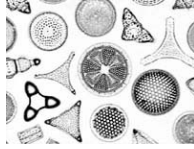


## Heterokontophyta: raznobličkaste alge 1

klorofil a, c, ksantofili,  $\beta$ -karoten  
olja, **krizolaminarin**, **manitol**, nikoli škrob

stena: celuloza + pektini, včasih impregnirana s **kremenom** ali razvita v obliki ohlapne lorike, lahko manjka

običkani stadiji so heterokontni, z dvema, navadno različno dolgima bičkoma, daljši navadno "omigetalčen" (**mastigoneme**)



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## Heterokontophyta: raznobličkaste alge 2

pri dnu golega bička stigma prilegla ob plastid

2 tipa flagelnarnega aparata

plastidi z ovojem ER, pod njim periplastidni retikulum

tilakoide po 3 v lamelah, ovojna lamela (!)

ekonomsko najpomembnejša skupina alg (+/- !)



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## Heterokontophyta: raznobličkaste alge 2

delitev: vsaj 9 razredov, obravnavamo 4:

sladkovodni

**Chrysophyceae**: zlatorjave alge

**Xanthophyceae**: rumene alge

sladkovodni+morski

**Bacillariophyceae**: kremenaste alge

morski, najbolj kompleksni

**Phaeophyceae**: rjave alge

"glive":

Oomycetes, Hyphochytridiomycetes,  
Labyrinthulomycetes

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## Heterokontophyta: Chrysophyceae 1

### Chrysophyceae: zlatorjave alge

klorofil a, c,  $\pm$ fukoksantin

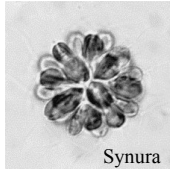
krizolaminarin, olja, (manitol)

stena lahko s kremenastimi luskami  
pod plazmalemo (*Synura*)

večinoma 2 plastida

zoo- in aplanospore ( $\text{SiO}_2$ ), (spolno  
izogamija, zigocista), haplonti (?)

akrokonti, krajši biček lahko  
popolnoma reduciran



Synura



Dinobryon

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## Heterokontophyta: Chrysophyceae 2

monadni (kokalni, rizopodijalni,  
kapsalni, redki trihalni)

stigma na bazi bička

precej miksotrofov, fagotrofija

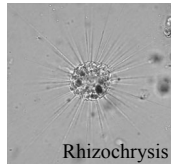
hladne čiste (zmerno kisle: prost  
 $\text{CO}_2$ !) sladke vode (morje: piko  
in nanoplankton), ~1000 vrst

delitev: več redov, npr.:

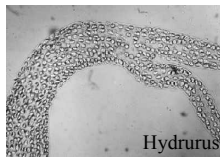
Ochromonadales,

Chrysamoebidales,

Chrysocapsales, ...



Rhizochrysis



Hydrurus

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## Heterokontophyta: Xanthophyceae 1

### Xanthophyceae : rumene alge

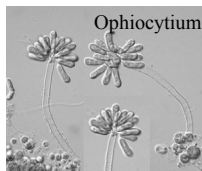
klorofil a (c, e), ni fukoksantina!

krizolaminarin, olja

stena pogosto dvodelna, lahko  
okremenjena (predvsem trajne  
oblike!)

plastidi zeleni (ob dodatku HCl  
modri)

spolno razmnoževanje redko  
(oogamija ali izogamija), zoo- in  
aplanospore



Ophiocytium



Tribonema

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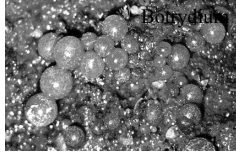
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## Heterokontophyta: Xanthophyceae 2

nekateri rizopodijalni miksotrofni akrokonti

kokalni in sifonalni (trihalni, kapsalni, monadni, rizopodijalni)

sladkovodne, vlažna tla, epifiti (morske), pogosto se pojavljajo v raztresenih populacijah, ~600 vrst



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## Heterokontophyta: Xanthophyceae 3

delitev:

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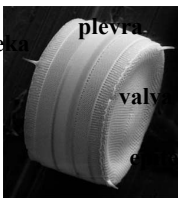
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## Heterokontophyta: Bacillariophyceae

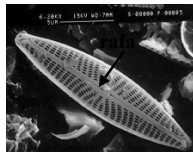
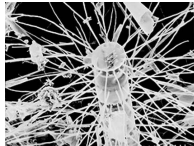
Bacillariophyceae (=Diatomeae): kremenaste alge, diatomeje



hipoteka



teka (frustula)



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## Heterokontophyta: Bacillariophyceae

klorofila a, c,  $\alpha+\beta$  karoten, fukoksantin  
krizolaminarin, olja, **volutin** (polifosfat), tudi manitol  
stena: pod plazmalemo se zasnjuje kremenasta lupinica  
1-mnogo rjavih plastidov, velika vakuola  
vegetativno z delitvijo, nespolno: trajne spore ( $<N$ ), izo-  
ali oogamija ( $\rightarrow$  **avksozigota**), diplonti  
številni fakultativni heterotrofi  
**rafa**, gamete uniciliatne ali ameboidno gibljive  
kokalni (trihalni, kapsalni), 100.000 vrst!  
voda, vlažna zemlja, simbionti foraminifer  
kremenčev pesek, vodilni fosili



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## Heterokontophyta: Bacillariophyceae

### Pennales

$\pm$ dvobočno somerne

2 plastida

jedro v sredini

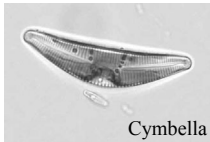
lahko razvita rafa

ni izrastkov

spolno: izogamija (2 ameboidni gameti)

zlasti sladkovodne

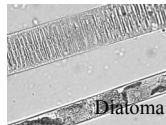
$>70$  M let morske, 60 M sladkovodne



Cymbella



Synedra



Diatoma

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## Heterokontophyta: Bacillariophyceae

### Centrales

$\pm$ radialno somerne

več plastidov

jedro ob steni

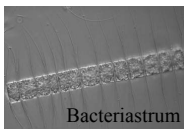
rafe ni

izrastki pogosti

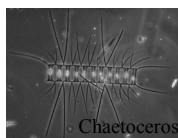
spolno: oogamija  
(spermatozoidi + jc)

zlasti morske

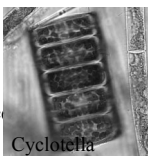
$>120$  M let (zgodnja kre



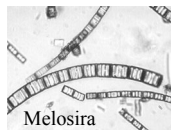
Bacteriastrium



Chaetoceros



Cyclotella



Melosira

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## Heterokontophyta: Bacillariophyceae

nadaljnja delitev:

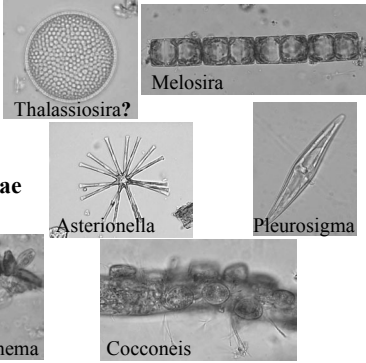
**Centrales**

**Pennales**

**Araphidineae**

**Monoraphidineae**

**Biraphidineae**



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## Heterokontophyta: Phaeophyceae

klorofil a, c,  $\beta$ -karoten ( $\alpha$ ), fukoksantin  
krizolaminarin, olja, manitol

stena znotraj celulozna, zunaj pektinska  
(sulfatirani polisaharidi (fukoidin) ter C

alginati (algin)), nikoli okremenjena  
nespolno razmnoževanje različni tipi spor,  
spolno  $\pm$ oogamija

gamete biciliatne, heterokontne, bička  
lateralno (!)

trihalni in parenhimatski, 2000 vrst  
predvsem morske, 5 rodov sladkovodni  
alginati, do 1930 J, prehrana



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## Heterokontophyta: Phaeophyceae

delitev:

>10 redov, npr.:

“Isogeneratae”

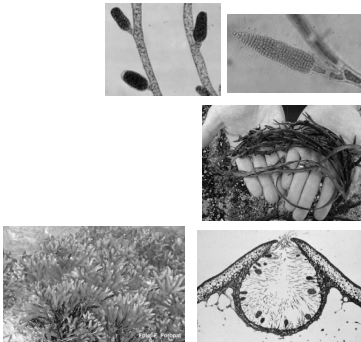
**Ectocarpales**

“Heterogeneratae”

**Laminariales**

“Cyclospora”

**Fucales**



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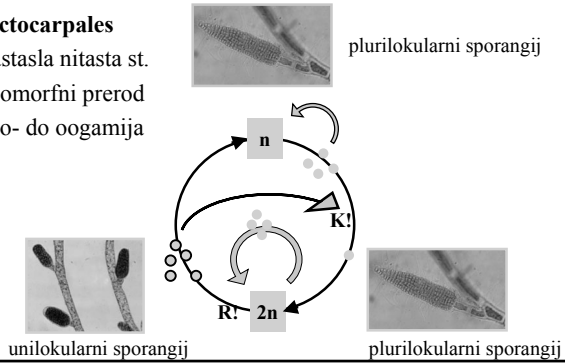
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## Heterokontophyta: Phaeophyceae

### Ectocarpales

rastasla nitasta st.  
izomorfni prered  
izo- do oogamija



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## Heterokontophyta: Phaeophyceae

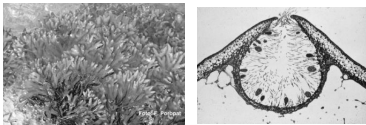
### Laminariales:

haplo diplonti  
sporofitska generacija  
prevladuje  
makro-/mikrotalus



### Fucales:

(psevo-)diplonti  
oogamija  
le makrotalus



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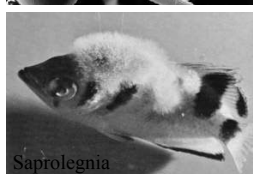
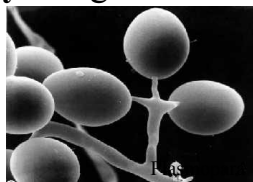
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## Heterokontophyta: "glive"

cl. Hyphochytridiomycetes  
cl. Labyrinthulomycetes  
cl. Oomycetes

plastidov ni  
drugotno heterotrofi  
trihalno/sifonalno organizirani  
heterokontne gibljive oblike



Saprolegnia

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## Heterokontophyta: Oomycetes

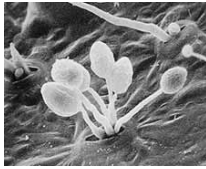
stena celulozna

gametangiogamija, zigota trajna, diplonti; nespolno: zoospore, sporangiji lahko kot aplanospore zoospore biciliatne, heterokontne, apikalno običkane

sifonalni

saprofiti na rastlinskem materialu, v vodi in na vlažnem, endoparaziti na rastlinah ali glivah

številne rastlinske bolezni(!), 500 vrst



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## Alge: Glaucophyta

**Glaucophyta:**

klorofil a (d?)

$\beta$ -karoten, ksantofili

fikobilini

škrob nastaja zunaj plastida

plastidi podobni koralnim modrozelenim cepljivkam

3 sladkovodne vrste bičkarjev



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## Alge: Rhodophyta 1

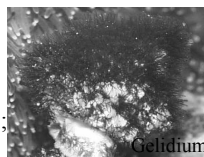
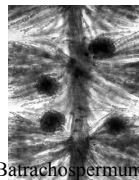
**Rhodophyta:** rdeče alge

klorofil a (d?),  $\alpha$ ,  $\beta$  karoten, ksantofili (lutein, zeaksantin), **fikobilina**

**floridejski škrob** (v citoplazmi), olja, **floridozid** (osmoregulacija!)

stena večplastna, celuloza + pektini (sulfatirani polisaharidi!), +  $\text{CaCO}_3$  plastidi preprosto zgrajeni (tilakoide proste), brez ER ovoja, rdečkasti

prerod lahko zapleten (dodatna sporofitska generacija: **gonimokarp**); oogamija



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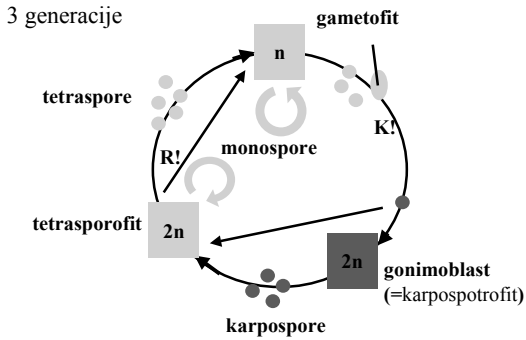
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## Alge: Rhodophyta 2




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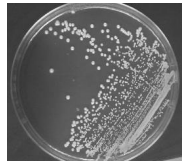
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## Alge: Rhodophyta 3

nespolno: **monospore (tetraspore)**  
večinoma diplonti, avtotrofi (heterotrofi)  
trihalni (kokalni)  
aktivno gibljivih oblik ni!, **spermaciji**  
goli



morske (obalno dno toplih morij), nekaj  
sladkovodnih; bentos, nekaj epifitov  
in (tudi heterotrofnih) ektoparazitov,  
>5000 vrst

vsaj 600 M let stari fosili

**agar, karagen, prehrana** (1 M t letno)




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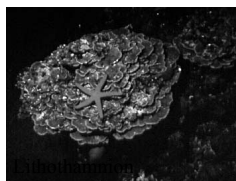
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## Alge: Rhodophyta

delitev:

cl. Bangiophyceae (4 o.)

cl. Florideophyceae (>10 o.)




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## Alge: **Rhodophyta: Bangiophyceae**

kokalni in trihalni

interkalarna/apikalna rast

**beljakovinski čepi** enostavni/0

plastidi pogosto zvezdasti, ležijo centralno

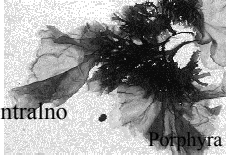
perod izo-/heteromorfni

spermogonij: več spermacijev, oogoniji brez trihogine, 1 j.c., **gonimokarpa** ni

zigota → 4-32 karpospor → tetrasporofit (*Conchocelis* stadij pri rodu *Porphyra*)

tetrasporofit → monospore → (R!) → gametofit

številne vrste z monofaznim heteromornim prerodom!



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## Alge: **Rhodophyta: Florideophyceae**

pogosto psevdoparenhimatske tvorbe

celice lahko polienergidne

rast predvsem apikalna

**beljakovinski čepi** vedno razviti, različni

plastidi v glavnem ležijo ob steni

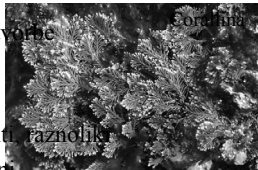
pretežno haplodiplonti, izo- ali heteromorfni prerod

**trihogine** razvite

oplojeni karpogonij se razvije v diploidni **gonimoblast**

(=karposporofit) → karpospore → tetrasporofit → R! →

tetraspore → gametofit



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## Alge: **Rhodophyta: Florideophyceae**

**uniaksialni** in **multiaksialni** (=fontanski) tip razrasti

nista vedno jasno različna

velika plastičnost pri izmeni generacij, zlasti znotraj diploidnih generacij

lahko razvite **pomožne celice**: na poganjkih vzporednih karpogonijalnim, v celice se preseli diploidno jedro zigote in gonimoblast se razvije iz njih

>10 redov, obravnavamo 2

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## Alge: **Rhodophyta**: Florideophyceae

### o. Batrachospermales

oba tipa steljke

R! v apikalni celici tetrasporofita (!),  
prava **metageneza!**

**pomožne celice** niso razvite

heterofazni heteromorfni haplodiplonti

sporofit mikrotalus ("*Chantransia*"  
stadij), gametofit makrotalus, ostane  
pritrjen na sporofit

sladkovodni



Batrachospermum

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## Alge: **Rhodophyta**: Florideophyceae

### o. Corallinales

inkrustacija z apnencem

multiaksialna steljka

tetrasporangiji v **konceptaklih**

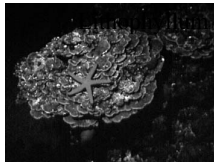
**nadomestne celice** pri dnu karpogonijalnih poganjkov

po oploditvi se zlije več nadomestnih celic v

polienergidno celico, ki se razraša v gonimoblast

izomorfnih haplodiplonti

rast z apikalnimi celicami, tudi interkalarna, traksialno se  
razvijajo **beljakovinski čepi** med plastidami



Corallina

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## Alge: **Chlorophyta 1**

Chlorophyta: zelene alge

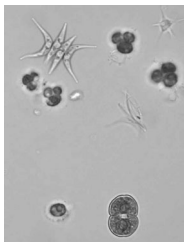
klorofila a, b (c),  $\beta$  ( $\alpha$ ,  $\chi$ ) karoten,  
ksantofili (**lutein...**)

škrob (v plastidih), redkeje fruktan  
(inulin?), olja

stena: celuloza + pektini (glikoproteini,  
sporopolenin); nastaja zunaj  
plazmaleme (kot pri višjih rastlinah)

plastidi zeleni, s **pirenoidi**, le z dvojno  
membrano

stigma na plastidu



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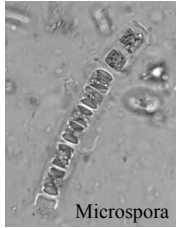
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## Alge: Chlorophyta 2

razmnoževanje: različni tipi spolnega, nespolnega in vegetativnega razmnoževanja ter preroda, večinoma **haplonti**, malo haplo diplontov

avtotrofi

biciliatni (tetra-, poli-), akrokontni, izokontni, (redke gamete ameboidno gibljive), flagelarni aparat sistematsko pomemben!



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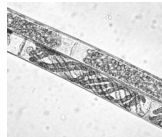
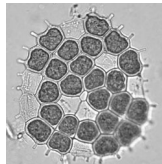
## Alge: Chlorophyta 3

vsi organizacijski nivoji razen pravega parenhimatskega

vodni, nekaj skupin (večina vrst!) sladkovodnih, več morskih, nekaj vrst kopenskih in epifitskih

okoli 10000 vrst

predniki višjih rastlin, tvorba lehnjaka, prehrana (*Ulvales*)



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## Alge: Chlorophyta

delitev: tradicionalna

delitev: sodobna

cl. **Chlorophyceae** (več o.)

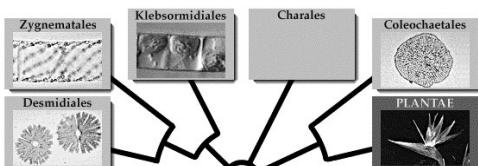
- flagelarni aparat

cl. **Zygnemophyceae** (2 o.)

- mitoza

cl. **Charophyceae** (1 o.)

- citokineza



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# Alge: Chlorophyta

## Težave z delitvijo:

- filogenetsko zelo pomembna skupina
- veliko raziskovalcev
- postopno kopičenje novih spoznanj na ultrastrukturnem nivoju
- različne možne interpretacije evolucije
- različni načini klasificiranja
  - kladistika/fenetika
  - cepilci (splitters)/lepilci (lumpers)
- ekonomsko razmeroma nepomembna skupina

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# Alge: Chlorophyta

## Lee 1999:

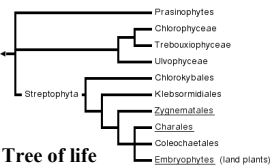
### ph. Chlorophyta

- cl. Micromonadophyceae
- cl. Chlorophyceae
- cl. Ulvophyceae
- cl. Charophyceae

## Strassburger 2002:

### subr. Chlorobionta (=Viridiplantae)

- ph. Chlorophyta (9 cl.)
- ph. Streptophyta
  - sph. Streptophytina (4 cl.)
  - sph. Bryophytina
  - sph. Pteridophytina
  - sph. Spermatophytina



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# Alge: Chlorophyta

## Kompromis:

### ph. Chlorophyta

#### subph. Chlorophytina

- cl. Chlorophyceae [s.str.] (4 o.)
- cl. Ulvophyceae (2 o.)
- cl. Cladophorophyceae (1 o.)
- cl. Bryopsidophyceae (2 o.)
- cl. Dasycladophyceae (1 o.)
- cl. Trentepohliophyceae (1 o.)
- ...

#### subph. Streptophytina

- cl. Klebsormidiophyceae (1 o.)
- cl. Zygnematophyceae (2 o.)
- cl. Charophyceae (1 o.)

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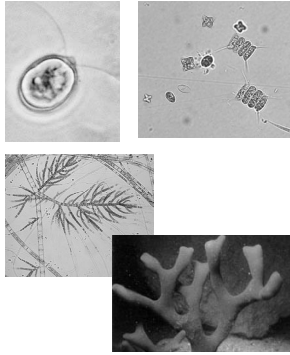
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## Alge: **Chlorophyta**: Chlorophytina

vsi organizacijski nivoji  
citokineza: **fikoplasti**  
različne oblike spolnega  
razmnoževanja  
običkanost akrokontna  
7000 vrst  
predvsem sladke vode



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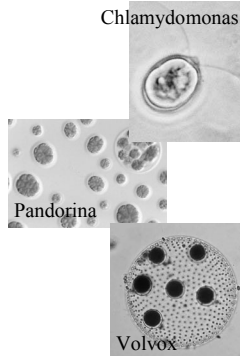
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## Alge: **Chlorophyta**: Chlorophytina

cl. Chlorophyceae [s. str.]  
o. Volvocales  
celice običkane  
brez celulozne stene  
kontraktilni vakuoli, stigma,  
člašast kloroplast  
spolnega razmn. pestro,  
**hipnozigota**  
nespolno: **avtospore**, gonidiji  
1000 vrst, mezotrofne sladke  
vode



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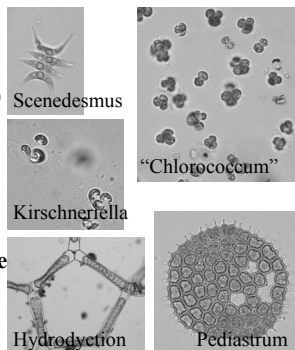
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## Alge: **Chlorophyta**: Chlorophytina

cl. Chlorophyceae  
o. Chlorococcales  
kokalne (trihalne, sifonalne)  
stena, kloroplast s  
pirenoidom  
običkane le gamete/spore  
izo- do oogamija  
aplano-/zoospore, **avtospore**  
plankton, bentos, simbionti  
1000 sladkovodnih vrst



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## Alge: **Chlorophyta**: Chlorophytina

### cl. Chlorophyceae

- o. Chaetophorales [s. str.]

trihalne, heterotrihne, 1 kpl  
spolno razmn. različno

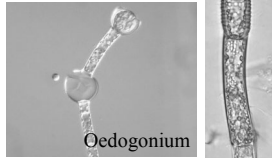
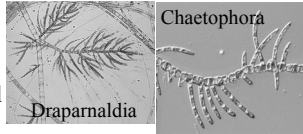
±epifitsko v sl. Vodi, 100 vrst

- o. Oedogoniales

trihalne, mrežast kloroplast  
oogamija, haplonti

**stefanokontne** giblj. oblike

550 vrst, ±evtrofne sl. vode



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## Alge: **Chlorophyta**: Chlorophytina

### cl. Ulvophyceae

kokalne, trihalne (sifonokl.)

kpl trakasti/valjasti

plazmodezme manjkajo

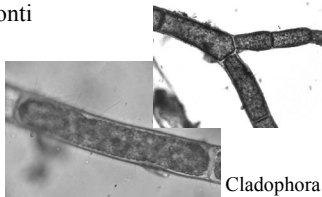
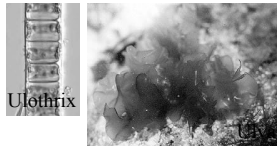
haplonti/izom. haplodiaplonti

±morske, 250 vrst

- o. Ulothricales
- o. Ulvales

### cl. **Cladophorophyceae**

- o. Cladophorales



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## Alge: **Chlorophyta**: Chlorophytina

### cl. **Bryopsidophyceae** (=Siphoneae)

sifonalne, navidez parenhimatske

bi-/tetra-/policiliatne, sifonoksantin

hapl(odipl)onti (!), anizogamija

morski

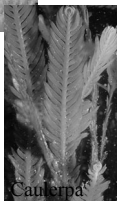
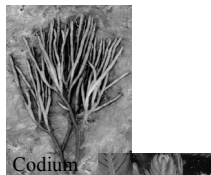
- o. Bryopsidales

homoplastidni, ni holokarpije, stefanokontni,  
zigota trihalna

- o. Halimadales

heteroplastidni, holokarpija, ni

stefanokontov, zigota=**protosfera**



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## Alge: **Chlorophyta**: Chlorophytina

### cl. **Dasycladophyceae**

= o. Dasycladales

stena: manan+CaCO<sub>3</sub>

haplonti, "metageneza"

morski



### cl. **Trentepohliophyceae**

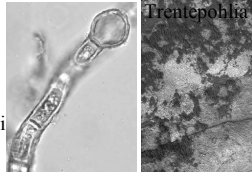
= o. Trentepohliales

trihalni, sporopolenin

poseben flagelarni aparat

hematokrom, polihidroksi alkoholi

haplodiaplonti, ≠kopenski, 60 vrst



Trentepohlia

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## Alge: **Chlorophyta**: Streptophytina

kokalni in trihalni  
organizacijski nivo

gametangiji pogosto s  
sterilnim ovojem

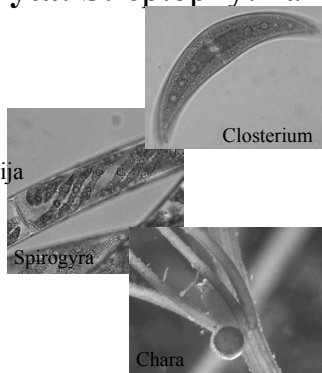
oogamija, lahko konjugacija

običkanost lateralna ali  
manjka

citokineza: **fragmoplasti**

~ 6000 vrst

sladke vode



Closterium

Spirogyra

Chara

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## Alge: **Chlorophyta**: Streptophytina

### cl. **Klebsormidiophyceae**

(=Coleochaetophyceae)

trihalni (kokalni)

1 kpl s pirenoidom

zoospore gole, luskaste

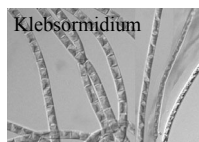
izogamija-oogamija, **hipnozigota**

oogonij s trihogino

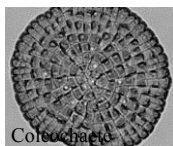
oplojen oogonij lahko obrasel,

trajen (**spermokarp**)

kopenske ali sladkovodne, epifiti



Klebsormidium



Coleochaete

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## Alge: Chlorophyta: Streptophytina

### cl. Zygnematomyceae: jarmaste alge

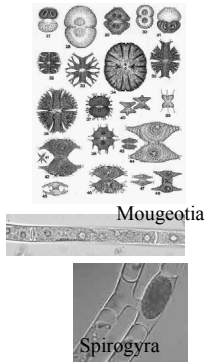
stena zaslužena, lahko polzijo  
ni običajnih stadijev  
konjugacija → hipnozigota  
sladkovodne

#### o. Desmidiatales: lepotke

kokalne, stena dvodelna  
redko izogamija

#### o. Zygnematales: jarmovke

nitaste (kokalne), stena enodelna  
izo- do oogamija



Mougeotia

Spirogyra

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## Alge: Chlorophyta: Streptophytina

### cl. Charophyceae: parožnice

kompleksna trihalna organizacija

eno- → večjedne celice

številni kpl brez pirenoida, vakuola

vegetativno, ni nespolnega!

oogamija, haplonti

gametangiji z ovojem

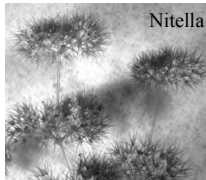
hipnozigota

“zakoreninjene”

sladkovodne, ~100 vrst, >400 M let



Chara



Nitella

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## Alge: pregled

### Streptophytina: značilnosti višjih rastlin

- lateralna subapikalna namestitve bičkov zooidov
- tip mitoze in citokineze
- zgradba stene
- nastajanje celuloznih mikrofibril
- DNA

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