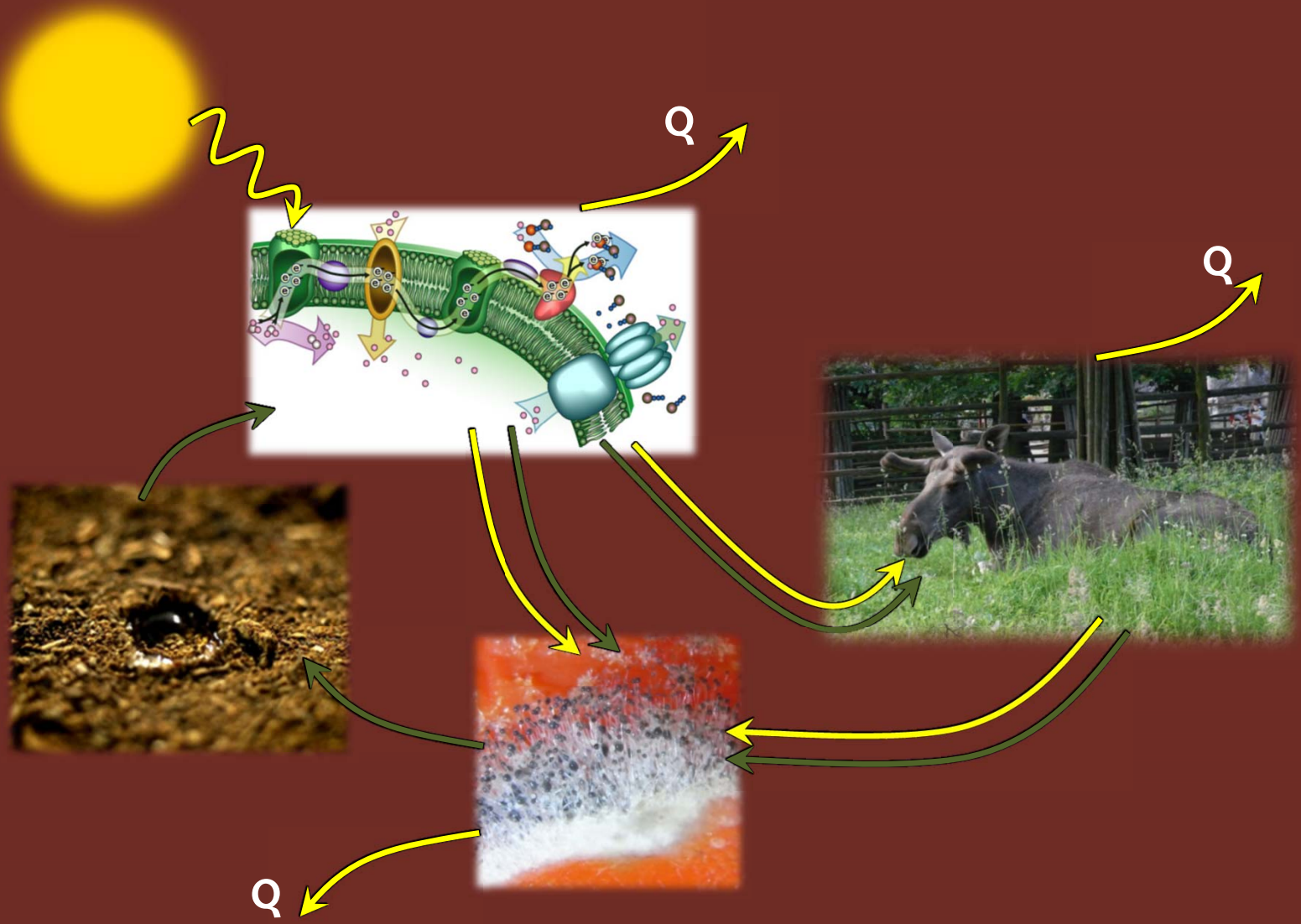
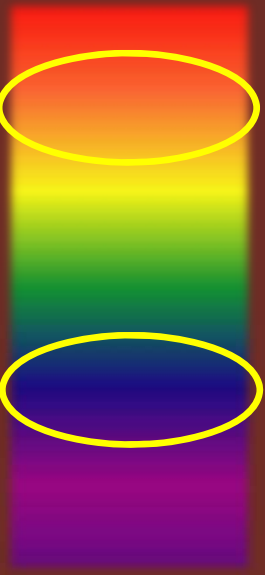
Protok energije kroz ekosustav



Kako smo (na)učili o fotosintezi?

1648 van Helmont

1771 Priestley



Engelmann 1883

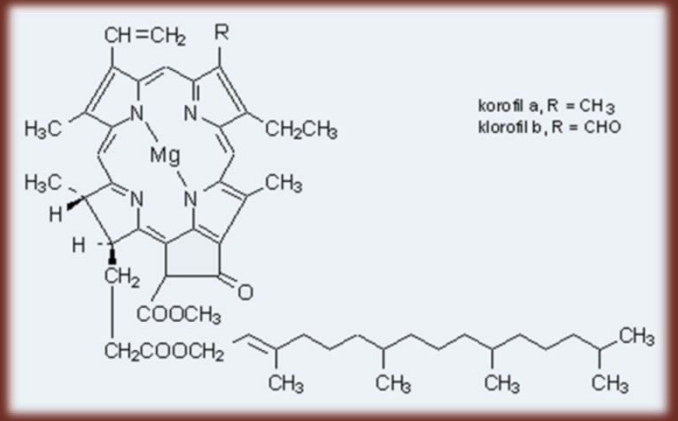
Primarna proizvodnja zasnovana na E sunčeve svjetlosti

Osnova?

Pigmenti!

Osnovni pigmenti:

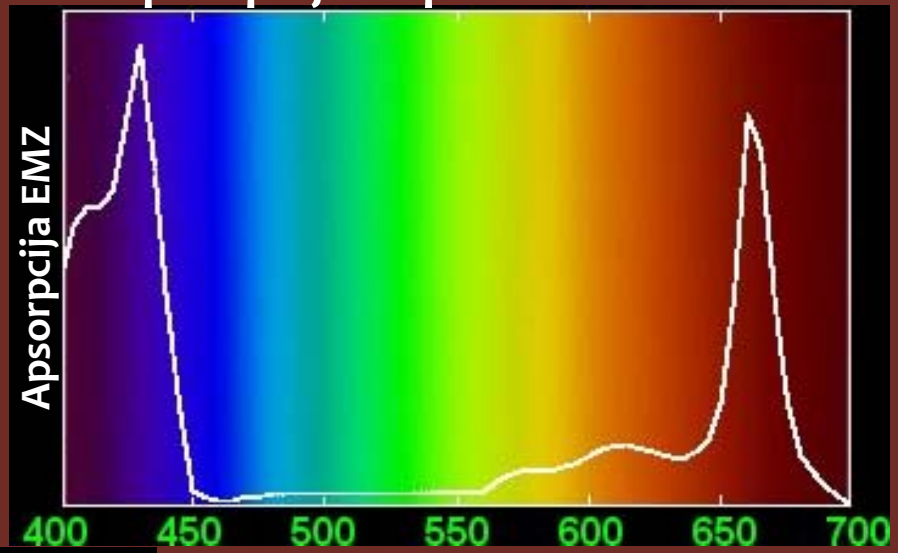
Klorofil *a* $C_{55}H_{72}O_5N_4Mg$
430 i 662 nm;
samo
prokarioti ga nemaju

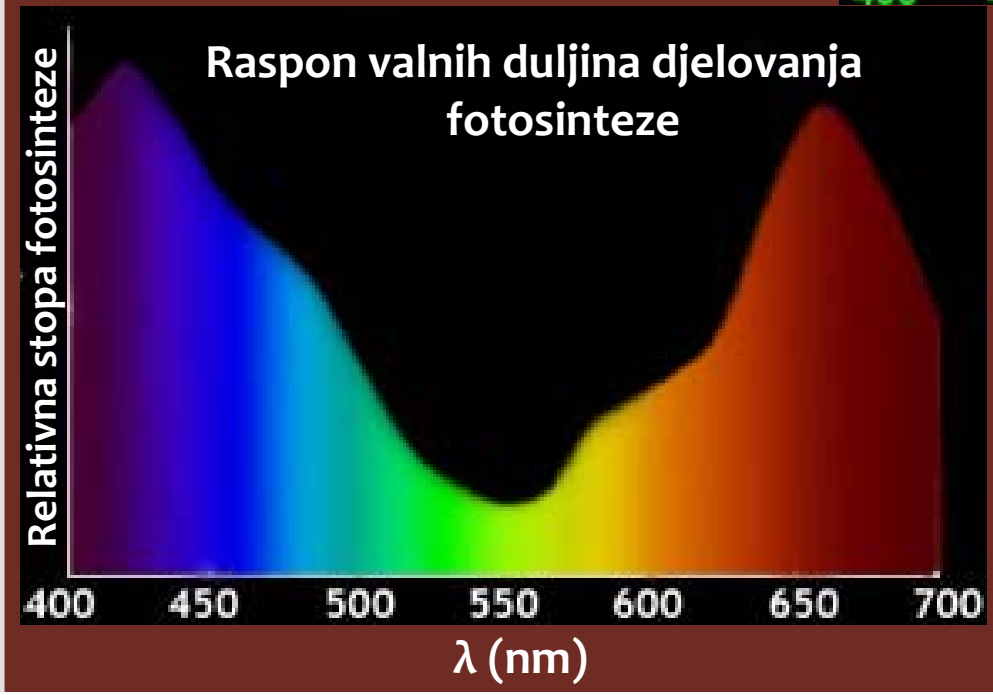


Klorofil *b* $C_{55}H_{70}O_6N_4Mg$
453 i 642 nm;
biljke, zelene alge i
neki prokarioti

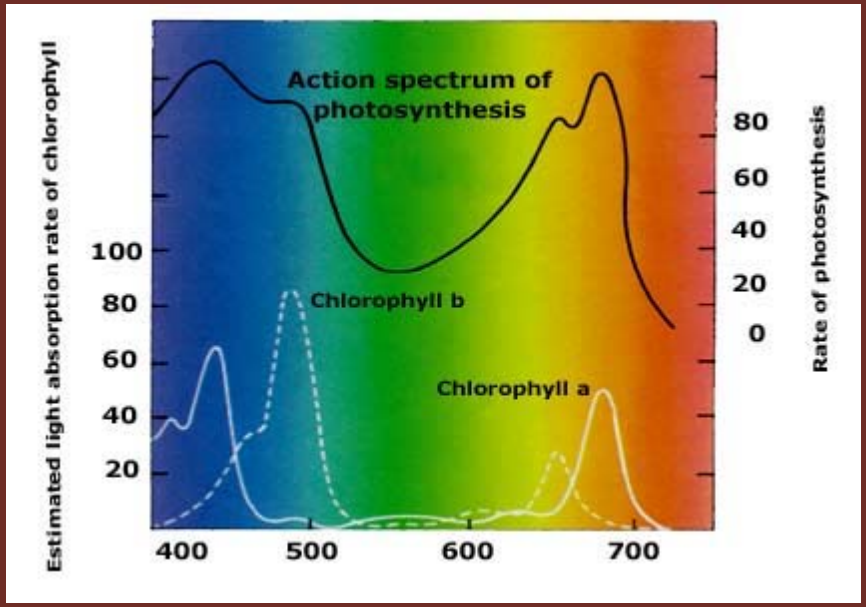
VIS i fotosinteza

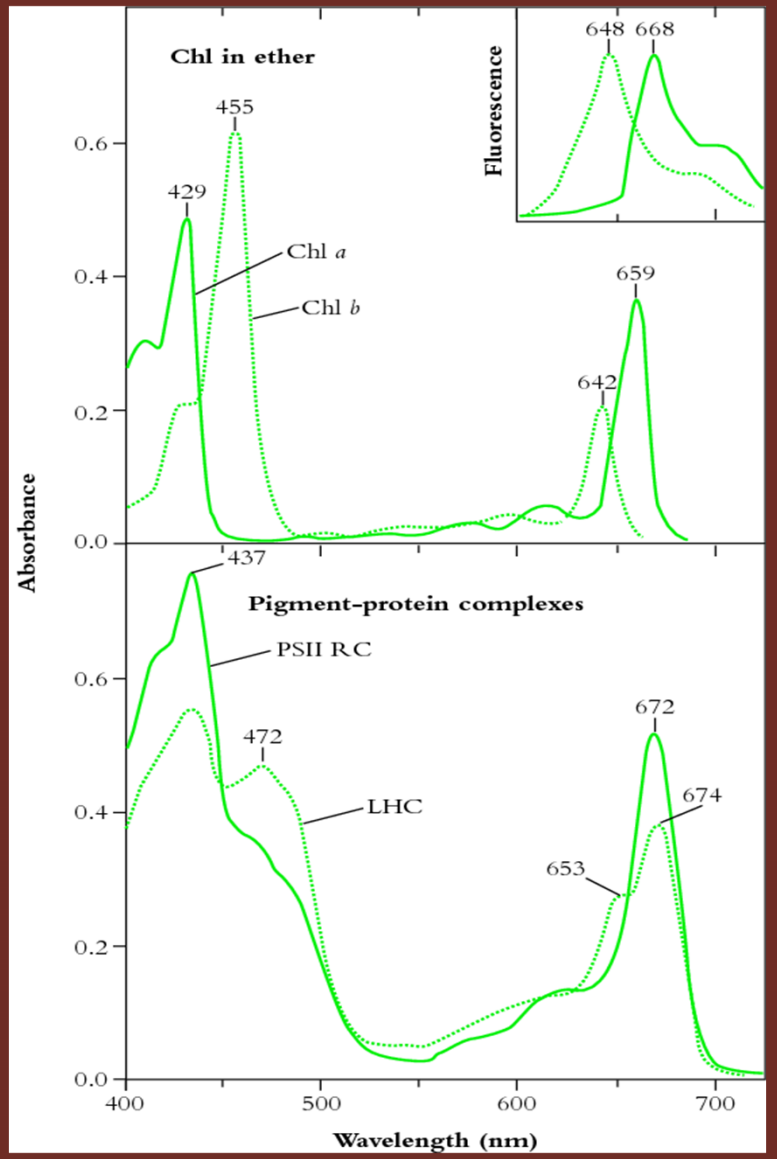
Apsorpcijski spektar klorofila *a*





Raspon λ djelovanja fotosinteze i osnovnih pigmenata

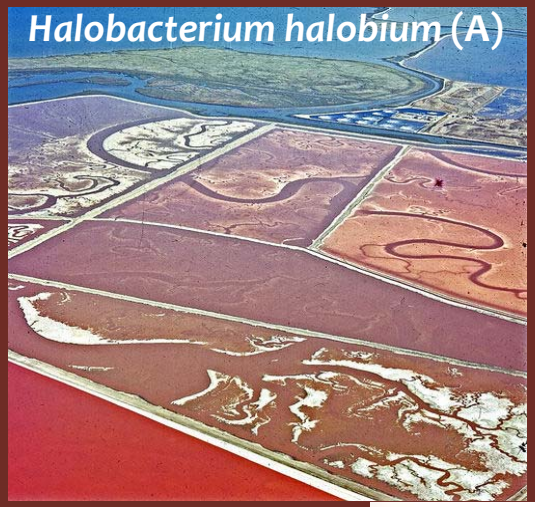


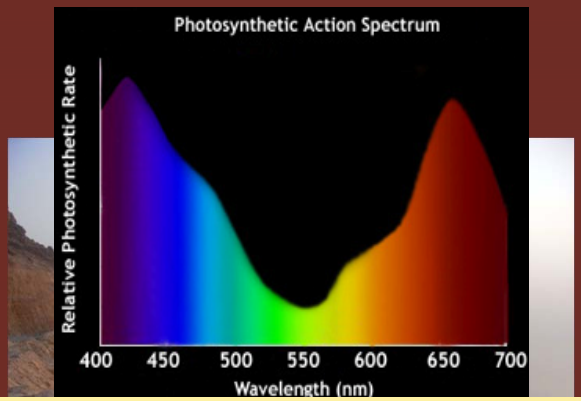


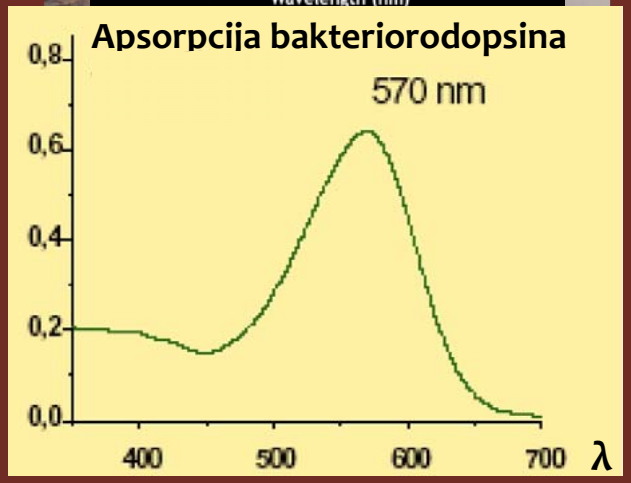
Zašto biljke ne koriste zeleni dio spektra, a zašto IR?

Sunčevo EMZ ≈ 4 % UV; 52 % IR; 44 % VIS

IR: λ > 700 nm → E ↓



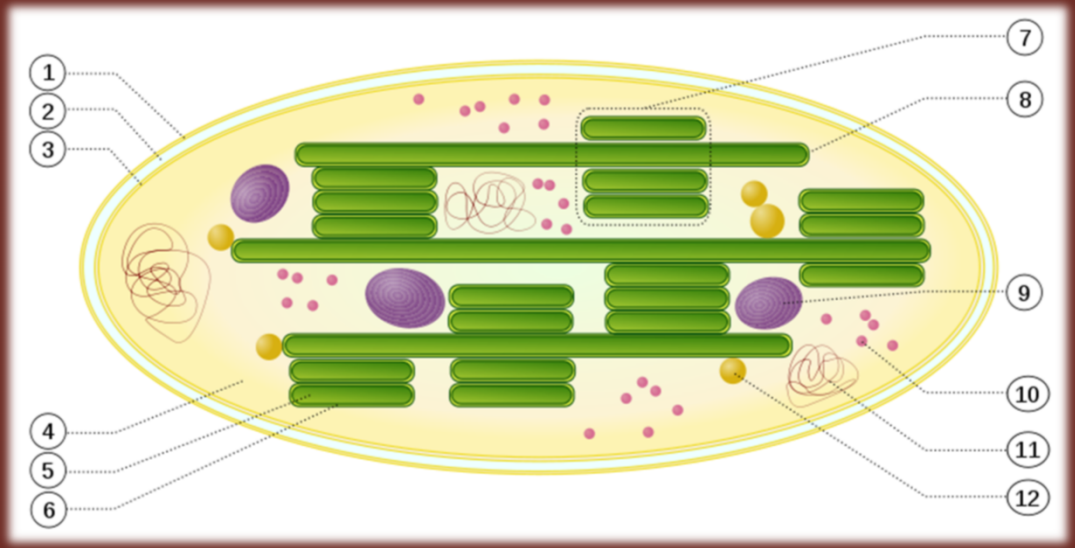




Pomoćni pigmenti:

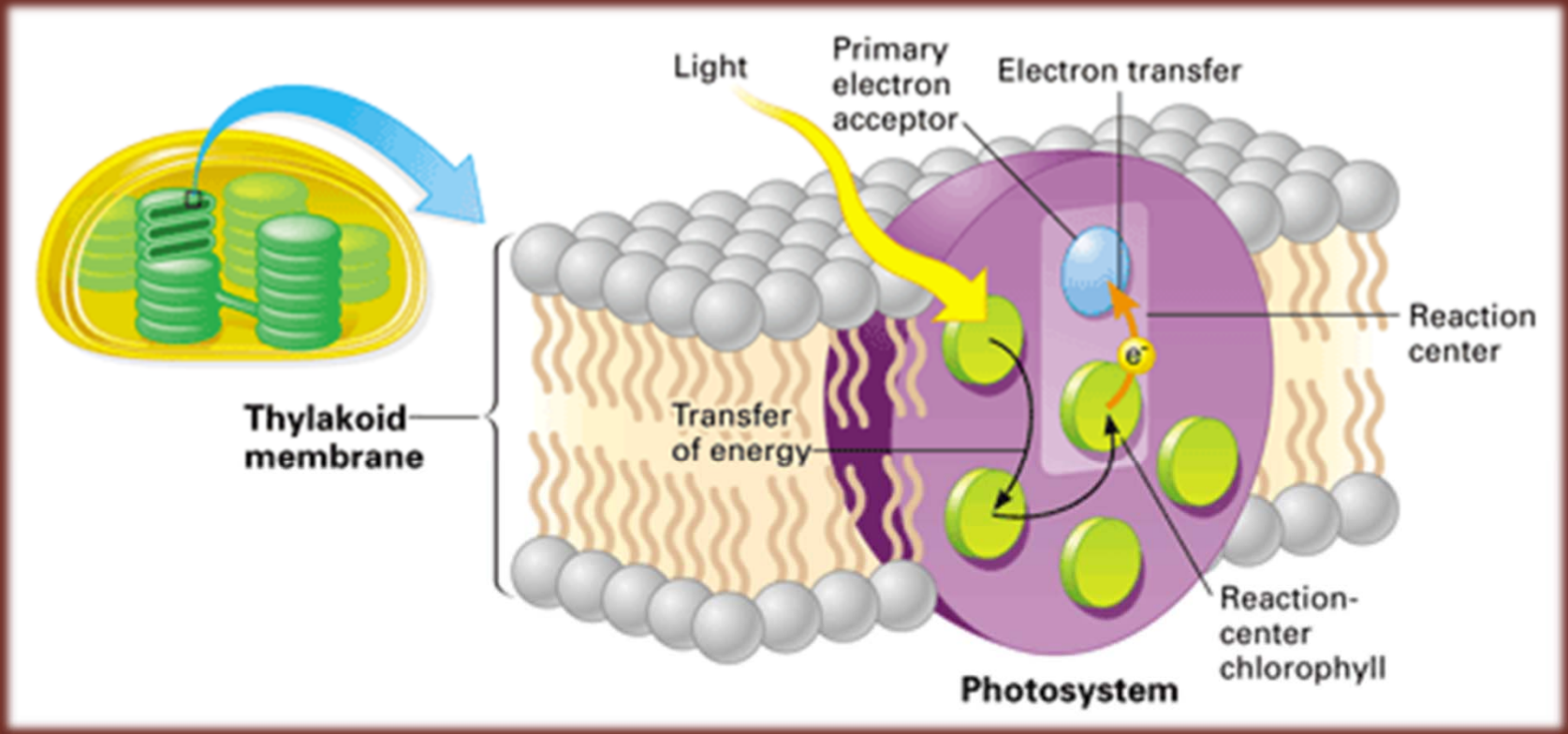
- Karoteni (β-karoten 400-550 nm)
- Ksantofili (Fukoksantin 510-525 nm)
- Fikobiliproteini (Fikocijanin 620 nm)

Gdje pigmenti obitavaju?



1-3 vanjska i unutarnja membrana s međumembranskim prostorom
4- stroma (plazma)
5 i 6- lumen i membrana TILAKOIDA
7- granum (snop tilakoida)

Gdje pigmenti obitavaju?

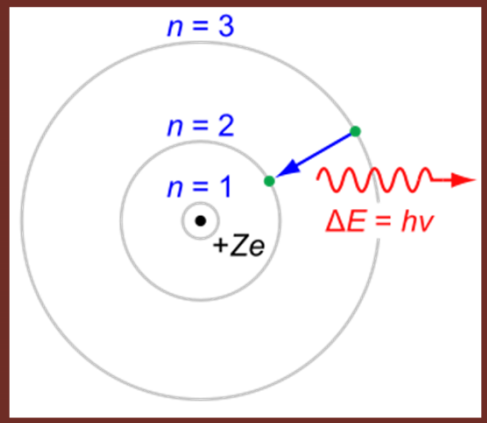


Sudbina energije fotona

hν pobuđuje e^-

e^- se vraća u nepobuđeno stanje i osobađa E

E (e^-) se predaje prihvatitelju



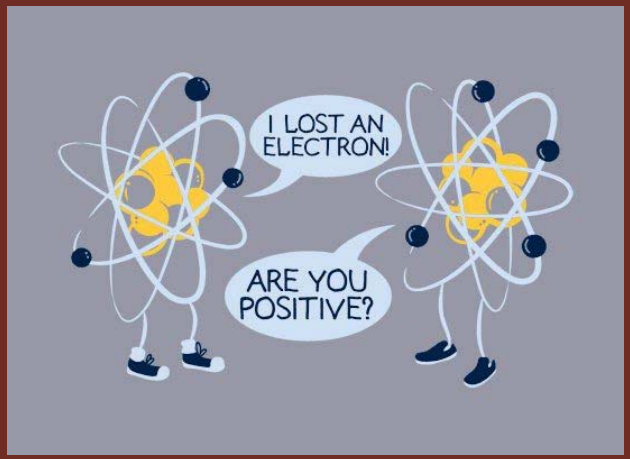
Kaskada e^- (redox)

svaka stepenica je na nižoj E razini – eksergone reakcije

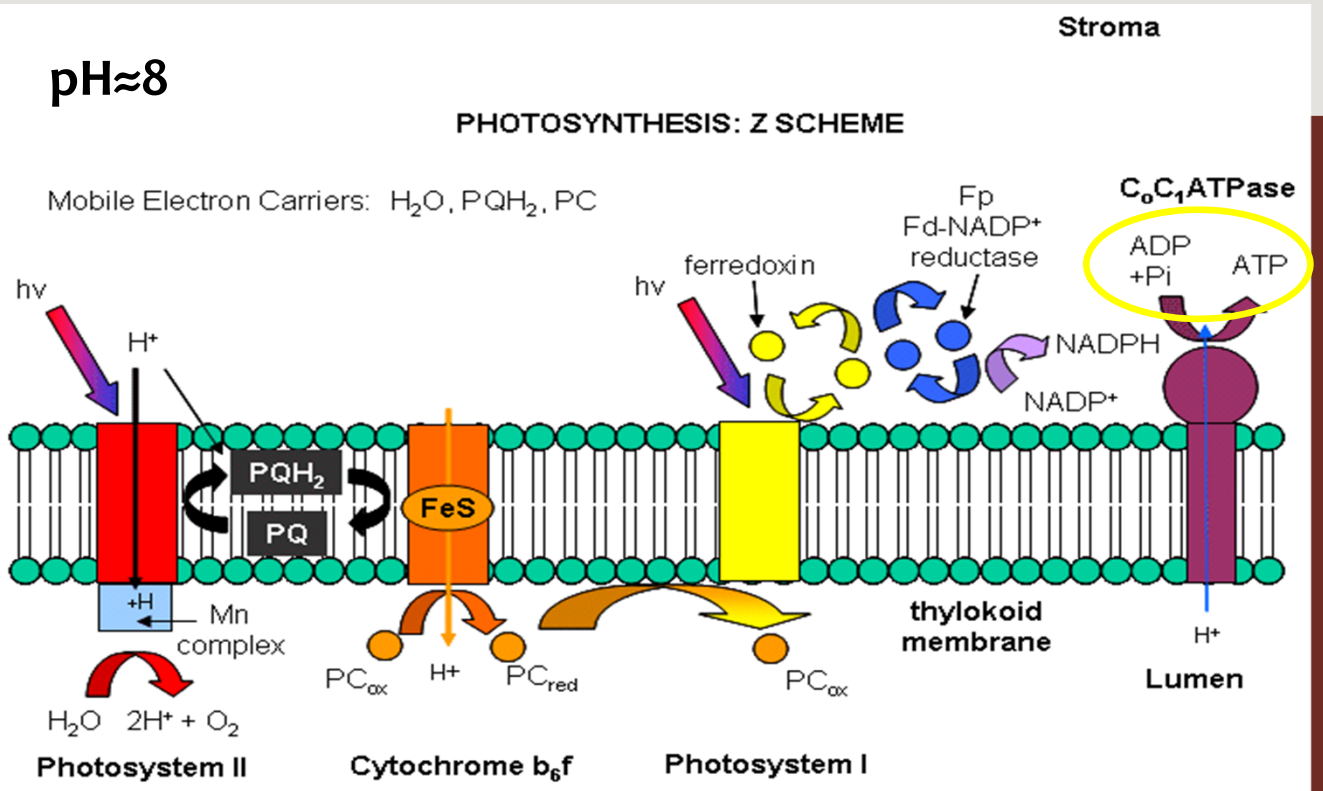
ΔE se ulaže u enderogonu sintezu ATP

FOTOFOSFORILACIJA

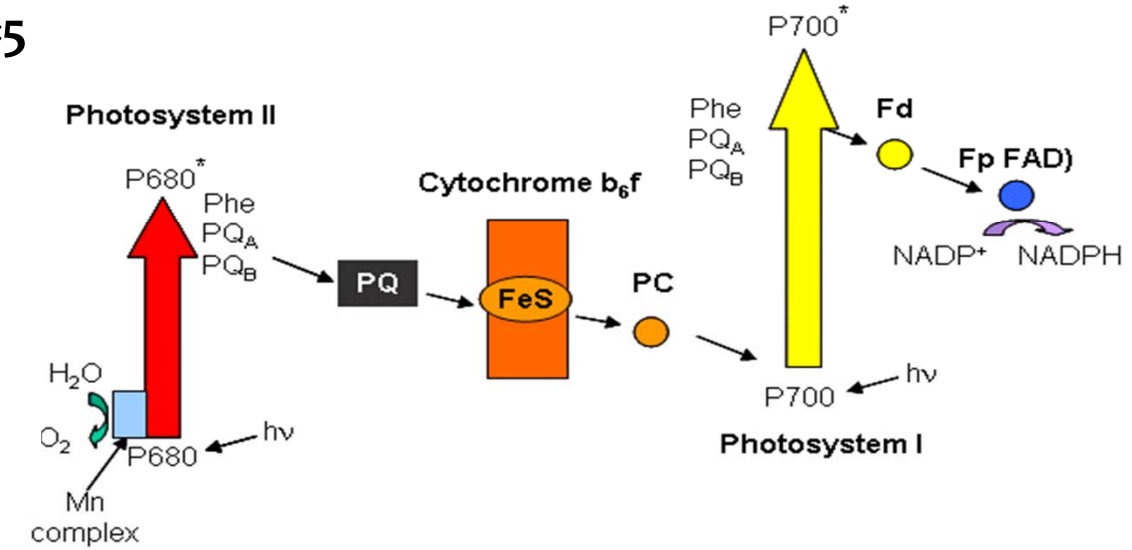
'energosinteza'

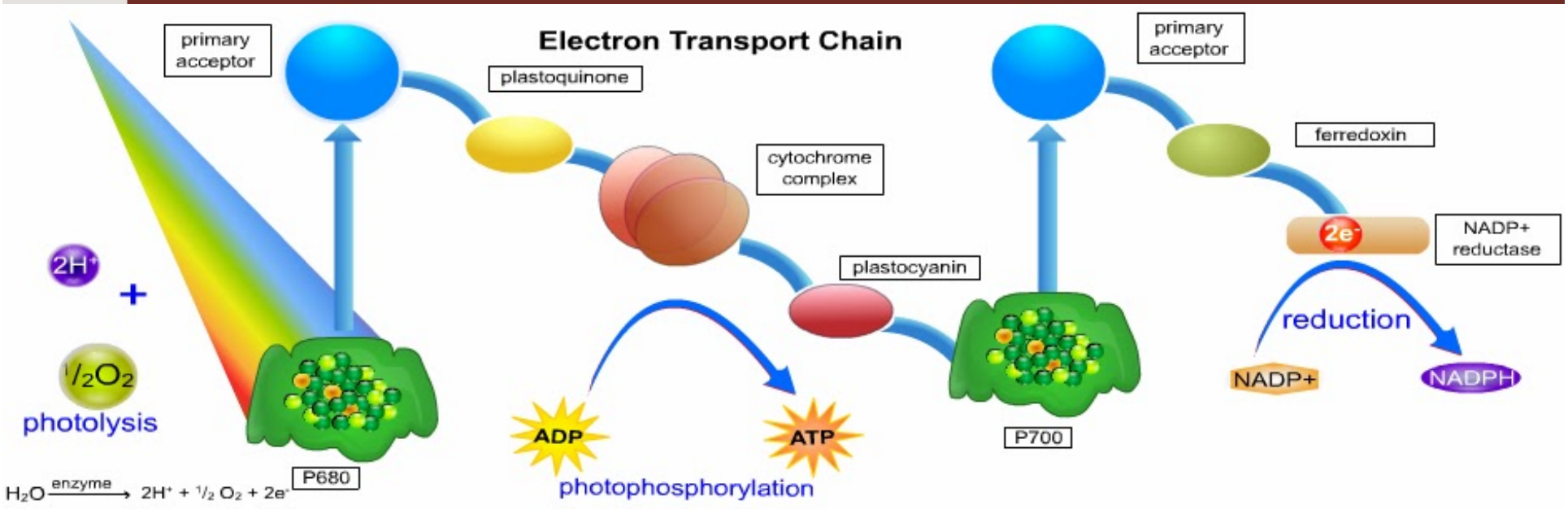


pH≈8


Stroma
PHOTOSYNTHESIS: Z SCHEME
Mobile Electron Carriers: H_2O, PQH_2, PC
hv
H+
PQH_2
PQ
FeS
+H
Mn complex
H_2O $2H^+ + O_2$
PC_{ox}
H+
PC_{red}
hv
ferredoxin
Fp
Fd-NADP+ reductase
NADPH
NADP+
C_oC_1ATPase
ADP +Pi
ATP
PC_{ox}
thylokoid membrane
H+
Lumen
Photosystem II
Cytochrome b_6f
Photosystem I

Ph≈5


Photosystem II
P680*
Phe
PQ_A
PQ_B
PQ
Cytochrome b_6f
FeS
PC
P700*
Phe
PQ_A
PQ_B
Fd
Fp FAD)
NADP+ NADPH
H_2O
O_2
P680
hv
Mn complex
P700
hv
Photosystem I



Neto:

$$8h\nu + 2NADP^+ + 3ADP + 3P_i + 2H_2O \rightarrow 2NADPH + 3ATP + 4e^- + O_2 + 2H^+$$

Biosinteza u fotosintezi (Calvin i Benson)

$CO_2 + RuBP\ (5C) \xrightarrow{Rubisco} 2\ 3\text{-PGA}$ (fosfoglicerinska kiselina)

$3\text{-PGA} \xrightarrow{2ATP\ 2\ NADPH} G\text{-}3\text{-}P$ (gliceraldehid-3-fosfat)

$G\text{-}3\text{-}P \xrightarrow{1ATP} RuBP$ (dio)

↓

6 C (fruktoza difosfat) ⟶

Glukoza

Saharoza

Škrob

Neto za 1 6C šećer:

6 × CC

$6CO_2+18ATP+12NADPH+12H_2O \rightarrow$

$C_6H_{12}O_6+18ADP+18P_i+12NADP^+ +6H_2O+6O_2$

Fotorespiracija

Pri visokim temperaturama (>28°C) tj. niskim CO_2

???

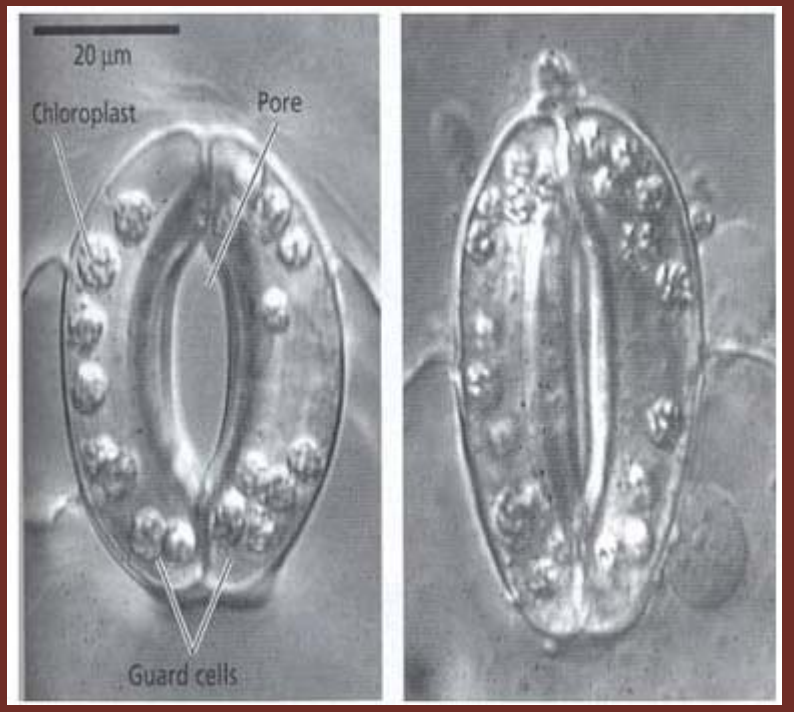
$m\ C_{(CO_2)} = 7.5 \times 10^{11}\ t$

$m\ C_{(CH\ u\ biljkama)} = 4.5 \times 10^{11}\ t$

Rubisco

O_2 + RuBP → 3-PGA + 2-PGA

(fosfoglikolna kiselina; 2C)



CO_2 400 ppm CO_2 50 ppm

$2PGA \rightarrow 2\ Gly \rightarrow Ser + CO_2\uparrow + ATP \rightarrow 3PGA \rightarrow$ Calvin

Učinkovitost

Matematički:

6.022×10^{23} molekula CO_2 u C6-šećer → 477 KJ (114 kcal)

6.022×10^{23} fotona pri $\lambda = 680$ nm → 176 KJ (42 kcal)

8 fotona za 1 CO_2

48.176×10^{23} fotona → 1408 KJ (336 kcal)

477 / 1408 = 34 %

Ali…

Bilanca tvari i energije u fotosintezi:

51 % izvan aktivnog raspona apsorpcije klorofila
10 % nepotpuna apsorpcija (reflektirani i propušteni fotoni)
15 % degradacija energetski viših fotona na razinu energije fotona 700 nm
37 % termodinamička ograničenja kemijskih reakcija
46 % stvaranje glukoze (biosinteza)
48 % fotorespiracija
29 % respiracija

100 % svjetlosti
49 % u rasponu apsorpcije - 10 %
44.1 % apsorbirano - 15 %
37.5 % sakupljeno u klorofilu - 37 %
23.6 % pretvoreno u ATP i NADH - 46 %
12.6 % pretvoreno u šećere - 48 %
6.6 % neto produkcija - 29 %
4.6 % NETO UČINKOVITOST

Biosinteza u fotosintezi

C4 put fotosinteze (mezofil!)

$CO_2 + PEP\ (3C) \xrightarrow{\text{PEP karboksilaza}} OA\ (4C) \rightarrow$

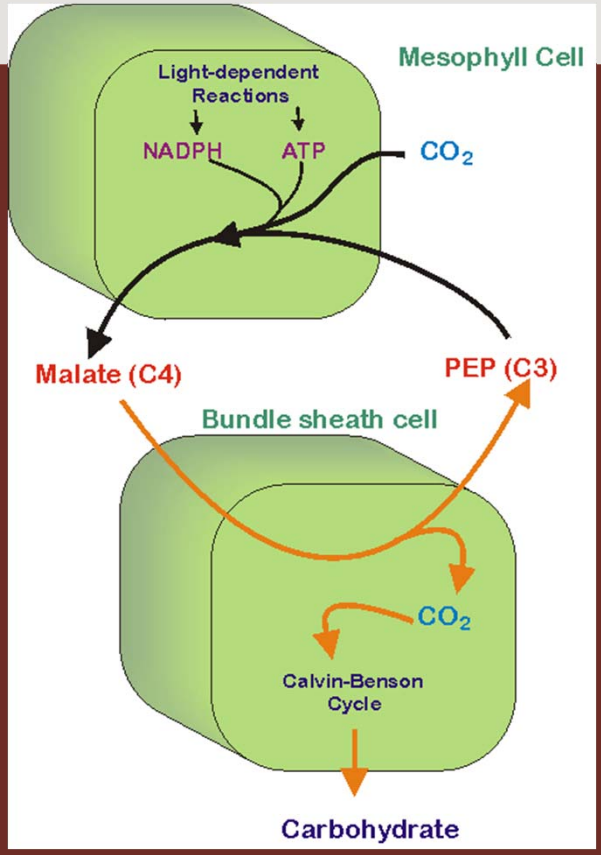
$\rightarrow$ Malat (Aspartat) (4C)

Transport – 1ATP

Oslobađanje CO_2 (20-120 × [CO_2])

3C spoj u mezofil – 1 ATP → PEP

C4 : C3 = 30 ATP : 18 ATP




Agave tequilana

Crassulacean Acid Metabolism (CAM)

U vakuole sukulentnih stanica pohranjuju 4C kiseline noću

Cactaceae, *Ananas*, *Polypodium*…

Učinkovitost vezanja energije u fotosintezi ≈ 1 %

Bajkal- 0.05 %
Biljke- 0.1-2 %
Kultivari- 1-4 %
~~Alge- 1-4 %~~
Šećerna trska- 7 %
~~laboratorij~~ alge i žitarice- 25 % (?)
Oenothera (Death valley)- 8 %

Bilanca tvari i energije u fotosintezi fitoplanktona:

5500MJ + 106 CO_2 + 122 H_2O + 16 HNO_3 + H_3PO_4 (+ ostali elementi) →
3258 mg ST protoplazme + ↑138 O_2 + ↑5445.4MJ

Protoplazma: 106C, 180 H, 46 O, 16N, 1 P +815g ostalih elemenata

$\Delta E = 54.6$ MJ

Sudbina fotosintata:

Oko pola fiksiranog C – disanje
Ostatak: sinteza celuloze (struktura),
glukoze i/ili škroba (pohranjena E)
saharoze (transport E)

Dio 3PGA – sinteza aminokiselina

ATP – $SO_4 \rightarrow SH$
Feredoksin i NADPH – $NO_2 \rightarrow NH_4^+$
(za AK)