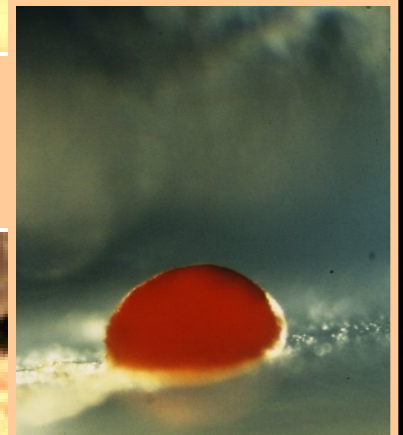


# Myxobakterie

Tvoří 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

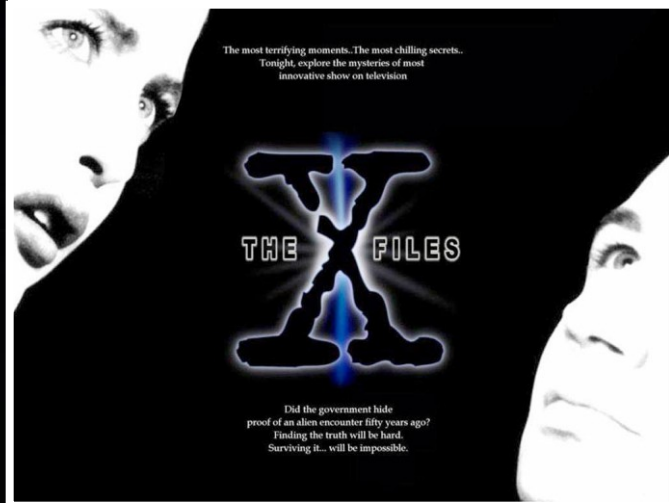
Bdellovibrio  
Desulfovibrio  
Desulfonema



*Myxococcus xanthus* a *Stigmatella aurantiaca*



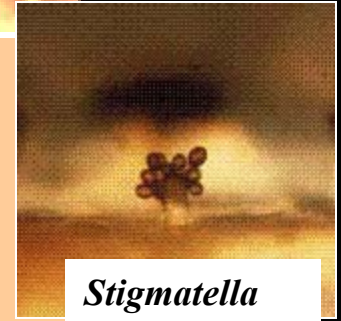
- **Intenzivní studium tajemství  
mezibuněčné komunikace a následné  
diferenciace**



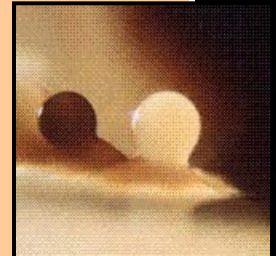
## gliding motility

- 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  

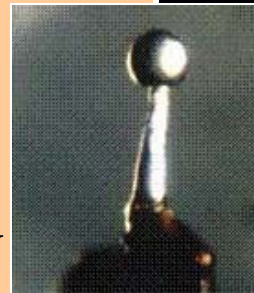
přežívání prokázáno 10 let



*Stigmatella  
aurantiaca*



*Myxococcus  
fulvus*



*Myxococcus  
stipitatus*

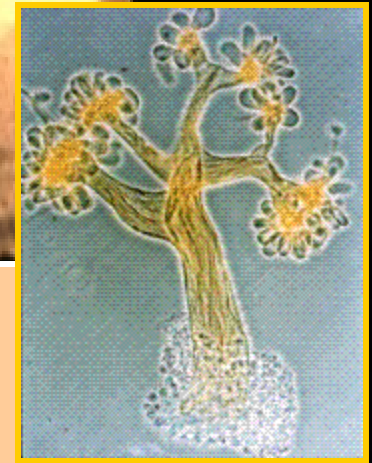
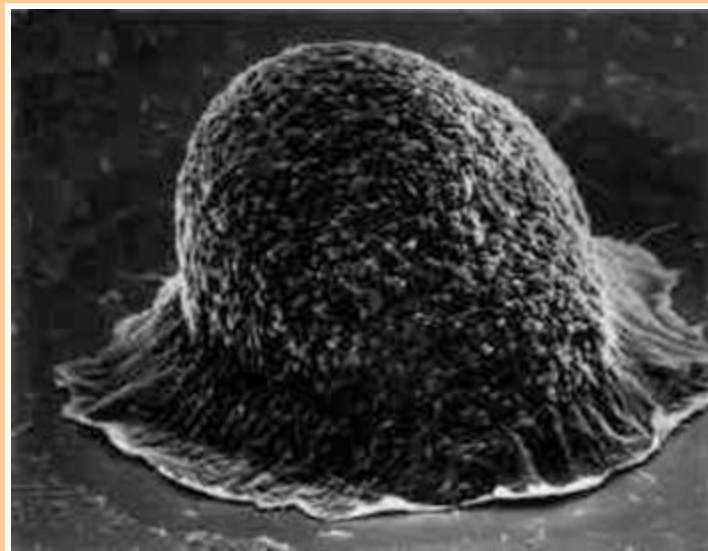
# Růst a vývoj

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

*Mycoplasma*  
577 to 590 kbp

*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	<i>Nannocystis exedens</i> , <sup>5</sup> <i>Sorangium cellulosum</i> , <sup>4</sup> <i>Archangium serpens</i> , <sup>4</sup> <i>Corallococcus coralloides</i> , <sup>4</sup> <i>Polyangium</i> spp., <sup>3</sup> <i>Cystobacter</i> spp., <sup>3</sup> <i>Melittangium</i> spp., <sup>3</sup> <i>Myxococcus fulvus</i> , <sup>2</sup> <i>Mx. virescens</i> , <sup>2</sup> and <i>Mx. stipitatus</i> <sup>2</sup>
Dung of herbivores	<i>Myxococcus fulvus</i> , <sup>5</sup> <i>Corallococcus coralloides</i> , <sup>5</sup> <i>Mx. virescens</i> , <sup>4</sup> <i>Cystobacter fuscus</i> , <sup>4</sup> <i>Cb. ferrugineus</i> , <sup>4</sup> <i>Archangium serpens</i> , <sup>4</sup> <i>Nannocystis exedens</i> , <sup>3</sup> <i>Cb. violaceus</i> , <sup>3</sup> <i>Polyangium</i> spp., <sup>3</sup> <i>Stigmatella erecta</i> , <sup>2</sup> <i>Mx. xanthus</i> , <sup>2</sup> <i>Melittangium</i> spp., <sup>2</sup> and <i>Cb. velatus</i> <sup>1</sup>
Bark and rotting wood	<i>Stigmatella aurantiaca</i> , <sup>4</sup> <i>Chondromyces apiculatus</i> , <sup>4</sup> <i>Sorangium cellulosum</i> , <sup>4</sup> <i>Corallococcus coralloides</i> , <sup>4</sup> <i>Myxococcus fulvus</i> , <sup>3</sup> <i>Cm. pediculatus</i> , <sup>2</sup> and <i>Haploangium</i> 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

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>

Families and genera:

Polyangiaceae

*Sorangium*

*Polyangium*

*Haploangium*

*Chondromyces*

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

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

Families and genera

Nannocystaceae

*Nannocystis*

Kofleriaceae

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



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

Nově: *Haliangiaceae*  
*Kofleriaceae*

<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 μm x 3-8 μm
  - štíhlé se špičatými konci (*Cystobacterinae*) 
  - robustní s kulatými konci (*Soranginae*) 
- **Plodnice** – 50 – 500 μm
  - často pestře zbarvené – karotenoidní pigmenty
  - různého tvaru a složitosti
- **Spory** – zkrácené ztluštělé buňky

**Cystobacterinae**

**Soranginae**

**Myxospory  
Cystobacter**

**Myxospory  
Myxococcus**

Fig. 1. Various types of myxobacterial cells. (a to d) Vegetative cells. (a and b) The Cystobacterinae 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 Soranginae type. (c) *Chondromyces crocatus* in a chamber culture. (d) *Sorangium compositum* in a chamber culture. (e to h) Myxospores of members of the Cystobacterinae. (e) Myxospores of *Cystobacter ferrugineus*, from a crushed, degenerated, *Archangium*-like, fruiting body; under oil immersion, the high optical refractivity 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 refractivity of the myxospores becomes very conspicuous. (h) Myxospores from a *Myxococcus xanthus* fruiting body; the optical refractivity 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
  - „They look like schmoos that are pulled along by their heads. How they are able to glide is a mystery.“ (Miyata, M., Ryu, W.S., and Berg, H.C. (2002): Force and velocity of *Mycoplasma mobile* gliding." *J. Bacteriol.* 184, 1827-1831)
- **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.

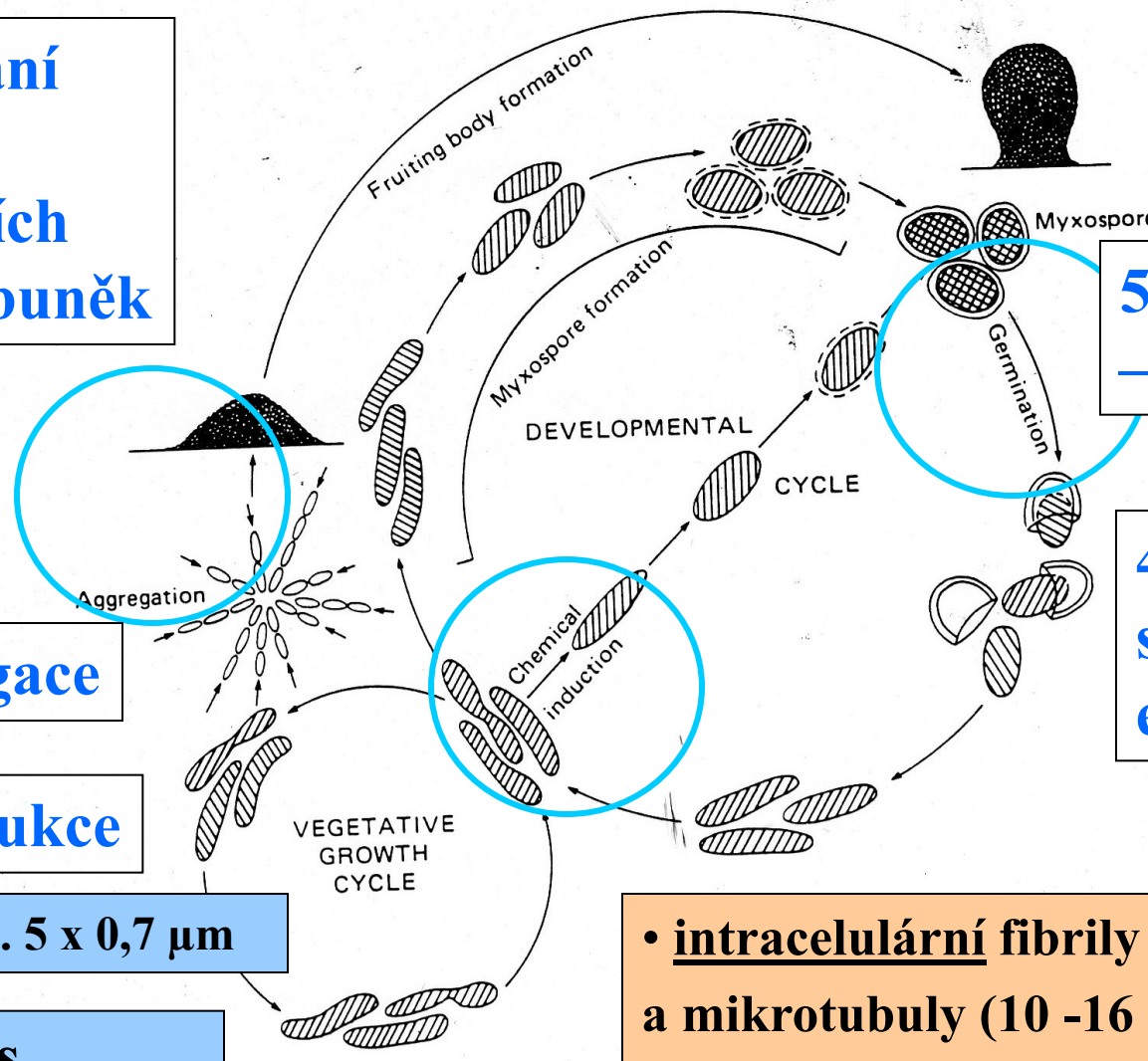
3. vylučování  
molekul  
umožňujících  
propojení buněk

2. agregace

1. indukce

veg.b. 5 x 0,7 μm

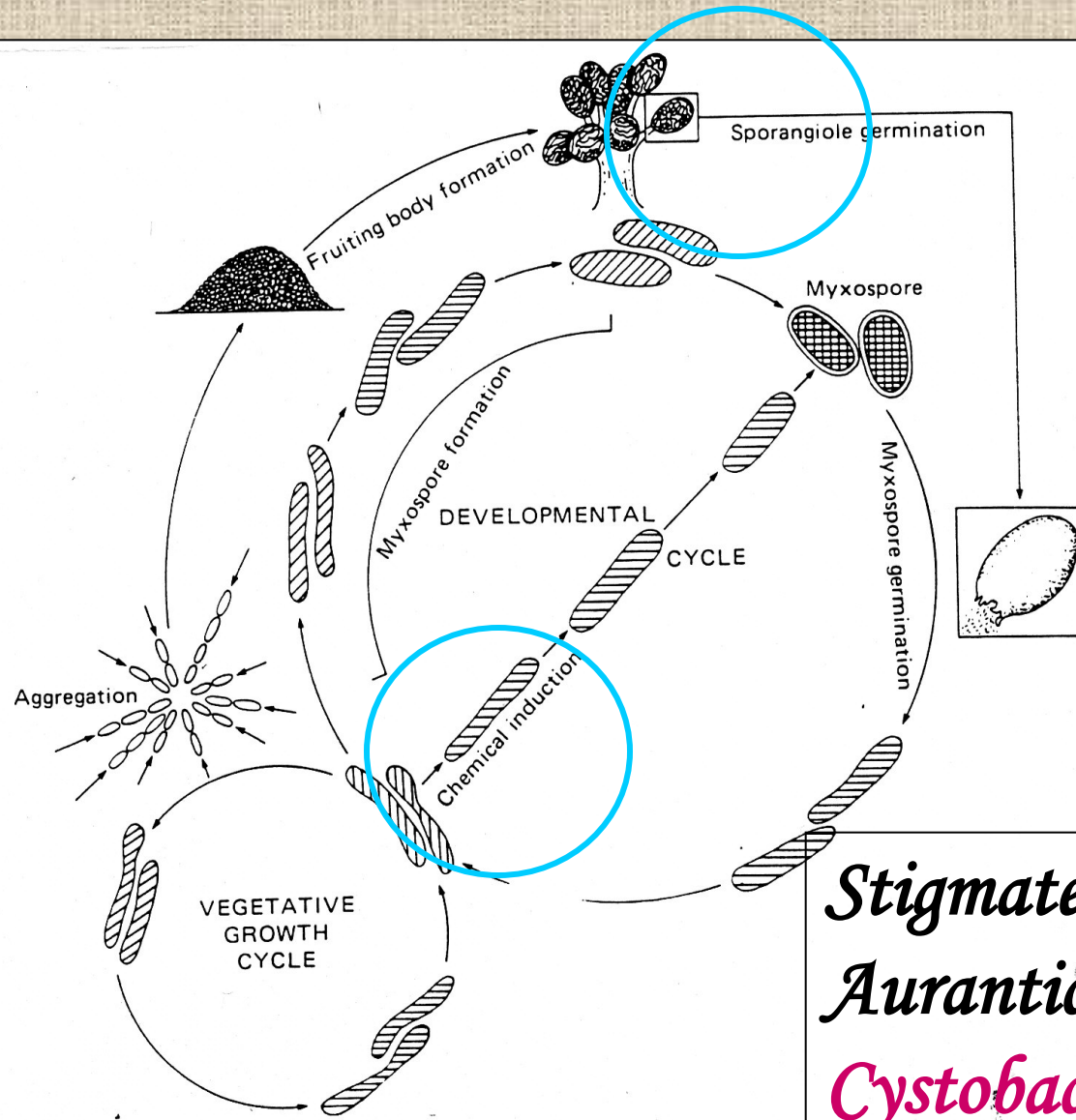
Život.cyklus  
*Myxococcus xanthus*  
*Myxococcaceae*



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



*Stigmatella*  
*Aurantica*  
*Cystobacteraceae*

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

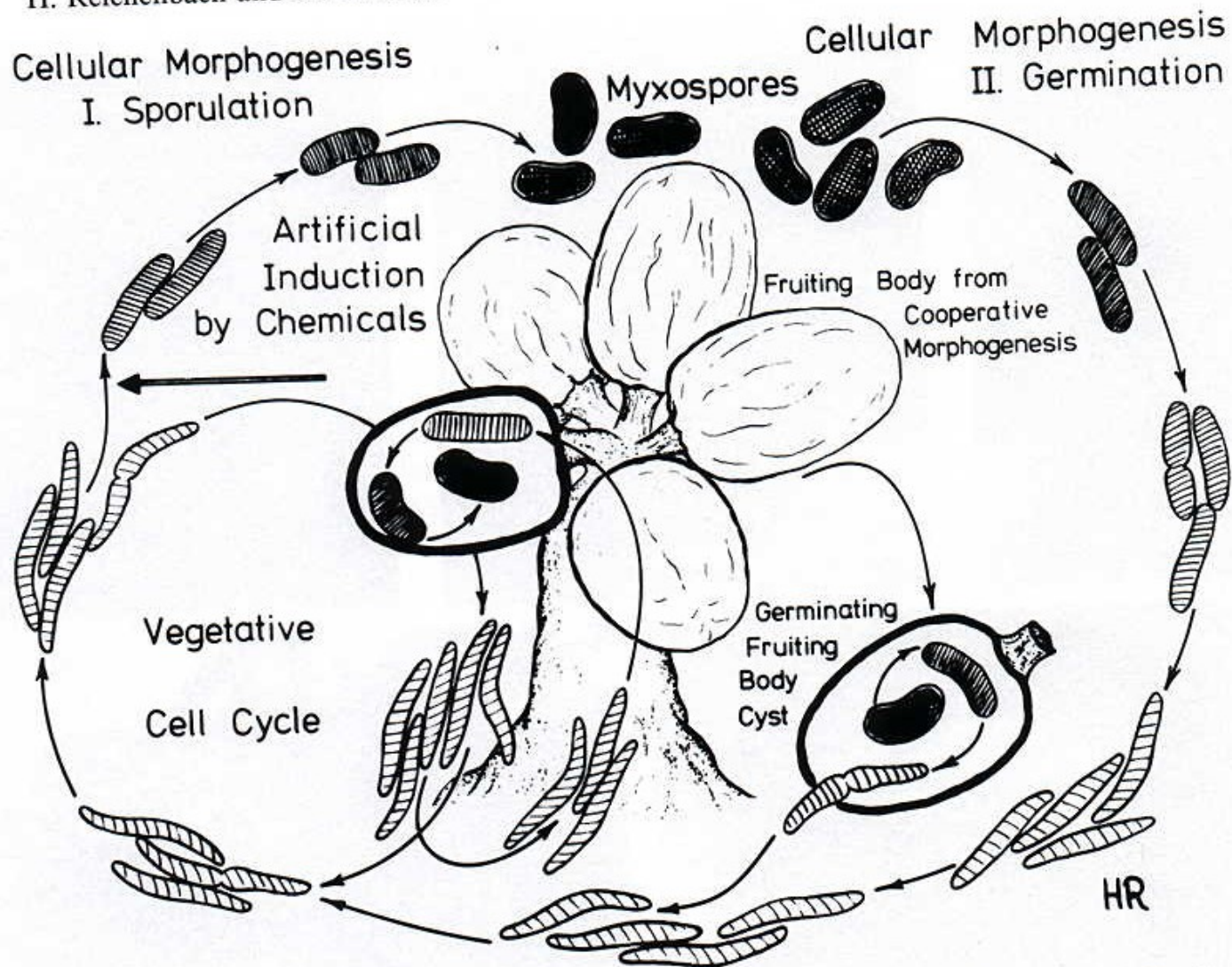
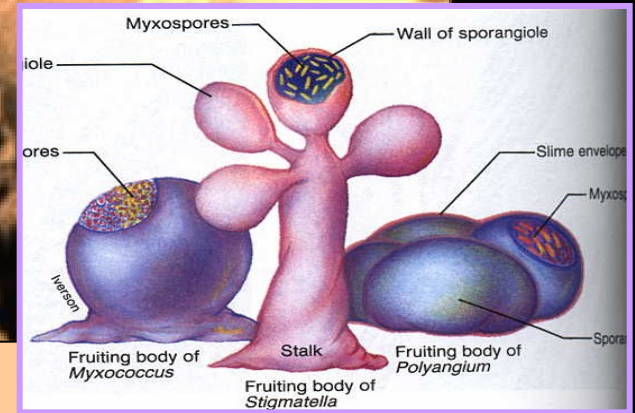


Fig. 3. Cellular morphogenesis in myxobacteria, shown with *Stigmatella aurantiaca* as an example. Fruiting body and cells are not drawn to scale. (From Gerth and Reichenbach, 1978.)

# Plodnice

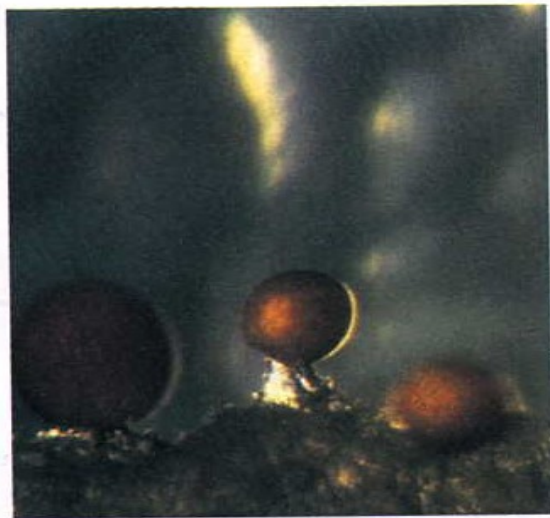
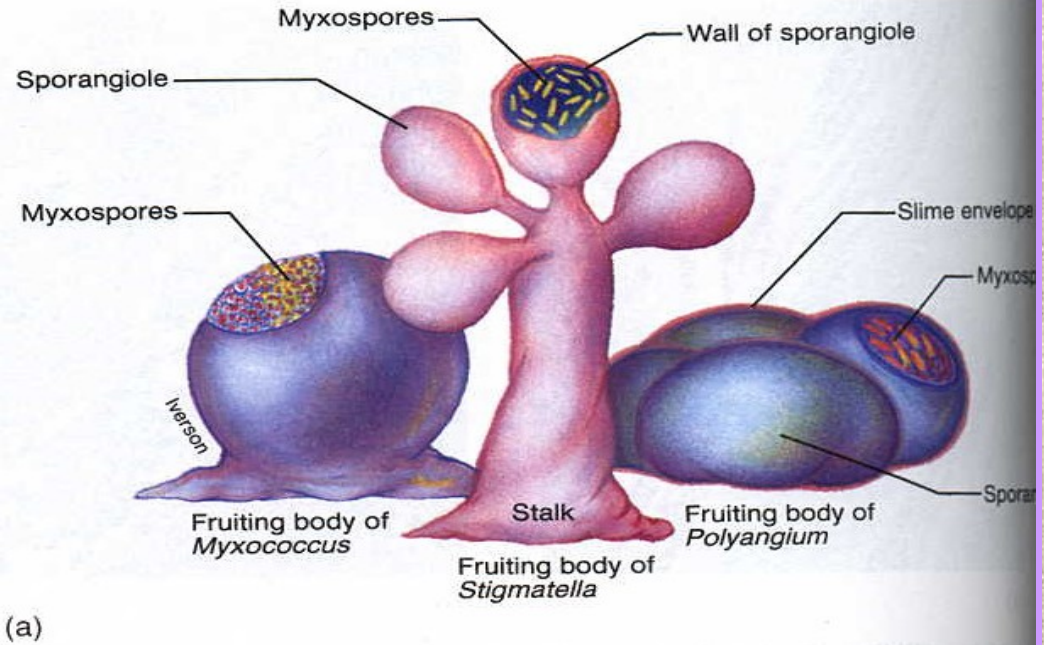


tvoreny

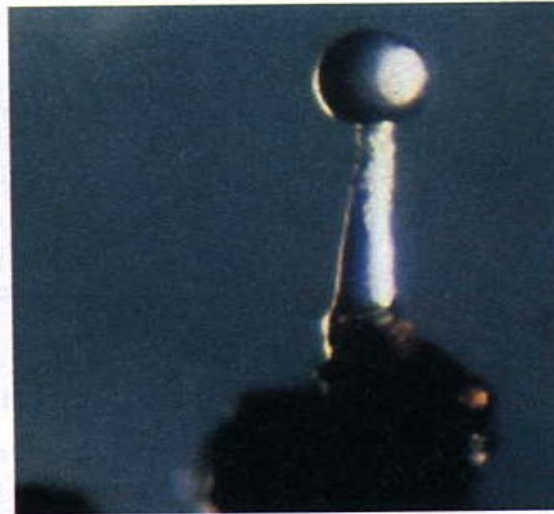
- A. měkkou sliz. strukturou - *Archangium*
  - B. tuhou slizovitou strukturou - *Cystobacter*
- Sporangioly - 1 nebo shluky
- 1. rostou přímo na substrátu
  - 2. vybavené stopkou

**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.

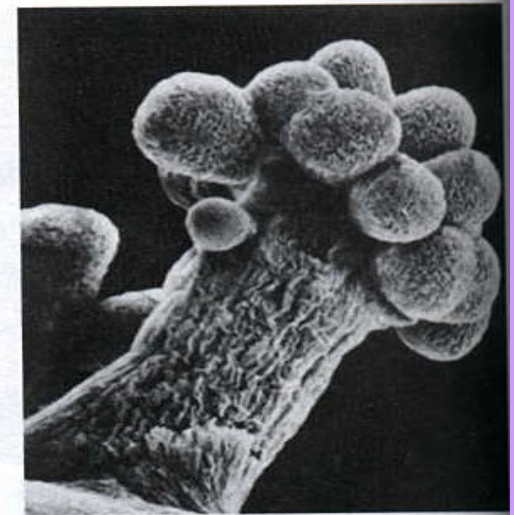
Plodnice a jejich struktura



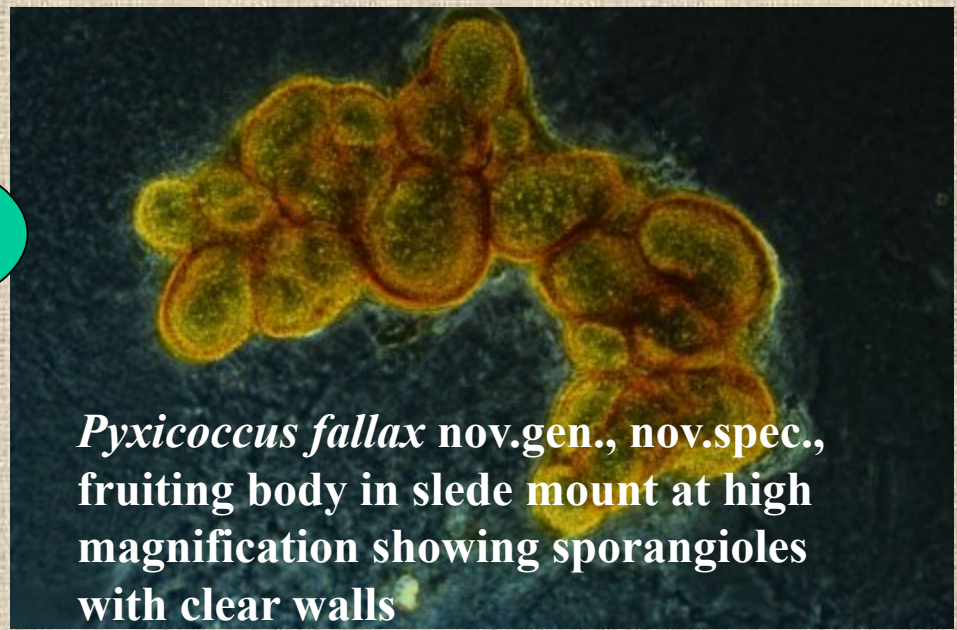
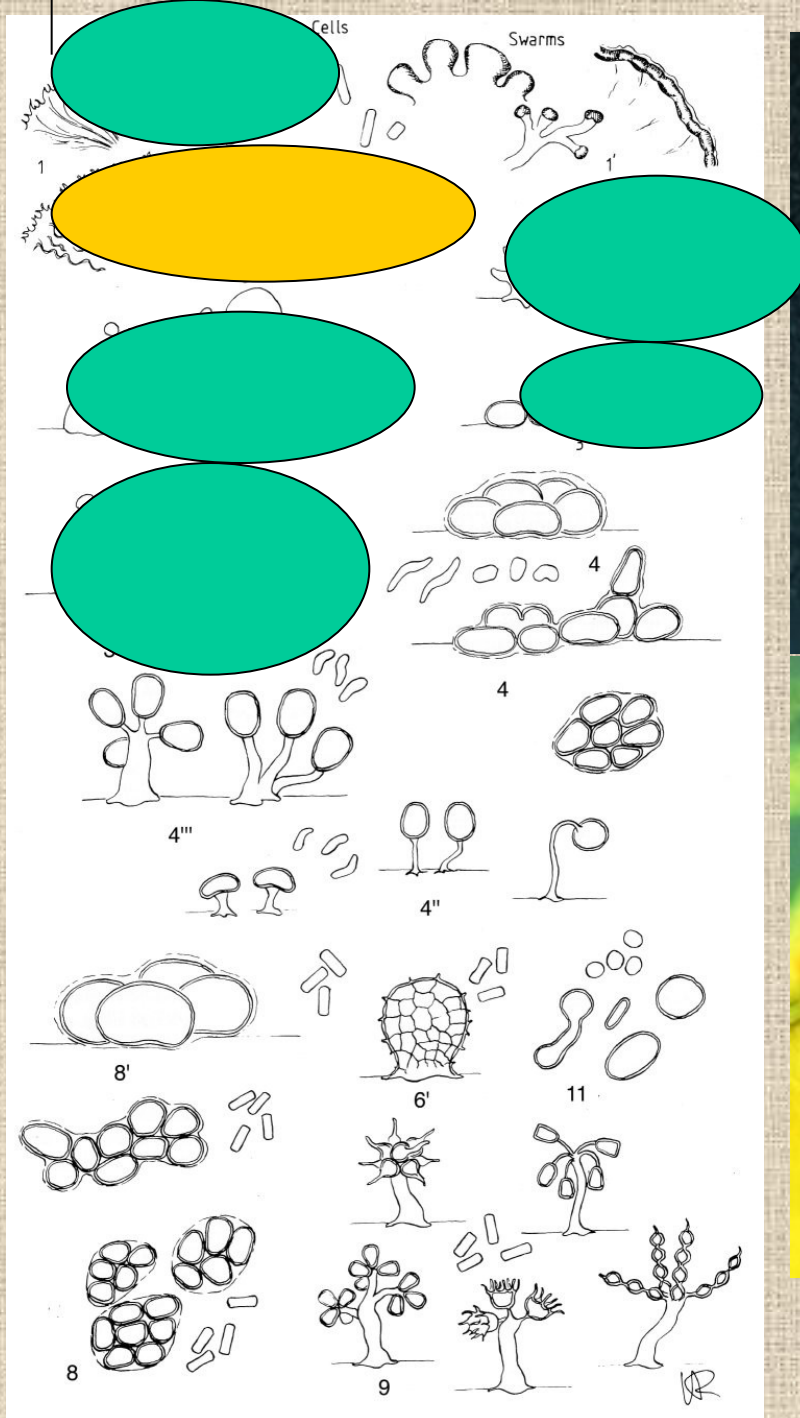
(b)



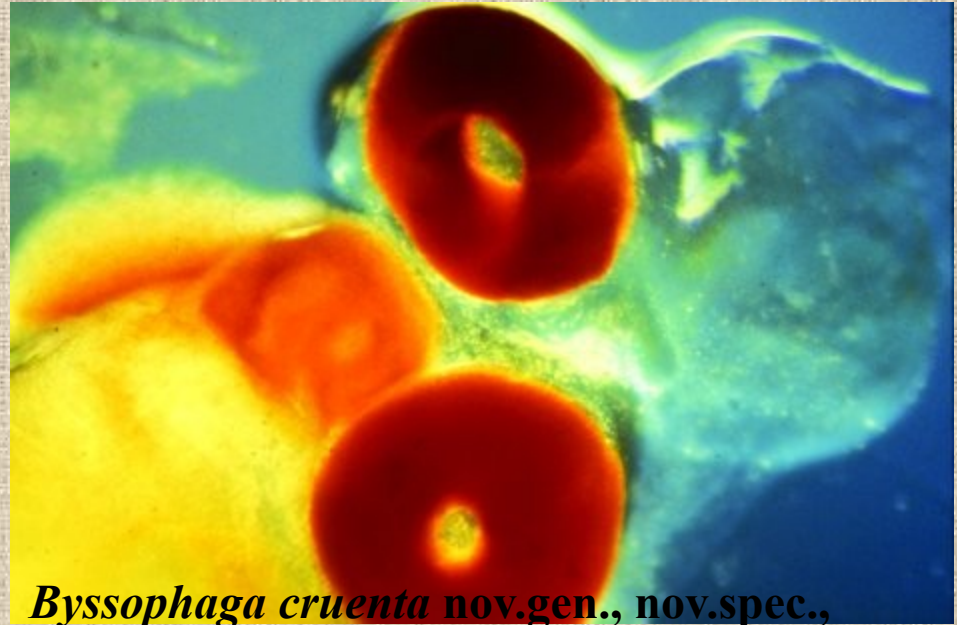
(c)



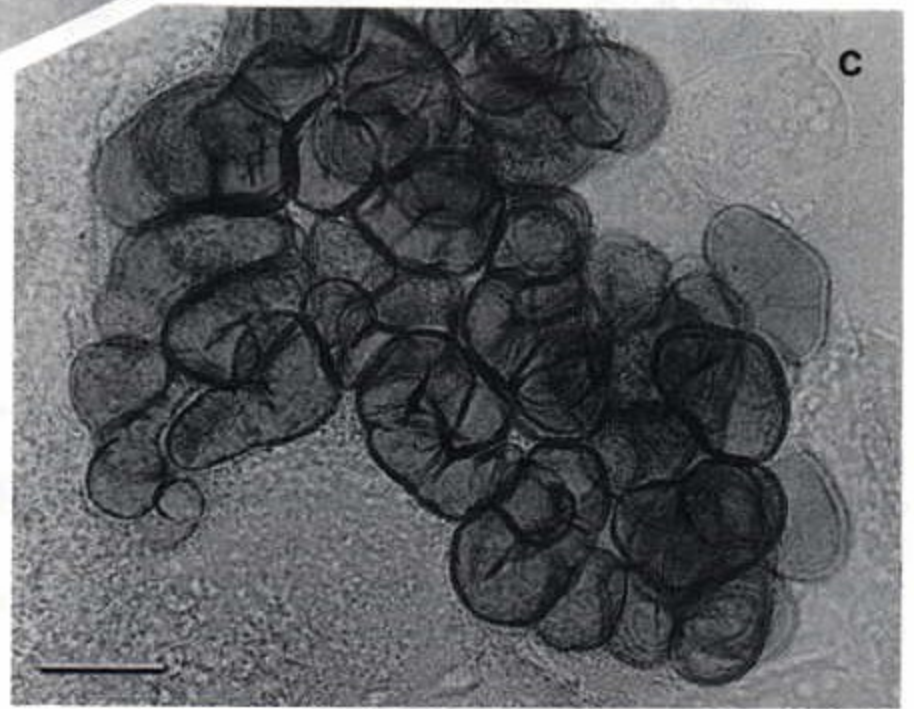
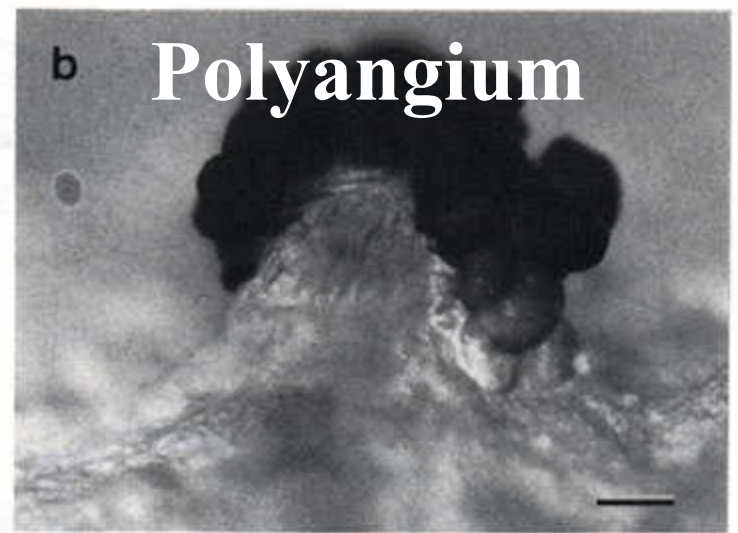
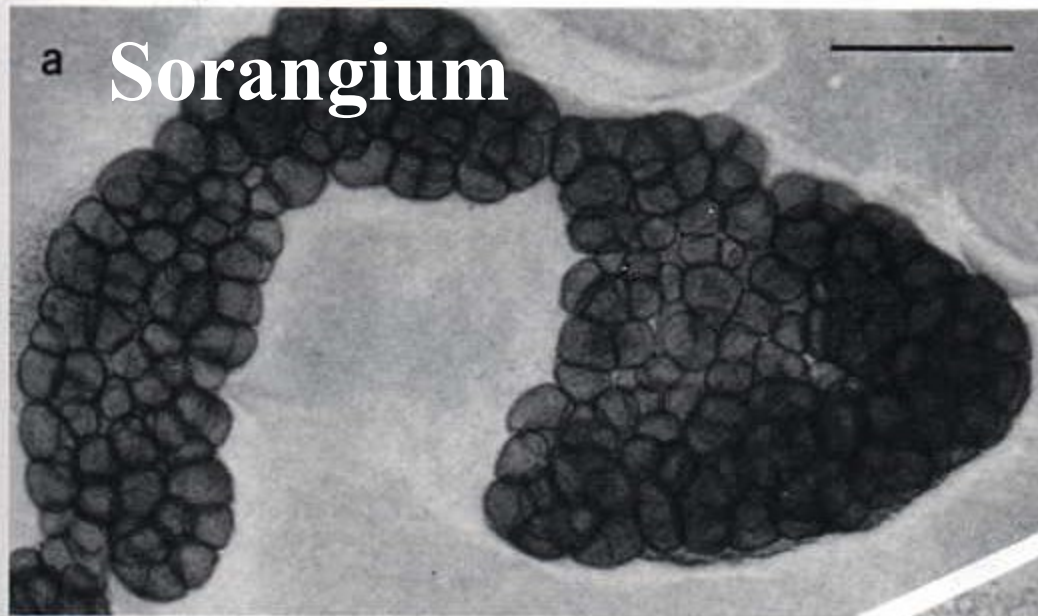
(d)



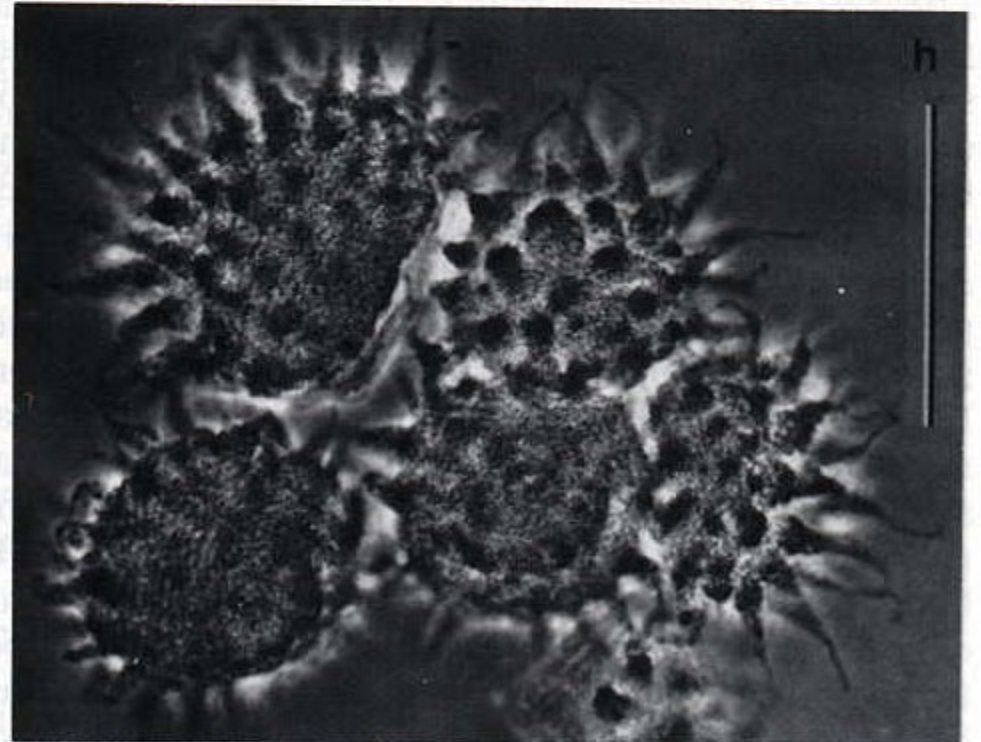
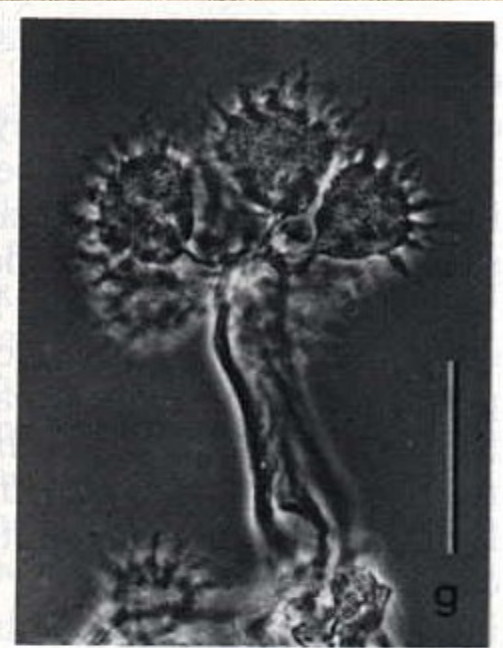
*Pyxicoccus fallax* nov.gen., nov.spec.,  
fruiting body in slide mount at high  
magnification showing sporangioles  
with clear walls



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

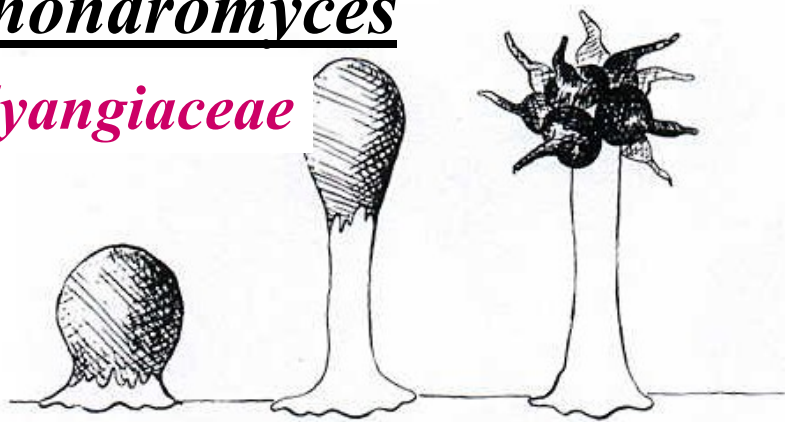






# Chondromyces

## *Polyangiaceae*



# Stigmatella

## *Cystobacteraceae*

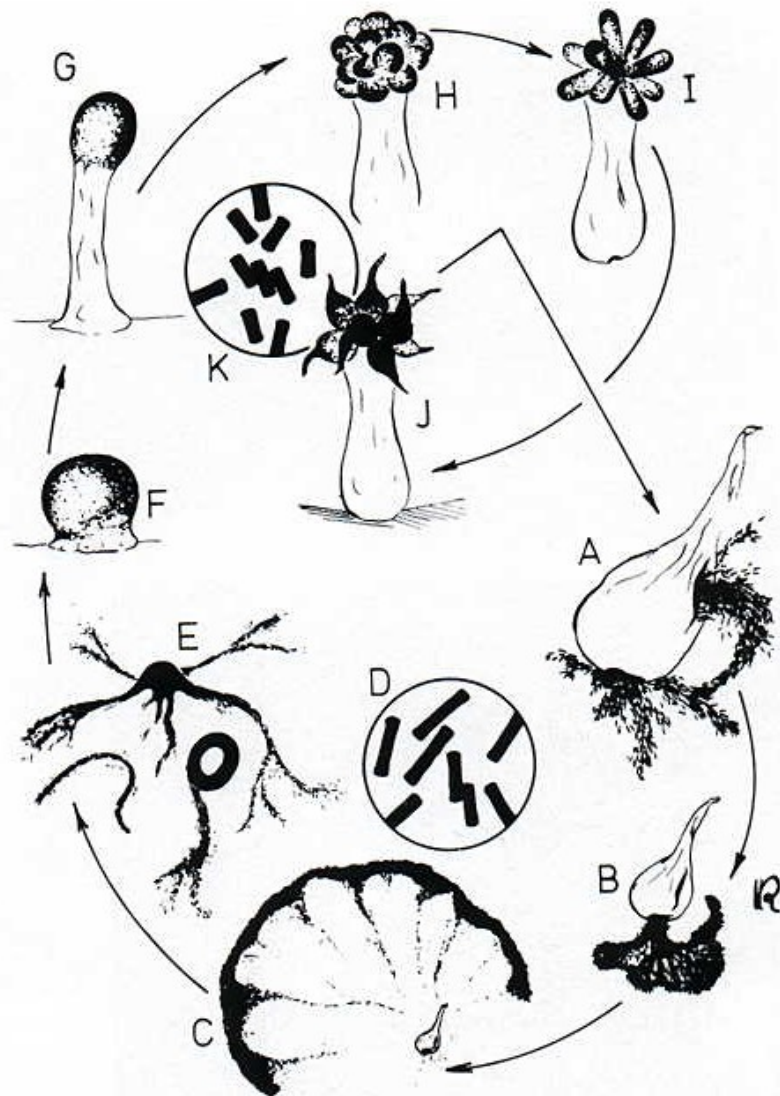
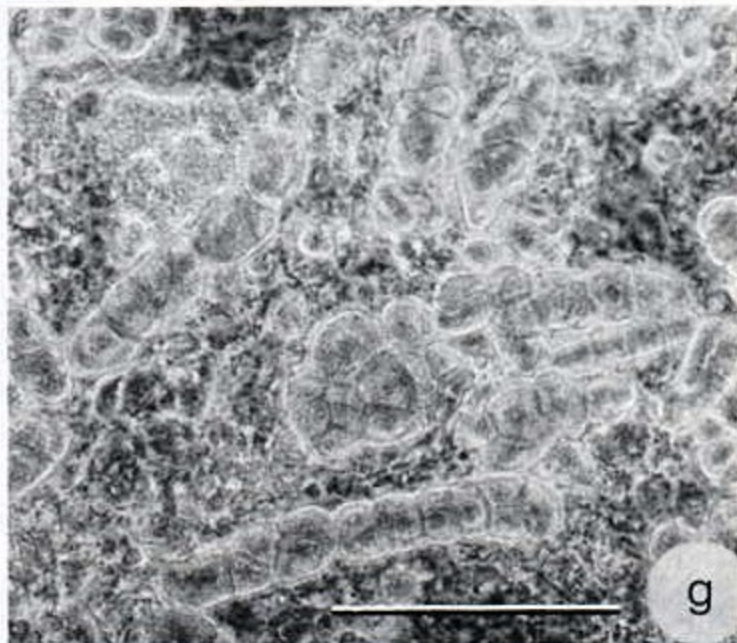
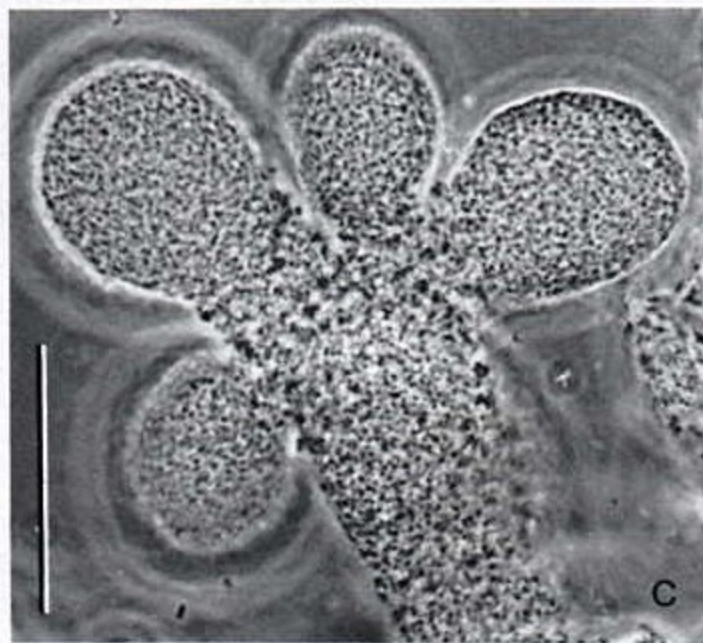
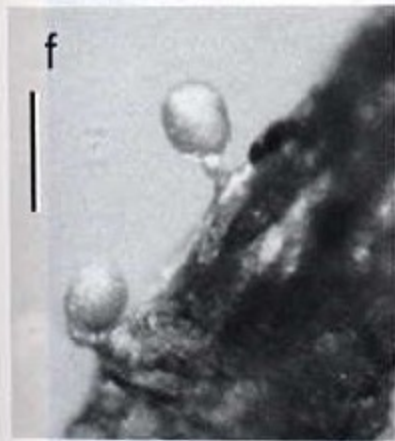
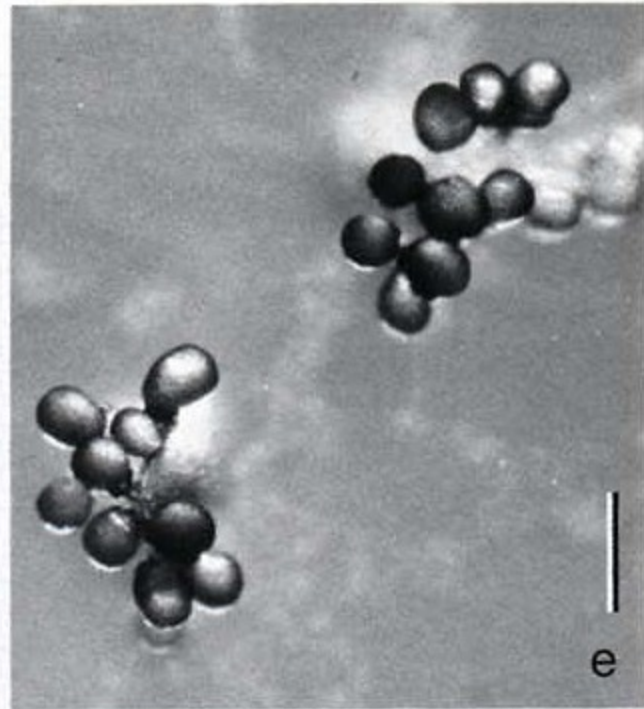
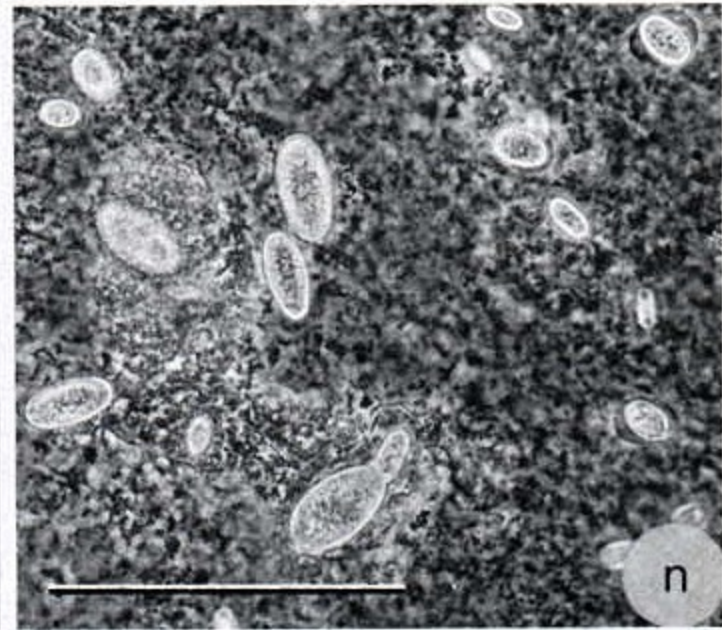
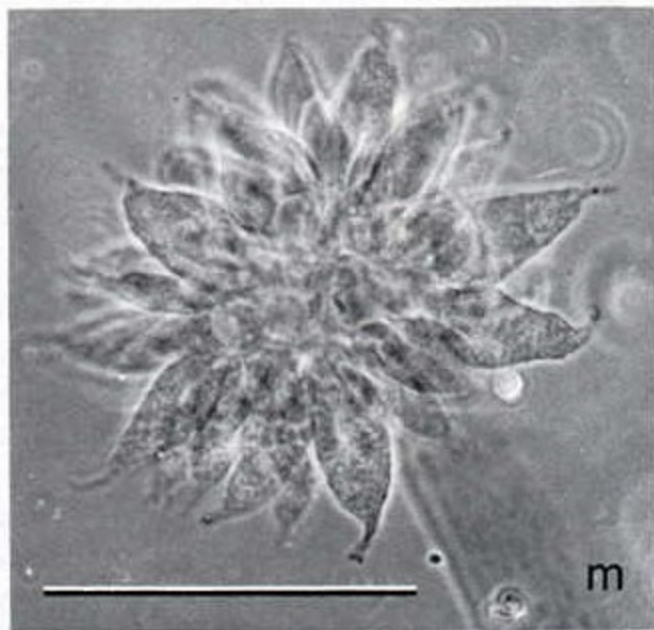
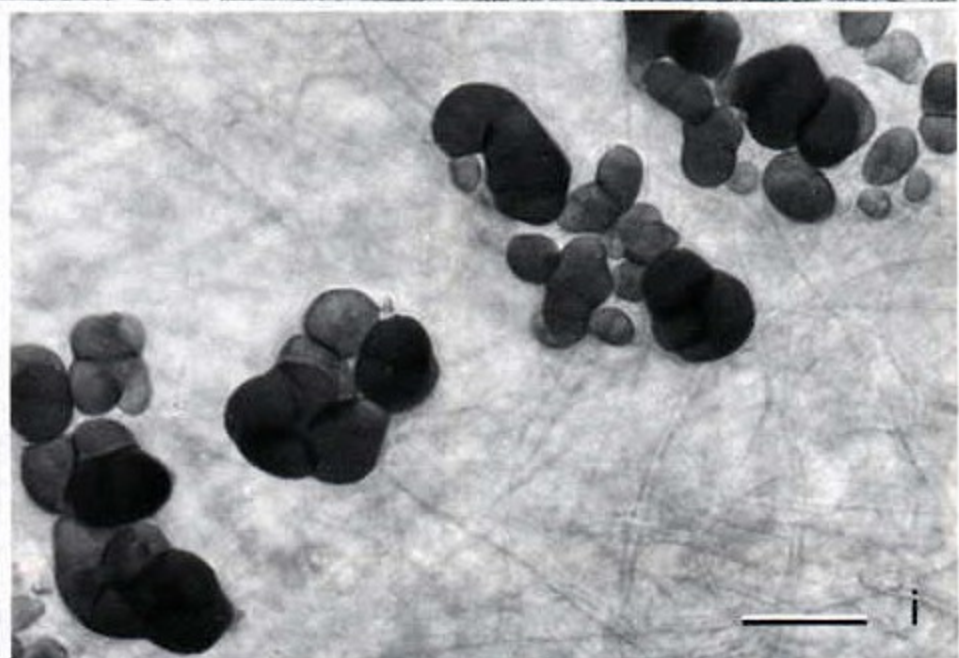


Fig. 12. Similar fruiting body shapes may be reached in different ways, as shown here for *Chondromyces apiculatus* (above) and *Stigmatella aurantiaca* (below), two organisms formerly thought to be closely related. The hatched areas indicate where the cells are located at the various stages.





# 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

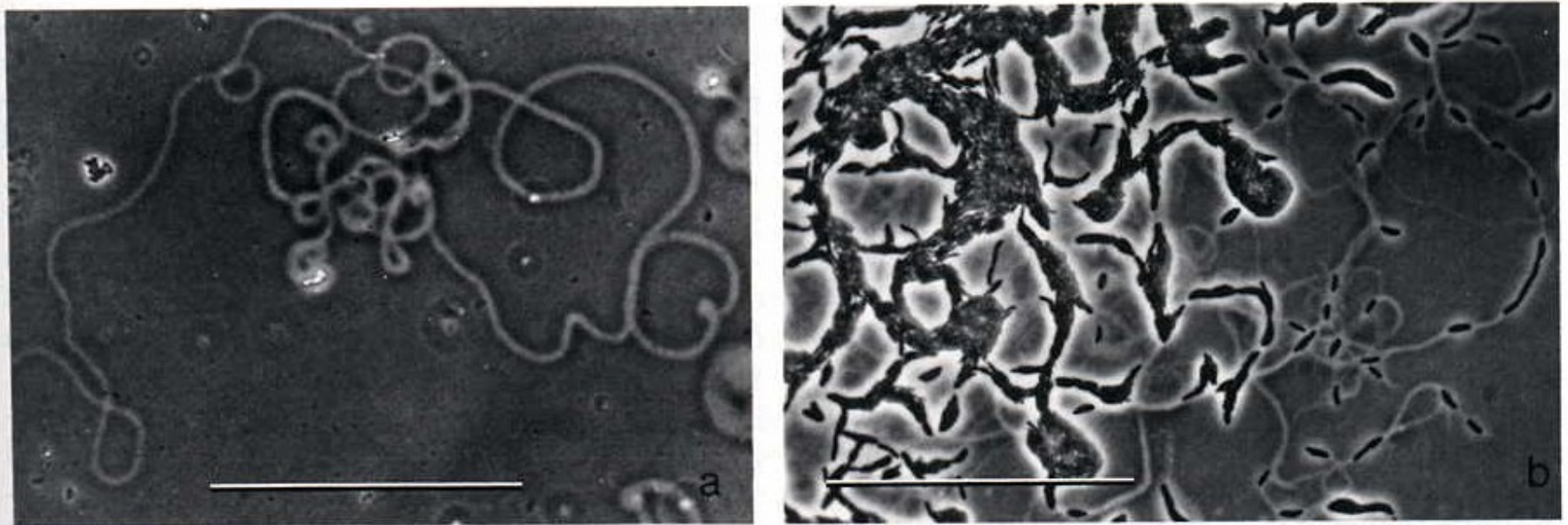
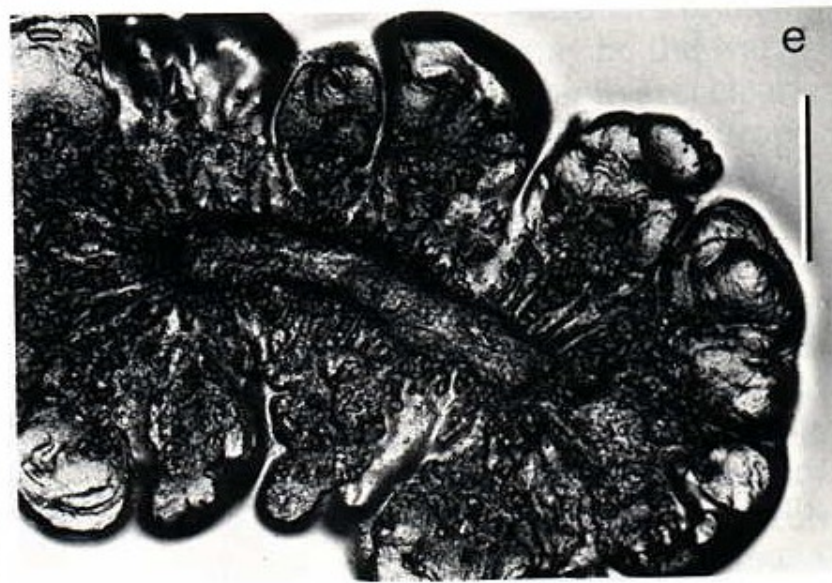
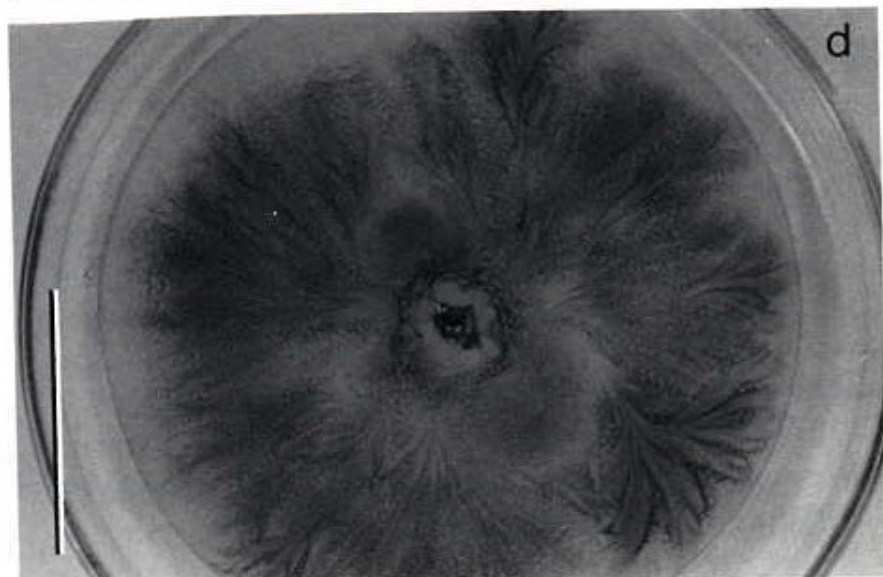
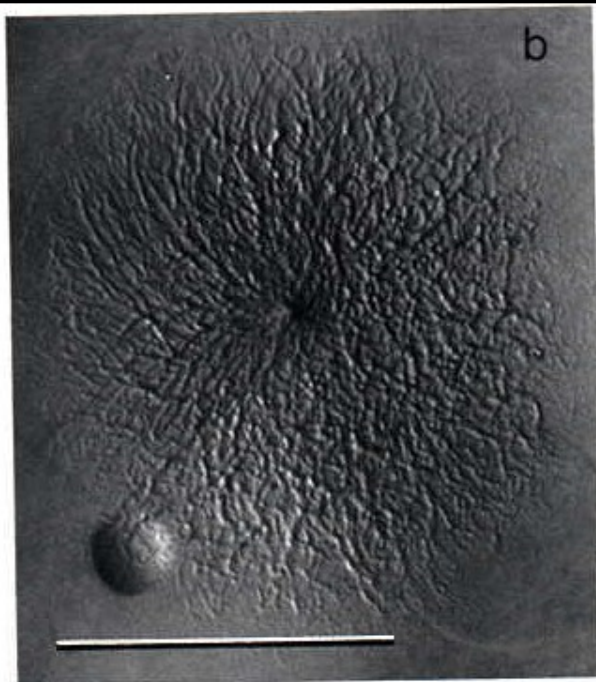
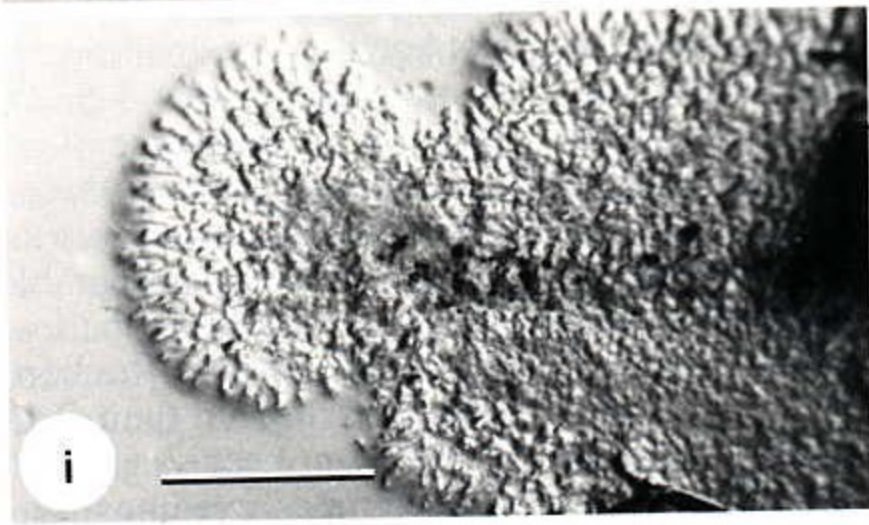
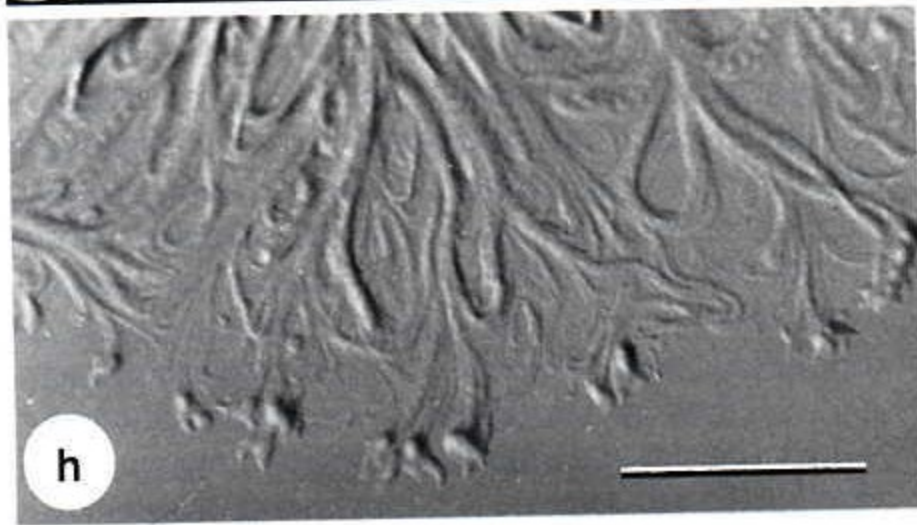
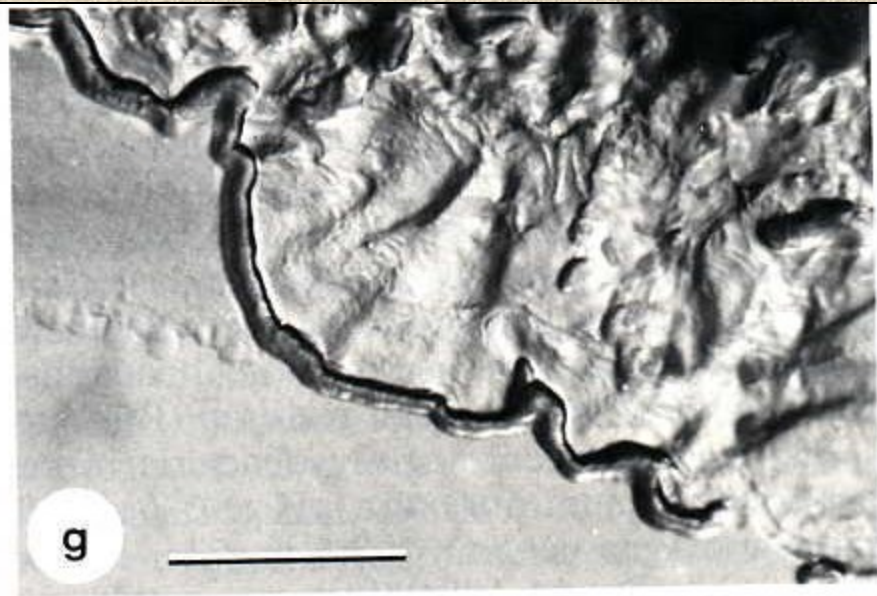
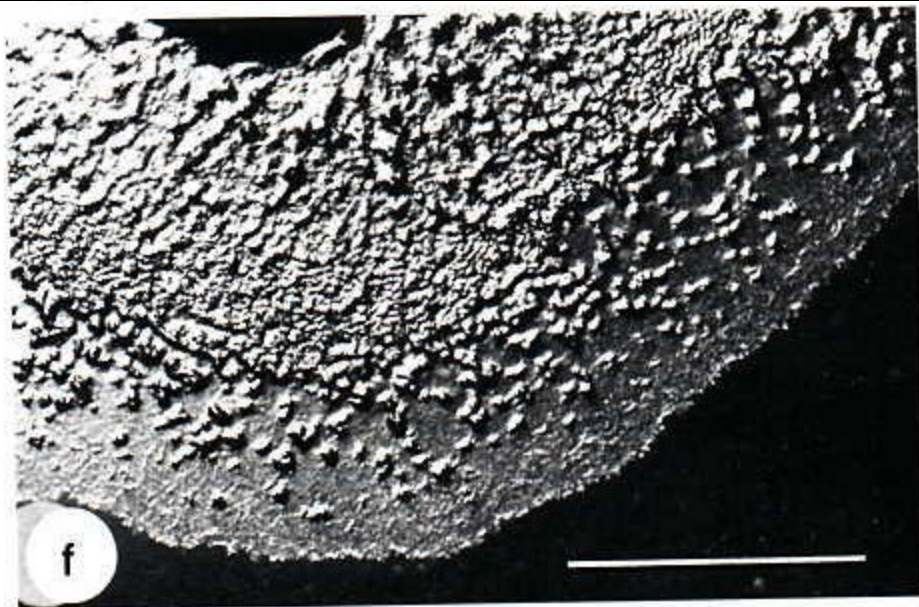


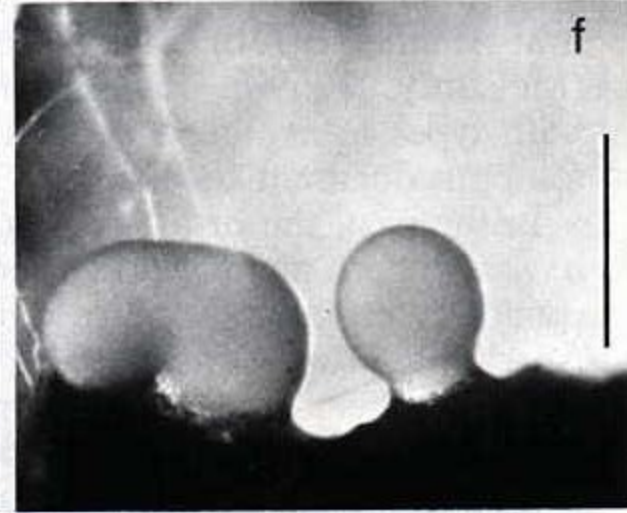
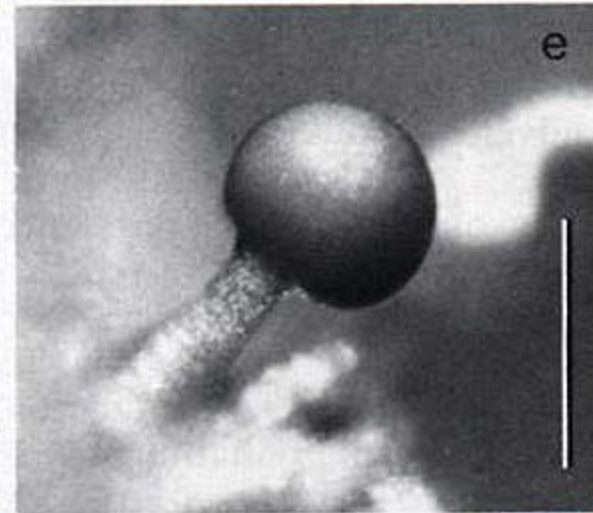
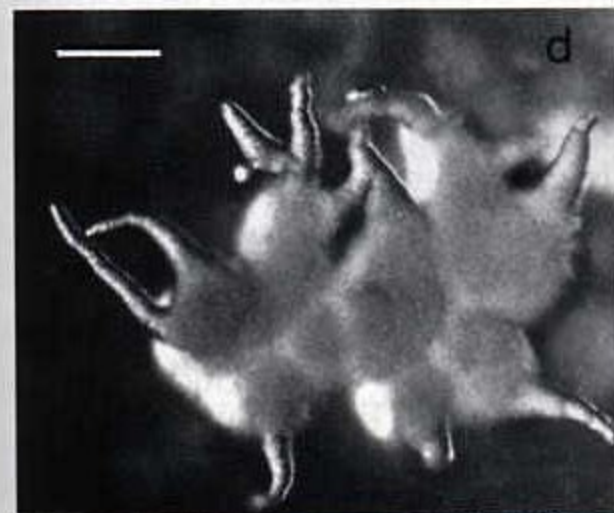
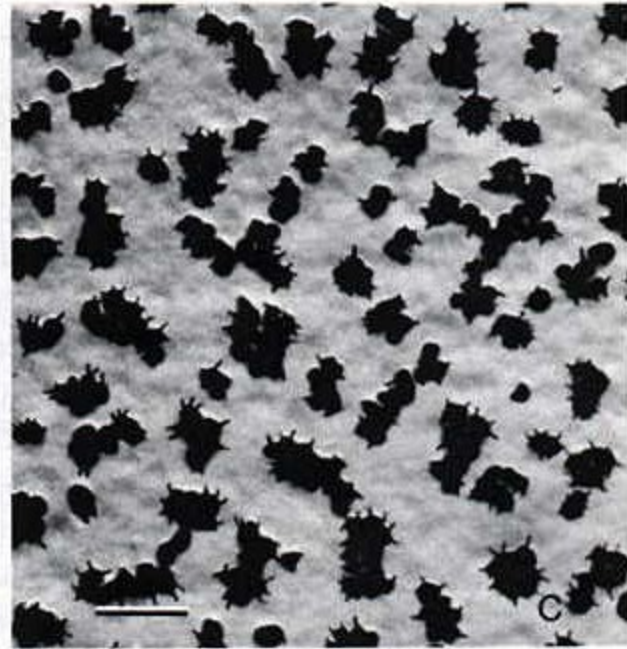
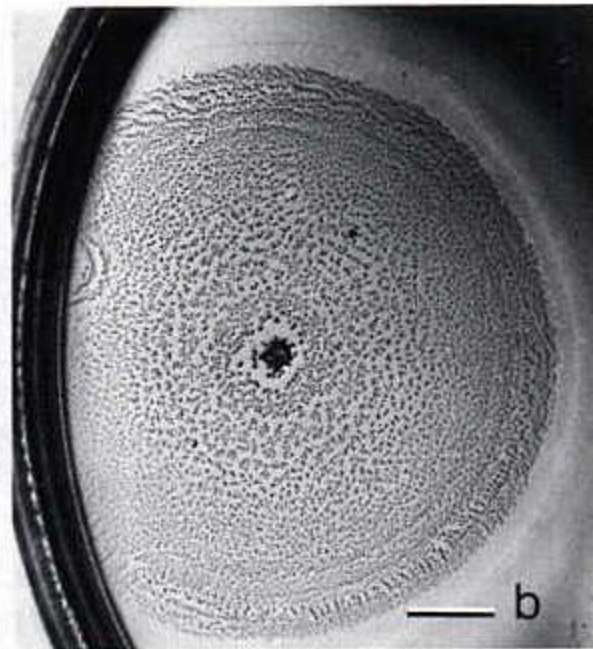
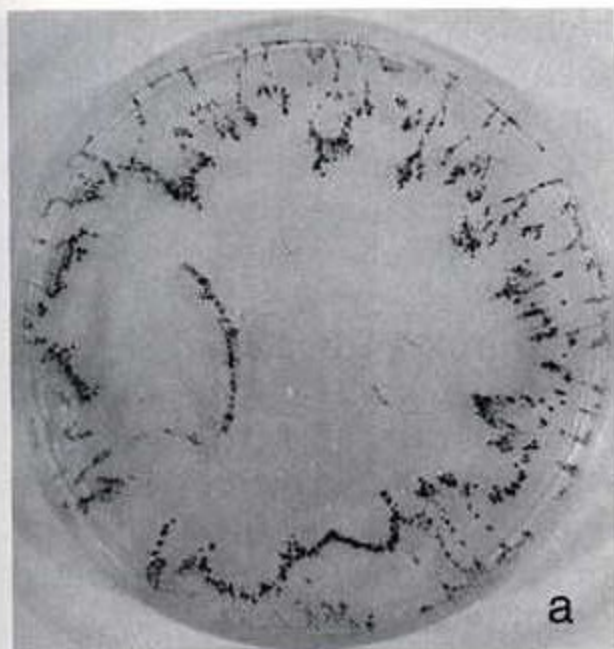
Fig. 5. Slime tracks as seen on thin agar layers in chamber cultures. (a) *Nannocystis exedens*. (b) *Myxococcus fulvus*; the spots seen on the left are cell clusters, not single cells. Bar = 100  $\mu\text{m}$ . Phase contrast.

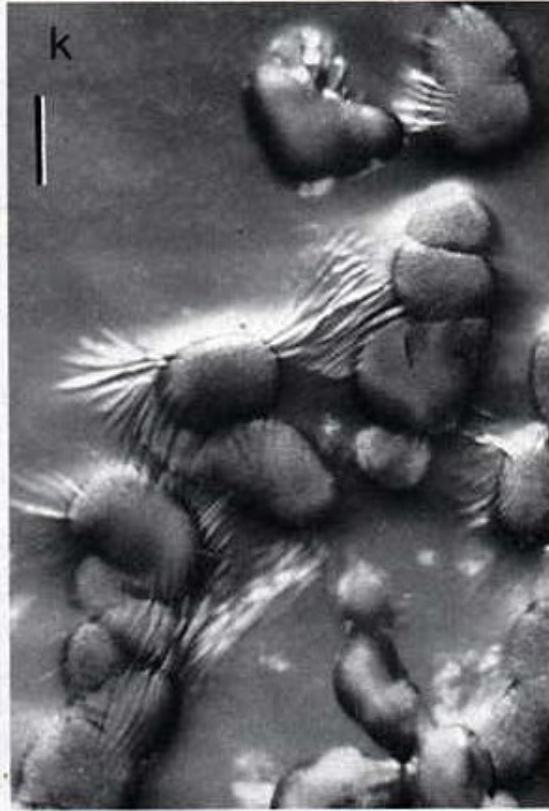
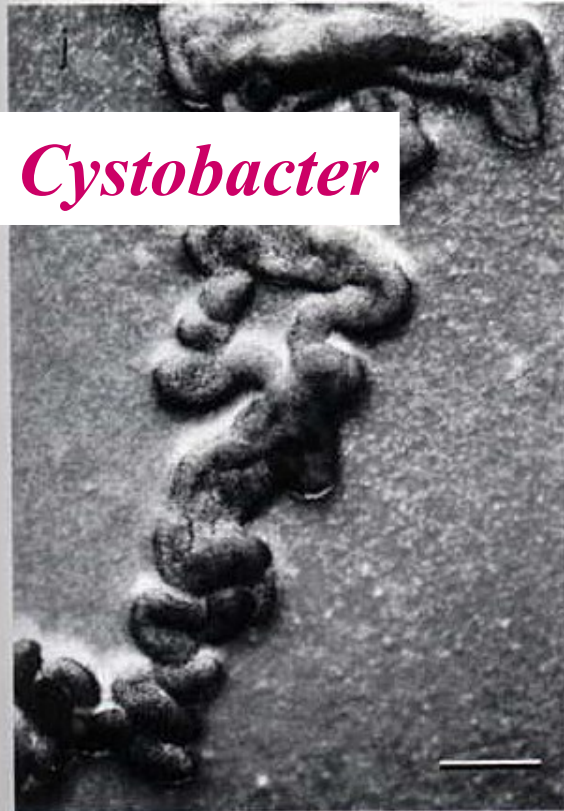
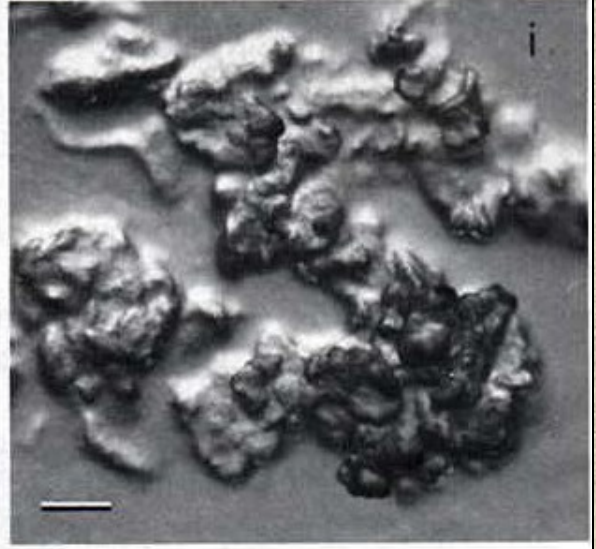
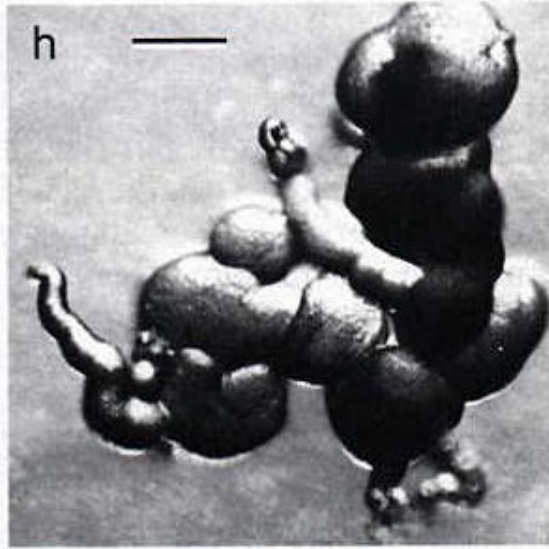
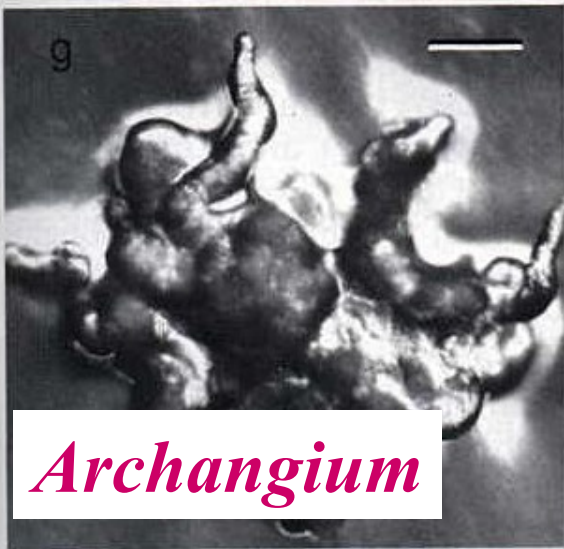
**Plazivé  
kolonie**











## 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**
- **Hartzell, P.L. and P. Youderian 1995 Genetics of gliding motility and development in *Myxococcus xanthus*. Arch. Microbiol. 164:309-323.**
- **Freese, A., H. Reichenbach and H. Lünsdorf. 1997 Further characterization and in situ localization of chain-like aggregates of the gliding bacteria *Myxococcus fulvus* and *Myxococcus xanthus*. J. Bacteriol. 179:1246-1252.**
- **Shimkets, L.J. 1993 The myxobacterial genome p.85-108 in Myxobacteria II M. Dworkin and D. Kaiser (eds) American Society for Microbiology Press**
- **Shimkets, L.J. (1999): Intercellular signaling during fruiting-body development of *Myxococcus xanthus*. Annu Rev Microbiol. 53:525-49.**

- **White, D. 1993 Myxospore and fruiting body morphogenesis. p.307-346 in Myxobacteria II M. Dworkin and D. Kaiser (eds) American Society for Microbiology Press**
- **Kaiser, D. and L. Kroos 1993 Intercellular signaling p.257-284 in Myxobacteria II M. Dworkin and D. Kaiser (eds) American Society for Microbiology Press**
- **Dworkin, M. 1996 Recent advances in the social and developmental biology of the myxobacteria. Microbiol. Rev. 60: 70-102.**
- **Reichenbach, H. 1993 Biology of the myxobacteria: Ecology and Taxonomy. p.13-62 in Myxobacteria II M. Dworkin and D. Kaiser (eds) American Society for Microbiology Press**



*Děkuji za Vaši pozornost*