Biološke makromolekule

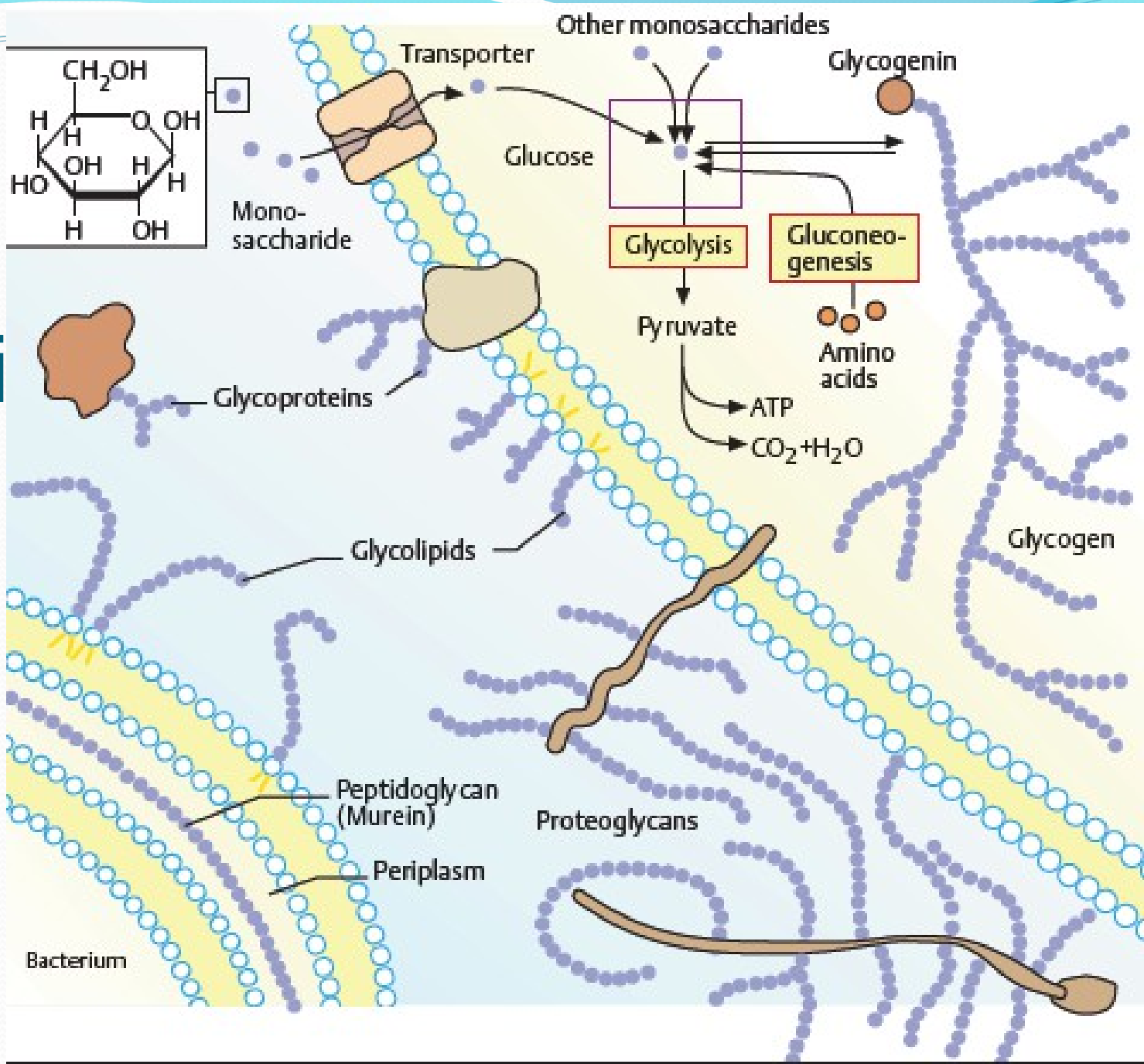
Ogljikovi hidrati

Lipidi

Ogljikovi hidrati

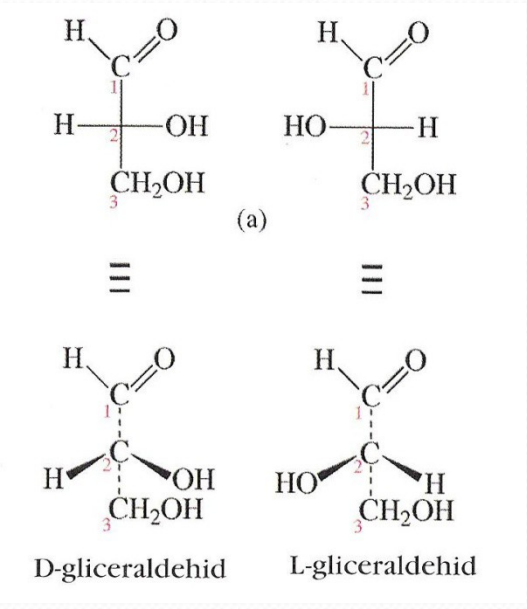
- Najdemo jih v vseh oblikah življenja.
- Imajo več različnih funkcij:
  - vloga v energijskem metabolizmu – lahko neposredno metabolično gorivo (glukoza, fruktoza) ali kot rezervne spojine (škrob, glikogen)
  - vloga pri strukturi organizmov – celična stena rastlin, gliv in bakterij, vezivna tkiva živali (hrustanec), zunanji oklep pri členonožcih
  - riboza in deoksiriboza sta komponenti nukleinskih kislin
  - s proteini in kompleksnimi lipidi kovalentno povezani ogljikovi hidrati delujejo kot označevalci na površini celice pri prepoznavanju drugih molekul.

Ogljikovi hidrati



Monosaharidi

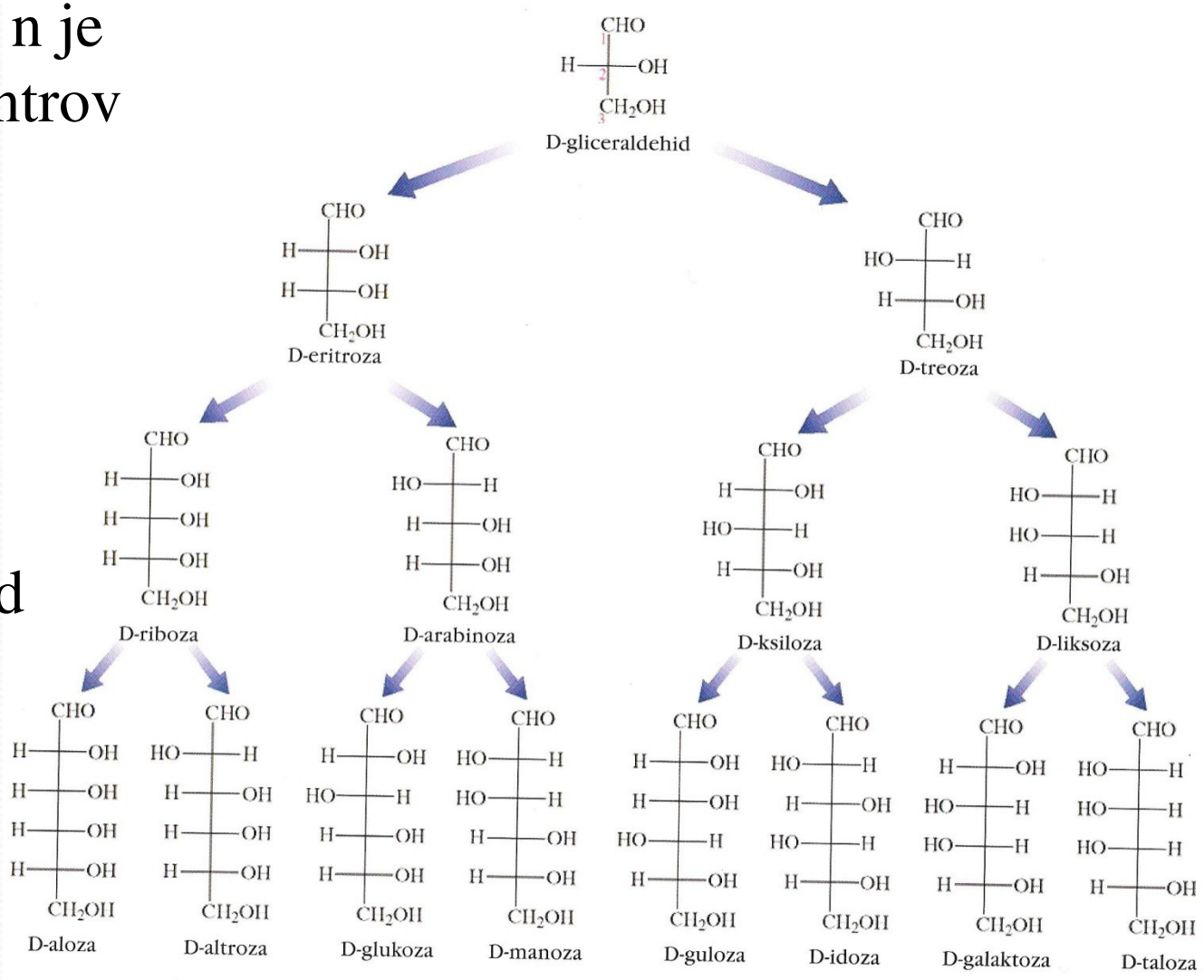
- najenostavnejši ogljikovi hidrati
- empirična formula: $(CH_2O)_n$ – večinoma v naravi n od 3 do 7 (trioze, tetroze, pentoze, heksoze, heptoze)
- ena sama aldehidna (aldoze)ali keto (ketoze) skupina, več OH skupin
- pri ogljikovih hidratih, ki imajo vsaj en kiralni center, obstajata 2 stereoizomeri (enantiomeri): D- in L-, ki označujeta absolutno konfiguracijo (prvotno smer zasuka polarizirane svetlobe v raztopini)
- gliceraldehid (v naravi D- konfiguracija) kot standard za določevanje D- ali L-



gliceraldehid (aldotrioza)

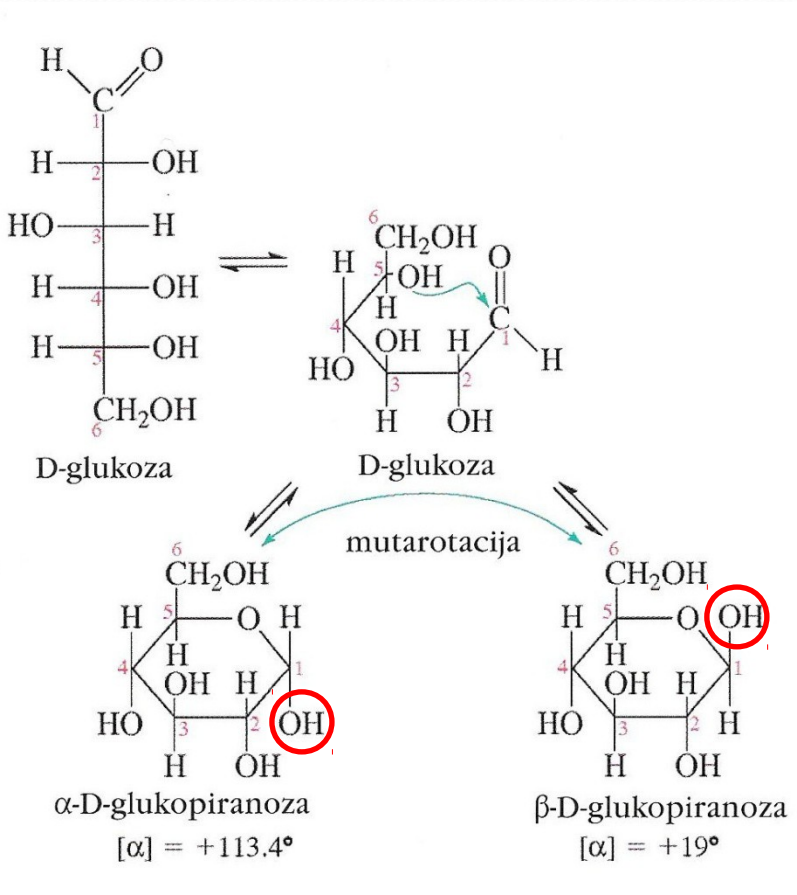
Monosaharidi

- število izomer: 2^n, n je število kiralnih centrov
- D- ali L- oznaka glede na razporeditev substituent na kiralnem C, ki je najbolj oddaljen od karbonilnega C



Monosaharidi - ciklizacija

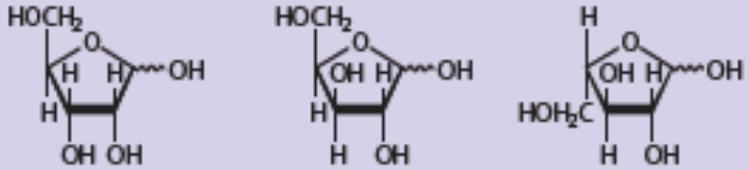
- pentoze in heksoze v raztopinah večinoma v ciklični obliki
- reakcija aldehidne skupine na C1 pri aldozi in –OH skupine: hemiacetal
- reakcija karbonilne skupine na C2 pri ketozi in –OH skupine: hemiketal
- 5-členski obroč: furanoza
- 6-členski obroč: piranoza
- α in β- obliki: anomera, razlika v porazdelitvi skupin na anomernem C (C1 pri aldozah, C2 pri ketozah):
  - α-konfiguracija: -OH skupina na anomernem C pod ravnino obroča
  - β -konfiguracija: -OH skupina na anomernem C nad ravnino obroča



Pomembni mono-saharidi

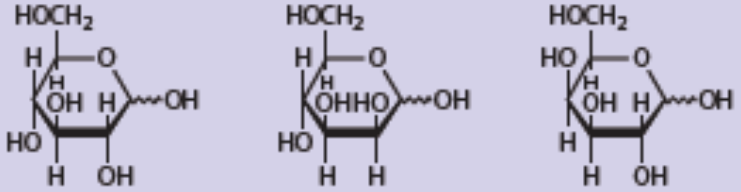
① aldoze

D-riboza (Rib) D-ksiloza (Xyl) L-arabinoza (Ara)



pentoza

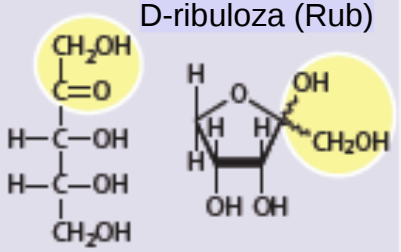
D-glukoza (Glc) D-manoza (Man) D-galaktoza (Gal)



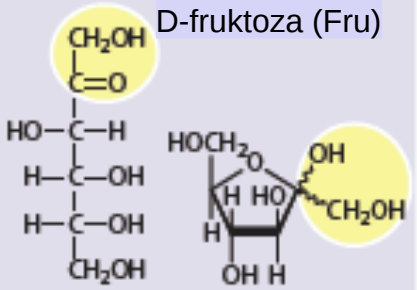
Hexoses

② ketoze

D-ribuloza (Rub)

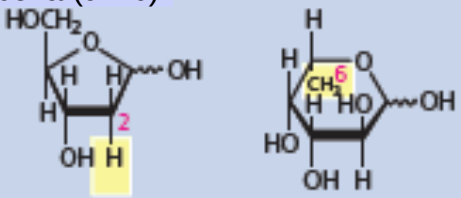


D-fruktoza (Fru)



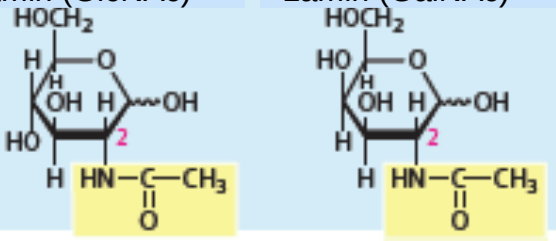
③ deoksialdoze

2-deoksi-D-riboza (dRib) L-fukoza (Fuc)



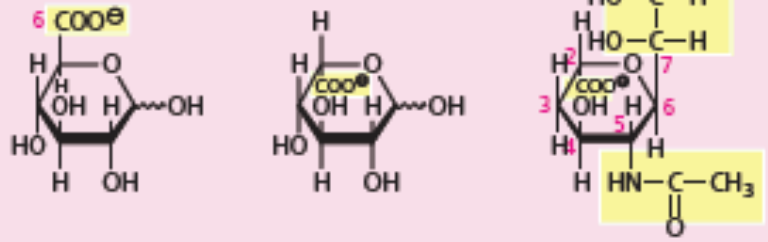
④ acetilirani aminosladkorji

N-acetil-D-gluko-zamin (GlcNAc) *N*-acetil-D-galakto-zamin (GalNAc)



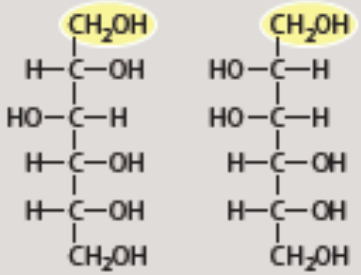
⑤ kislinski monosaharidi

D-glukuronska kislina (GlcUA) L-iduronska kislina (IduUA) *N*-acetilneuramiska kislina (NeuAc)



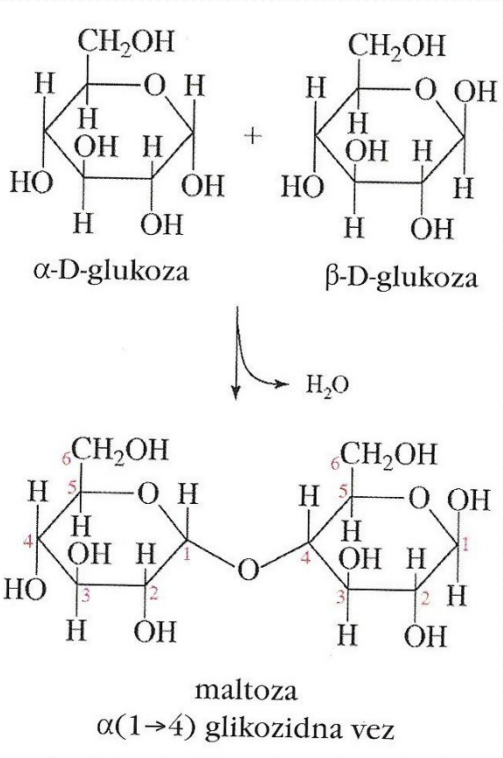
⑥ sladkorni alkoholi

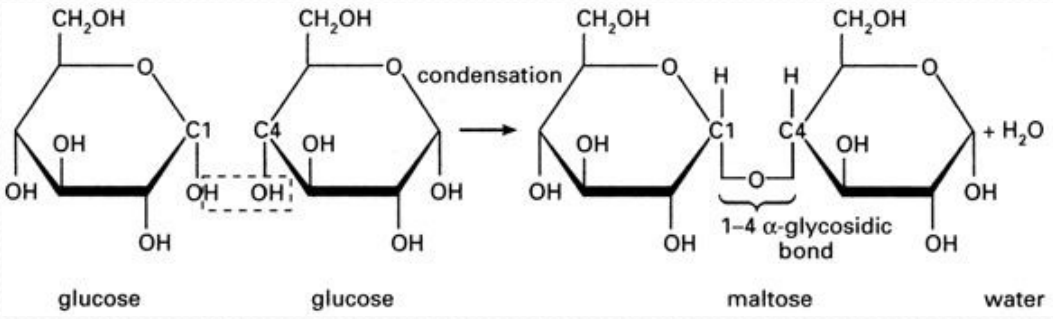
D-sorbitol D-manitol

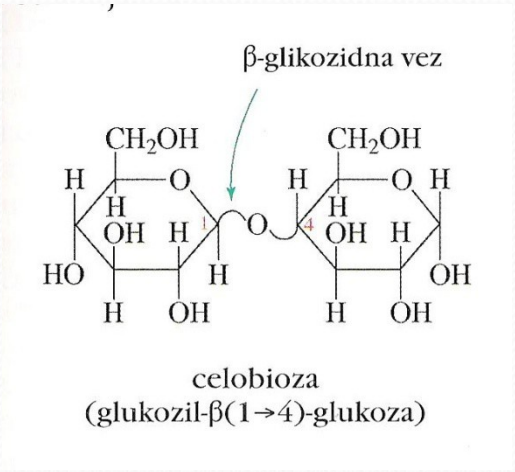


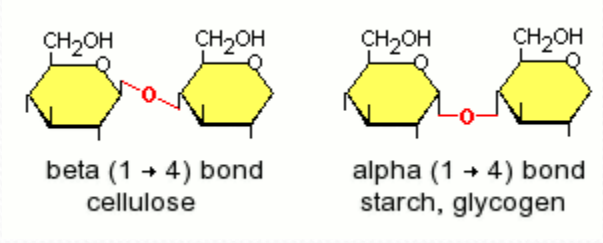
Nastanek glikozidov

- kondenzacija: nastanejo glikozidi z *O*-glikozidno vezjo
- disaharidi, oligosaharidi in polisaharidi

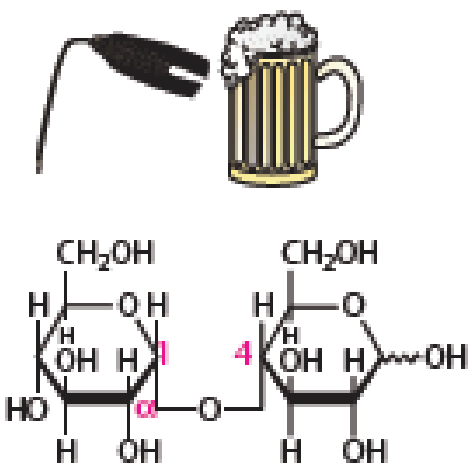






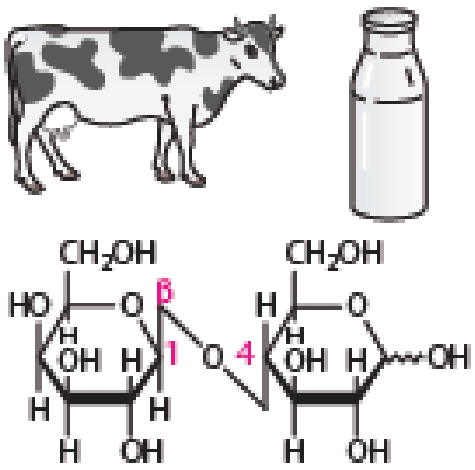


Disaharidi



1. Maltose
α-D-Glucopyranosyl-
(1→4)-D-glucopyranose

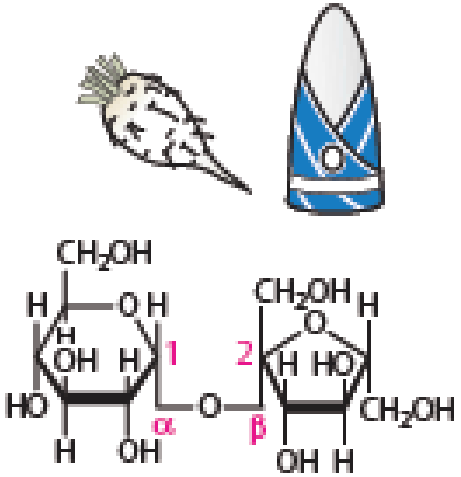
maltoza
2 D-glukozi, vez α(1→4)



2. Lactose
β-D-Galactopyranosyl-
(1→4)-D-glucopyranose

laktoza
galaktoza + glukoza, vez β(1→4)

mlečni sladkor

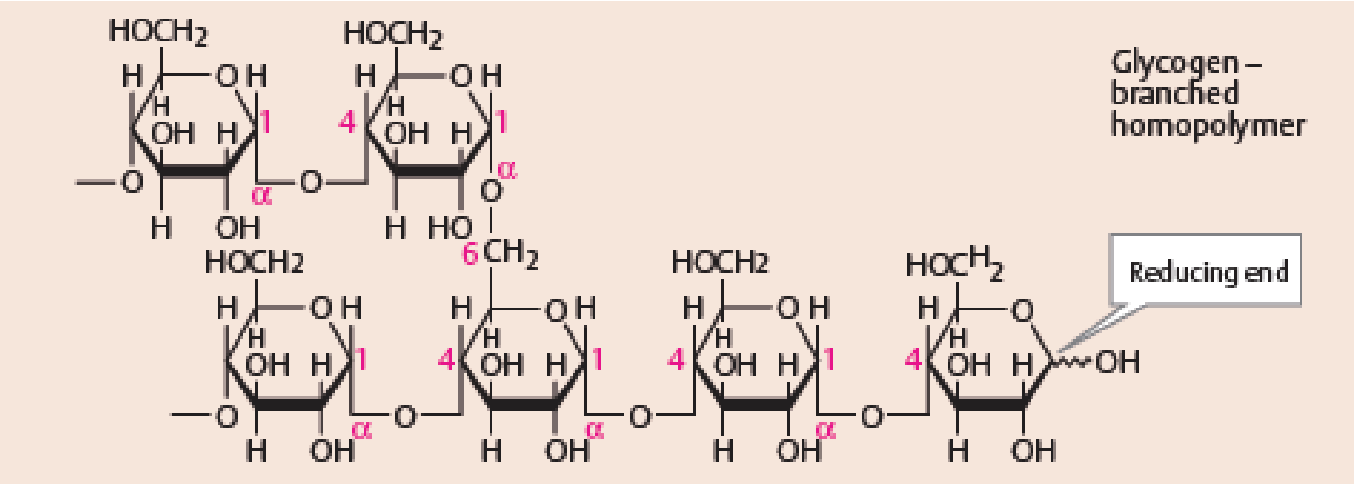


3. Sucrose
α-D-Glucopyranosyl-
(1↔2)-β-D-fructofuranoside

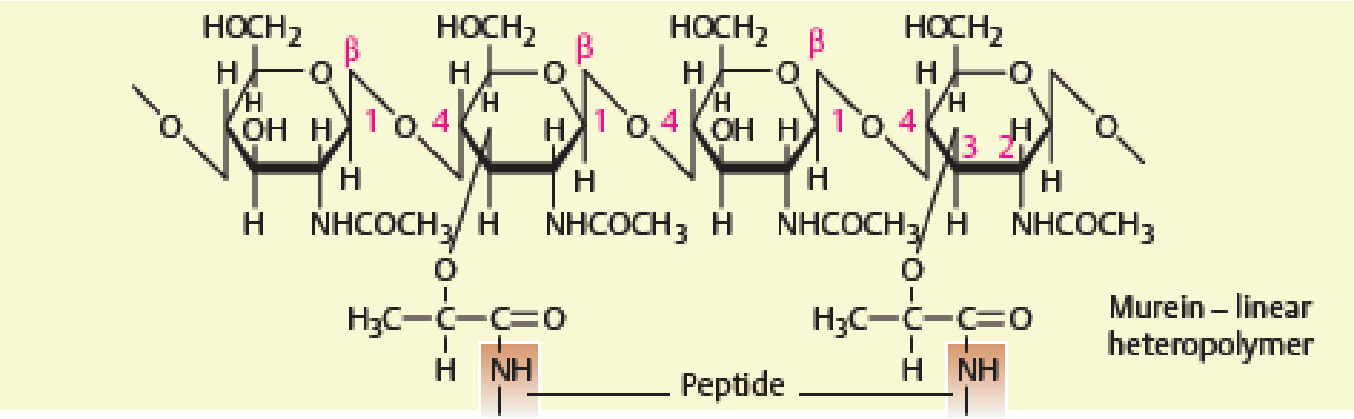
saharoza
glukoza + fruktoza, vez α,β(1→2)

namizni sladkor

Polisaharidi



glikogen,
rezervni polisaharid v živalih



murein,
v celičnih stenah bakterij

polisaharid	mono-saharid 1	mono-saharid 2	vez	razve-janje	nahajanje	vloga
Bacteria						
Murein	D-GlcNAc	D-MurNAc[1)]	β1→4	—	celična stena	SC
Dextran	D-Glc	—	α1→6	α1→3	sluz	WB
Plants						
Agarose	D-Gal	L-aGal[2)]	β1→4	β1→3	rdeče alge (agar)	WB
Carrageenan	D-Gal	—	β1→3	α1→4	rdeče alge	WB
Cellulose	D-Glc	—	β1→4	—	celična stena	SC
Xyloglucan	D-Glc	D-Xyl (D-Gal, L-Fuc)	β1→4	β1→6 (β1→2)	celična stena hemiceluloza	SC SC
Arabinan	L-Ara	—	α1→5	α1→3	celična stena (pektin)	
Amylose	D-Glc	—	α1→4	—	amiloplasti	RC
Amylopectin	D-Glc	—	α1→4	α1→6	amiloplasti	RC
Inulin	D-Fru		β2→1	—	skladiščne celice	RC
Animals						
Chitin	D-GlcNAc	—	β1→4	—	Insects, crabs	SK
Glycogen	D-Glc	—	α1→4	α1→6	Liver, muscle	RK
Hyaluronic acid	D-GlcUA	D-GlcNAc	β1→4 β1→3	—	Connective tissue	SK,WB

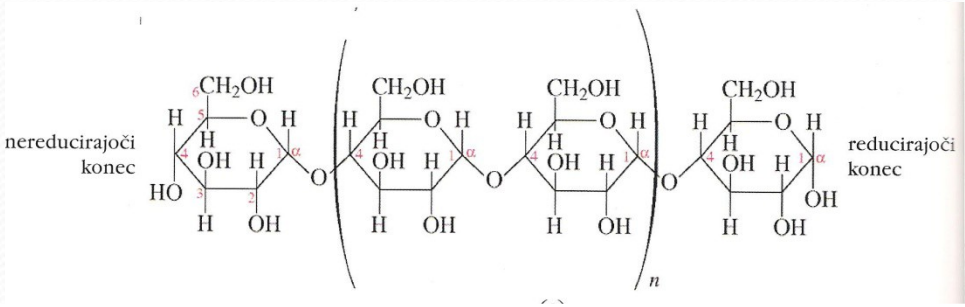
SC– strukturni ogljikov hidrat , RC– rezervni ogljikov hidrat

WB– ogljikov hidrat, ki veže vodo

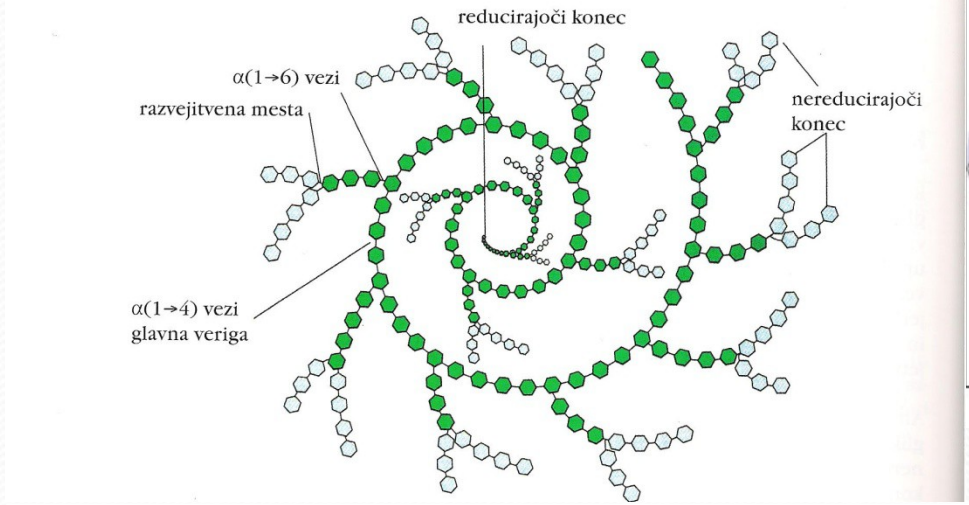
[1)] *N*-acetylmuramic acid, [2)] 3,6-anhydrogalactose

Rezervni polisaharidi: škrob

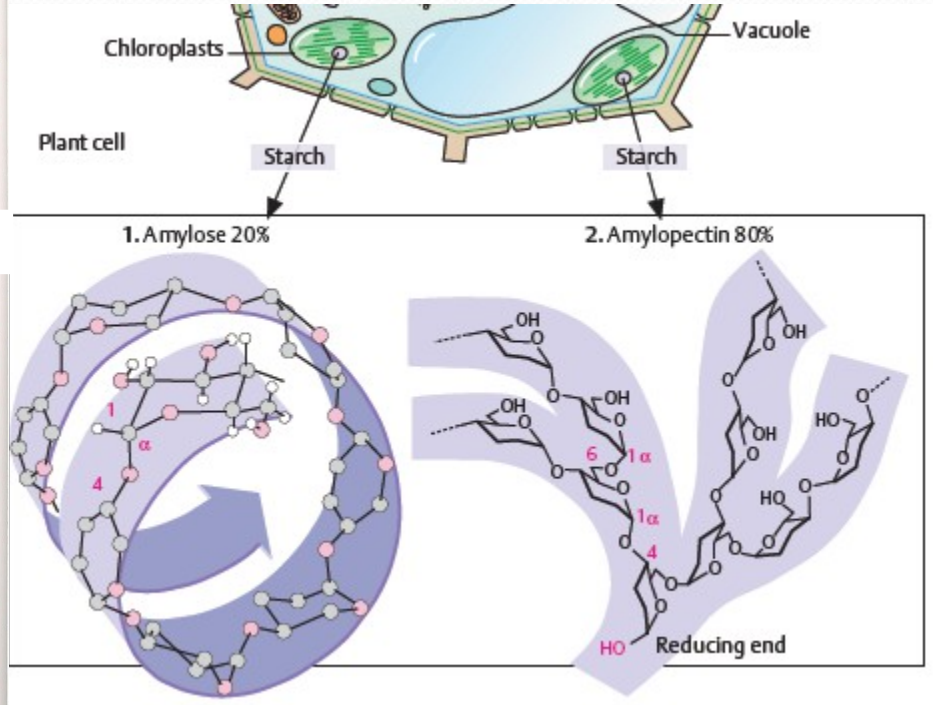
v rastlinah



amiloza (20 %): nerazvejan polimer glukoze, α(1→4) vezi

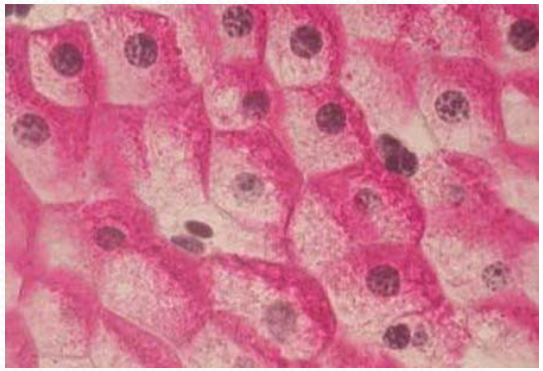


amilopektin (80 %): razvejan polimer glukoze, v glavni verigi α(1→4) vezi, razvejanja z α(1→6) vezmi na pribl. vsakih 25 glukoz

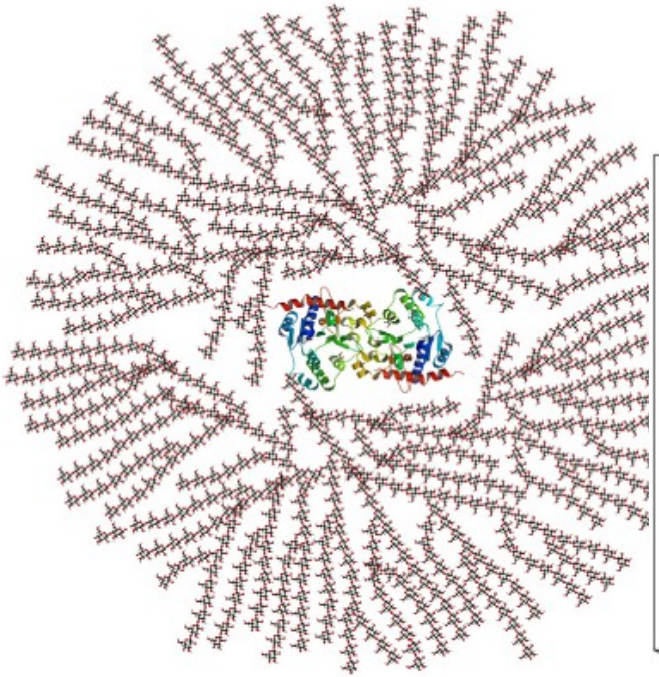


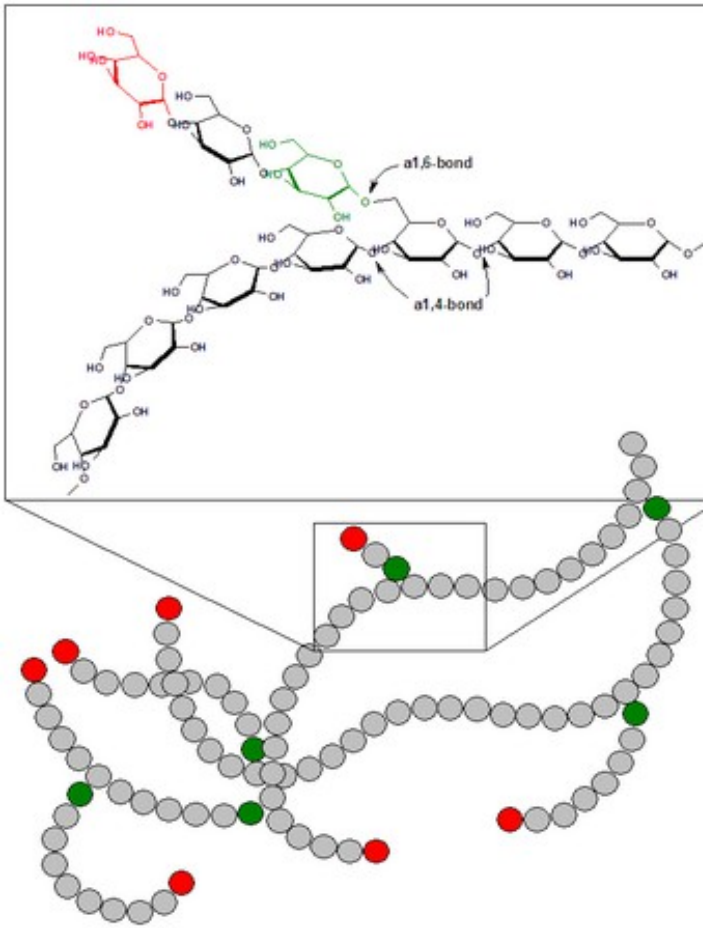
Rezervni polisaharidi: glikogen

v živalih



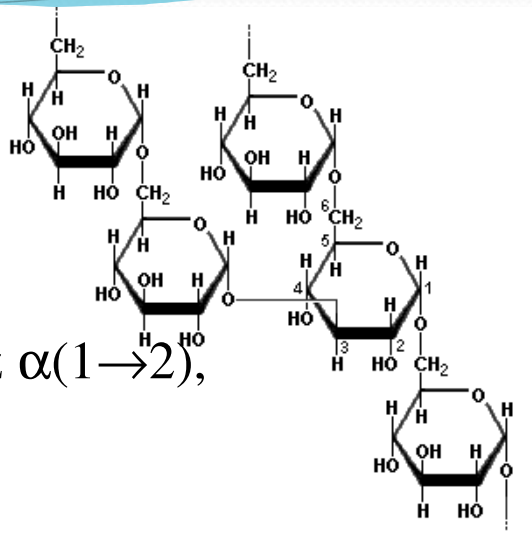
glikogen (rjav) v celicah ledvic





struktura podobna amilopektinu (v glavni verigi $\alpha(1\rightarrow4)$ vezi, razvejanja z $\alpha(1\rightarrow6)$ vezmi), le da ima več razvejanih mest (na pribl. 10 glukoz se razveja)

Rezervni polisaharidi



- dekstran (kvasovke, bakterije)

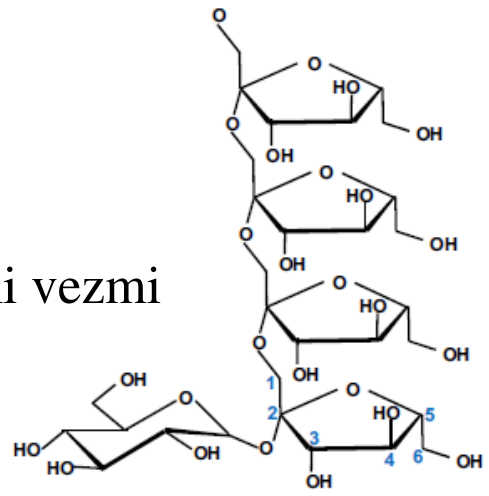
glukozni ostanki, povezani z α(1→6) vezmi in razvejitve z α(1→2), α(1→3) in α(1→4) glikozidnimi vezmi

- fruktan (v zelenjavi): inulin, levan, graminan

drugi najbolj razširjen polisaharid, ki se enostavno presnavlja; β-D-fruktofuranoza

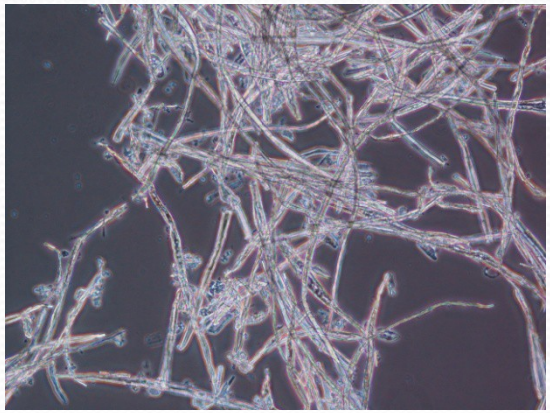
  - inulin (v več kot 36.000 rastlinah, največ v Jeruzalemski artičoki, cikoriji, česnu)

homopolimer D-fruktoze, povezane z β(2→1) glikozidnimi vezmi

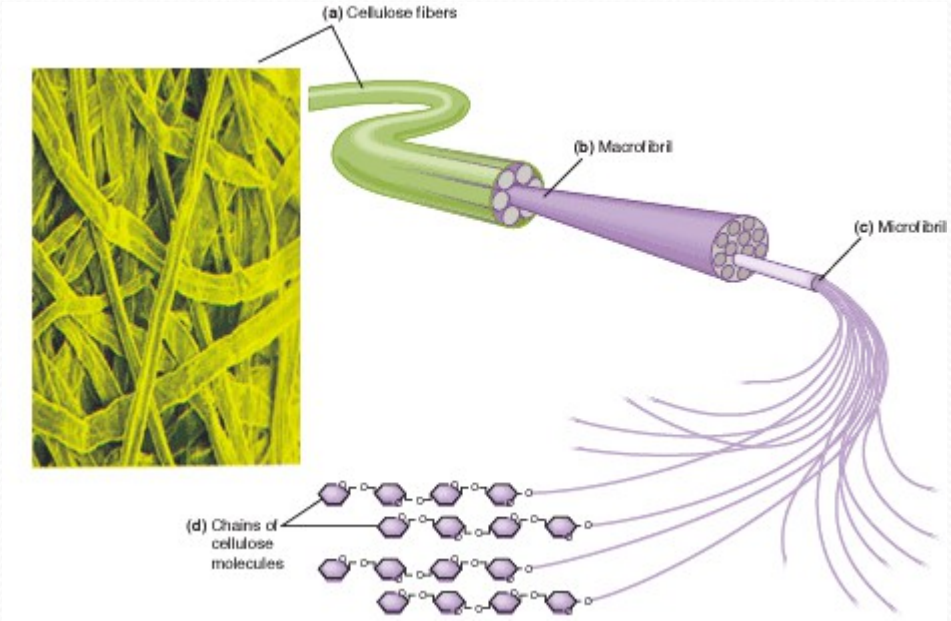


Strukturni polisaharidi

- celuloza, hitin, mukopolisaharidi
- deloma se sintetizirajo v notranjosti celic, a se dokončno sestavijo zunaj celice
  - gradijo trdno zaščitno celično steno
  - oblikujejo želatinozno zaščitno prevleko

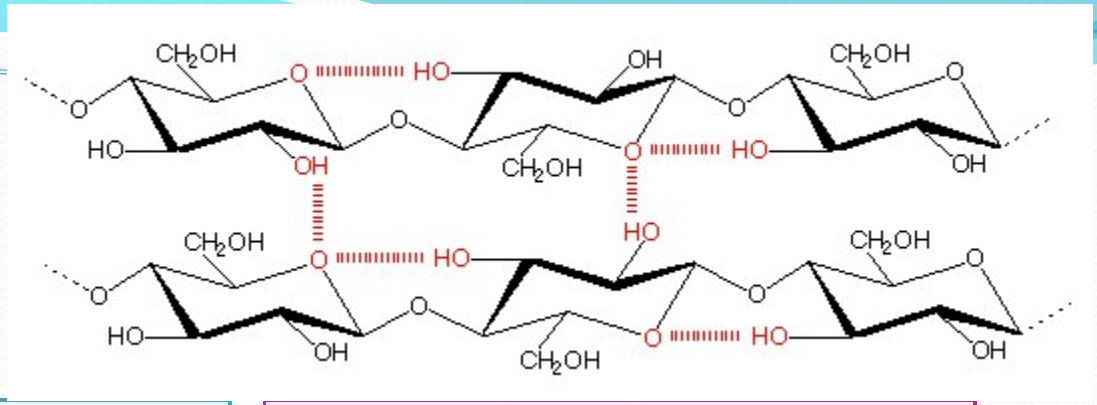


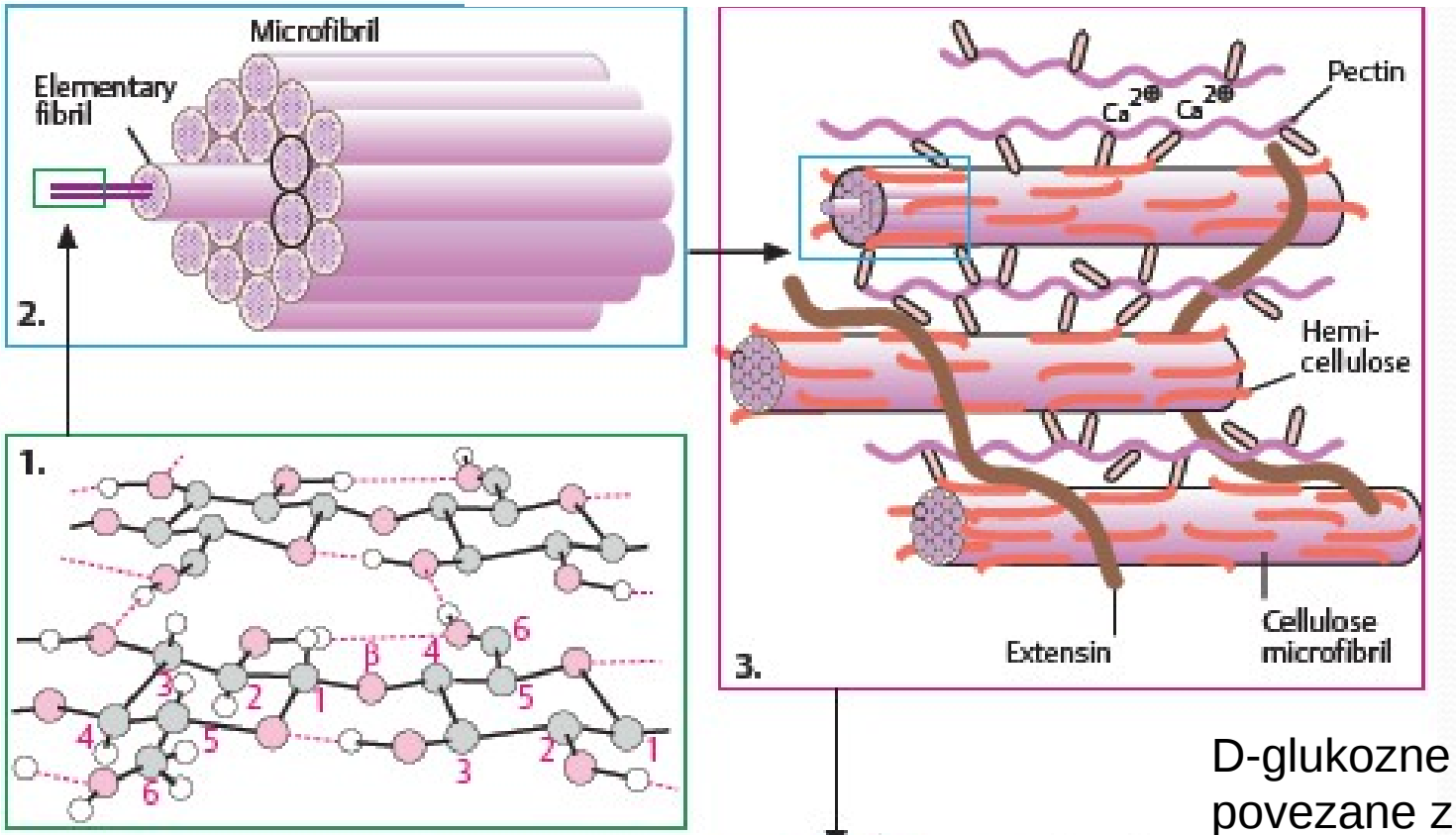
celuloza



Celuloza

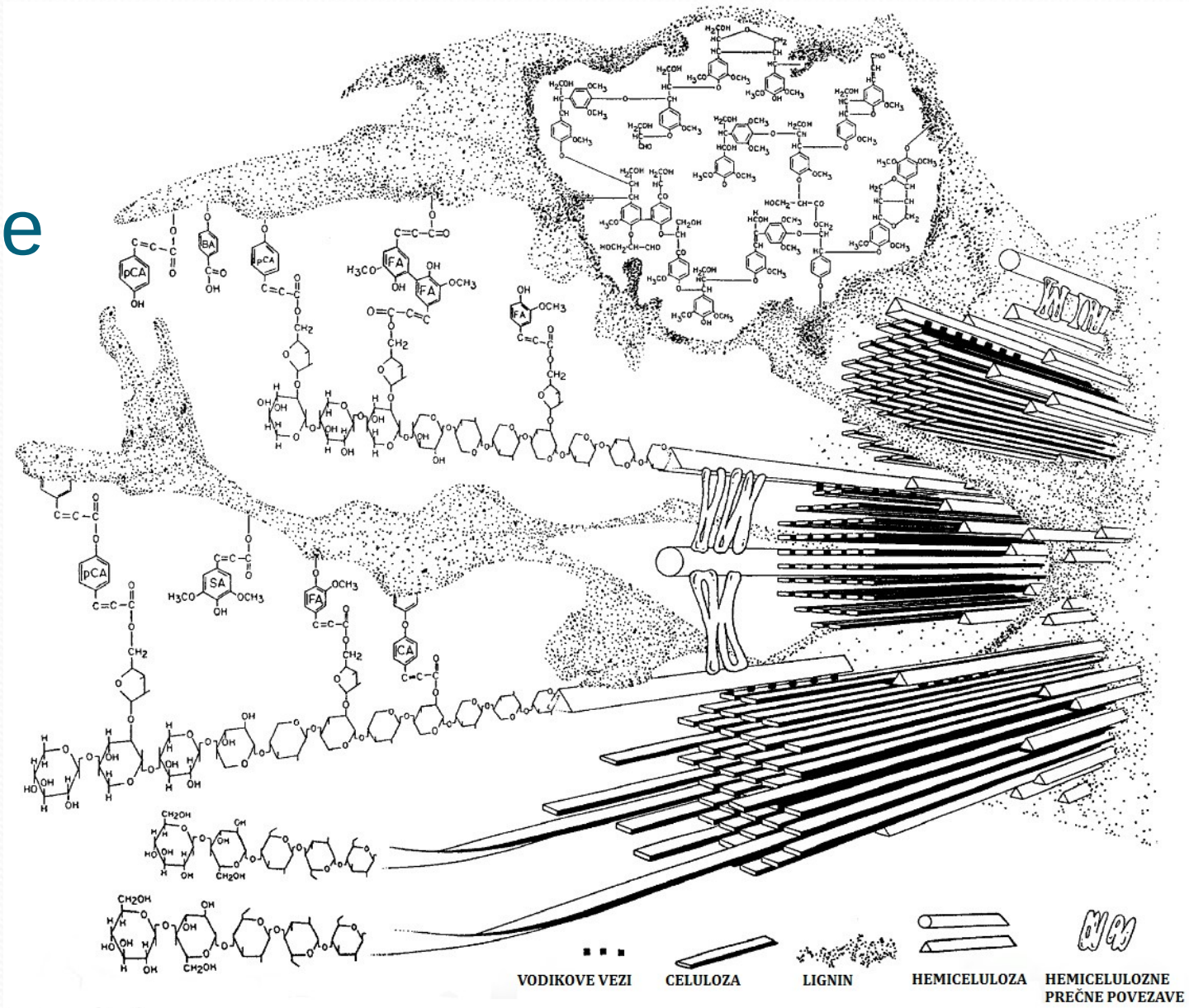
Povprečno 10.000 – 15.000 glukoznih ostankov





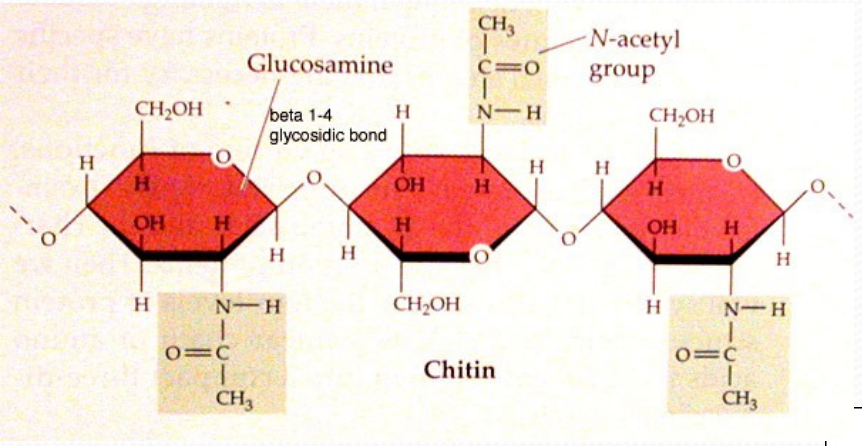
D-glukozne enote, povezane z β (1→4) glikozidnimi vezmi

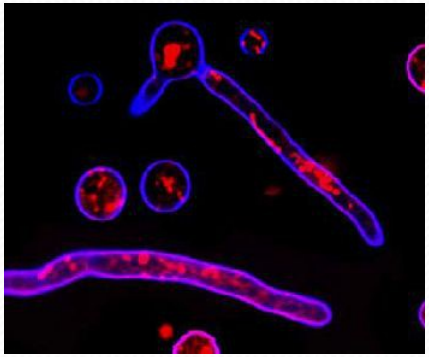
Shema sekundarne celične stene trav



Hitin

N-acetilglukozamin, povezan z β(1→4) vezjo



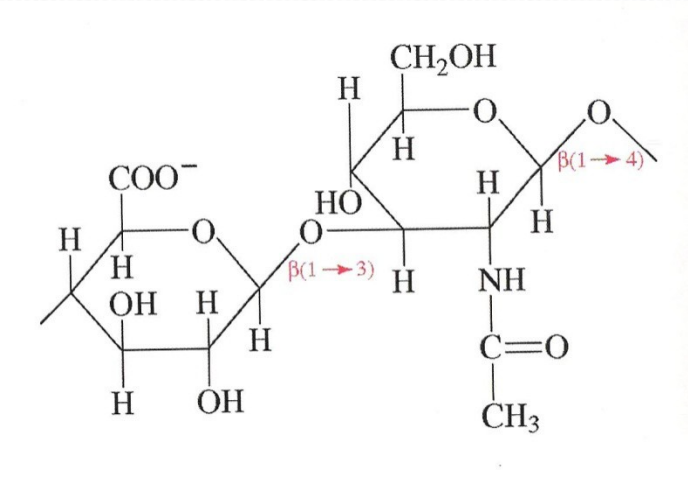


v celičnih stenah kvasov, gliv in alg
(modro – v steni glive *Trichoderma reesei*)

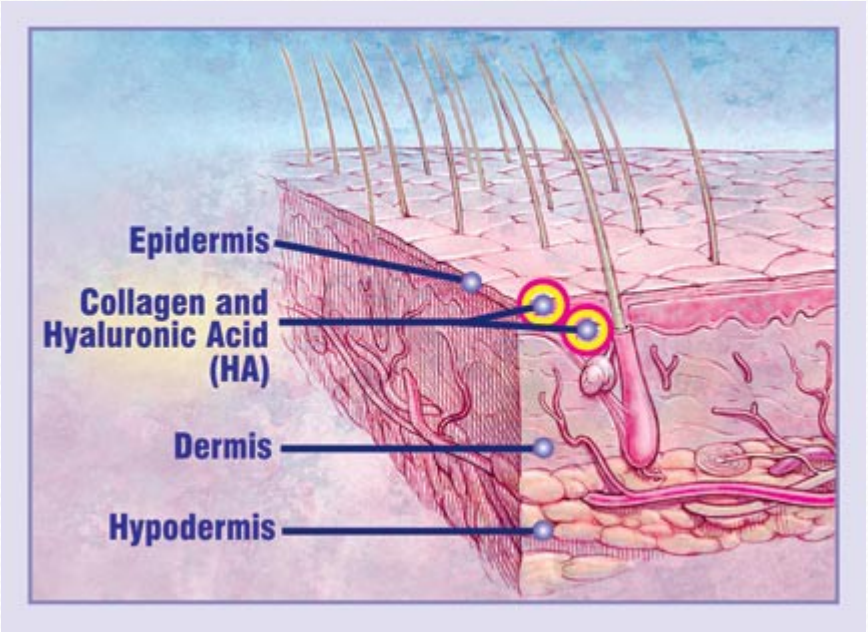
zaščitni oklep členonožcev (žuželk, rakov, pajkovcev)

Mukopolisaharidi

- v vezivnem tkivu (hrustanec in kite) in zunajceličnem matriksu višje razvitih živali
  - hialuronska kislina



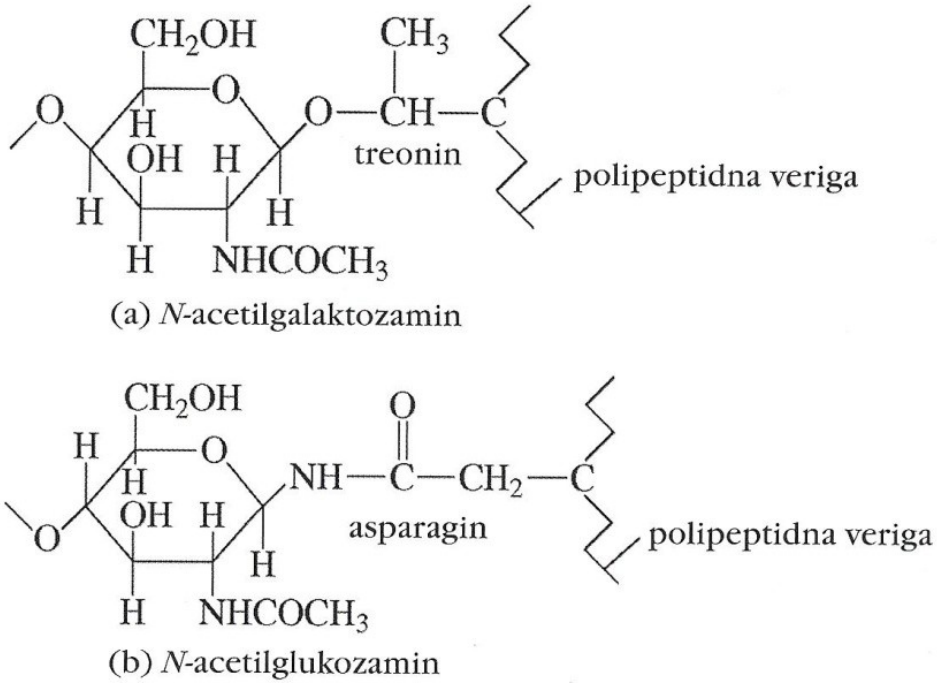
N-acetilglukozamin in D-glukuronska kislina, povezana z β(1→3) in β(1→4) vezjo



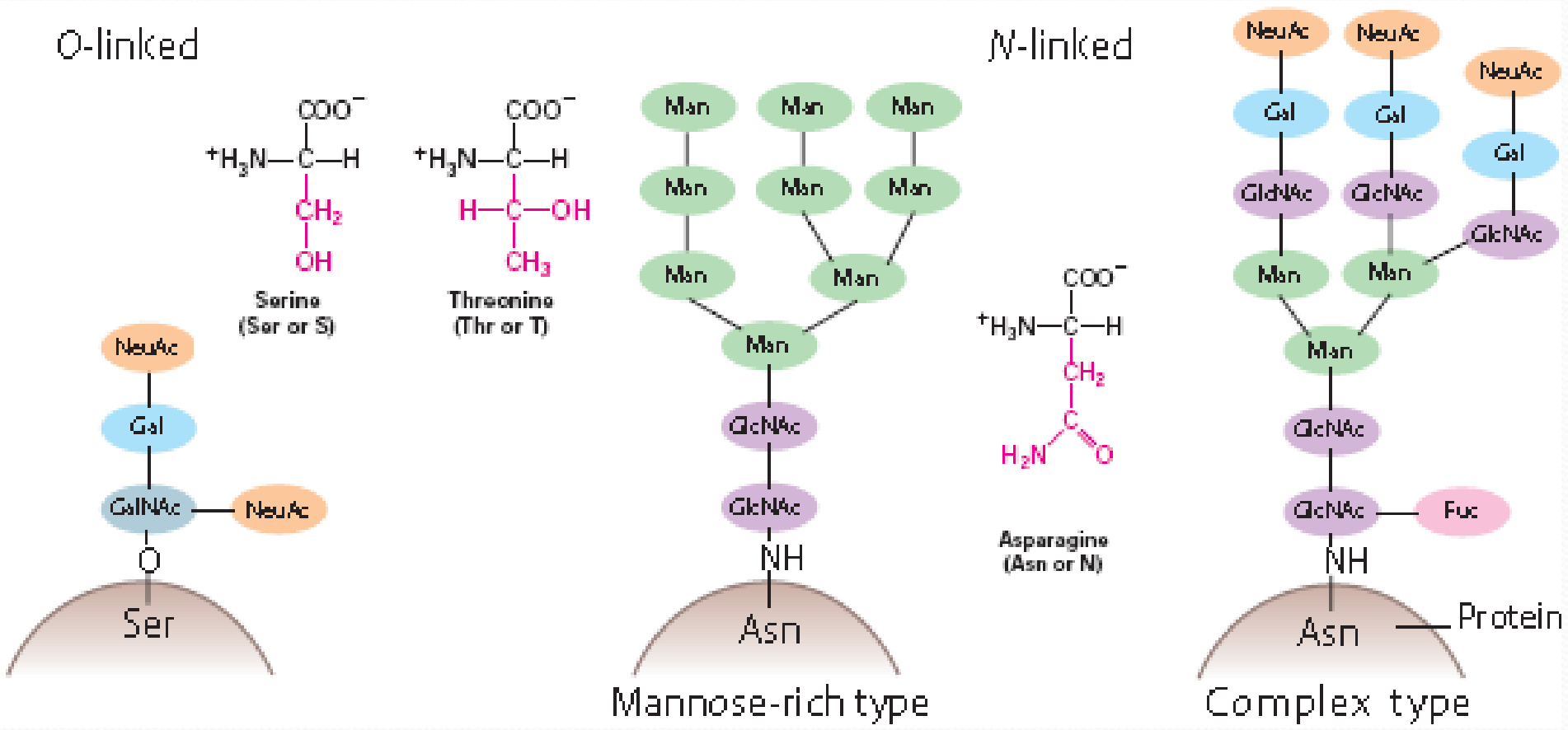
v matriksu vezivnega tkiva človeške kože

Glikoproteini

- ogljikov hidrat kovalentno vezan na protein
- običajno vsebujejo 1-30 % ogljikovih hidratov, nekateri tudi do 60 %
- 2 vrsti vezi:
  - *O*-glikozidna vez med –OH na anomernem C in –OH na Ser ali Thr
  - *N*-glikozidna vez med –OH na anomernem C in amidnim N na Asn

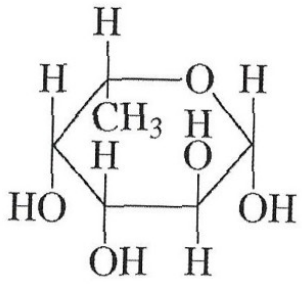


Vrste glikoproteinov

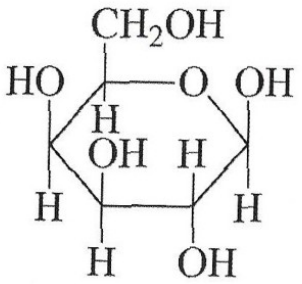


Glikoproteini

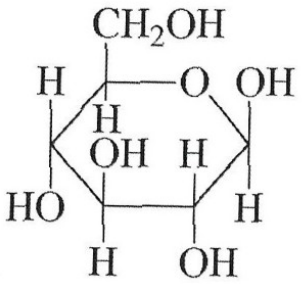
najpogostejši monomeri, ki sestavljajo oligosaharide v glikoproteinih



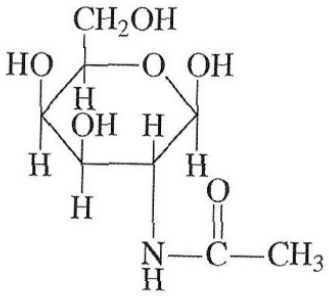
β-L-fukoza



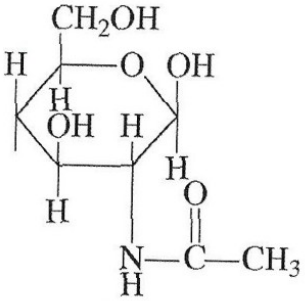
β-D-galaktoza



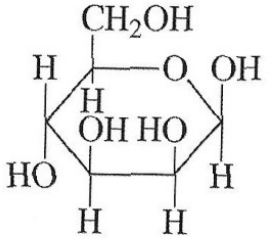
β-D-glukoza



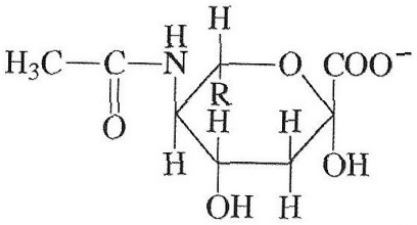
β-D-*N*-acetilgalaktozamin



β-D-*N*-acetilglukozamin



β-D-manoza



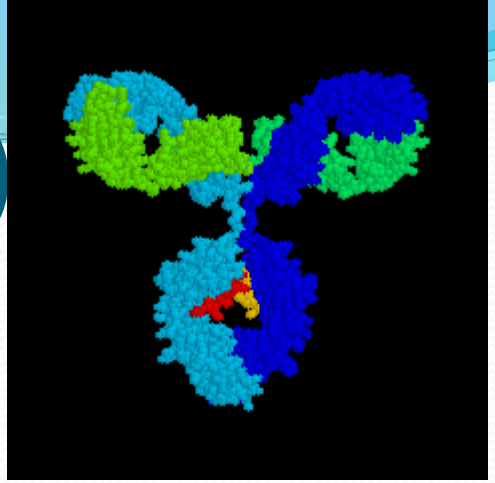
sialna kislina
(*N*-acetilnevraminat)

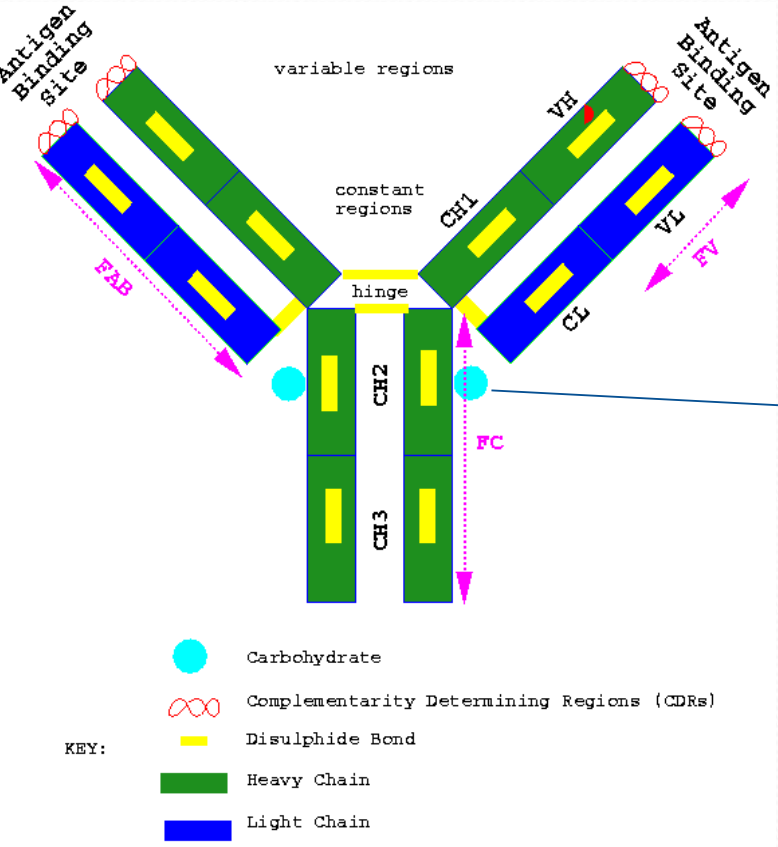
Glikoproteini

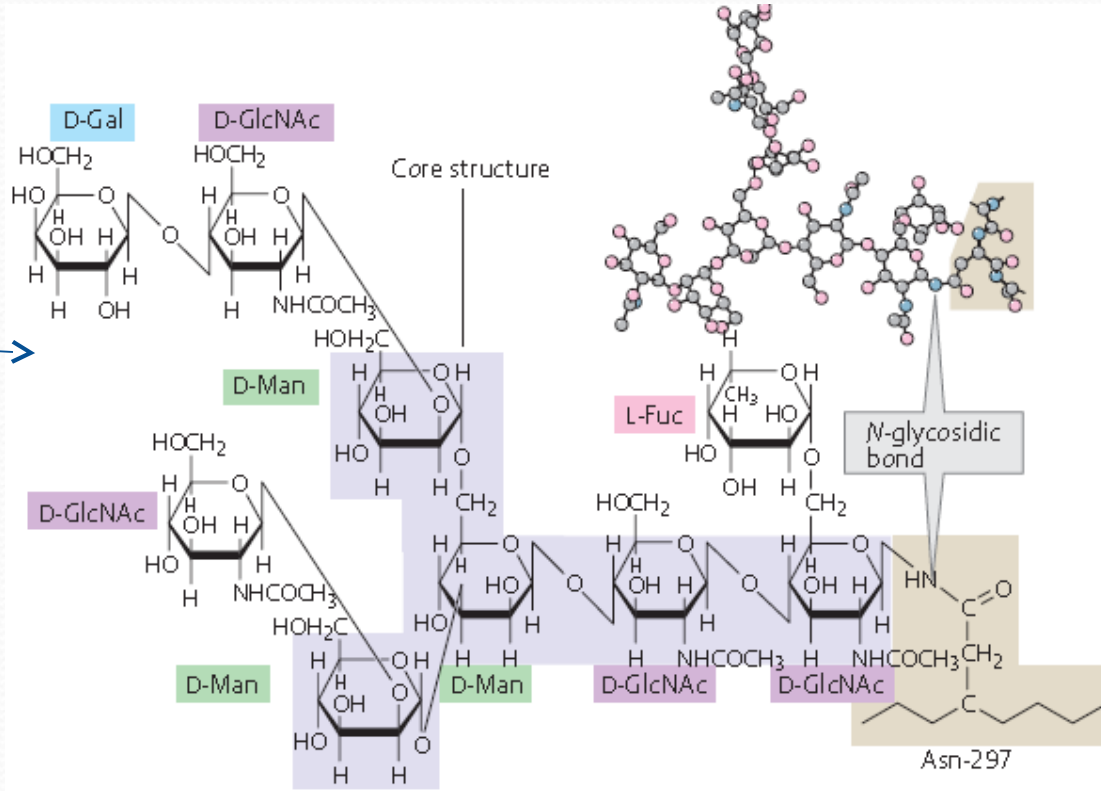
- fiziološko pomembne molekule, sodelujejo tudi pri delovanju imunskega sistema
- oligosaharidi, pripeti na proteine, pomembni pri medsebojnem prepoznavanju celic in molekul
- na površinah celic kot markerji za identifikacijo specifičnih vrst celic
- krvne skupine (A, B, O): različna zgradba oligosaharidov na membrani eritrocitov
- maligne celice: spremembe glikoproteinov na površini
- označevanje staranja proteinov
- mnogi virusi imajo na površini proteine, na katere se lahko vežejo oligosaharidi

Imunoglobulin G (IgG)

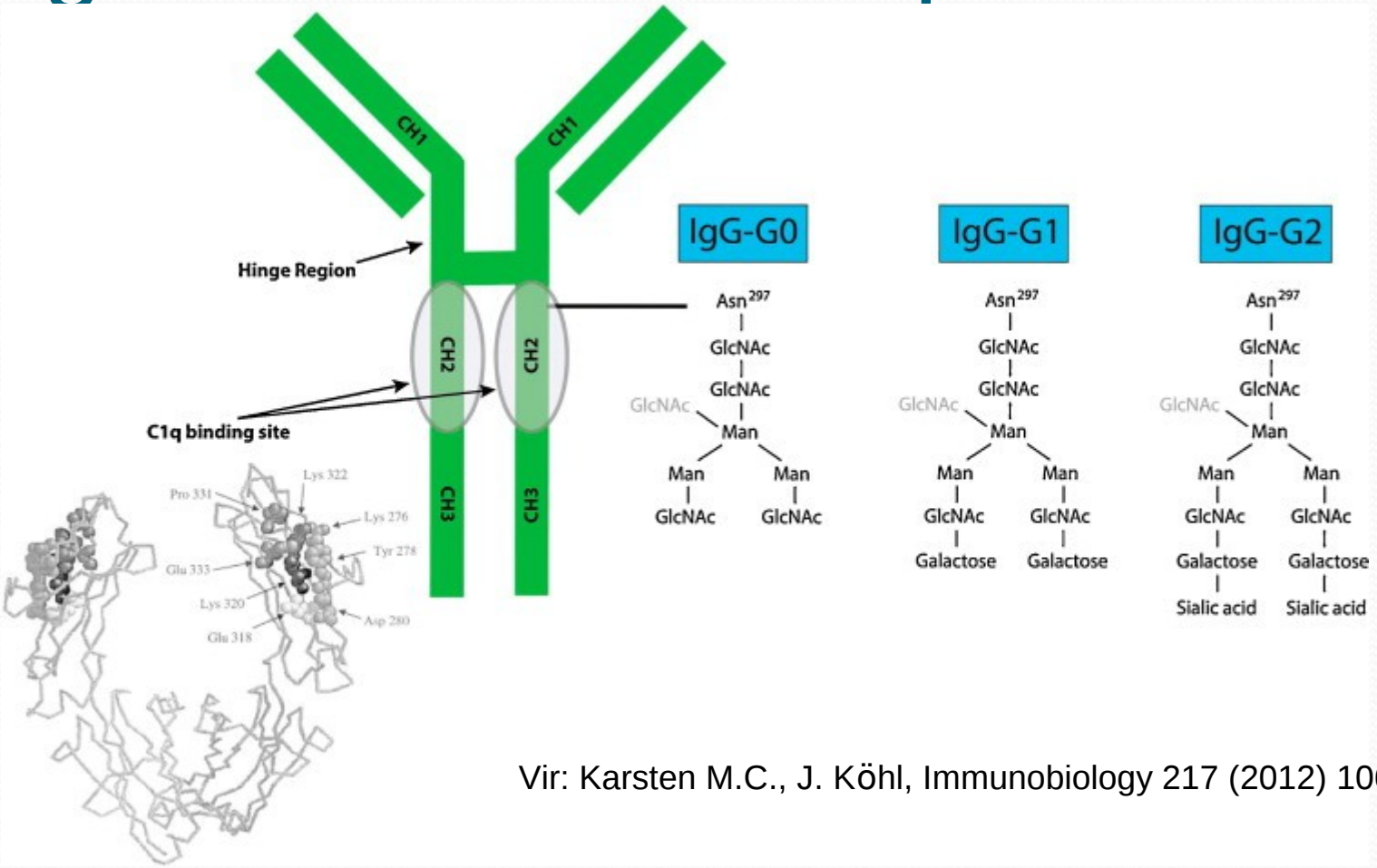
- http://www.path.cam.ac.uk/~mrc7/movies/igroty.gif







N-glikanska sestava protiteles IgG



Vir: Karsten M.C., J. Köhl, Immunobiology 217 (2012) 1067–1079

A biantennary oligosaccharide core is attached to Asn297 within the IgG CH2 domain comprising two N-acetyl-glucosamine (GlcNAc) residues and three mannose residues, two of which are linked to two terminal GlcNAc residues (IgG-G0). In addition to this core structure, IgG antibodies may contain additional galactose (IgG-G1) or galactose and sialic acid residues (IgG-G2). C1q binding site is highlighted; the detailed structure is based on crystallography works by Deisenhofer (1981) and Thommesen et al. (2000).

Glikolipidi

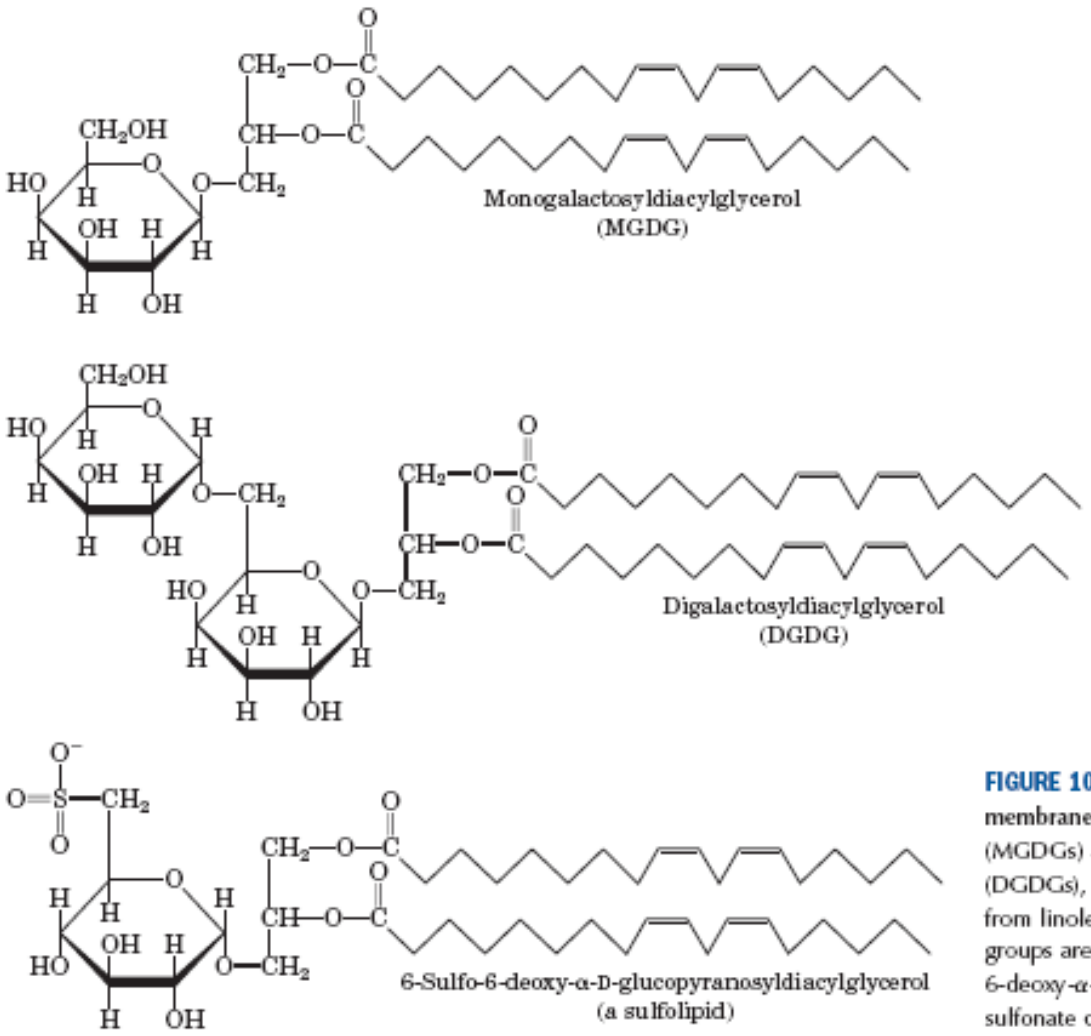
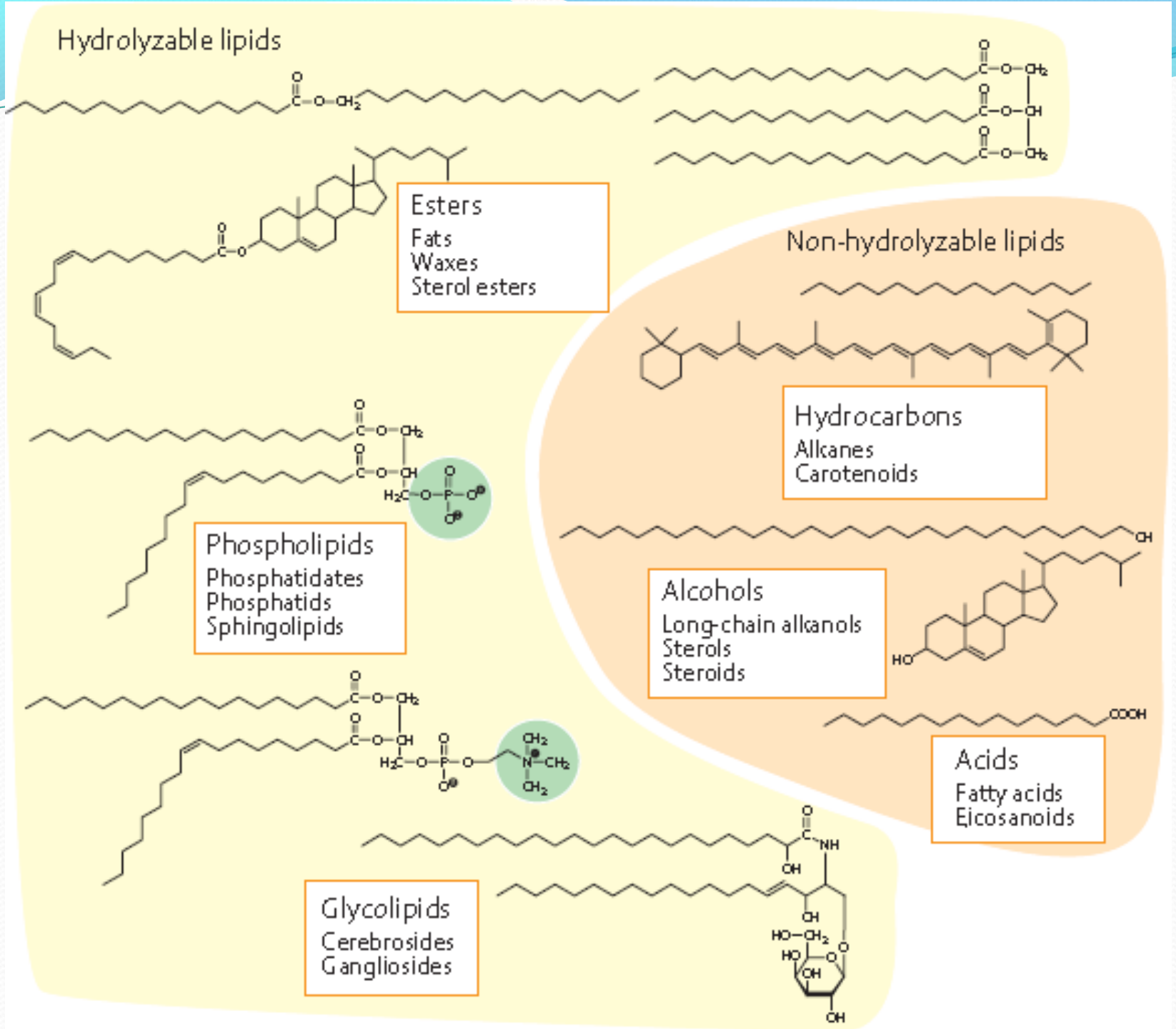


FIGURE 10–10 Three glycolipids of chloroplast membranes. In monogalactosyldiacylglycerols (MGDGs) and digalactosyldiacylglycerols (DGDGs), almost all the acyl groups are derived from linoleic acid ($18:2(\Delta^{9,12})$) and the head groups are uncharged. In the sulfolipid 6-sulfo-6-deoxy-α-D-glucopyranosyldiacylglycerol, the sulfonate carries a fixed negative charge.

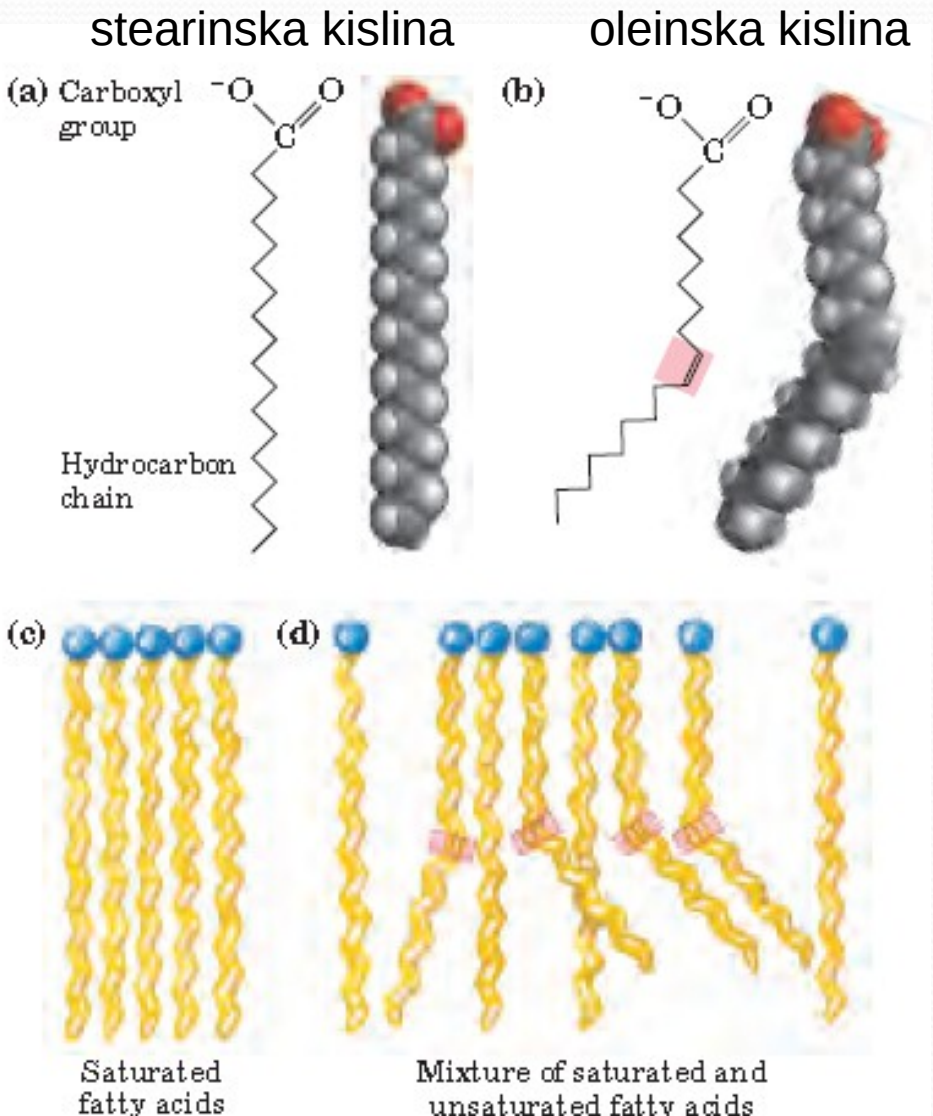
Lipidi

- zaradi svoje hidrofobne narave bolj topni v nepolarnih topilih kot v vodi – povezuje jih topnost in ne kemijska zgradba
- metabolično gorivo v celicah
- shranjevanje energije v obliki maščob in olj
- strukturni lipidi: fosfolipidi in steroli v bioloških membranah
- vloga kot signali, kofaktorji encimov, prenašalci elektronov, hormoni, šaperoni (zvitje proteinov) in pigmenti


Hydrolyzable lipids
Esters
Fats
Waxes
Sterol esters
Phospholipids
Phosphatidates
Phosphatids
Sphingolipids
Glycolipids
Cerebrosides
Gangliosides
Non-hydrolyzable lipids
Hydrocarbons
Alkanes
Carotenoids
Alcohols
Long-chain alkanols
Sterols
Steroids
Acids
Fatty acids
Eicosanoids

Maščobne kisline

- vsebujejo polarno karboksilno skupino (–COOH), vezano na nerazvejano alifatsko verigo
- amfifilne spojine: polarna glava + nepolaren rep
- 4 do 36 C atomov, večina med 12 in 24
- večina ima sodo število C atomov
- večina vezi je C-C, le 1, 2 ali več dvojnih vezi med C atomi
- mononenasičene maščobne kisline dvojna vez običajno med C 9 in 10



Carbon skeleton	Structure*	Systematic name†	Common name (derivation)	Melting point (°C)	Solubility at 30 °C (mg/g solvent)	
					Water	Benzene
12:0	$CH_3(CH_2)_{10}COOH$	*n*-Dodecanoic acid	Lauric acid (Latin *laurus*, "laurel plant")	44.2	0.063	2,600
14:0	$CH_3(CH_2)_{12}COOH$	*n*-Tetradecanoic acid	Myristic acid (Latin *Myristica*, nutmeg genus)	53.9	0.024	874
16:0	$CH_3(CH_2)_{14}COOH$	*n*-Hexadecanoic acid	Palmitic acid (Latin *palma*, "palm tree")	63.1	0.0083	348
18:0	$CH_3(CH_2)_{16}COOH$	*n*-Octadecanoic acid	Stearic acid (Greek *stear*, "hard fat")	69.6	0.0034	124
20:0	$CH_3(CH_2)_{18}COOH$	*n*-Eicosanoic acid	Arachidic acid (Latin *Arachis*, legume genus)	76.5		
24:0	$CH_3(CH_2)_{22}COOH$	*n*-Tetracosanoic acid	Lignoceric acid (Latin *lignum*, "wood" + *cera*, "wax")	86.0		
16:1(Δ^9)	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	*cis*-9-Hexadecenoic acid	Palmitoleic acid	1–0.5		
18:1(Δ^9)	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	*cis*-9-Octadecenoic acid	Oleic acid (Latin *oleum*, "oil")	13.4		
18:2($\Delta^{9,12}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-9,12-Octadecadienoic acid	Linoleic acid (Greek *linon*, "flax")	1–5		
18:3($\Delta^{9,12,15}$)	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-,*cis*-9,12,15-Octadecatrienoic acid	α-Linolenic acid	−11		
20:4($\Delta^{5,8,11,14}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_3COOH$	*cis*-,*cis*-,*cis*-,*cis*-5,8,11,14-Icosatetraenoic acid	Arachidonic acid	−49.5		

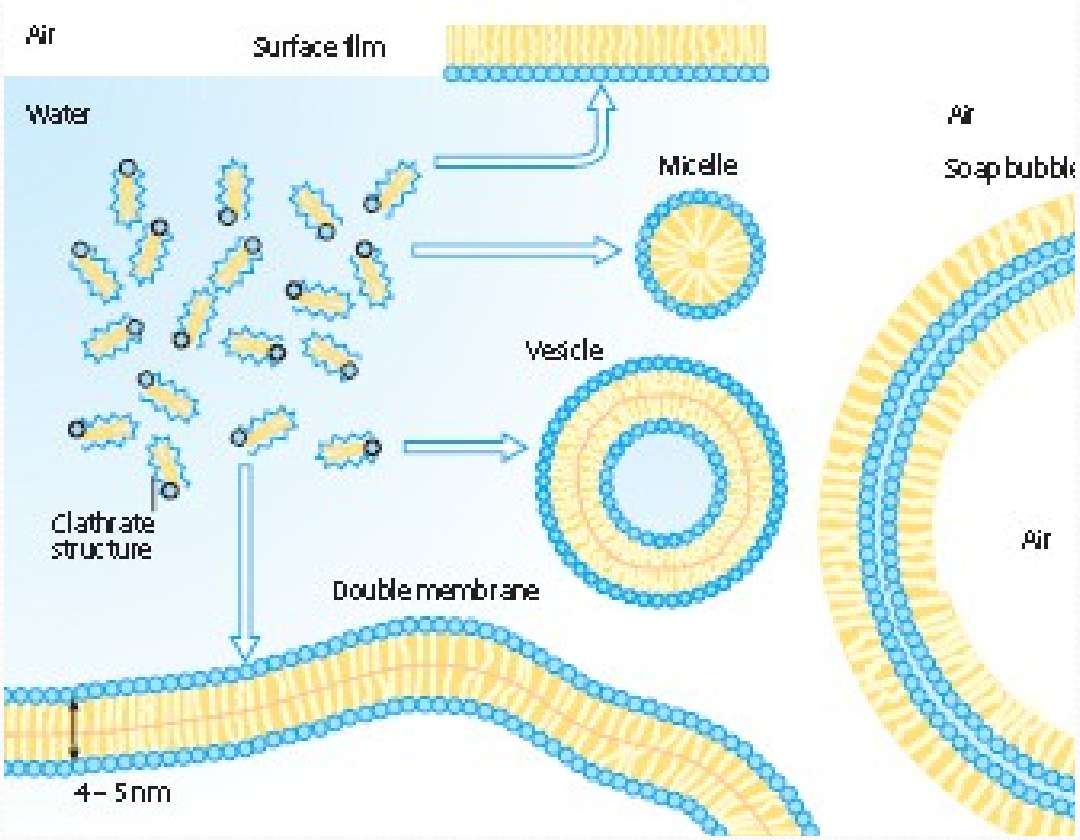
Mila

- Na in K soli maščobnih kislin so mila:

$$CH_3(CH_2)_{10}COOH + NaOH \rightarrow CH_3(CH_2)_{10}COO^-Na^+ + H_2O$$

lavrinska kislina

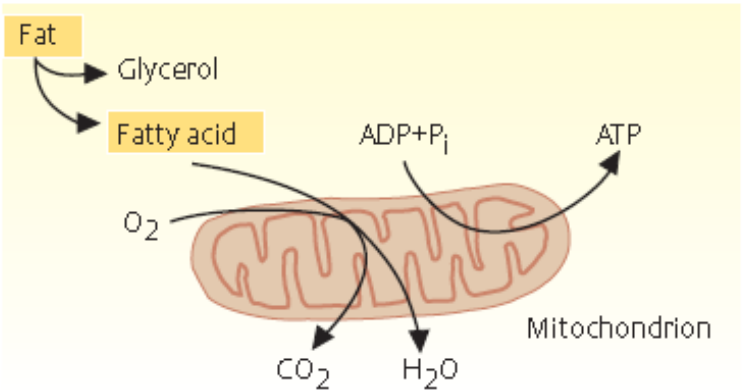
natrijev lavrat (milo)



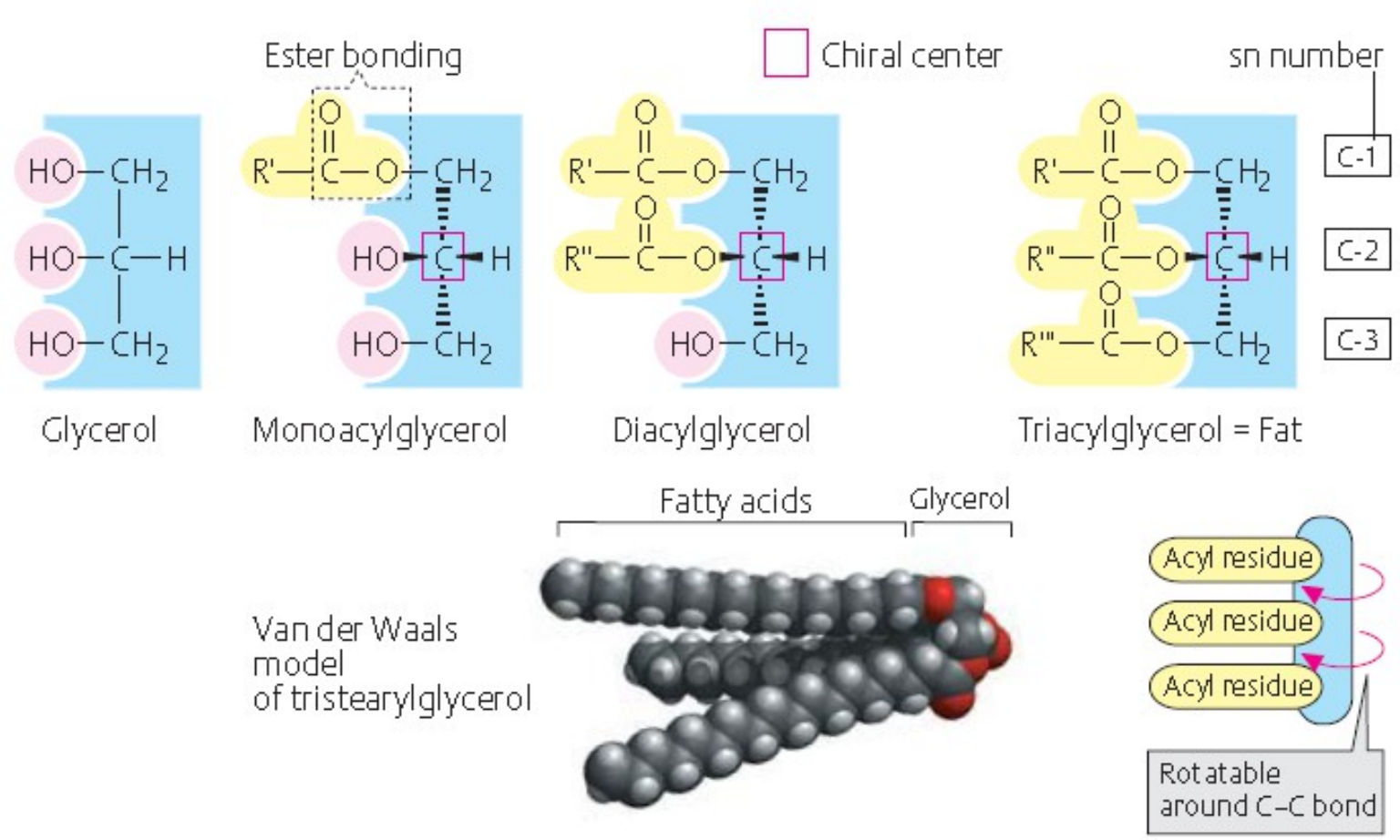
mila se topijo v vodi, a ne nastanejo prave raztopine – tvorba micel

Triacilgliceroli

- estri 3 maščobnih kislin in glicerola
- nepolarni lipidi
- shranjevanje energije
- živali: maščobe (tudi izolacija), rastline: olja
- vežejo se na serumske albumine v krvi in krožijo po organizmu
- v mišicah se oksidirajo do CO_2 in H_2O in pri tem sproščajo veliko energije

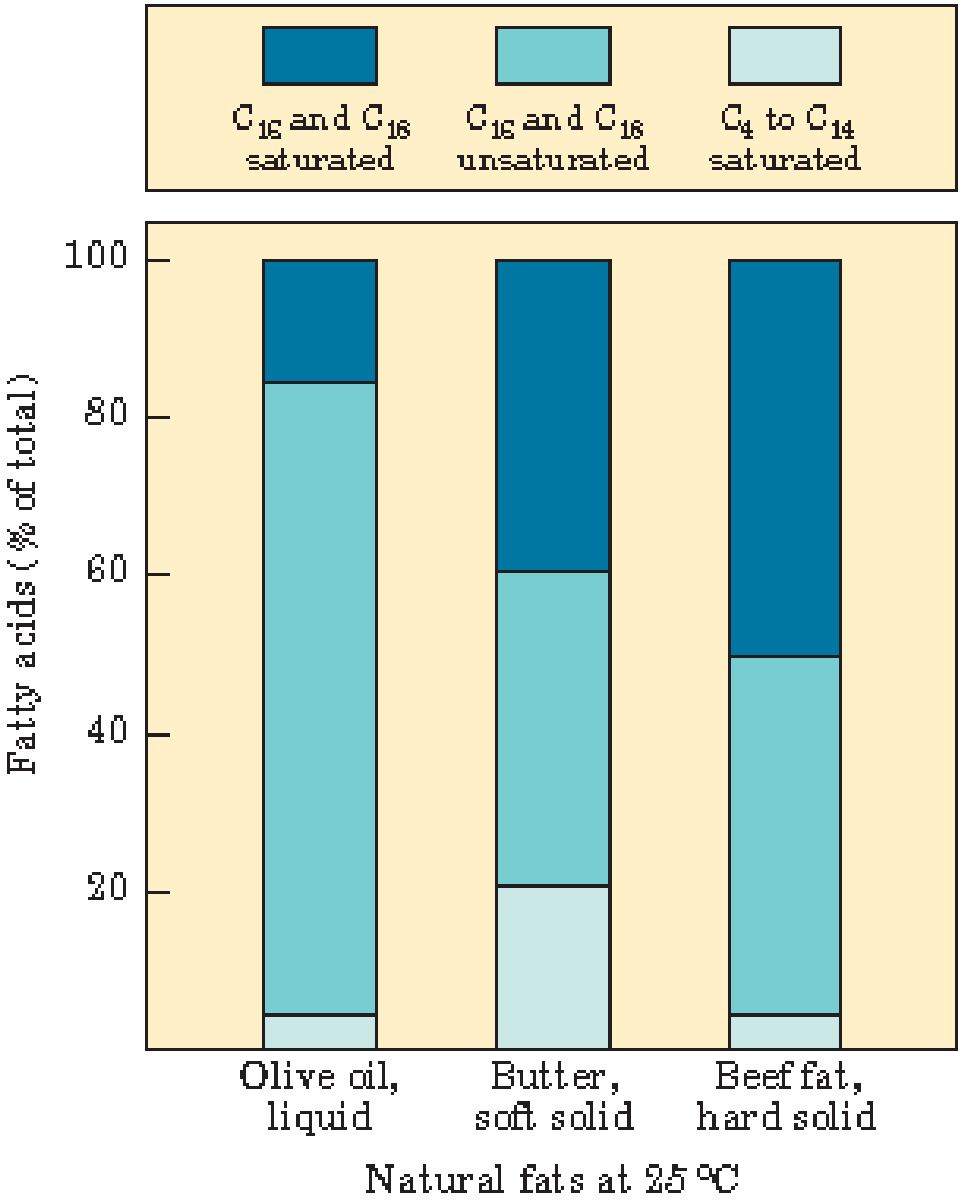


Struktura triacilglicerolov



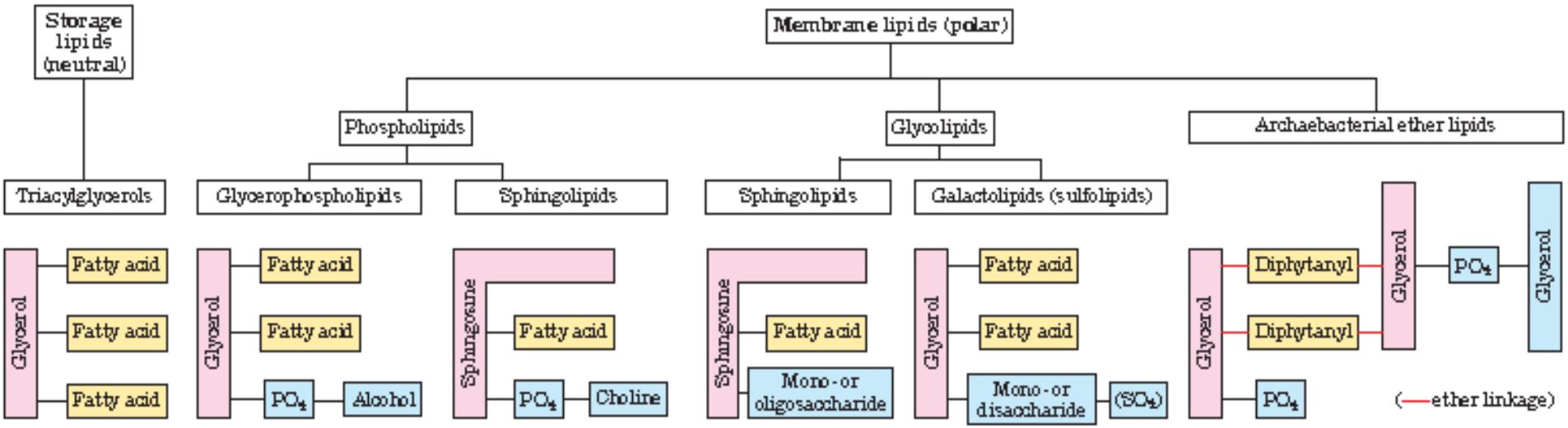
Lastnosti maščob

oksidacija nenasičenih maščobnih kislin: žarkost

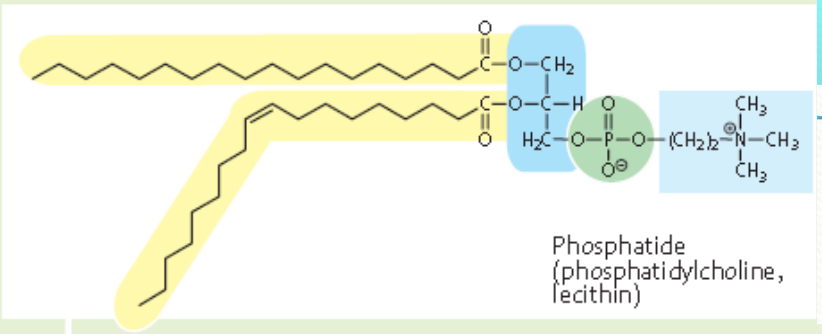


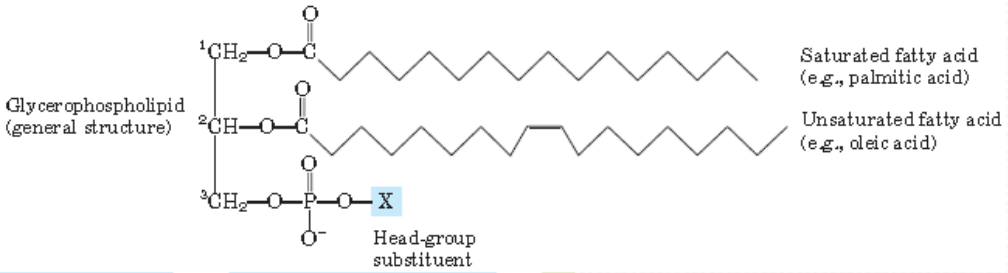
Polarni lipidi

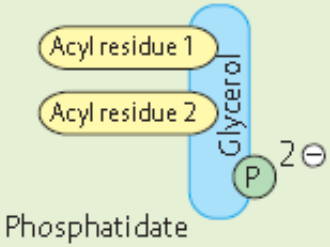
- gradniki bioloških membran – zaščitna plast celic
- amfifilni (polarna glava, nepolaren rep)
- 2 skupini:
  - glicerofosfolipidi (fosfogliceridi): fosfatidna kislina
  - sfingolipidi: sfingozin

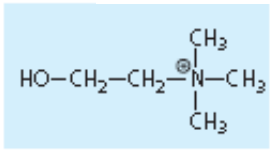


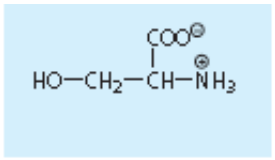
Fosfolipidi

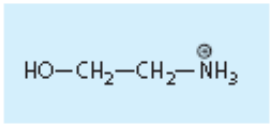


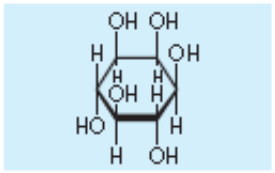


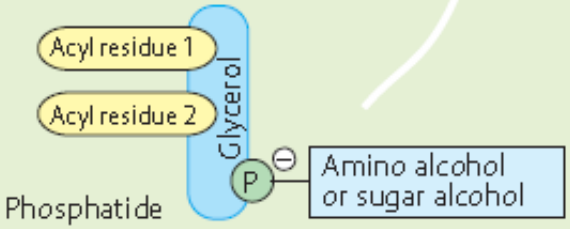


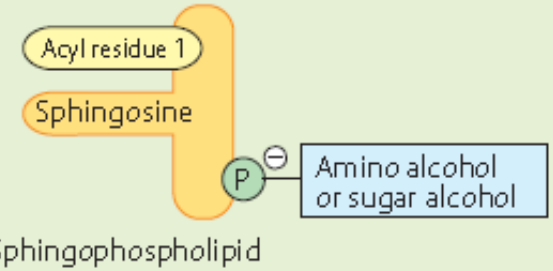


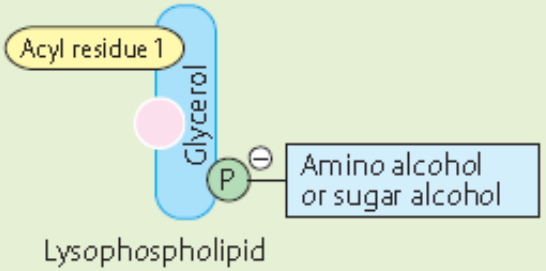


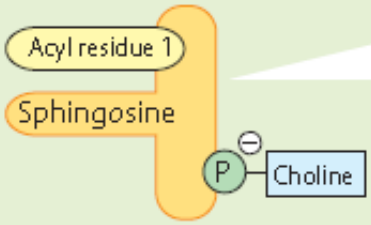


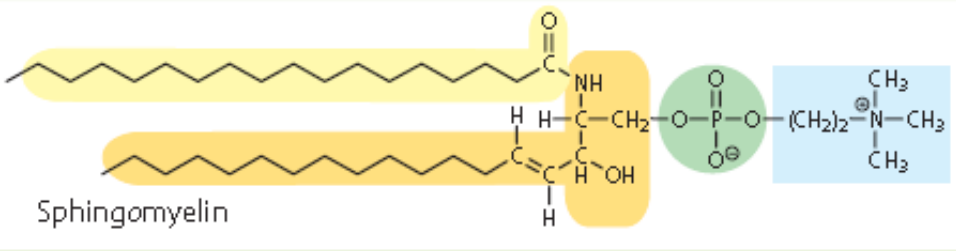




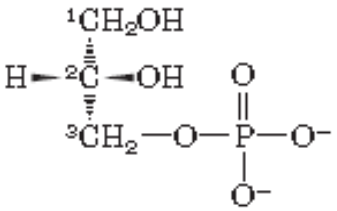




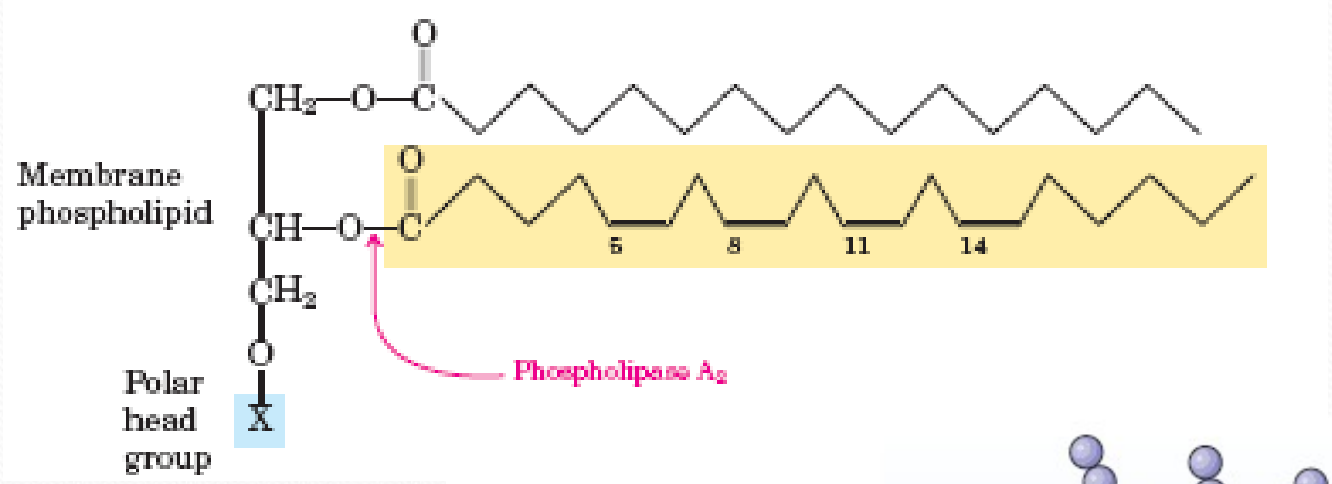


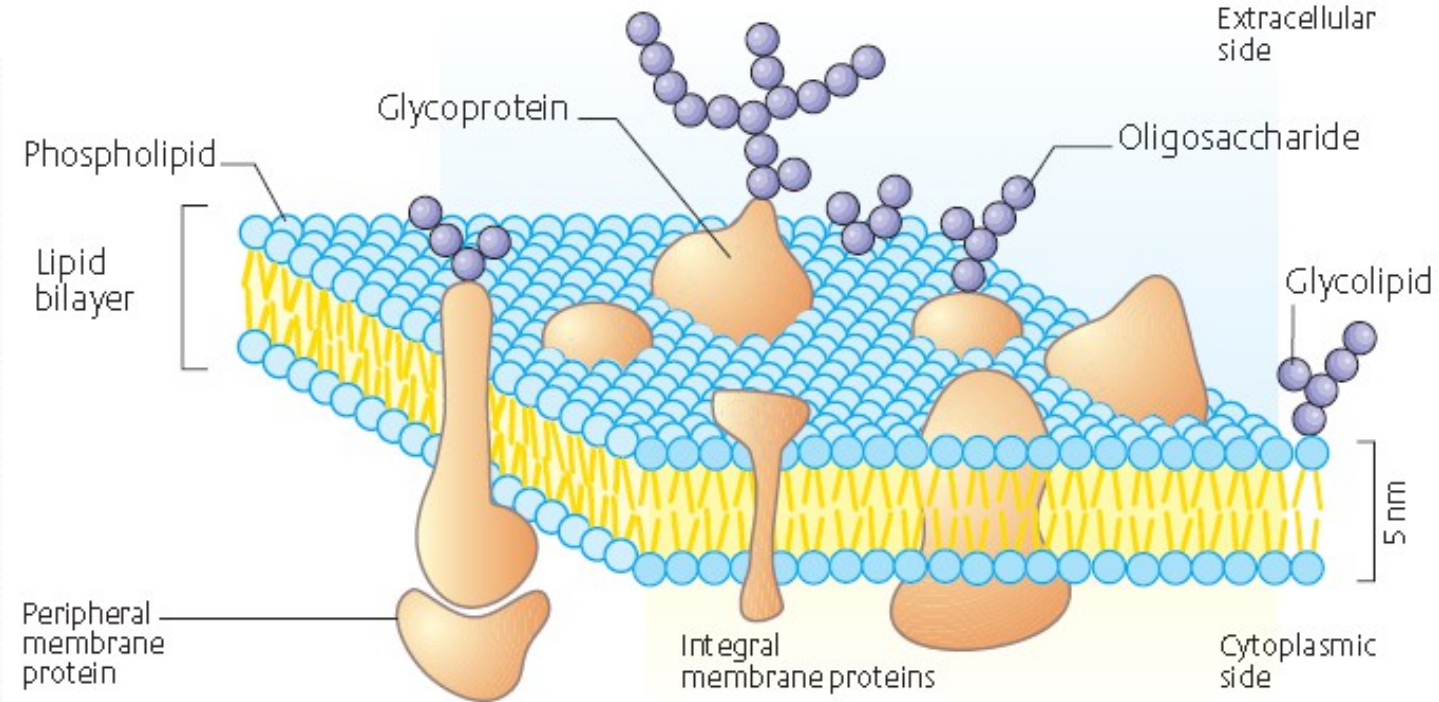


- na mestu 1 ponavadi nasičene maščobne kisline, na mestu 2 pa nenasičene
- tretja –OH skupina glicerola zaestrena s fosforjevo (V) kislino

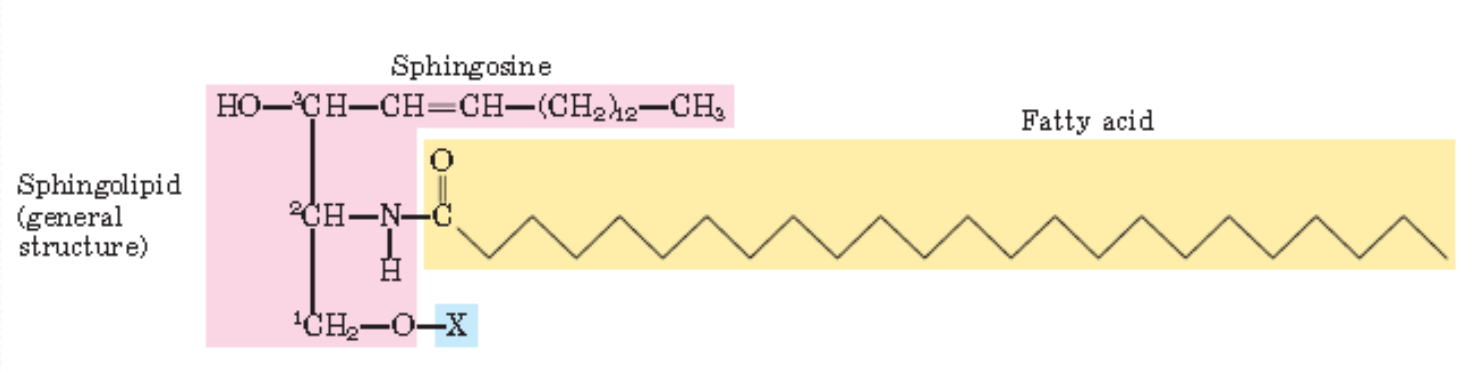


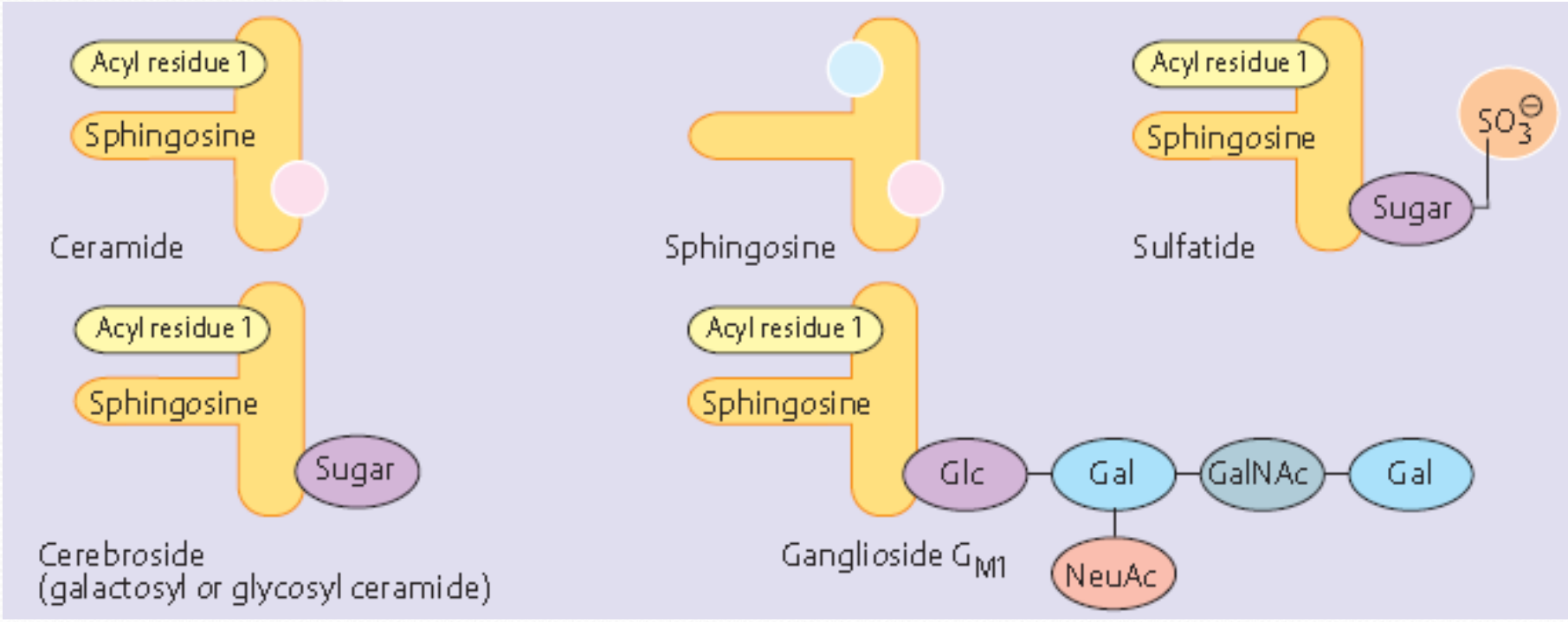
Lipidni dvosloj - membrane





Sfingolipidi





Glikosfingolipic

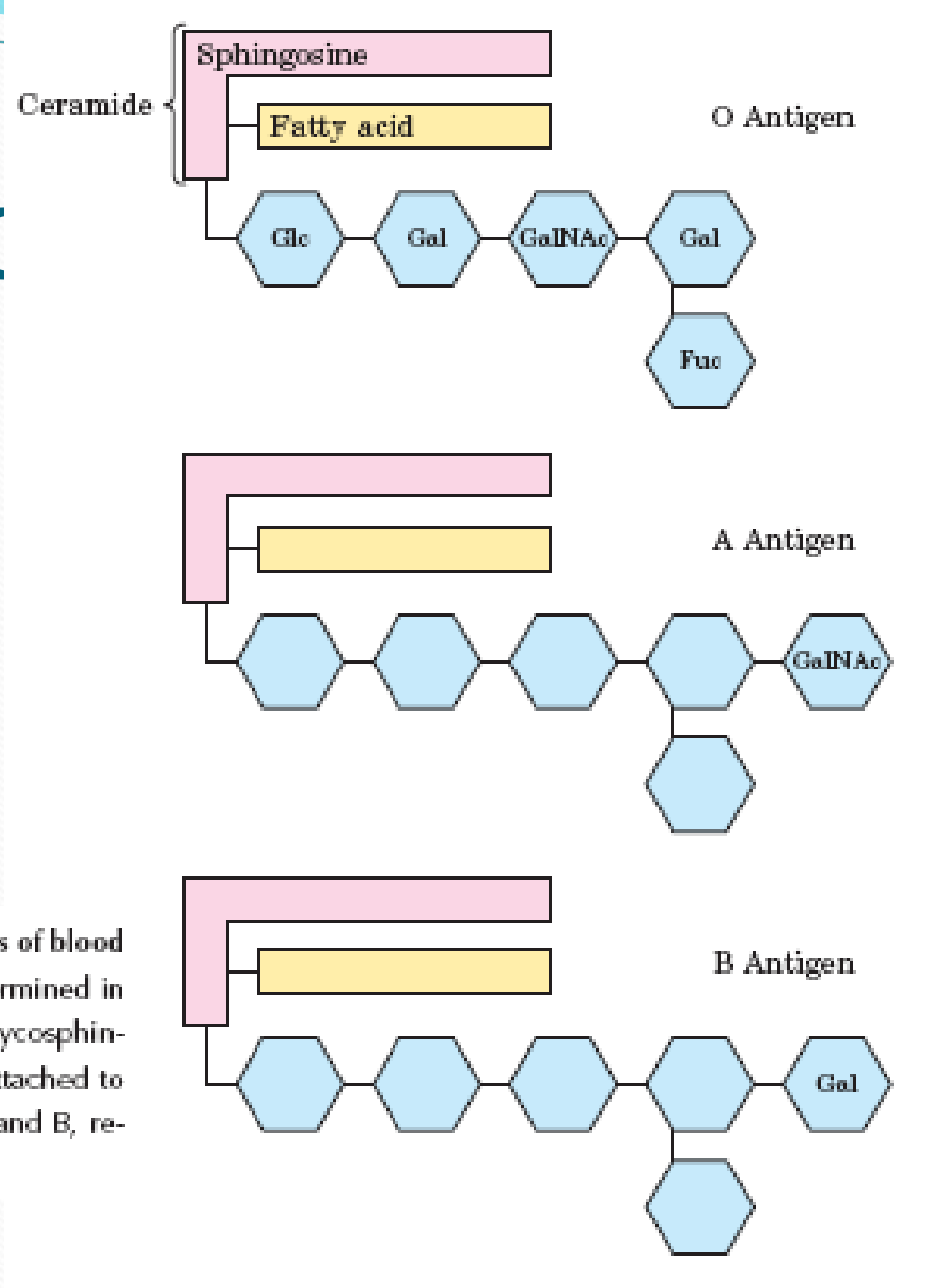
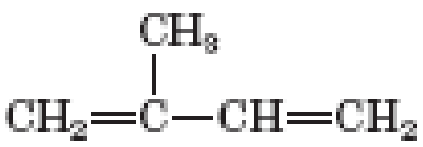
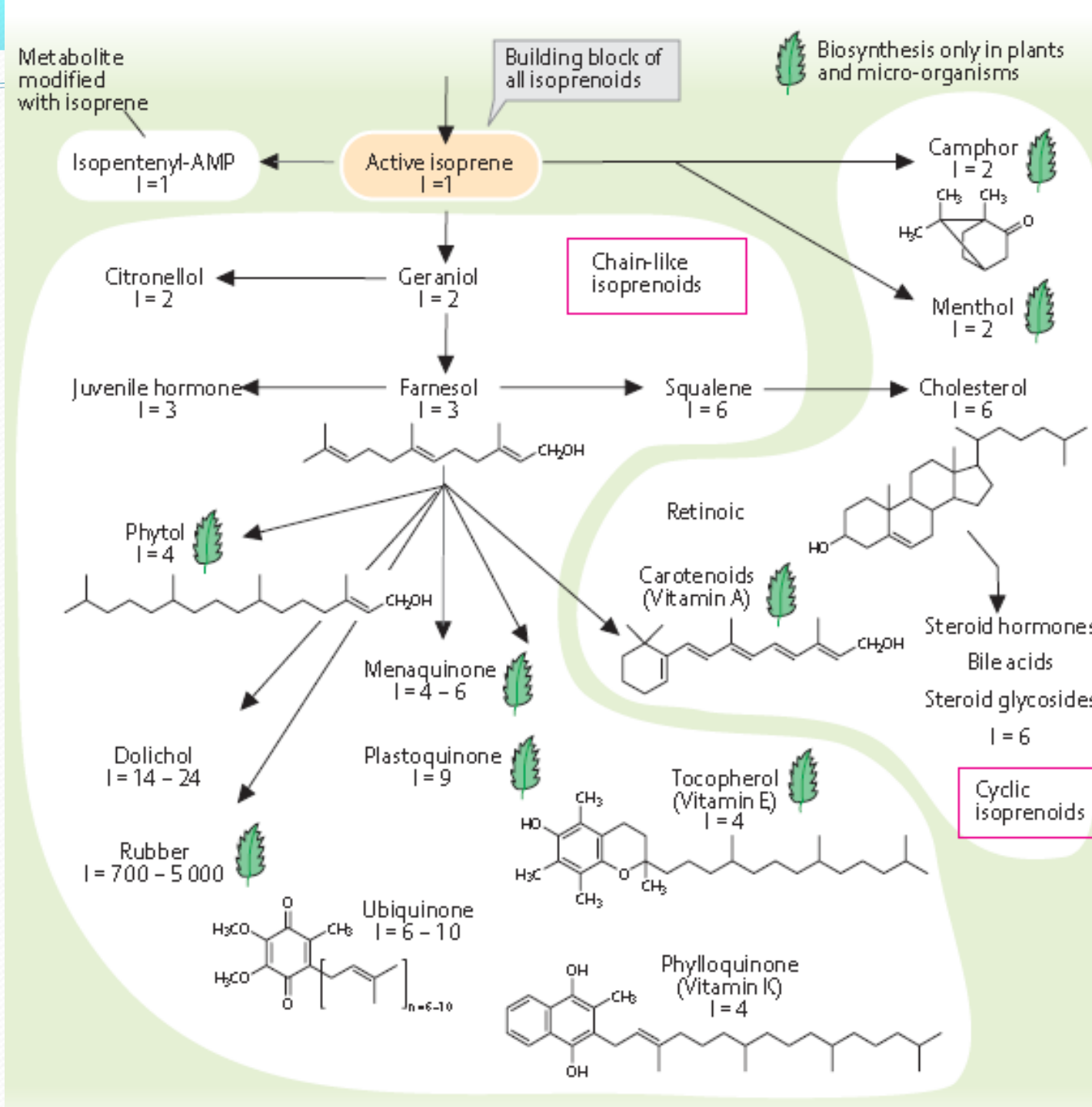


FIGURE 10–14 Glycosphingolipids as determinants of blood groups. The human blood groups (O, A, B) are determined in part by the oligosaccharide head groups (blue) of these glycosphingolipids. The same three oligosaccharides are also found attached to certain blood proteins of individuals of blood types O, A, and B, respectively. (Fuc represents the sugar fucose.)

Terpeni oz. izopre-noidi



izopren

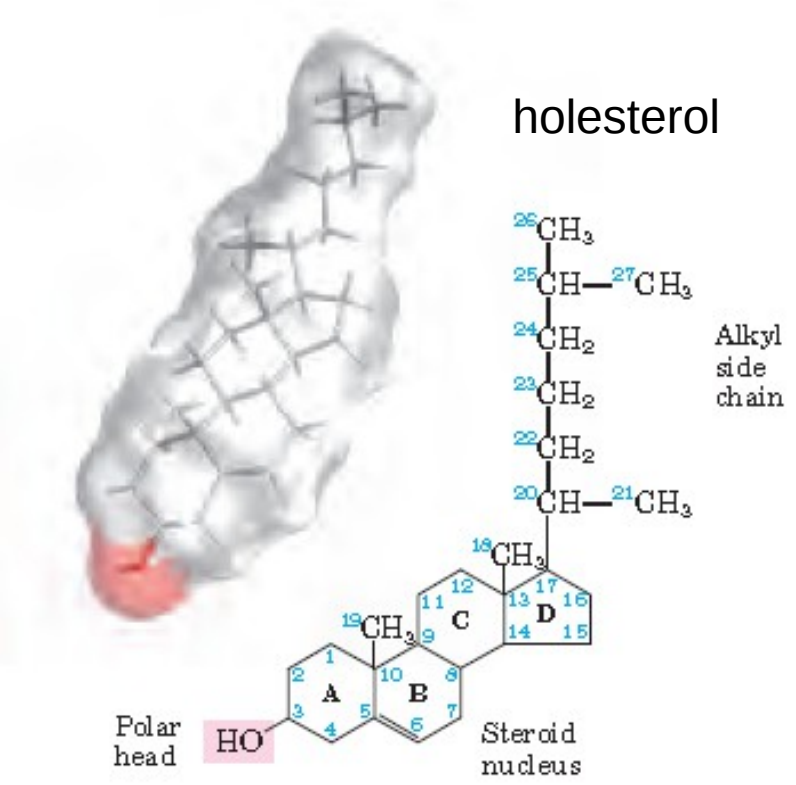


Terpeni

- pomembni terpeni v rastlinah in živalih: limonen, β-karoten, giberilinska kislina, skvalen, likopen
- mnogi dajejo rastlinam značilno barvo in vonj
- skvalen je intermediat v biosintezi živalskih in rastlinskih steroidov

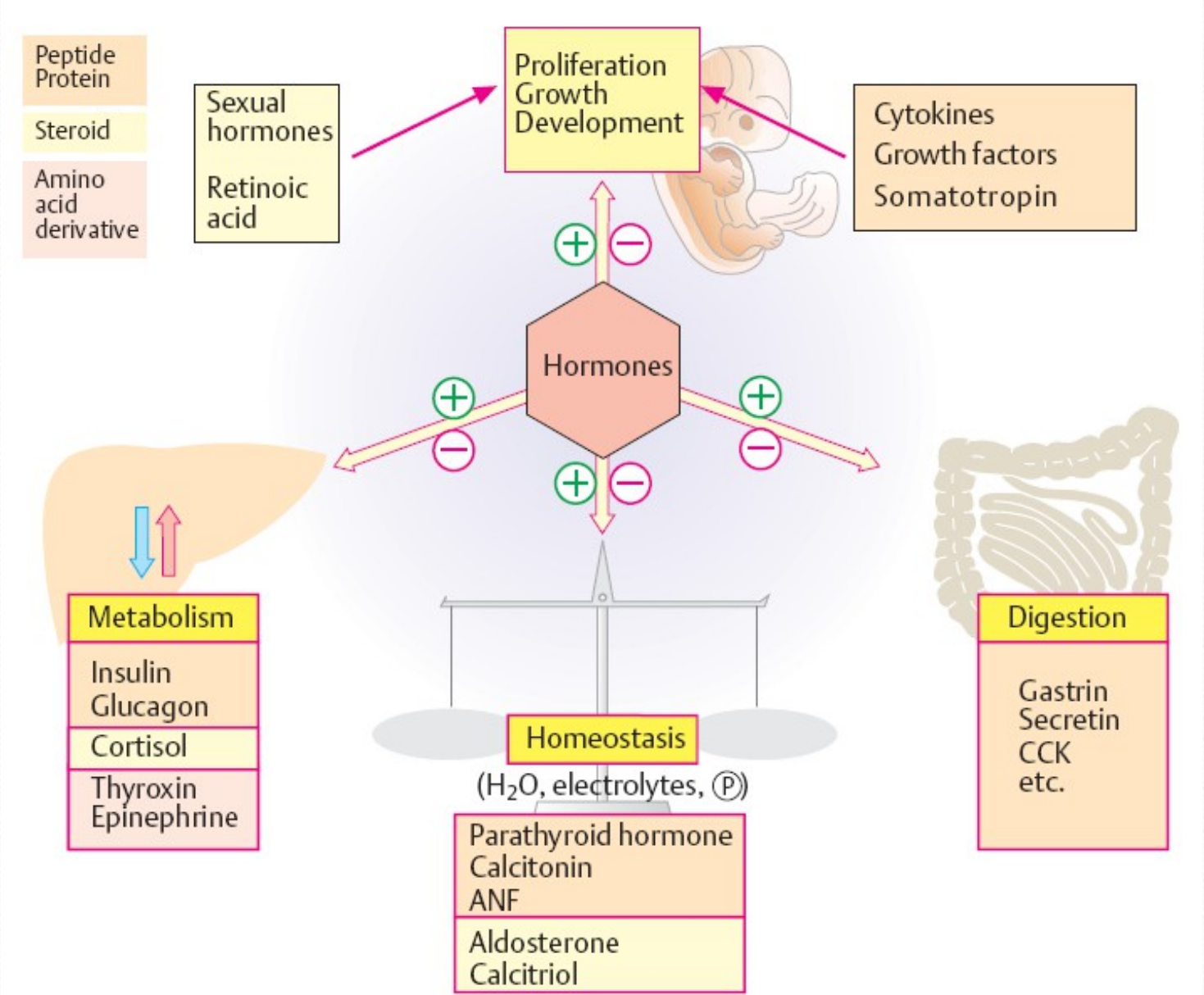
Steroidi

- holesterol izhodna molekula za sintezo steroidnih hormonov in žolčnih kislin
- hormoni so zelo kompleksne snovi v organizmu, ki jih izločajo nekatere žleze

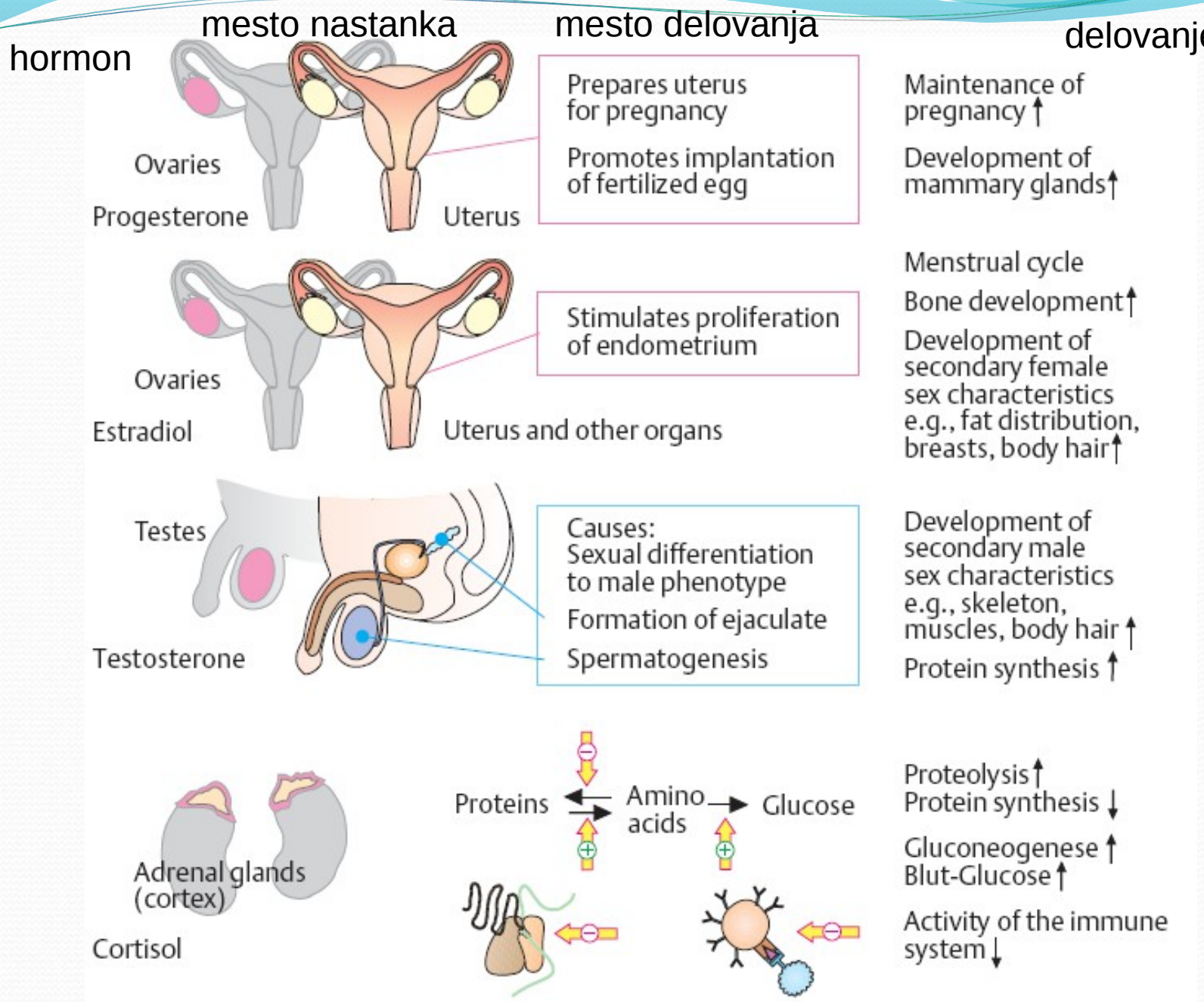


- od hormonov so odvisne posamezne naravne funkcije delovanja organizma. Izločajo se neposredno v kri in se z njo prenašajo po celem telesu, kjer vplivajo na različne organe.
- hormoni so povečini prenašalci informacij med organi oziroma med tkivi v organizmu.
- hormoni delujejo le na določene ciljne organe, kjer se vežejo na specifične receptorje.

Hormoni - pregled

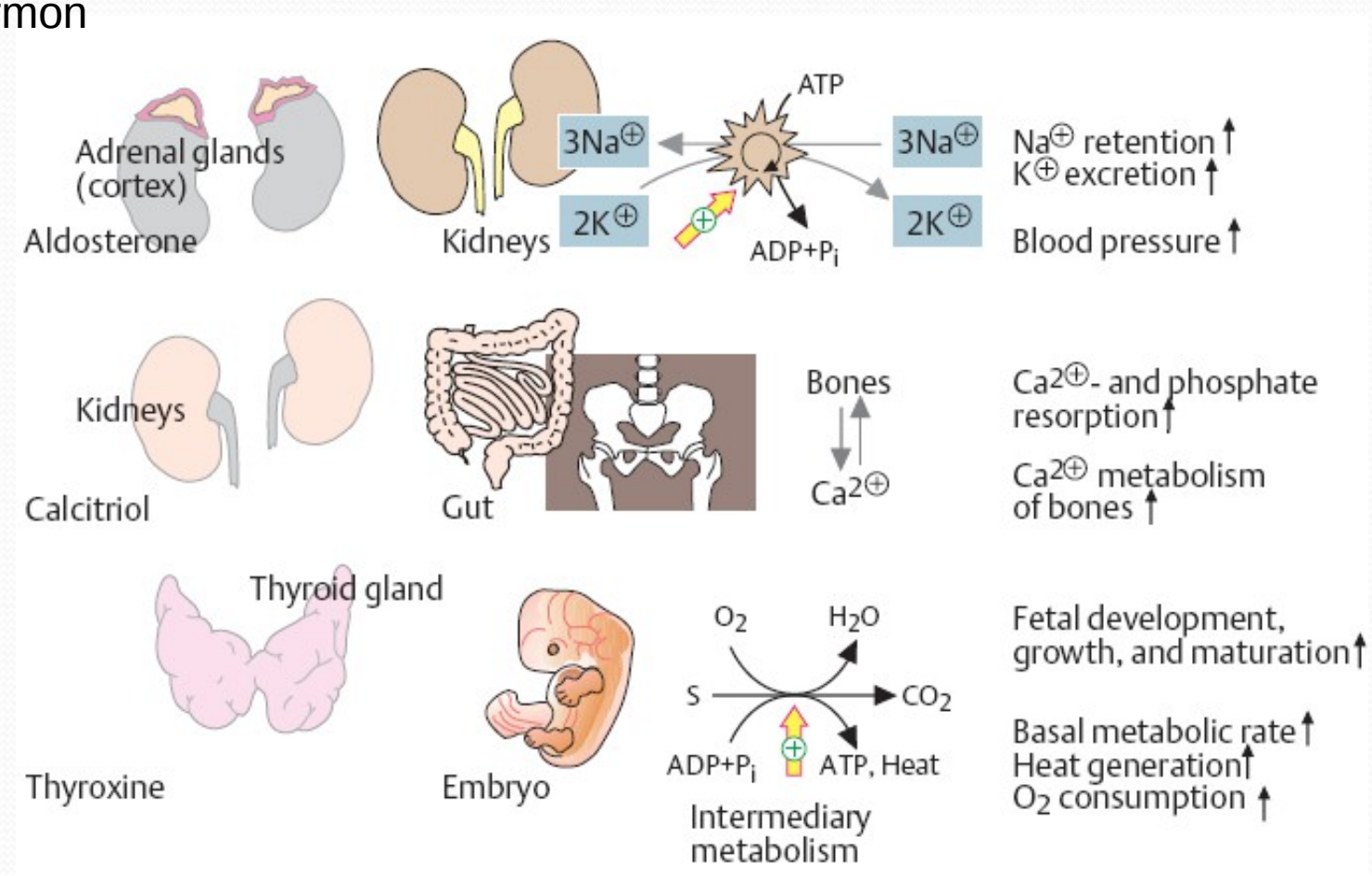


Steroidni hormoni



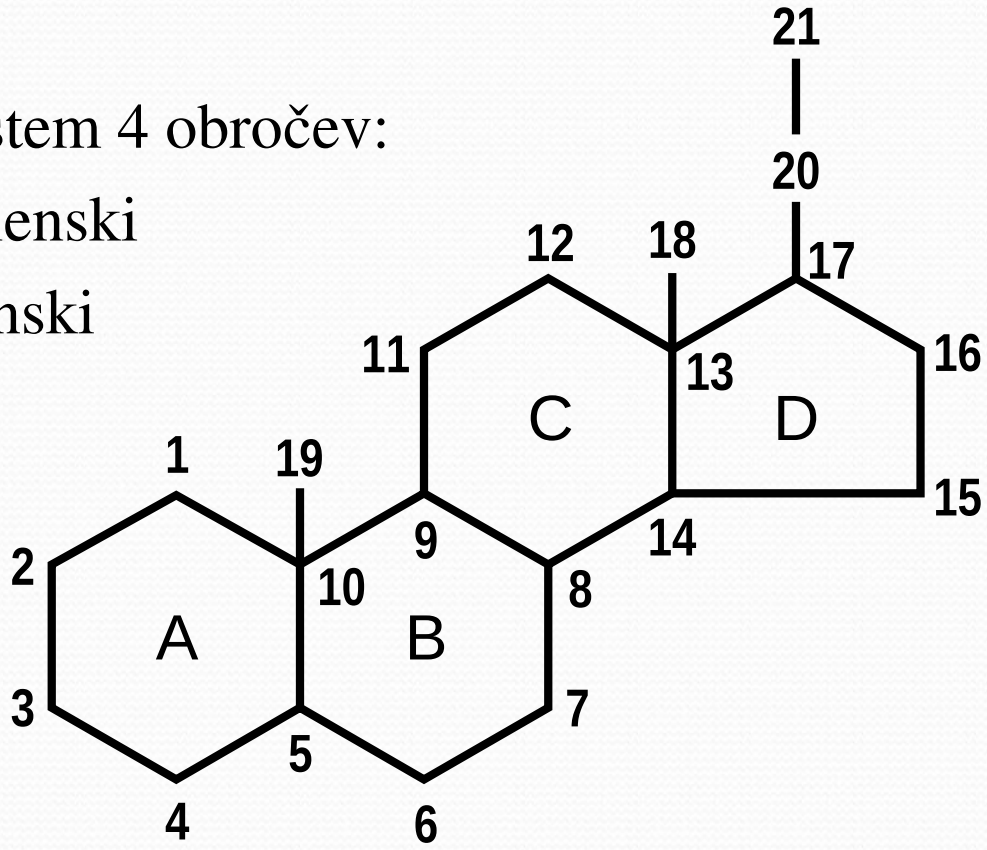
Steroidni hormoni

hormon	mesto nastanka	mesto delovanja	delovanje
Aldosterone	Adrenal glands (cortex)	Kidneys	$Na^{\oplus}$ retention ↑ $K^{\oplus}$ excretion ↑ Blood pressure ↑
Calcitriol	Kidneys	Gut, Bones	$Ca^{2\oplus}$- and phosphate resorption ↑ $Ca^{2\oplus}$ metabolism of bones ↑
Thyroxine	Thyroid gland	Embryo, Intermediary metabolism	Fetal development, growth, and maturation ↑ Basal metabolic rate ↑ Heat generation ↑ O_2 consumption ↑

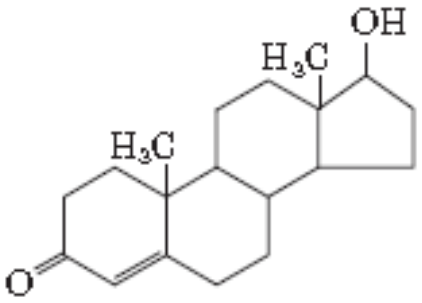


Označevanje steroidnega skeleta

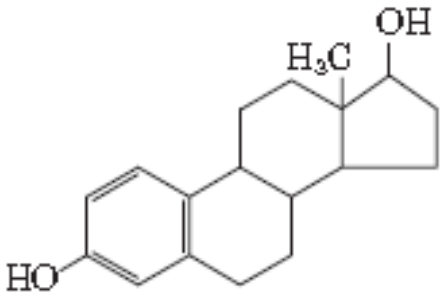
- značilen sistem 4 obročev:
  - trije 6-členski
  - en 5-členski



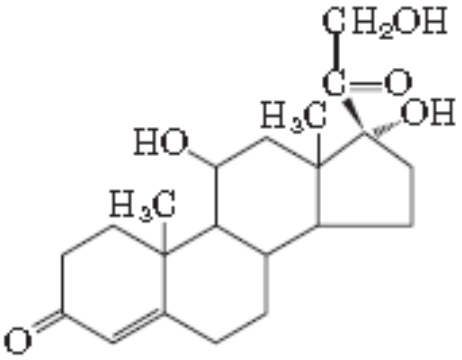
Najpomembnejši steroidi, ki izhajajo iz holesterola



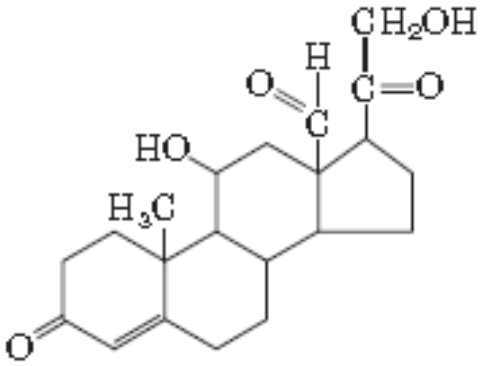
Testosterone



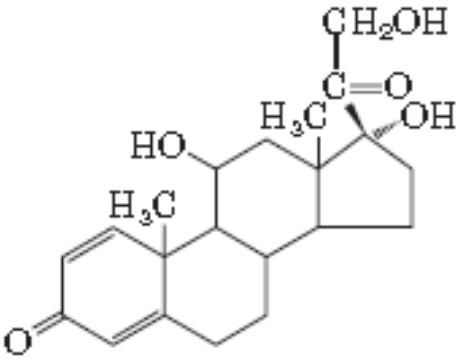
Estradiol



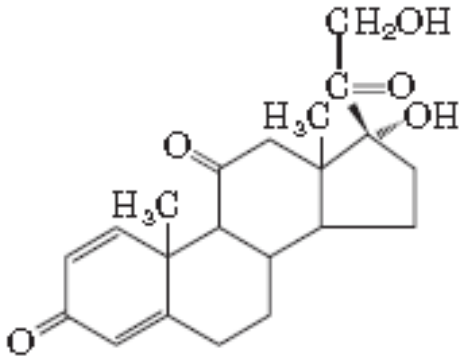
Cortisol



Aldosterone



Prednisolone



Prednisone

Uporaba steroidov (steroidni terapevtiki in hormoni)

- kortikosteroidi: -OH ali =O na C11, -OH na 17α
- kontracepcijska sredstva (C. Djerassi)

Terapevtski in biološki učinki:

- protivnetni učinki
- pomirjevala
- antialergiki
- diuretiki
- anaboliki
- progestageni
- antimikotiki
- za zniževanje visokega pritiska
- za zdravljenje nekaterih vrst raka
- za zdravljenje osteoporoze
- imunosupresorji
- delovanje proti virusu herpes simplex
- inhibicija HIV integraze – (okuženi s HIV ter oboleli za AIDS)

Vitamini, topni v lipidih

vitamini A, D, E in K