B. Slime Mold

(*Dictyostelium discoideum*)

“Dicty”

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**Complete Life Cycle**

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**Self-organization in Bio-inspired Robotics**

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

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**Self-copying Robot (2005)**

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**Amoeba Stage**

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

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**Amoebas**
Aggregation Stage

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

Spiral Waves

- Spiral accelerate cell aggregation (18 vs. 3 µm/min.)
- Waves propagate 120 – 60 µm/min.
- 1 frame = 36 sec.

Center of Spiral

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

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

Mound Stage

- Cells differentiate
- Some form an elongated finger

Concentric Waves in Mounds

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

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

Multi-armed Spirals

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

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

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

Movement of Young Slug

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

Movement of Older Slug

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

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

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

Stages of Culmination

Cell Differentiation at Culmination

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

Early Culmination

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

Late Culmination
Part 2: Slime Mold 9/5/08

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

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)

Belousov-Zhabotinski Reaction

Hodgepodge Machine

Demonstration of Hodgepodge Machine

Run NetLogo B-Z Reaction Simulator
or
Run Hodgepodge simulator at CBN Online Experimentation Center
<mitpress.mit.edu/books/FLAOH/cbnhtml/java.html>
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

Reading

Read Flake, ch. 16