Lesson 01: Genetic material

The course plan :

1. Chemical nature of the genetic material

2. Structure of nucleic acids (DNA-RNA)

3. DNA replication: in prokaryotes and eukaryotes

4. Chromosome organization

Introduction :

Genetics is the science that studies heredity and genes in living beings, it is a sub-discipline of biology.

Today, genetics has diversified into several different branches such as:

• developmental genetics• developmental genetics

• medical genetics

• genomics

• quantitative genetics

• population genetics

1. **Nature chemical of material genetic (acids nucleic acids)**

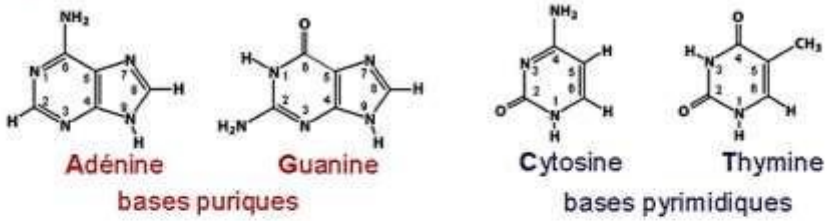
1-1- DNA (deoxyribonucleic acid)

The unit of base of acid deoxyribonucleic (DNA) is the nucleotide.

A nucleotide is composed of three elements:

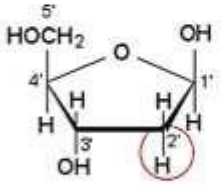
- A base nitrogenous : it exists four different bases
    - Two bases puric acid : Adenine (HAS) Guanine (G)
    - Two bases pyrimidines : Cytosine (C) And Thymine (T)
- A sugar : deoxyribose called pentose (molecule with five carbons)
- A band phosphate (PO_4)

1. Bases

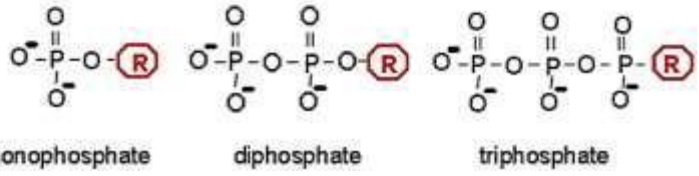


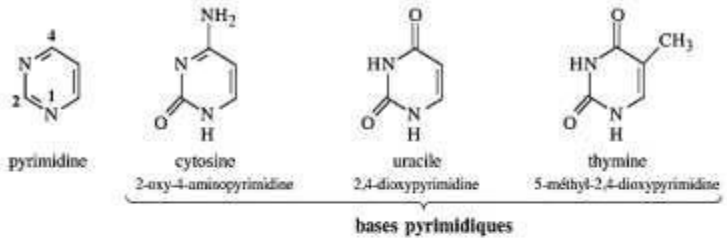
2. Glucide

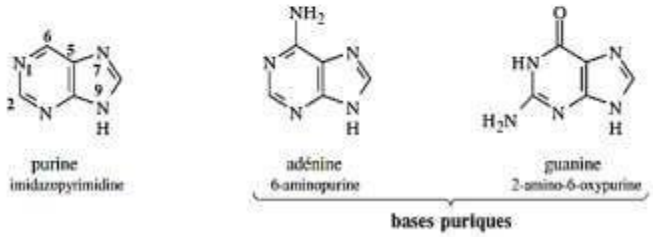
pentose : désoxyribose



3. Groupe phosphate







A nucleoside East formed from a sugar connected has a base nitric by **a connection osidic.**

THE nucleotide is a nucleoside connected to a phosphate group, by **a phosphoric acid sugar bond .**

So we obtains : a nucleotide monophosphate , diphosphate and triphosphate.

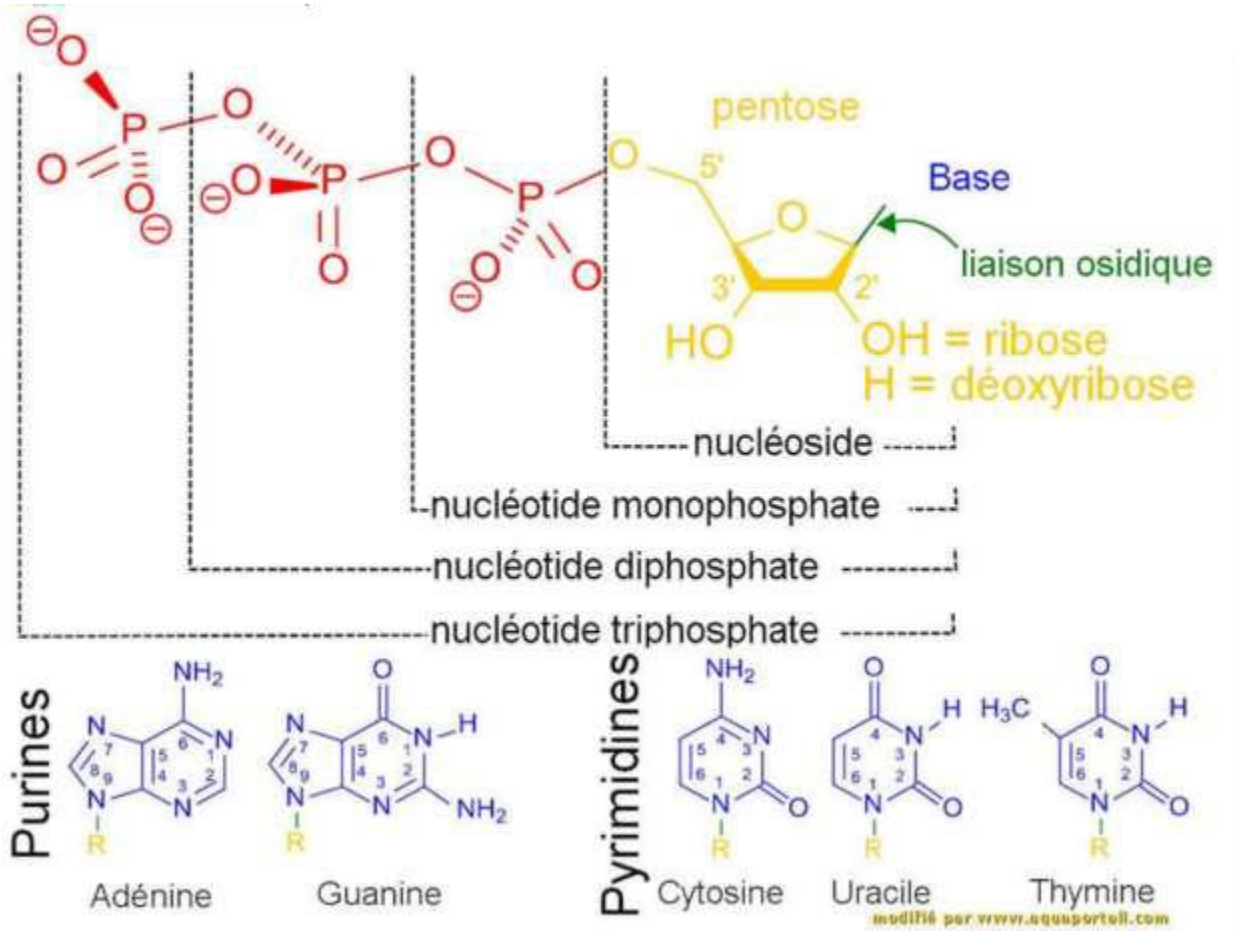


Figure 1 : Composition chemical of a nucleotide

1-2- RNA (acid ribonucleic acid)

Another class of nucleic acids, it is called ribonucleic acid (RNA). It is an intermediate between DNA And THE proteins, he East synthesized In THE core, to leave of DNA during of the transcription.

Its nature chemical is slightly different of DNA For THE following properties :

- RNA contains ribose sugars instead of the deoxyribose sugars that are found in DNA.
- RNA contains there pyrimidine uracil (U) At place of there Thymine (T), and U matches with HAS.

2- Structure of the nucleic acids

2- 1- DNA (acid deoxyribonucleic acid)

THE nucleotides **of a chain** are associates between them by a **connection phosphodiester** oriented of 3' to 5' (between the phosphate group of one nucleotide and the deoxyribose of another nucleotide). They can therefore form long polynucleotide chains .

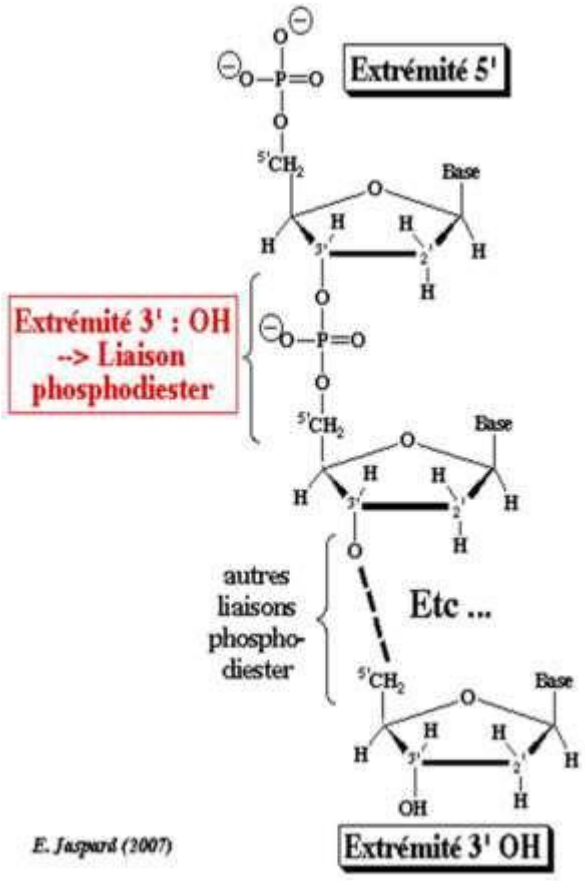


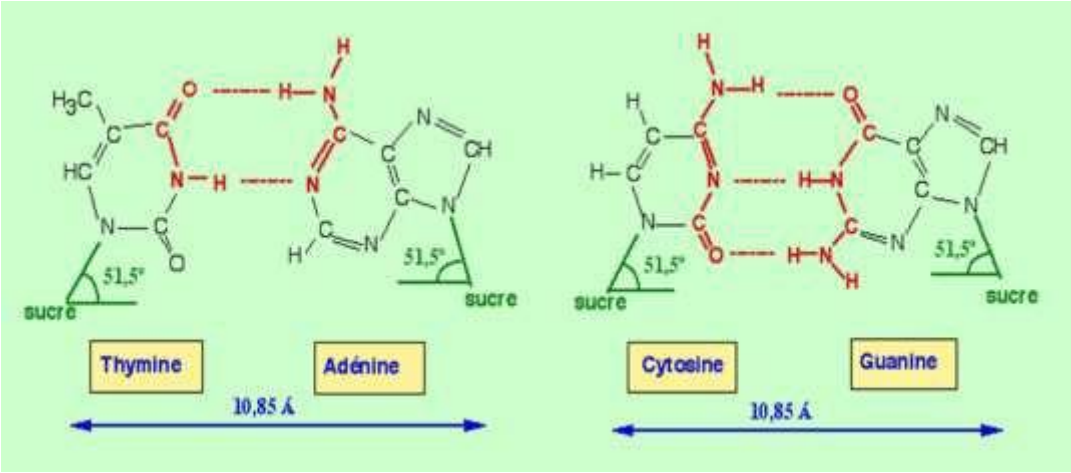
Figure 2: A chain of polynucleotides

DNA is made up of two **antiparallel (running in** opposite directions) **polynucleotide chains:**

- The two chains are associated by **weak hydrogen bonds** between the bases which therefore form pairs: A with T (2 weak bonds) and C with G (three weak bonds).

Purines only associate with pyrimidines and *vice versa*. The bases are said to be **paired** , and the two chains are **complementary** by their nucleotides.

- In a chain THE ends are polarized of 3' towards 5', In the other chain they are of reverse order from 5' to 3'.



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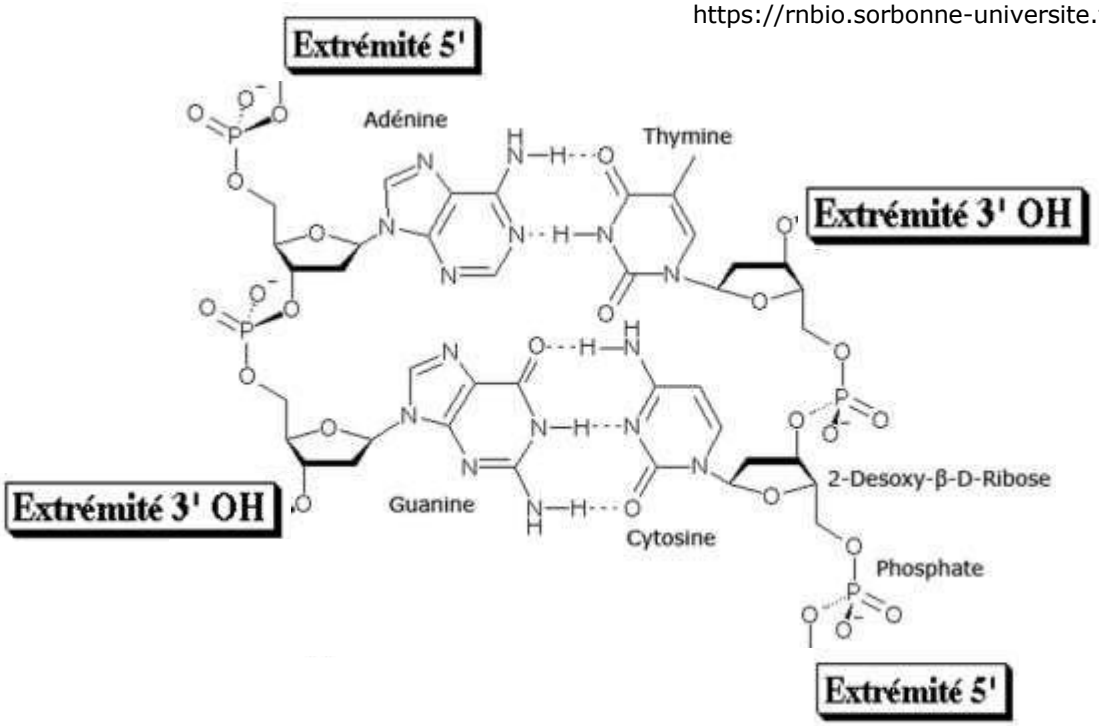


Figure 3 : Two chains polynucleotides complementary

The two chains are wrapped around each other: double helix (double-stranded structure). The bases are buried inside the structure, with the sugar-phosphate backbone on the outside. Once unwound, the DNA molecule can reach up to 7 cm long. The diameter of the molecule is 2 nanometers (nm), the pitch (one turn) is 3.4 nm long and contains 10 base pairs (the

distance between 2 bases of the same strand is 0.34 nm.

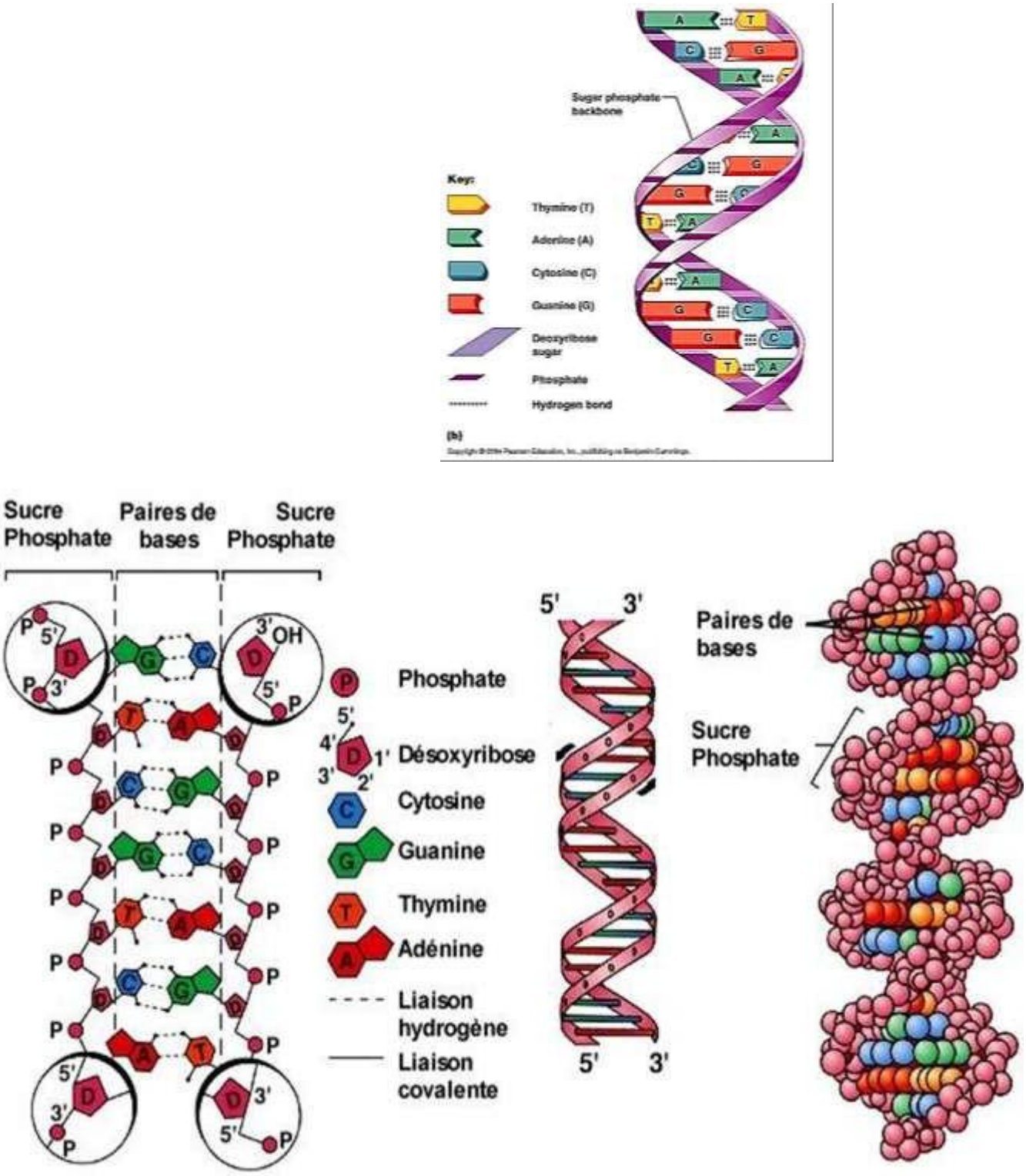


Figure 4: Structure DNA

Each cell of a individual contains THE same molecules of DNA In her core (except in case of illness, mutations, etc.).

The DNA molecule is fragile and the two chains can easily separate (the DNA is said to be denatured) by moderate heating (<50°C) and reassociate (renaturation) if the temperature

drops.

- **Chargaff 's Rule**

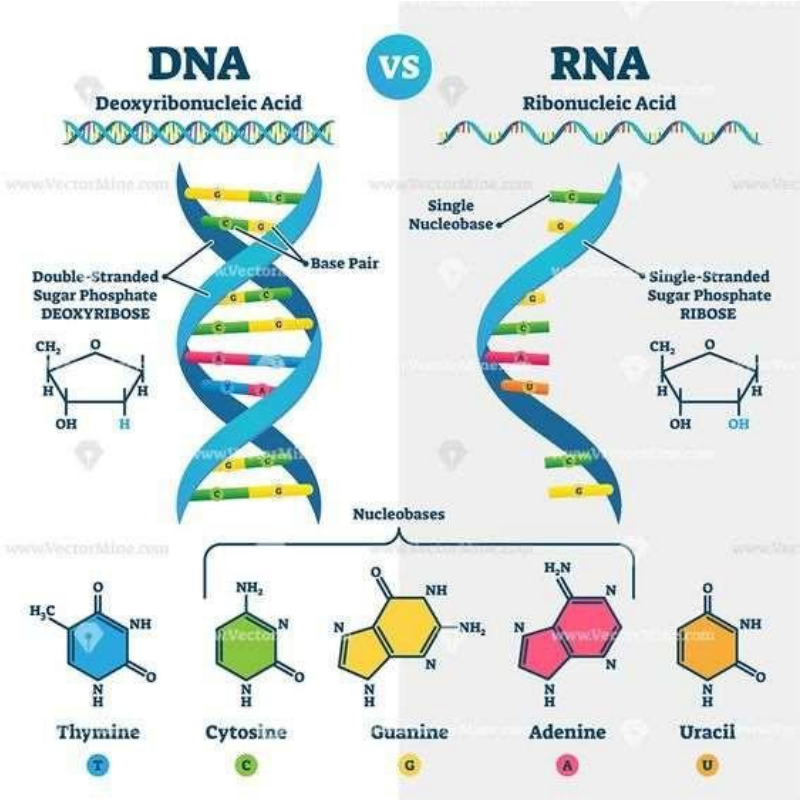
Named after the person who noticed (in the 1940s) that:

- Regardless of the species of origin, DNA always contains as much purine as pyrimidine, i.e.: (A + G) = (C + T) or (A+G) / (C+T) = 1
- Furthermore, there is as much thymine as adenine A/T = 1 and as much guanine as cytosine G/C = 1

2-2- RNA (acid ribonucleic acid)

There structure of RNA East different of that of DNA For THE following properties :

- Cellular RNA is single-stranded, while DNA is double-stranded (double-stranded). However, some viruses have a genome composed of single-stranded DNA, others (but fewer) have a genome composed of single-stranded RNA, and others (even fewer) have a genome composed of double-stranded RNA .
- THE molecules of RNA are a lot more short that THE DNA molecules .
- See below THE differences chemicals and structural between DNA and RNA :



3. Functions of the acids nucleic

3-1- DNA

Thus DNA is a long polymer of thousands of nucleotide base pairs (bp), or a macromolecule composed of a certain number of similar subunits called monomers, covalently attached:

- Container information genetic of the cell and of the organization: Providing THE information necessary for the development of life.
- Responsible persons of there transmission of heritage genetic of generation to generation
- Controlling there manufacturing of the proteins necessary to there life.

3- 2- RNA

THE different RNAs have all A role particular In THE process complex of there protein synthesis:

- rRNA (ribosomal RNA): forms ribosomes with proteins. rRNA is by far the the most abundant RNA in the cell.
- mRNA (RNA messenger) : vehicle information genetic of DNA At site of fixing found on the ribosomes where it is translated into polypeptide chains.
- tRNA (RNA transfer) : door has her end A acid amine Who will be complementary of codon carried by the mRNA which is associated with it by the rules of genetics.

4. Organization of DNA in chromosome

The eukaryotic nuclear genome is fundamentally fragmented into **multiple chromosomes linear** . The number of chromosomes varies widely among species.

THE painting below, contains a few examples :

Animaux				Végétaux			
Drosophile	8	Homme	46	Crocus	6	Tomate	24
Grenouille	26	Chimpanzé	48	Jacinthe	8	Riz	24
Hamster chinois	22	Vache	60	Pois	14	Lis	24
Chat	38	Cheval	64	Oignon	16	Tabac	48
Souris	40	Ane	62	Levure	18	Pomme de terre	48
Rat	42	Chien	78	Maïs	20	Fougère	100
Singe Rhésus	42	Poule	78	Haricot	22		
Lapin	44						

A **chromosome** consists of one chromatid (single chromosome – in the G1 phase of the cell cycle) or **two chromatids** (double chromosome = duplicated – in the G2 phase of the cell cycle). In the latter case, these are two identical chromatids (sister chromatids).

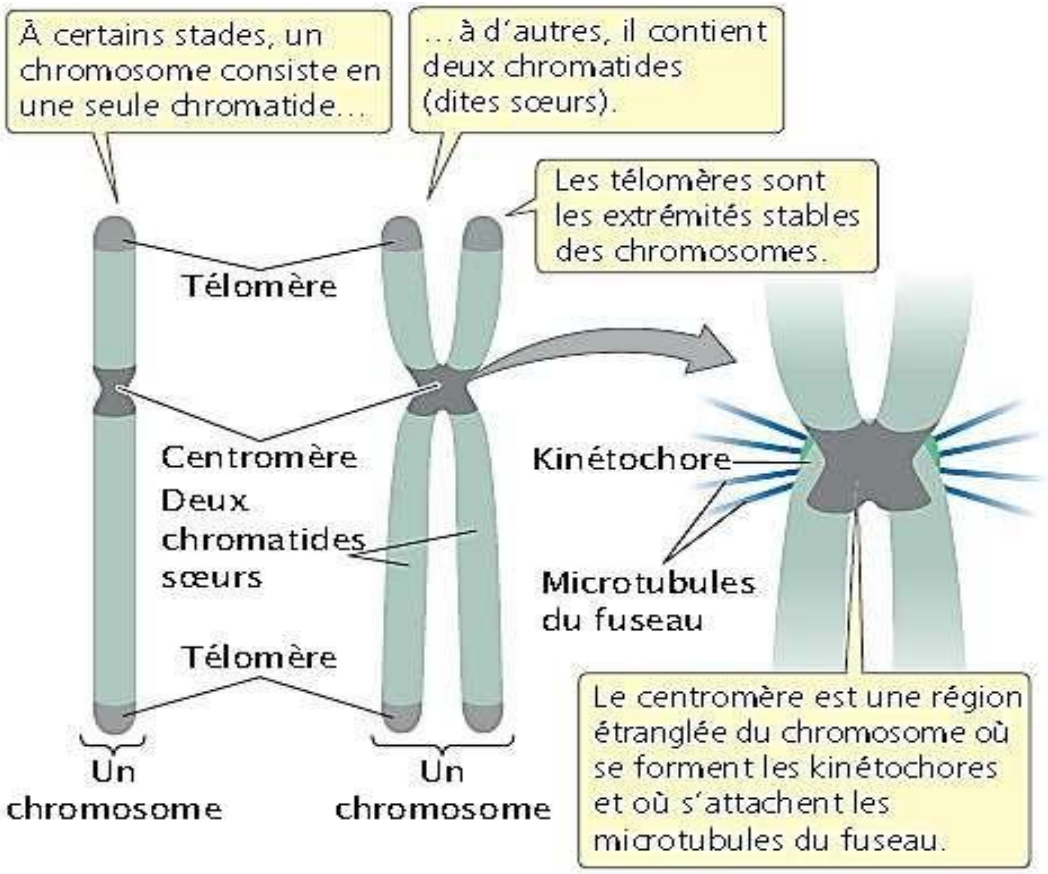
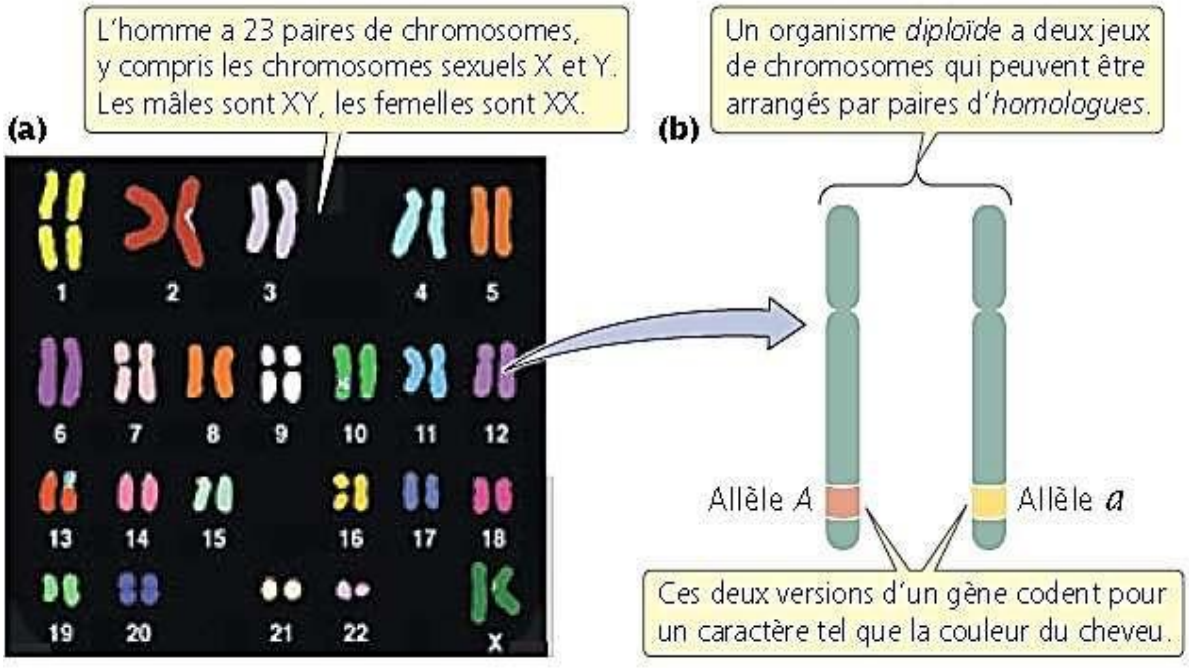
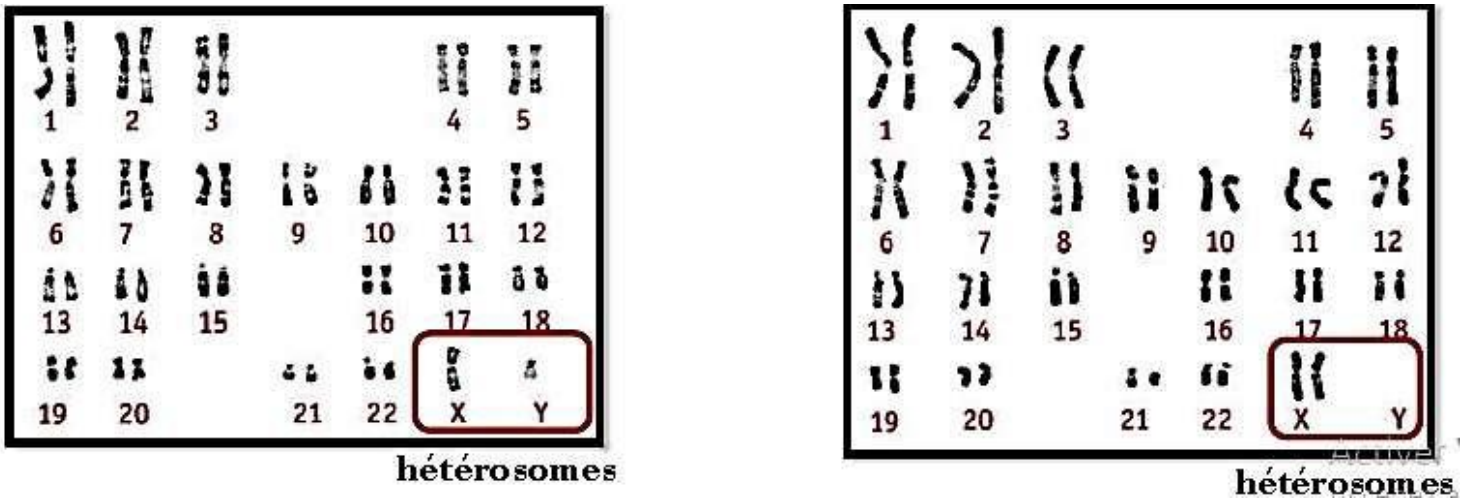


Figure 5: Schema representative of a chromosome metaphasic

THE cells eukaryotes have two games of chromosomes :



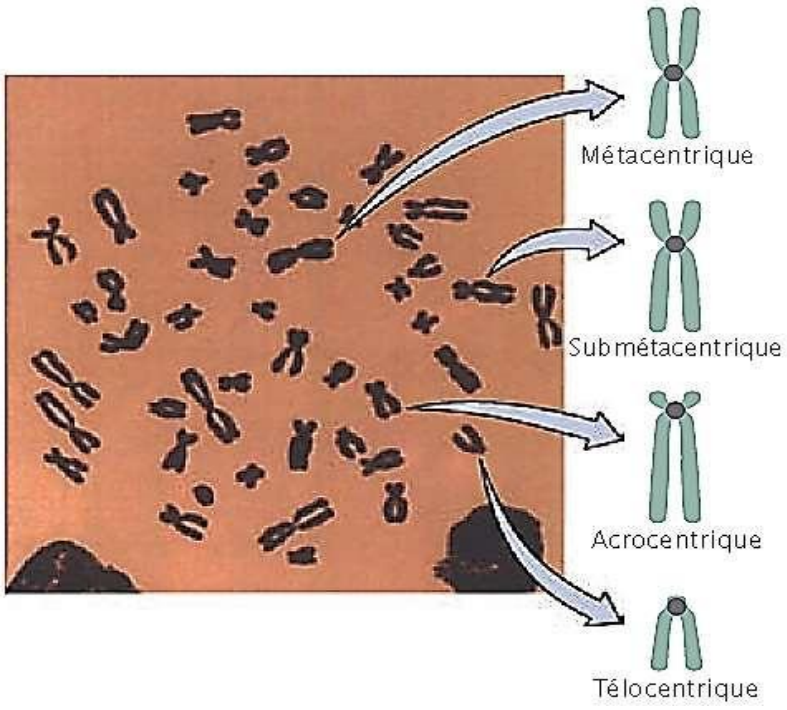
For many species one of the chromosome pairs may be morphologically different from one sex to the other, these are **heterosomes** : sex chromosomes are involved in determining sex. THE others pairs born are not sexual ; are constituted of chromosomes counterparts similar, they are **autosomes.**



Karyotype of the human karyotype of women

Figure 6 : Karyotype human

According to there position of centromere, on distinguished four types main of Eukaryotic chromosomes : Metacentric, Submetacentric , Acrocentric, Telocentric



Chromatin is a eukaryotic DNA molecule associated with proteins: there are two types of associated proteins, working proteins (enabling transcription, replication, genetic expression, etc.) and **structural proteins including histones** .

THE histones are of the proteins strongly rich basics in acids amino acids arginine And lysine, which facilitate binding to negatively charged DNA. The main histones are H1, H2A, H2B, H3 and H4.

The association **DNA + proteins (** DNA, 147 base pairs, is wrapped around the structure formed by histonesaround the structure formed by histones (histone octamer) (H2A, H2B, H3, H4) **)** to do according to A model GOOD defined : **THE nucleosome** Who constitutes the first level of DNA compaction in the nucleus. This structure is then regularly repeated to form the nucleofilament or nucleosomal fiber ; which can, itself, adopt more compact levels of organization.

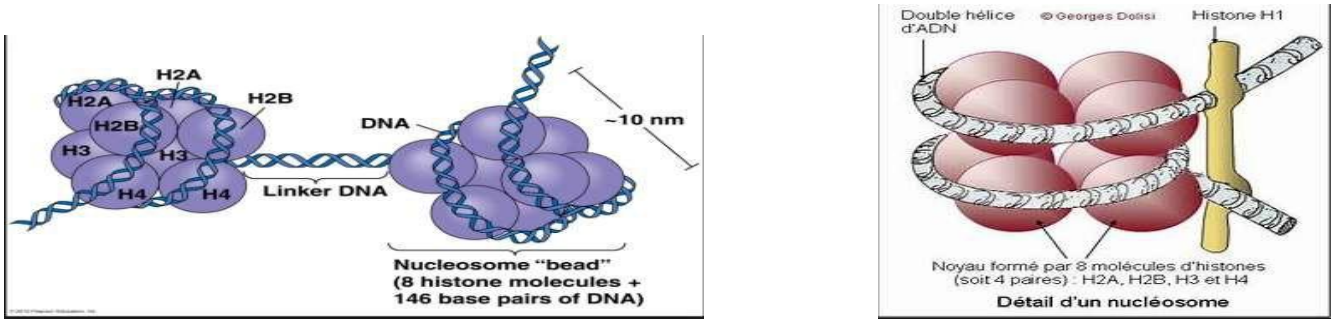


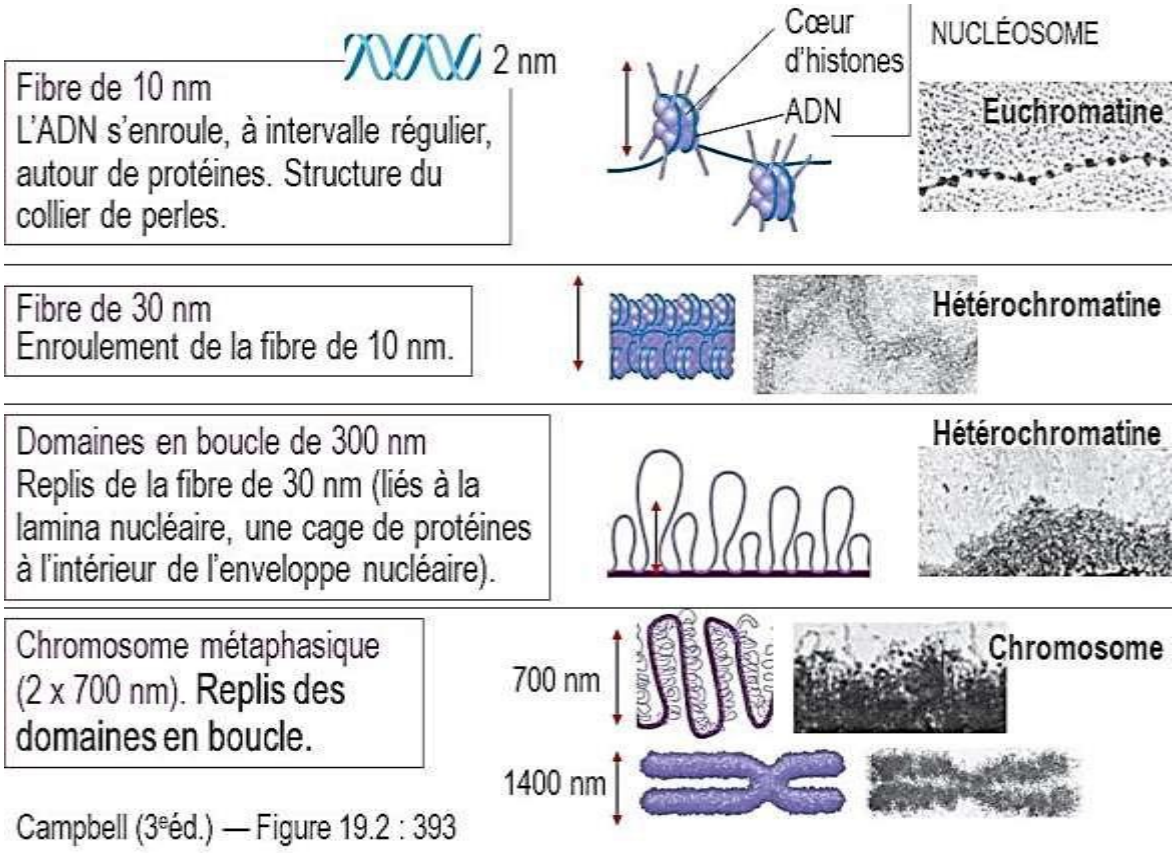
Figure 7 : Fiber nucleosomal = DNA+ protein

It is the more or less accentuated degree of spiralization and compaction of the nucleosomal fiber which generates the two aspects of **chromatin** :

- **Heterochromatin** (inactive And condensed), localized mostly in periphery of core and of the nucleolus.
- **Euchromatin** related to different functional states of DNA (active and dispersed), distributed inside nucleoplasm.

THE Genoa of the Eukaryotes born can not to express oneself (born can not serve of matrix has there synthesis of proteins) if they are associates of manner forte to histones. By consequent, there first stage in gene expression involves dissociation of DNA from histones.

The appearance physical of material genetic is explained by his miscellaneous levels of condensation :



- Le **nucléoplasme** contient : ADN, ARN et protéines
- **Hétérochromatine**: forme condensée de l'ADN, contient l'ADN qui est considérée comme en grande partie inactif (télomères, ADN ne contenant pas de gènes, gènes non transcrits).
- **Euchromatine**: Forme déballée de l'ADN qui est considérée comme contenant la portion active de l'ADN (gènes transcrits).
- **Nucléole**: contient les gènes de l'ARNr, site de synthèse des ribosomes (formés d'ARNr).

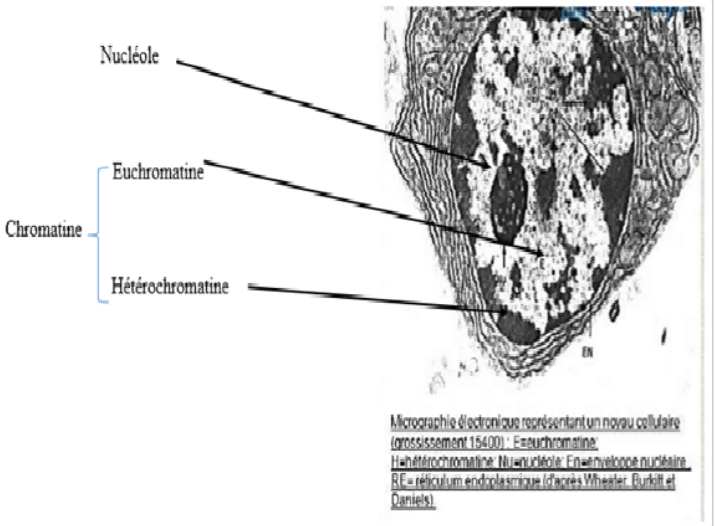


Figure 08: Appearance of DNA in the nucleus of cells

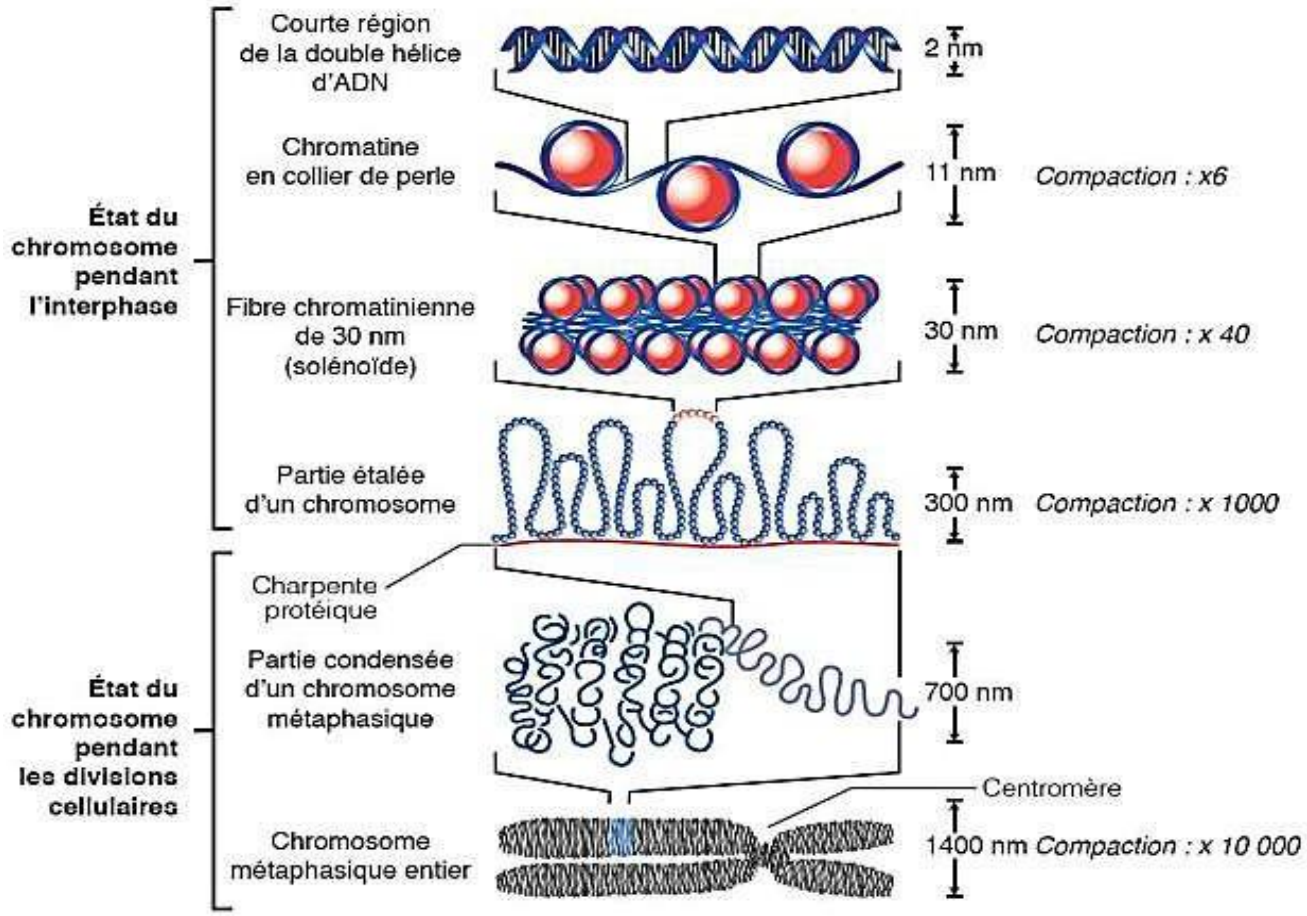


Figure 9 : Levels structural hypothetical of the organization of DNA in chromosome during condensation in eukaryotes according to Seggara et *al* . (2014) *in* Tanguy (2017)

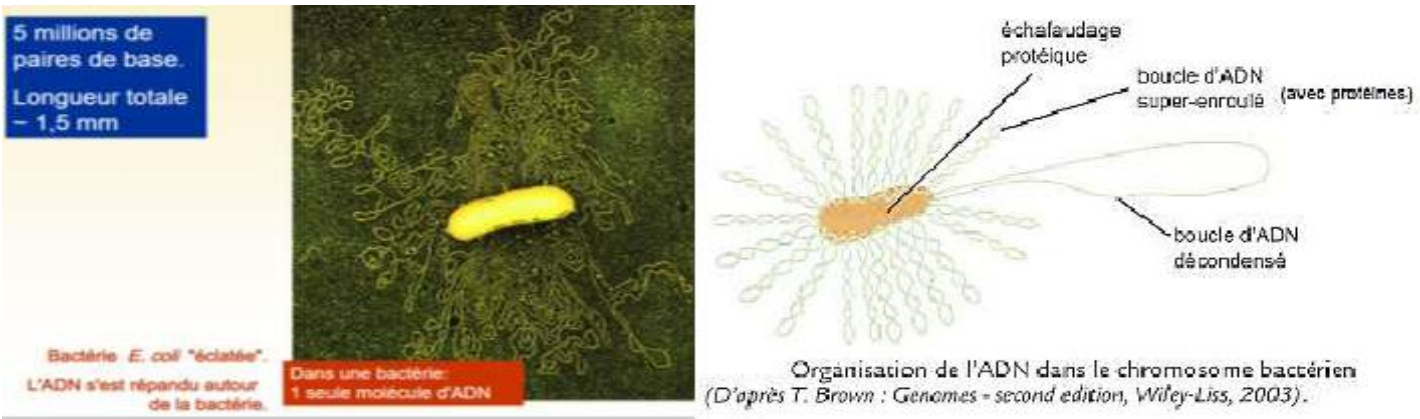


Figure 10 : Organization of chromosome bacterial (Tangury , 2017)

In prokaryotes, the chromosome is made up of *"naked" DNA* (absence of histone-type proteins, but there are associated proteins all the same, notably those which intervene in regulation and some structural proteins which we call **NAP** , *Nucleoid Associated Proteins*) *circular (rarely linear) and folded into about fifty loops associated with a protein core* . Condensation is permitted by **supercoiling** of the DNA permitted by NAPs; **topoisomerases** also manage the degree of coiling and therefore compaction of the DNA. The bacterial chromosome is often **circular** .

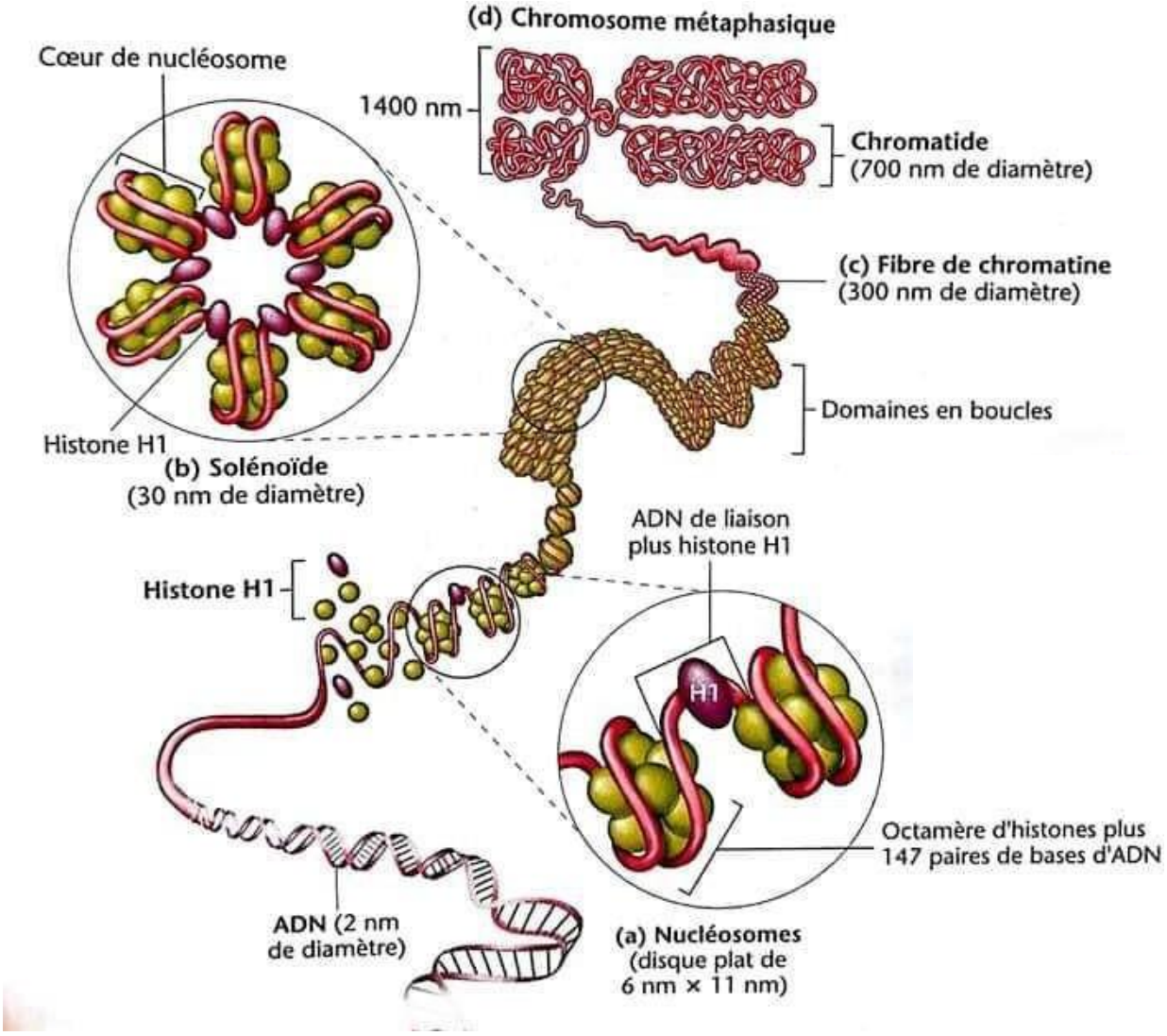
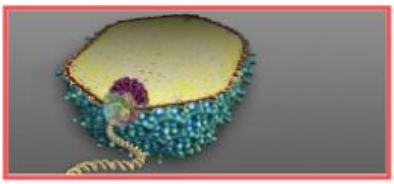
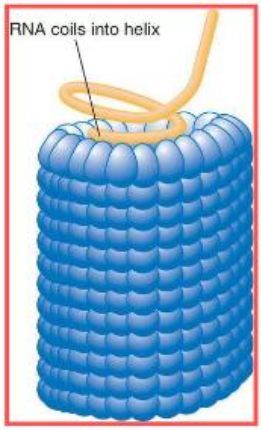
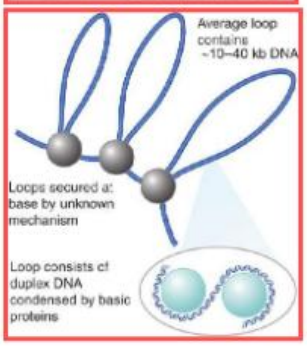


Figure 11 : Of DNA to the chromosome

Compactage de l'ADN chez les micro-organismes







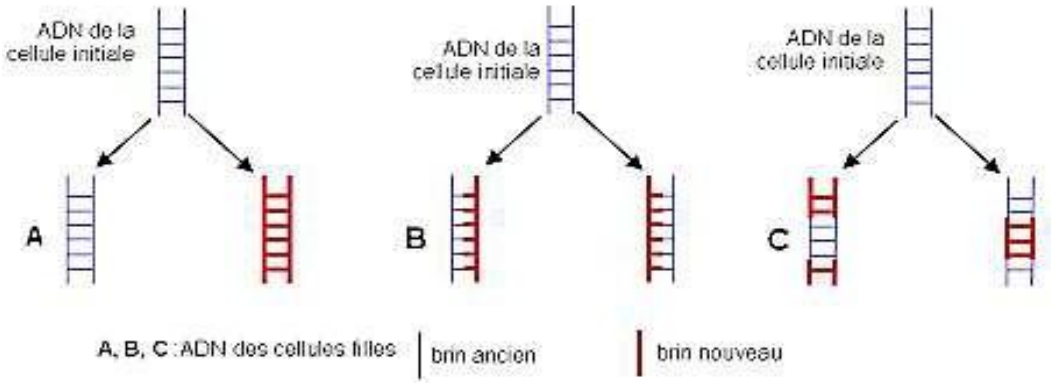
- **Chez les virus, une molécule d'ADN génomique est associé à des molécules protéiques et emballés dans des capsides virales.**
- **Chez les bactéries, l'ADN génomique est associé à des protéines et est emballé comme une masse compacte à l'intérieur du centre de la cellule. Il est appelé comme "nucléoïde"**

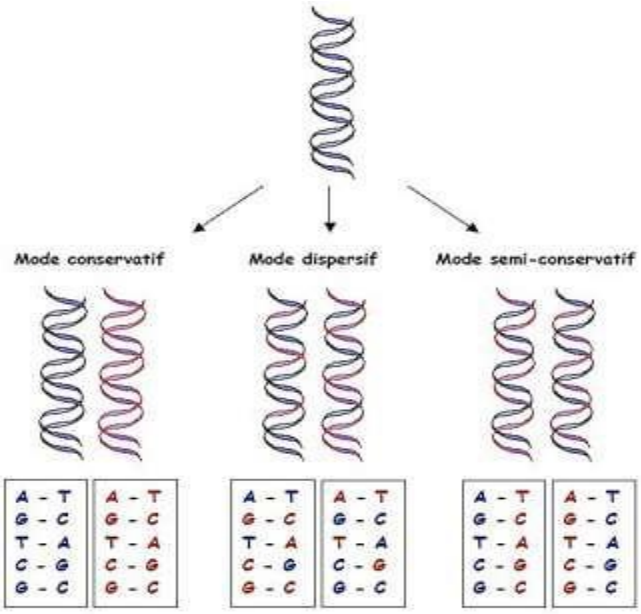
5. Replication of DNA

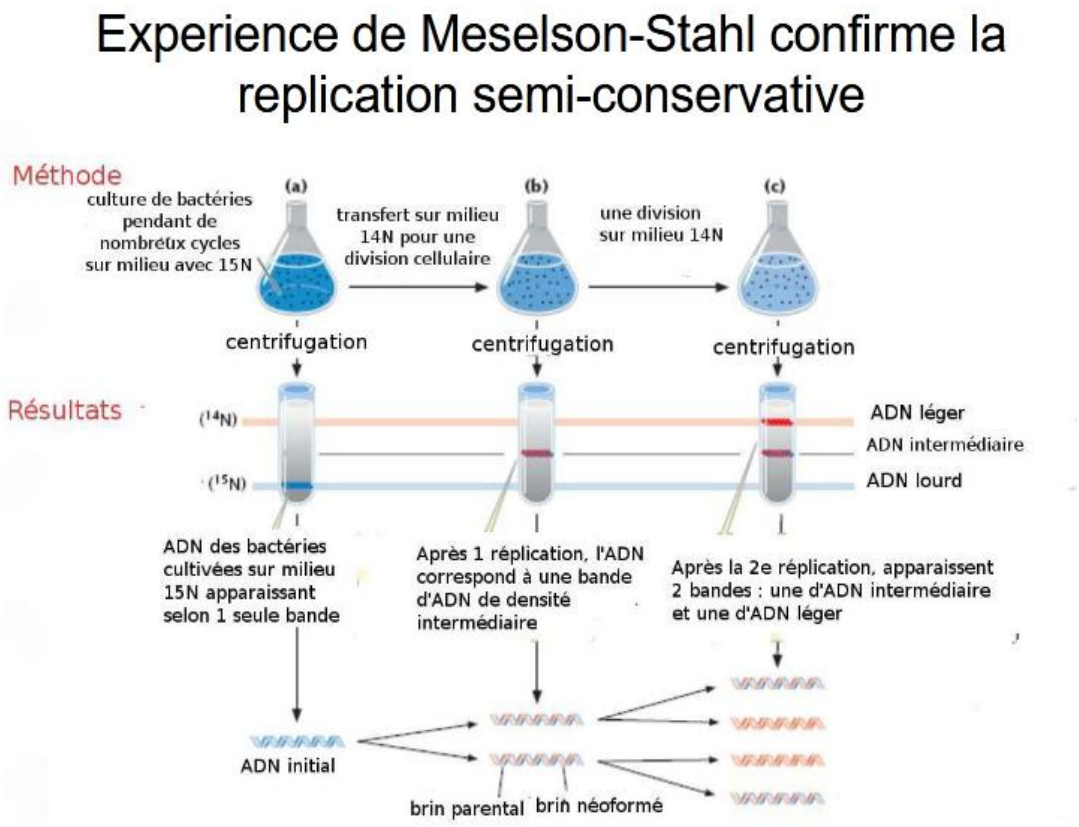
two molecules to be obtained from a DNA molecule. **identical has there molecule initial** , This Who allow has information genetic of to transmit from a mother cell to daughter cells during **cell division** .

DNA is replicated by the unwinding of the two strands of the double helix and the synthesis of a new strand complementary to each of the separate strands constituting the original double helix.

There replication East said **semi-conservative** because each molecule girl East in do composed has 50% of a parent molecule.







DNA replication occurs through the unwinding and opening of nucleotide chains (DNA parent molecules), each of which becomes a template.

The replication eye refers to the shape what does the molecule take during of replication. Replication occurs at x ends of each eye (replication forks) until that the whole molecule has been copied and the replication eyes joined together.

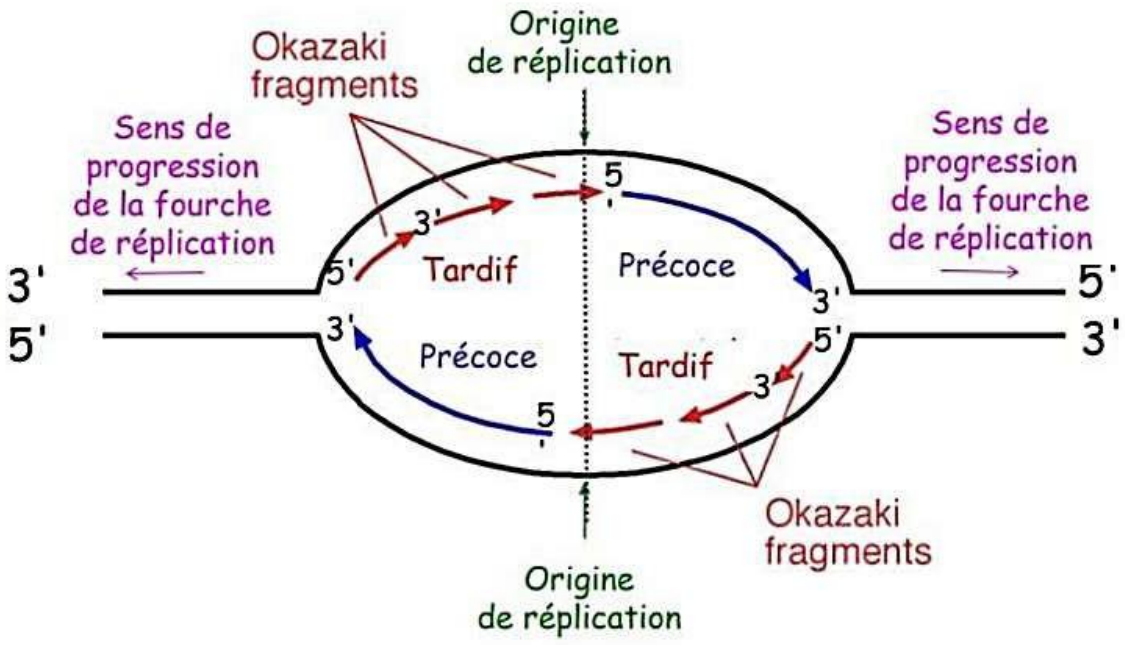


Figure 13: Eye of replication with two opposite forks

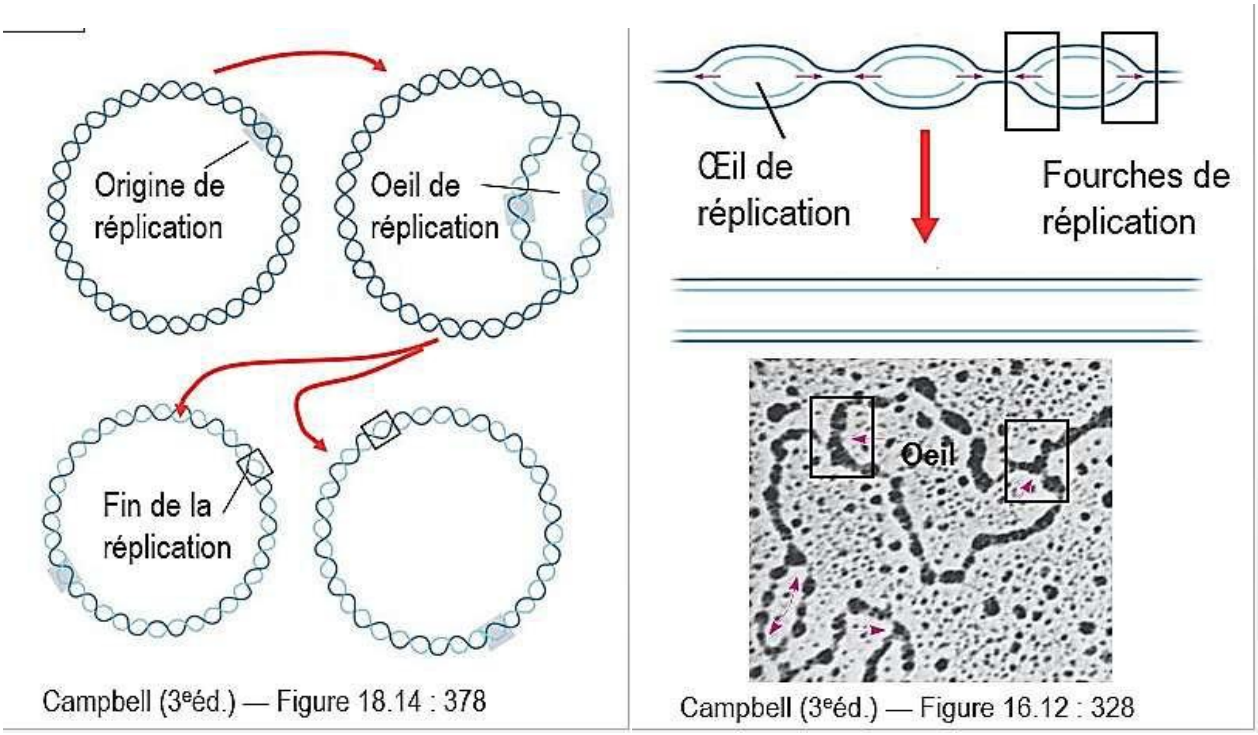
In there fork of replication :

- A strand is synthesized in the direction of movement of the fork (continuous synthesis) => **synthesis of the early strand**

-A strand East synthesized In THE sense reverse (synthesis discontinued) => synthesis of fragments juxtaposed called Okazak fragments **(late strand).**

In prokaryotes , the origin of replication is often **single** and replication proceeds in both orientations from this point.

In **eukaryotes** , replication occurs from **multiple origins** . Hundreds or even thousands of thousands of replication eyes open on each of the linear chromosomes.



Prokaryotes **Eukaryotes**

Figure 14: Forks of replication : comparison between prokaryote and eukaryotic

THE progress of there replication :

- Each DNA molecule unwinds and separates into two strands which will serve as a template for the DNA synthesis (by breaking hydrogen bonds).
- **THE proteins of replication** will go to stick to the origins allowing the opening of the two strands of DNA and thus cause replication forks to appear.
- DNA nucleoside triphosphates, already synthesized and present in the nucleus, approach the 3' ends of the two forming DNA strands.
- Replication occurs in the 5'–3' direction, with nucleosides pairing with DNA bases **by hydrogen bonds** and according to the rules of complementarity: A-T/GC, in an antiparallel mode.
- This process involves a nucleotide polymerization enzyme which is **DNA polymerase.** This enzyme needs to synthesize a DNA chain: The four deoxyribonucleotides 5'- triphosphates (dATP , DGP , dTTP , dCTP) and Mg2+, and the DNA template.
- DNA polymerases prokaryotes are of 3 types (I, II and III) and THE DNA

polymerases eukaryotes of 5 types (α, β, δ, ε and γ).

- DNA polymerase adds of the deoxyribonucleotides has the end 3'OH of a primer, he releases pyrophosphate of each nucleoside Who is added And used energy cleared by there reaction For join (polymerize) nucleotides together by **phosphodiester bonds .**
- In the other DNA template, fragments consist of an RNA primer and a thousand DNA nucleotides : a primer RNA is synthesized by **the primase** then DNA polymerase III polymerizes DNA from this primer. Then the RNA primer is degraded and DNA polymerase I plugs the gaps. Finally, **ligase** glues the fragments together

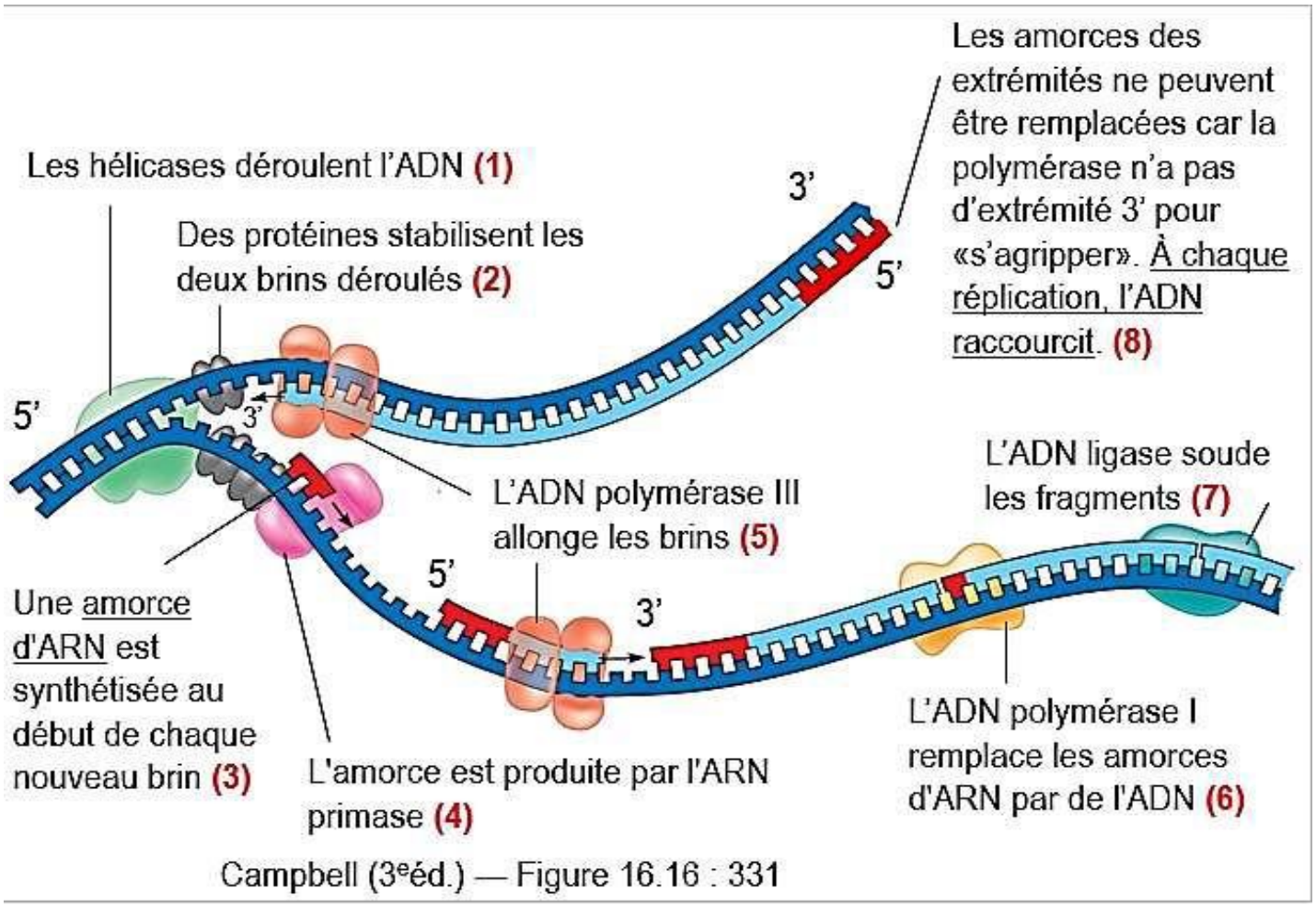


Figure 15: Steps and the proteins involved In there replication of DNA

les étapes de la réplication

Étape	Description
1. Initiation	Formation d'une origine de réplication avec des protéines qui reconnaissent et se lient à la séquence d'ADN.
2. Déroulement	Déroulement de la double hélice par une enzyme appelée hélicase, formant ainsi des fourches de réplication.
3. Synthèse des amorces	Synthèse de courtes amorces d'ARN par une enzyme appelée primase. Ces amorces permettent le démarrage de la synthèse d'ADN.
4. Synthèse des brins en continu et en discontinu	Synthèse du brin continu (brin avancé) dans la direction 5' vers 3' par ADN polymérase. Synthèse du brin discontinu (brin retardé) sous forme d'Okazaki.
5. Élongation	Ajout de nucléotides complémentaires à chaque brin en utilisant l'ADN polymérase.
6. Liaison des fragments	Liaison des fragments d'Okazaki par une enzyme appelée ligase.
7. Vérification et correction	L'ADN polymérase vérifie l'exactitude de la nouvelle séquence d'ADN et effectue des corrections au besoin.
8. Terminaison	Arrêt de la réplication une fois que l'ensemble du génome a été copié.