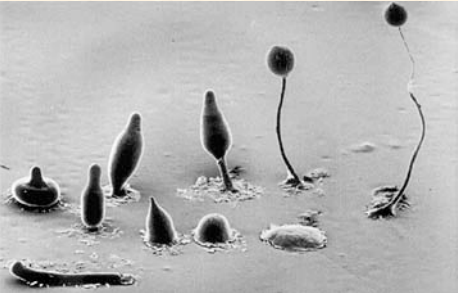


B.
Slime Mold
(Dictyostelium discoideum)
“Dicty”

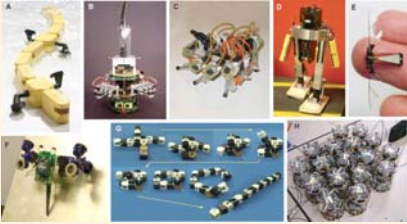
9/5/08 1

Complete Life Cycle




9/5/08 2

Self-organization in Bio-inspired Robotics




R. Pfeifer et al., *Science* 318, 1088-1093 (2007)



9/5/08 Published by AAAS 3

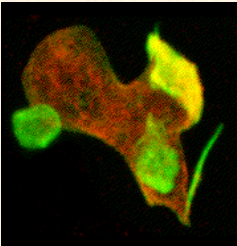
Self-copying Robot (2005)



- Hod Lipson, Cornell
- Programmable blocks
- 2 swiveling pyramidal halves
- Magnetic connections
- 10 cm across
- One stack can assemble another

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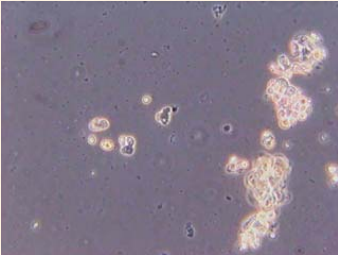
Amoeba Stage



- Single cell
- Lives in soil
- Free moving
- Engulfs food (bacteria)
- Divides asexually

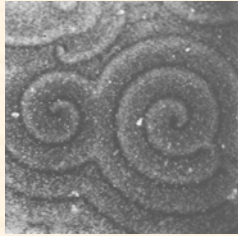
9/5/08 5

Amoebas



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Aggregation Stage

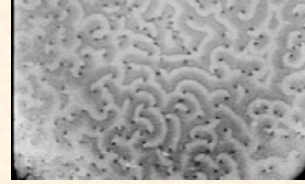


- Triggered by exhaustion of food
- Aggregate by *chemotaxis*
- Form expanding concentric rings and spirals
- Up to 125 000 individuals

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7

Spiral Waves



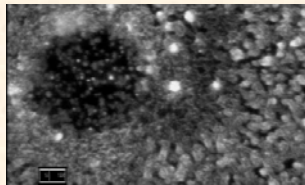
- Spiral accelerate cell aggregation (18 vs. 3 $\mu\text{m}/\text{min.}$)
- Waves propagate 120 – 60 $\mu\text{m}/\text{min.}$
- 1 frame = 36 sec.

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(video < Zool. Inst., Univ. München)

8

Center of Spiral



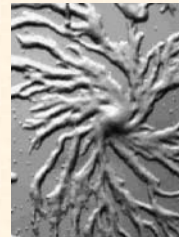
- Mechanisms of spiral formation are still unclear
- Involves symmetry breaking
- 1 frame = 10 sec.

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(video < Zool. Inst., Univ. München)

9

Stream Formation Stage



- Streams result from dependence of wave propagation velocity on cell density
- Breaks symmetry
- As density increases, begin to adhere
- Begin to form *mound*

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Mound Stage

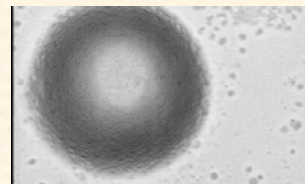


- Cells differentiate
- Some form an elongated finger

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Concentric Waves in Mounds



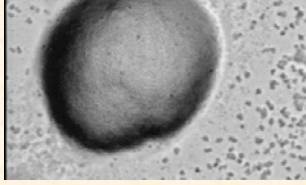
- Concentric or spiral waves
- Mound comprises 10^3 to 10^5 cells
- Cells begin to differentiate
- 1 frame = 20 sec.

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(video < Zool. Inst., Univ. München)

12

Multiple Centers



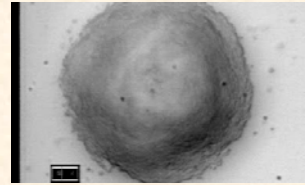
- Multiple pacemakers
- Wave fronts mutually extinguish (typical of excitable media)
- One center eventually dominates

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(video < Zool. Inst., Univ. München)

13

Multi-armed Spirals



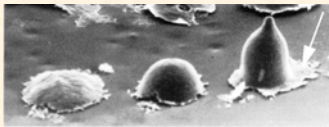
- This mound has 5 spiral arms
- Up to 10 have been observed

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(video < Zool. Inst., Univ. München)

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Formation of Acellular Sheath



- Composed of cellulose & a large glycoprotein
- Covers mound and is left behind slug as trail
- Function not entirely understood:
 - protection from nematodes (worms)
 - control of diffusion of signaling molecules

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Slug Stage

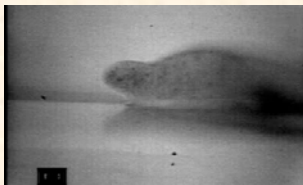


- Prestalk elongates, topples, to form slug
- Behaves as single organism with 10^5 cells
- Migrates; seeks light; seeks or avoids heat
- No brain or nervous system

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Movement of Young Slug



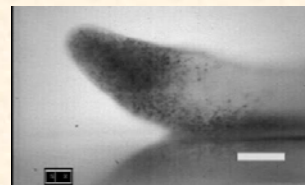
- Time-lapse (1 frame = 10 sec.)
- Note periodic up-and-down movement of tip

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(video < Zool. Inst., Univ. München)

17

Movement of Older Slug



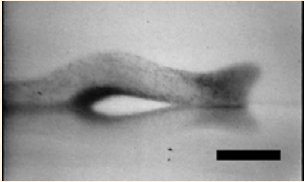
- Note rotating prestalk cells in tip
- Pile of anterior-like cells on prestalk/prespore boundary
- Scale bar = 50 μ m, 1 frame = 5 sec.

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(video < Zool. Inst., Univ. München)

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Migration of Older Slug



- Scale bar = 100 μm , 1 frame = 20 sec.

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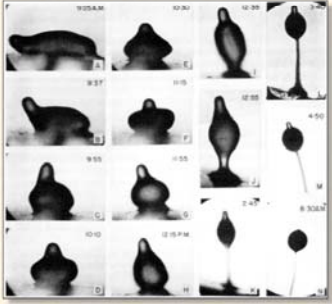
Culmination Stage



- Cells differentiate into base, stalk, and spores
- Prestalk cells form rigid bundles of cellulose & die
- Prespore cells (at end) cover selves with cellulose & become dormant

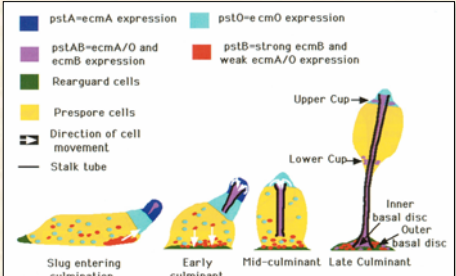
9/5/08 20

Stages of Culmination



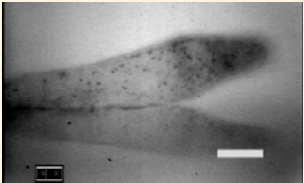
9/5/08 21

Cell Differentiation at Culmination



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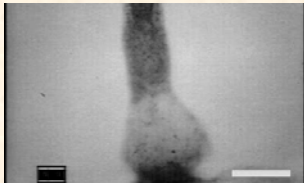
Early Culmination



- During early culmination all cell in prestalk rotate
- Scale bar = 50 μm , 1 frame = 25 sec.

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Late Culmination



- Vigorous rotation at prestalk/prespore boundary
- Scale bar = 100 μm , 1 frame = 10 sec.

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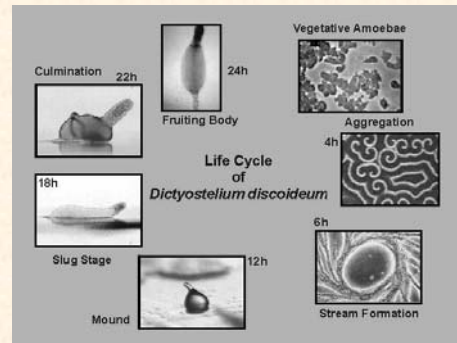
Fruiting Body Stage



- Spores are dispersed
- Wind or animals carry spores to new territory
- If sufficient moisture, spores germinate, release amoebas
- Cycle begins again

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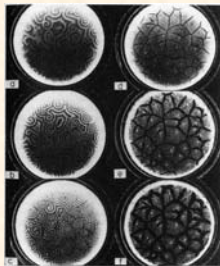
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Emergent Patterns During Aggregation



- a-c. As aggregate, wave lengths shorten
- d. Population divides into disjoint domains
- e-f. Domains contract into "fingers" (streaming stage)

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fig. from Solé & Goodwin

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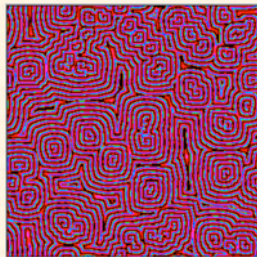
Belousov-Zhabotinski Reaction



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Hodgepodge Machine



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Demonstration of Hodgepodge Machine

[Run NetLogo B-Z Reaction Simulator](#)

or

[Run Hidgepodge simulator at CBN Online Experimentation Center](#)

<mitpress.mit.edu/books/FLAOH/cbnhtml/java.html>

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Universal Properties

- What leads to these expanding rings and spirals in very different systems?
- Under what conditions do these structures form?
- What causes the rotation?
- These are all examples of *excitable media*

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Reading

Read Flake, ch. 16



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