# EKSCITACIJA I KONTRAKCIJA SKELETNIH I GLATKIH MIŠIĆA

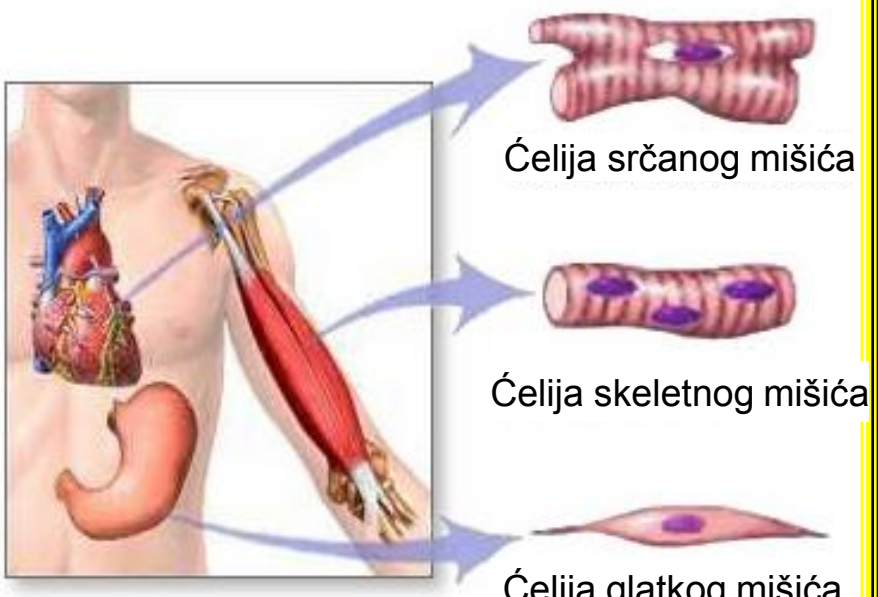
# KARAKTERISTIKE MIŠIĆNOG TKIVA

Ekscitabilnost
Kontraktilnost
Rastegljivost
Elastičnost

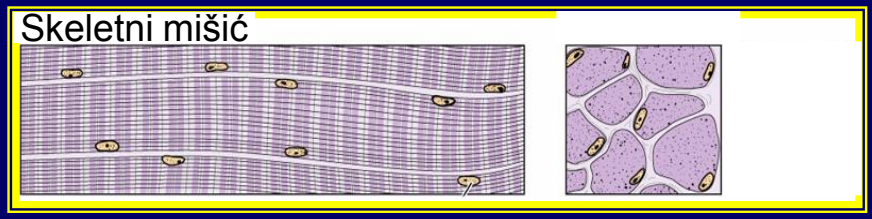
## Mišići imaju sledeće uloge:

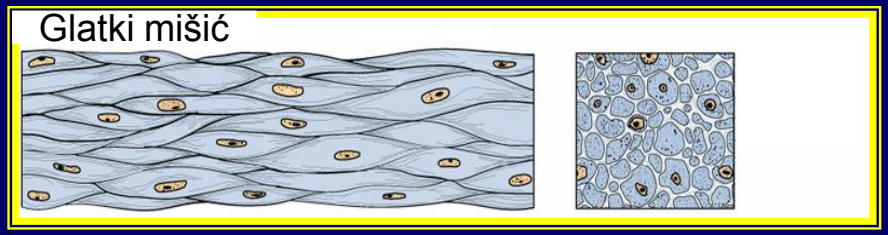
- proizvode pokrete tela i njegovih delova
- proizvode pokrete unutrašnjih organa
- omogućavaju govor
- održavaju položaj tela i ravnotežu
- podupiru meka tkiva
- održavaju telesnu temperaturu

# Vrste mišića

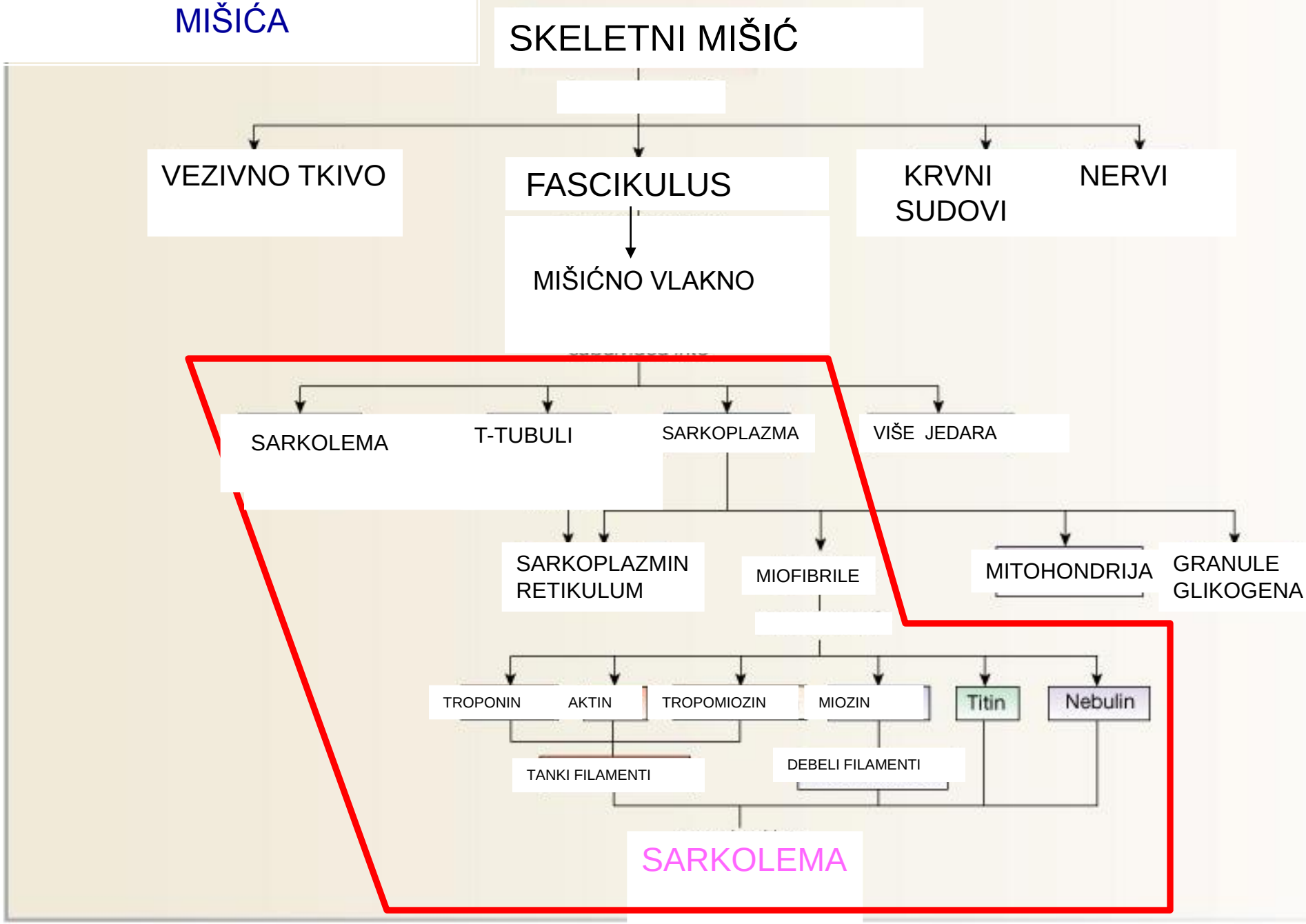




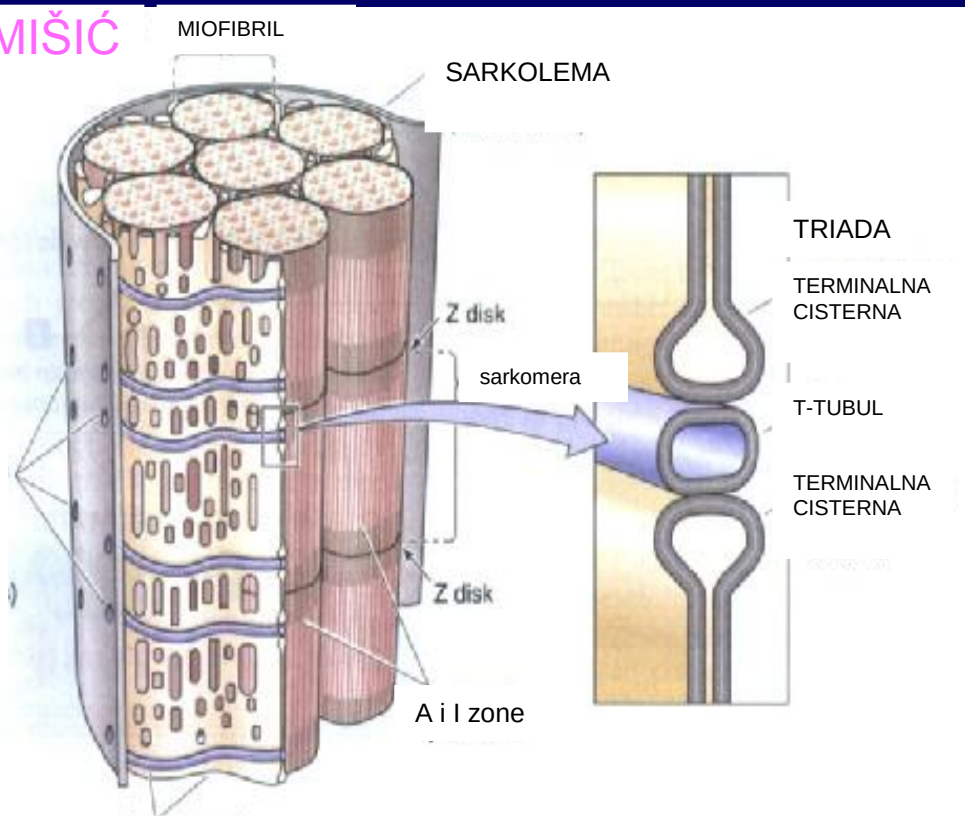


# ORGANIZACIJA SKELETNOG MIŠIĆA



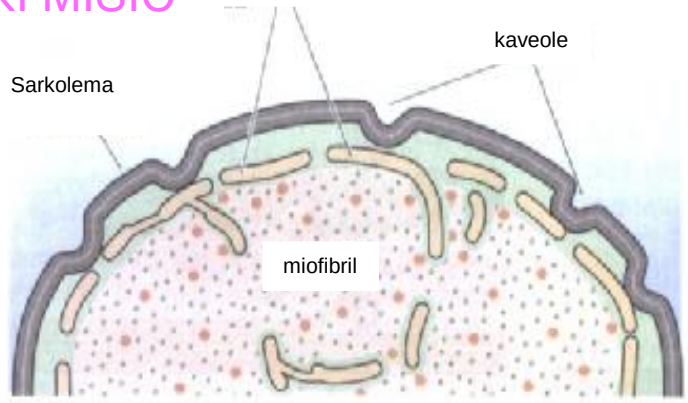
# SKELETNI MIŠIĆ



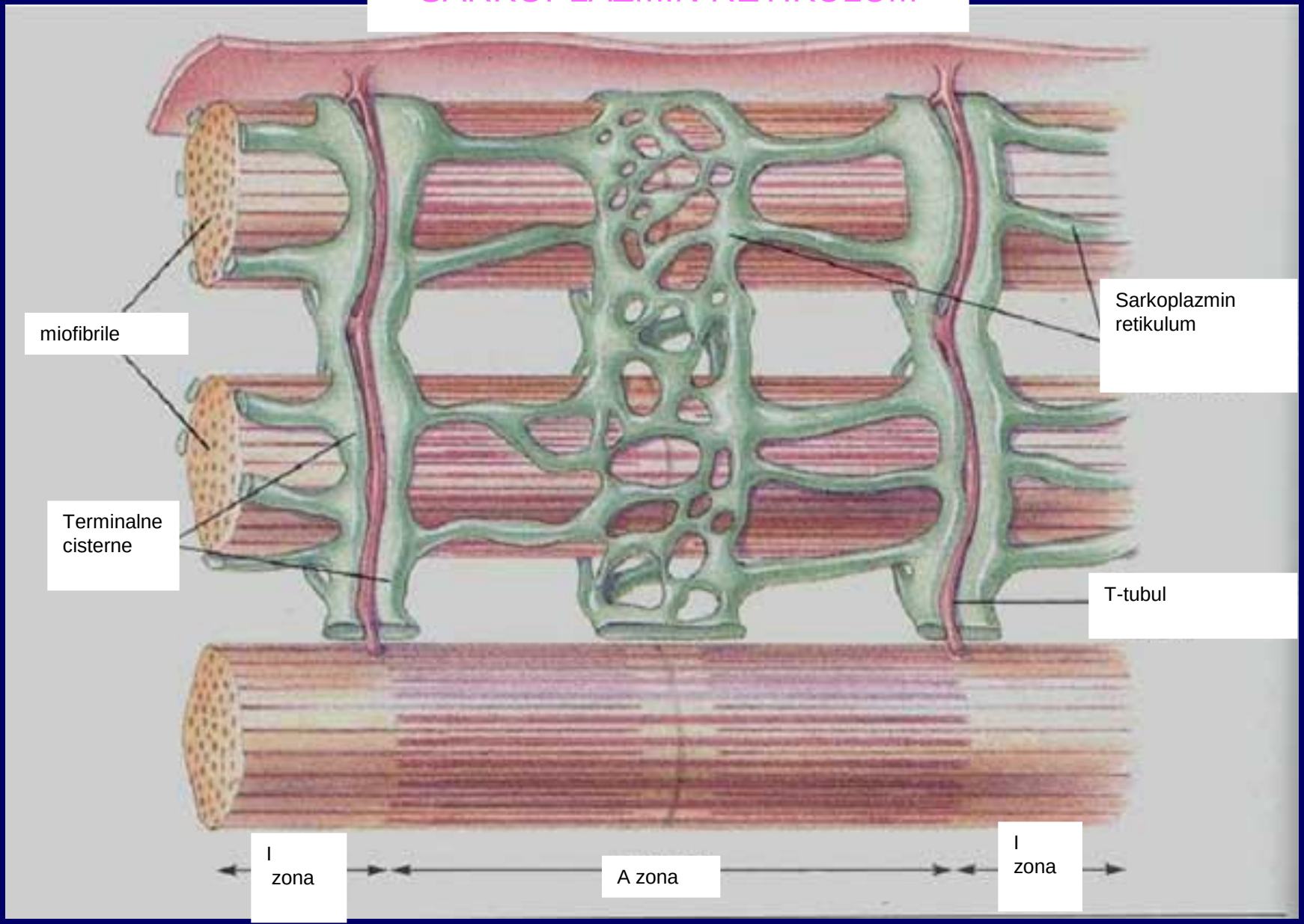

T-tubuli

Sarkoplazmin retikulum

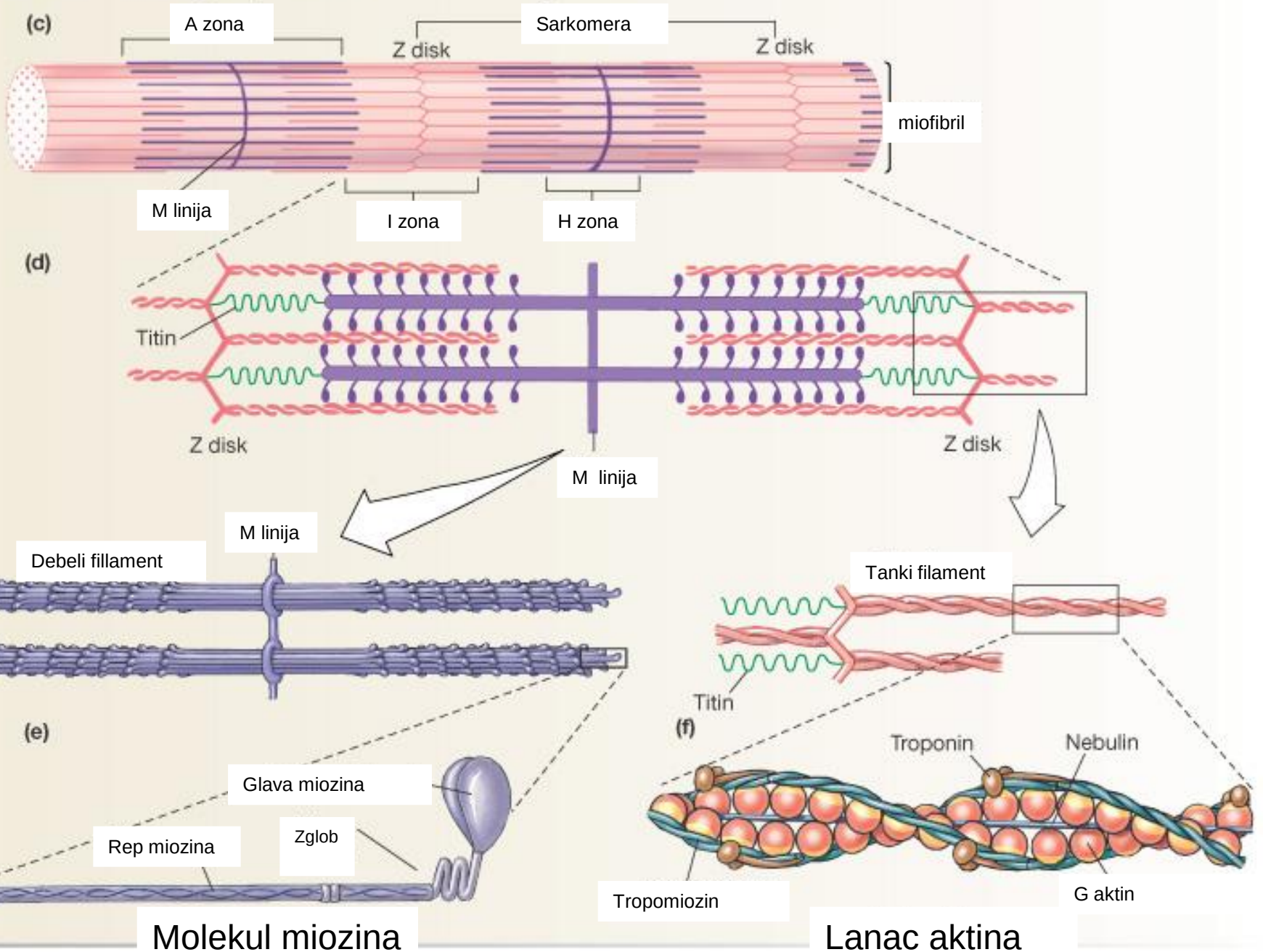
# GLATKI MIŠIĆ

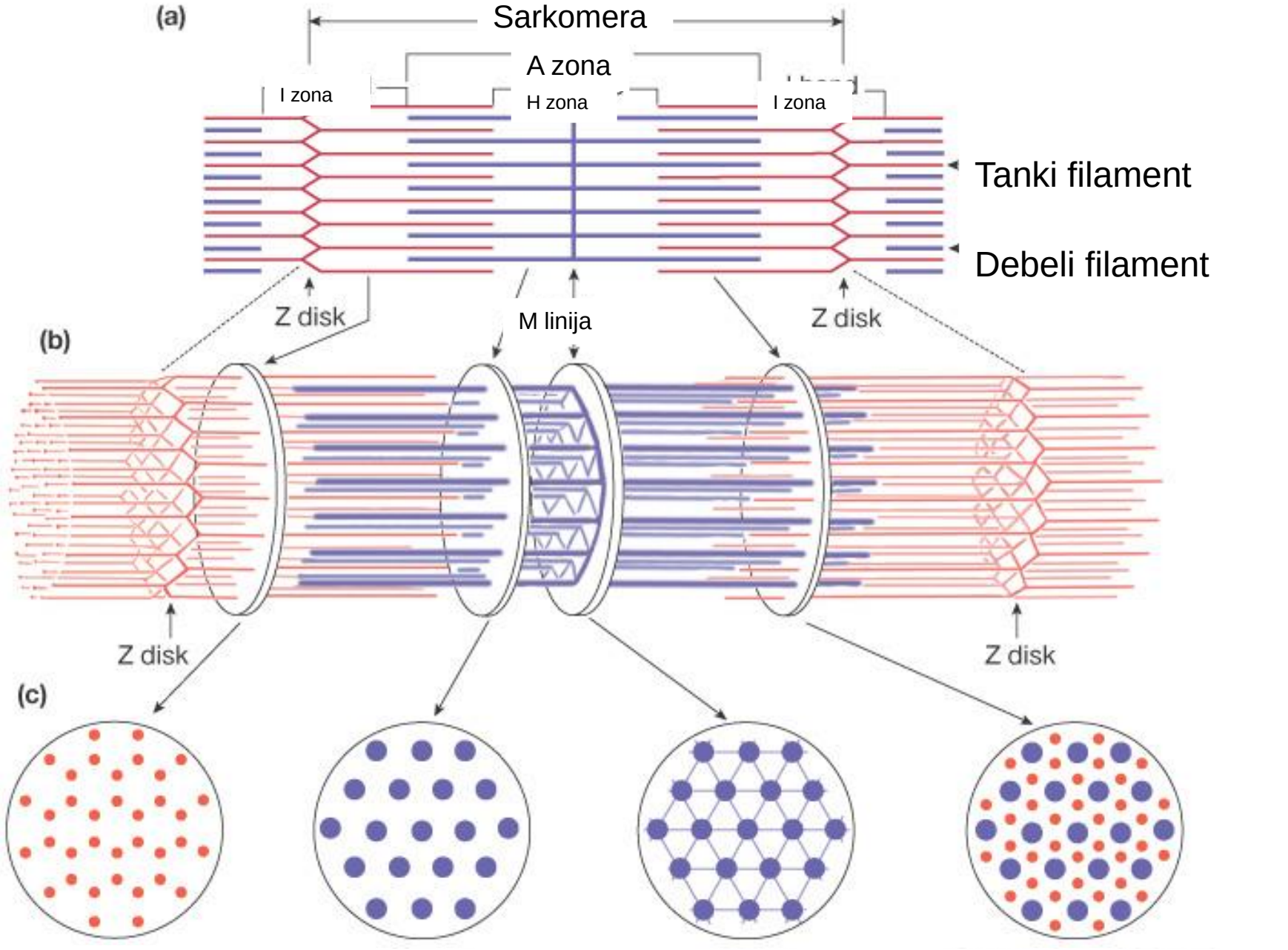


# SARKOPLAZMIN RETIKULUM



# ULTRASTRUKTURA MIŠIĆNOG VLAKNA





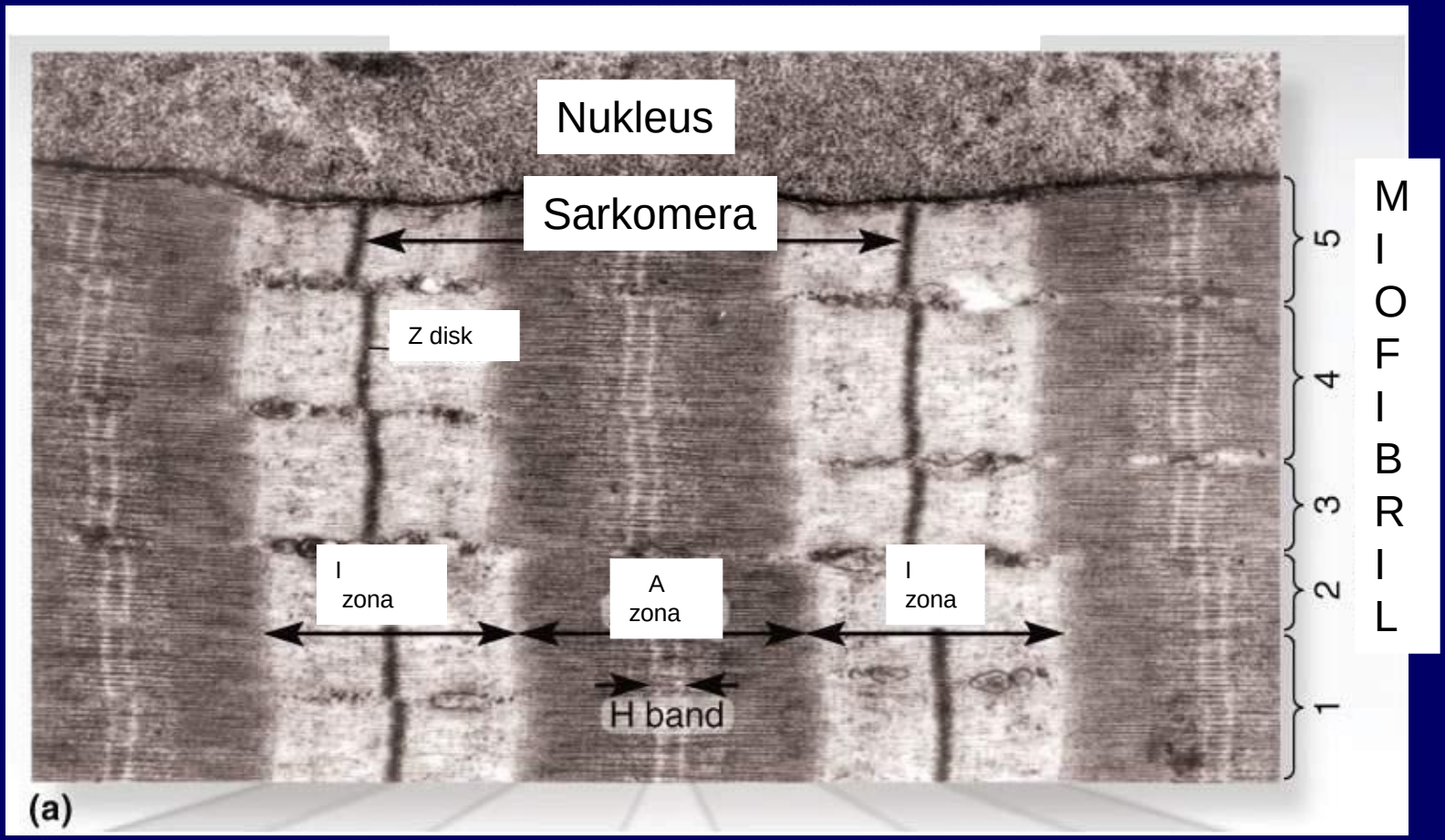

**I zona**
samo tanki filamenti

**H zona**
samo debeli filamenti

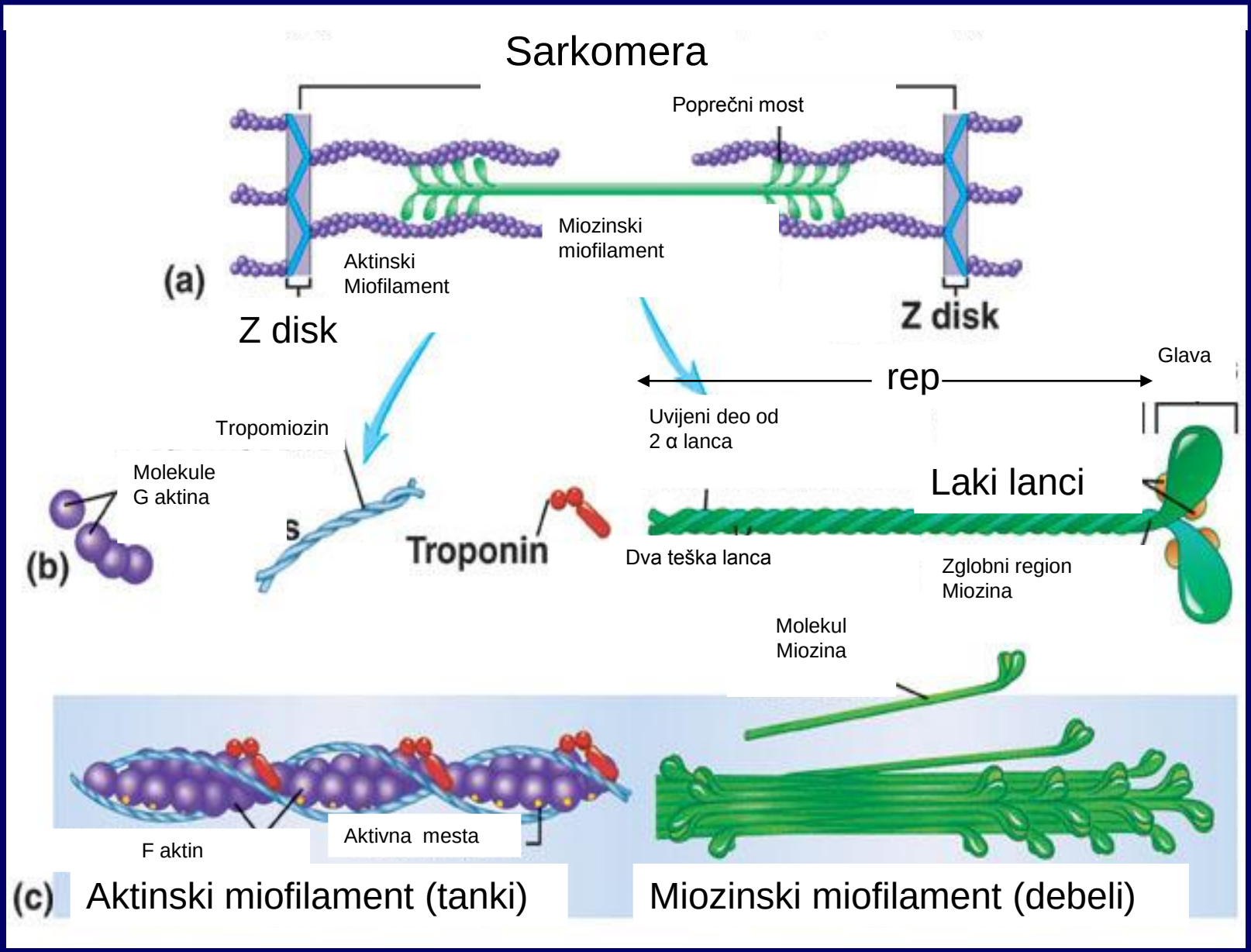
**M linija**
debeli fiilamenti povezani akcesornim proteinima

**Spoljašnji rub A zone**
Preklapanje debelih i tankih fillemanata

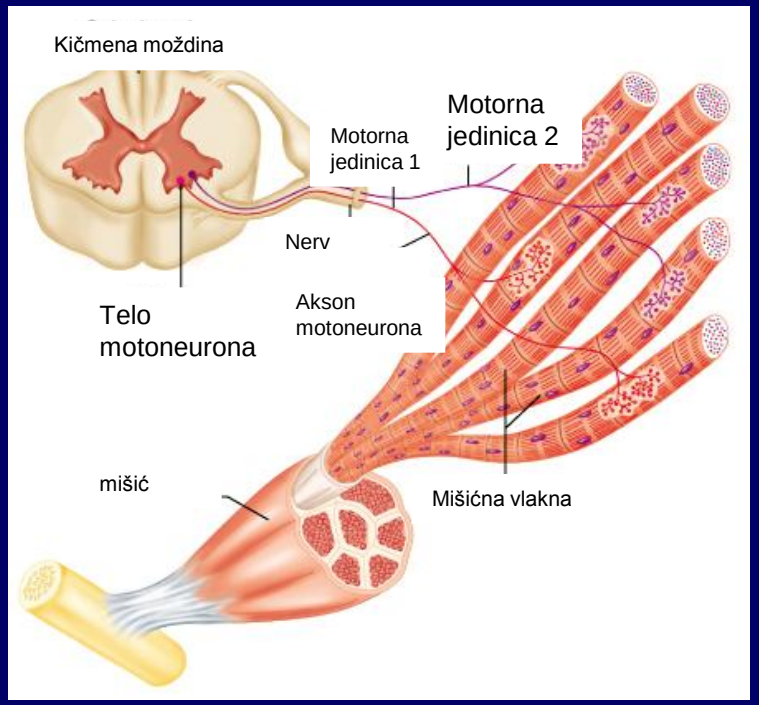
# POPREČNA ISPRUGANOST

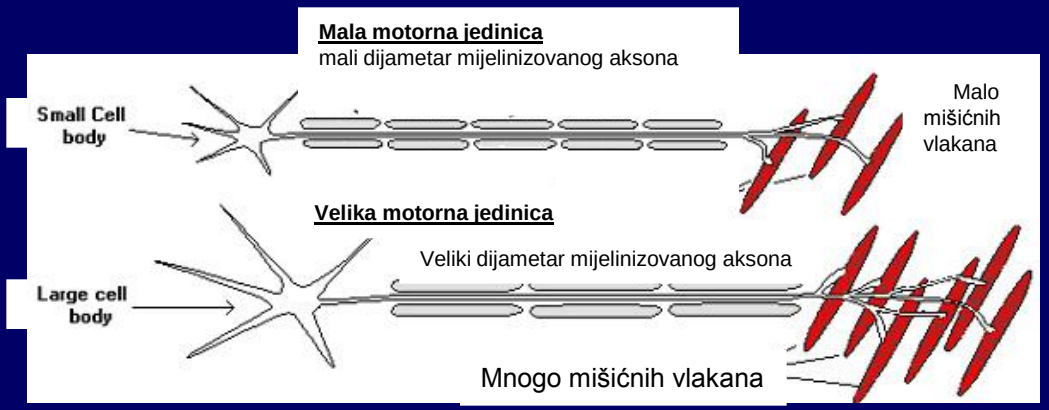


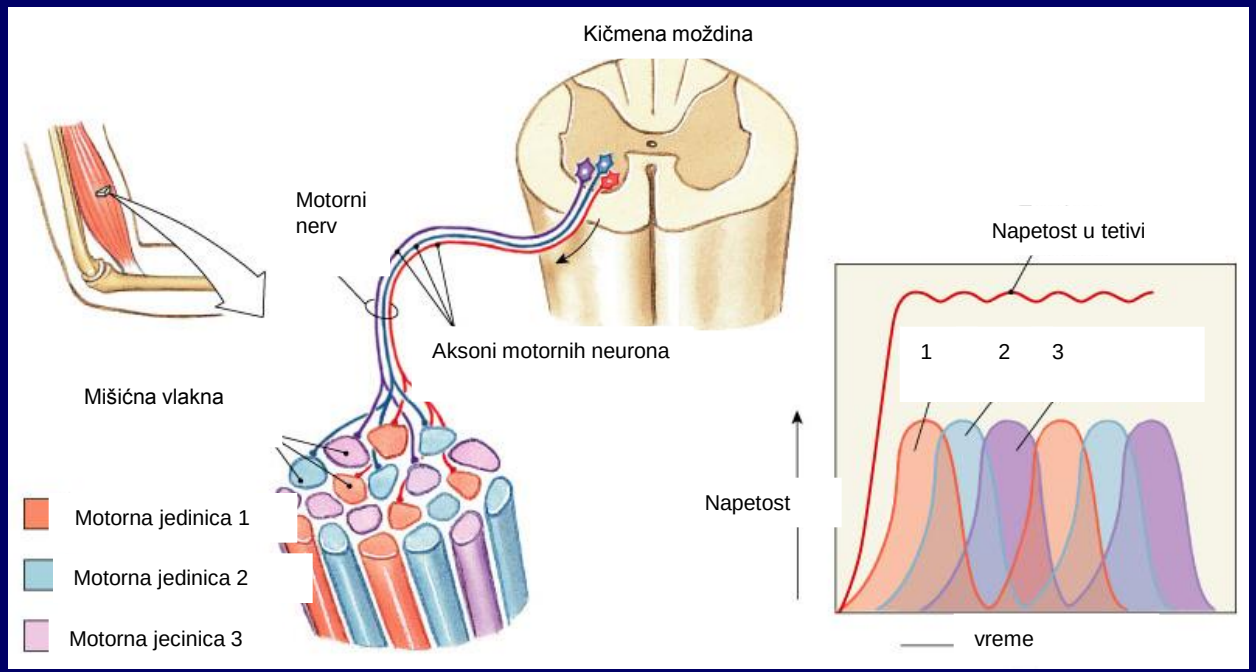
# STRUKTURA AKTINA I MIOZINA



# Motorna jedinica skeletnog mišića



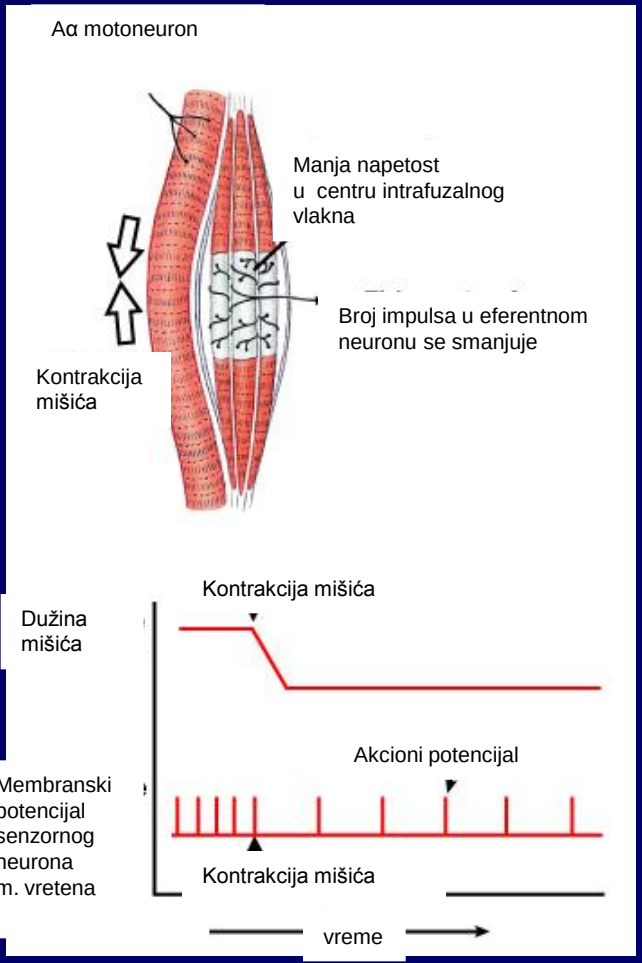




-MALE MOTORNE JEDINICE
(za precizne pokrete)

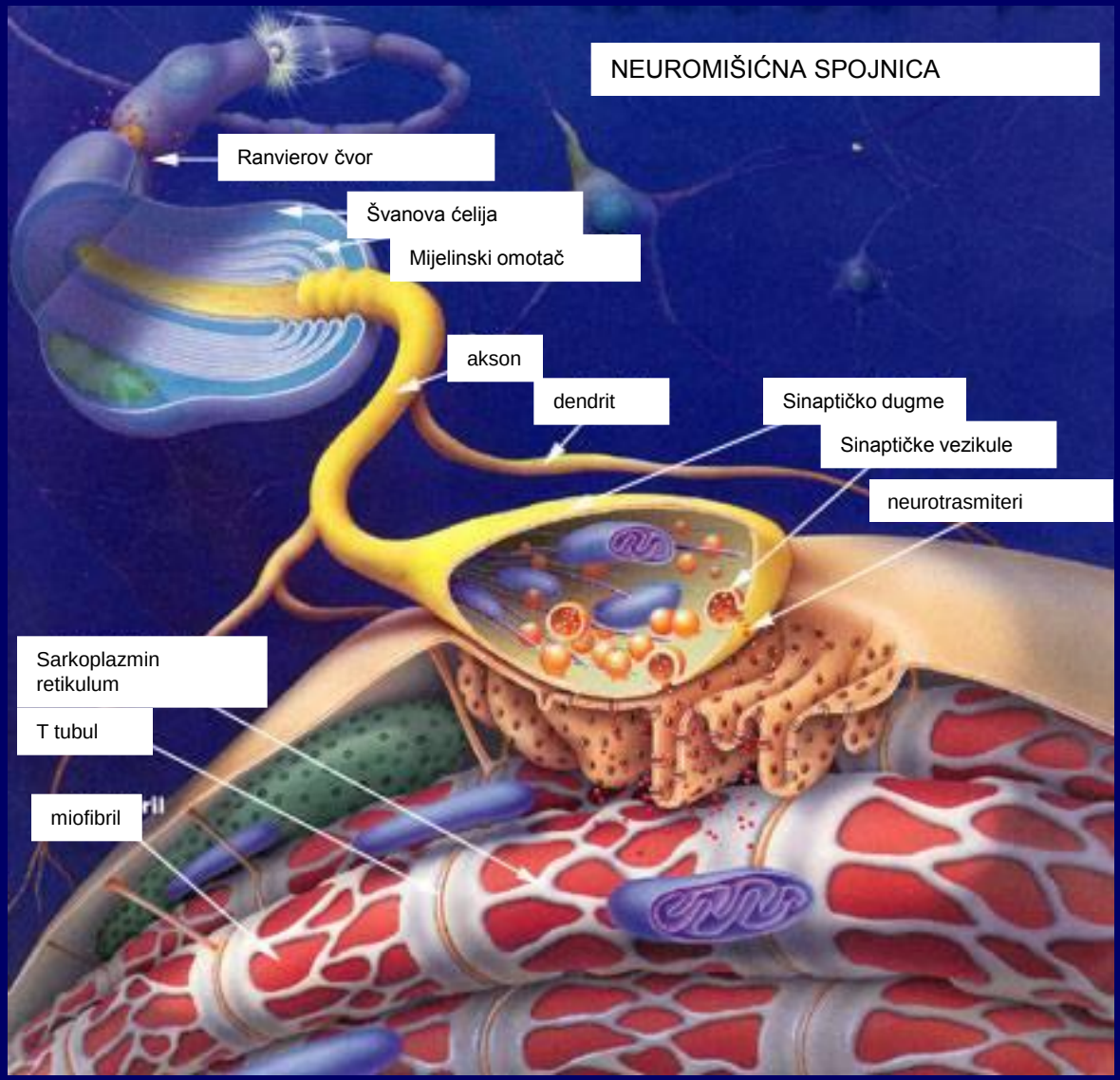
- VELIKE MOTORNE JEDINICE (za grube pokrete)

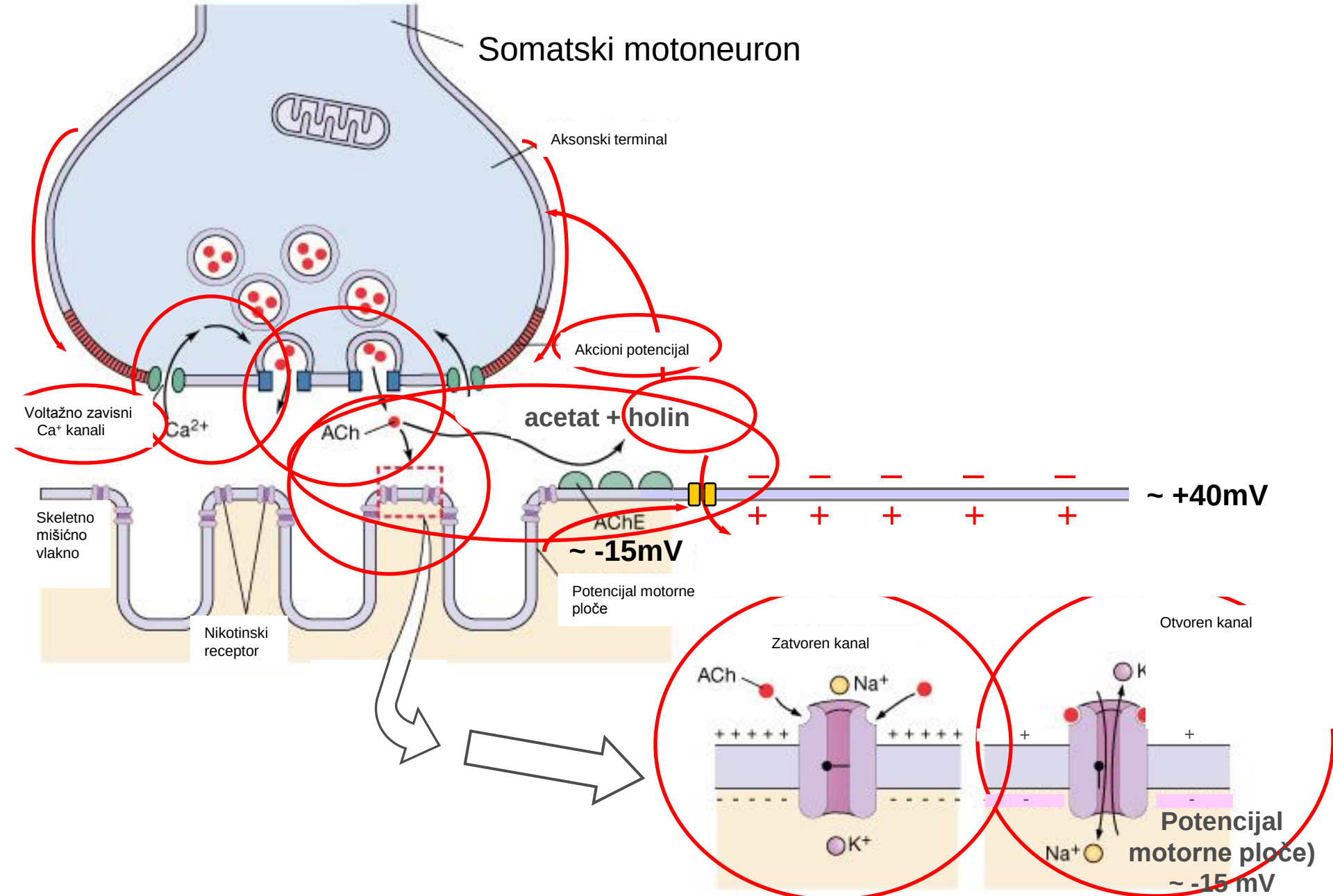
# RECEPTORI U SKELETNIM MIŠIĆIMA



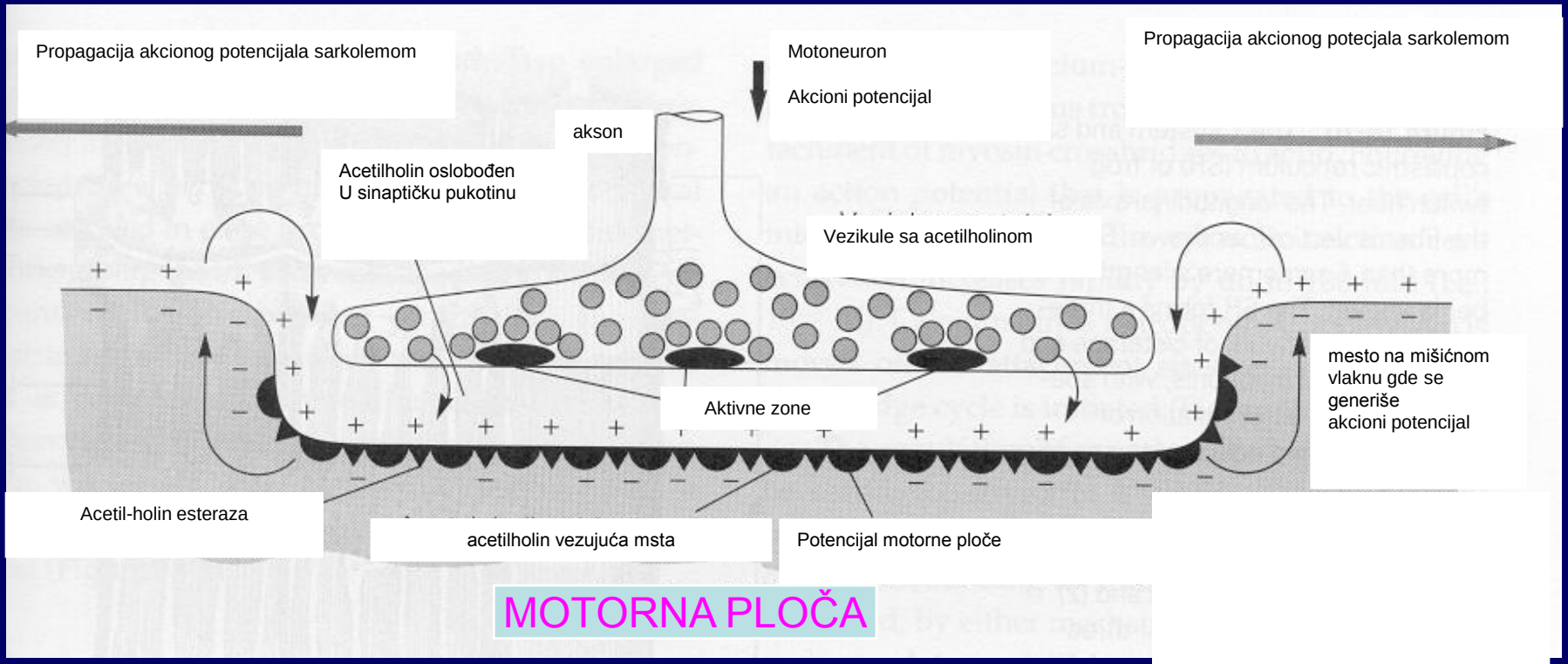

- **MIŠIĆNO VRETENO (DETEKTOR PROMENE DUŽINE MIŠIĆA)**
- **GOLDŽIJEV TETIVNI ORGAN (DETEKTOR PROMENE NAPETOSTI U MIŠIĆU)**

# NERVNO-MIŠIĆNA SINAPSA

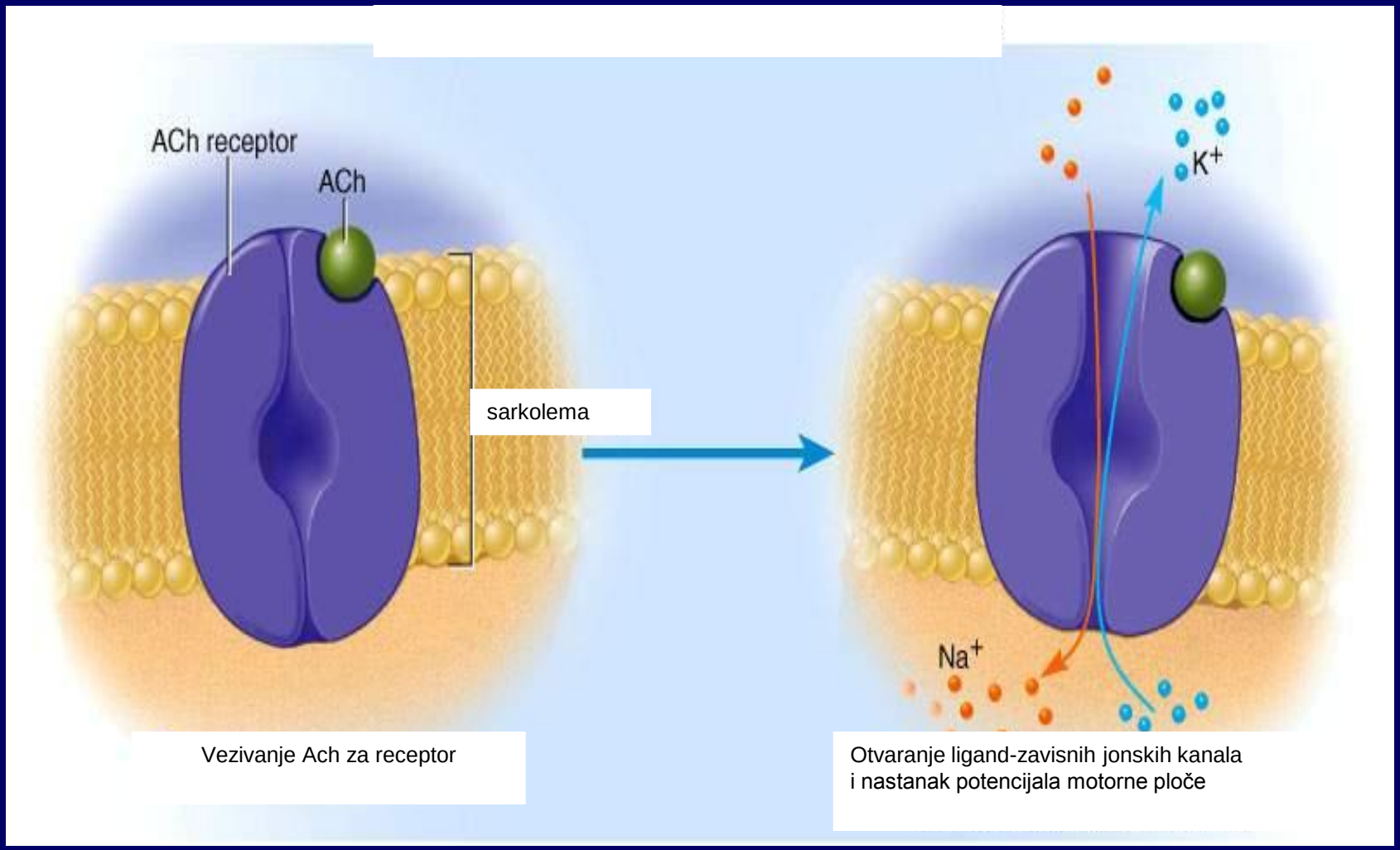



Somatski motoneuron
Aksonski terminal
Akcioni potencijal
Voltažno zavisni Ca⁺ kanali
Ca2+
ACh
acetat + holin
~ +40mV
Skeletno mišićno vlakno
AChE
~ -15mV
Potencijal motorne ploče
Nikotinski receptor
Zatvoren kanal
Otvoren kanal
ACh
Na+
K+
Na+
Potencijal motorne ploče)
~ -15 mV

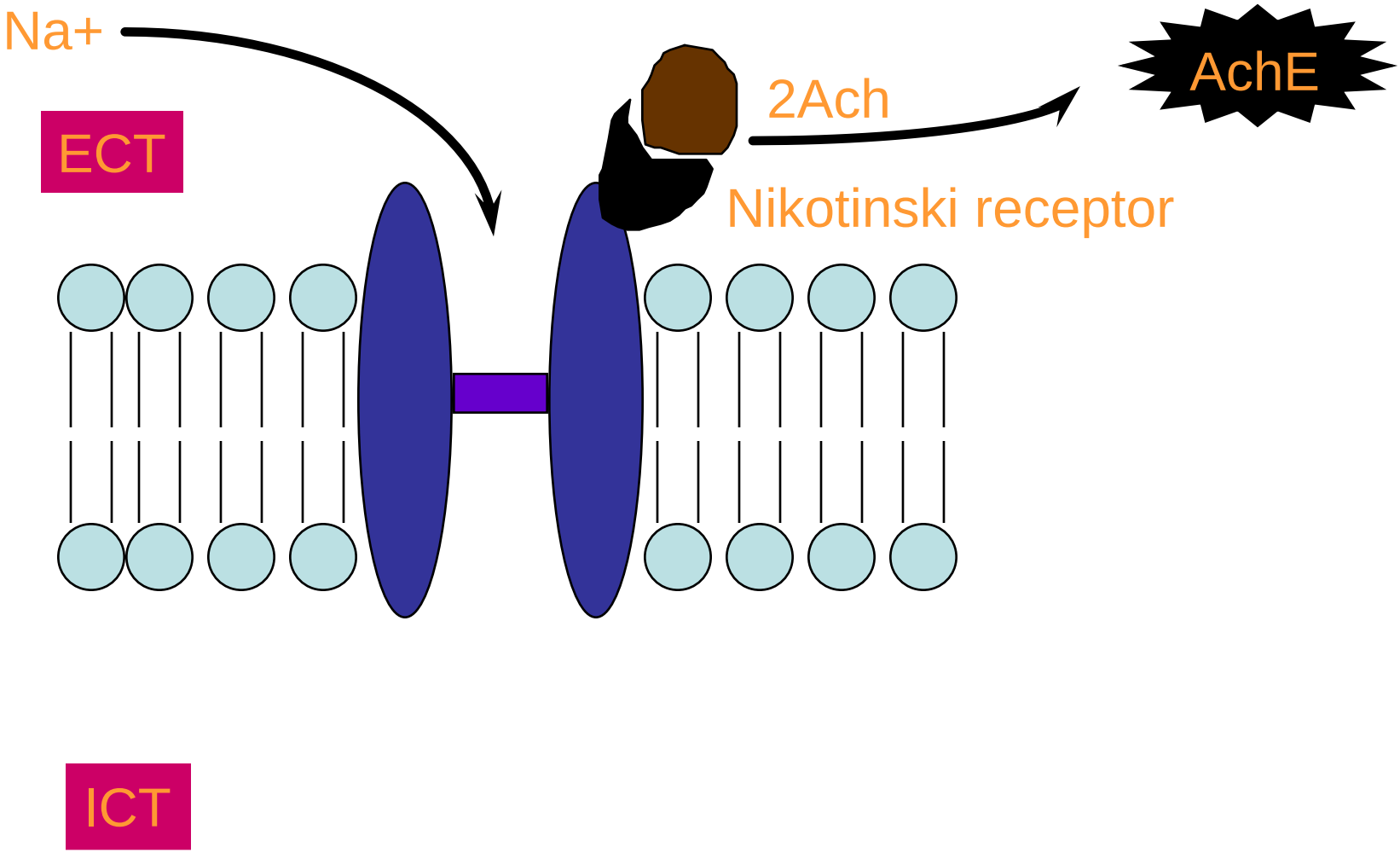
# PROPAGACIJA AKCIONOG POTENCIJALA U OBA SMERA DUŽ SARKOLEME

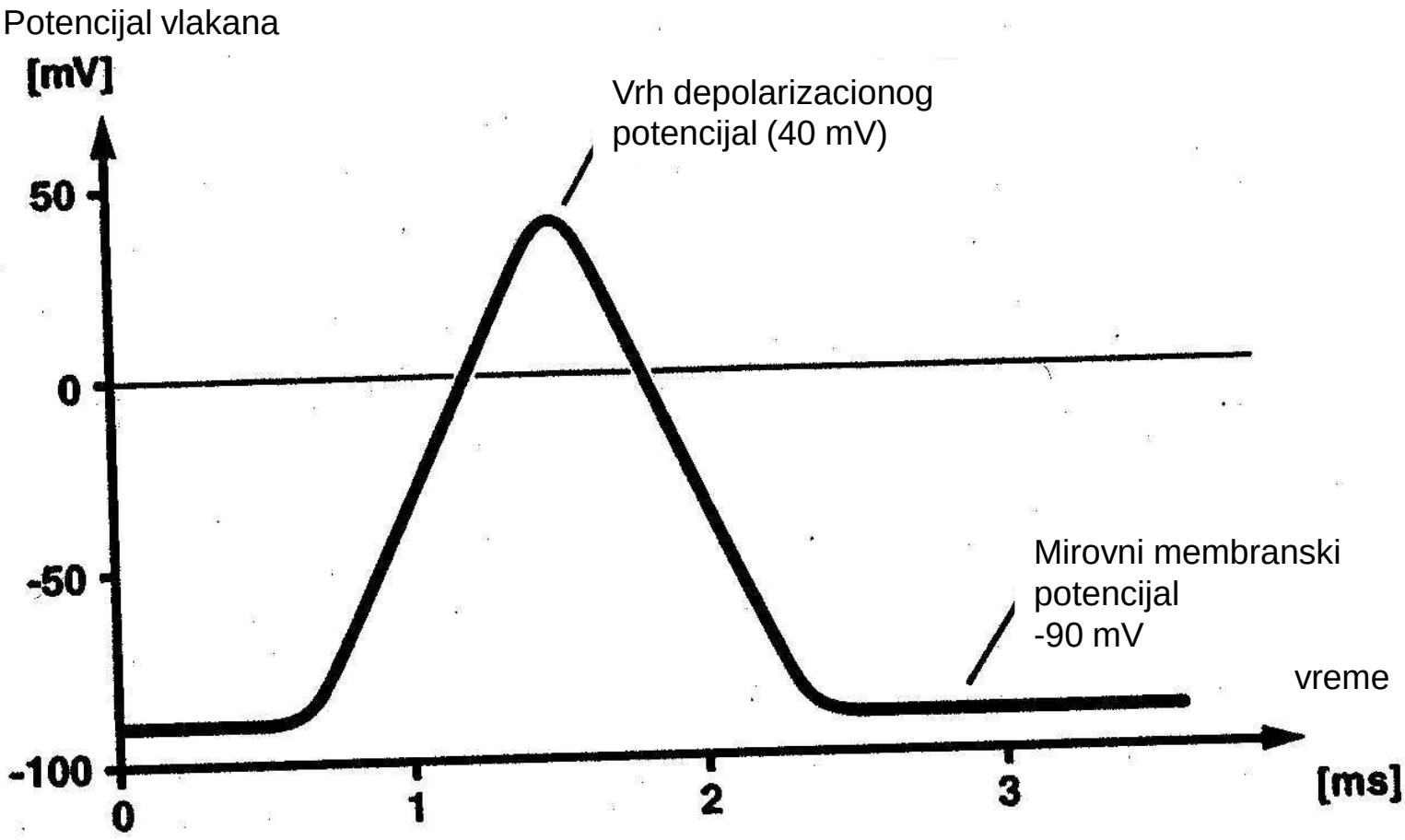


# MEHANIZAM NASTANKA POTENCIJALA MOTORNE PLOČE



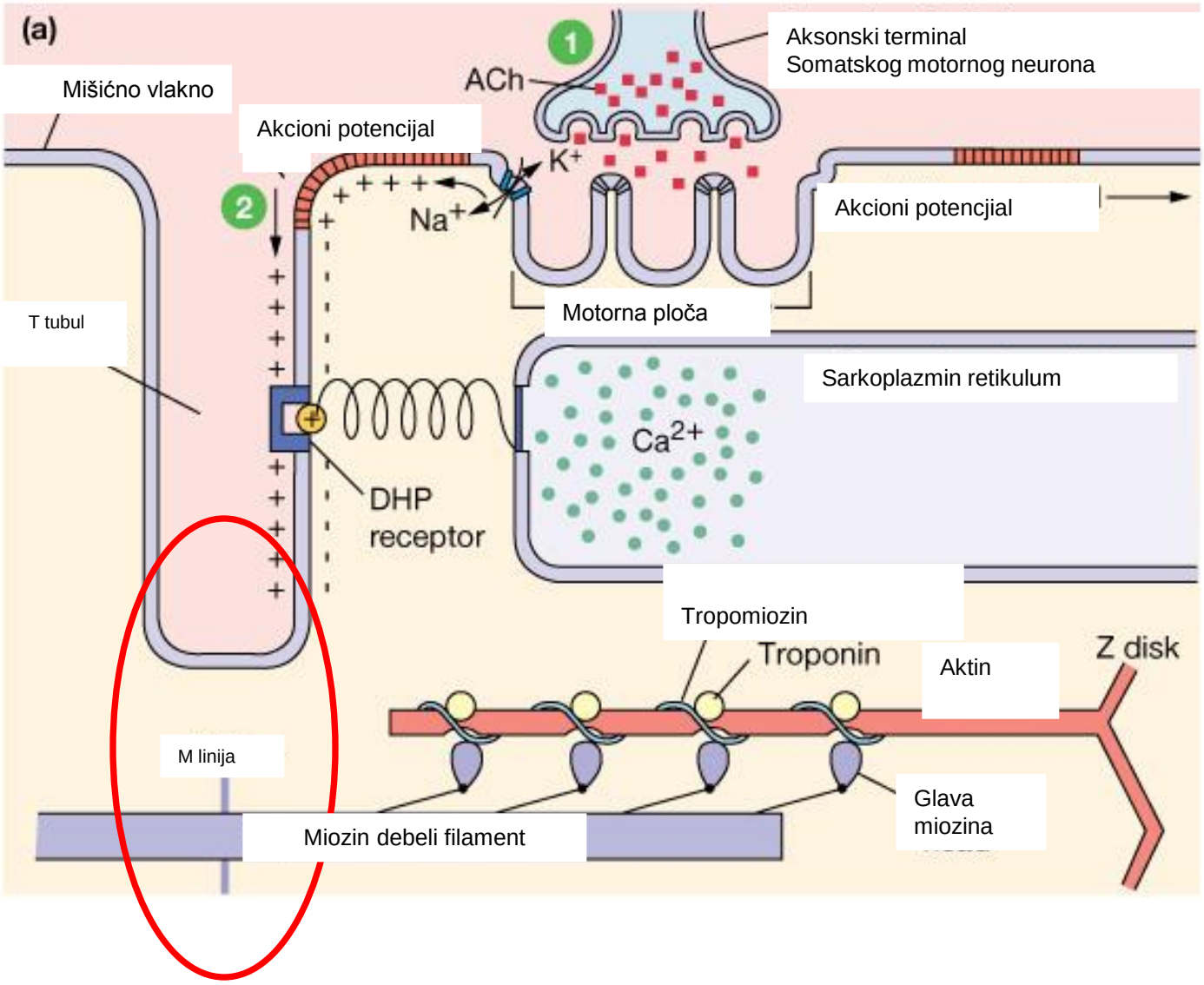
# HEMIJSKI ZAVISNI JONSKI KANALI






ŠEMATSKI PRIKAZ AKCIONOG POTENCIJALA MIŠIĆNOG VLAKNA

# PROPAGACIJA AKCIONOG POTENCIJALA DUŽ SARKOLEME I U T-TUBULE

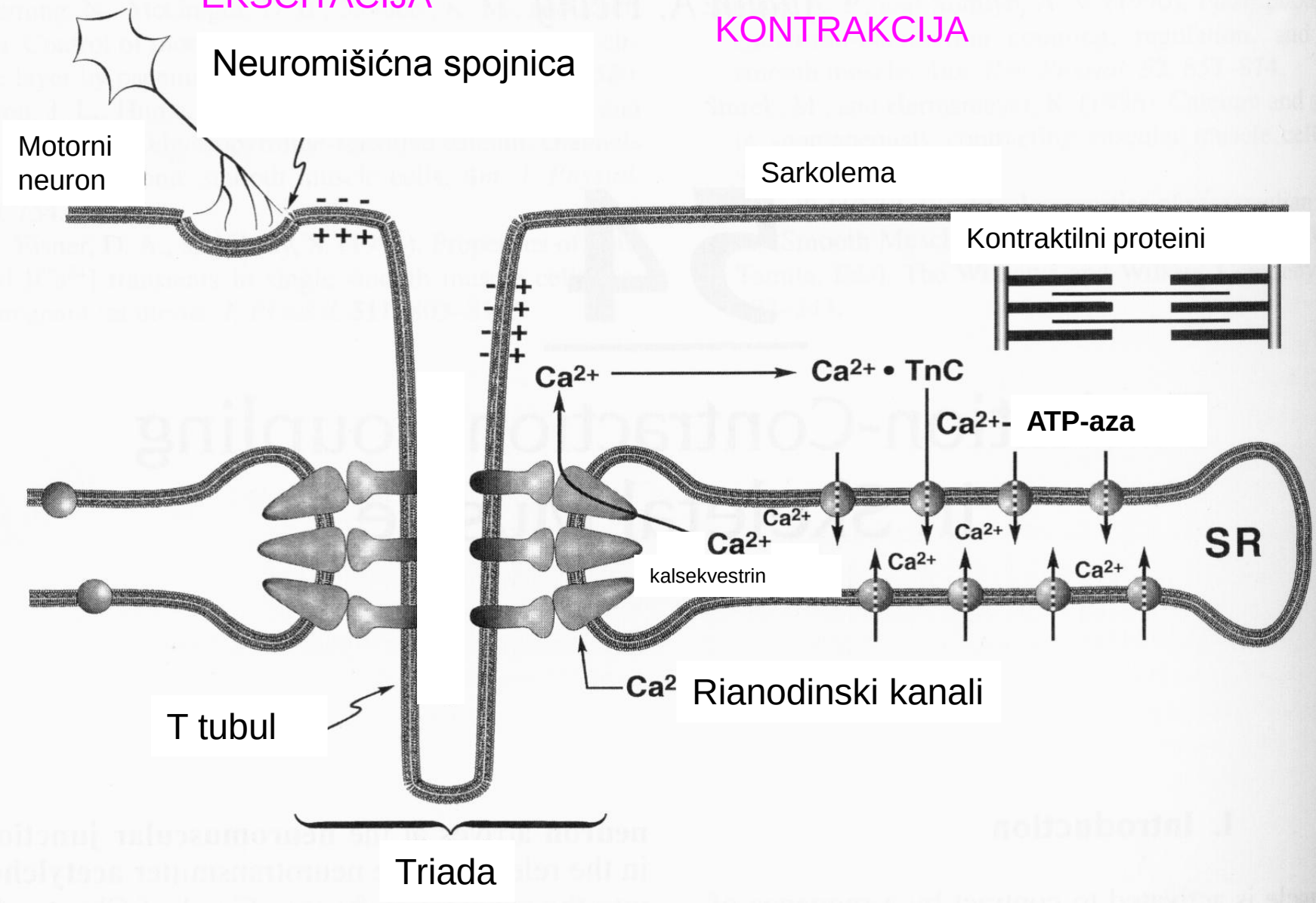



1. Somatski motoneuron oslobađa Ach u neuromišićnu sinapsu

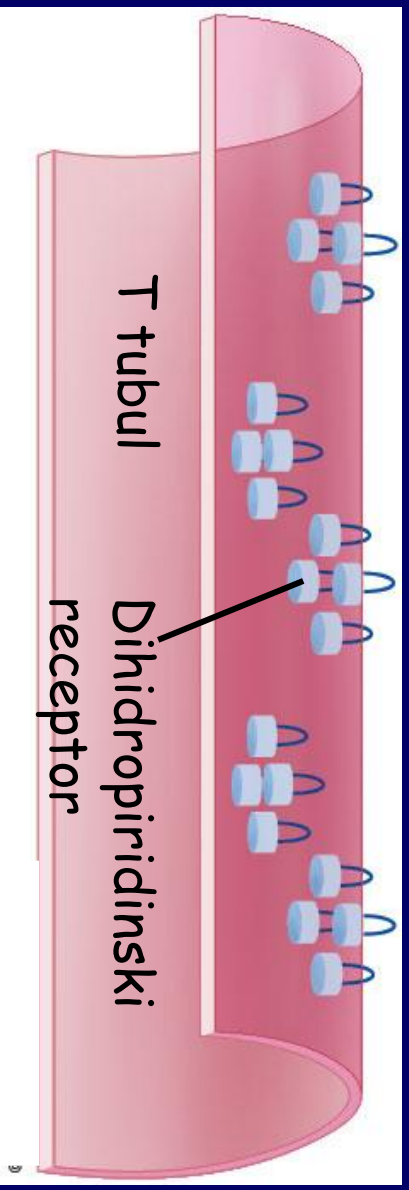
2. Ulazak $Na^+$ kroz Ach zavisne jonske kanale inicira akcioni potencijal mišića

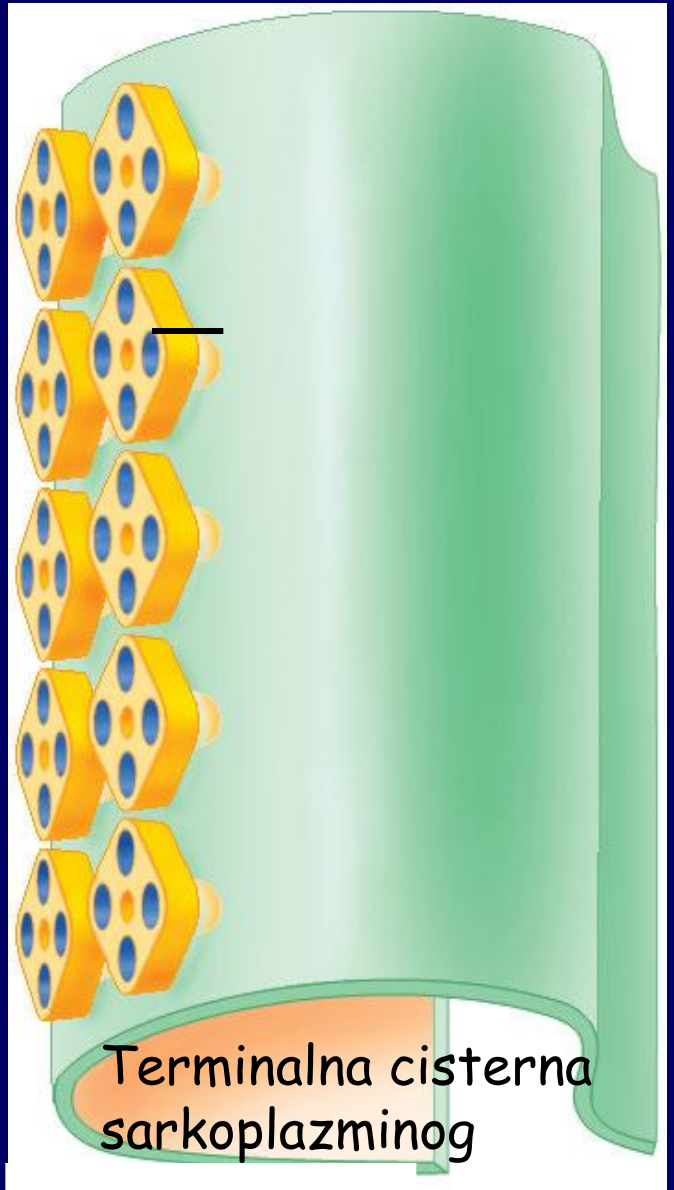
EKSCITACIJA

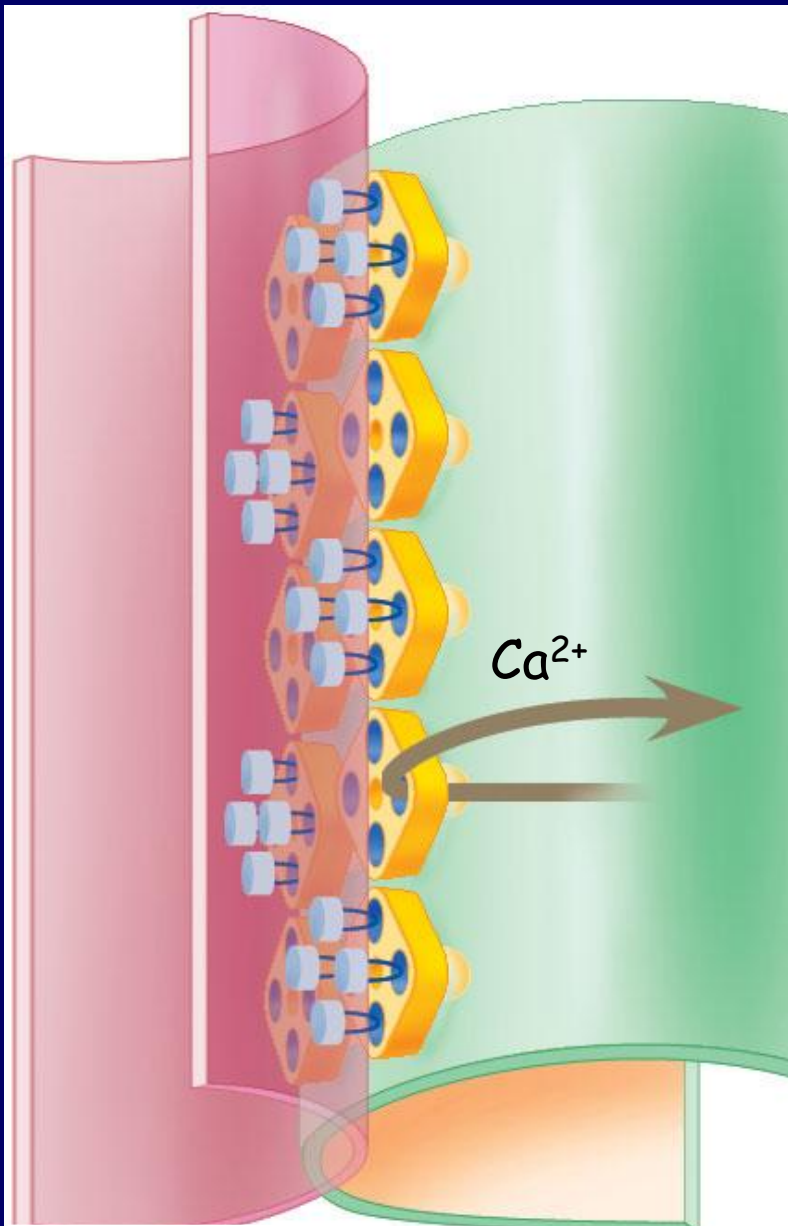
KONTRAKCIJA



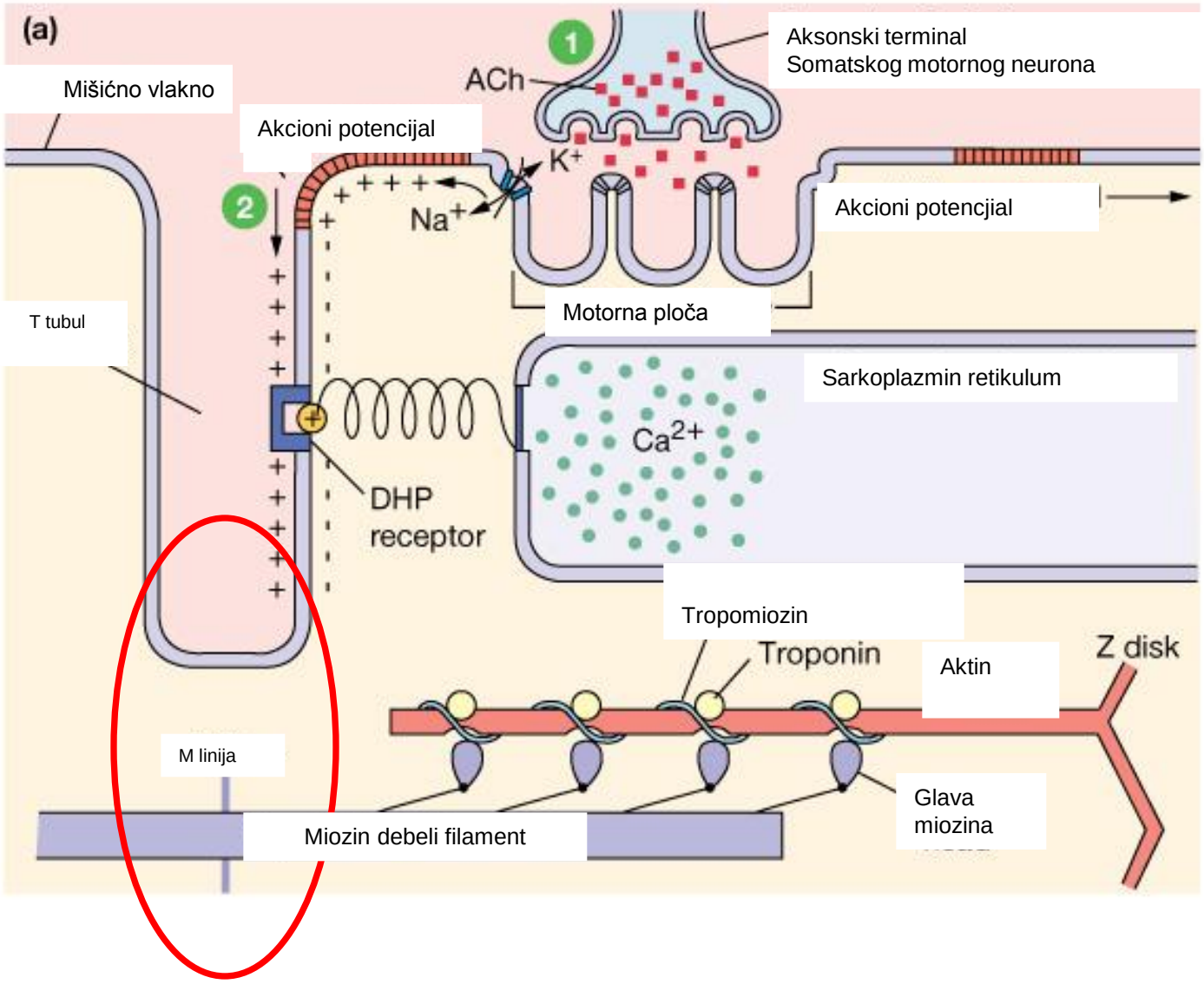
# DEPOLARIZACIJA T-TUBULA OTVARA KANALE U SARKOPLAZMINOM RETIKULUMU



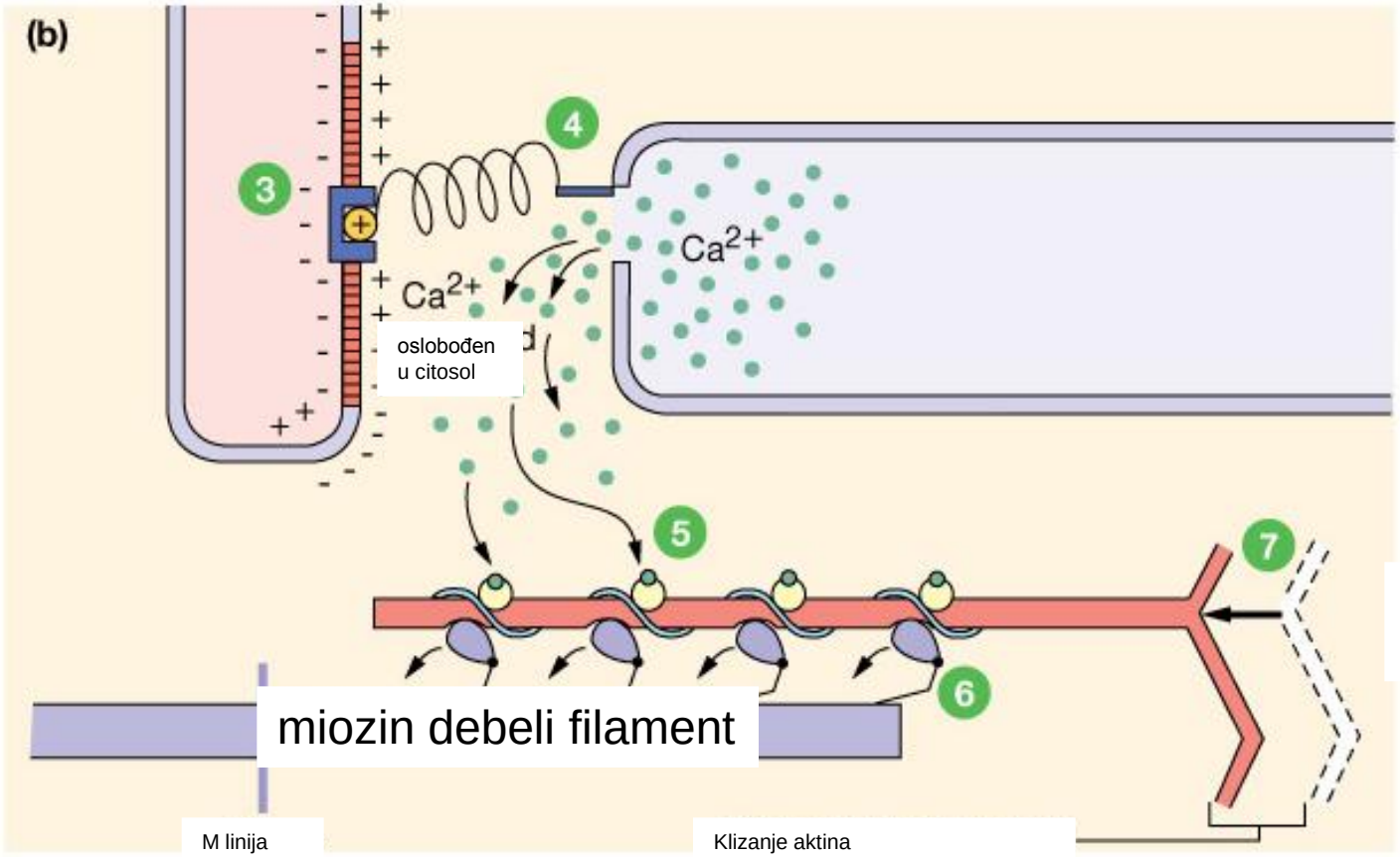
# KONTRAKCIJA SKELETNOG MIŠIĆA




1. Somatski motoneuron oslobađa Ach u neuromišićnu sinapsu

2. Ulazak $Na^+$ kroz Ach zavisne jonske kanale inicira akcioni potencijal mišića

# KONTRAKCIJA SKELETNOG MIŠIĆA




3. Akcioni potencijal uT tubulima menja konformaciju DHPR

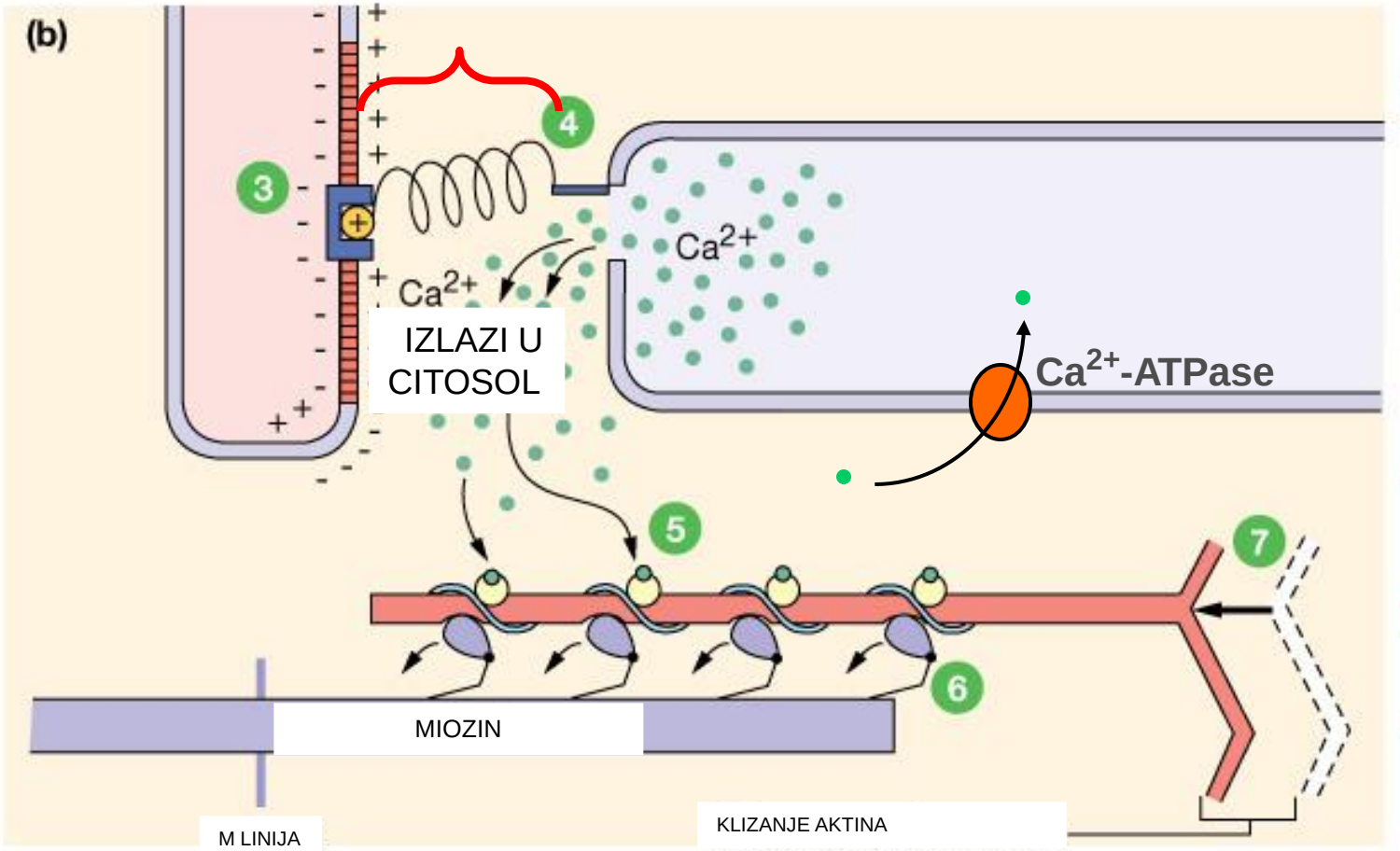
4. Oslobađanje $Ca^{2+}$ Iz sarkoplazminog retikuluma u citosol

5. Ca2+ se vezuje za troponin i omogućava vezivanje miozina sa aktinom

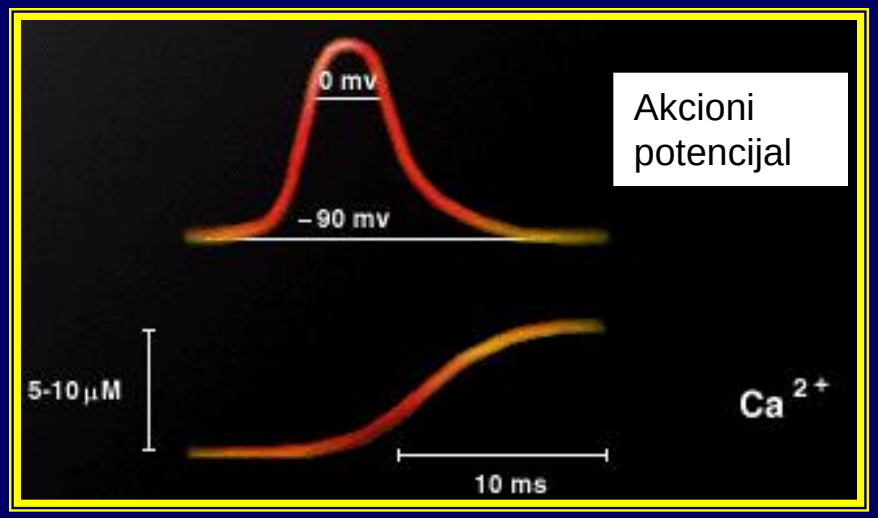
6. Miozinske glavice Vrše snažan zaveslaj

7. Aktin kliže ka centru sarkomere

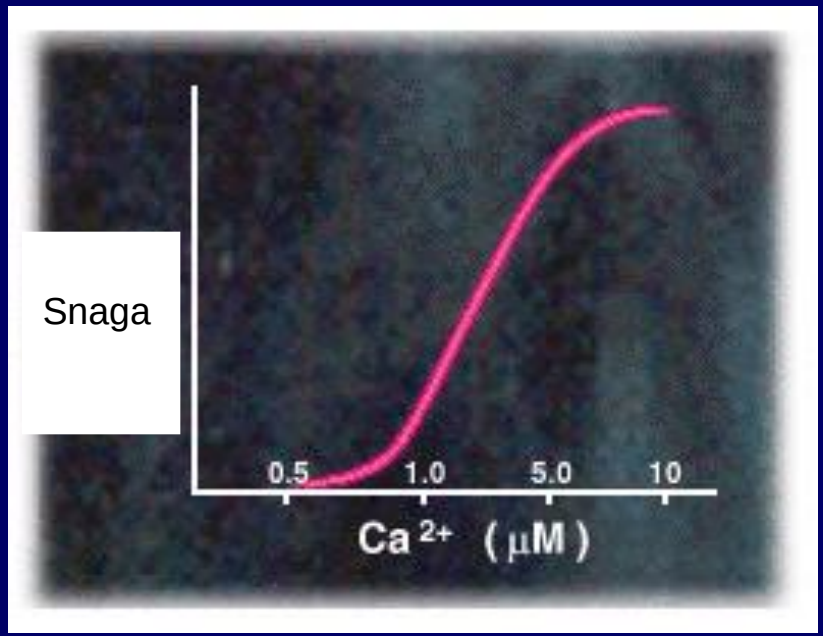
~10 nm.


(b)
4
3
Ca2+
Ca2+
IZLAZI U CITOSOL
Ca2+-ATPase
5
7
6
MIOZIN
M LINIJA
KLIZANJE AKTINA

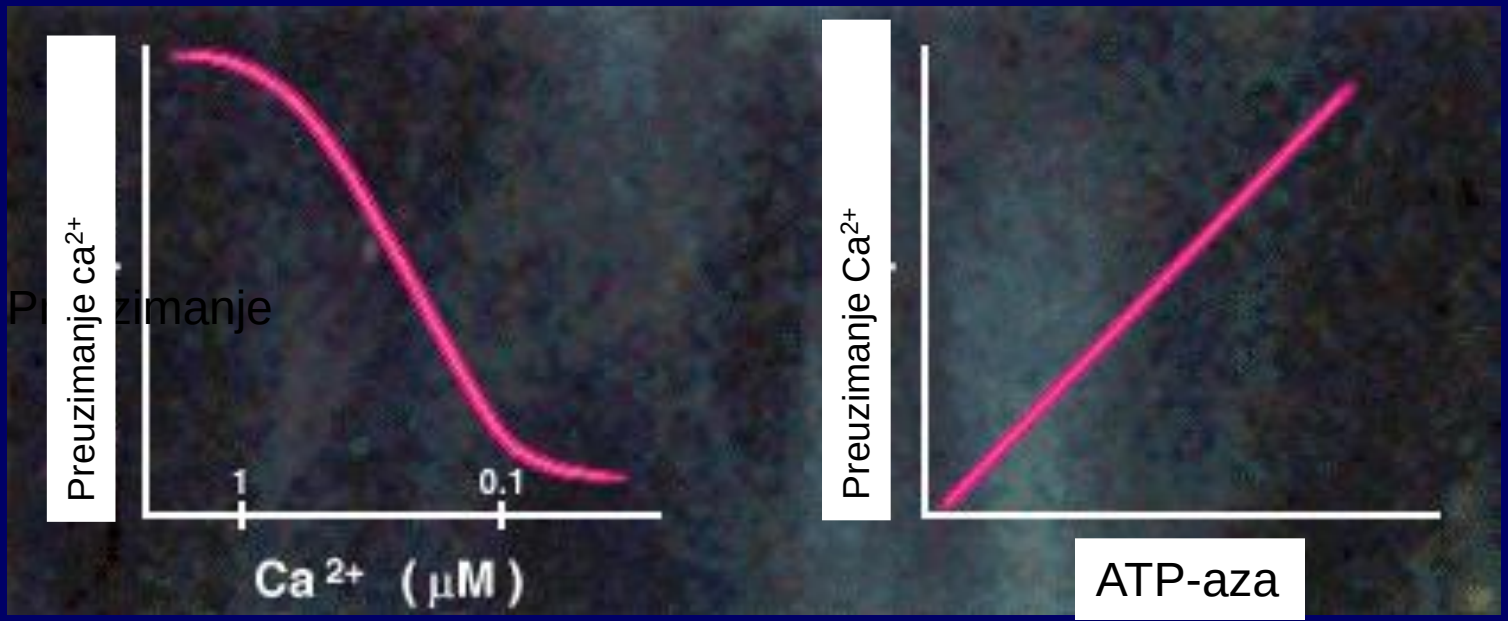
# Širenje AP izaziva porast intracelularne koncentracije kalcijuma



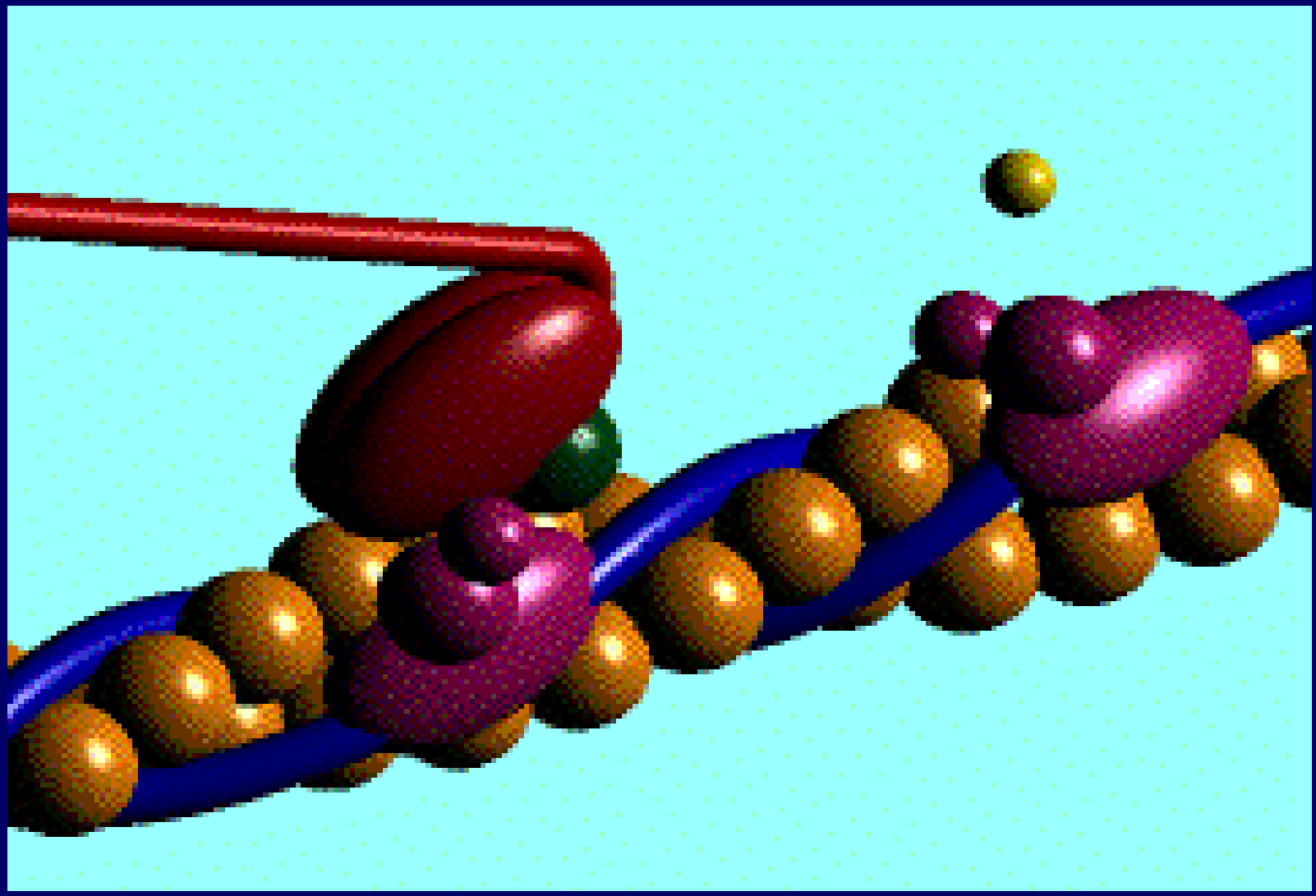

## Odnos koncentracije $Ca^{2+}$ i snage mišićne kontrakcije



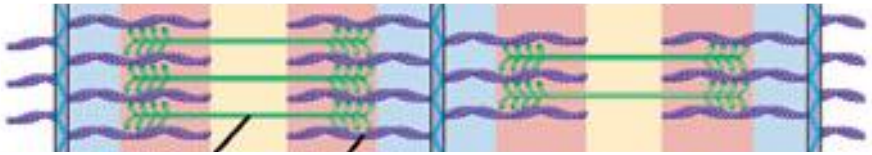
# ATP I RELAKSACIJA MIŠIĆ



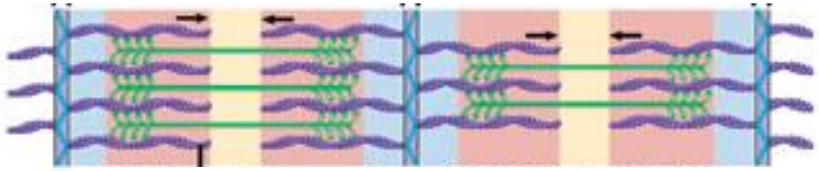
# MEHANIZAM MIŠIĆNE KONTRAKCIJE



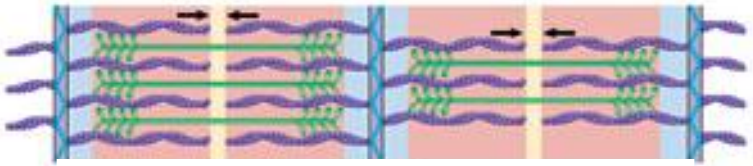
Relaksacija mišića



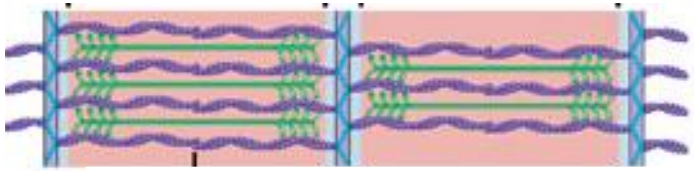
Kontrakcija mišića



Kontrakcija mišića

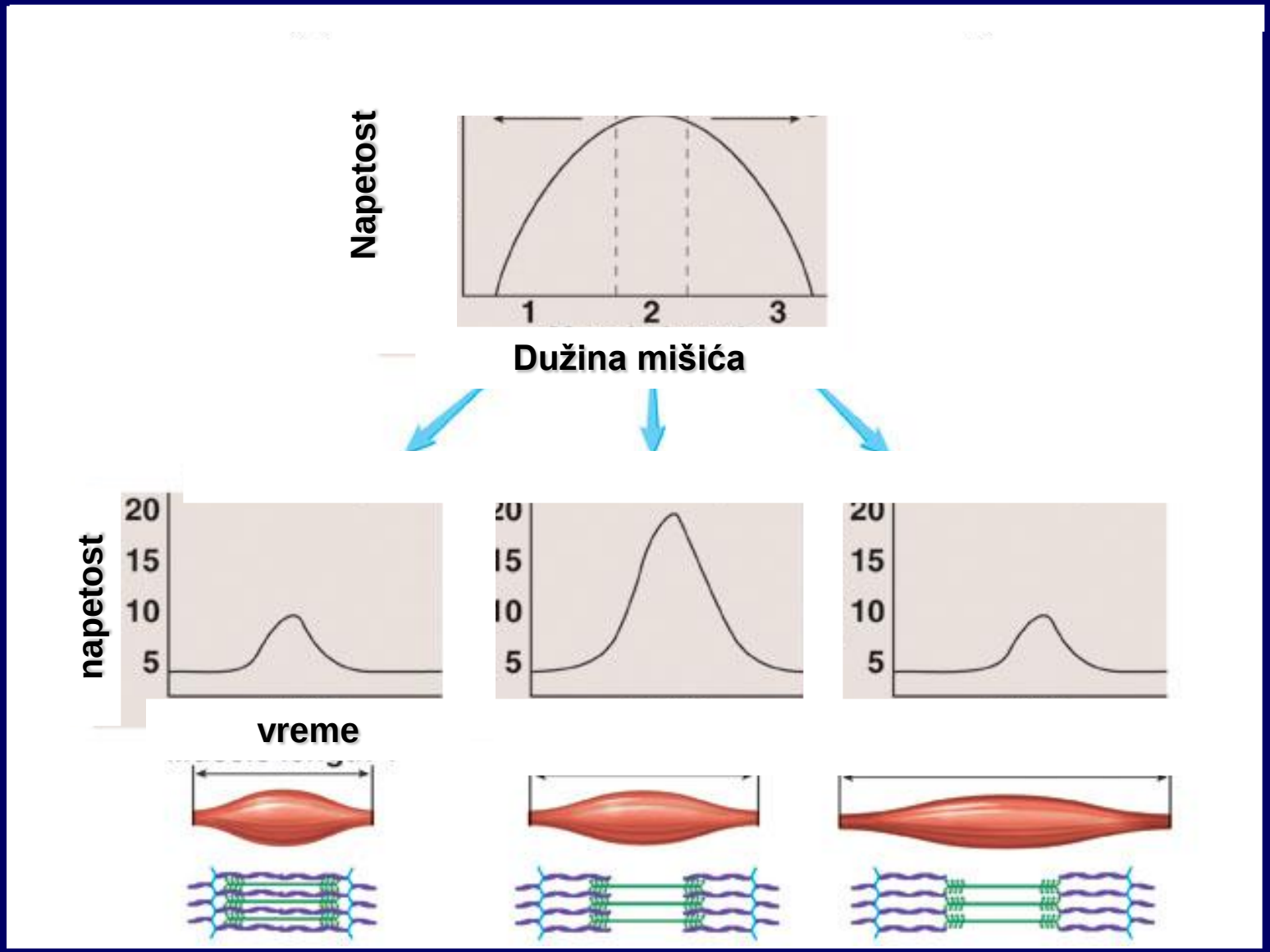


Potpuna kontrakcija mišića



# SKRAĆIVANJE SARKOMERE

# DUŽINA MIŠIĆA I TENZIJA



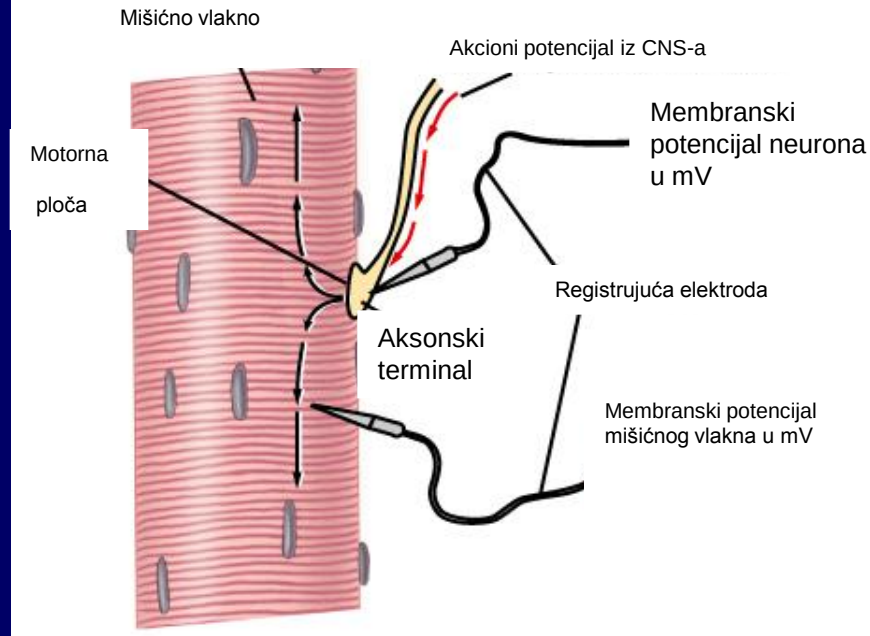
# Vrste mišićnih kontrakcija

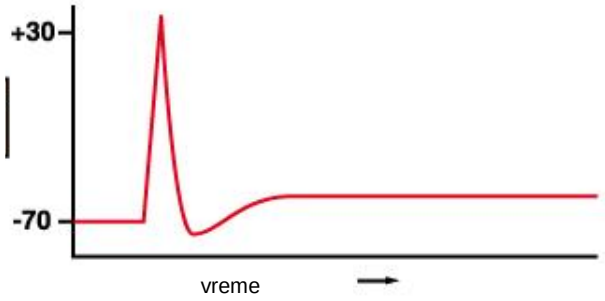
**izometrična i izotonična**

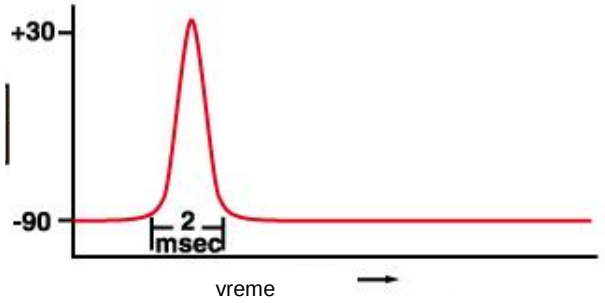
**tonična (mišićni tonus) i fazična(pokret)**

**pojedinačna (prosta) i složena (tetanus)**

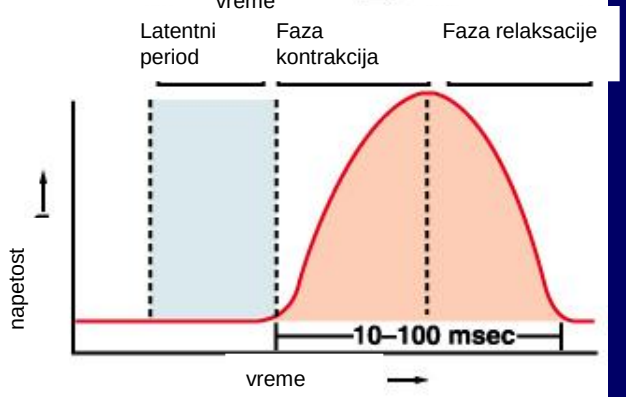
# PROSTA MIŠIĆNA KONTRAKCIJA - TRZAJ



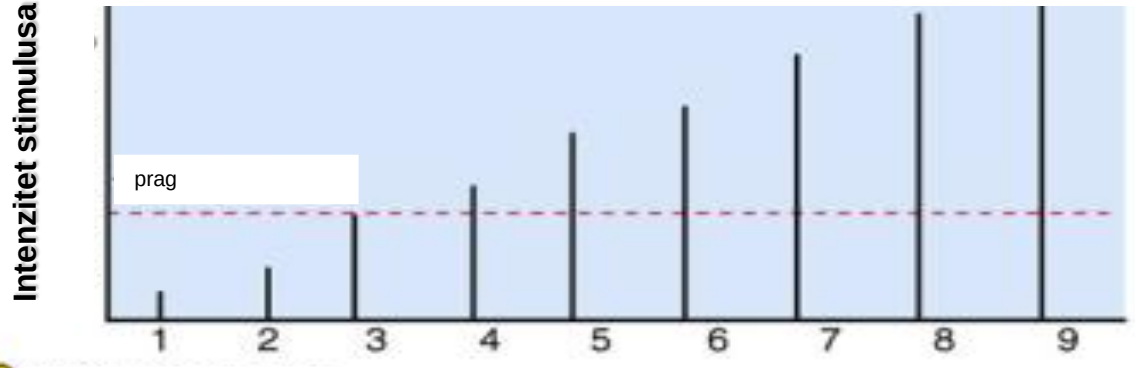




Snaga mišićne kontrakcije

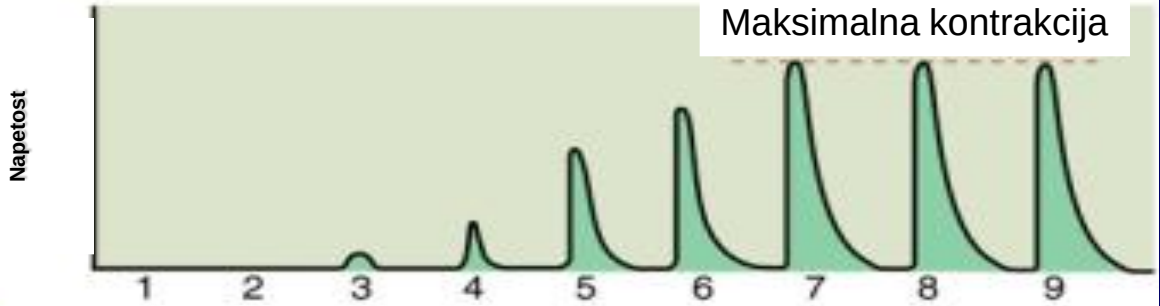


# INTENZITET STIMULUSA I MIŠIĆNA TENZIJA



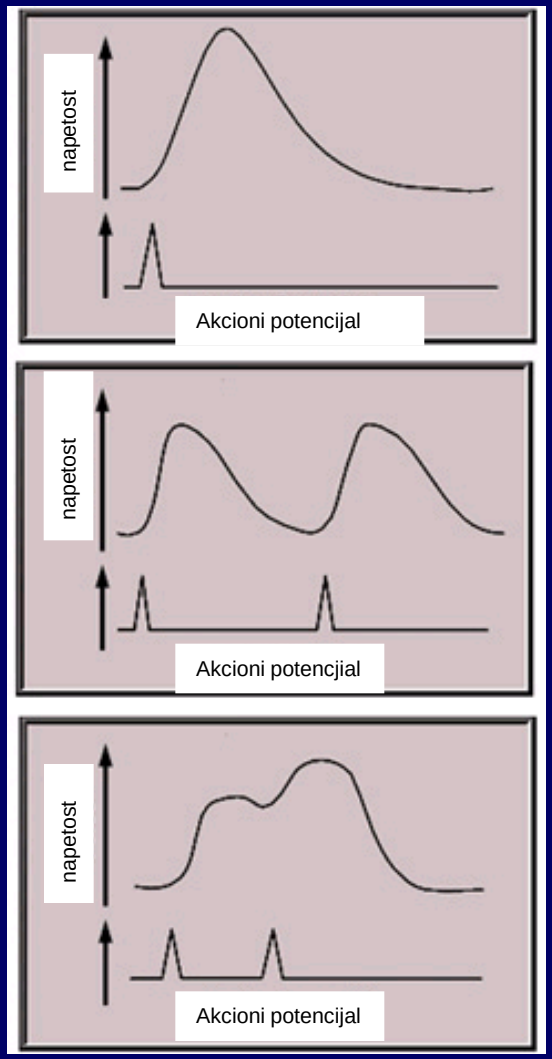

1 Stimulusi za nerve

2 Proporcija ekscitiranih nervnih vlakana

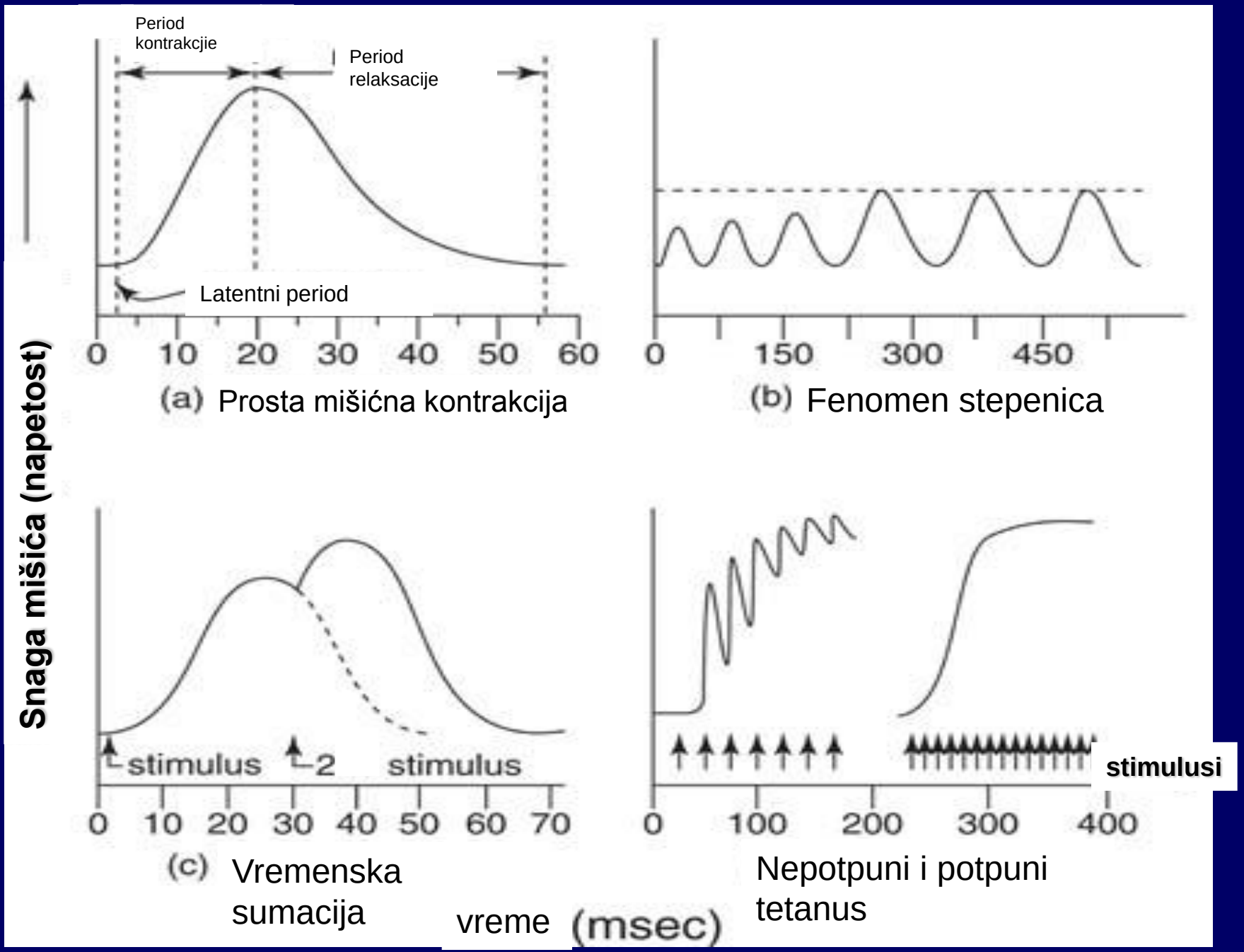



3 Odgovor mišića

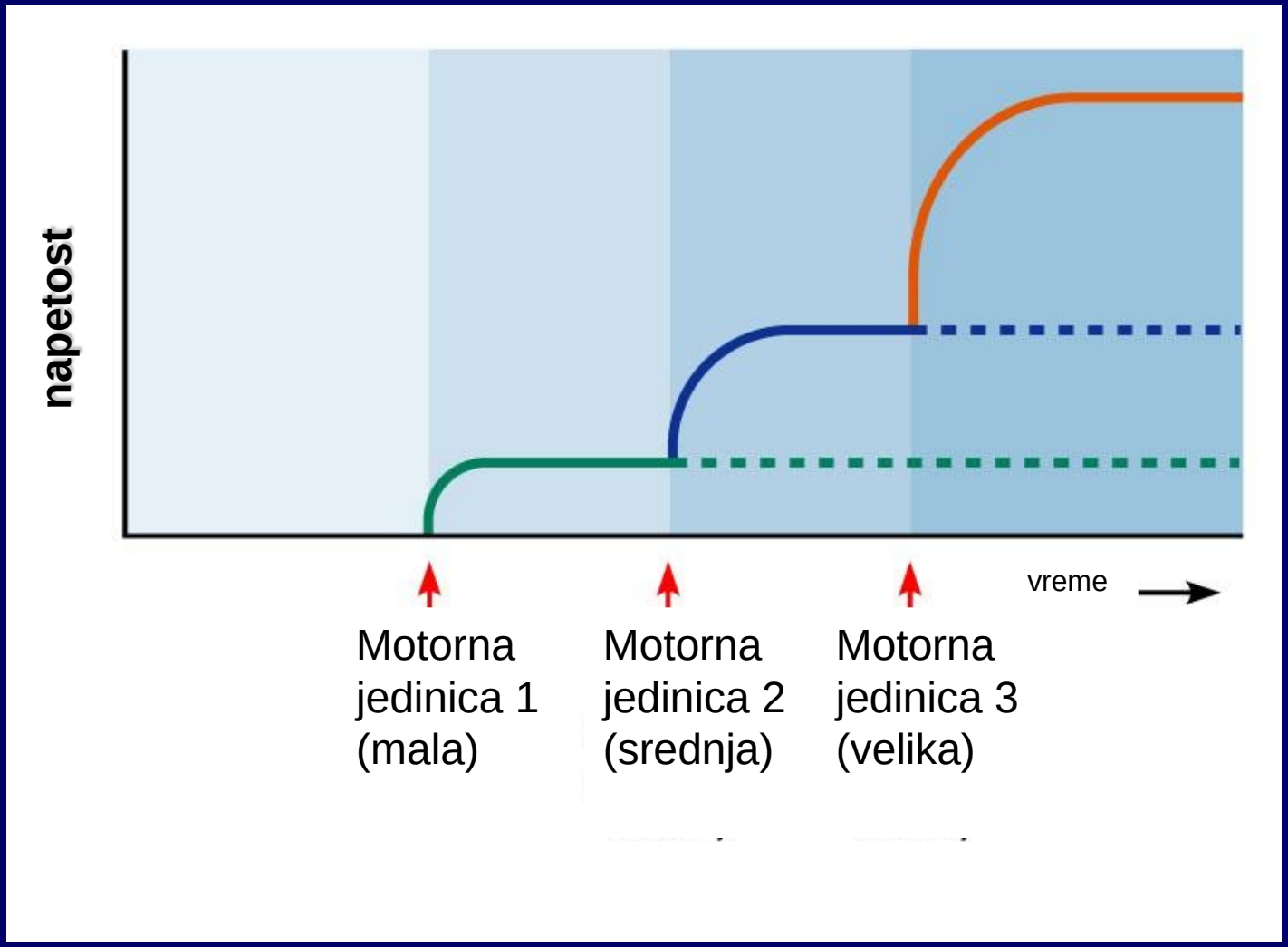
# PROSTA I SLOŽENA MIŠIĆNA KONTRAKCIJA



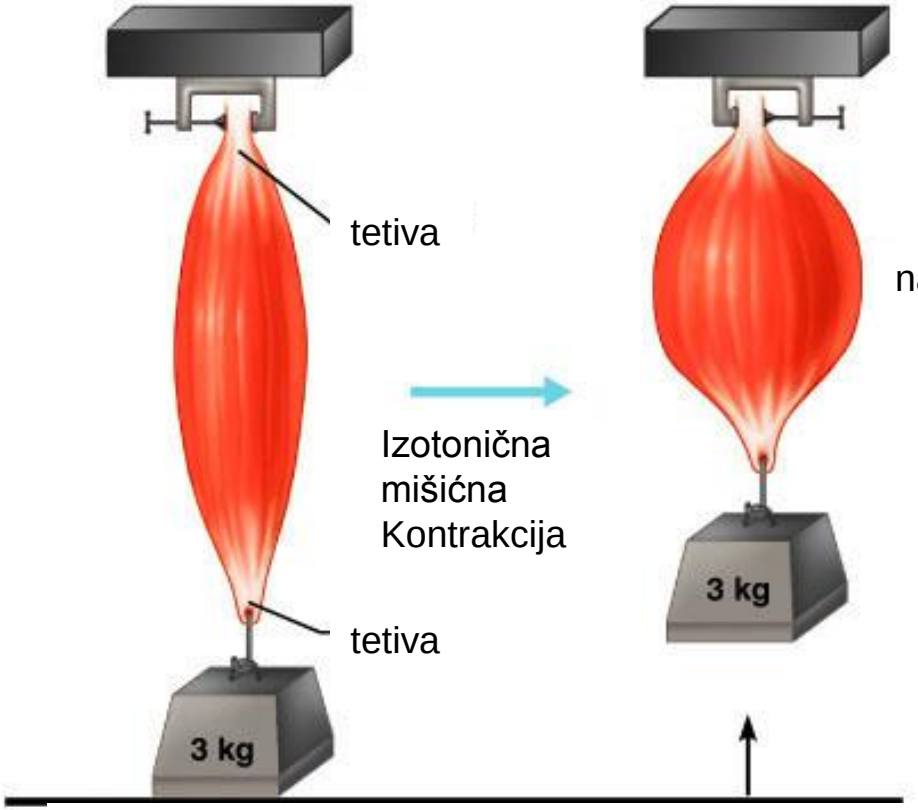

VREMENSKA SUMACIJA

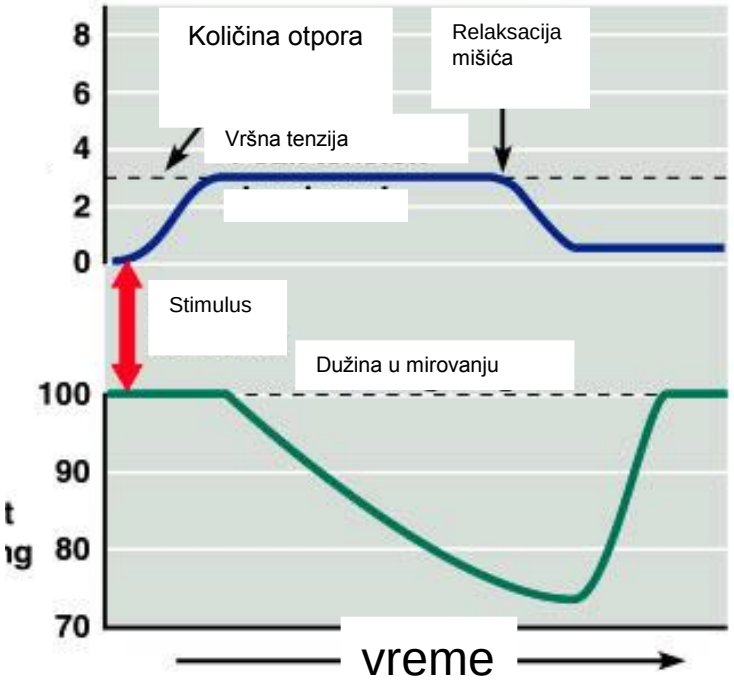

Period kontrakcije
Period relaksacije
Latentni period
0 10 20 30 40 50 60
(a) Prosta mišićna kontrakcija
0 150 300 450
(b) Fenomen stepenica
stimulus
2
stimulus
0 10 20 30 40 50 60 70
(c) Vremenska sumacija
0 100 200 300 400
stimulusi
Nepotpuni i potpuni tetanus
Snaga mišića (napetost)
vreme (msec)

# REGRUTOVANJE MOTORNIH JEDINICA (PROSTORNA SUMACIJA)



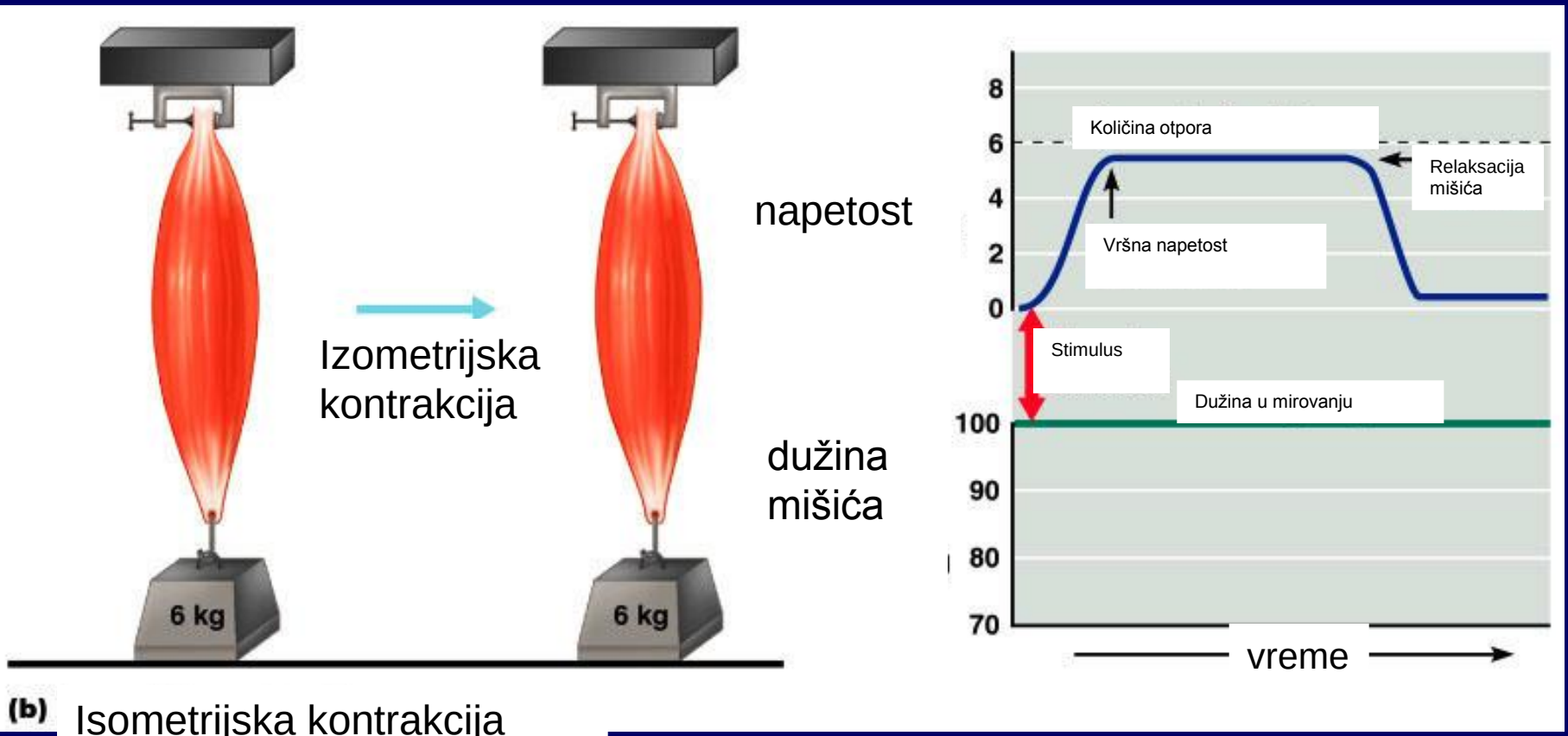
# IZOTONUSNA MIŠIĆNA KONTRAKCIJA



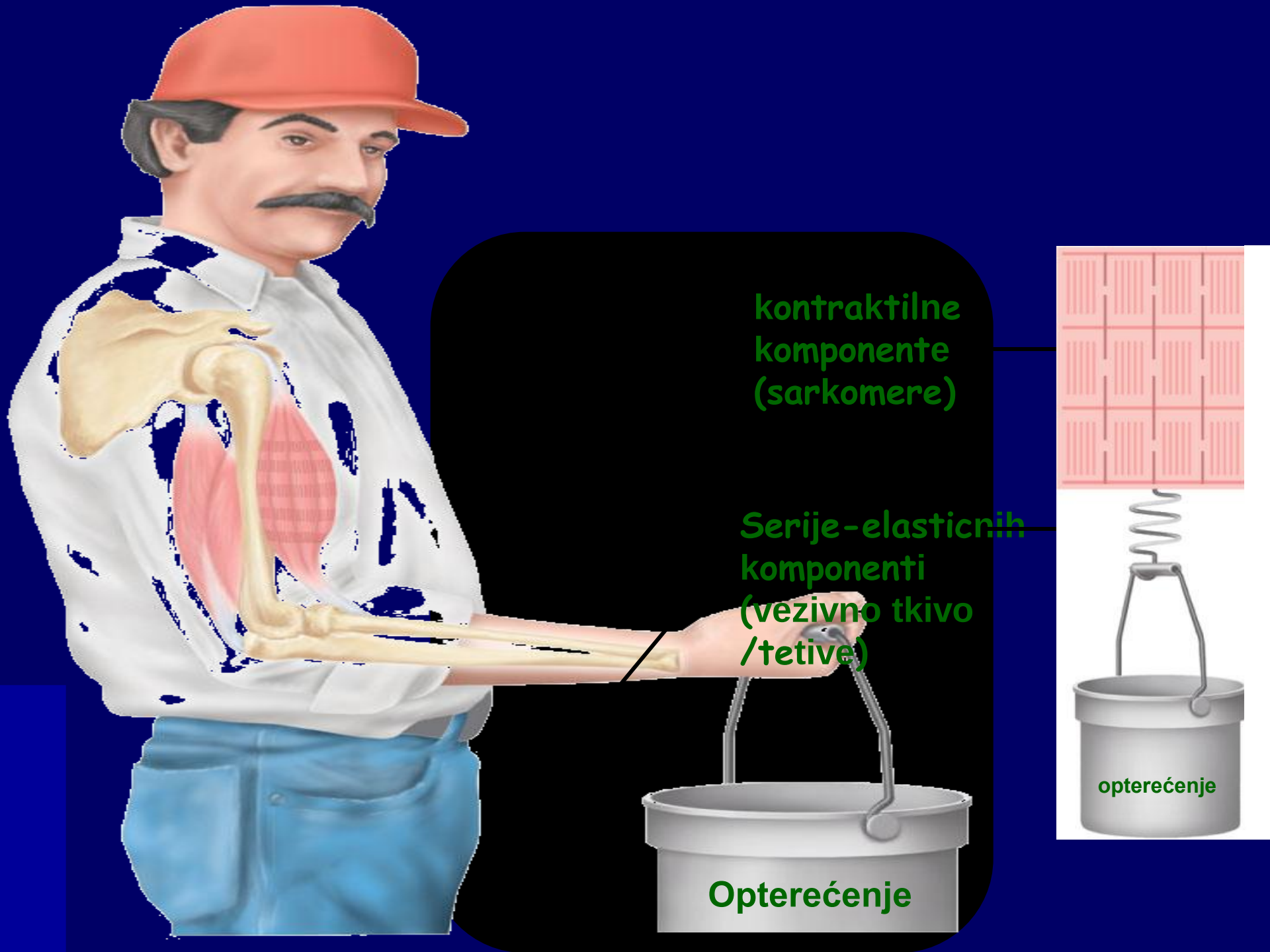




(a) Izotonusna (koncentrična) kontrakcija

# IZOMETRIJSKA MIŠIĆNA KONTRAKCIJA

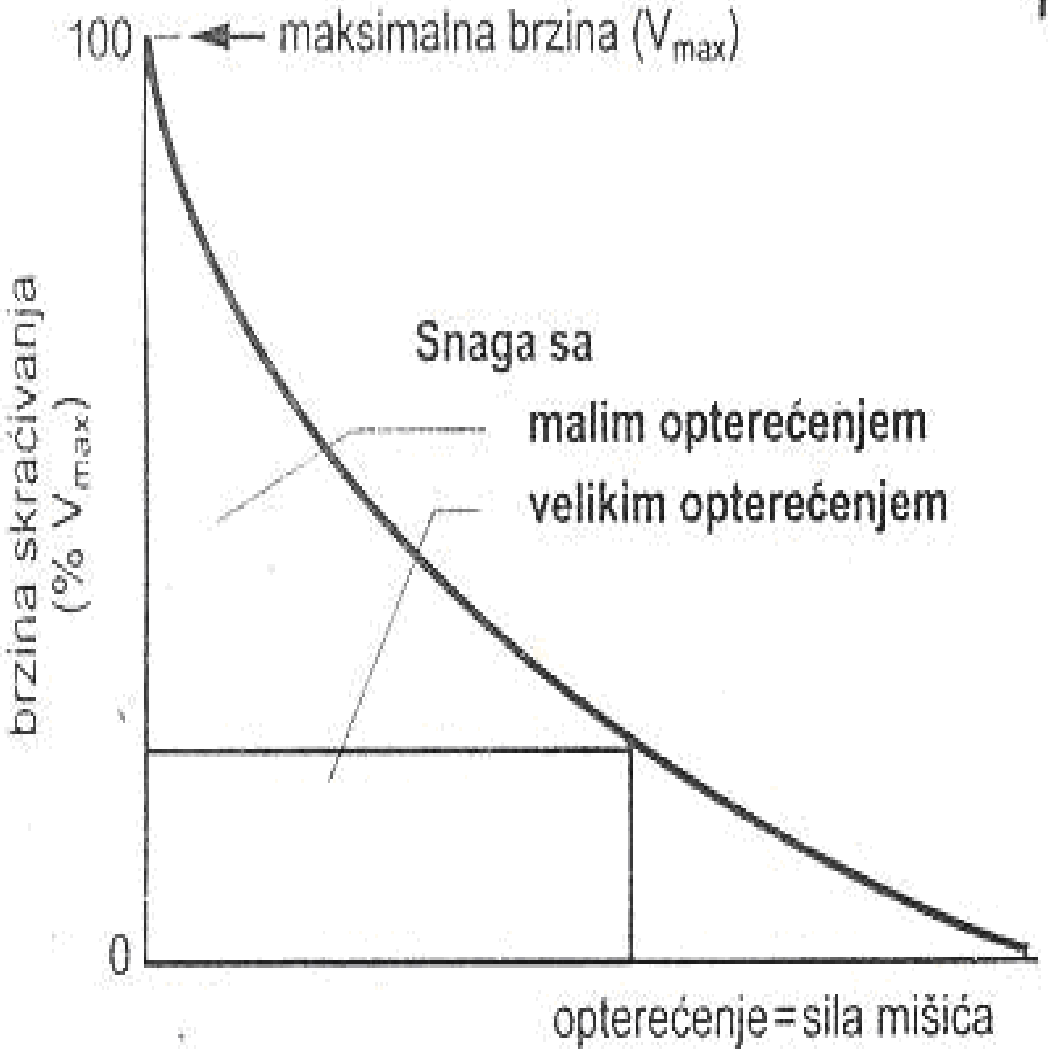



(b) Isometrijska kontrakcija

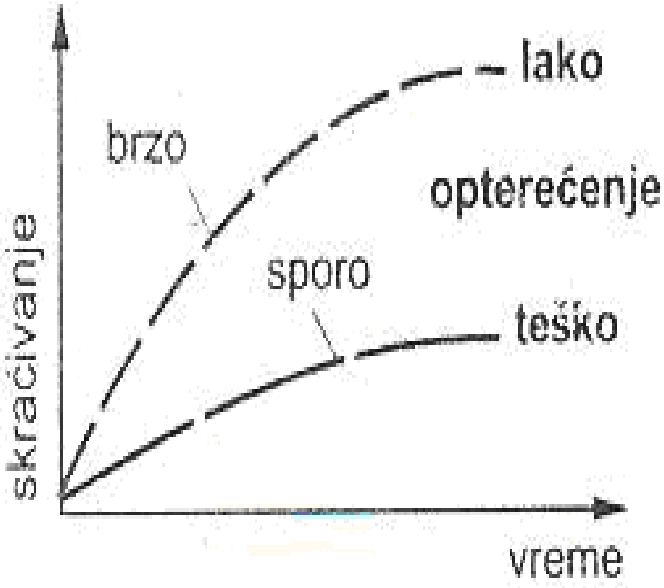

kontraktilne komponente (sarkomere)
Serije-elastičnih komponenti (vezivno tkivo /tetive)
Opterećenje
opterećenje

# Mišićna snaga (ili opterećenje) i brzina skraćivanja

1




2



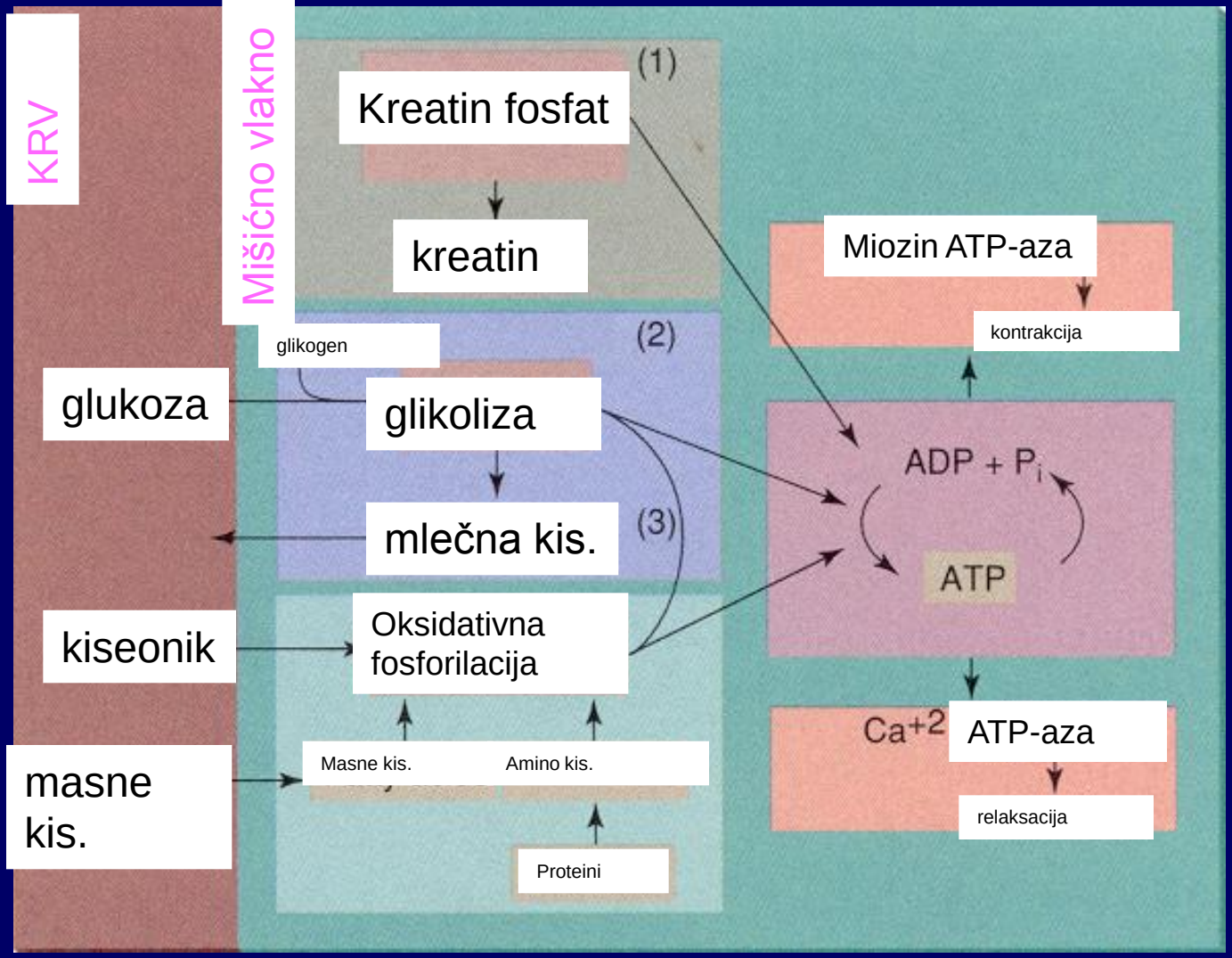
# ENERGIJA ZA RAD MIŠIĆA

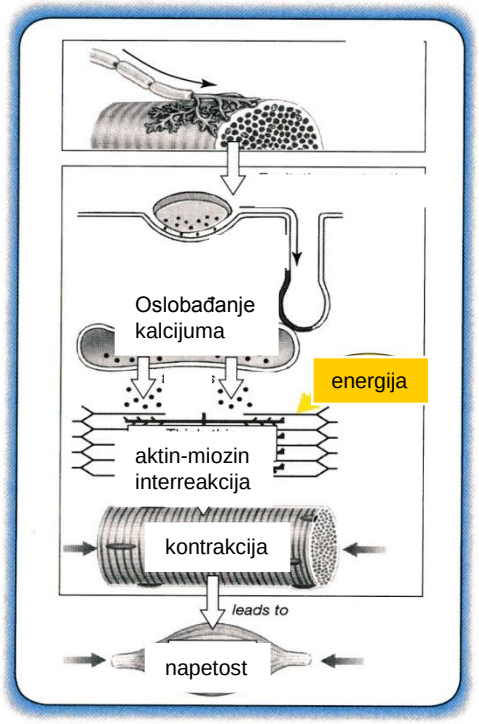
**ENERGIJA ATP-a JE POTREBNA ZA:**

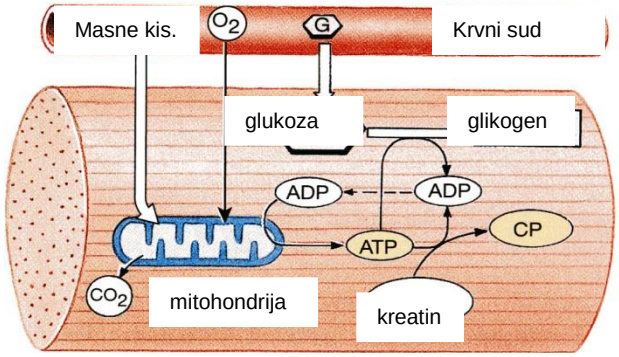
1. **CIKLUSE POPREČNIH VEZA (50-80% ATP-A)**
2. **PREUZIMANJE $Ca^{2+}$ U SARKOPLAZMIN RETIKULUM (20-30% ATP-a)**
3. **RAD PUMPE ZA $Na^{+}$ I $K^{+}$**
4. **OSNOVNE ĆELIJSKE PROCESE**

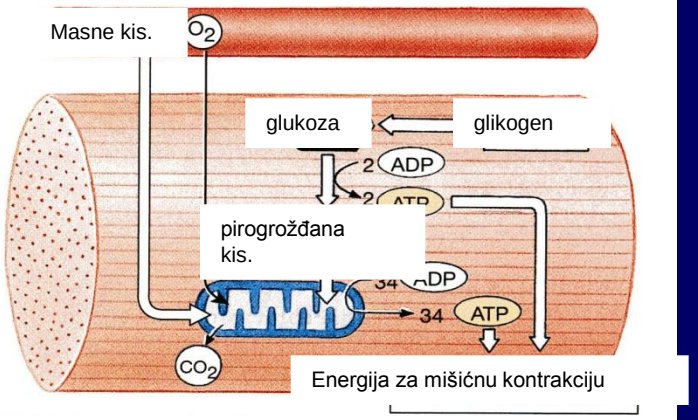
# IZVORI ATP-a U SKELETNOM MIŠIĆU

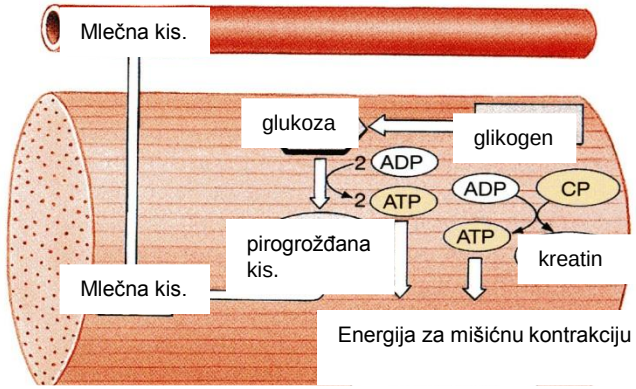
1. GLIKOGEN DEPONOVAN U ĆELIJI (prvih desetak minuta rada)
2. GLUKOZA I SLOBODNE MASNE KISELINE IZ KRVI
3. SLOBODNE MASNE KISELINE IZ KRVI (posle tridesetak minuta rada)


KRV
Mišično vlakno
(1)
Kreatin fosfat
kreatin
Miozin ATP-aza
kontrakcija
glikogen
(2)
glukoza
glikoliza
ADP + Pi
(3)
mlečna kis.
ATP
kiseonik
Oksidativna fosforilacija
Ca+2
ATP-aza
masne kis.
Masne kis.
Amino kis.
relaksacija
Proteini


Oslobađanje kalcijuma
energija
aktin-miozin interreakcija
kontrakcija
leads to
napetost

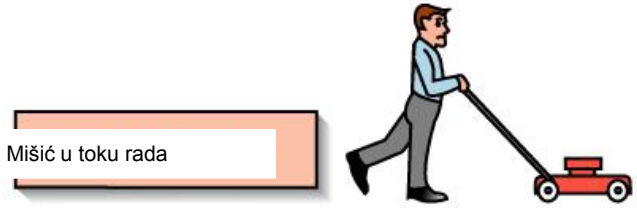

Masne kis.
$O_2$
G
Krvni sud
glukoza
glikogen
ADP
ADP
ATP
CP
$CO_2$
mitohondrija
kreatin


Masne kis.
$O_2$
glukoza
glikogen
2 ADP
pirogrožđana kis.
34
ATP
$CO_2$
Energija za mišićnu kontrakciju


Mlečna kis.
glukoza
glikogen
2 ADP
2 ATP
ADP
CP
ATP
kreatin
pirogrožđana kis.
Mlečna kis.
Energija za mišićnu kontrakciju

# ENERGIJA ZA RAD SKELETNIH MIŠIĆA


ATP iz metabolizma + kreatin → ADP + kreatin-fosfat




kreatin-fosfat + ADP → ATP + P kreatin

Potreban je za

1. Miozin ATP-aze
2. $Ca^{2+}$ - ATP-aze (relaksacija)
3. $Na^{+}$-$K^{+}$- ATP-aze

# SISTEMI ZA GENERISANJE ATP-a U MIŠIĆIMA

**NEPOSREDNO DOSTUPAN (ATP I CrP)**

- **NAJBRŽE SNABDEVANJE SA ATP-om**
- **NE TROŠI SE KISEONIK**

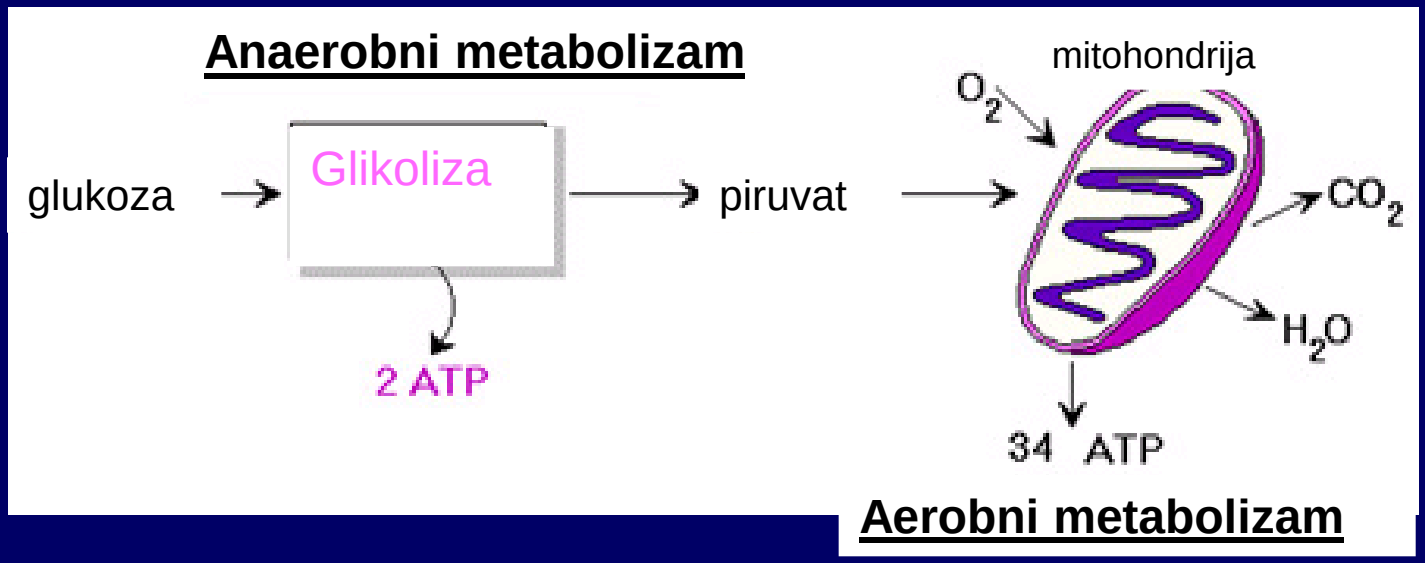
**ANAEROBNA GLIKOLIZA**

- **GLAVNI ENERGETSKI SISTEM KAD SU POTREBE ZA ATP-om VELIKE**
- **NE TROŠI SE KISEONIK**

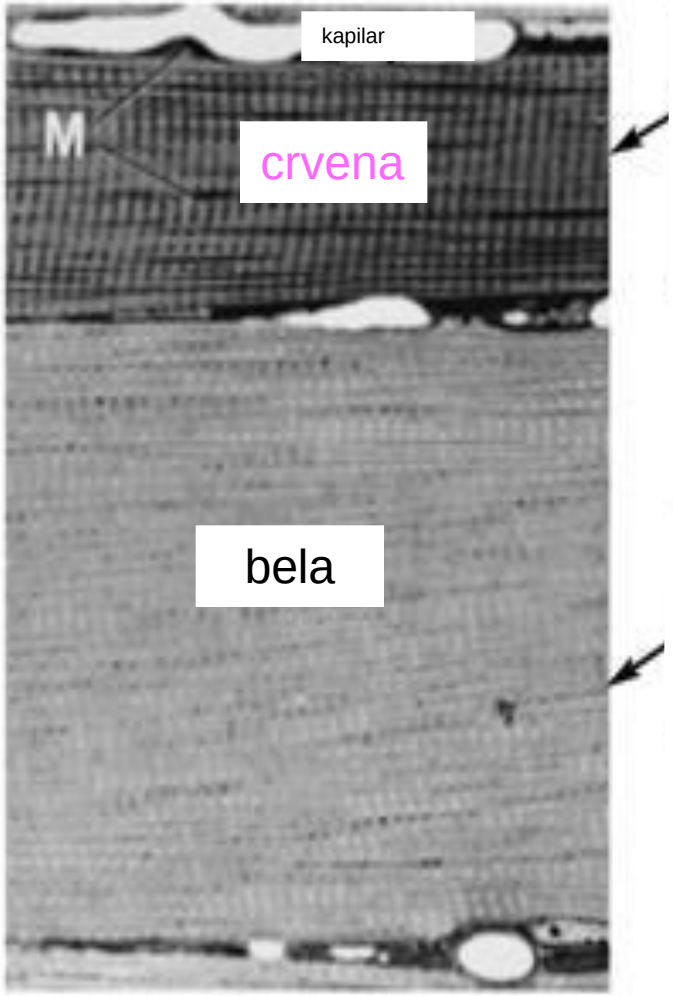
**OKSIDATIVNA FOSFORILACIJA**

- **GLAVNI ENERGETSKI SISTEM KAD SU POTREBE ZA ATP-om MALE**
- **TROŠI SE KISEONIK**

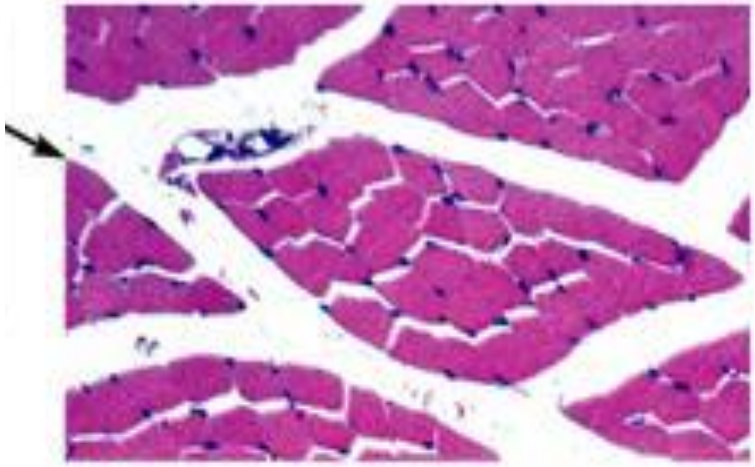
# ANAEROBNI I AEROBNI METABOLIZAM



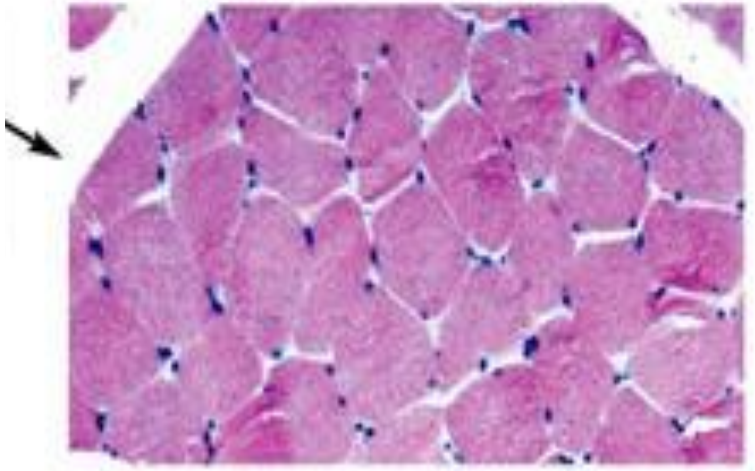
# Spora i brza mišićna vlakna



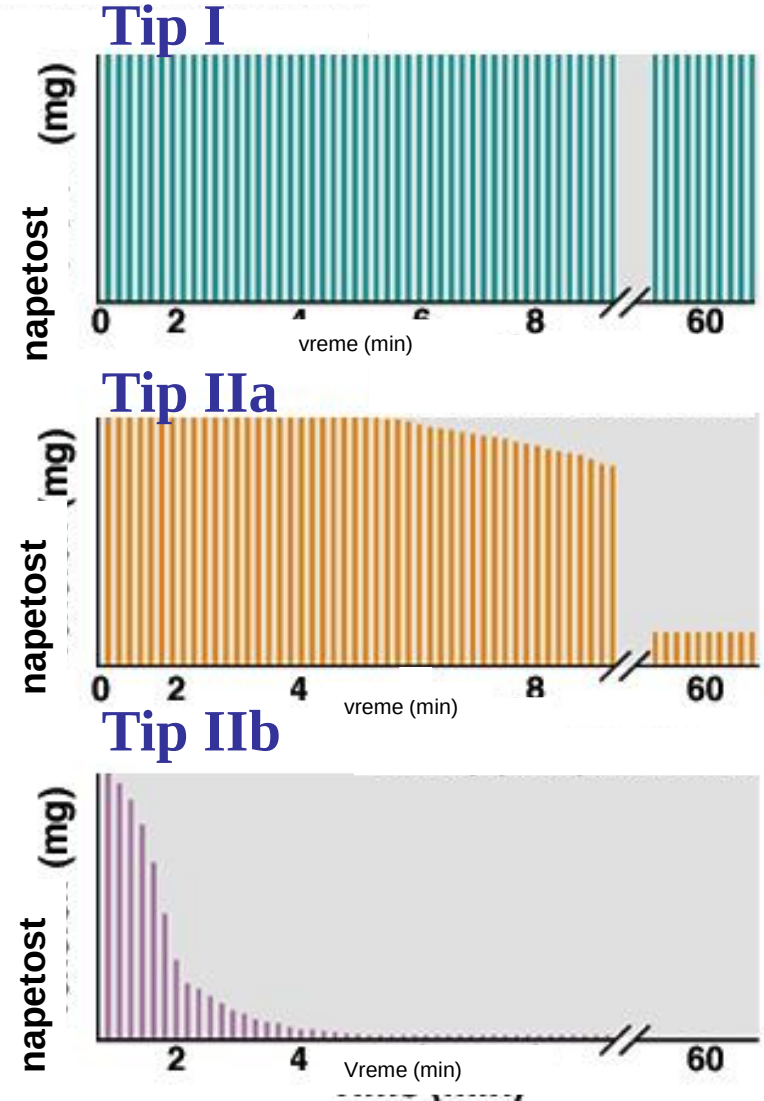

Spora vlakna

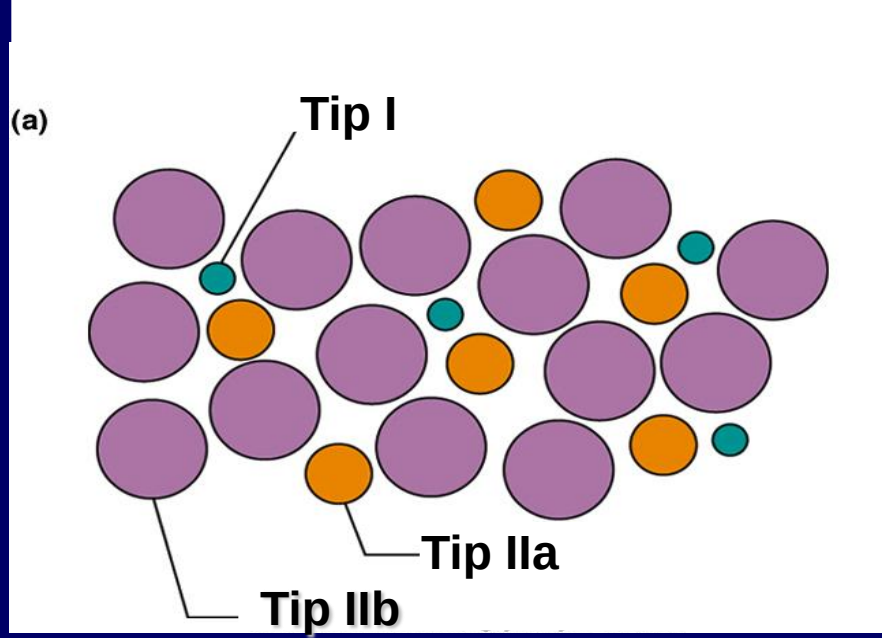


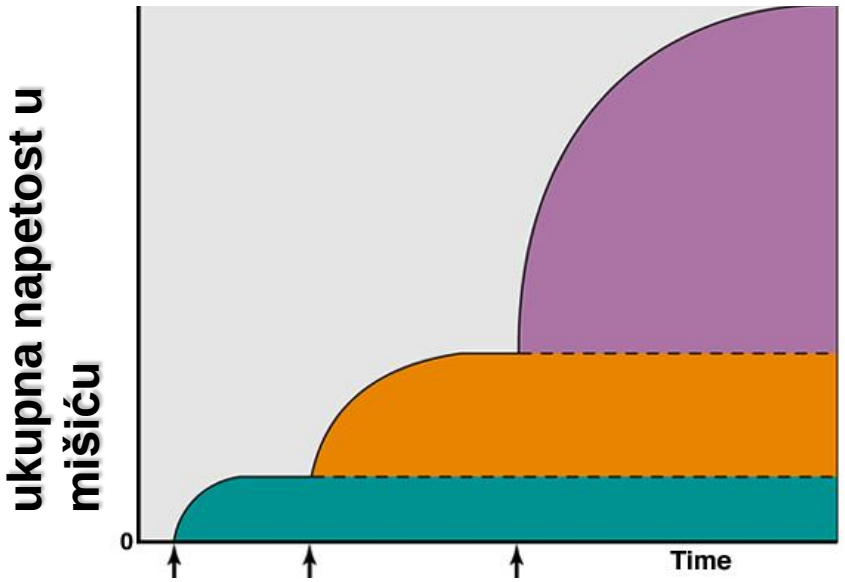
**Brza vlakna**

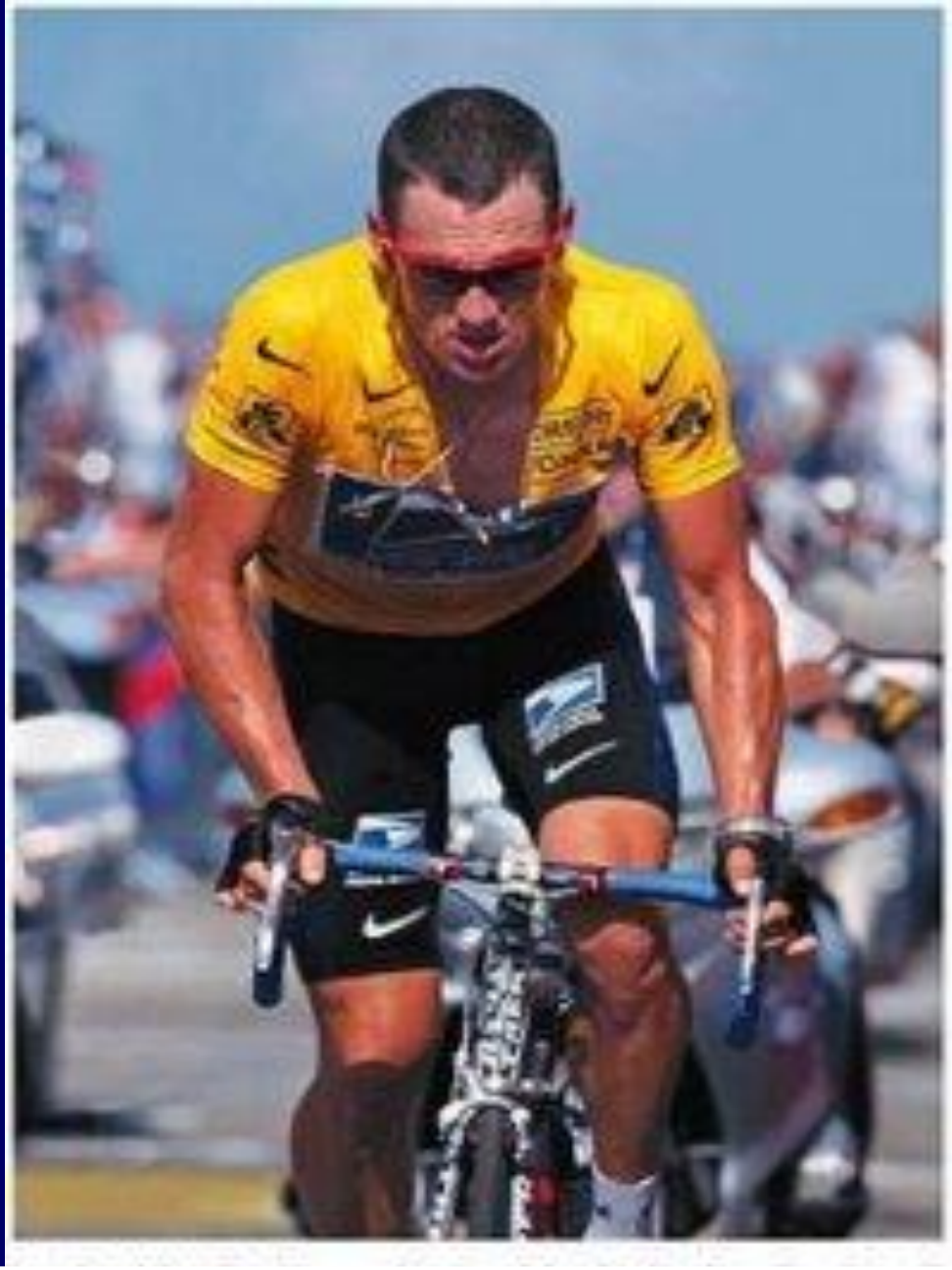


# VRSTE MIŠIĆNIH VLAKANA



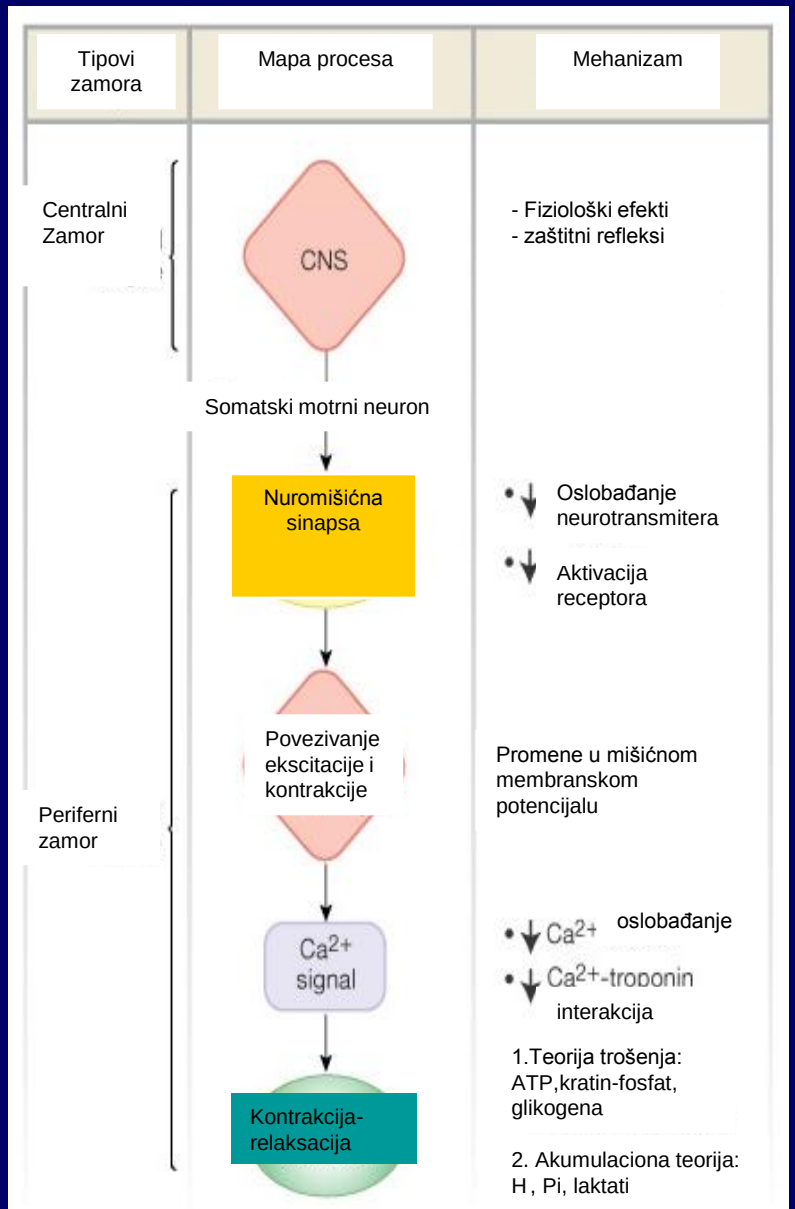





# MIŠIĆNI ZAMOR

- Centralni
- Periferni



# ZAMOR MIŠIĆA

# GLATKI MIŠIĆI

A VIŠEJEDINIČNI

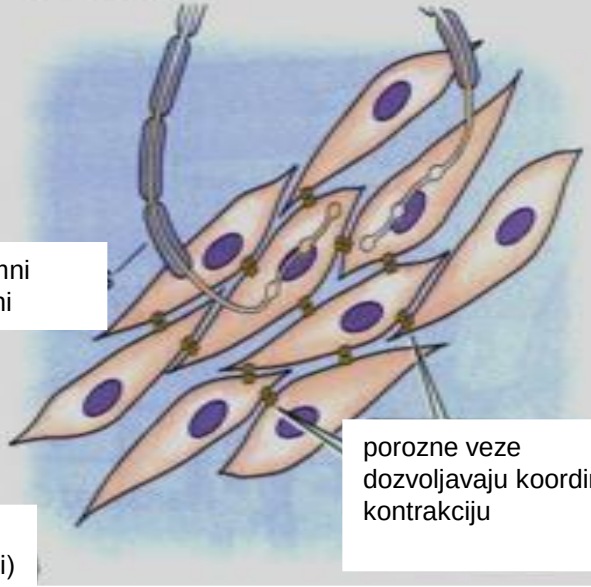
B JEDNOJEDINIČNI

električni
Izolovane ćelije dozvoljavaju finiju motornu kontrolu

autonomni neuroni

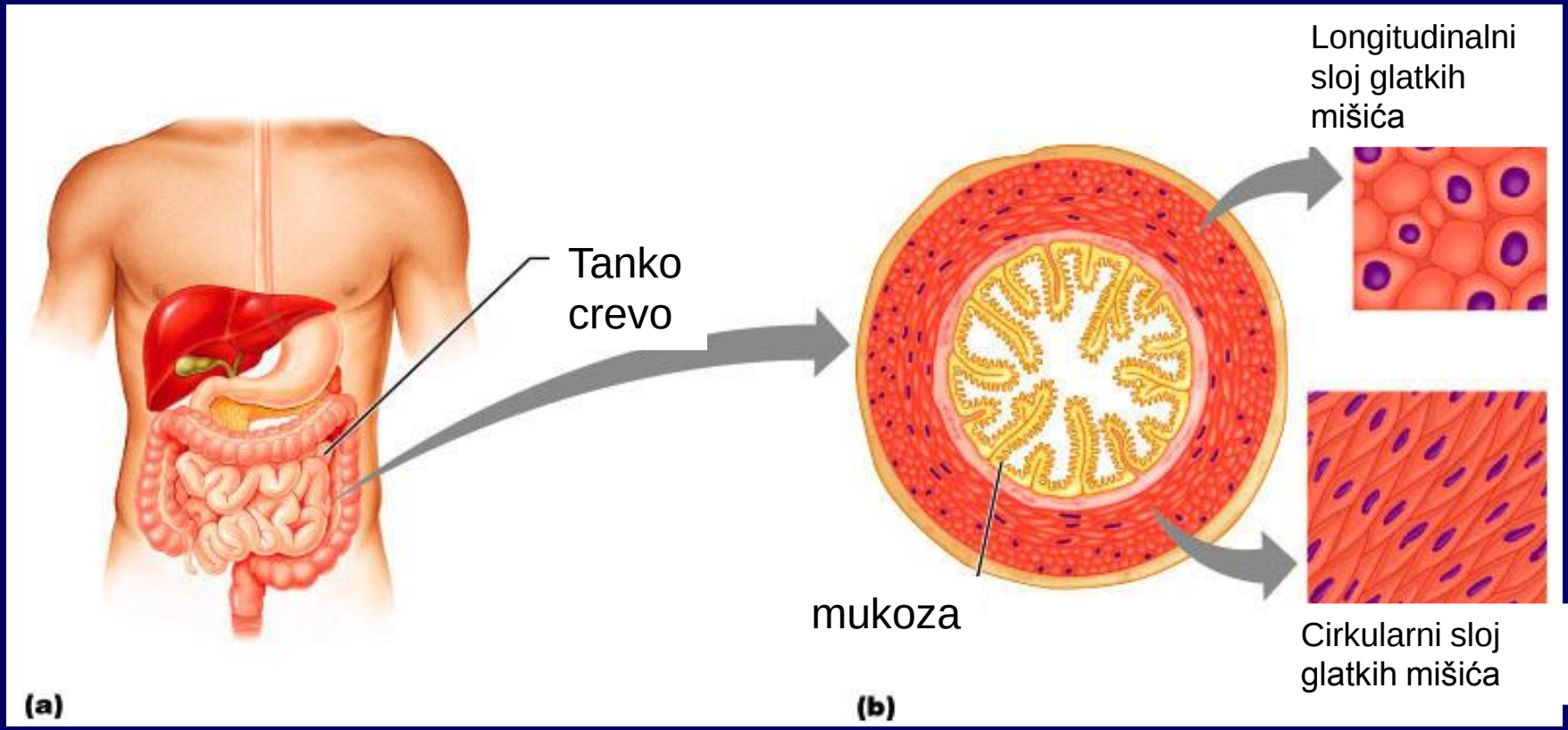
ćelija glatkog mišića

varikoziteti (sinaptički kontakti)

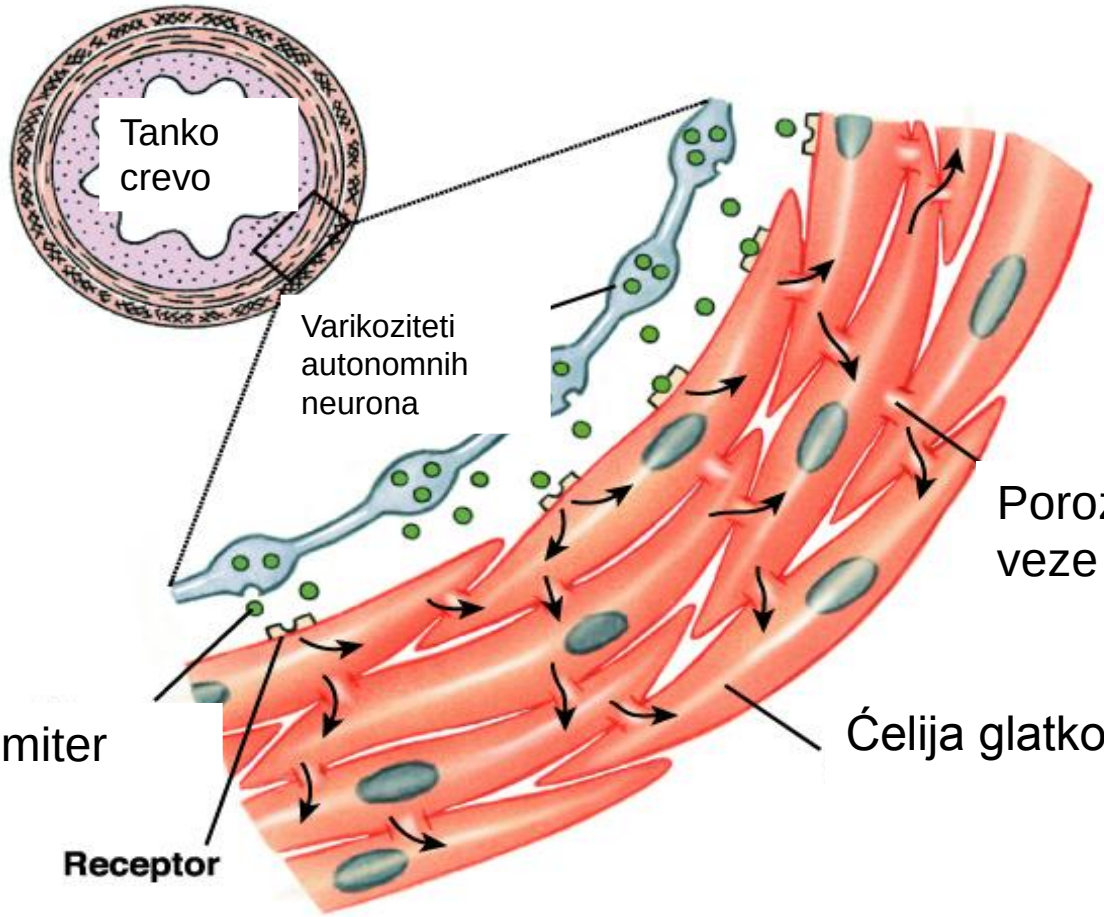


porozne veze dozvoljavaju koordinisanu kontrakciju

# GLATKI MIŠIĆI - JEDNOJEDINIČNI



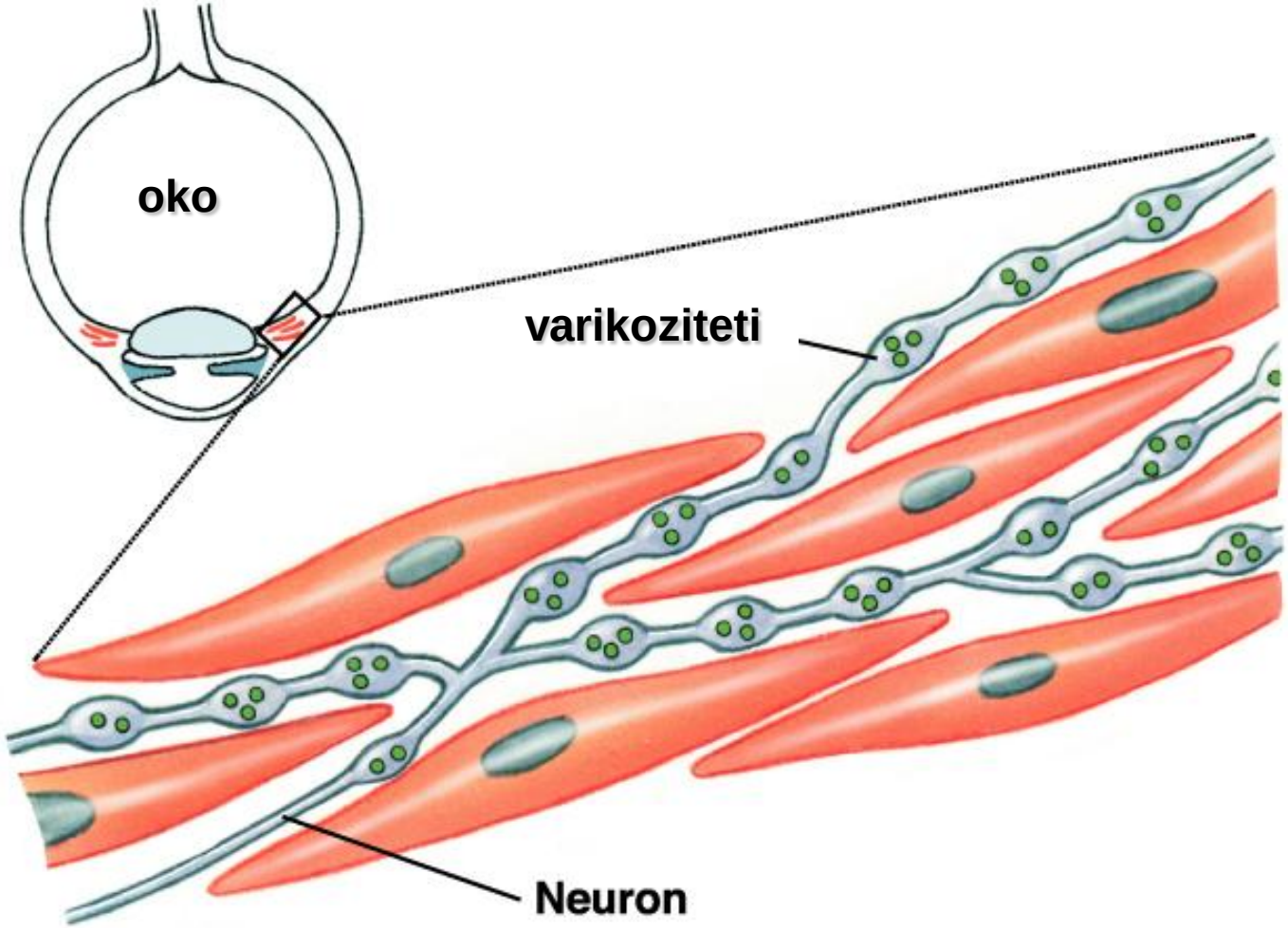
# JEDNOJEDINIČNI GLATKI MIŠIĆI



# ORGANI SA JEDNOJEDINIČNIM GLATKIM MIŠIĆIMA

- TANKO CREVO
- MOKRAĆNA BEŠIKA
- LIMFNI SUDOVI
- KOLON
- URETERI
- ARTERIOLE
- UTERUS (MIOMETRIUM)

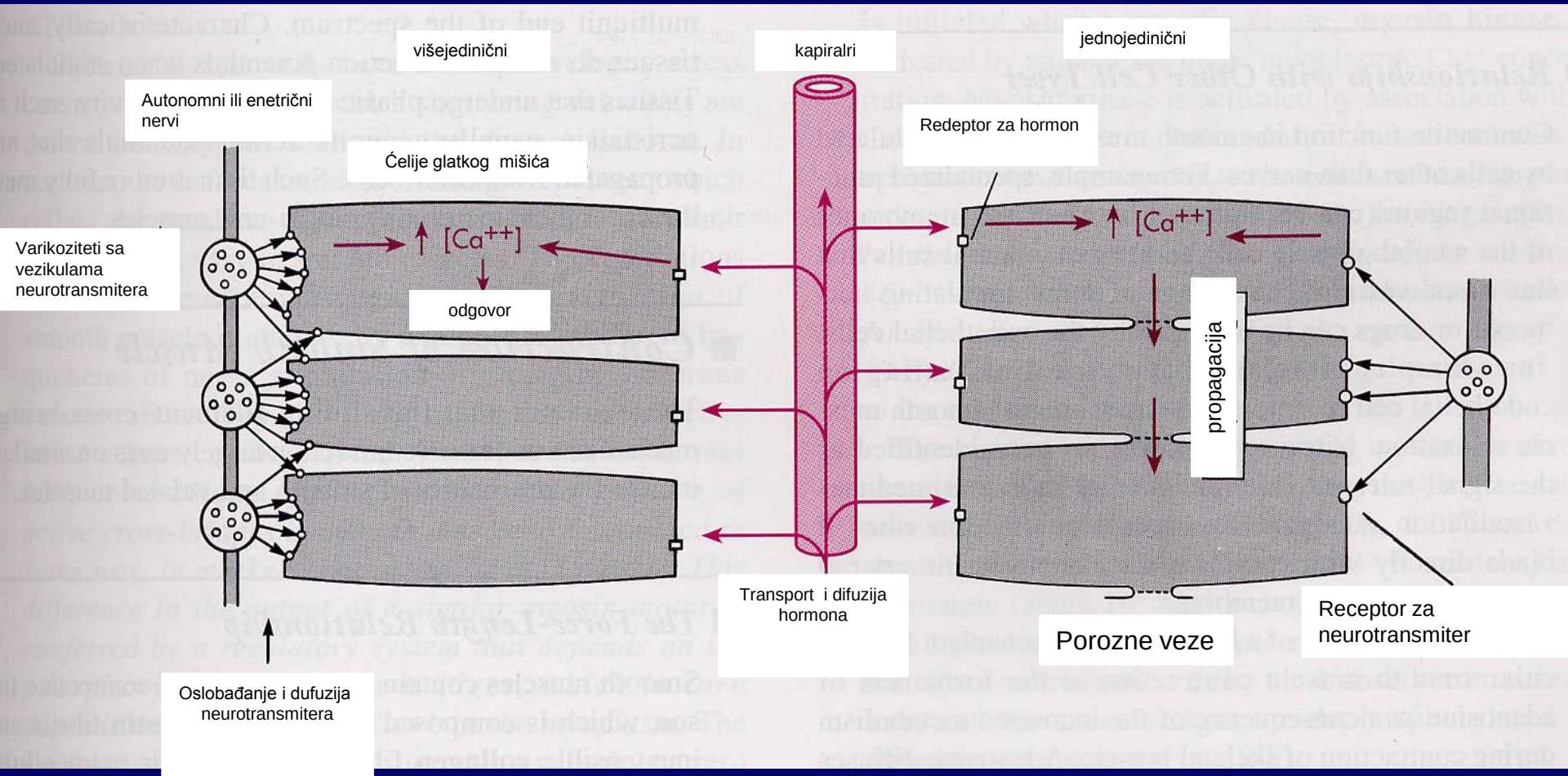
# VIŠEJEDINIČNI GLATKI MIŠIĆI



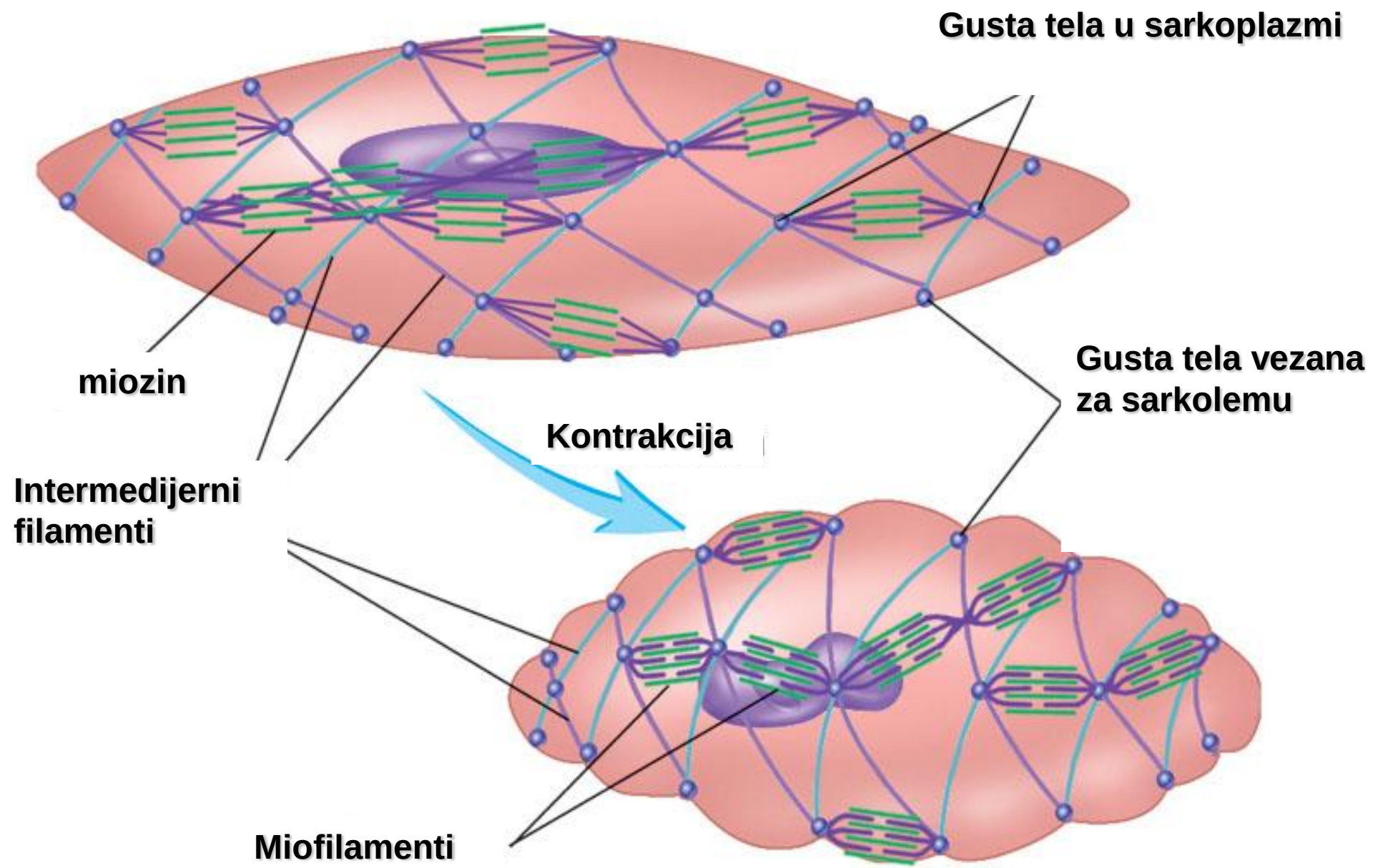
# ORGANI SA VIŠEJEDINIČNIM GLATKIM MIŠIĆIMA

- CILIJARNI MIŠIĆ
- MIŠIĆI TRAHEJE
- SFINKTERI U GIT-u
- VELIKI KRVNI SUDOVI
- MIŠIĆI IRISA
- MIŠIĆI BRONHIOLA
- VAS DEFERENS

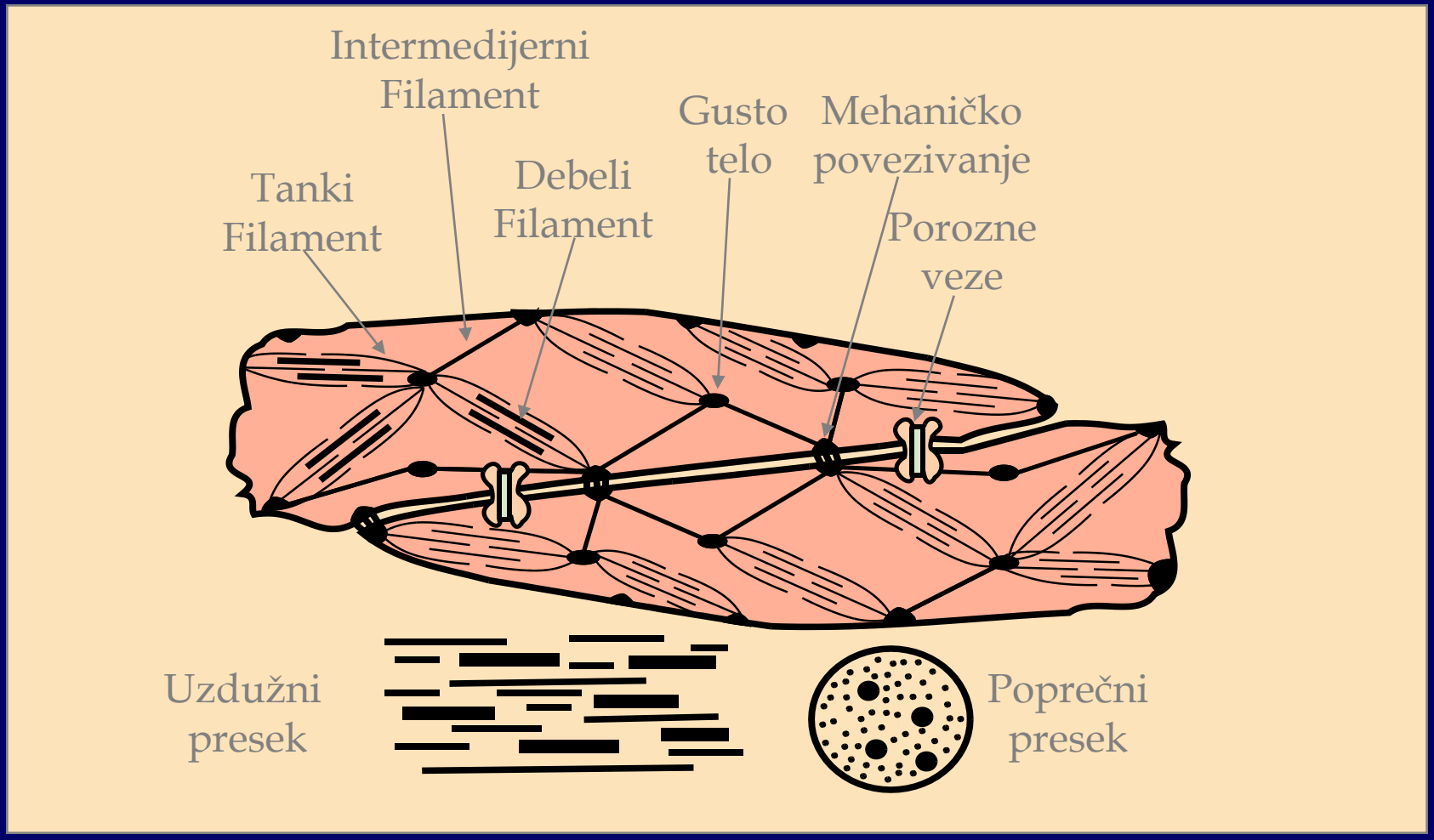
# RAZLIKE VIŠEJEDINIČNOG I JEDNOJEDINIČNOG GLATKOG MIŠIĆA



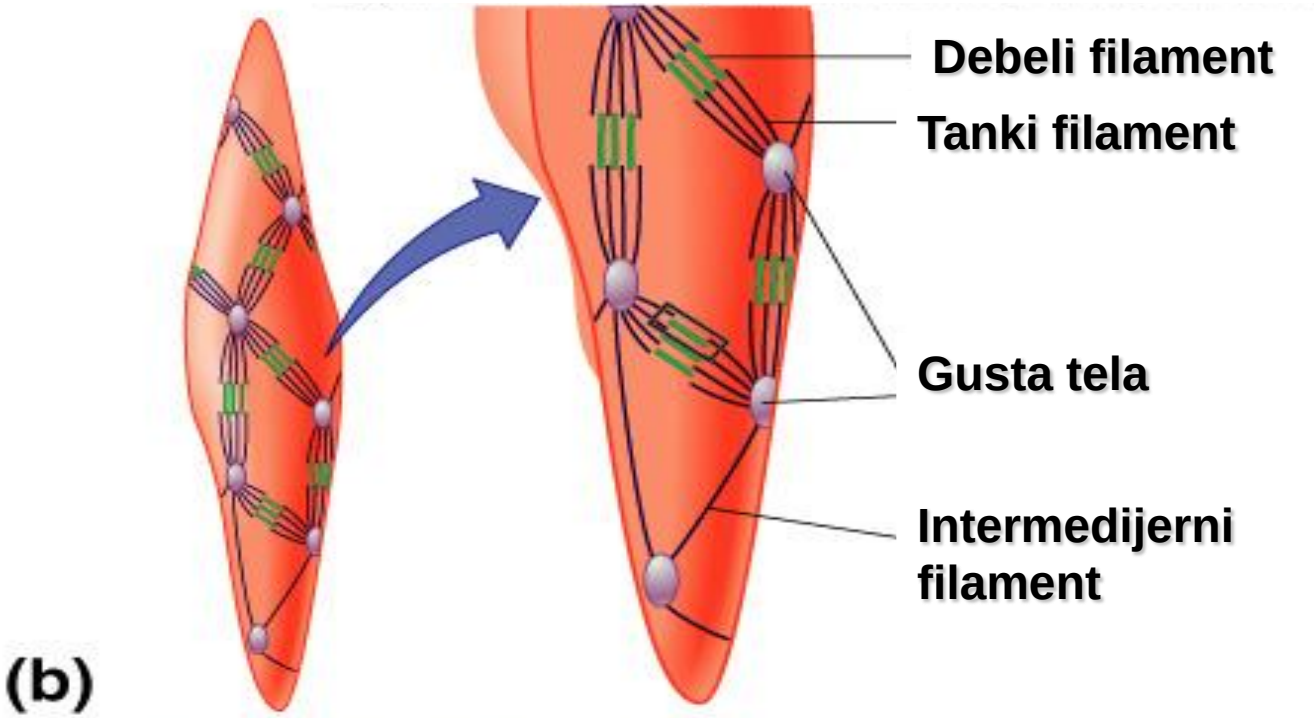
# ĆELIJA GLATKOG MIŠIĆA

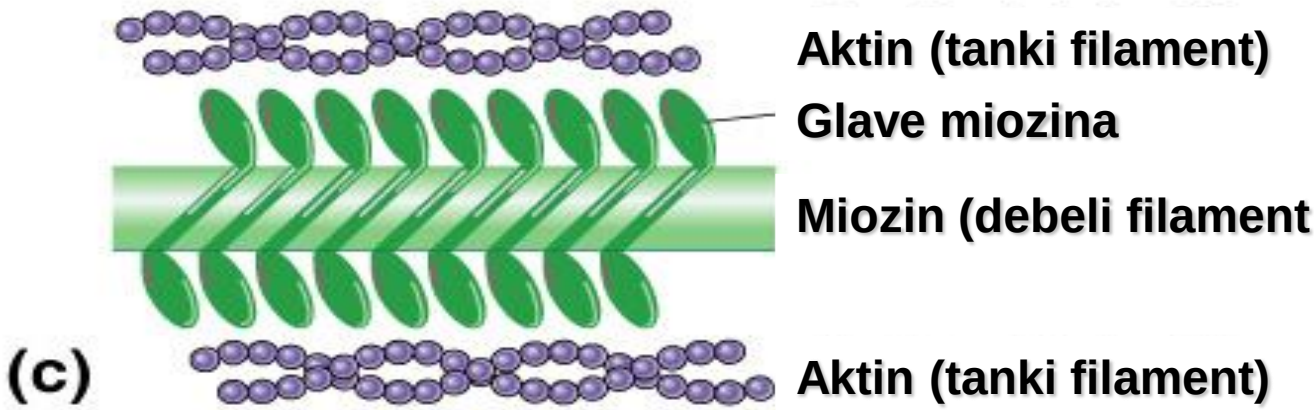


# GRAĐA JEDNOJEDINIČNOG GLATKOG MIŠIĆA

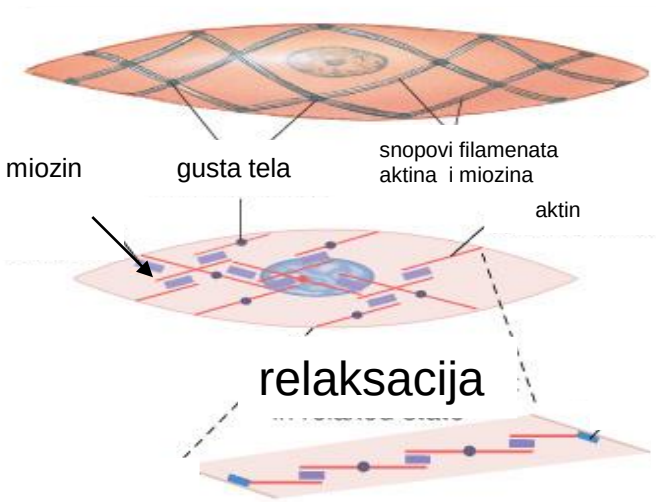


# GLATKI MIŠIĆ-KONTRAKTILNI APARAT

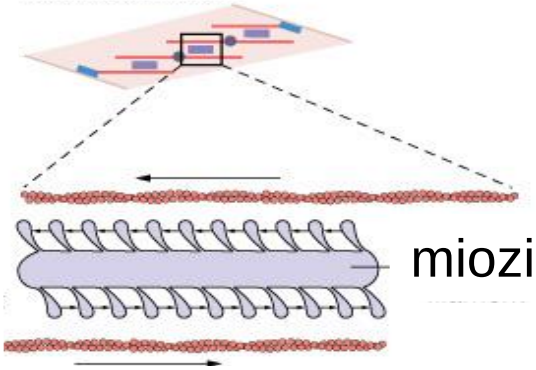


# GLATKI MIŠIĆI- KARAKTERISTIKE



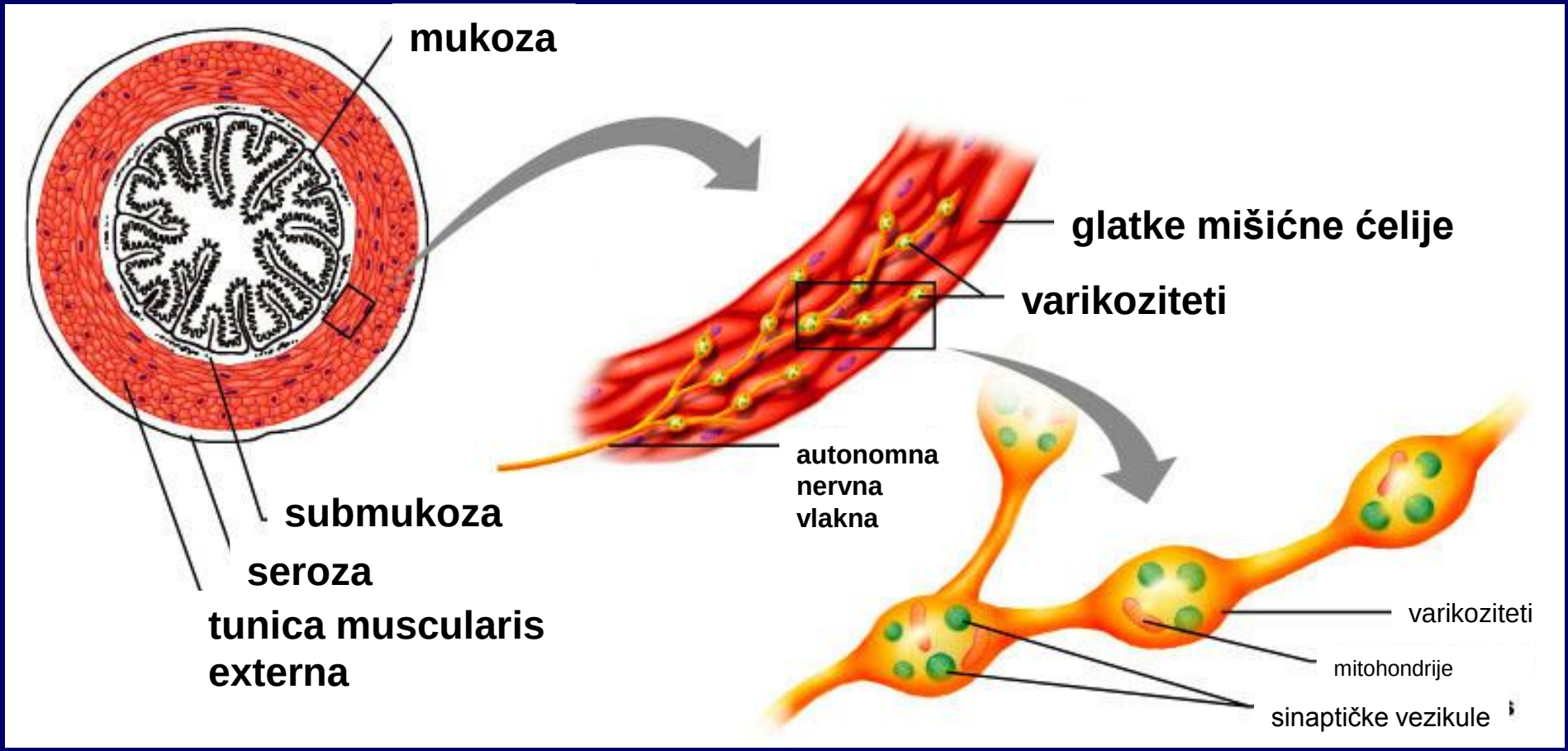

kontrakcija



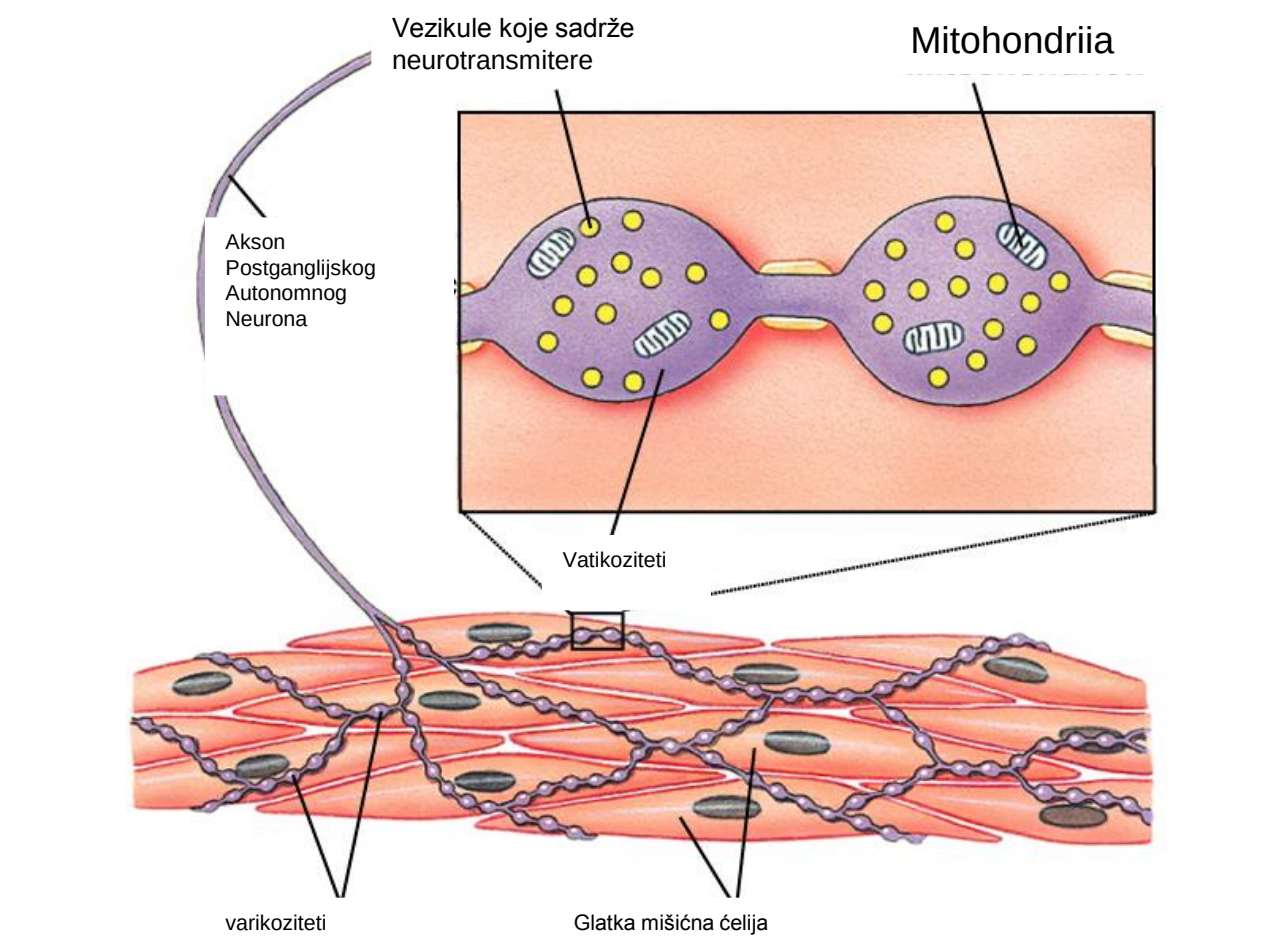
aktin

miozin

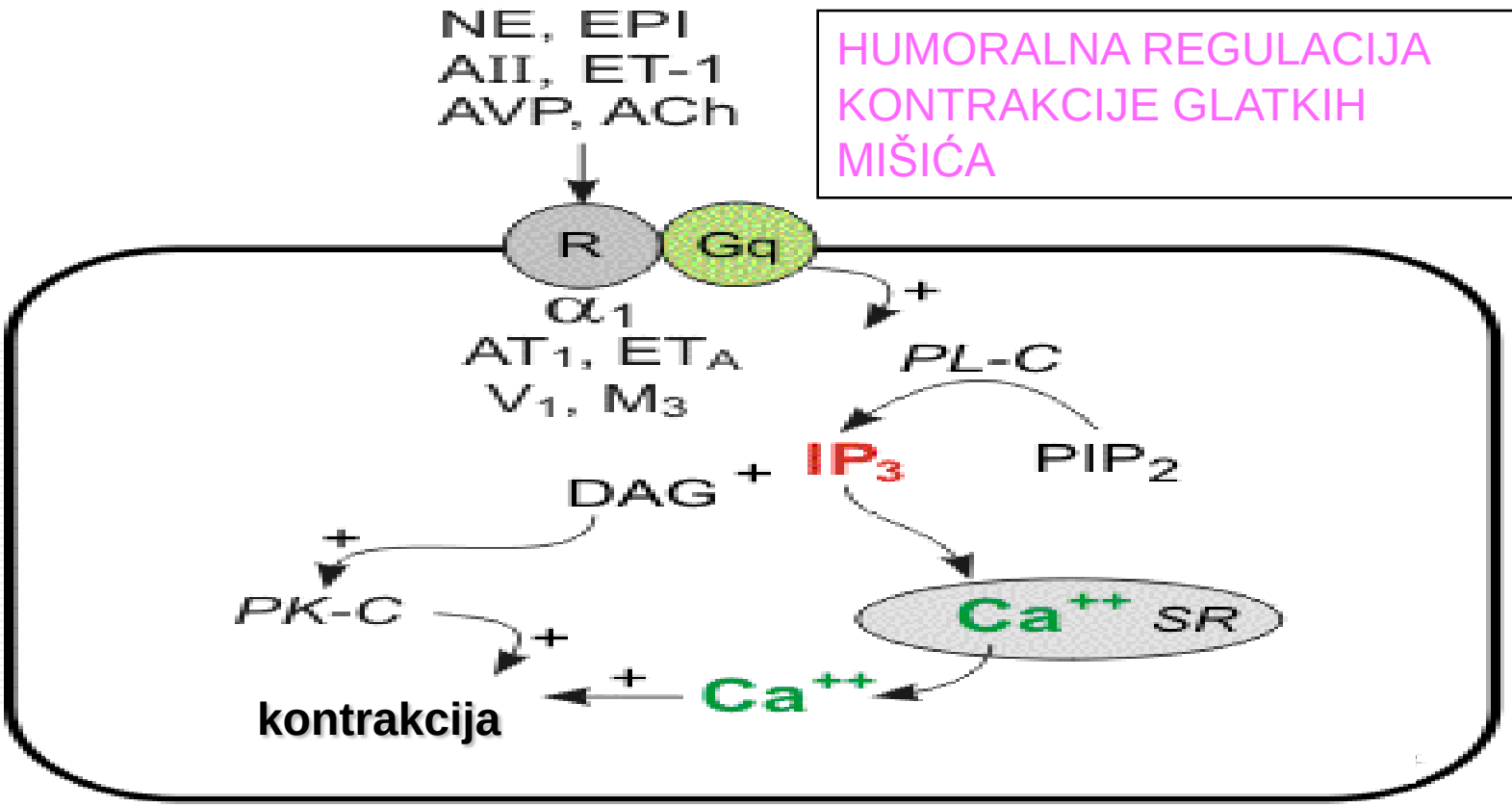
# INERVACIJA GLATKIH MIŠIĆA



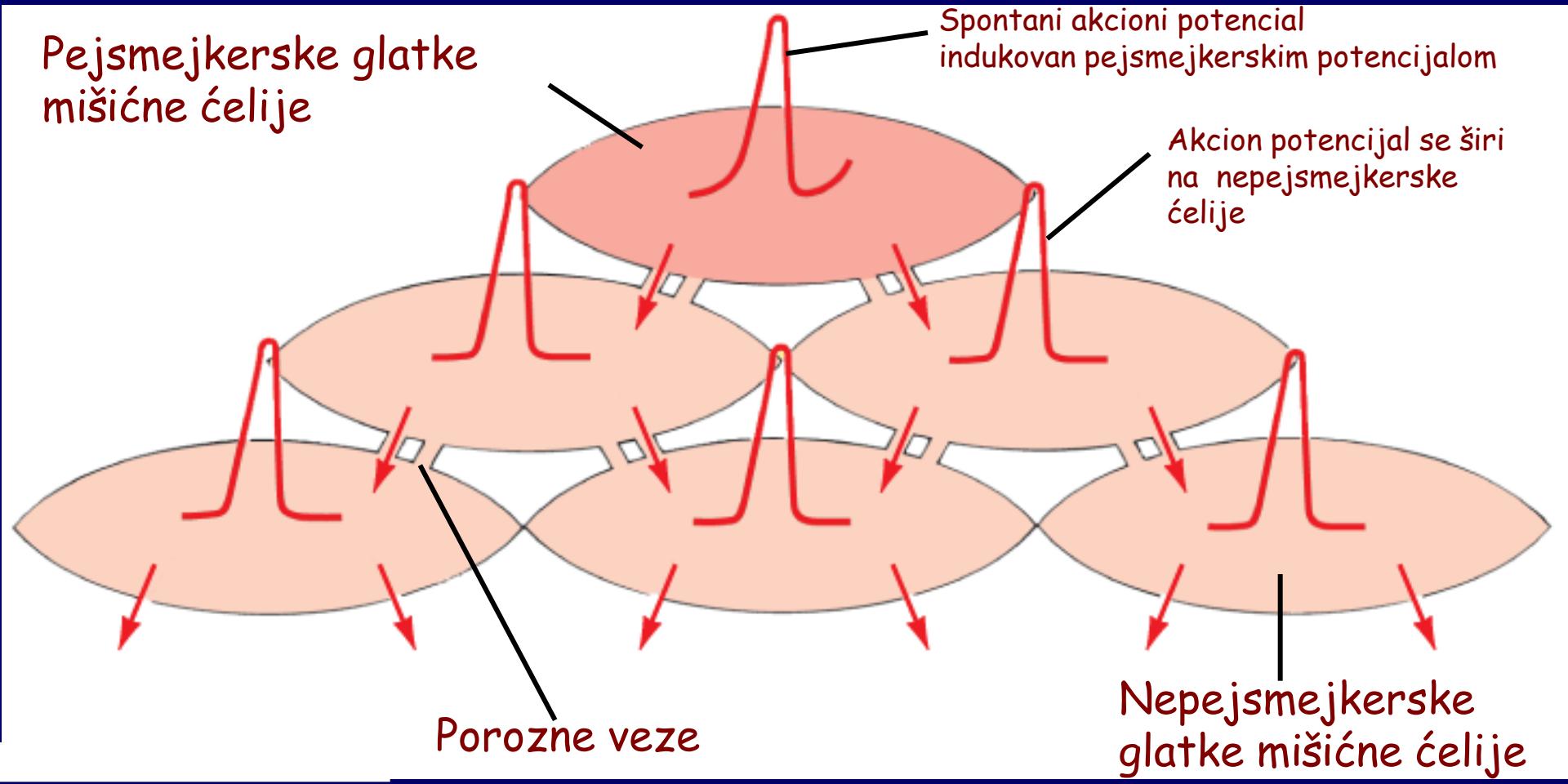
# NERVNO-EFEKTORNE SINAPSE ANS



HUMORALNA REGULACIJA KONTRAKCIJE GLATKIH MIŠIĆA

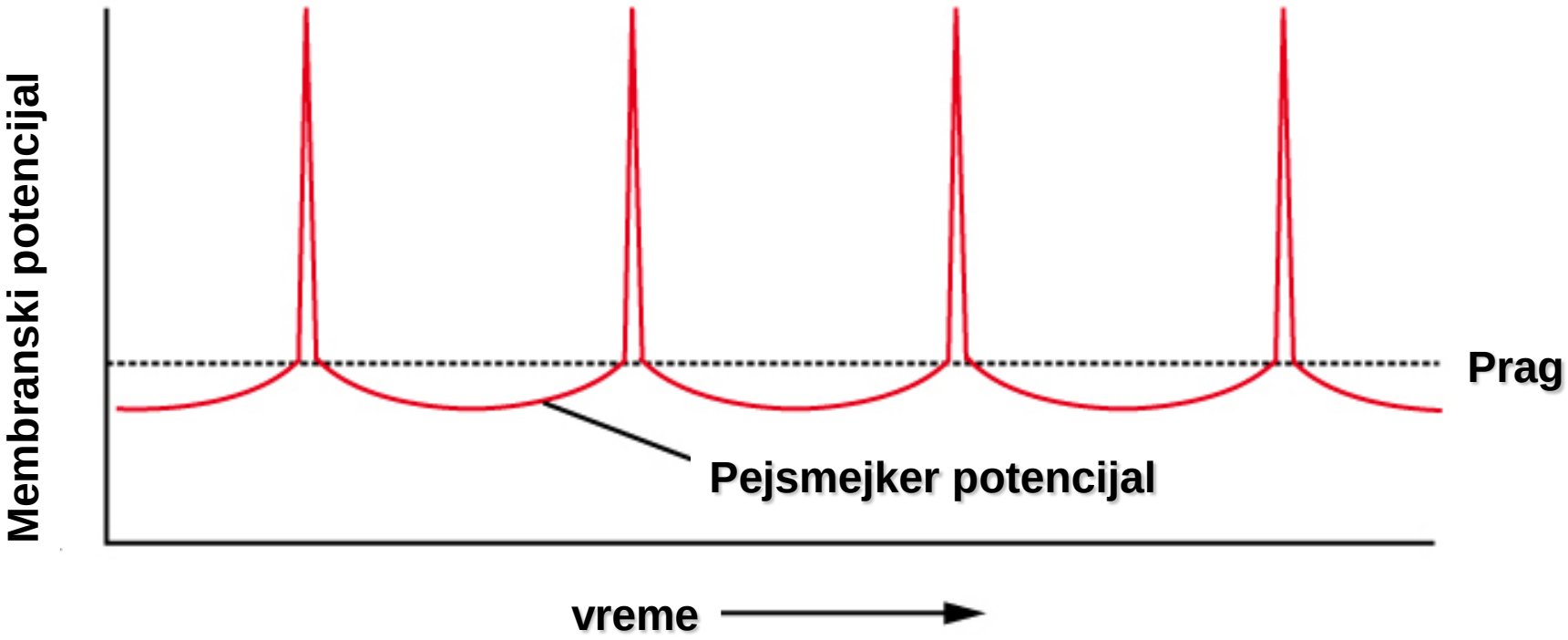


# PEJSMEJKERSKE GLATKE MIŠIĆNE ĆELIJE

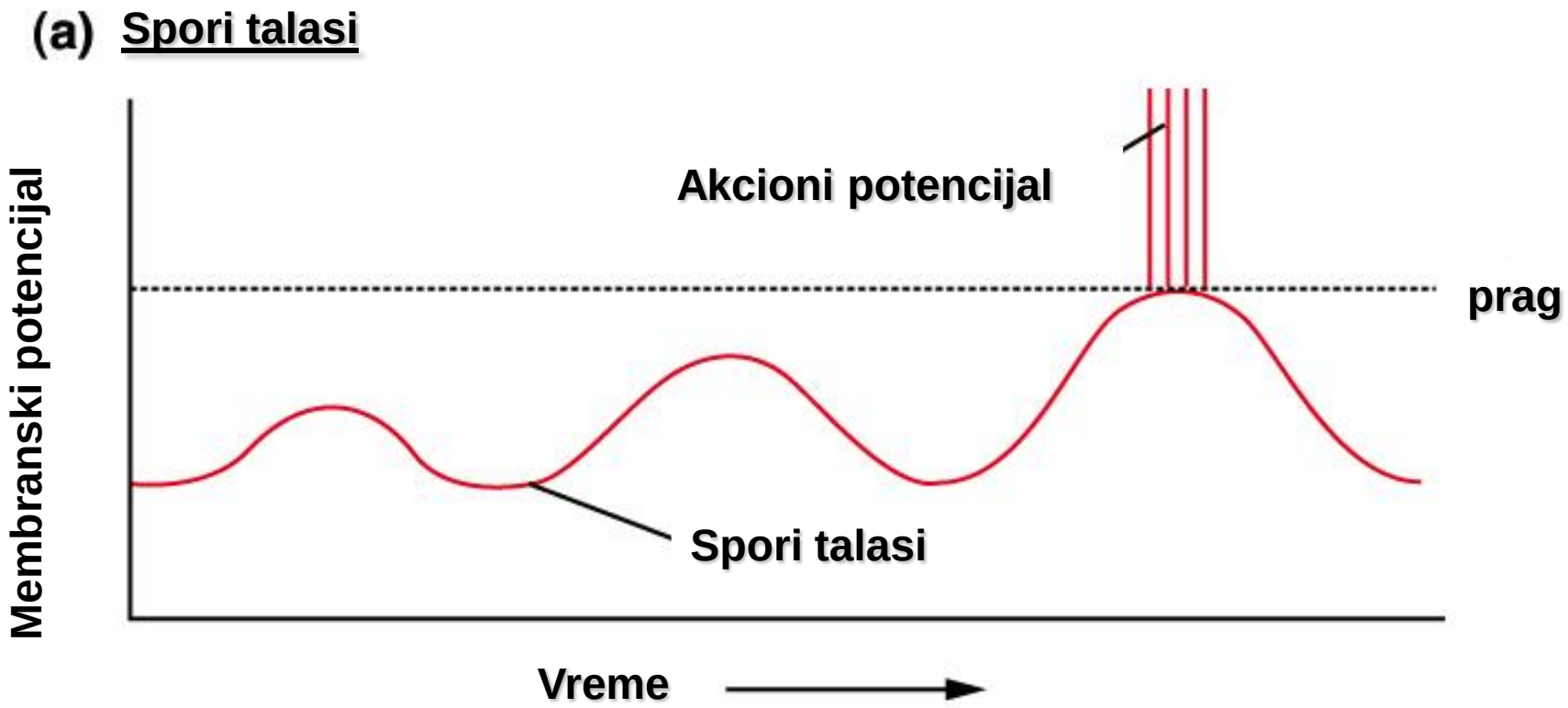


# PEJSMEJKERSKI POTENCIJAL

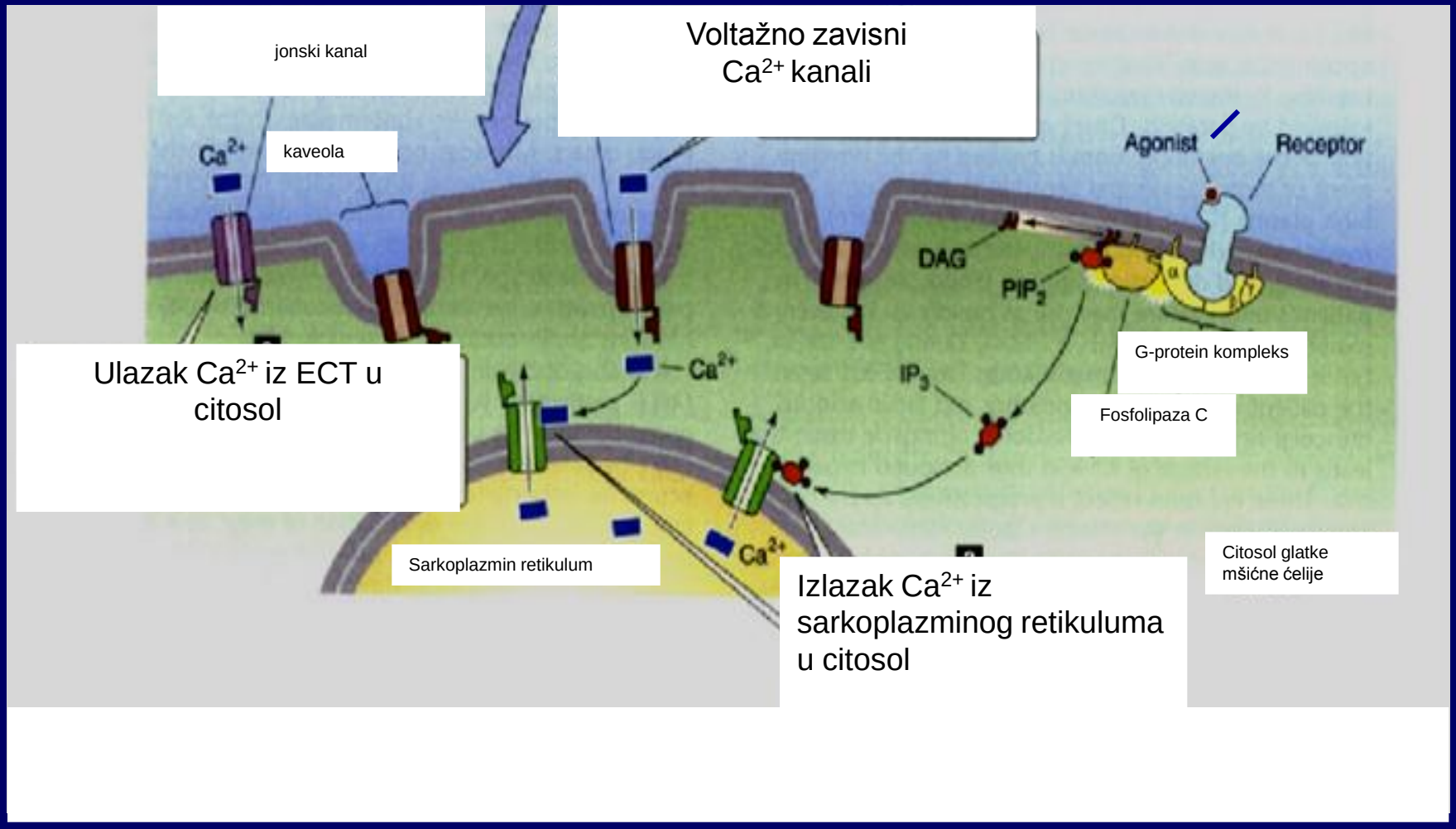
(b) Pejsmejker potencijal



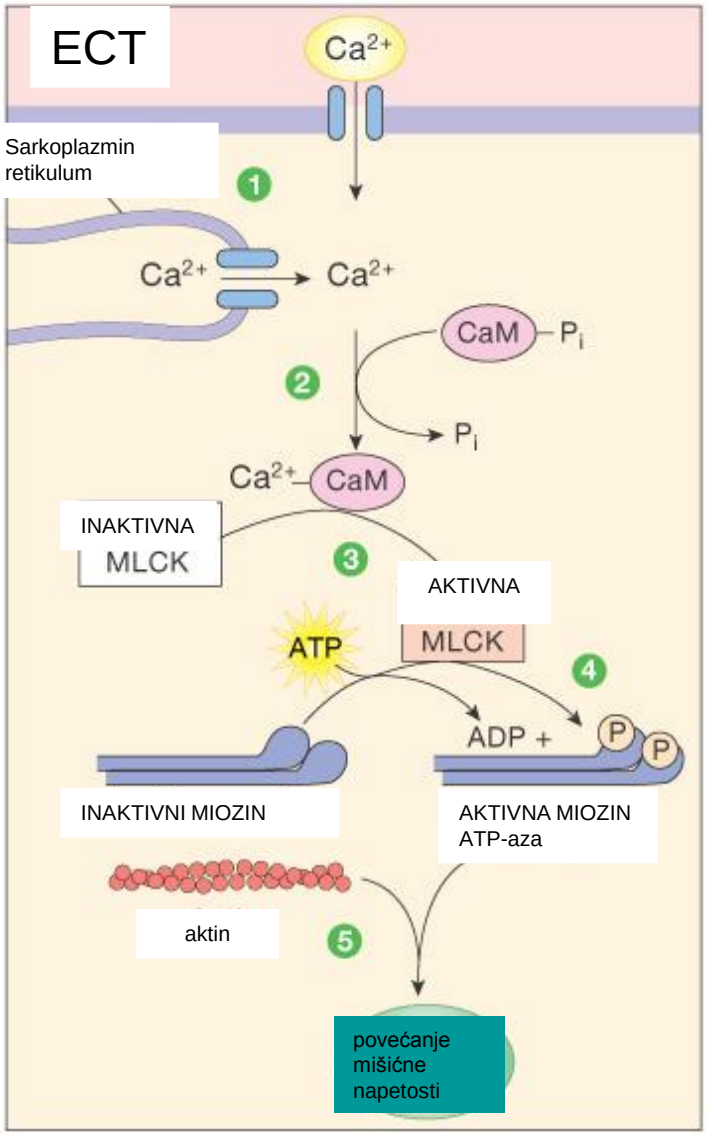
# SPORI TALASI I AKCIONI POTENCIJALI



# EKSCITACIJA



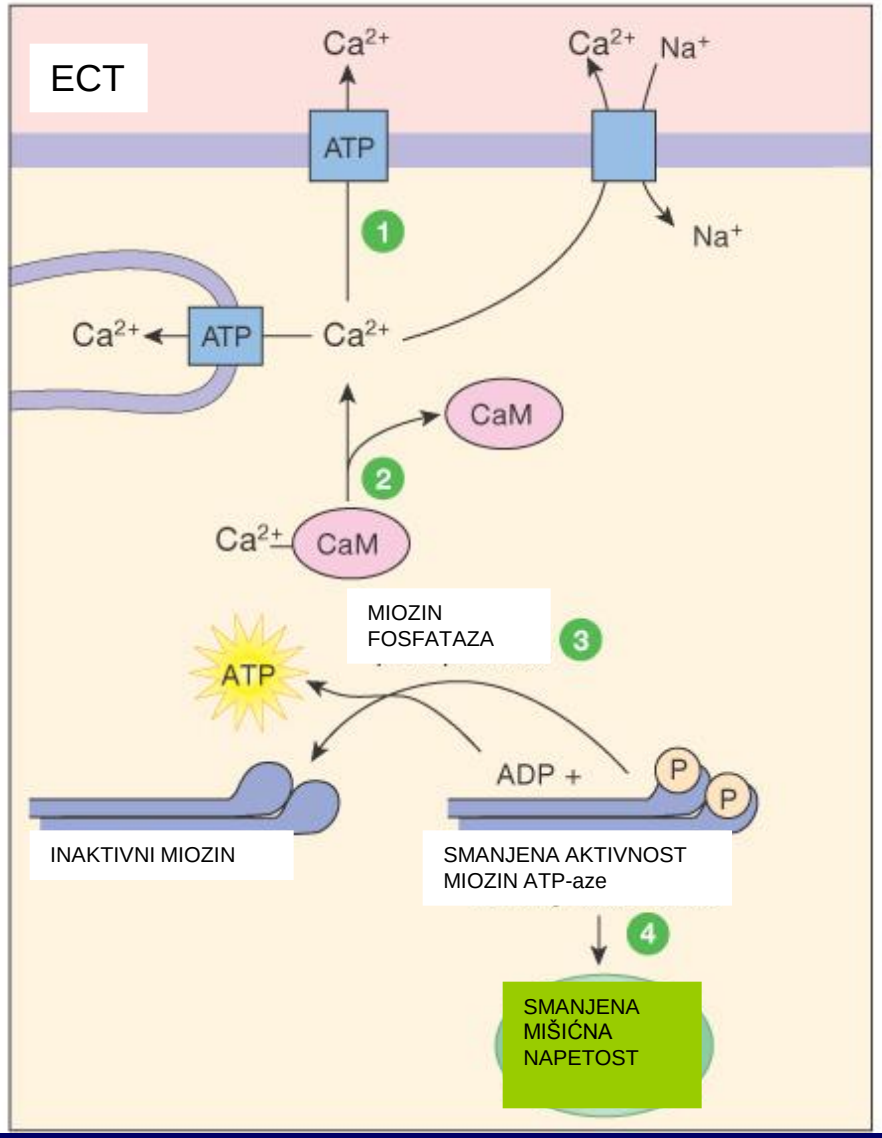
# MEHANIZAM KONTRAKCIJE GLATKIH MIŠIĆA




1. Povećanje intracelularne koncentracije $Ca^{2+}$ ulaskom Iz ECT i izlaskom iz sarkoplazminog retikuluma
2. $Ca^{2+}$ se vezuje za kalmodulin (CaM)
3. $Ca^{2+}$ - kalmodulin aktivira kinazu lakih lanaca miozina (MLCK)
4. MLCK fosforiliše lake lance u glavicama miozina i povećava miozin ATP-aznu aktivnost
5. Aktivni poprečni mostovi miozina kližu duž aktina i stvaraju mišićnu napetost

Figure 12-28: Smooth muscle contraction

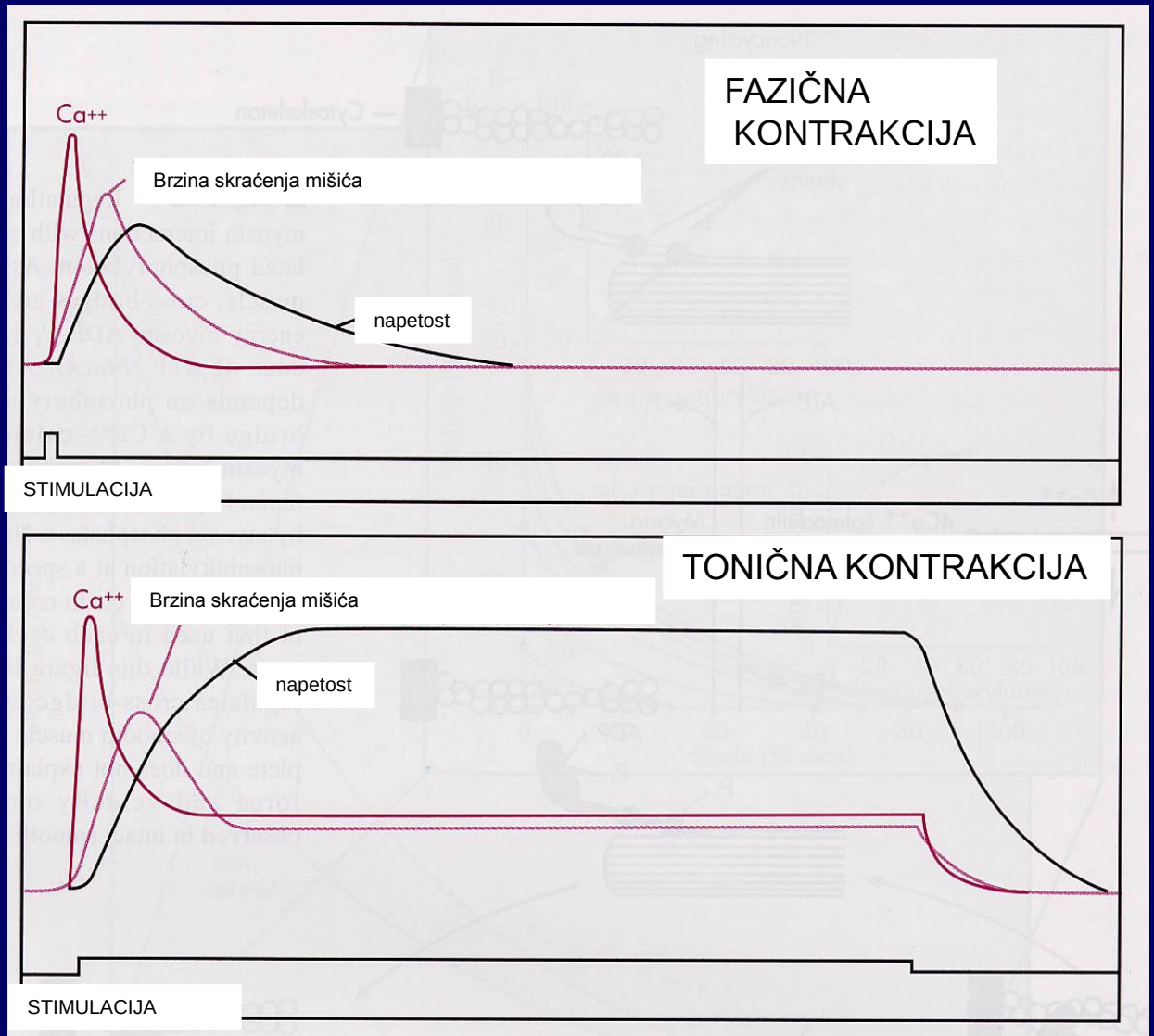
# MEHANIZAM RELAKSACIJE GLATKIH MIŠIĆA




1. Smanjenje koncentracije $Ca^+$ pumpanjem u ECT ili u sarkoplazmin retikulum
2. Odvajanje kalcijuma od kalmodulina
3. Miozin fosfataza odvaja fosfat sa miozina i smanjuje se miozin ATP-azna aktivnost
4. Smanjenje miozin ATP-aze smanjuje mišićnu napetost

Figure 12-29: Relaxation in smooth muscle

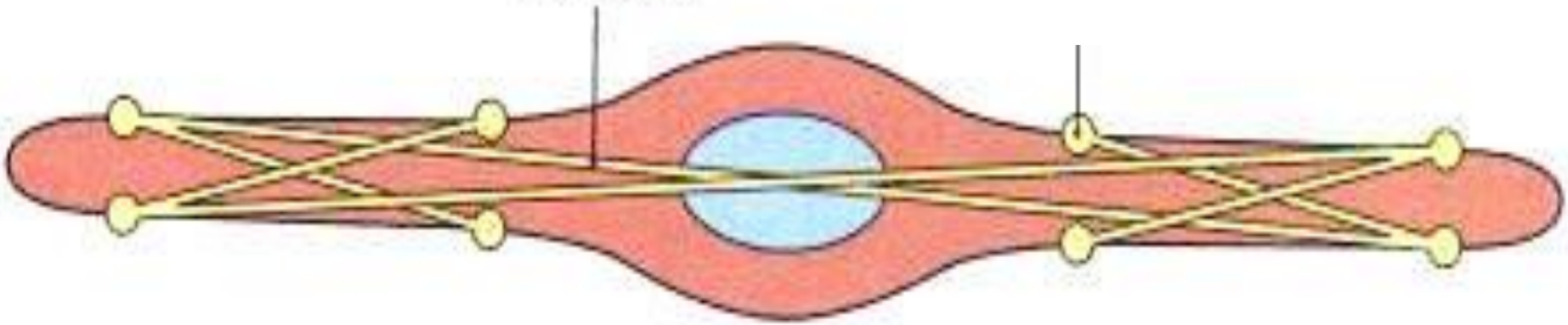
# FAZIČNA I TONIČNA KONTRAKCIJA



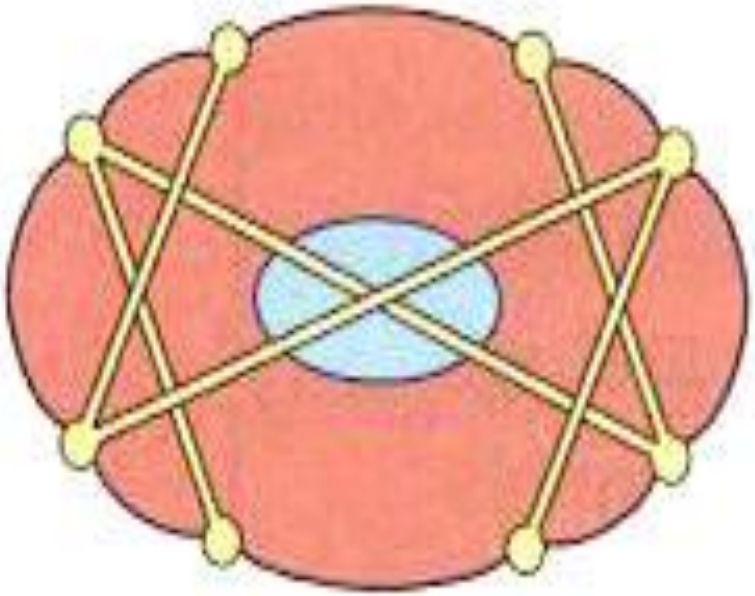
KONTRAKTILNI FILAMENT

GUSTO TELO

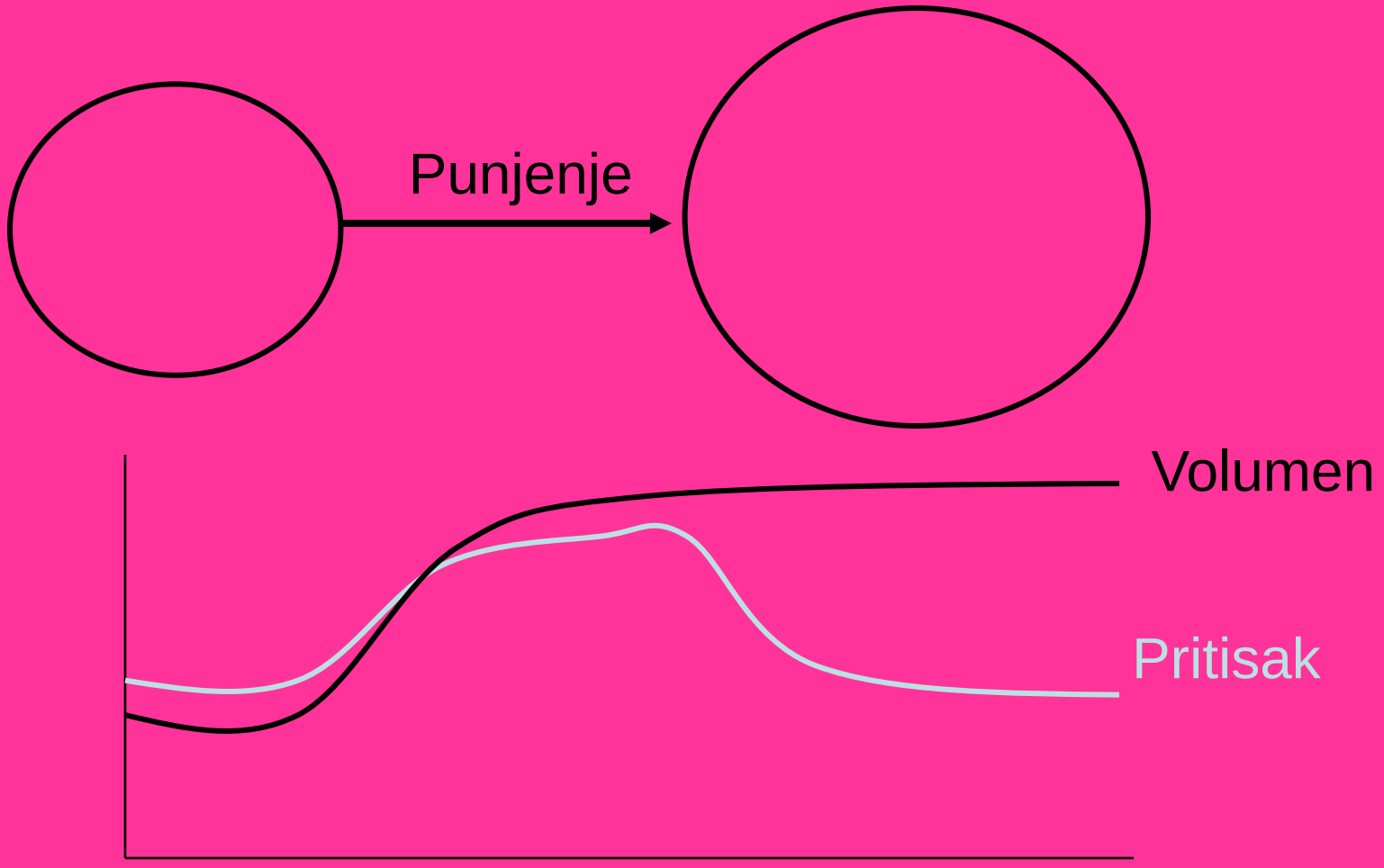
RELAKSACIJA



KONTRAKCIJA



# PLASTIČNOST– mokraćna bešika



# – TEZE –

Osobine mišićnog tkiva
Uloge mišića

SKELETNI MIŠIĆI
Funkcionalna morfologija skeletnih mišića (sarkoplazmin retikulum, transverzalni tubuli, miofilamenti, sarkomera)
Ekscitacija skeletnih mišića (nervno-mišićna sinapsa)
Kontrakcija i relaksacija mišića (vrste mišićnih vlakana prema brzini kontrakcije)
Snaga mišićne kontrakcije
Mišićni tonus
Motorna jedinica
Izvori energije za mišićnu kontrakciju (kiseonički dug)
Ponašanje mišića kao celine (prostorna i vremenska sumacija)
Podela mišićnih kontrakcija (pojedinačnaei složene; izotonične i izometrične;
fazične i tonične)

GLATKI MIŠIĆI
Vrste glatkih mišića
Funkcionalna morfologija glatkih mišića (sarkolema)
Ekscitacija glatkih mišića
Kontrakcija i relaksacija glatkih mišića
Specifičnosti kontrakcije glatkog mišića (fenomen zaključavanja, plastičnost)
Razlike u kontrakciji skeletnog i glatkog mišića