



Fotosinteza i svjetlost u kemiji

Doc. dr. sc. Vladimir Stilinović
Prirodoslovno-matematički fakultet
Sveučilište u Zagrebu

Fotosinteza

1. Priprava nove tvari pod utjecajem svjetla.
2. Kemijska reakcija spajanja dviju (ili više) molekula pod utjecajem svjetla.
3. Proces kojime biljke (i drugi organizmi) pretvaraju svjetlosnu energiju u kemijsku.

Fotosinteza

spajanje molekula u veće **pod
utjecajem svjetla**

Fotoliza

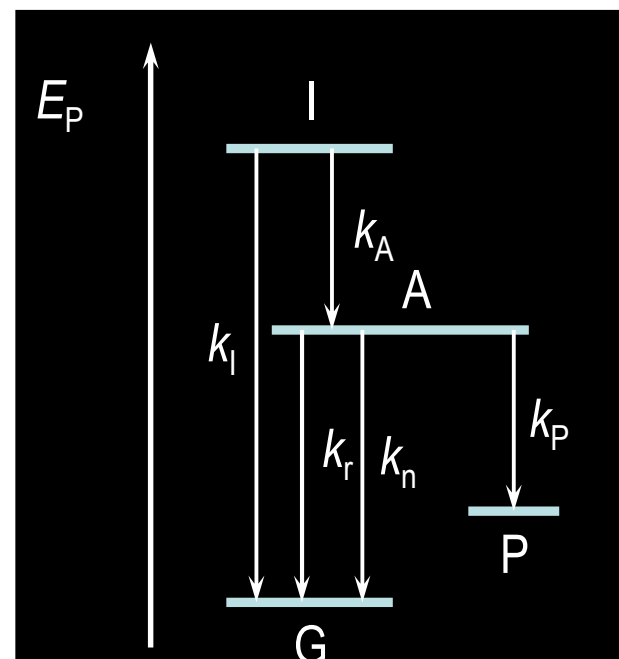
razlaganje molekula na manje **pod
utjecajem svjetla**

Fotoizomerizacija

promjena raspodjele atoma u
molekuli **pod utjecajem svjetla**

Svjetlost u kemiji

- Molekula apsorbira kvant zračenja (foton)
- Pobuđena molekula je reaktivnija vrsta od molekule u osnovnom stanju
- Pobuđena molekula može emitirati zračenje (fluorescencija i fosforascencija), izgubiti energiju u sudarima s drugim molekulama ili pak kemijski reagirati.

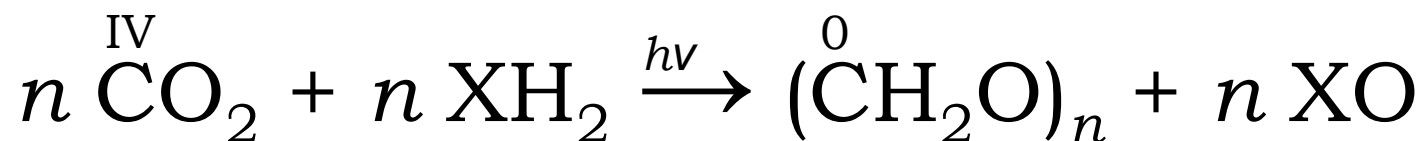


Svjetlost u kemiji

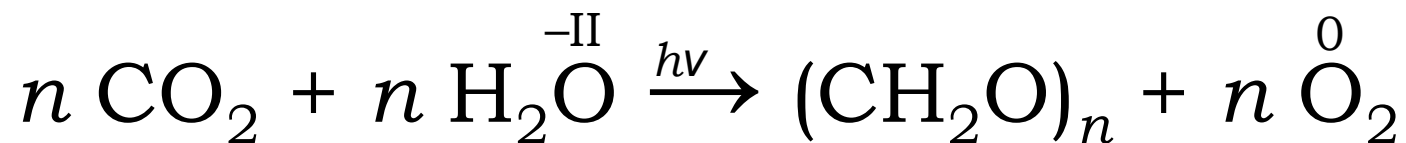
- Samo dio zračenja dovodi do kemijske reakcije – kvantno iskorištenje (mjeri se aktinometrijski)
- Molekula mora imati 'antenu' = kromofor
- Molekula koja sama ne apsorbira zračenje može primiti energiju od susjeda koji apsorbira - senzitizer

Fotosinteza

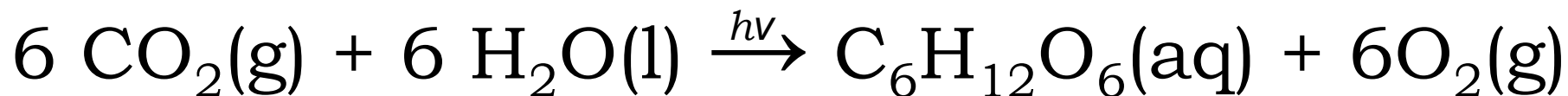
Ukupna reakcija - svjetlom potpomognuta redukcija ugljikova dioksida u ugljikohidrat



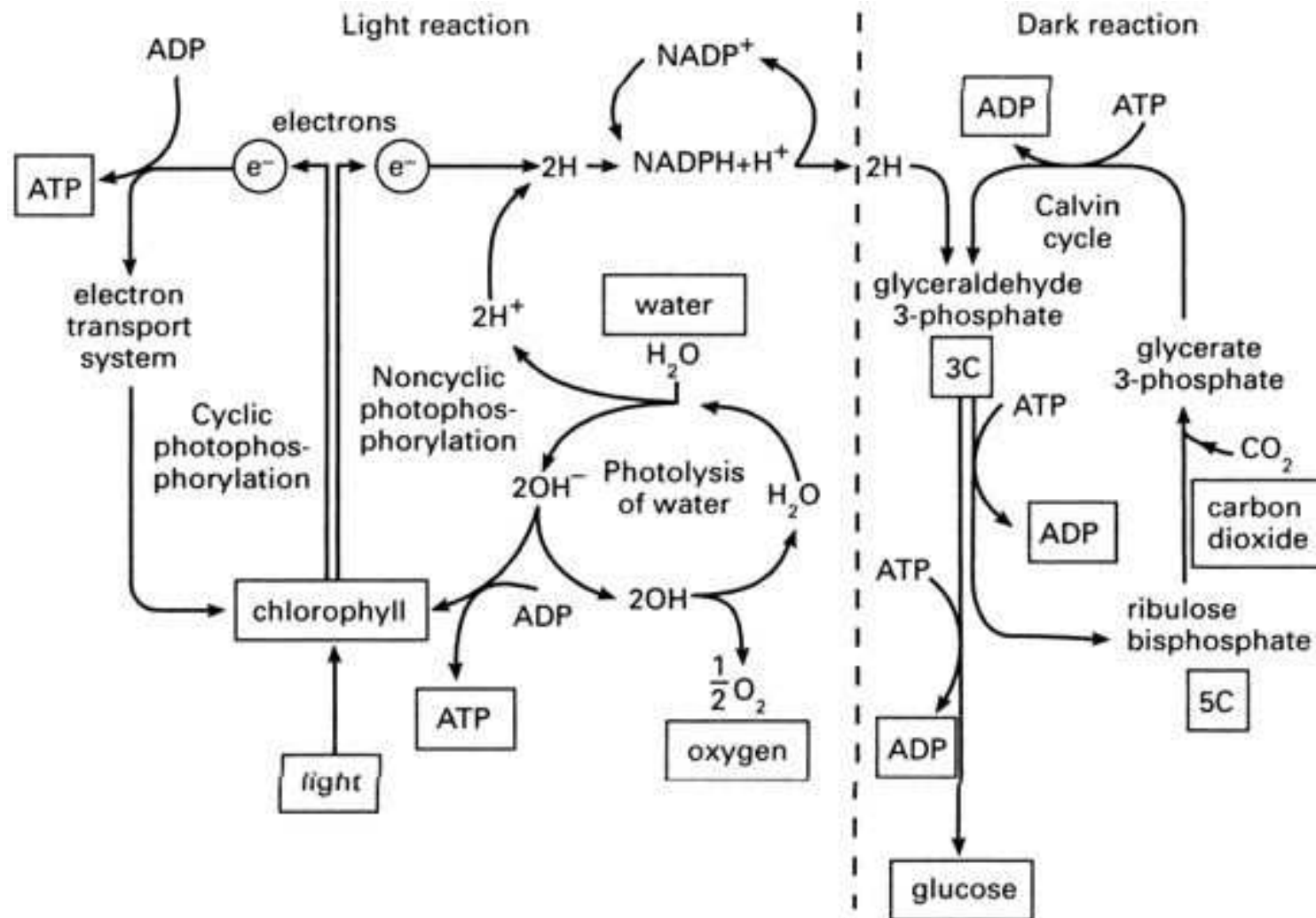
Kada je reducens voda



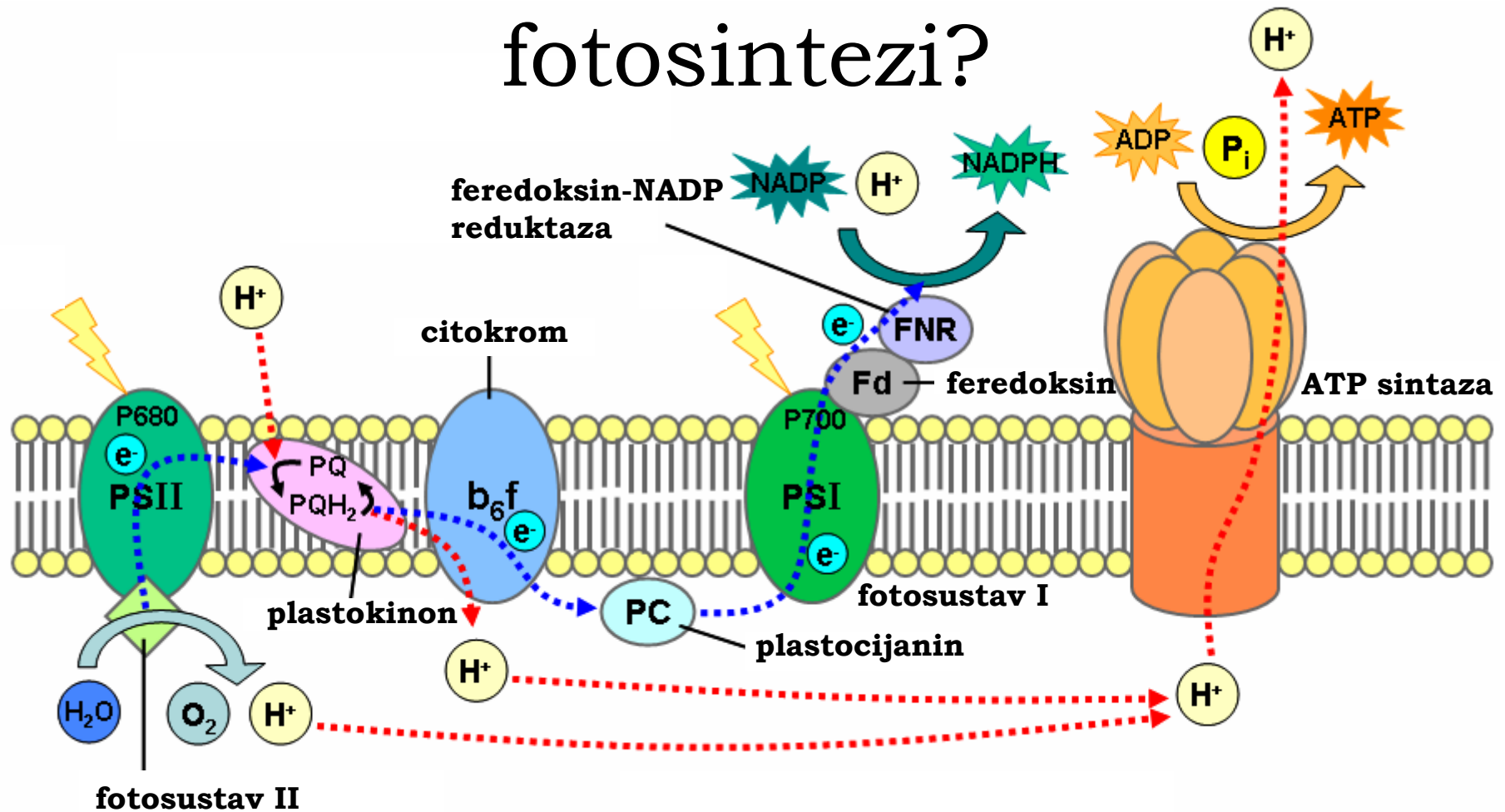
i kada nastaje fruktoza (glukoza)



O mehanizmu



Što točno radi svjetlost u fotosintezi?



Redukcija NADP^+ u NADPH

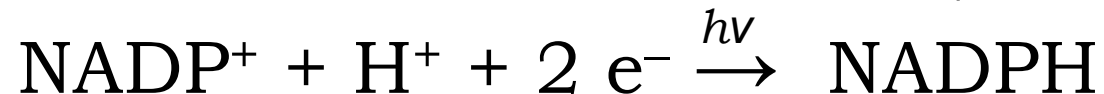
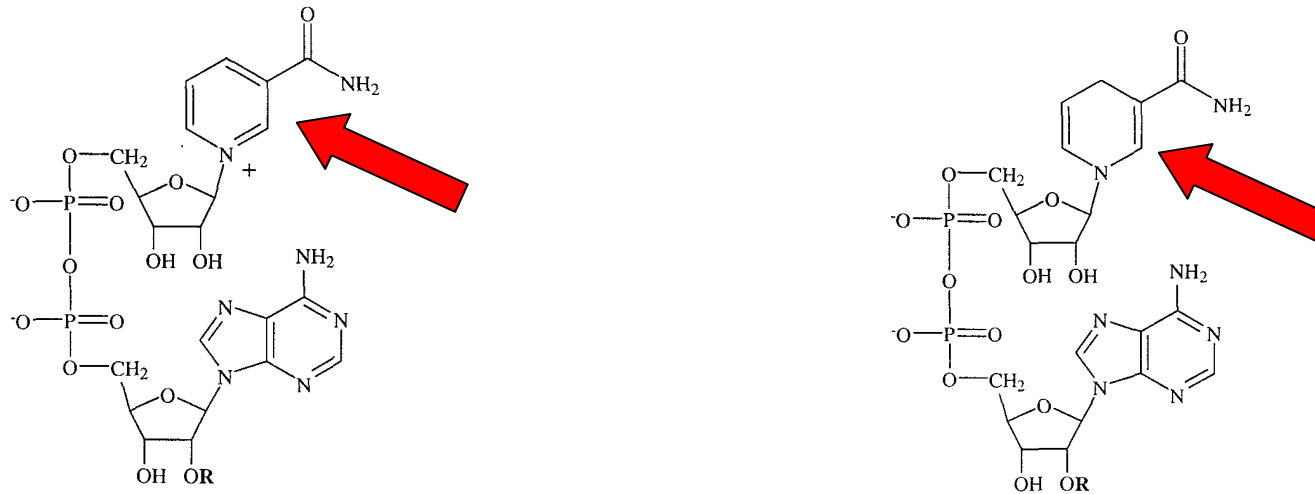
Fotoliza vode

Što točno radi svjetlost u fotosintezi?

Fotoliza (fotokemijska oksidacija) vode:

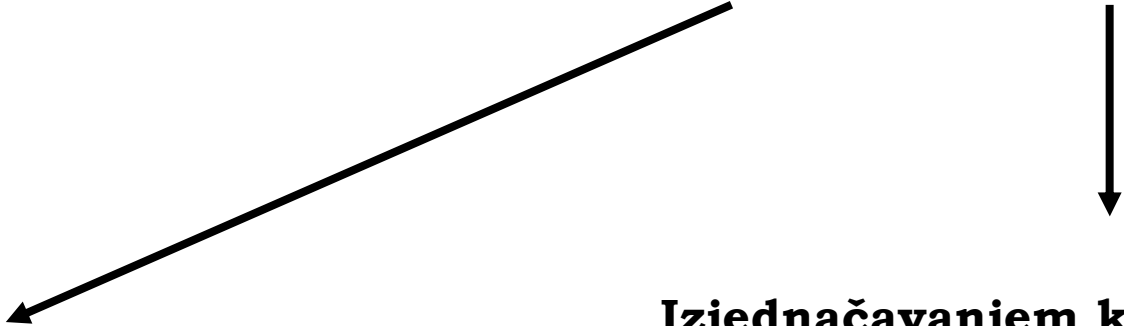
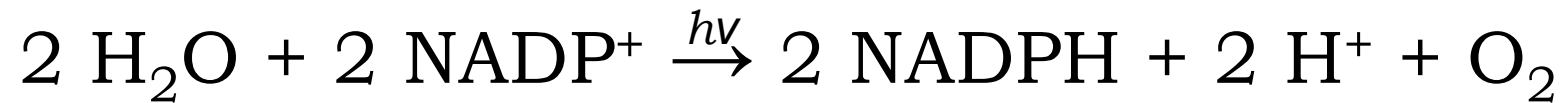


Sinteza NADPH (fotokemijska redukcija NADP^+)



Što točno radi svjetlost u fotosintezi?

Ukupna reakcija:

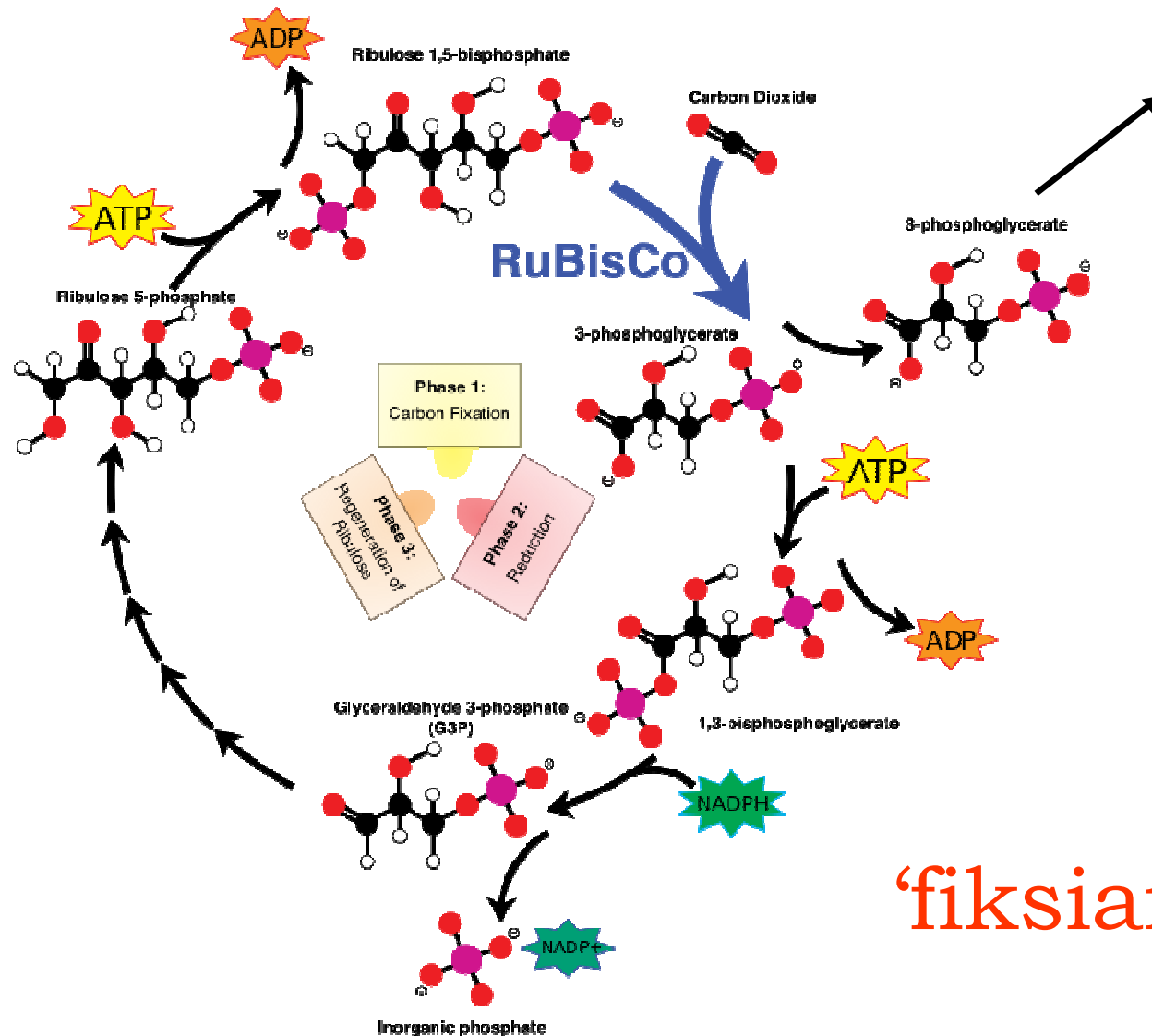


Reducens za CO_2 –
oksidira se nazad u
 NADP^+

Izjednačavanjem koncentracije H^+
unutar i izvan tilakoida dobija se
energija – ATP sintaza

Hidroliza ATP-a daje energiju za
redukciju CO_2

Dalje do šećera – Calvinov ciklus

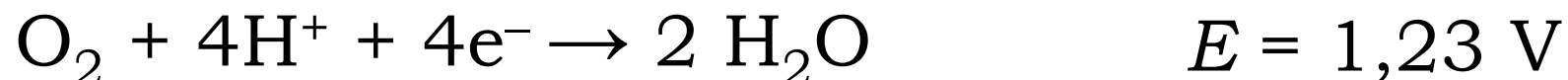


2 molekule 3-fosfogliceraldehida spajaju se u molekulu fruktoze

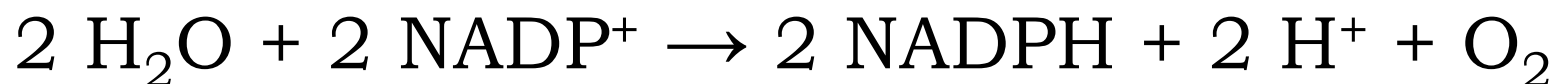
‘fiksiranje ugljika’

Što bi bilo bez svjetla?

Redukcijski potencijali:

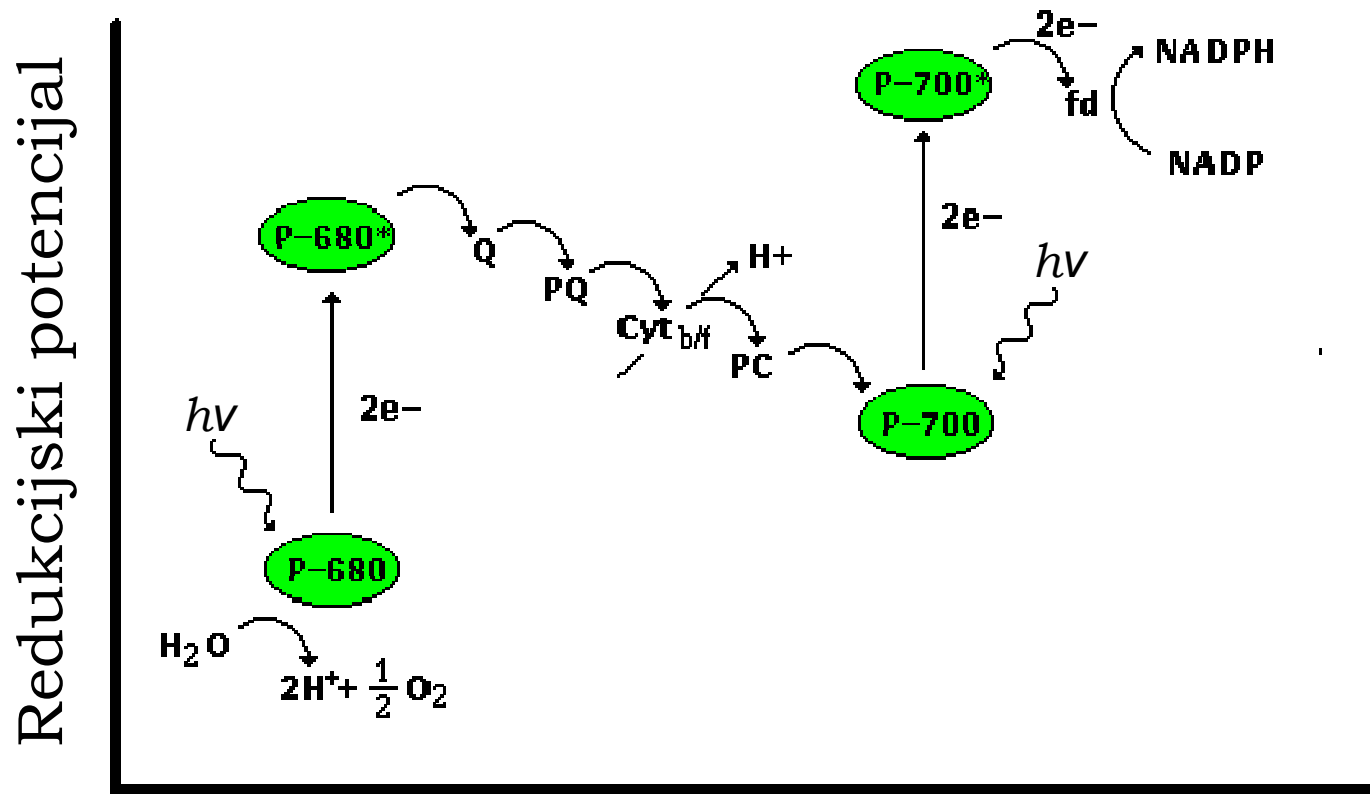


Dakle za



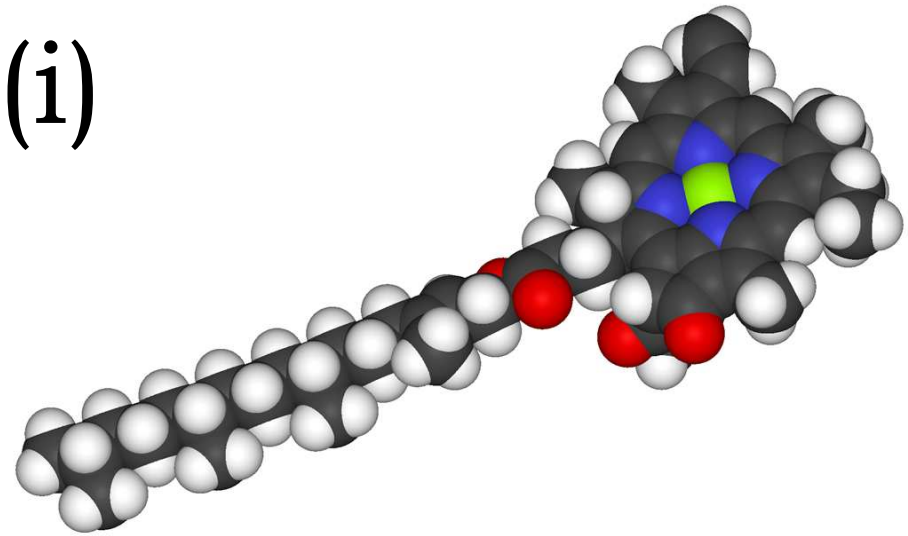
$\Delta_r G = -zFE_{\text{mf}} = + 722 \text{ kJ mol}^{-1} \rightarrow$ reakcija **nije**
spontana!

Kisik bi morao oksidirati NADPH!

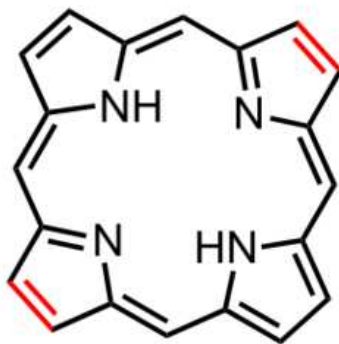


Molekula u pobuđenom stanju lakše otpušta elektrone od one u osnovnom → pobuđena molekula je jači reducens od nepobuđene

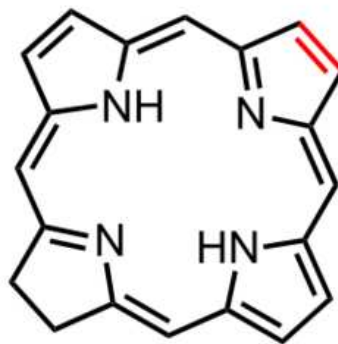
Klorofil(i)



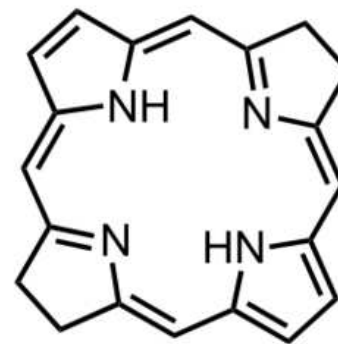
- Zeleni pigmenti
- Magnezijevi kompleksi supstituiranih klorinskih (ili porfirinskih) prstenova



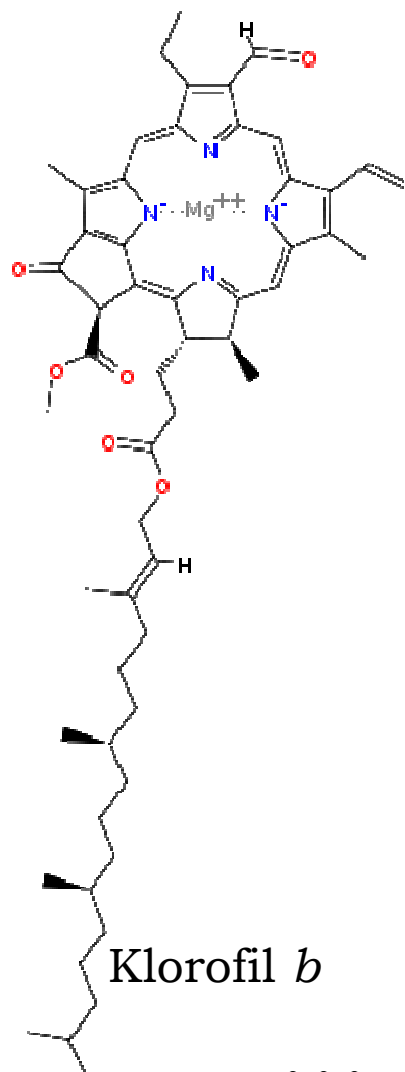
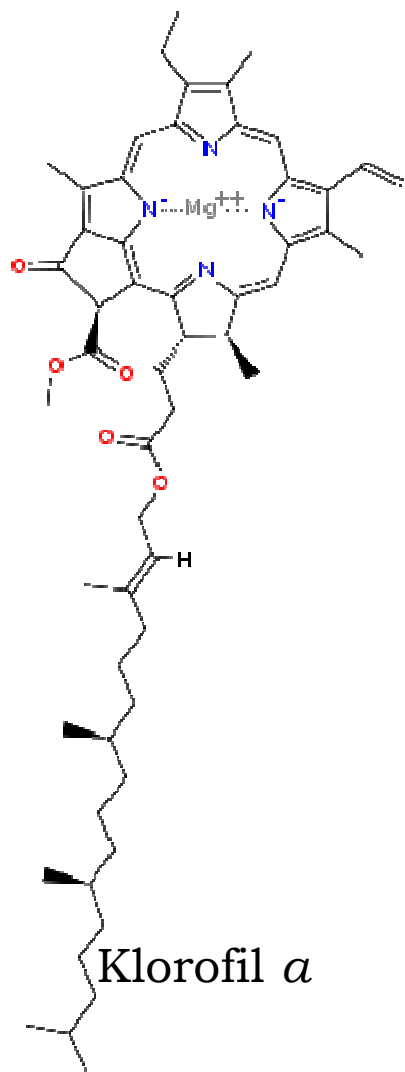
porfirin



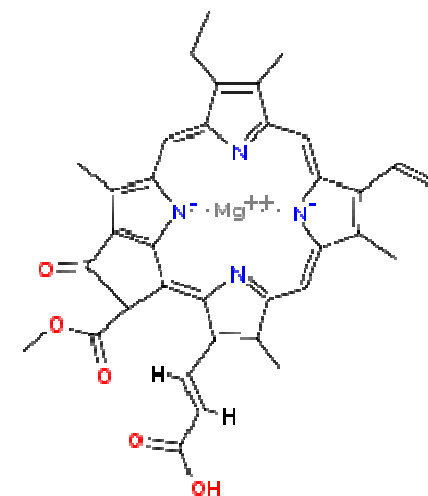
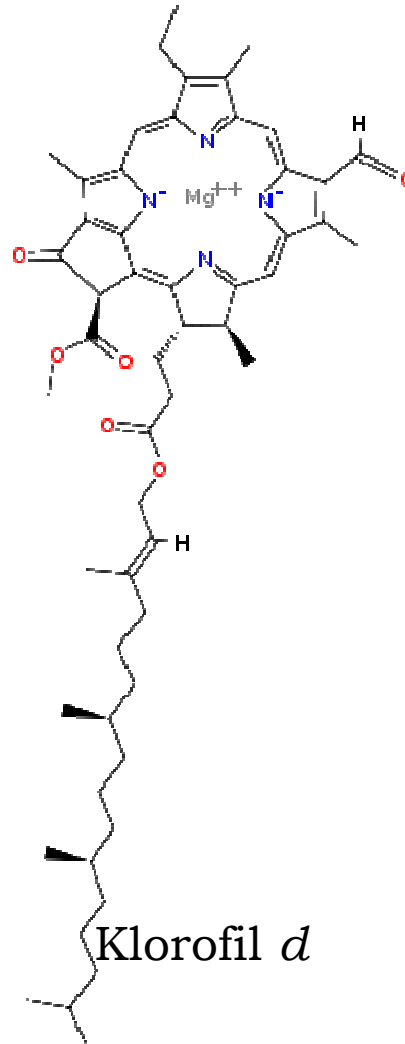
klorin



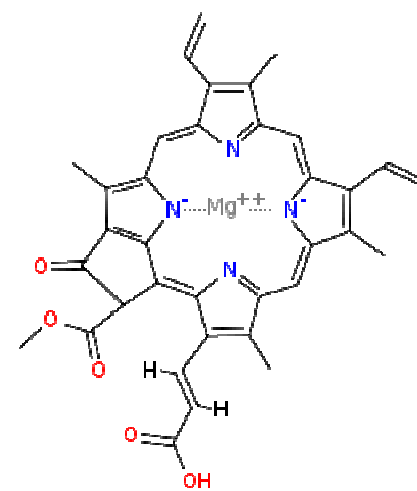
bakterioklorin



...



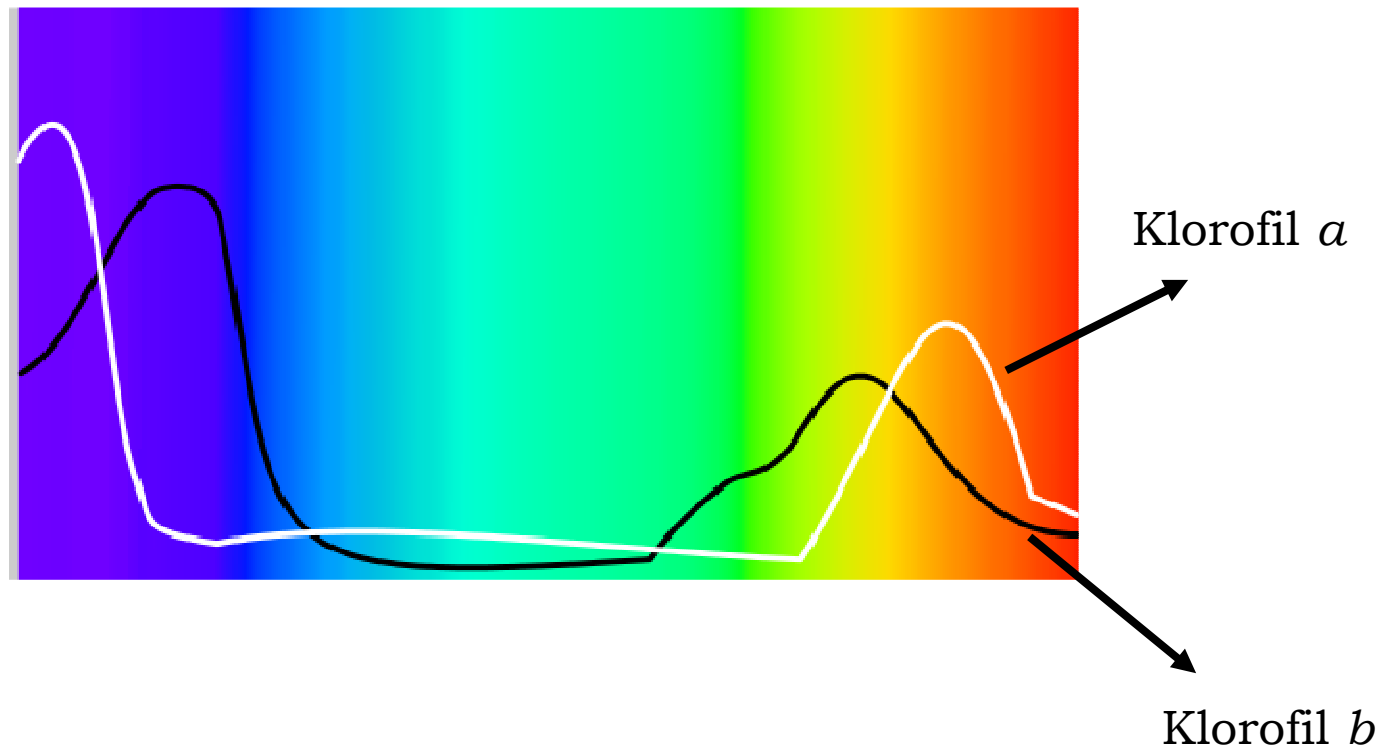
Klorofil *c1*



Klorofil *c2*

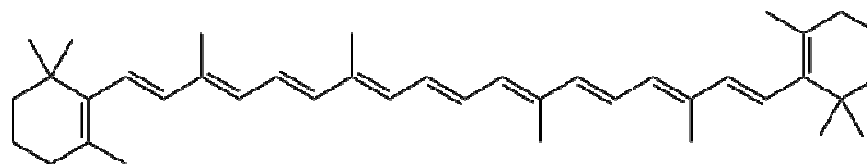
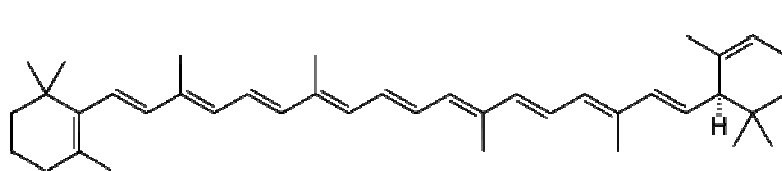
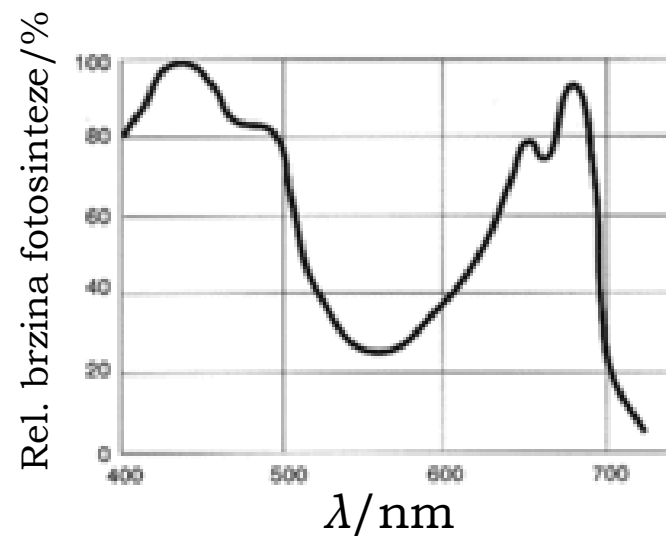
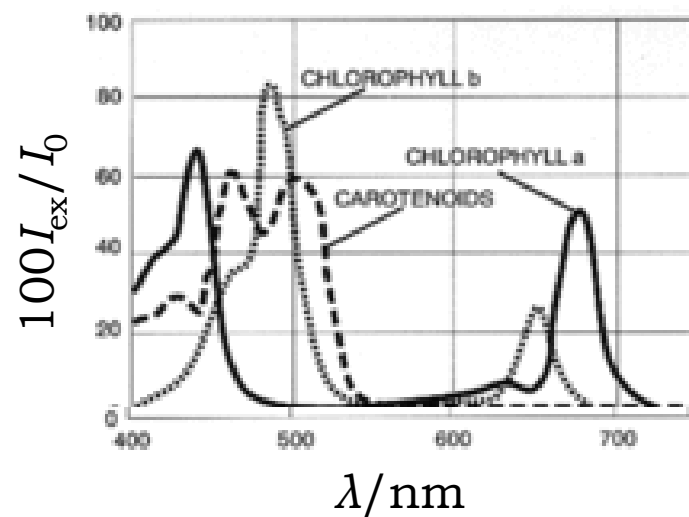
Zeleni pigment

- Boja klorofila posljedica apsorpcije zračenja



Fotosintetski aktivno zračenje

Dio spektra koji apsorbiraju klorofili (zeleni) i karotenoidi (crveni/narančasti)



Što je s ostatkom spektra?



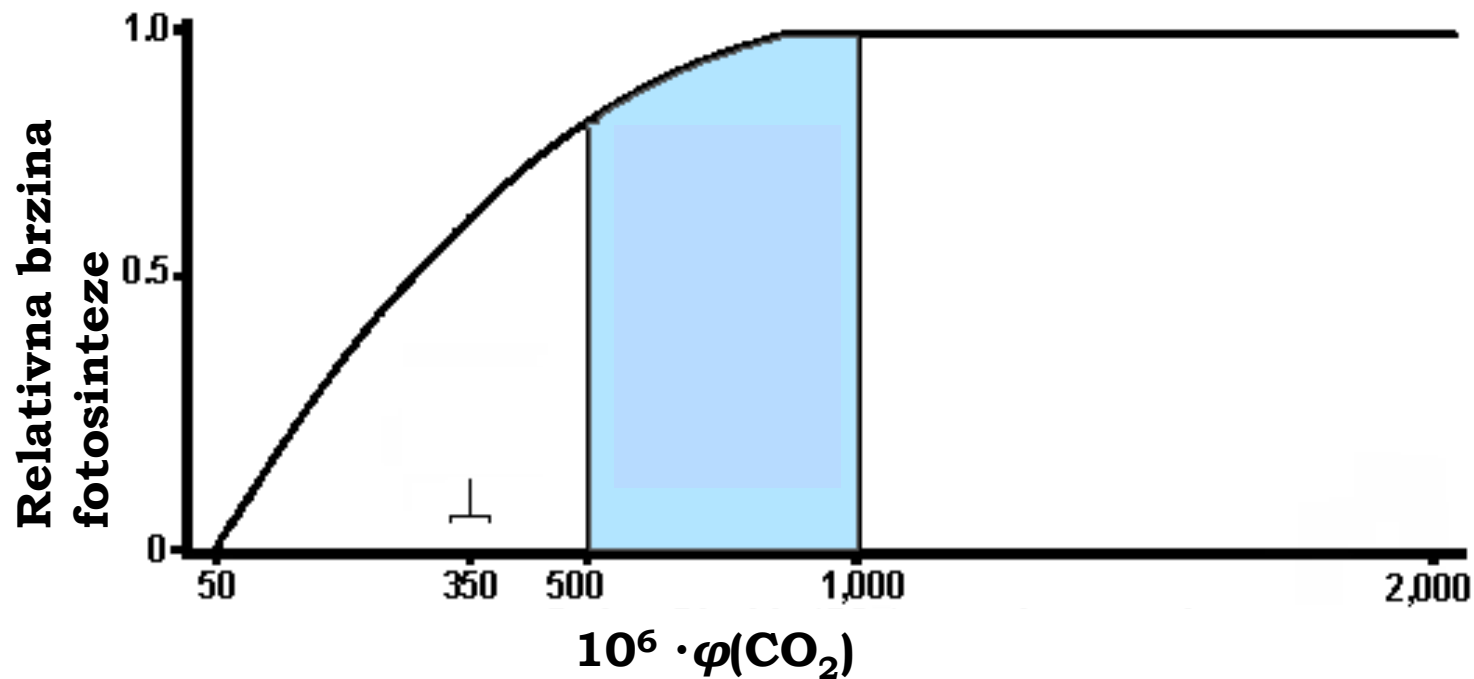
Brzina fotosinteze

Pojedini koraci:

Prijenos energije na klorofilu	$10^{-15} \text{ s} - 10^{-12} \text{ s}$
Prijenos elektrona i fotokemijske reakcije	$10^{-12} \text{ s} - 10^{-9} \text{ s}$
Sinteza ATP	$10^{-6} \text{ s} - 10^{-3} \text{ s}$
Fiksiranje ugljika i sinteza stabilnih produkata	$10^{-3} \text{ s} - 1 \text{ s}$

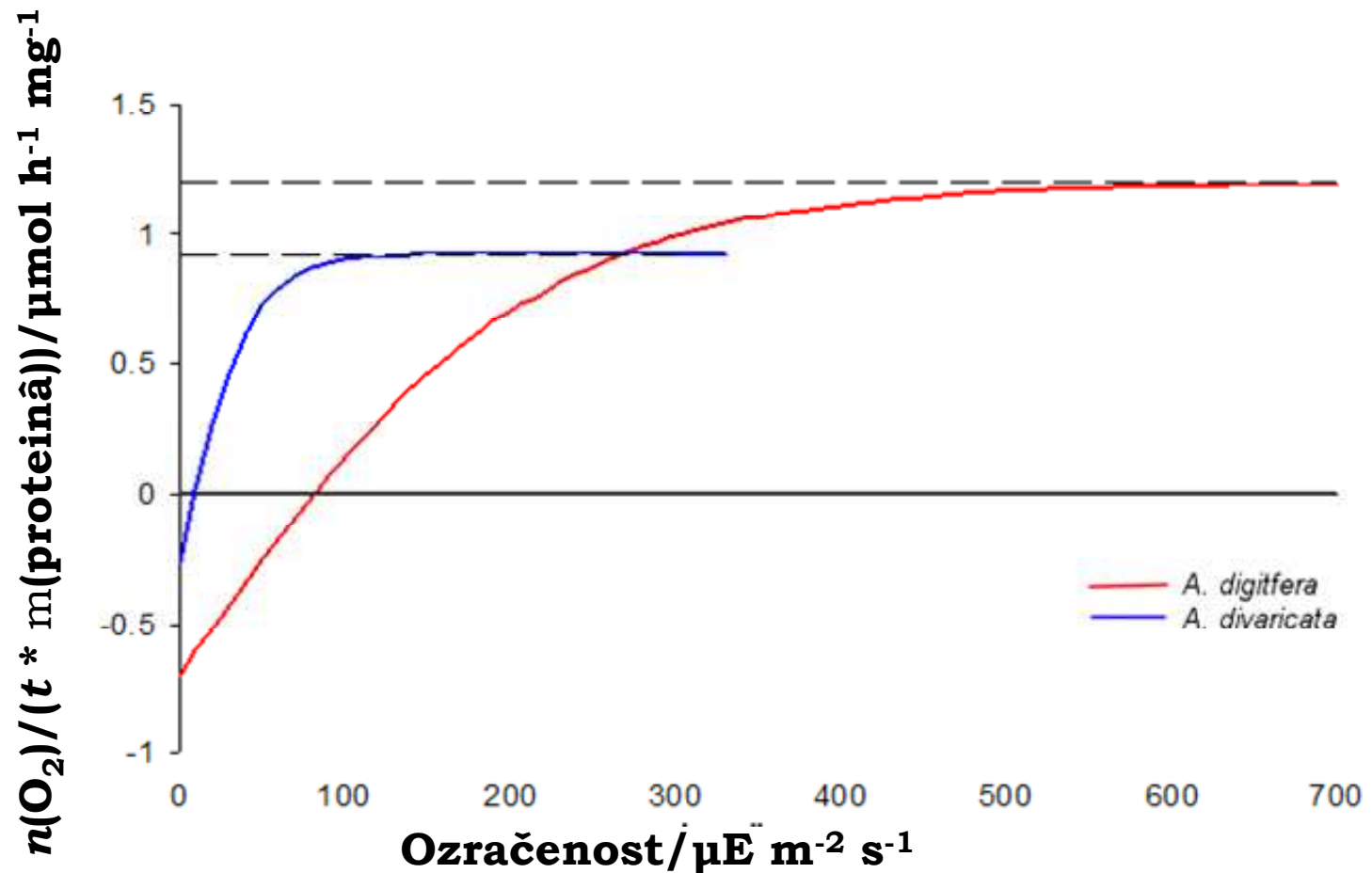
Na ukupnu brzinu utječe

- Parcijalni tlak ugljikova dioksida



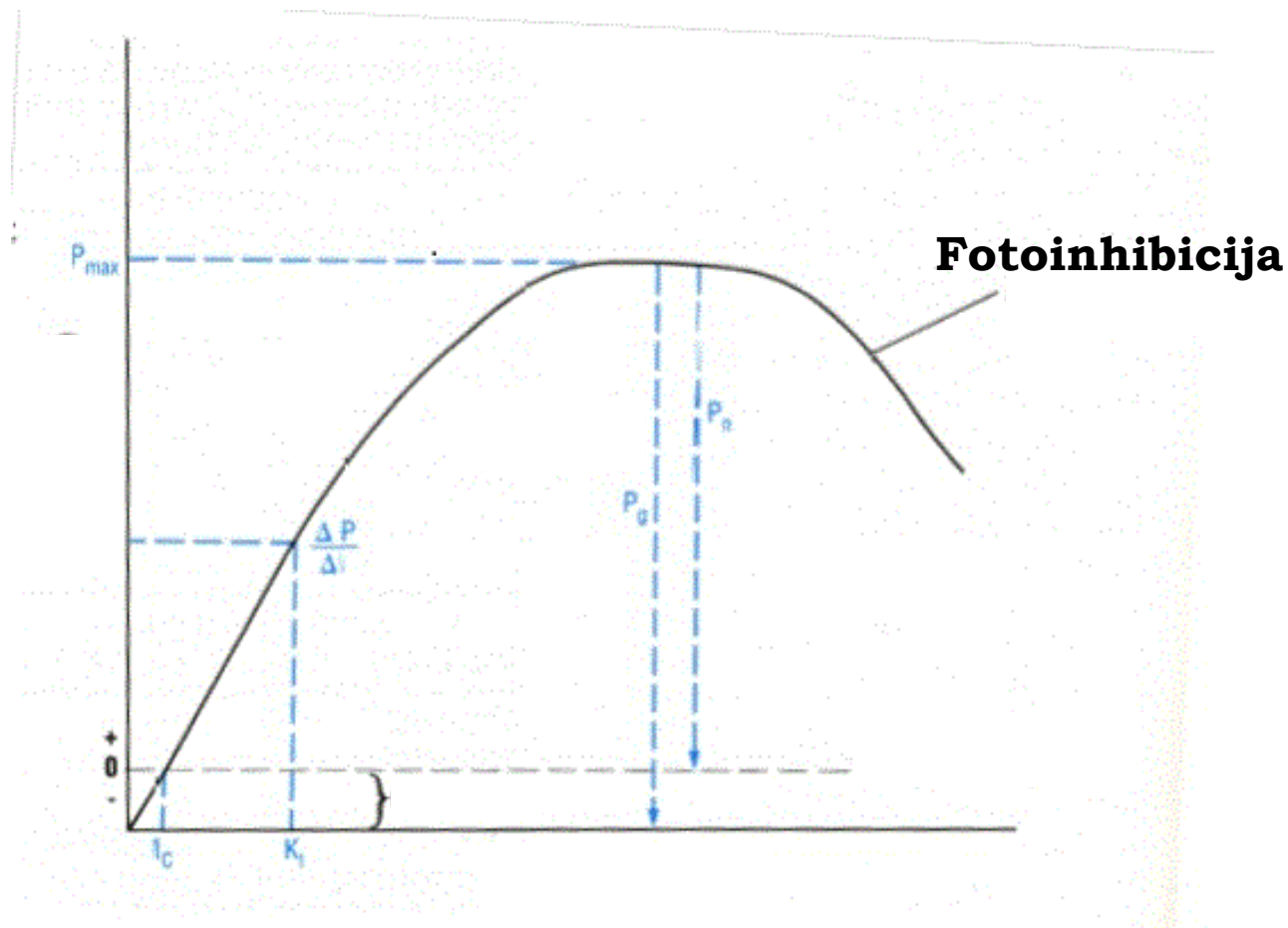
Na ukupnu brzinu utječe

- Intenzitet svjetlosti



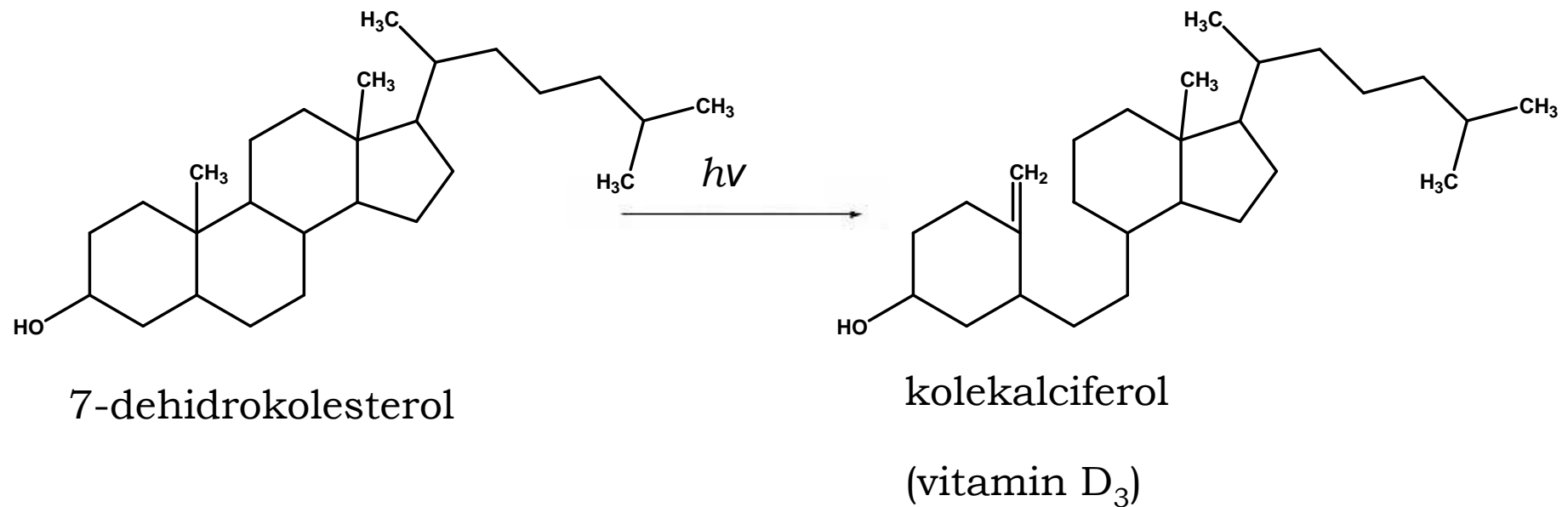
Fotoinhibicija

- Pri jakim intenzitetima brzina opada

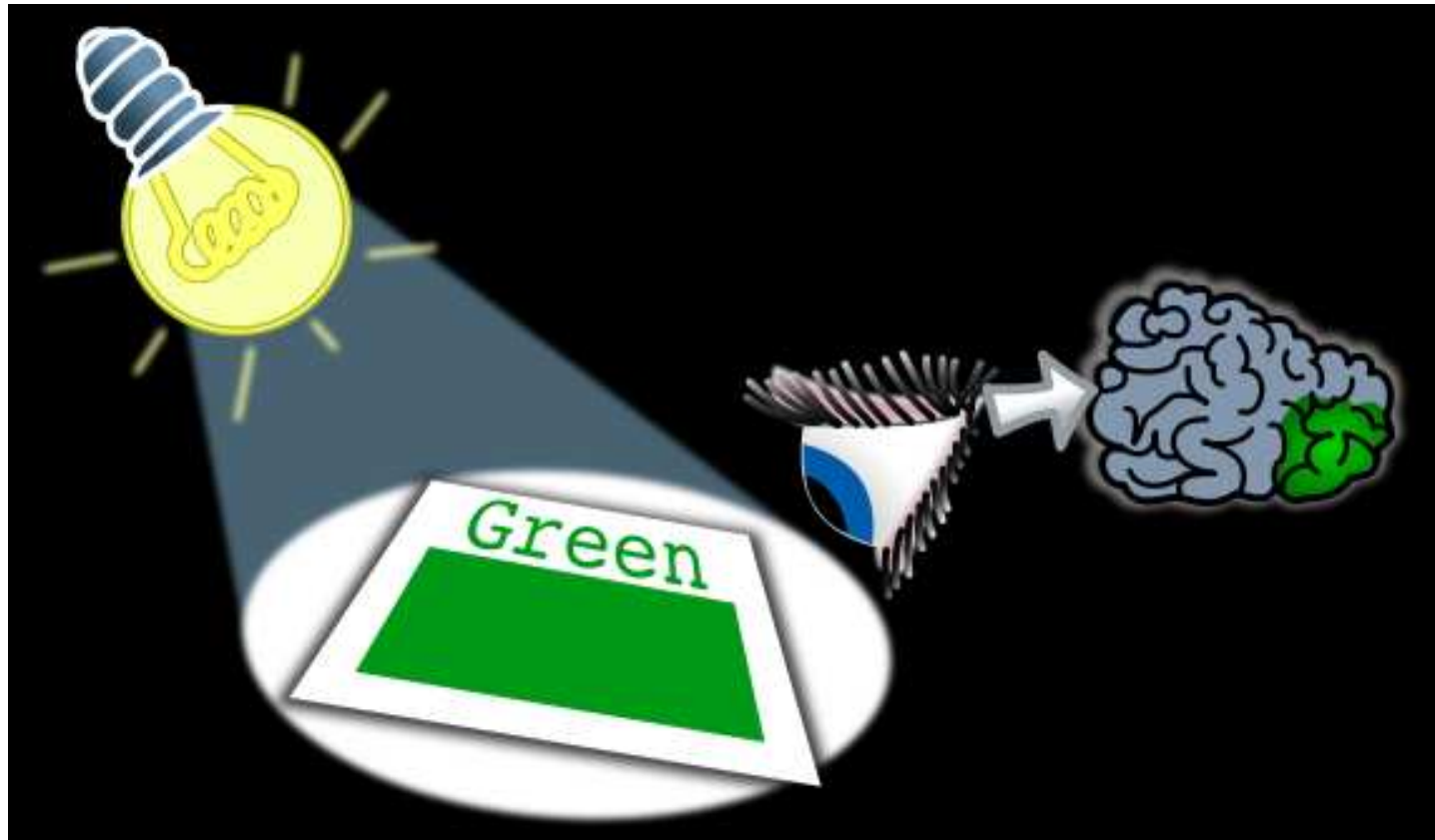


Možemo li i mi fotosintetizirati?

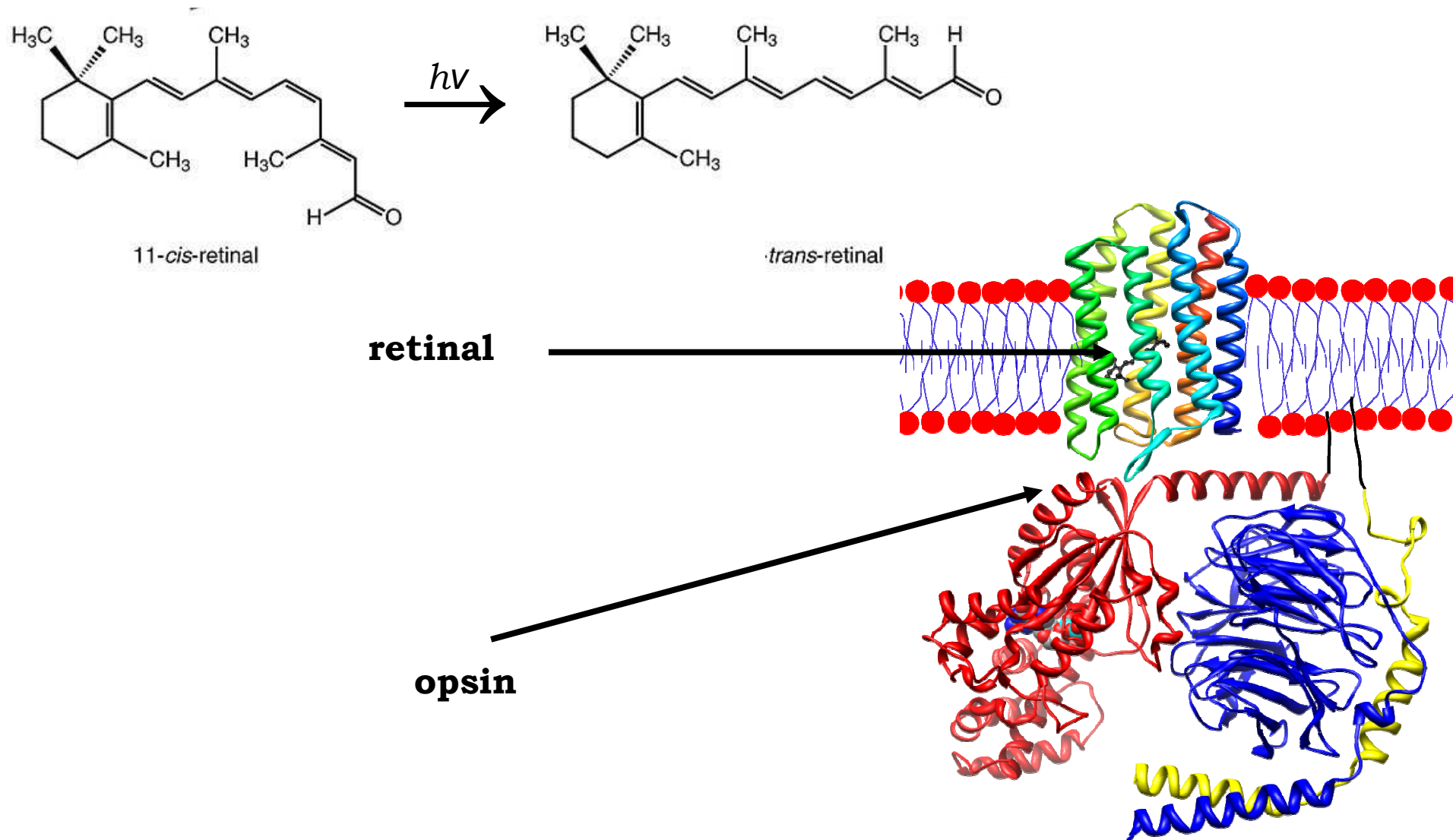
- Da – ali ne šećere!

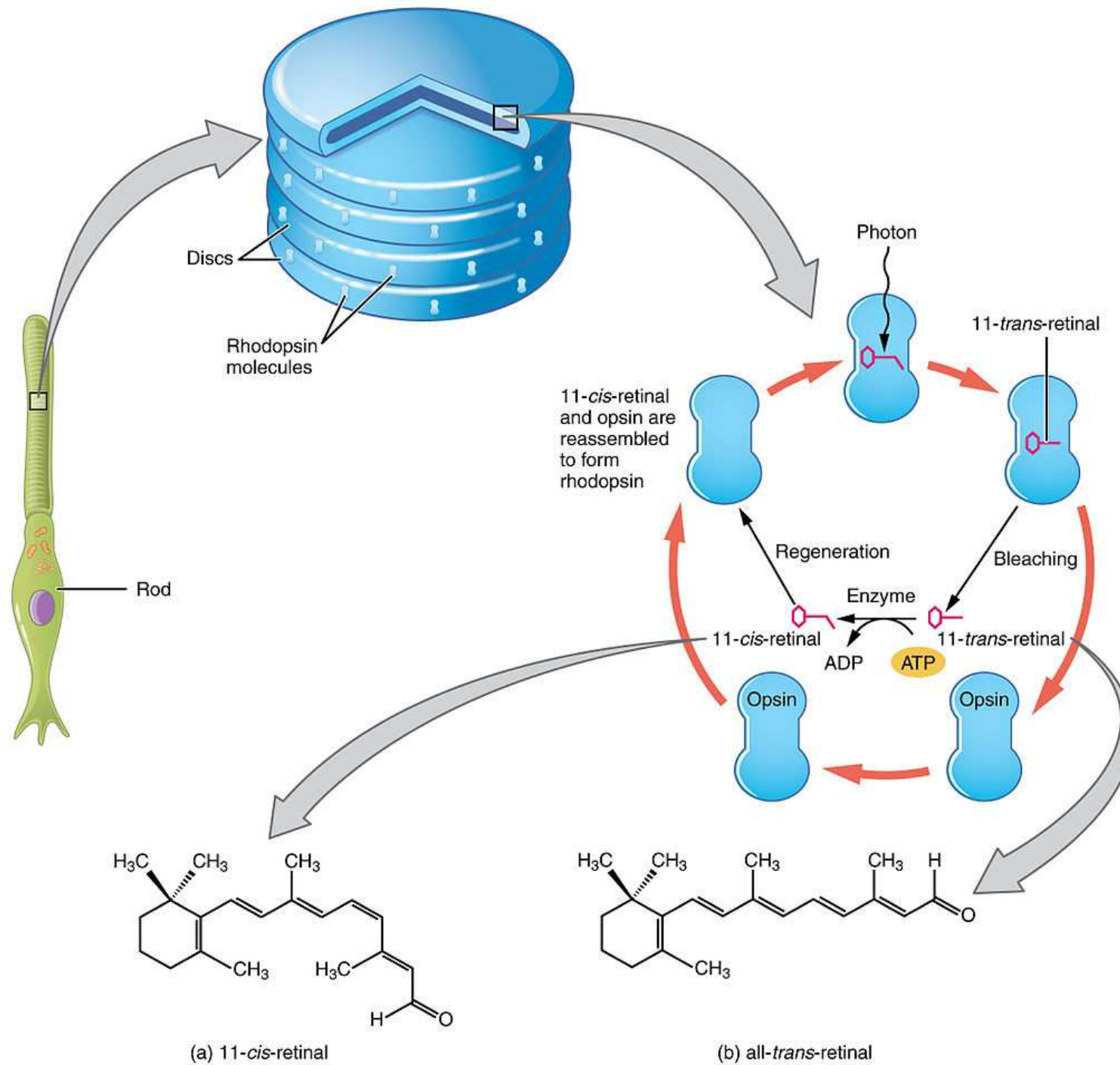


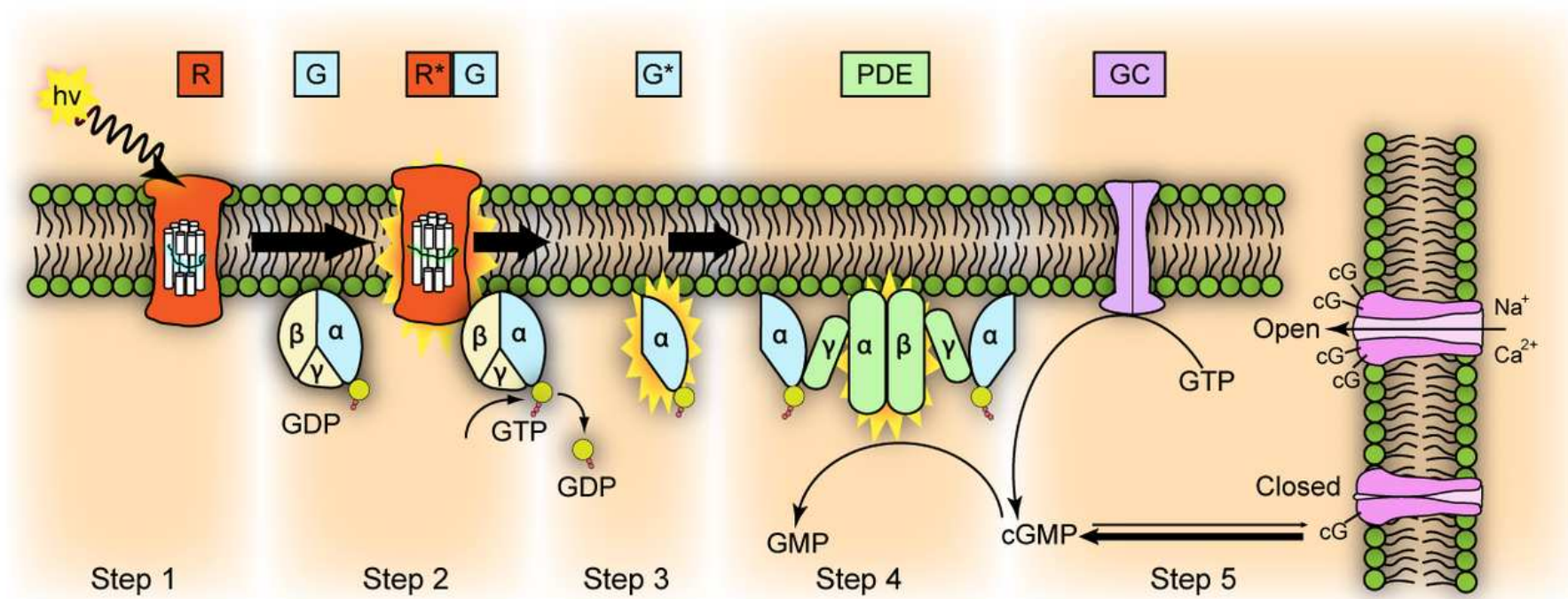
Slično ali različito – fotokemija vida



Fotoizomerizacija retinala

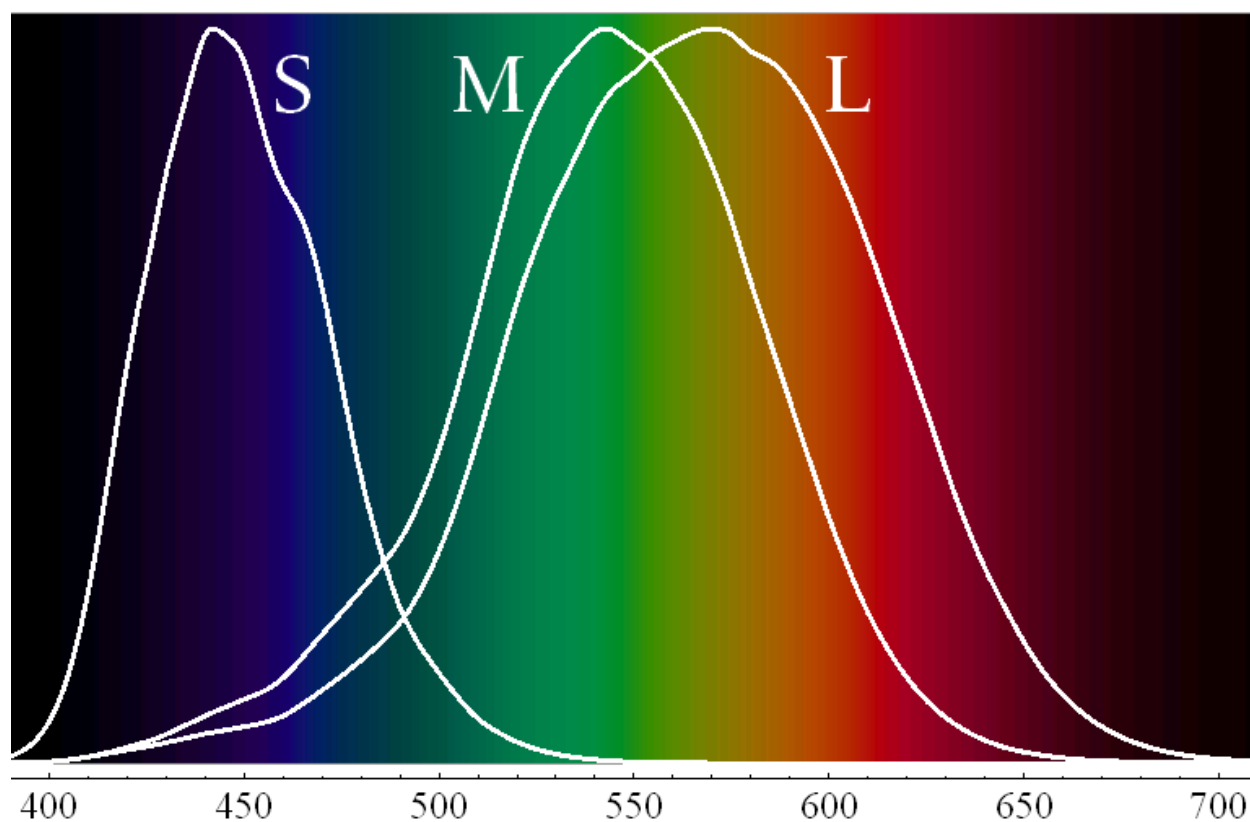


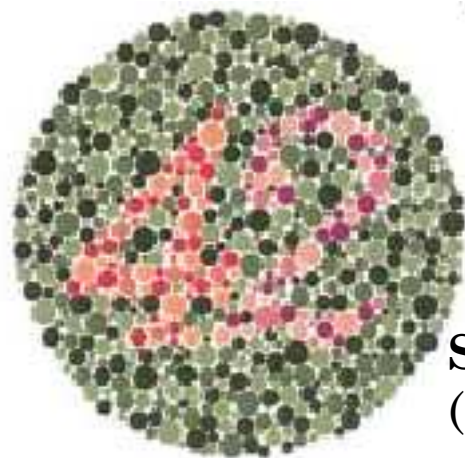
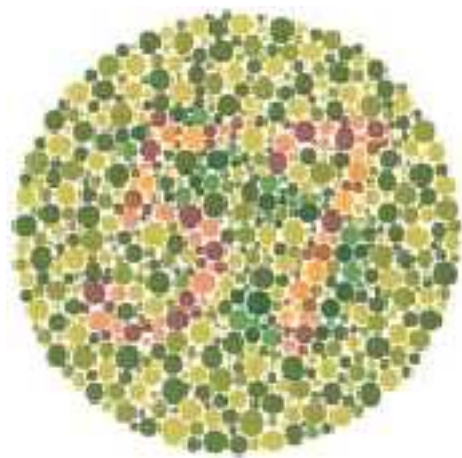




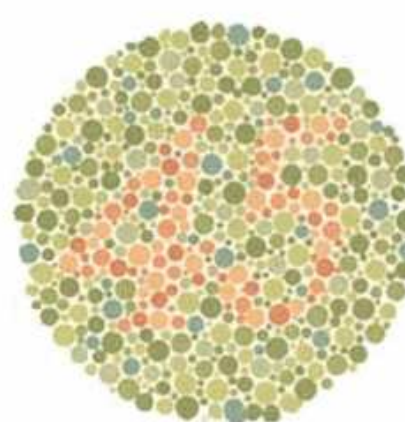
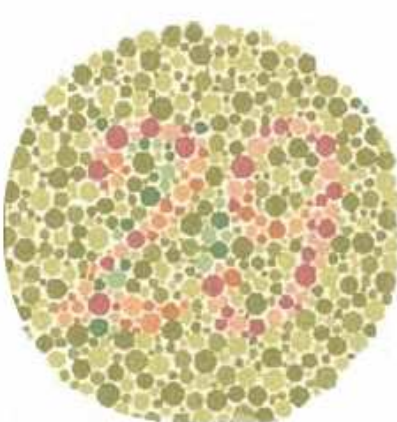
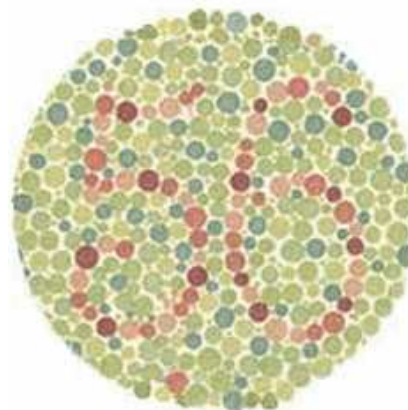
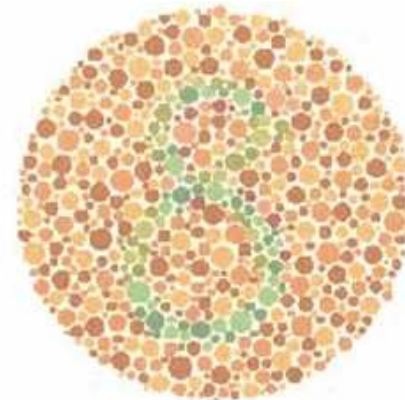
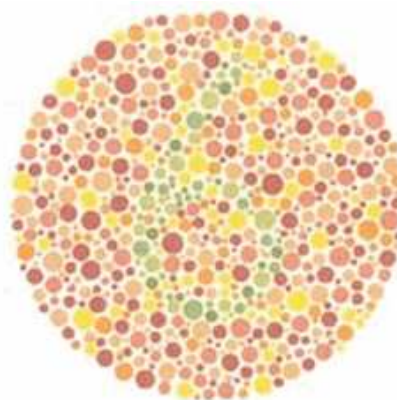
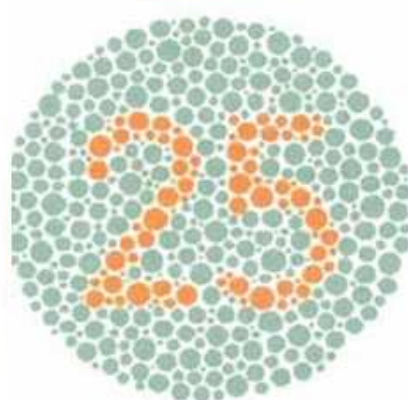
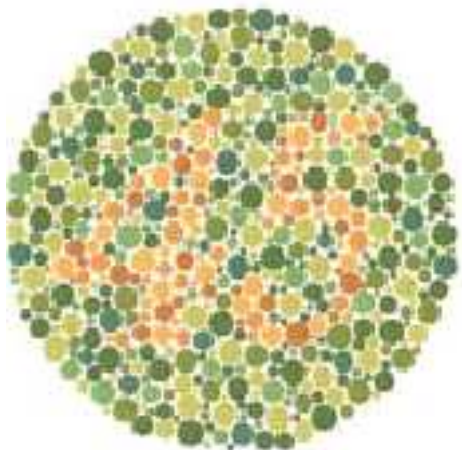
Zašto vidimo boje?

- Različiti opsini – apsorpcijski spektar retinala ovisan o okolini





Shinobu Ishihara
(1879.-1963.)





THE AMERICAN FLAG AS SEEN

- I.- BY MOST PEOPLE.
- II.- BY RED-BLIND PERSONS.
- III.- BY GREEN-BLIND PERSONS.
- IV.- BY VIOLET-BLIND PERSONS.
- V.- BY TOTALLY COLOR-BLIND PERSONS.

Slično, različito i onda opet slično



Slana jezera u okolici San Francisca (California, USA)

Fotosinteza u halofilnih arhea temeljena na retinalu namjesto na klorofilu!

Hipoteza Purpurne Zemlje – prije razvoja klorofila, Zemlja je bila crveno-ljubičasta zbog prisutstva ranih fotosintetskih vrsta

Još fotokemije – fotografija

- Klasična fotografija – fotoliza srebrovih halogenida



(X = Cl, Br)



Nicéphore Niépce, *Pogled kroz prozor na Le Gras*, 1826.

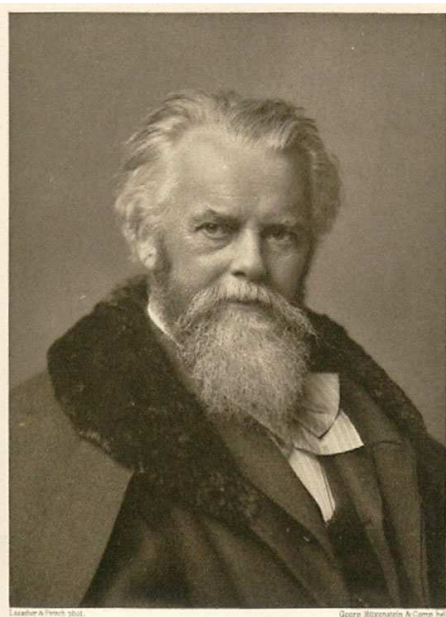


Ljudi u crnom –

Srebrovi halogenidi
neosjetljivi na crveno,
narančasto, žuto i
zeleno

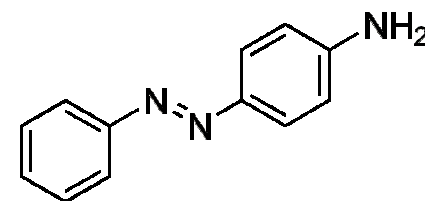
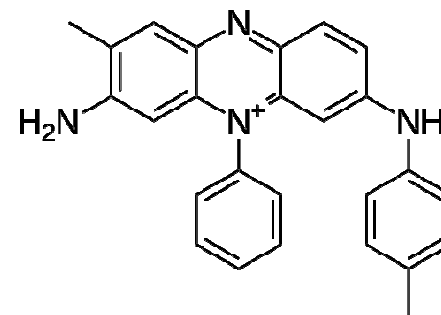
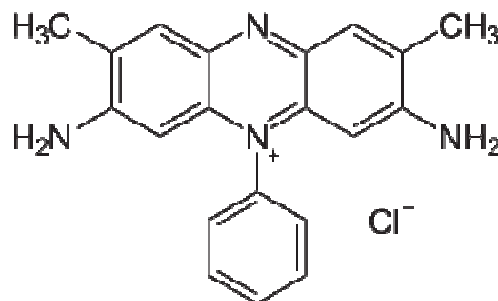


Osjetljivost filma



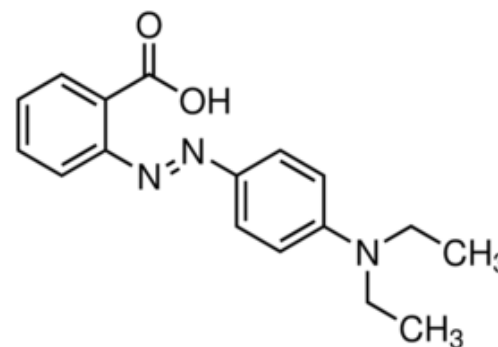
Hermann Wilhelm Vogel
(1834.–1898.)

1873. Anilinske boje



Adolf Miethe
(1862.–1927.)

1901. Etilno crvenilo





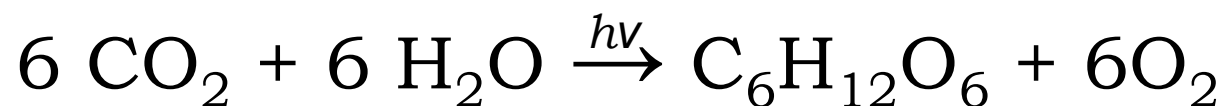
William Saunders, *Kineski glumci*, 1870-ih



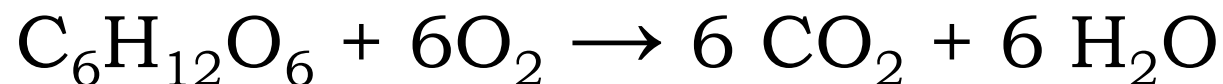
Sergej Mihajlovič Prokudin-Gorski, *Autoportret*, 1912.

Završne kontemplacije

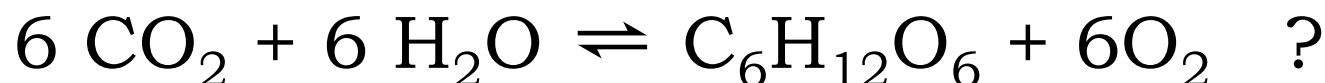
Fotosintezom iz ugljikova(IV) oksida i vode nastaju šećer i kisik



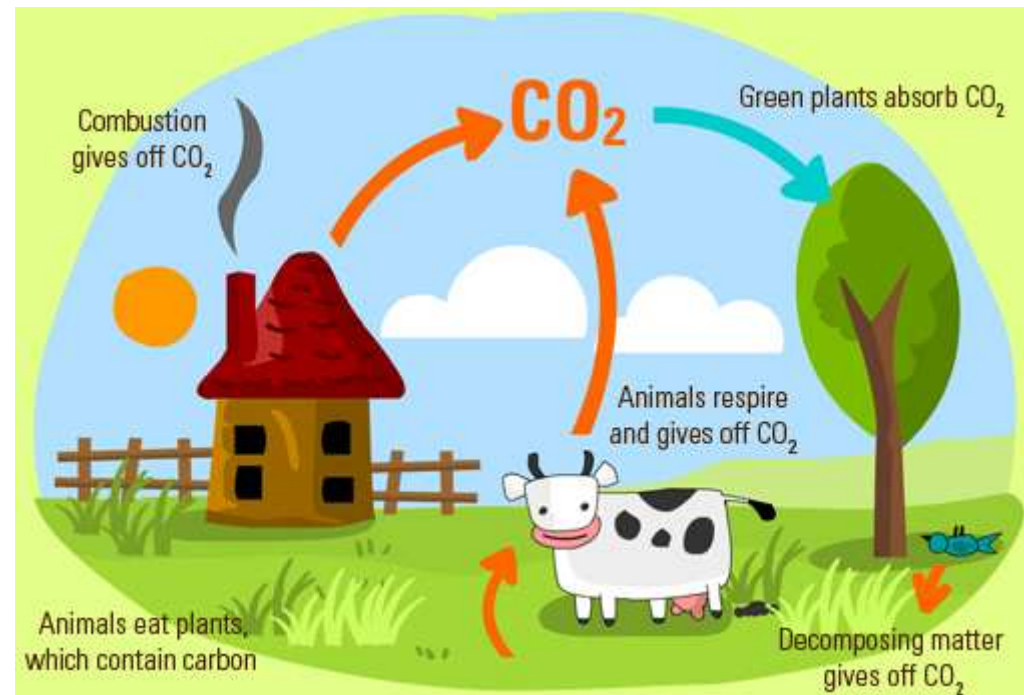
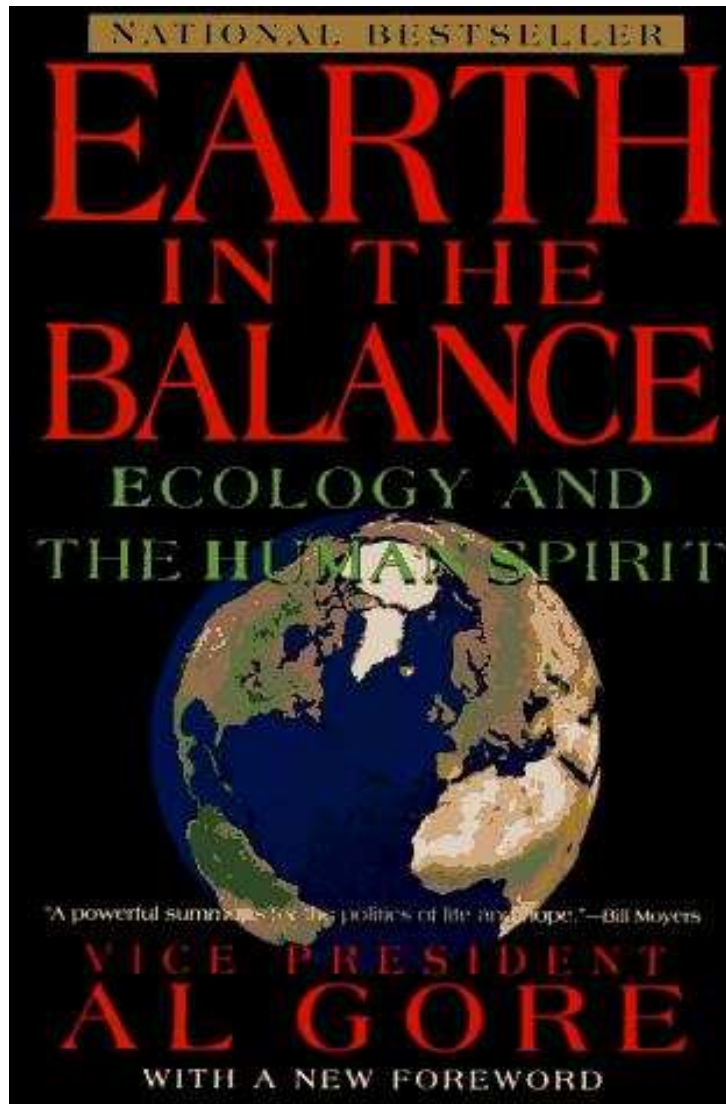
(Staničnim) disanjem reakcijom šećera i kisika nastaju ugljikov(IV) oksid i voda



Vrijedi li dakle



Je li Zemlja u ravnoteži?



Je li vjetrenjača u ravnoteži?

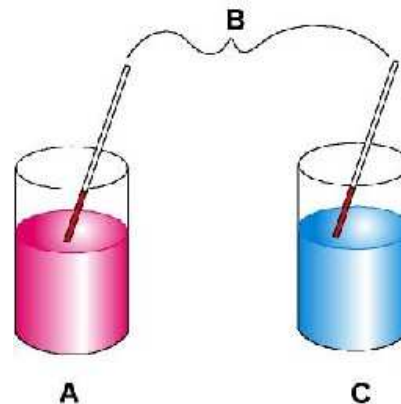


Ravnoteža

- Stanje sustava u kojemu su svi suprotni utjecaji izjednačeni
- Stanje sustava u kojemu ne dolazi do promjene nikoje varijable koja definira dotično stanje



Mehanička ravnoteža



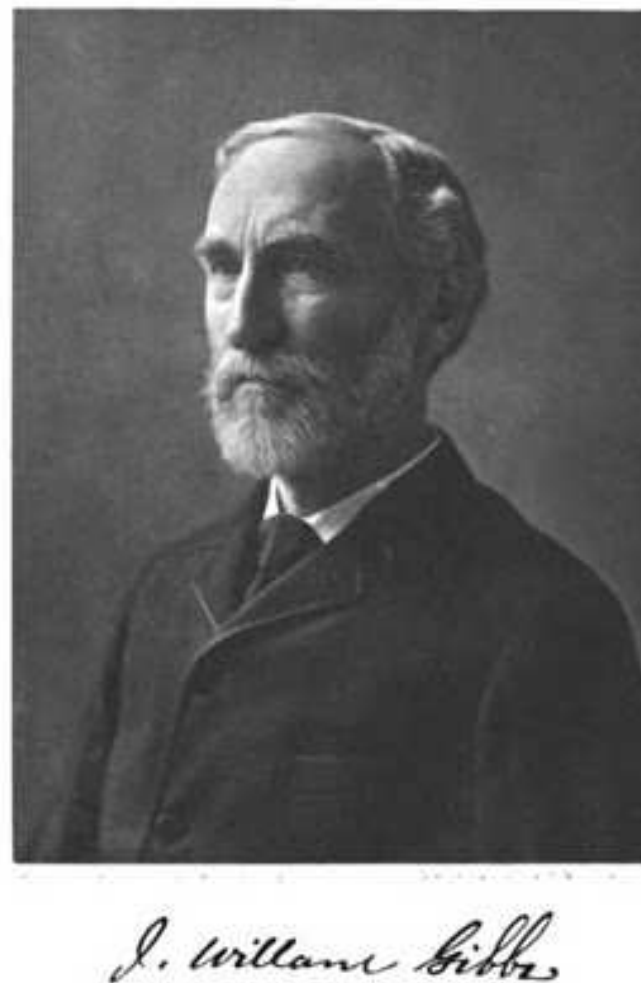
Termička ravnoteža



Jacobus Henricus van't Hoff (1852. – 1911.)

Kemijska ravnoteža je dinamička

U ravnotežnom stanju kemijska reakcija se i dalje odvija, ali je ukupna promjena koncentracija reaktanata i produkata jednaka nuli.



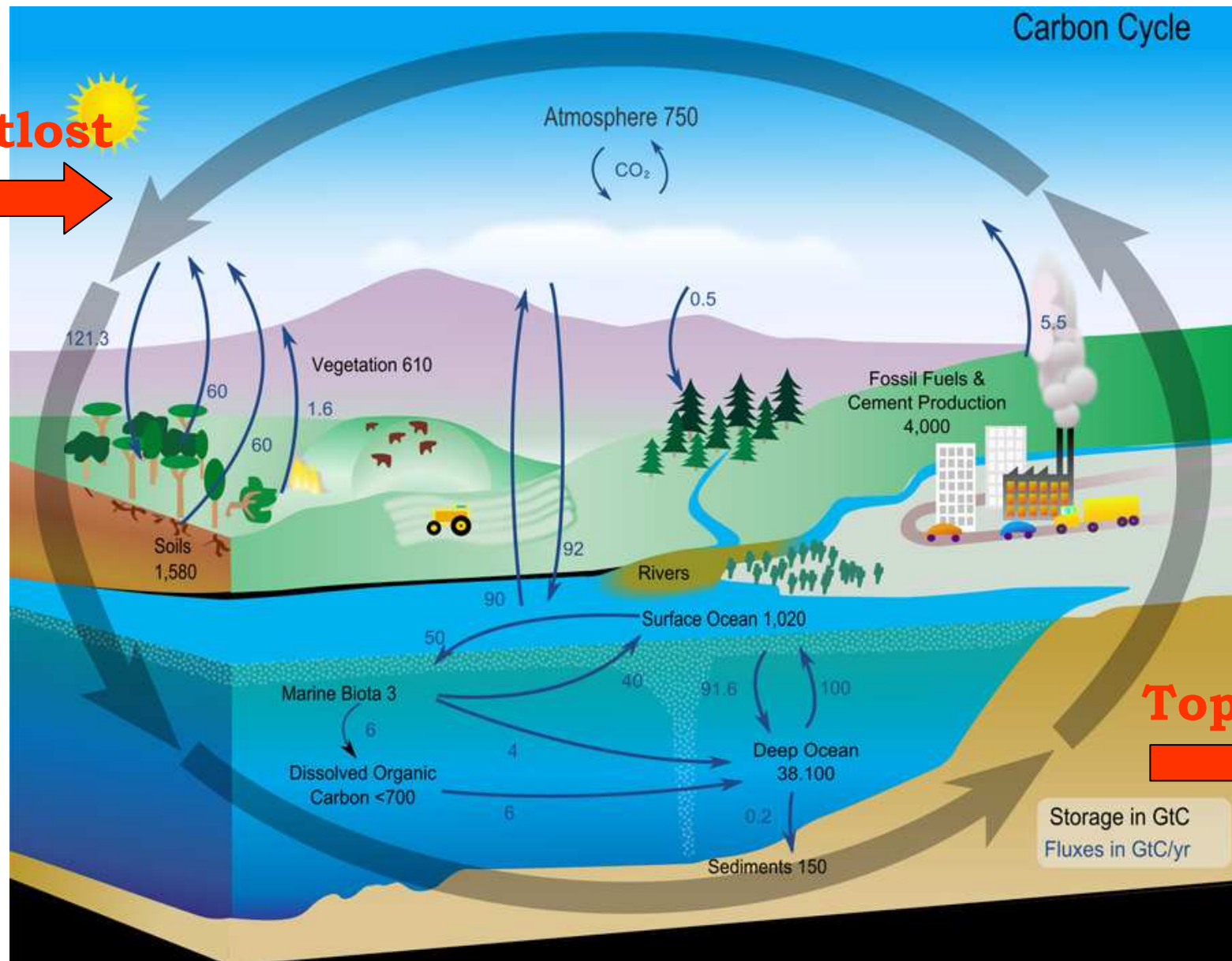
Josiah Willard Gibbs (1839. – 1903.)

Kemijska ravnoteža je stanje minimalne slobodne energije

Kemijska ravnoteža je termodinamička pojava.

Carbon Cycle

Svjetlost



Toplina



Namjesto zaključka

Više šuma = više kisika

