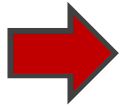


Cours Biochimie I

Leçon 4: Structure de la DNA et RNA



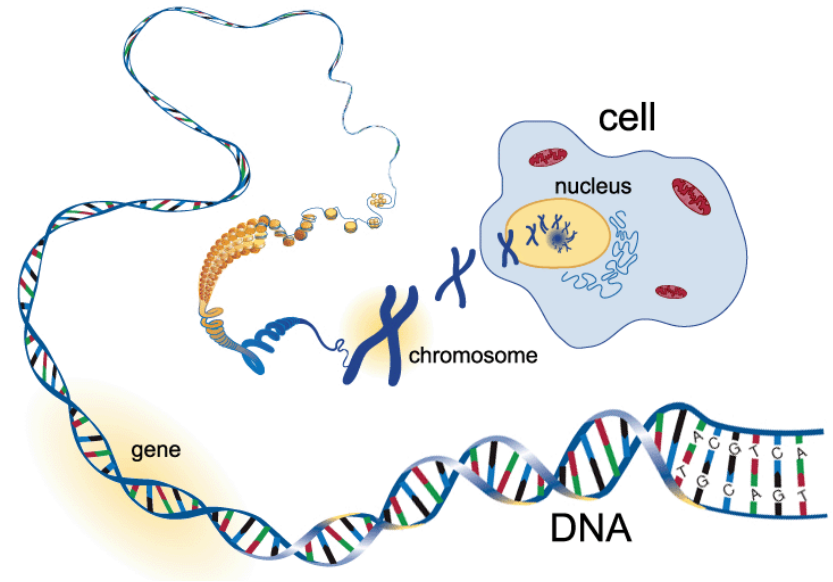
Leçon	Subject	Page en Stryer
1	Introduction en biochimie / classes de biomolécules / aminoacides	4-17 (1.2, 1.3), 25-40 (2.1, 2.2)
2	Composition et structure des protéines	40-59 (2.3-2.6)
3	Exploration des protéines et des protéomes	65-90 (3.1-3.3), 93-101 (3.5, 3.6)
4	Structure de la DNA et RNA	107-119 (4.1-4.3)
5	Explorer les gènes et les génomes	134-144 (5.1, 5.2 premières 3 pages)
6	Synthèse des protéines / expression recombinante	117-119 (4.3), 119-127 (4.4), 142-148 (5.2)

Christian Heinis

christian.heinis@epfl.ch, BCH 5305

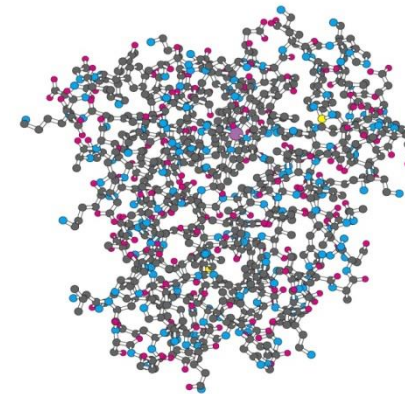
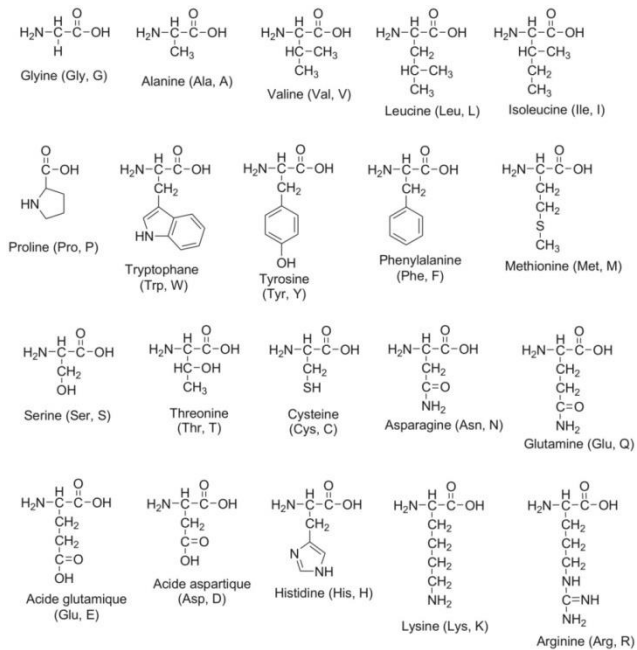
Leçon 4

- Composition du DNA
 - Bases, sucres, phosphates
- Découverte du DNA
 - Histoire
 - Expériences importantes
- Structure du DNA
- DNA réplication, méthode de PCR
- Flux de l'information



Composition du DNA

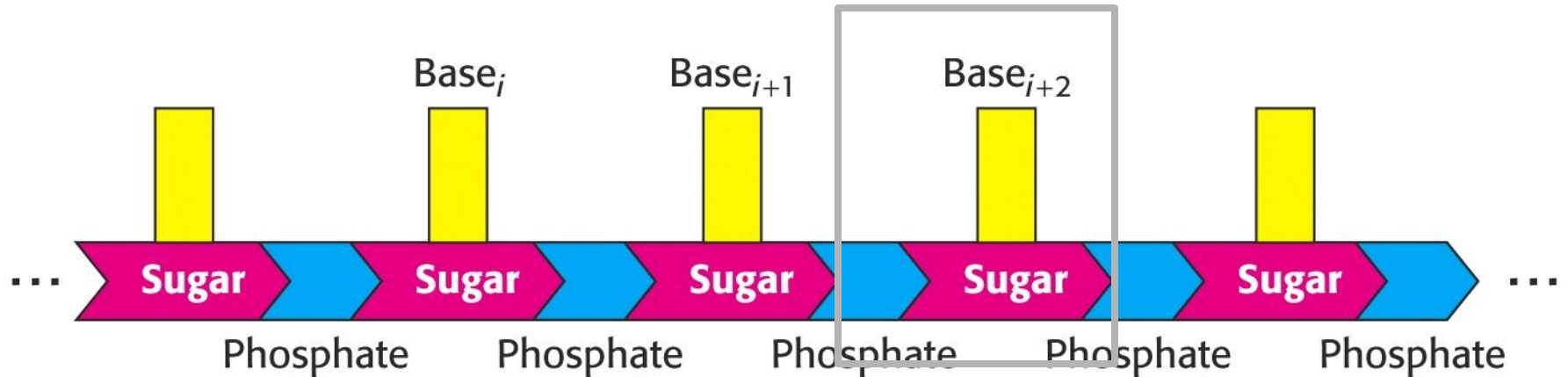
Quel sont les composants du DNA?



protéine

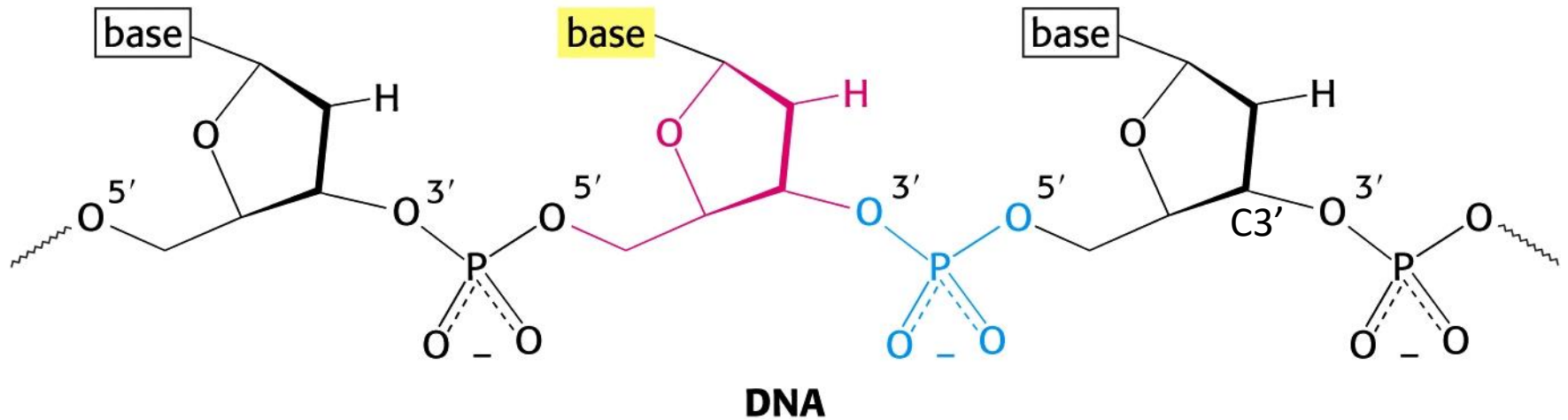
aminoacides

Bases, sucres et phosphates



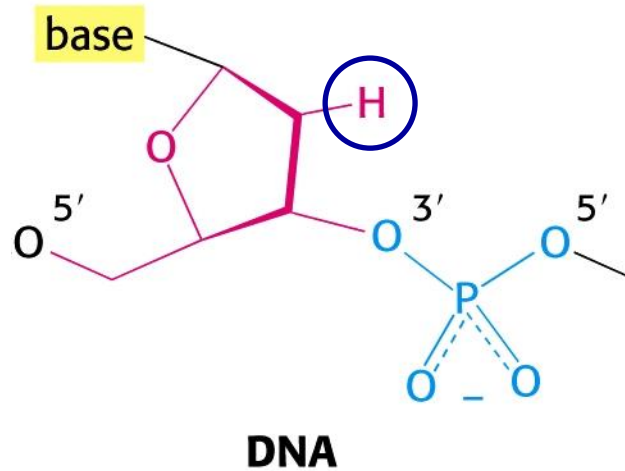
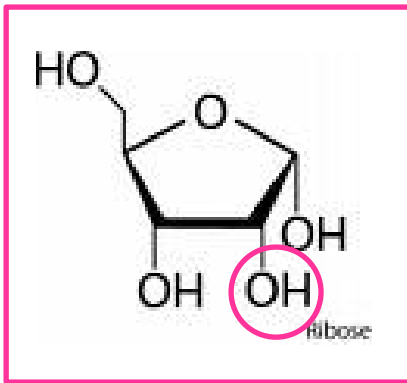
- Long polymère linéaire
- Un squelette invariant: sucres reliés par des phosphates
- Bases variantes
- Un monomère = nucléotide

Le squelette sucre-phosphate



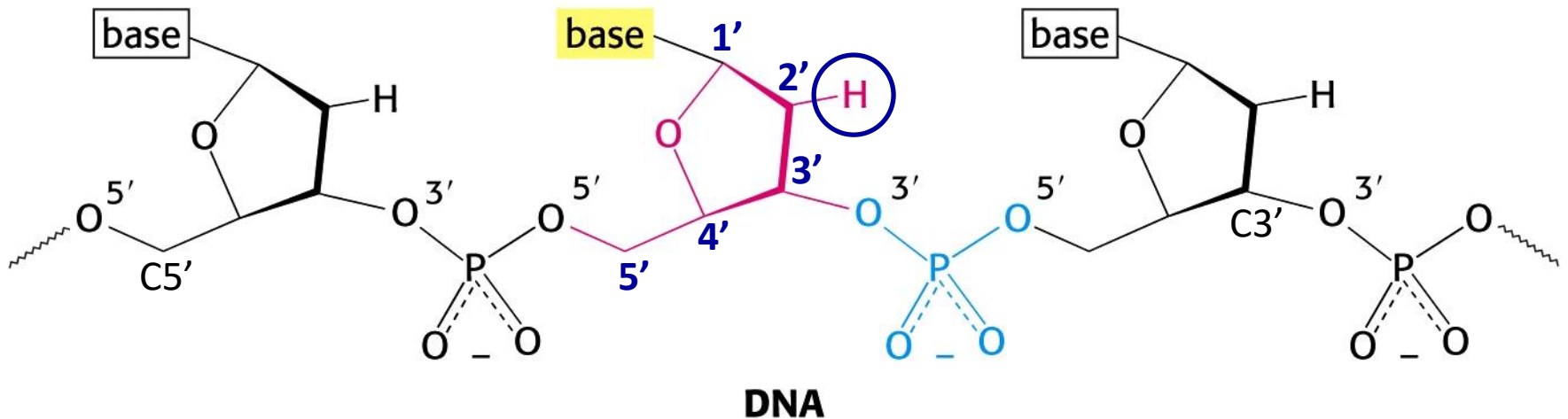
Le squelette sucre-phosphate

ribose



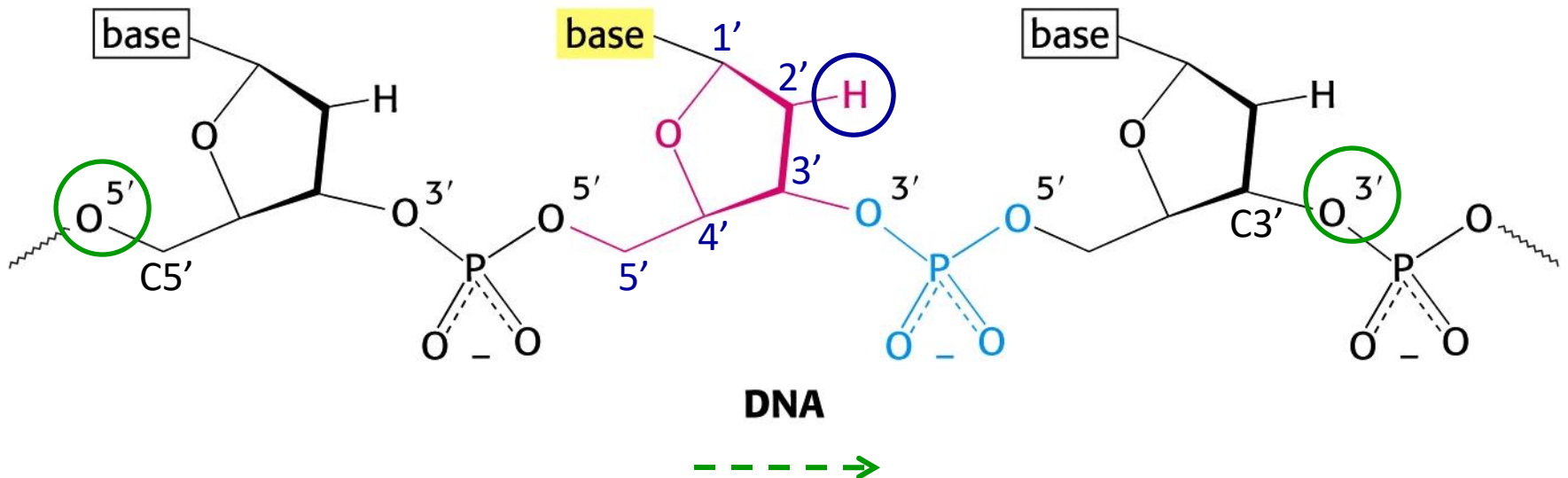
- Sucre: **déoxyribose** → acide **déoxyribonucléique** (ADN)

Le squelette sucre-phosphate



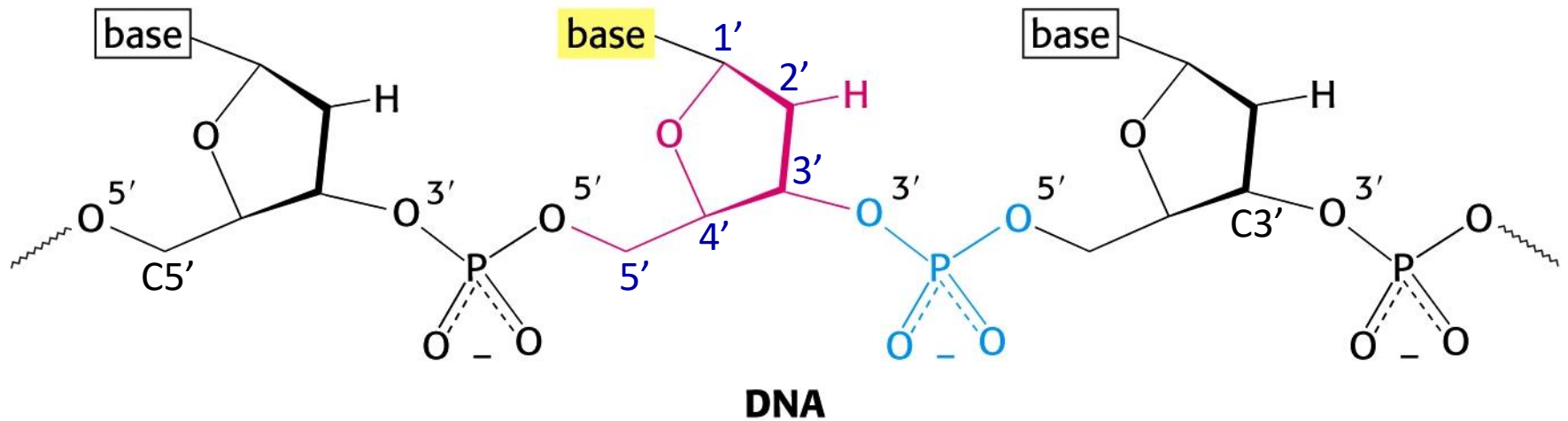
- Sucre: **déoxyribose** → acide **déoxyribonucléique** (ADN)
- Nomenclature du ribose: carbone 1', 2', 3', 4', 5'

Le squelette sucre-phosphate



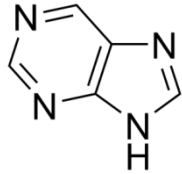
- Sucre: **déoxyribose** → acide **déoxyribonucléique** (ADN)
- Nomenclature du ribose: carbone 1', 2', 3', 4', 5'
- On dessine le DNA dans la direction 5' → 3'

Le squelette sucre-phosphate

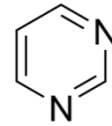


Quelles sont les bases?

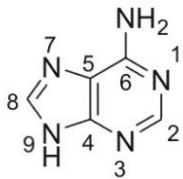
Les bases



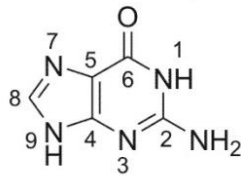
Purine



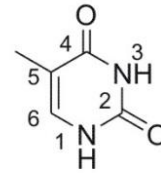
Pyrimidine



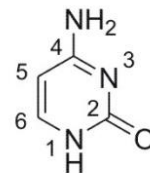
Adenine



Guanine



Thymine



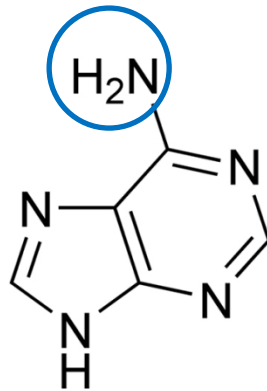
Cytosine

4 Bases

L'adénine

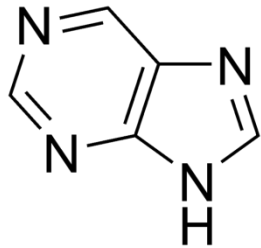


purine

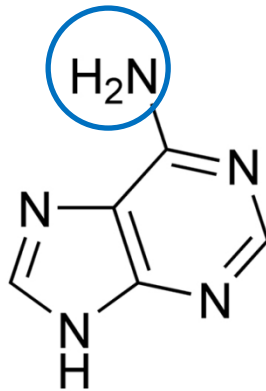


adénine

L'adénine



purine



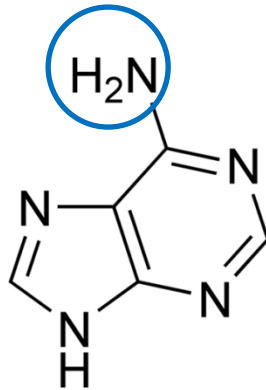
adénine

Dans quelle position est-ce que l'adénine est connecté au ribose?

L'adénine

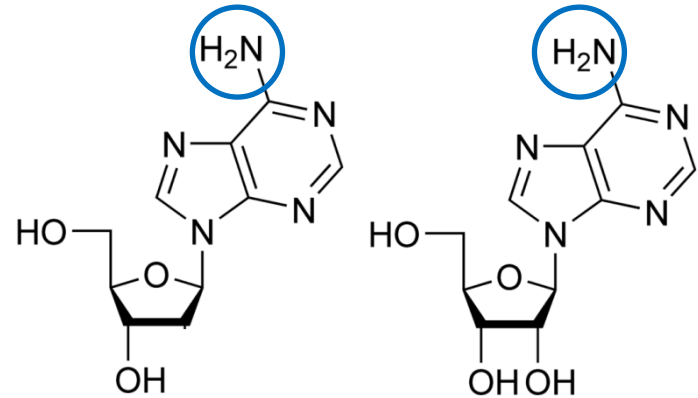


purine



adénine

‘base’



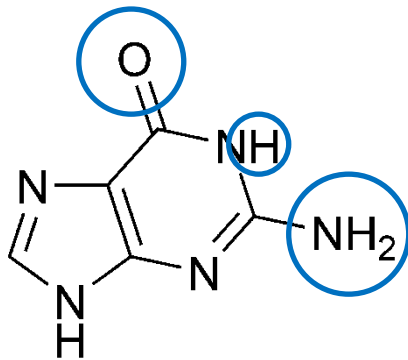
adénosine

‘nucléoside’

La guanine



purine



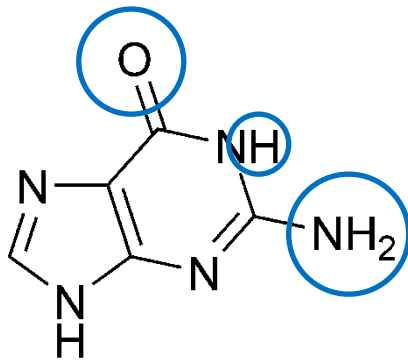
guanine

‘base’

La guanine

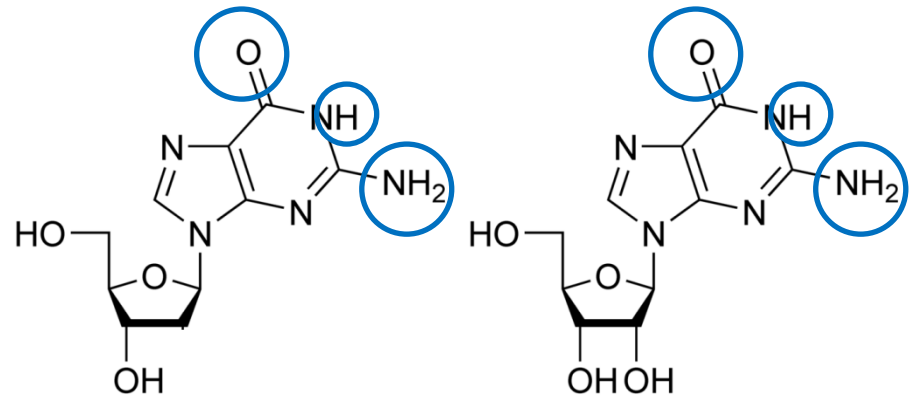


purine



guanine

‘base’

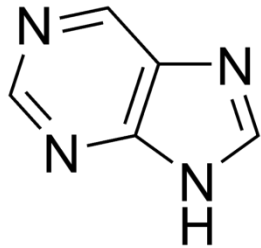


guanosine

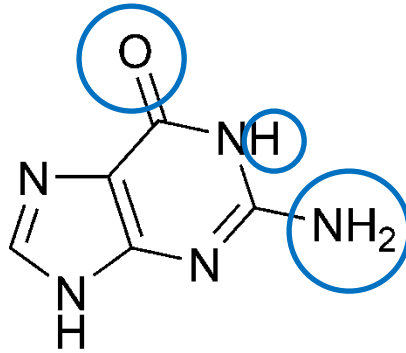
‘nucléoside’

Quelle est la différence entre les bases guanine et adénine?

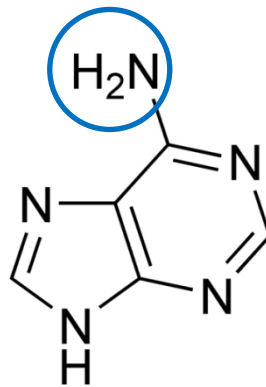
Les purines



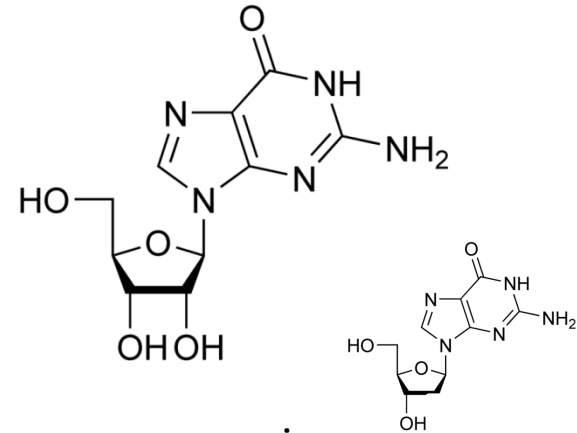
purine



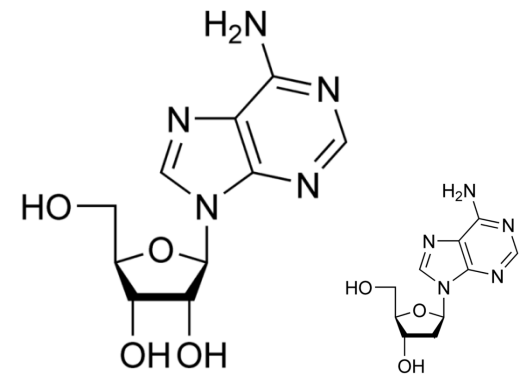
guanine



adénine

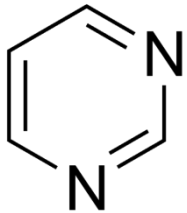


guanosine

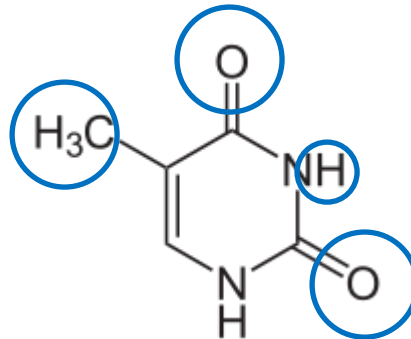


adénosine

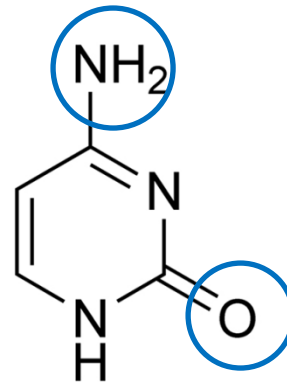
La thymine et la cystosine



pyrimidine

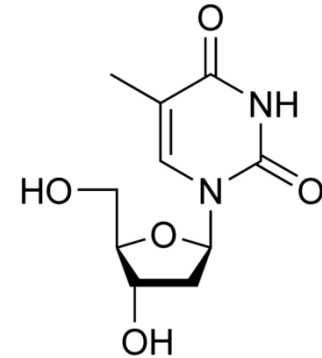


thymine

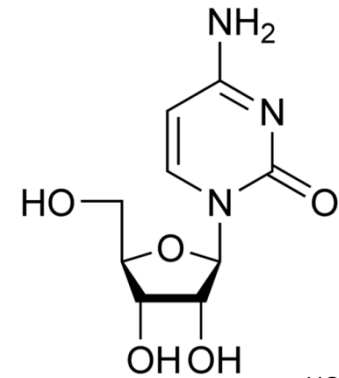


cytosine

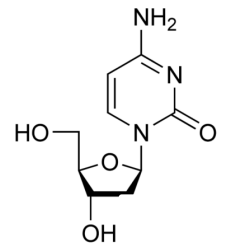
'base'



thymidine

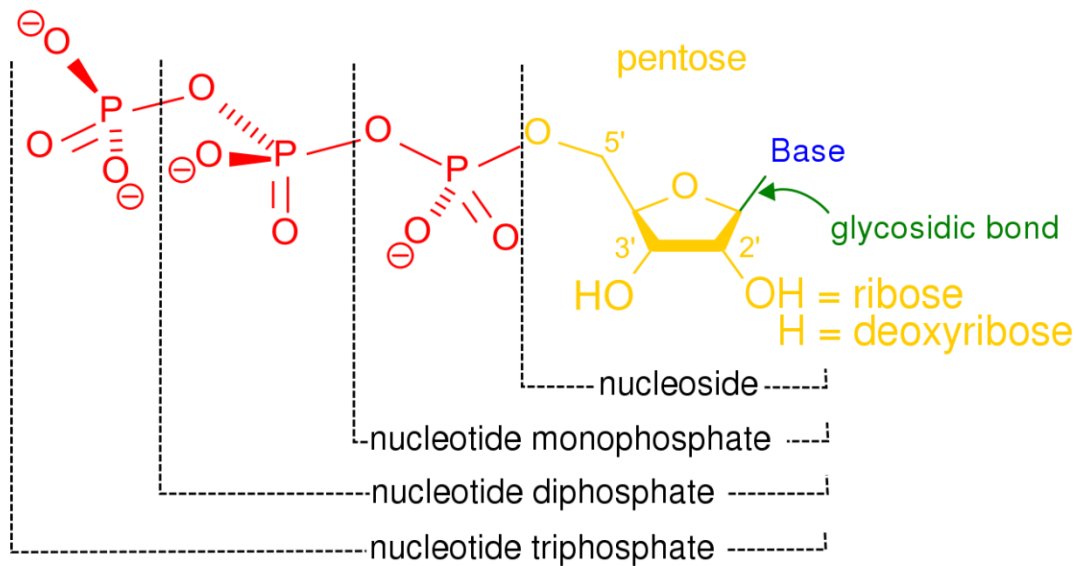


cytidine

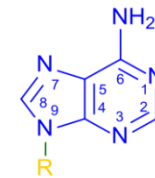


'nucléoside'

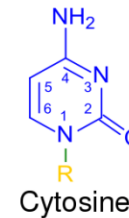
Nomenclature: bases, nucléosides et nucléotides



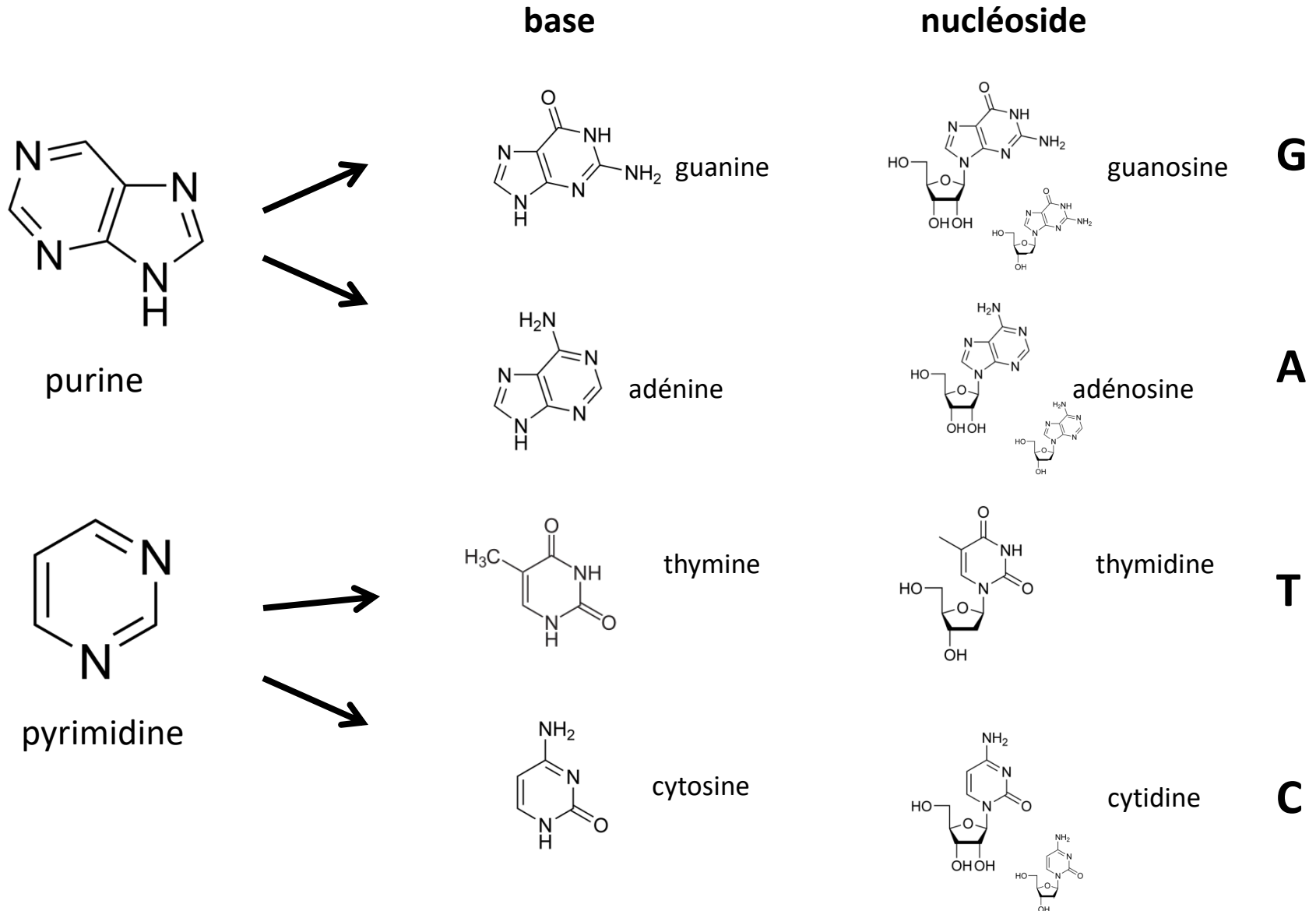
Purines



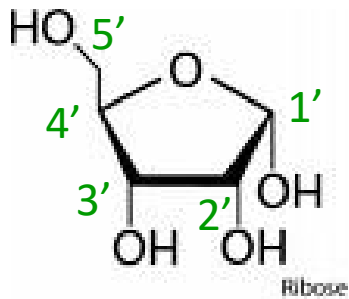
Pyrimidines



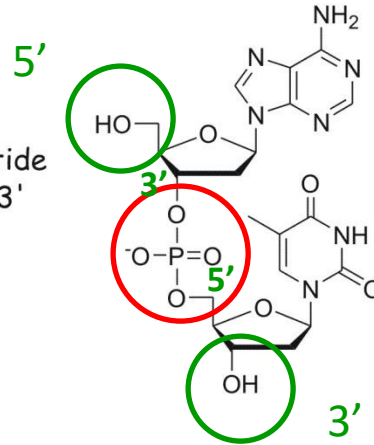
Nomenclature: bases, nucléosides et nucléotides



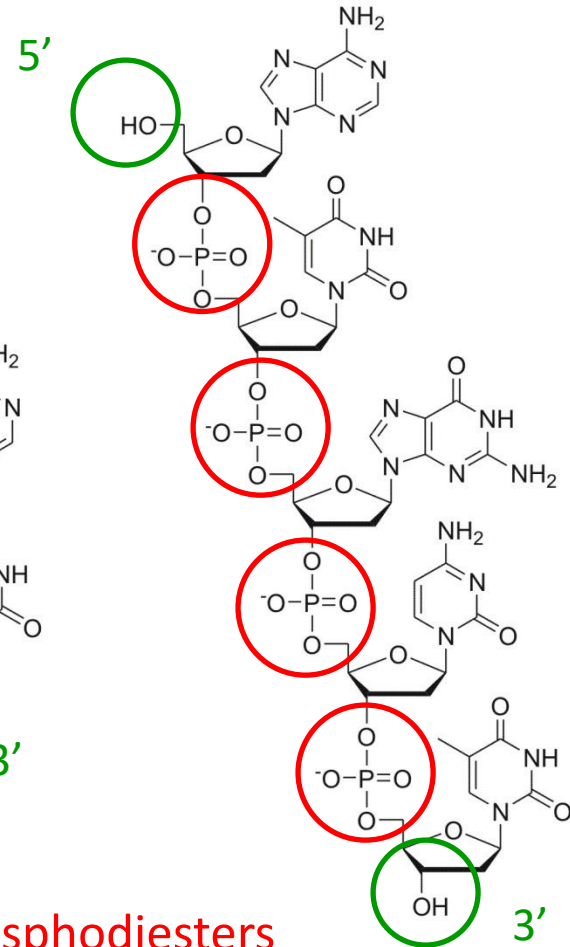
Nucléotides



dinucleotide
5'-AT-3'



pentanucleotide
5'-ATGCT-3'



- Les nucléotides sont liés par des liaisons **phosphodiesters**
- Les liaisons phosphodiesters sont formées par les **3'-hydroxyles** et les **5'-hydroxyles**
- Le polymère a une polarité; par convention une séquence de DNA est écrite dans la direction **5' → 3'** (p.ex. 5'-ATGCT-3')

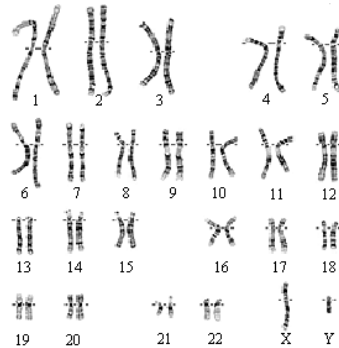
Le DNA code l'information génétique

Combien de nucléotides y-a-t-il dans le génome humain?

Quelle est la longueur du DNA?

Le DNA code l'information génétique

- Les molécules de DNA ont des longueurs frappantes:
 - Bactérie (p.ex. *E.coli*): 4'600'000 nucléotides
 - Génome humain: 3'000'000'000 nucléotides

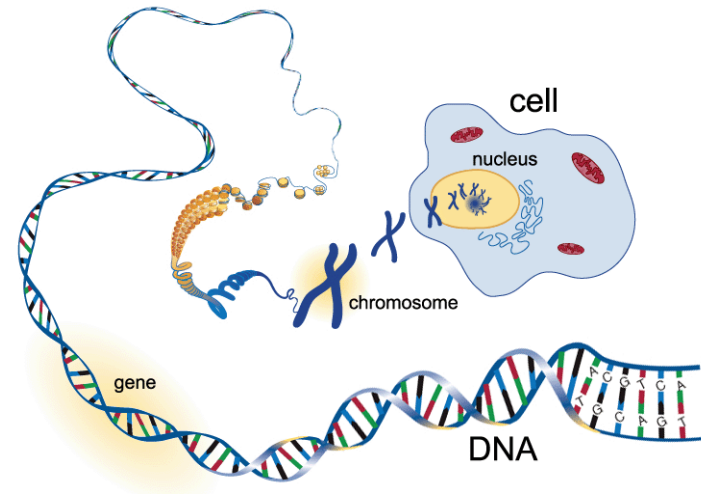


organisés en 24
chromosomes

- Si une molécule de DNA pouvait être étirée, sa longueur serait de 30 cm!

Découverte du DNA

- Composition du DNA
 - Bases, sucres, phosphates
- ➔ • Découverte du DNA
 - Histoire
 - Expériences importantes
- Structure du DNA
- DNA réplication, méthode de PCR
- Flux de l'information



Découverte du DNA



Découverte du DNA ('nuclein') 1869



Découverte du DNA ('nuclein') en 1869 par Friedrich Miescher à Tübingen (il avait mit les nucleus des cellules leucocytes dans une solution basic et ensuite les fait précipiter avec une solution acide)



Figure 1.5 The laboratory at Tübingen where Miescher isolated nuclein (courtesy of the University of Tübingen Library, Tübingen, Federal Republic of Germany).

Friedrich Miescher



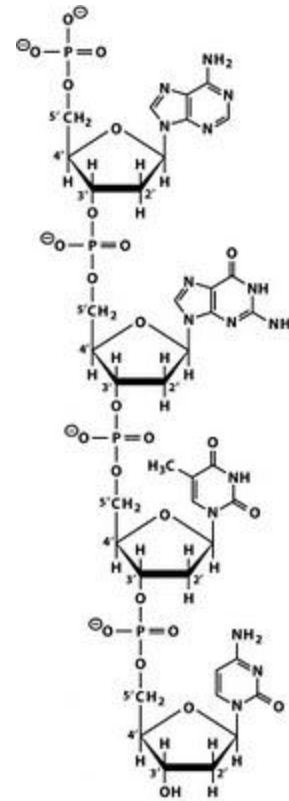
- Prix Friedrich Miescher (le prix le plus important en Suisse pour la recherche en biomédecine)
- Institut Friedrich Miescher (à Bale)

Structure chimique des nucléotides 1940s



Lord Alexander Todd

Découverte de la connectivité du DNA (5'-3'). Prix Nobel en 1957



Composition des bases dans le DNA 1949



Erwin Chargaff

TABLE 5.1 Base compositions experimentally determined for a variety of organisms

Species	A:T
Human being	1.00
Salmon	1.02
Wheat	1.00
Yeast	1.03
<i>Escherichia coli</i>	1.09
<i>Serratia marcescens</i>	0.95

Composition des bases dans le DNA 1949



Erwin Chargaff

TABLE 5.1 Base compositions experimentally determined for a variety of organisms

Species	A:T	G:C
Human being	1.00	1.00
Salmon	1.02	1.02
Wheat	1.00	0.97
Yeast	1.03	1.02
<i>Escherichia coli</i>	1.09	0.99
<i>Serratia marcescens</i>	0.95	0.86

Composition des bases dans le DNA 1949



Erwin Chargaff

TABLE 5.1 Base compositions experimentally determined for a variety of organisms

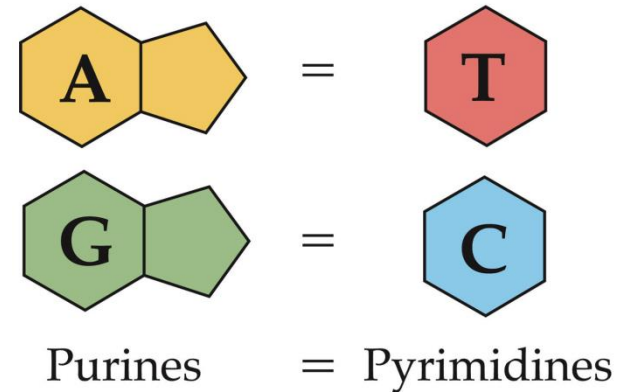
Species	A:T	G:C	A:G
Human being	1.00	1.00	1.56
Salmon	1.02	1.02	1.43
Wheat	1.00	0.97	1.22
Yeast	1.03	1.02	1.67
<i>Escherichia coli</i>	1.09	0.99	1.05
<i>Serratia marcescens</i>	0.95	0.86	0.70

Composition des bases dans le DNA 1949



TABLE 5.1 Base compositions experimentally determined for a variety of organisms

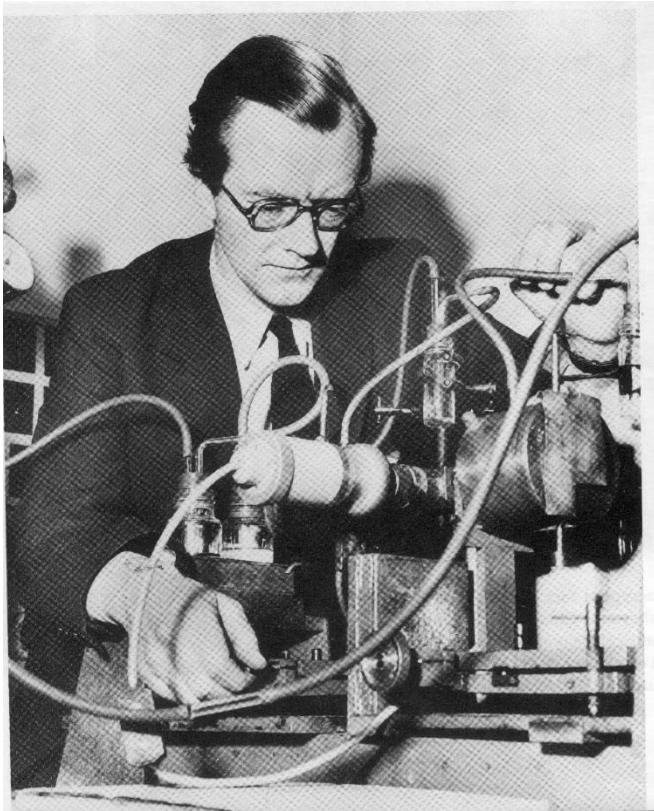
Species	A:T	G:C	A:G
Human being	1.00	1.00	1.56
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<i>Escherichia coli</i>	1.09	0.99	1.05
<i>Serratia marcescens</i>	0.95	0.86	0.70



Erwin Chargaff

Le ratio de A:T et G:C est toujours proche de 1;
indépendamment de l'organisme

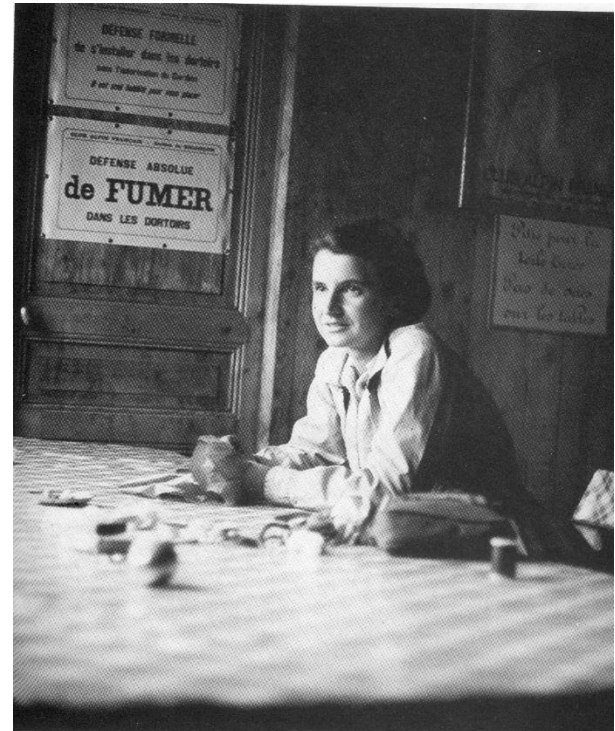
X-ray structure of DNA 1953



Maurice Wilkins

At the time professor at Kings College

Prix Nobel en 1962

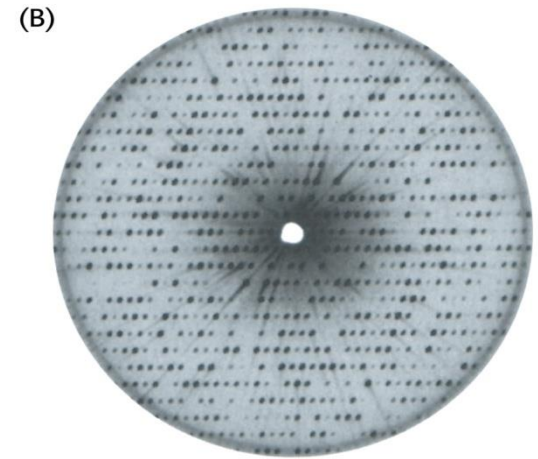
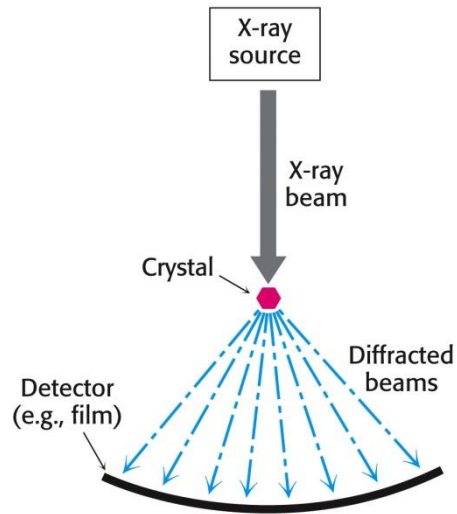
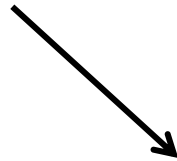


Rosalind Franklin

At the time researcher at Kings College

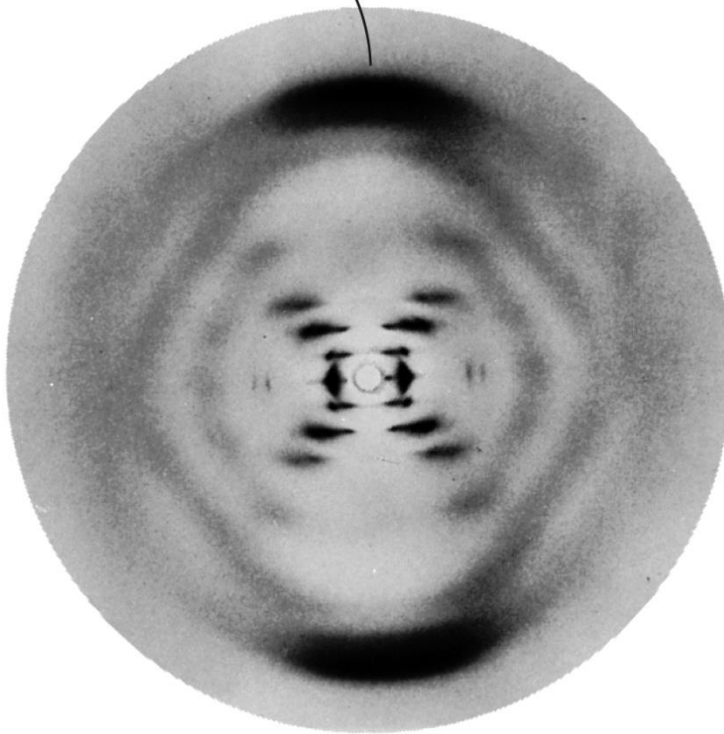
Structure tridimensionnelle d'une protéine

Cristallographie par rayons X



X-ray structure of DNA

3.4-Å spacing



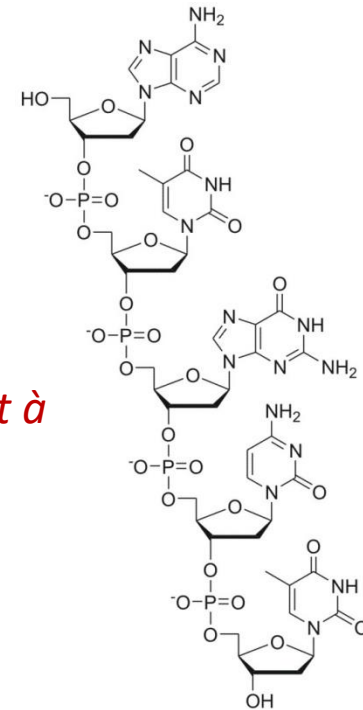
- Diffraction de rayons X par une fibre de DNA
- Structure **hélicoïdale régulière**
- **Répétitive** dans des unités de **3.4 Å**

Découverte de la structure du DNA par James Watson et Francis Crick (1953)



- Deux brins polynucléotidiques s'enroulent

*Les bases
irrégulières sont à
l'extérieur de
l'hélice?*



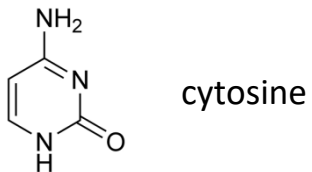
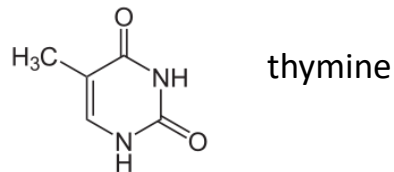
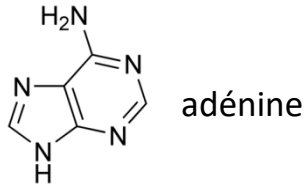
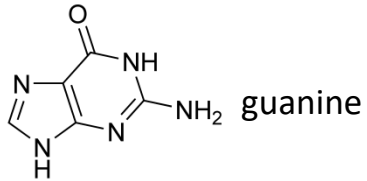
Découverte de la structure du DNA par James Watson et Francis Crick (1953)



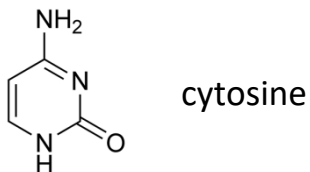
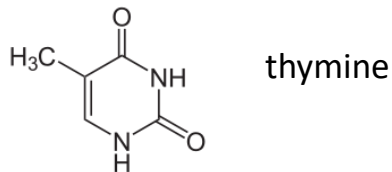
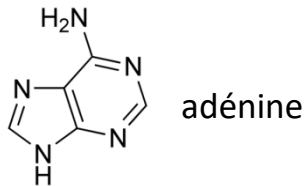
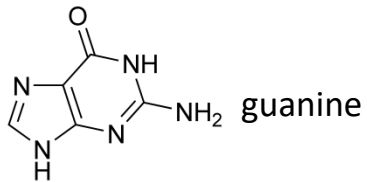
- Les **squelettes sucre-phosphate** sont à **l'extérieur** (→ pas de répulsions électrostatiques!)
- Les **bases** sont à **l'intérieur** !

Comment une structure aussi régulière est-elle capable de s'accommoder si les bases à l'intérieur sont si différentes?

Structure du DNA par James Watson et Francis Crick

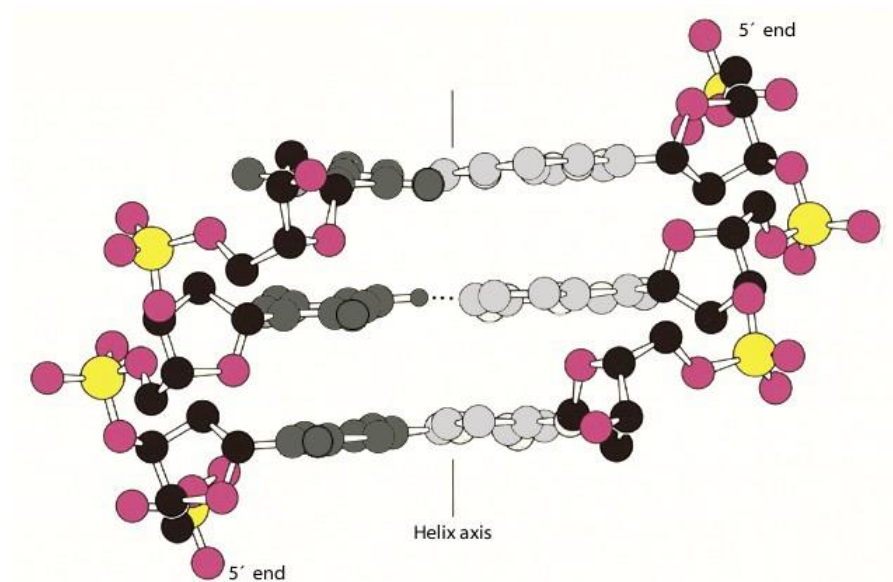


Structure du DNA par James Watson et Francis Crick



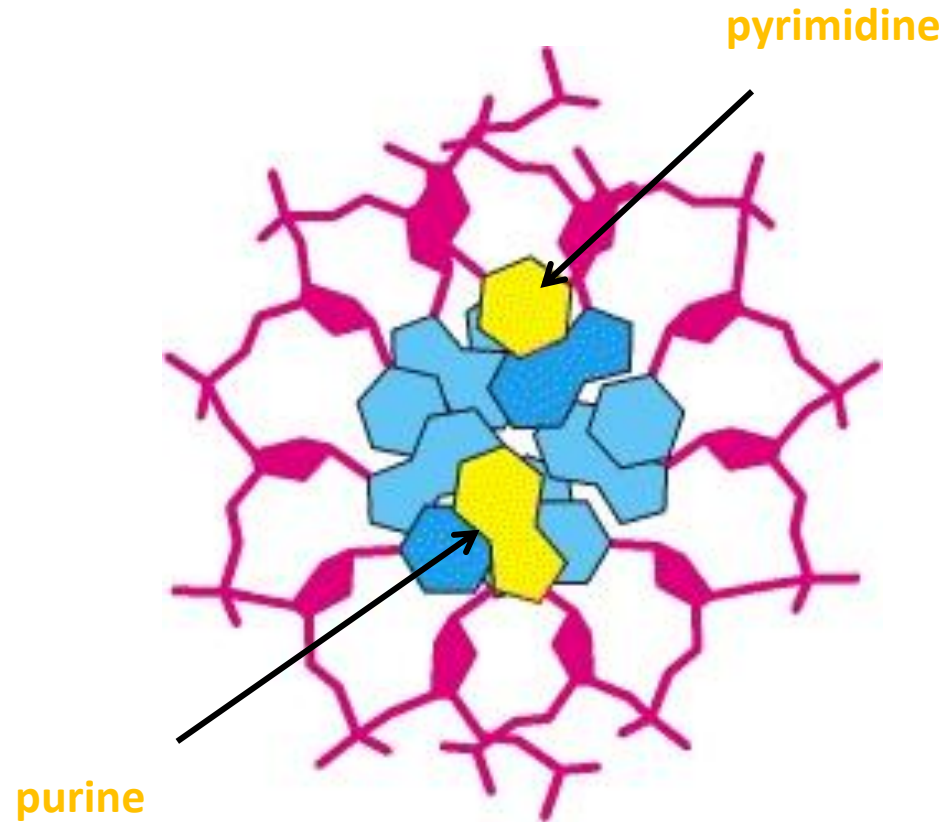
Hélice de DNA

(vue latérale; 3 paires de bases)



Structure du DNA par James Watson et Francis Crick

Hélice de DNA
(vue de haut)



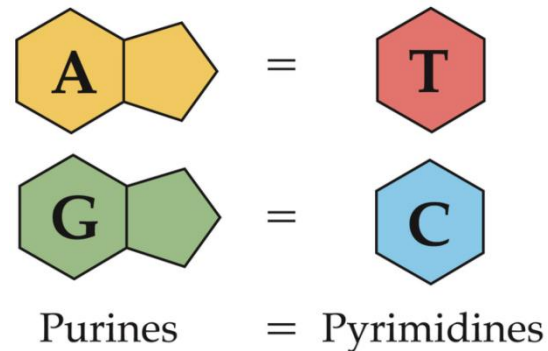
Structure du DNA par James Watson et Francis Crick

La structure de DNA peut expliquer les résultats de Erwin Chargaff



TABLE 5.1 Base compositions experimentally determined for a variety of organisms

Species	A:T	G:C	A:G
Human being	1.00	1.00	1.56
Salmon	1.02	1.02	1.43
Wheat	1.00	0.97	1.22
Yeast	1.03	1.02	1.67
<i>Escherichia coli</i>	1.09	0.99	1.05
<i>Serratia marcescens</i>	0.95	0.86	0.70

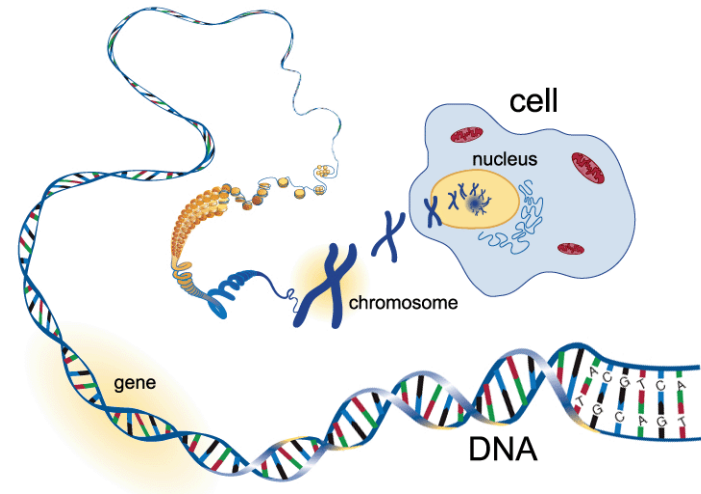


Structure du DNA

- Composition du DNA
 - Bases, sucres, phosphates
- Découverte du DNA
 - Histoire
 - Expériences importantes

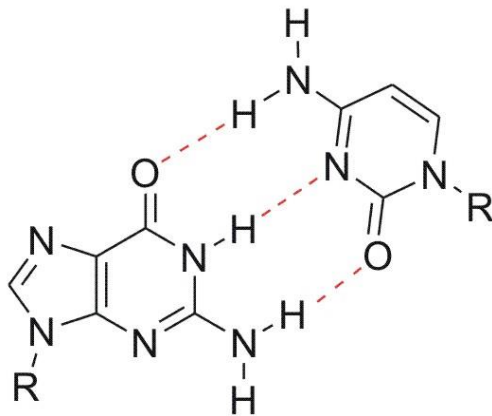


- Structure du DNA
- DNA réplication, méthode de PCR
- Flux de l'information

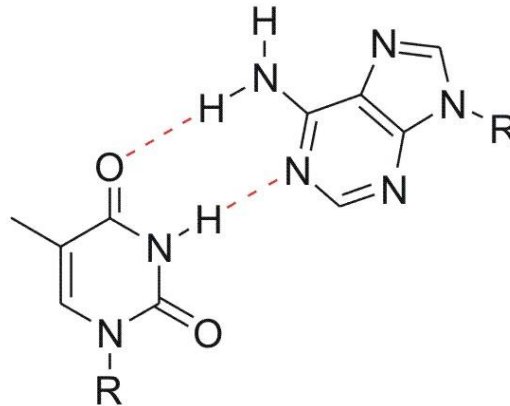


La double-hélice du DNA

Les deux chaînes sont assemblées par des **liaisons hydrogène** entre les paires de bases; G-C, A-T, purine-pyrimidine



G-C

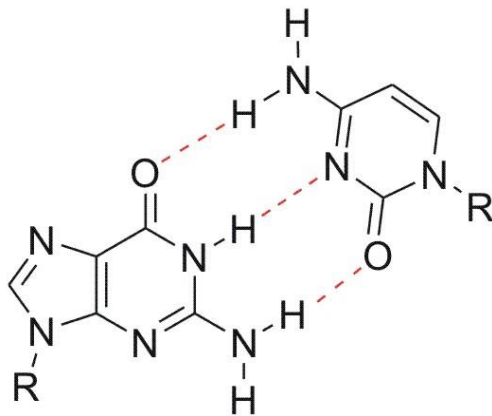


T-A

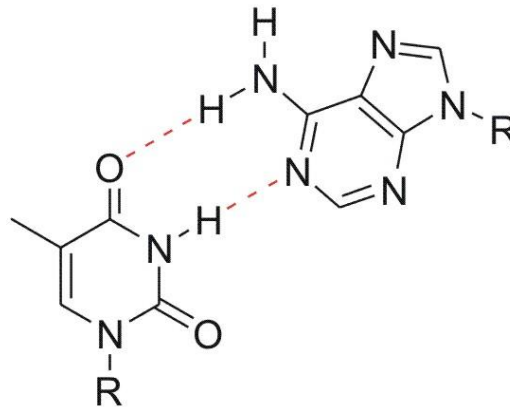
Quelle est l'énergie d'une liaison hydrogène?

La double-hélice du DNA

Les deux chaînes sont assemblées par des **liaisons hydrogène** entre les paires de bases; G-C, A-T, purine-pyrimidine



G-C

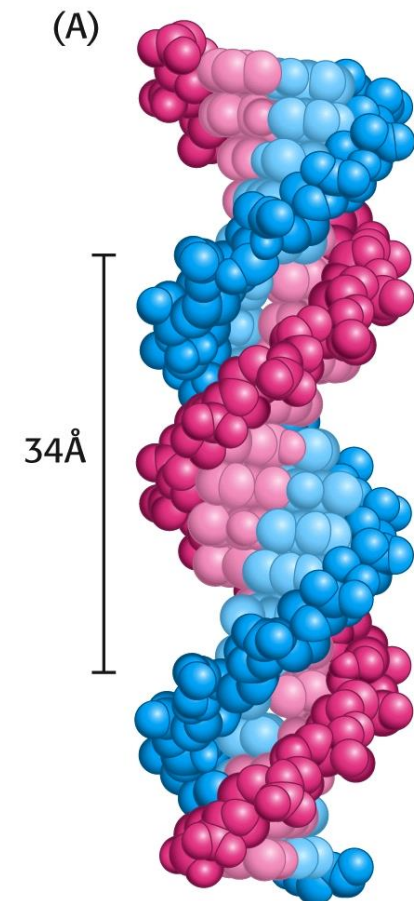
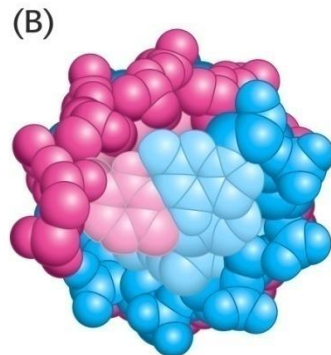


T-A

L'énergie d'une liaison hydrogène: 1-5 kcal /mol

La double-hélice du DNA

- Deux brins hélicoïdaux sont enroulés l'un autour de l'autre
- Sens d'enroulement: droite
- Les bases sont à l'intérieur, les phosphates et les deoxyriboses à l'extérieur
- La structure hélicoïdale se répète tous les 10 nucléotides ($\sim 34 \text{ \AA}$)
- Le diamètre de l'hélice est $\sim 20 \text{ \AA}$



Dimensions du DNA

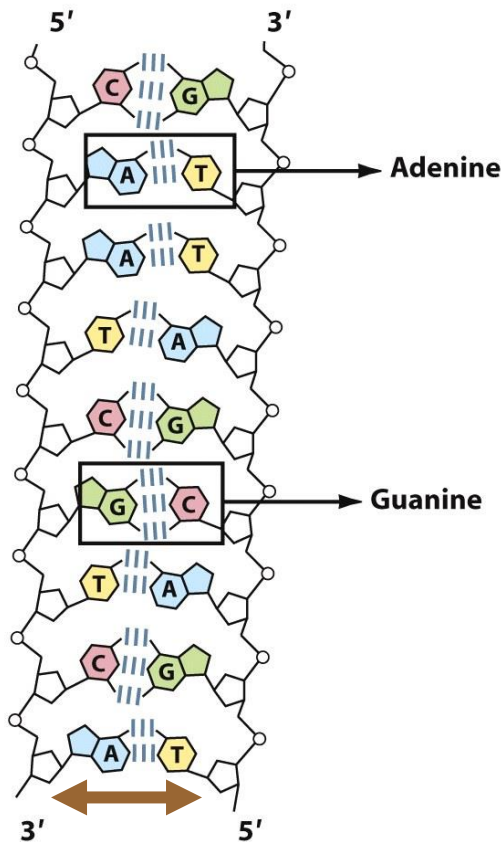
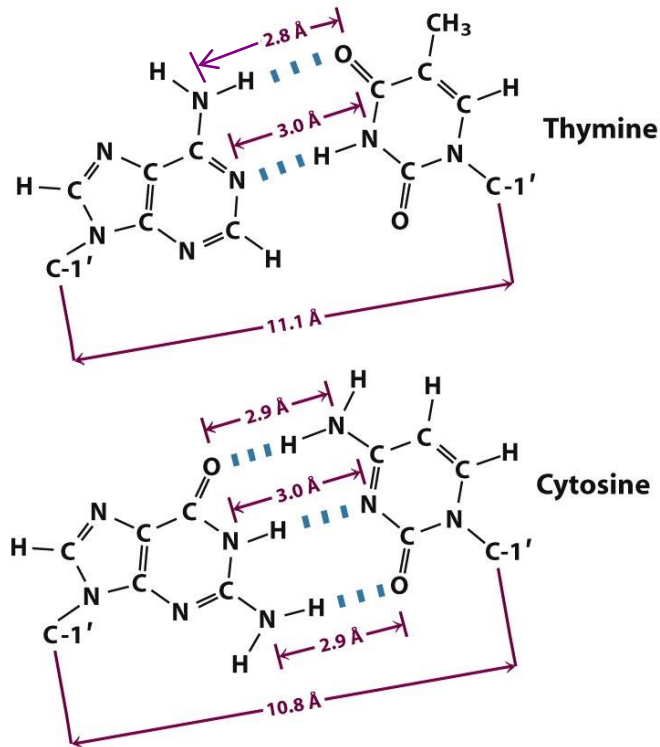


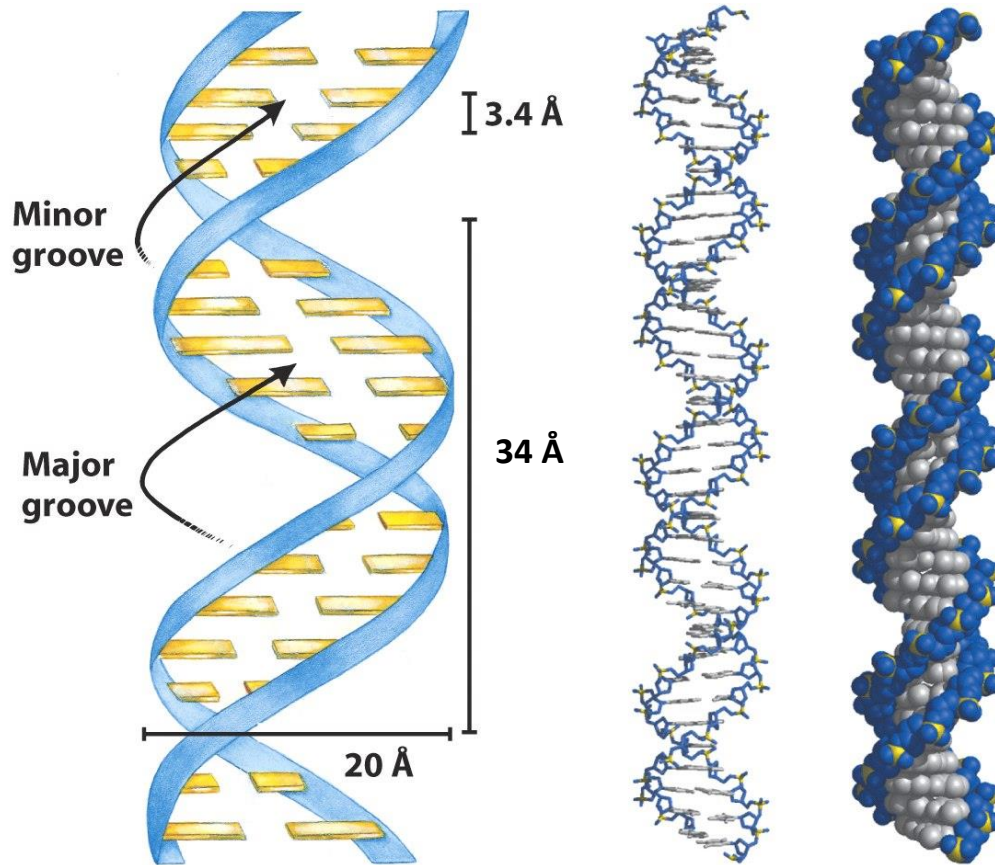
Figure 8-11

Lehninger Principles of Biochemistry, Fifth Edition
© 2008 W. H. Freeman and Company



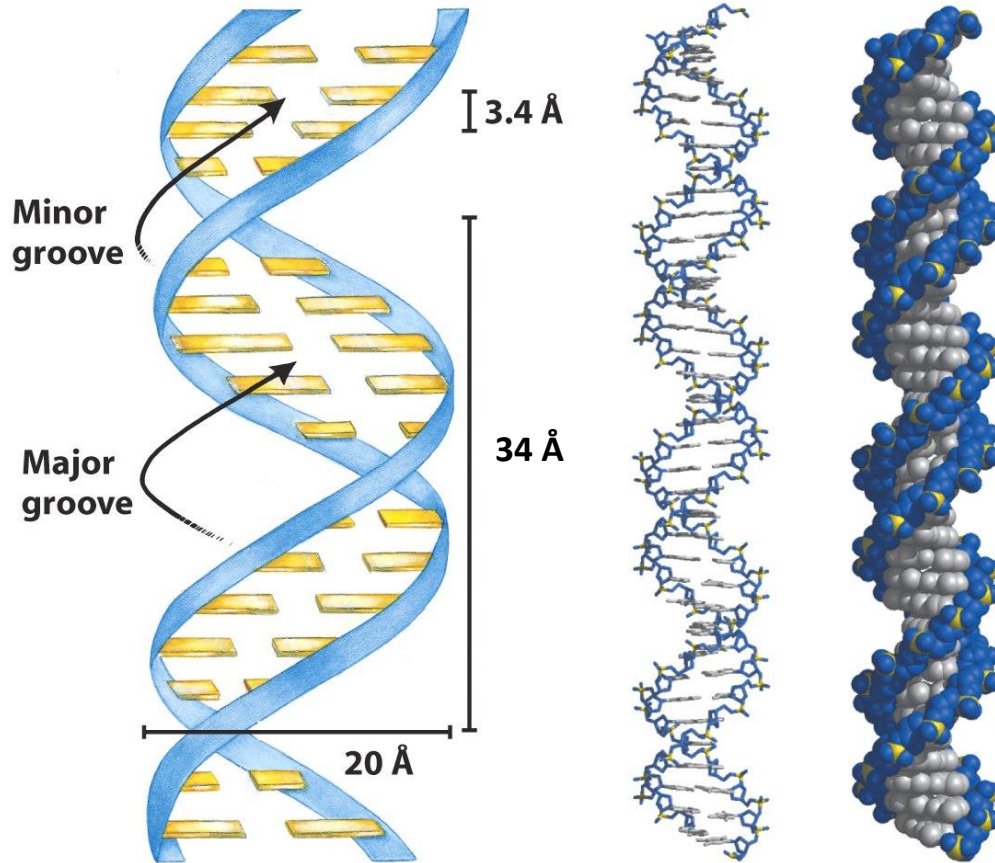
- Liaison hydrogène: 2.8 – 3.0 Å
- Distance des C1' (des sucres): 11.1 et 10.8 Å

Dimensions du DNA



Quelle est la longueur d'une double hélice avec deux brins de 100 nucléotides?

Dimensions du DNA

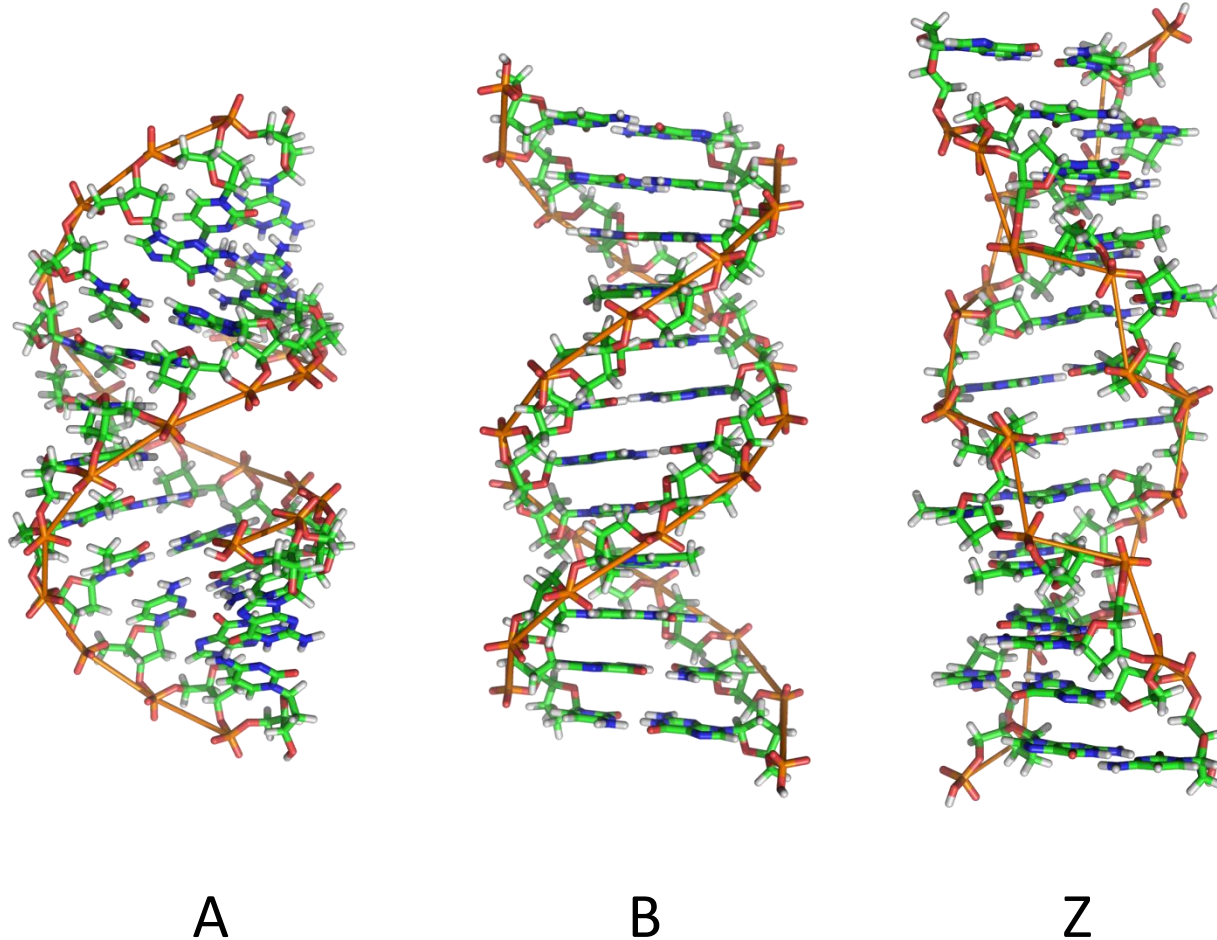


Quelle est la longueur d'une double hélice avec deux brins de 100 nucléotides?

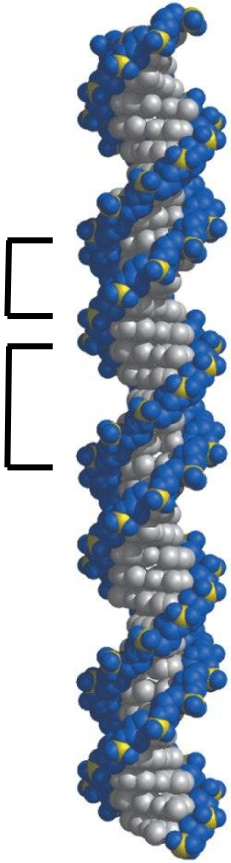
- 100 paires de bases
- Distance axial: 3.4 Å

→ $340 \text{ Å} = 34 \text{ nm}$

Il y a des formes différentes d'hélices du DNA

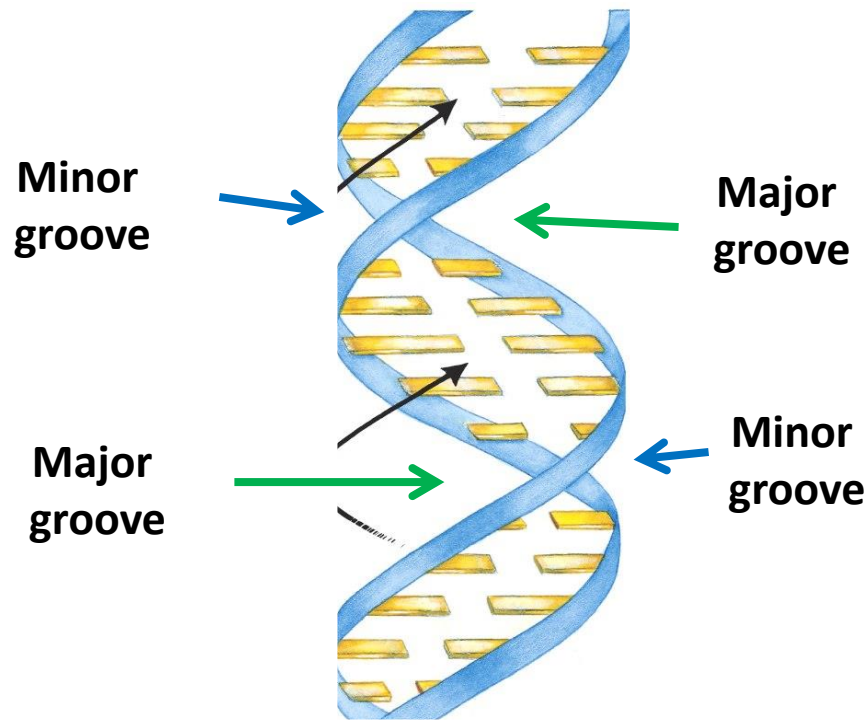
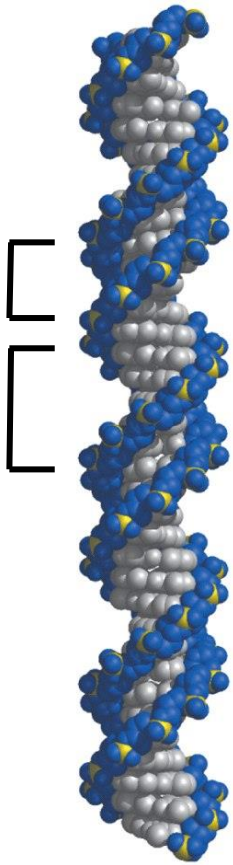


Sillons dans la double hélice de DNA



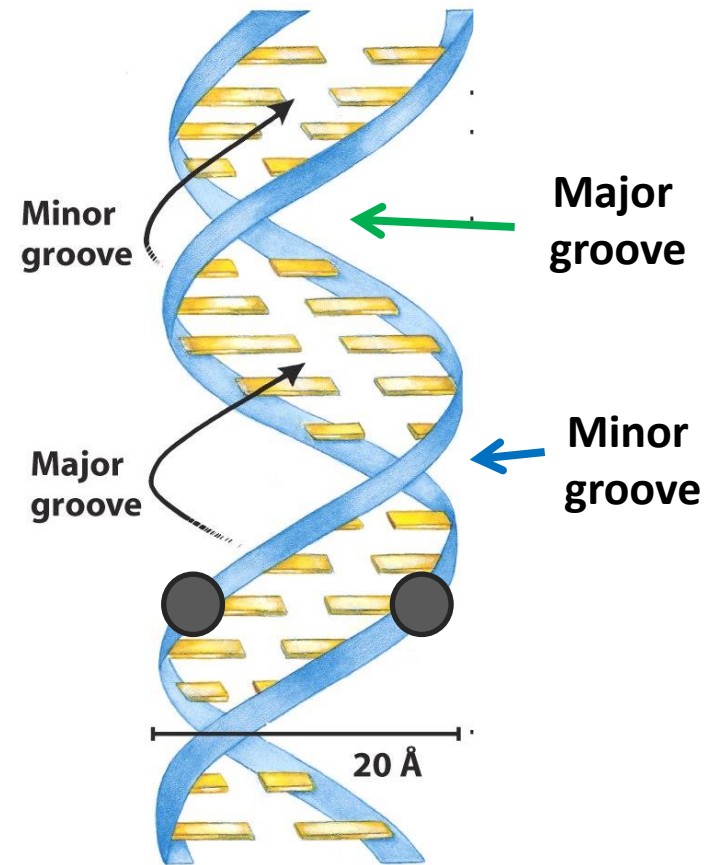
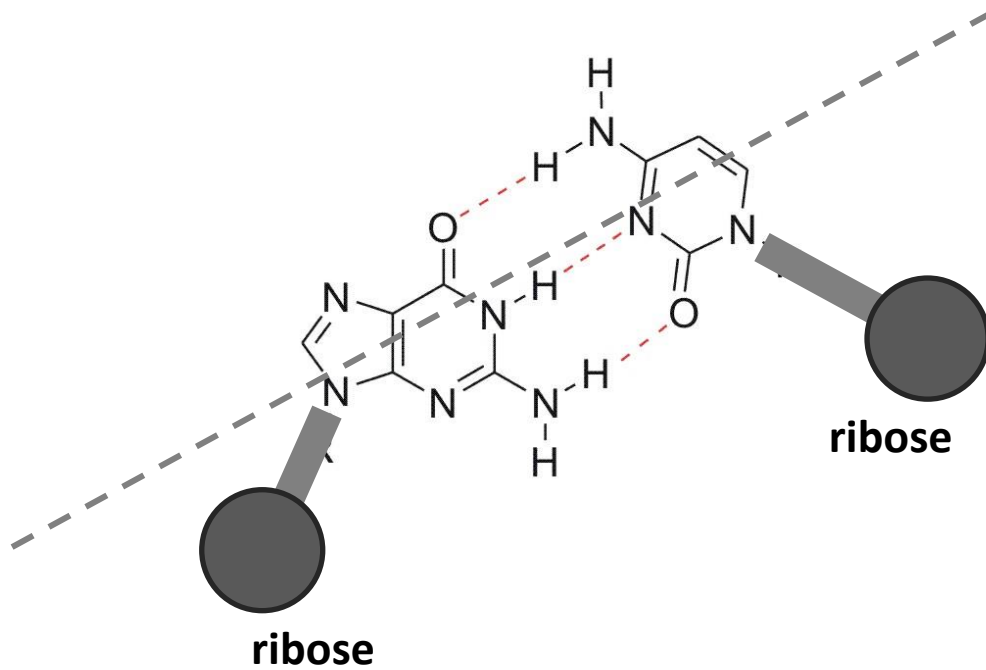
dessinée par un graphiste
(structure fausse)

Sillons dans la double hélice de DNA

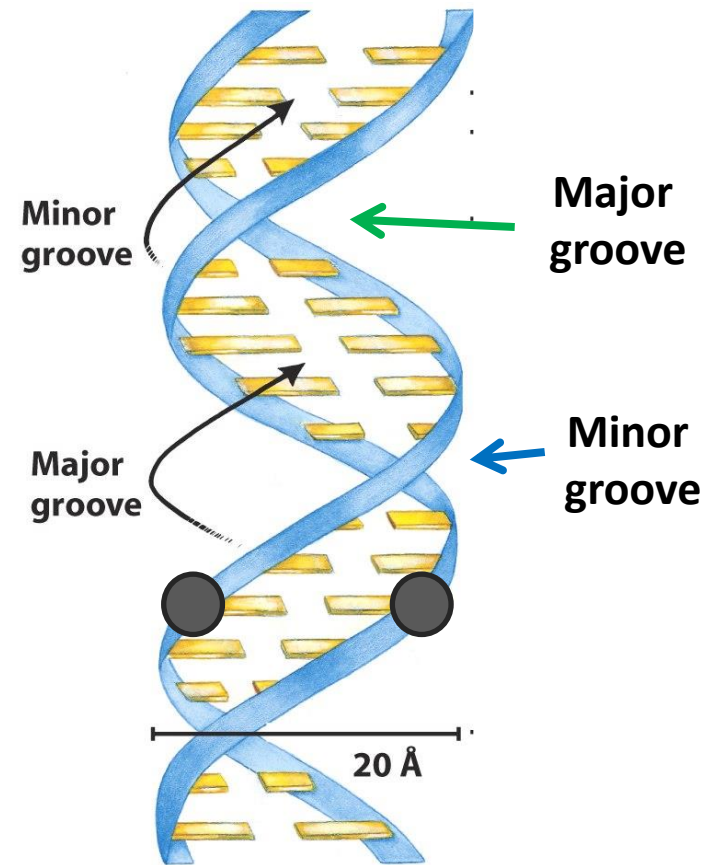
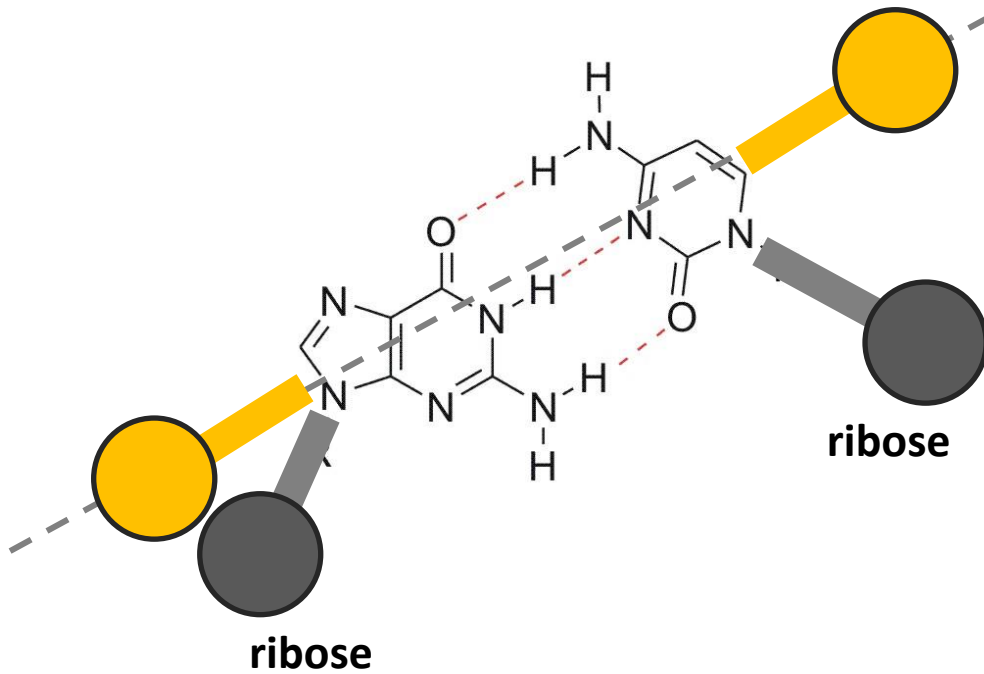


dessinée par un graphiste
(structure fausse)

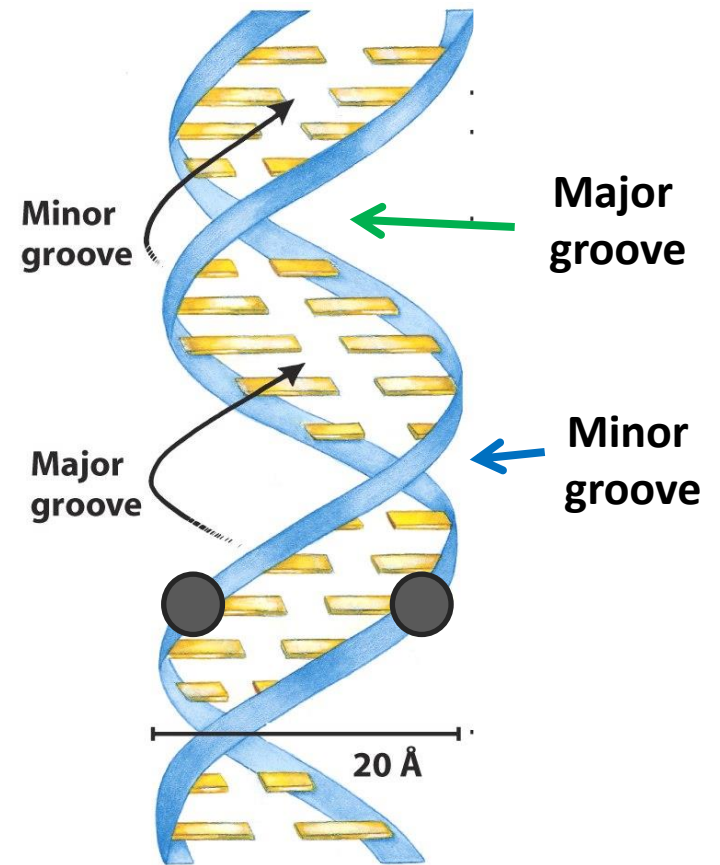
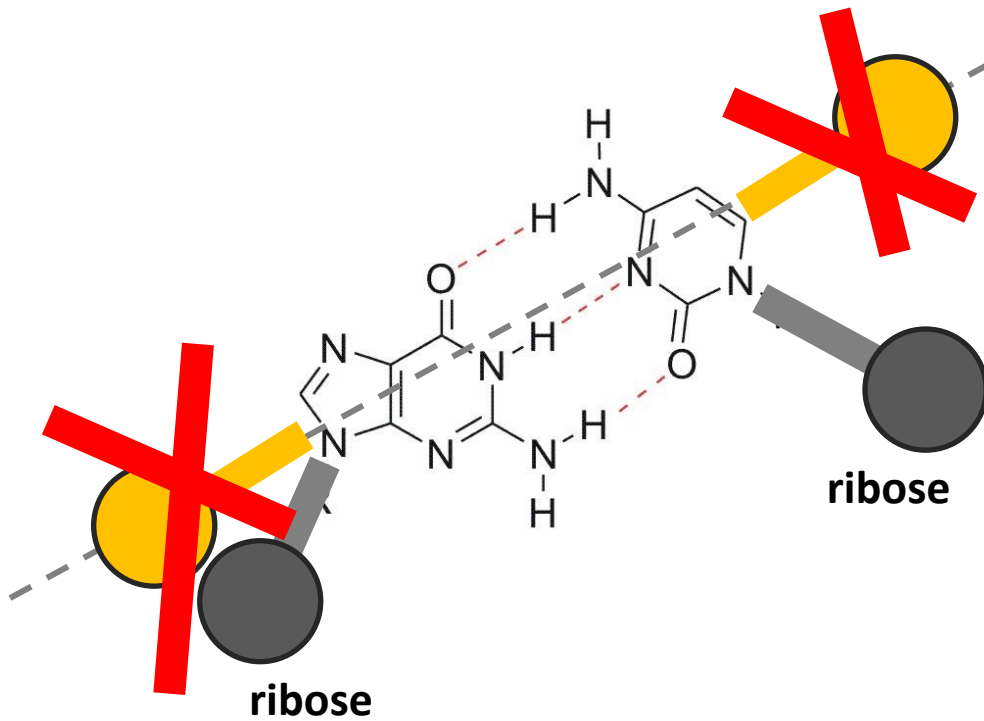
Sillons dans la double hélice de DNA



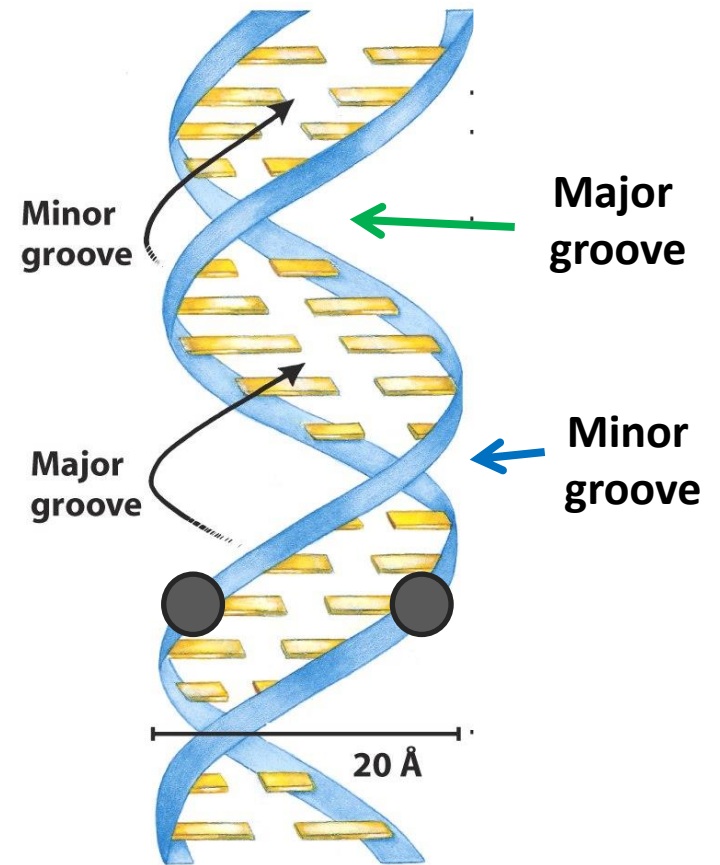
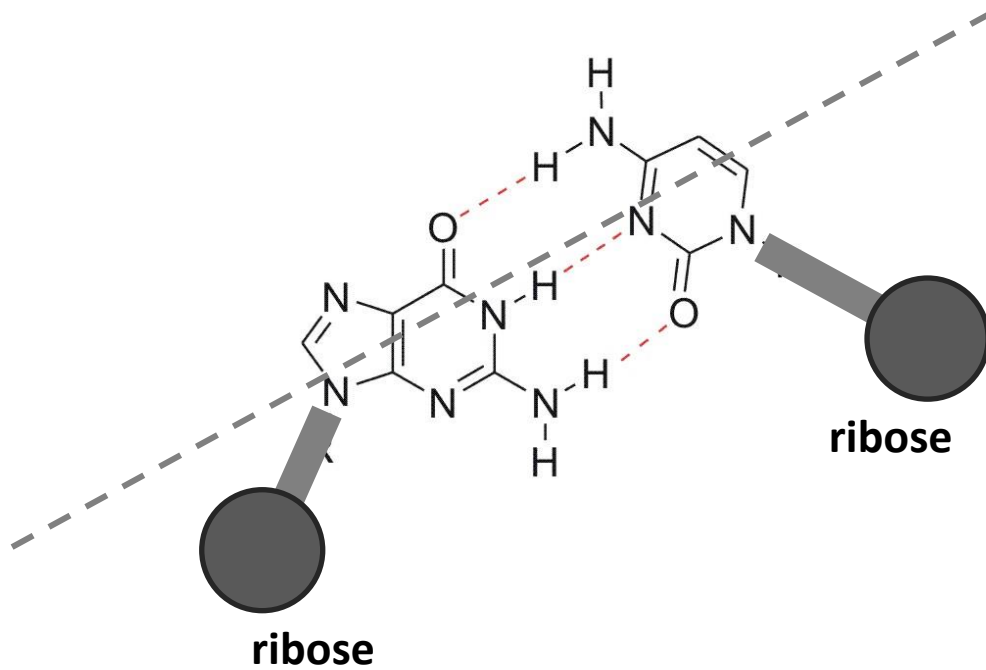
Sillons dans la double hélice de DNA



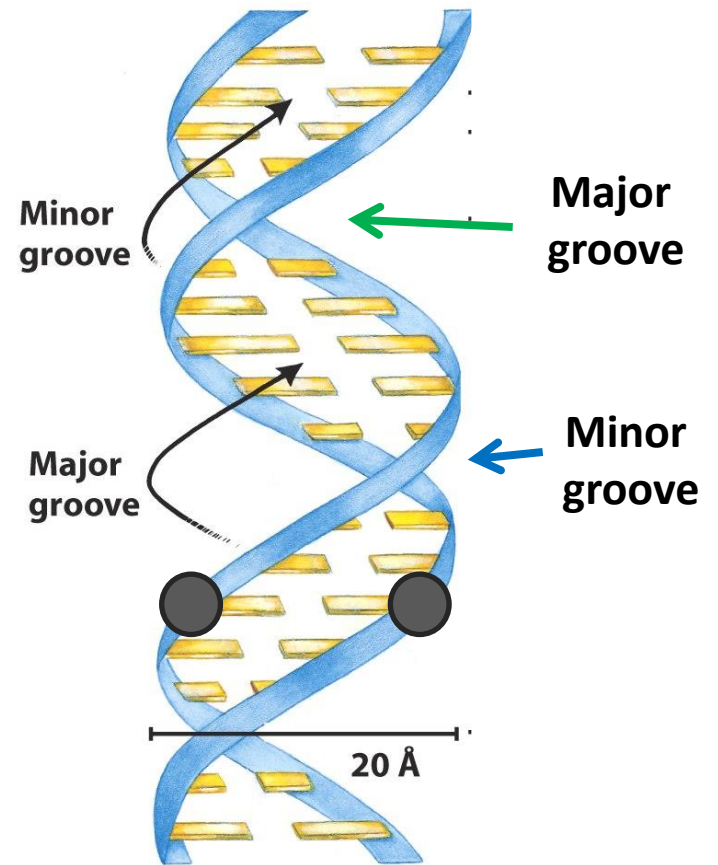
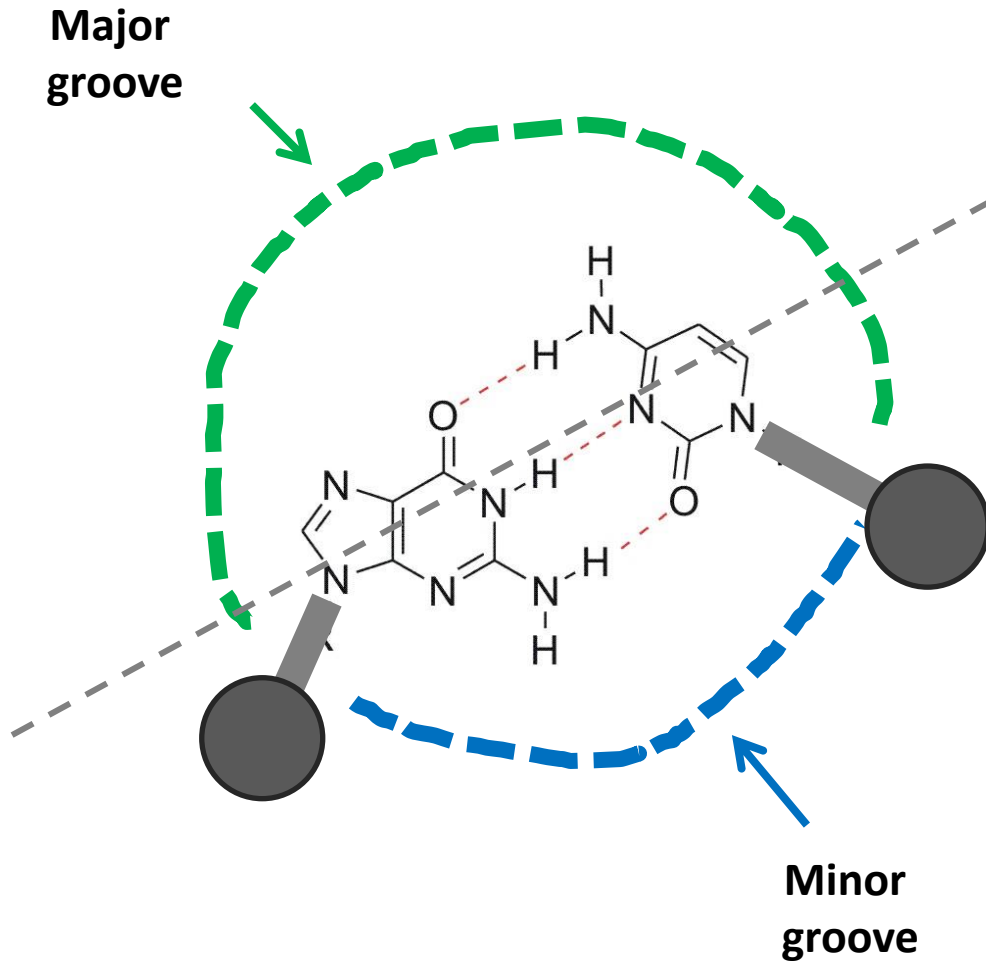
Sillons dans la double hélice de DNA



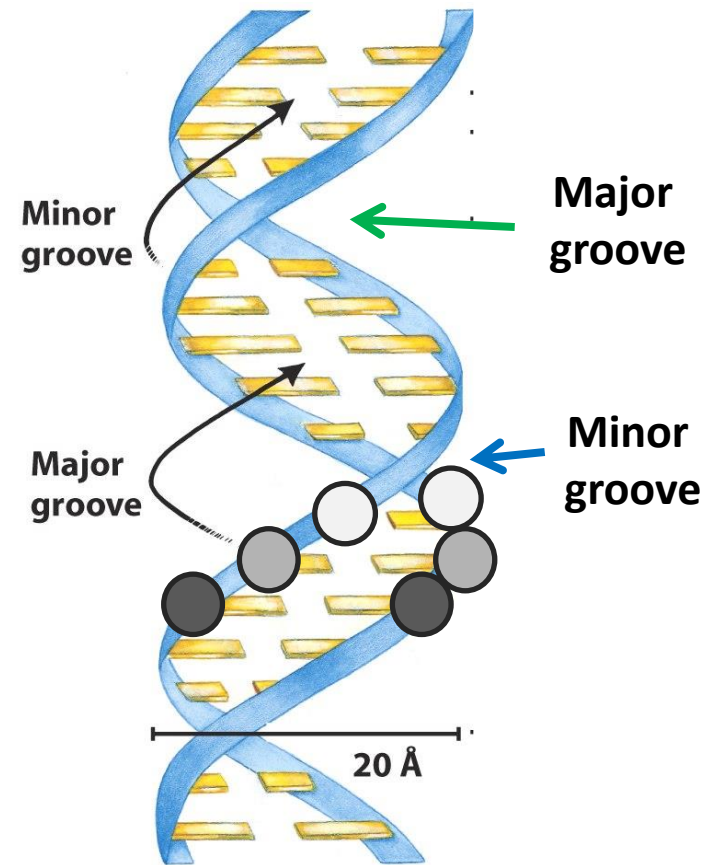
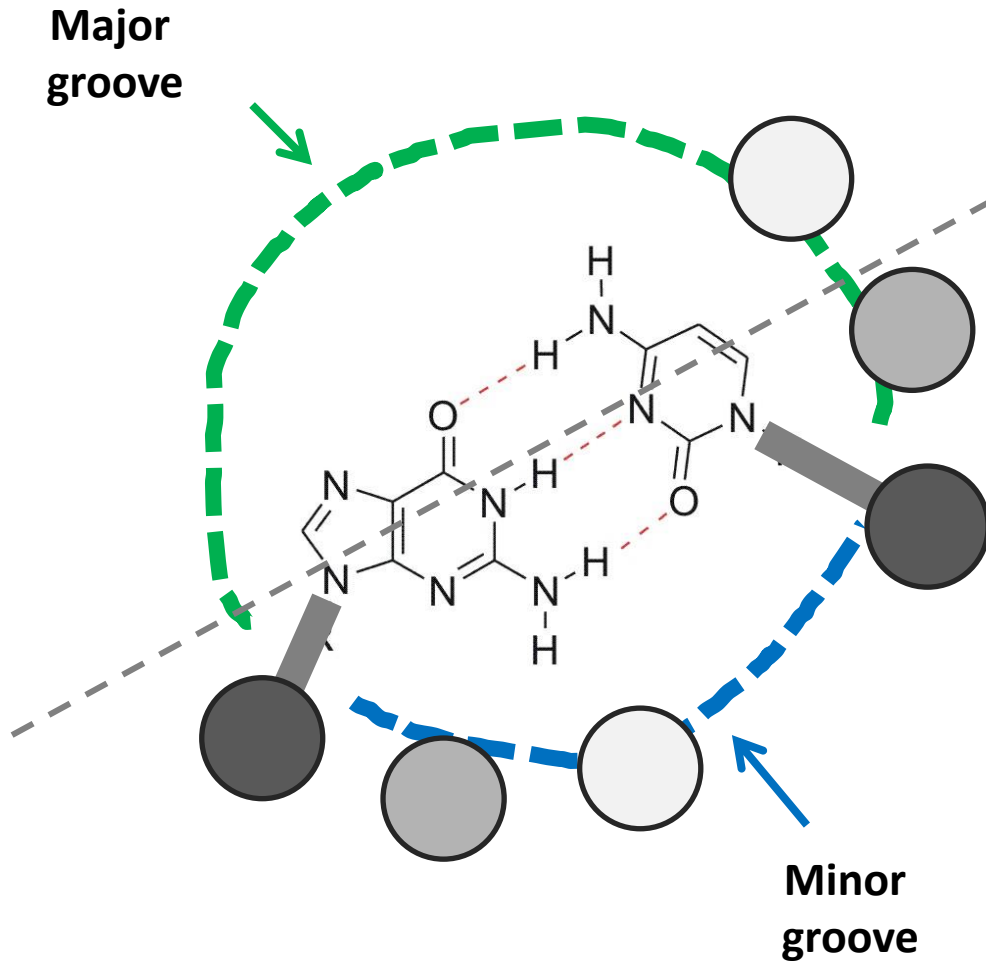
Sillons dans la double hélice de DNA



Sillons dans la double hélice de DNA



Sillons dans la double hélice de DNA



La structure du DNA a donné des informations sur la fonction

J. D. Watson, F. H. C. Crick

« Molecular structure of nucleic acids »

Nature **171**, 737-738 (1953)

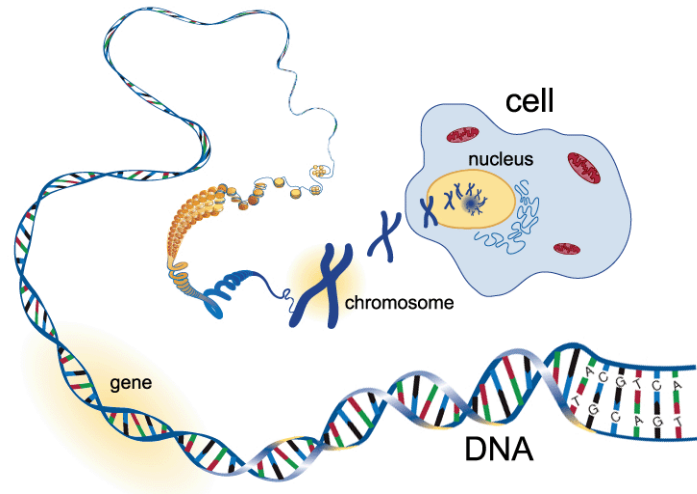
...It has not escaped our notice that the specific pairing we have postulated **immedetiately suggests a possible copying mechanism** for the genetic material.....



De quelle 'copying machanism' est-ce que Watson et Crick parle?

DNA réplication, méthode PCR

- Composition du DNA
 - Bases, sucres, phosphates
 - Découverte du DNA
 - Histoire
 - Expériences importantes
 - Structure du DNA
- ➡
- DNA réplication, méthode de PCR
 - Flux de l'information



DNA répllication

La séquence d'un brin de la double hélice permet de déduire la séquence de l'autre brin!

Exemple:

5'-ATGGGC-3'

DNA répllication

La séquence d'un brin de la double hélice permet de déduire la séquence de l'autre brin!

Exemple:

5'-ATGGGC-3'

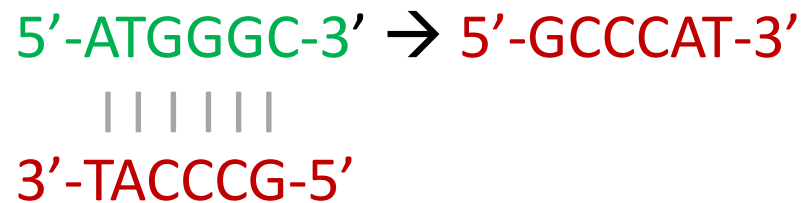
||| ||

3'-TACCCG-5'

DNA répllication

La séquence d'un brin de la double hélice permet de déduire la séquence de l'autre brin!

Exemple:



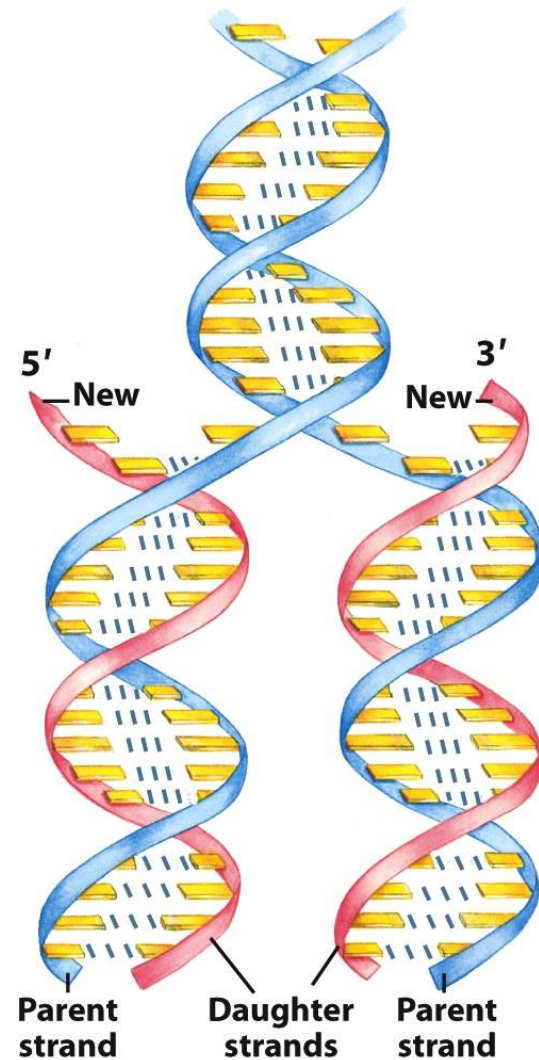
DNA répliation

- La séquence d'un brin de la double hélice permet de déduire la séquence de l'autre brin!

Exemple:

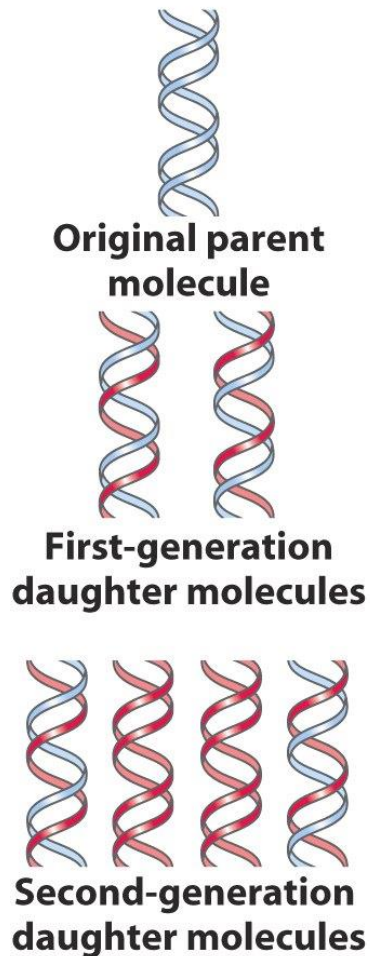
5'-ATGGGC-3' → 5'-GCCCAT-3'

- La séparation des deux brins peut fournir deux matrices
- Deux nouvelles double hélices peuvent être synthétisées



Comment est-ce qu'on pourrait vérifier si cette hypothèse est correcte?

Réplication semi-conservative



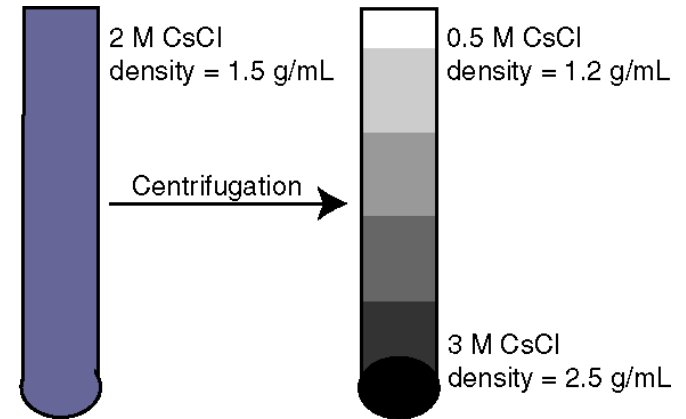
Expérience de Matthew Meselson et Franklin Stahl:

1. Marquer le **DNA** de bactérie **parental** avec l'isotope ^{15}N (en cultivent E.coli dans un milieu avec $^{15}\text{NH}_4\text{Cl}$)
2. Transférer les bactéries brusquement dans un milieu avec ^{14}N .
3. Analyser la distribution de ^{15}N et ^{14}N

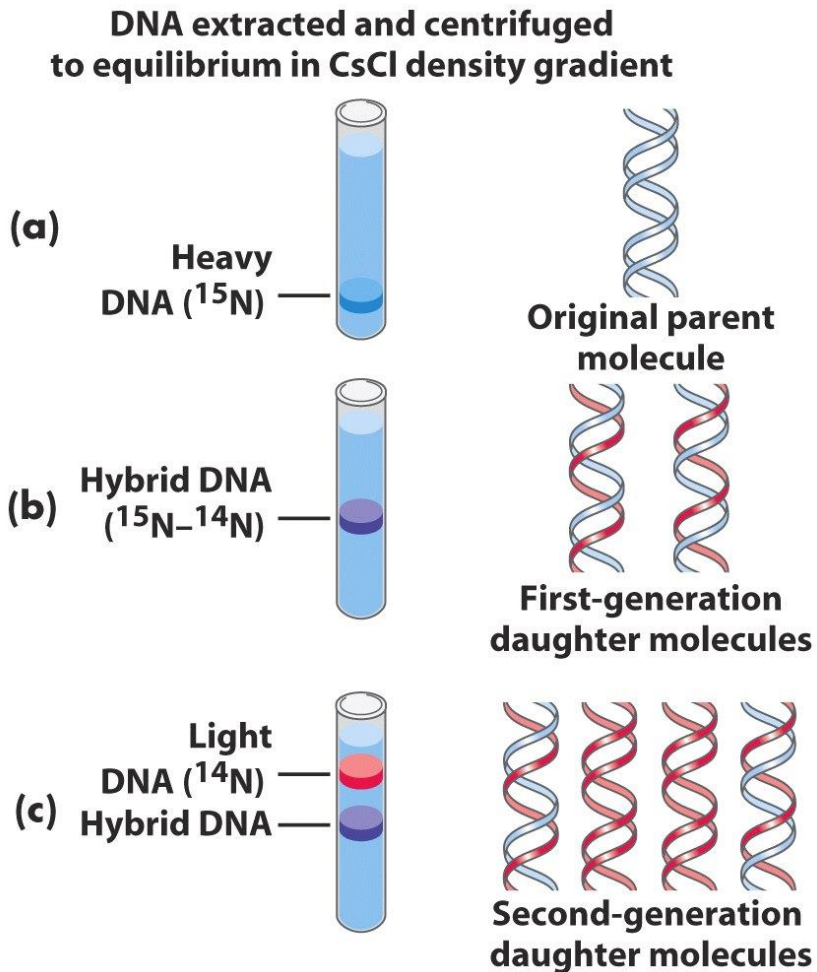


Sédimentation à l'équilibre en gradient de densité

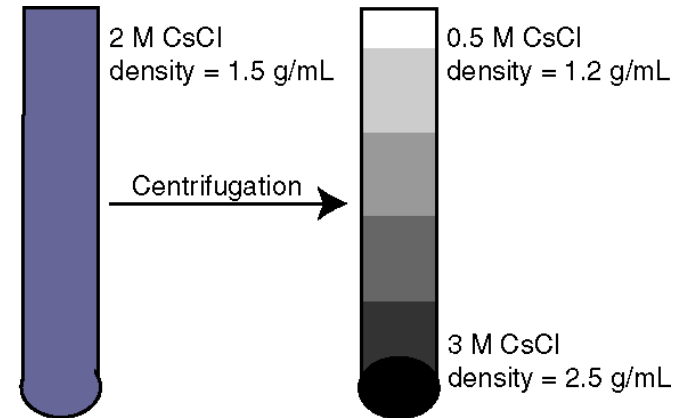
chlorure de césium



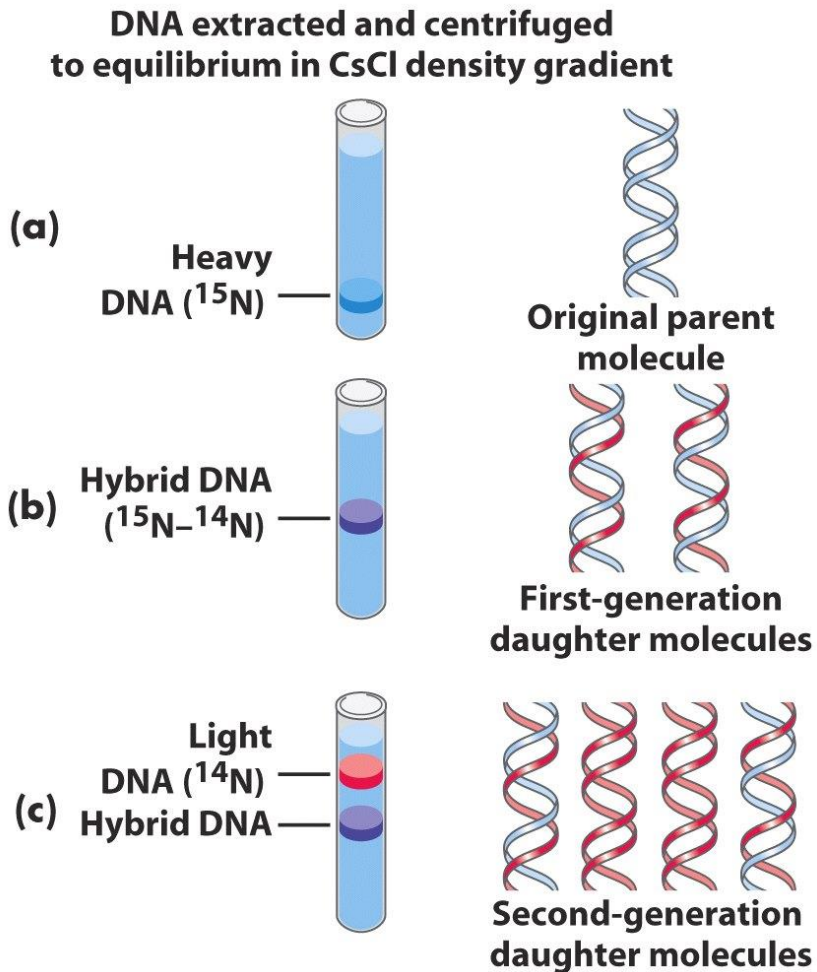
Sédimentation à l'équilibre en gradient de densité



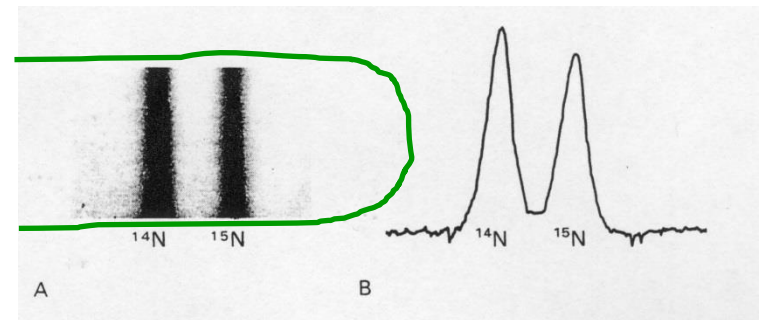
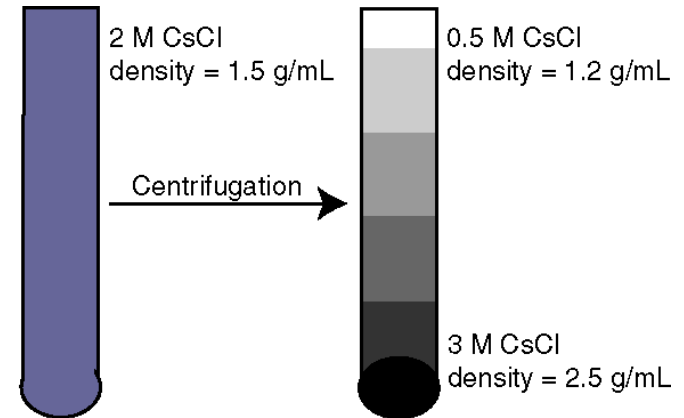
chlorure de césium



Sédimentation à l'équilibre en gradient de densité

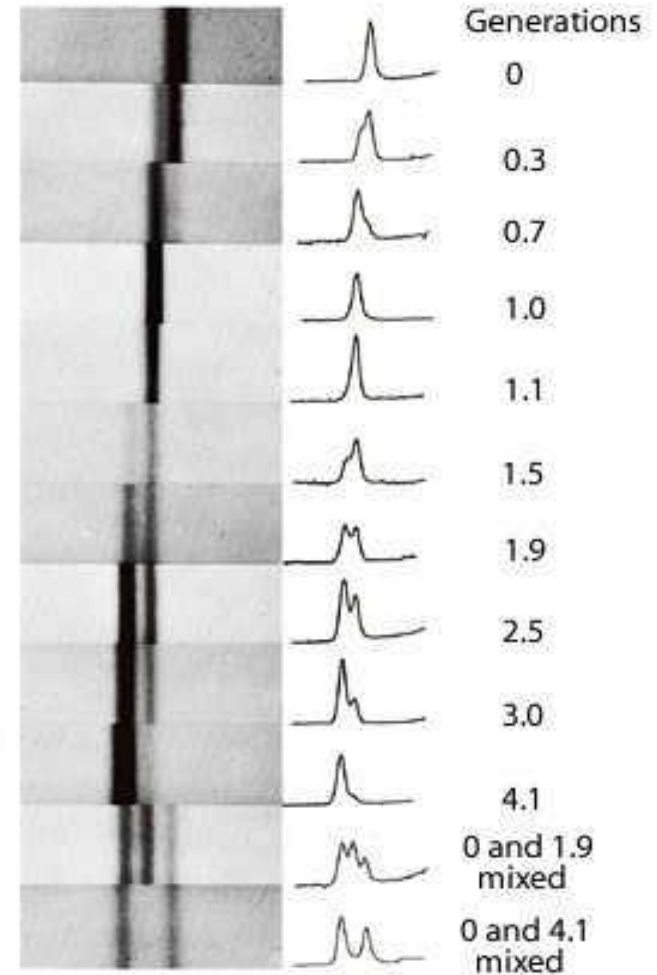
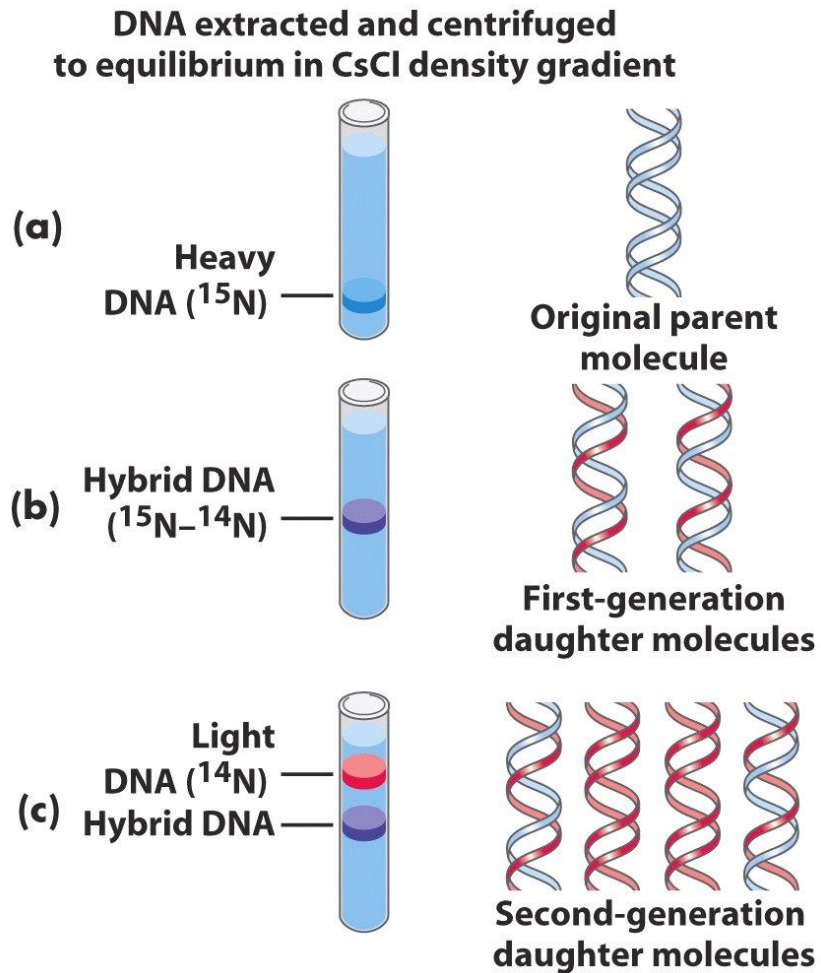


clorure de césium

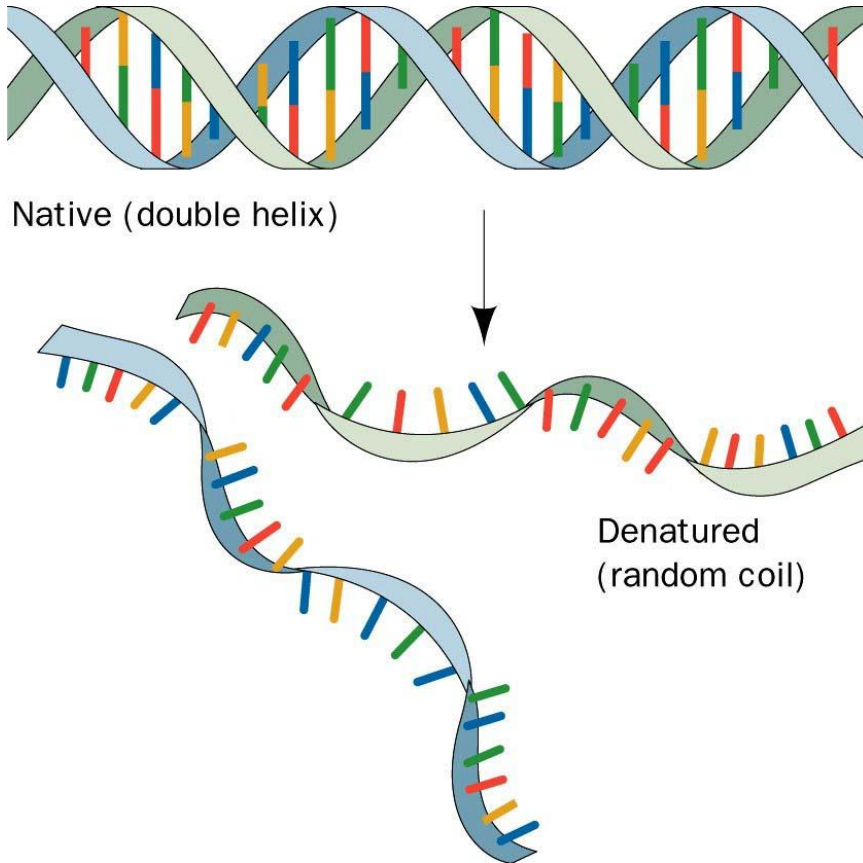


Meselson & Stahl *PNAS* **44**, 671 (1956)

Réplication semi-conservative



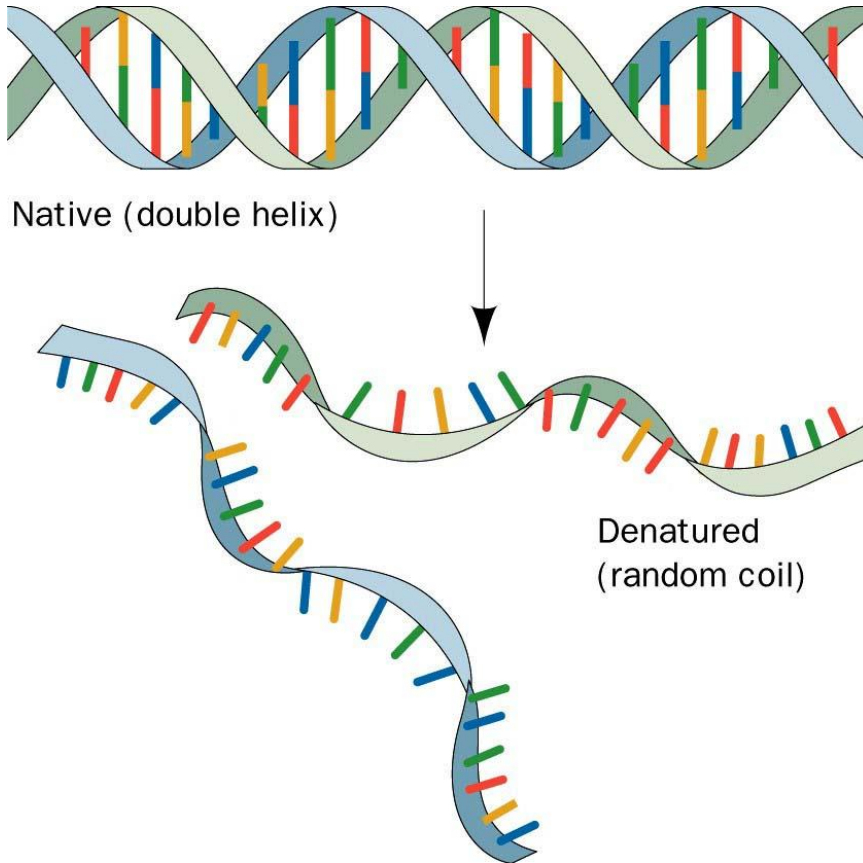
Dissociation des brins de DNA



Pour la réplication et les autres processus, les deux brins doivent être séparés

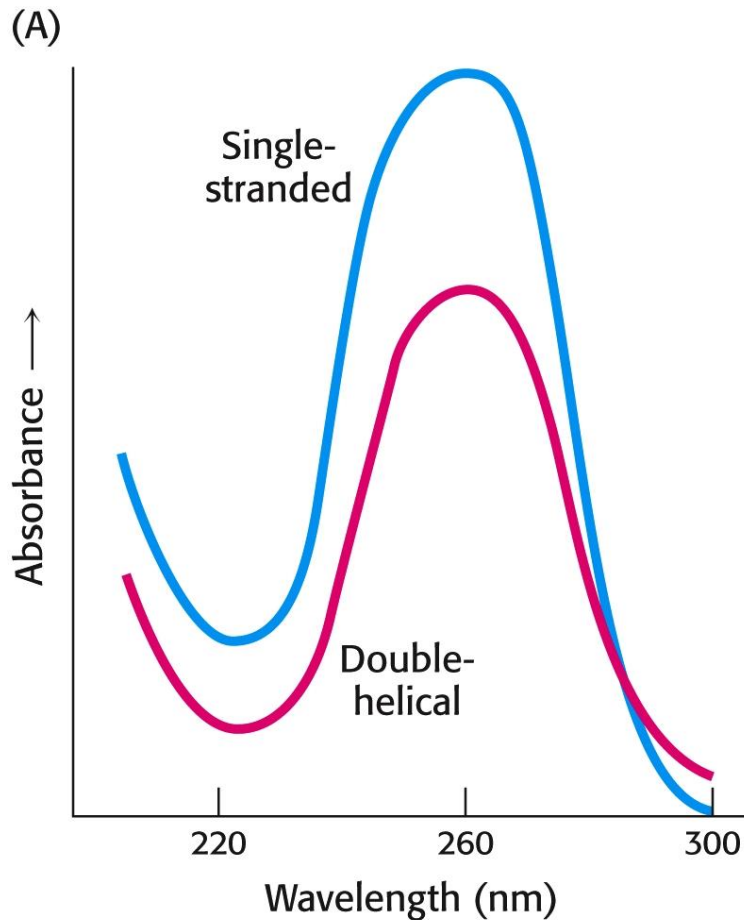
Comment est-ce que les brins de la double hélice peuvent être séparés?

Dissociation des brins de DNA



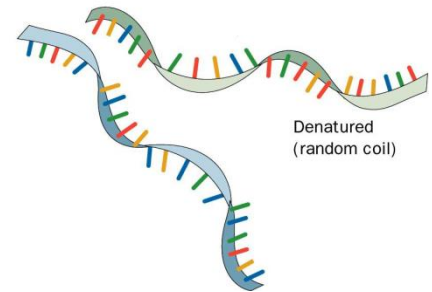
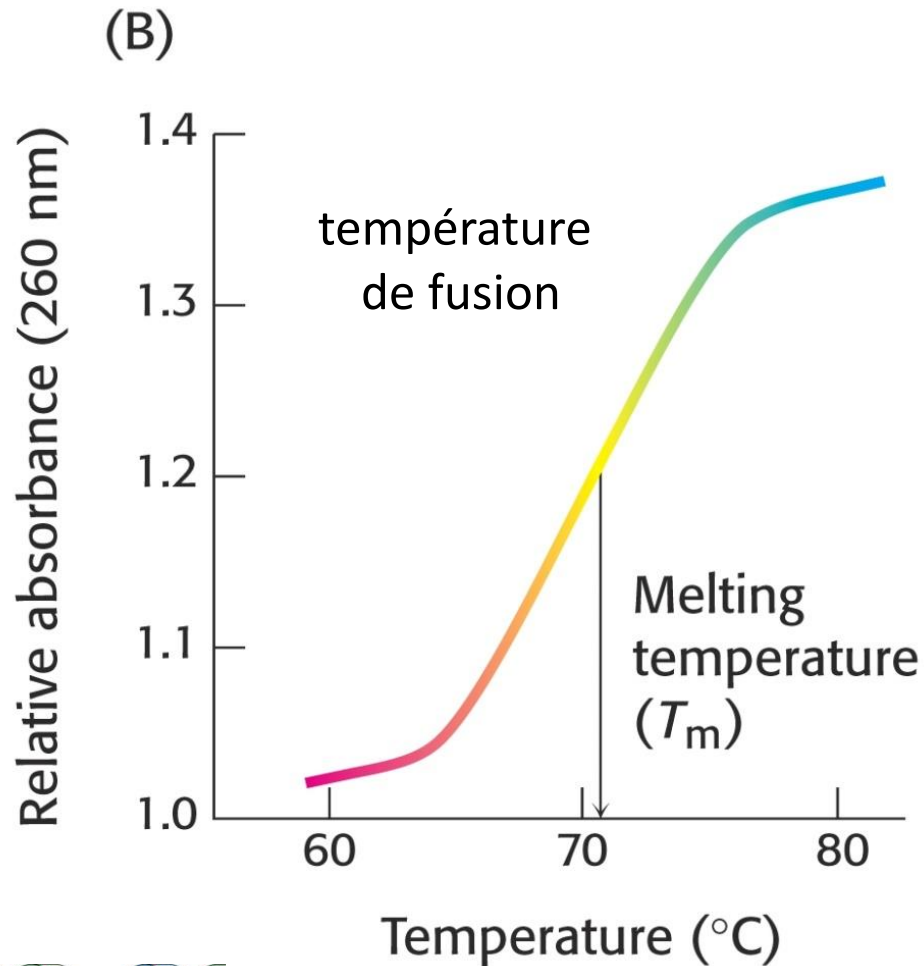
- Méthodes de séparation:
 - chaleur
 - acide (détruire les liaisons hydrogène)
- Dans les cellules, les brins sont dissociés par des enzymes en utilisant de l'énergie: hélicase

Dissociation des brins de DNA

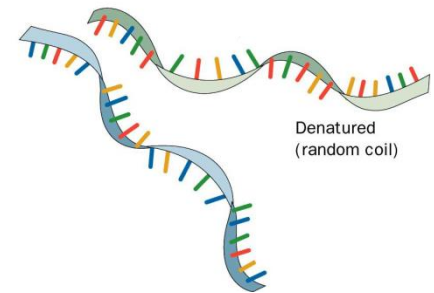
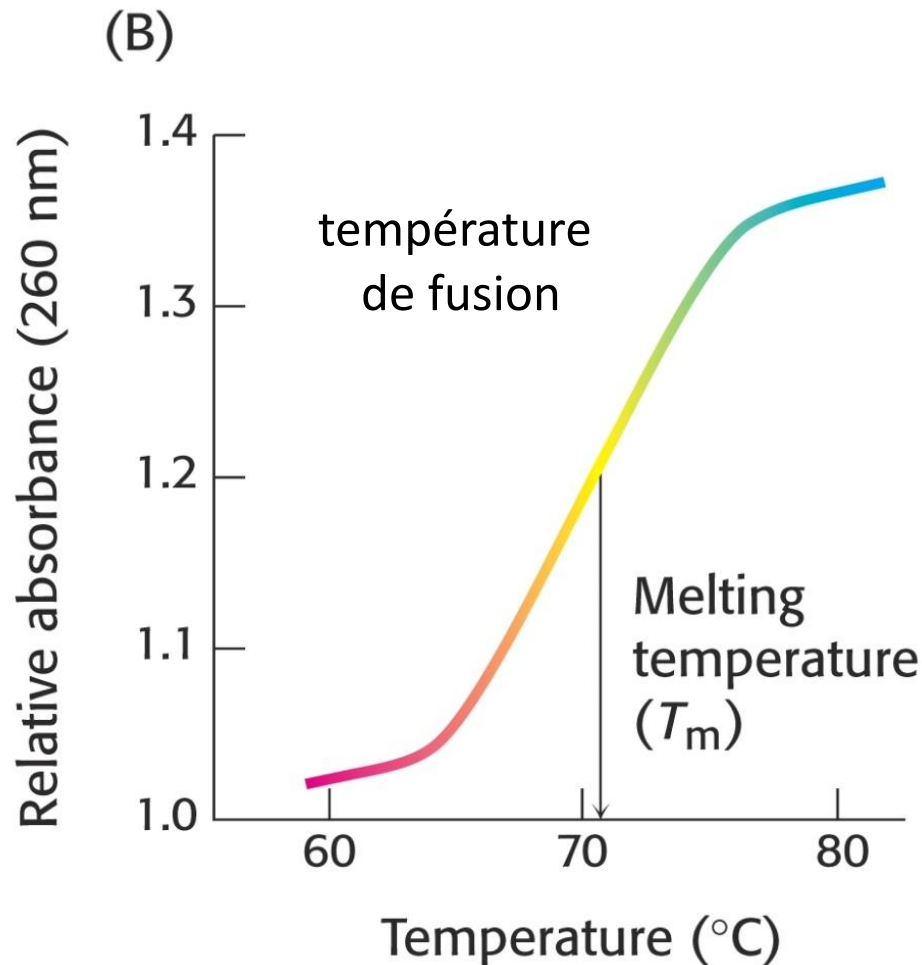


- Les bases forment des doubles hélices absorbant moins de lumière que les brins séparés
- L'absorption de la lumière est maximale à une longueur d'onde de 260 nm

Dissociation des brins de DNA



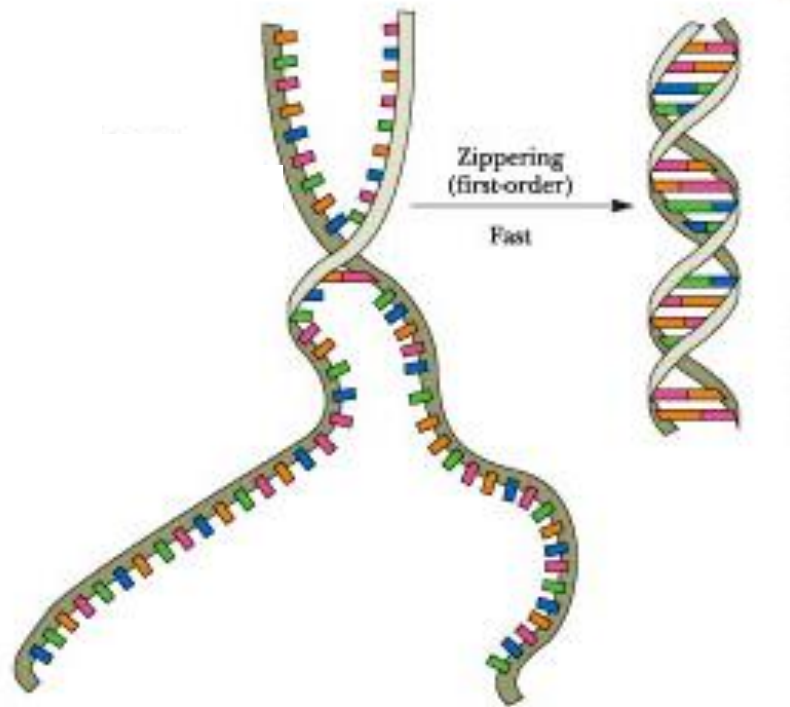
Dissociation des brins de DNA



*Est-ce que la
dénaturation du
DNA est réversible?*



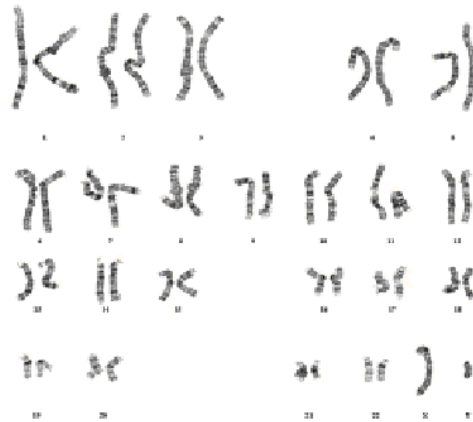
Renaturation des brins: **hybridation**



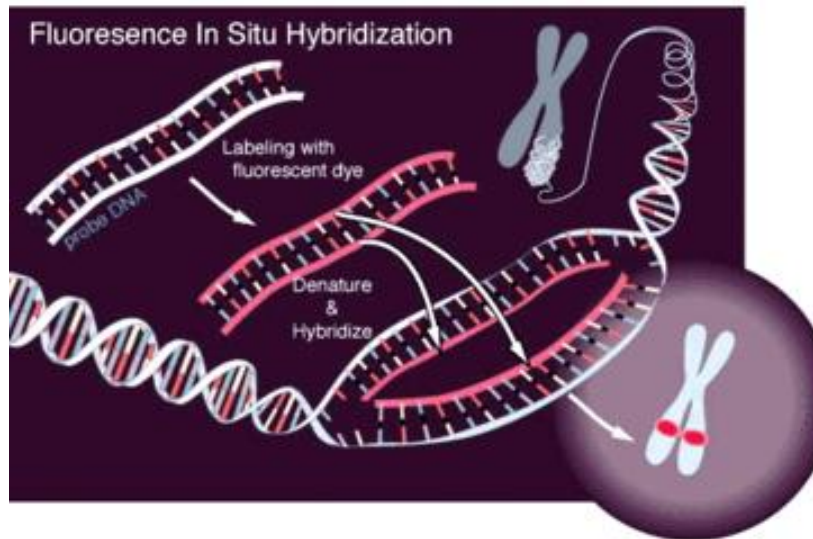
- Des brins complémentaires séparés peuvent se lier = **hybridation**
- L'hybridation est utilisée dans plusieurs méthodes.
Exemple: *Fluorescence In Situ Hybridation (FISH)*

Fluorescence In Situ Hybridization (FISH)

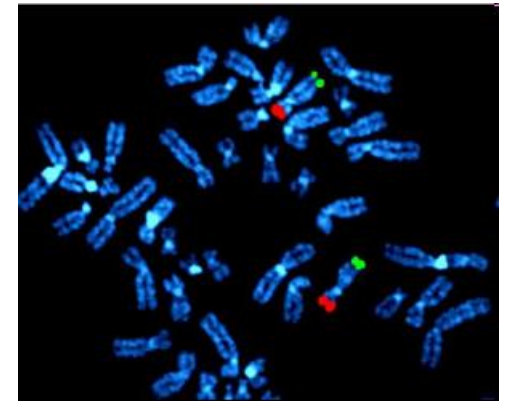
A



B



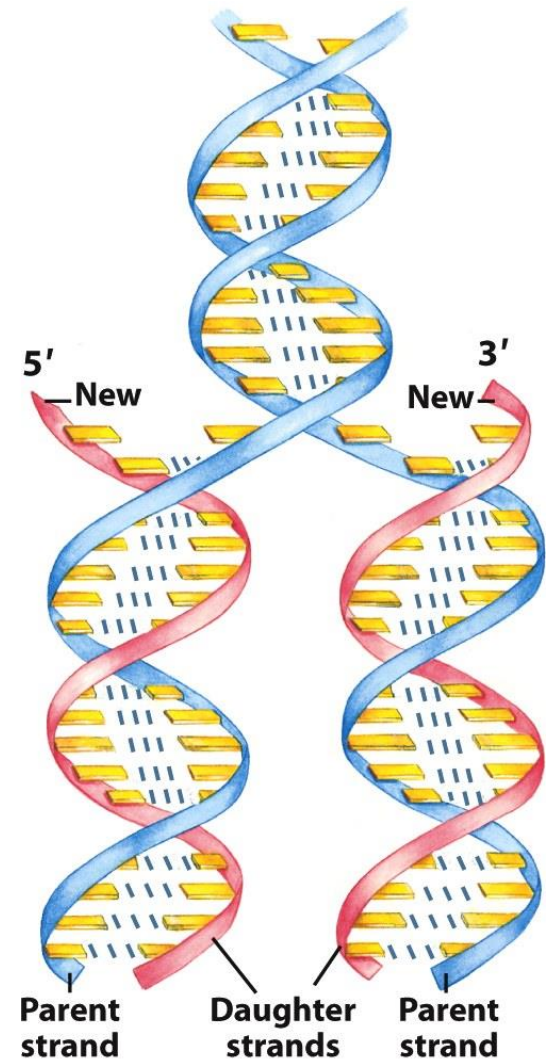
C



DNA réplcation

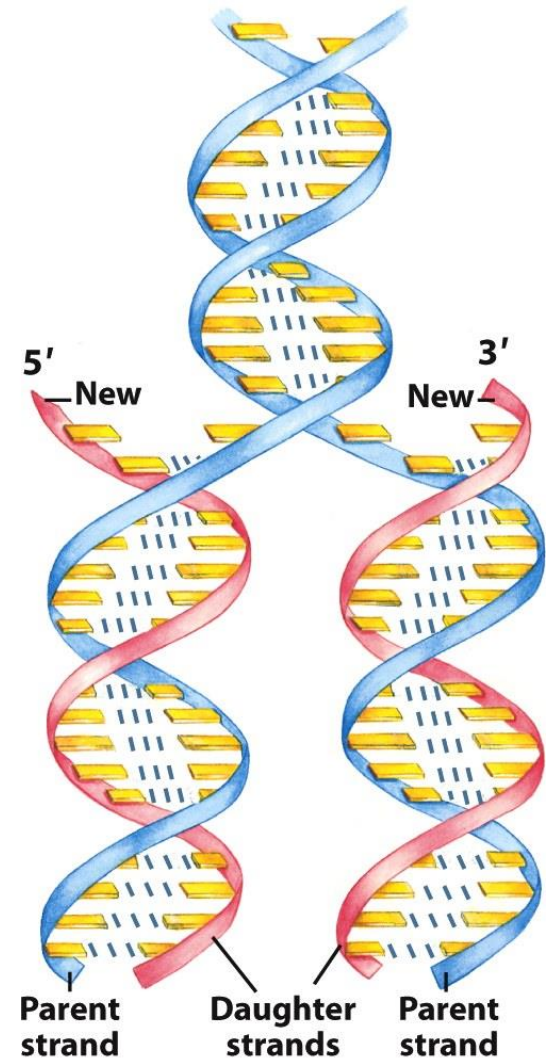
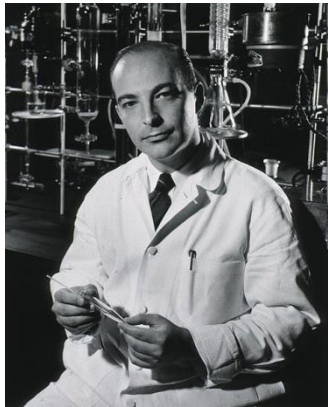
- Dans les cellules, les brins de DNA sont copiés (Meselson & Stahl)
- Les deux brins d'une double hélice peuvent être séparés

Comment est-ce que le processus de duplication marche dans les cellules?



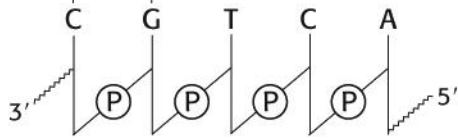
DNA répllication

- Le DNA est répliqué par une enzyme:
DNA polymérase
- En 1958, Arthur Kornberg a isolé la
DNA polymérase de *E. coli*



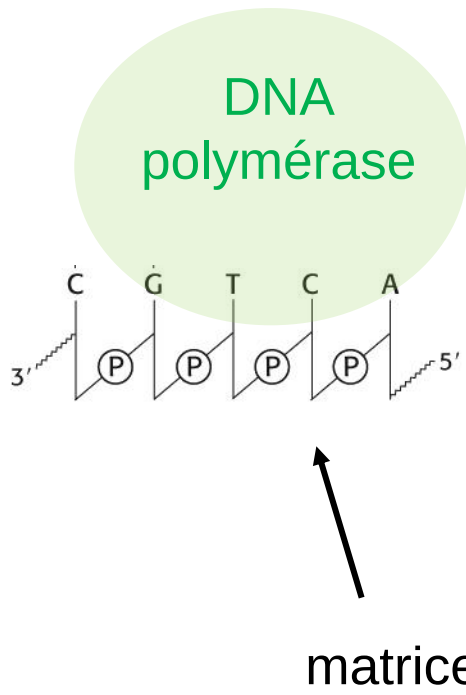
- Il a reçu le prix Nobel en 1959

Réplication du DNA par la DNA polymérase

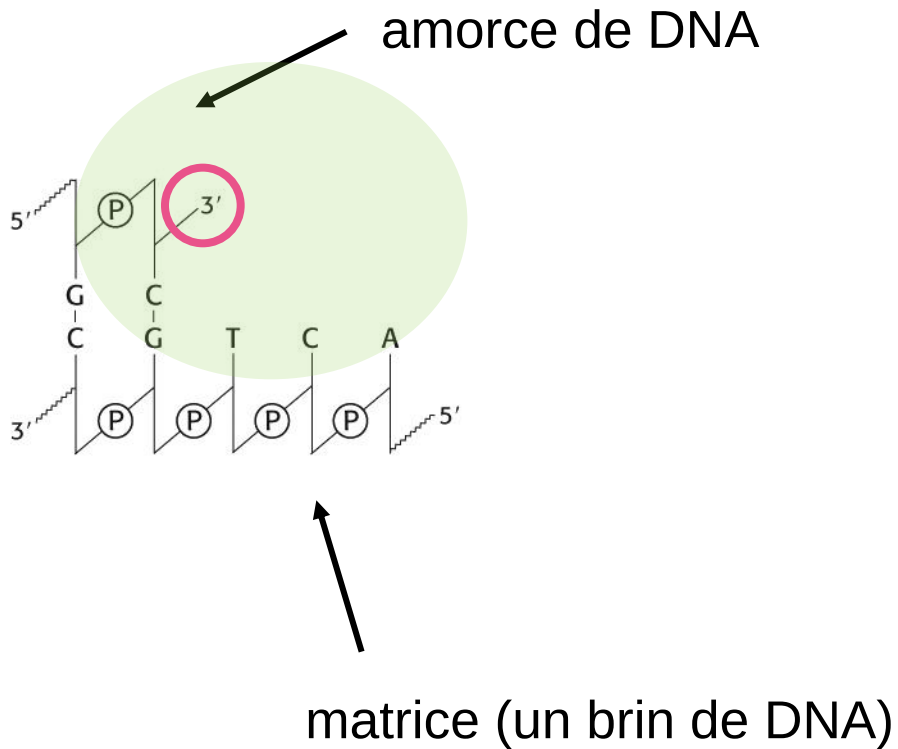


matrice (un brin de DNA)

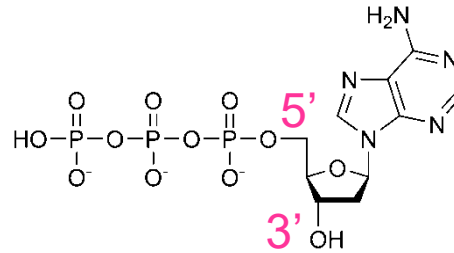
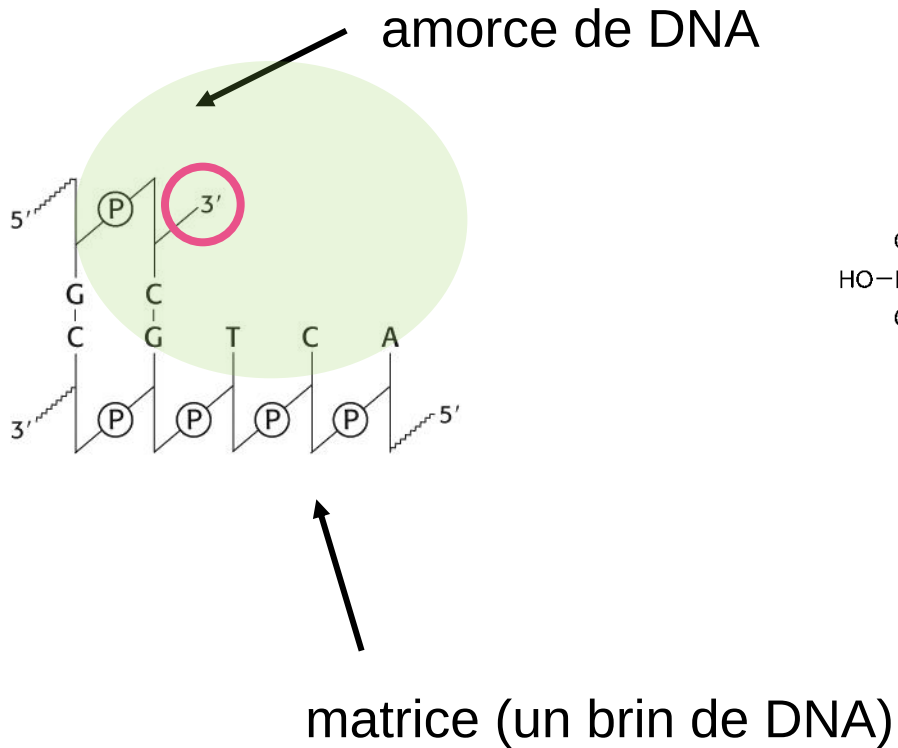
Réplication du DNA par la DNA polymérase



Réplication du DNA par la DNA polymérase

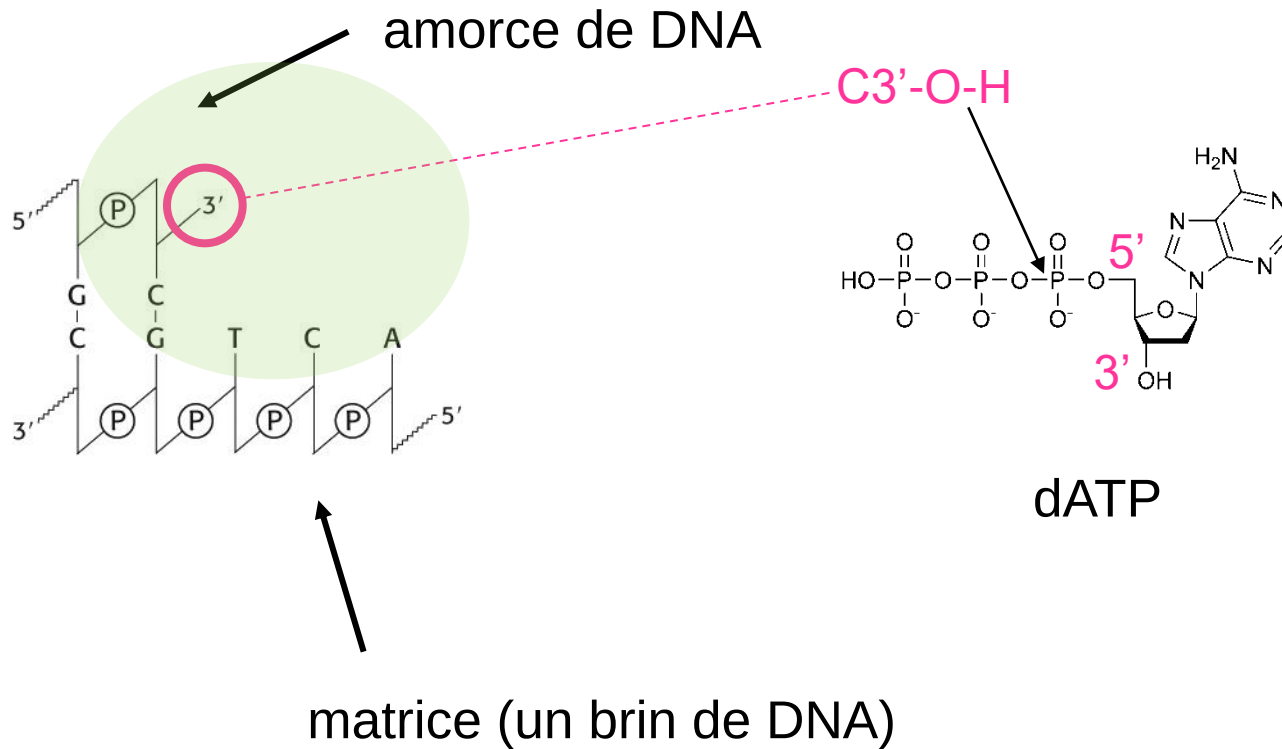


Réplication du DNA par la DNA polymérase

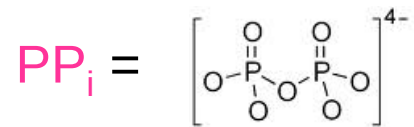
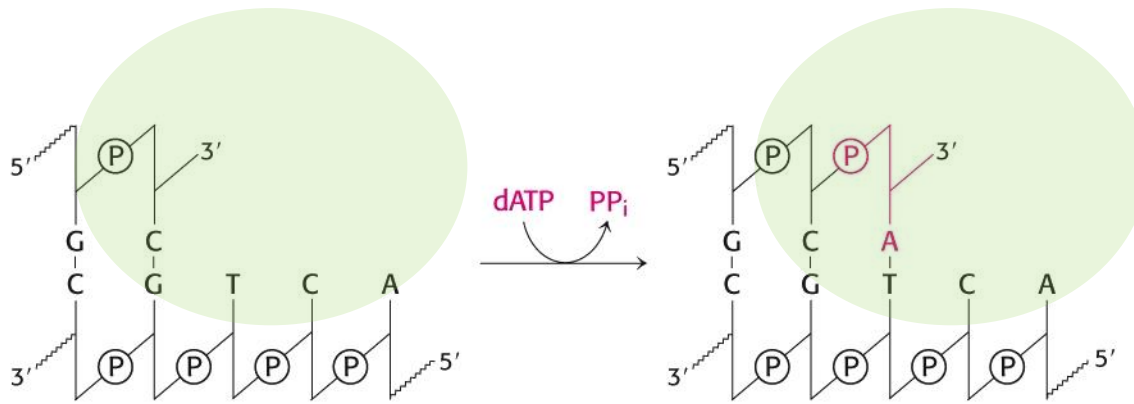


dATP

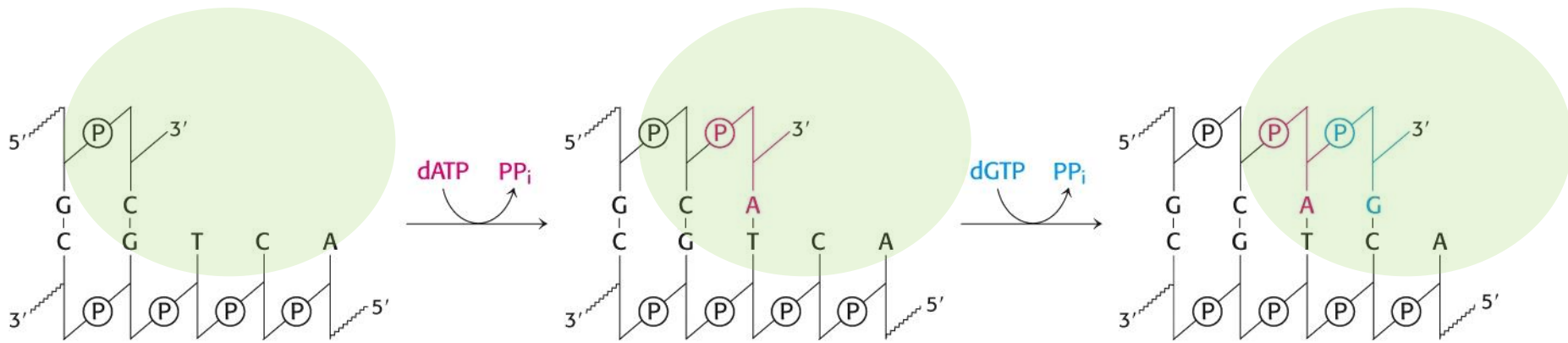
Réplication du DNA par la DNA polymérase



Réplication du DNA par la DNA polymérase

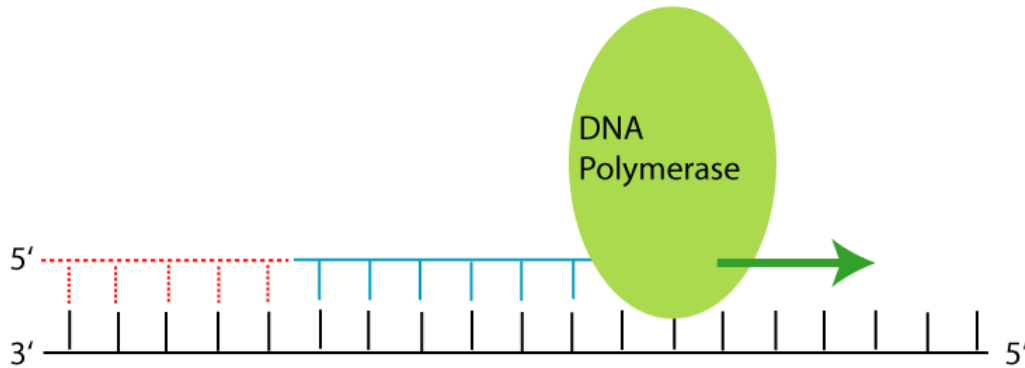


Réplication du DNA par la DNA polymérase

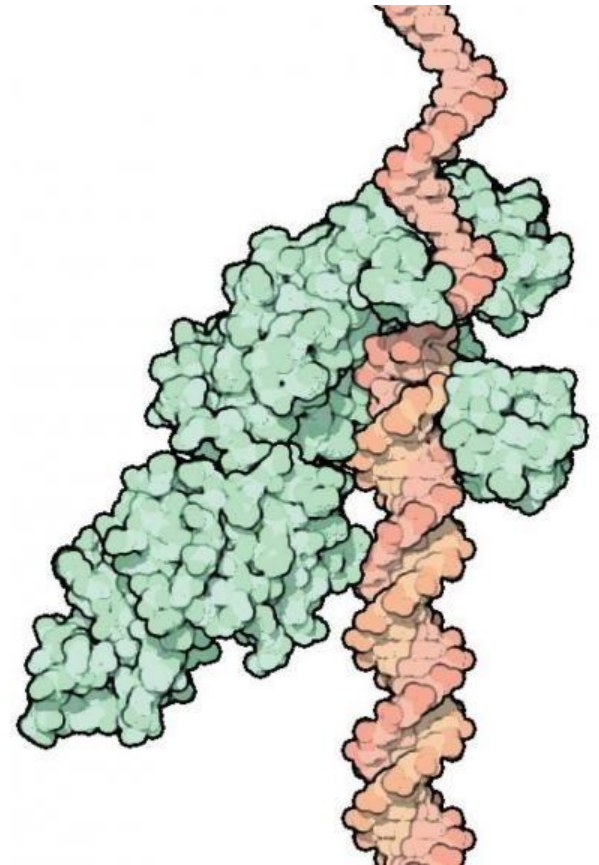


- DNA polymérase catalyse la ligation des nucleotides
- Élongation dans la direction 5' → 3'

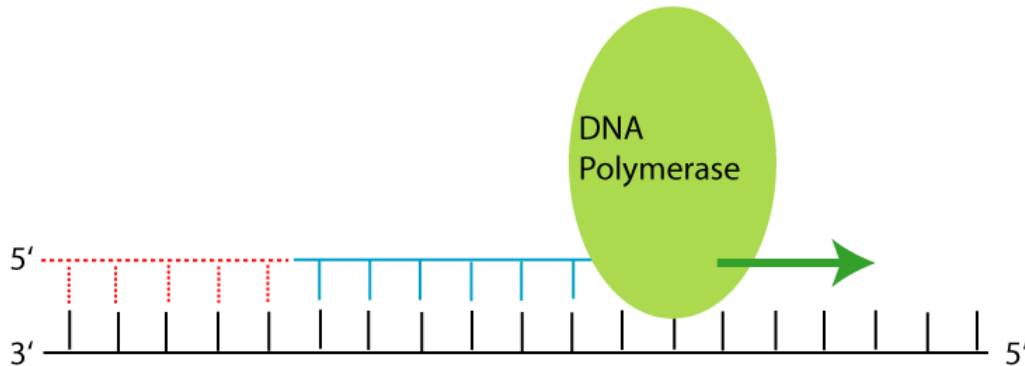
Réplication du DNA



*Quels réactifs sont nécessaire
pour la réplication du DNA?*

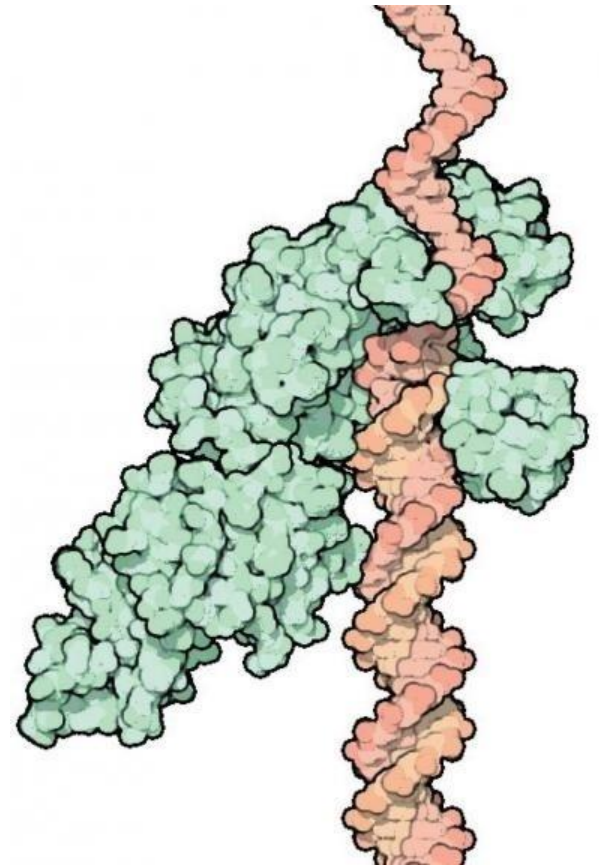


Réplication du DNA

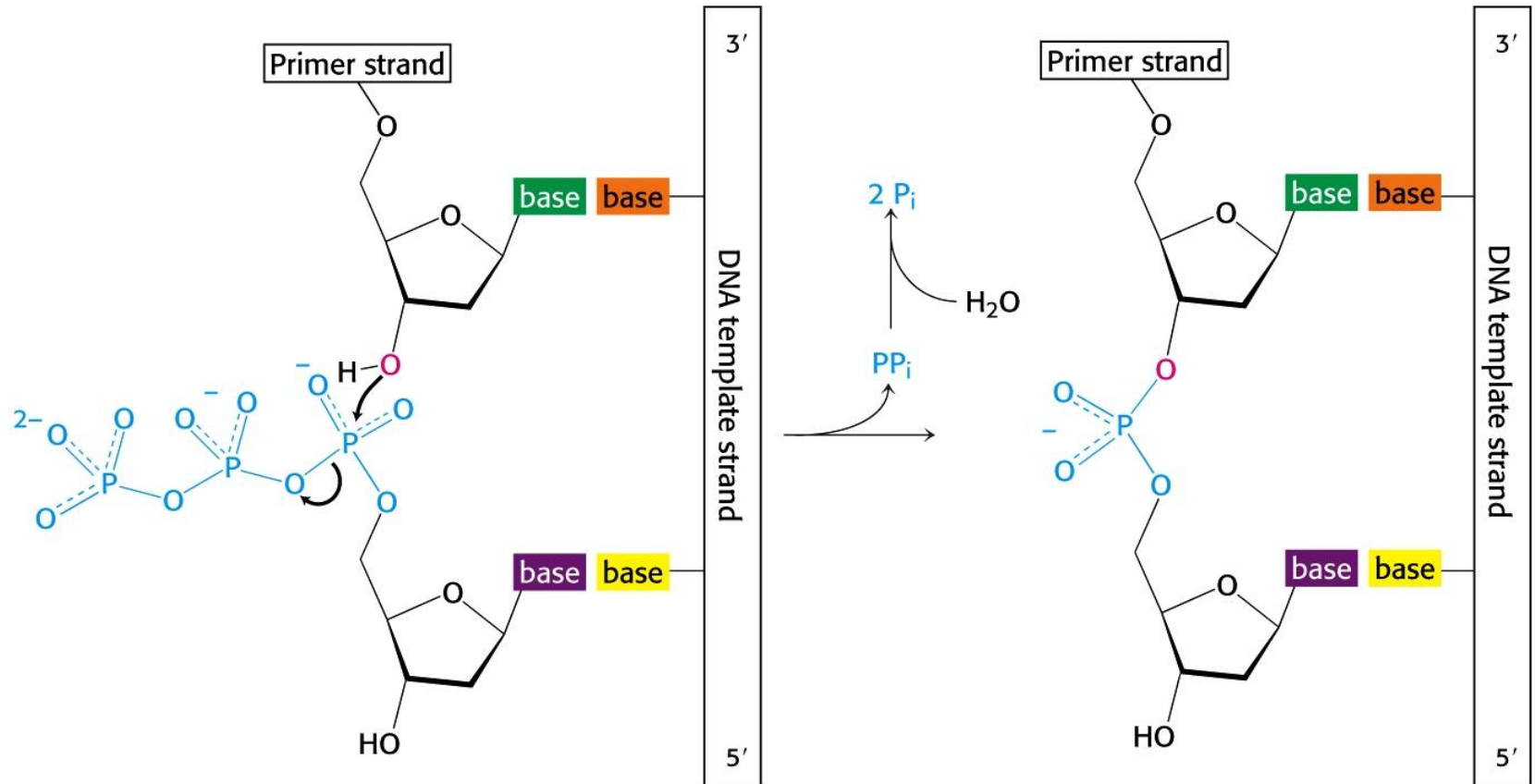


Réactifs:

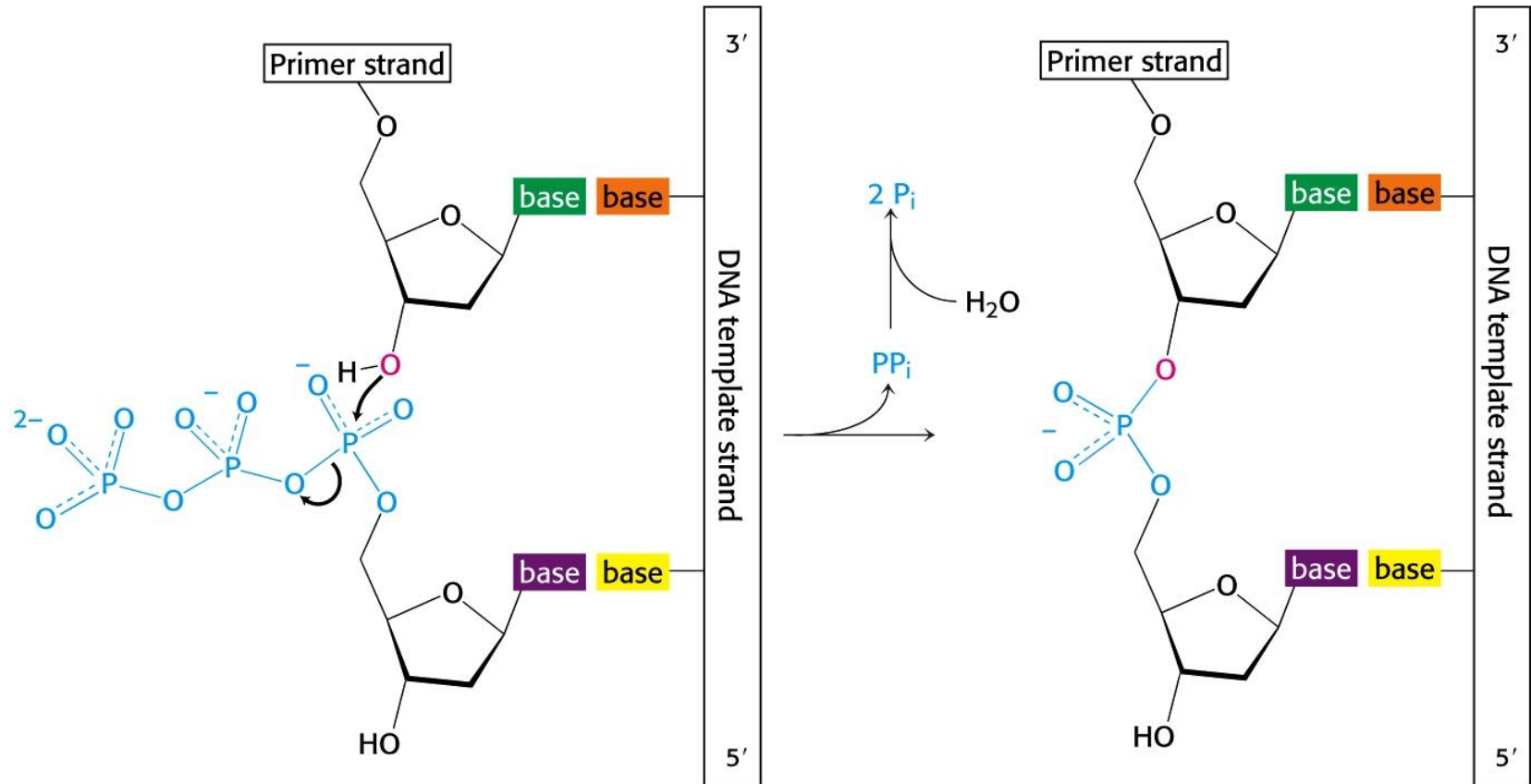
- matrice (brin de DNA)
- **amorce de DNA ('primer')**
- déoxynucléotides 5'-triphosphate (dATP, dGTP, dTTP, dCTP)
- **DNA polymérase**



Réplication du DNA: ligation des nucléotides

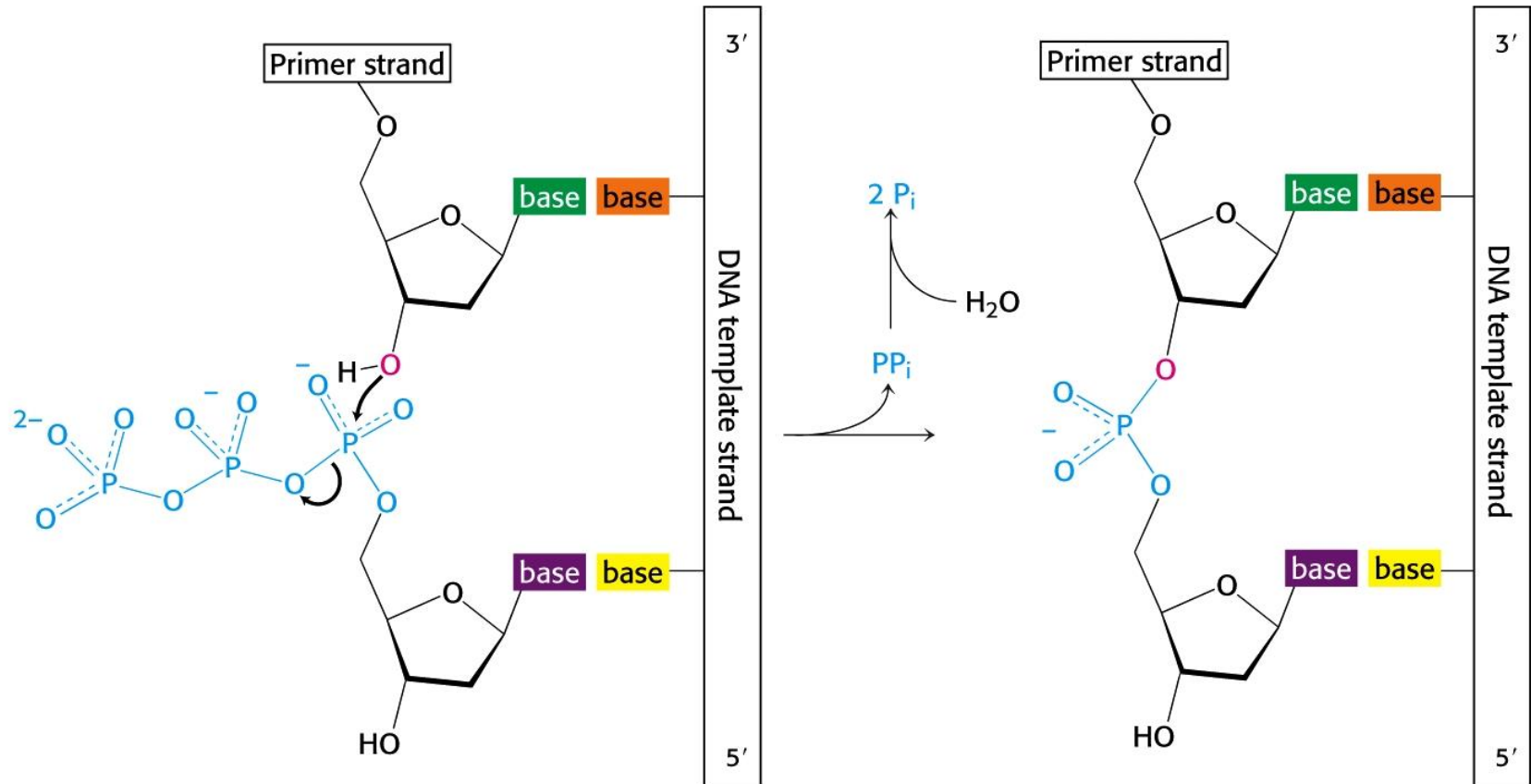


Réplication du DNA: ligation des nucléotides



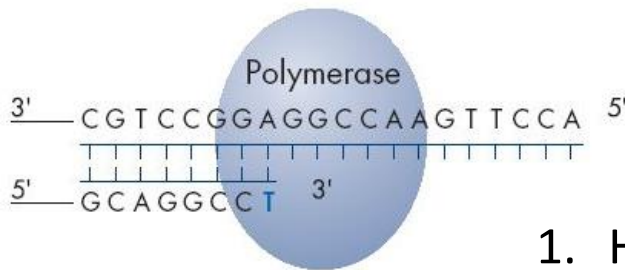
Combien d'erreurs est-ce que la DNA polymérase fait?

Réplication du DNA: ligation des nucléotides



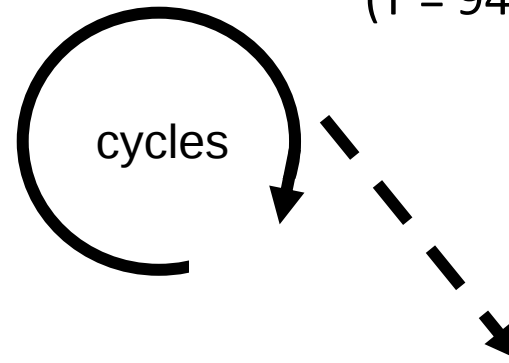
- La DNA polymérase a aussi une fonction « proof-reading »
- 1 erreur par 10^8 étapes d'élongation!!

Copier des séquences de DNA au laboratoire avec la DNA polymérase



1. Hybridisation
de l'amorce
($T = 50^{\circ}\text{C}$)

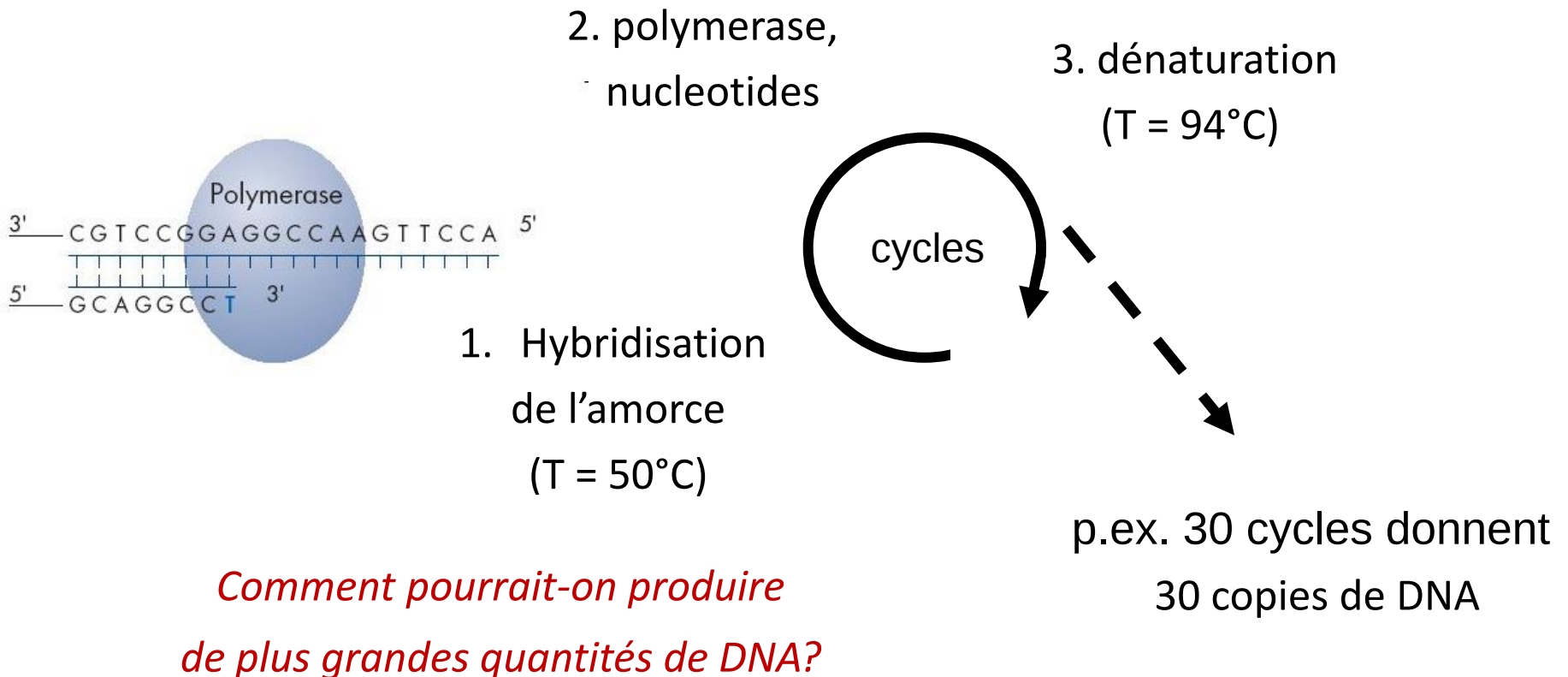
2. polymerase,
nucleotides



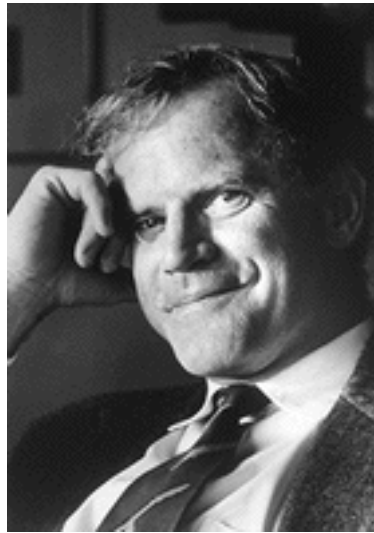
3. dénaturation
($T = 94^{\circ}\text{C}$)

p.ex. 30 cycles donnent
30 copies de DNA

Copier des séquences de DNA au laboratoire avec la DNA polymérase



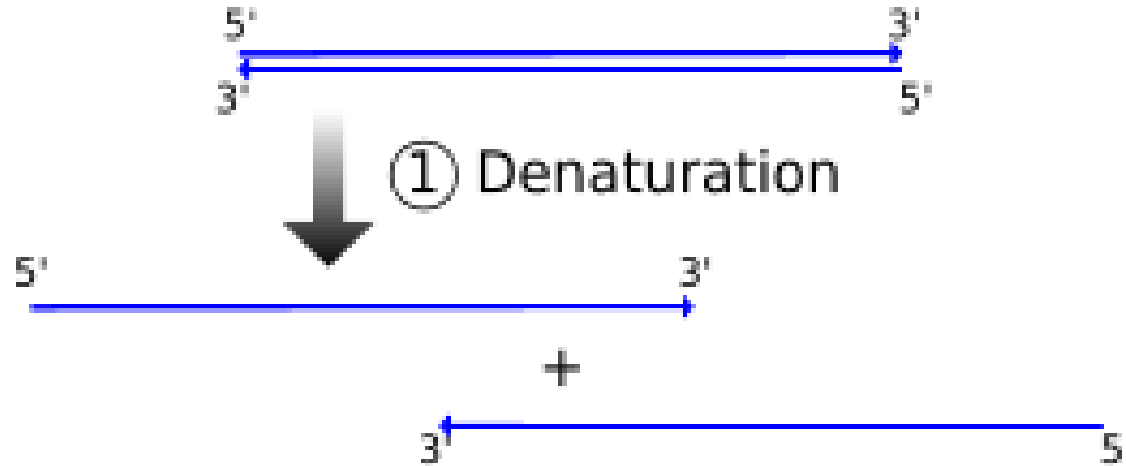
Amplification des séquences de DNA par la « polymerase chain reaction » (PCR)



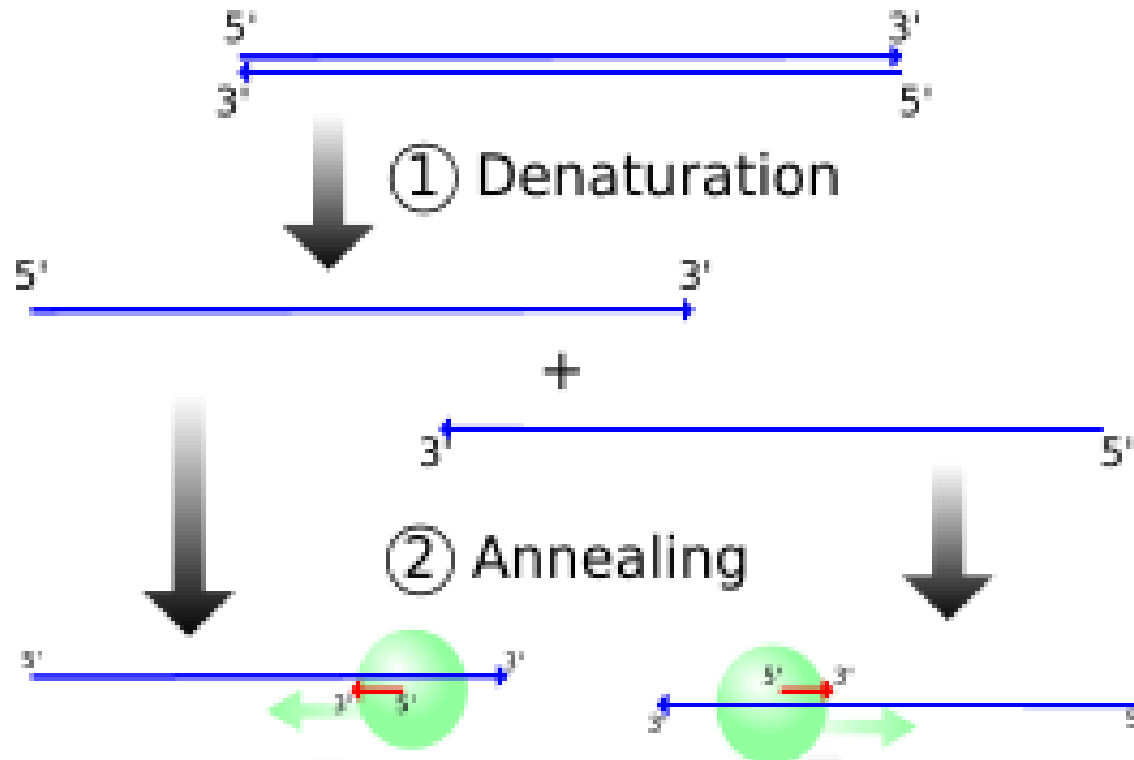
Kary Mullis

Prix Nobel in 1993

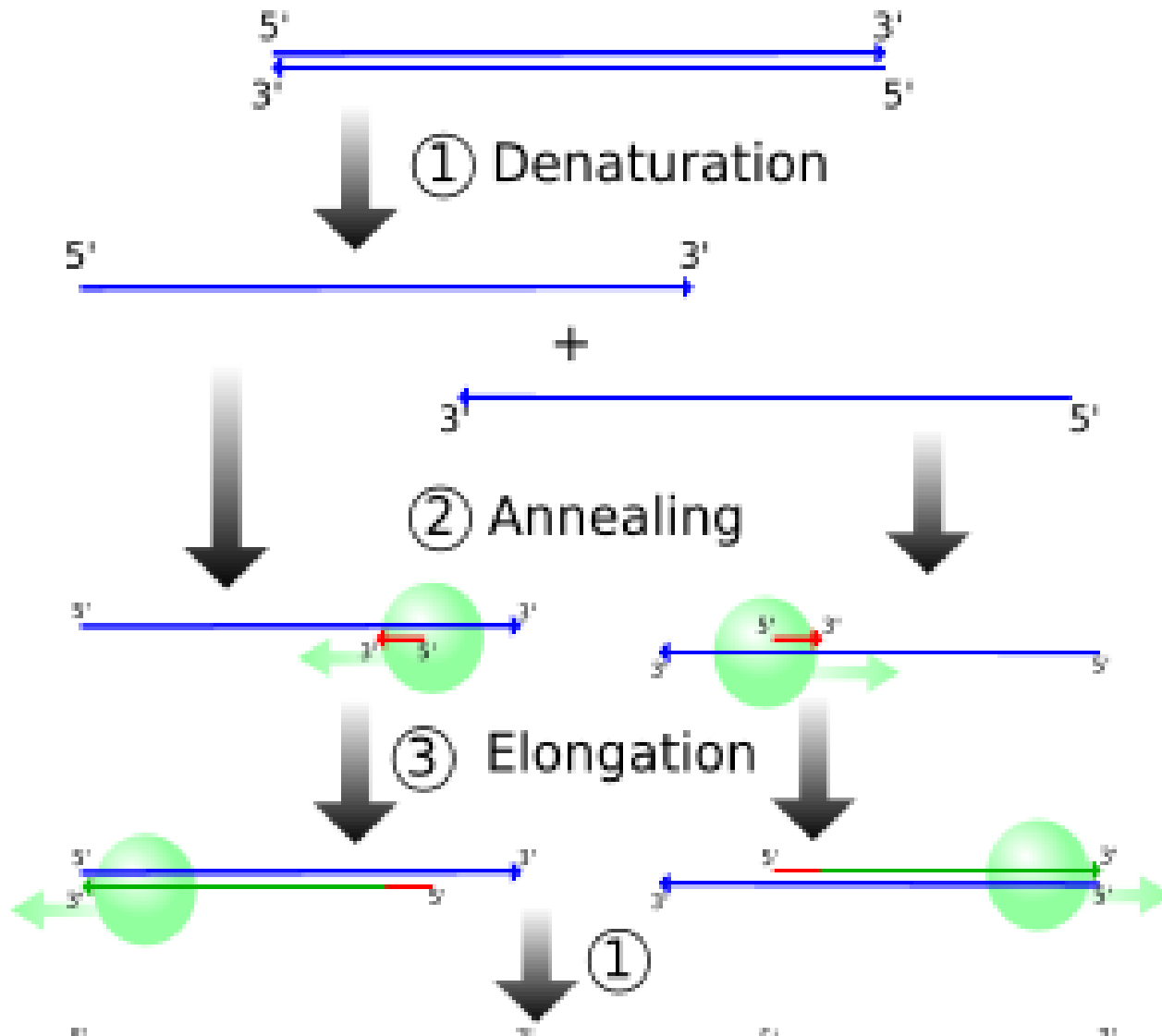
Amplification des séquences de DNA par la « polymerase chain reaction » (PCR)

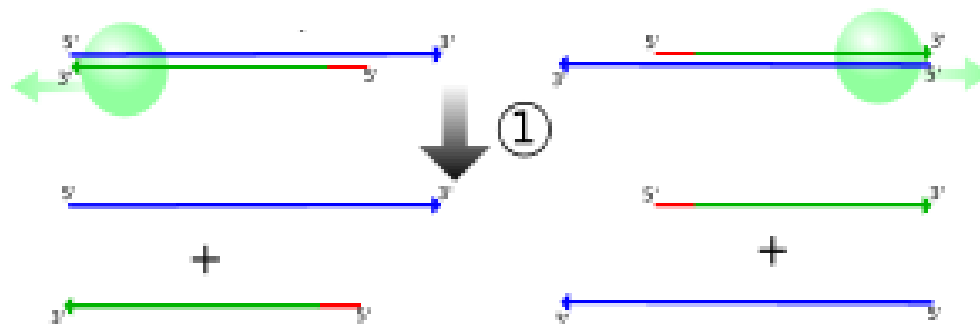


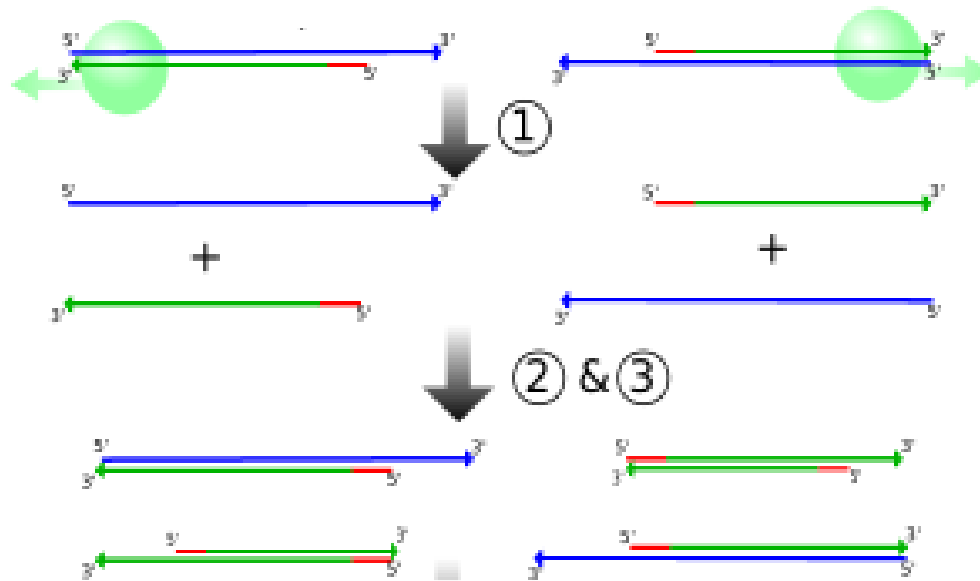
Amplification des séquences de DNA par la « polymerase chain reaction » (PCR)

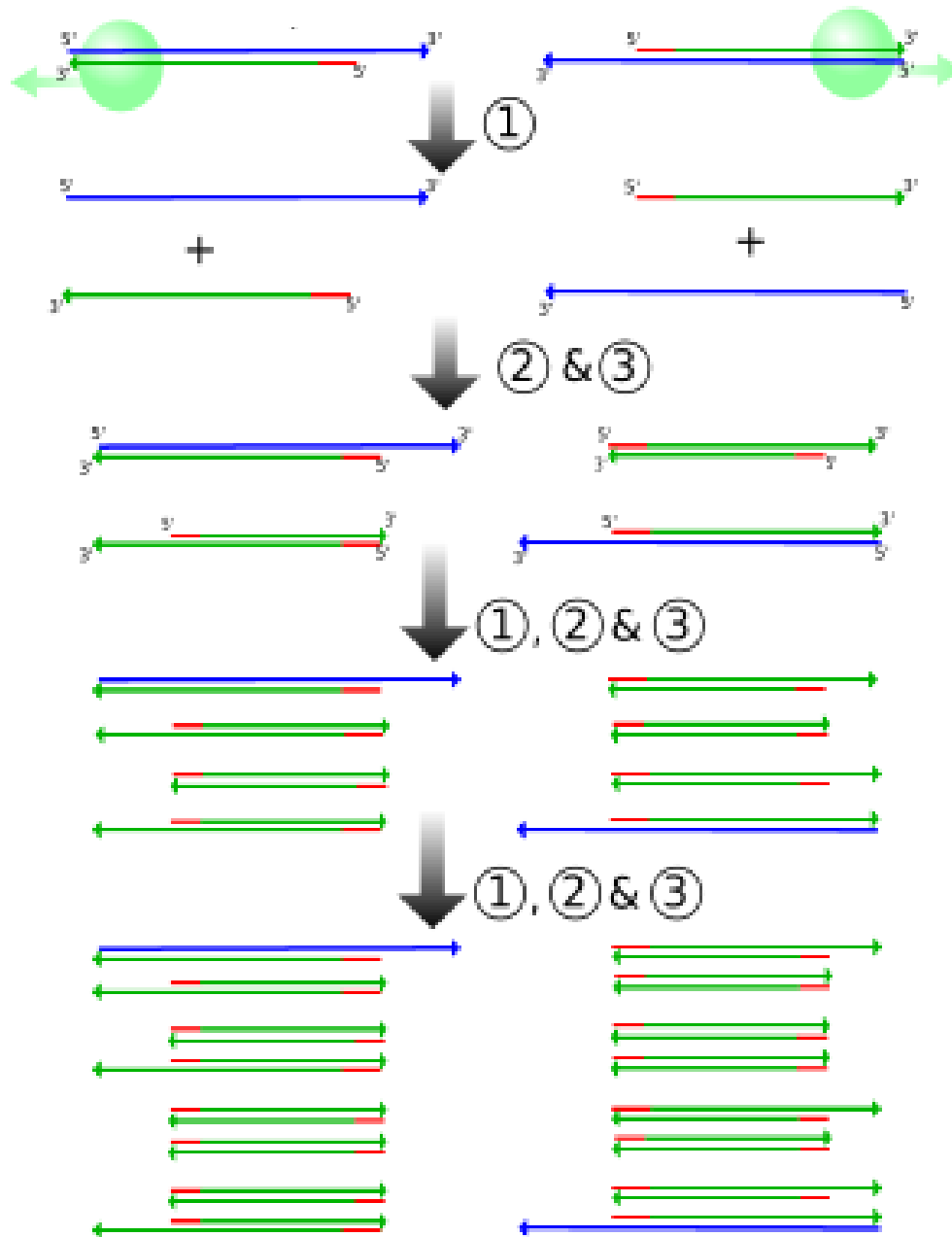


Amplification des séquences de DNA par la « polymerase chain reaction » (PCR)









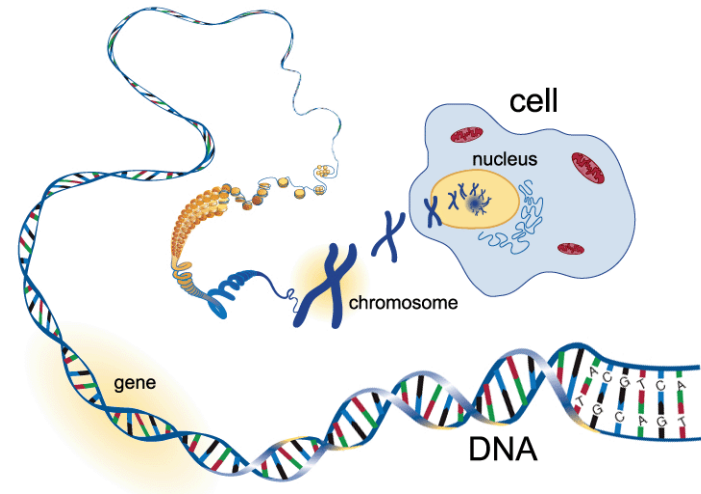
PCR vs réplication normale

Copies de DNA:

Cycles	PCR	Réplication normale
0	1	1
1	2	2
2	4	3
3	8	4
4	16	5
5	32	6
6	64	7
7	128	8
8	256	9
9	512	10
10	1024	11
....		

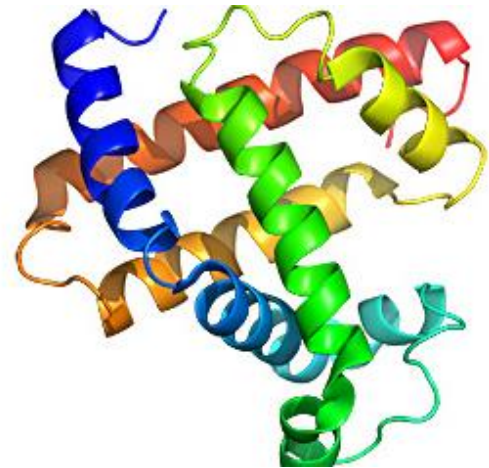
Flux de l'information

- Composition du DNA
 - Bases, sucres, phosphates
- Découverte du DNA
 - Histoire
 - Expériences importantes
- Structure du DNA
- DNA réplication, méthode de PCR
- ➡ • Flux de l'information

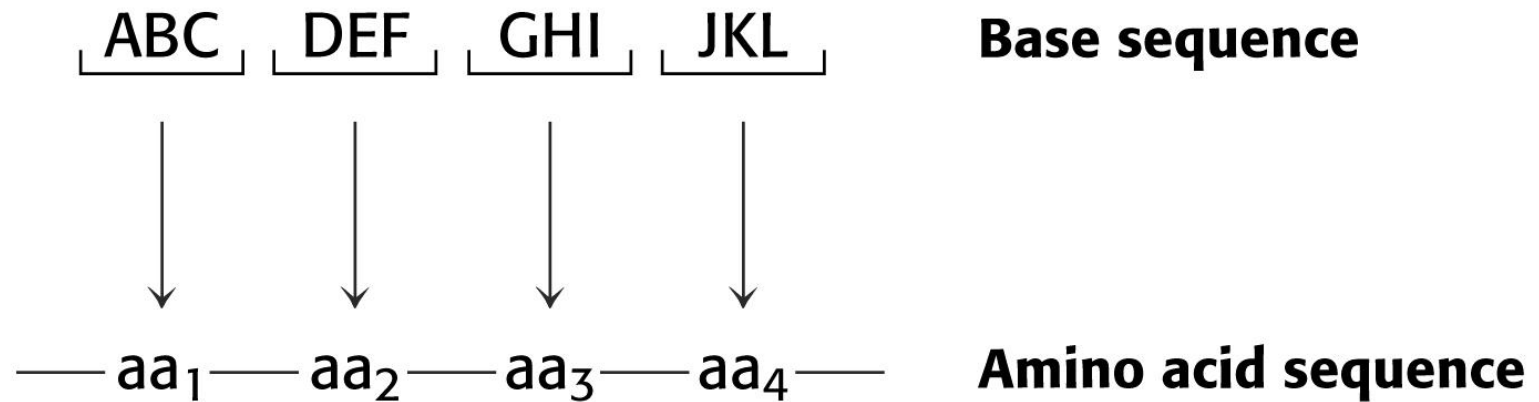


Flux de l'information

*Comment est-ce que l'information contenue dans le
DNA peut être transformée en protéines?*



Flux de l'information

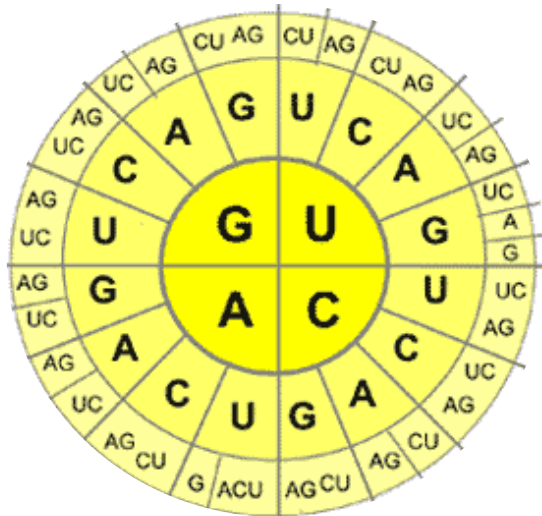


- Les aminoacides sont codés par des groupes de trois bases
- Le code n'a pas de ponctuation: ABCDEFGHI et pas ABC,DEF,GHI,

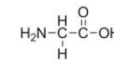
Combien de triplets de base différentes sont possible?

p.ex. AAA, AAC, AAG, AAT, ACA, ACC,

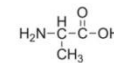
Flux de l'information



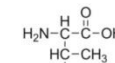
$$4^3 = 64$$



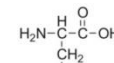
Glycine (Gly, G)



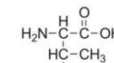
Alanine (Ala, A)



Valine (Val, V)



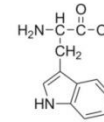
Leucine (Leu, L)



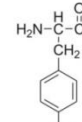
Isoleucine (Ile, I)



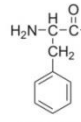
Proline (Pro, P)



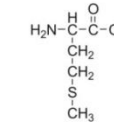
Tryptophan (Trp, W)



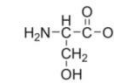
Tyrosine (Tyr, Y)



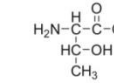
Phenylalanine (Phe, F)



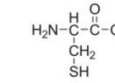
Methionine (Met, M)



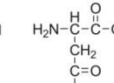
Serine (Ser, S)



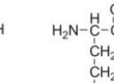
Threonine (Thr, T)



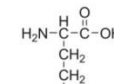
Cysteine (Cys, C)



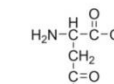
Asparagine (Asn, N)



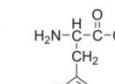
Glutamine (Glu, Q)



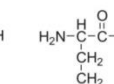
Acide glutamique (Glu, E)



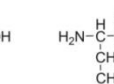
Acide aspartique (Asp, D)



Histidine (His, H)



Lysine (Lys, K)



Arginine (Arg, R)

Le code génétique

p.ex. serine:

TCT

TCC

TCA

TCG

AGT

AGC

Le code génétique est
presque universel

TABLE 5.4 The genetic code

First position (5' end)	Second position				Third position (3' end)
U	U	C	A	G	U C A G
	Phe	Ser	Tyr	Cys	
	Phe	Ser	Tyr	Cys	
	Leu	Ser	Stop	Stop	
	Leu	Ser	Stop	Trp	
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G
	Val	Ala	Glu	Gly	G

Note: This table identifies the amino acid encoded by each triplet. For example, the codon 5' AUG 3' on mRNA specifies methionine, whereas CAU specifies histidine. UAA, UAG, and UGA are termination signals. AUG is part of the initiation signal, in addition to coding for internal methionine residues.

Le code génétique

p.ex. serine:

TCT

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AGT

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Le code génétique est
presque universel

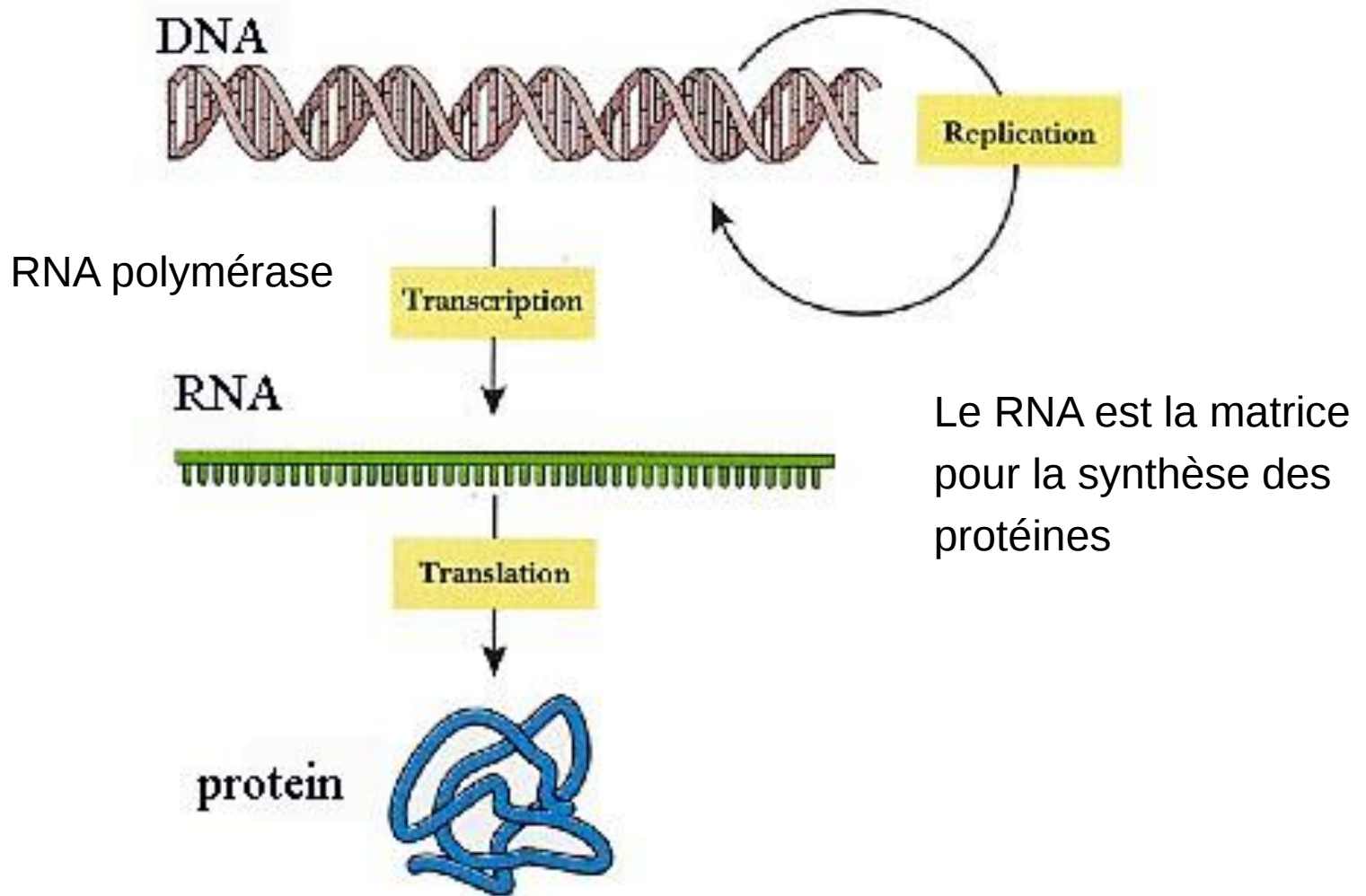
*Comment est-ce que les codes
de bases sont transformés en
aminoacides?*

TABLE 5.4 The genetic code

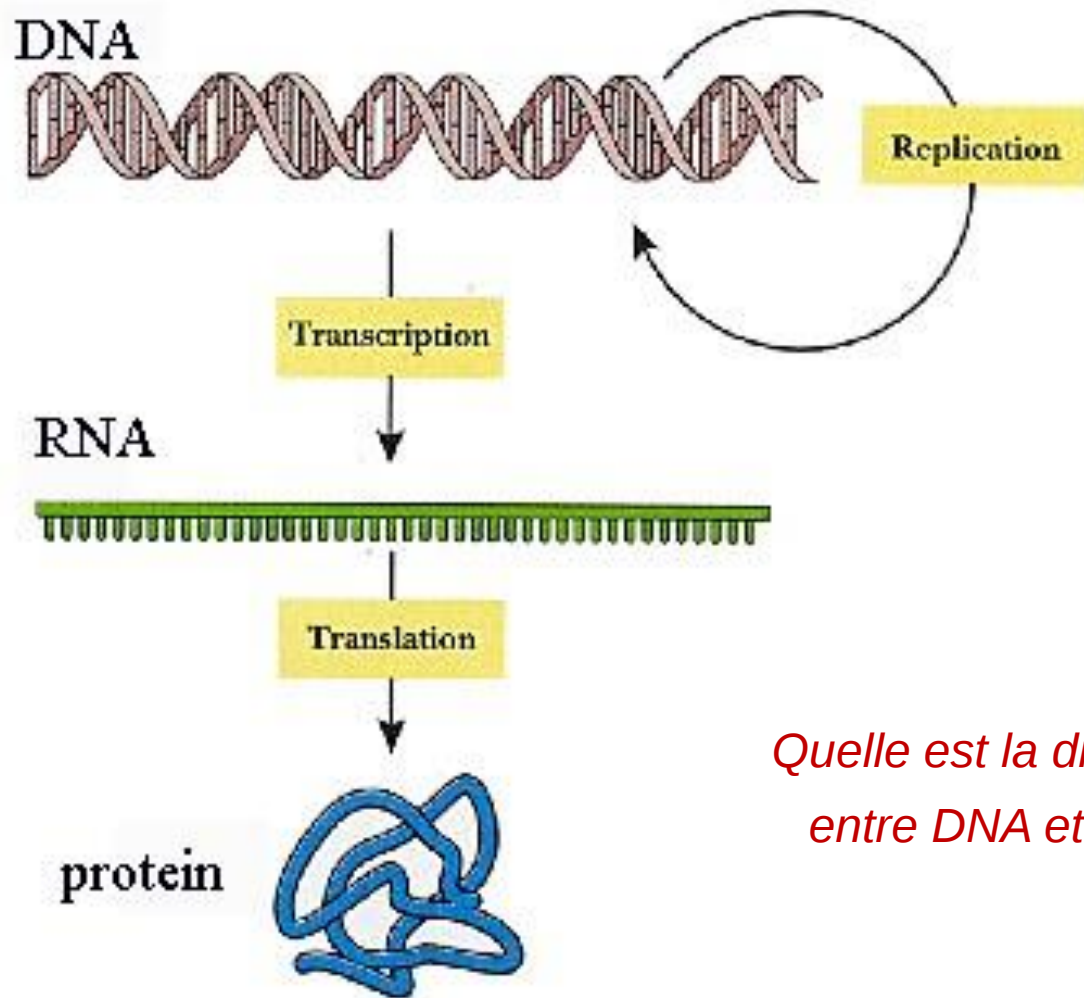
First position (5' end)	Second position				Third position (3' end)
U	U	C	A	G	U C A G
	Phe	Ser	Tyr	Cys	
	Phe	Ser	Tyr	Cys	
	Leu	Ser	Stop	Stop	
	Leu	Ser	Stop	Trp	
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G
	Val	Ala	Glu	Gly	G

Note: This table identifies the amino acid encoded by each triplet. For example, the codon 5' AUG 3' on mRNA specifies methionine, whereas CAU specifies histidine. UAA, UAG, and UGA are termination signals. AUG is part of the initiation signal, in addition to coding for internal methionine residues.

DNA → RNA → protéine

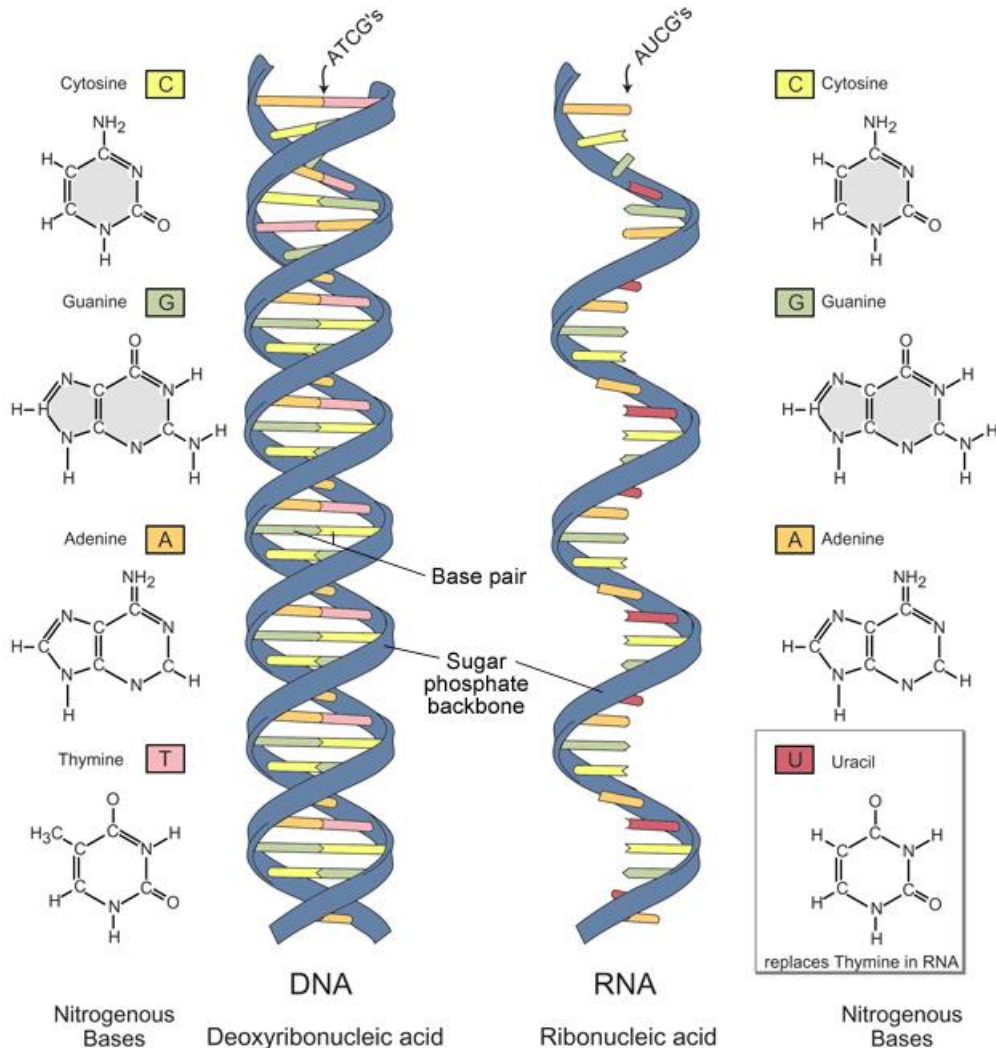


DNA → RNA → protéine



*Quelle est la différence
entre DNA et RNA?*

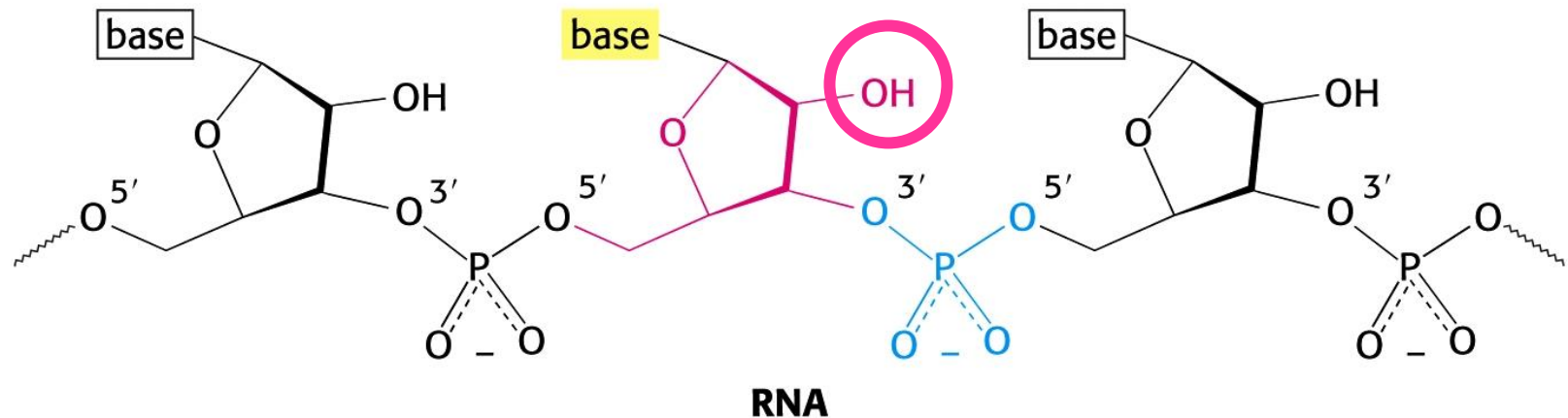
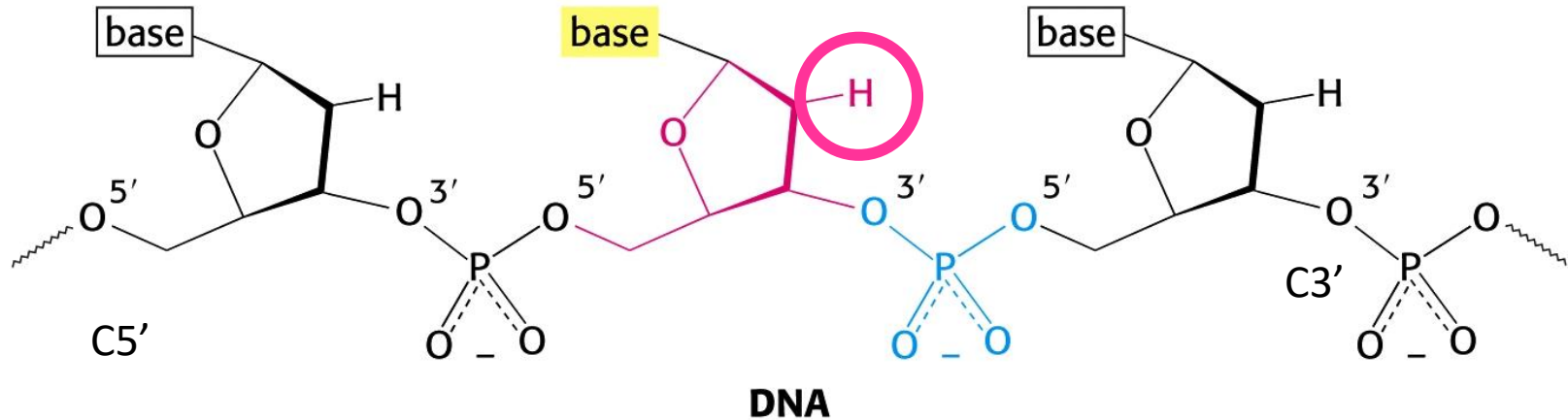
Les différences entre DNA et RNA



Structure:

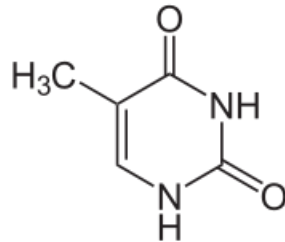
- Le sucre:
DNA: deoxyribose
RNA: ribose
- Les bases:
DNA: thymine
RNA: uracil

Le squelette sucre-phosphate du DNA et du RNA

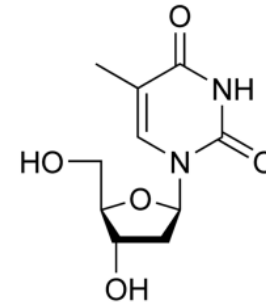


Les bases de DNA et de RNA

DNA

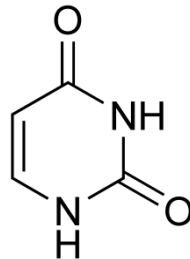


thymine

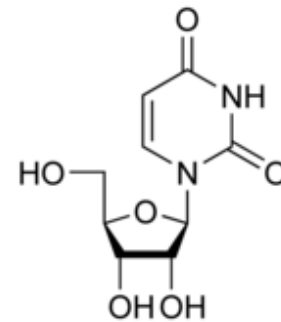


thymidine

RNA

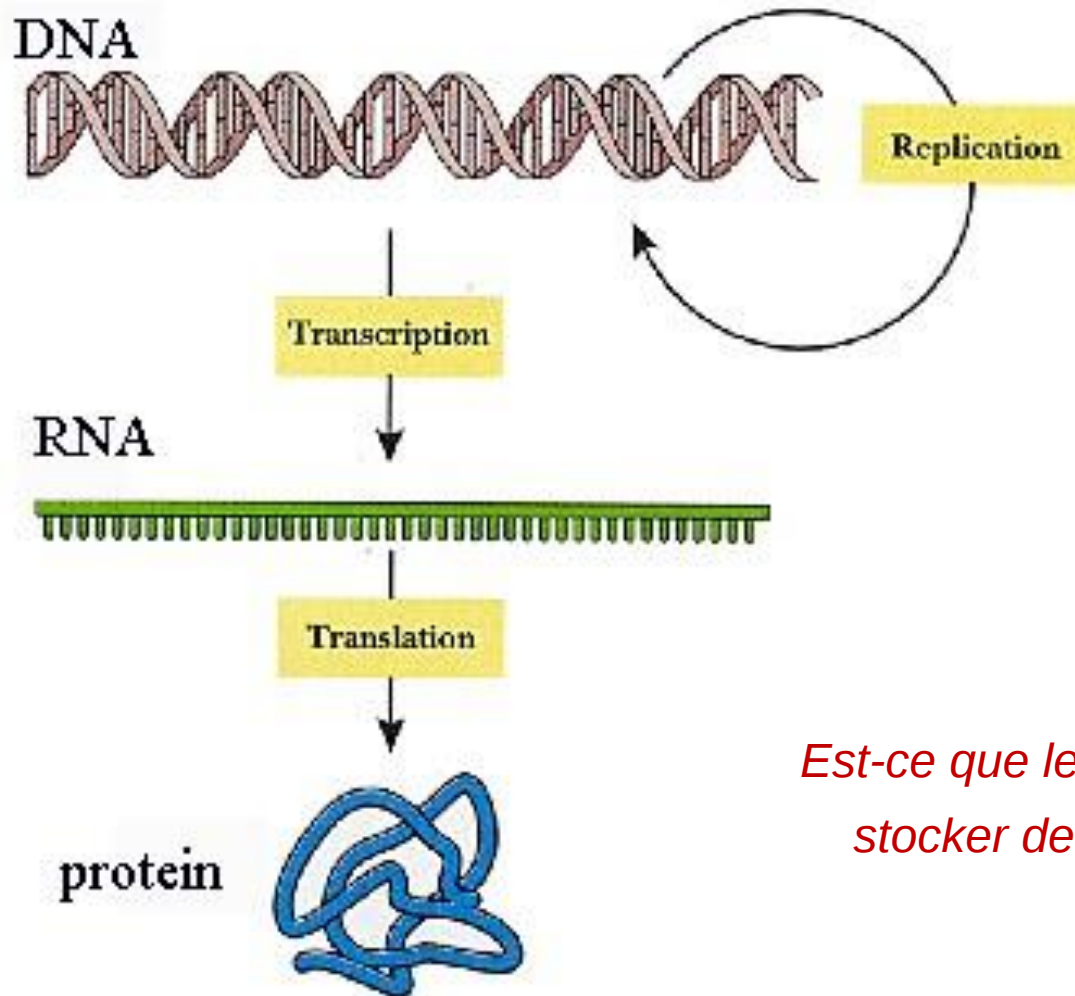


uracile



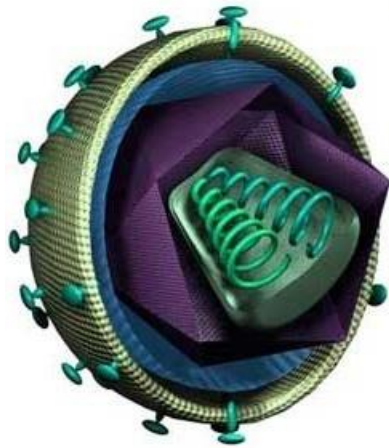
uridine

DNA → RNA → protéine

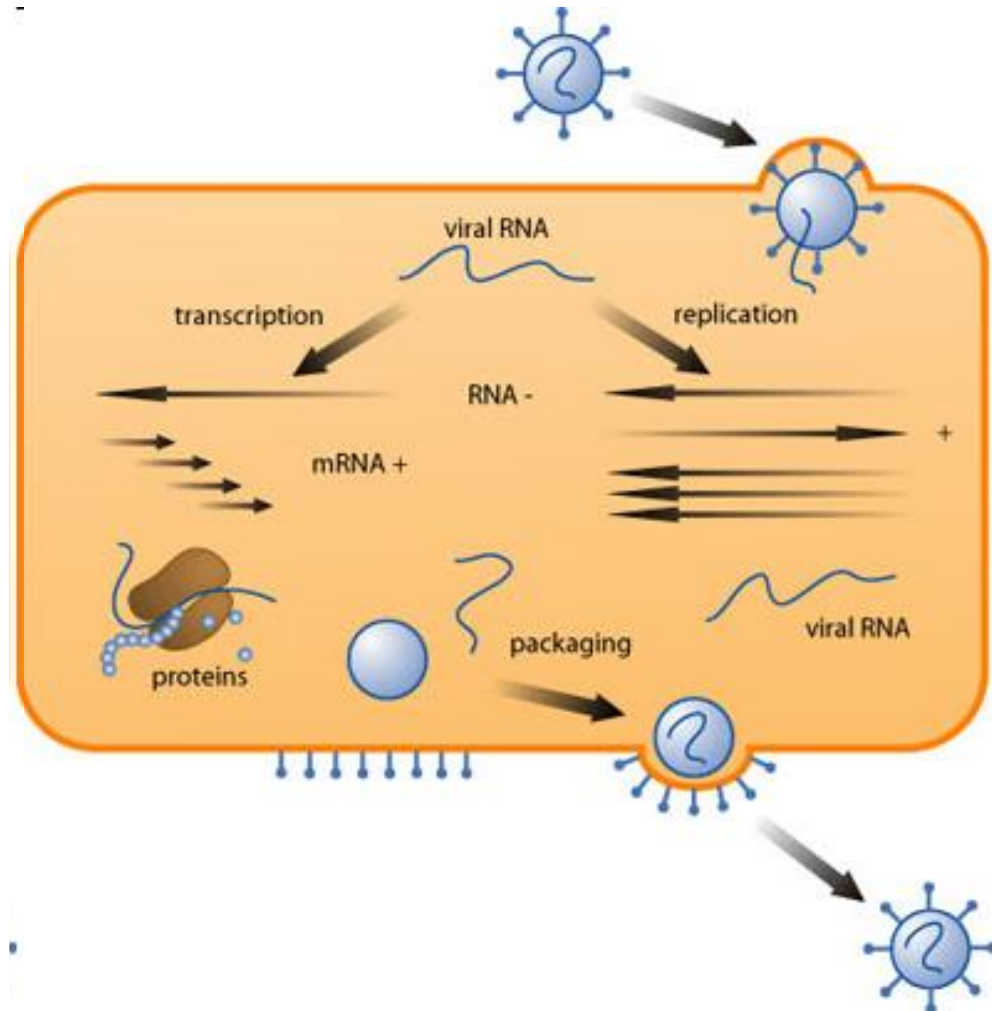


Est-ce que le RNA peut aussi stocker de l'information?

Virus de RNA

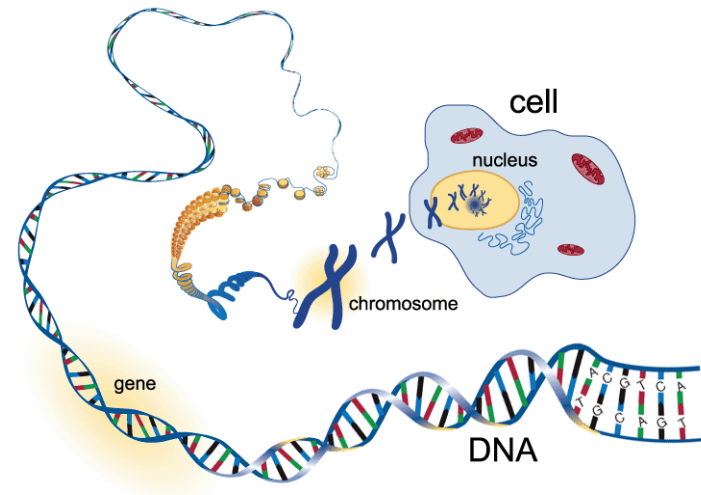


p.ex. VIH



DNA

- Composition du DNA
 - Bases, sucres, phosphates
- Découverte du DNA
 - Histoire
 - Expériences importantes
- Structure du DNA
- DNA réplication, méthode de PCR
- Flux de l'information



Série 3

Question 1

$$A = \epsilon \cdot l \cdot C \quad \leftarrow 2 \text{ mg/L}$$

$\uparrow \quad \quad \quad \nwarrow$
 $15'000 \text{ M}^{-1} \text{ cm}^{-1} \quad 1 \text{ cm}$

$A = 1.796$

$$M_w = 16700 \text{ Da}$$

$$16700 \text{ g/L} = 1 \text{ M}$$

$$2 \text{ g/L} = ? \cdot 10^{-4} \text{ M}$$

$$A = 1.796$$

Série 3

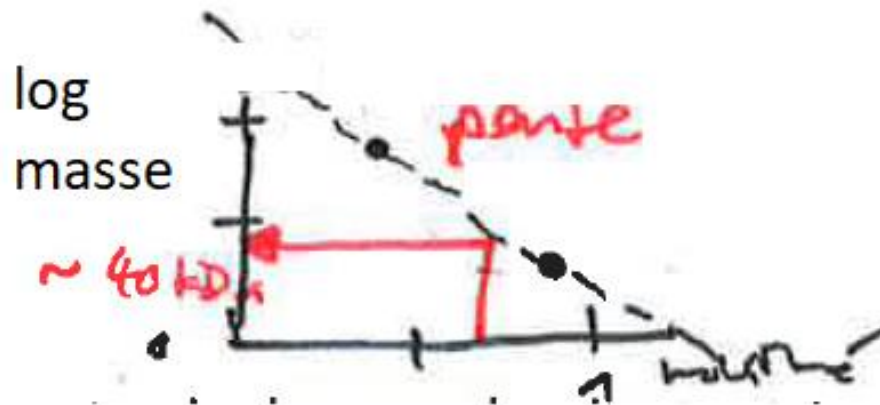
Question 1

$$A = -\log \frac{I_t \leftarrow \text{transmis}}{I_0 \leftarrow \text{incidente}} \rightarrow \frac{I_t}{I_0} = 10^{-A} = \underline{1.6\%}$$

% lumière transmis : 1.6%

Série 3

Question 2



$$\text{Log (masse)} = -0.89 \times (\text{mobilité}) + 5.28$$

$$m = 34.1 \text{ kDa}$$

Série 3

Question 3

Comparer les masses: ils sont différents → chromatographie par gel filtration

Comparer les points isoélectriques: ils sont différents → chromatographie par échange d'ions

Cherchez si il existe des ligands (en pubmed, google, etc.) → chromatographie d'affinité

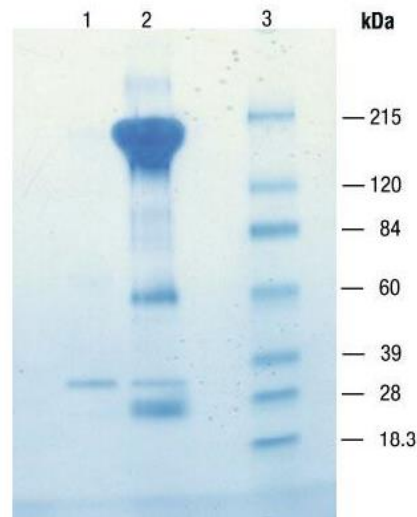
Série 3

Question 4

Ligne 1: une protéine, environ 30 kDa, petit quantité

Ligne 2: environ 4 protéines, environ 200, 60, 30 et 25 kDa, une en grande quantité

Ligne 3: marker de 7 protéines connus



Série 3

Question 5

Spectrométrie de masse

SDS-PAGE