Self-organization: pattern and function arising from a decentralized system

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!)

What is self-organization?
"the dynamics of a system can tend by themselves to increase the inherent order of a system"
- Wikipedia

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.

What is emergence?
"The whole is greater than the sum of its parts"
Are the patterns resulting from self-organization always emergent?

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
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

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.

Are there general processes of self-organization?

Positive and negative feedback loops

Information transfer: passive and active

Trade-off: exploitation and exploration

Multiple interactions

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

Self-assembly = Low-energy assembly = **equilibrium**
- Nédélec et al., Wikipedia, Stuart Kauffman

Self-organization = constant input of energy and/or matter = **non-equilibrium**
- Nédélec et al., Wikipedia, Stuart Kauffman

Is this a reasonable distinction?

Example of self-organization: the cytoskeleton

Architecture of the cell
Microtubules: tubulin
Actin filaments: actin

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!
Asters and spindles

Example of self-organization: the cytoskeleton

How to make an aster?
Nucleate at centrosome (figure 1a)

How to make an aster?
Make lots of tubules and move them together with motors
Dynein: - end directed motor (figure 1b)

Start with a mix: pigments and tubes

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)

Spindle formation:
Discussion