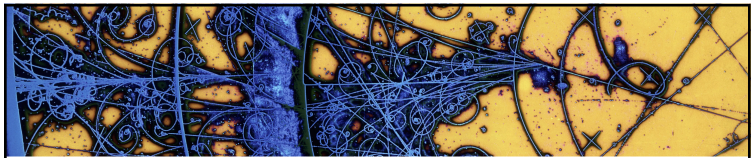

CSC2720H: Systems Thinking for Global Problems

Prof Steve Easterbrook

Dept of Computer Science

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Course Goals

- → To provide new thinking tools for complex problems
- → To provide concepts & terms to help understand dynamic, complex systems
- → To persuade you that systems thinking offers a coherent intellectual field of study
- → To encourage you to apply these ideas in your own research
- → To build a coherent understanding of climate change from a systems perspective

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Outline

- → Course Intro
  - Website: http://www.cs.toronto.edu/~sme/SystemsThinking
  - Books
  - Assignments
- → Key Ideas
  - Linear Thinking vs Systems Thinking
  - Parts vs Wholes; Reductionism vs Holism
  - Dynamic equilibrium
  - Modeling: Stocks & Flows; Feedback loops
  - Second order cybernetics
  - System transformation, collapse, and resilience
  - Boundary critique & critical perspectives

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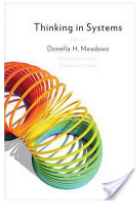
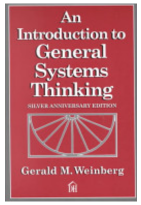
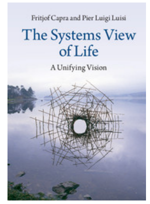
Books



Donella Meadows
Thinking In Systems

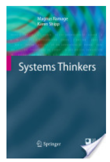


Gerald Weinberg
Intro to General Systems Thinking

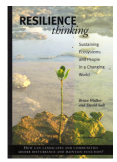


Fritjof Capra & Pier Luisi
The Systems View of Life

Michael C. Jackson
Systems Approaches to Management



Ramage & Shipp
Systems Thinkers



Bryan Walker & David Salt
Resilience Thinking

Assignments

- **Class Participation (10%)**
  - Show up; Do stuff; Get credit
- **A systems dynamics analysis (15%)**
  - Work in groups of 2-3. Must agree topic with me.
  - Present as a 5-minute talk to the class (second half of term)
  - Prepare a handout (2 page, 2 sided) summarizing your analysis
- **Term Paper (75%)**
  - A research paper that you might publish (publication isn't required!)
  - Preferably something that links to your own research area
  - E.g. A Case Study applying ST; a critical survey of some subfield of ST; etc.

Why Systems Thinking?

- What makes a traffic jam?
- How do epidemics spread?
- Why does the stock market fluctuate?
- How should we address climate change?

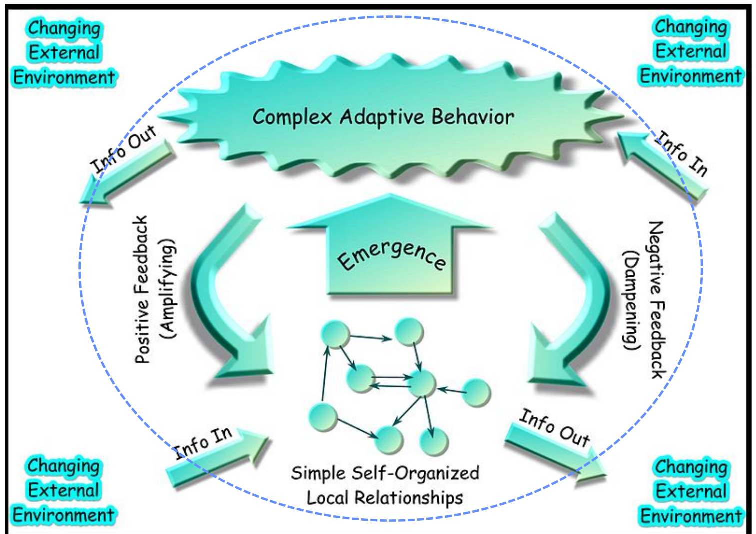
- What general principles characterize the behaviour of complex systems?

Course Overview

1. Intro (today!)
2. Feedback Loops
3. Metabolism of the Anthropocene
4. Delay and Inertia
5. Resilience and Collapse
6. Tools for analyzing systems
7. Chaos and Complexity Theory
8. Theories of Change
9. Leverage Points
10. Interpretivist Systems Thinking
11. Critical approaches: Boundary Critique
12. Course wrap-up

So what is a system?

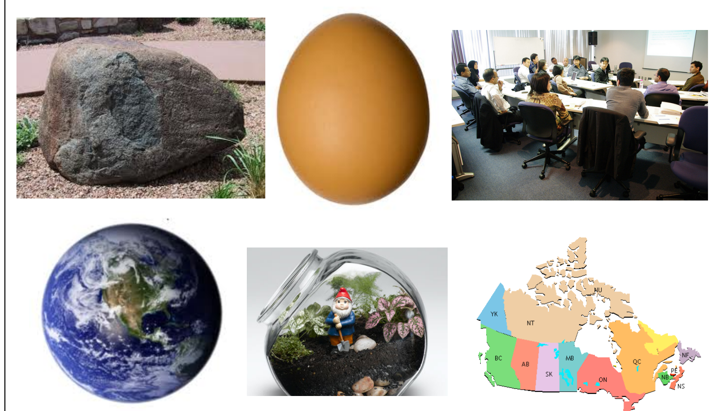
- **Ackoff:** A system is a set of two or more elements that satisfies the following conditions:
  - The *behaviour of each element* has an effect on *the behaviour of the whole*
  - The behaviour of the elements and their effect on the whole are *inter-dependent*
  - However sub-groups of elements are formed, *each has an effect* on the behaviour of the whole and none has an *independent* effect on it
- **Weinberg:** A system is a way of looking at the world
  - Systems don't really exist!
  - Just a convenient way of describing things (cf: set theory)



Elements of a system

- **Boundary**
  - Separates a system from its environment
  - Often not sharply defined
  - In CS terms, "an interface"
- **Environment**
  - Part of the world with which the system can interact
  - System and environment are inter-dependent
  - A system cannot exist independent of its environment
- **Observable Interactions**
  - How the system interacts with its environment (inputs and outputs)
  - A closed system has no interaction with its environment (Note: in thermodynamics this would be an "isolated system")
  - No system can ever be fully closed
- **Subsystems**
  - Can decompose a system into parts
  - Each part is also a system
  - The environment for each subsystem is the rest of the system
  - Subsystems are inter-dependent
- **Control Mechanism**
  - How the behaviour of the system is regulated to allow it to endure
  - Often a natural mechanism, relying on feedback loops
  - Any system that endures long enough to be observed and described must have regulating feedback loops
- **Emergent Properties**
  - Properties that hold of a system, but not of its constituent elements
  - Properties that cannot be predicted from studying the parts

Open vs. Closed?



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Hard vs. Soft Systems

Hard Systems:

- The system is…
  - …precise,
  - …well-defined
  - …quantifiable
- No disagreement about:
  - Where the boundary is
  - What the interfaces are
  - The internal structure
  - Control mechanisms
  - The purpose (??)
- Examples
  - A car (?)

Soft Systems:

- The system…
  - …is hard to define precisely
  - …is an abstract idea
  - …depends on your perspective
- Not easy to get agreement:
  - The system doesn't (really) exist
  - Calling something a system helps us to understand it
  - Identifying the boundaries, interfaces, controls, helps us to predict behaviour
  - The 'system' is a theory of how some part of the world operates
- Examples:
  - Human activity systems

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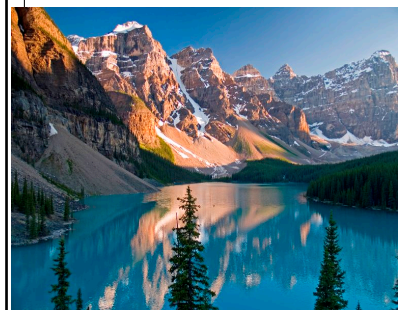
Principle of Complementarity

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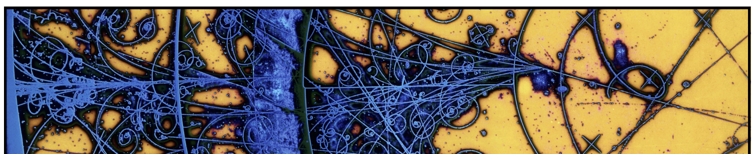

Systems Activity:

AVALANCHE

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Levels of Perspective

- **Events:**
  - Who does what to whom?
  - What happened?
- **Patterns:**
  - Re-occurring patterns of behaviour
  - What is happening over time?
- **Structure:**
  - How are the parts of the system organized?
  - Why is this happening?
- **Mental Models:**
  - Assumptions or worldviews of participants & observers
  - How do our mental models create or sustain the structure of the system?

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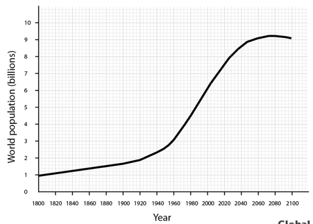
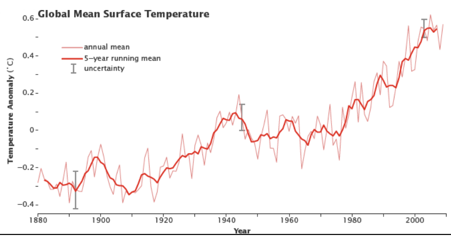
Picturing systems





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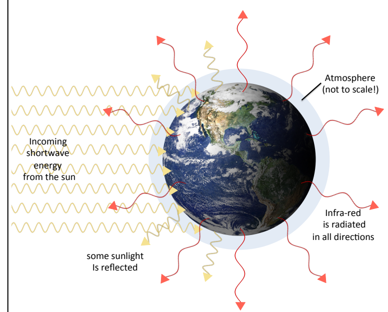
The Climate System (high level view)



$$W = \sigma(T^4 - T_e^4)$$

Heat radiated (in Watts per square meter)
Temperature of the object (in Kelvin)
Temperature of its environment (in Kelvin)

$$W = \varepsilon\alpha\sigma(T^4 - T_e^4)$$

Emissivity of the object (a fraction)
Absorbance of its environment (a fraction)

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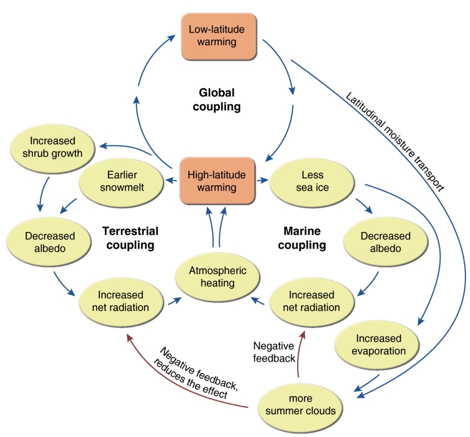
Causal Loop Diagrams



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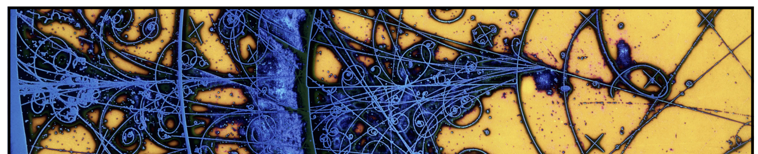

Systems Activity:

FRAMES

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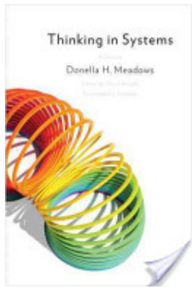
Reading for Next Week



Chapters 1 & 2 of Meadows

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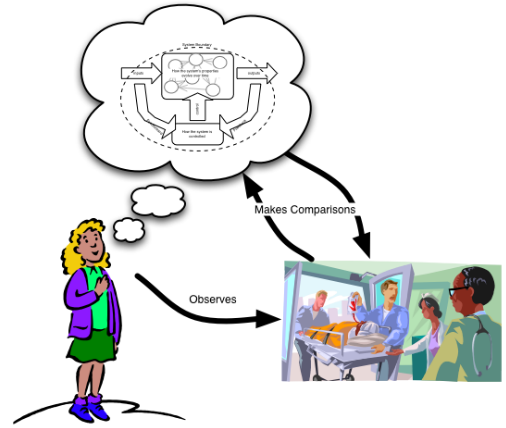
Summary: Systems Thinking



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