Sveučilište u Zagrebu
Prirodoslovno-matematički fakultet

143963 Animalna fiziologija

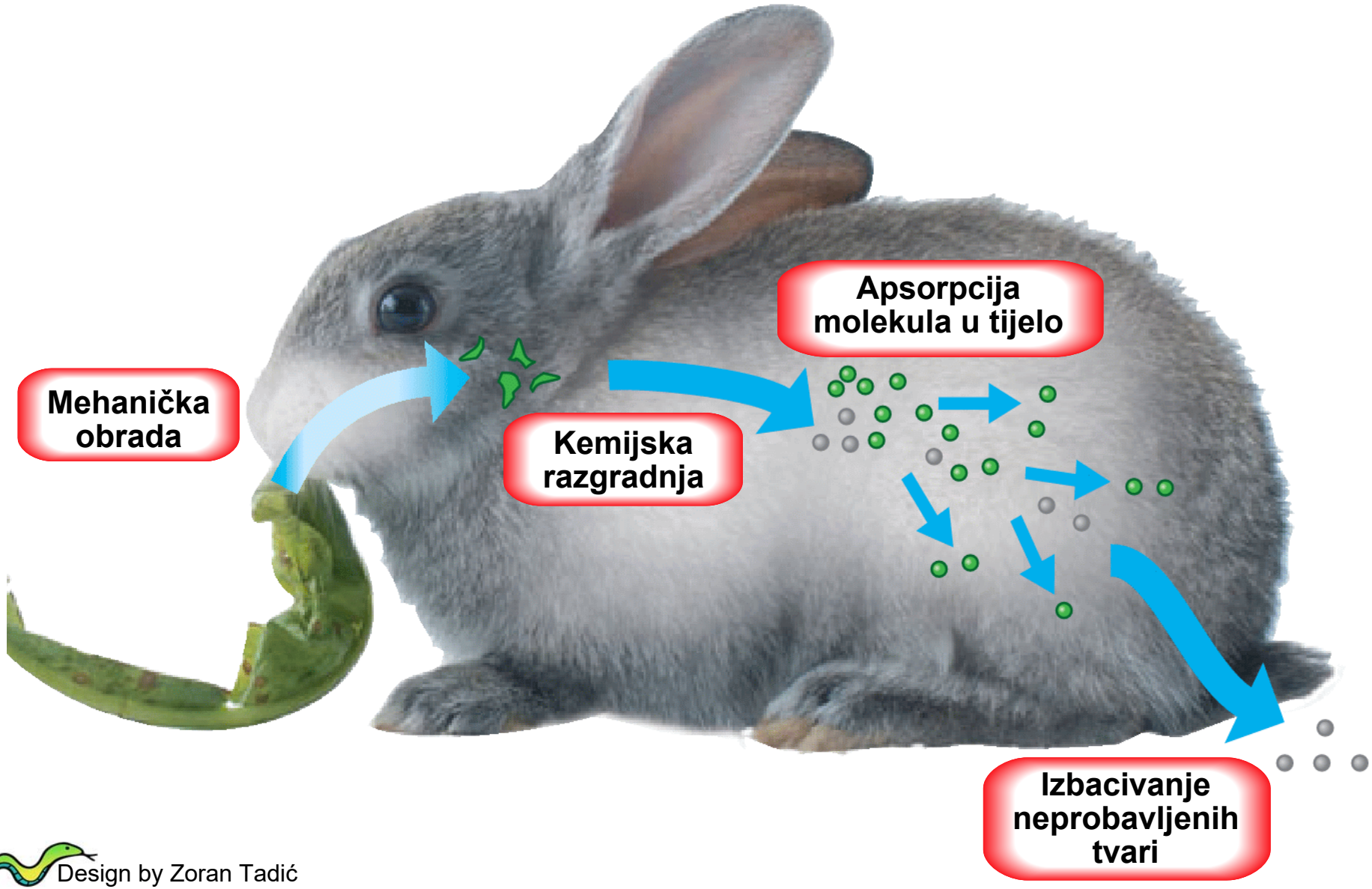
Probava

Zoran Tadić

Zavod za animalnu fiziologiju
Rooseveltov trg 6
Zagreb

ztadic@biol.pmf.hr
http://zaf.biol.pmf.unizg.hr/Tadic/

Zadaće probavnog sustava



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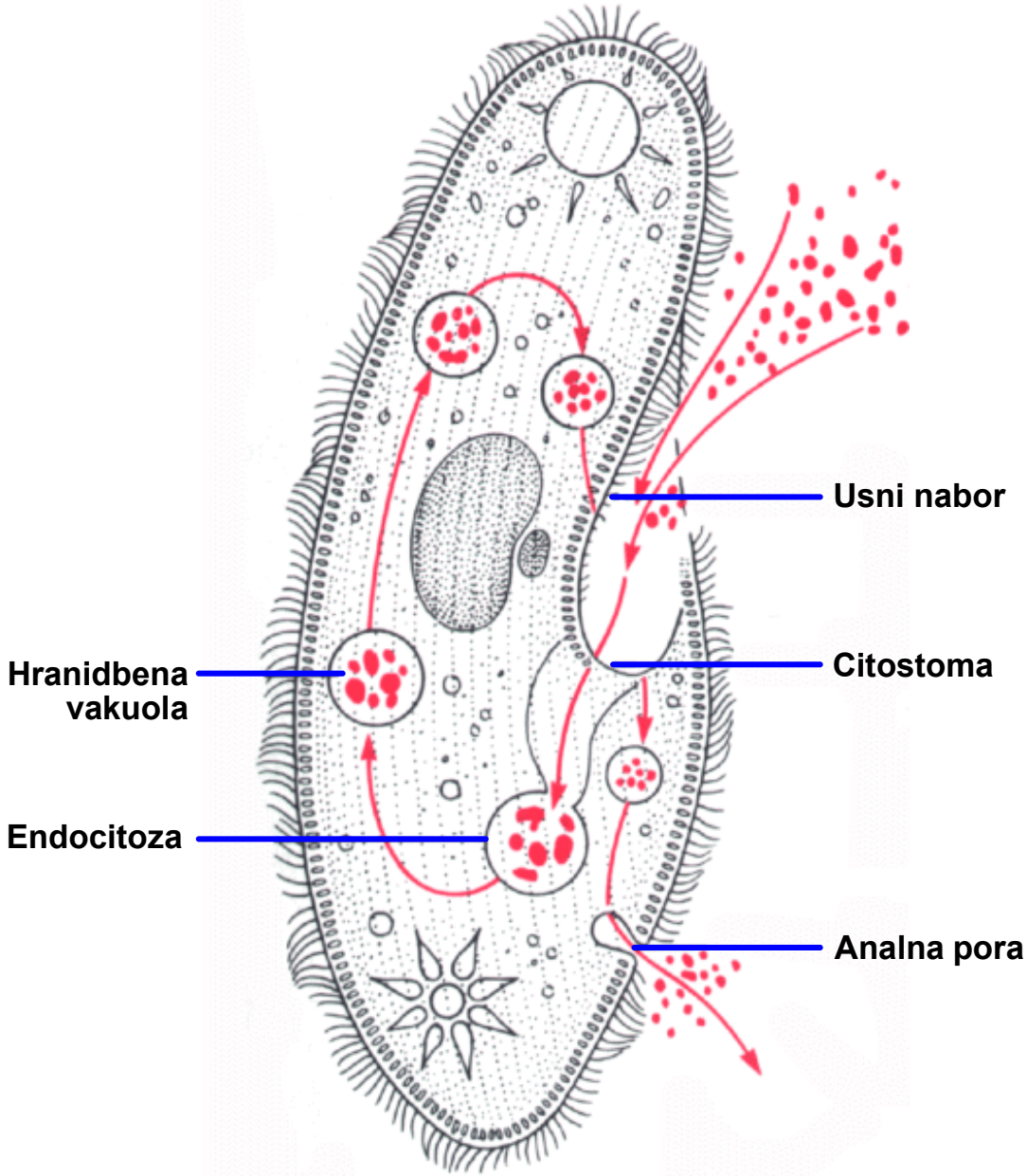
Probava u papučice



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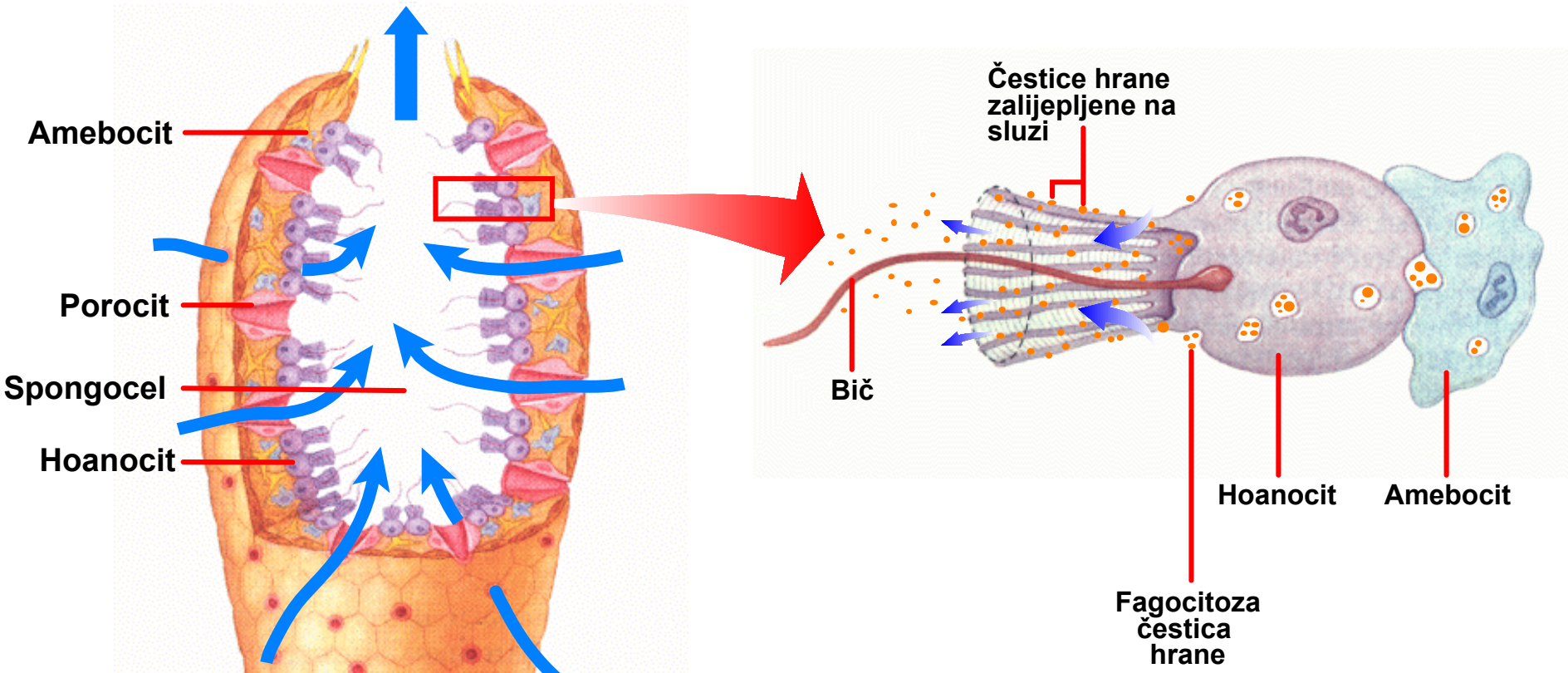
Probava u spužvi



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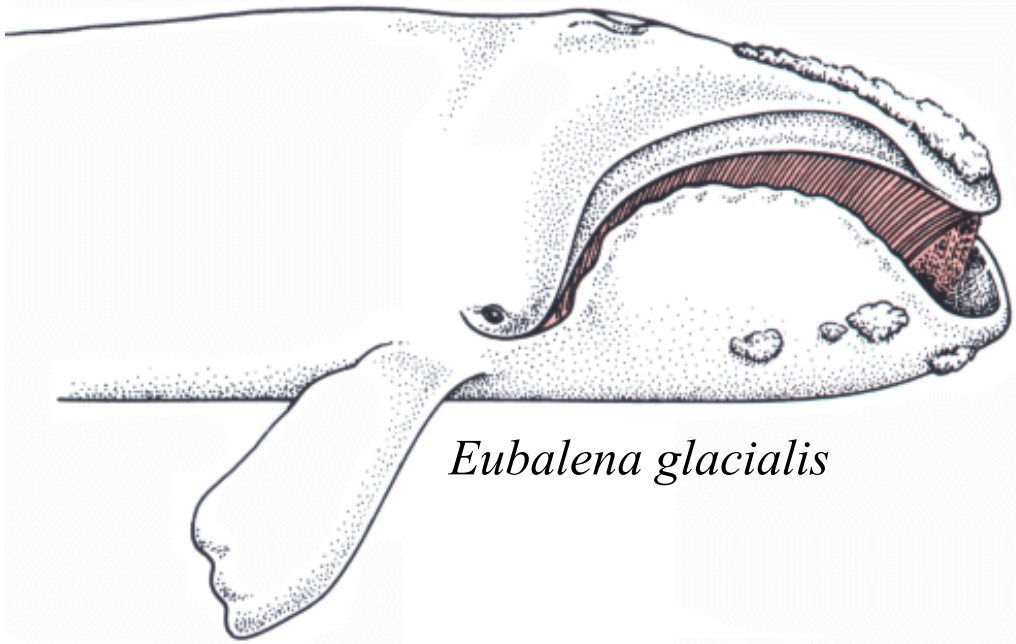
Hranjenje filtracijom u viših kralježnjaka



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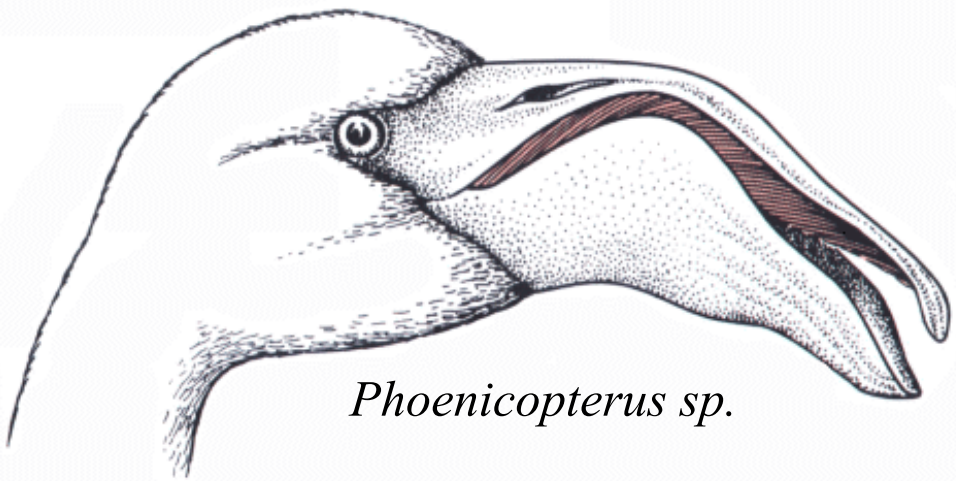

Phoenicopterus sp.

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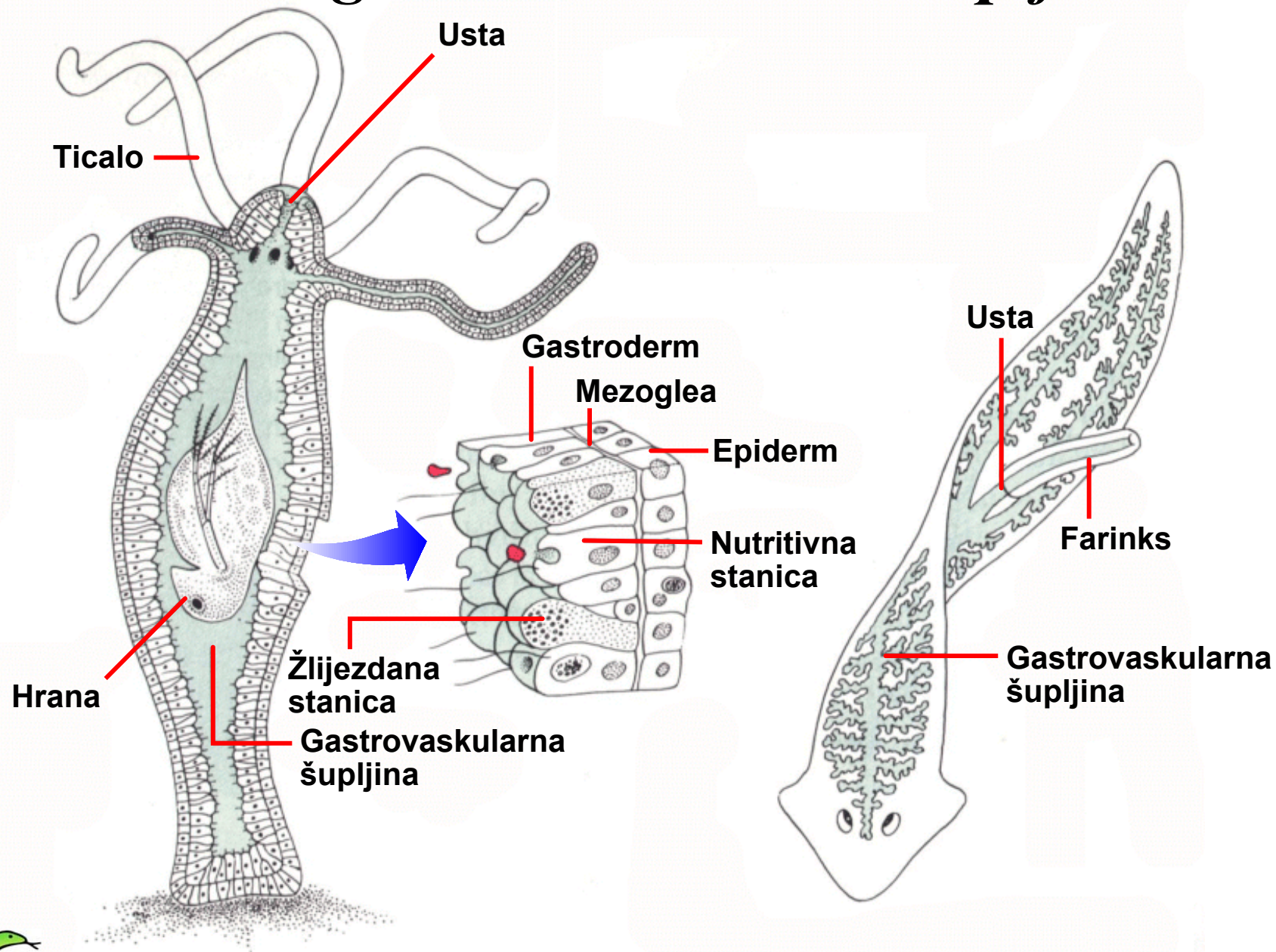
Probava u gastrovaskularnim šupljinama



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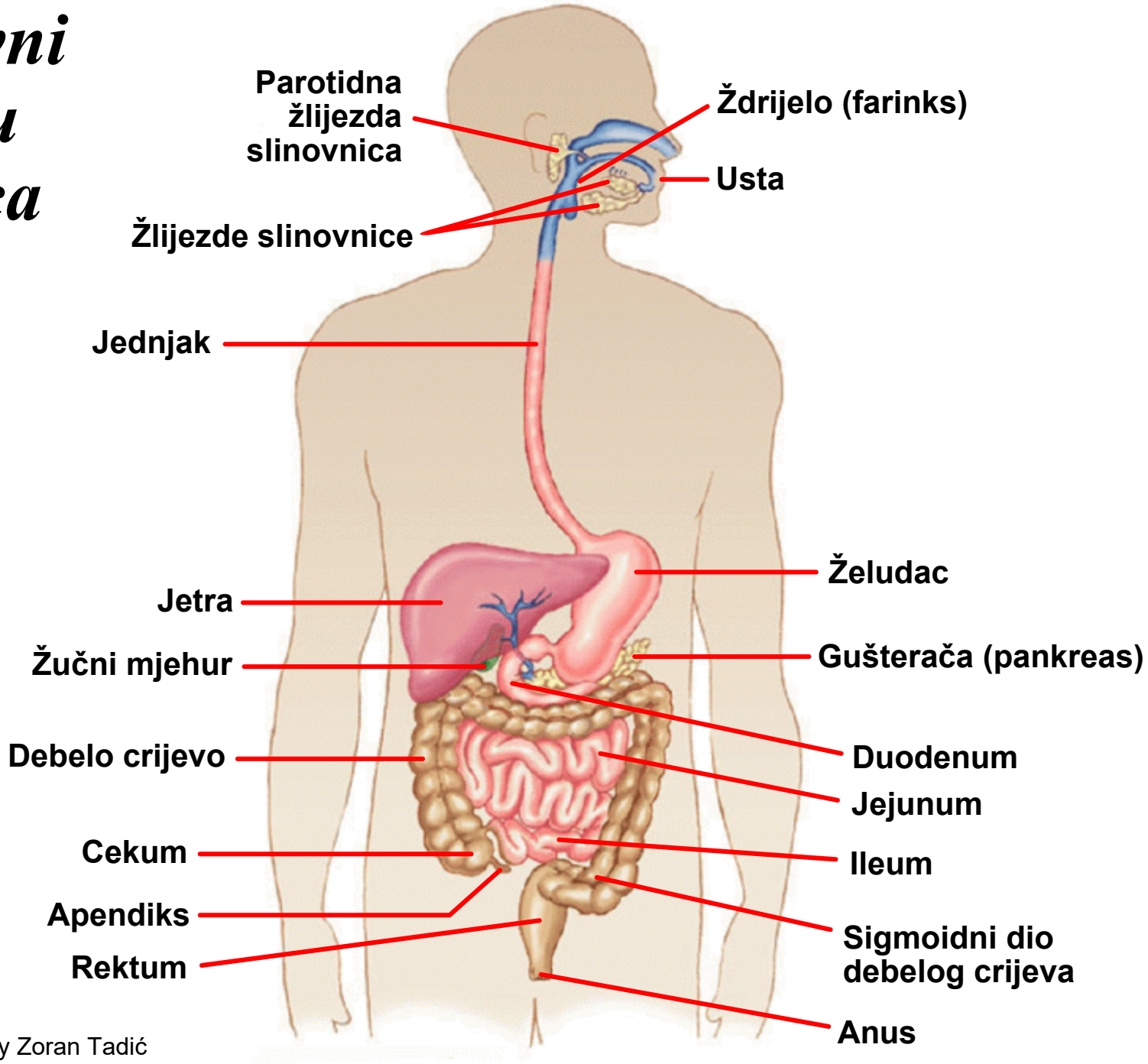
Probavni kanal u sisavaca



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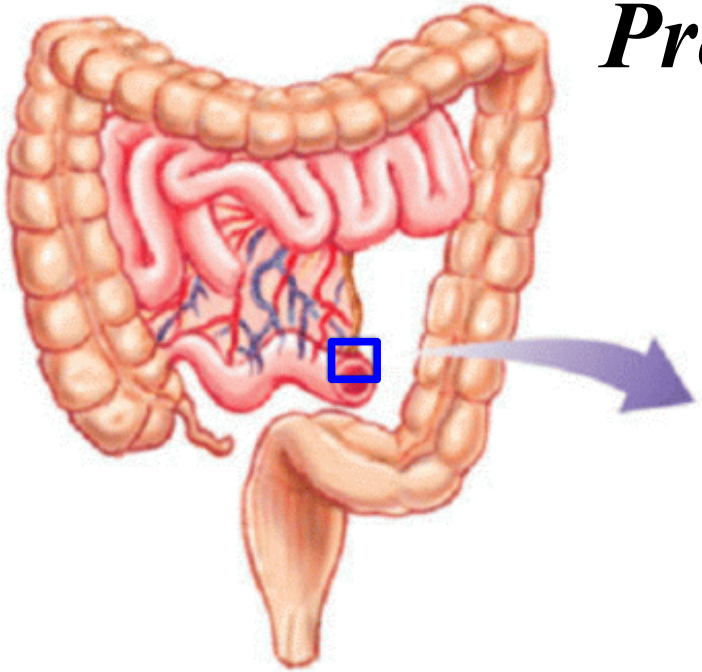
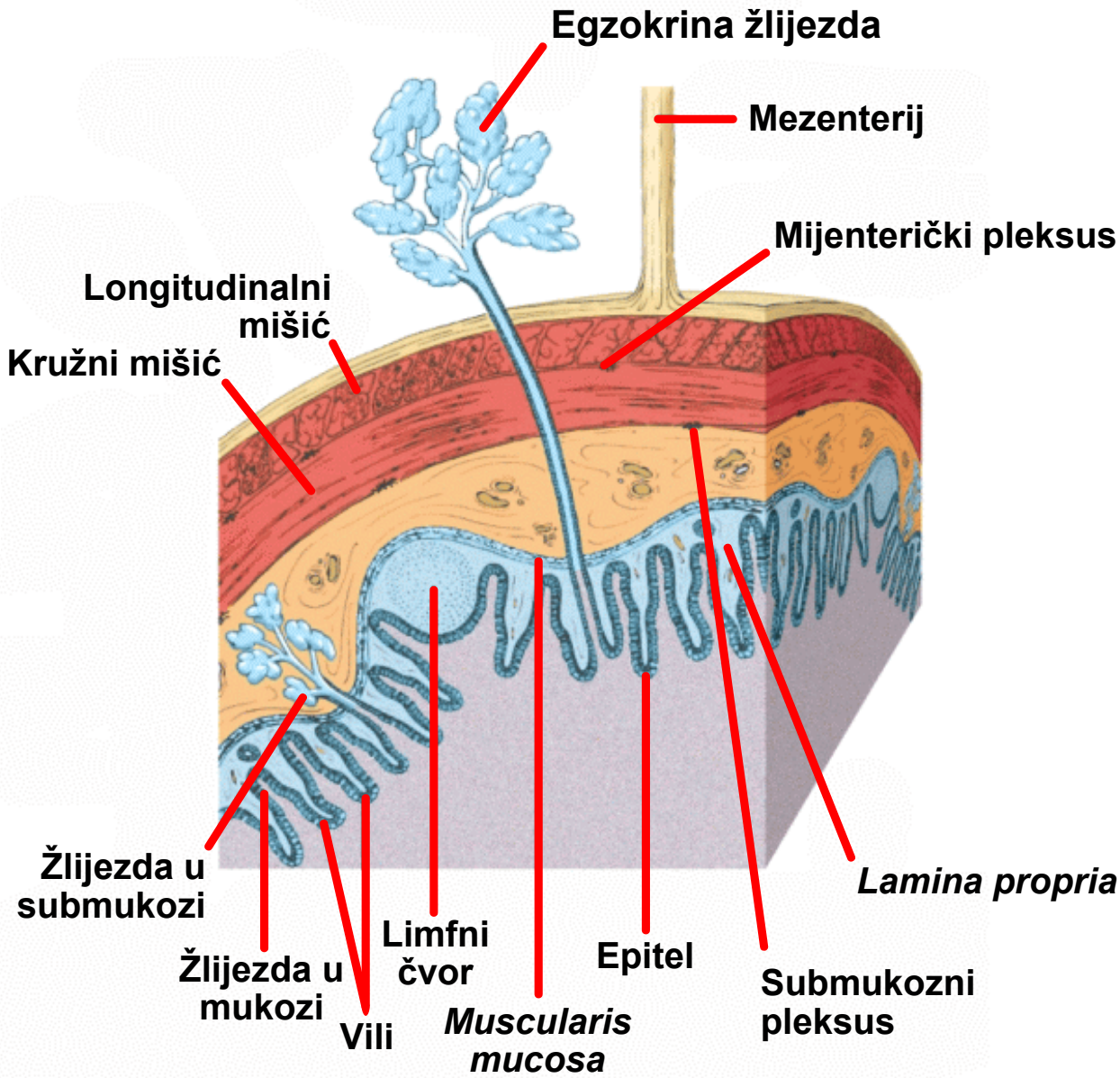
Presjek kroz probavni kanal





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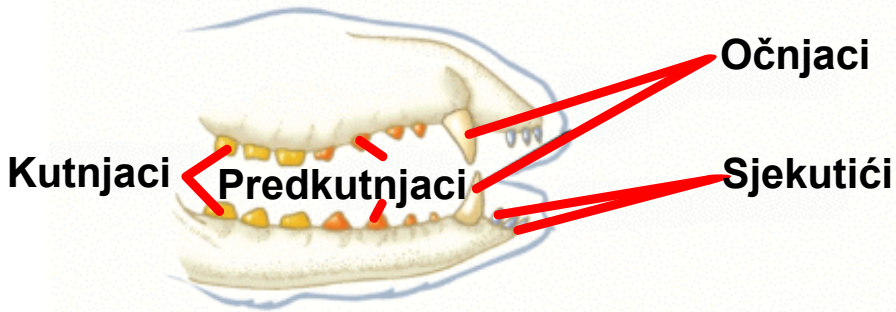
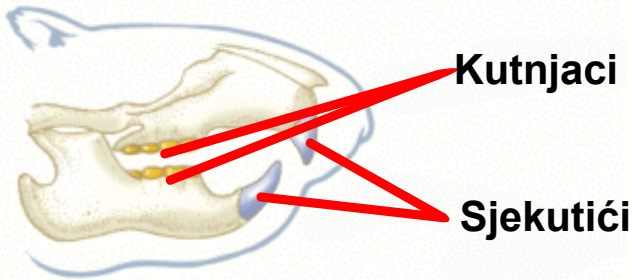
Zubi u sisavaca

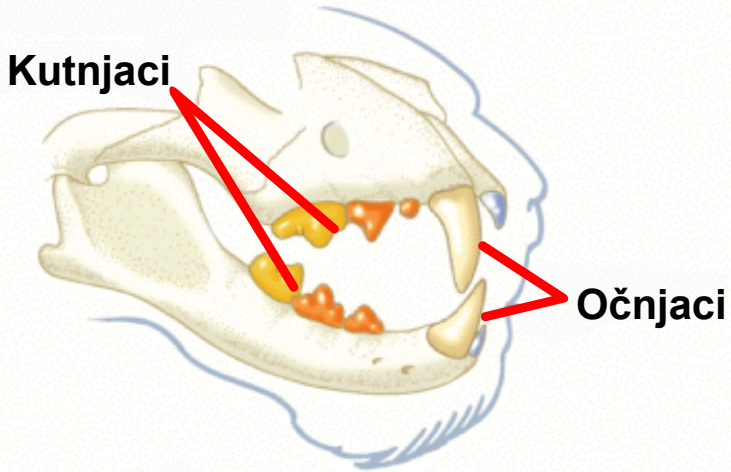
Model placentalnog sisavca



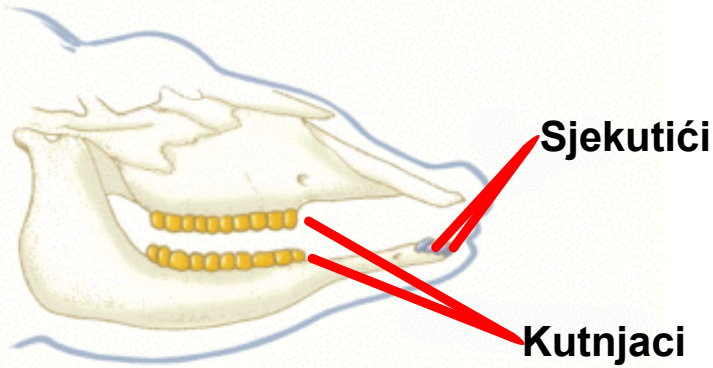
Vjeverica



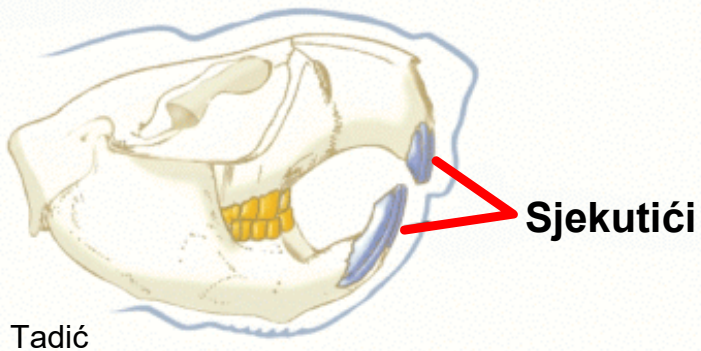
Lav



Govedo



Dabar



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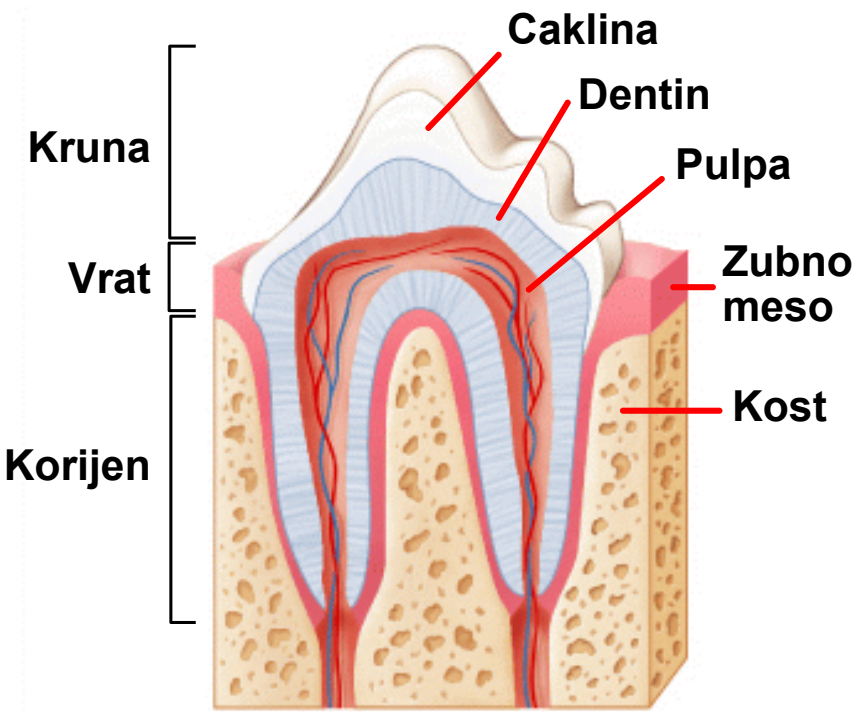
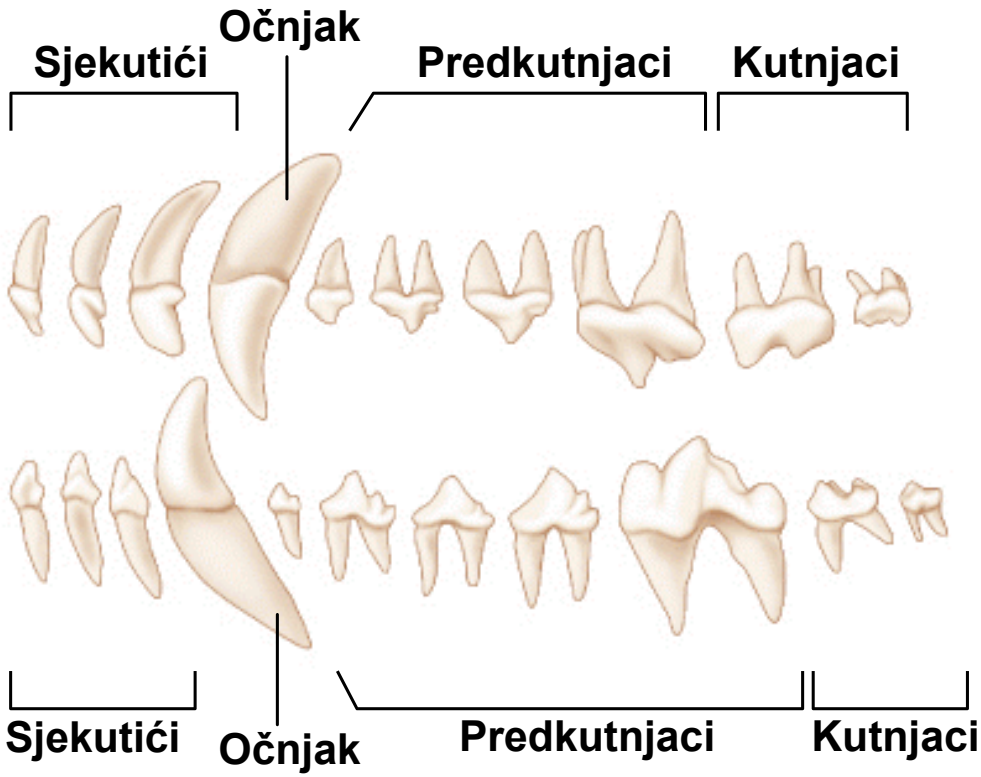
Građa zubi





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Pikanterije iz fiziologije: Zubni karijes

Zubni karijes (”pokvareni zubi”) je bakterijska zaraza zubiju koja dovodi do demineralizacije i razaranja tvrdih dijelova zuba zbog bakterijske fermentacije i proizvodnje kiseline.

Odgovorne bakterije:

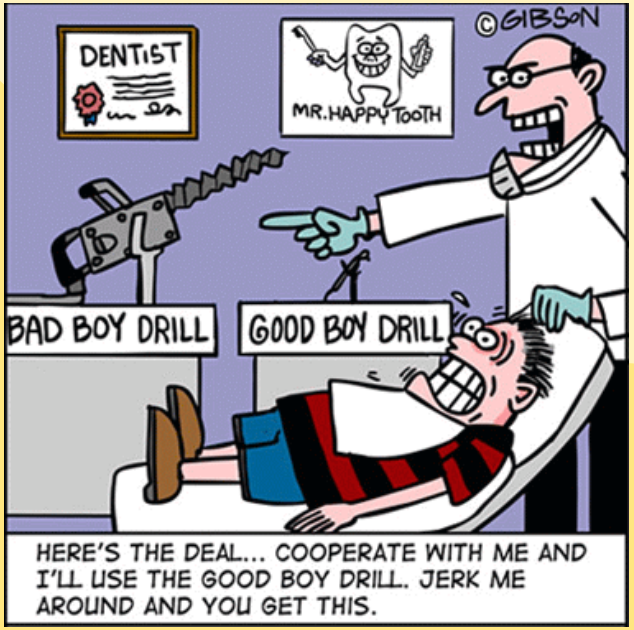
- ***Streptococcus mutans***
- ***Streptococcus sobrinus***
- ***Lactobacillus sp.***

4 čimbenika potrebna za nastanak:

- **Kvaliteta zuba**
- **Bakterije**
- **Fermentabilni ugljikohidrati**
- **Vrijeme**

Ako pH u ustima padne ispod 5,5 demineralizacija ide brže od remineralizacije

Mehanizam nastanka:



- **Različite su osobe različito podložne karijesu ➜ proces deminralizacije ne završava uvijek "rupom" u zubu**
- **Podložnost karijesu ovisi o građi zubi, svojstvima sline i higijenskim navikama ➜ netko pere zube malo i nema karijesa, netko pere stalno i ima “groblje zuba” u ustima.**
- **Pranje navečer i ujutro, korištenje zubne svile i posebnog tuša za zube.**
- **Iako danas postoje odlične metode za sanaciju karijesa, ne postoji način sanacije velikih, uništenih dijelova zuba ➜ umjetne krune ili kliješta ➜ (novo!) umjetni implantati!**

Zubna proteza, gebis ili dentijera

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Kljunovi u ptica

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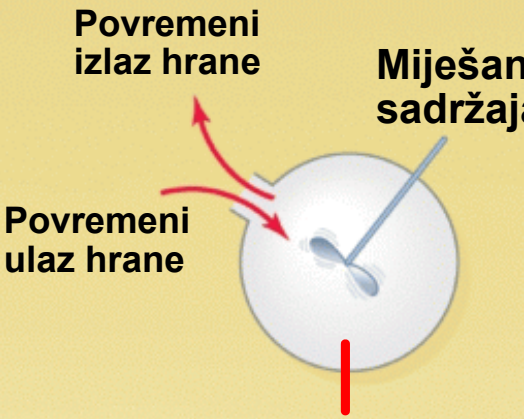
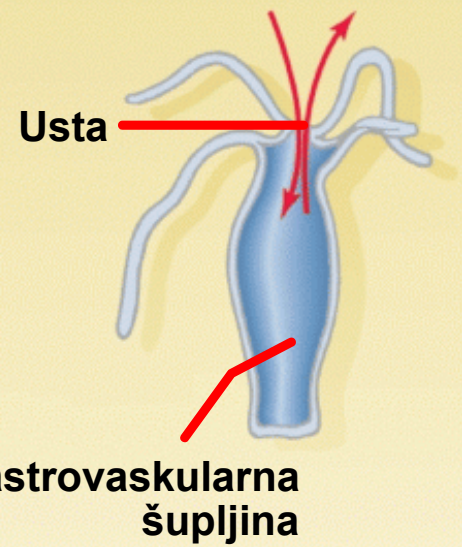
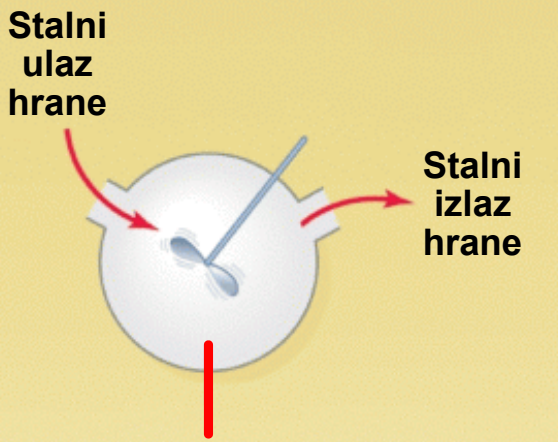
Načini probave u probavnom kanalu

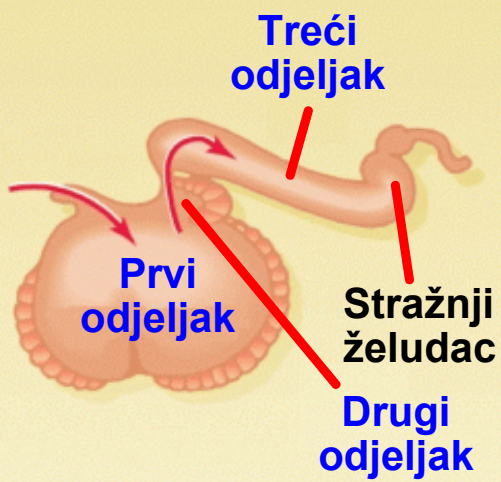
Šaržni reaktor





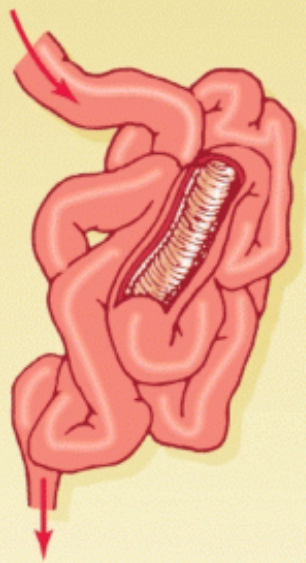
Protočni reaktor s miješanjem



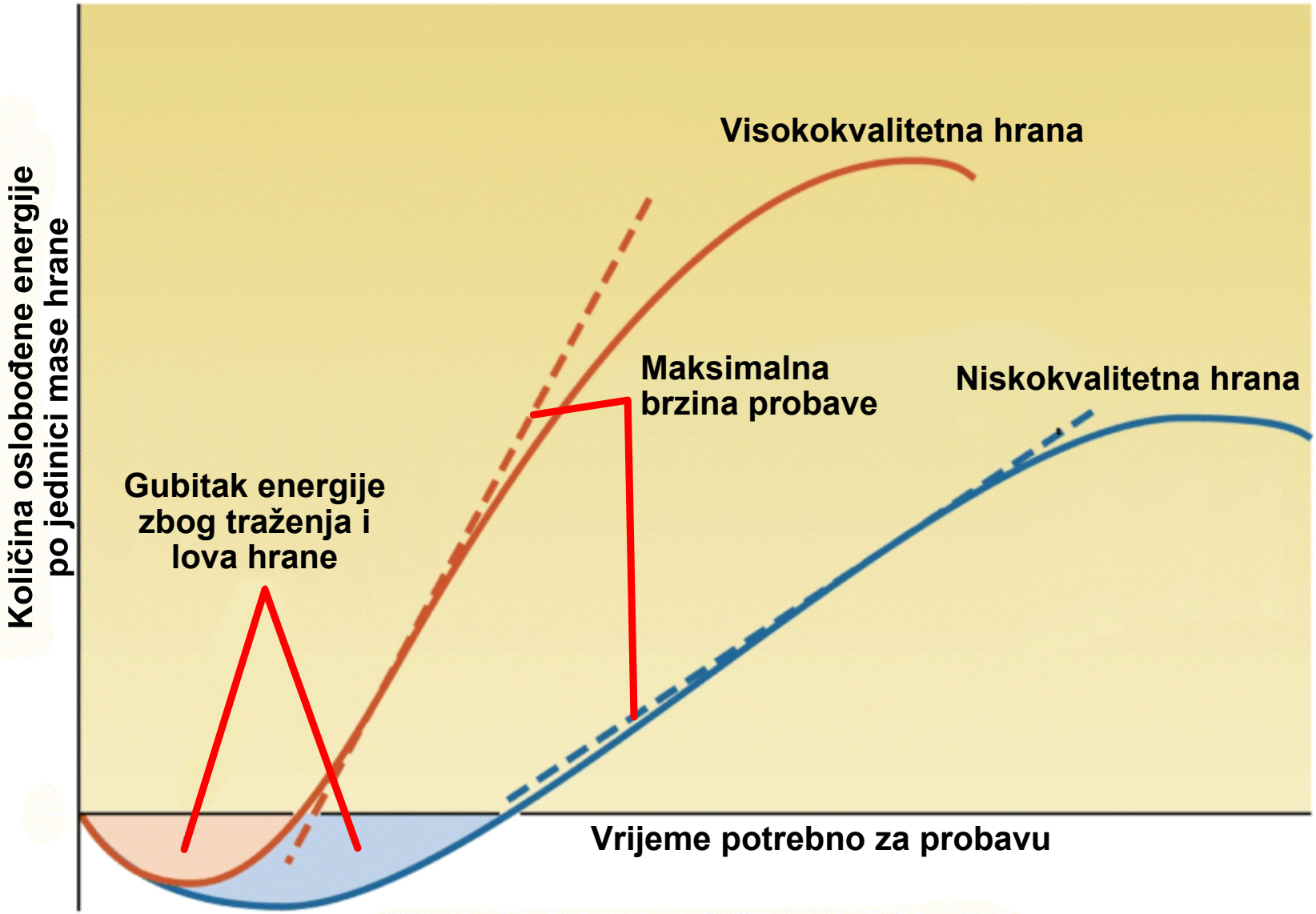


Bolusno protočni reaktor

U proprečnom prerezu, u stanju dinamičke ravnoteže sastav je isti, na bilo kojem dijelu kanala



Duljina probave visoko- i niskokvalitetne hrane



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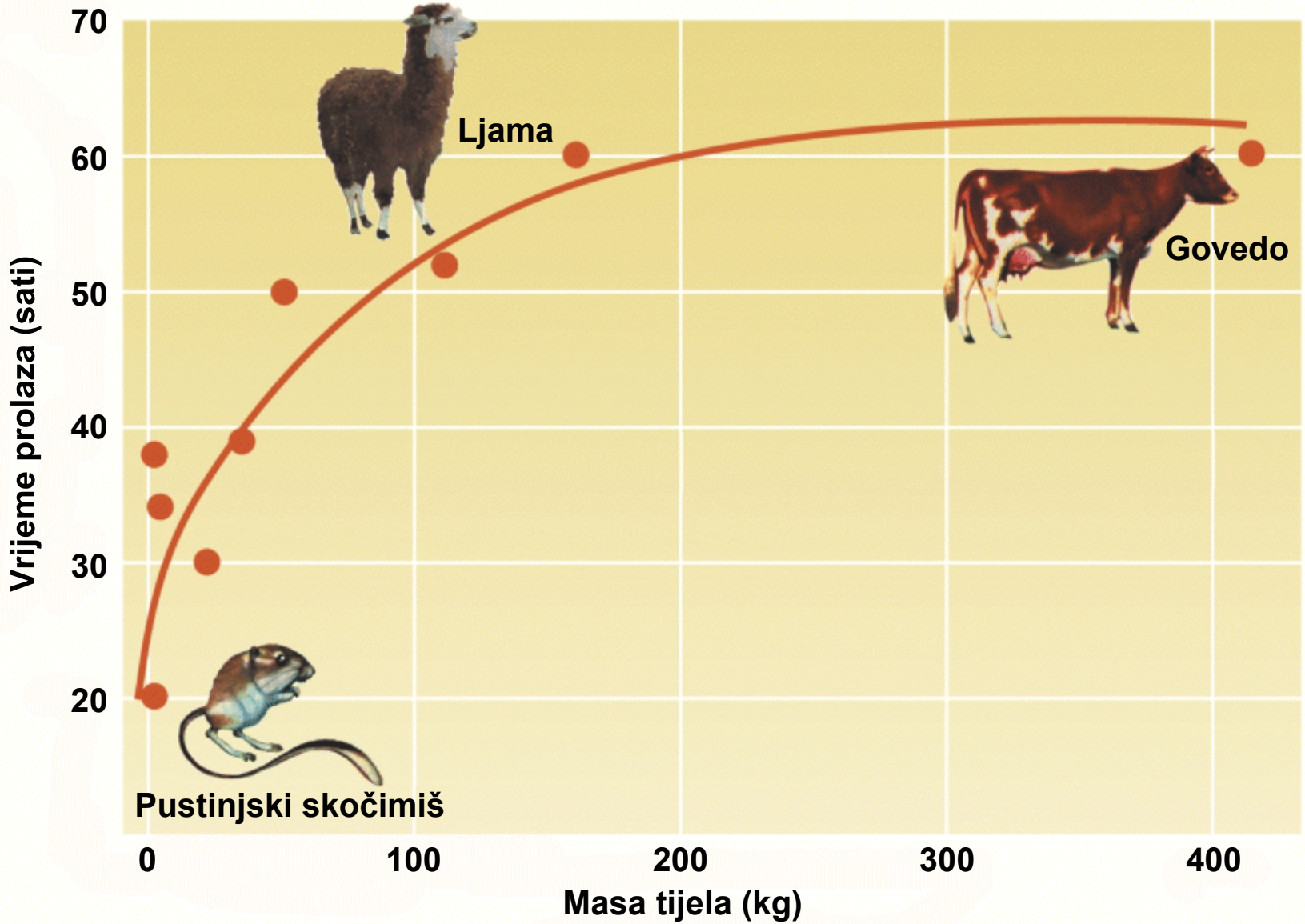
Odnos mase tijela i duljine probave



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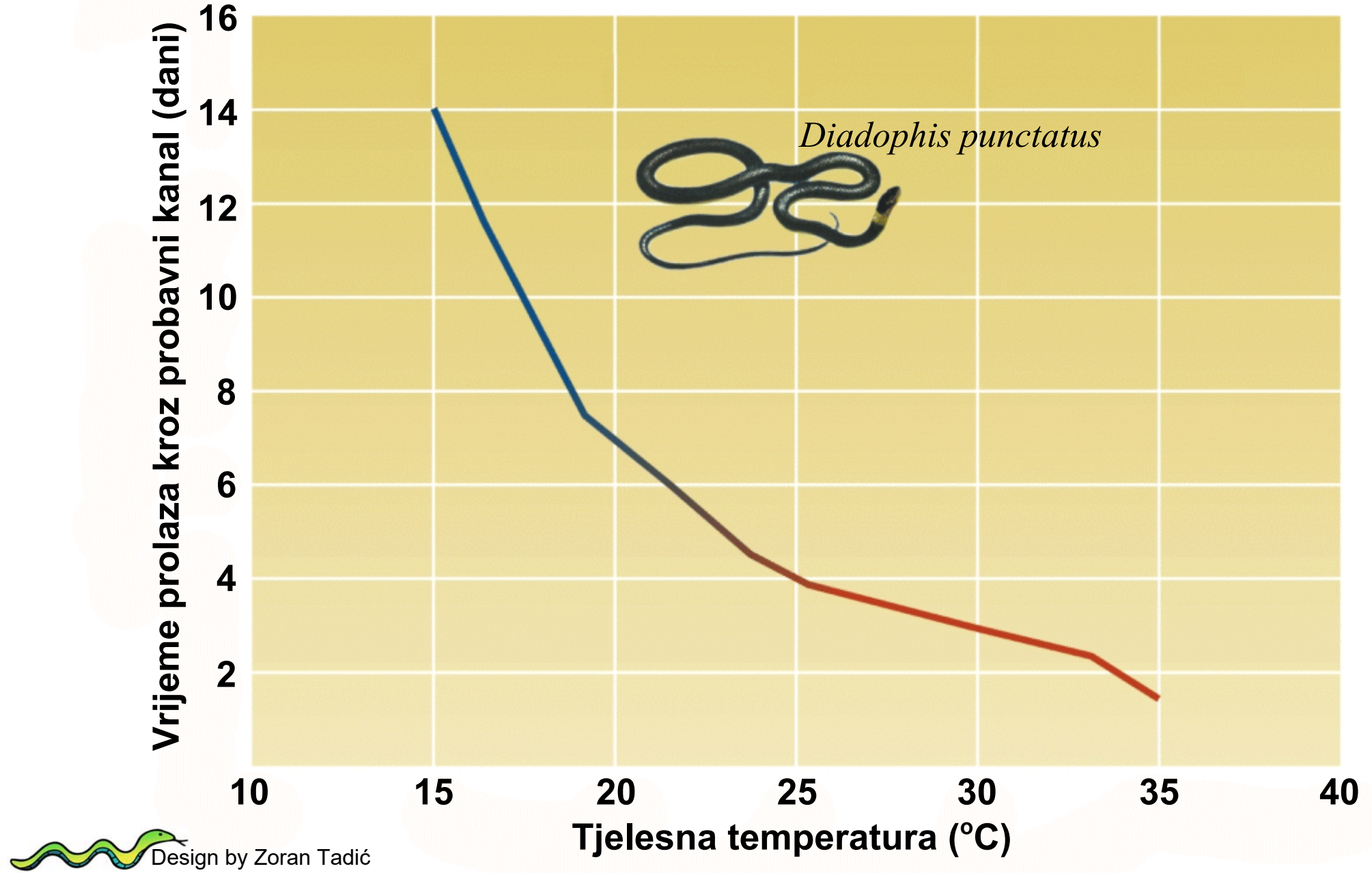
Djelovanje temeprature na probavu ektoterma



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Python sebae

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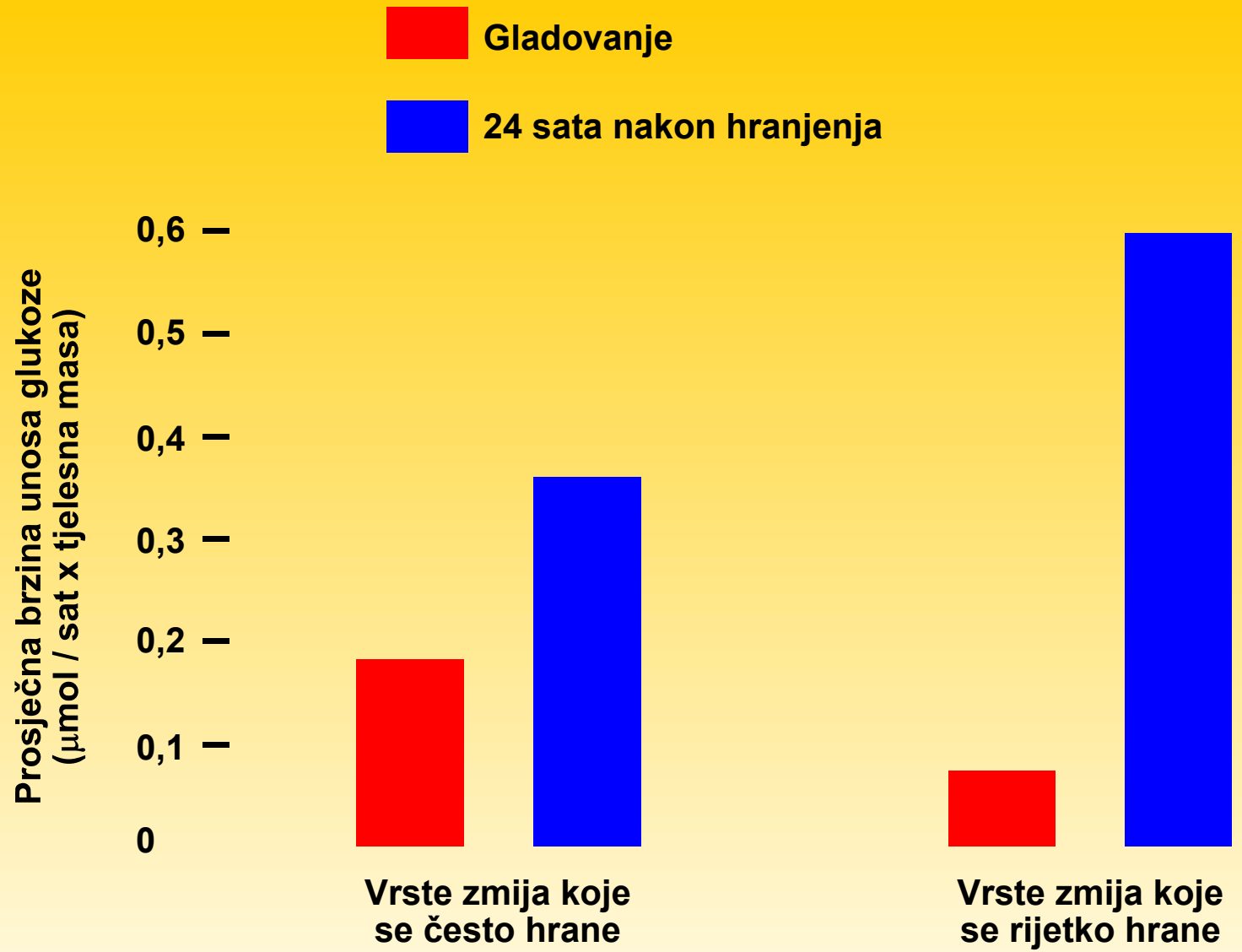

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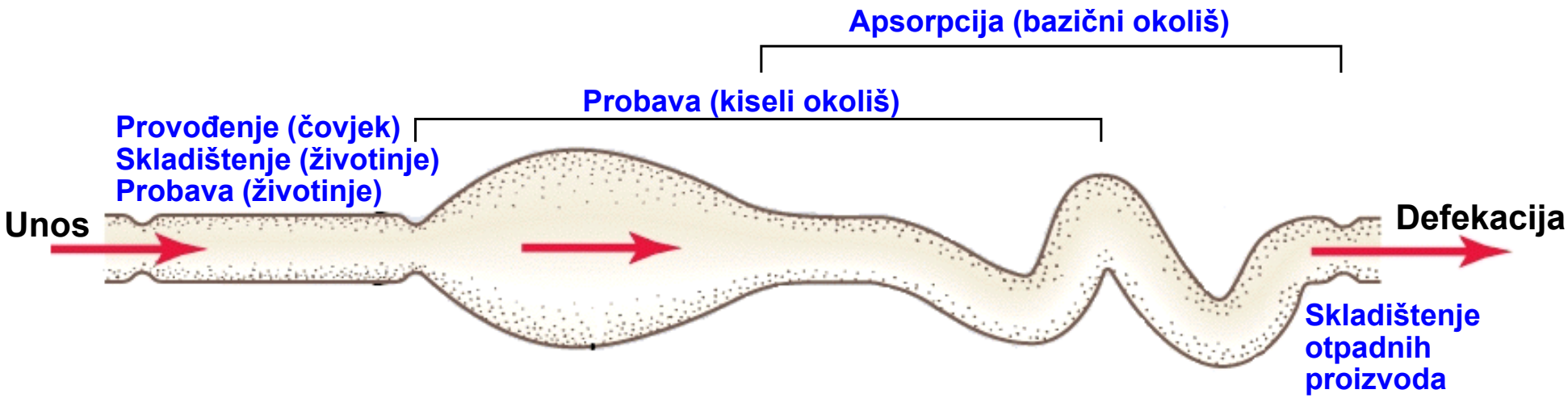
Probava u probavnom kanalu



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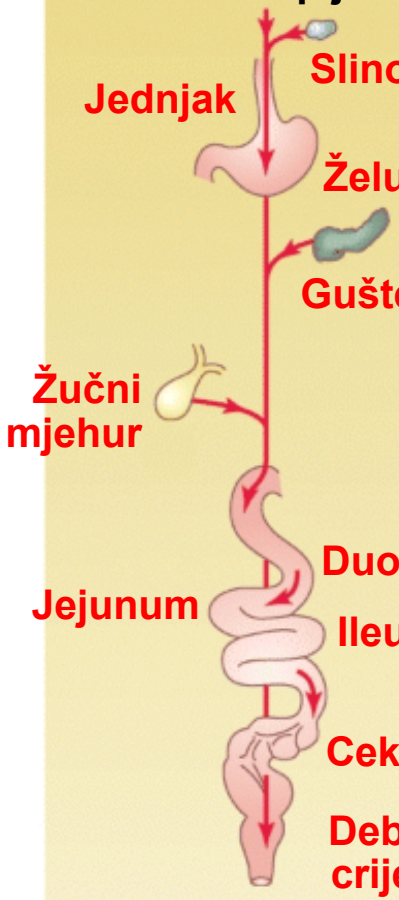
Izlučevine probavnog sustava



Područje	Izlučevina	Dnevna količina (litra)	pH	Sastav*
Slinovnice	Slina	1+	6,5	Amilaza, bikarbonat
Želudac	Želučani sok	1- 3	1,5	Pepsinogen, HCl, renin (u male djece), intrinzični faktor
Gušterača	Gušteračin sok	1	7 - 8	Tripsinogen, kimotripsinogen, karboksi- i aminopeptidasa, lipaza, amilaza, maltaza, nukleaza, HCO_3^-
Žučni mjehur	Žuč	1	7 - 8	Žučne soli i pigmenti, masti i masne kiseline, kolesterol
Duodenum, Jejunum, Ileum	*Succus entericus*	1	7 - 8	Enterokinaza, karboksi- i aminopeptidaze, maltaza, laktaza, saharaza, lipaza, nukleaze

* Navedeni sastav je bez sluzi i vode koji čine oko 95% svake od navedenih izlučevina.

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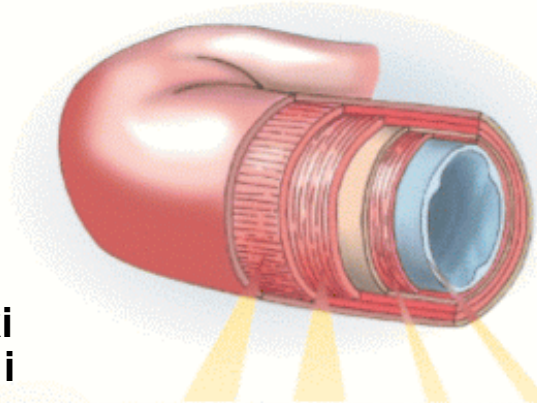
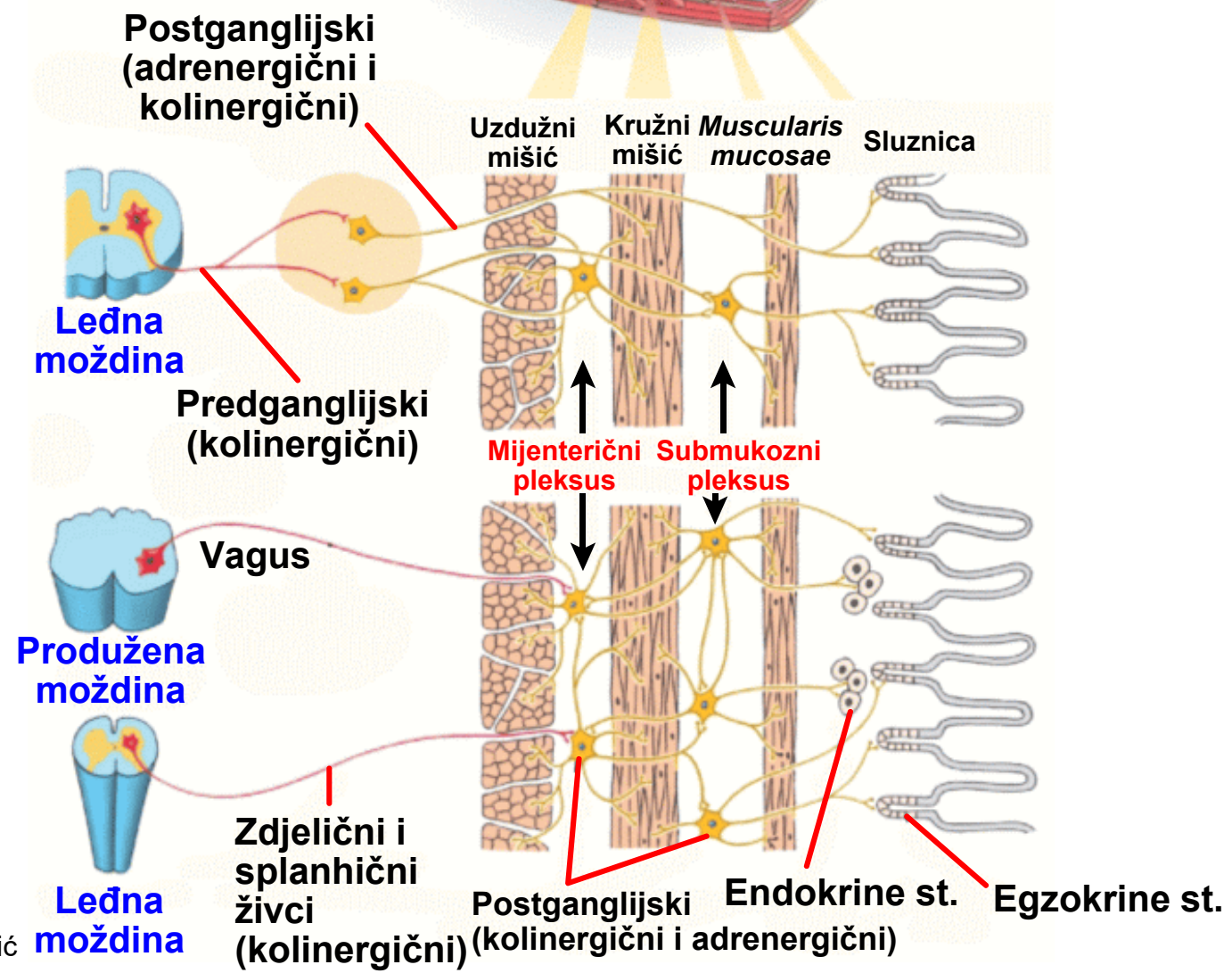
Živčana kontrola probavnog sustava





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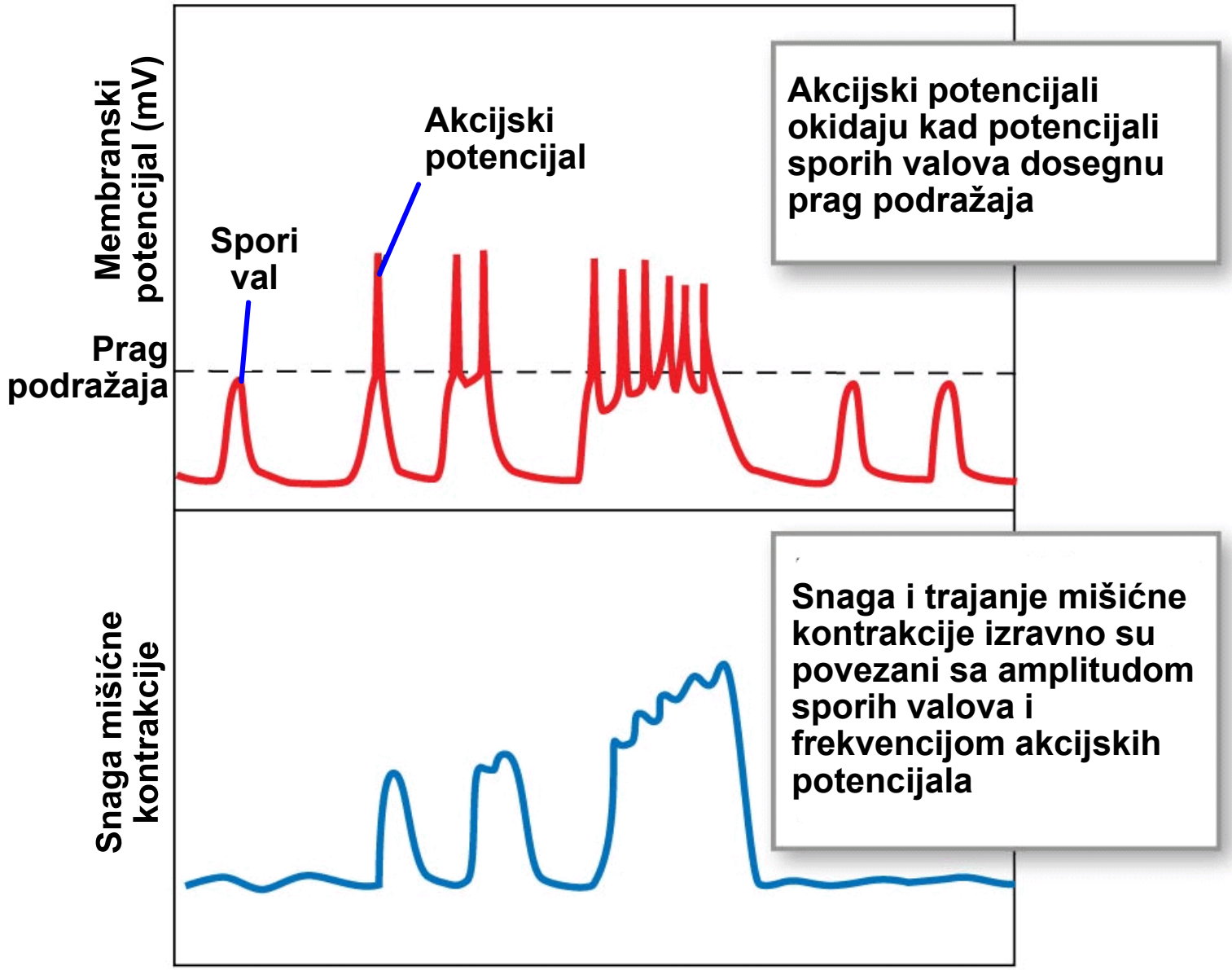
Akcijski potencijali i kontrakcije glatkih mišića



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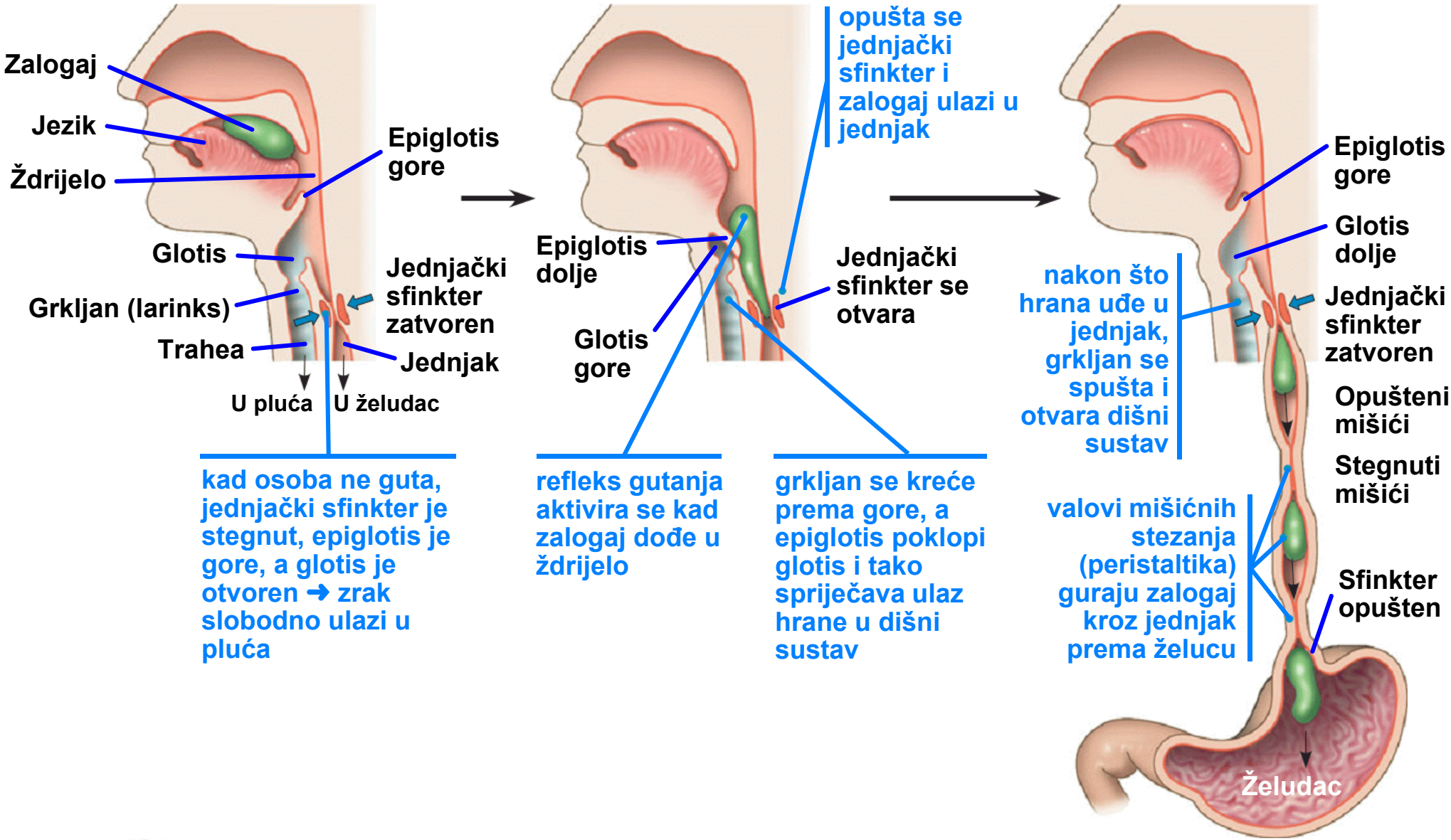
Mehanizam gutanja (orofaringalni refleks)



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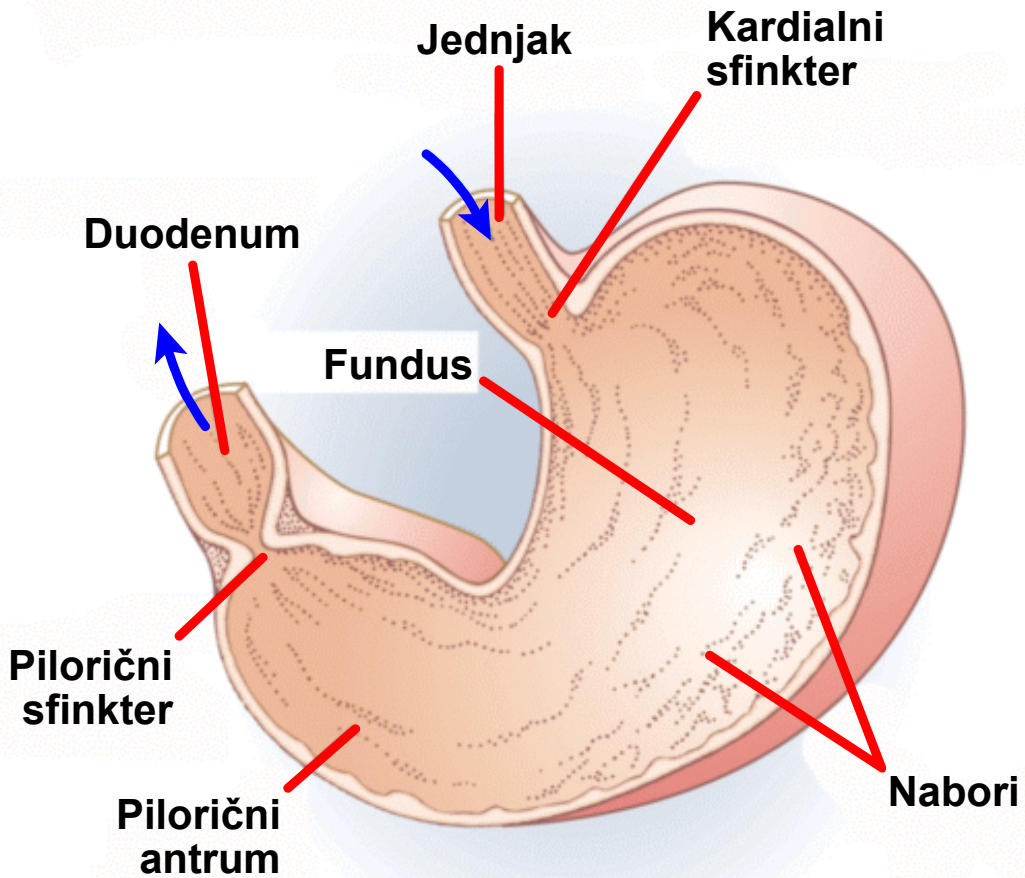
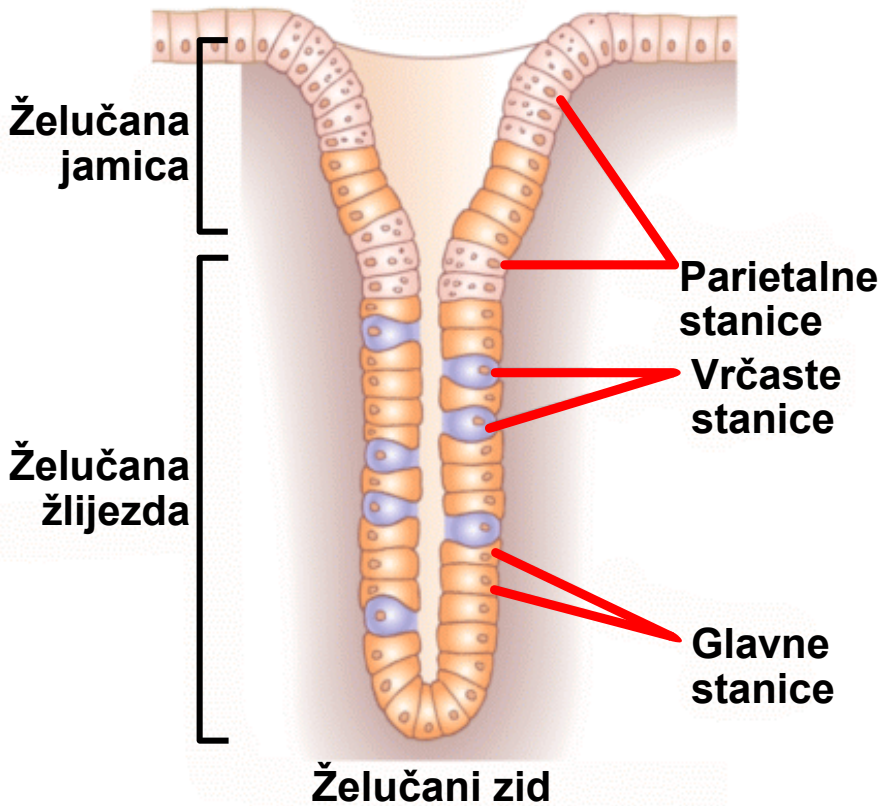
Monogastrički želudac





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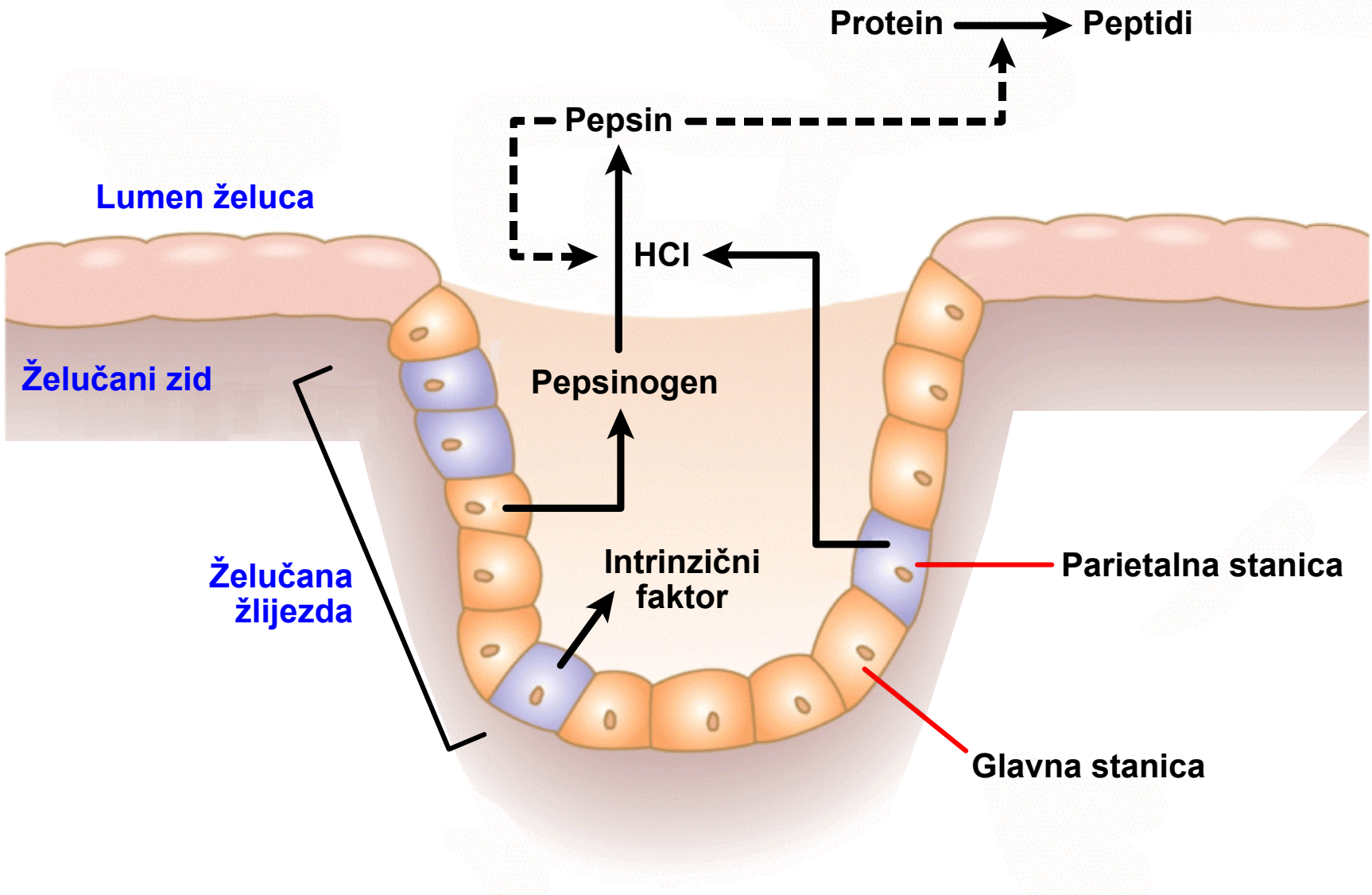
Probava u želucu



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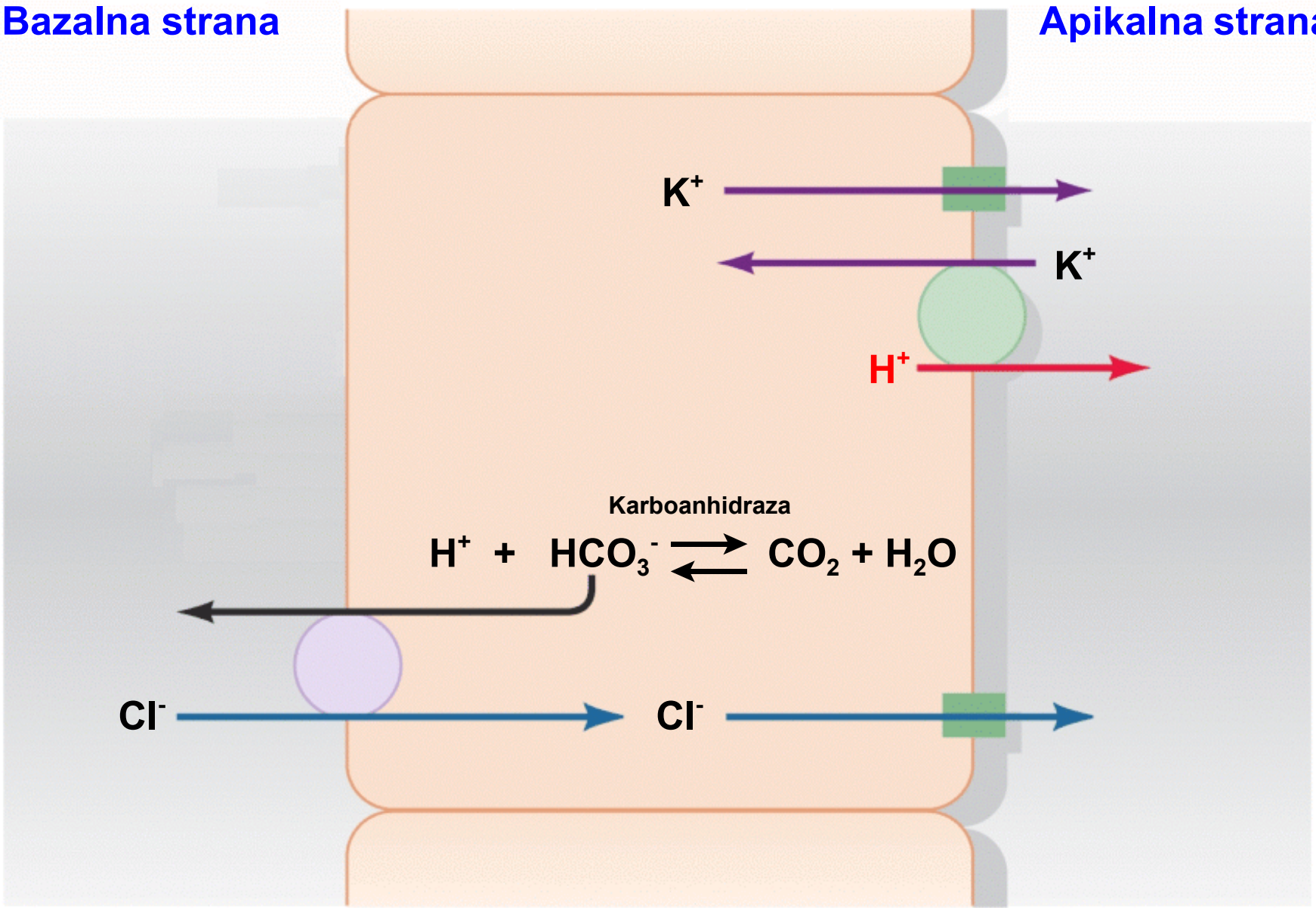
Mehanizam lučenja HCl u želucu



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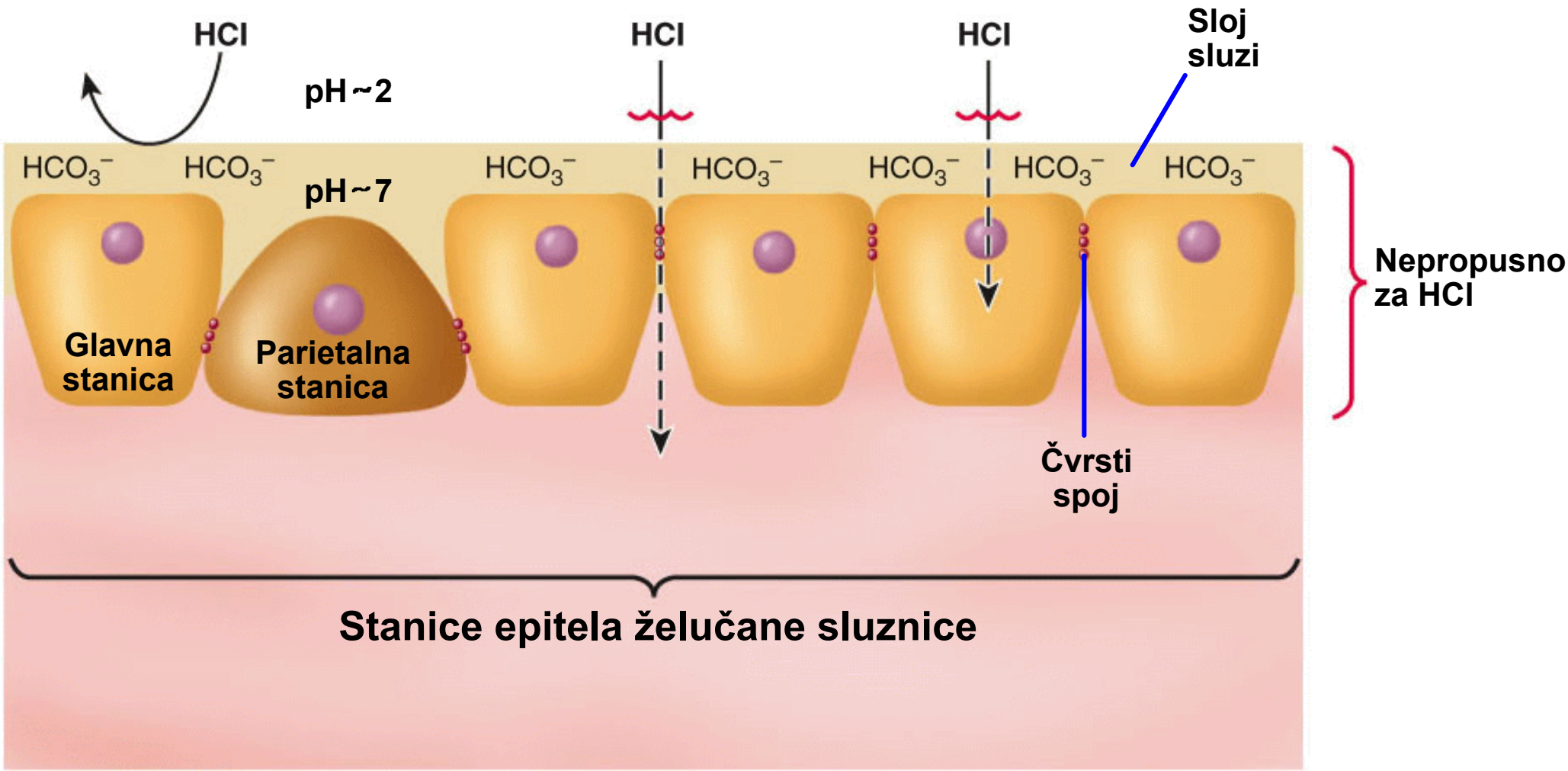
Zašto želudac sam sebe ne razori kiselinom?



Spriječavanje prolaza

- H^+ ion ne može proći kroz apikalnu membranu epitelnih stanica (kanali!)
- H^+ ion ne može proći između epitelnih stanica (čvrsti spojevi!)
- H^+ ion ne može proći kroz sloj sluzi, jer ga puferira bikarbonatni ion u njoj

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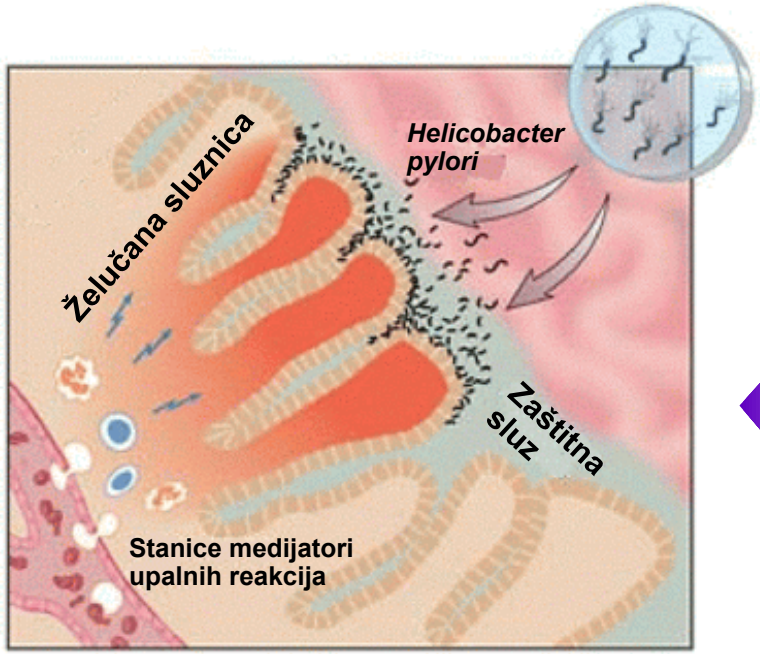
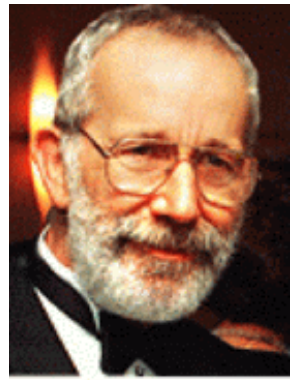


Helicobacter pylori

Barry J. Marshall (1951 -)



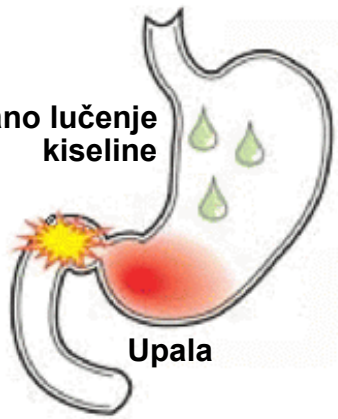
J. Robin Warren (1937 -)

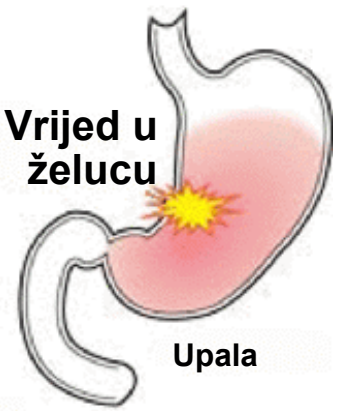
H. pylori **izaziva gastritis u donjem dijelu želuca. Prva faza je obično asimptomatska**

Nobelova nagrada za fiziologiju ili medicinu 2005. godine:

"Za otkriće bakterije *Helicobacer pylori* i njene uloge u nastanku gastritisa i želučanog vrijeda ("čira na želucu")."

Produljeno djelovanje *H. pylori* dovodi do vrijeda u duodenumu.





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Faze lučenja želučanog soka (gastričke sekrecije)

- **Cefalička faza (grč. *κέφαλος*, kephalos - glava)** -započinje prije nego hrana dođe u želudac ➜ vidni, mirisni i okusni podražaji

- **Gastrička faza (grč. *γαστήρ*, gaster - trbuh)** - započinje kad hrana dođe u želudac

- **Intestinalna faza (lat. *intestinus* - unutrašnji, domaći; lat. *intestina* - probavilo, crijevo)** - započinje kad hrana dođe u crijevo

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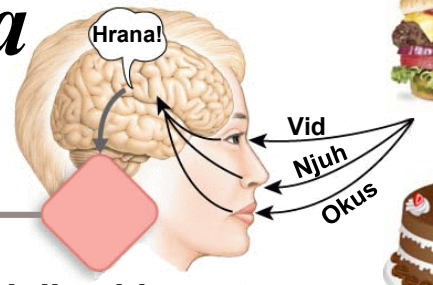
Gastrička i cefalička faza



Medulla oblongata

Hrana

1 Hrana ili cefalički refleksi potiču lučenje želučanog soka

Vagus

Aminokis. ili peptidi

Enterički osjetilni neuron

G stanica

Gastrin

Lumen želuca

Želučana sluznica

2 Gastrin potiče lučenje HCl, izravno stimulirajući parietalne stanice ili histaminom, preko ECL stanica

D stanica

Somatosta-tin

4 Povećana konc. H^+ potiče D stanice na lučenje somatostatina, što regulira lučenje pepsina i H^+

Negativna povratna sprega

Histamin

ECL stanica

3 Kiselina potiče lučenje pepsinogena kratkim refleksnim lukom

H^+

Parietalna st.

Enterički pleksusi

Enterički osjetilni neuron

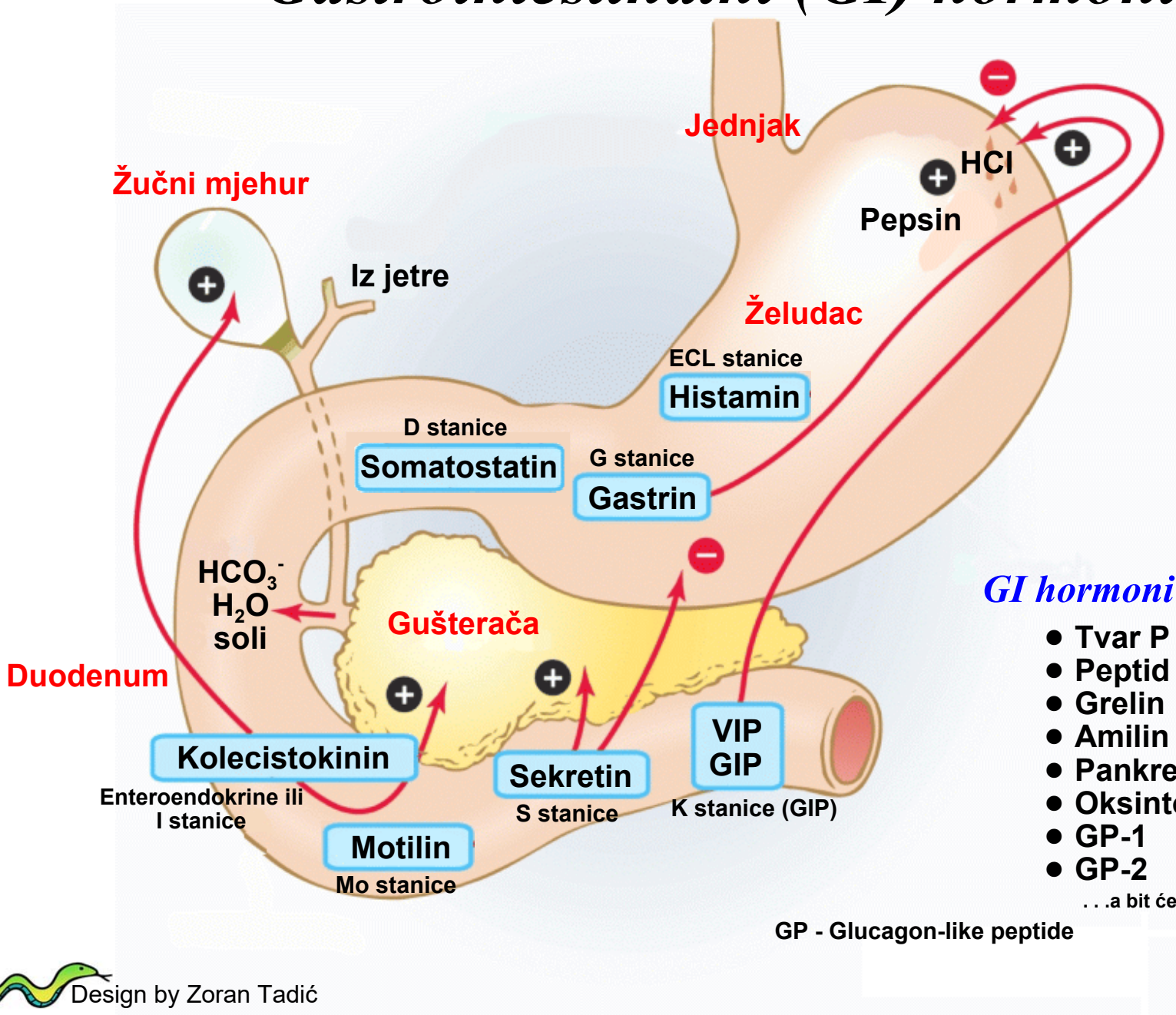
Pepsin

Pepsinogen

Glavna st.

Design by Zoran Tadić

Gastrointestinalni (GI) hormoni



GI hormoni su još i:

- Tvar P
- Peptid YY
- Grelin
- Amilin
- Pankreatski polipeptid
- Oksintomodulin
- GP-1
- GP-2

. . .a bit će toga sigurno još!

GP - Glucagon-like peptide

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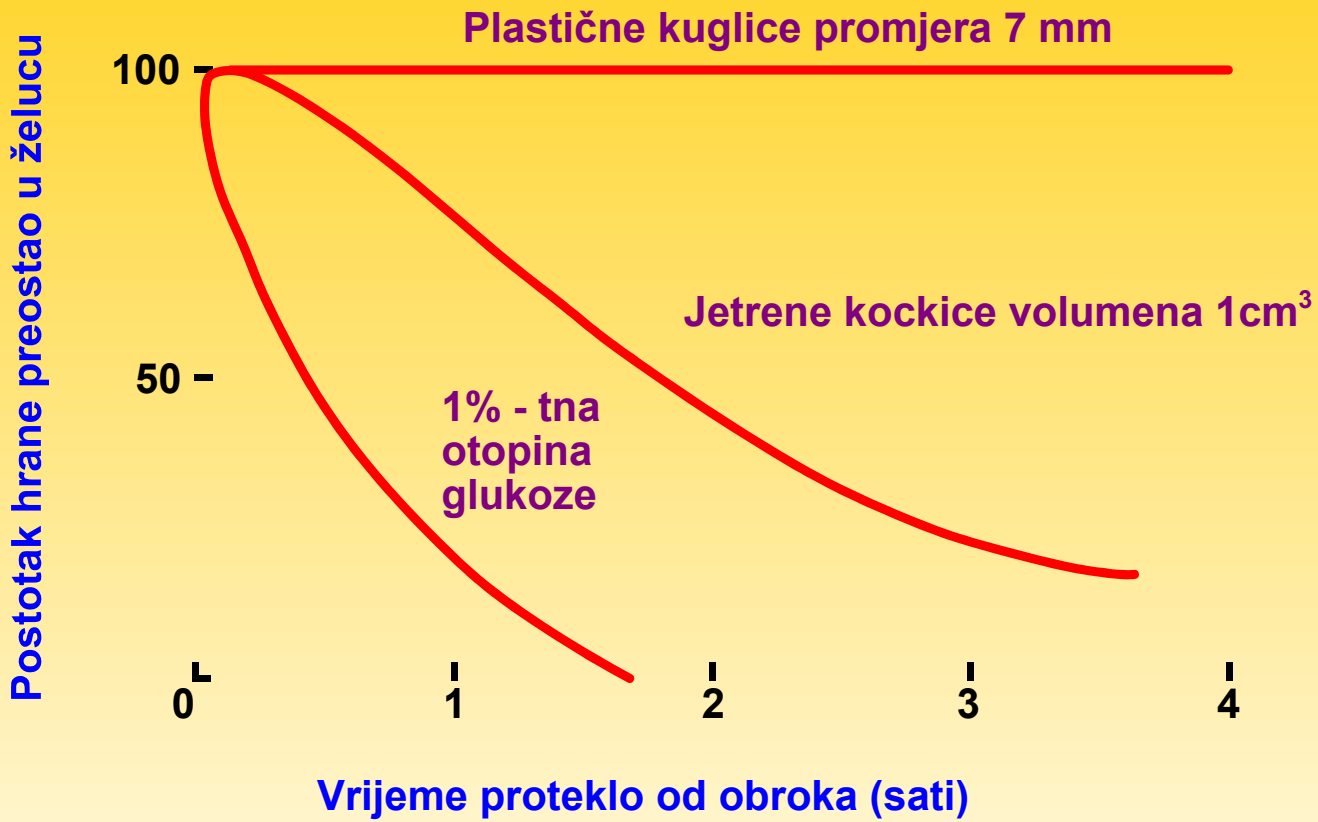
Brzina probave ovisi o tome što smo pojeli



Design by Zoran Tadić

Duodenalni čimbenici koji usporavaju pražnjenje želuca

- **Masti** - Probava masti traje dulje nego probava drugih molekula (probavljaju se samo u tankom crijevu) ➜ potiču lučenje holecistokinina (CKK) ➜ kontrakcija piloričnog sfinktera i žučnog mjehura ➜ lučenje žuči
- **Kiselina** - Potiče lučenje HCO_3^- (gušterača) radi neutralizacije. Slobodna HCl ➜ lučenje sekretina ➜ usporavanje pražnjenja želuca
- **Hipertoničnost** - Razgradnja molekula hrane ➜ povećanje toniciteta ➜ ulaz vode (iz krvi) u duodenum ➜ refleksna inhibicija pražnjenja želuca
- **Širenje** - Širenje inhibira ulaz želučanog sadržaja u duodenum dok se duodenum ne isprazni

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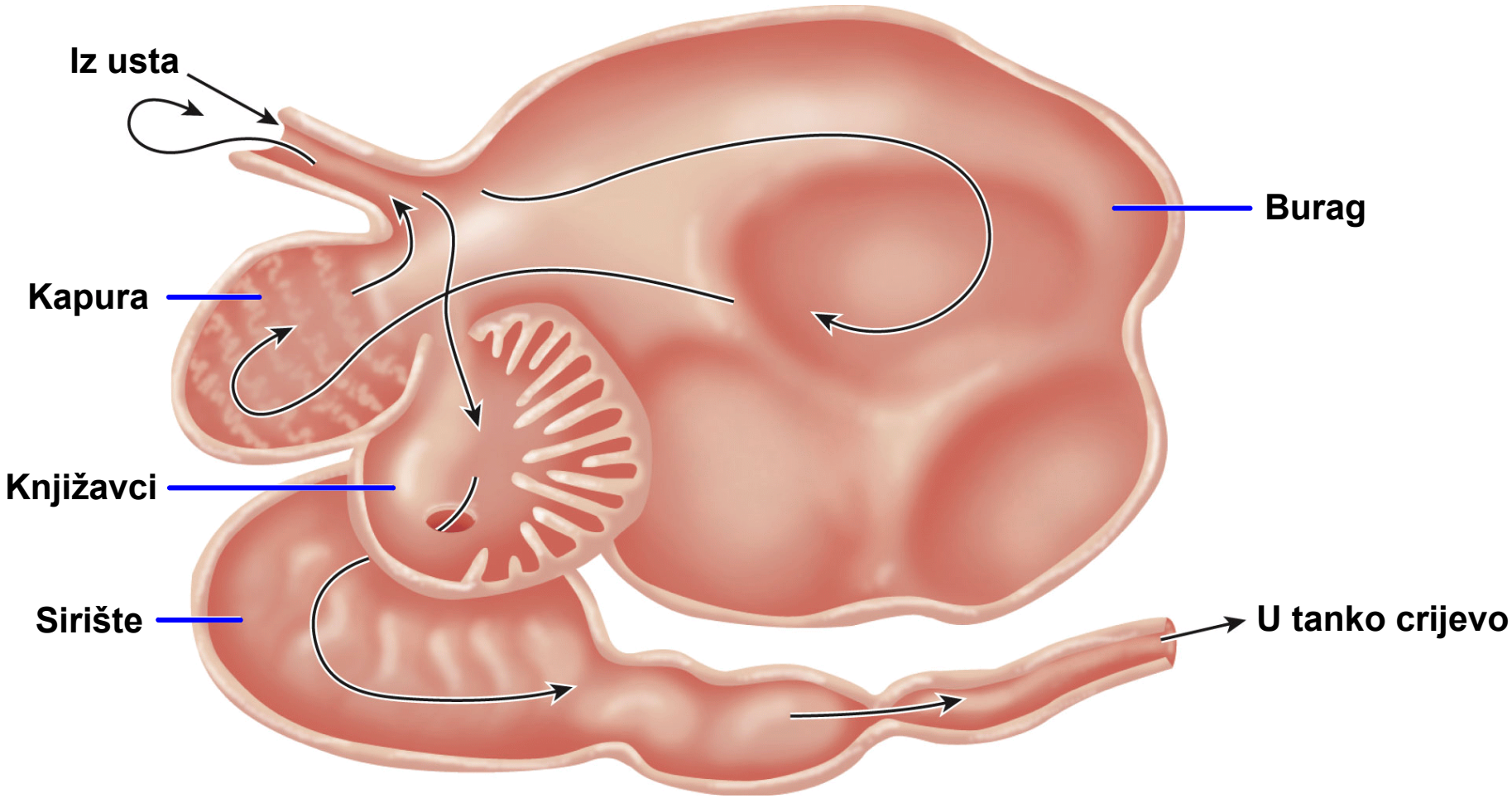
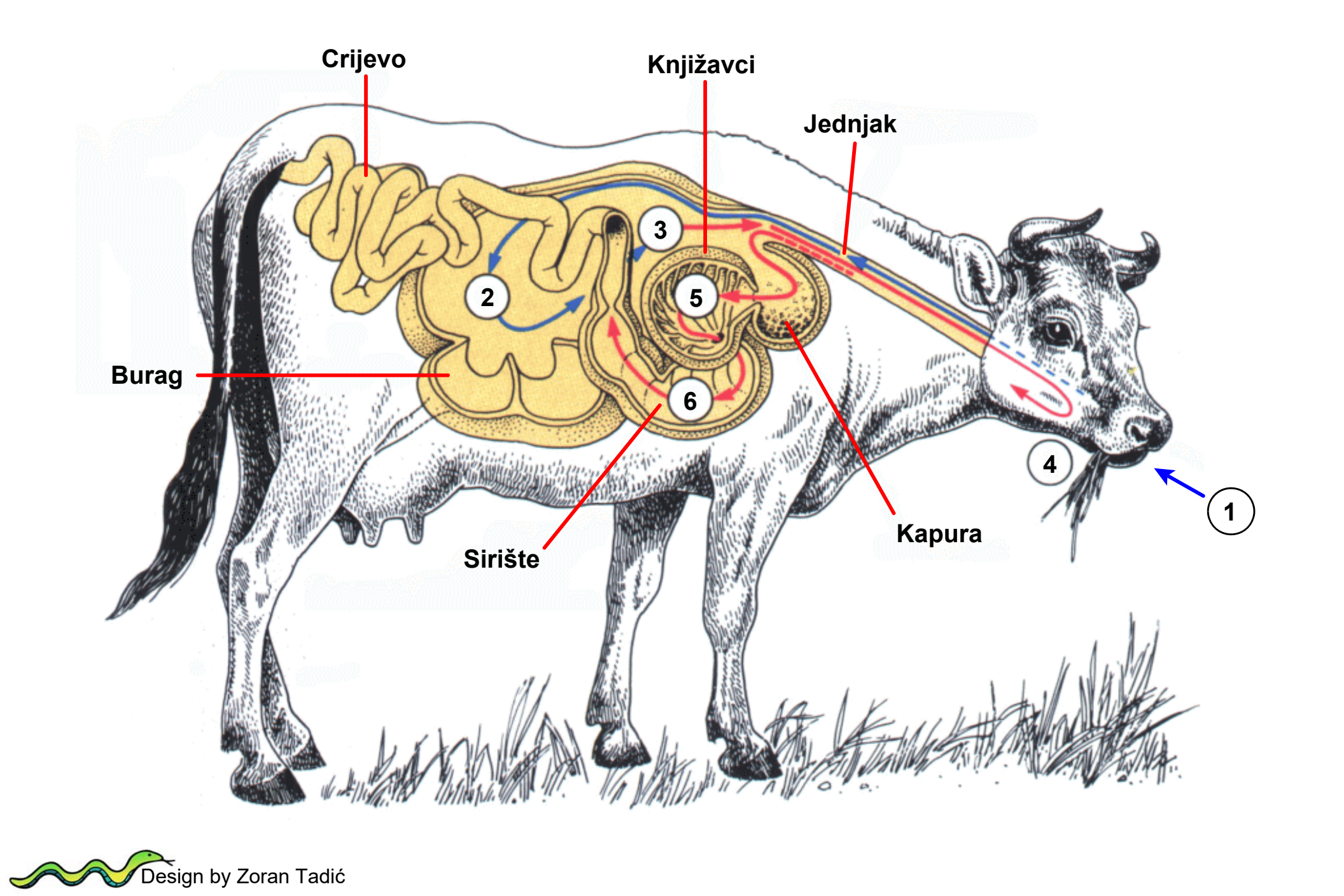
Digastrički želudac = želudac + fermentacijske pretkomore

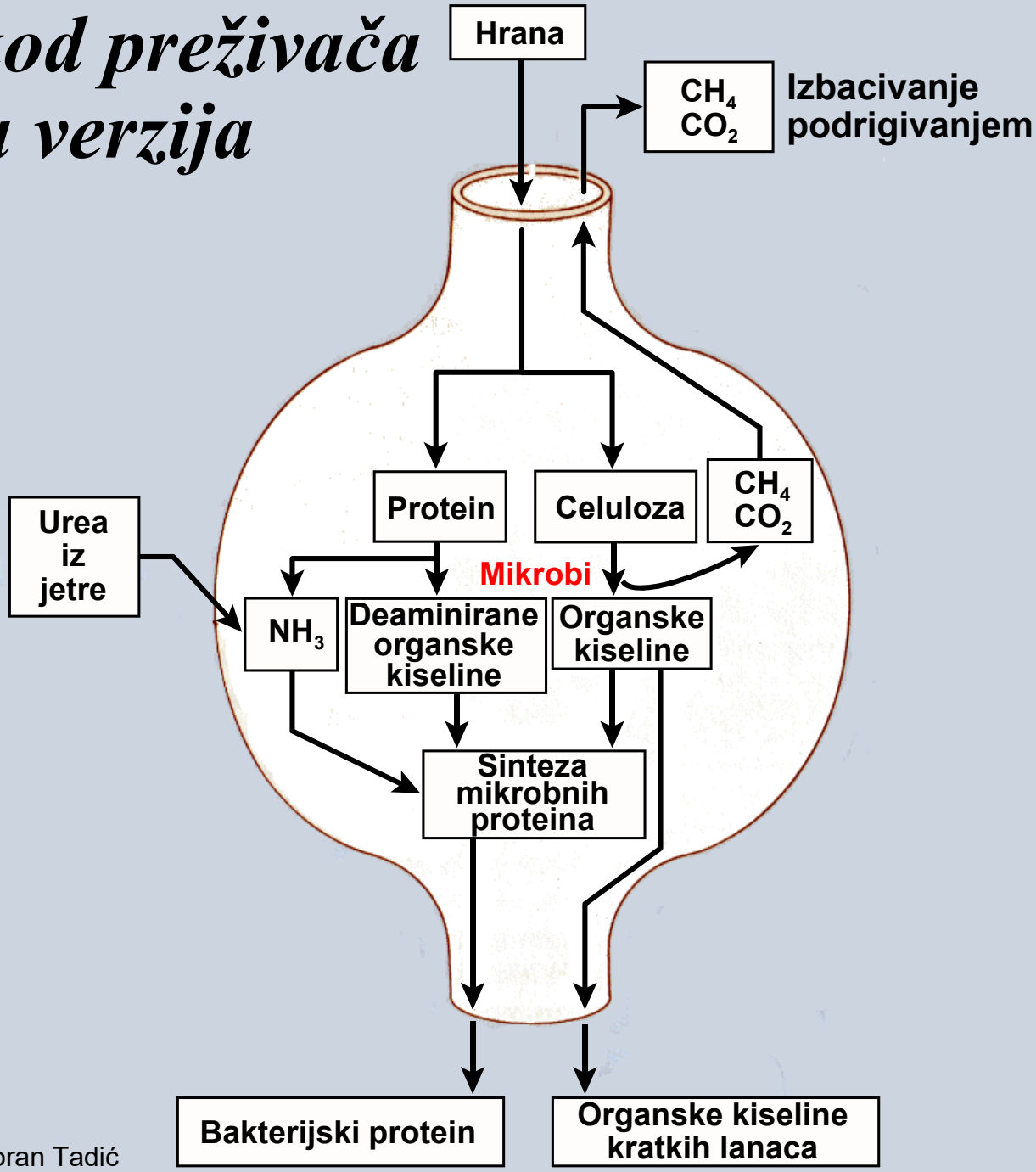


Design by Zoran Tadić



Design by Zoran Tadić

Probava kod preživača - skraćena verzija



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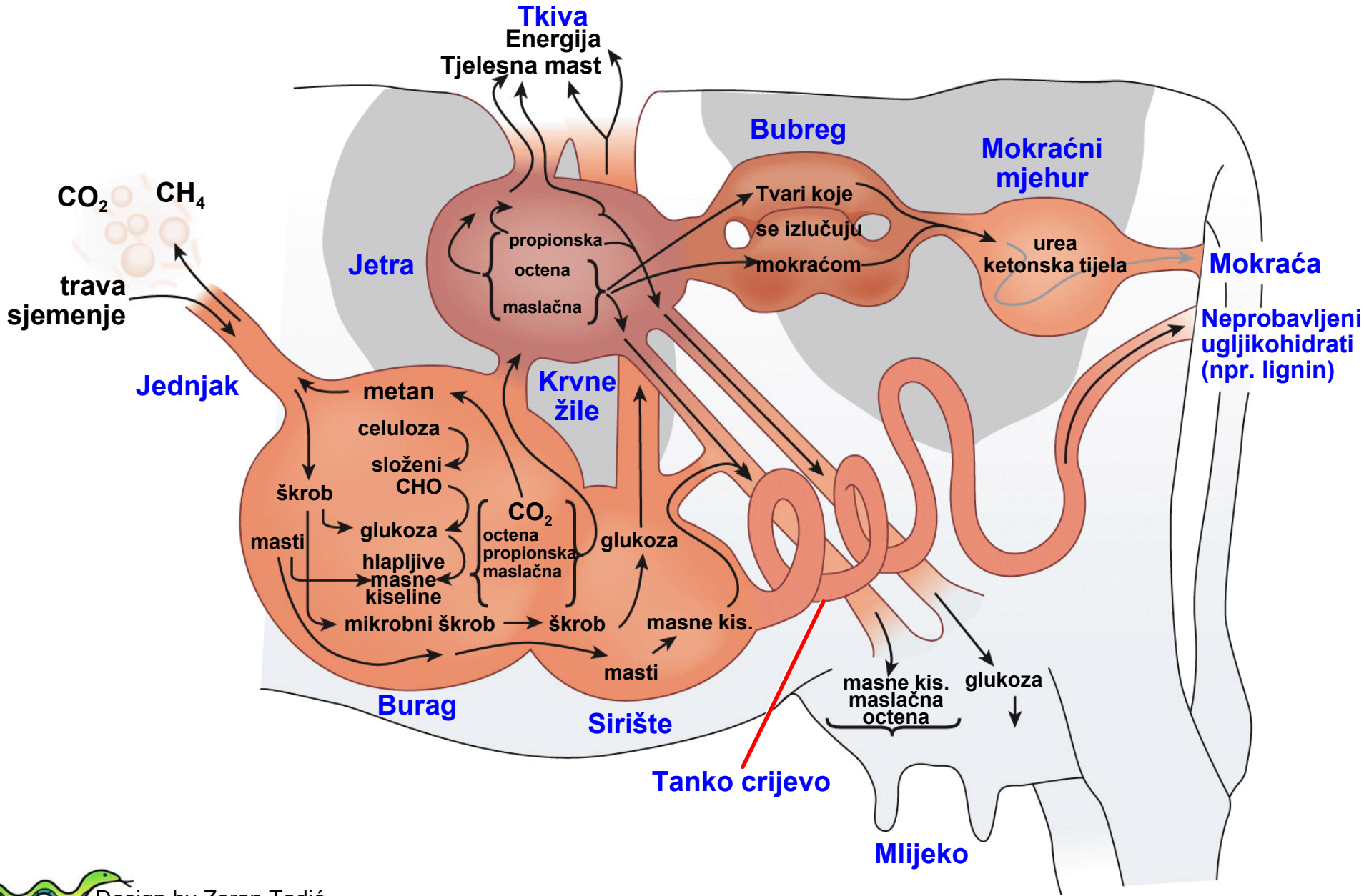
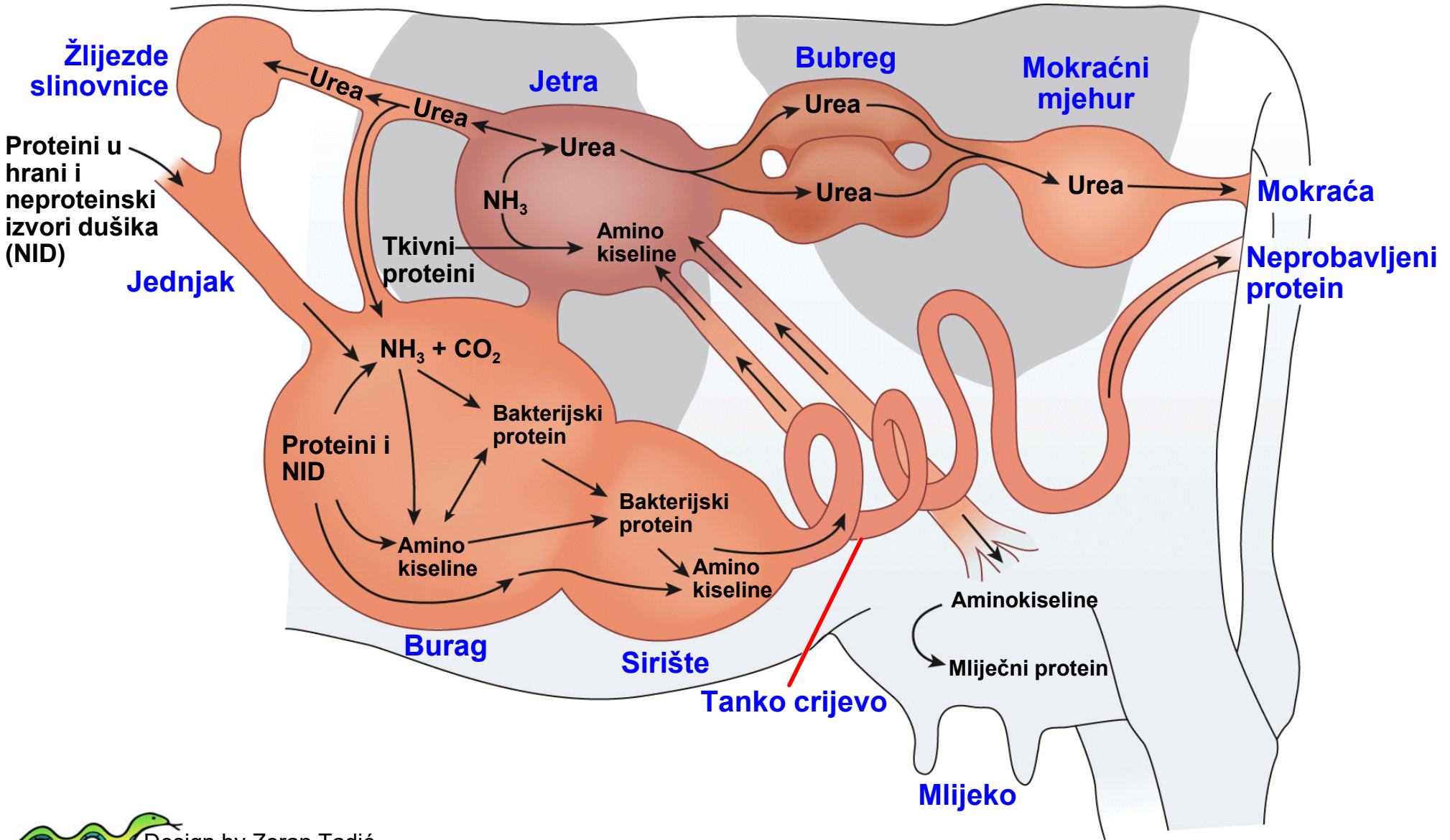
Probava ugljikohidrata - detaljna slika



Design by Zoran Tadić

Probava proteina - detaljna slika



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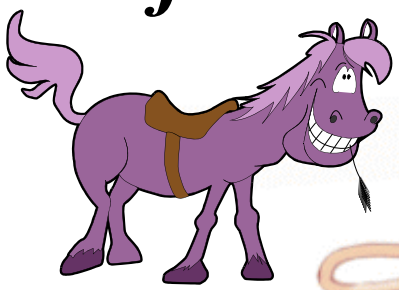
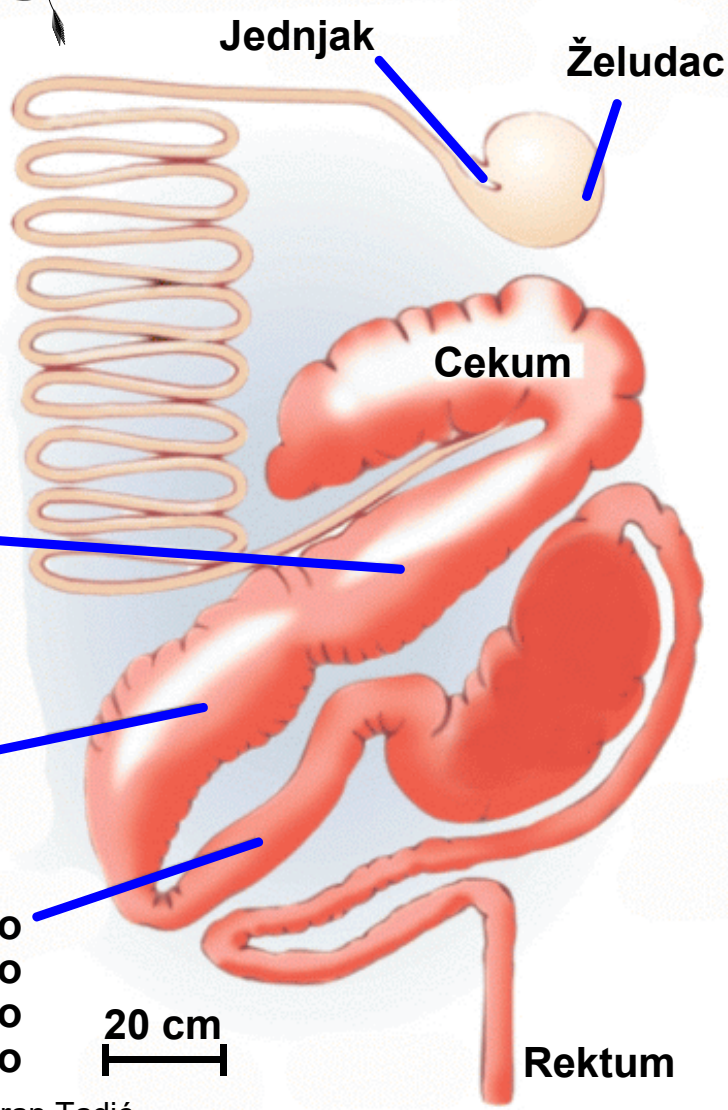
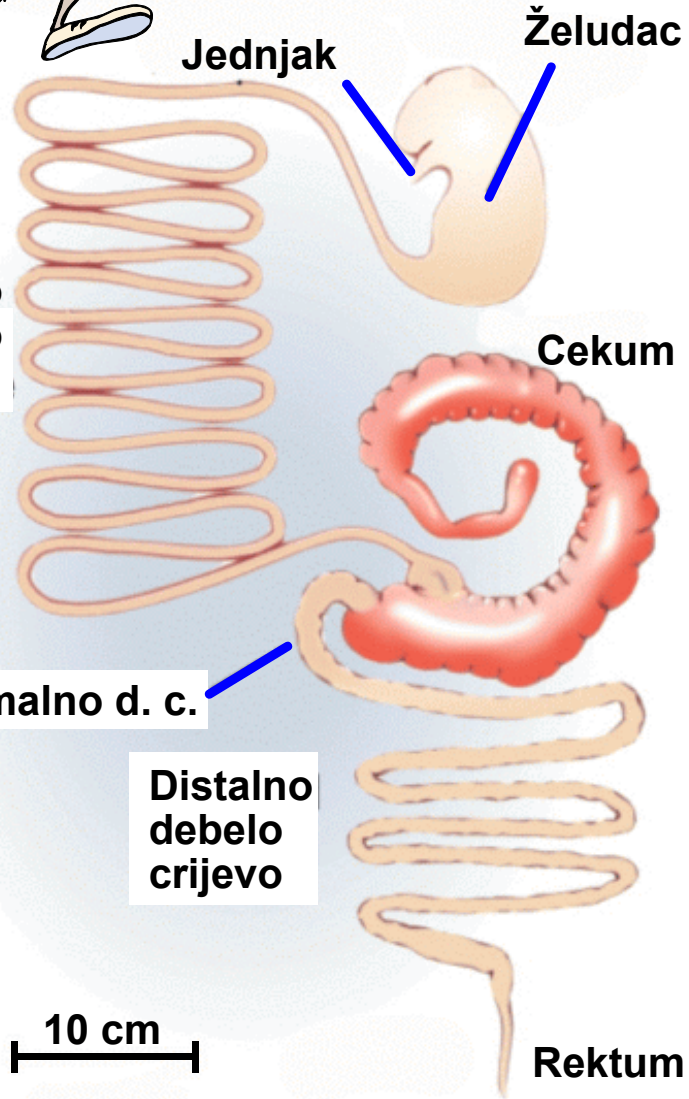
A što je s konjima i sličnim biljojedima bez buraga?



Fermentacija u debelom crijevu

Fermentacija u cekumu





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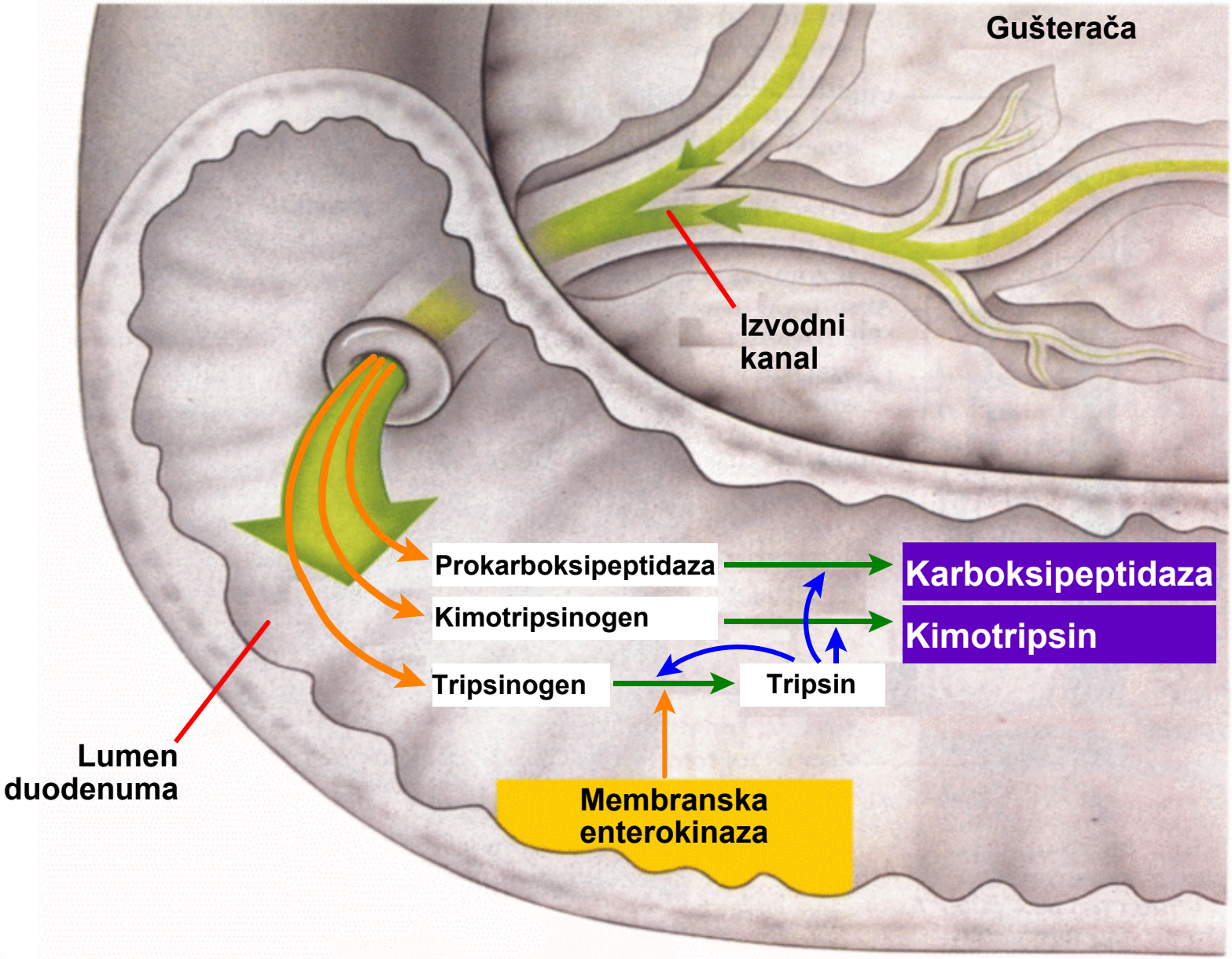
Aktivacija probavnih enzima u duodenumu



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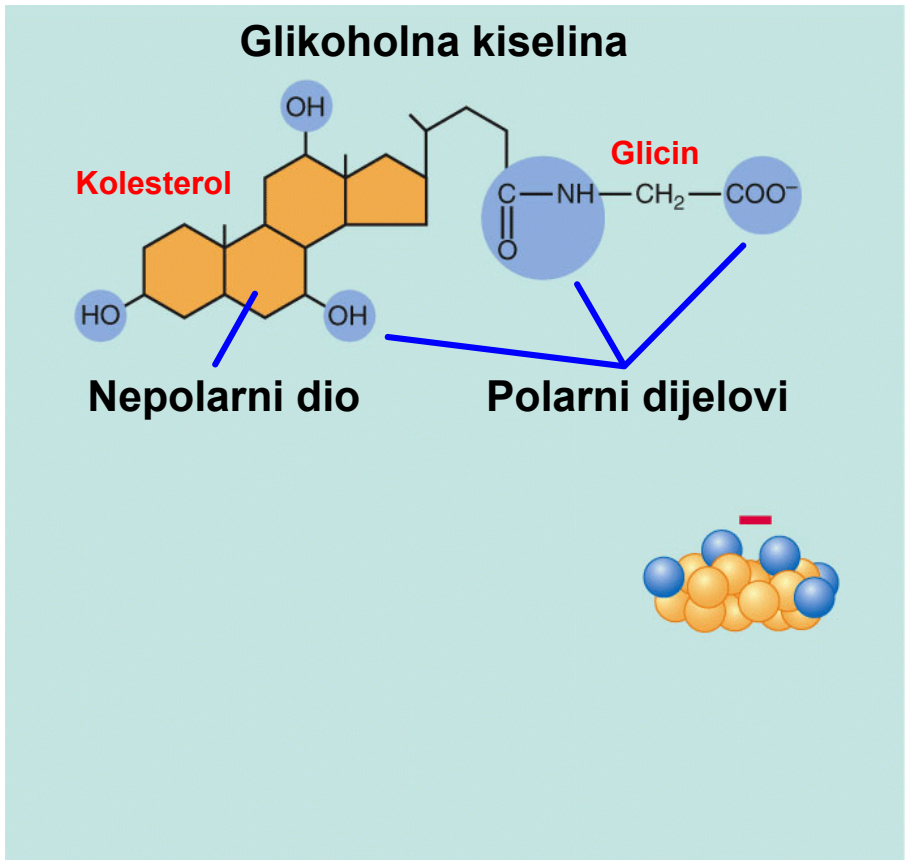
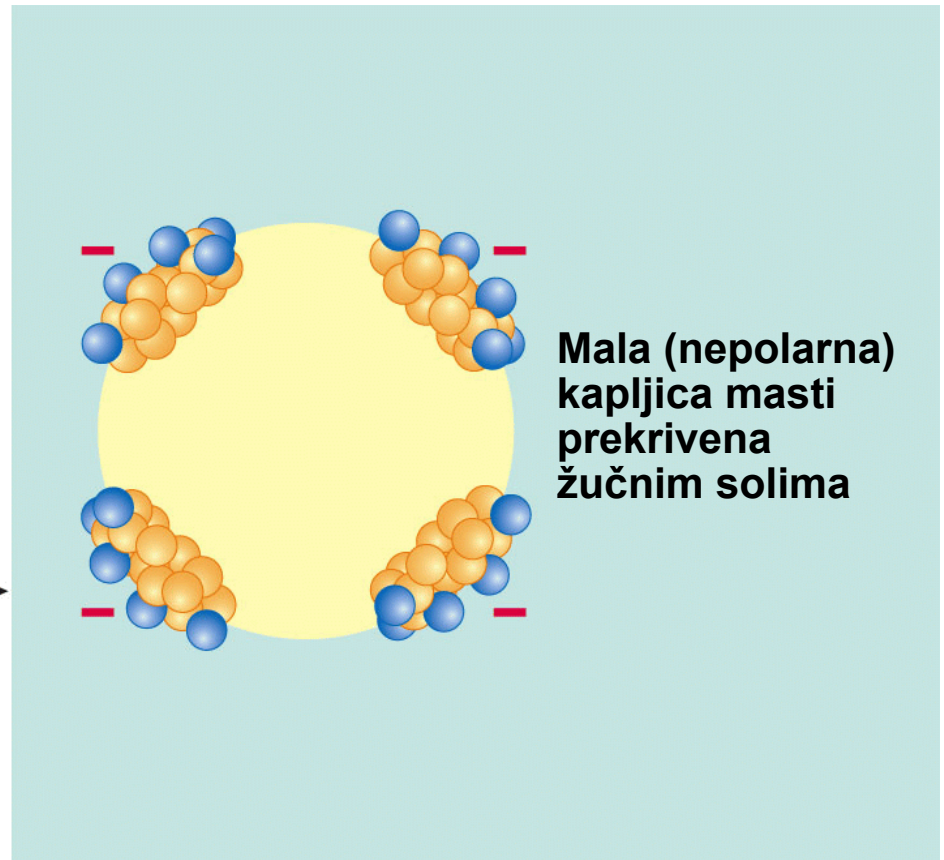
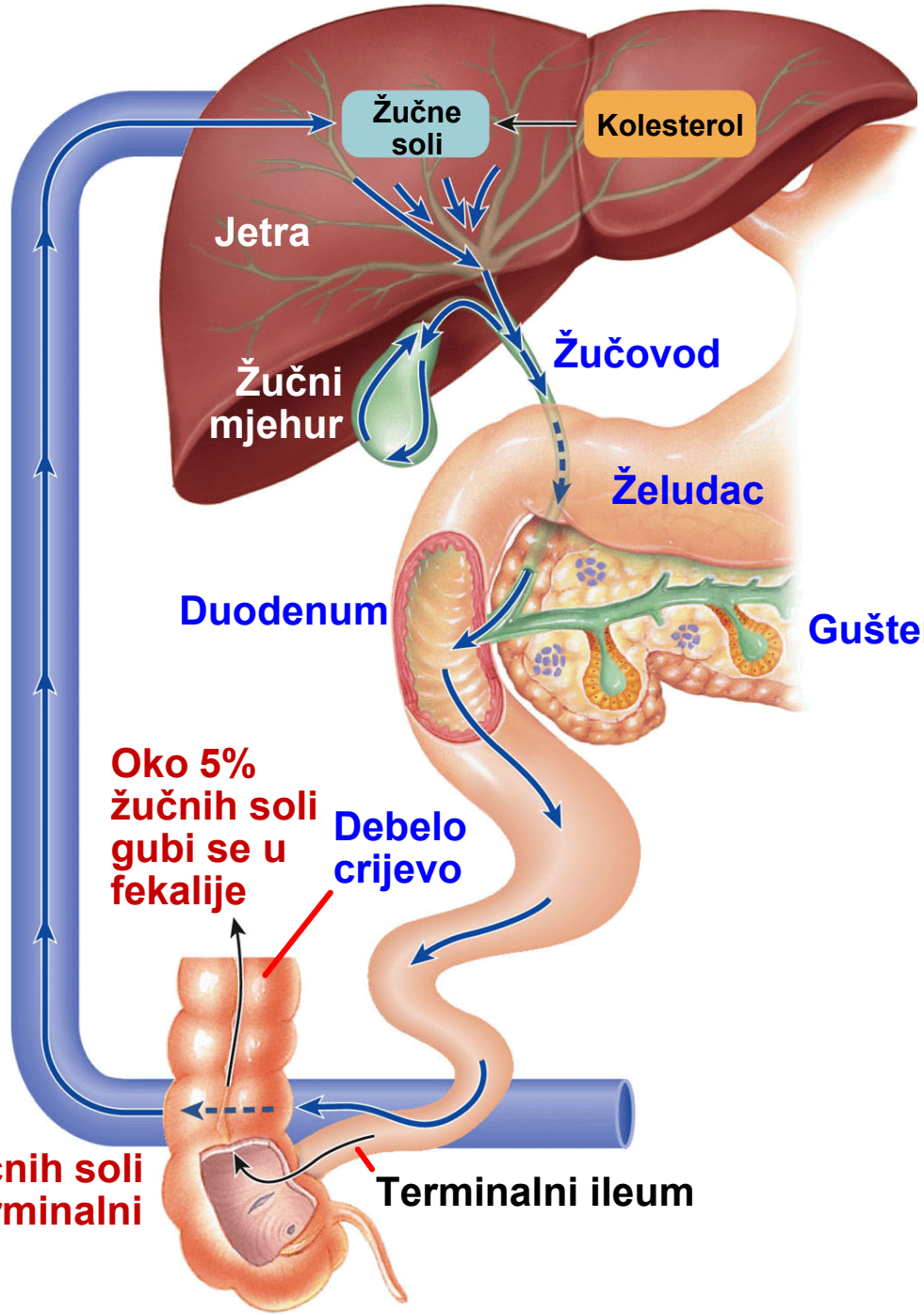
Emulzifikacija masti žučnim solima





Design by Zoran Tadić

Enterohepatička cirkulacija žučnih soli



Izlučene žučne soli sastoje se od oko 95% recikliranih soli i samo od oko 5% novosintetiziranih žučnih soli

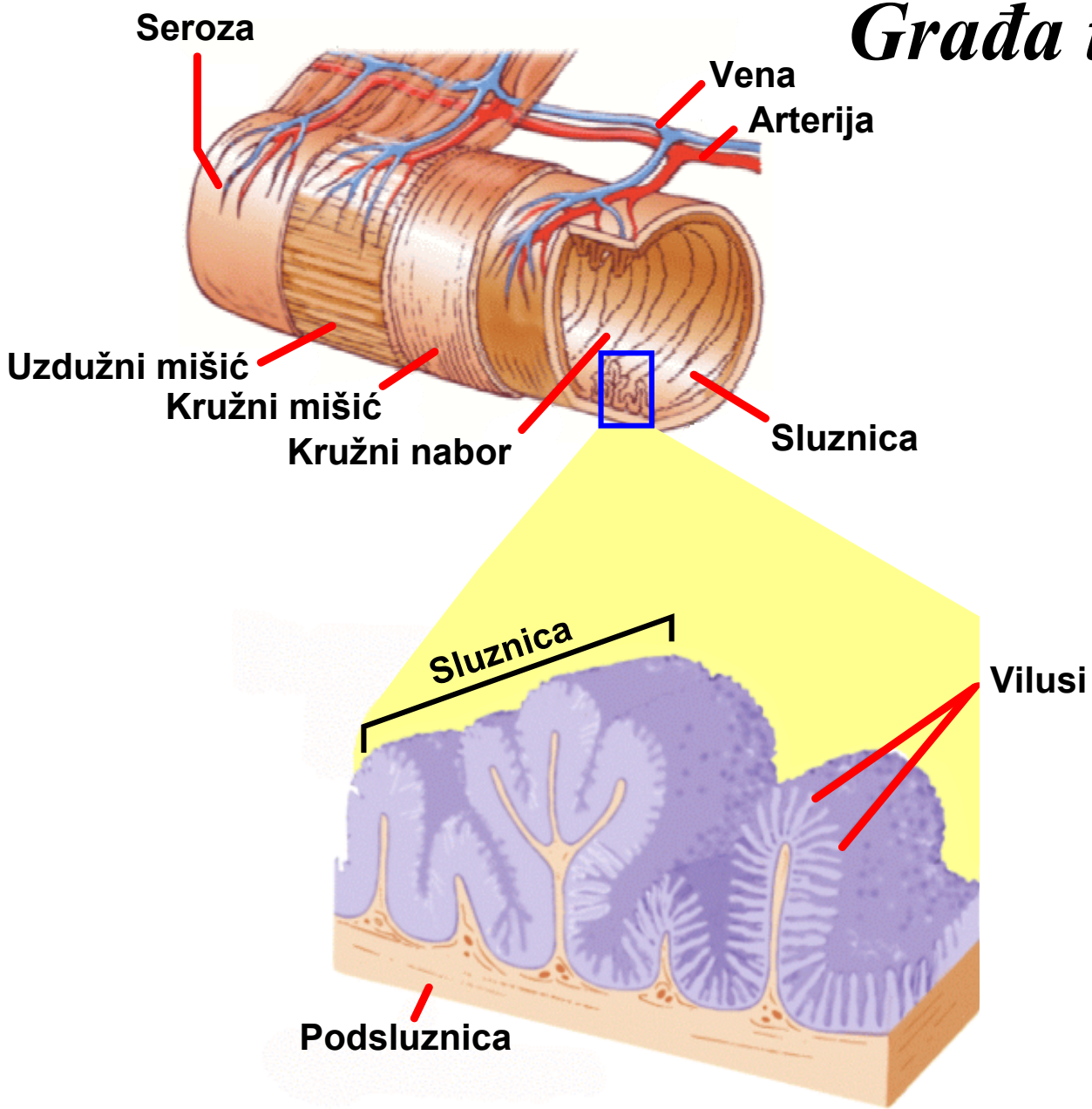
Žučne soli vraćaju se u jetru enterohepatičkom cirkulacijom

Oko 5% žučnih soli gubi se u fekalije

Oko 95% žučnih soli apsorbira terminalni ileum

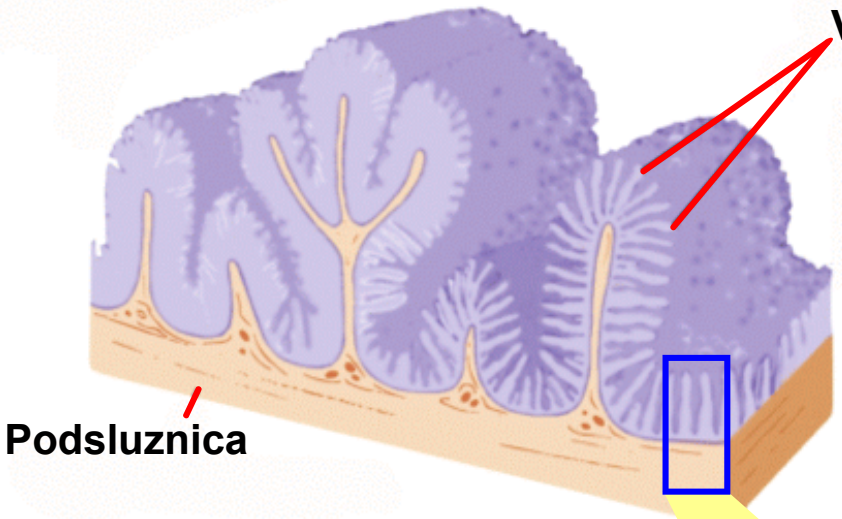
Design by Zoran Tadić

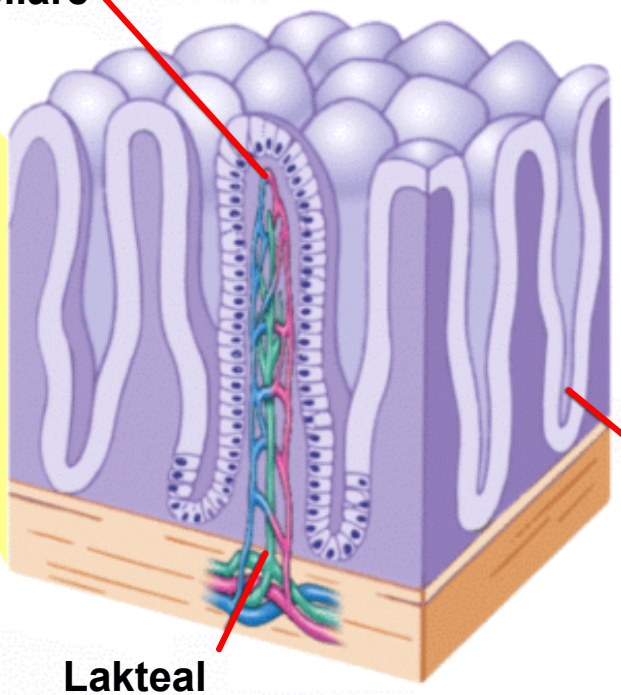
Građa tankog crijeva



Design by Zoran Tadić

Građa tankog crijeva

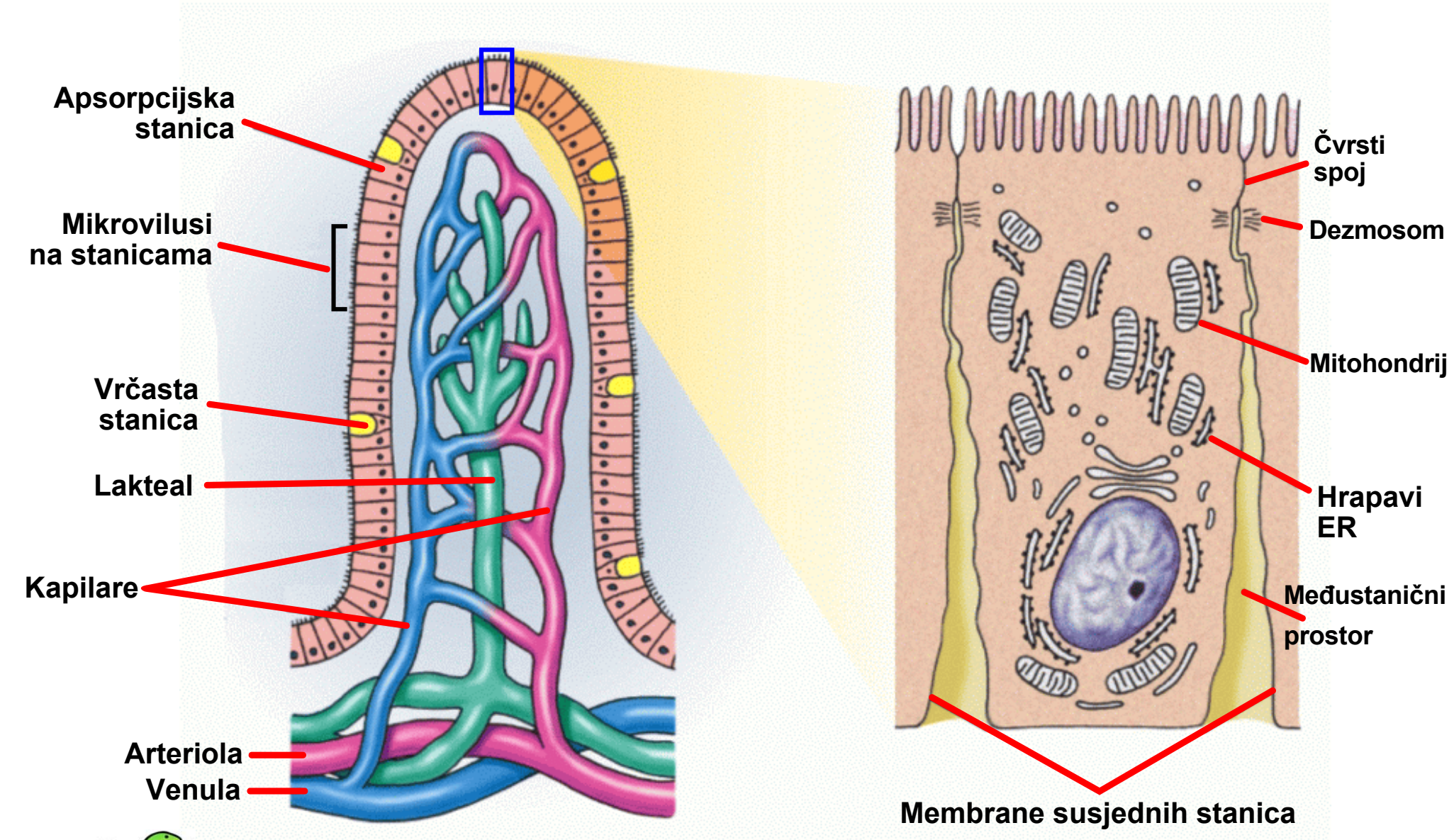




Design by Zoran Tadić

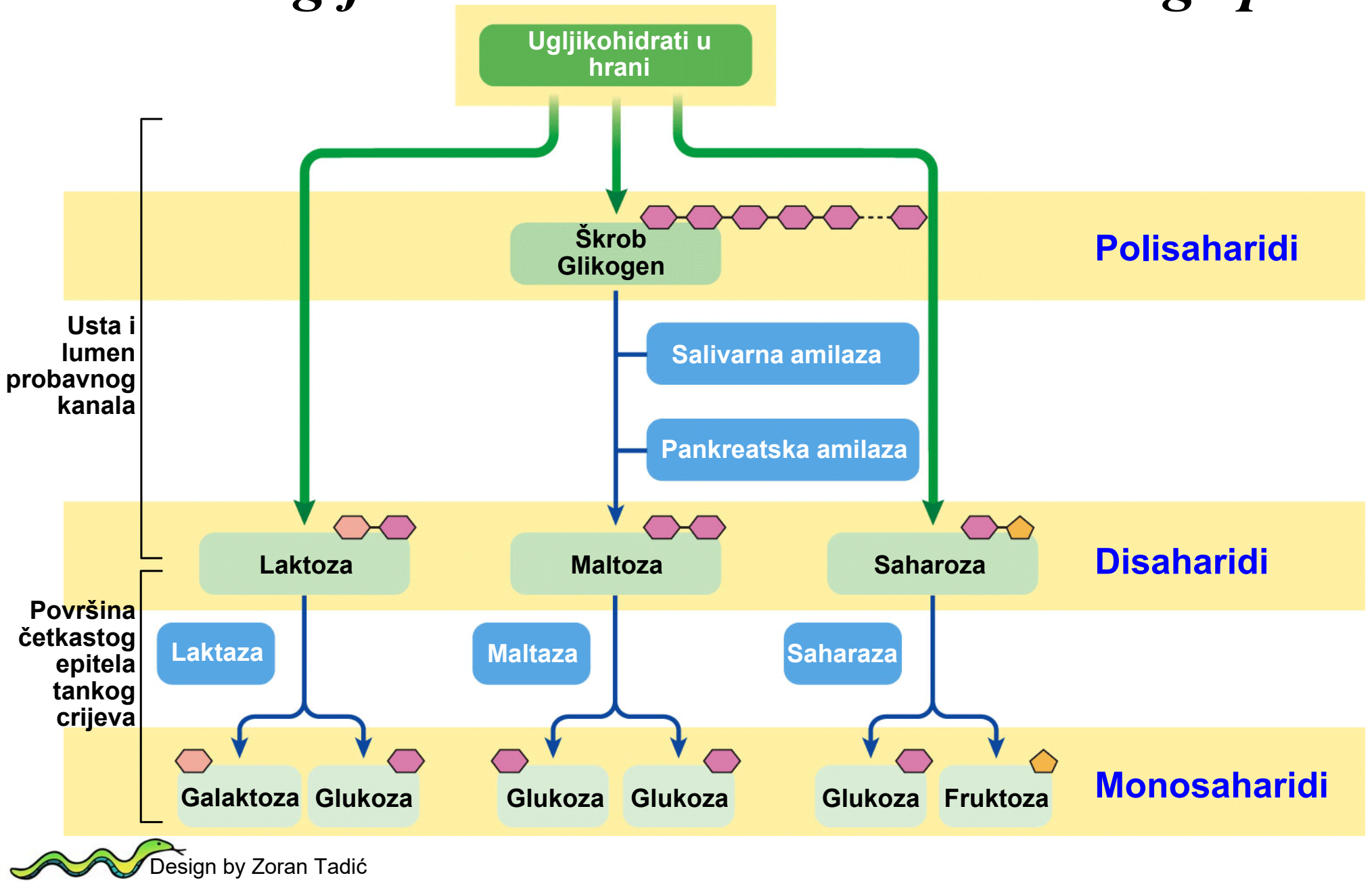
Design by dr. Zoran Tadić

Crijevna resica i apsorpcijska stanica tankog crijeva



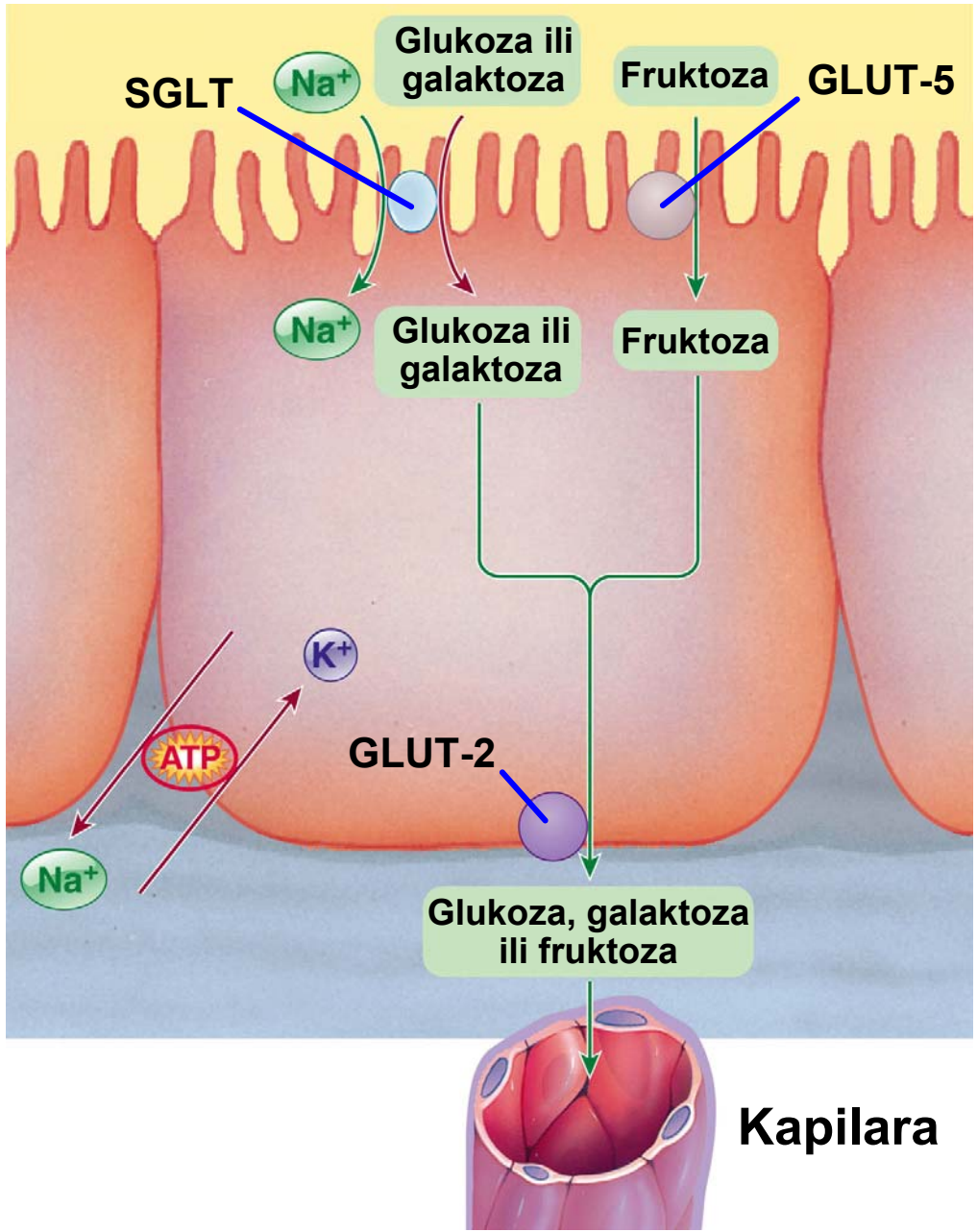
Design by Zoran Tadić

Probava ugljikohidrata od usta do četkastog epitela



Design by Zoran Tadić

Apsorpcija ugljikohidrata



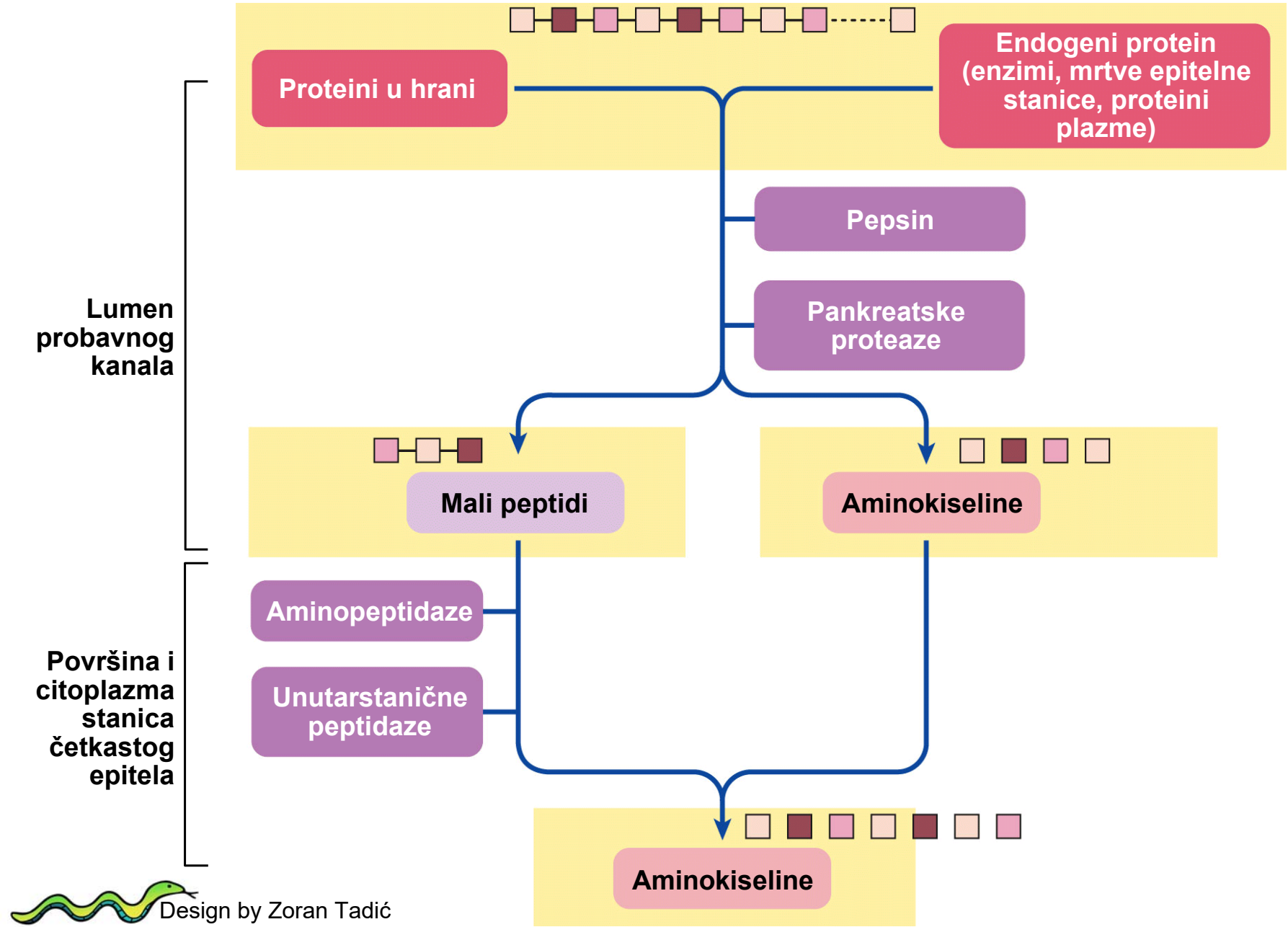
Olakšana difuzija

Simport

Difuzija

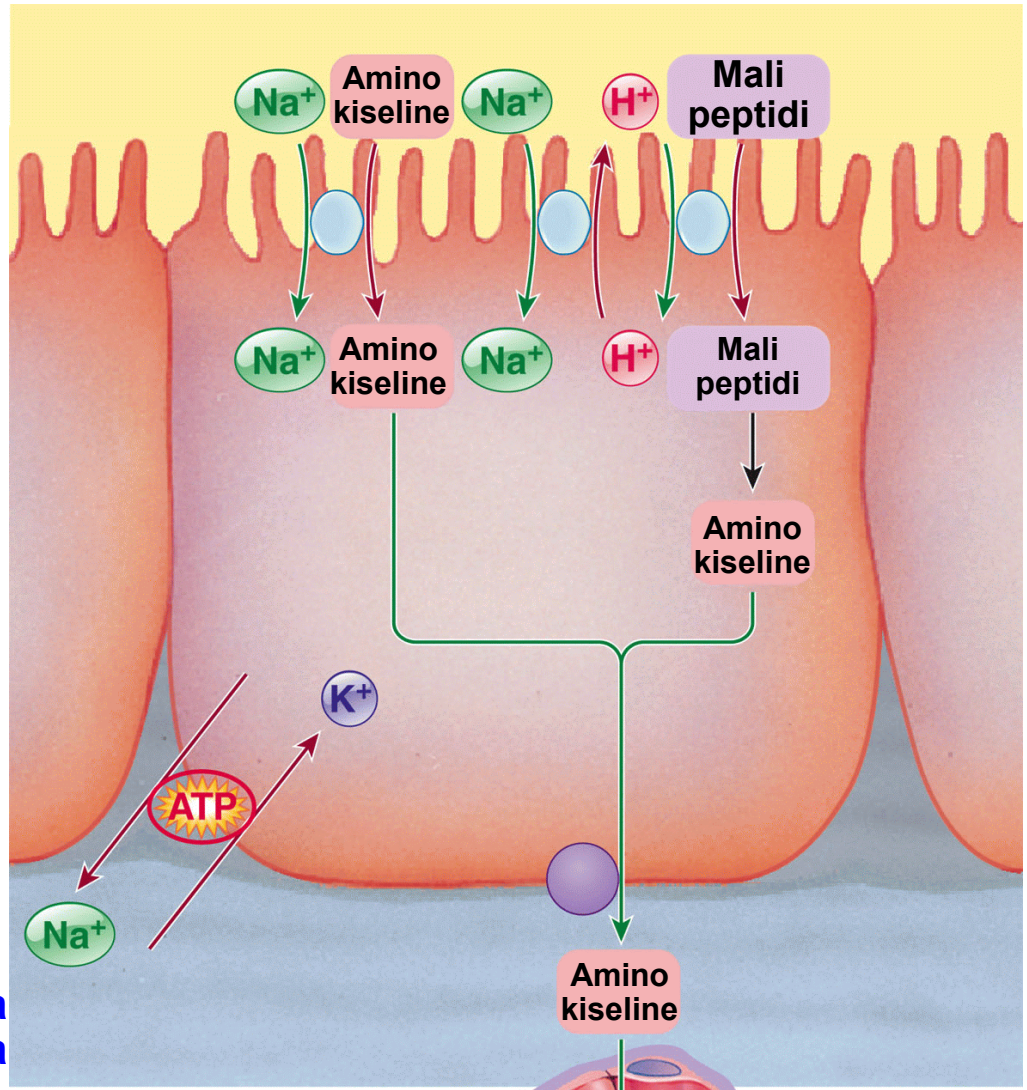
Design by Zoran Tadić

Probava proteina od usta do četkastog epitela



Design by Zoran Tadić

Apsorpcija aminokiselina



Olakšana difuzija

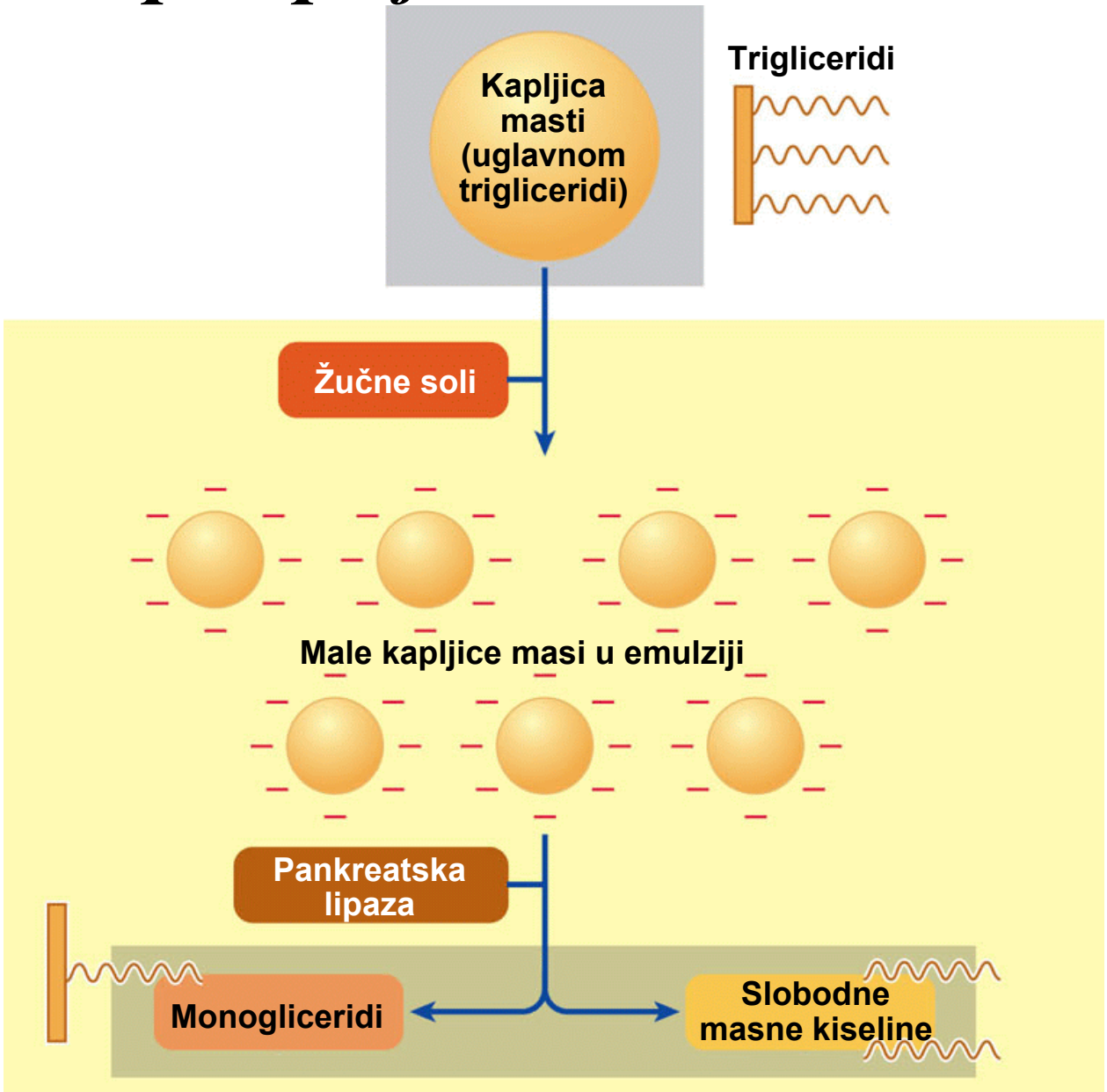
Simport

Antiport

Difuzija

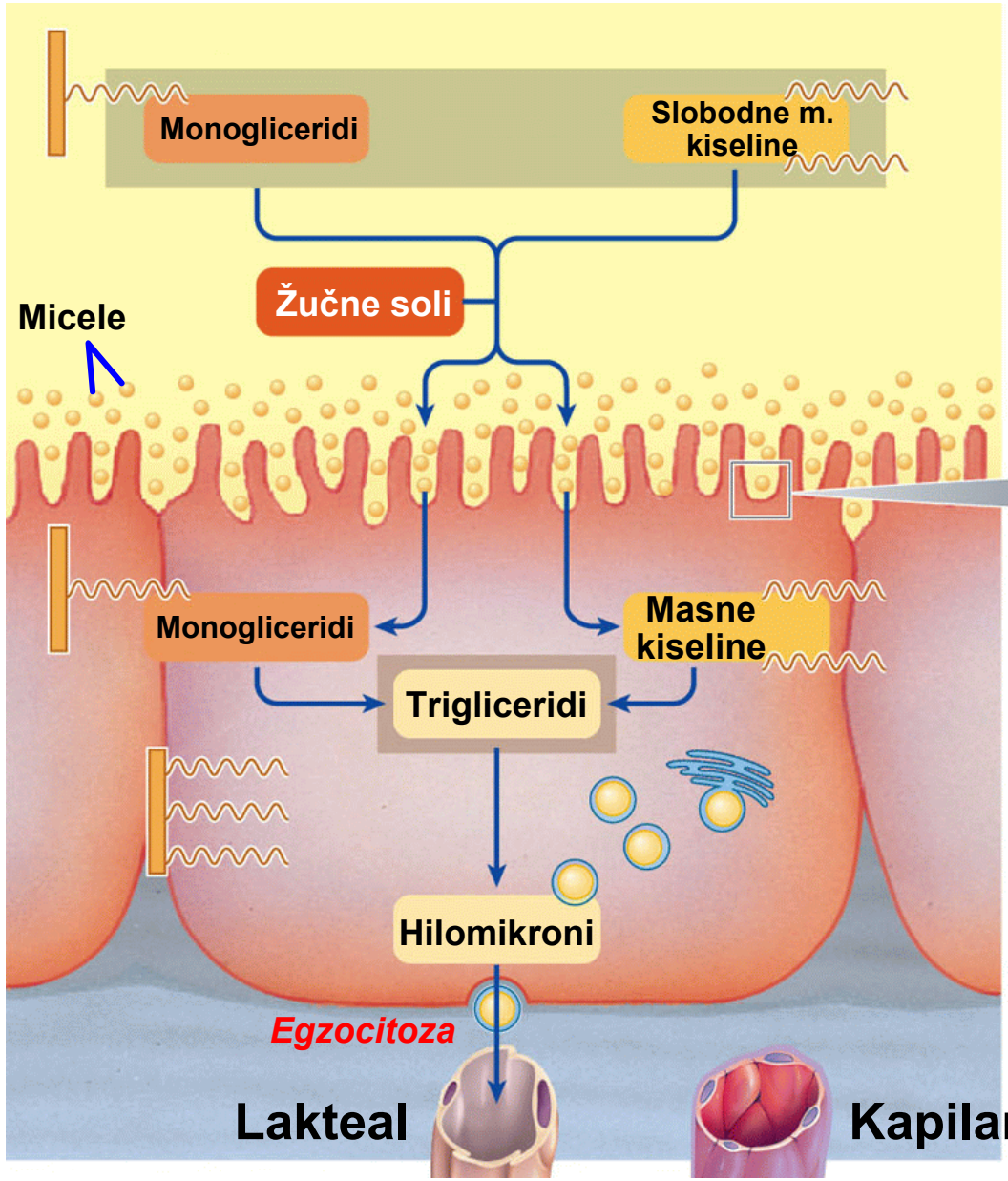
Design by Zoran Tadić

Probava i apsorpcija masti u tankom crijevu 1



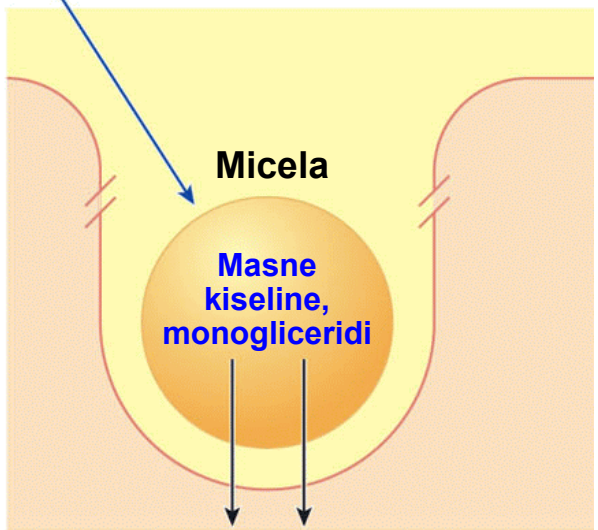
Design by Zoran Tadić

Probava i apsorpcija masti u tankom crijevu 2



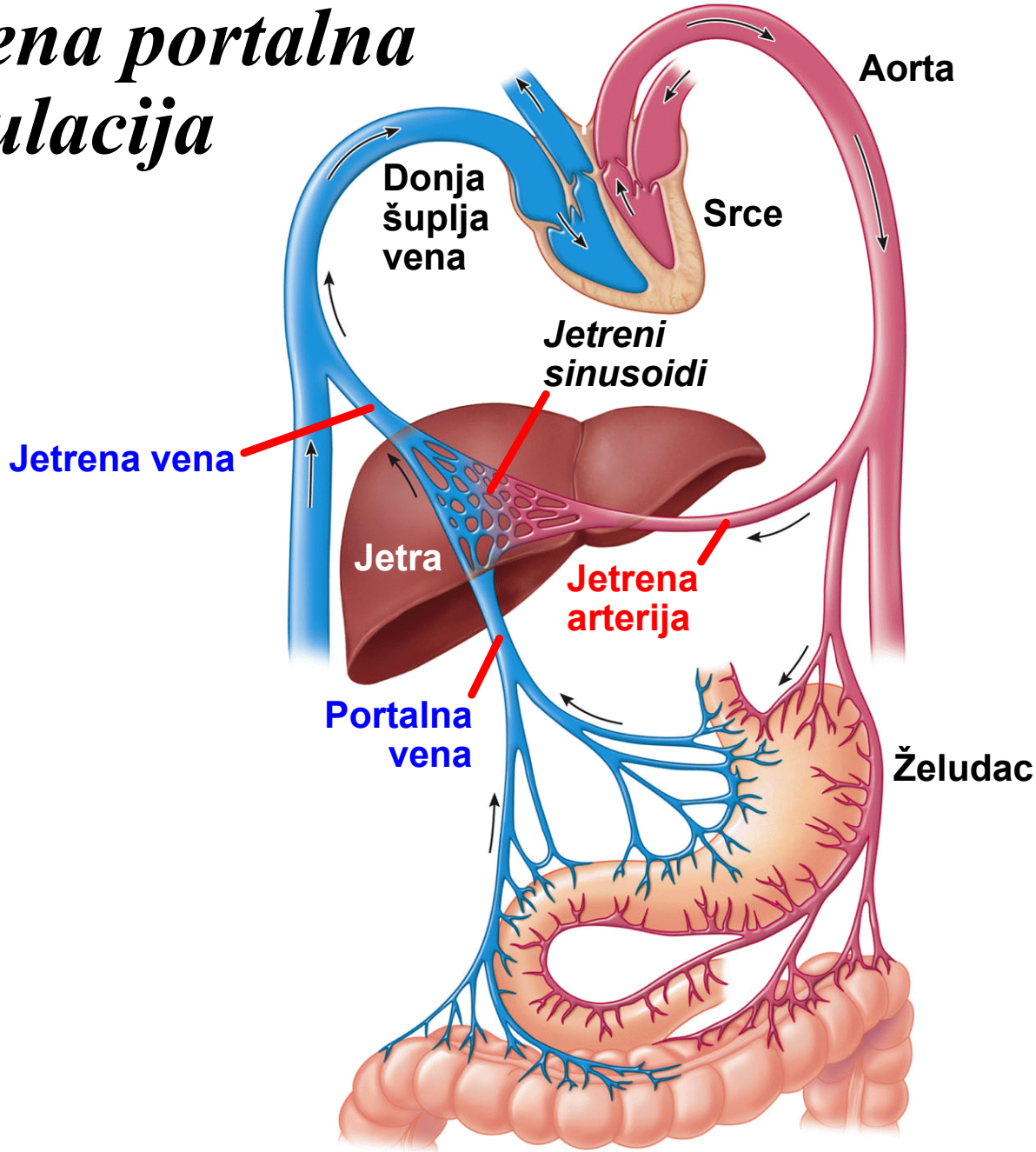
Lumen tankog crijeva

Intersticijska tekućina



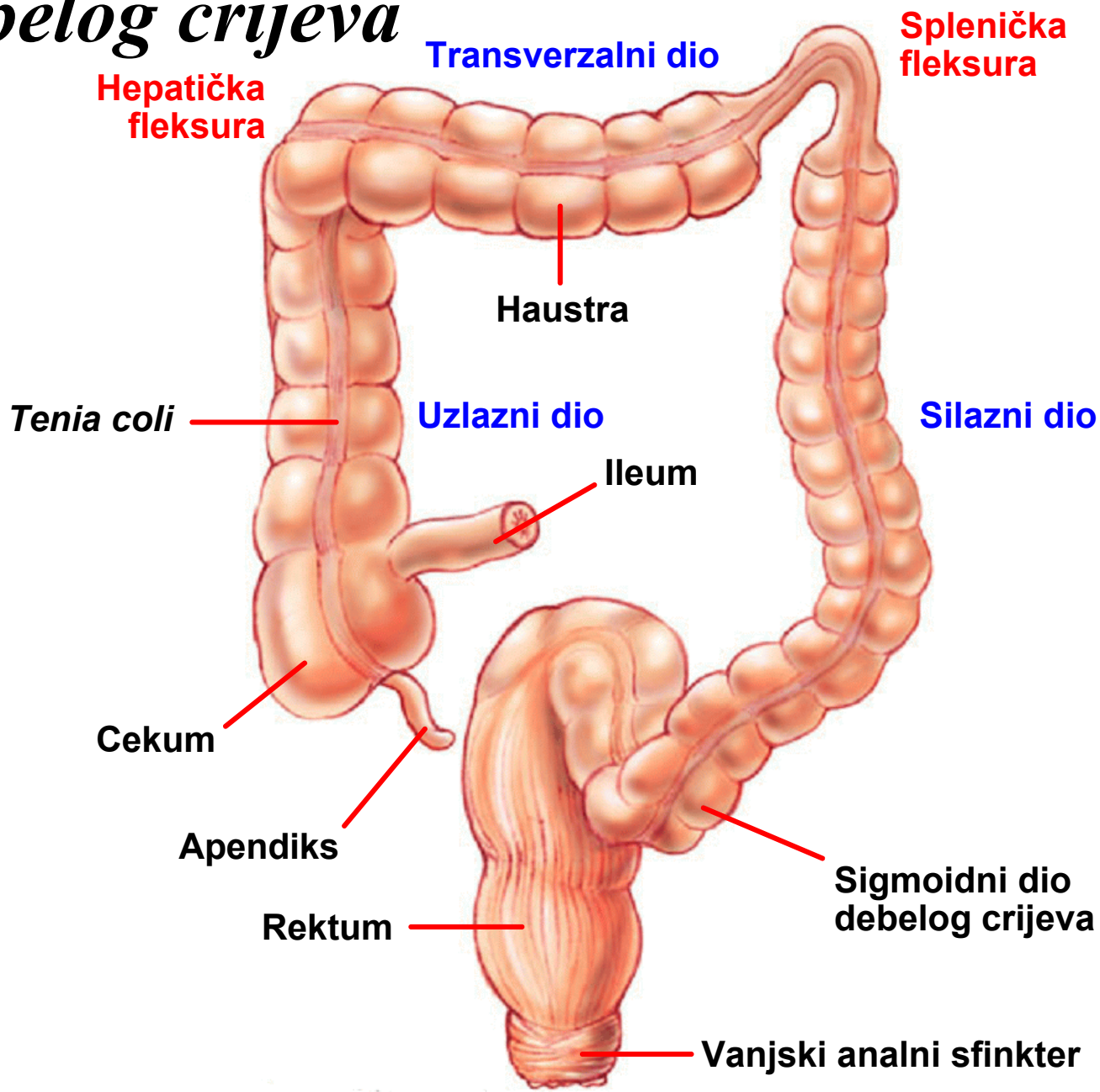
Design by Zoran Tadić

Jetrena portalna cirkulacija



Design by Zoran Tadić

Građa debelog crijeva



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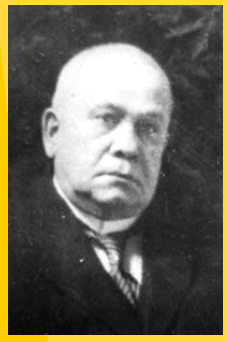
Pikanterije iz fiziologije: Crohnova bolest



Antoni Leśniowski
(1867 - 1940)

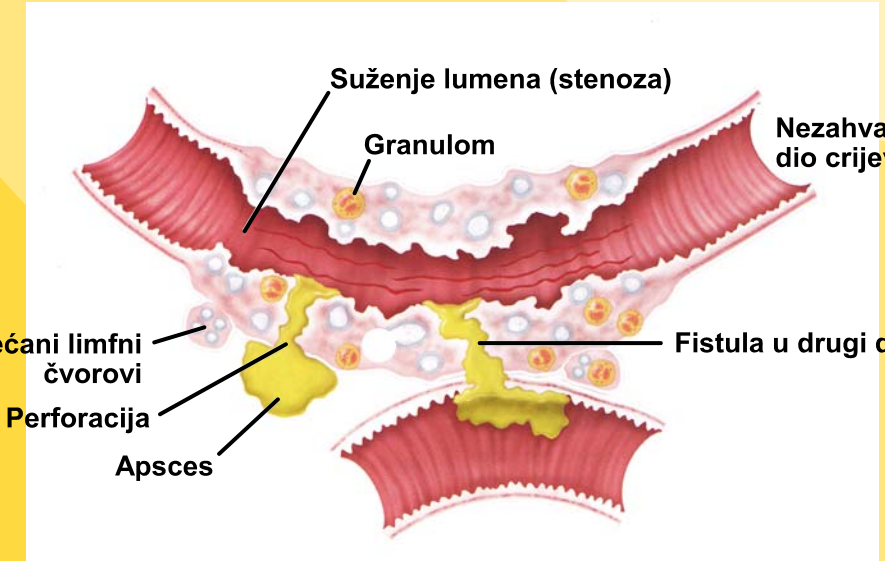
Crohnova bolest je imunobolest koja se najčešće manifestira kao *transmuralna upala crijeva*, ali može zahvatiti bilo koji organ. Prvi ju je 1904. godine opisao poljski liječnik Antoni Leśniowski, ali ime je dobila po američkom liječniku Burrillu Crohnu koji ju je opisao 1932. godine.

Burrill B. Crohn
(1884 - 1983)

Najnoviji pogled na Crohnovu bolest:

- **Javlja se interakcijom čimbenika okoliša, genetičke podložnosti i bakterija. Danas se smatra oblikom imunodeficijencije.**
- **Trenutno ne postoji lijek. Liječenje se svodi na održavanje remisije ili (u akutnoj fazi) kontrole simptoma.**
- **Mogući uzrok: Neusklađeno lučenje citokina (makrofazi) ➜ neusklađena urođena imunost ➜ stalni upalni odgovor na bakterije (najčešće u crijevu) - adaptivna imunost pokušava kompenzirati pogrešan rad urođene imunosti = Crohnova bolest?**

- **Genetička podložnost: Crohnova je bolest možda kvantitativnogenetička bolest gdje svaki gen malo pridonosti riziku nastanka bolesti (cca. 1:200).**
- **h^2 = 0,6 - 0,7 ➜ bolest je kvantitativnogenetičke naravi?**



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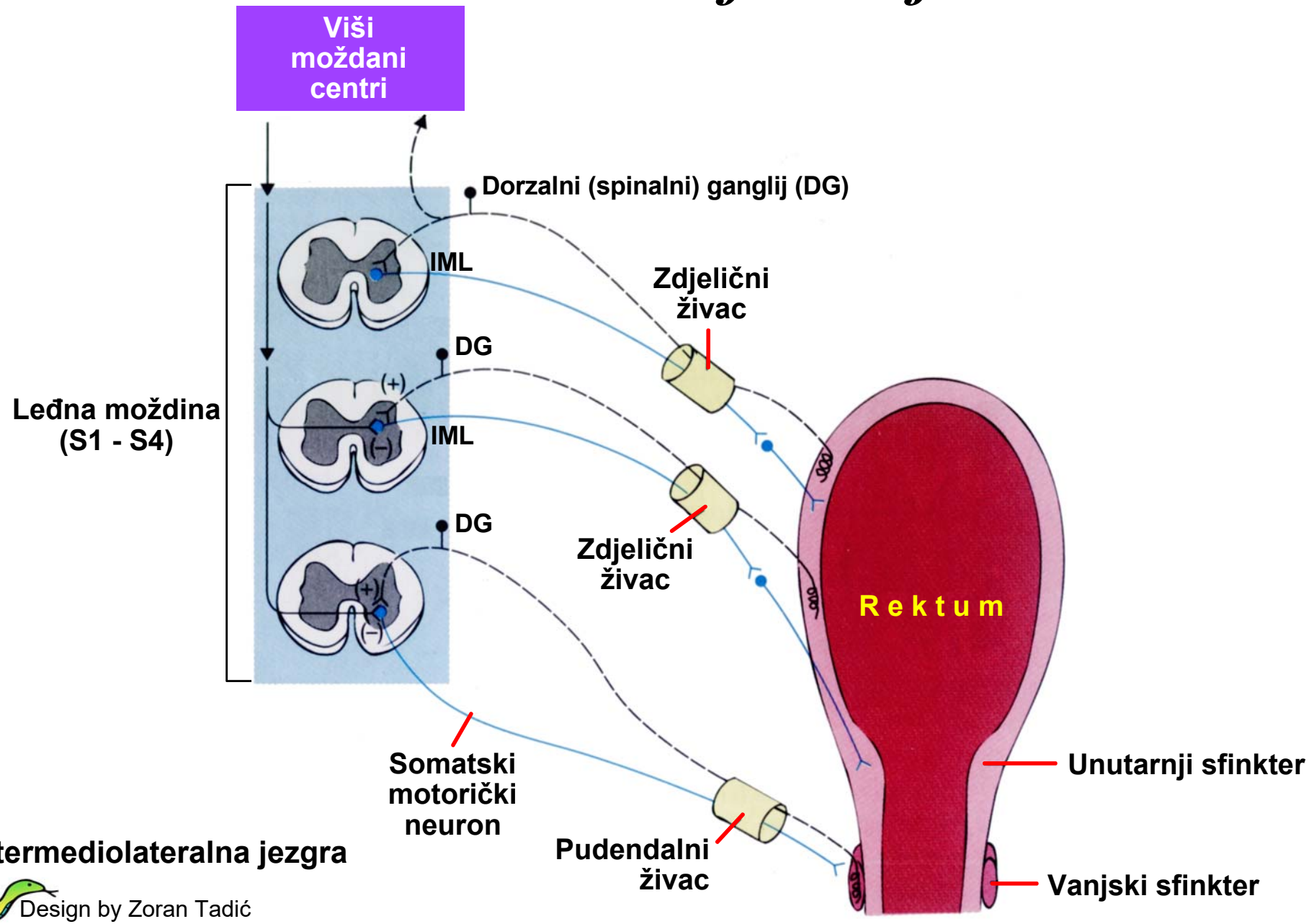
Mehanizam defekacije



IML = Intermediolateralna jezgra

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Pikanterije iz fiziologije: Ispuštanje plinova iz crijeva

Plinovi u crijevima dolaze iz dva izvora:

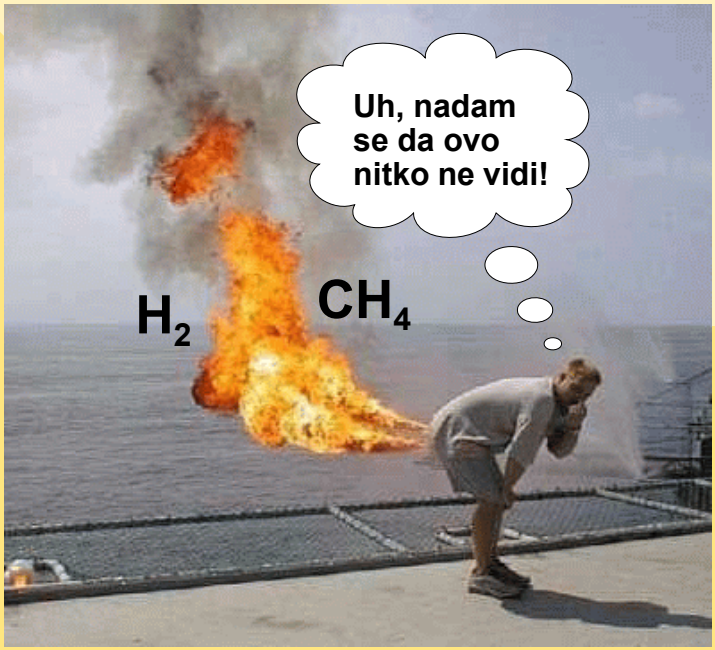
- **Progutani zrak (do 500 ml zraka uđe u probavni trakt hranom) ➜ najveći dio izbaci se podrigivanjem, manji ulazi u tanko crijevo**
- **Bakterijska fermentacija u debelom crijevu ➜ glavni proizvođač plinova u crijevu**

Neka hrana posebno potiče razvoj plinova, posebno biljke iz porodice *Fabaceae* (grah, grašak, slanutak, bob i sl.) ➜ koža sjemenke je neprobavljiva ➜ u debelom crijevu je napadaju bakterije ➜ fermentacija ➜ obilje plinova! ➜ flatus (hrv. prdac) ← potpuno normalna, hrvatska riječ koja je s vremenom, postala prosta riječ !

Sastav plinova:

- **99% volumena čine plinovi bez mirisa: metan, vodik, ugljični dioksid (oko 74%), dušik i kisik (ostatak volumena). Točni sastav ovisi o hrani. Vodik i metan su zapaljivi, ali se u samo oko 70% osoba izbačeni plinovi mogu zapaliti!**
- **1% su plinovi koji daju miris: sumporovodik, metil merkaptan, dimetil sulfid, dimetil disulfid, dimetil trisulfid**

<u>Fiziologija izbacivanja plinova:</u> Kontrakcija trbušnih mišića i vanjskog analnog sfinktera u isto vrijeme ➜ tlak u crijevu naraste iznad atmosferskog ➜ plinovi izlete velikom brzinom ➜ od velike brzine vibriraju rubovi analnog otvora ➜ karakterističan, dobro poznati zvuk (prđenja).



Neobično važni podaci:

- **Plinove ispuštamo oko 14 puta dnevno i u zrak ispustimo između 450 i 1500 ml plinova. Najveći je flatus obično ujutro, nakon ustajanja. Ovo vrijedi ako ne jedemo grah i slične mu biljke.**
- **Koliko je ispuštanje plinova važna fiziološka i društvena aktivnost, govori nam engleska riječ *fart* (prditi) koja je jedna od najstarijih riječi u engleskom jeziku, otprilike stara kao i riječi *yes* i *no*.**

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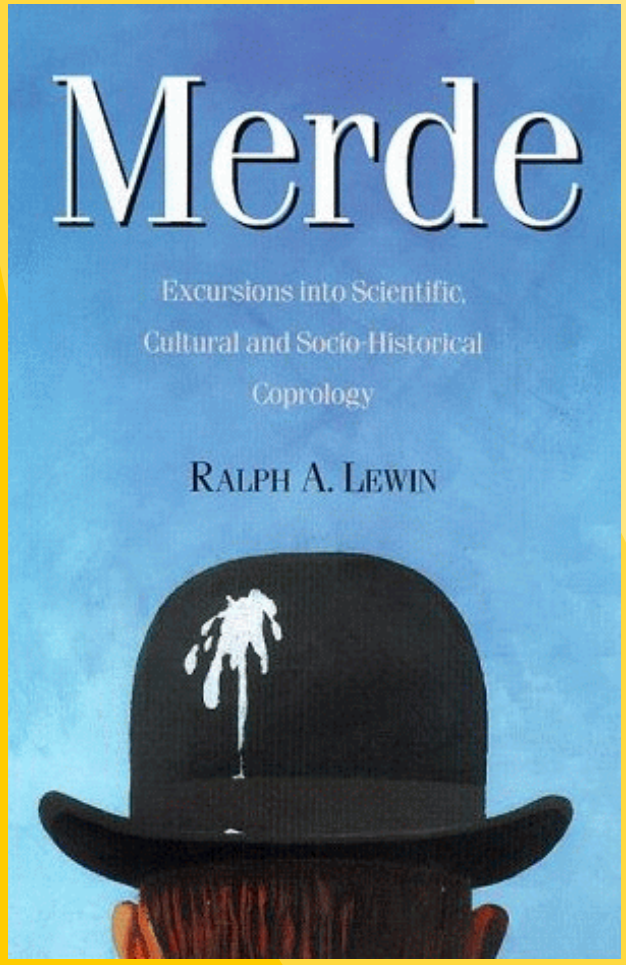
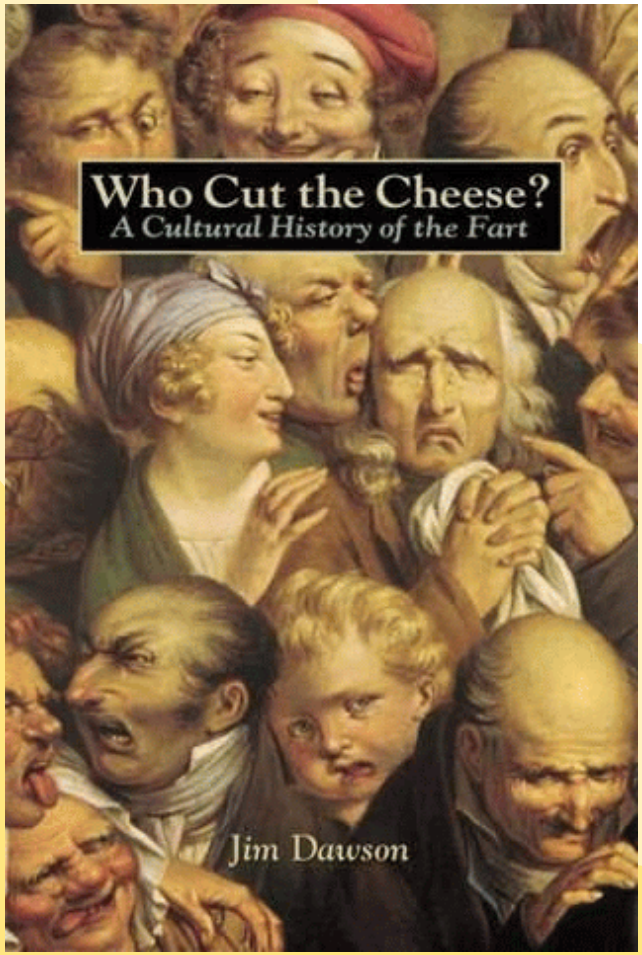
Knjige o neobično važnim fizioprocesima



Ralph A. Lewin: "Merde: Excursions into Scientific, Cultural and Socio-Historical Coprology", Aurum Press, 1999, ISBN: 1854106341



Jim Dawson: "Who Cut the Cheese?: A Cultural History of the Fart", Ten Speed Press, 1999, ISBN: 1580080111

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