



Prenos snovi med celico in okolico

Prenos snovi med celico in okolico

1

- Transportni procesi

2

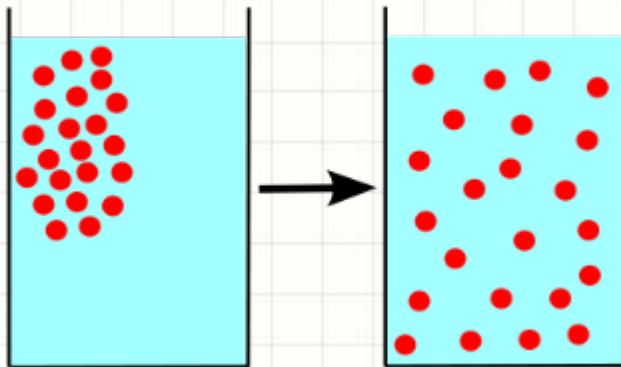
- Pasivni transport

3

- Aktivni transport

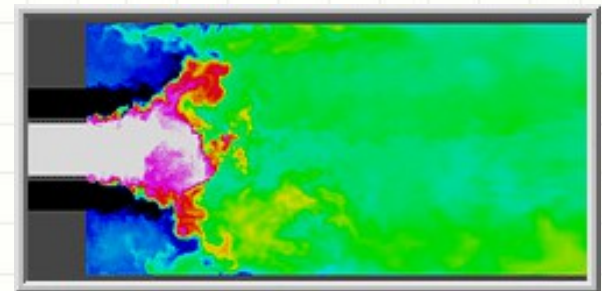
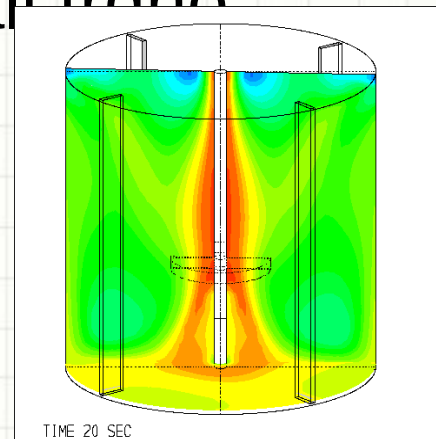
Prenos snovi

- Difuzija: molekularni prenos snovi zaradi razlike v koncentraciji topljenca



- Aktivni transport: nasproten difuziji, s pomočjo kemijske energije

- Konvekcija: vezana na gibanje tekočine ob fazni meji s plinom, kapljevino ali trdno snovjo

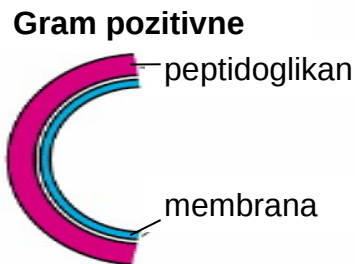


Celična ovojnica

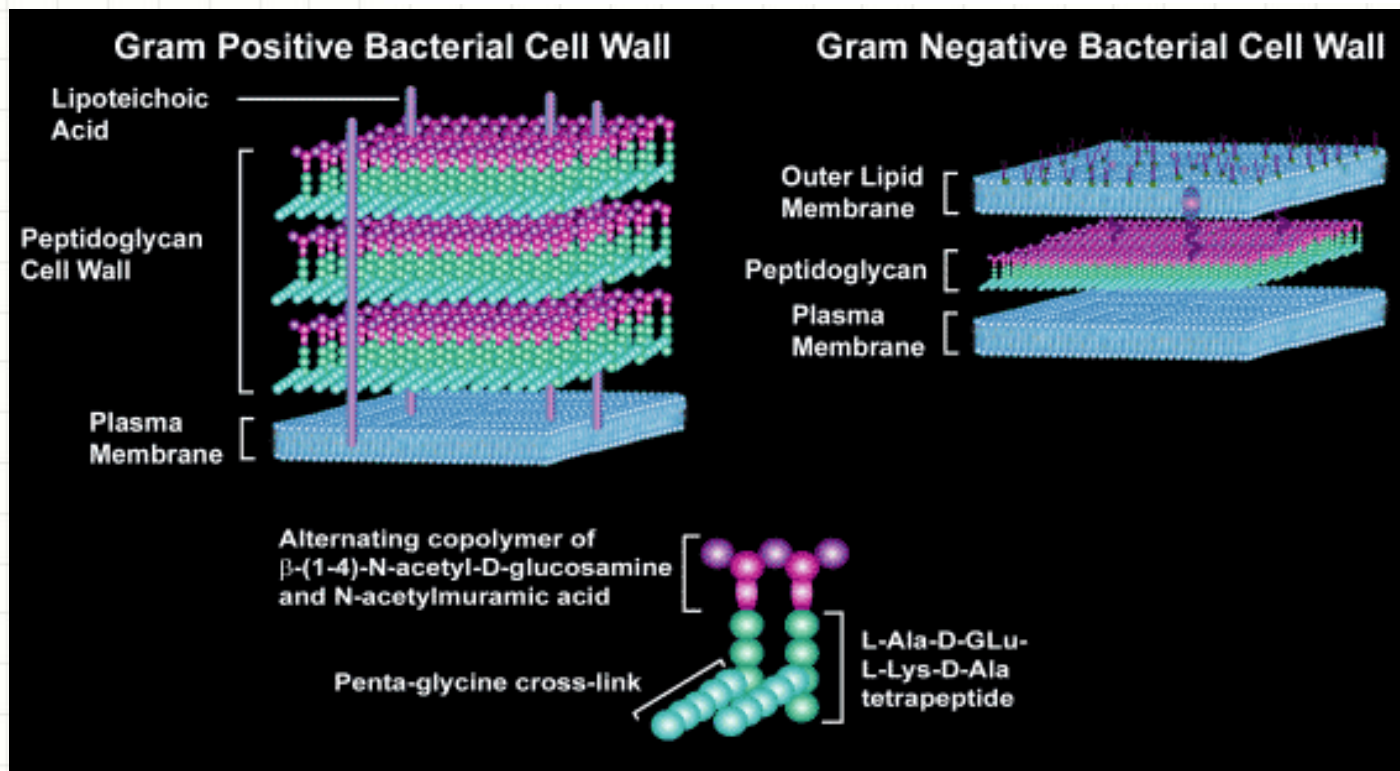
- Večina mikroorganizmov in rastline:
 - Celična stena
 - rigidna struktura
 - sestava: polisaharidi, peptidoglukani, lipopolisaharidi
 - vloga: zaščita pred mehanskimi in osmoznimi poškodbami
 - Citoplazemska membrana
 - **fluidna** struktura
 - sestava: fosfolipidni dvosloj, proteini
 - vloga: selektivno permeabilna ločnica, skozi katero poteka izmenjava hranil in odpadkov

Zgradba celične stene - bakterije

manj prepustna
celična stena, tudi
debelejša

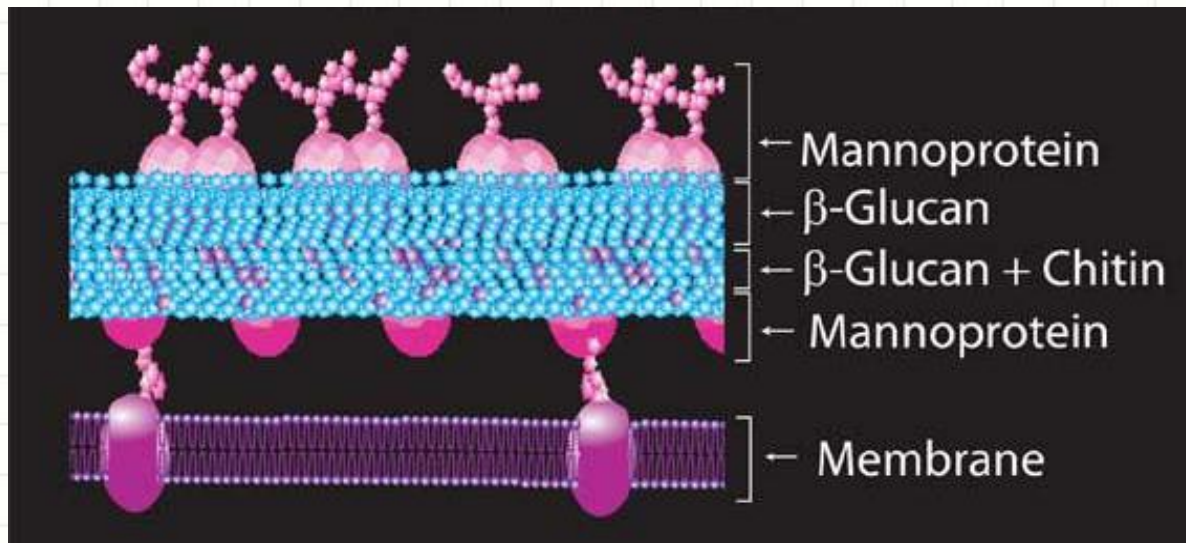


bolj prepustna
celična stena,
etanol
ekstrahira
kompleks
kristalno
vijoličnega
barvila z
jodom

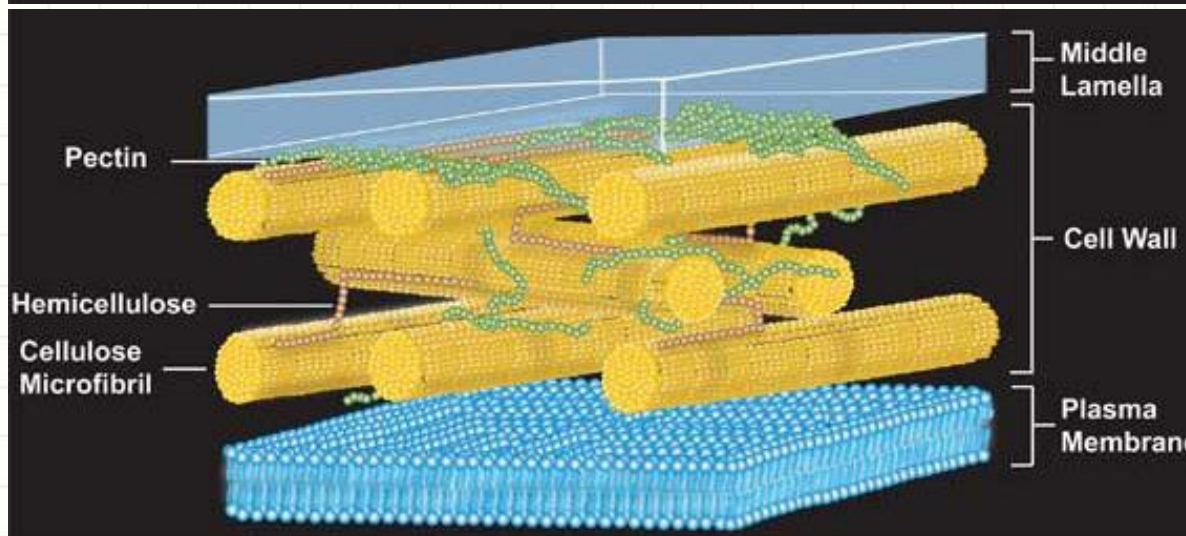


Zgradba celične stene eukariontov: kvasovke, rastline

velike
razlike
med
različnimi
vrstami!



kvasovke

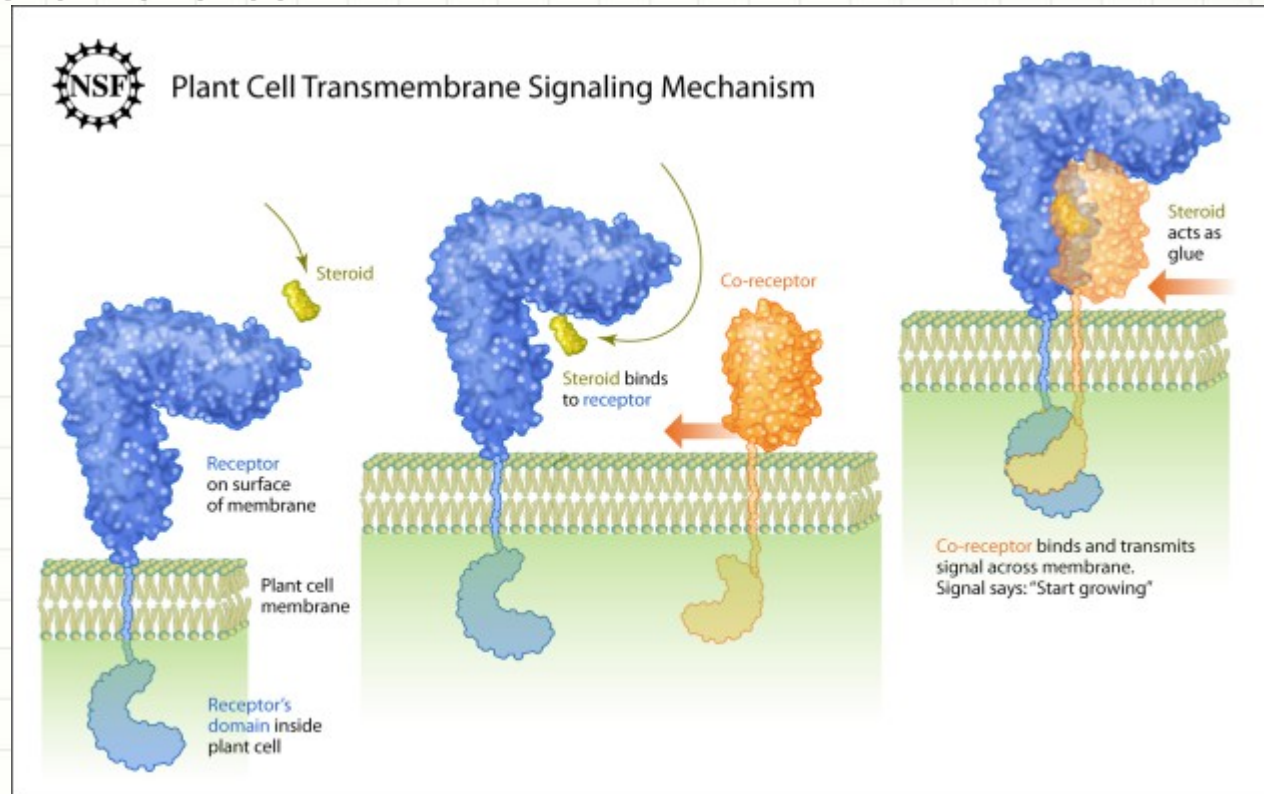


rastline

Biološke membrane - vloga

- Zaščitni ovoj
- **Selektivna permeabilnost: izmenjava snovi z okolico**
- Sporazumevanje celic z okolico

- Mesto vezave receptorskih molekul in prenos kemijskih signalov:
- Receptor veže ligand (npr. hormon)
- Inducira ali regulira intracelularne reakcije



- Omogoča prenos energije (kompleksi proteinov)
 - Mitohondrijske membrane: sinteza ATP
 - Fotosintetski organizmi: svetlobna energija se s pomočjo proteinov v tilakoidni membrani kloroplastov ujame v barvila

fosfolipidni dvosloj

Sestava membran

Nadmolekulske strukture:
povezani lipidi, proteini in ogljikovi hidrati (vezani na lipide – glikolipidi - ali proteine - glikoproteini)

– Second level

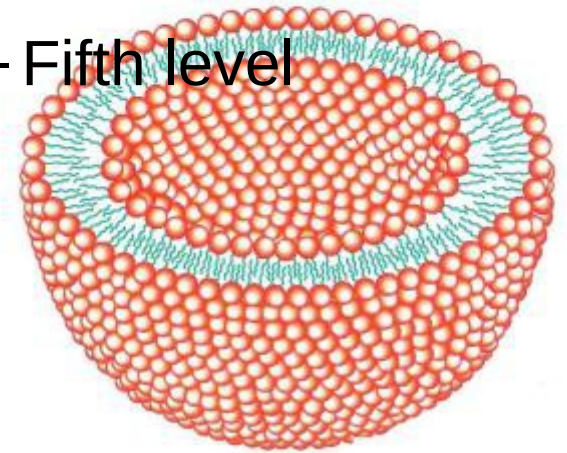
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• Fourth level

– Fifth level



(a)

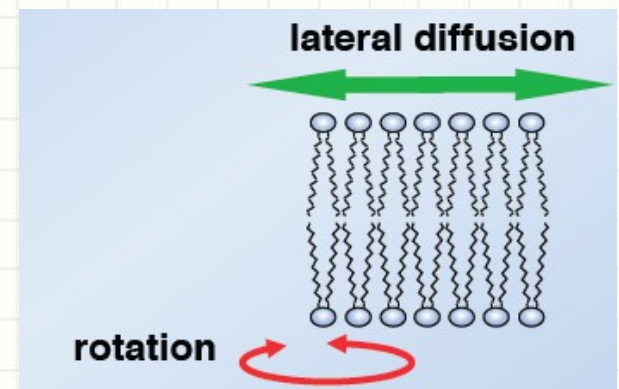


(b)

izvor membrane	utežni odstotki ^a	
	lipidi	proteini
mielin	80	18
mišja jetra	52	45
človeški eritrociti	43	49
koruzni listi	45	47
mitohondriji (zunanja)	48	52
mitohondriji (notranja)	24	76
<i>Escherichia coli</i>	25	75

^aČe je skupna vrednost manj kot 100 %, pripada manjkajoči del ogljikovim hidratom.

model tekočega mozaika:



Citoplazemska membrana

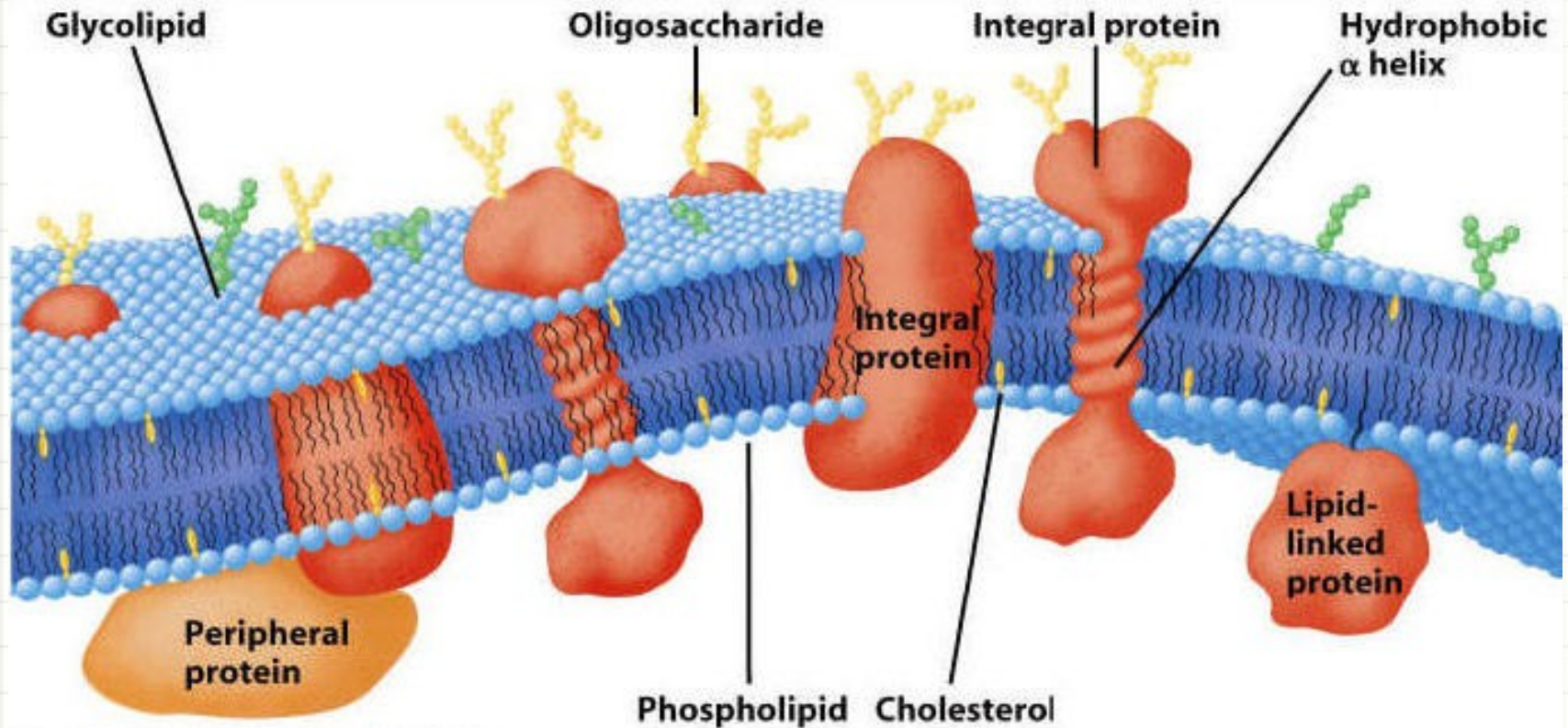


Figure 9-26 Fundamentals of Biochemistry, 2/e
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debelina: cca. 5 nm

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Model tekočega mozaika

Singer in Nicholson, 1972

Lateralno gibanje proteinov in lipidov

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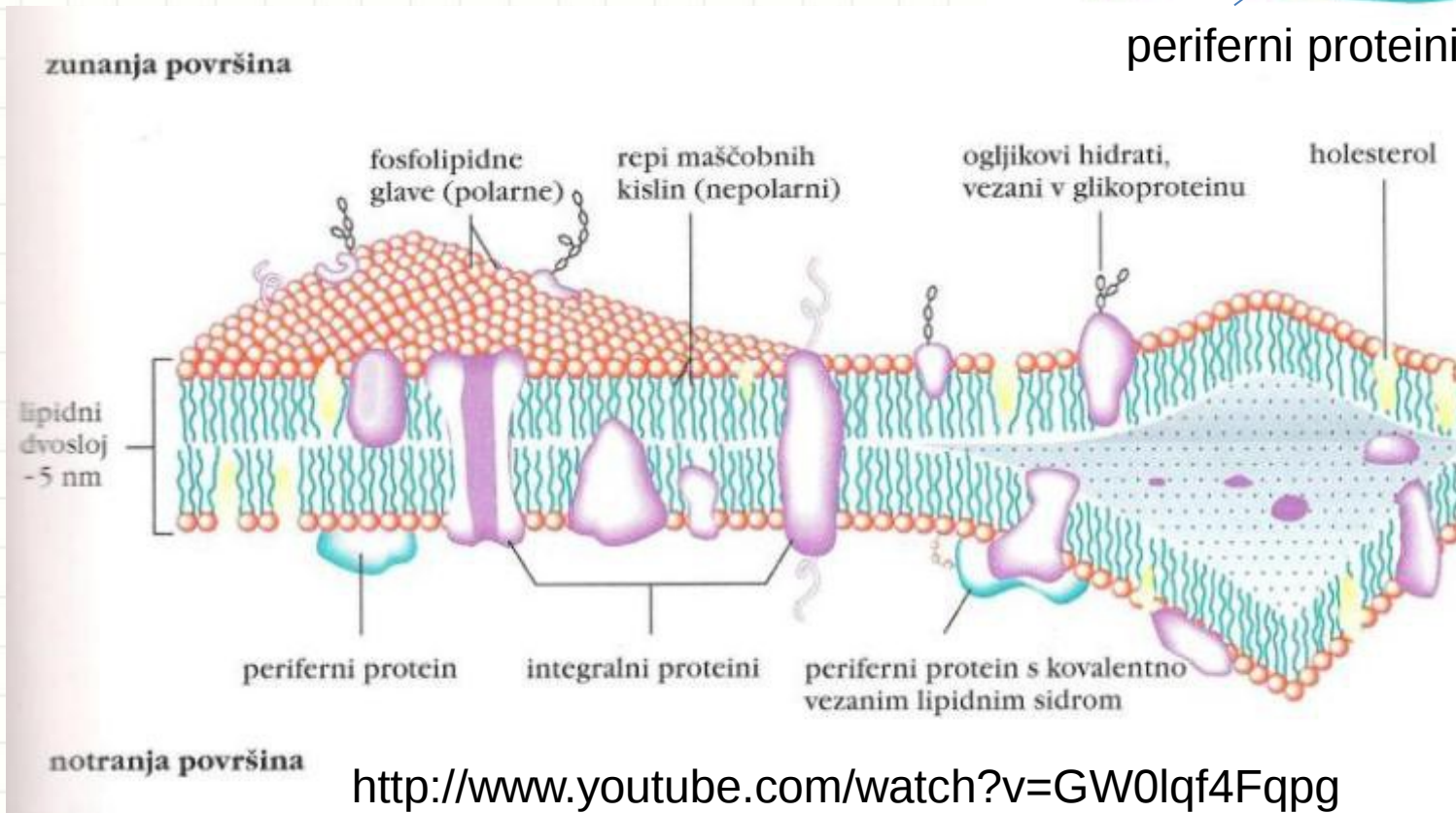
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integralni proteini

Fifth level

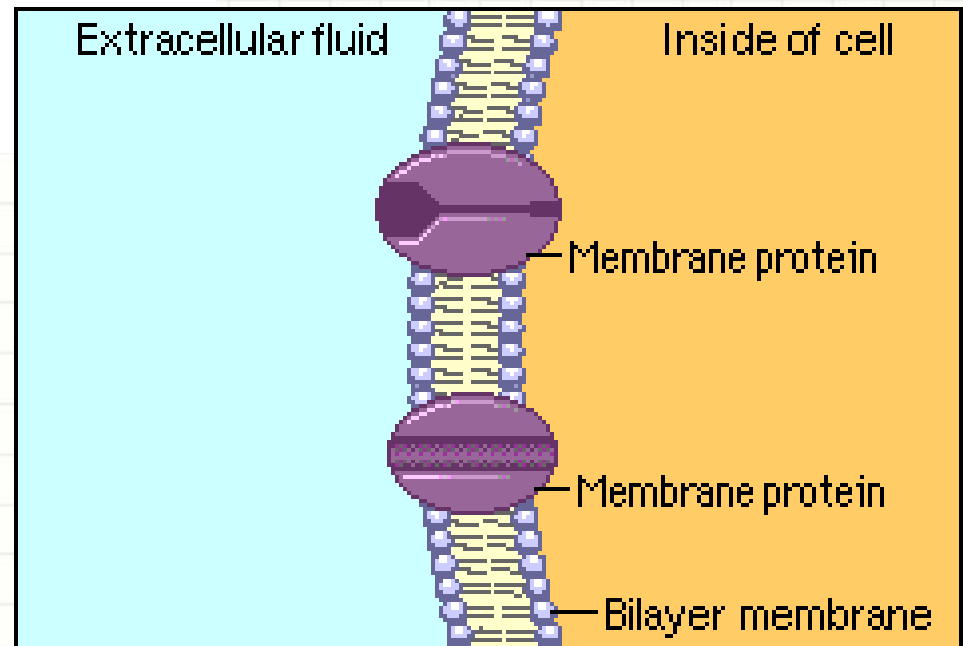
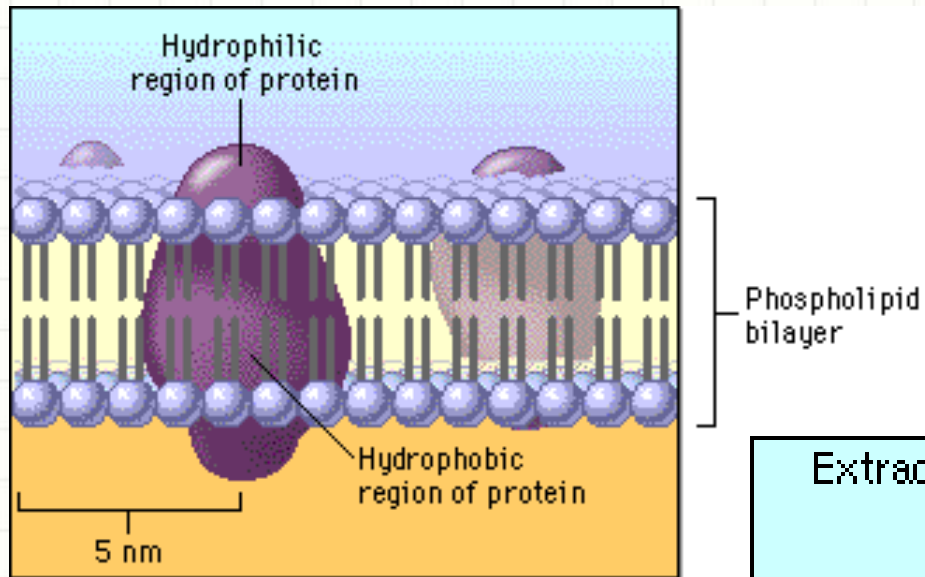
periferni proteini



<http://www.youtube.com/watch?v=GW0lqf4Fqpg>

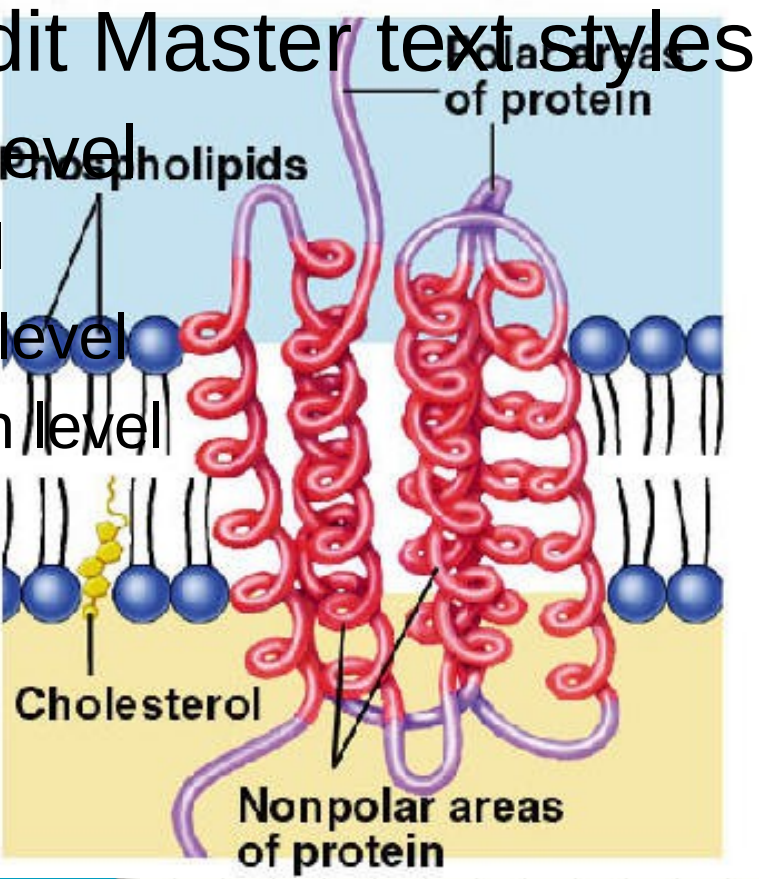
<http://www.youtube.com/watch?>

Integralni proteini



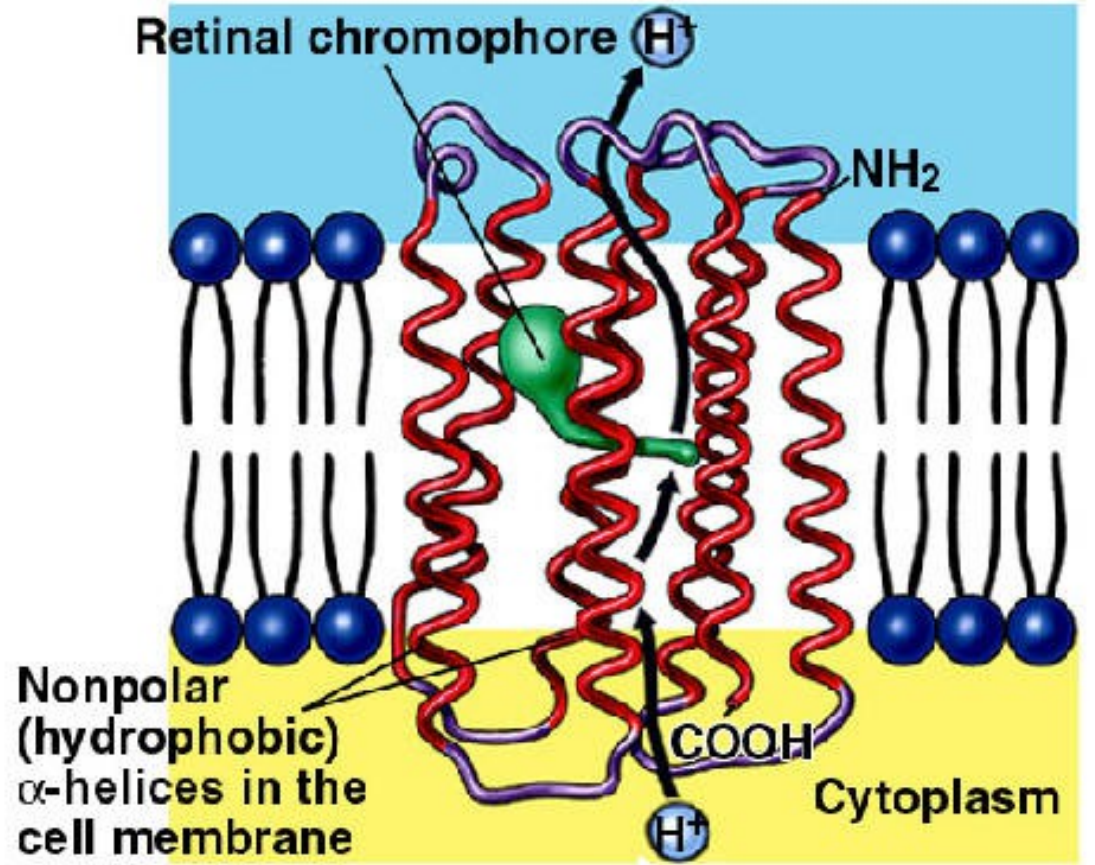
Proteini v membrani

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A channel protein



Primer: glikoforin A

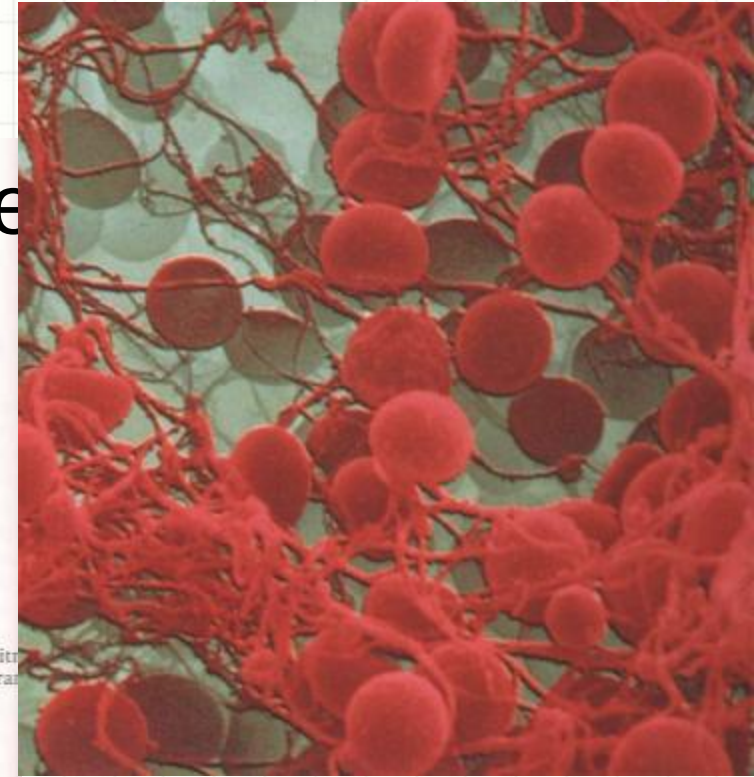
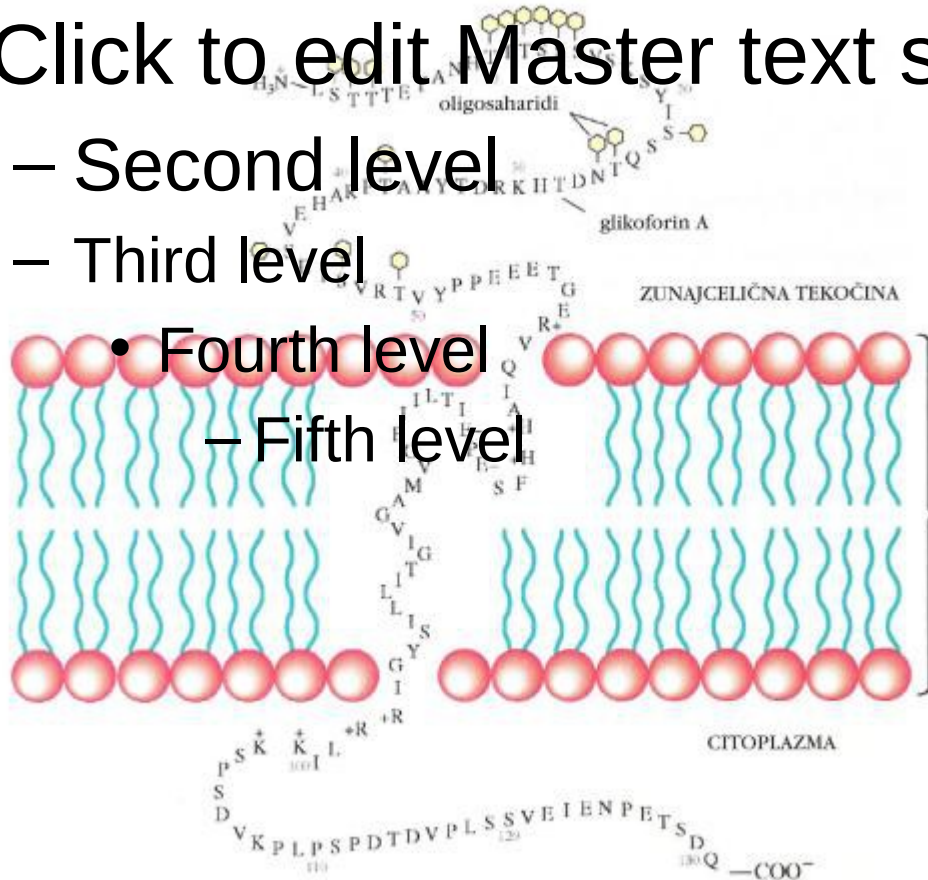
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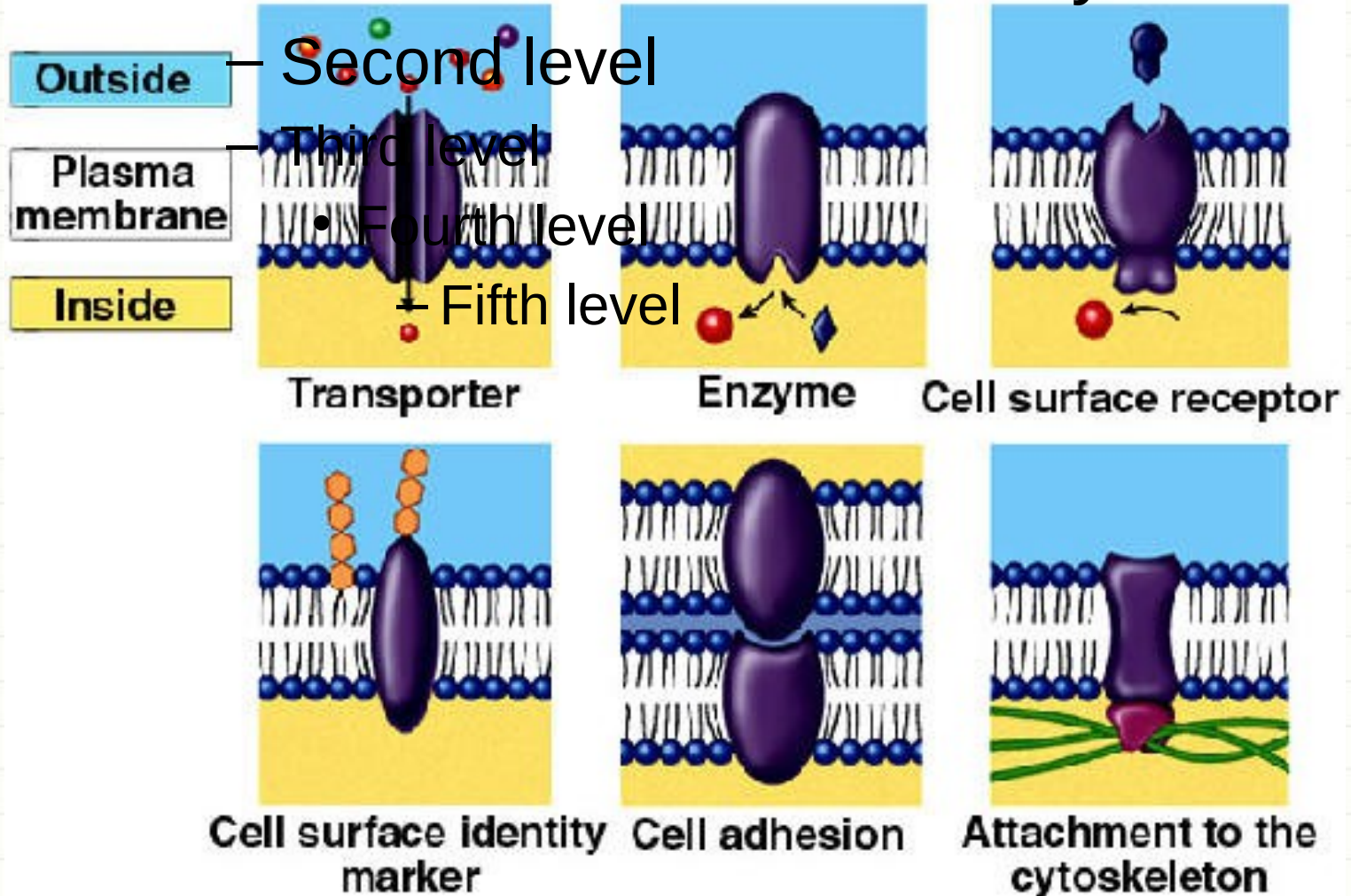
integralni protein v membrani eritrocitov, ni poznana biološka vloga

131 AK, 16 oligosaharidnih skupin (100 monosaharidov)
nepolarno področje cca 30 AK – v membrani, polarna področja izven membrane

Vloge proteinov v membrani

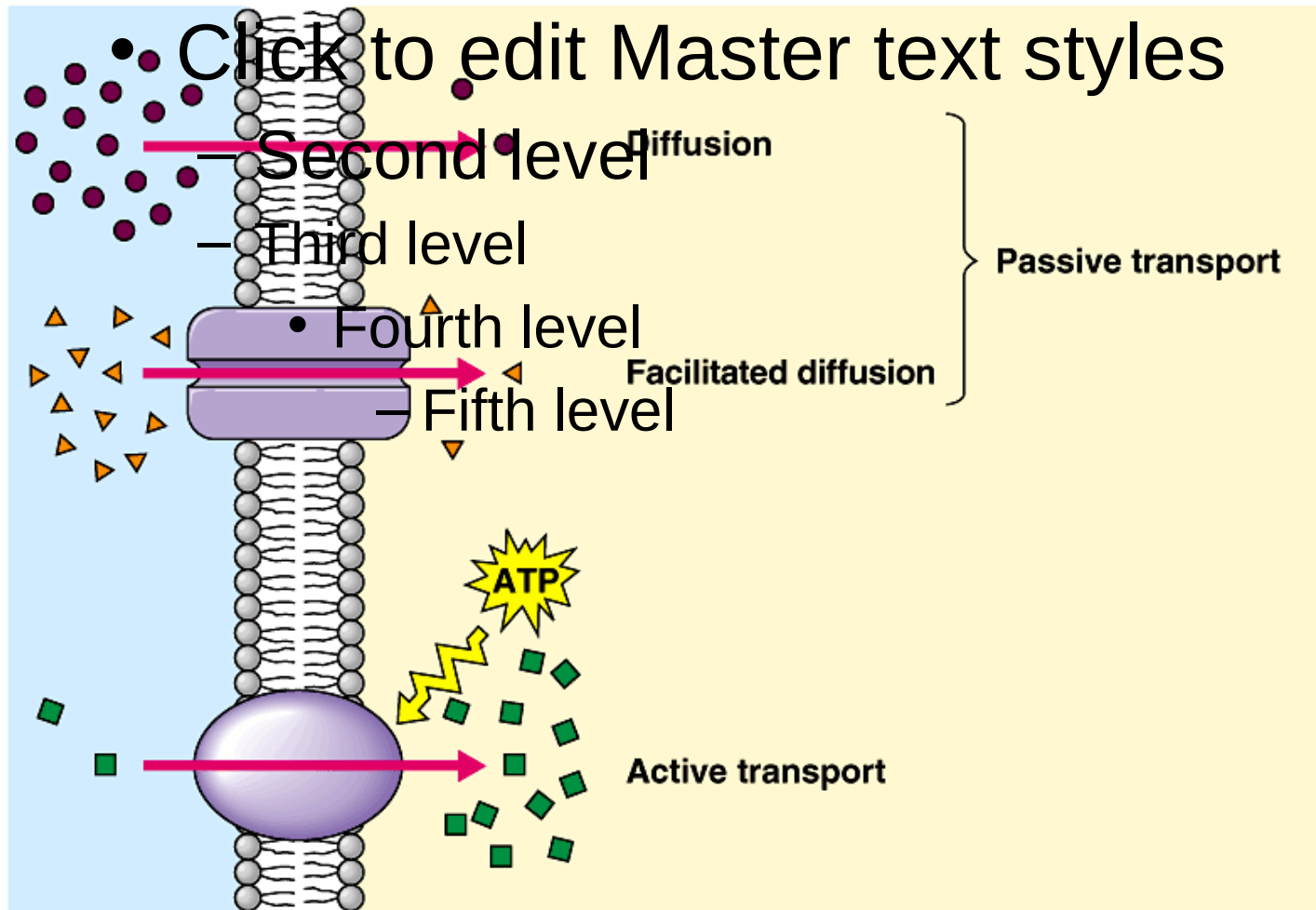
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Functions of Plasma Membrane Proteins

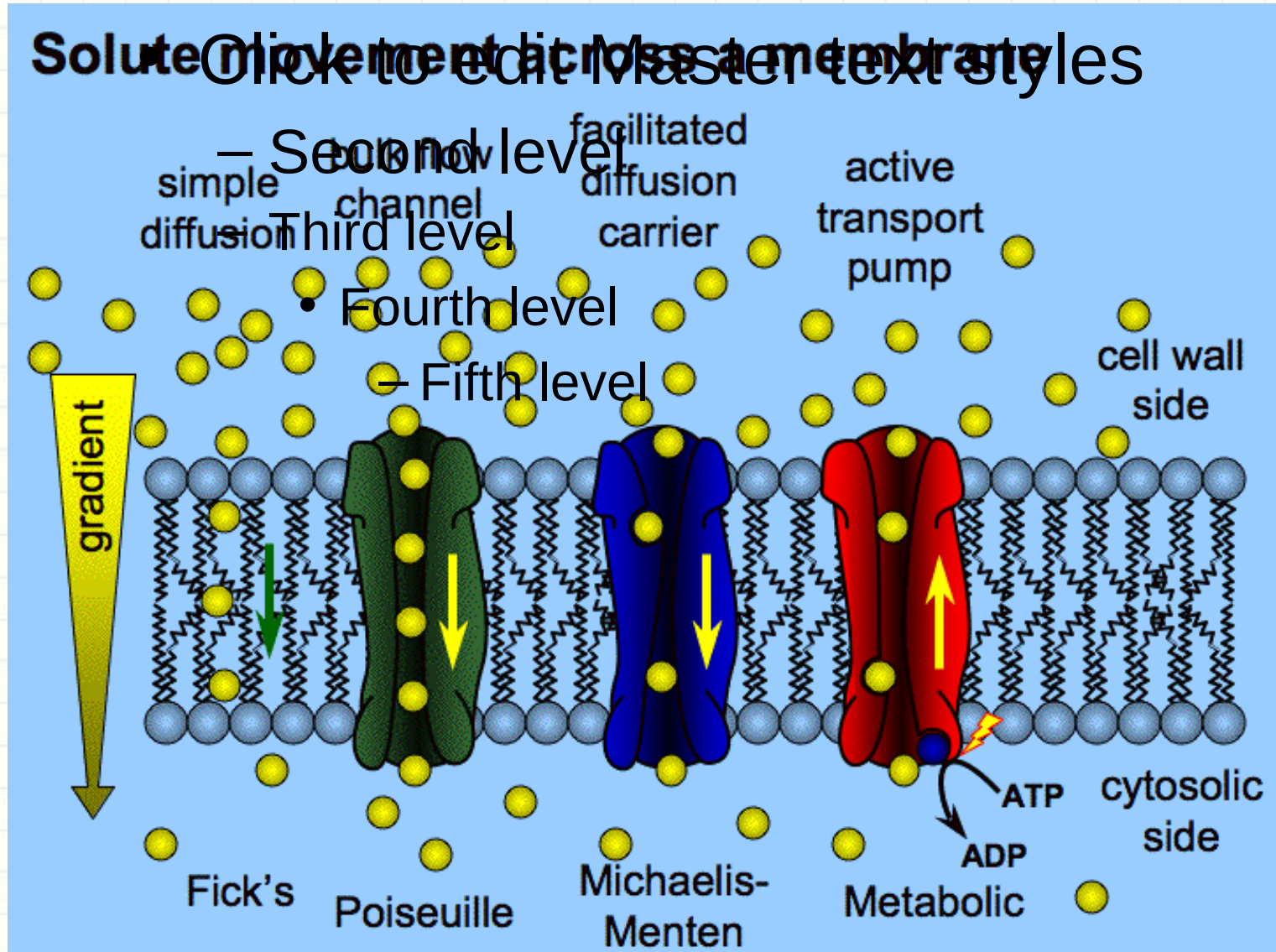


Prenos skozi membrane:

- pasivni transport: difuzija, olajšana difuzija in osmoza
- aktivni transport (potreben ATP): črpalke, endocitoza, eksocitoza



Načini prenosa skozi membrane



Prenos snovi pri različnih mikroorganizmih

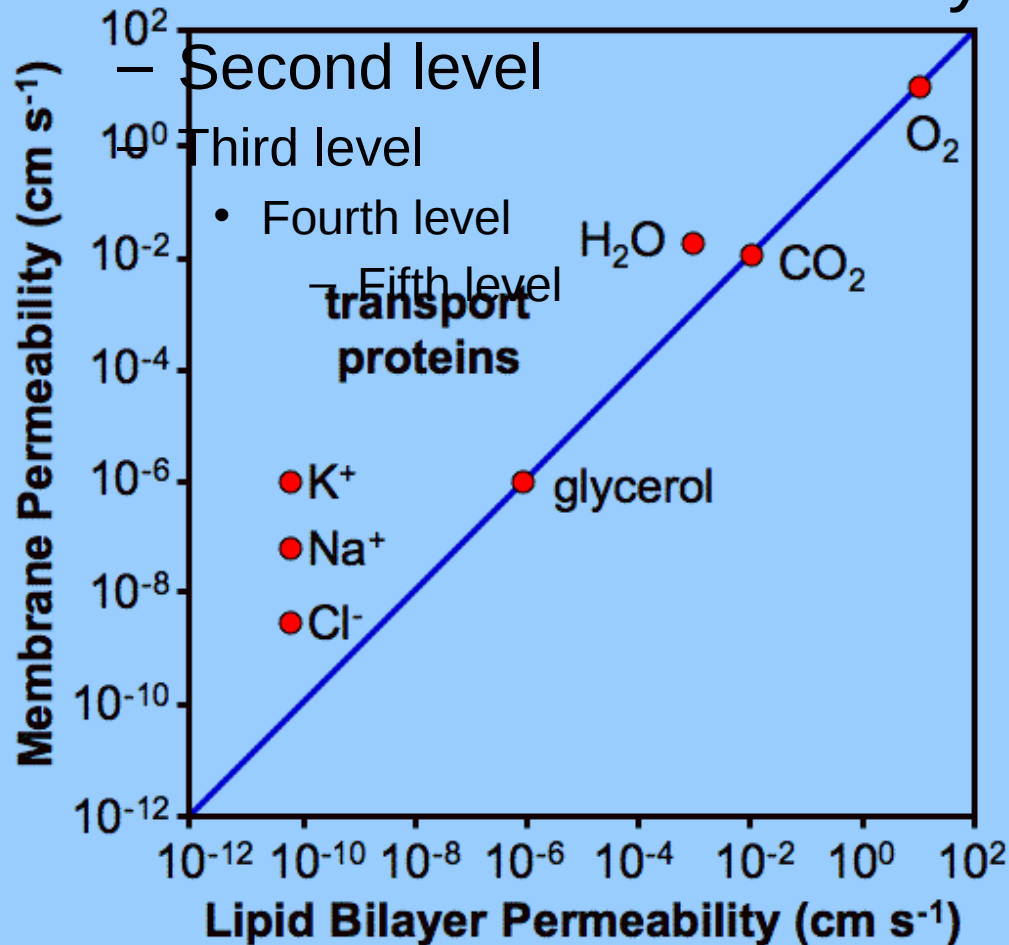
Table 2.2. Summary of transport processes for different substrates and metabolic products in microorganisms. For details see the text, sections 2.1.1.4–2.1.1.9.

Compound	Bacteria	Fungi
Amino acids	Active transport	Active transport
Glucose	Active transport (PTS and permease)	Facilitated diffusion and active transport
Lactose	Active transport (PTS and permease)	Facilitated diffusion and active transport
Glycerol	Free and facilitated diffusion	Free and facilitated diffusion
Ethanol	Free diffusion	Free diffusion
Lactic acid	Active transport and free diffusion	Free diffusion
Acetic acid	Free diffusion	Free diffusion
Carbon dioxide	Free diffusion	Free diffusion
Oxygen	Free diffusion	Free diffusion

PTS – fosfotransferazni sistem

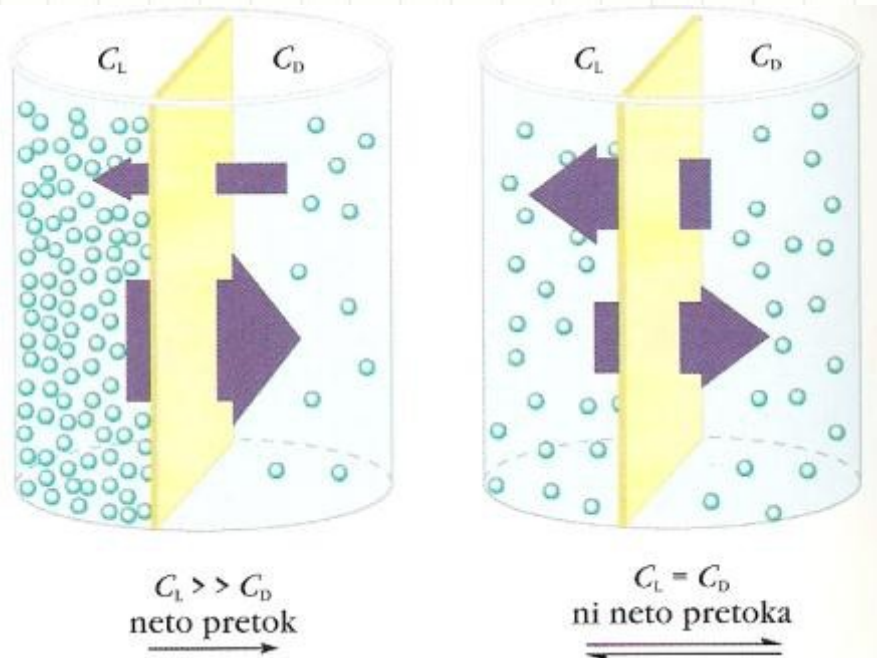
Permeabilnost membran za različne topljence

Membranes are differentially permeable to solutes



Pasivni prenos snovi membrane

Difuzija

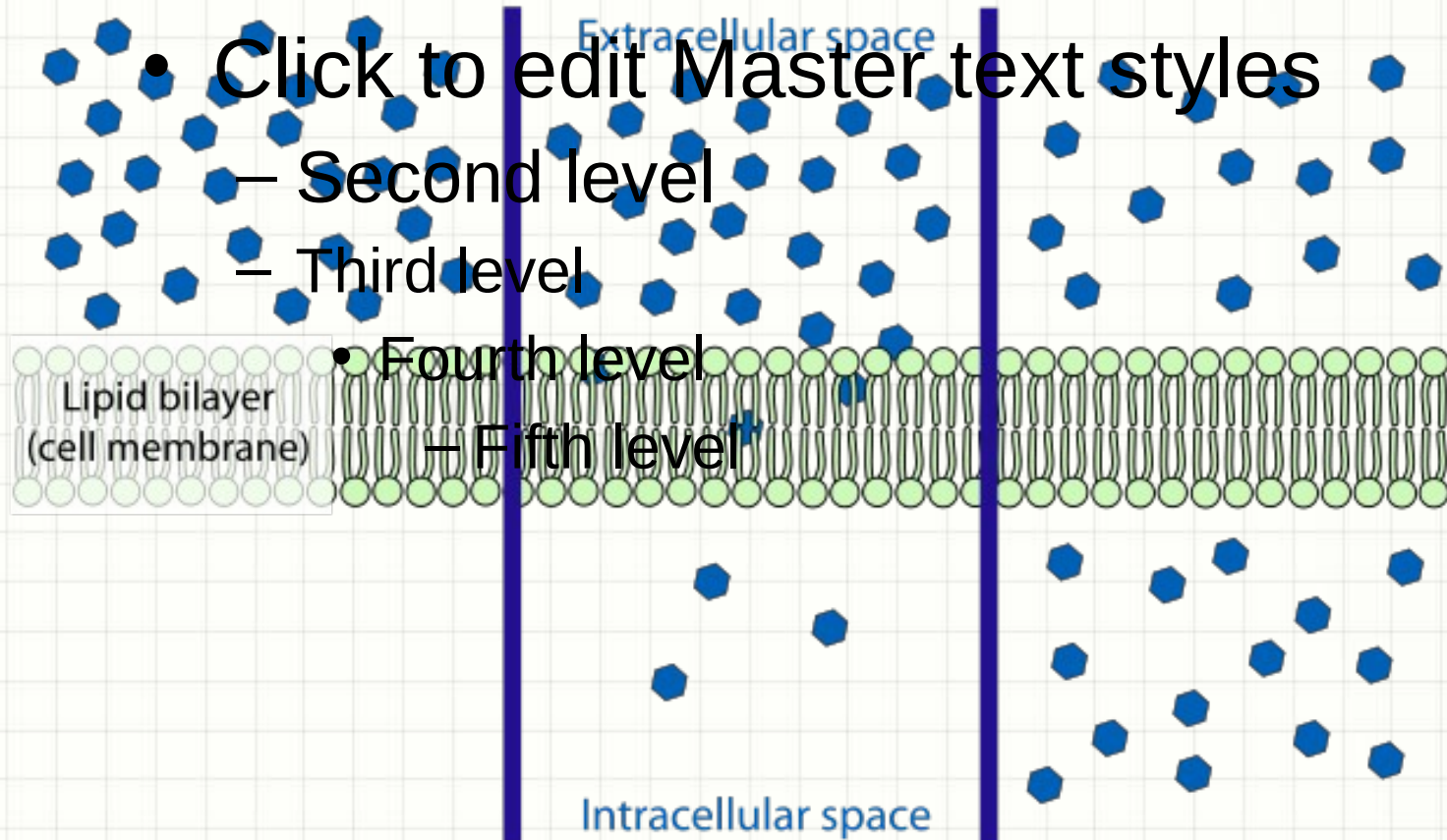


- prenos snovi skozi semipermeabilne membrane določa razlika koncentracij topljenca
- neto pretok vedno poteka v smeri **s področja z višjo k področju z nižjo koncentracijo** topljenca
- energijsko ugoden proces (entropija narašča, prosta entalpija se povečuje)

prost prenos skozi biološke membrane:
maščobne kisline, CO₂, N₂, O₂, CH₄

Difuzija skozi fosfolipidni dvosloj

1. Prenos topljenca iz zunajceličnega vodnega okolja v hidrofobno notranjost
2. Difuzija skozi hidrofobno fosfolipidno plast
3. Prenos topljenca v notranjost celice – vodno okolje



Difuzija skozi membrane

1. Fickov zakon, predpostavljeno ravnotežje na fazni meji: $\vec{J}_A = -D_{AB} \cdot \nabla C_A$

$$J = \frac{\dot{W}}{A} = P \cdot (c_a - c_b) = \frac{D_{mem}}{d_{mem}} K_p (c_a - c_b)$$

J snovni fluks komponente v celico [mol/m² s]

\dot{W} molski tok [mol/s]

A površina [m²]

P koeficient permeabilnosti [m/s]

D_{mem} difuzivnost komponente v membrani [m²/s]

d_{mem} debelina membrane [m]

$K_p = \frac{c_{mem}^*}{c_{voda}^*}$ porazdelitveni koeficient za komponento v sistemu membrana/voda

c_a koncentracija izven celice (abiotska faza) [mol/m³]

c_b koncentracija v citoplazmi (biotska faza) [mol/m³]

$$P = \frac{D_{mem} K_p}{d_{mem}}$$

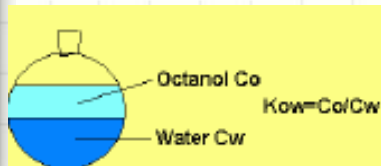
Koeficient permeabilnosti in Kp

Koeficient permeabilnosti

$$P = \frac{D_{mem} K_p}{d_{mem}}$$

Porazdelitveni koeficient

$$K_p = \frac{c_{mem}}{c_{voda}^*}$$



Compound	Permeability coefficient P (cm s ⁻¹)	Partitioning coefficient K_p
Carbon dioxide	4.5×10^{-1}	
Bicarbonate	1.9×10^{-7}	
Water	6.6×10^{-4}	
Urea	2.8×10^{-7}	1.5×10^{-4}
Methanol	2.5×10^{-4}	
Ethanol	1.4×10^{-4}	
Ethenediol	1.7×10^{-5}	4.9×10^{-4}
1,2-Propanediol		1.7×10^{-3}
1,4-Butanediol		2.1×10^{-3}
Formic acid		1.5×10^{-2}
Acetic acid		3.0×10^{-2}
Propionic acid		1.5×10^{-1}
Butyric acid		4.4×10^{-1}
Acetamide	1.4×10^{-5}	8.3×10^{-4}
Formamide	2.0×10^{-5}	7.6×10^{-4}
Lactamide	1.5×10^{-6}	
Butyramide	5.0×10^{-5}	
Glucose	5.0×10^{-8}	
Glycerol	2.0×10^{-7}	7.0×10^{-5}

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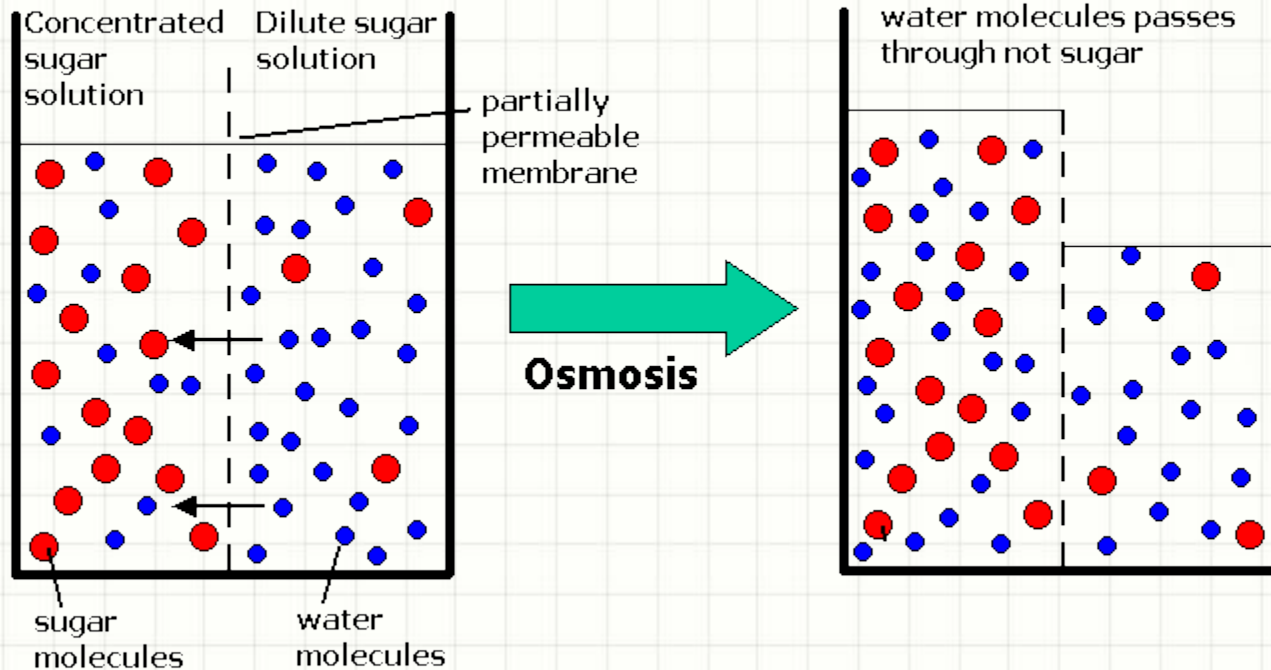
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Table 2.3. Permeability coefficients for compounds in membranes of the plant cell *Chara ceratophylla* and the olive oil-water partitioning coefficient. To evaluate the permeability of other compounds one may use certain rough measures of how chemical groupings on a permeant can be expected to affect the membrane permeability (Stein, 1990): An extra hydroxyl group on the molecule decreases the permeability 100- or 1000-fold. A carboxyl group has an even larger effect. An extra amide group is more or less equivalent to two extra hydroxyl groups. Conversely, an extra methyl group in the compound is likely to increase the permeability five-fold, while a doubling of molecular volume decreases the permeability 30-fold.

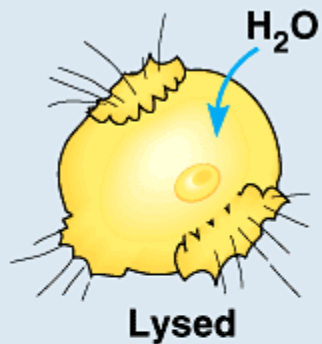
Difuzija vode - osmoza

- Difuzija vode preko semipermeabilne membrane s područja više koncentracije vode na područje s nižom koncentracijom vode

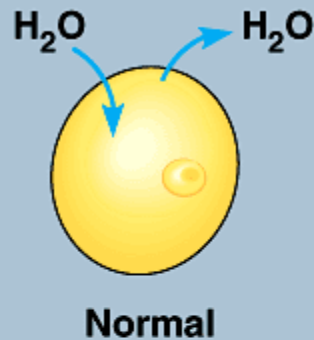


Hipertonična, izotonična in hipotonična raztopina

Hypotonic solution



Isotonic solution

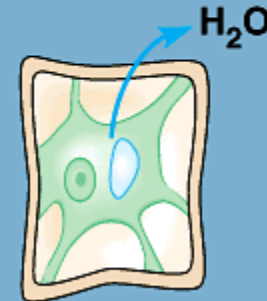
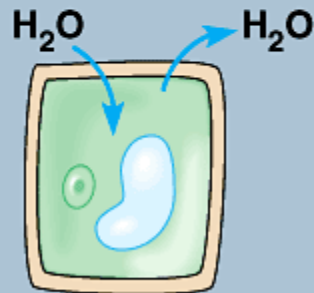
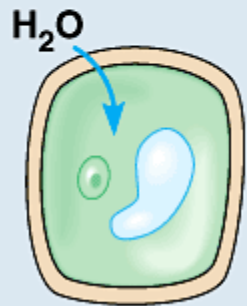


Hypertonic solution



Animal cell

Izotonična
raztopina 0,9 %
NaCl (9 g/L)



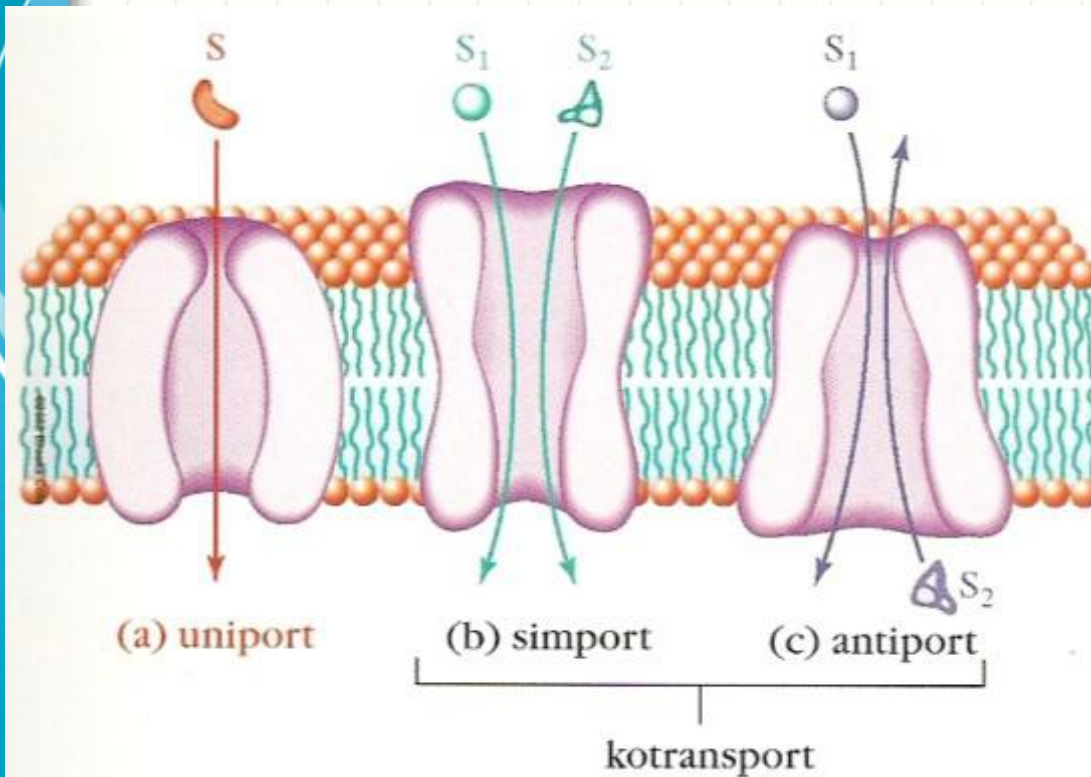
Plant cell

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Hipotonična raztopina je raztopina z nižjim osmotskim tlakom od vsebine celic, krvne plazme, medcelične tekočine. Primer: destilirana voda, raztopina NaCl s koncentracijo pod 5 g/L. Eritrociti bi v hipotonični raztopini popokali, ker bi šla voda iz celice v eritrocite.

Olajšana difuzija

- S pomočjo transportnih proteinov

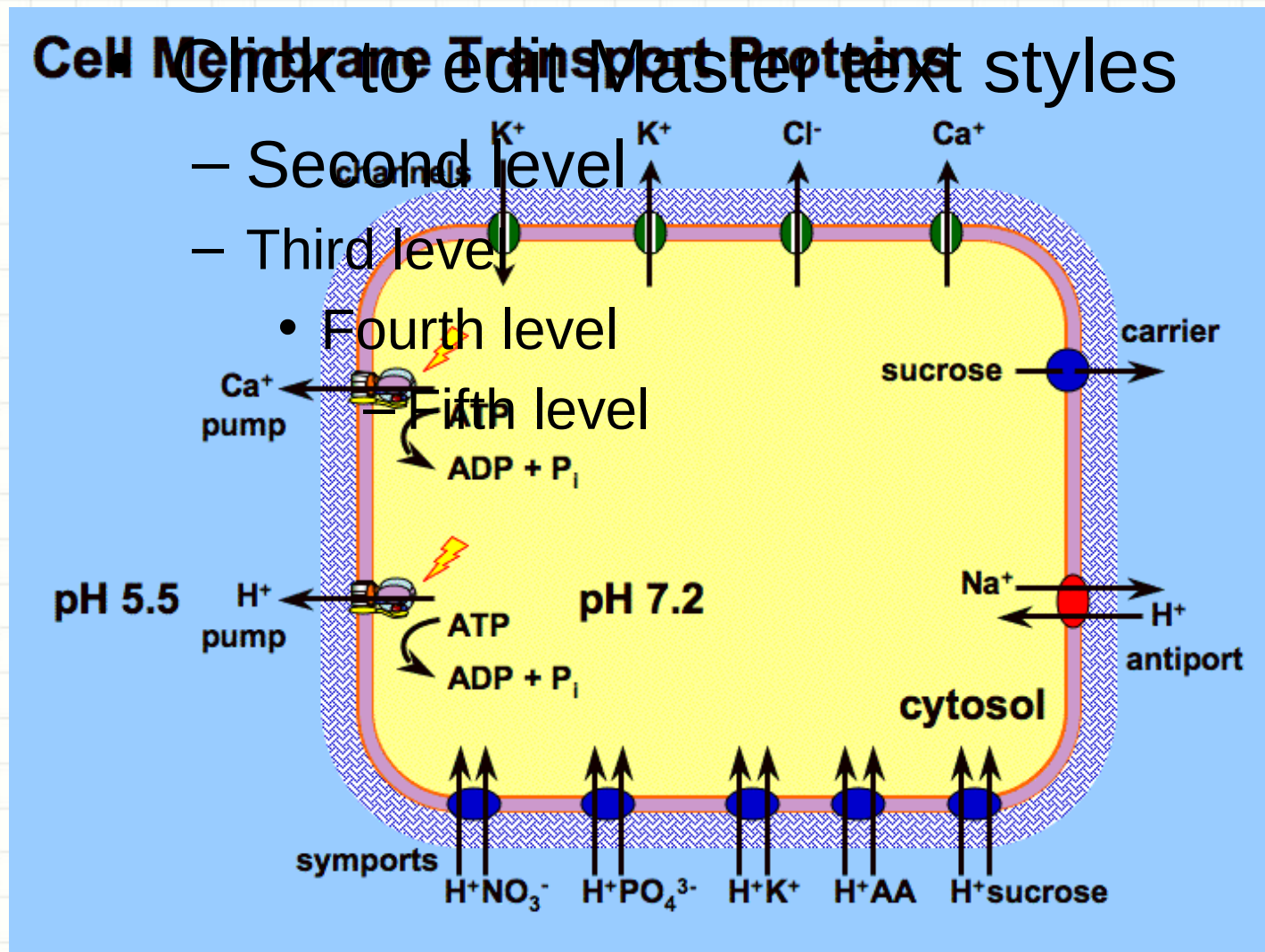


- uniport: prenos 1 vrste molekul topljenca
- simport: prenos 2 vrst molekul topljenca v isto smer
- antiport: prenos 2 vrst molekul topljenca v nasprotno smer

- **permeaze**: proteini, ki omogočajo prenos snovi s konformacijsko spremembo
- **akvaporini**: proteini, ki omogočajo prenos vode

aktivni ali pasivni transport: odvisno od energijskih razmer

Transportni proteini v membranah

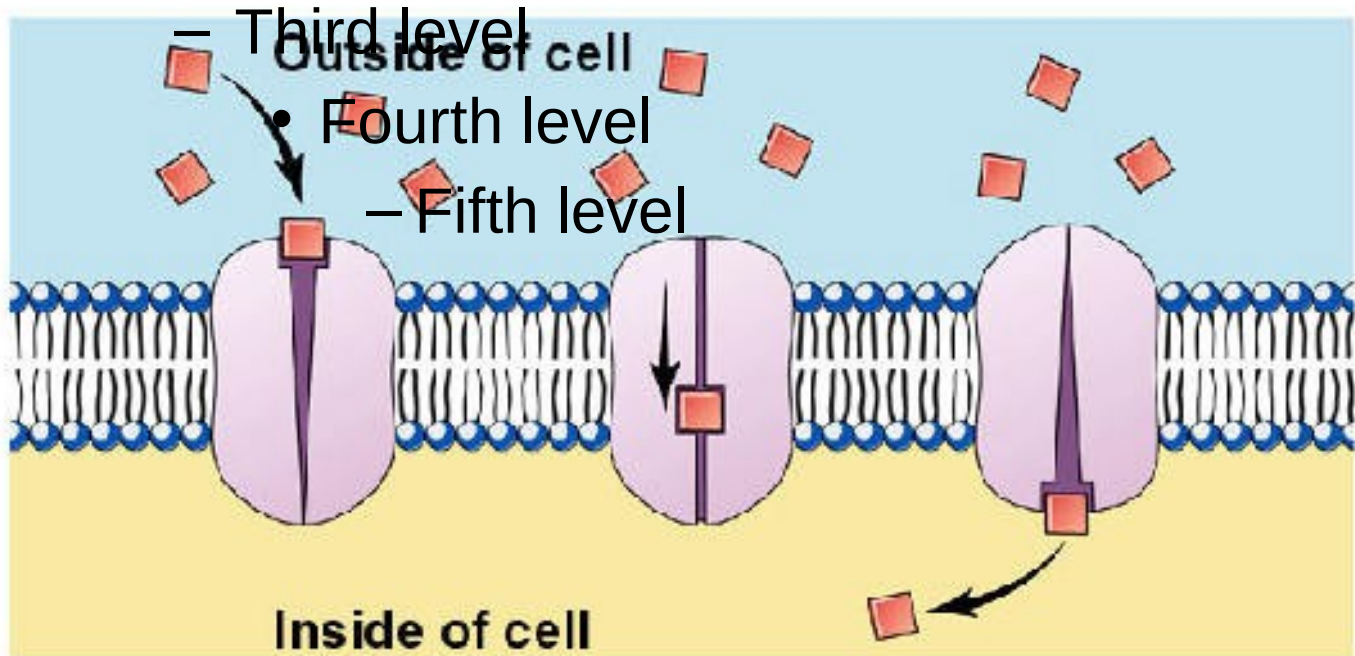


Olajšana difuzija: uniport

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Facilitated Diffusion



Olajšana difuzija

- Proteini:

- Kanalčki: prenos ionov v smeri gradienta (konc. ali el.)

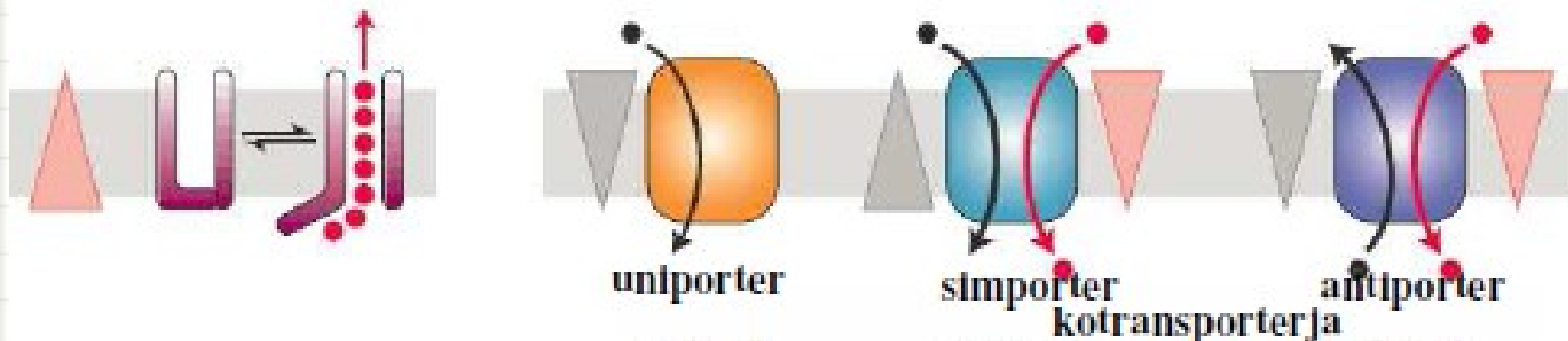
- Transporterji: prenos povezan s konformacijsko spremembo proteina

kanalčki

(10^7 – 10^8 ions/s)

transporterji

(10^2 – 10^4 molecules/s)



Primer: glukoza-permeaza

prenos glukoze skozi membrane eritrocitov

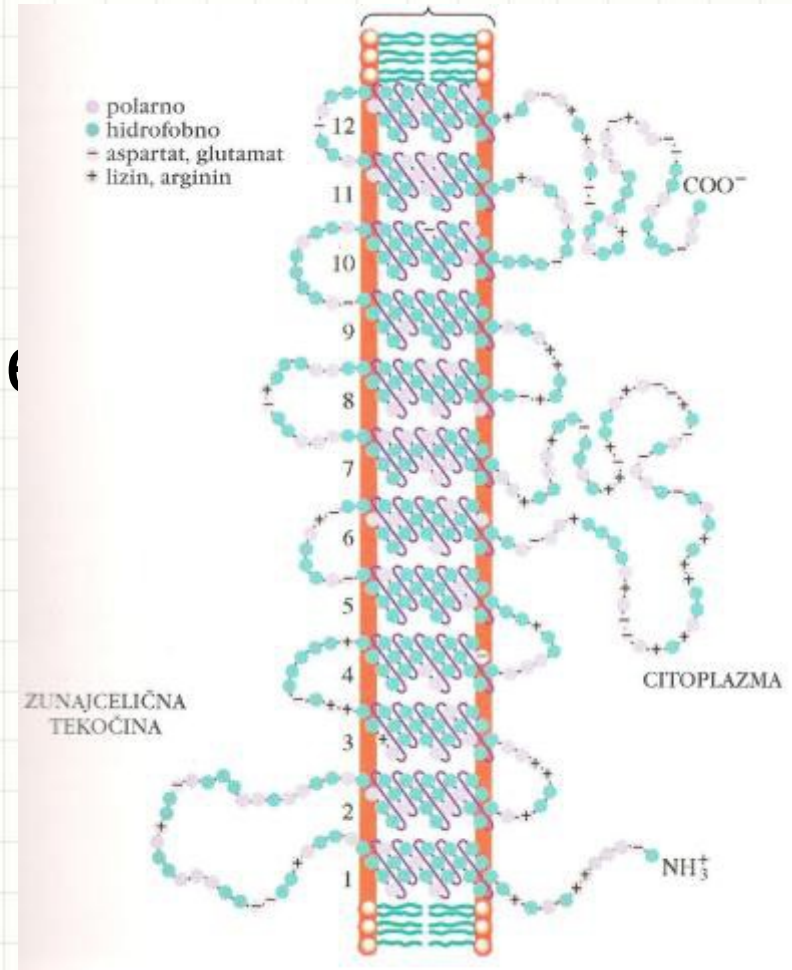
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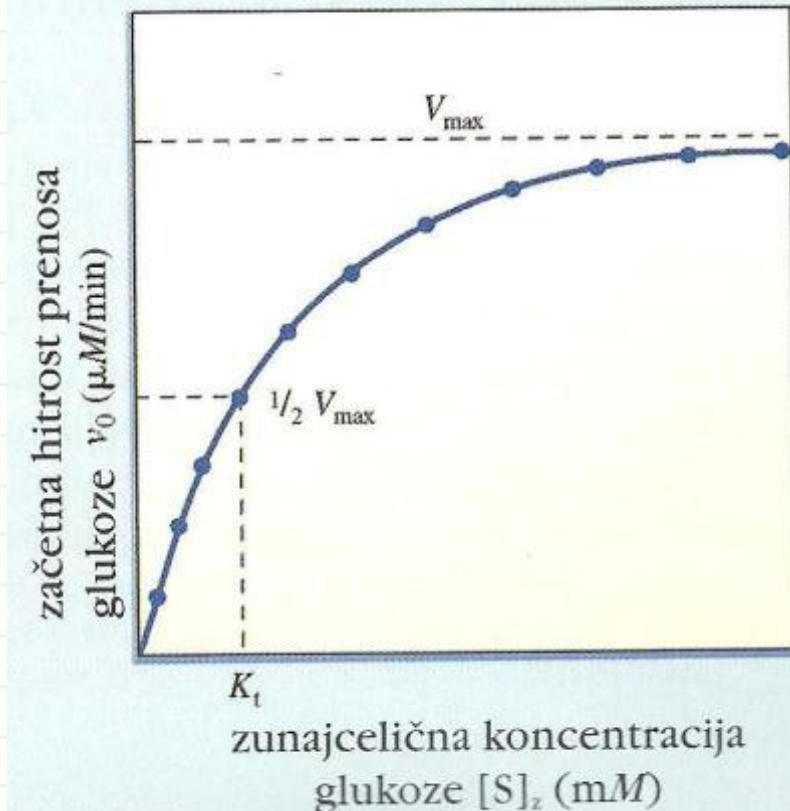
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492 AK: 12 hidrofobnih
+ 13 hidrofilnih področij

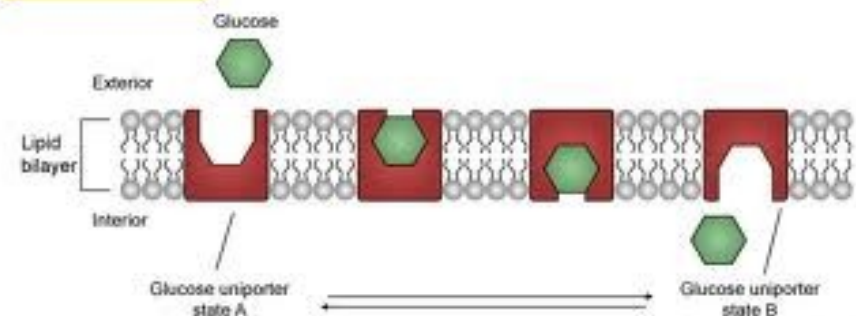
Transport skozi membrane z olajšano difuzijo - kinetika

Primer: glukoza-permeaza v membrani eritrocita



- Hitrost transporta bistveno višja kot samo z difuzijo (ni koeficienta permeabilnosti)
- Podobnost z encimsko kinetiko, le da se substrat tu ne spremeni
- 3 stopnje:
 - Vežava glukoze na specifično mesto na zunajcelični strani proteina
 - Prehod glukoze skozi kanal
 - Sproščanje glukoze na citoplazemski strani

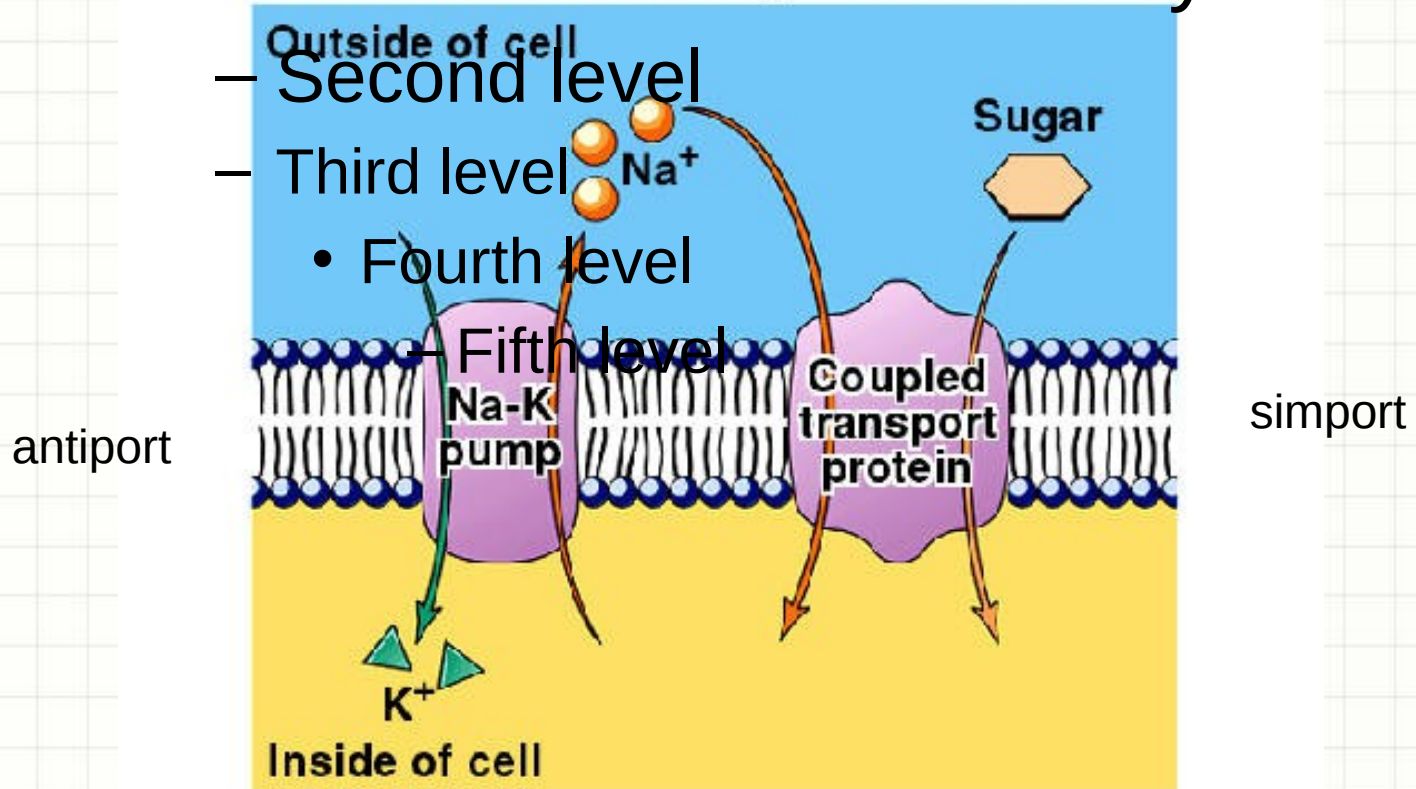
Facilitated Diffusion



Olajšana difuzija: kotransport

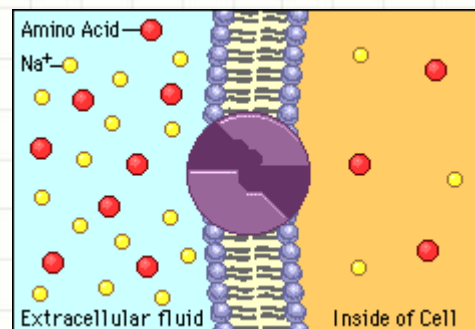
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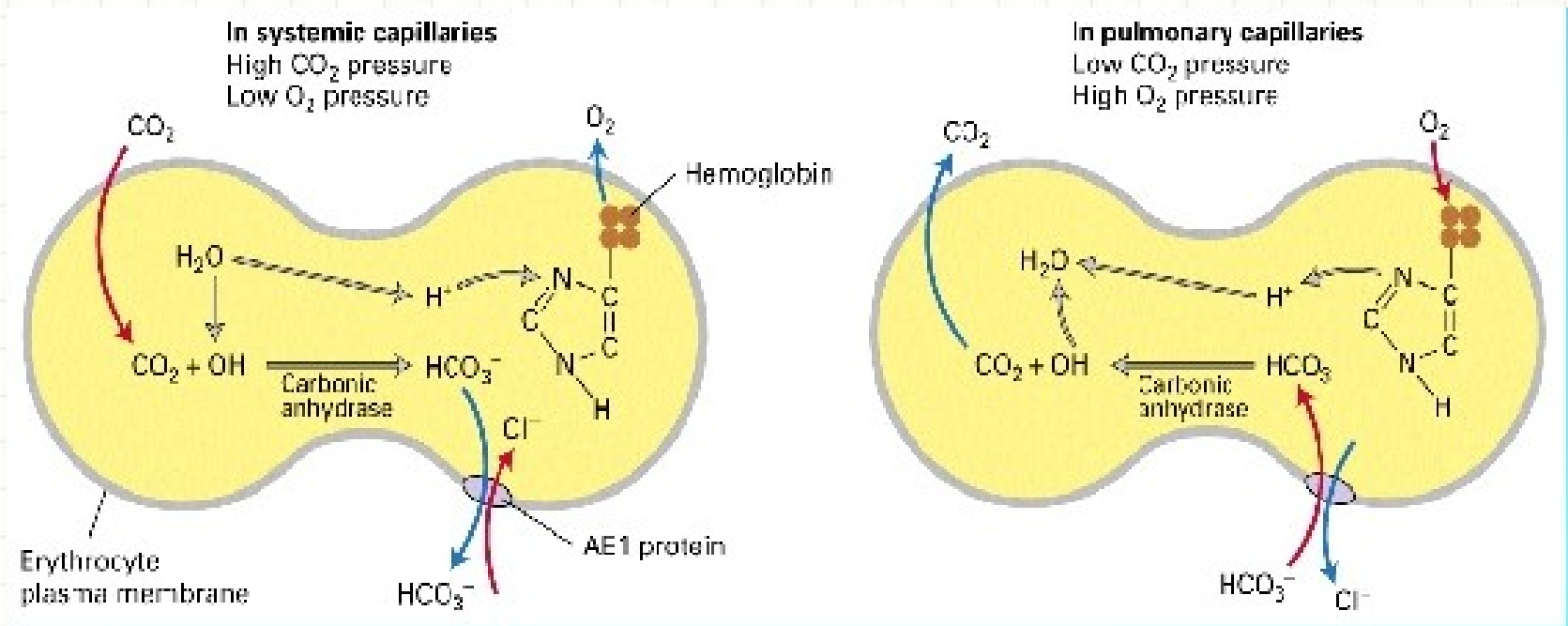
Kotransportni sistemi, ki jih poganjajo gradienti H⁺ ali Na⁺

Organism or tissue	Transported solute (moving against its gradient)	Cotransported solute (moving down its gradient)	Type of transport
<i>E. coli</i>	Lactose	H ⁺	Symport
	Proline	H ⁺	Symport
	Dicarboxylic acids	H ⁺	Symport
Intestine, kidney of vertebrates	Glucose	Na ⁺	Symport
	Amino acids	Na ⁺	Symport
Vertebrate cells (many types)	Ca ²⁺	Na ⁺	Antiport
Higher plants	K ⁺	H ⁺	Antiport
Fungi (<i>Neurospora</i>)	K ⁺	H ⁺	Antiport

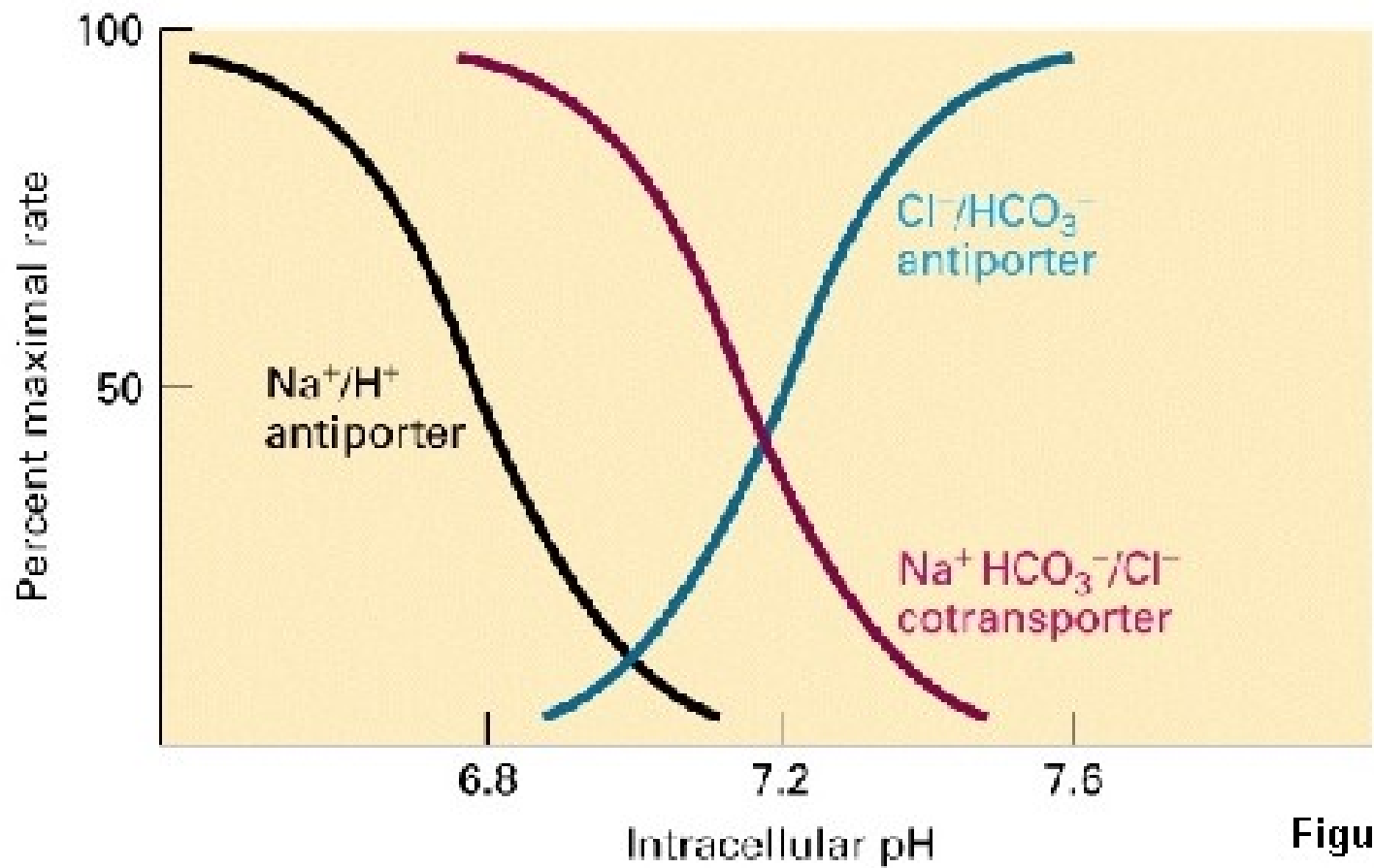


AE1 protein, Cl⁻/HCO₃⁻ antiporter

- Ključen za transport CO₂ z eritrociti



Številni kotransporterji uravnavajo pH citosola



Primer: ATP-sintaza

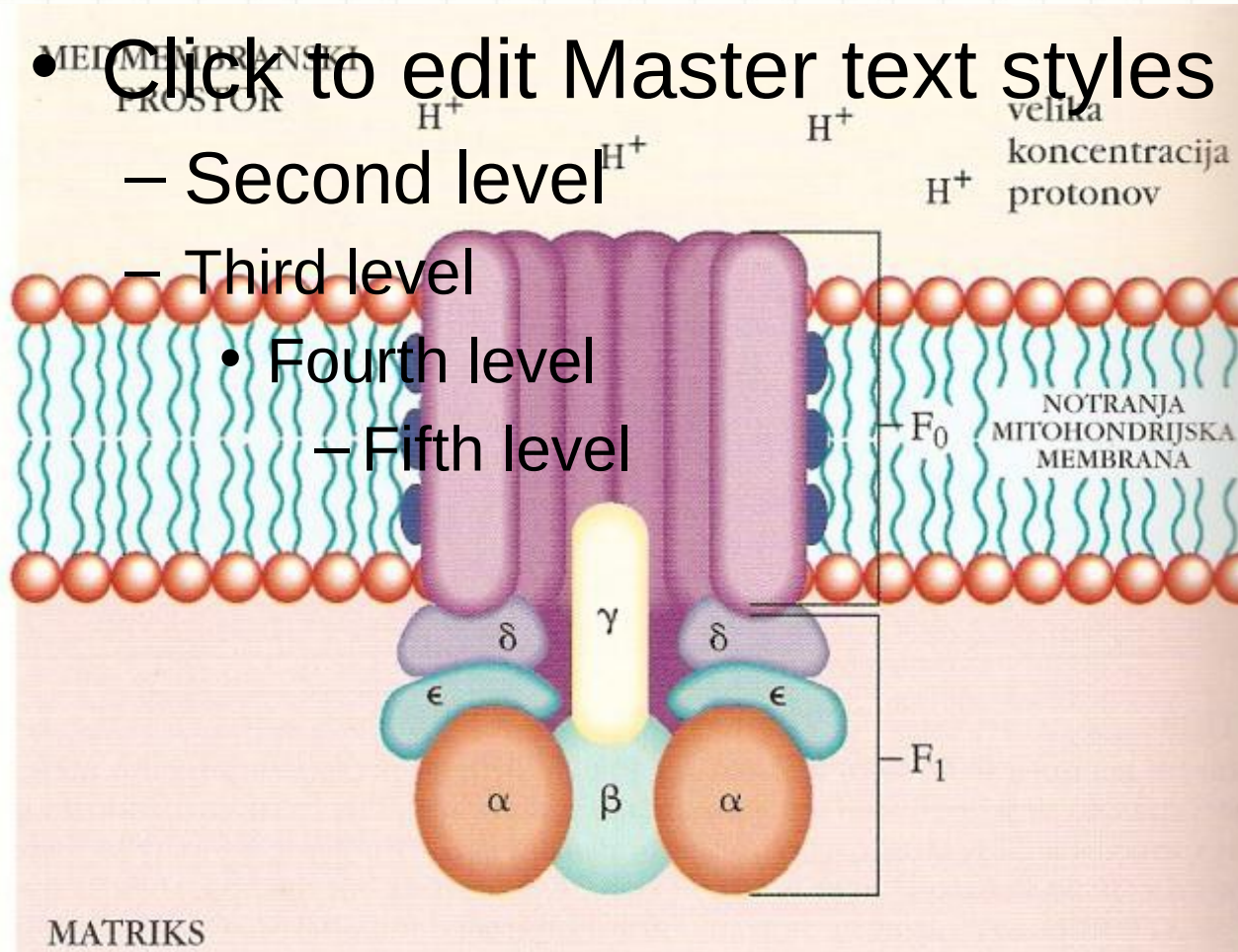
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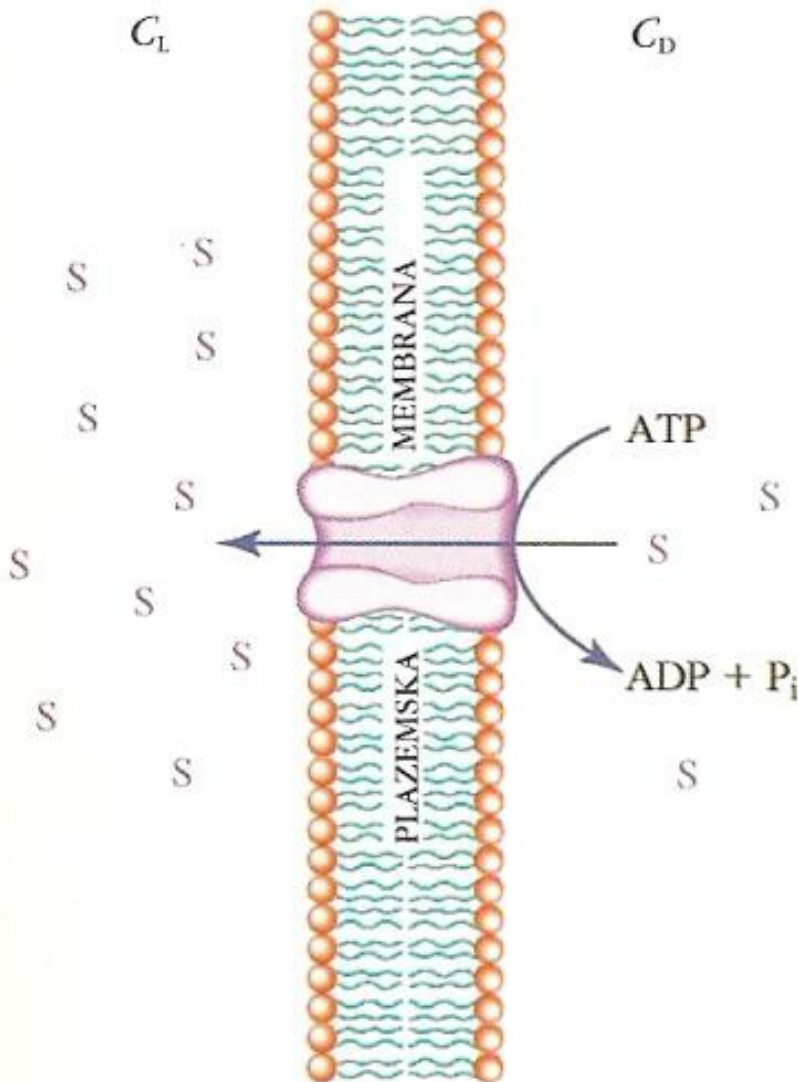
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Prenos H⁺

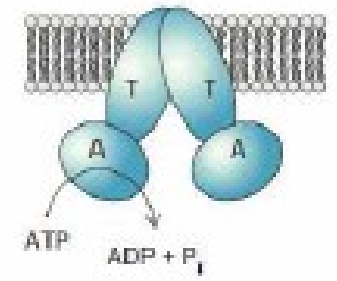
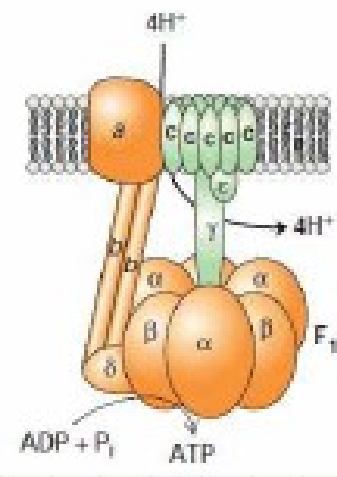
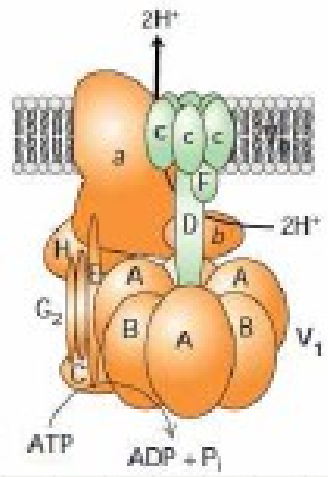
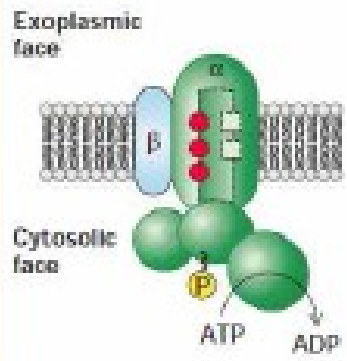
Nobelova nagrada 1997:
J. Walker in P. Boyer

Aktivni transport: zahteva ATP



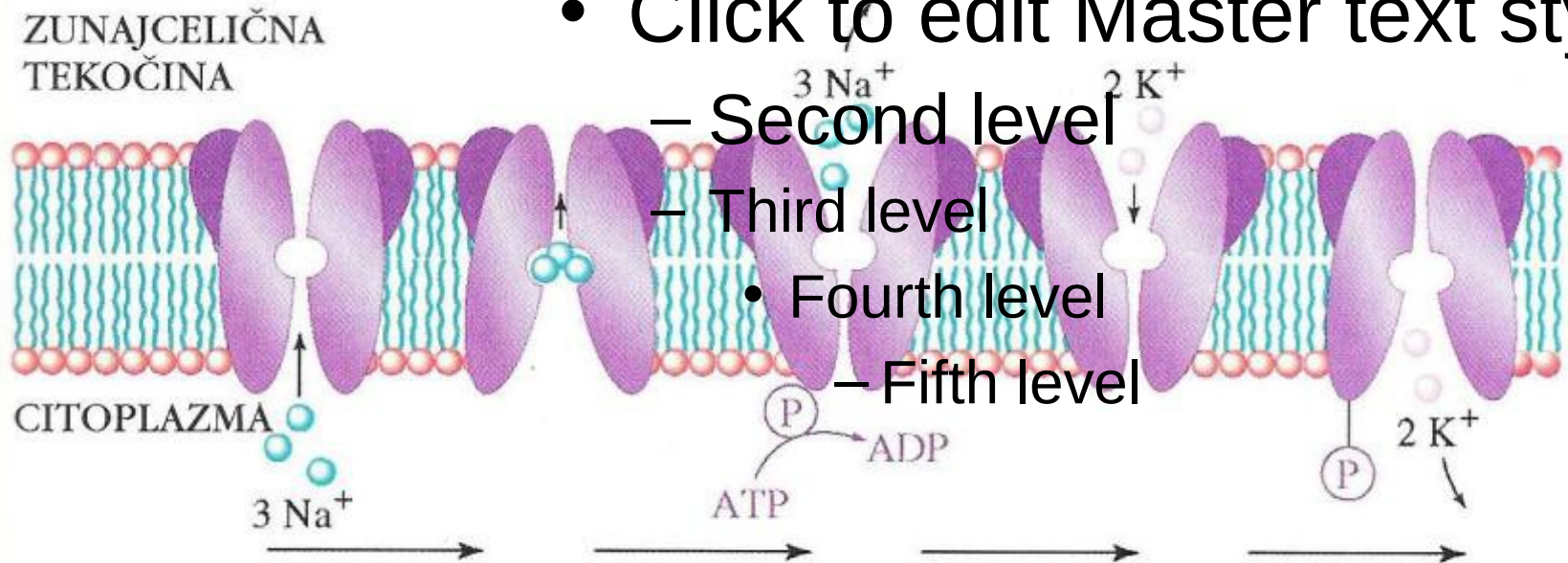
- prenos snovi topljenca s področja z **manjšo koncentracijo** na področje z **višjo koncentracijo**
- za to je potrebna energija: izvira iz cepitve fosfoanhidridne vezi v ATP ali iz svetlobne energije

4 tipi ATP-gnanih črpalk



Primer: Na⁺ / K⁺ -ATPazna črpalka

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1. stopnja

Trije Na⁺ se vežejo na citoplazemski strani prenašalnega proteina

3. stopnja

Dva K⁺ se vežeta na zunanjski strani prenašalnega proteina.

2. stopnja

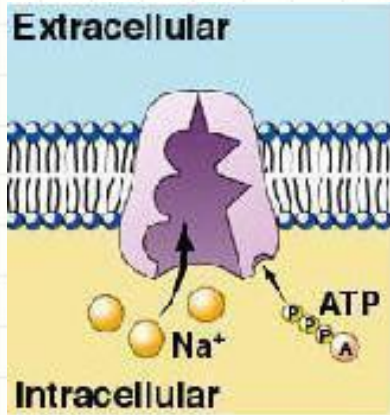
Encimsko katalizirana fosforilacija sproži konformacijsko spremembo, ki prečrpa tri Na⁺ na zunanjo stran celice.

4. stopnja

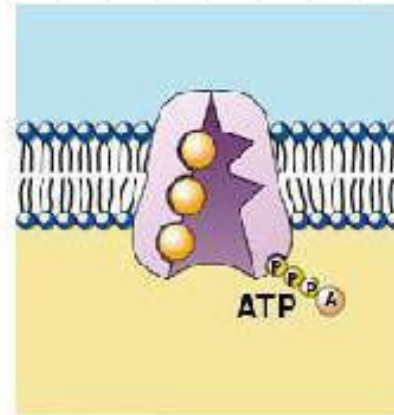
Encimsko katalizirana hidrolitična odcepitev fosfatne skupine vrne prenašalni protein v njegovo prvotno konformacijo in prečrpa dva K⁺ v celico.

$[Na^+]_{znotraj} < [Na^+]_{zunaj}$
12mM 145 mM

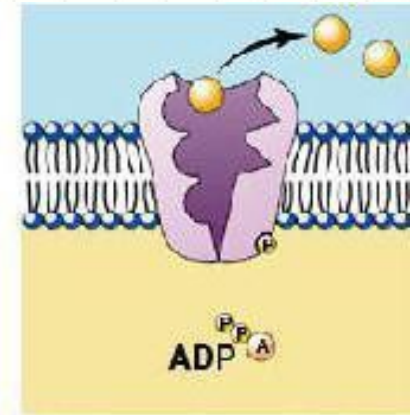
$[K^+]_{znotraj} > [K^+]_{zunaj}$
140 mM 4 mM



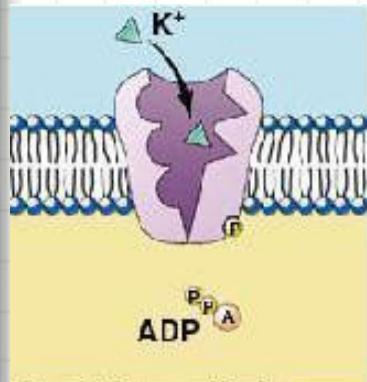
1. Protein in membrane binds intracellular sodium.



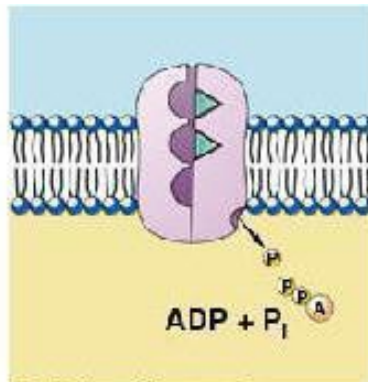
2. ATP phosphorylates protein with bound sodium.



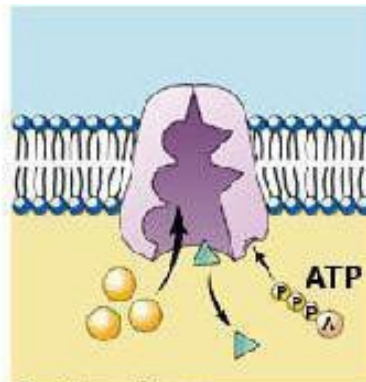
3. Phosphorylation causes conformational change in protein, allowing sodium to leave.



4. Extracellular potassium binds to exposed sites.



5. Binding of potassium causes dephosphorylation of protein.

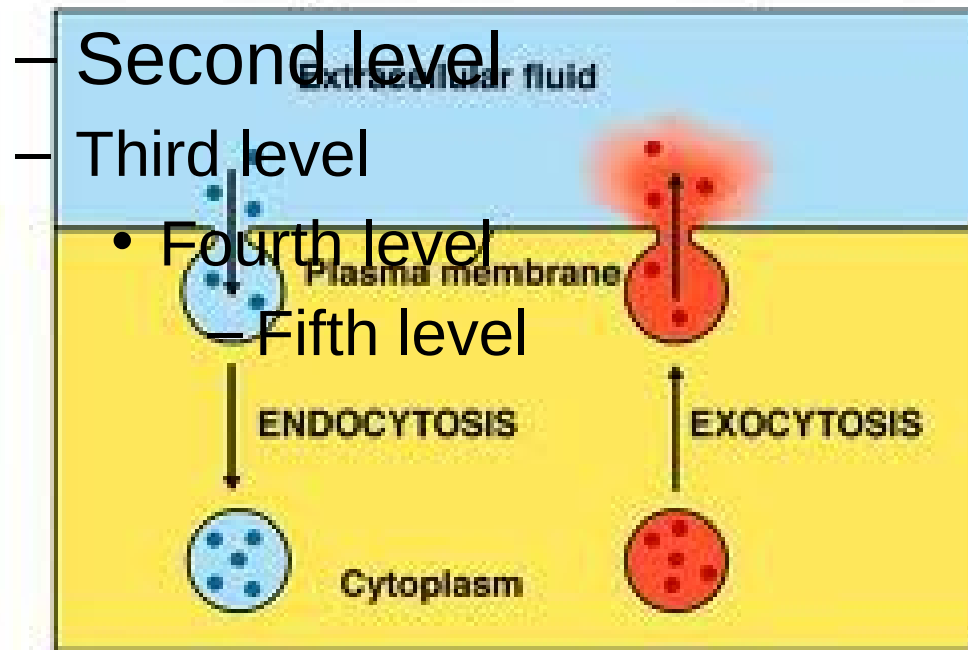


6. Dephosphorylation of protein triggers change back to original conformation, potassium moves into cell, and the cycle repeats.

Aktivni transport: endo-in eksocitoza

Yander/ Sherman/ Luciano/ Human Physiology, 7th edition, Copyright © 1998 McGraw-Hill Companies, Inc. All Rights Reserved.

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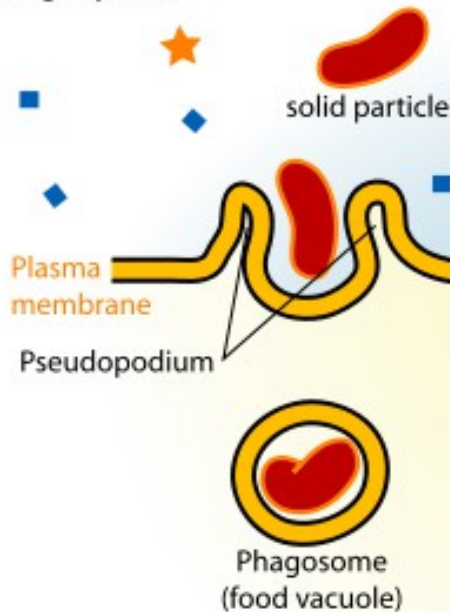
Endocitoza

Celice v glavnem uporabljajo tri tipe endocitoze:

1. **fagocitozo** (za požiranje manjših organizmov ali organskih delčkov),
2. **pinocitozo** (za vsrkavanje tekočin) in
3. **receptorsko vodeno endocitozo** (za sprejemanje specifičnih molekul, kot so lipoproteini).

Endocytosis

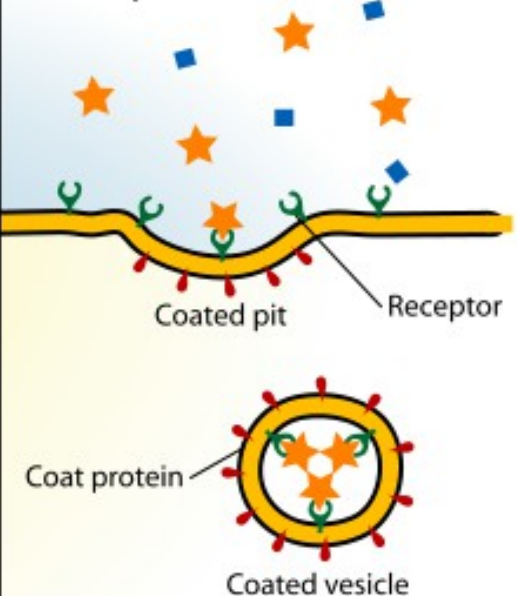
Phagocytosis



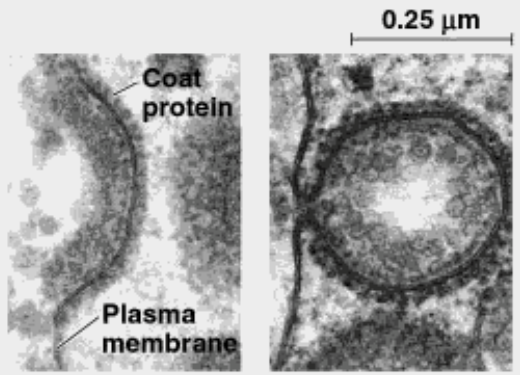
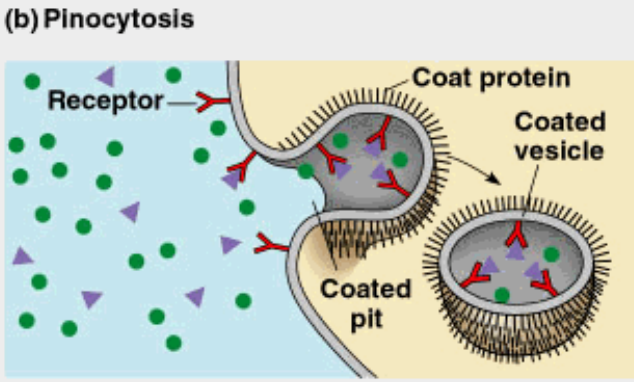
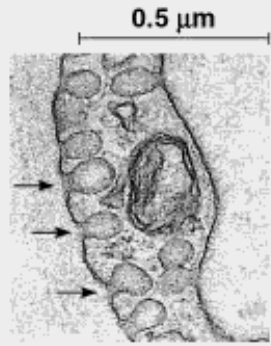
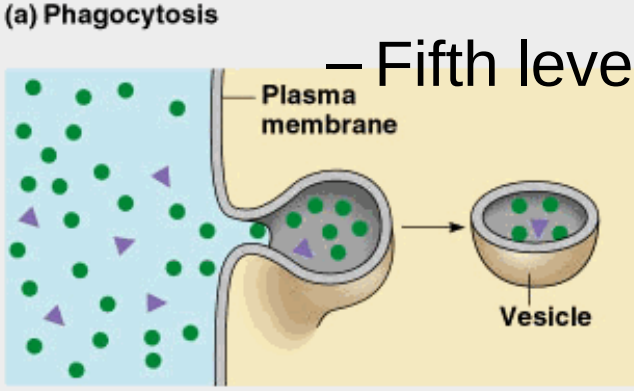
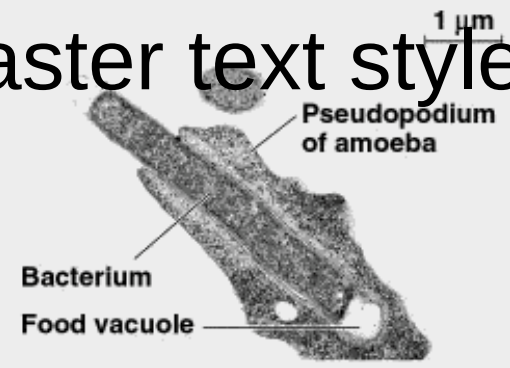
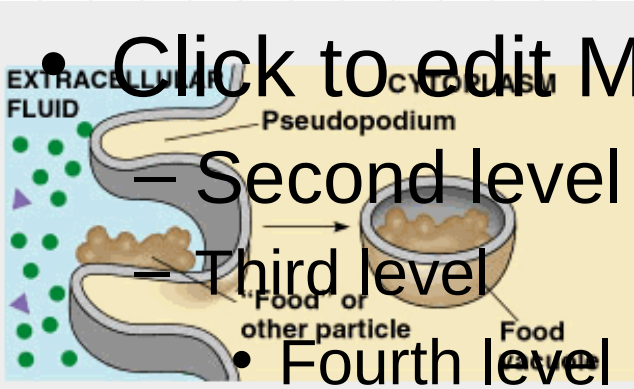
Pinocytosis



Receptor-mediated endocytosis



Endocytosis



Fagocitoza

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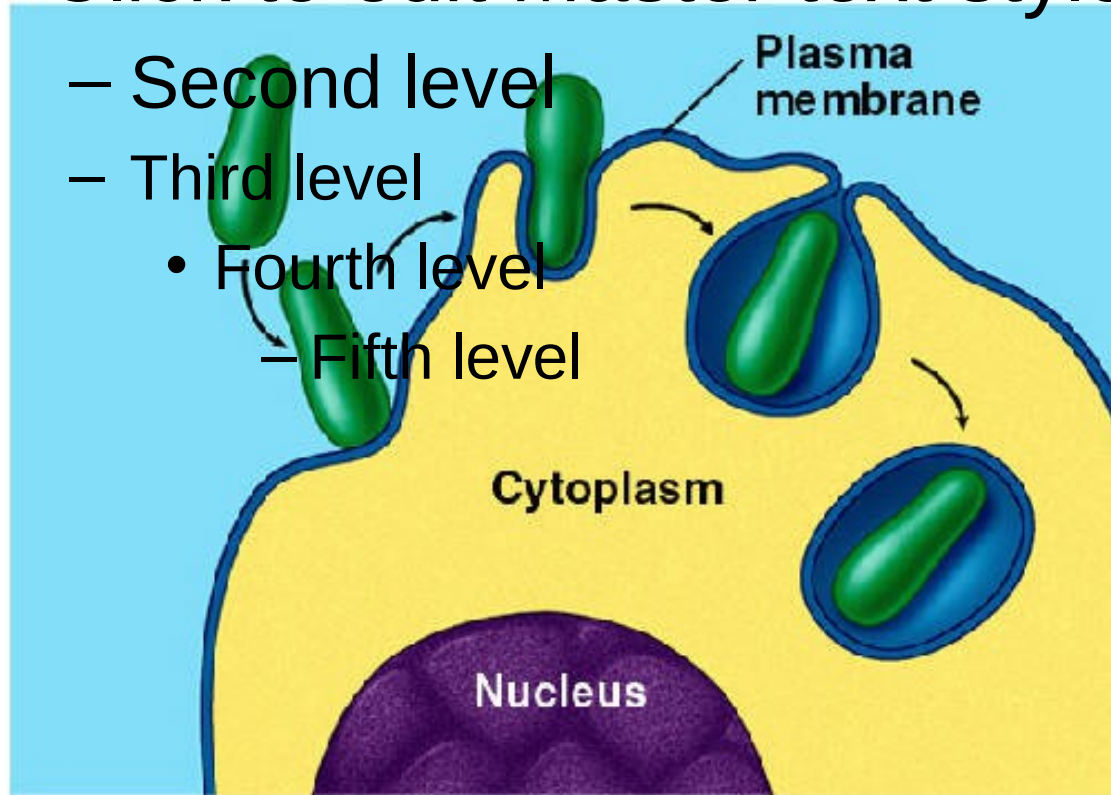
- **Endocytosis - Phagocytosis**
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- Second level

- Third level

- Fourth level

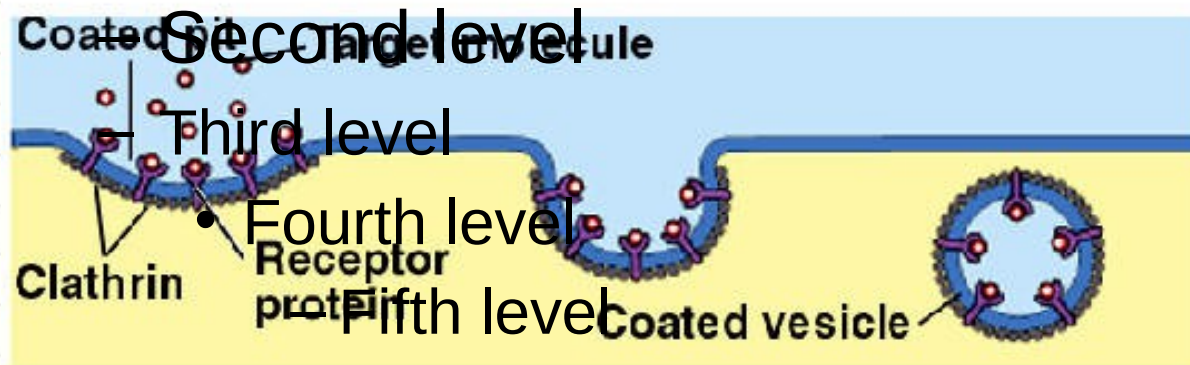
- Fifth level



Receptorsko vodena endocitoza

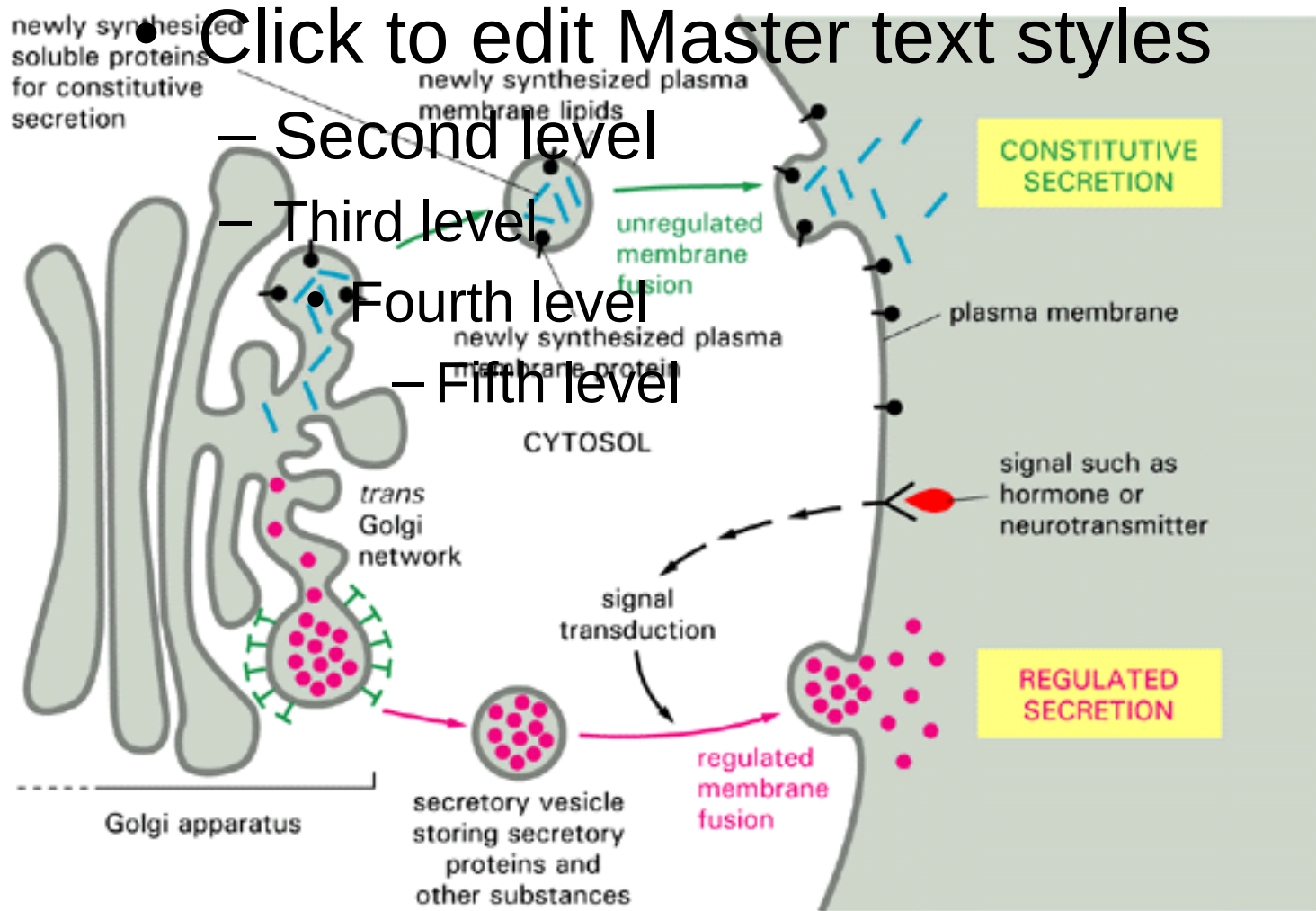
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Eksocitoza – izločanje snovi

konstitutivno in regulirano



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– Second level

– Third level

• Fourth level

– Fifth level