Swarm Chemistry

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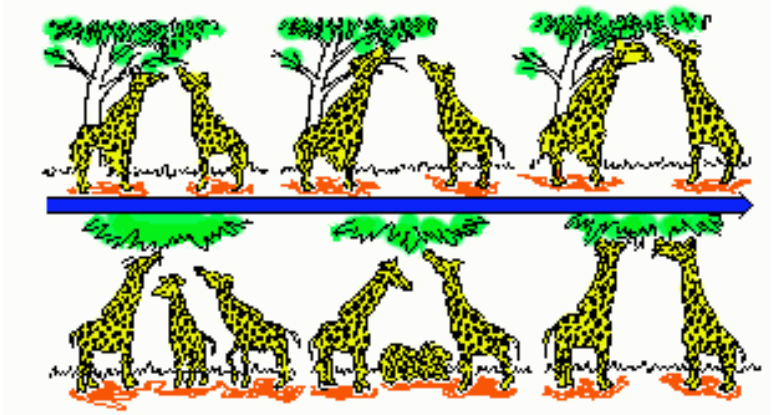
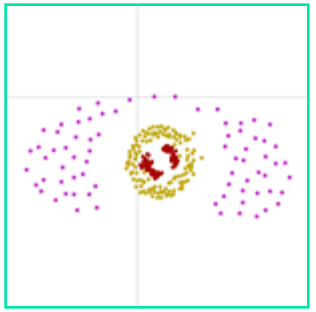


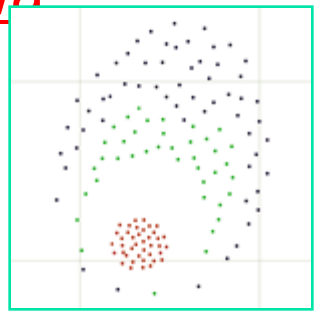
iba lab.

Swam chemistry

- 佐山弘樹@Binghamton Universityが考えた複雑系シミュレーション
- Boidの拡張
- Algorithmic chemistryの実例

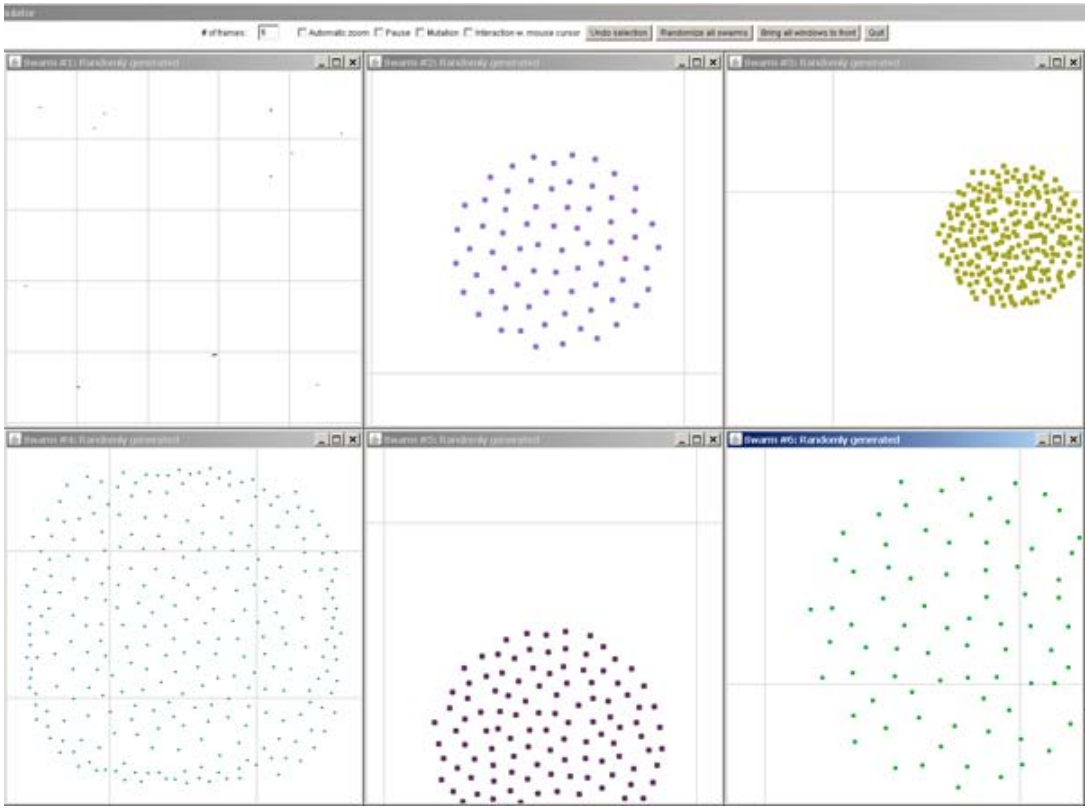


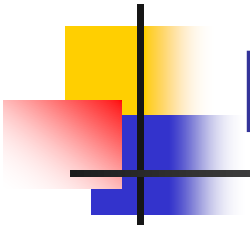
- 情報源
  - http://bingweb.binghamton.edu/~sayama/SwarmChemistry/
  - **Hiroki Sayama**, Swarm chemistry, *Artificial Life* 15:105-114, 2009。



Swarm chemistry: sample

- 見本のjava applet





Model

- A swarm population in swarm chemistry consists of a number of simple, semi-autonomous agents.
- They can move in a two-dimensional continuous space.
- Each agent can perceive positions and velocities of other agents within its local perception range.
- It can change its velocity in discrete time steps according to the kinetic rules.
  - adopted and modified from the rules in Reynolds' boids system

Kinetic rules

- If there are no local agents within its perception range, steer randomly (straying).
- Otherwise:
  - – Steer to move toward the average position of local agents (cohesion).
  - – Steer toward the average velocity of local agents (alignment).
  - – Steer to avoid collision with local agents (separation).
  - – Steer randomly with a given probability (whim).
- Approximate one's speed to one's own normal speed (pacekeeping).

Algorithm

1: **for all** $i \in$ agents **do**

2: $N \leftarrow \{j \neq i$ that satisfies $|\vec{x_j} - \vec{x_i}| < R^l\}$

// Finding other agents within its local perception range

3: **if** $|N| = 0$ **then**

4: $\vec{a} \leftarrow (r_{\pm.5}, r_{\pm.5})$ // Straying

5: **else**

6: $\langle \vec{x} \rangle \leftarrow \Sigma_{j \in N} \vec{x_j}/|N|$ // Calculating the average position of local agents

7: $\langle \vec{v} \rangle \leftarrow \Sigma_{j \in N} \vec{v_j}/|N|$ // Calculating the average velocity of local agents

8: $\vec{a} \leftarrow c_1^l (\langle \vec{x} \rangle - \vec{x_i}) + c_2^l (\langle \vec{v} \rangle - \vec{v_i}) + c_3^l \Sigma_{j \in N} (\vec{x_i} - \vec{x_j})/|\vec{x_i} - \vec{x_j}|^2$

// Cohesion, alignment, and separation

9: **if** $r < c_4^l$ **then**

10: $\vec{a} \leftarrow \vec{a} + (r_{\pm 5}, r_{\pm 5})$ // Whim

11: **end if**

12: **end if**

Algorithm

1: **for all** $i \in$ agents **do**

2: $N \leftarrow \{j \neq i$ that satisfies $|\vec{x}_j - \vec{x}_i| < R\}$

// Finding other agents within its local perception range

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7: $\langle \vec{v} \rangle \leftarrow \Sigma_{j \in N} \vec{v}_j / |N|$ // Calculating the average velocity of local agents

8: $\vec{a} \leftarrow c_1^i (\langle \vec{x} \rangle - \vec{x}_i) + c_2^i (\langle \vec{v} \rangle - \vec{v}_i) + c_3^i \Sigma_{j \in N} (\vec{x}_i - \vec{x}_j) / |\vec{x}_i - \vec{x}_j|^2$

// Cohesion, alignment, and separation

9: **if** $r < c_4^i$ **then**

10: $\vec{a} \leftarrow \vec{a} + (r_{\pm 5}, r_{\pm 5})$ // Whim

11: **end if**

12: **end if**

i番目のagentの位置

[-0.5, 0.5]の一様乱数

加速度（一時変数）

i番目のagentの速度

[0, 1]の一様乱数

Algorithm

13: $\overrightarrow{v_i'} \leftarrow \overrightarrow{v_i} + \overrightarrow{a}$ // Acceleration

14: $\overrightarrow{v_i'} \leftarrow \min(V_m^i / |\overrightarrow{v_i'}|, 1) \cdot \overrightarrow{v_i'}$ // Prohibiting overspeed

15: $\overrightarrow{v_i'} \leftarrow c_5^i (V_n^i / |\overrightarrow{v_i'}| \cdot \overrightarrow{v_i'}) + (1 - c_5^i) \overrightarrow{v_i'}$ // Pacekeeping

16: **end for**

17: **for all** $i \in$ agents **do**

18: $\overrightarrow{v_i} \leftarrow \overrightarrow{v_i'}$ // Updating velocity

19: $\overrightarrow{x_i} \leftarrow \overrightarrow{x_i} + \overrightarrow{v_i}$ // Updating location

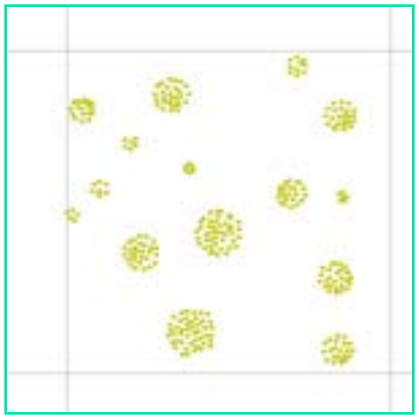
20: **end for**

Kinetic Parameters

Name	Min	Max	Meaning	Unit
R^i	0	300	Radius of local perception range	pixel
V_n^i	0	20	Normal speed	pixel $step^{-1}$
V_m^i	0	40	Maximum speed	pixel $step^{-1}$
c_1^i	0	1	Strength of cohesive force	$step^{-2}$
c_2^i	0	1	Strength of aligning force	$step^{-1}$
c_3^i	0	100	Strength of separating force	$pixel^2$ $step^{-2}$
c_4^i	0	0.5	Probability of random steering	—
c_5^i	0	1	Tendency of pacekeeping	—

Unique values are assigned to these parameters for each agent i as its own kinetic properties.

Example



Blobs

300 * (20.8, 1.95, 20.75, 0.95, 0.99, 9.31, 0.05, 0.68)

(R, Vn, Vm, c1, c2, c3, c4, c5) format

Population size

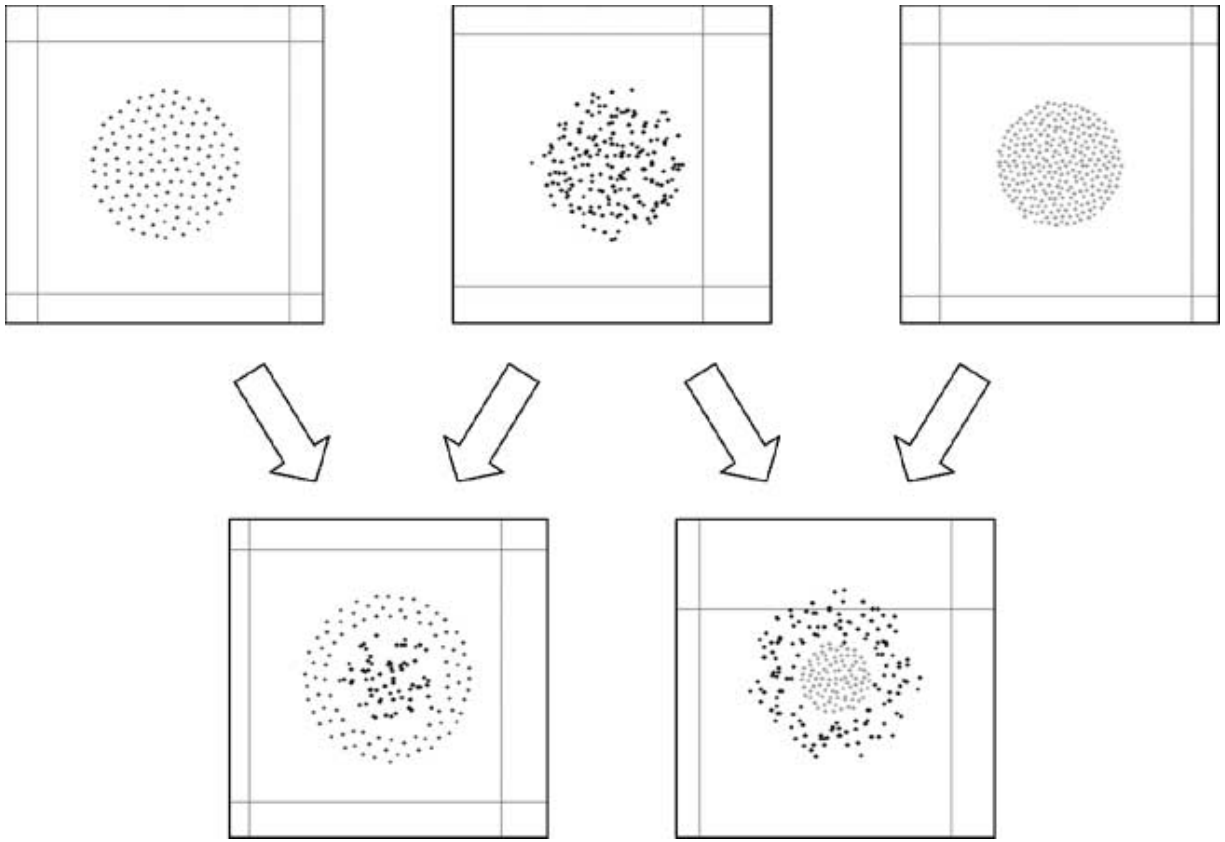
Coloring:
(c1, c2, c3/100) --→ (R, G, B) values

Chemical reactions

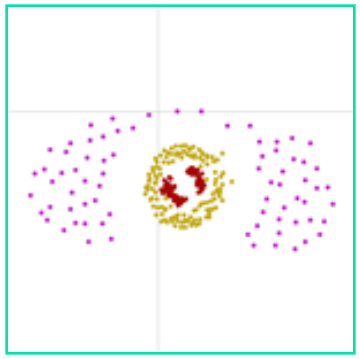
(260.37, 0.84, 12.55, 0.69, 0.59, 47.16, 0.49, 0.9)

(185.11, 10.86, 19.97, 0.53,0.05, 19.12, 0.05, 0.44)

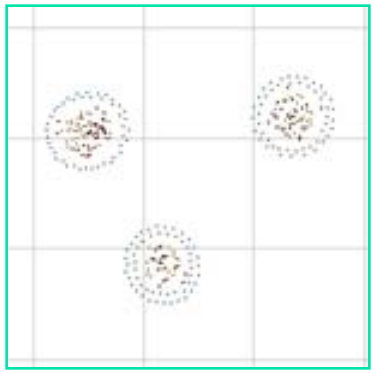
(211.12, 16.22, 1.13, 0.73, 0.89, 15.82, 0.39, 0.54)



Example



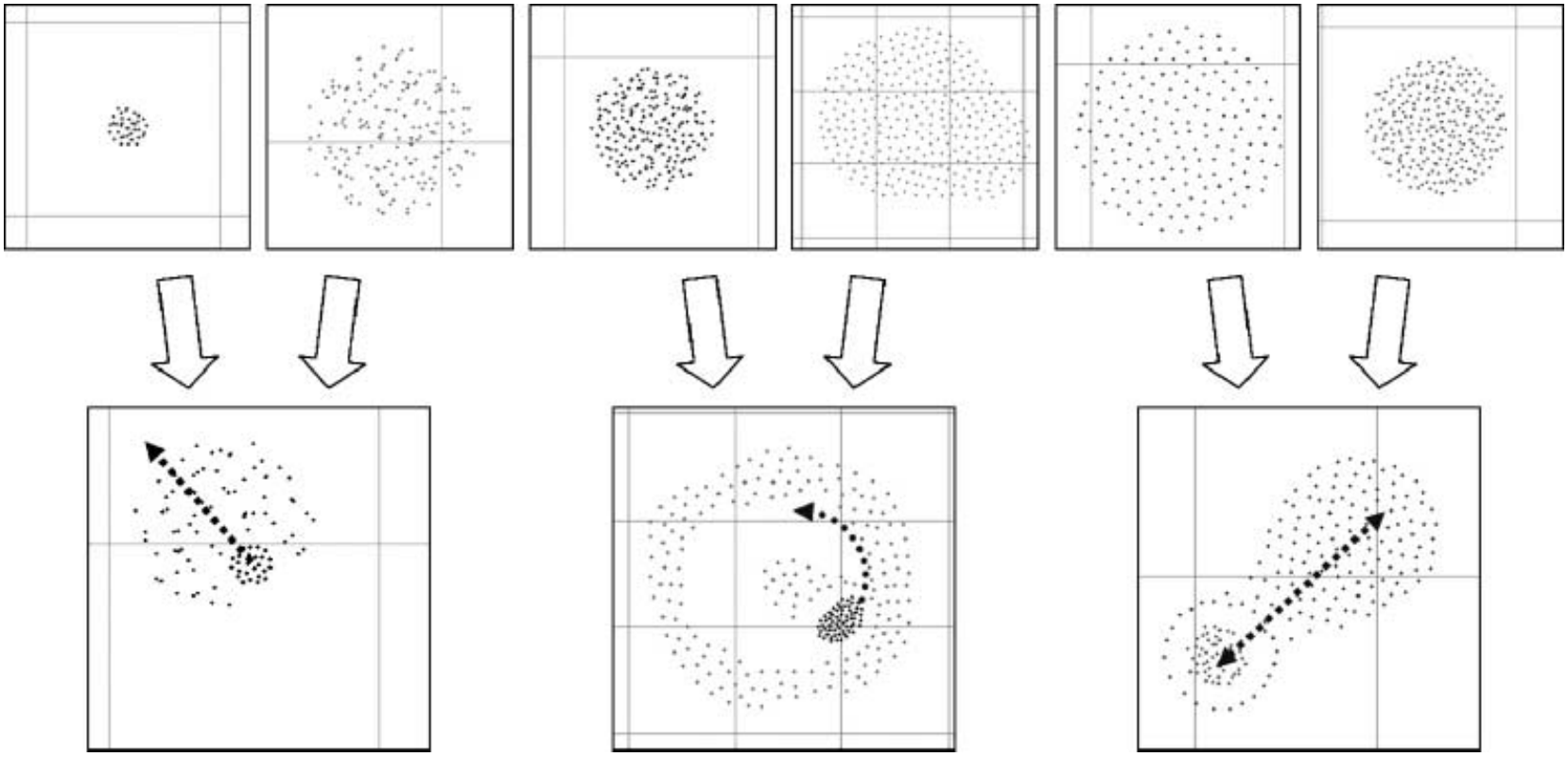
Pulsating Eye
102 * (293.86, 17.06, 38.3, 0.81, 0.05, 0.83, 0.2, 0.9)
124 * (226.18, 19.27, 24.57, 0.95, 0.84, 13.09, 0.07, 0.8)
74 * (49.98, 8.44, 4.39, 0.92, 0.14, 96.92, 0.13, 0.51)
Contributed by Benjamin Bush



Chaos Cells
144 * (109.03, 6.71, 12.7, 0.47, 0.6, 61.43, 0.02, 0.21)
89 * (117.15, 16.33, 31.88, 0.39, 0.13, 12.96, 0.48, 0.8)
67 * (76.3, 8.59, 26.57, 0.7, 0.64, 28.39, 0.3, 0.35)
Contributed by Jesse Fagan

From left to right:
(231.53, 2.72, 26.49, 0.89, 0.0, 23.23, 0.47, 0.78)
(292.29, 15.44, 25.33, 0.98, 0.46, 94.01, 0.29, 0.16)
(241.98, 6.93, 5.43, 0.59, 0.02, 26.39, 0.17, 0.77)
(74.54, 1.24, 36.59, 0.11, 0.84, 51.18, 0.3, 0.41)
(86.89, 1.8, 22.26, 0.57, 0.35, 80.8, 0.35, 0.64)
(70.55, 5.52, 7.39, 0.97, 0.45, 35.51, 0.45, 0.06)

Pattern Generation



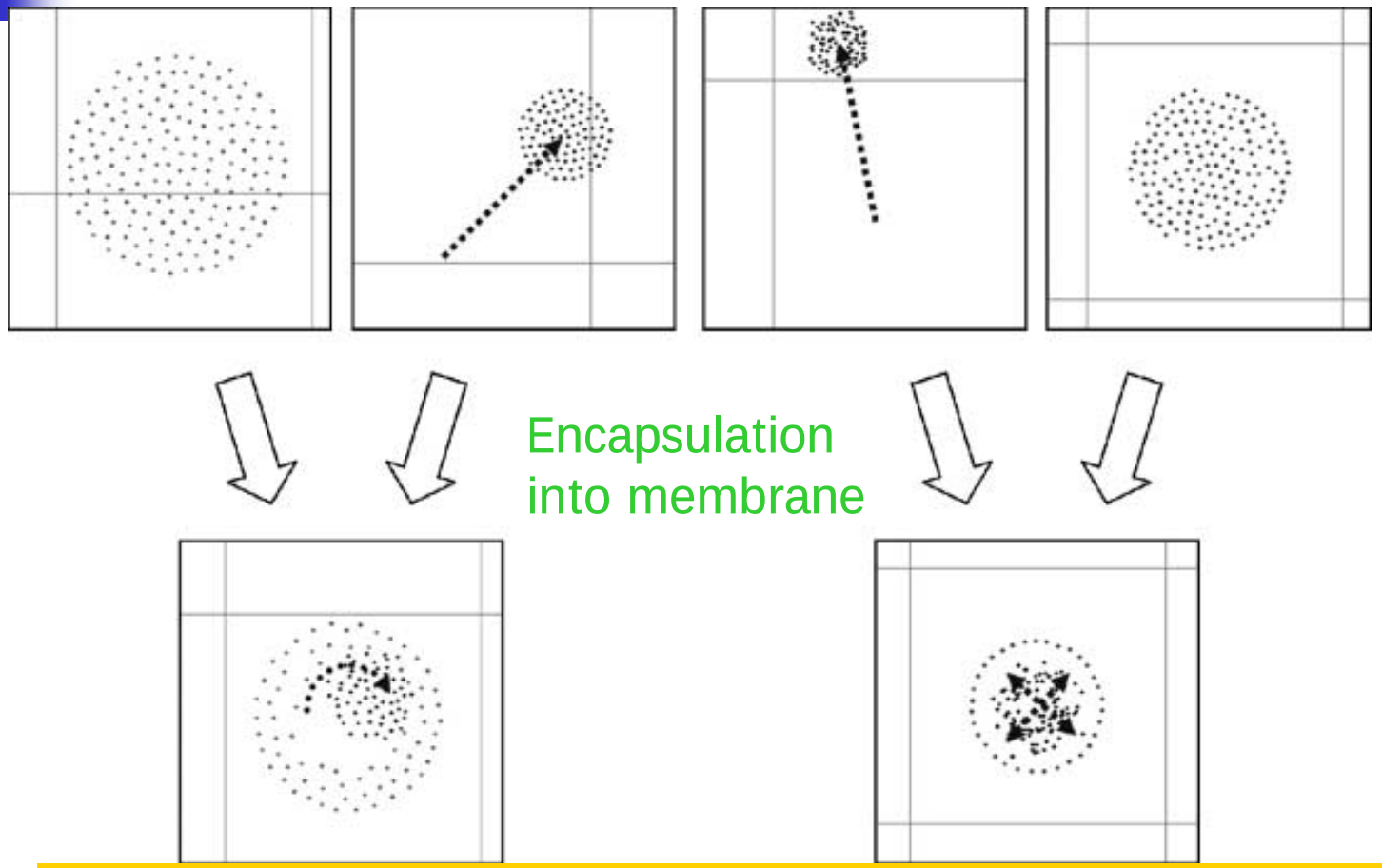
Linear motion

Rotation

Linear oscillation

From left to right:
(278.56, 10.88, 1.23, 0.26, 0.78, 27.69, 0.07, 0.77)
(89.41, 8.12, 18.29, 0.4, 0.51, 13.3, 0.03, 0.58)
(116.78,16.82, 30.15, 0.46, 0.22, 8.47, 0.2, 0.87)
(246.36, 0.02, 20.62, 0.91, 0.12, 47.96, 0.41, 0.77)

Pattern Generation



Let us find interesting patterns!!