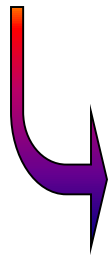


I CARBOIDRATI

- I componenti della gran parte della materia organica sulla terra (ogni anno più di 100 miliardi di tonnellate di CO₂ sono convertite da alghe e piante in cellulosa ed altri prodotti)
- Ricoprono diversi ruoli in tutte le forme di vita



1. **Riserva energetica** (glicogeno negli animali; amido nelle piante)
2. **Sostegno strutturale** negli acidi nucleici (ribosio nell'RNA; deossiribosio nel DNA)
3. **Elementi strutturali**: nella parete cellulare di batteri e cellule vegetali; nell'esoscheletro degli artropodi
4. **Coniugati con lipidi e proteine**: mediatori del **riconoscimento cellulare**

I CARBOIDRATI

TRE PRINCIPALI GRUPPI:

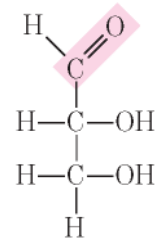
1. **MONOSACCARIDI:** o semplicemente zuccheri, sono costituiti da una singola catena poliossidrilica (es. D-glucosio)
2. **OLIGOSACCARIDI [DISACCARIDI]:** corte catene di unità monosaccaridiche legate mediante **legami glicosidici** (disaccaridi es: saccarosio, trisaccaridi; et cetera)
3. **POLISACCARIDI:** lunghe catene di centinaia di unità monosaccaridiche legate mediante **legami glicosidici** (es: lineari → cellulosa; ramificati → amido)

MONOSACCARIDI

- Composti **carbonilici** (poliidrossi aldeidi o poliidrossi chetoni) di formula generale $(\text{CH}_2\text{O})_n$: "idrati di carbonio"
- composti da un'unica catena lineare di atomi di carbonio (da 3 a 7) legati a funzioni -OH
- legami C-C semplici

due famiglie

Aldosi
(C=O sul primo C)

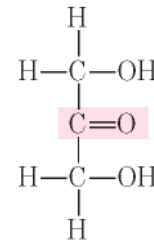


Gliceraldeide,
un aldotriosio

suffisso → -osio

3C → aldo-triosi
4C → aldo-tetrosi
5C → aldo-pentosi
6C → aldo-esosi
7C → aldo-eptosi

Chetosi
(C=O sul secondo C)

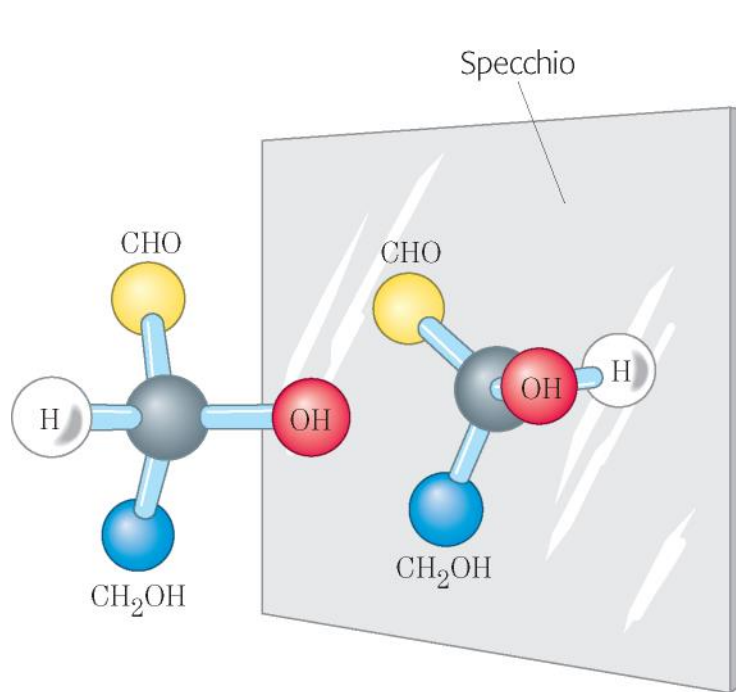


Diidrossiacetone,
un chetotriosio

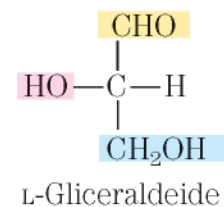
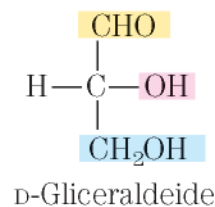
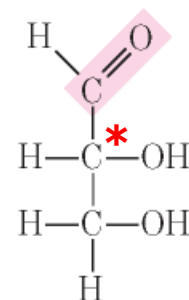
suffisso → -ulosio

3C → cheto-triosi
4C → cheto-tetrosi
5C → cheto-pentosi
6C → cheto-esosi
7C → cheto-eptosi

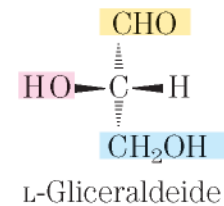
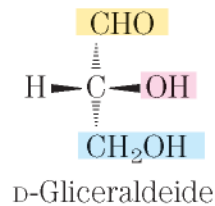
I monosaccaridi sono composti chirali



Modelli a palle-e-bastoncini



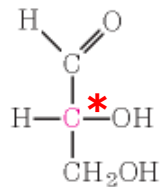
Formule di proiezione di Fischer



Formule in prospettiva

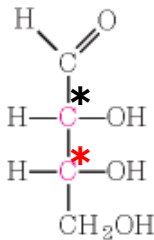
D-Aldosi

Tre atomi di carbonio

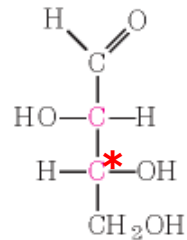


D-Gliceraldeide

Quattro atomi di carbonio

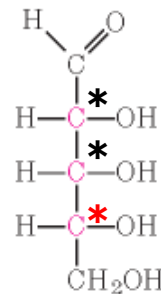


D-Eritrosio

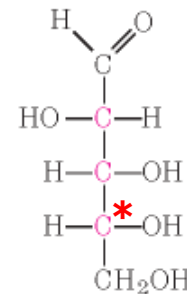


D-Treosio

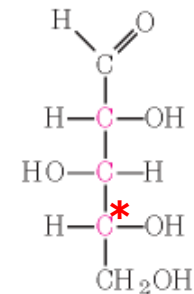
Cinque atomi di carbonio



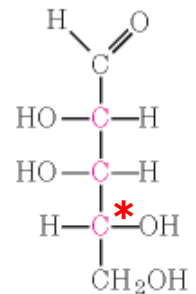
D-Ribosio



D-Arabinosio

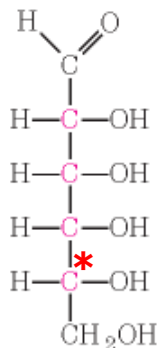


D-Xilosio

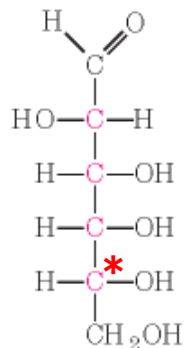


D-Lixosio

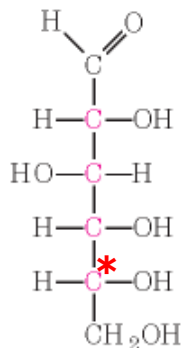
Sei atomi di carbonio



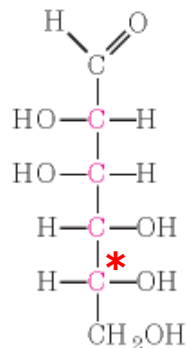
D-Allosio



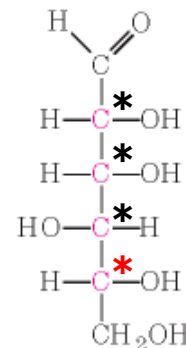
D-Altrosio



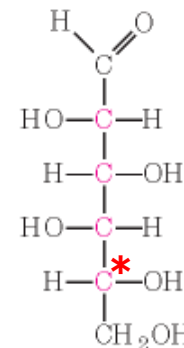
D-Glucosio



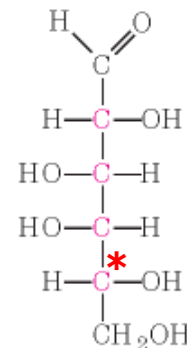
D-Mannosio



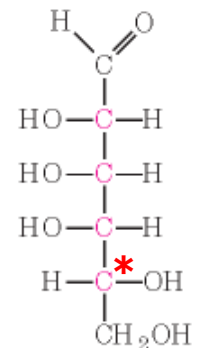
D-Gulosio



D-Idosio



D-Galattosio



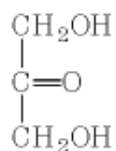
D-Talosio

n centri chirali → 2ⁿ stereoisomeri

serie D → isomeri predominanti in natura

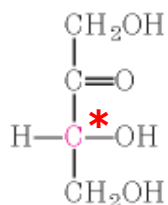
D-Chetosi

**Tre atomi
di carbonio**



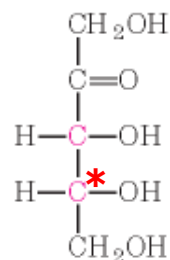
Diidrossiacetone

**Quattro atomi
di carbonio**

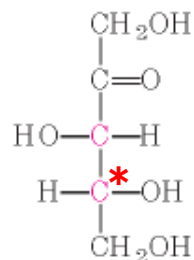


D-Eritrulosio

**Cinque atomi
di carbonio**

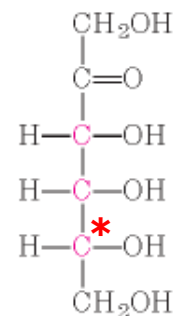


D-Ribulosio

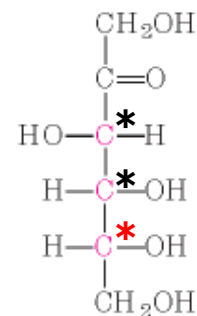


D-Xilulosio

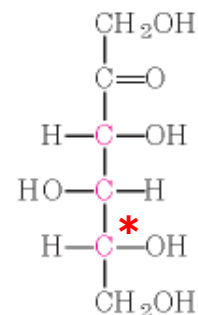
Sei atomi di carbonio



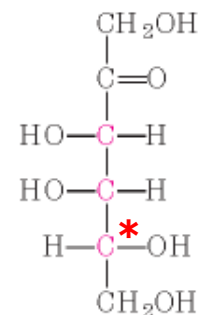
D-Psicosio



D-Fruttosio



D-Sorbosio

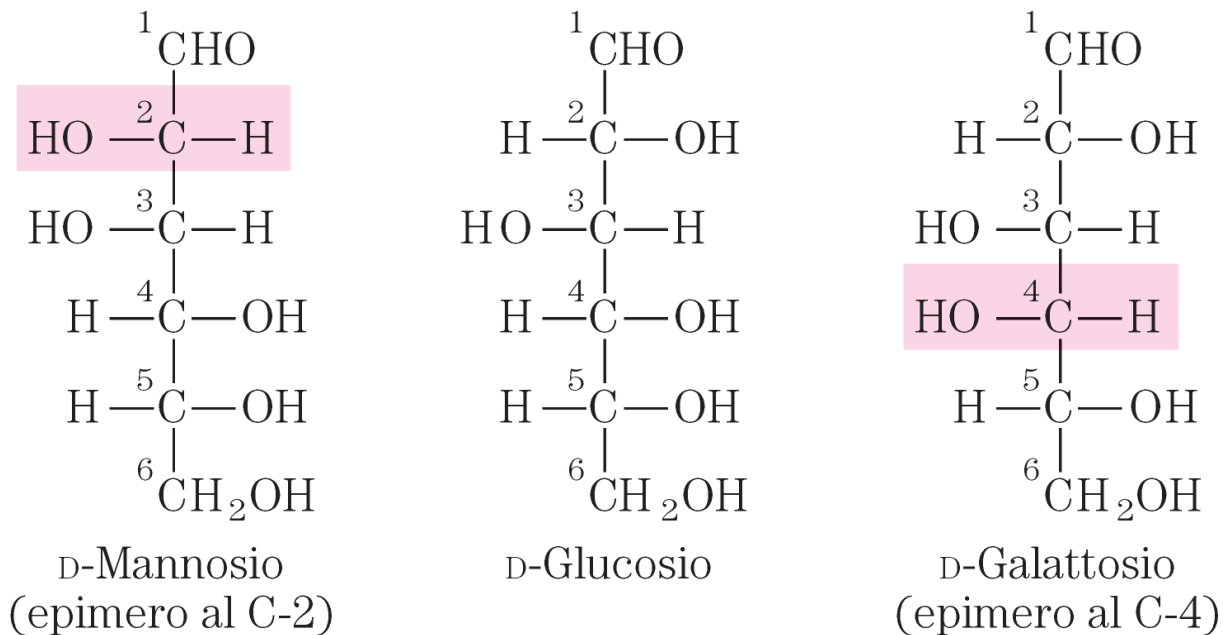


D-Tagatosio

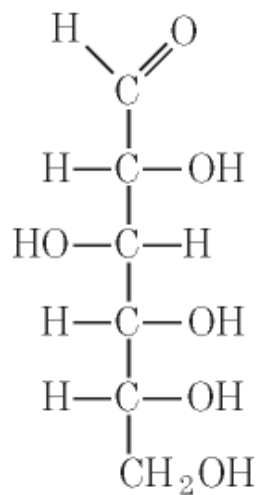
n centri chirali → 2ⁿ stereoisomeri

serie D → isomeri predominanti in natura

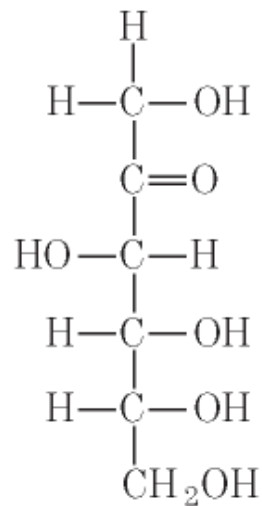
EPIMERI: zuccheri che differiscono solo per la configurazione di uno dei centri chirali



Gli epimeri sono isomeri di configurazione

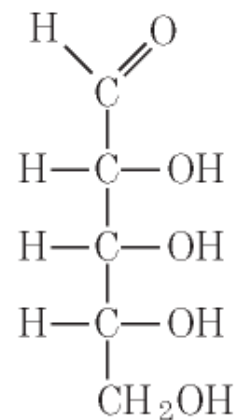


D-Glucosio,
un aldosesio



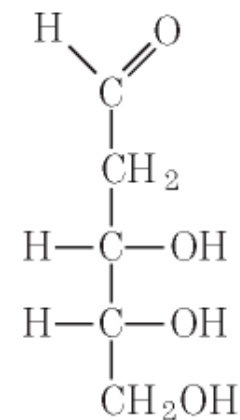
D-Fruttosio,
un chetoesosio

**D-glucosio e D-fruttosio
sono isomeri di struttura**



D-Ribosio,
un aldopentosio

RNA

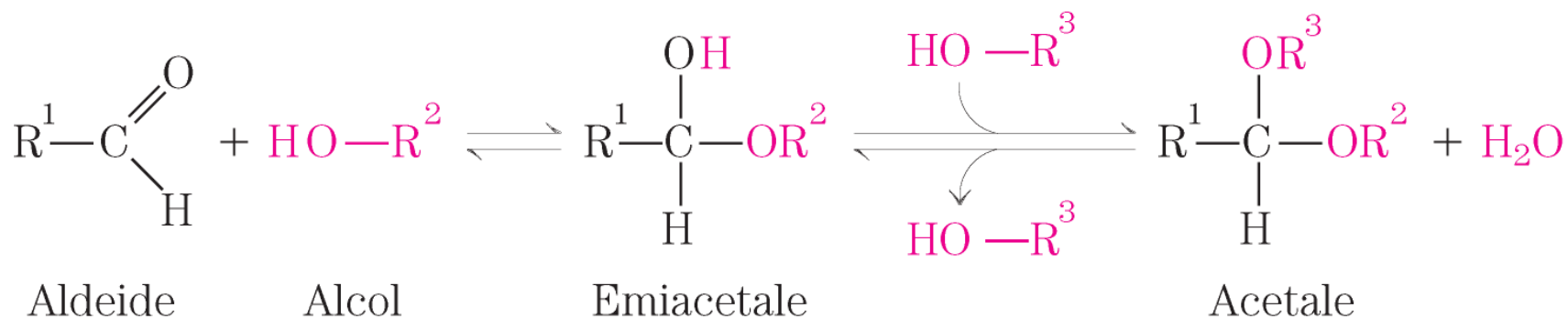


2-Deossi-D-ribosio,
un aldopentosio

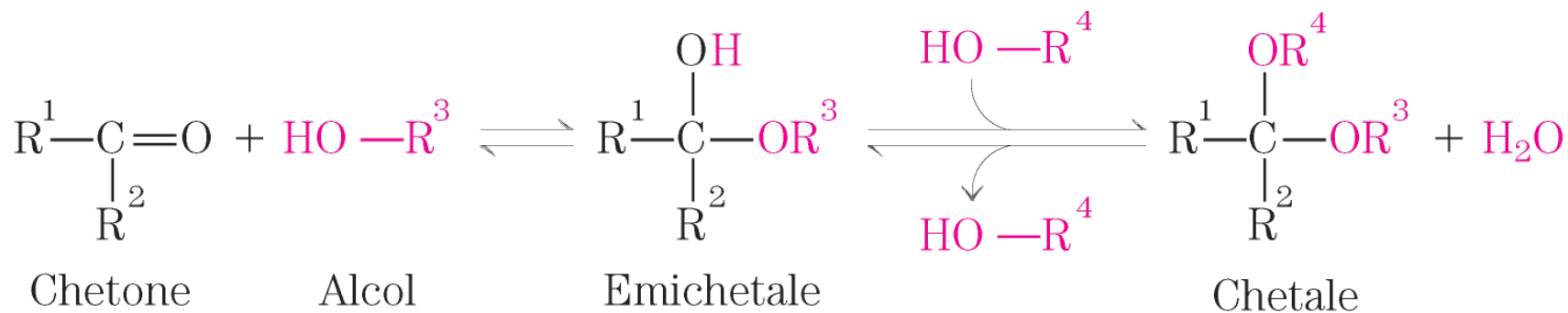
DNA

Reazioni generali dei composti carbonilici

Formazione di emi-acetali ed acetali



Formazione di emi-chetali e chetali

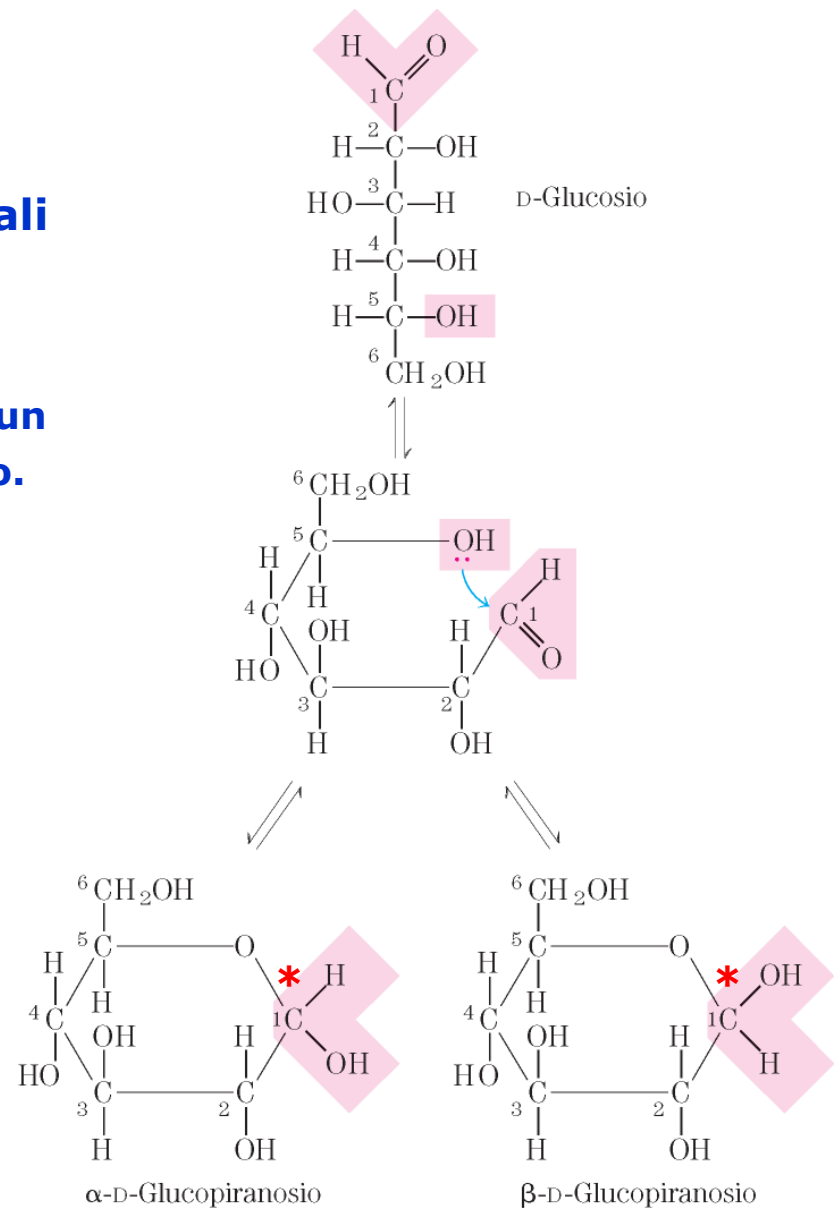


Strutture cicliche degli zuccheri: formazione di emi-acetali o emi-chetali

La formazione delle strutture cicliche genera un nuovo centro chirale detto carbonio anomero.

Si identificano due serie di stereoisomeri detti **ANOMERI**

- α : -OH anomero e gruppo terminale -CH₂OH da parti opposte rispetto all'anello
- β : -OH anomero e -CH₂OH dalla stessa parte rispetto all'anello

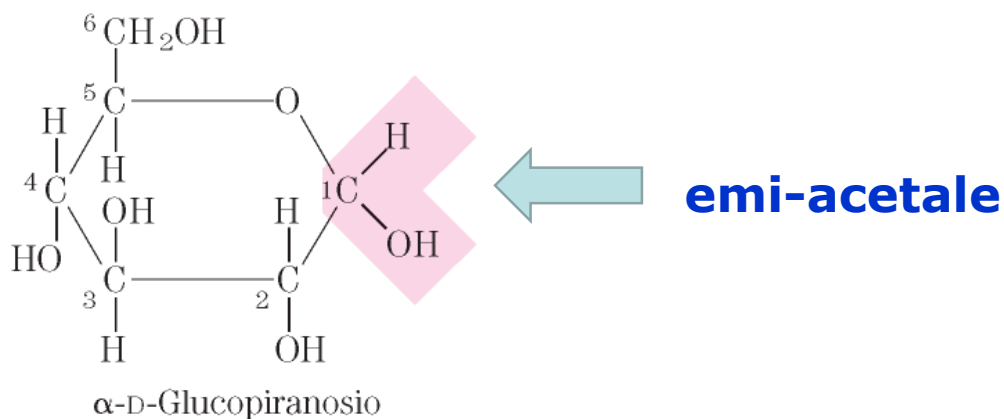
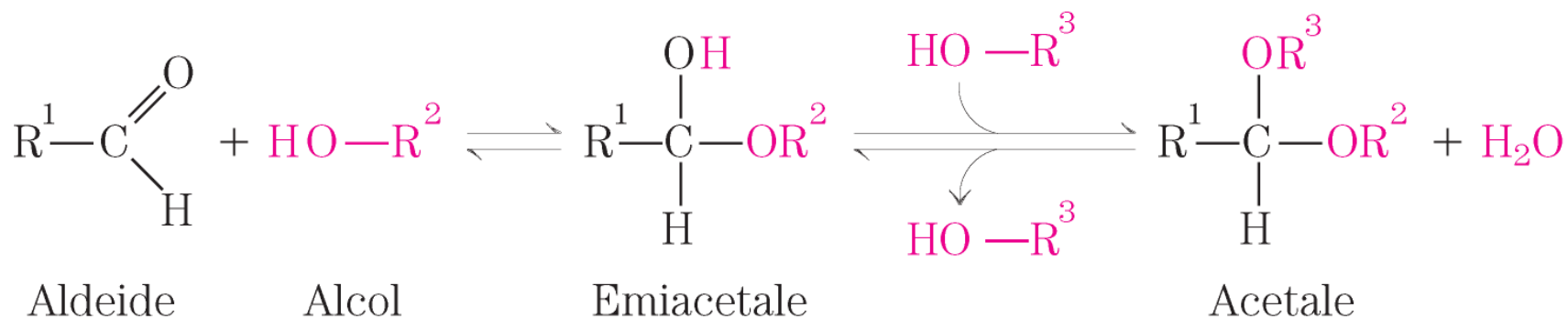


Proiezioni di Haworth

- carbonio anomero a destra
- ossigeno eterociclico in alto

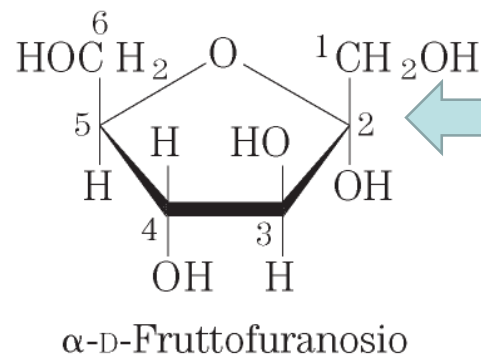
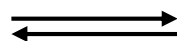
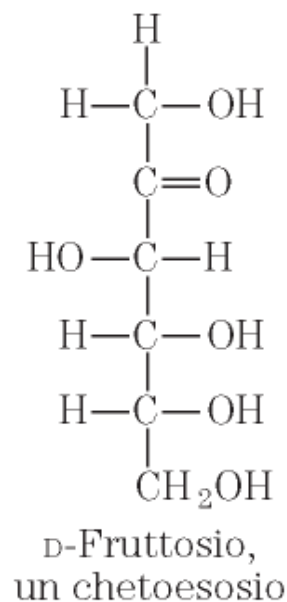
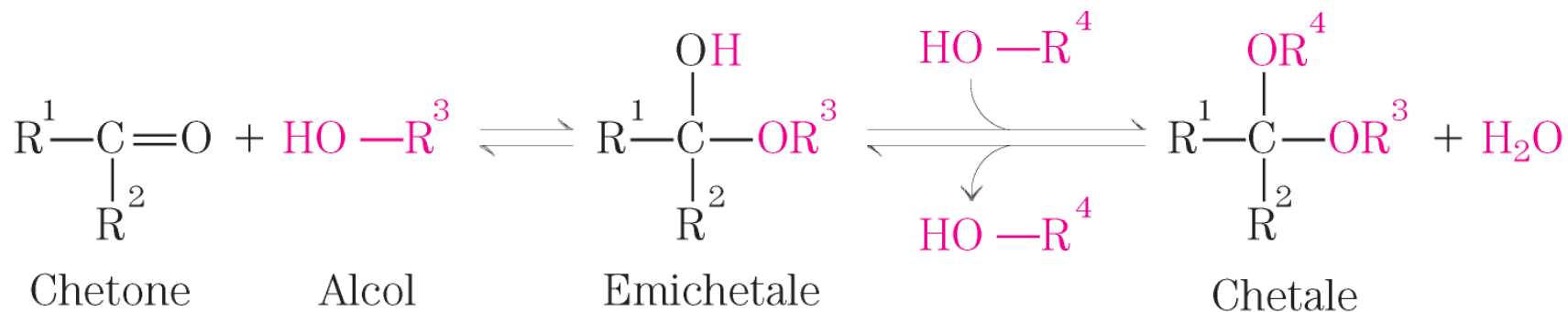
Reazioni generali dei composti carbonilici

Formazione di emi-acetali ed acetali



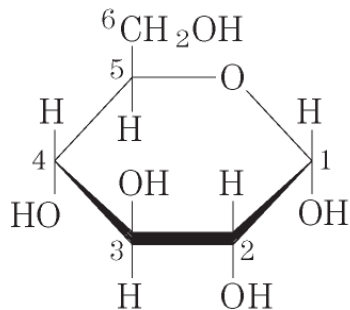
Reazioni generali dei composti carbonilici

Formazione di emi-chetali e chetali

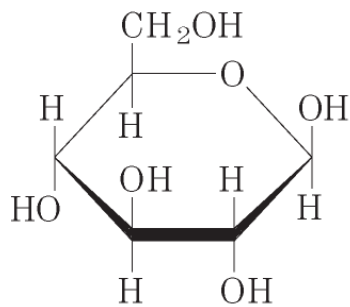


emi-chetale

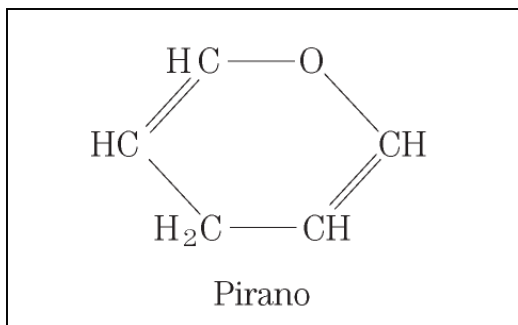
**Anello a 6 termini:
piranosio**



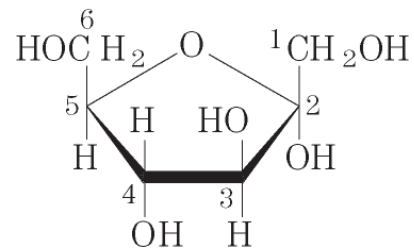
α -D-Glucopiranosio



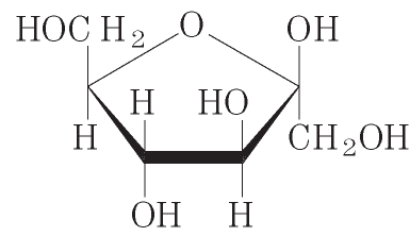
β -D-Glucopiranosio



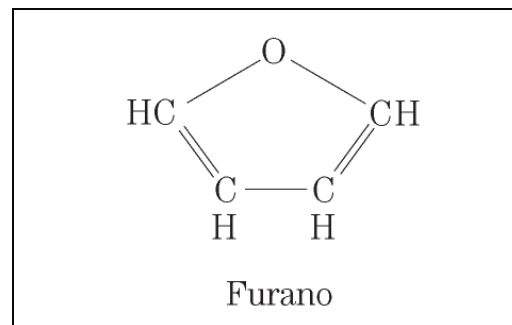
**Anello a 5 termini:
furanosio**



α -D-Fruttofuranosio



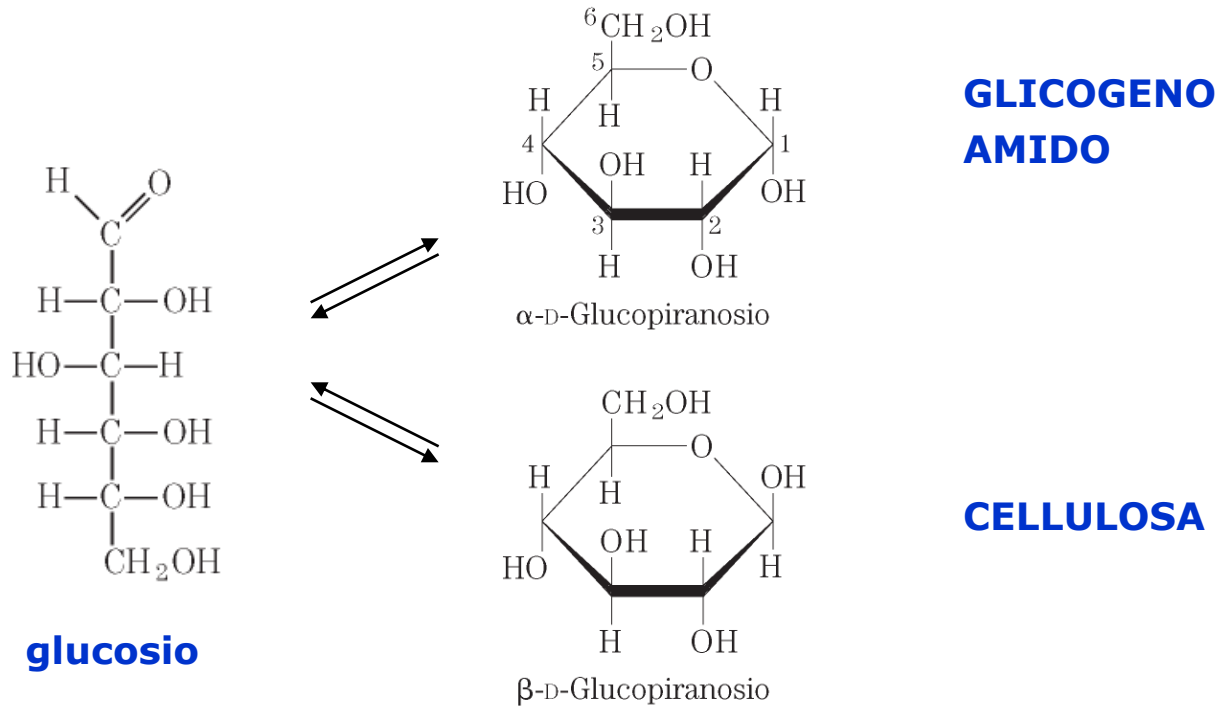
β -D-Fruttofuranosio



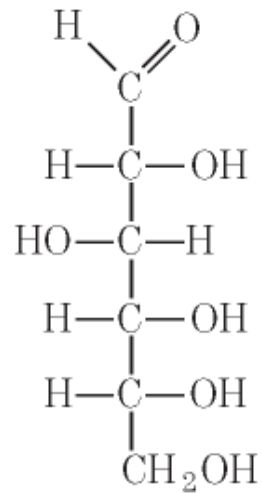
diversi anomeri dello stesso zucchero



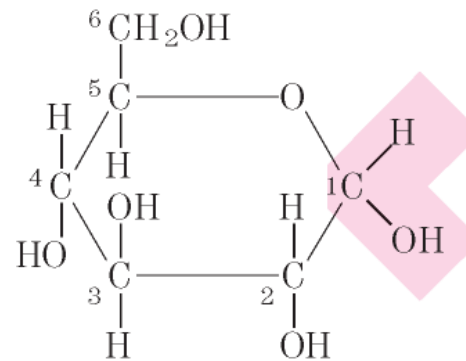
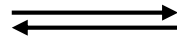
diverse strutture e proprietà dei corrispondenti polisaccaridi



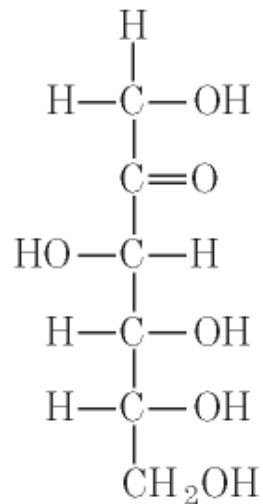
Reazioni dei monosaccaridi in acqua



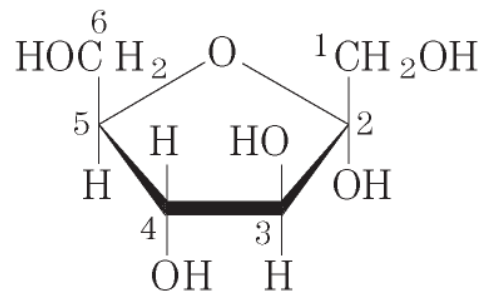
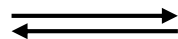
D-Glucosio,



α -D-Glucopiranosio



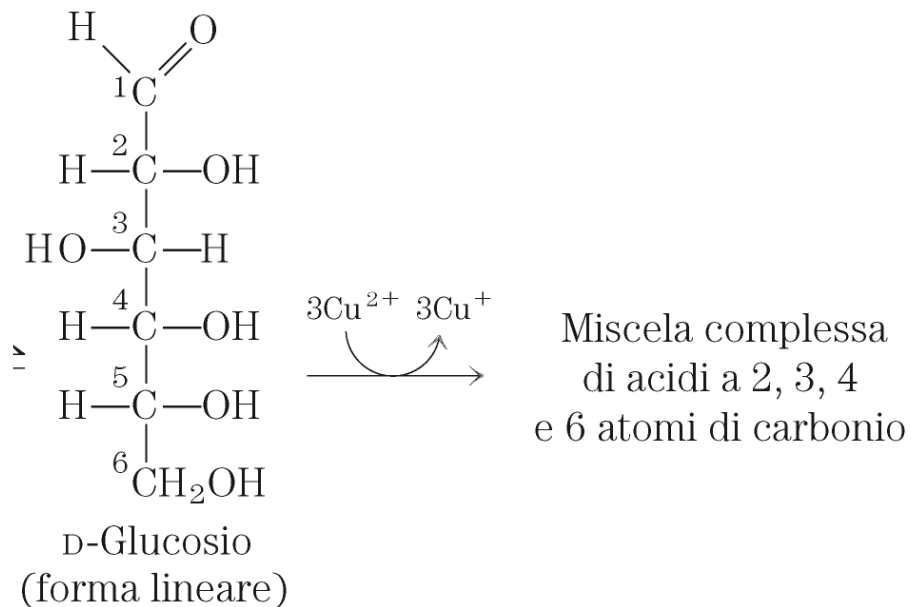
D-Fruttosio,



α -D-Fruttofuranosio

Zuccheri riducenti

I monosaccaridi possono essere ossidati, la reazione avviene sullo zucchero in forma aperta a carico del carbonio anomero



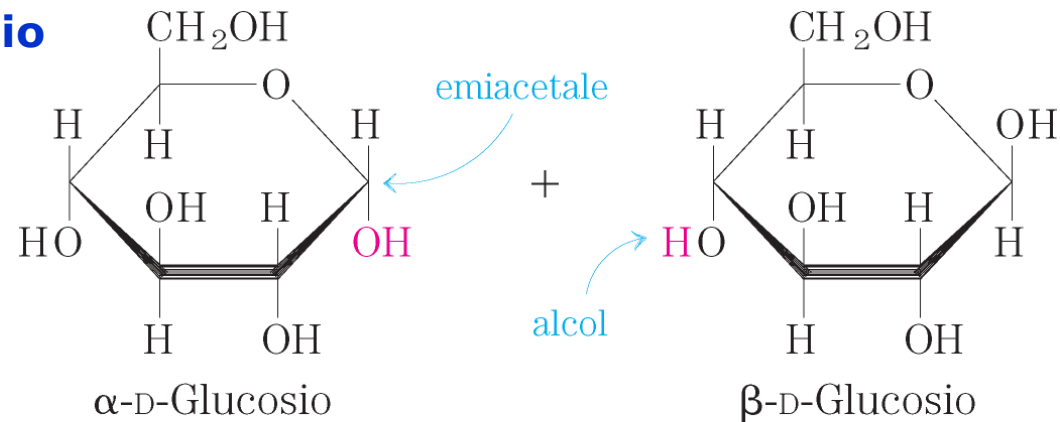
I CARBOIDRATI

TRE PRINCIPALI CLASSI:

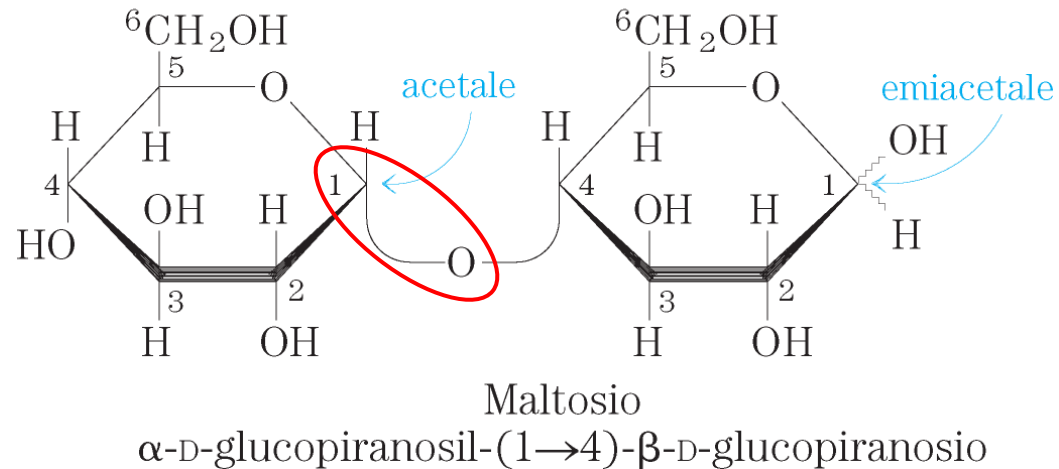
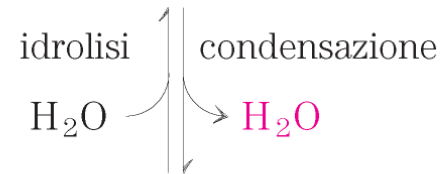
1. **MONOSACCARIDI:** o semplicemente zuccheri, sono costituiti da una singola catena poliossidrilica (D-glucosio)
2. **OLIGOSACCARIDI:** corte catene di unità monosaccaridiche legate mediante **legami glicosidici** (disaccaridi, trisaccaridi; es: saccarosio)
3. **POLISACCARIDI:** lunghe catene di centinaia di unità monosaccaridiche legate mediante **legami glicosidici** (es: lineari→cellulosa; ramificate→ amido, glicogeno)

OLIGOSACCARIDI

Il gruppo ossidrilico di uno zucchero attacca il carbonio anomero di un altro zucchero



legame O-glicosidico

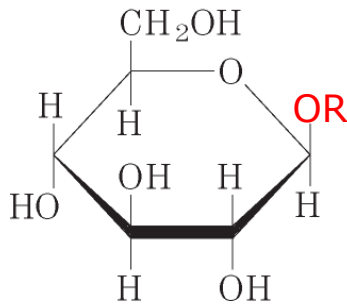


DISACCARIDI

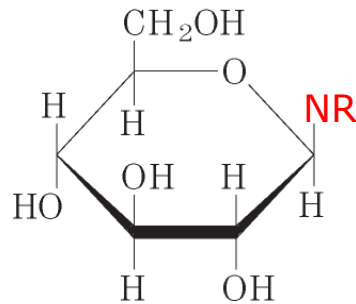
GLICOSIDI

Sono derivati degli zuccheri in cui il C anomerico è sostituito con gruppi del tipo OR, NR, R rispettivamente:

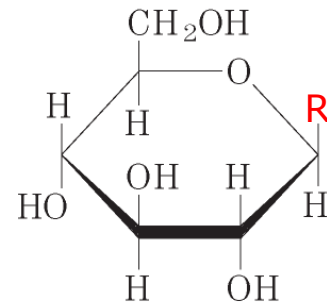
- **O-glicosidi**: il sostituito R è legato attraverso un atomo di ossigeno
- **N-glicosidi**: il sostituito R è legato attraverso un atomo di azoto
- **C-glicosidi**: il sostituito R è legato attraverso un atomo di carbonio.



O-glicosidi



N-glicosidi

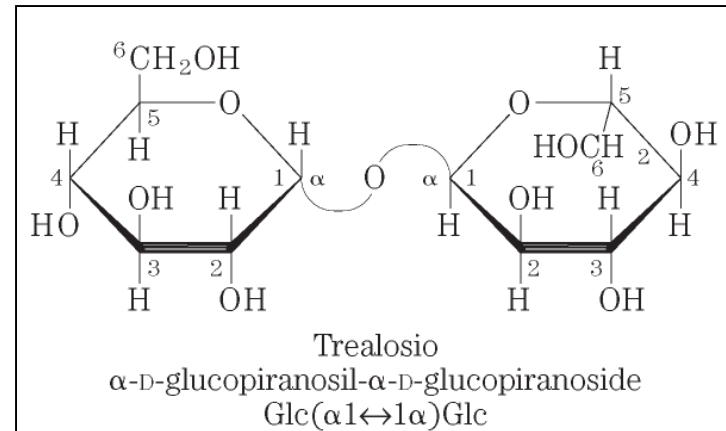
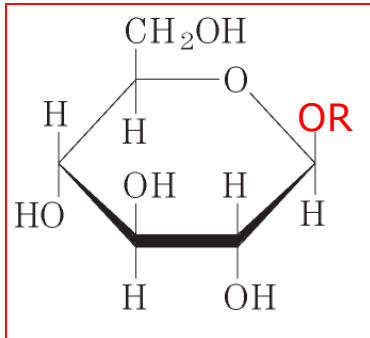


C-glicosidi

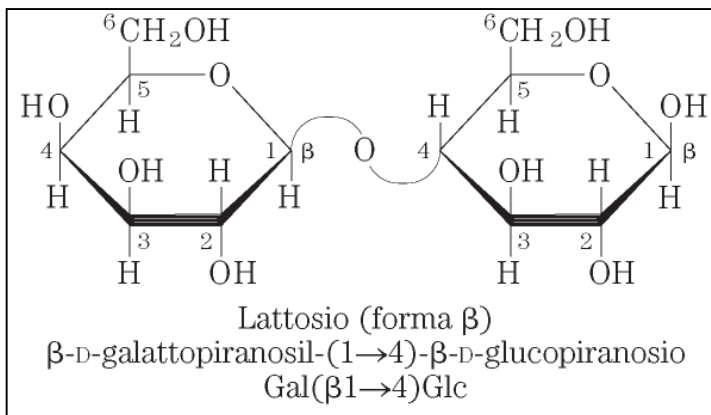
R: catena idrocarburica più o meno sostituita, un ciclo o un eterociclo, un altro monosaccaride

DISACCARIDI COMUNI

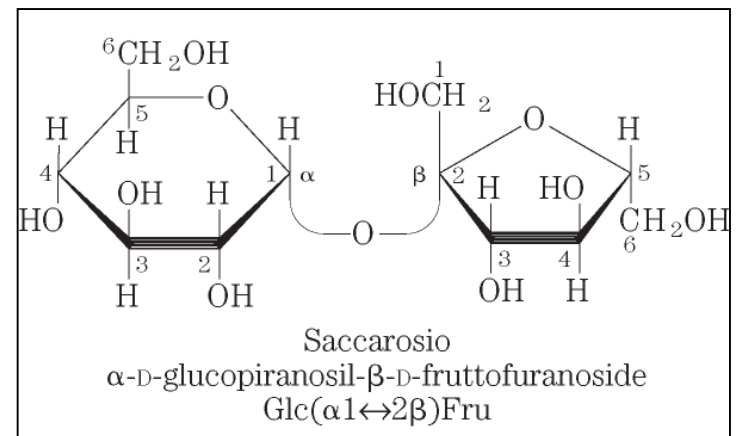
•**O-glicosidi:** il sostituito è legato attraverso un atomo di ossigeno



in lieviti, funghi ed insetti; in alcuni organismi consente la sopravvivenza in mancanza di acqua ed a temperature elevate



rappresenta il 98% degli zuccheri presenti nel latte

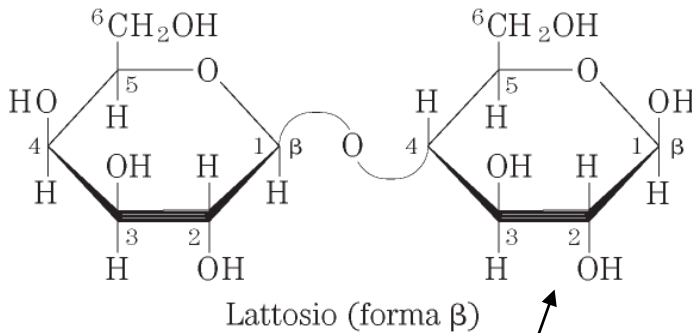


nella canna da zucchero e barbabietola da zucchero

DISACCARIDI COMUNI: zuccheri riducenti

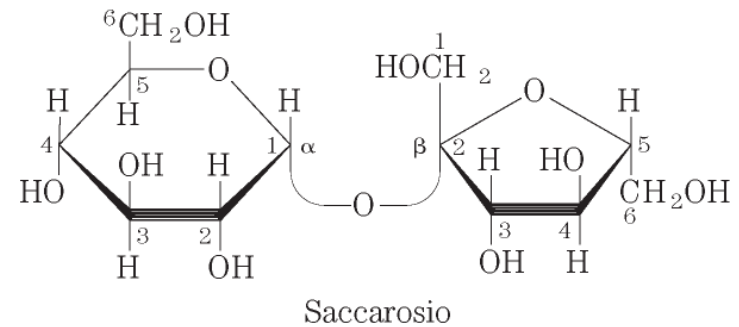
I disaccaridi possono essere ossidati: la reazione avviene sullo zucchero che presenta il carbonio anomero libero, ovvero non impegnato in un legame glicosidico (tale unità viene detta estremità riducente)

disaccaride riducente

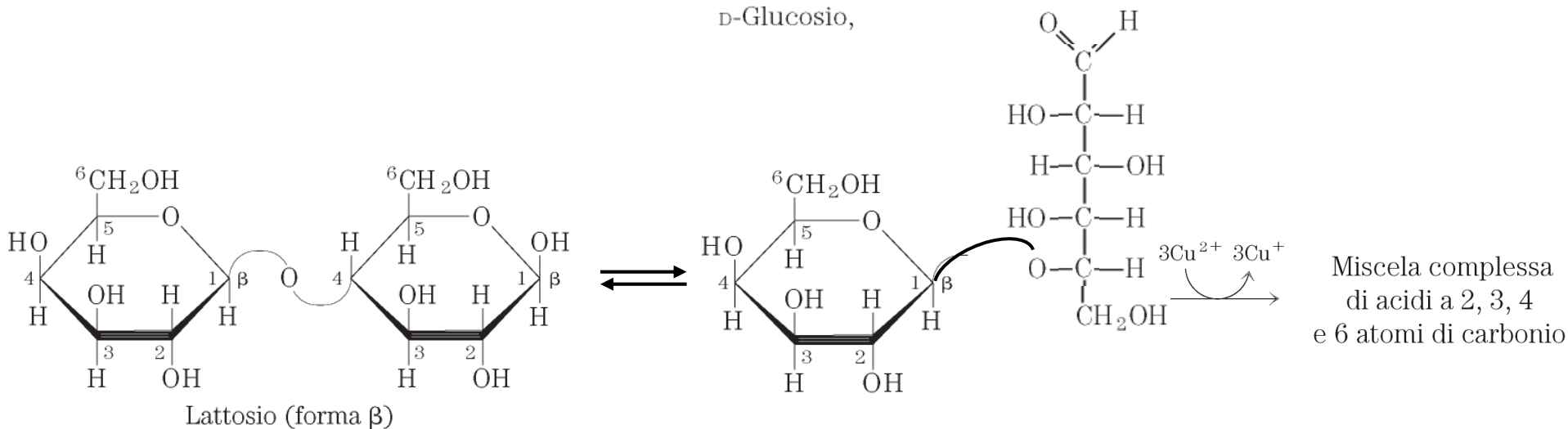
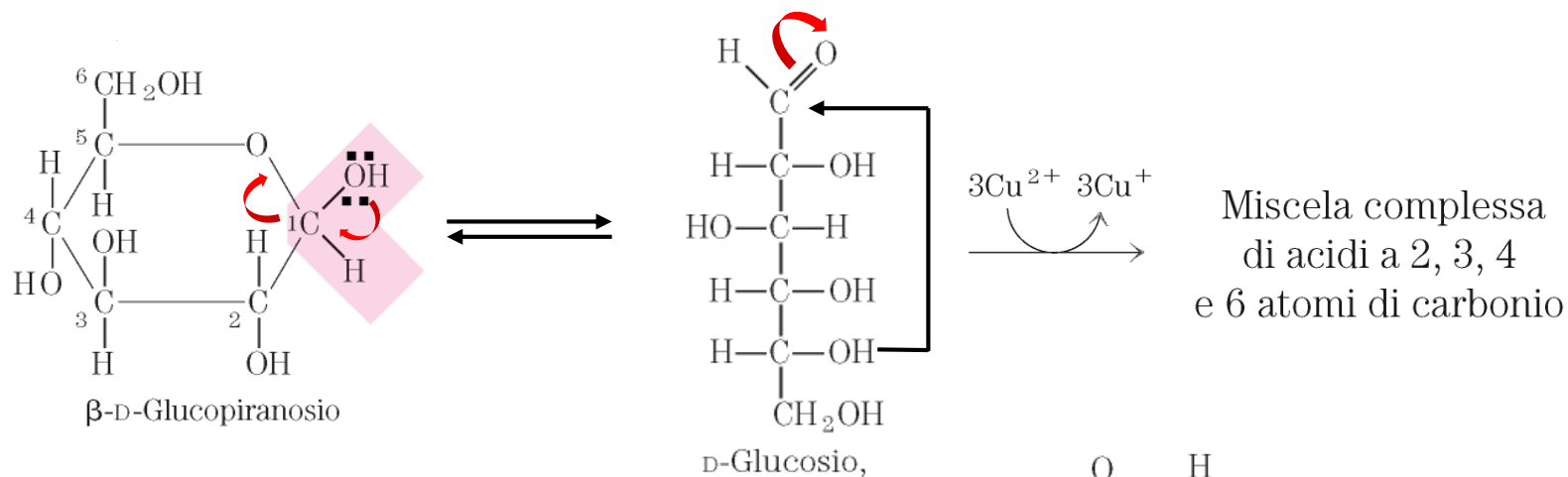


estremità riducente

disaccaride non riducente

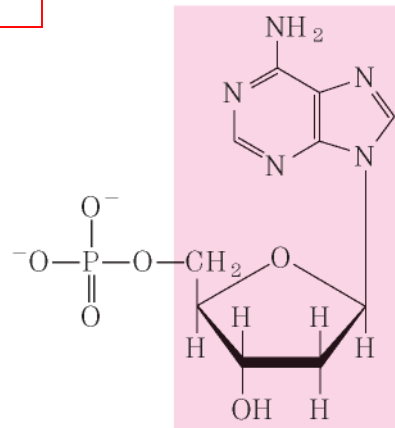
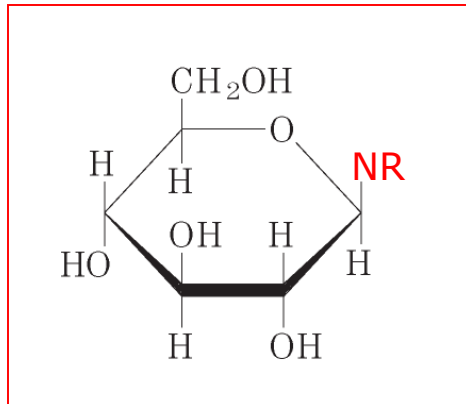


Reazioni dei monosaccaridi in acqua



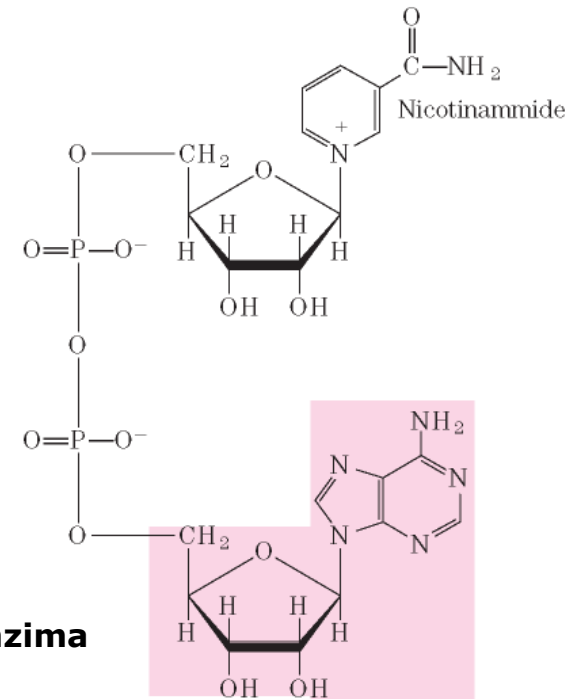
GLICOSIDI

- **N-glicosidi:** il sostituito è legato attraverso un atomo di azoto



Nucleotide:

Deossiadenilato
(deossiadenosina
5'-monofosfato)



Coenzima

Nicotinamide adenin dinucleotide (NAD⁺)

I CARBOIDRATI

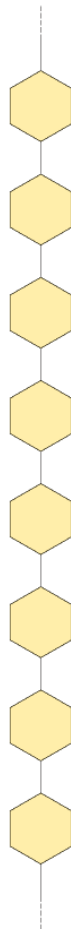
TRE PRINCIPALI CLASSI:

1. **MONOSACCARIDI:** o semplicemente zuccheri, sono costituiti da una singola catena poliossidrilica (D-glucosio)
2. **OLIGOSACCARIDI:** corte catene di unità monosaccaridiche legate mediante **legami glicosidici** (disaccaridi, trisaccaridi; es: saccarosio)
3. **POLISACCARIDI:** lunghe catene di centinaia di unità monosaccaridiche legate mediante **legami glicosidici** (es: lineari→cellulosa; ramificate→ amido)

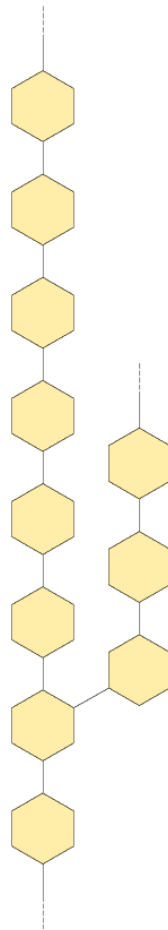
POLISACCARIDI

Omopolisaccaridi

Non ramificato



Ramificato

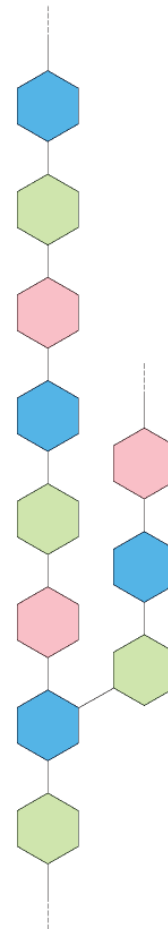


Eteropolisaccaridi

Due tipi
di monomero,
non ramificato



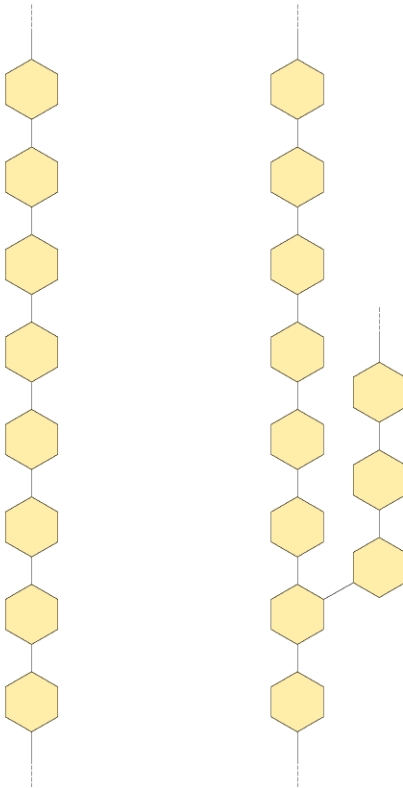
Diversi tipi
di monomero,
ramificato



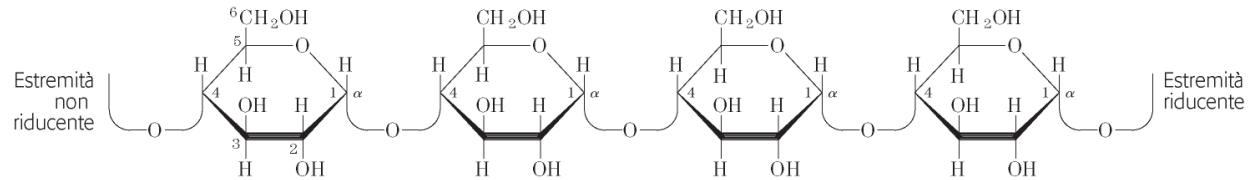
POLISACCARIDI

Omopolisaccaridi

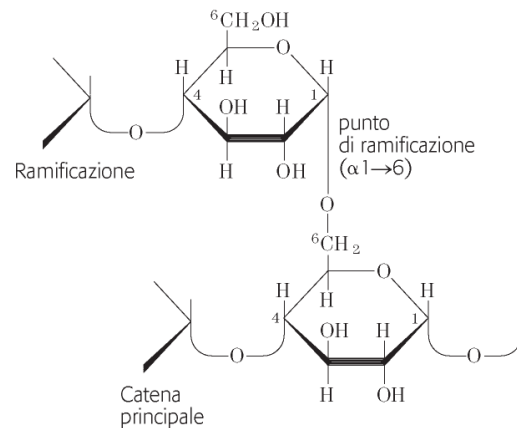
Non ramificato Ramificato



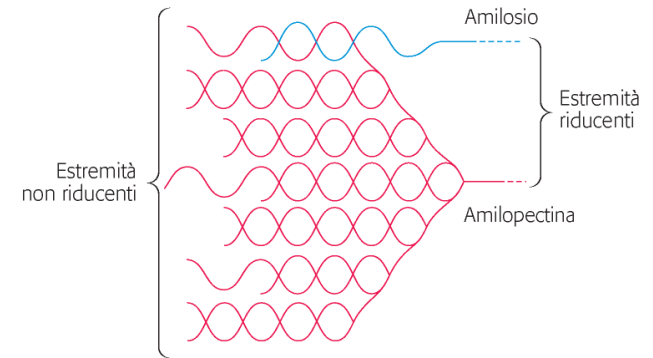
AMIDO



(a) Amilosio, non ramificato



(b) Amilopectina, ramificato



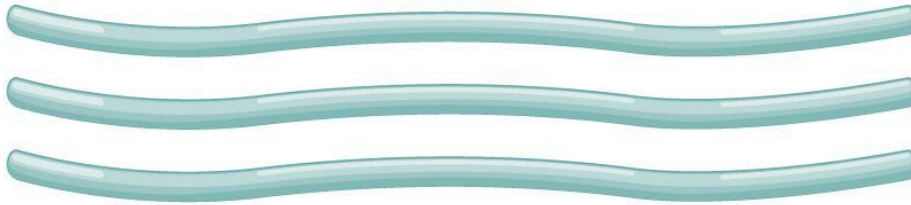
(c)

GLICOGENO

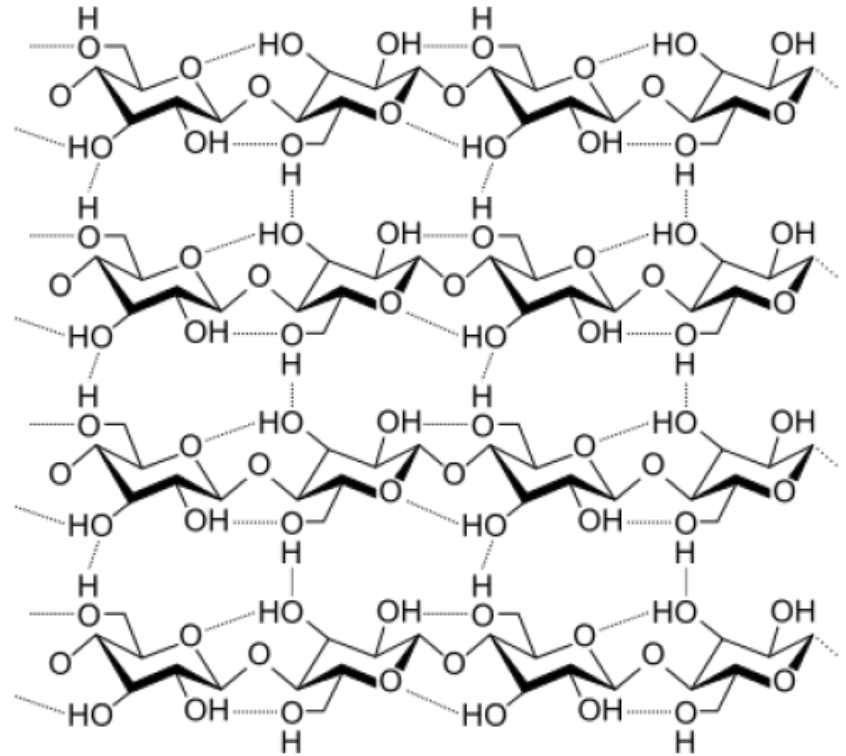
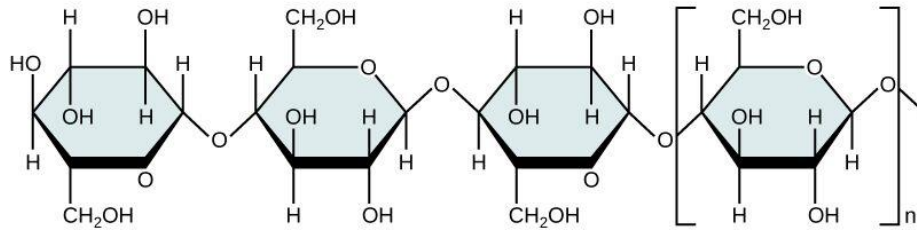
Struttura simile all'amilopectina, con maggior grado di ramificazione

POLISACCARIDI

Cellulose fibers



Cellulose structure

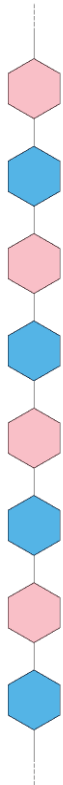


CELLULOSA

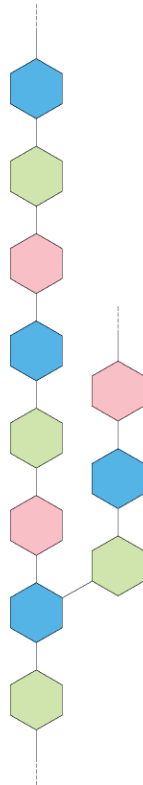
**Struttura lineare costituita da molecola di β -glucosio
che danno luogo a catene organizzate in fibre**

Eteropolisaccaridi

Due tipi
di monomero,
non ramificato



Diversi tipi
di monomero,
ramificato

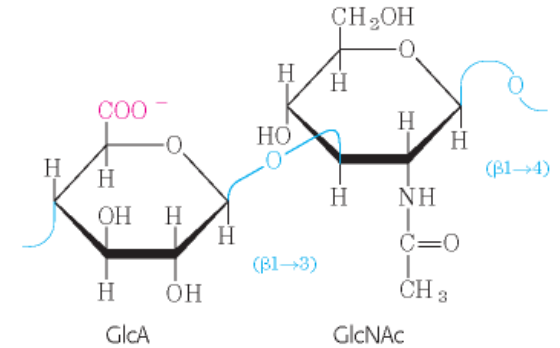


POLISACCARIDI

Glicosamminoglicano
Numero di disaccaridi
per catena

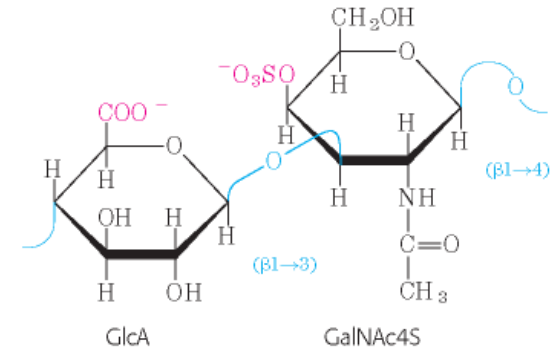
**Disaccaride
ripetuto**

lalluronato
~50 000



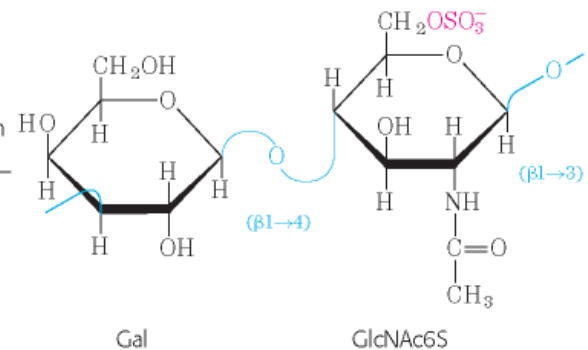
**Matrice extracellulare
di cartilagini e tendini**

Condroitin
4-solfato
20-60



**In cartilagini, tendini,
legamenti e parete
dell'aorta**

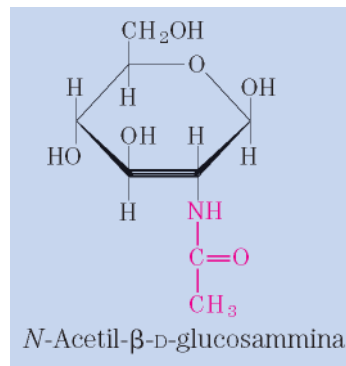
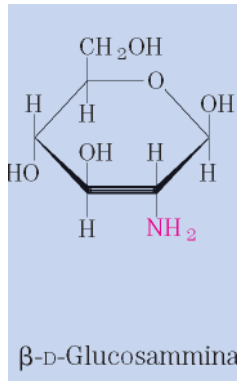
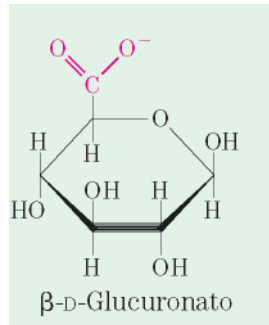
Cheratan
solfato
~25



**In strutture cornee,
ossa e cartilagini**

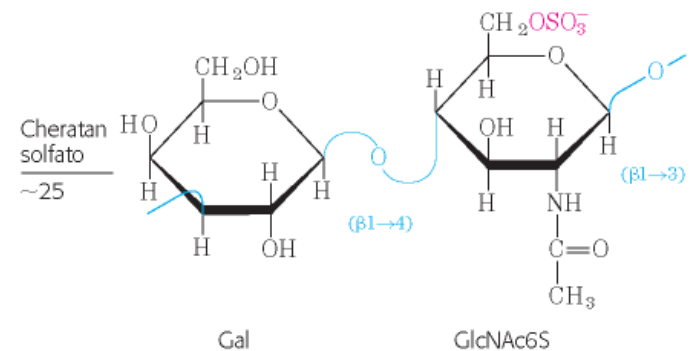
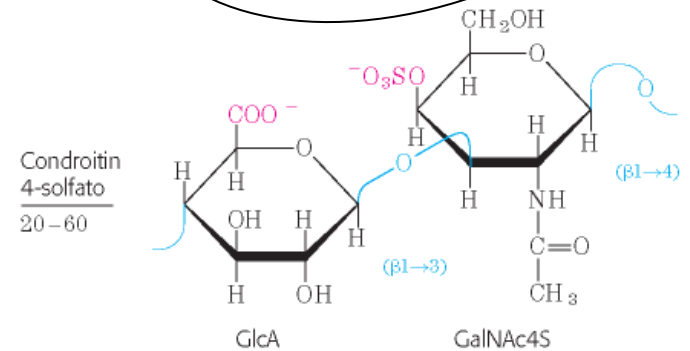
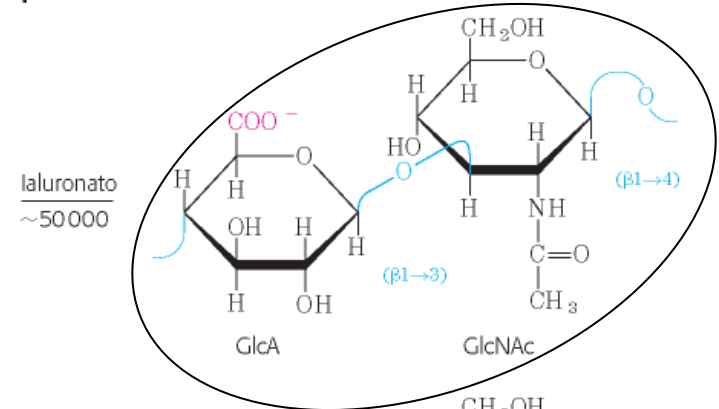
GLICOSAMMINOGLICANI

- Polimeri lineari costituiti da unità disaccaridiche ripetute
- Le unità disaccaridiche sono costituite da zuccheri modificati

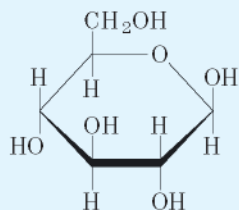


Glicosamminoglicano
Numero di disaccaridi
per catena

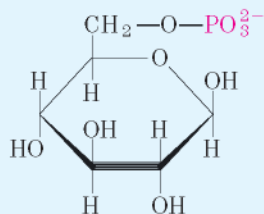
Disaccaride
ripetuto



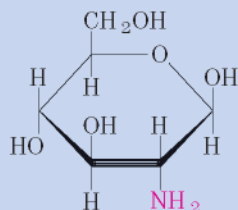
Famiglia del glucosio



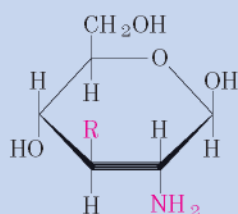
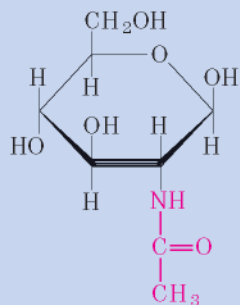
β -D-Glucosio



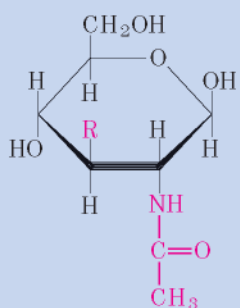
β -D-Glucosio 6-fosfato



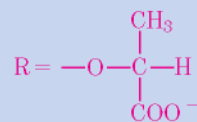
β -D-Glucosammina *N*-Acetil- β -D-glucosammina



Acido muramico



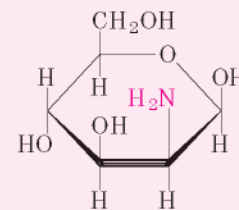
Acido *N*-acetilmuramico



Ammino-zuccheri

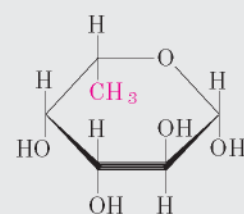


β -D-Galattosammina

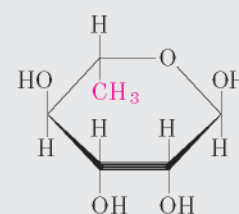


β -D-Mannosammina

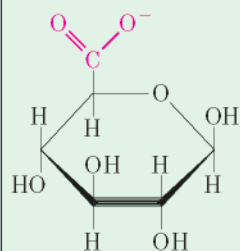
Deossi-zuccheri



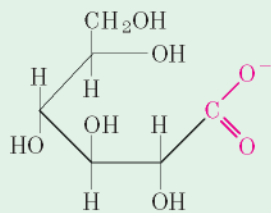
α -L-Fucosio



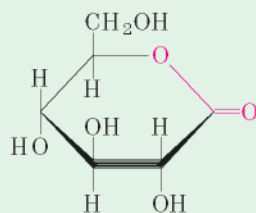
α -L-Ramnosio



β -D-Glucuronato

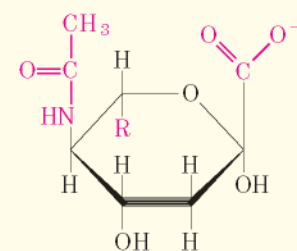


D-Gluconato

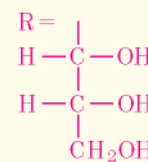


D-Glucono- δ -lattone

Zuccheri acidi

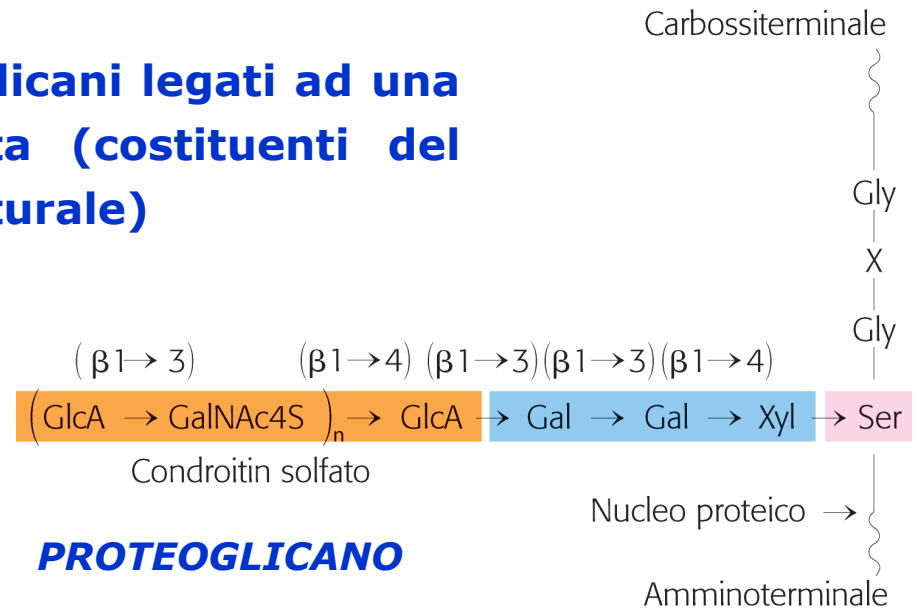


Acido *N*-acetilneuraminico
(acido sialico)



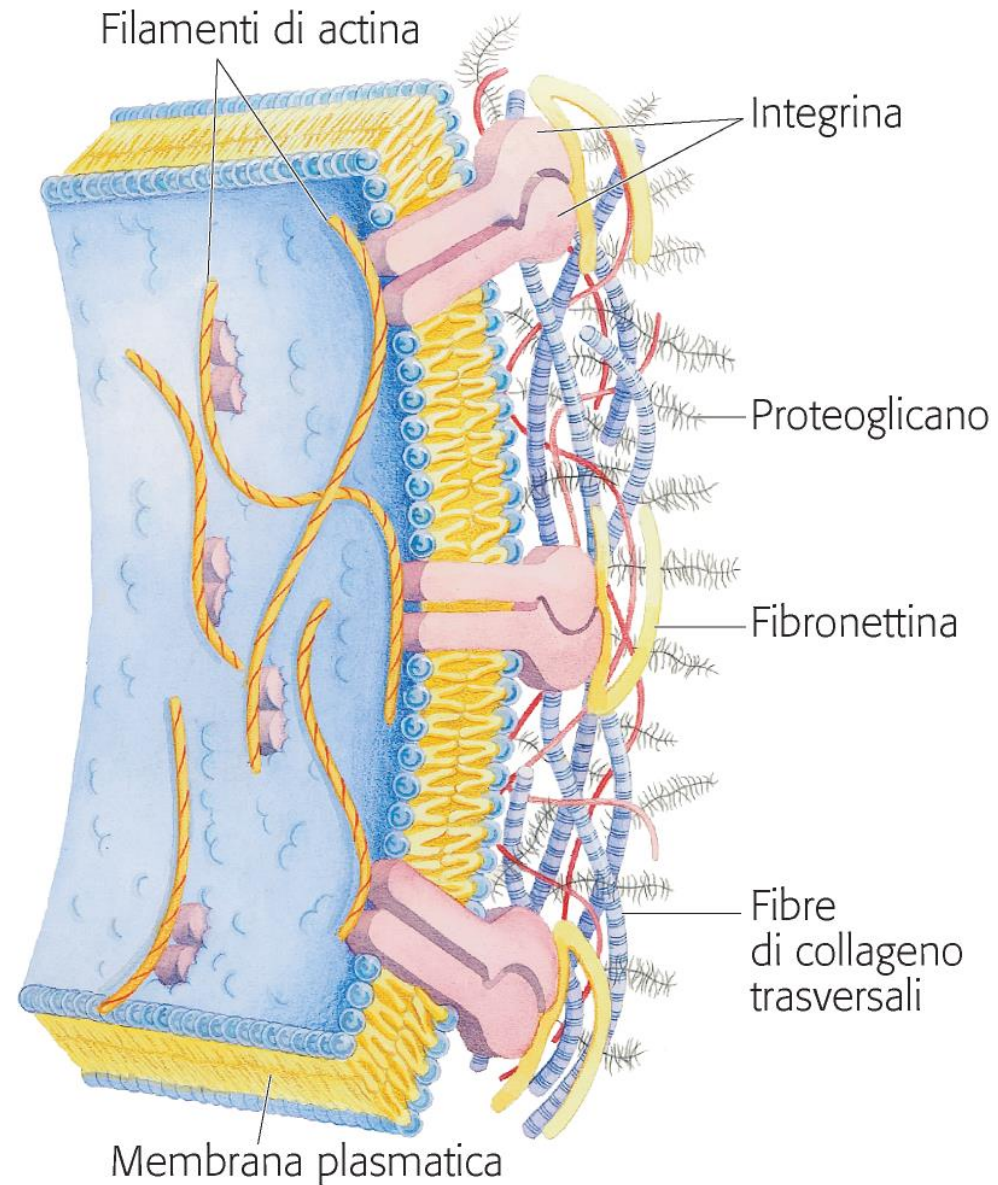
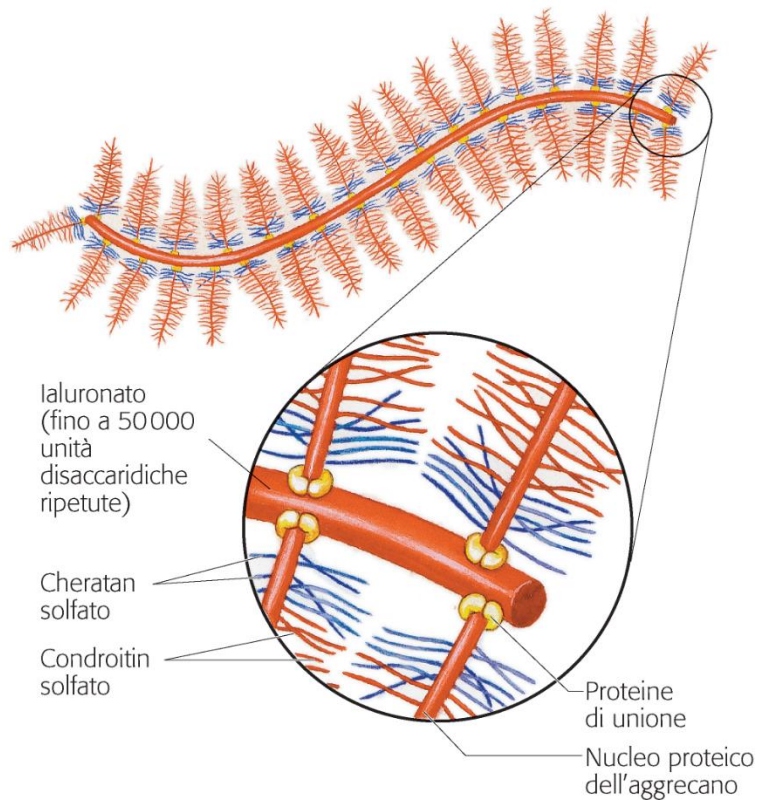
GLICOCONIUGATI

- PROTEOGLICANI:** glicosamminoglicani legati ad una proteina di membrana o secreta (costituenti del tessuto connettivo, funzione strutturale)

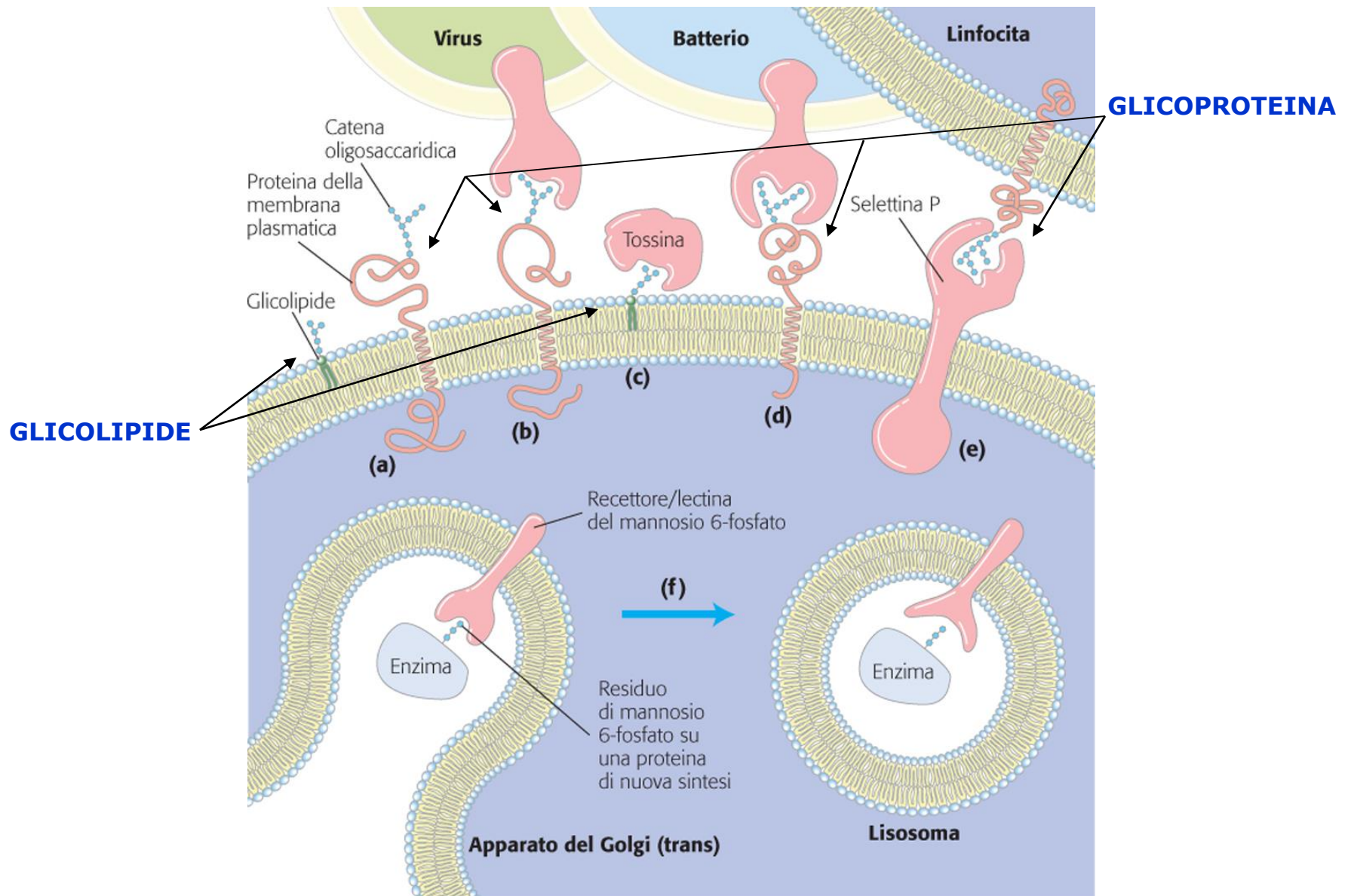


- GLICOPROTEINE:** uno o più oligosaccaridi legati covalentemente ad una proteina (sulla superficie esterna delle cellule, siti di riconoscimento per proteine)
- GLICOLIPIDI:** lipidi di membrana le cui teste idrofiliche sono costituite da oligosaccaridi (siti di riconoscimento per proteine)

•PROTEOGLICANI



•GLICOPROTEINE e GLICOLIPIDI



NUCLEOTIDI ED ACIDI NUCLEICI

NUCLEOTIDI

- **Costituenti degli acidi nucleici**
- **Trasportatori di energia**
- **Componenti di cofattori di enzimi**
- **Messaggeri chimici**

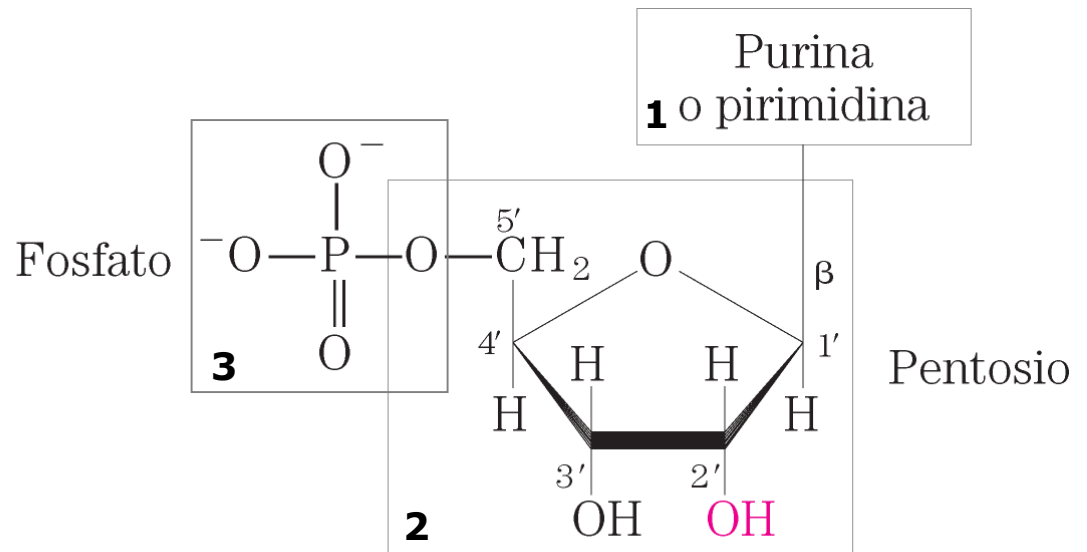
ACIDI NUCLEICI

- **molecole “informazionali”**
- **conservazione e trasmissione dell'informazione genetica**

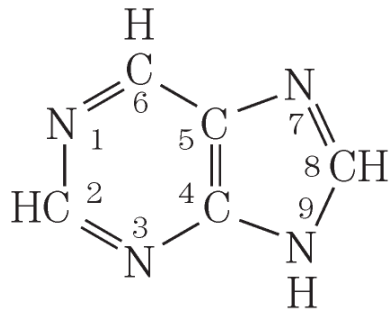
STRUTTURA GENERALE DEI NUCLEOTIDI

Tre componenti principali

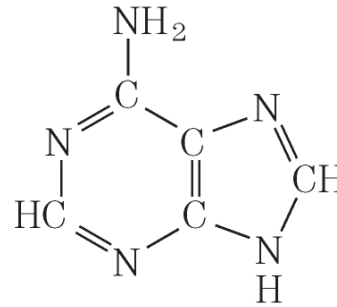
1. una base azotata
2. un pentosio
3. un gruppo fosfato



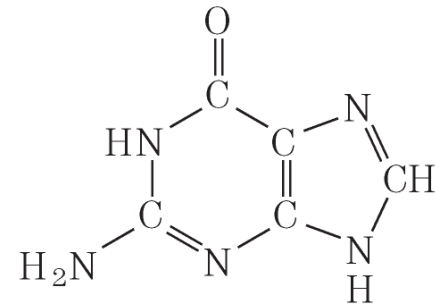
BASI AZOTATE



Purina

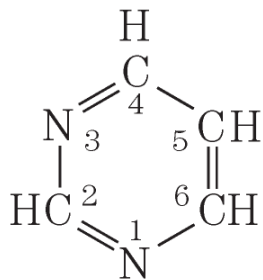


Adenina

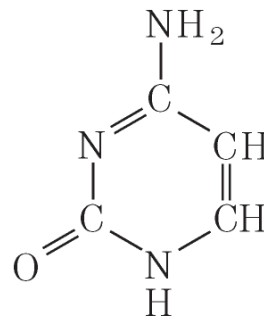


Guanina

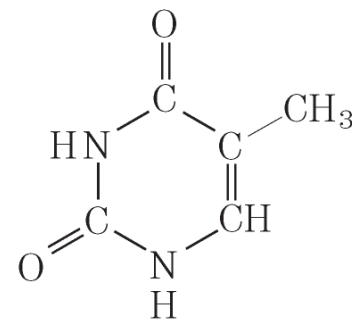
Purine



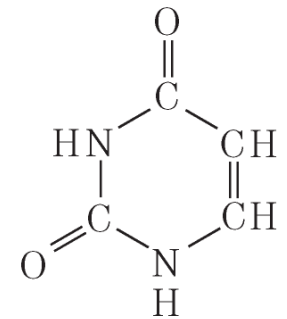
Pirimidina



Citosina



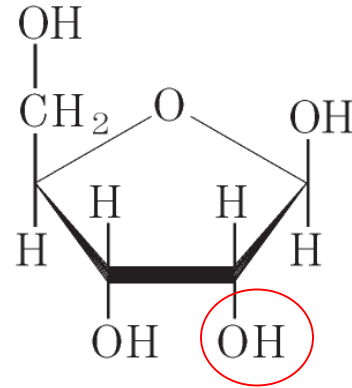
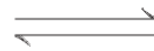
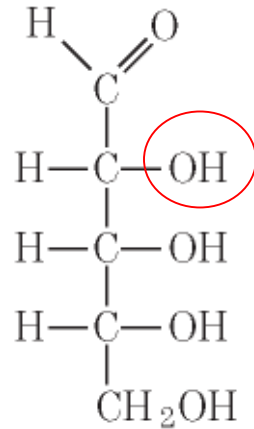
Timina
(DNA)



Uracile
(RNA)

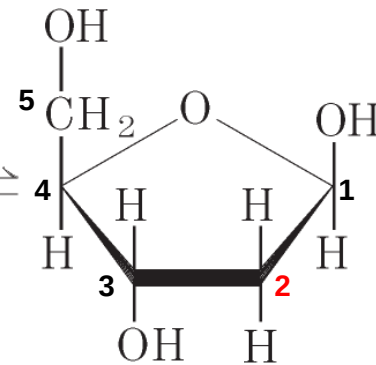
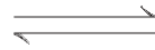
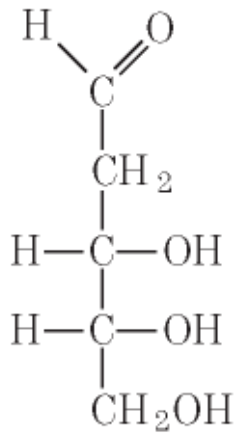
Pirimidina

PENTOSI



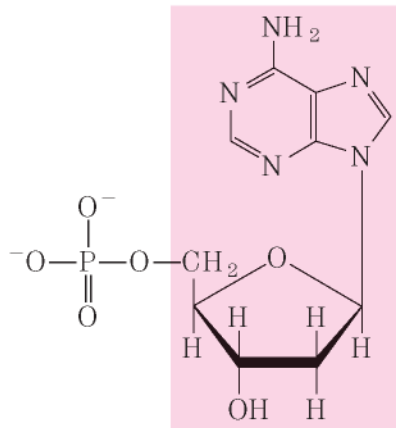
D-Ribosio (RNA)

forma β-furanosica



2-deossi-D-Ribosio (DNA)

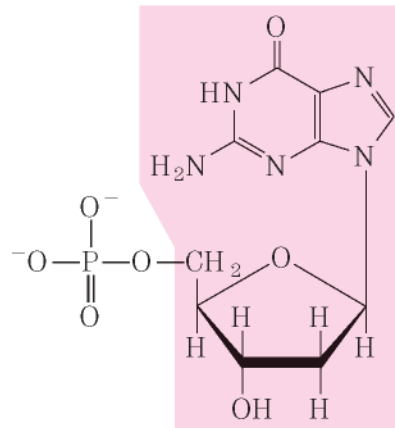
NUCLEOTIDI DEL DNA (deossiribonucleotidi o deossinucleotidi)



Nucleotide: Deossiadenilato
(deossiadenosina
5'-monofosfato)

Simboli: A, dA, dAMP

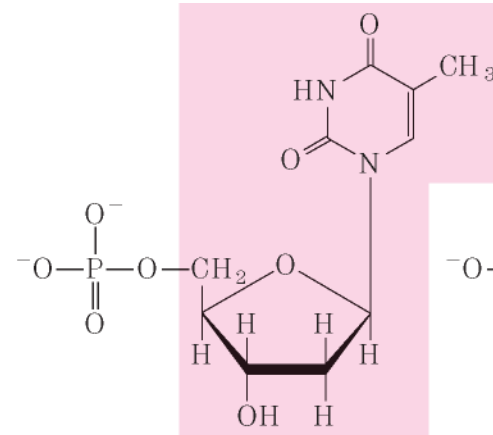
Nucleoside: Deossiadenosina



Nucleotide: Deossiguanilato
(deossiguanosina
5'-monofosfato)

Simboli: G, dG, dGMP

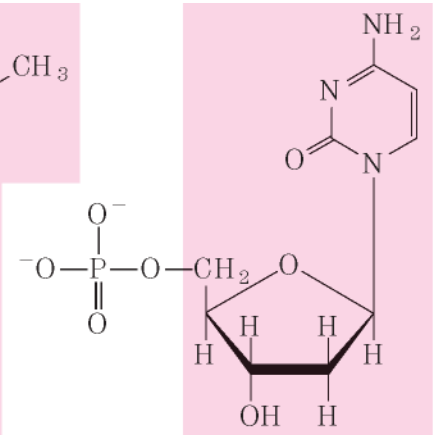
Nucleoside: Deossiguanosina



Nucleotide: Deossitimidilato
(deossitimidina
5'-monofosfato)

Simboli: T, dT, dTMP

Nucleoside: Deossitimidina



Nucleotide: Deossicitidilato
(deossicitidina
5'-monofosfato)

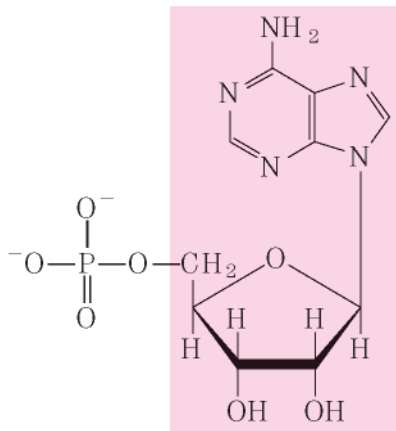
Simboli: C, dC, dCMP

Nucleoside: Deossicitidina

NUCLEOTIDE: nucleoside monofosfato

NUCLEOSIDE: nucleotide privo del gruppo fosforico

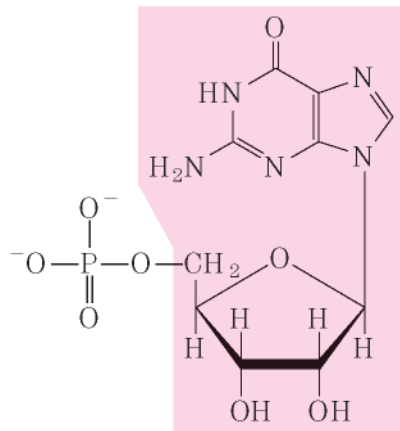
NUCLEOTIDI DELL'RNA (ribonucleotidi o nucleotidi)



Nucleotide: Adenilato (adenosina 5'-monofosfato)

Simboli: A, AMP

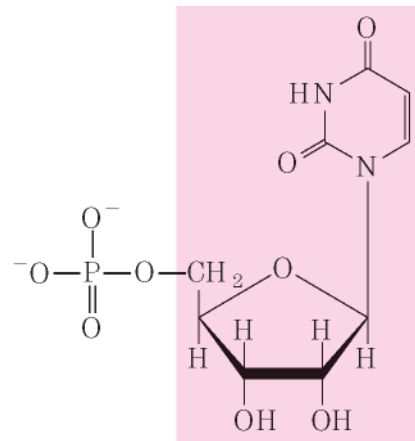
Nucleoside: Adenosina



Nucleotide: Guanilato (guanosina 5'-monofosfato)

Simboli: G, GMP

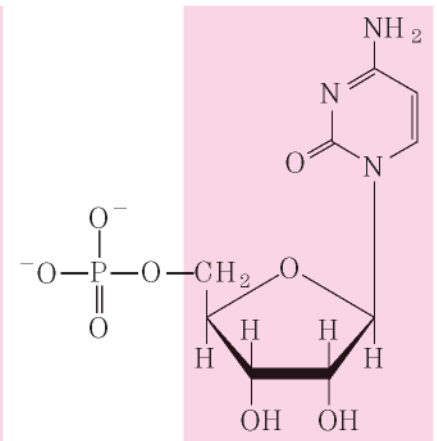
Nucleoside: Guanosina



Nucleotide: Uridilato (uridina 5'-monofosfato)

Simboli: U, UMP

Nucleoside: Uridina



Nucleotide: Citidilato (citidina 5'-monofosfato)

Simboli: C, CMP

Nucleoside: Citidina

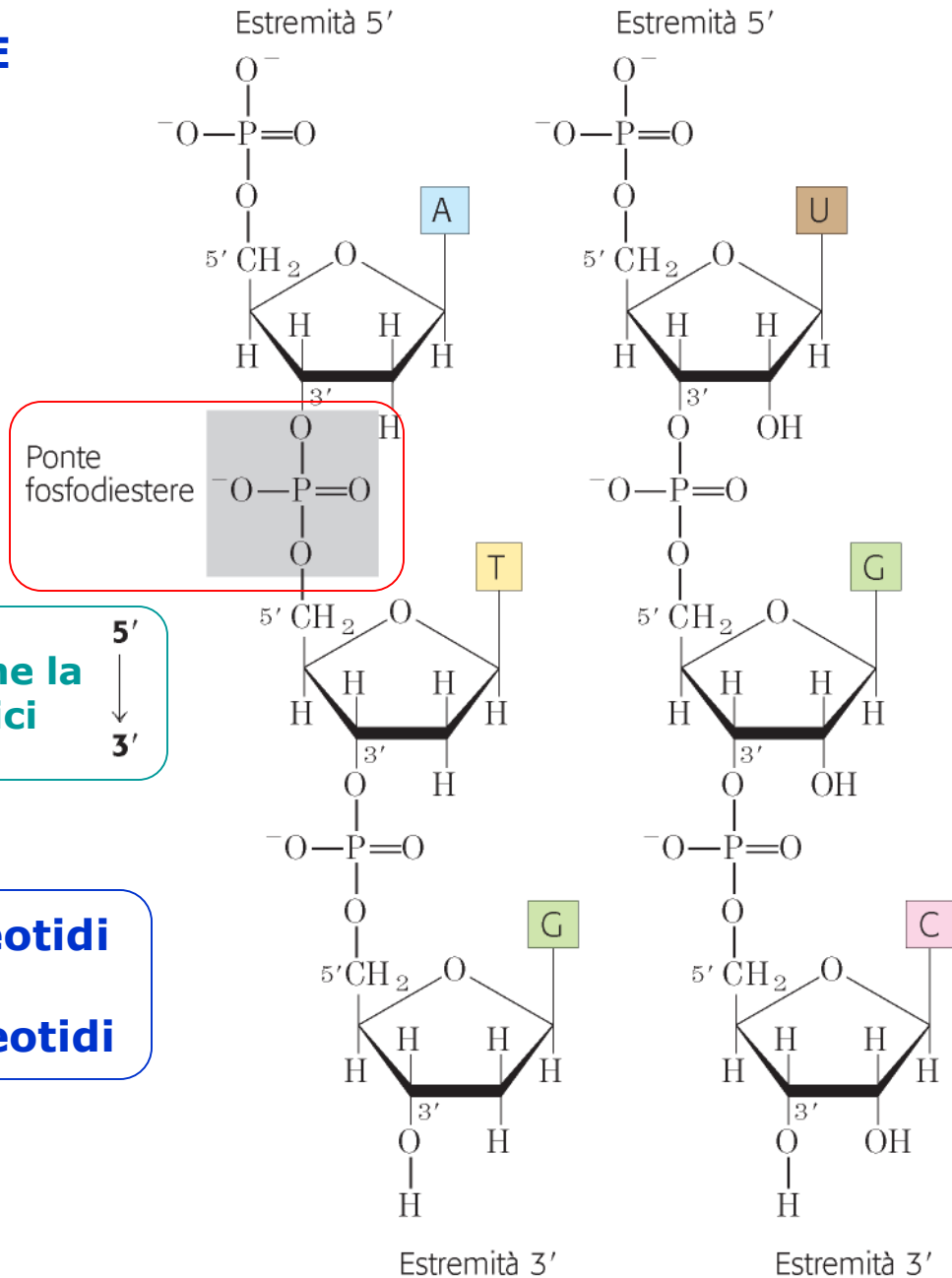
NUCLEOTIDE: nucleoside monofosfato

NUCLEOSIDE: nucleotide privo del gruppo fosforico

SCHELETRO COVALENTE DEGLI ACIDI NUCLEICI

DNA

RNA

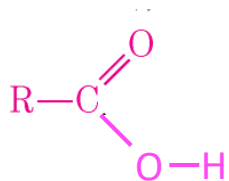


**Direzione lungo cui avviene la
sintesi degli acidi nucleici**

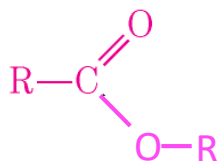
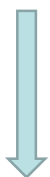
5'
↓
3'

catene corte: oligonucleotidi

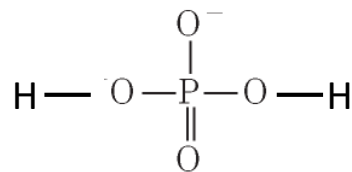
catene lunghe: polinucleotidi



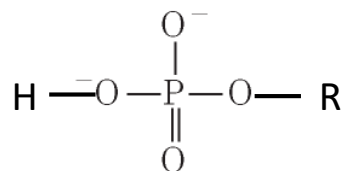
ACIDO CARBOSSILICO



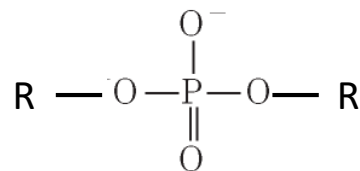
**ESTERE DELL'ACIDO
CARBOSSILICO
O
ESTERE**



ACIDO FOSFORICO



**ESTERE DELL'ACIDO
FOSFORICO
O
FOSFOESTERE**



FOSFODIESTERE

TAPPE NELLO STUDIO DELLA STRUTTURA DEL DNA

STUDI di Friederich MIESCHER (1868)

Isolamento e caratterizzazione della "nucleina"

STUDI di O. AVERY, C. McLEOD e M. McCARTY (anni '40)

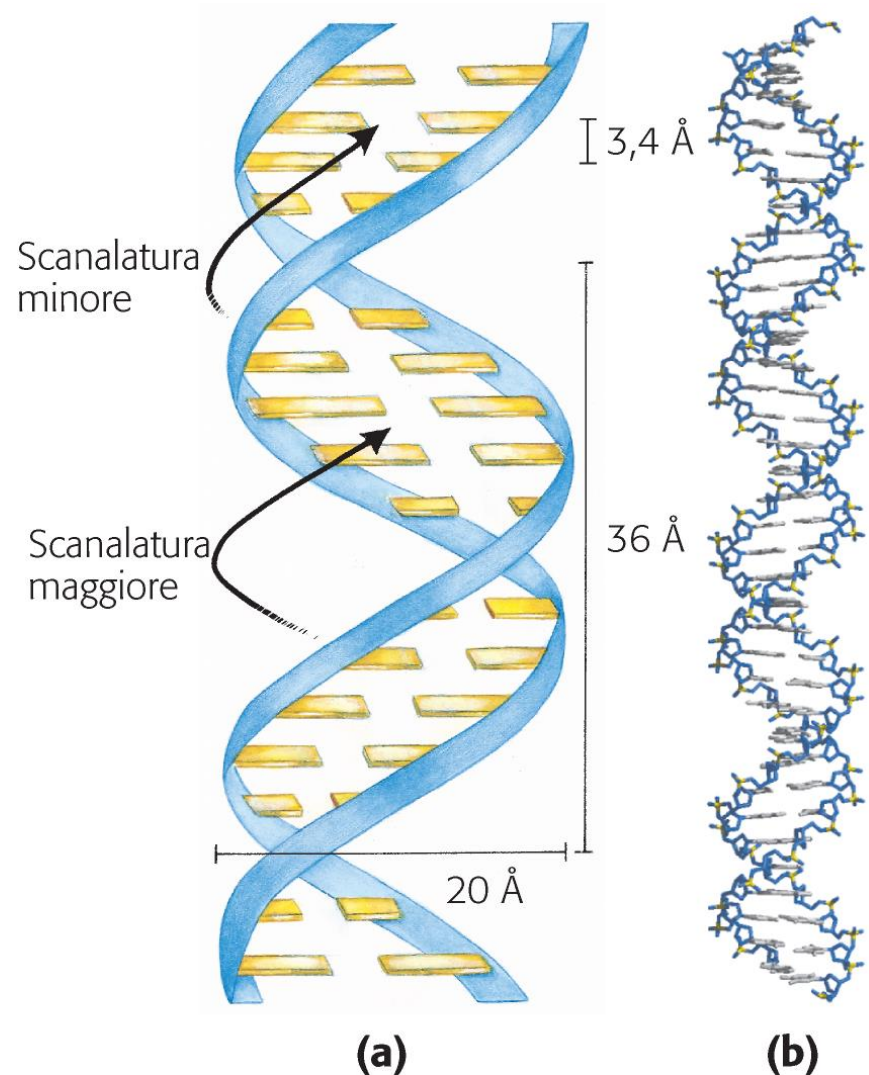
Studi su *Streptococcus pneumoniae* confermano che il DNA è responsabile della trasmissione dei caratteri genetici

REGOLE DI Erwin CHARGAFF (fine anni '40)

- 1. La composizione in basi del DNA varia da una specie all'altra**
- 2. Molecole di DNA da tessuti diversi della stessa specie hanno stessa composizione in basi**
- 3. La composizione del DNA in una data specie non varia con l'età, lo stato nutrizionale o con l'ambiente**
- 4. In tutte le molecole di DNA, indipendentemente dalla specie, $A = T$ e $G = C$ (ovvero la somma dei residui purinici è uguale alla somma di quelli pirimidinici $A + G = T + C$)**

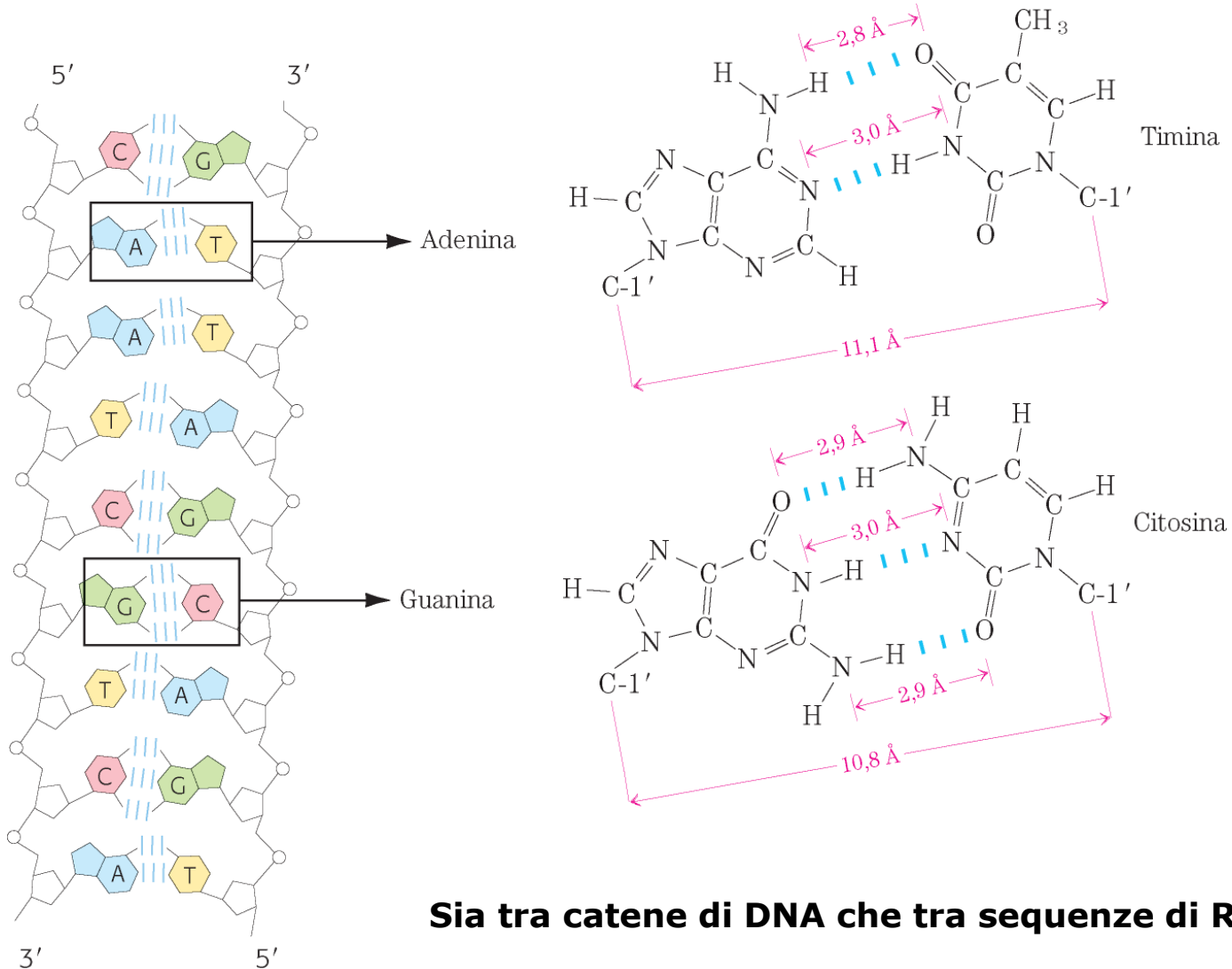
Modello di James WATSON e Francis CRICK (1953)

- **doppia elica destrorsa**
- **distanza tra basi consecutive: 3,4 Å**
- **10,5 coppie di basi ogni 36 Å**



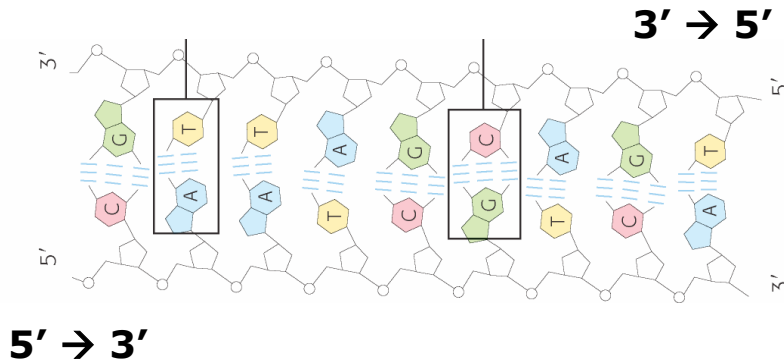
DNA a doppia elica o "duplex"

DISPOSIZIONE DEI LEGAMI IDROGENO NELLE COPPIE DI BASI

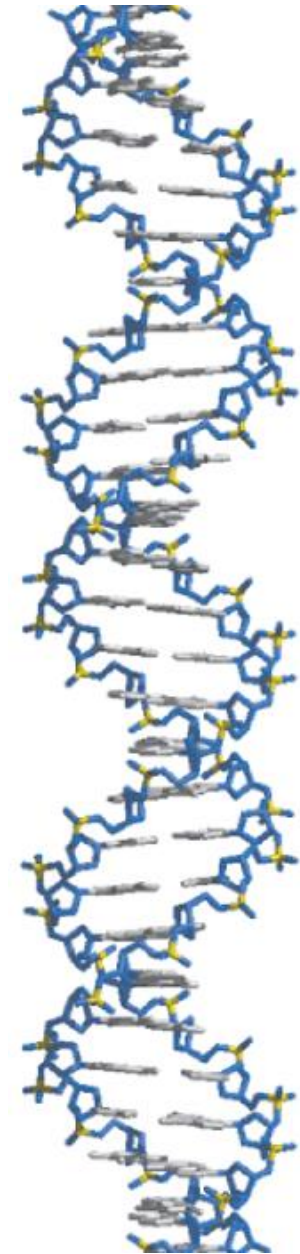


STRUTTURA DELLA DOPPIA ELICA

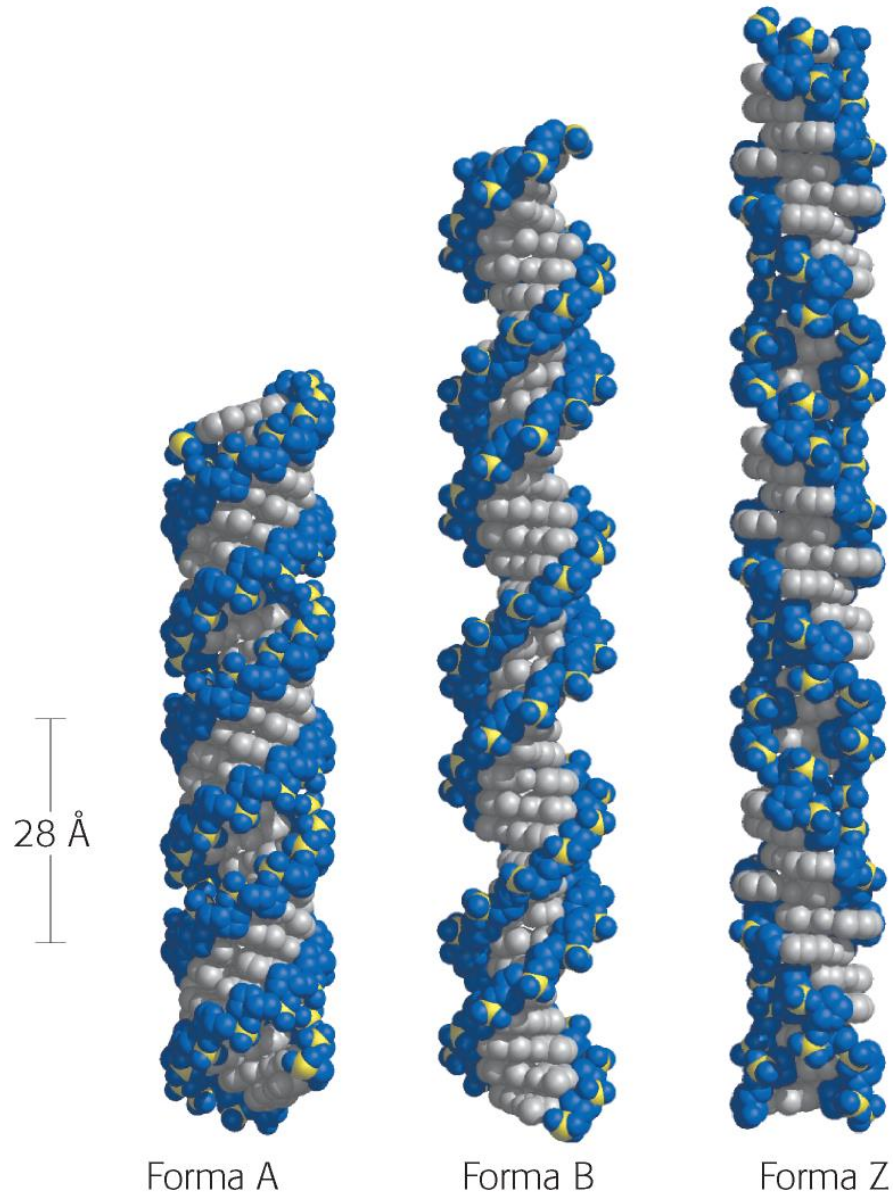
1. catene in disposizione antiparallela
2. catene appaiate: sequenze complementari



3. coppie di basi perpendicolari all'asse dell'elica:
coppie di basi consecutive si dispongono
parallelamente tra di loro grazie ad interazioni
dipolari e di van der Waals

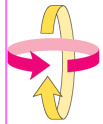


STRUTTURA DELLA DOPPIA ELICA



Possibili strutture di DNA ed RNA

Palindromo



T T A G C A C G T G C T A A
A A T C G T G C A C G A T T

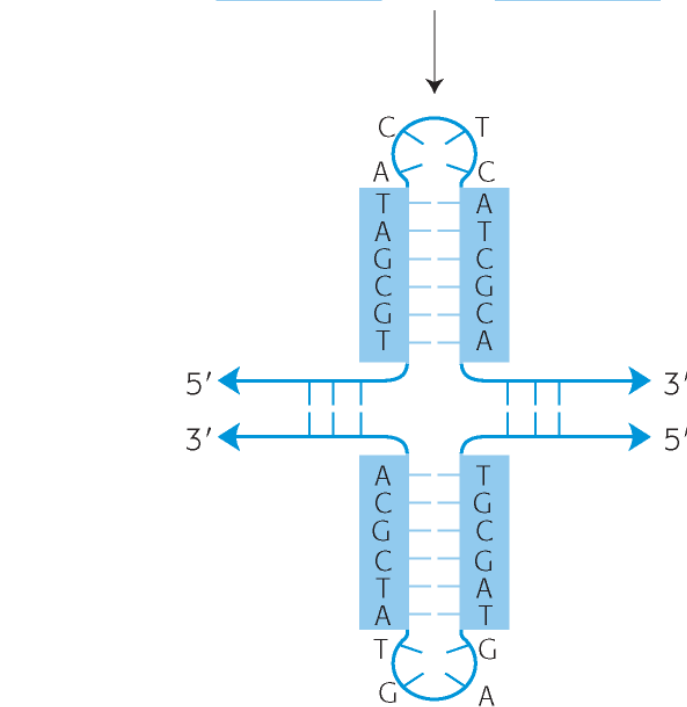
Rotazione di 180°

Ripetuto speculare



T T A G C A C C A C G A T T
A A T C G T G G T G C T A A

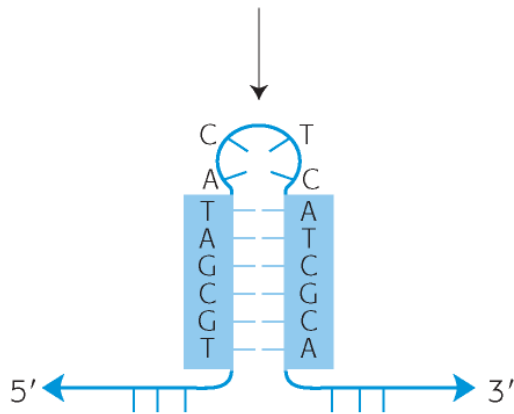
5'← T G C G A T A C T C A T C G C A → 3'
3'← A C G C T A T G A G T A G C G T → 5'



(b)

Struttura a croce
DNA duplex

5'← T G C G A T A C T C A T C G C A → 3'



(a)

Struttura a forcina
DNA a singola elica od RNA

Tipi di molecole di RNA

1. RNA messaggero o mRNA
2. RNA transfer o tRNA
3. RNA ribosomico o rRNA

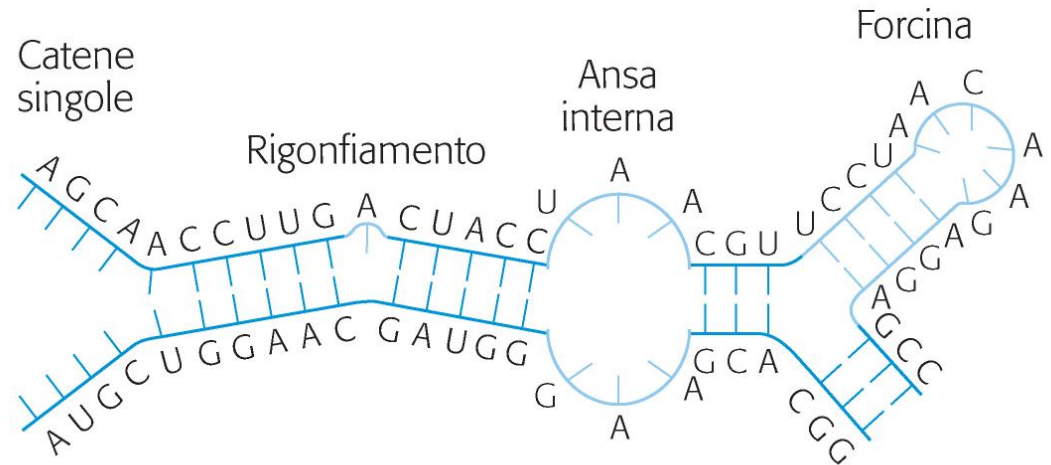
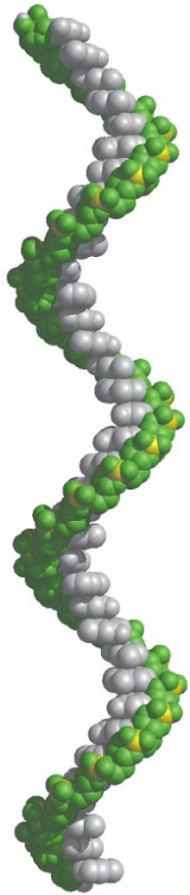


(a) mRNA monocistronico

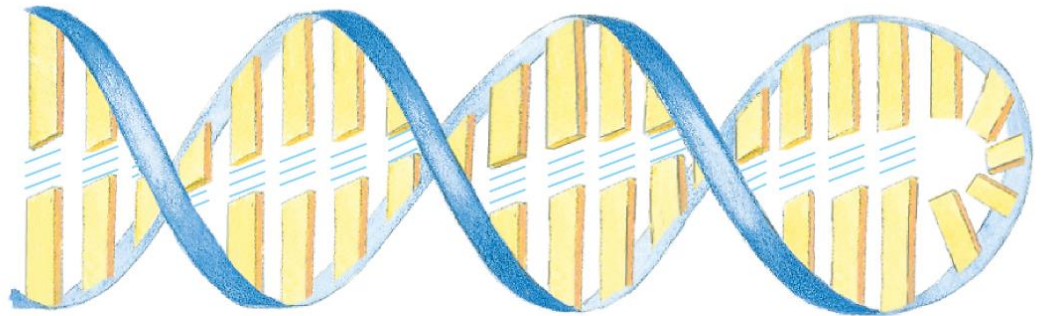


(b) mRNA policistronico

Struttura delle molecole di RNA



(a)



Doppia elica nella struttura a forcina

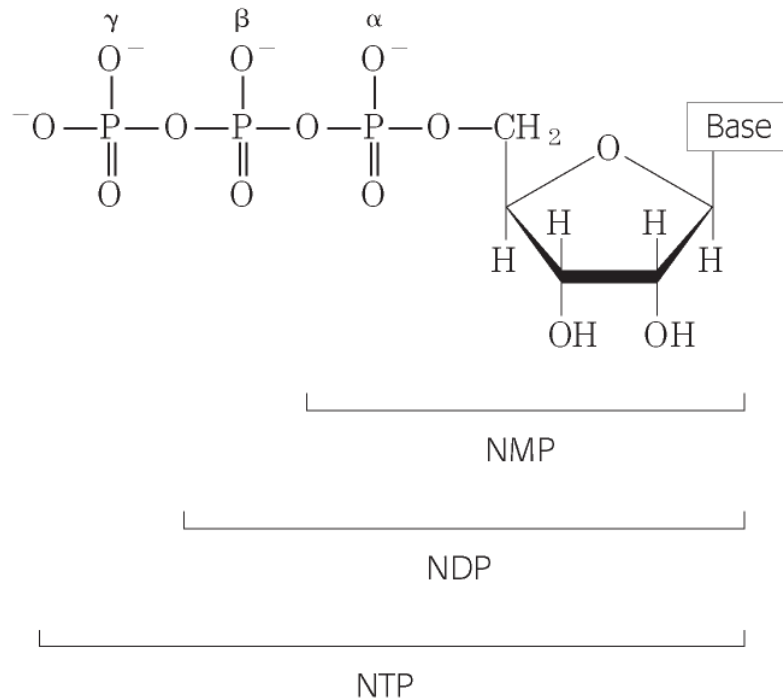
(b)

Elica destrorsa di RNA

Strutture secondarie di RNA

altri ruoli biologici dei nucleotidi

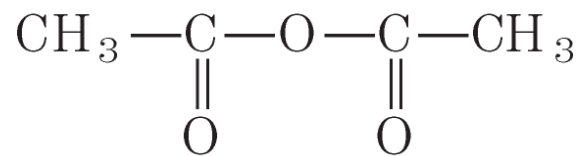
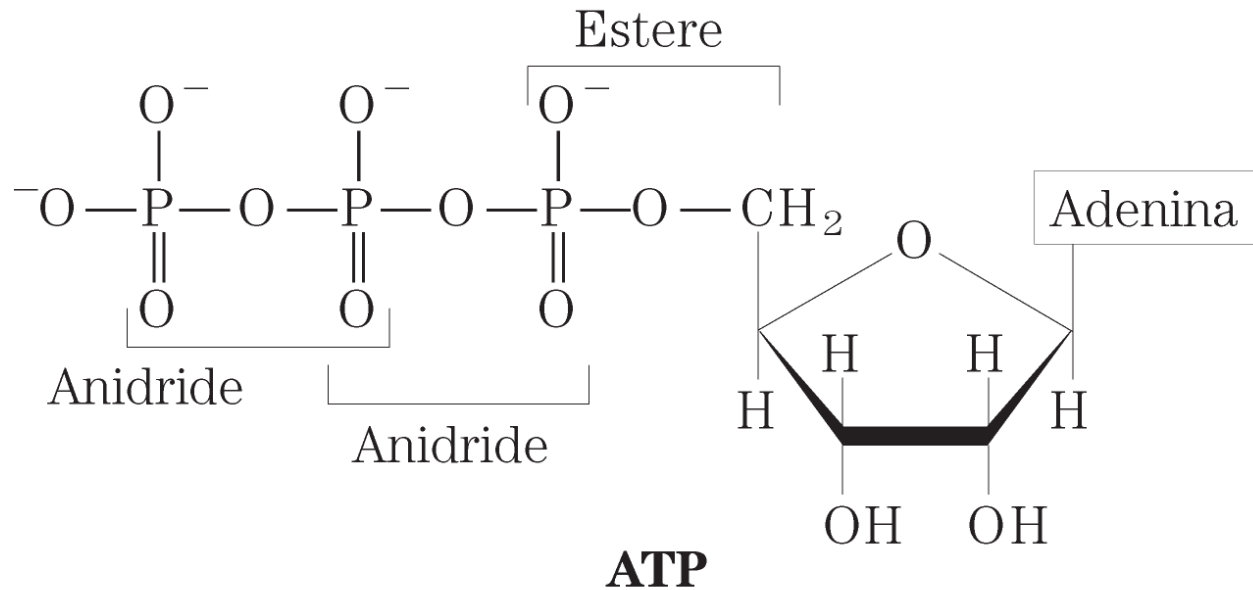
- **Trasportatori di energia**
- **Componenti di cofattori di enzimi**
- **Messaggeri chimici**



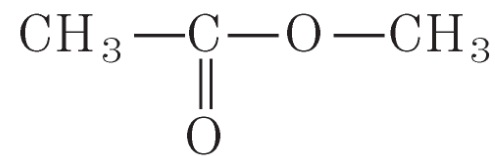
Abbreviazioni dei ribonucleosidi 5'-fosfato			
Base	Mono-	Di-	Tri-
Adenina	AMP	ADP	ATP
Guanina	GMP	GDP	GTP
Citosina	CMP	CDP	CTP
Uracile	UMP	UDP	UTP

Abbreviazioni dei deossiribonucleosidi 5'-fosfato			
Base	Mono-	Di-	Tri-
Adenina	dAMP	dADP	dATP
Guanina	dGMP	dGDP	dGTP
Citosina	dCMP	dCDP	dCTP
Timina	dTMP	dTDP	dTTP

- **Trasportatori di energia**

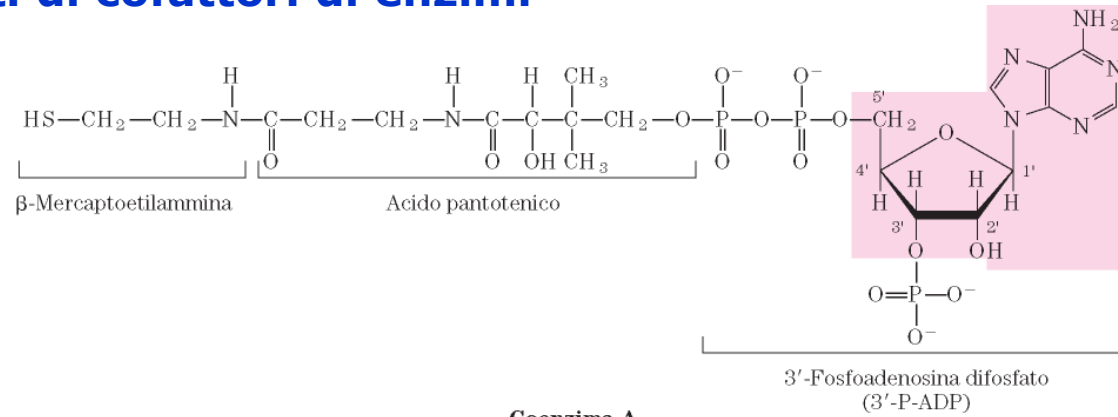


Anidride acetica,
un'anidride
acida carbossilica

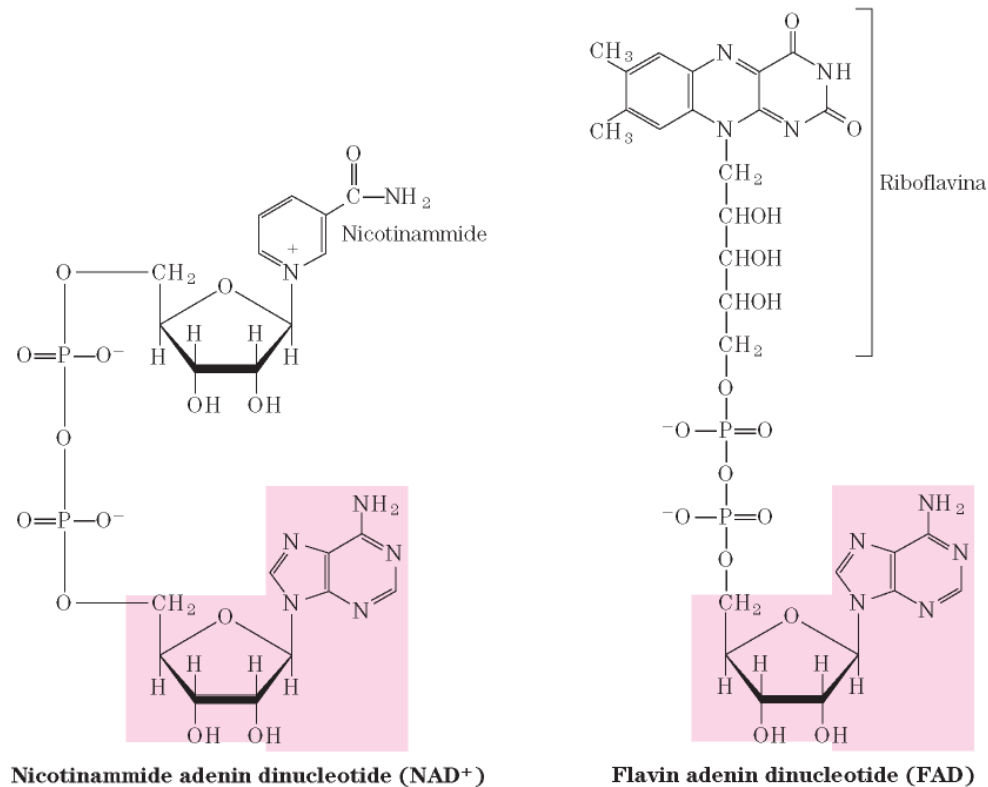


Metilacetato,
un estere
acido carbossilico

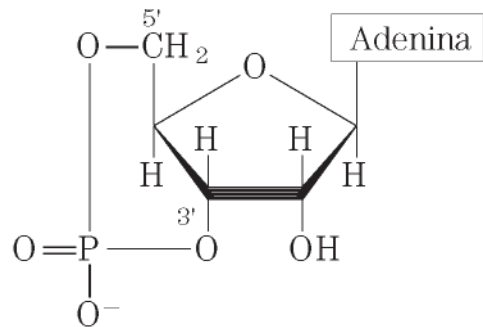
•Componenti di cofattori di enzimi



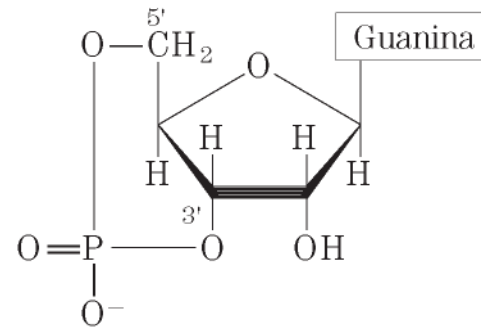
Coenzima A



- **Messaggeri chimici**



Adenosina 3',5'-monofosfato ciclico
(AMP ciclico, cAMP)



Guanosina 3',5'-monofosfato ciclico
(GMP ciclico, cGMP)