



What is self-organization?

The system needs:

- multiple agents that can interact
- No leader, preconceived vision, or plan
- No external directing influence

End result: increased order of the system (organization!)

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What is self-organization?

“the dynamics of a system can tend by themselves to increase the inherent order of a system”
- Wikipedia

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What is self-organization?

“Self-organization is a process in which pattern at the global level of a system emerges solely from numerous interactions among the lower-level components of the system. Moreover, the rules specifying interactions among the system’s components are executed using only local information, without reference to the global pattern.”

- Self-Organization in Biological Systems, by Camazine et al.

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What is emergence?

“The whole is greater than the sum of its parts”

Are the patterns resulting from self-organization always emergent?

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What are complex systems?

Complex systems are... complicated!

A reductionist strategy is not sufficient to understand complex systems

Difficult to model or simulate

Emergent patterns, often self-organized

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Complexity vs. Chaos

Chaotic systems are deterministic
- if initial conditions are replicated perfectly, we will get the same result

Complex systems are not necessarily deterministic
- the result depends on history, so we may get different results with the same initial conditions

The edge of chaos: Is there a region between deterministic order and randomness that is complex, yielding general patterns?

-At Home in the Universe, by Stuart Kauffman

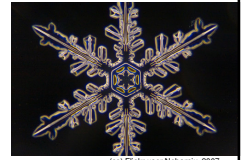
Complex Systems

We cannot predict the exact form of a complex system.

How dependent is the overall phenomenon on the details?

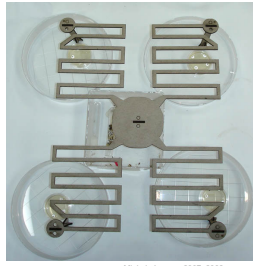
Do complex systems show general properties and processes?

At Home in the Universe, by Stuart Kauffman



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Are there general processes of self-organization?



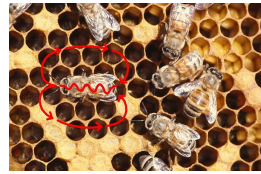
Michele Lanan, 2007, 2008

Are there general processes of self-organization?

Positive and negative feedback loops

Information transfer: signals and cues

- Self Organization in Biological Systems, by Camazine et al.



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Are there general processes of self-organization?

Positive and negative feedback loops

Information transfer: passive and active

Trade-off: exploitation and exploration



Michele Lanan, 2004

Are there general processes of self-organization?

Positive and negative feedback loops

Information transfer: passive and active

Trade-off: exploitation and exploration

"Multiple interactions"

?

Self-organization and self-assembly: what is the difference?

Self-assembly = Low-energy assembly = **equilibrium**

- Nédélec et al., Wikipedia, Stuart Kauffman



(cc) Flickr user Red Betty Black, 2005

Self-organization and self-assembly: what is the difference?

Self-organization = constant input of energy and/or matter = **non-equilibrium**

- Nédélec et al., Wikipedia, Stuart Kauffman



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Self-organization and self-assembly: what is the difference?

Self-assembly = Low-energy assembly = **equilibrium**

Self-organization = constant input of energy and/or matter = **non-equilibrium**

Is this a reasonable distinction?



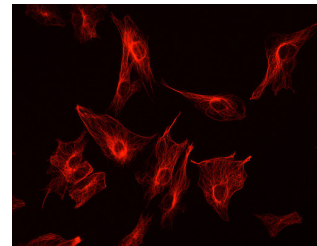
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Example of self-organization: the cytoskeleton

Architecture of the cell

Microtubules: tubulin

Actin filaments: actin

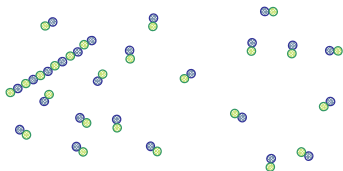


(c) Jonas Hannestad, 2005

Example of self-organization: the cytoskeleton

Microtubules: formed from α - and β - tubulin dimers

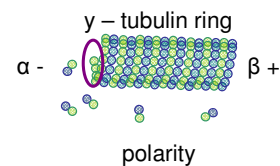
The dimers fit end-to-end, making filaments



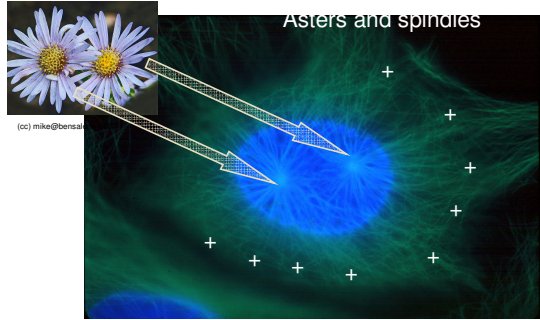
Example of self-organization: the cytoskeleton

Microtubule nucleation

Important component of microtubule organizing centers!

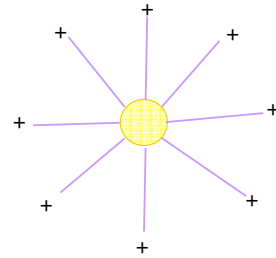


Example of self-organization: the cytoskeleton



Example of self-organization: the cytoskeleton

How to make an aster?

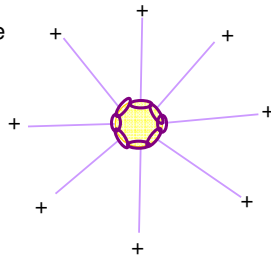


Example of self-organization: the cytoskeleton

How to make an aster?

Nucleate at centrosome

(figure 1a)



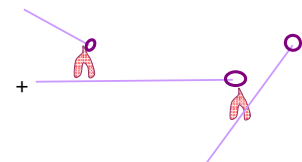
Example of self-organization: the cytoskeleton

How to make an aster?

Make lots of tubules and move them together with motors

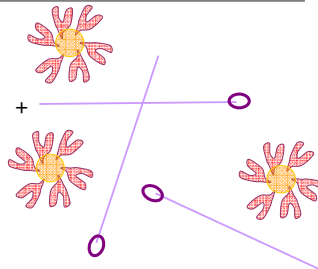
Dynein: - end directed motor

(figure 1b)



Example of self-organization: the cytoskeleton

Start with a mix: pigments and tubes

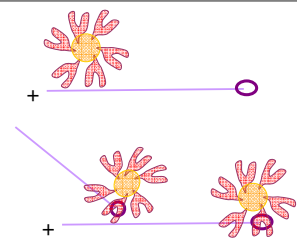


Example of self-organization: the cytoskeleton

Start with a mix: pigments and tubes

Use motors to move nucleating centers to the - end

(figure 1c)



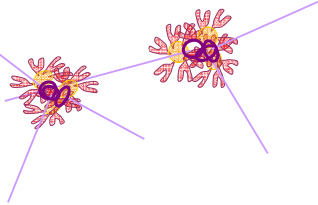
Example of self-organization: the cytoskeleton

Start with a mix:
pigments and tubes

Use motors to move
nucleating centers to
the - end

Eventually asters all
move together

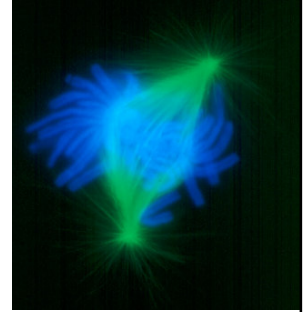
(figure 1c)



Example of self-organization: the cytoskeleton

Spindle formation:

Discussion



http://www.wadsworth.org/bms/SCBlinks/web_mil2/res_mil.htm