

# Myxobakterie

Bioaktivní sekundární metabolity

- G- tyčinky, půdní bakterie, degradace MML
- řád *Myxococcales*, Deltaproteobacteria
- klouzavý pohyb (gliding motility)
- komplexní růstový cyklus s tvorbou plodnic a klidových stádií – myxospor
- nejprostudovanější druhy

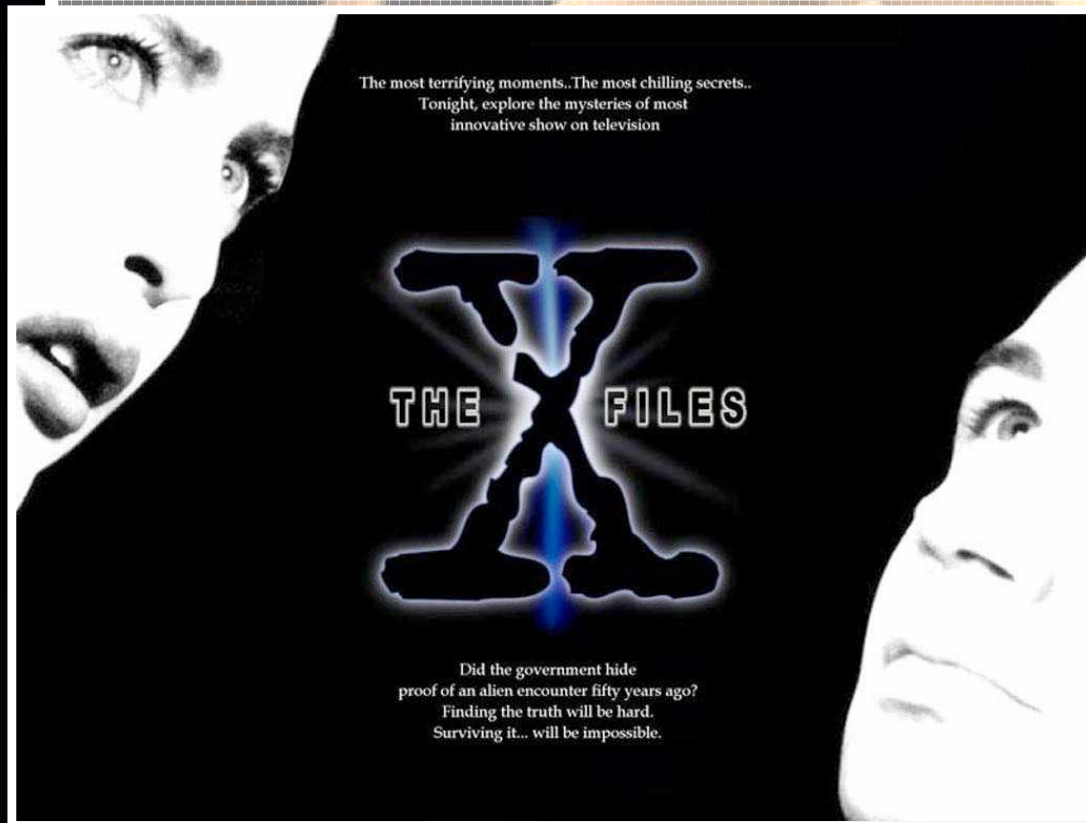
*Myxococcus xanthus* a *Stigmatella aurantiaca*



Bdellovibrio  
Desulfovibrio  
Desulfonema



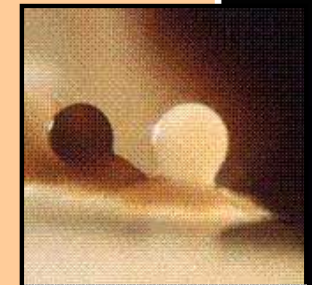
- **Intenzivní studium tajemství  
mezibuněčné komunikace a následné  
diferenciace**



- Následkem klouzavého pohybu roste v koloniích podobných **tenkých filmům**
- Hladovění: **kooperativní morfogeneze**
  - shluk veg.buněk tvoří **plodnice**
  - plodnice – 50-500  $\mu\text{m}$ , viditelné
- Zráním plodnice: diferenciací vedoucí k tvorbě **myxospor z veg. buněk**
- Myxospory – krátké refraktilní buňky, s obsahem tuku, rezistentní k vysychání, UV  
přežívání prokázáno 10 let



*Stigmatella  
aurantiaca*



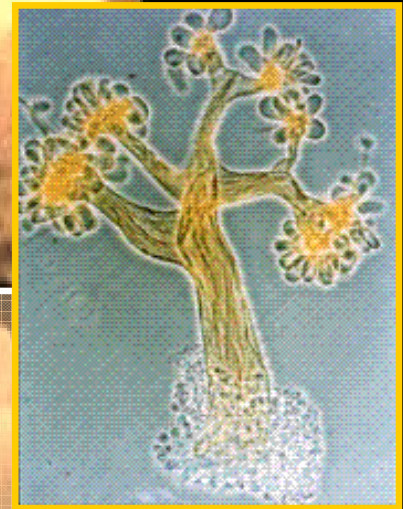
*Myxococcus  
fulvus*



*Myxococcus  
stipitatus*

# Růst a vývoj

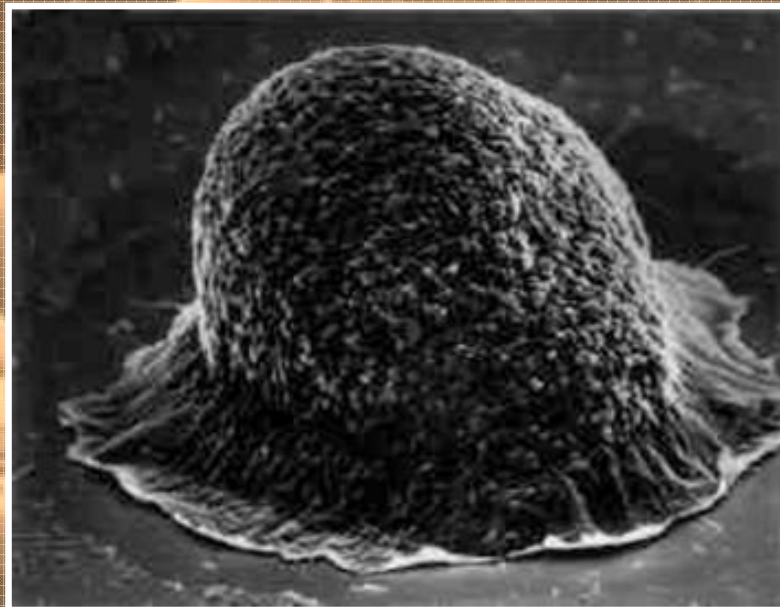
- Souborem interakcí mezi buňkami
- "social bacteria"
- Genom: 9 454 000 – 9 870 000 bp



*Chondromyces  
crocatus*



Studium  
genetiky  
diferenciace  
prokaryot,  
fágů,  
myxofágů



# Výskyt

Mikropredátoři, saprofágové.

Rozkládají buněčný materiál kvasinek,  
Bakterií, celulózu.

Tlející kůra, listí, exkrementy býložravců.

## Substrate

## Myxobacterial species typically found<sup>b</sup>

Soil

*Nannocystis exedens*,<sup>5</sup> *Sorangium cellulosum*,<sup>4</sup> *Archangium serpens*,<sup>4</sup> *Corallococcus coralloides*,<sup>4</sup> *Polyangium* spp.,<sup>3</sup> *Cystobacter* spp.,<sup>3</sup> *Melittangium* spp.,<sup>3</sup> *Myxococcus fulvus*,<sup>2</sup> *Mx. virescens*,<sup>2</sup> and *Mx. stipitatus*<sup>2</sup>

Dung of herbivores

*Myxococcus fulvus*,<sup>5</sup> *Corallococcus coralloides*,<sup>5</sup> *Mx. virescens*,<sup>4</sup> *Cystobacter fuscus*,<sup>4</sup> *Cb. ferrugineus*,<sup>4</sup> *Archangium serpens*,<sup>4</sup> *Nannocystis exedens*,<sup>3</sup> *Cb. violaceus*,<sup>3</sup> *Polyangium* spp.,<sup>3</sup> *Stigmatella erecta*,<sup>2</sup> *Mx. xanthus*,<sup>2</sup> *Melittangium* spp.,<sup>2</sup> and *Cb. velatus*<sup>1</sup>

Bark and rotting wood

*Stigmatella aurantiaca*,<sup>4</sup> *Chondromyces apiculatus*,<sup>4</sup> *Sorangium cellulosum*,<sup>4</sup> *Corallococcus coralloides*,<sup>4</sup> *Myxococcus fulvus*,<sup>3</sup> *Cm. pediculatus*,<sup>2</sup> and *Haploangium* spp.<sup>2</sup>

<sup>a</sup> The frequency of myxobacteria on a specific substrate may vary substantially in different environments. Furthermore, some species may be underestimated from a particular source because the isolation technique usually applied may not result in the isolation of a particular organism.

<sup>b</sup> Frequency of the encountered species: <sup>5</sup>, ubiquitous; <sup>4</sup>, very frequent; <sup>3</sup>, moderately frequent; <sup>2</sup>, relatively rare; and <sup>1</sup>, rare.

# Taxonomie

Order: Myxococcales

**Suborder: Cystobacterineae**

Families and genera:

Myxococcaceae

*Myxococcus*

*Corallococcus* (formerly *Chondrococcus*)<sup>2</sup>

*Pyxicoccus* nov. gen.<sup>b</sup>

Cystobacteraceae

*Archangium*

*Cystobacter*

*Melittangium*

*Stigmatella*

*Hyalangium* nov. gen.<sup>b</sup>

**Suborder: Sorangineae**

Families and genera:

Polyangiaceae

*Sorangium*

*Polyangium*

*Haploangium*

*Chondromyces*

*Byssophaga* nov. gen.<sup>b</sup>

*Jahnia* nov. gen.<sup>b</sup>

**Suborder: Nannocystineae**

Families and genera

Nannocystaceae

*Nannocystis*

Kofleriaceae

*Kofleria* nov. gen.<sup>b</sup>

*Haliangium* nov. gen.<sup>b</sup>

<sup>a</sup> Three recently described and unusual genera, *Anaeromyxobacter* (<citeref rid="sanford2002">Sanford et al., 2002</citeref>), *Enhygromyxa* (<citeref rid="iizuka2003b">Iizuka et al. 2003b</citeref>), and *Plestiocystis* (<citeref rid="iizuka2003a">Iizuka et al., 2003a</citeref>), are missing from Table 3 and the illustrated key (Fig. 15) because they have not yet been characterized thoroughly enough to accurately place them in this taxonomic scheme.

<sup>b</sup> These novel genera are validly described in <citeref rid="reichenbach2004">Reichenbach (2004)</citeref>.

# Morfologie myxobakterií

- Vegetativní buňky – 0,5–1 $\mu\text{m}$  x 3-8  $\mu\text{m}$ 
  - štíhlé se špičatými konci (*Cystobacterinae*)
  - robustní s kulatými konci (*Soranginae*)
- Plodnice – 50 – 500  $\mu\text{m}$ 
  - často pestře zbarvené – karotenoidní pigmenty
  - různého tvaru a složitosti
- Spory – zkrácené ztlustělé buňky

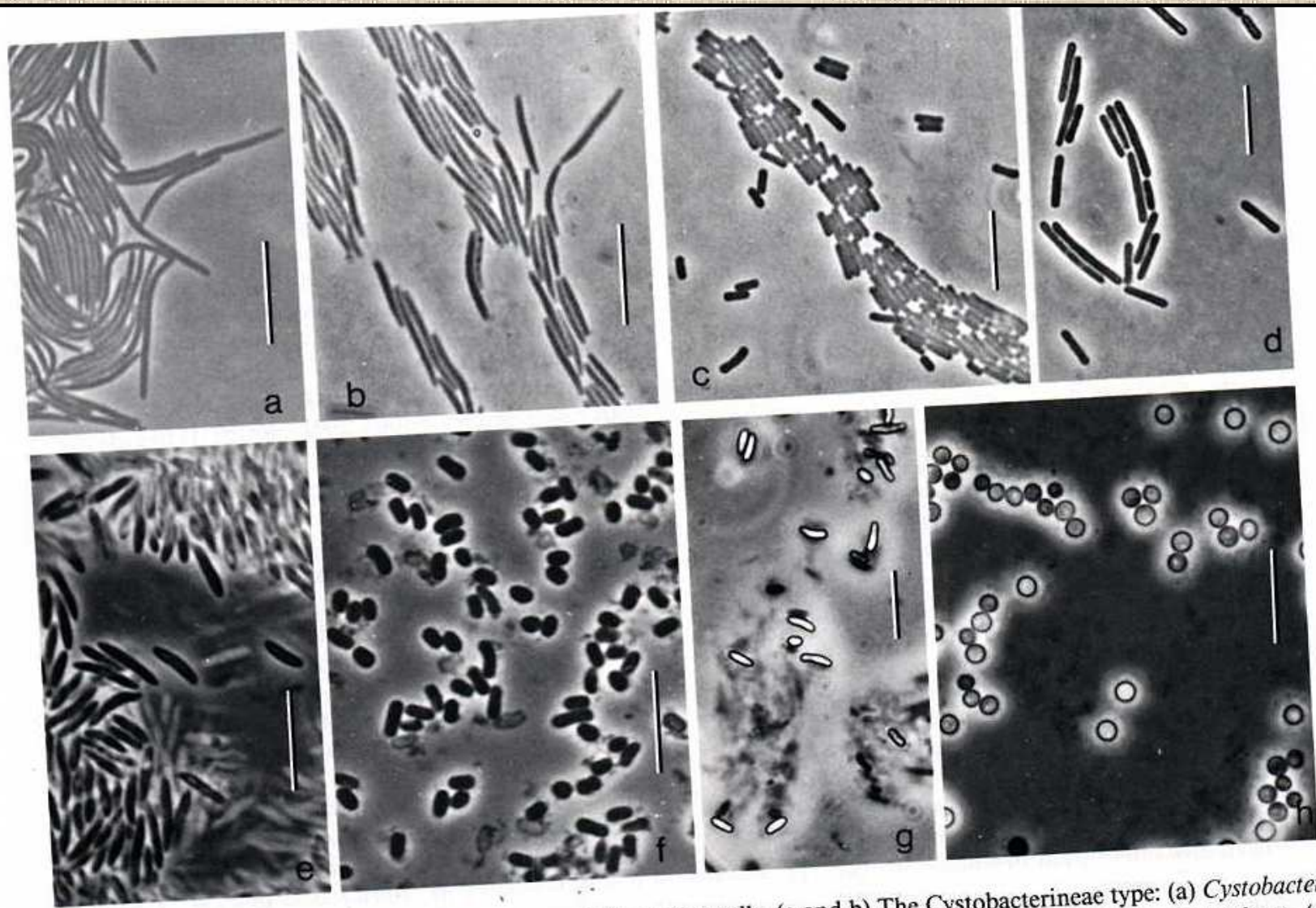


Fig. 1. Various types of myxobacterial cells. (a to d) Vegetative cells. (a and b) The Cystobacterineae type: (a) *Cystobacter ferrugineus*, cells from a liquid culture. (b) *Stigmatella aurantiaca*, cells in situ on agar surface in a chamber culture. (c and d) The Sorangineae type. (c) *Chondromyces crocatus* in a chamber culture. (d) *Sorangium compositum* in a chamber culture. (e to h) Myxospores of members of the Cystobacterineae. (e) Myxospores of *Cystobacter ferrugineus*, from a crushed, degenerated, *Archangium*-like, fruiting body; under oil immersion, the high optical refractility of the myxospores is not apparent. (f) Myxospores of *Cystobacter velatus* from a crushed fruiting body sporangiole; oil immersion. (g) Experimentally induced myxospores of *Stigmatella aurantiaca* on the agar surface in a chamber culture; under the 40 $\times$  dry objective, the high optical refractility of the myxospores becomes very conspicuous. (h) Myxospores from a *Myxococcus xanthus* fruiting body; the optical refractility of these spherical myxospores is so high that it is recognizable even under oil immersion. All photographs are in phase contrast. Bars = 10  $\mu$ m.



# Životní cyklus myxobakterií

- Vegetativní buňky – sliz, klouzavý pohyb, binární dělení, tvorba shluků a koordinovaný pohyb
  - pohyb za novým zdrojem živin – slizové cestičky
- Tvorba plodnic – shlukování a diferenciacce
  - Impuls: vyčerpání živin, laboratoř: 0,5M glycerol
- Tvorba myxospor z někt. veg. Buněk uvnitř plodnic
  - indukce – chemicky
  - primárně – v plodnicích – uzavřeny ve sporangiolech, zkrácené ztluštěné buňky

# TVORBA PLODNIC MYXOBAKTERIÍ

Plodnice: několik mm.

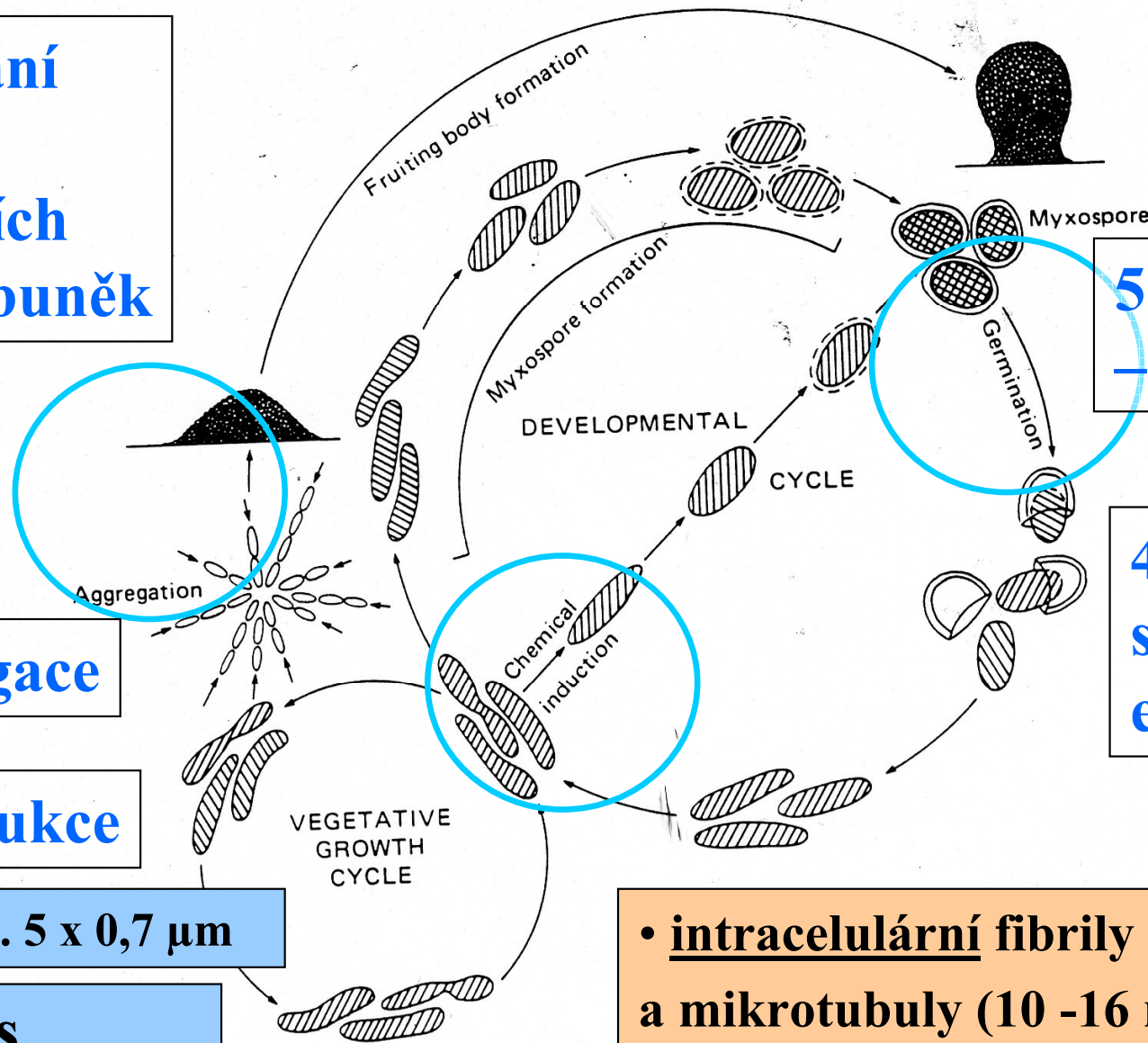
3. vylučování  
molekul  
umožňujících  
propojení buněk

2. agregace

1. indukce

veg.b. 5 x 0,7 μm

**Život.cyklos**  
*Myxococcus xanthus*  
veg.b. 5 x 0,7 μm



5. maturace  
– myxospory

4. speciální  
strukturní  
elementy

- intracelulární fibrily (4 – 6 nm)  
a mikrotubuly (10 -16 nm)
- spirálovité pásy na povrchu buňky
- slizovité materiály - fibrily

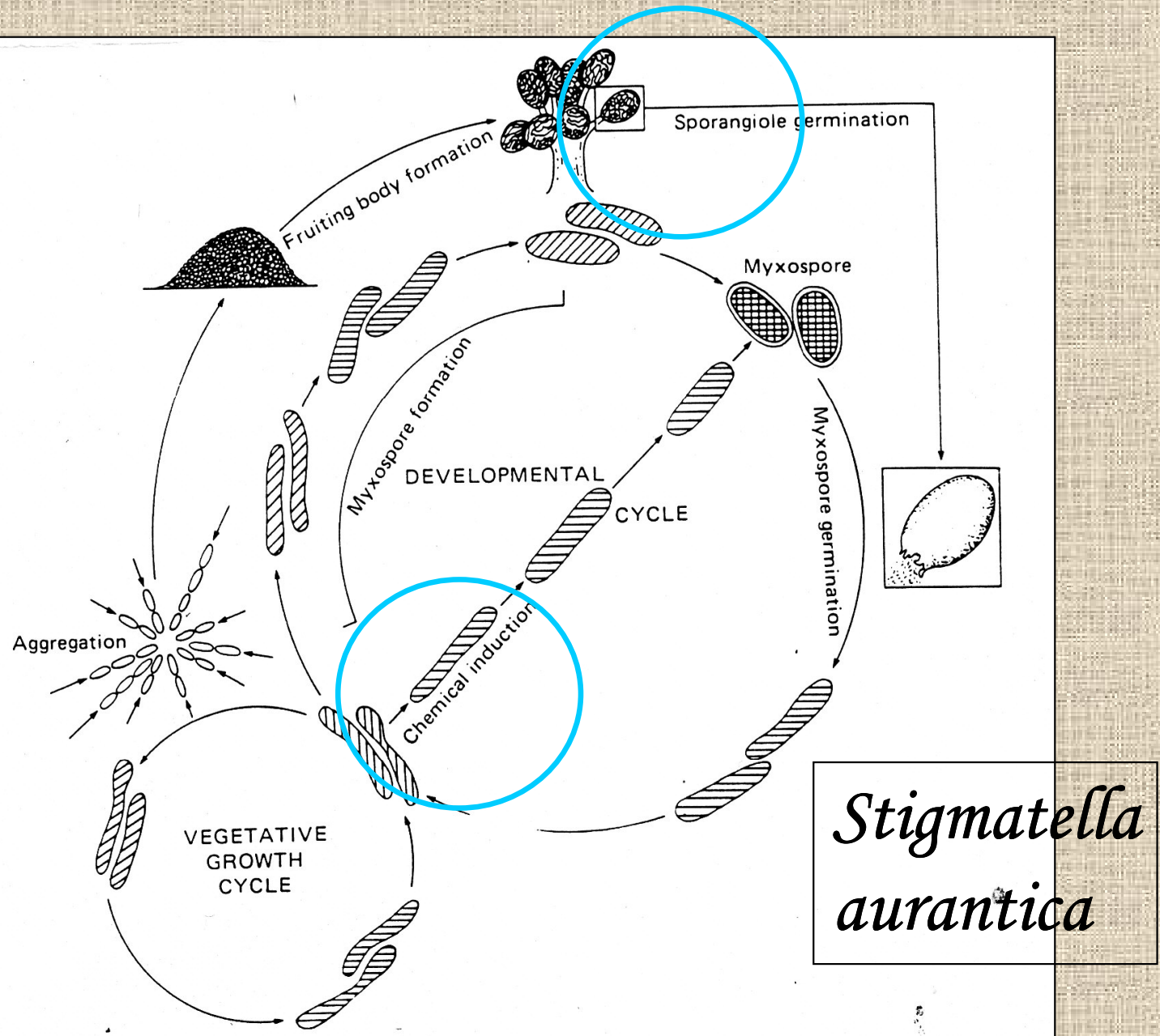


Fig. 27. Diagram of the life cycle of *Stigmatella aurantiaca*. (From Dworkin, 1985.)

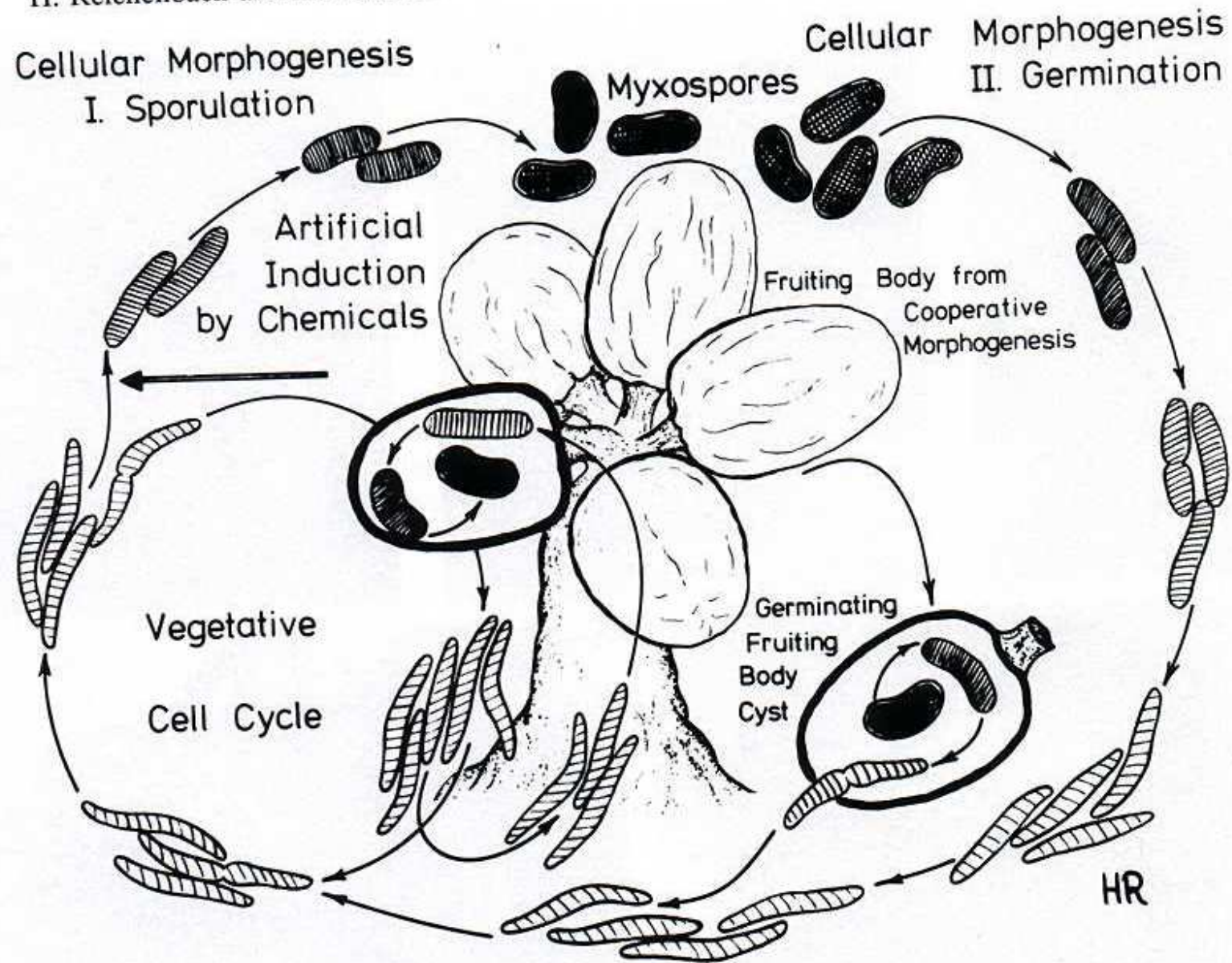


Fig. 3. Cellular morphogenesis in myxobacteria, shown with *Stigmatella aurantiaca* as an example. Fruiting body and cells are not drawn to scale. (From Gerth and Reichenbach, 1978.)

# Plodnice

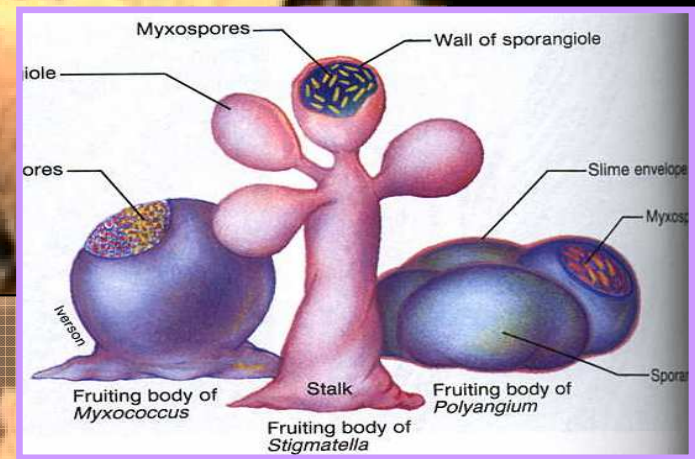
tvorěny

- A. měkkou sliz. Strukturou - *Archangium*
- B. tuhou slizovitou strukturou - *Cystobacter*

Sporangioly

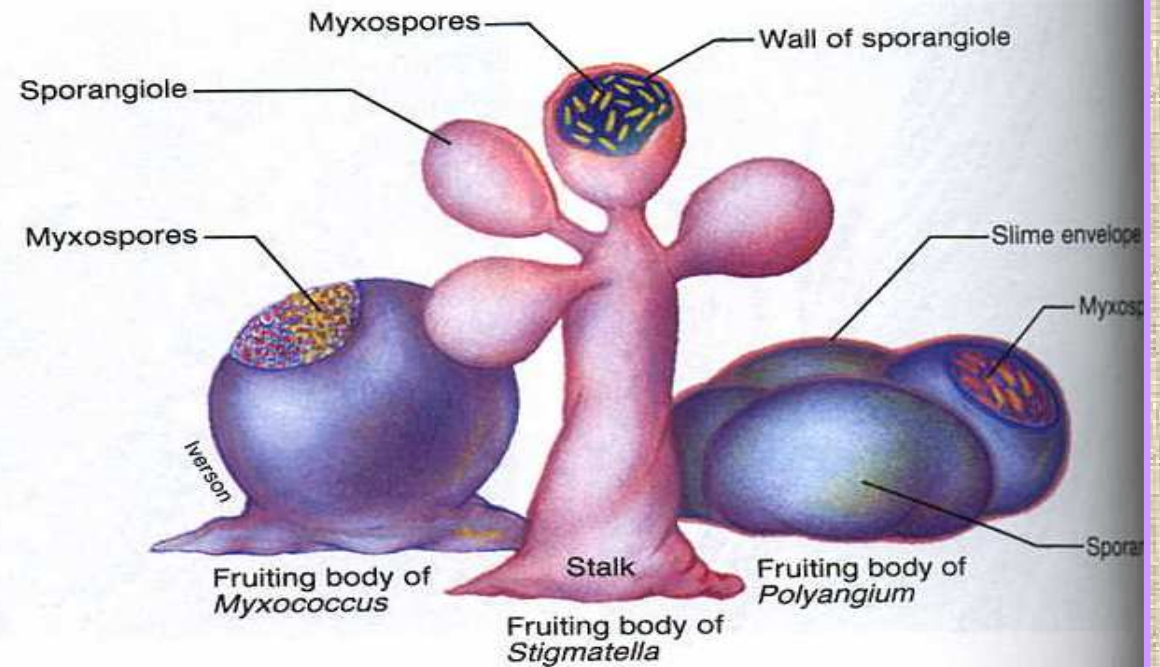
- 1. rostou přímo na substrátu
- 2. vybavené stopkou

- Sporangiole jednotlivě nebo ve shlucích
- Sporangiole přímo na substrátu nebo v něm
- Sporangiole na stopce



**Figure 22.28 Myxobacterial Fruiting Bodies.**  
 (a) An illustration of typical fruiting body structure.  
 (b) *Myxococcus fulvus*. Fruiting bodies are about 150–400  $\mu\text{m}$  high.  
 (c) *Myxococcus stipitatus*. The stalk is as tall as 200  $\mu\text{m}$ .  
 (d) *Chondromyces crocatus* viewed with the SEM. The stalk may reach 700  $\mu\text{m}$  or more in height.

Plodnice a jejich struktura



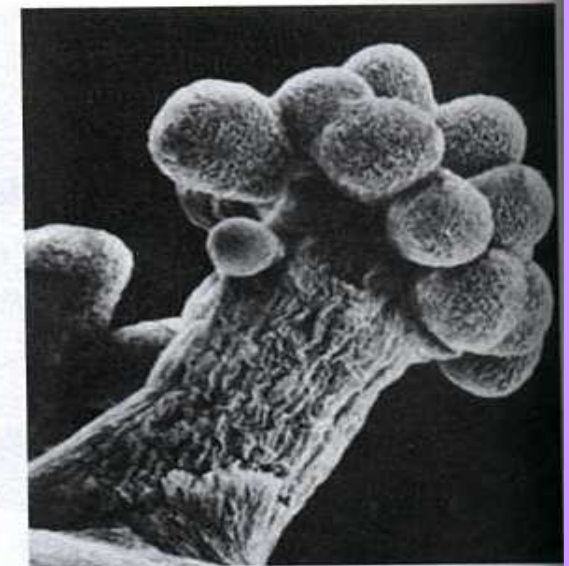
(a)



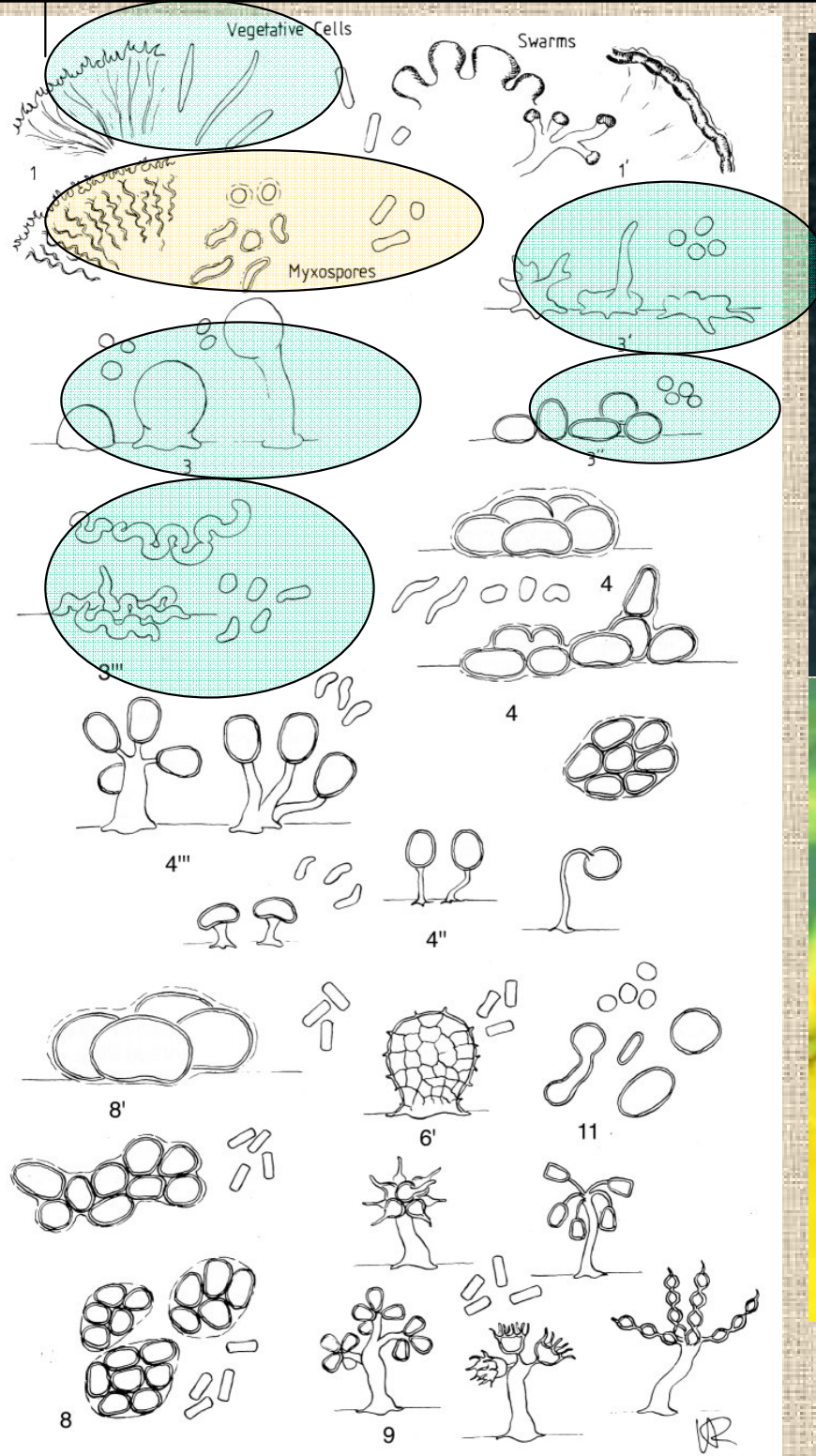
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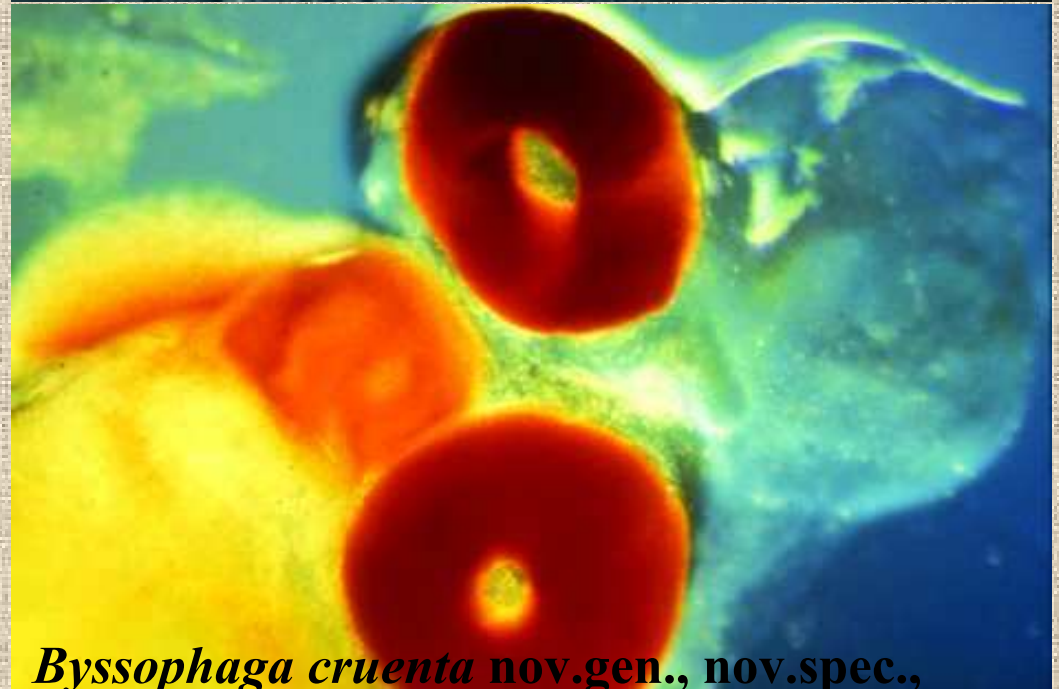
(c)



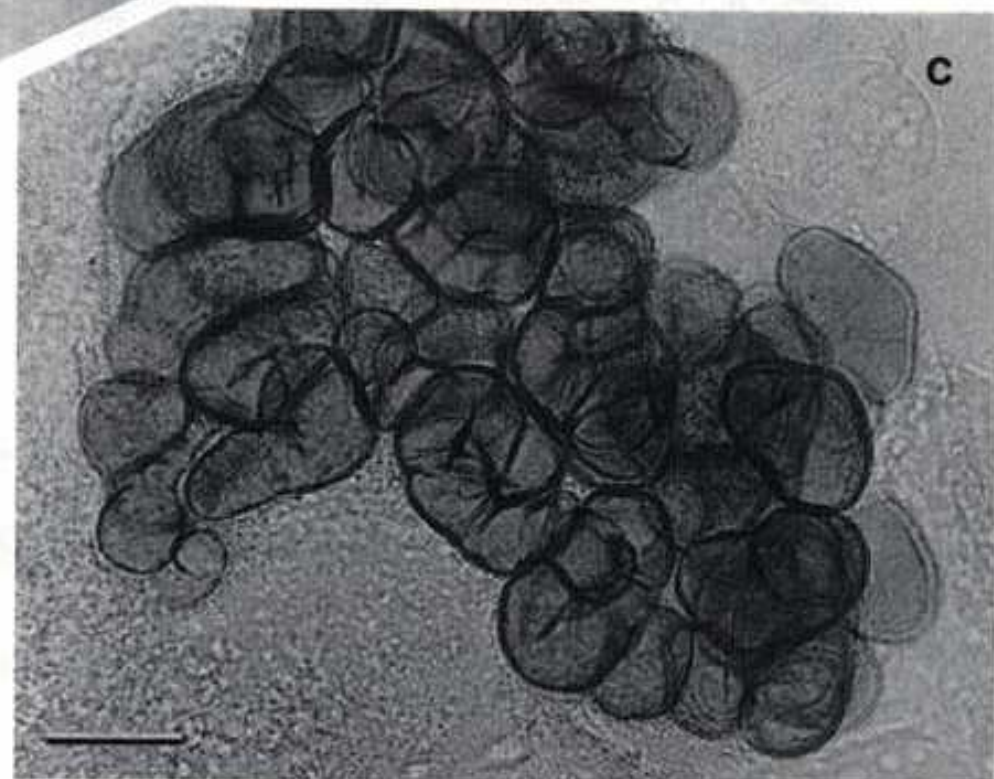
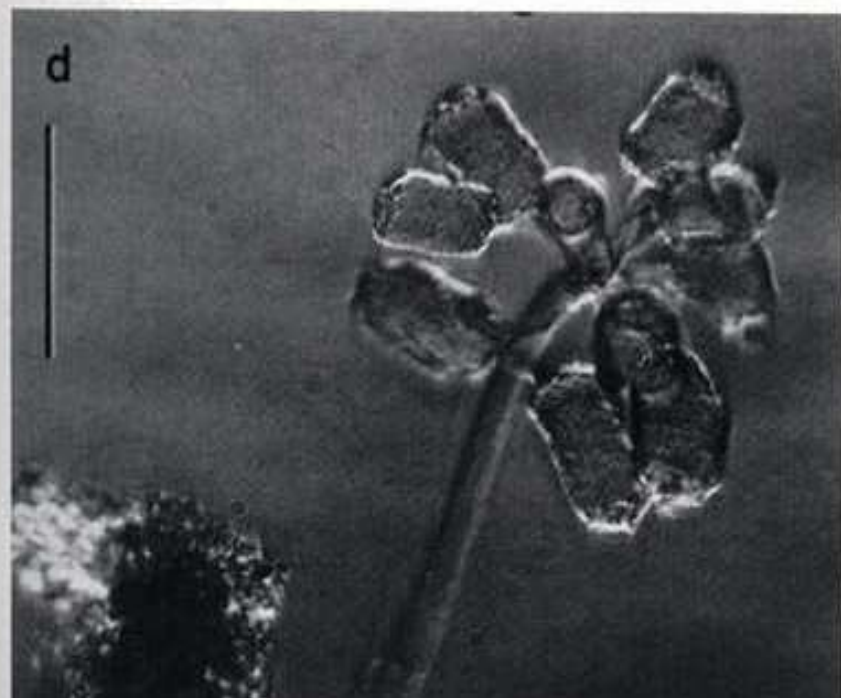
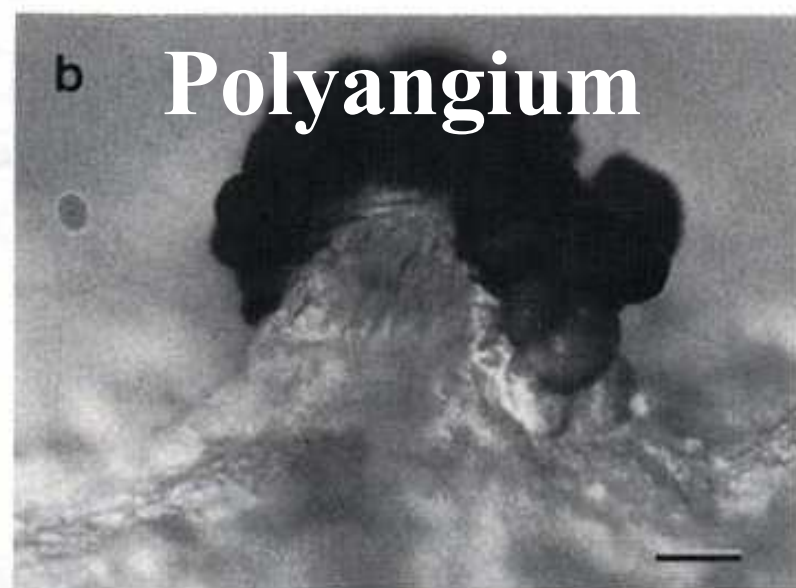
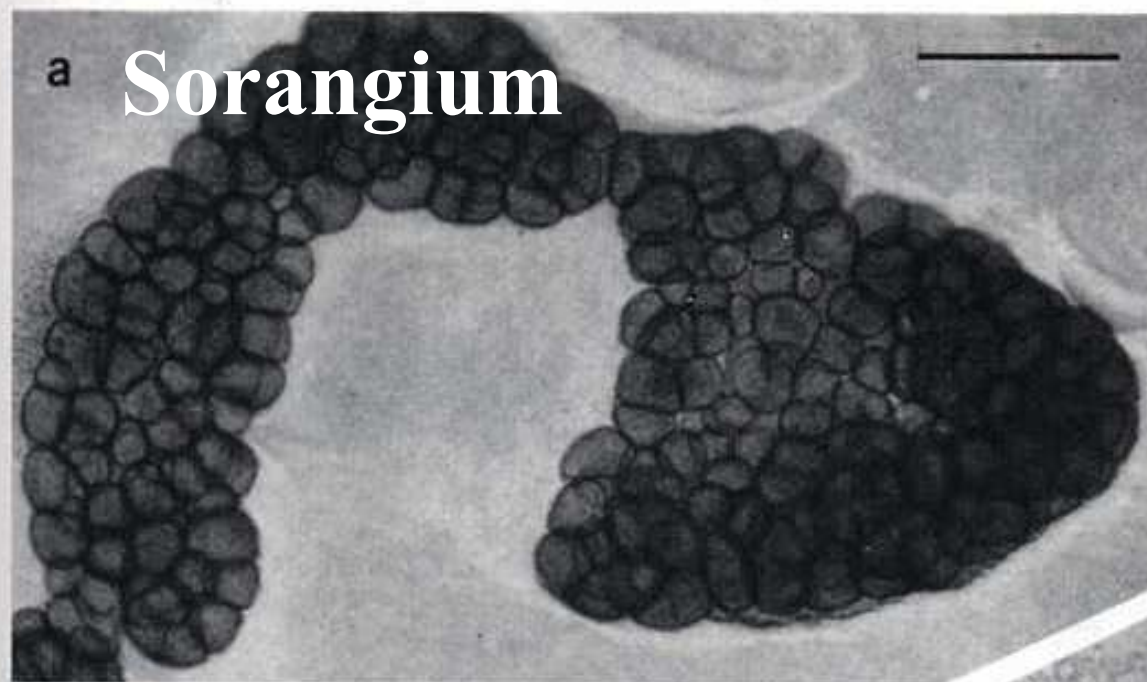
(d)



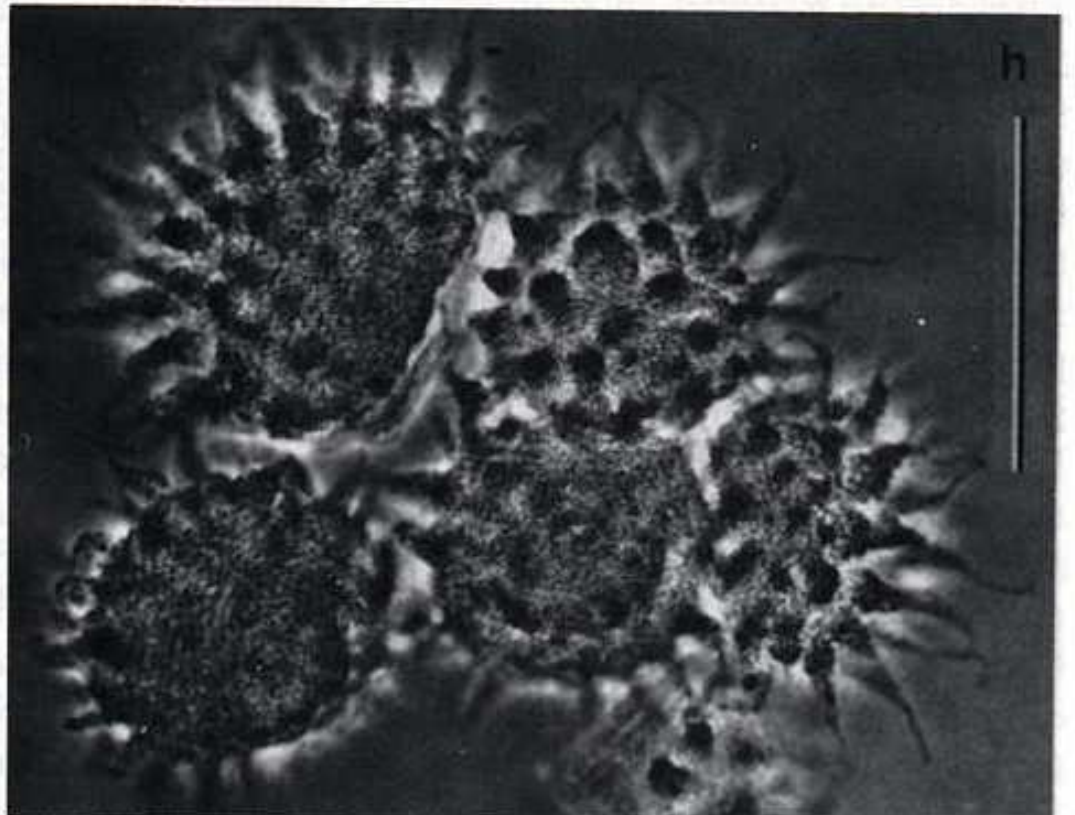
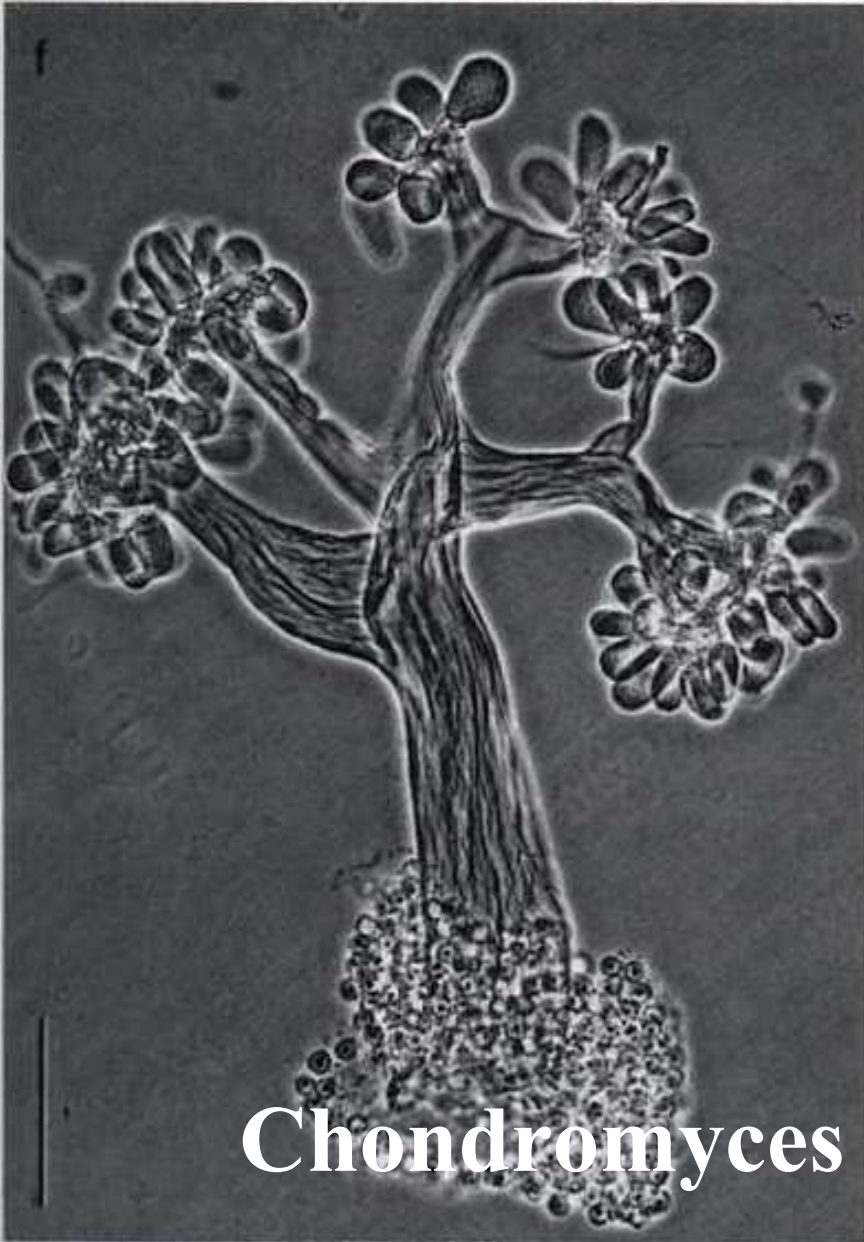
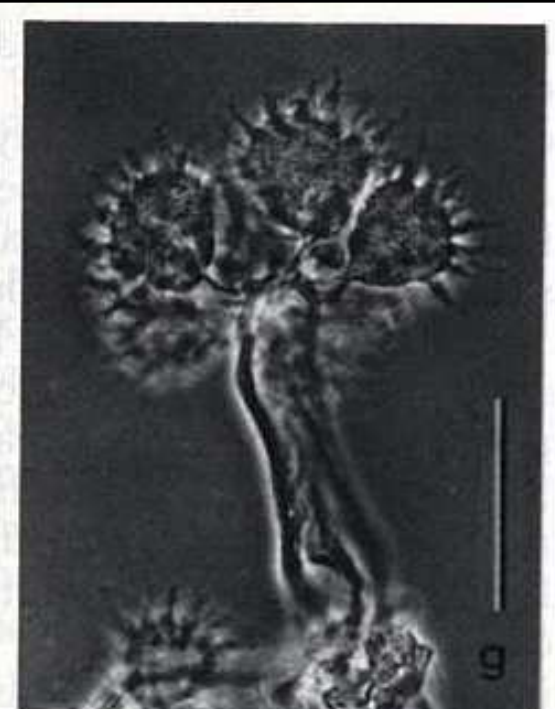
*Pyxicoccus fallax* nov.gen., nov.spec.,  
fruiting body in slide mount at high  
magnification showing sporangioles  
with clear walls



*Byssophaga cruenta* nov.gen., nov.spec.,  
strain By c2 (type strain), cells assembled  
in massive rings on the agar surface







**Chondromyces**

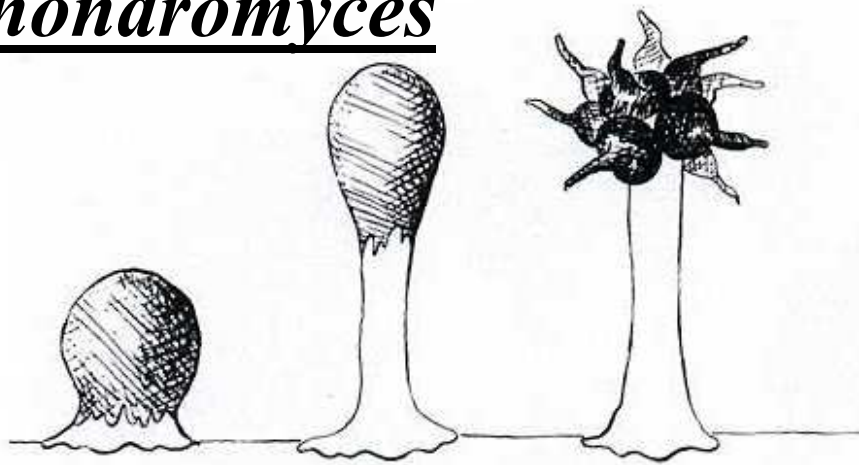
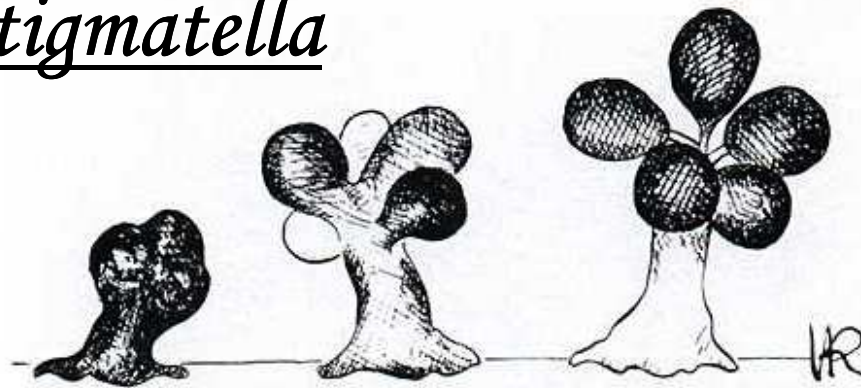
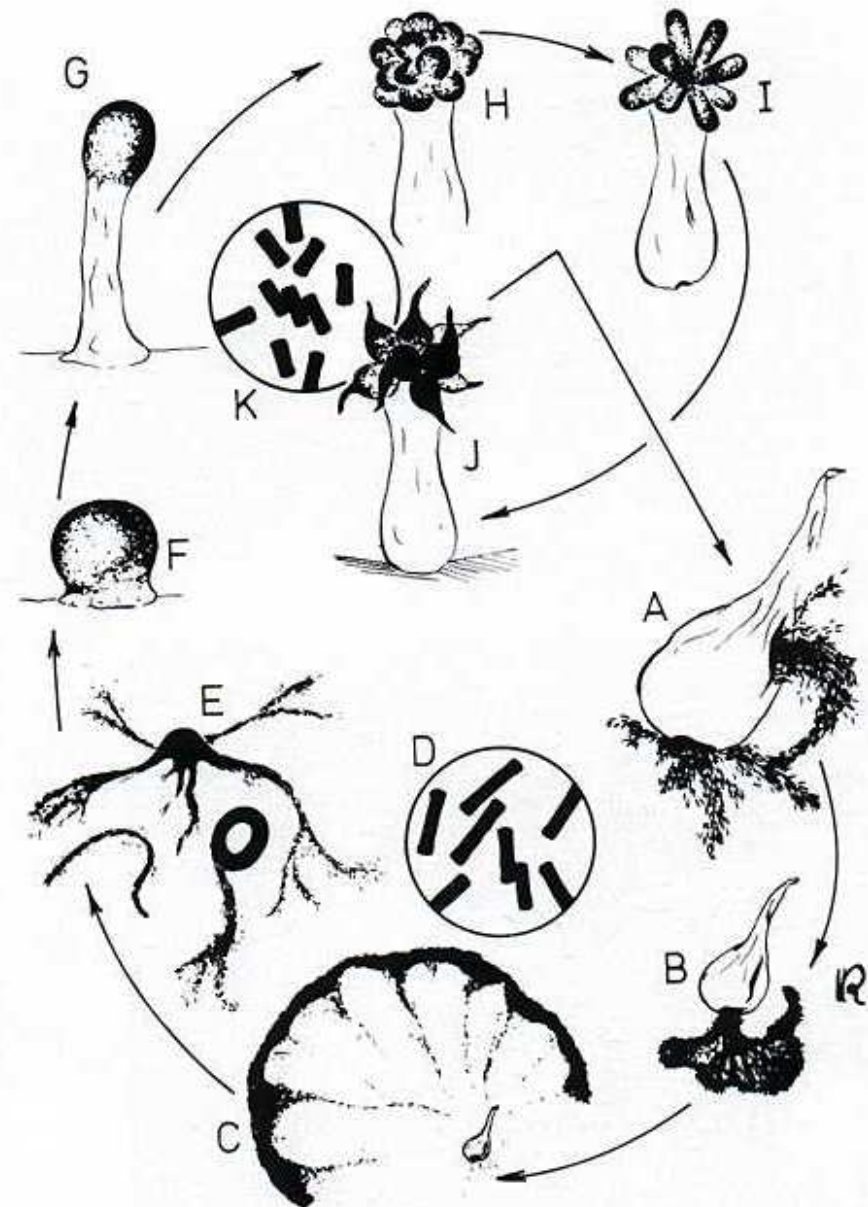
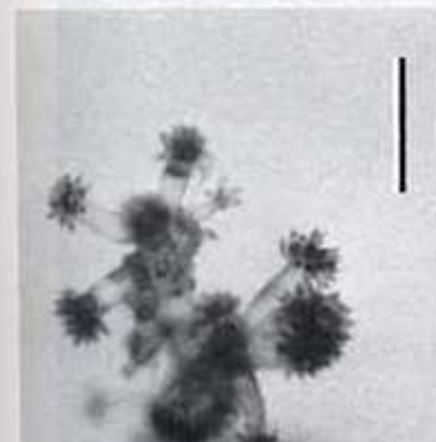
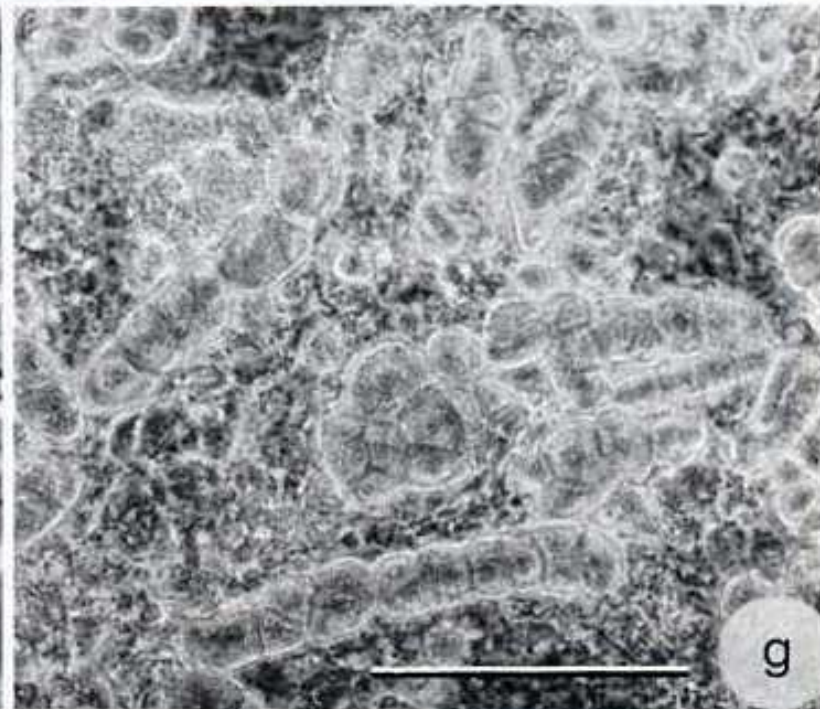
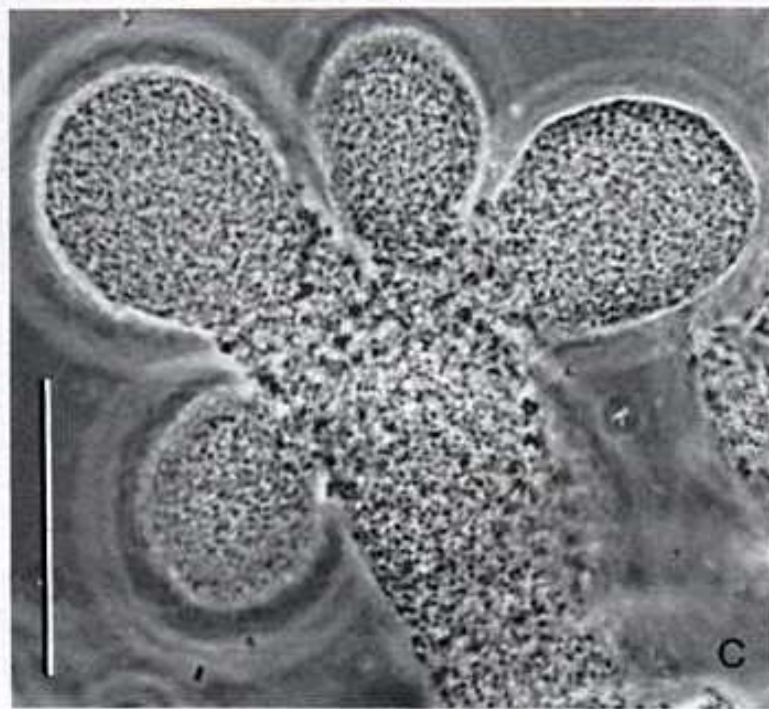
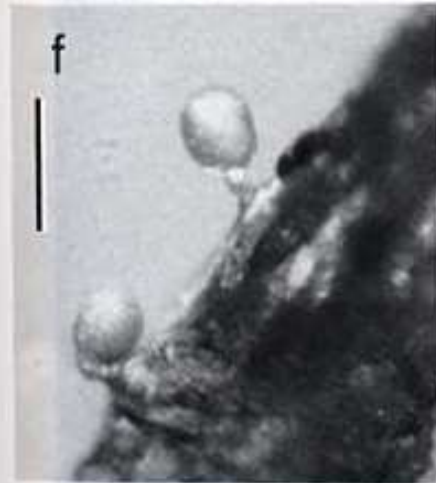
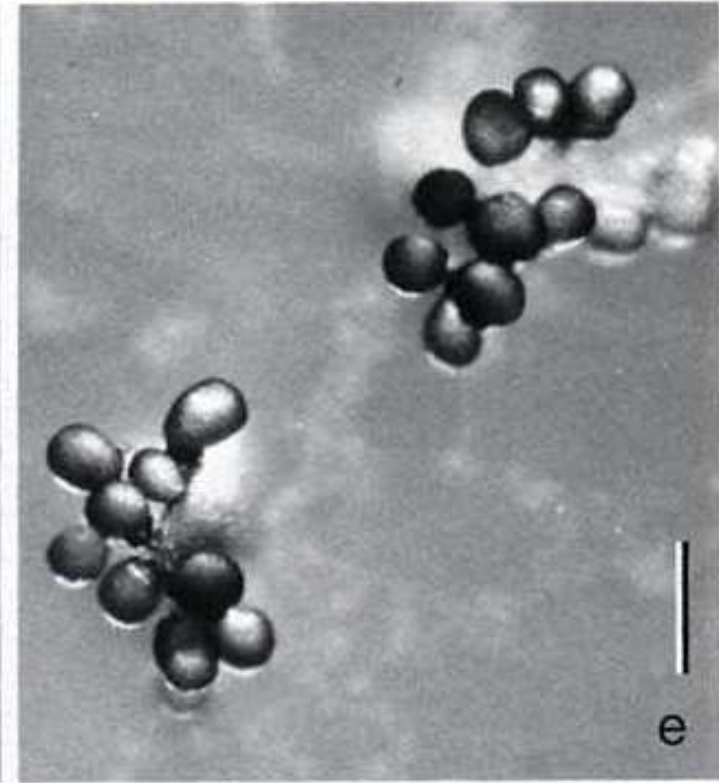
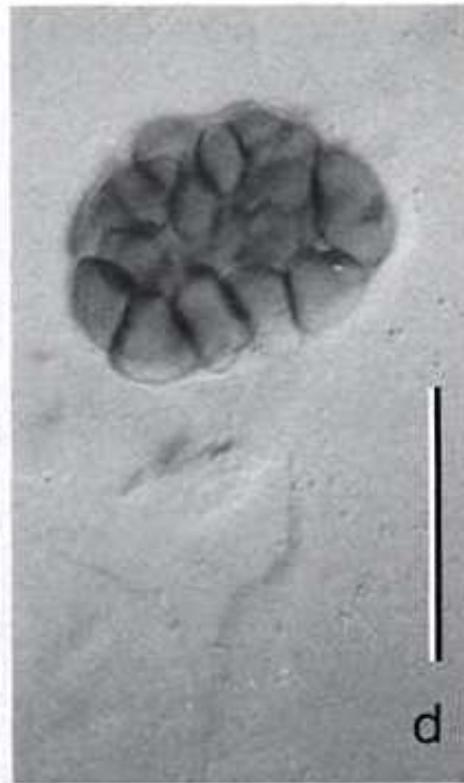
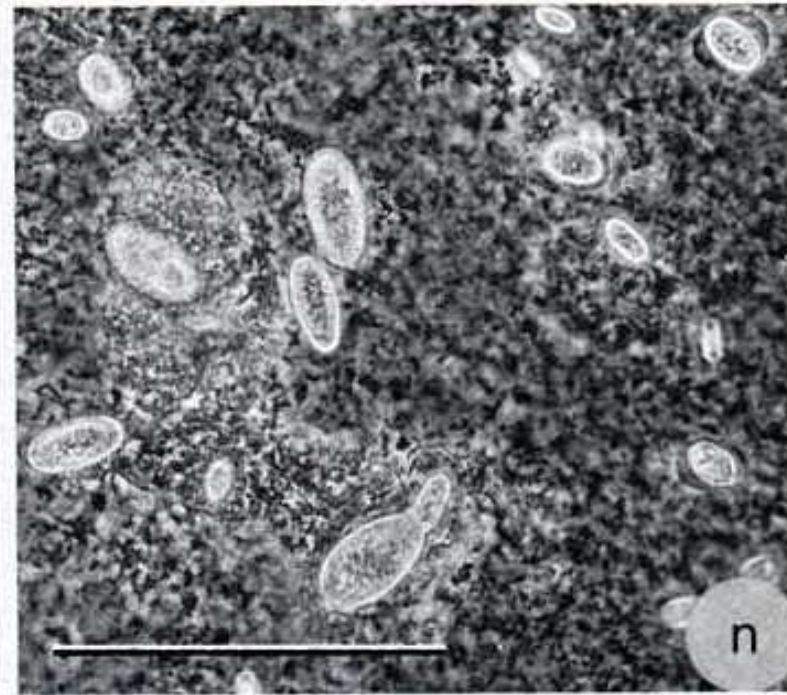
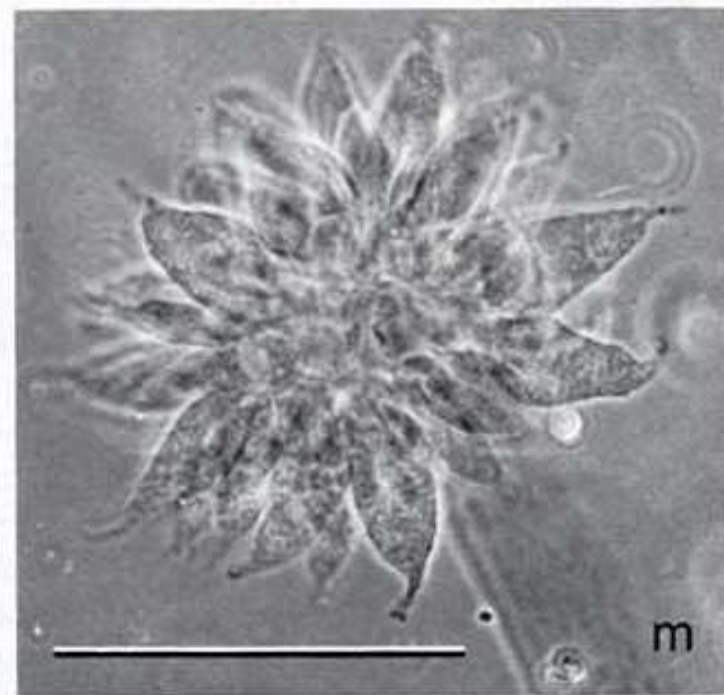
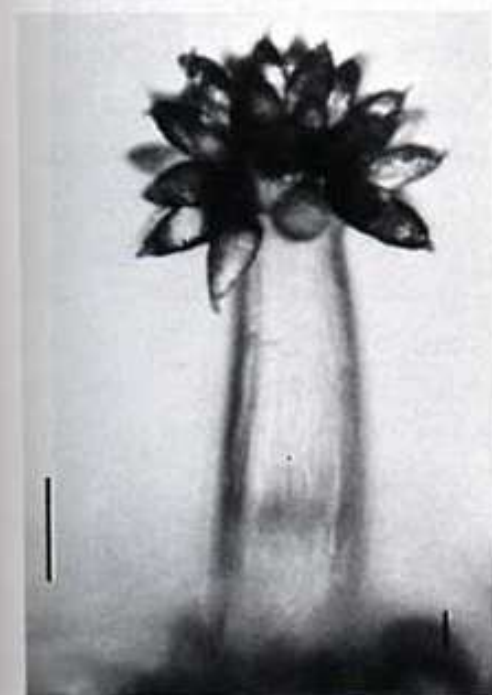
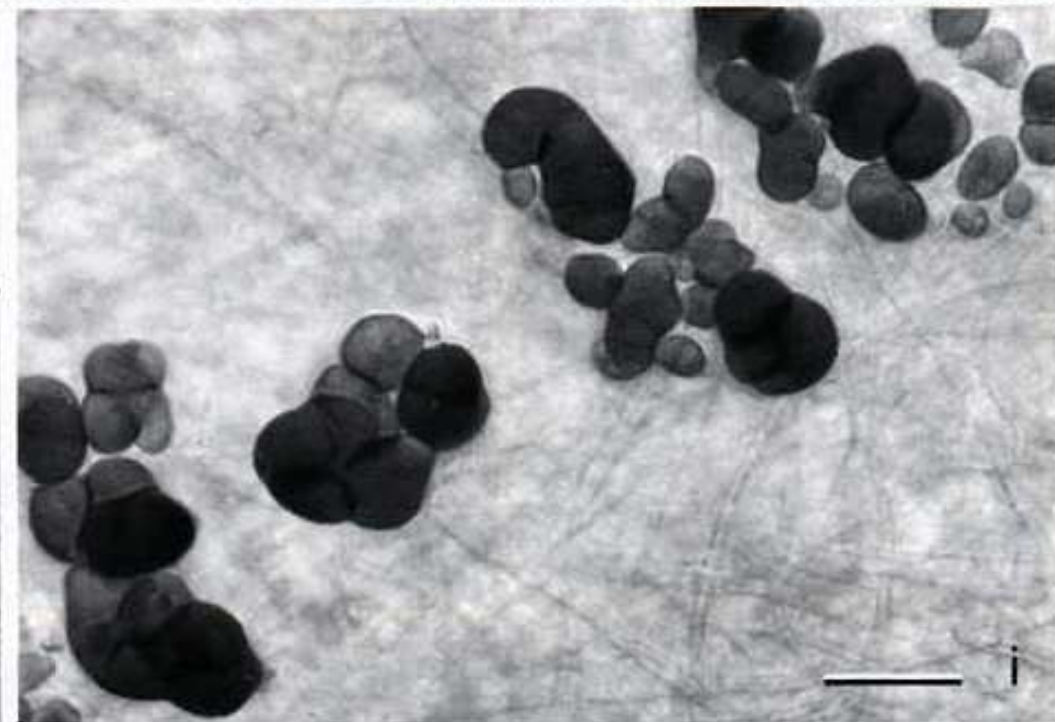
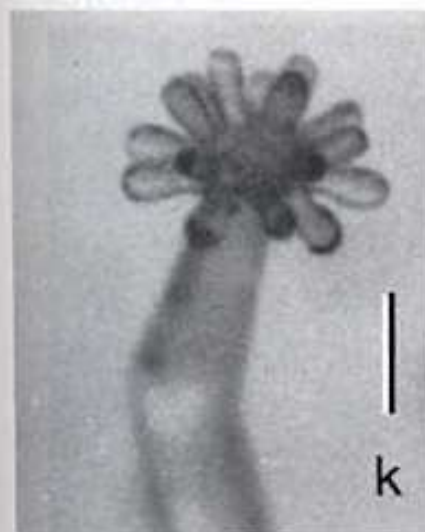
*Chondromyces**Stigmatella*

Fig. 12. Similar fruiting body shapes may be reached in different ways, as shown here for *Chondromyces apiculatus* (above) and *Stigmatella aurantiaca* (below), two organisms formerly thought to be closely related. The hatched areas indicate where the cells are located at the various stages.







# Gliding motility

- Bez aparátu pohybu, cestičky
- geneticky prokázány 2 systémy
- **A**
  - pohyb individuální buňky
  - 33 genů
  - pravděpodobně souvisí s transportem biopolymerů
- **S**
  - social (skupinový)
  - plodnice
  - fimbrie typu IV

# Cestičky na agaru vznikající klouzavým pohybem

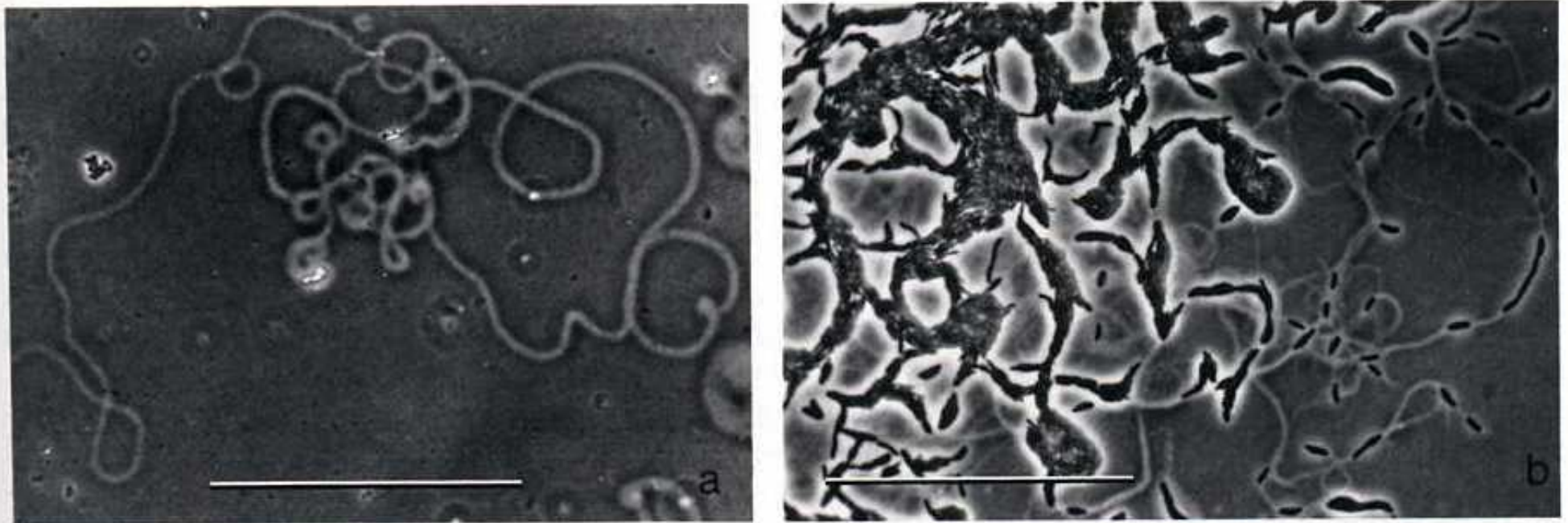
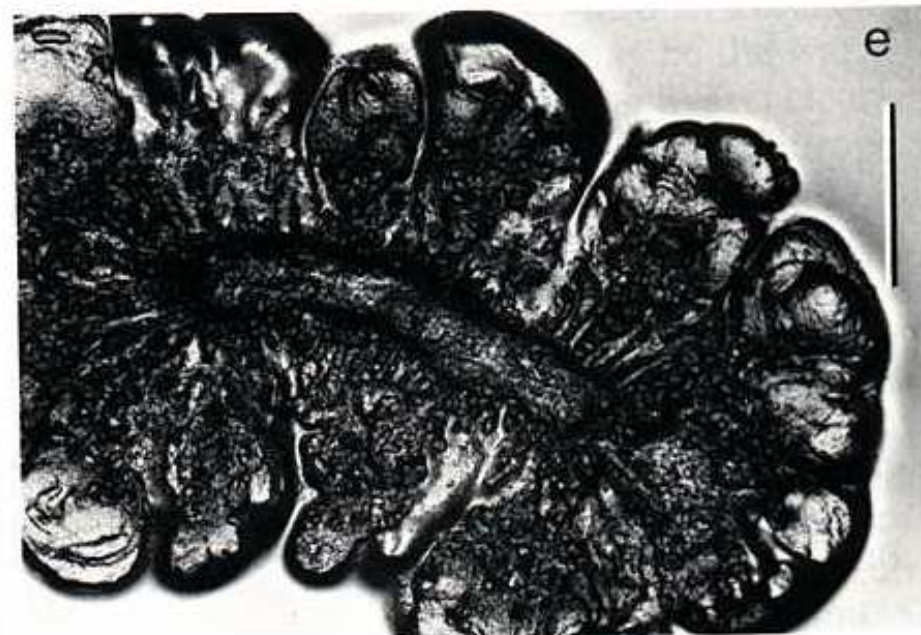
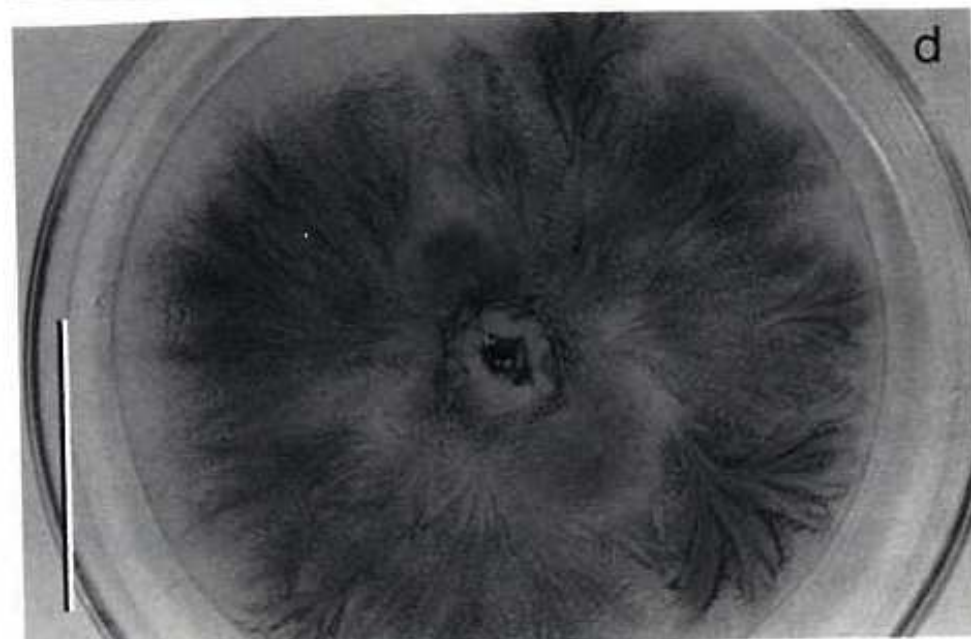
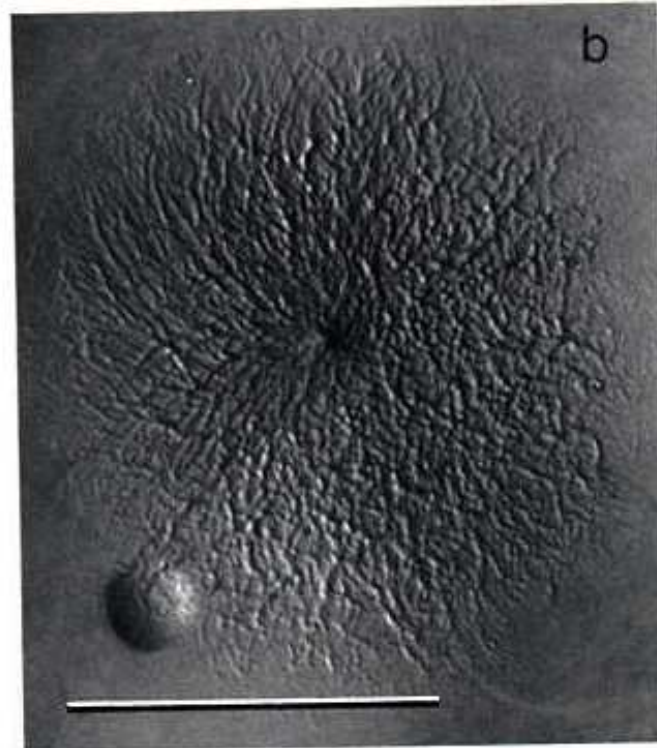
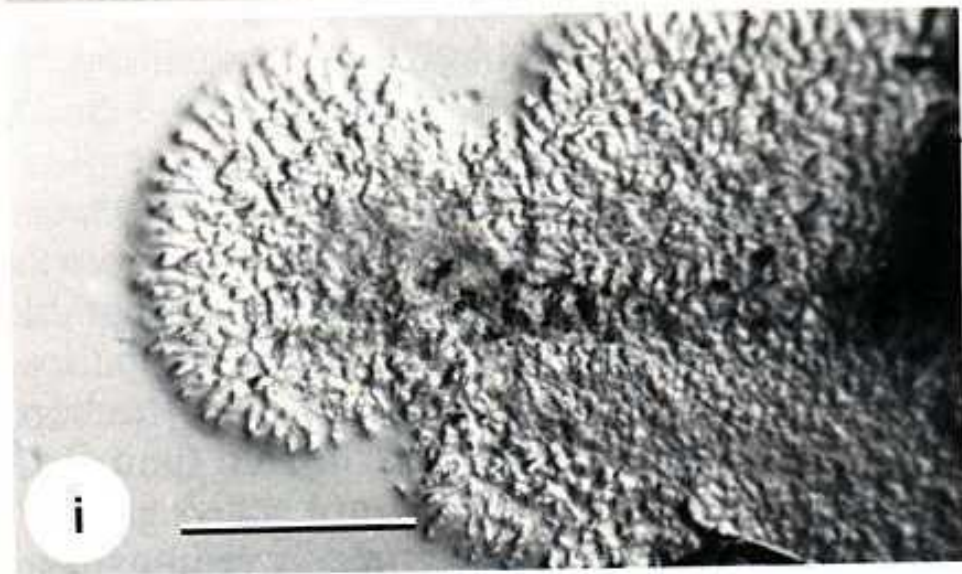
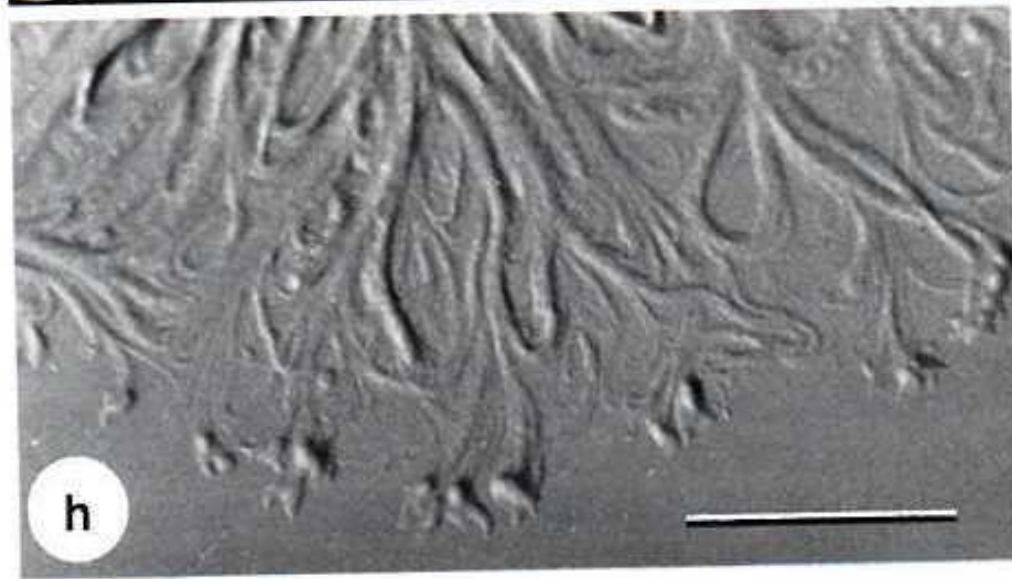
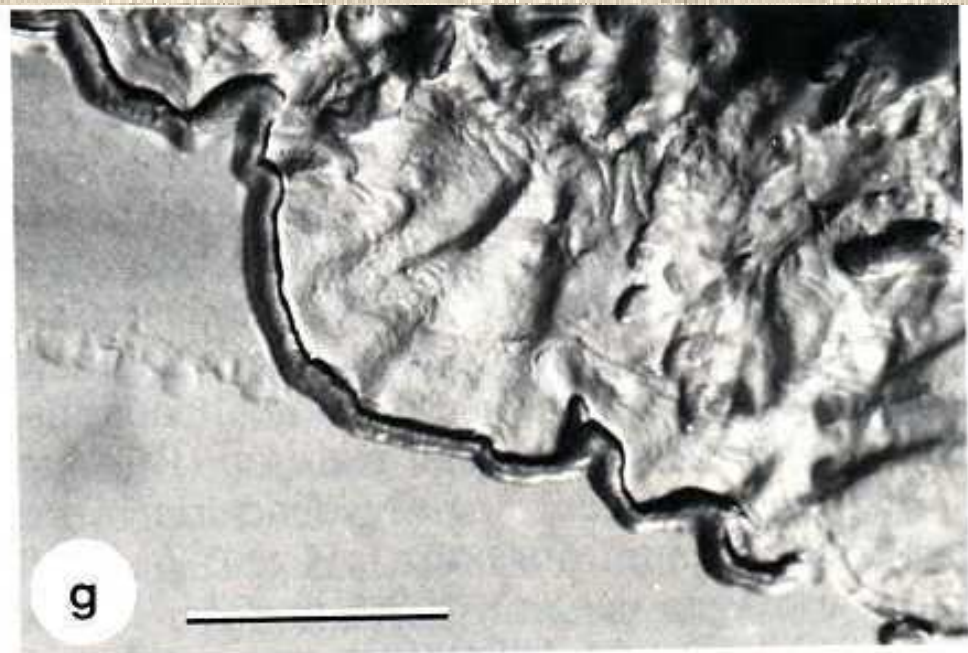
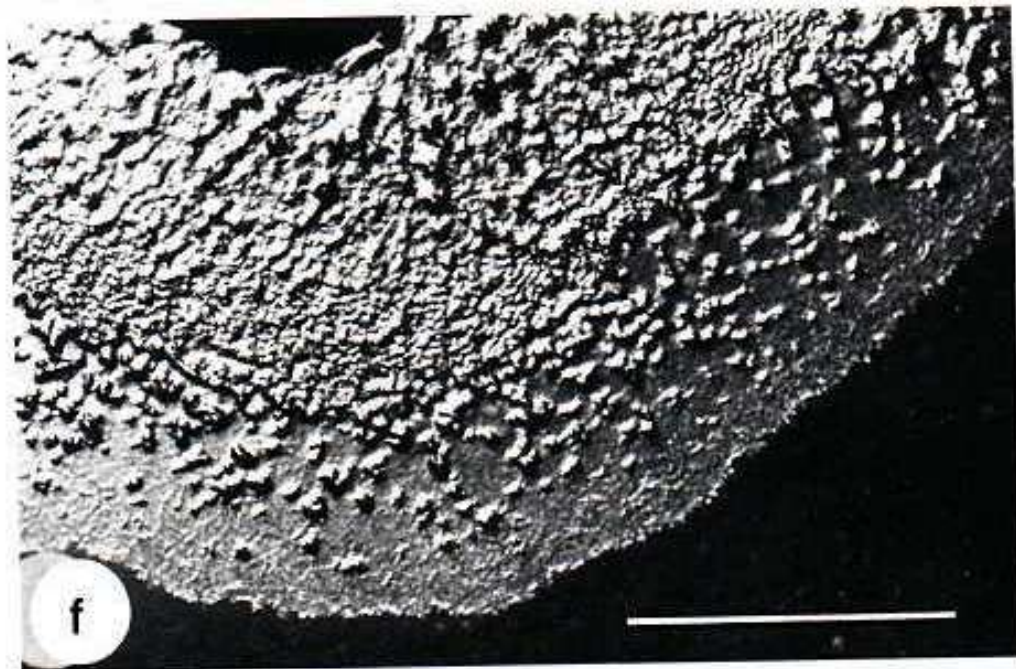


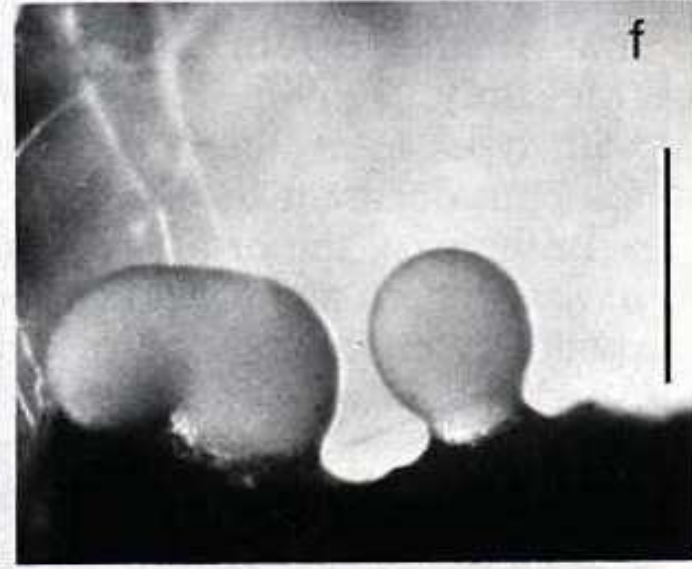
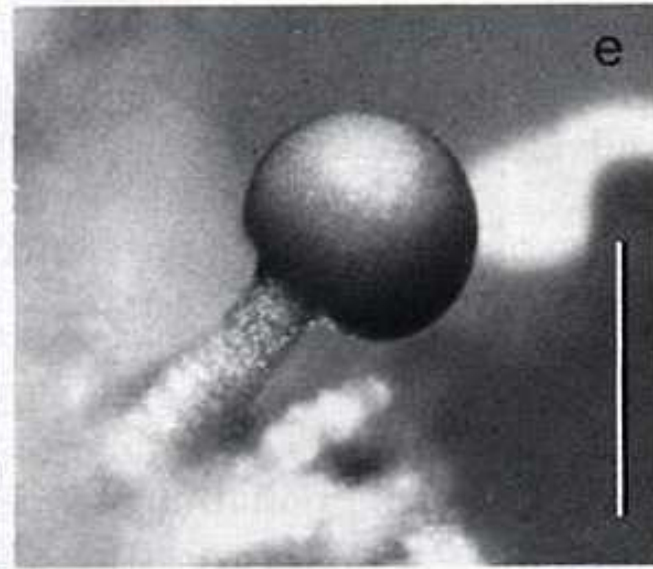
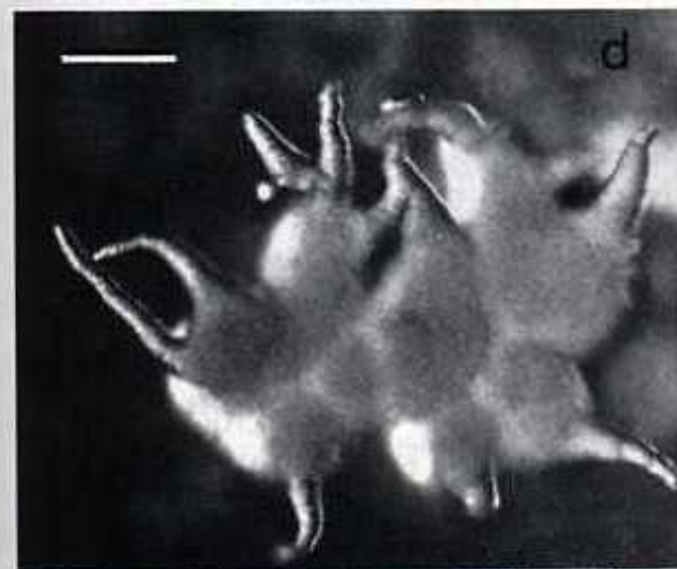
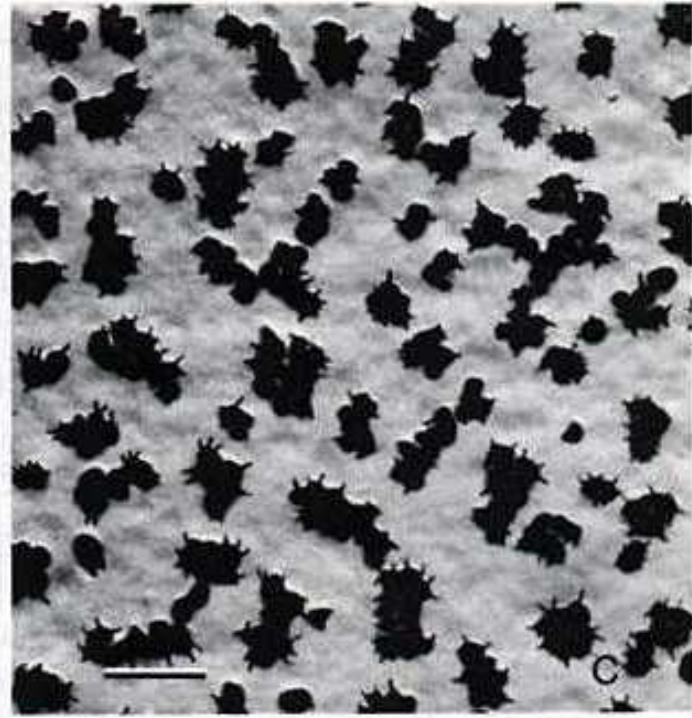
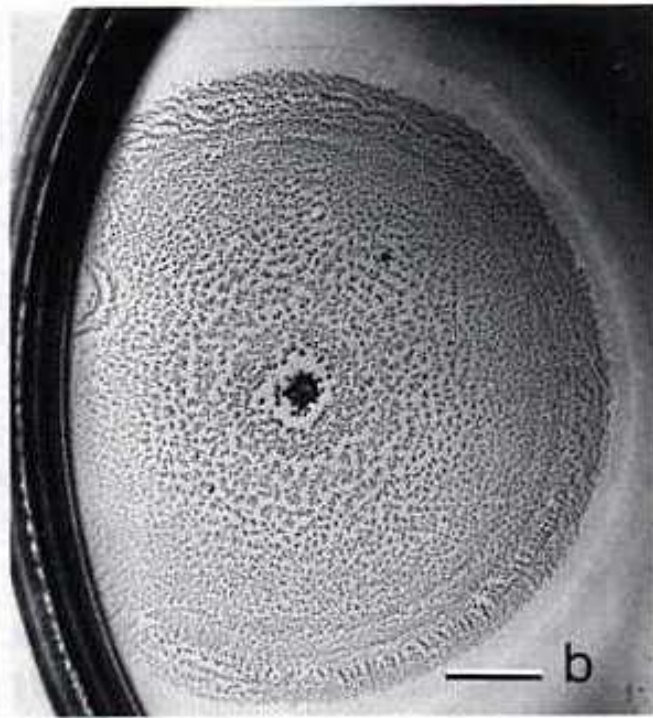
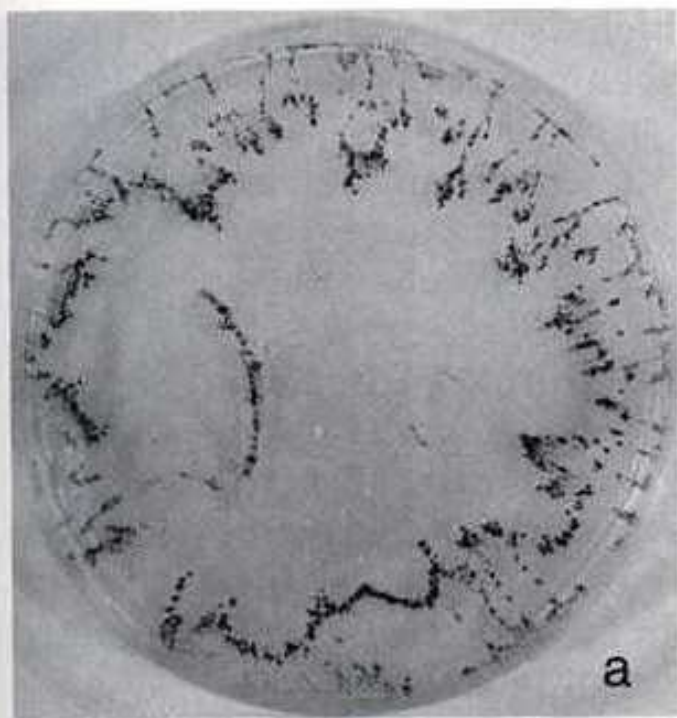
Fig. 5. Slime tracks as seen on thin agar layers in chamber cultures. (a) *Nannocystis exedens*. (b) *Myxococcus fulvus*; the spots seen on the left are cell clusters, not single cells. Bar = 100  $\mu\text{m}$ . Phase contrast.

Plazivé  
kolonie





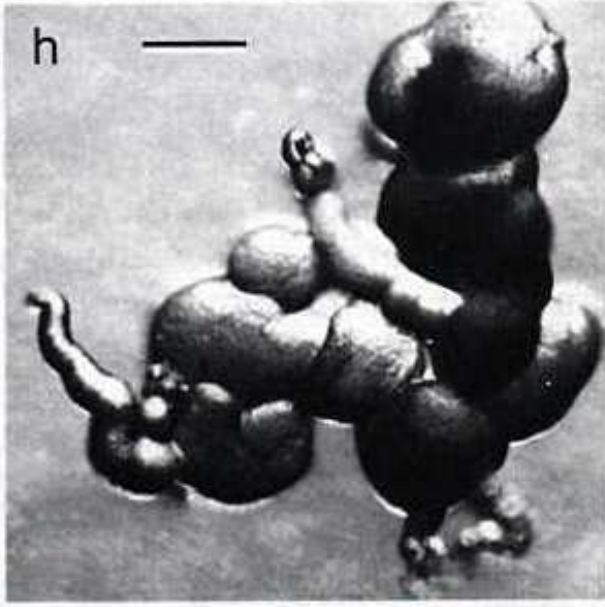




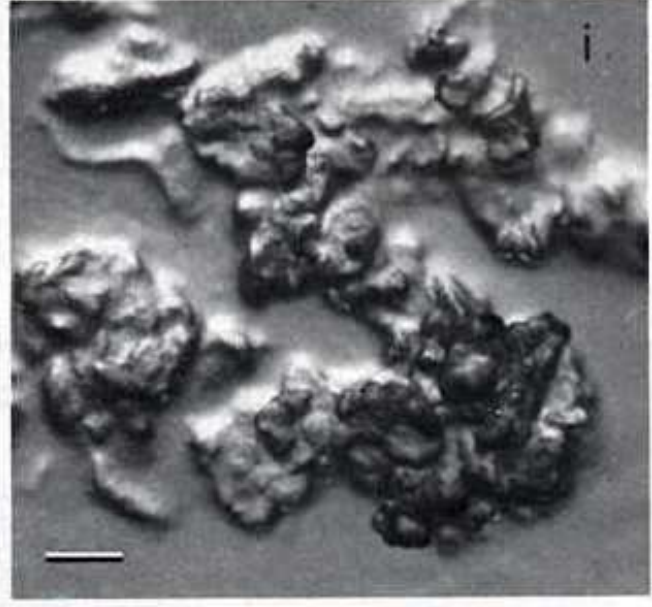
g Archangium



h



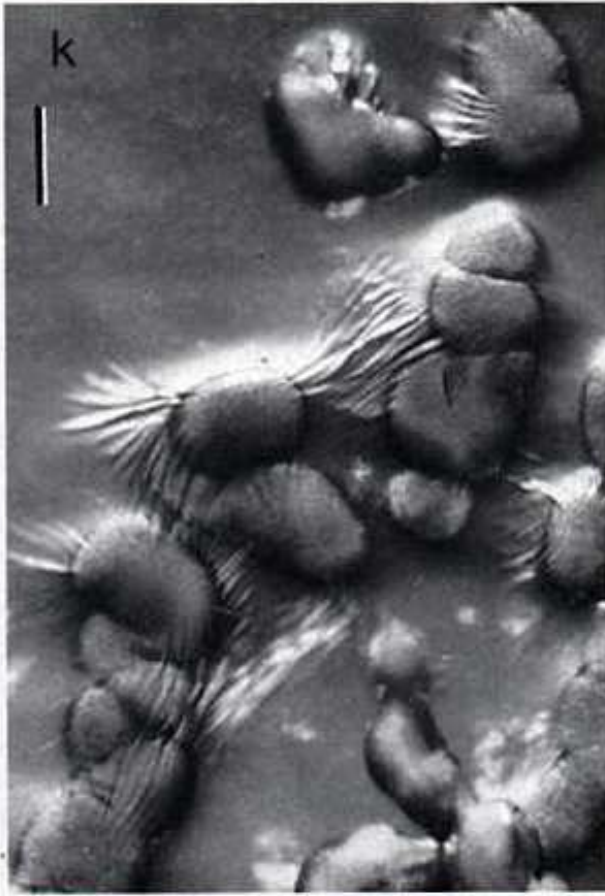
i



j Cystobacter



k



## D. Strídání jednobuněčného a vláknitého nebo mnohobuněčného stádia

- *Flexibacter filiformis* – vláknitá, klouzavá bakterie
- 1. stádium – dlouhá vlákna
- 2. stádium – krátké, kulovité buňky vyplněné tukem
  - přechod do 2. stádia – se vstupem do stacionární fáze nebo s přechodem do vyšší teploty (35°C)

- **McBride, M.J. P. Hartzell and D.R. Zusman. 1993** Motility and tactic behavior of *Myxococcus xanthus*. p285-306. in *Myxobacteria II* M. Dworkin and D. Kaiser (eds) American Society for Microbiology Press
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*Děkuji za Vaši pozornost*