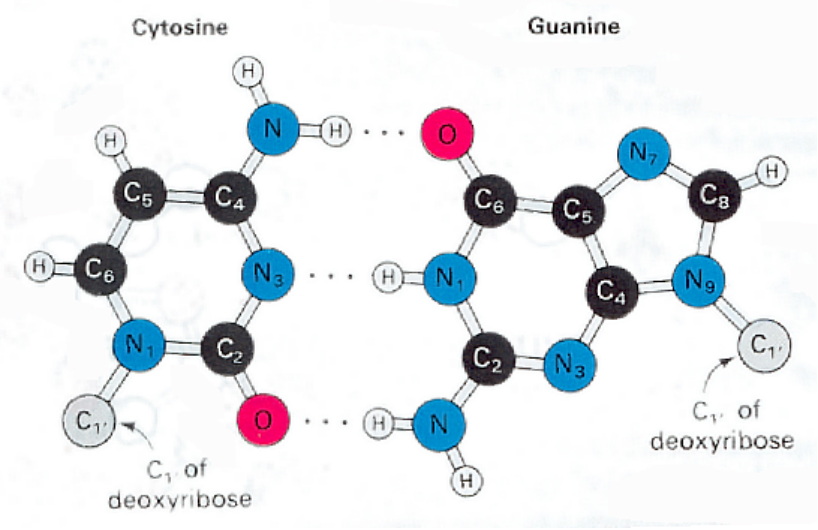



# *Base pairing in a DNA double helix*




**Double helix favorded by:**

1. π-stacking of nucleic bases
2. H-bonding between n.b.
3. phosphate repulsion

# *Base pairing in a DNA double helix*

⇒ very stable structure in physiological conditions. Sensitive to temperature increases, acidic (pH<4) or highly alkaline (pH>10) conditions

⇒ Temperature increases trigger the double strand dissociation = melting
⇒ Melting temperature (Tm) = temperature for which 50% of DNA is hybridized
⇒ Tm depends on DNA sequence and hybridizing domain and salt (NaCl, $MgCl_2$) concentrations:

| **Sequence (5'->3')** | **Tm (C°)** |
|---|---|
| ATCG / CGAT | -38.8 |
| ATCGATCG / CGATCGAT | +26.4 |
| ATCGATCGATCG / CGATCGATCGAT | +49.4 |
| ATCGATCGATCGATCG / CGATCGATCGATCGAT | +61.2 |
| AAAAAAAA / TTTTTTTT | +9.1 |
| GGGGGGGG / CCCCCCCC | +41.5 |
| ATCGATCG / CGATCGAT (1mM NaCl) | +19.4 |

Calcultated with http://www.biophp.org/minitools/melting_temperature/demo.php, 150 mM NaCl and 5 mM $MgCl_2$.

# *DNA self-assembling into a double helix*

Tm= -38.8 °C

5’----AAGTCCTCTTCTATCG
3’----TTCTGGTCAAGT

GTTGCGTGAGCC----3’
TAGCCAACGCACTCGG----5’

Tm= +26.4 °C

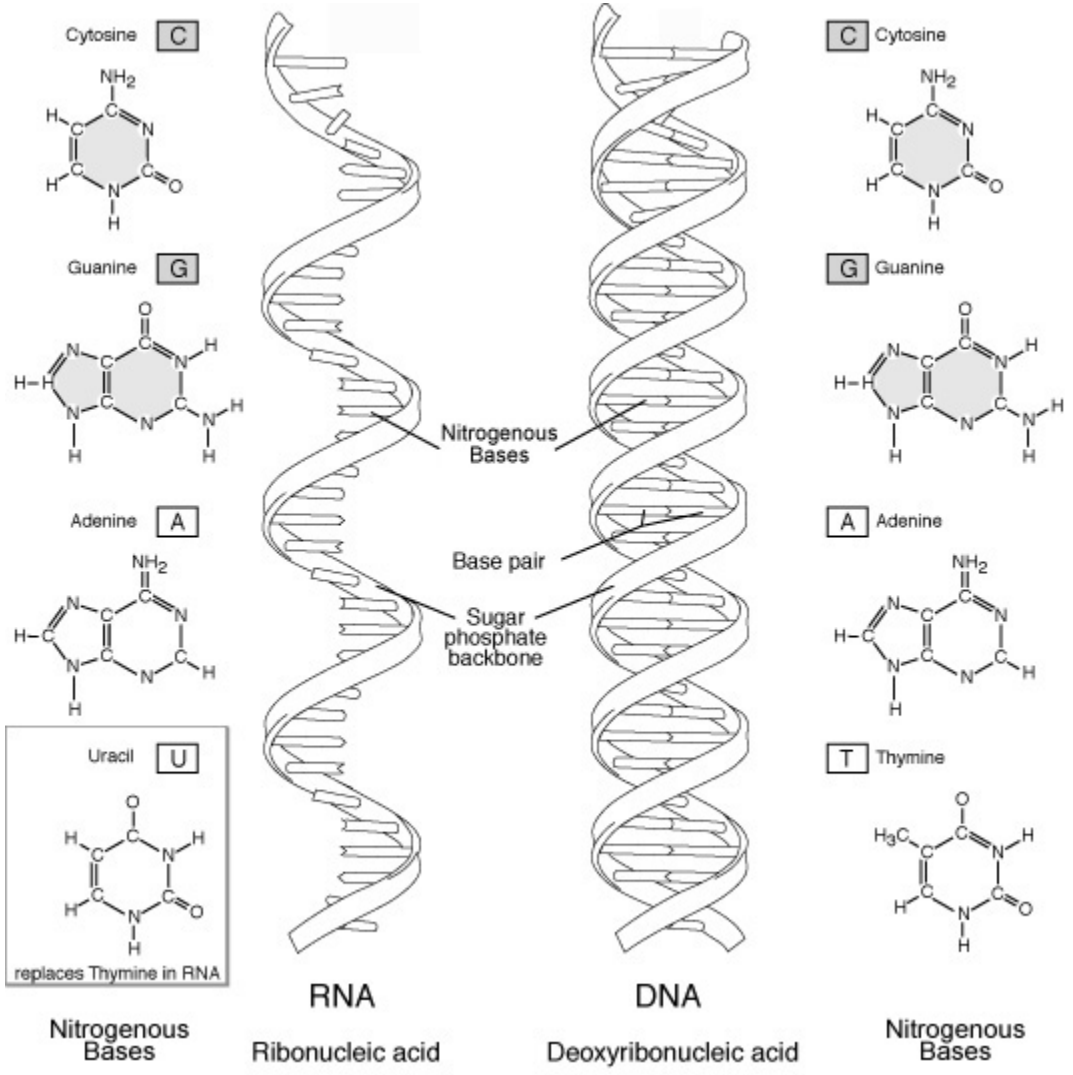
5’----AAGTCCTCATCGATCG
3’----TTCTGGTC

CGTGAGCC----3’
TAGCTAGCGCACTCGG----5’

5’----AAGTCCTCATCGATCGCGTGAGCC----3’
3’----TTCTGGTC TAGCTAGCGCACTCGG----5’

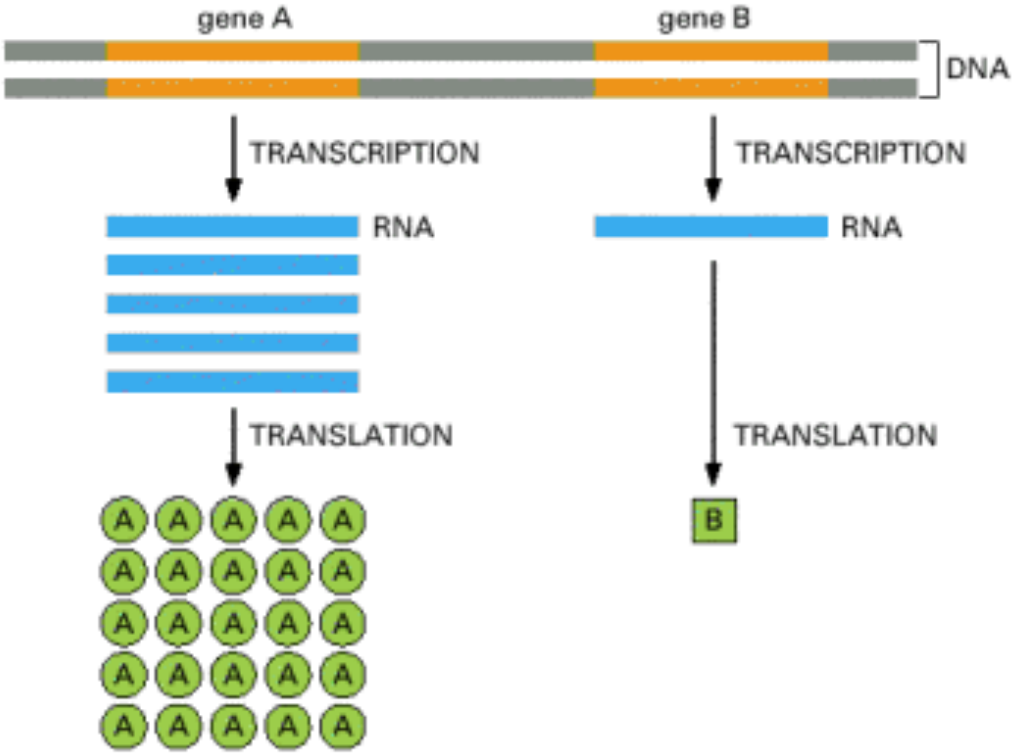
# *RNA structure and functions*

RNA looks like DNA but:
-single strand
-Uracile
-biological / chemical unstability
-many different functions!

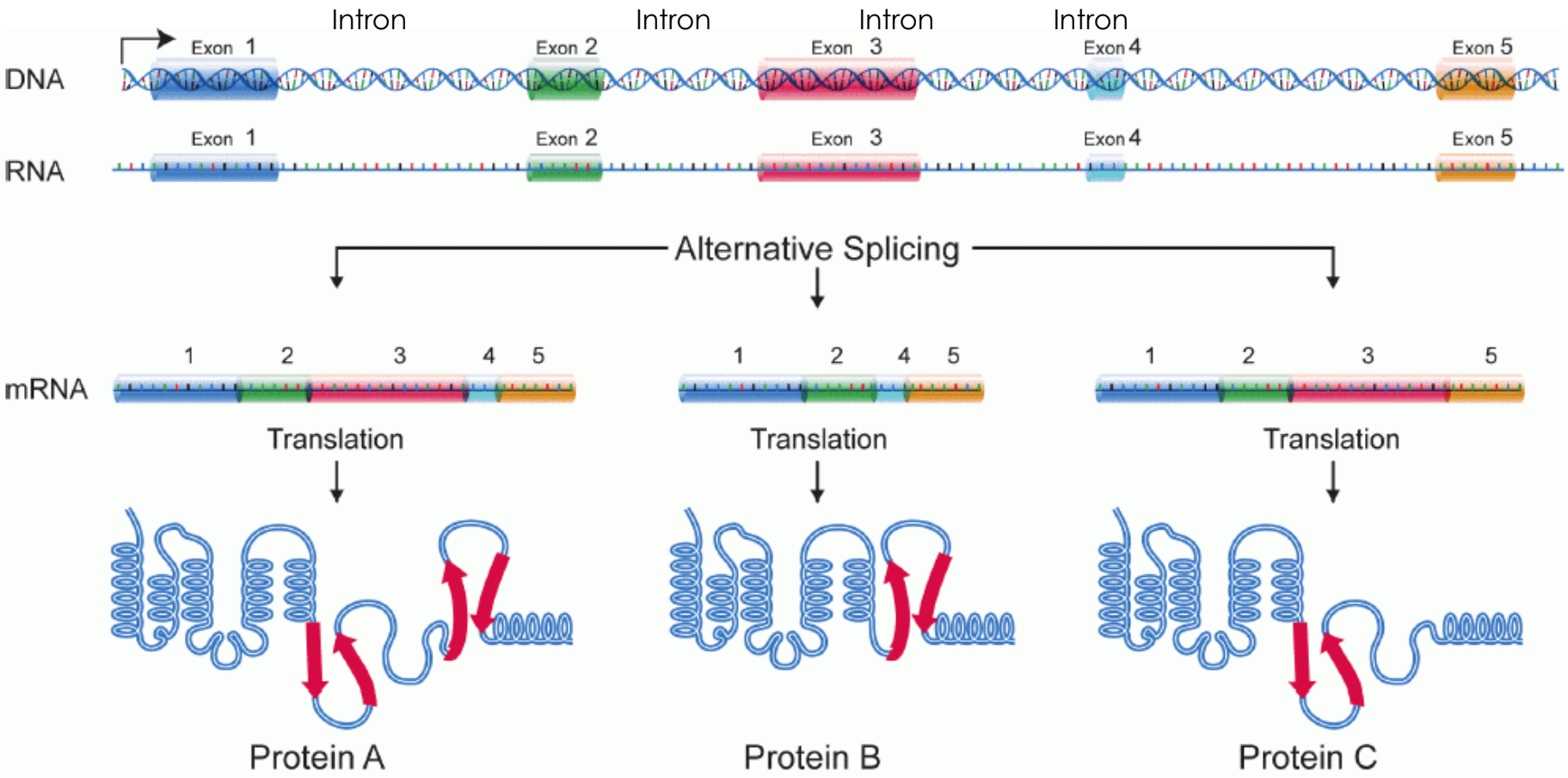



RNA may have different functions (transfert, ribosomal, expression regulation, interference)

# *The central dogma in Molecular Biology*



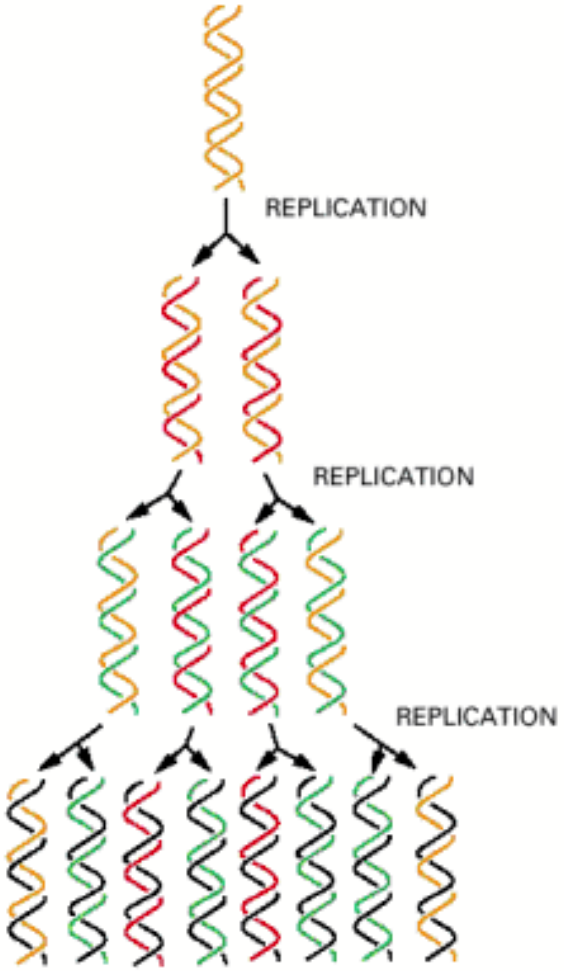
# *Gene structure and function*



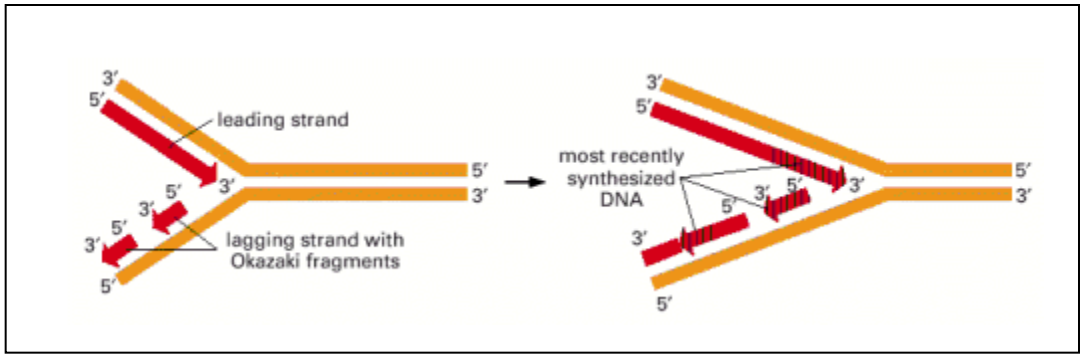

Source: Wikipedia

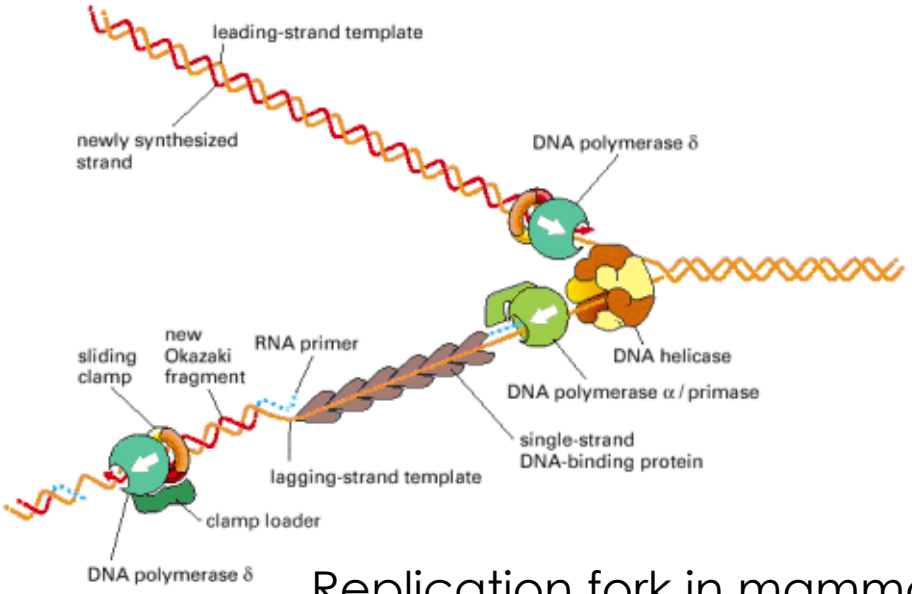
*One gene → Several proteins!!*

# *Duplication of DNA and genetic information storage*



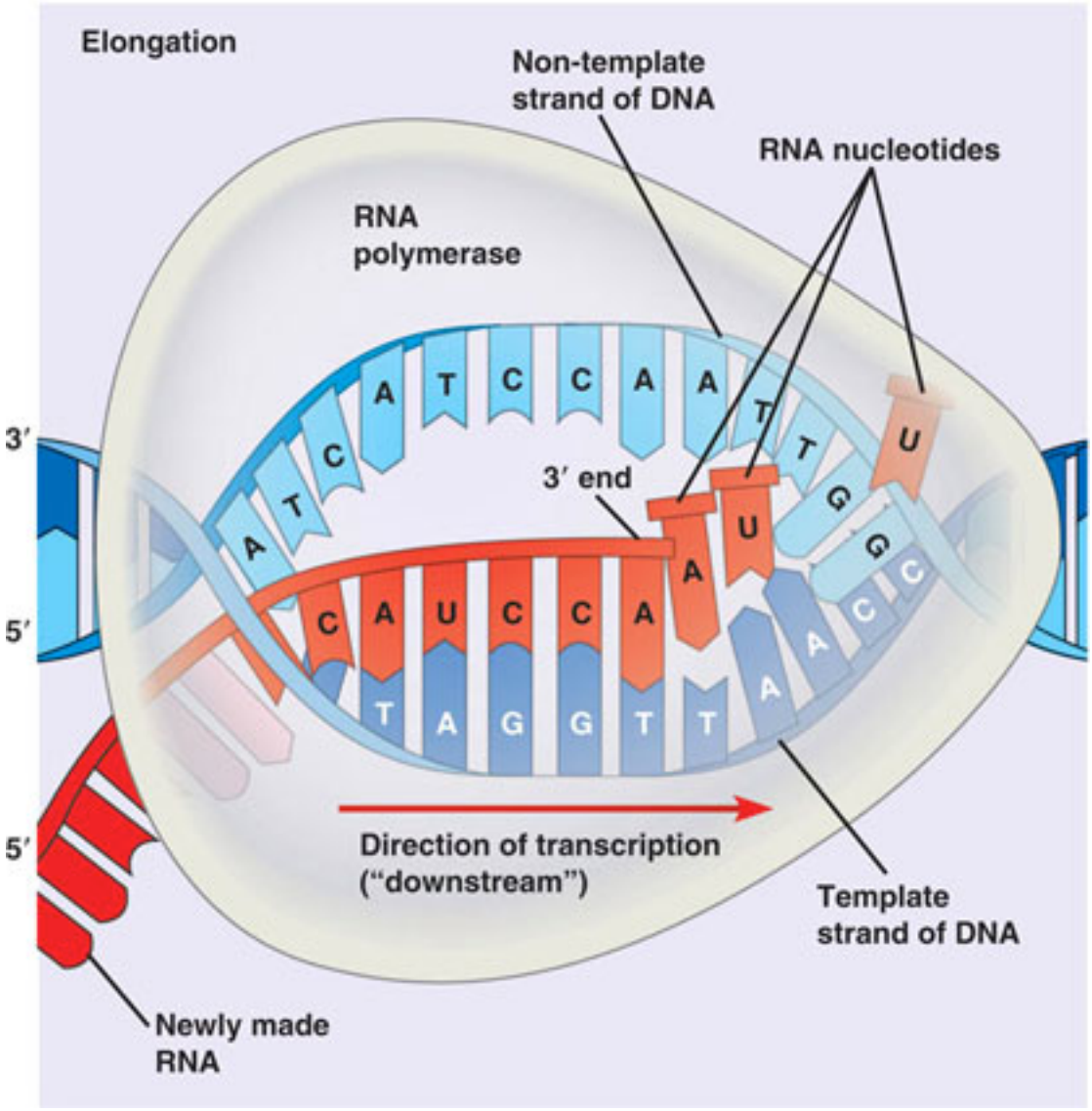

semi-replicative process



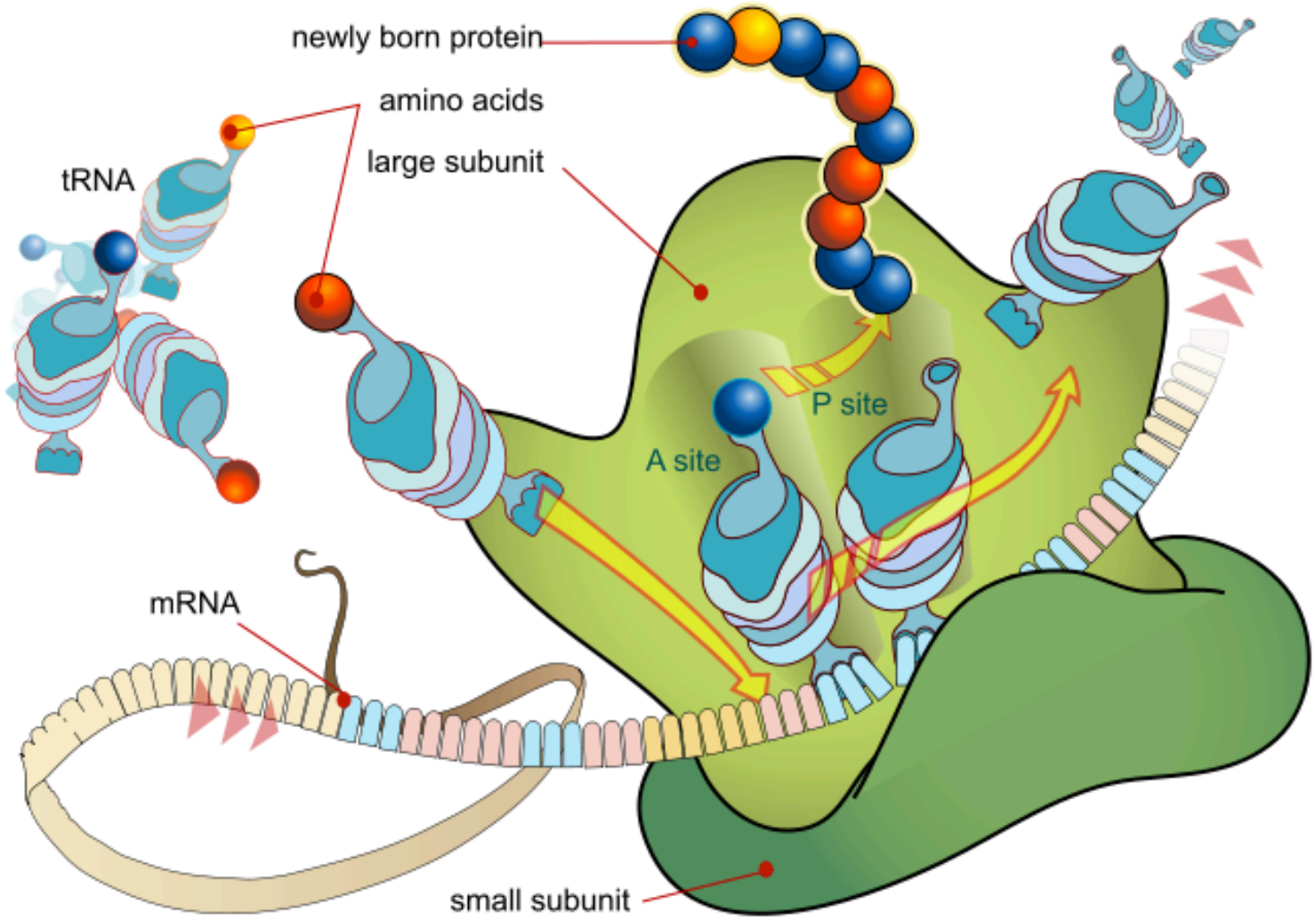




Replication fork in mammals

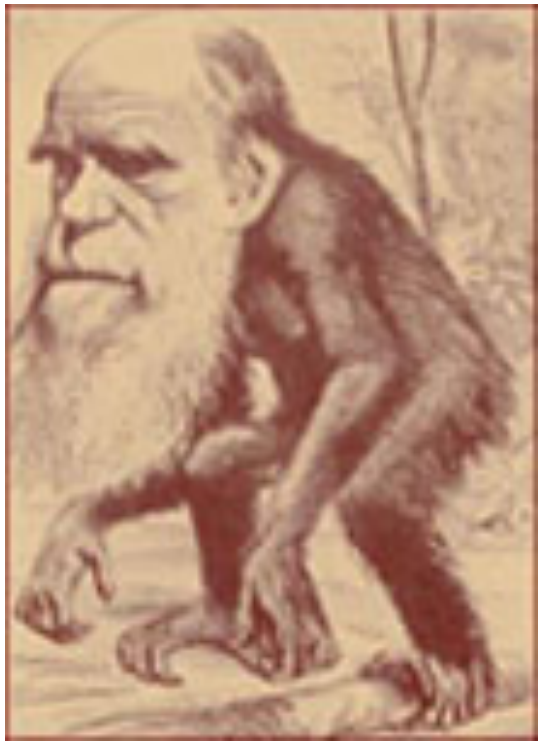
# *Gene transcription in RNA*



# *Traduction of mRNA into proteins*



# *Nucleic acid unstability - Darwinian origin of life*



Principles of Darwinism:
-Evolution is ineluctable
-Natural selection generates evolution
-Possible thanks to genetic variability

Darwin argued that since offspring tend to vary slightly from their parents, mutations that make an organism better adapted to its environment will be encouraged and developed by the pressures of natural selection, leading to the evolution of new species differing widely from one another and from their common ancestors.

"Estimated human intergeneration mutation rate of ~1.1 × $10^{-8}$ per position per haploid genome" Roach et al., Science 30 Apr 2010, Vol. 328, 5978, pp.636-639

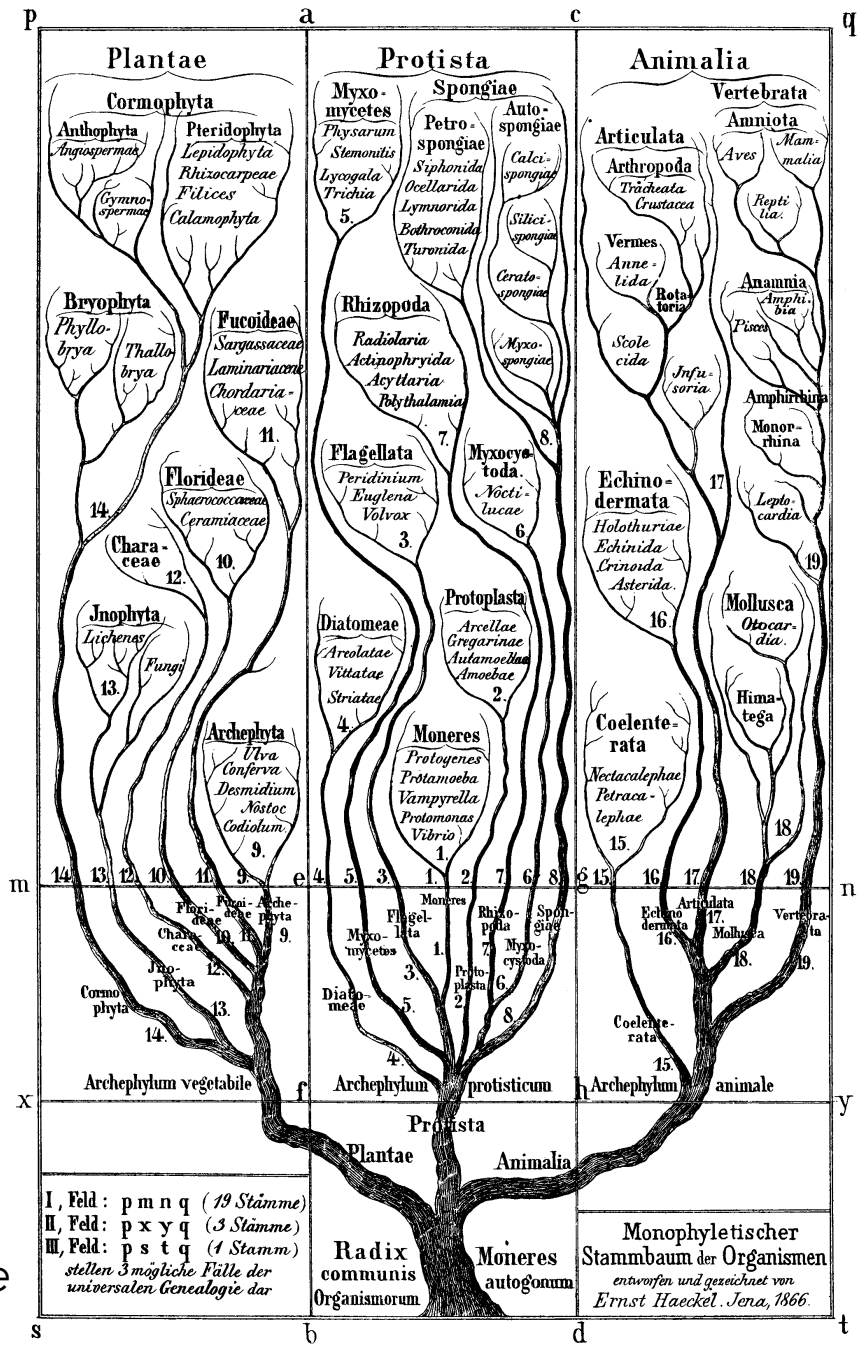
TIME SCALE ISSUES!
(thousands of years, or more)

# *Phylogenesis*

Molecular phylogeny builds the story of evolution for the living organisms

<u>The dogma:</u>
« the closer are two living organisms, the closer are the sequences of their biomolecules (DNA, RNA and proteins).»

<u>Most used sequences:</u>
rRNA >> DNA > proteins




*Tree of Life*

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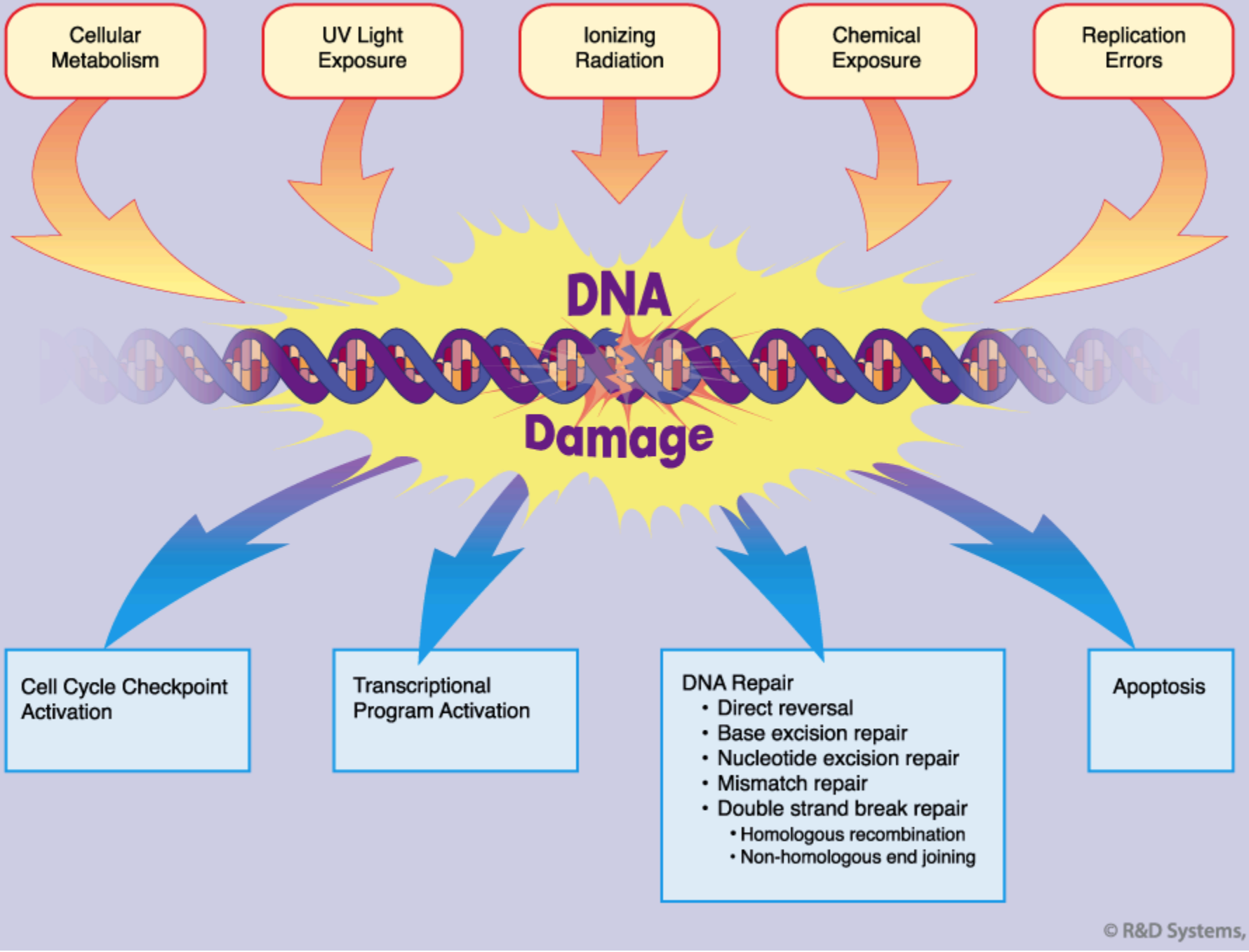


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