

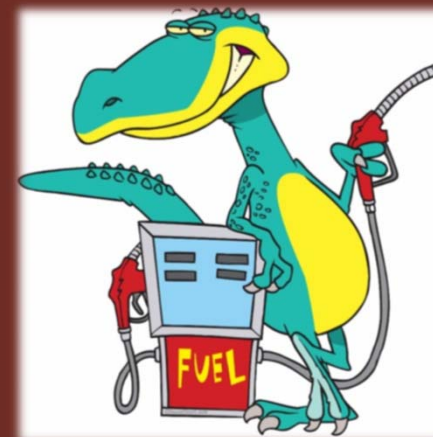
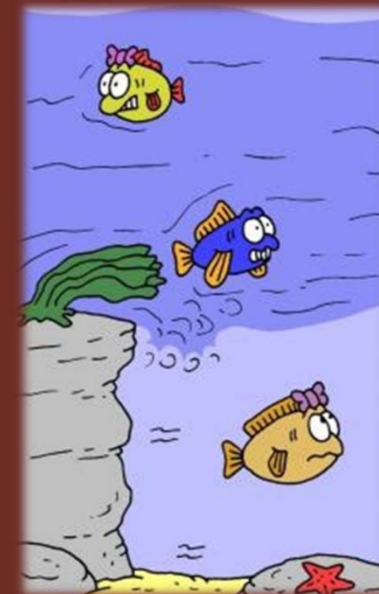
## Posredna sunčeva energija:

Fosilna goriva

Struje fluida (vjetar, more)

Ciklus vode (hidrološki ciklus)

...



# Geotermalna energija

## Uzroci:

Radioaktivni raspad

Energija iz vremena postanka Zemlje

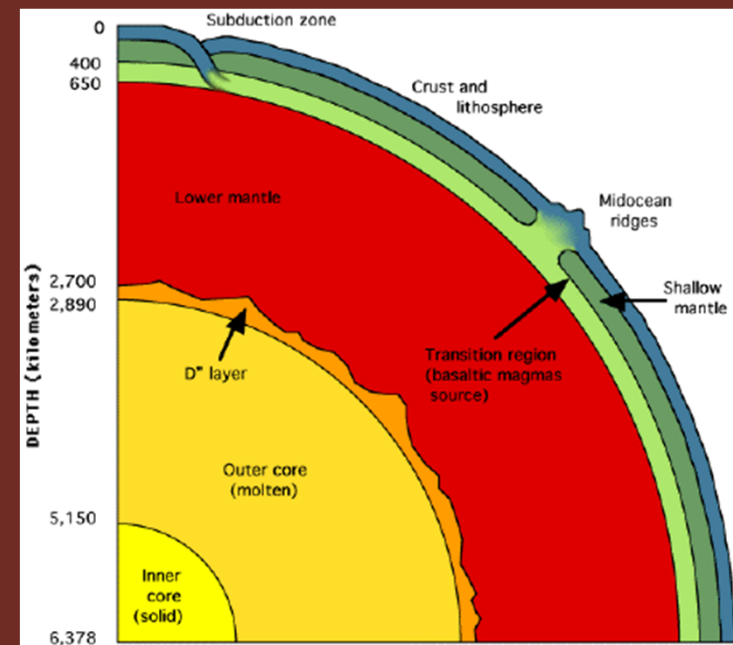
Gravitacijska toplina

Latentna toplina

## Posljedice:

Vulkanska aktivnost i tektonika

Magnetno polje Zemlje (?)



$T \approx 7000 \text{ K}$

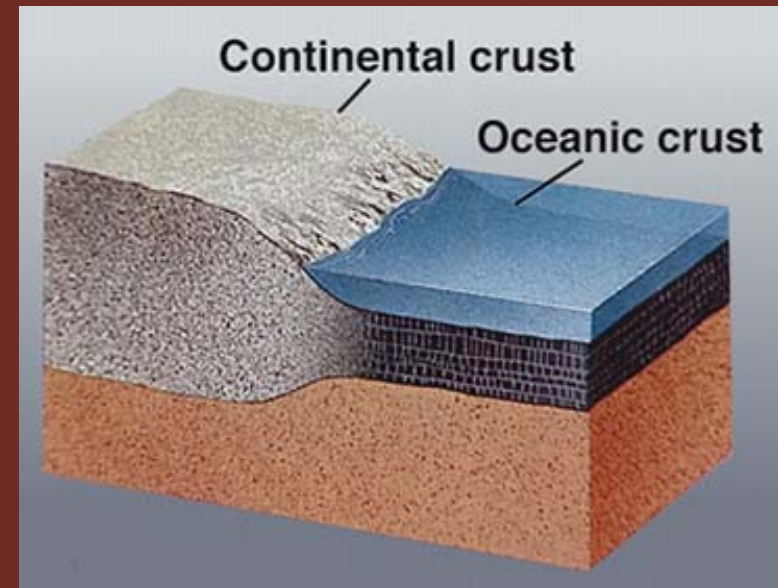
$p \approx 360 \text{ GPa}$

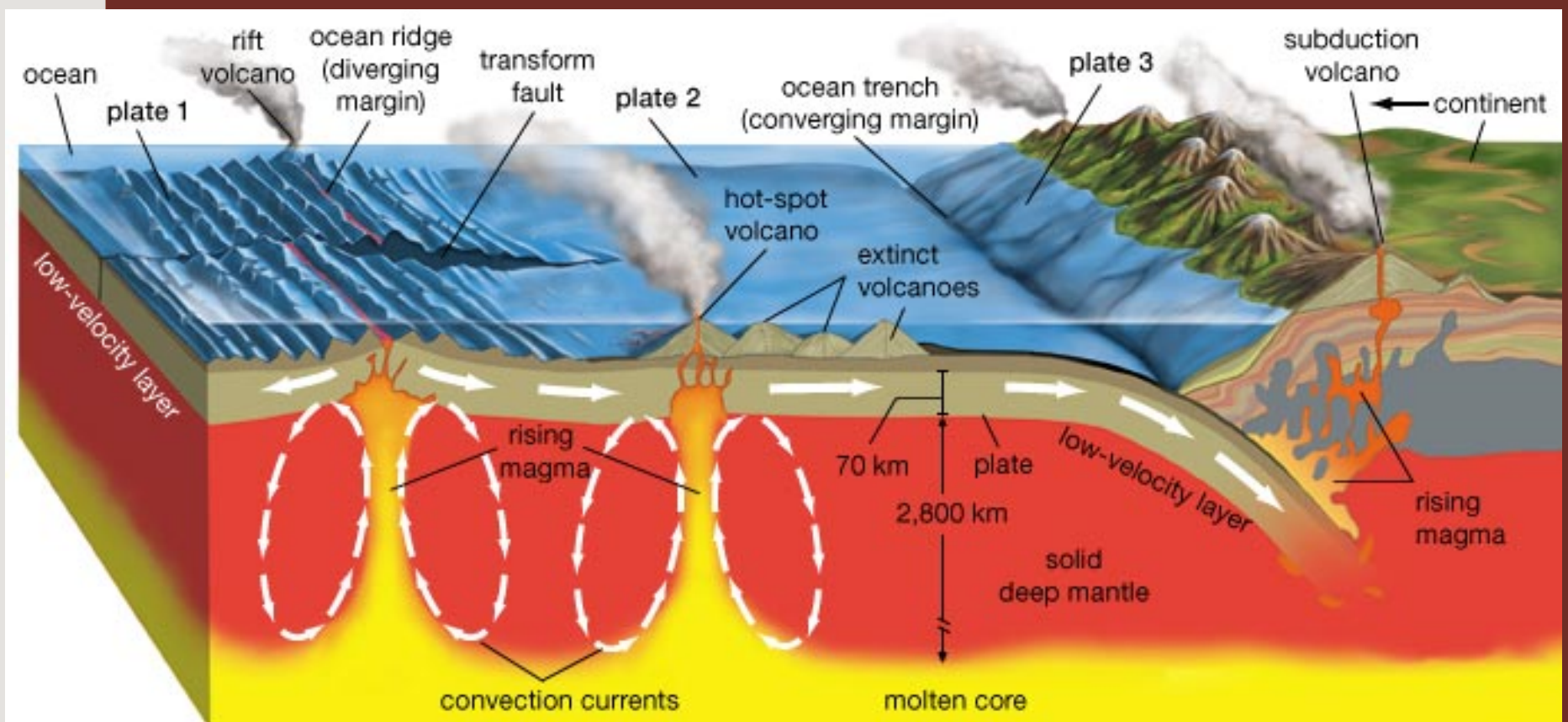
## Geotermalna energija

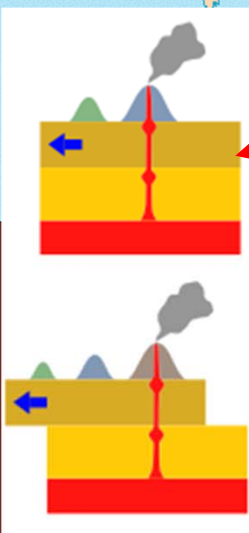
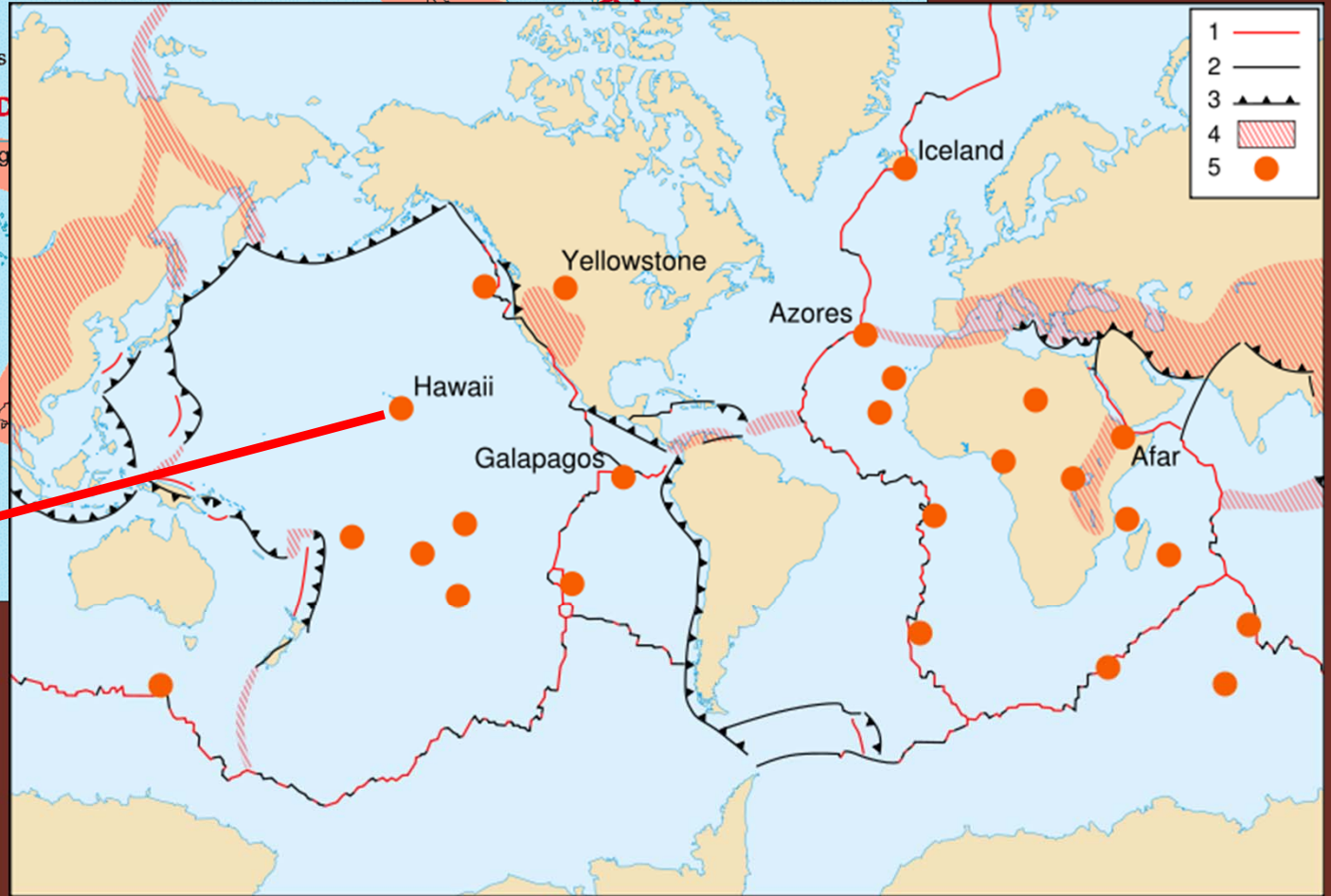
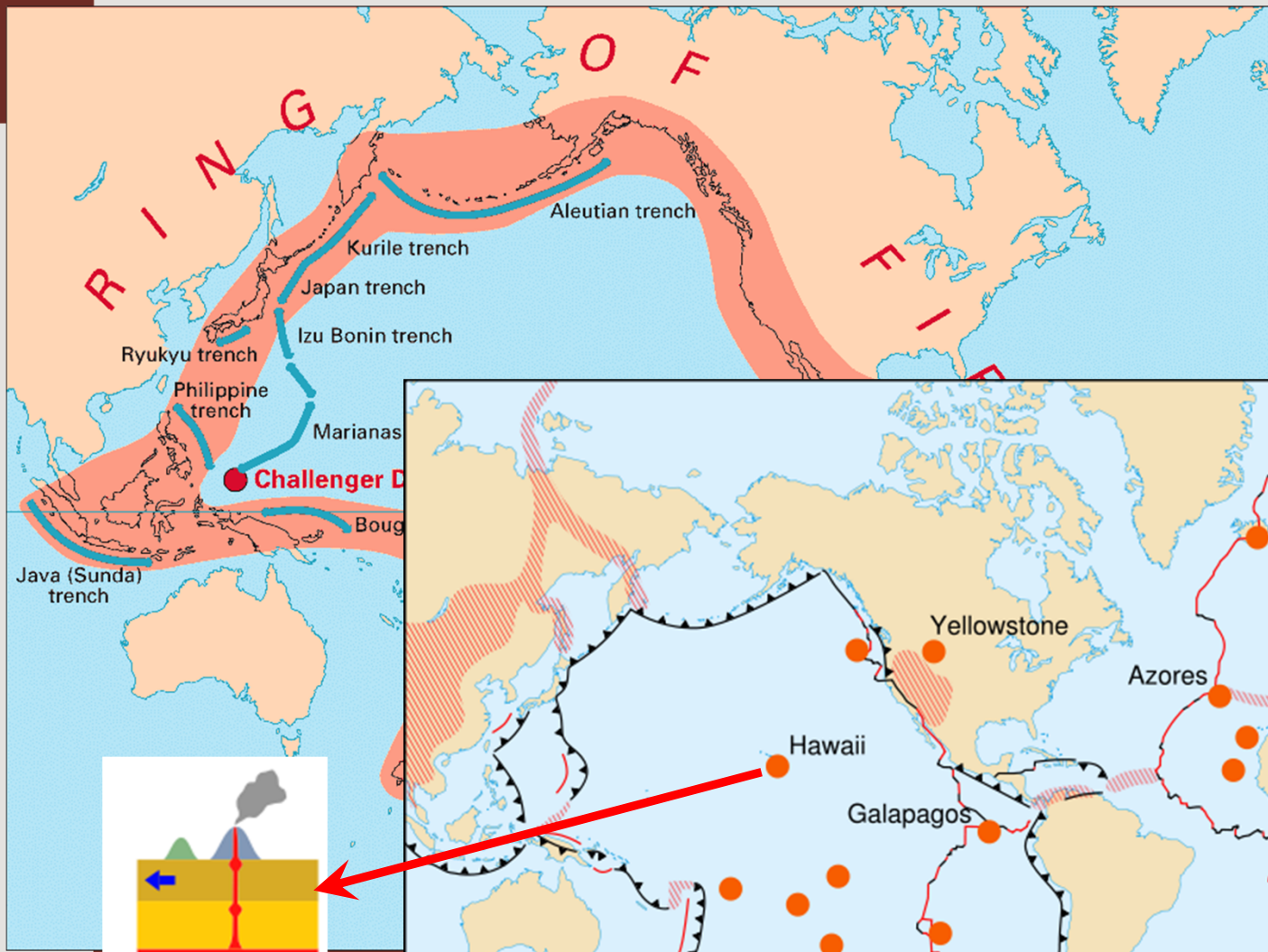
### Geotermalni gradijent

25-30 K/km (0.1 MW/km<sup>2</sup>)

HR- 18 K/km, 29 kW/km<sup>2</sup>  
49 K/km, 76 kW/km<sup>2</sup>







Grand prismatic spring



Fly Geyser

## Ekstremofili

### Termofili

*Thermus aquaticus* (Bakterija - kemo)

*Thermosynechococcus elongatus* (MZA)

*Phormidium* (MZA)

*Chloroflexus* (MZA)

*Calothrix* (MZA)

*Thermococcus litoralis* (Arhea - kemo)

*Cyanidium caldarium* (Alga)



BTW

Bizovačke toplice 96°C

Old faithfull 93°C

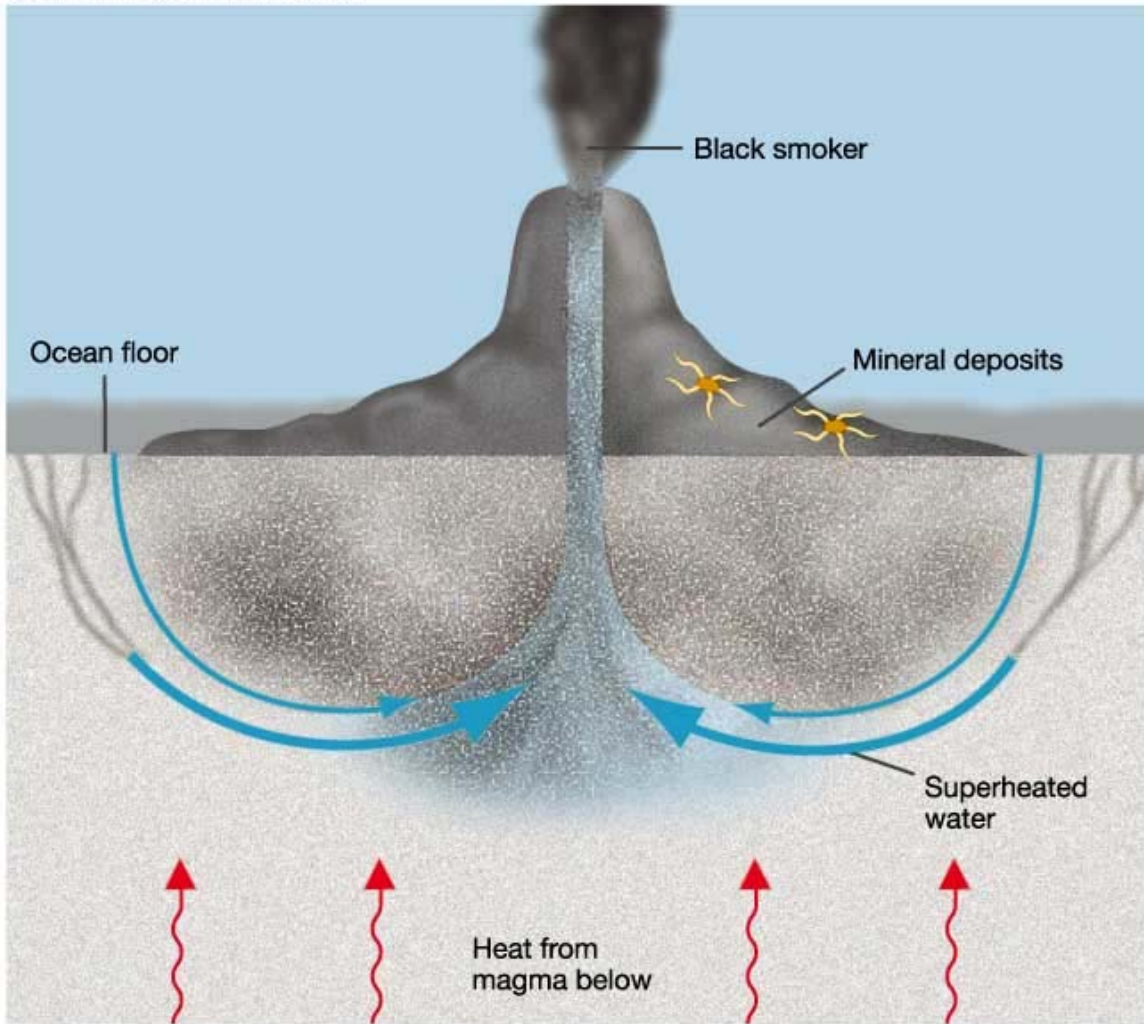




*Macaca fuscata*

*Jigokudani*

Formation of black smokers



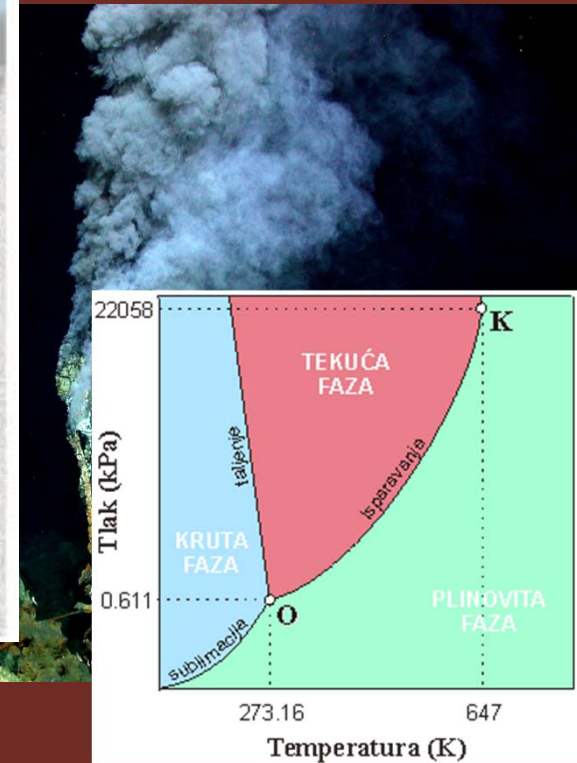
Crni dimljivci

$\Delta T$ ,

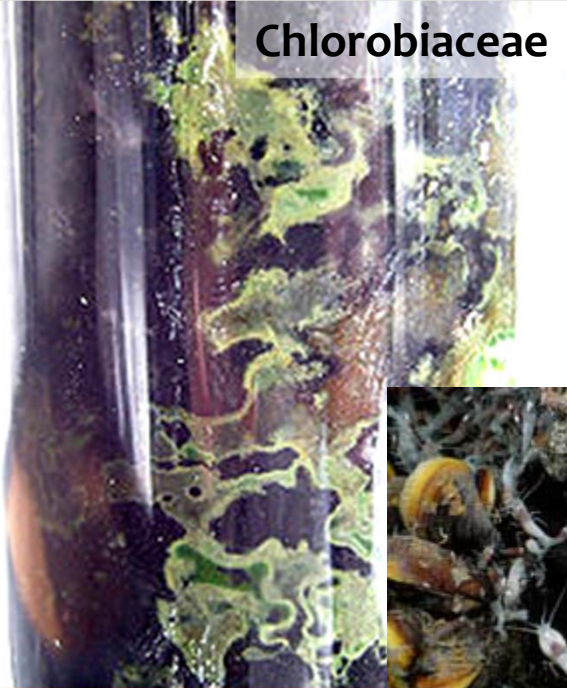
$\Delta \text{pH} (\approx 3)$

$\text{H}_2\text{S}$

Cu, Fe, Zn



**Chlorobiaceae**



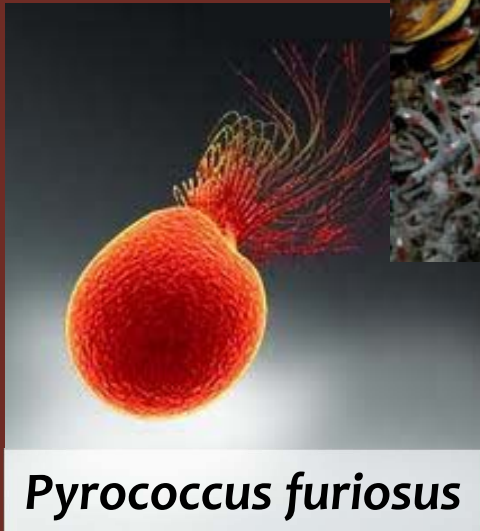
**Ekstremofili**

***Bathymodiolus termophilus***



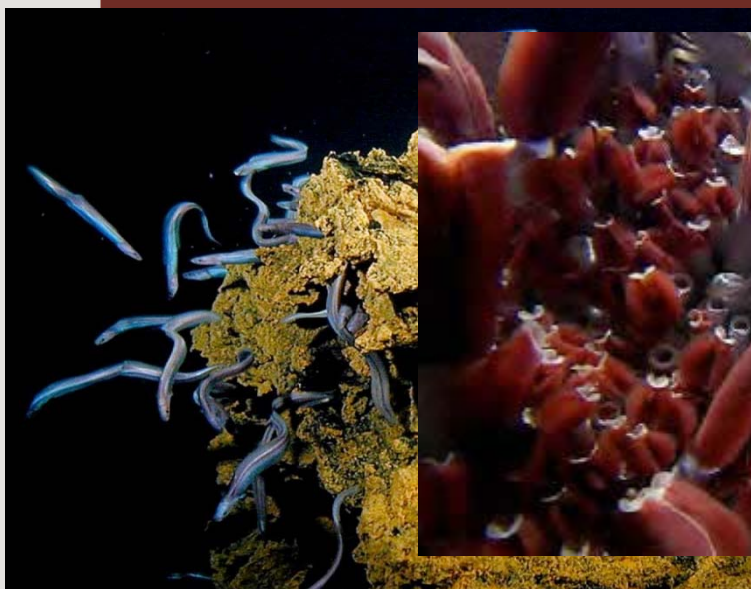
***Rimicaris exoculata***

***Calyptogenia magnifica***



***Pyrococcus furiosus***

## Ekstremofili



*Dysommima rugosa*

*Tevnia jerichonana* *Riftia pachyptila*

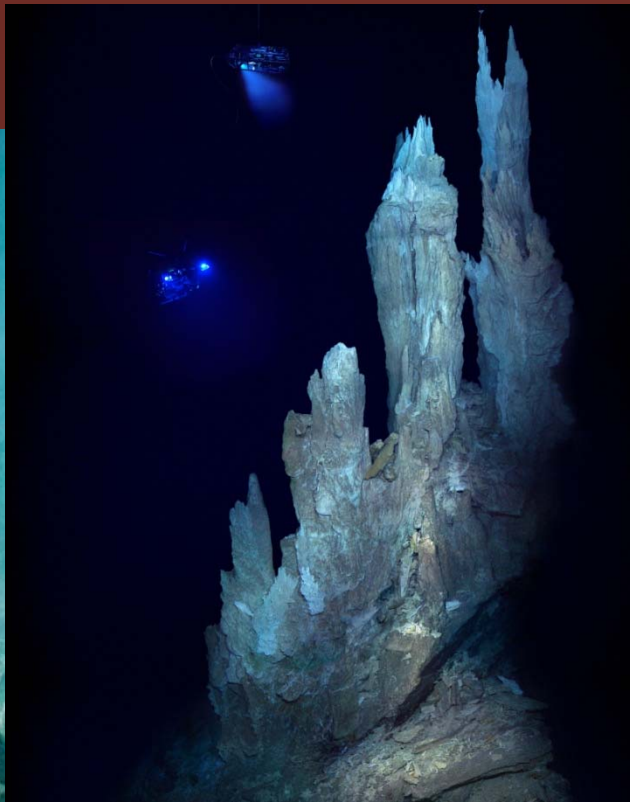
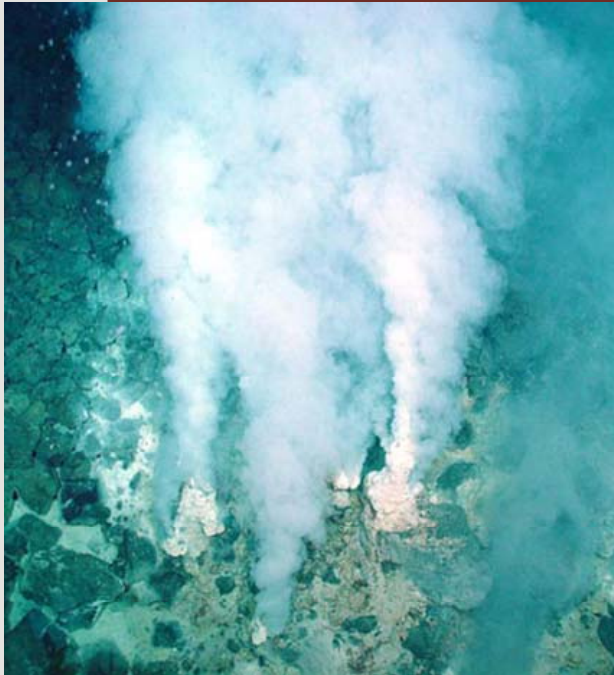
## Bijeli dimljivci

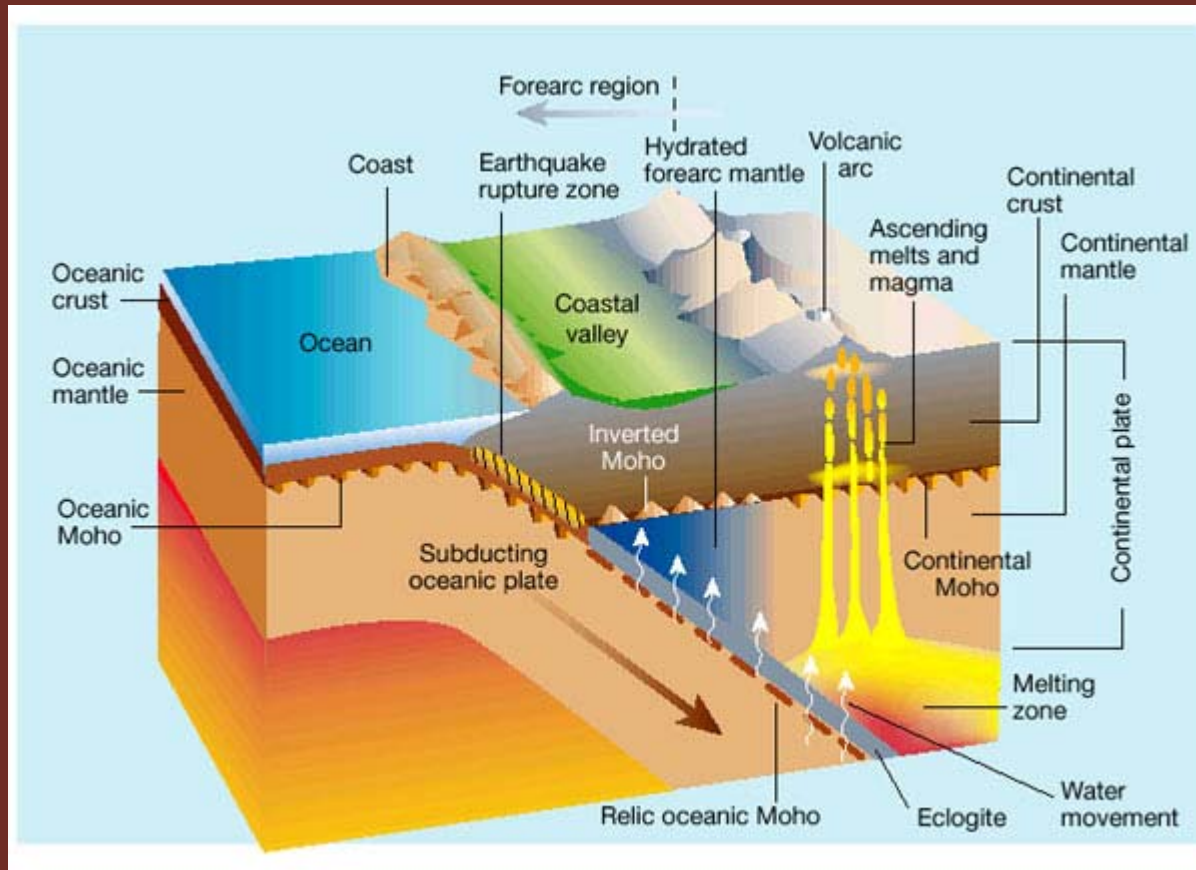
Ba, Ca, Si

pH > 9

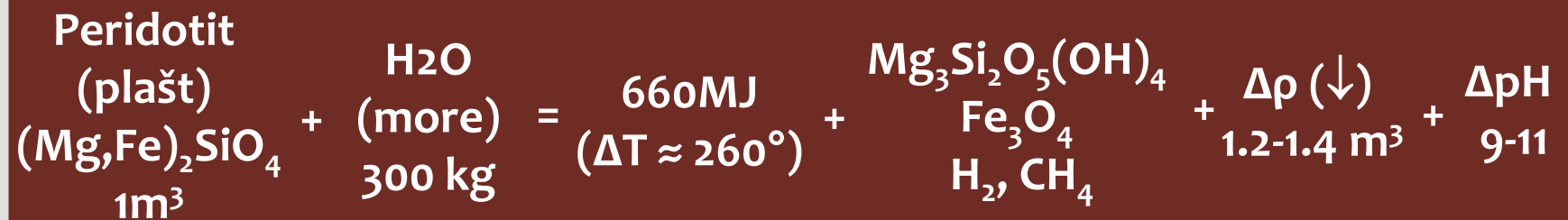
CH<sub>4</sub>

CaCO<sub>3</sub>





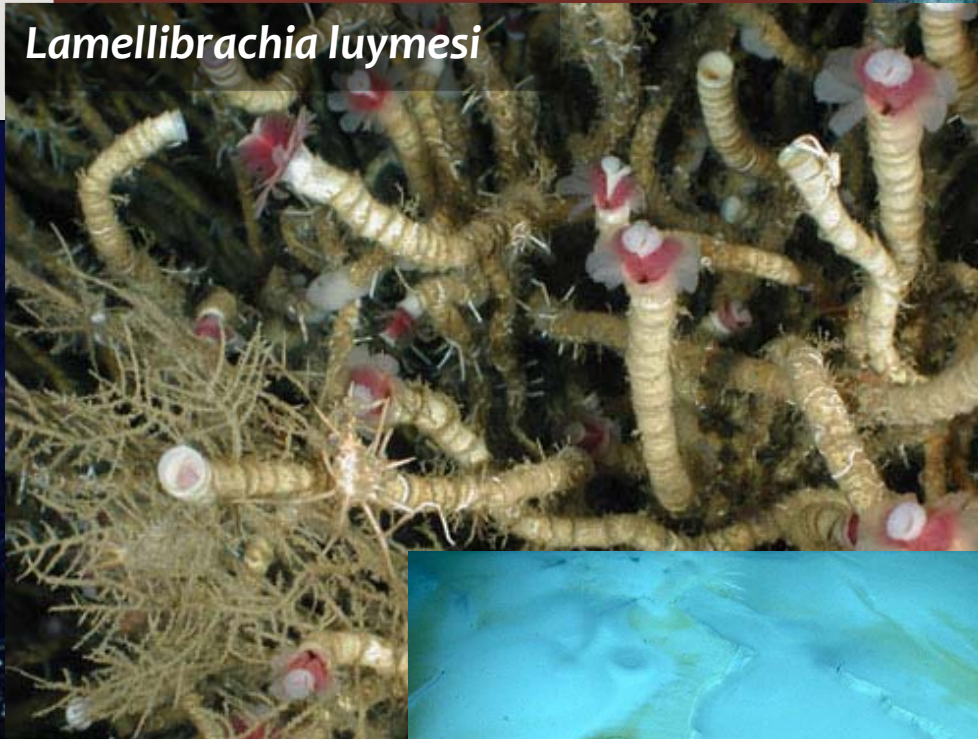
## Serpentinizacija



Hladni izvori

H<sub>2</sub>S, CH<sub>4</sub>, nafta, NaCl

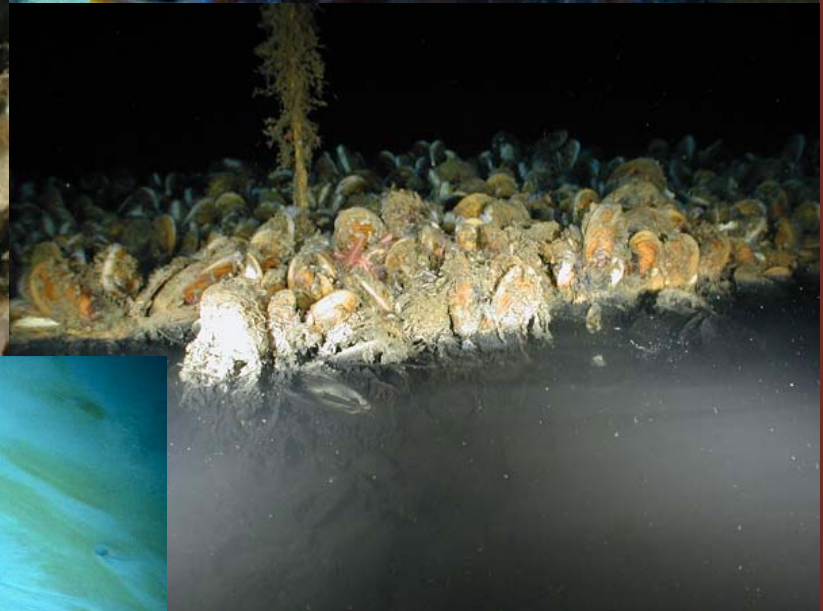
*Lamellibrachia luymesii*



*Bathymodiolus childressi*



*Beggiatoa* sp.



## Podjela organizama prema načinu pribavljanja energije

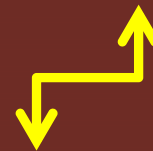
E	e <sup>-</sup>	C	
hv	Organski spoj	Organski spoj	Fotoorganoheterotrof
		CO <sub>2</sub>	Fotoorganoautotrof
	Anorganski spoj	Organski spoj	Fotolithoheterotrof
		CO <sub>2</sub>	Fotolitoautotrof
Kemijski spojevi	Organski spoj	Organski spoj	Kemoorganoheterotrof
		CO <sub>2</sub>	Kemoorganoautotrof
	Anorganski spoj	Organski spoj	Kemolithoheterotrof
		CO <sub>2</sub>	Kemolitoautotrof

Miksotrofi

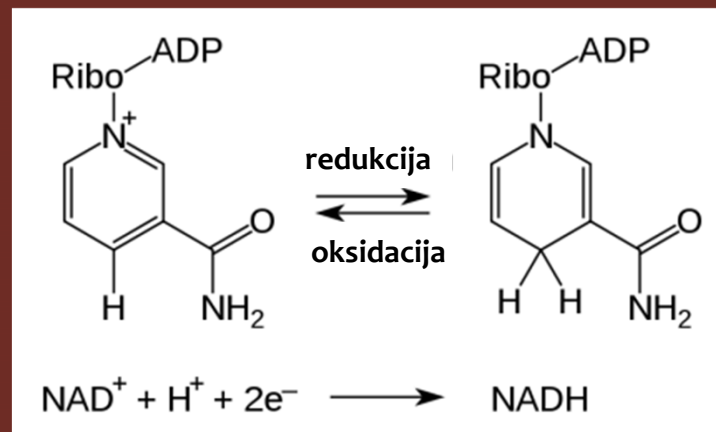
## Kemo(lito)autotrofi

Dobivaju E metaboliziranjem anorganskih spojeva

oksidacija anorganskog spoja

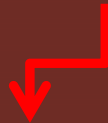


redukcija odgovarajućeg koenzima



## Kemo(lito)autotrofi

Transfer  $e^-$  s koenzima (transportnim lancem) omogućuje stvaranje transmembranskog gradijenta  $H^+$



Stvaranje ATP

Kranji prihvatilac  $e^-$  je najčešće kisik, ali ima i anaeroba (Fe,  $SO_4$ ,  $NO_3$ , Mn,  $CO_2$ )

Supstrat metabolizma mogu biti:

H,  $NO_2^-$ ,  $NH_4^+$ ,  $H_2S$ , S,  $S_2O_3^{2-}$ ,  $Fe^{2+}$

**Kemosinteza:  
Oksidacija vodika**



*Aquifex, Alcaligenes*

*Pyrodictium* - anaerob - reducira elementarni S (produkt je H<sub>2</sub>S)

*Clostridium, Acetobacterium* reduciraju CO<sub>2</sub> do CH<sub>3</sub>COO<sup>-</sup>

$\Delta E = -236.8 \text{ kJ/mol} (-56,6 \text{ kcal/mol})$



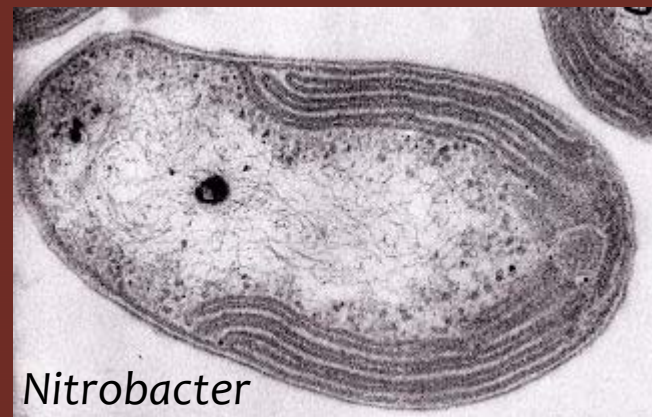
**Kemosinteza:  
Oksidacija N-spojeva**



*Nitrobacter, Nitrosomonas*

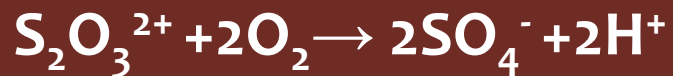
$$\Delta E_{\text{NH}_3} = -271.9 \text{ kJ/mol } (-65 \text{ kcal/mol})$$

$$\Delta E_{\text{NO}_2} = -72.8 \text{ kJ/mol } (-17.4 \text{ kcal/mol})$$



*Nitrobacter*

**Kemosinteza:  
Oksidacija S-spojeva**



*Beggiatoa, Thiobacillus, Sulfolobus*

$$\Delta E_{\text{H}_2\text{S}} = -527 \text{ kJ/mol } (-125.9 \text{ kcal/mol})$$

$$\Delta E_{\text{S}} = -495.8 \text{ kJ/mol } (-118.5 \text{ kcal/mol})$$

$$\Delta E_{\text{S}_2\text{O}_3} = -935.9 \text{ kJ/mol } (-223.7 \text{ kcal/mol})$$



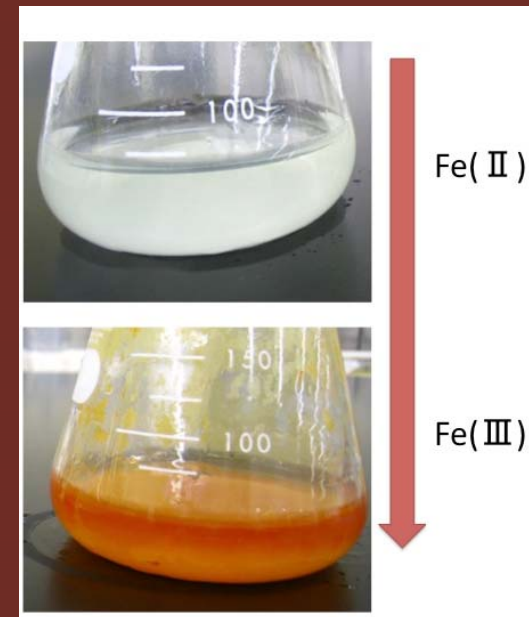
**Kemosinteza:**

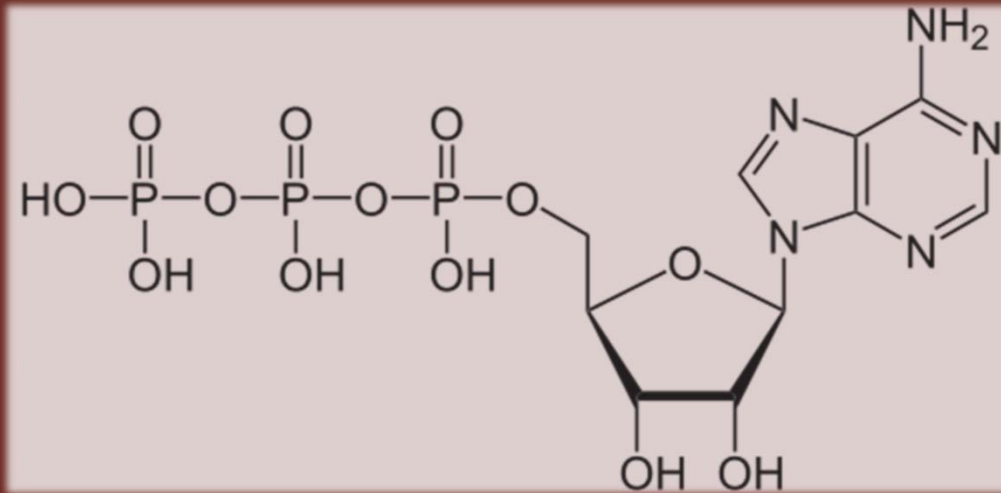
**Oksidacija Fe<sup>2+</sup> u Fe<sup>3+</sup>**



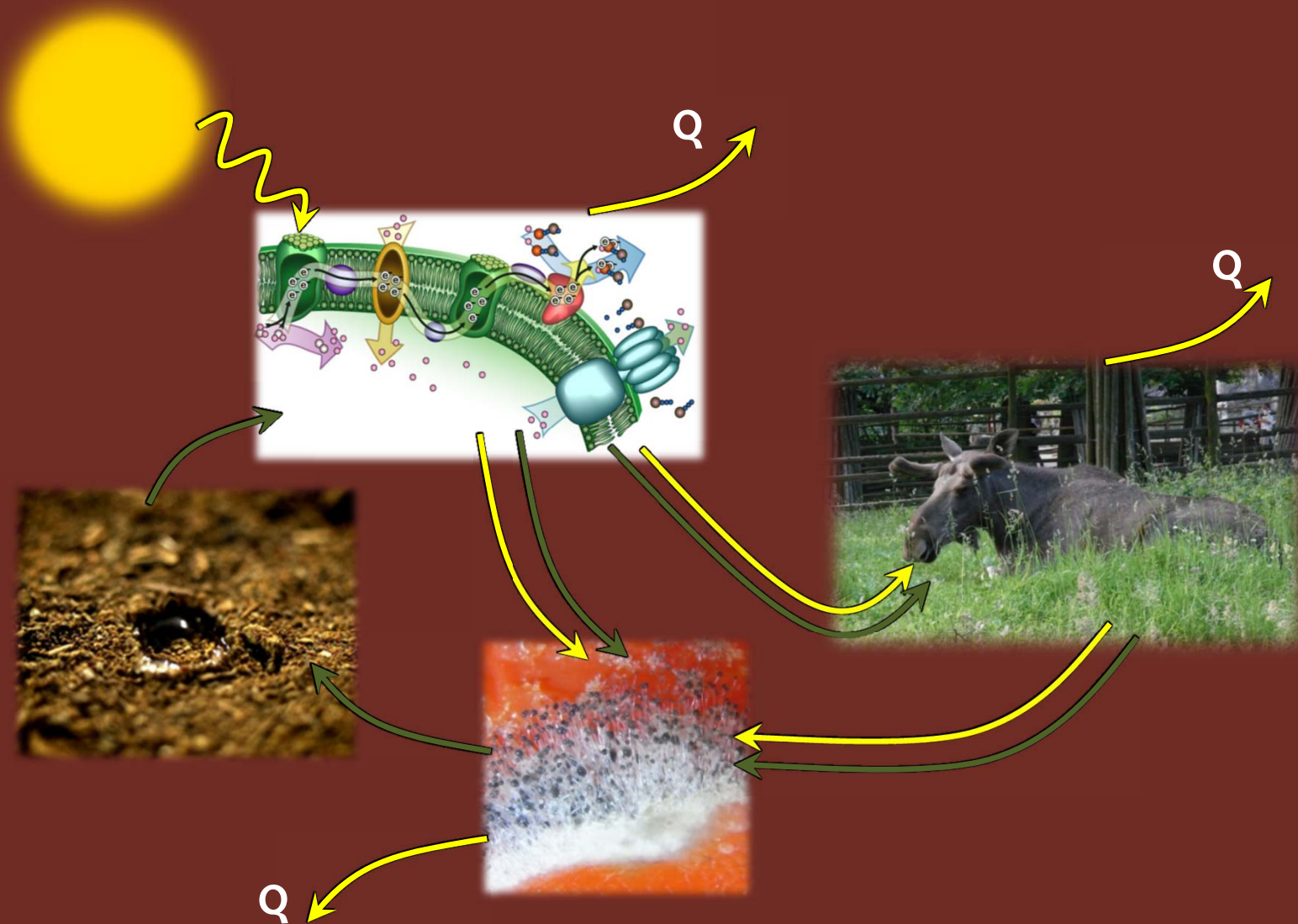
*Thiobacillus ferrooxidans*

$\Delta E = -46.9 \text{ kJ/mol}$  ( $-11.2 \text{ kcal/mol}$ )





# Protok energije kroz ekosustav



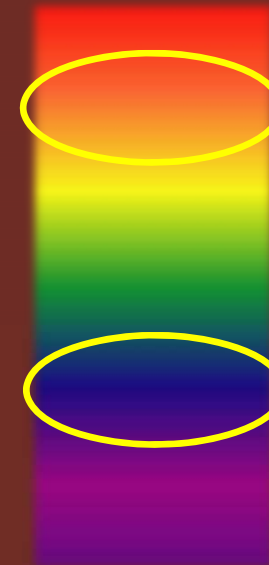
# Kako smo (na)učili o fotosintezi?



1648 van Helmont



1771 Priestley



*Spirogyra*

Engelmann 1883

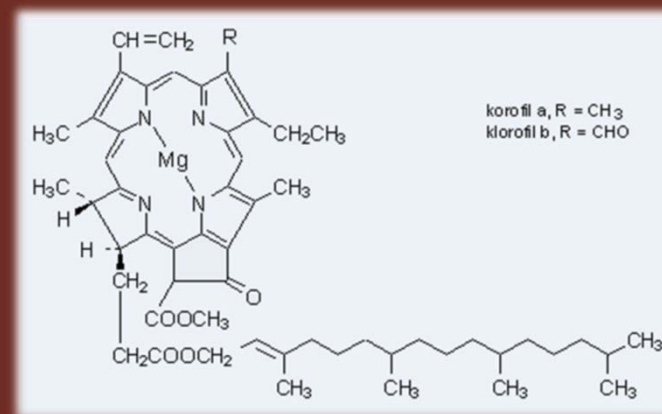
## Primarna proizvodnja zasnovana na E sunčeve svjetlosti

Osnova? ↘  
Pigmenti!

Osnovni pigmenti:

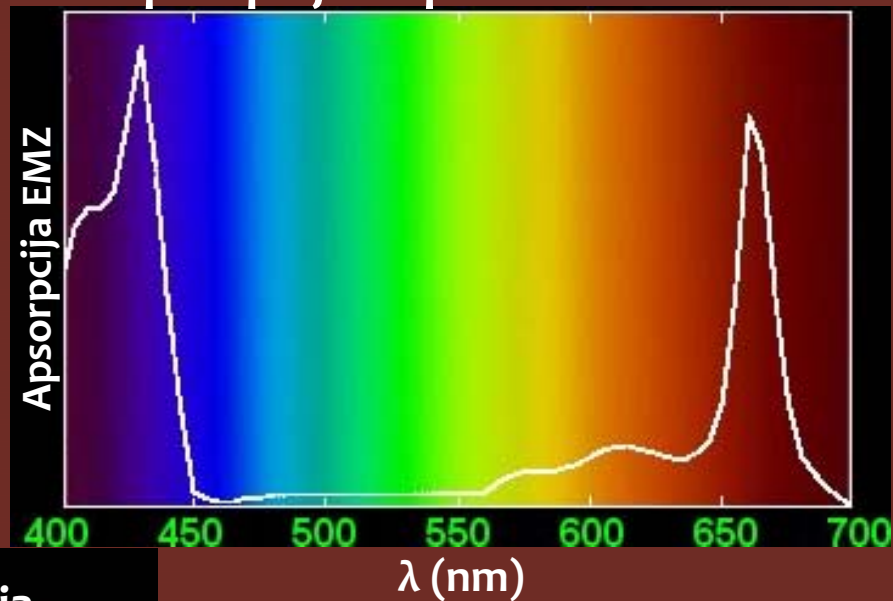
**Klorofil a**  $C_{55}H_{72}O_5N_4Mg$   
430 i 662 nm;  
samo  
prokarioti ga nemaju

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

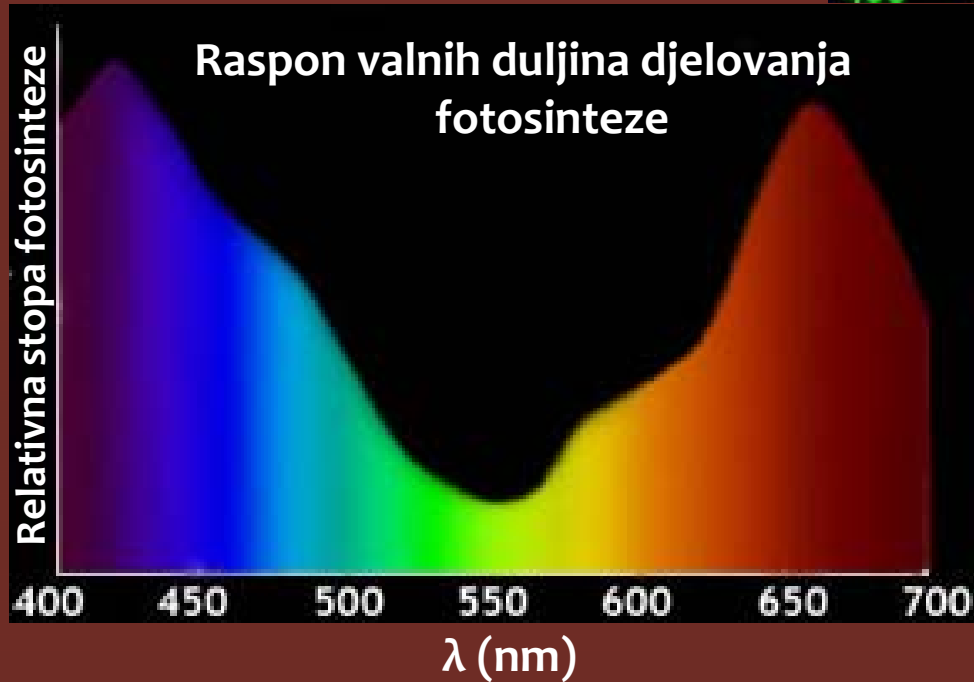


## VIS i fotosinteza

### Apsorpcijski spektar klorofila $a$



### Raspon valnih duljina djelovanja fotosinteze



## Raspon valnih duljina djelovanja fotosinteze i osnovnih pigmenata:

