COMPLEXITY: What is it? Why is it important?

Thomas Homer-Dixon

October 6, 2020

CASCADE INSTITUTE

CASCADE INSTITUTE

Mission Statement: The Cascade Institute will identify *high-leverage intervention points* in cognitive, institutional, and technological systems that, if effectively exploited, could shift global civilization away from a path that leads to calamity and towards one that leads to fair and sustainable prosperity.

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What is a "system"?

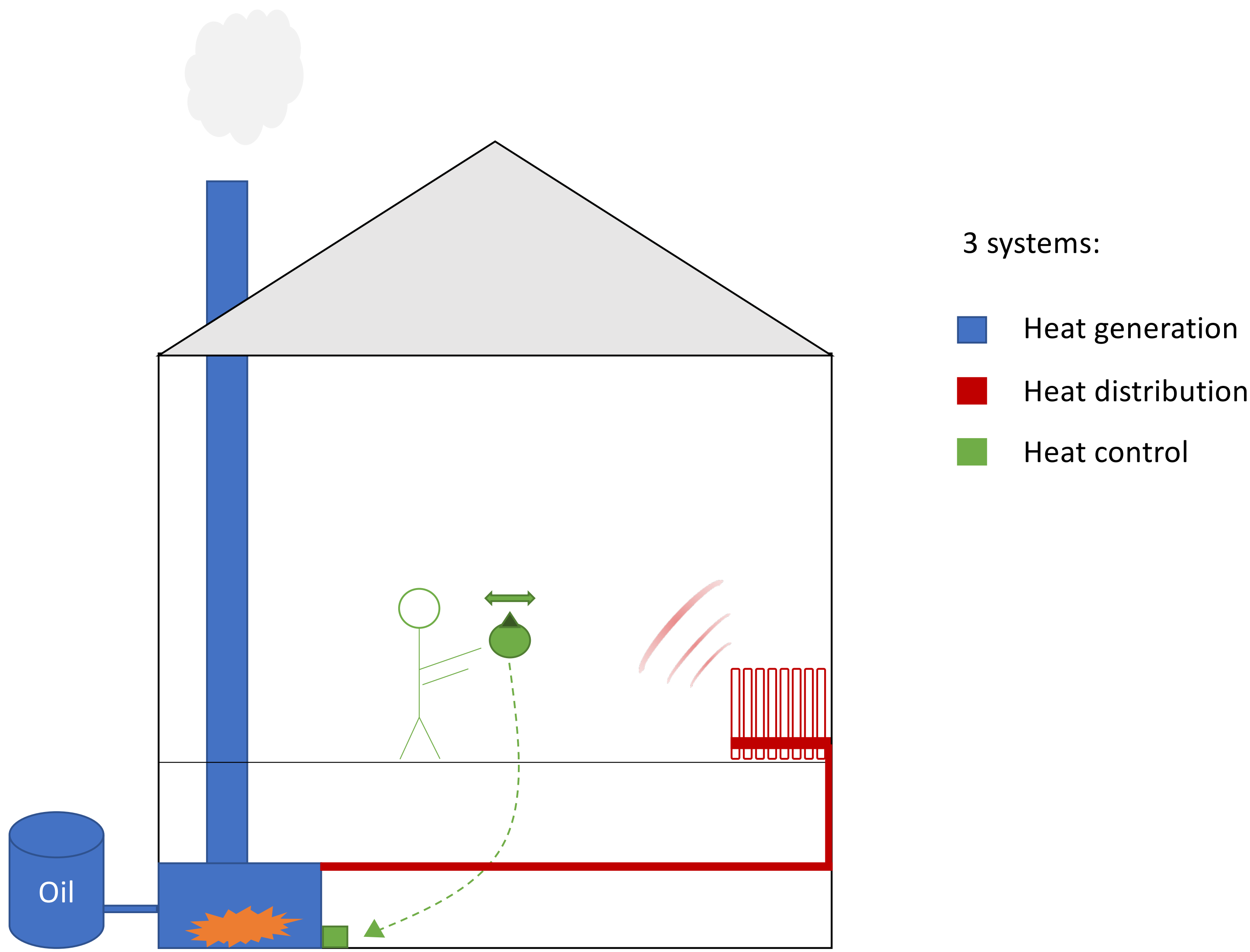
A system consists of:

1. *components*,
2. *links* between those components,
3. a *persistent pattern* of relationships among those links,
4. *a flow of energy* through the links that sustains the pattern, and
5. a *boundary* of some kind.

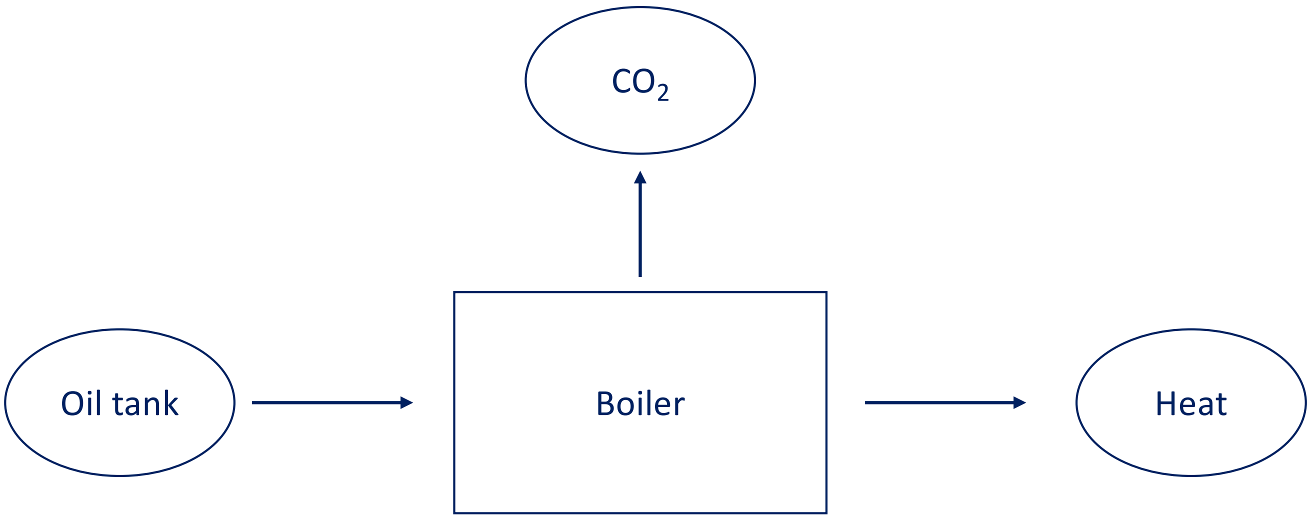
In representations of systems, links can stand for:

- *Flows* (of material, energy, and/or information between system components);
- *Causal relationships* (between state variables); or
- *Semantic or intensional* relations between meaningful mental states.

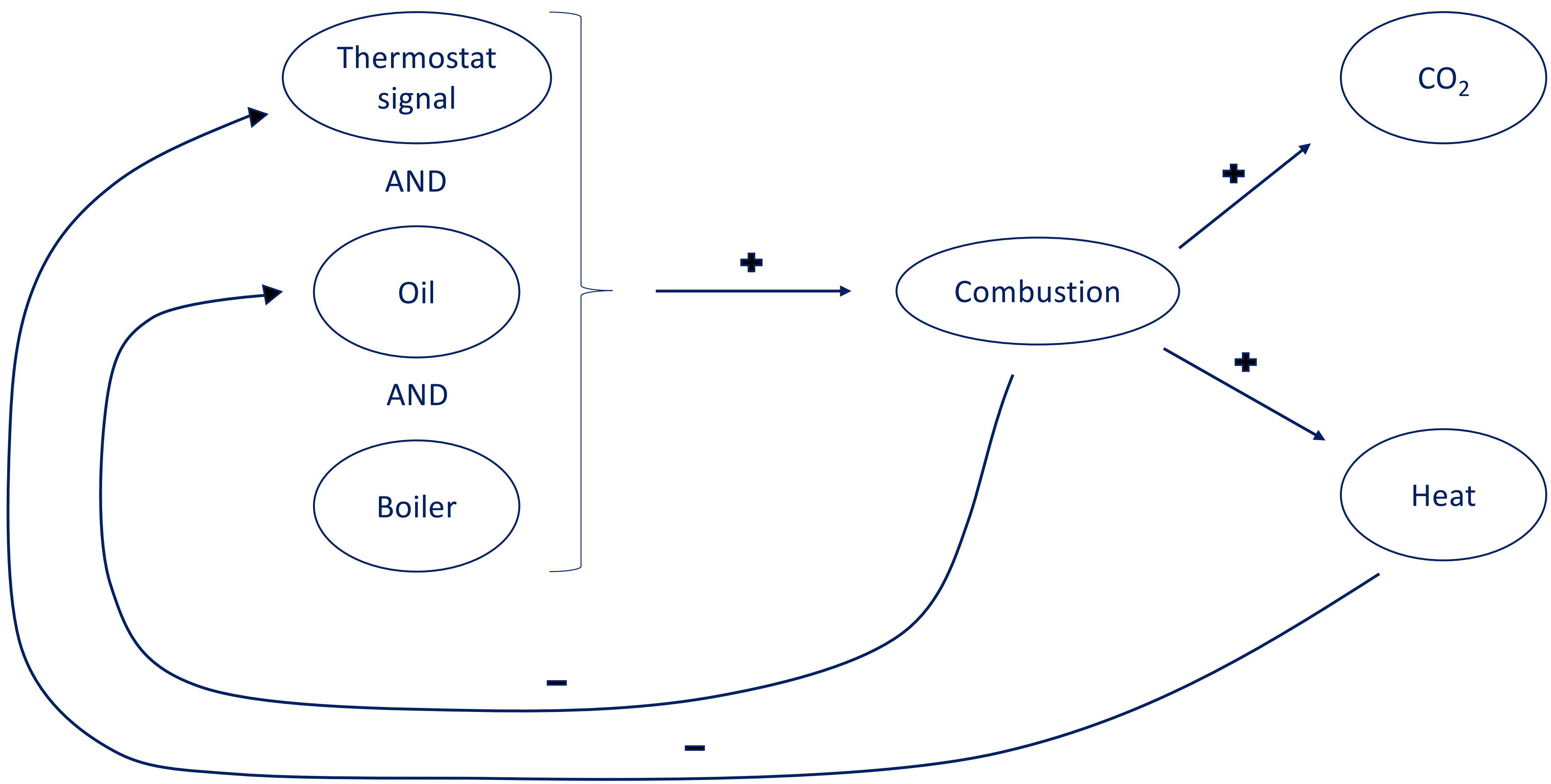
Flow "maps" tend to represent *specific systems* (i.e., they're idiographic); causal "maps" tend to represent *classes of systems* (i.e., they're nomothetic). Mental maps can represent the belief/value states of either individuals or of classes of individuals.


Oil
3 systems:
Heat generation
Heat distribution
Heat control

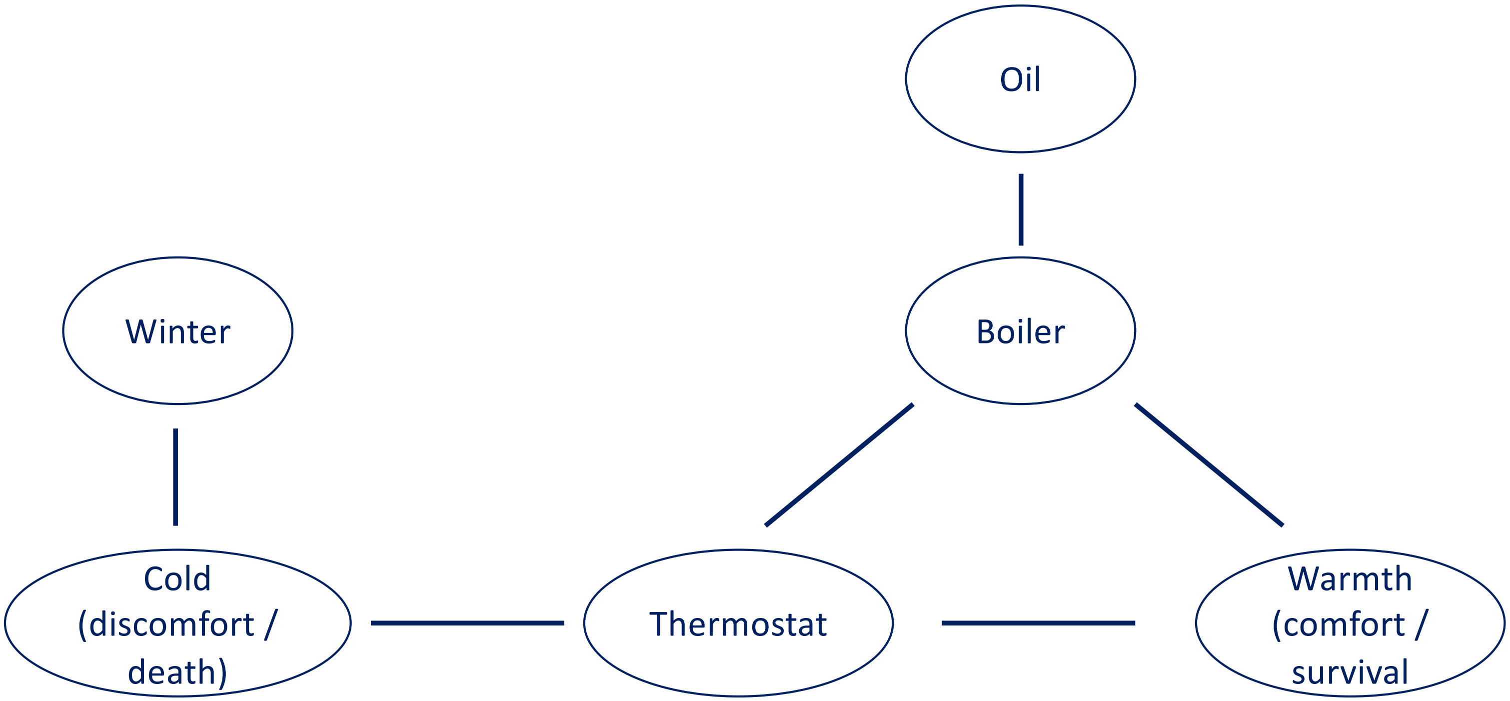
Stock/flow model



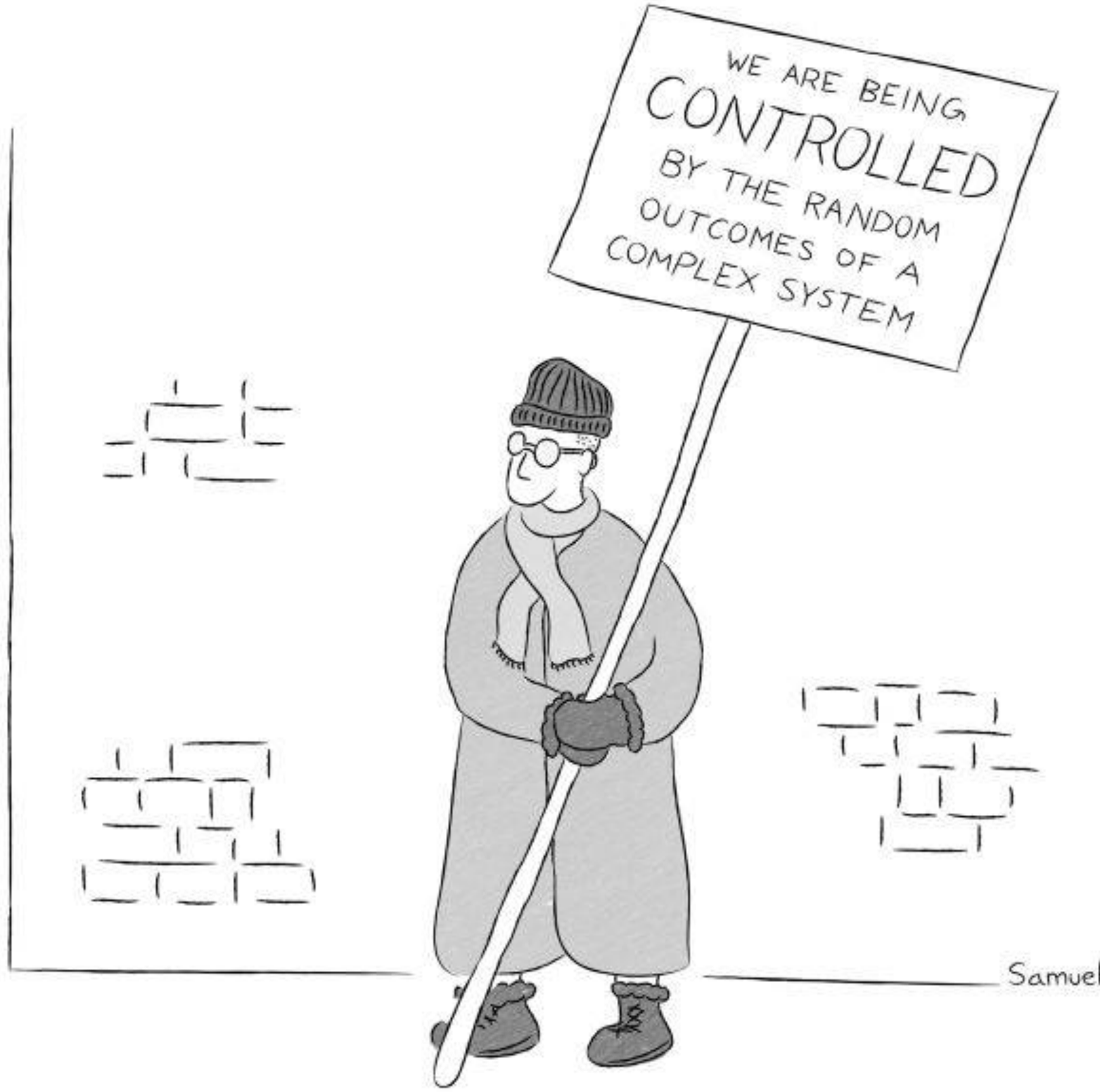
Causal model



Semantic/intensional model



COMPLEXITY
The basic story


WE ARE BEING CONTROLLED BY THE RANDOM OUTCOMES OF A COMPLEX SYSTEM
Samuel

We need to shift from seeing the world
as mainly composed of

SIMPLE MACHINES

to seeing it as increasingly composed of

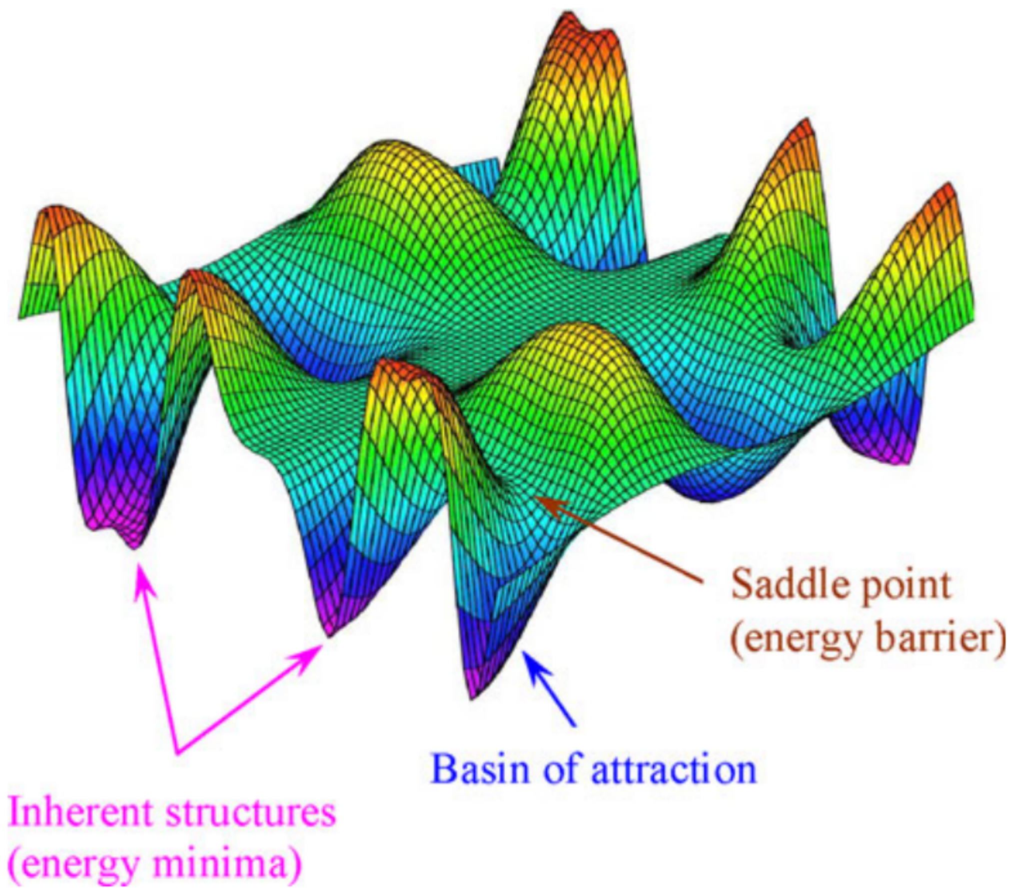
COMPLEX SYSTEMS

We commonly assume that
SIMPLE MACHINES

- can be taken apart, analyzed, and fully understood (they are no more than the sum of their parts),
- show proportionality of cause and effect,
- exhibit “normal” or equilibrium patterns of behavior, and therefore
- can be managed, because their behavior is predictable.

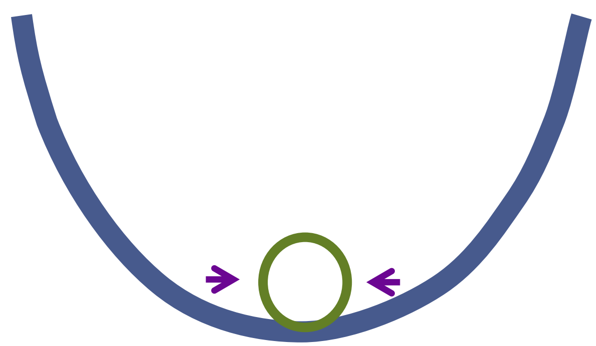
COMPLEX SYTEMS

- are more than the sum of their parts (they have *emergent properties*).
- show disproportionality of cause and effect (their behavior is often *nonlinear*, because of *feedbacks* and *synergies*),
- can flip from one pattern of behavior to another (they have *multiple equilibriums)*, and therefore
- CANNOT be easily managed, because their behavior is often *unpredictable*.

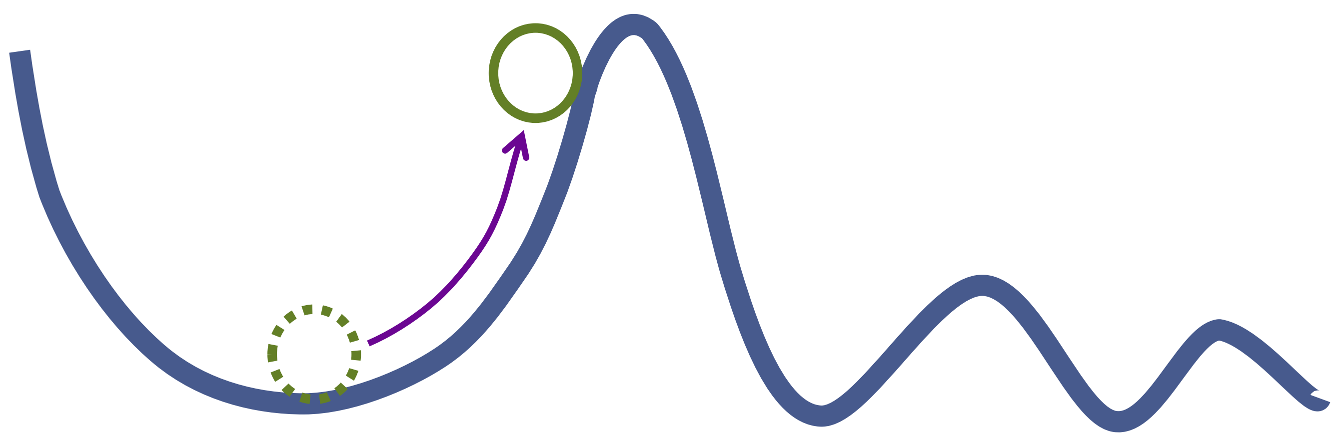


Sheng, Ma, and Kramer, "Relating dynamic properties to atomic structure in metallic glasses," *JOM* , 2012.

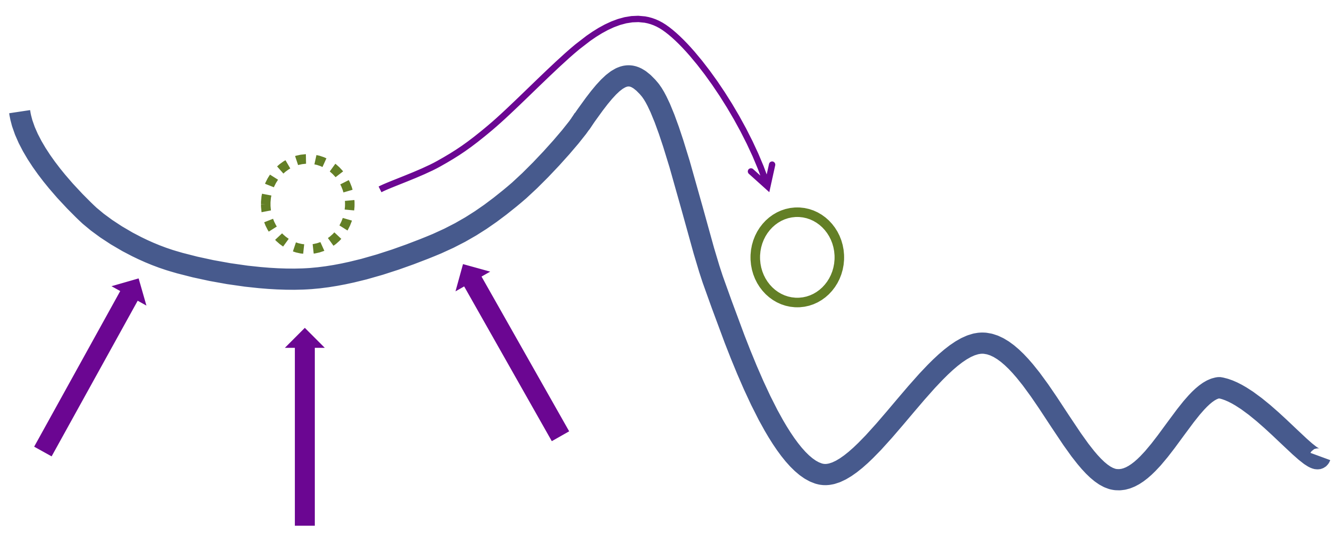
Equilibrium



Multiple equilibriums



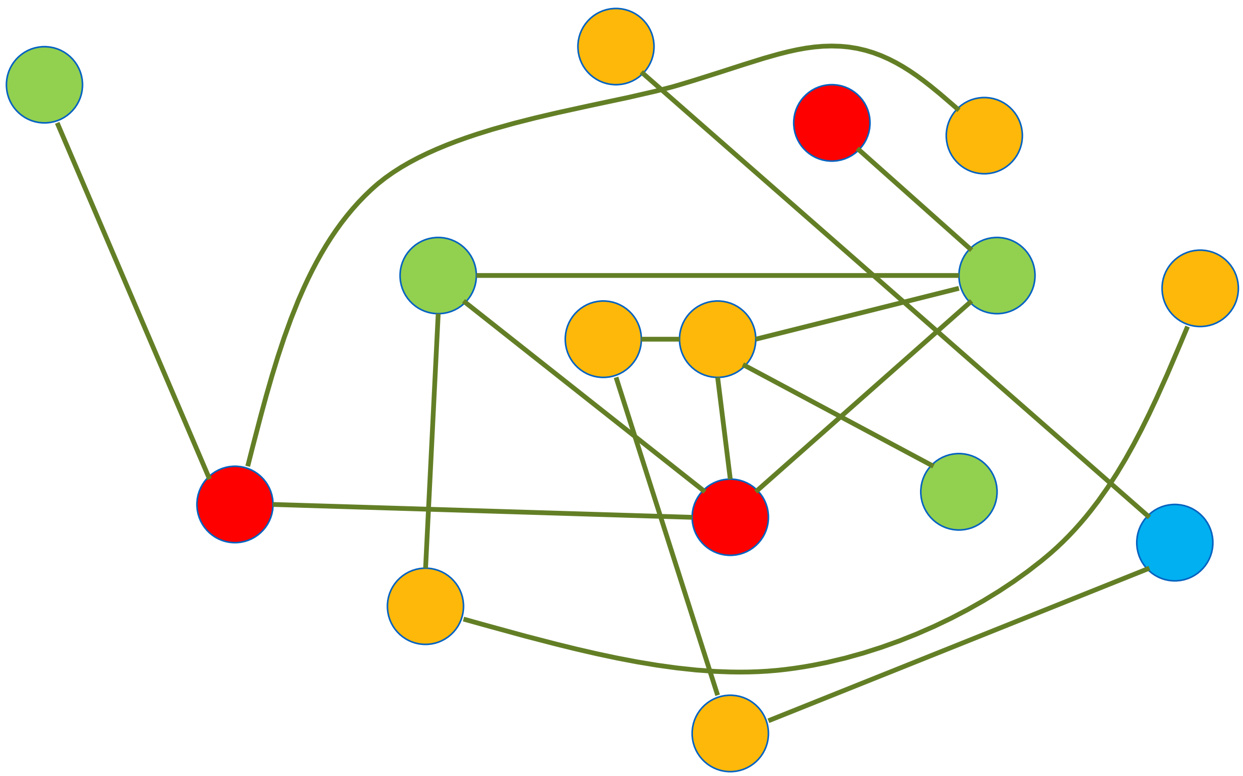
Tipping Event



What is causing our economies and societies to become more complex?

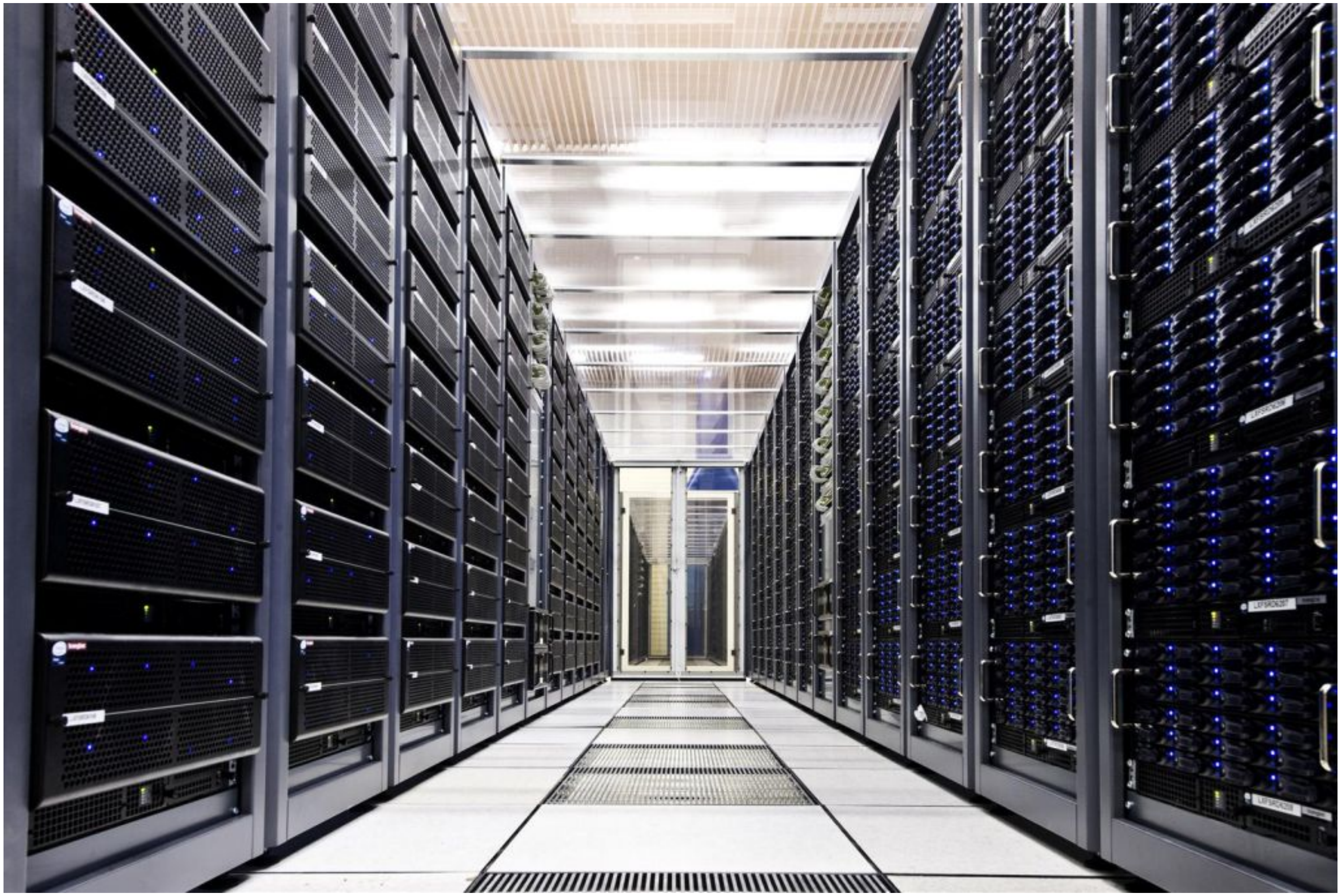
Key factor:
Performance improvements at the level of system units, i.e., organizations, firms, people, and technologies, especially due to advances in information technology

One result: our networks have more nodes, more connections, and faster movement of material, energy, and information along these connections. They are more “tightly coupled.”

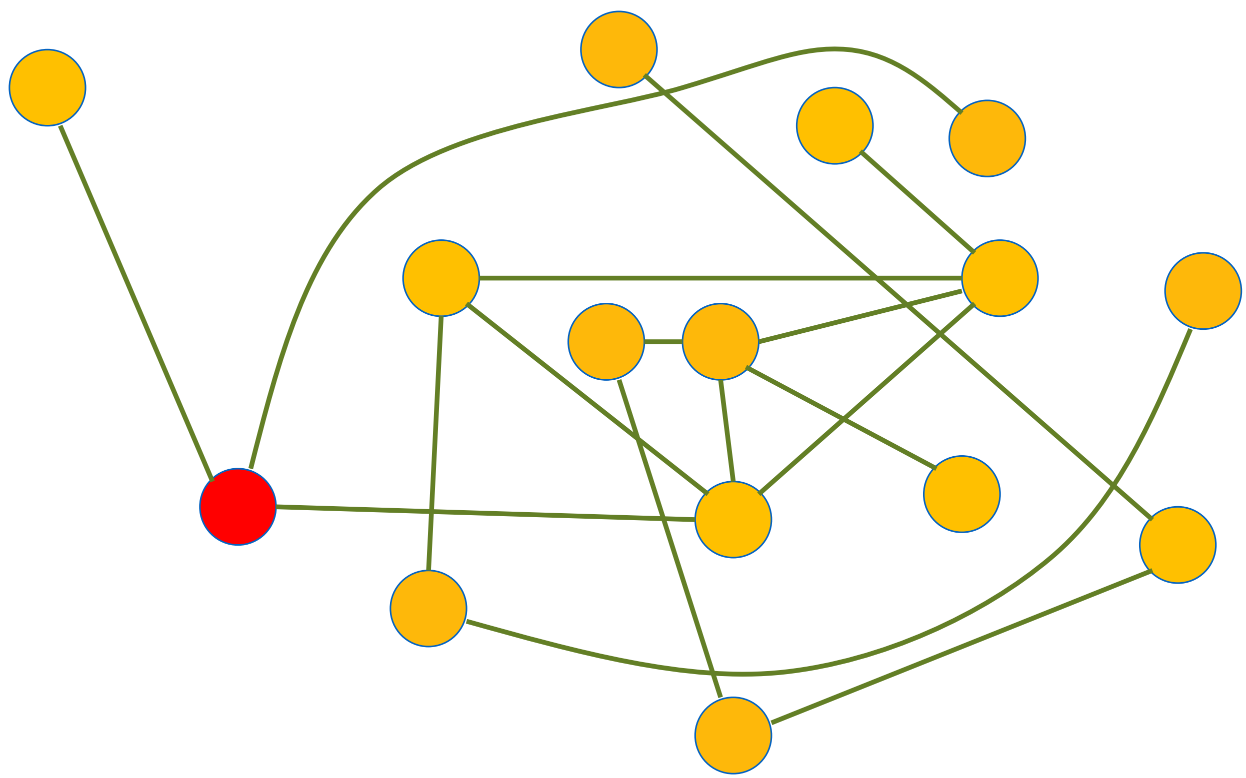


Source: Alessandro Vespignani, “Complex networks: The fragility of interdependency,” *Nature* 464, 984-985(15 April 2010).


AGNES RICKMERS



Greater connectivity sometimes causes technologies, institutions, procedures, and cultures to become more homogenous. Diversity declines.



Complexity can be a good thing, because

it’s a source of:

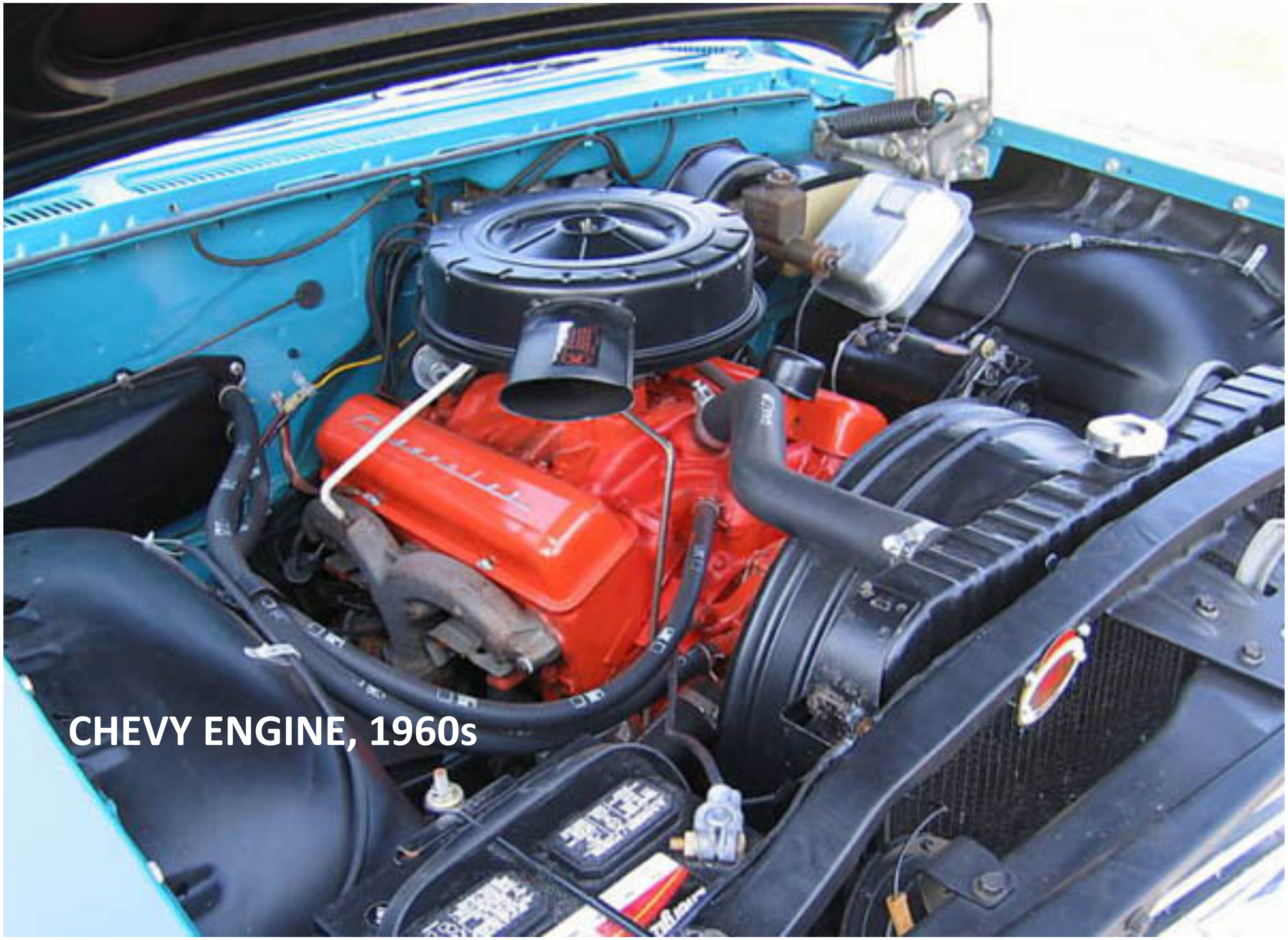
Innovation
(through novel combinations, if diversity is maintained)

and

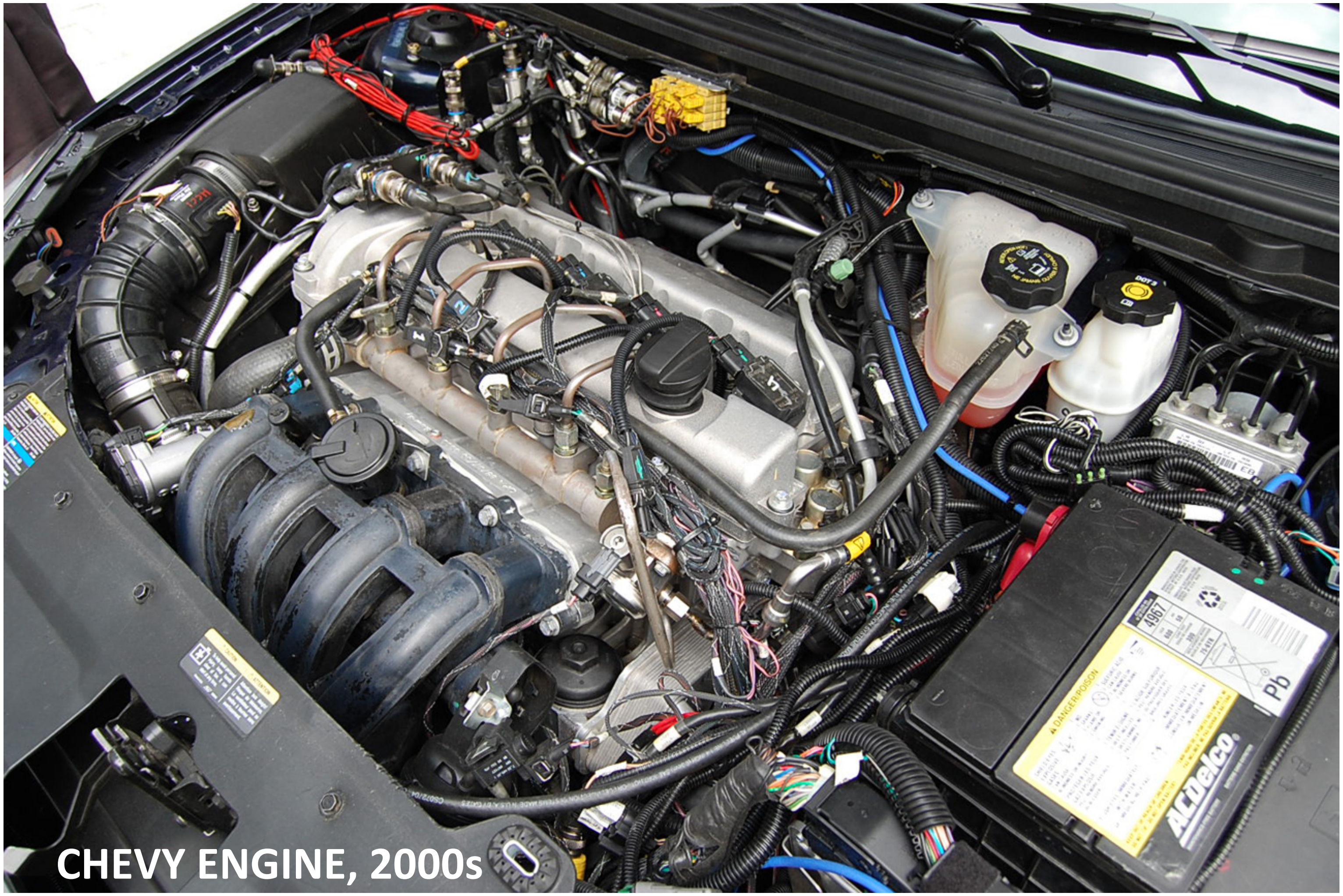
Adaptability
(through distributed problem solving)

Complexity can be a bad thing, because it can cause:

- *System opaqueness*



CHEVY ENGINE, 1960s



CHEVY ENGINE, 2000s

Complexity can be a bad thing, because it can cause:

System opaqueness

➢ *Cascading failures*

(connectivity x low diversity = danger)

Complexity can be a bad thing, because it can cause:

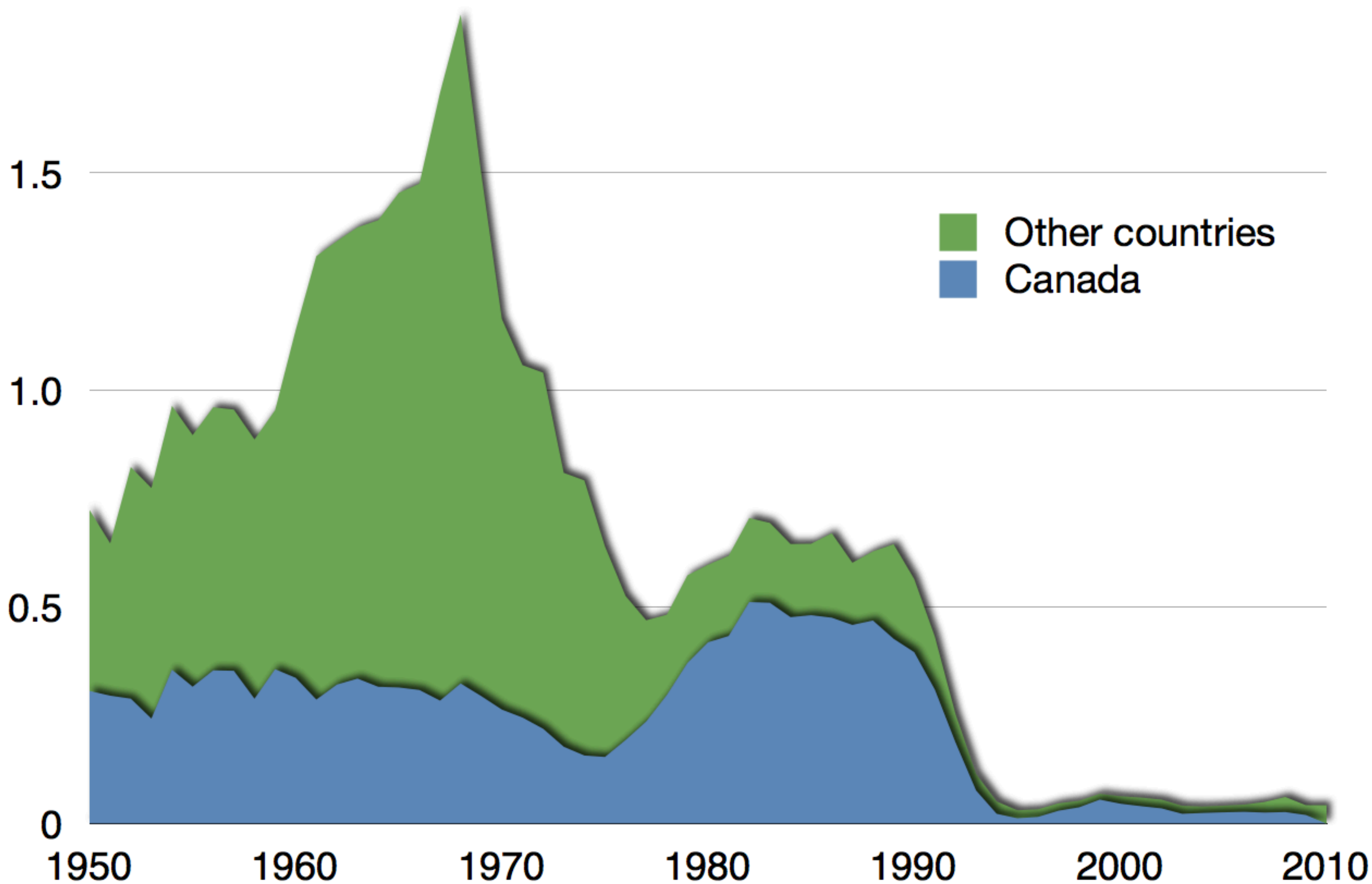
System opaqueness

Cascading failures

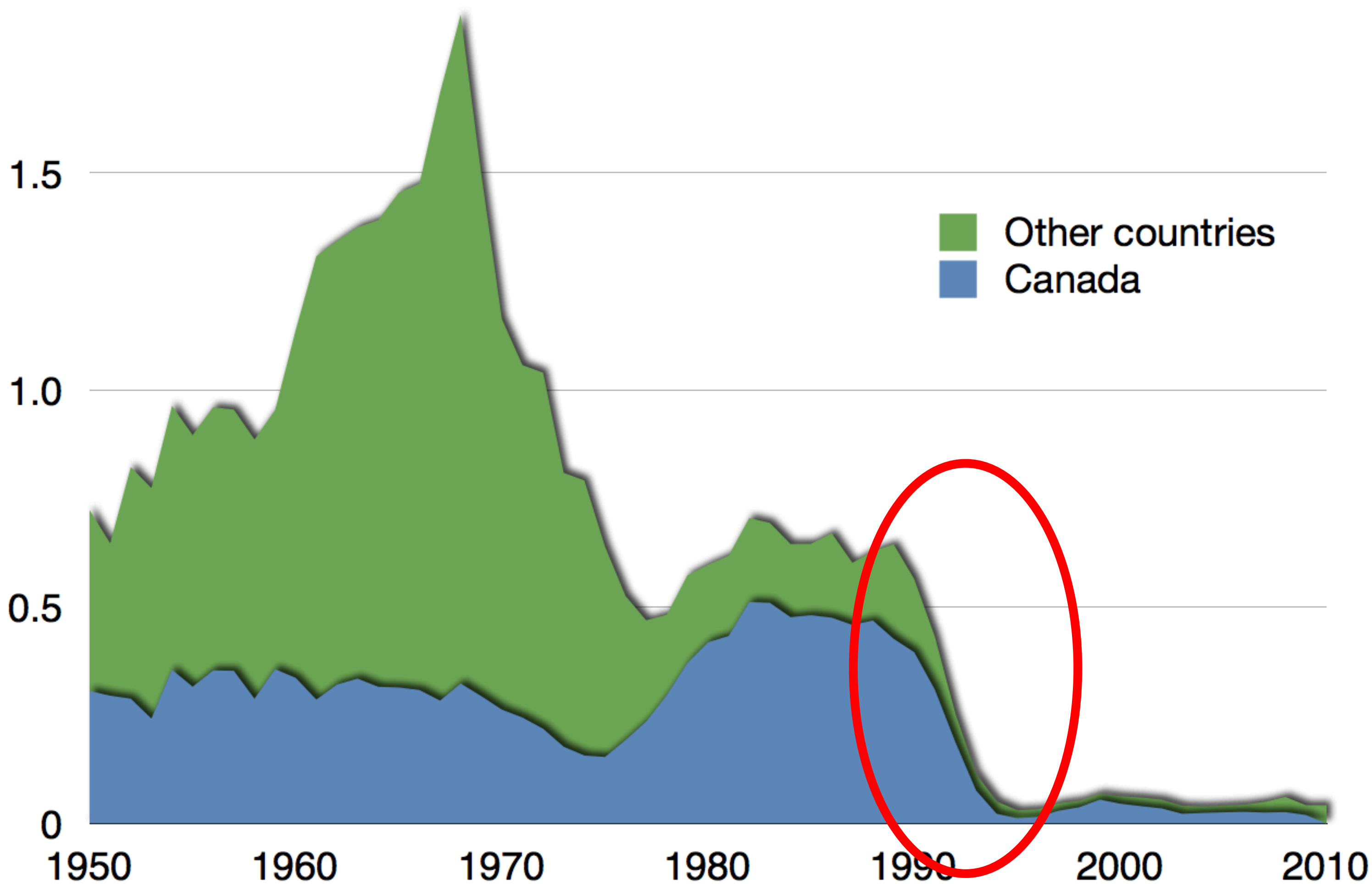
and

- *System flips*


1921



1.5
1.0
0.5
0
1950
1960
1970
1980
1990
2000
2010
Other countries
Canada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COMPLEXITY
Going deeper
(with help from Matto Mildenberger, UCSB)

PROPERTIES OF COMPLEXITY

Constitutive properties (causes) $\longrightarrow$ Behavioral properties (observable effects)

PROPERTIES OF COMPLEXITY

Constitutive properties (complexity's causes)	→	Behavioral properties (its observable effects)
Connectivity		Emergence
Interactive causation		Thermodynamic disequilibrium
Feedbacks		Nonlinearity
		Multiple equilibriums
Diversity		Unpredictability
Decentralization		Sensitivity to initial conditions
Thermodynamic openness		Path dependency
Large energy gradients		Contingency
Competition		Power-law frequency distributions
Evolution		

Complexity, Core Constitutive Properties

Non-adaptive complexity

Adaptive complexity

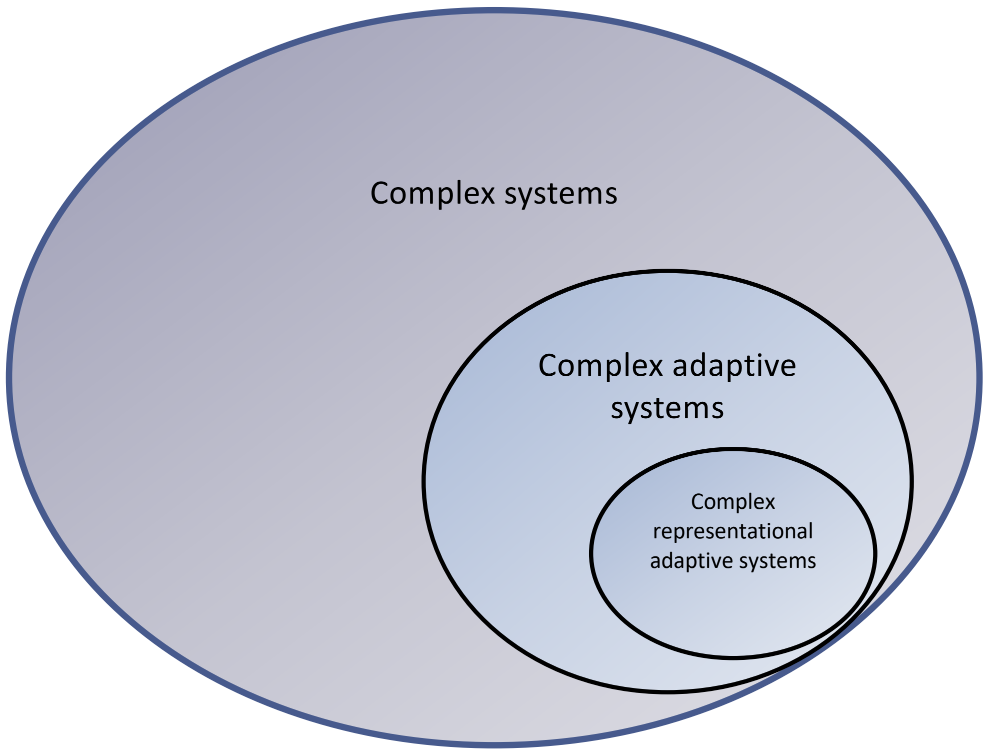
Complexity, Core Constitutive Properties

Non-adaptive complexity

Causation with interaction in densely and recursively connected systems.

Adaptive complexity

All of above, plus agents with **internal models** of external environment that govern behavioral response to this environment and that *coevolve under selection pressure*.


Complex systems
Complex adaptive systems
Complex representational adaptive systems

Complex adaptive system

Complex system

Complex representational adaptive system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PLACES TO INTERVENE IN A SYSTEM

IN ORDER OF INCREASING EFFECTIVENESS

(according to Donella Meadows)

12. Constants, parameters, numbers (such as subsidies, taxes, standards)
11. The sizes of buffers and other stabilizing stocks, relative to their flows
10. The structure of material stocks and flows (such as transport networks, population age structures)
9. The lengths of delays, relative to the rate of system change
8. The strength of negative feedback loops, relative to the impacts they are trying to correct against
7. The gain around driving positive feedback loops
6. The structure of information flows (who does and does not have access to what kinds of information)
5. The rules of the system (such as incentives, punishments, constraints)
4. The power to add, change, evolve, or self-organize system structure
3. The goals of the system
2. The mindset or paradigm (worldview) out of which the system—its goals, structure, rules, delays, parameters—arises
1. The power to transcend paradigms

CI's conceptualization of high-leverage intervention points (HLIPs)

		System *sensitivity* to intervention (at identified point)	
		Low	High
Potential *effectiveness* of intervention (at identified point)	High	Meadows, top of list	HLIPs
	Low	Not of interest	Meadows, bottom of list

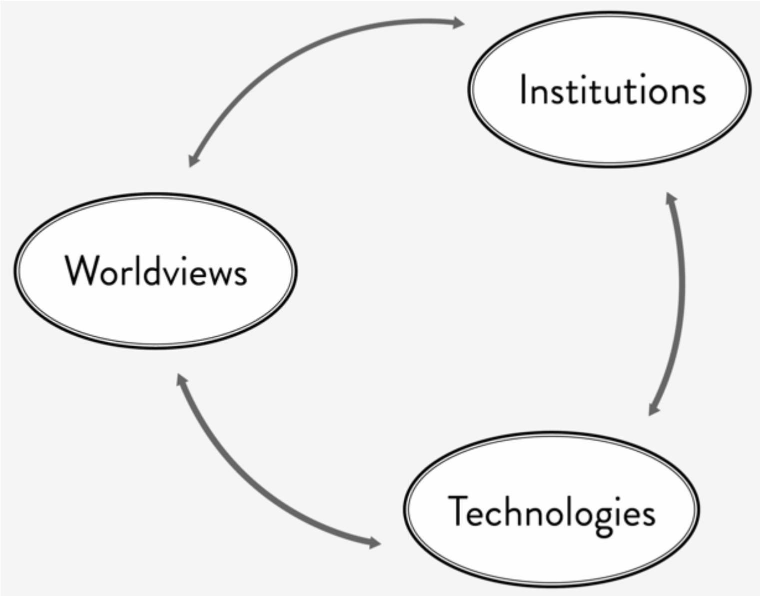
Cascade Institute: Scientific Foundations

1. Complexity Science

- High causal interaction
- Feedback loops
- Nonlinear behavior (“tipping events”)

Cascade Institute: Scientific Foundations

2. WIT Analysis



PNAS

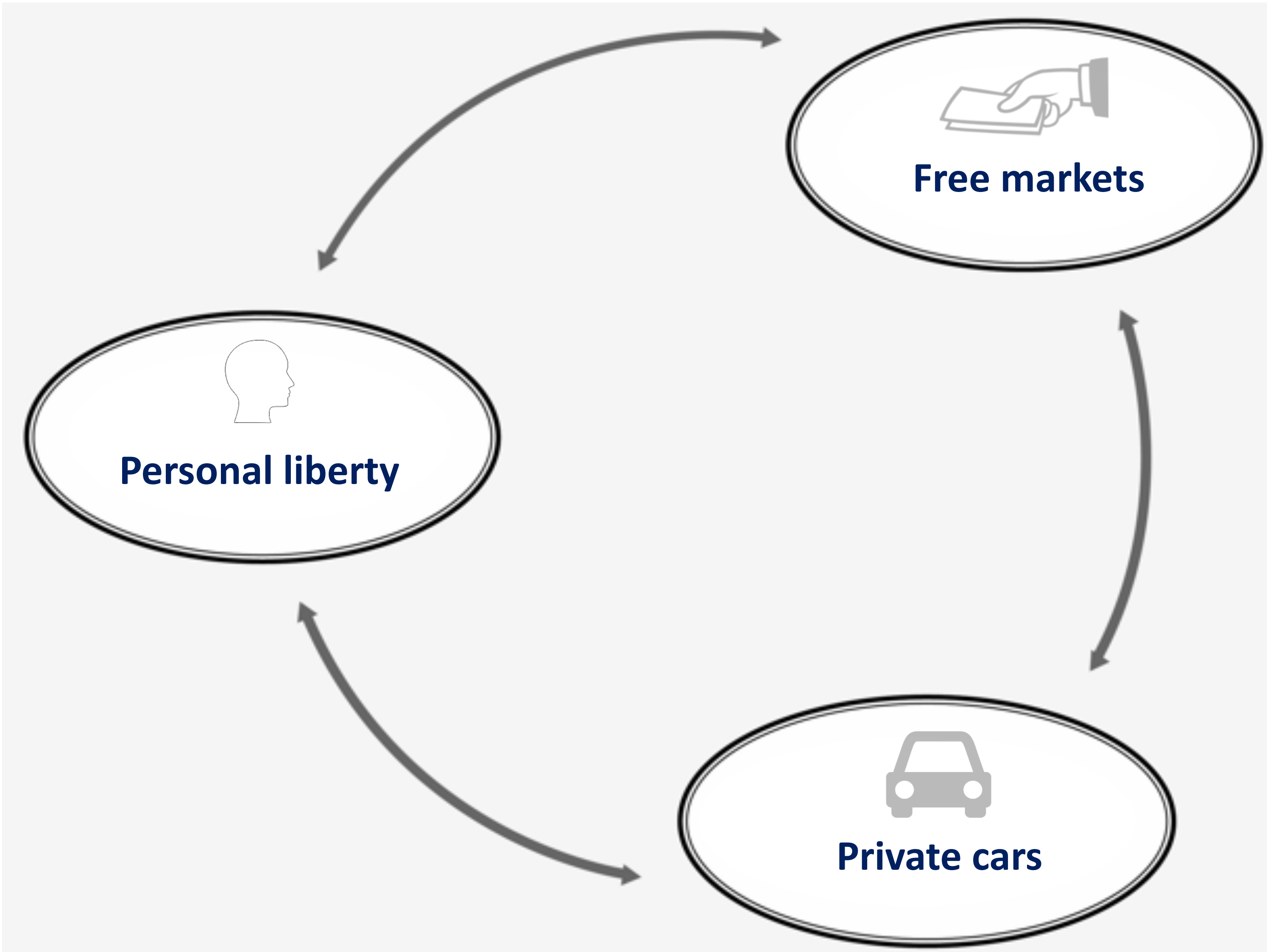
PERSPECTIVE

Overcoming systemic roadblocks to sustainability: The evolutionary redesign of worldviews, institutions, and technologies

Rachael Beddoe[a], Robert Costanza[a,b], Joshua Farley[a,c], Eric Garza[a,b], Jennifer Kent[d], Ida Kubiszewski[a,b], Luz Martinez[a,b], Tracy McCowen[c], Kathleen Murphy[a], Norman Myers[e,1], Zach Ogden[c], Kevin Stapleton[c], and John Woodward[c]

[a]*Rubenstein School of Environment and Natural Resources, George D. Aiken Center,* [b]*Gund Institute for Ecological Economics, and* [c]*Community Development and Applied Economics, University of Vermont, Burlington, VT 05405;* [d]*Independent Environmental Researcher, Oxford OX4 3SE, United Kingdom; and* [e]*21st Century School, Oxford University, Oxford OX3 8FS, United Kingdom*

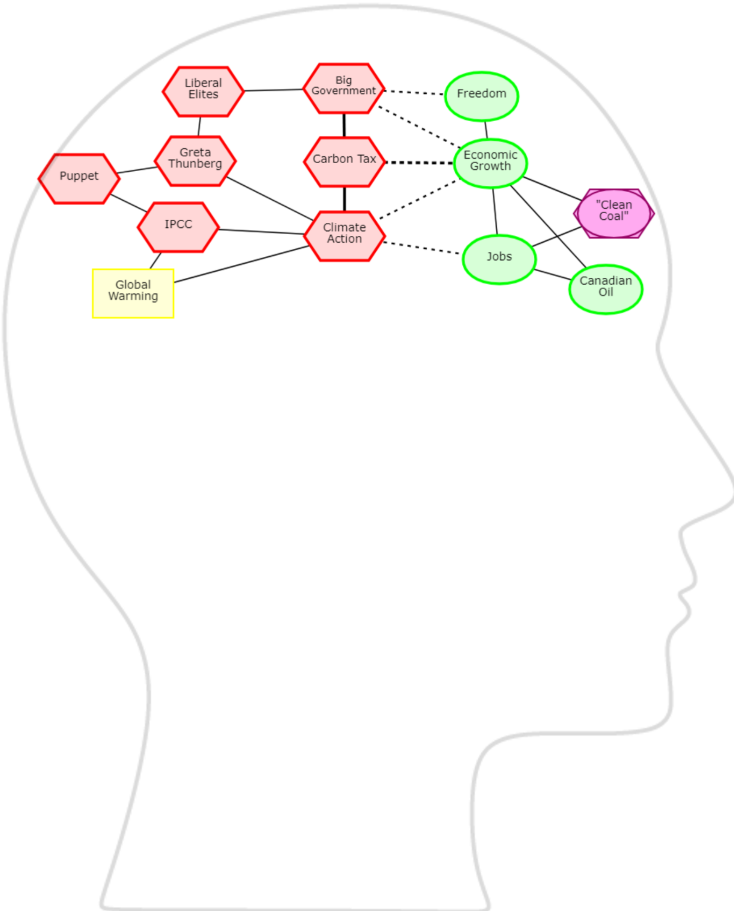
Contributed by Norman Myers, December 16, 2008 (sent for review October 9, 2008)


Free markets
Personal liberty
Private cars

Cascade Institute: Change mechanisms

Beliefs	Concept meanings arise holistically from people's networks of beliefs; these networks can be strategically restructured.
Emotions	People strive for emotional coherence in their networks of beliefs. On environmental issues, powerful emotions include fear, sadness, disgust, hope, and awe.
Norm cascades	Norms emerge from the conjunction of beliefs about ethical principles and the emotional resonance of those beliefs. Norm dissemination is a nonlinear function of social network structure, interaction rates, cultural sanctions on novelty, and homophily (attraction to like others). *Contagion model.*
Political mobilization	Mobilization depends on the nature of the audience and on the audience's degree of engagement. Second-order beliefs (beliefs about others' beliefs) are a key variable. *Critical transition model.*
Financial risk	Risk estimates shift as market expectations coordinate around lower returns on fossil-fuel investments and as new accounting practices diffuse through financial networks. *Contagion and critical transition models.*

Cascade Institute: System-mapping Tools



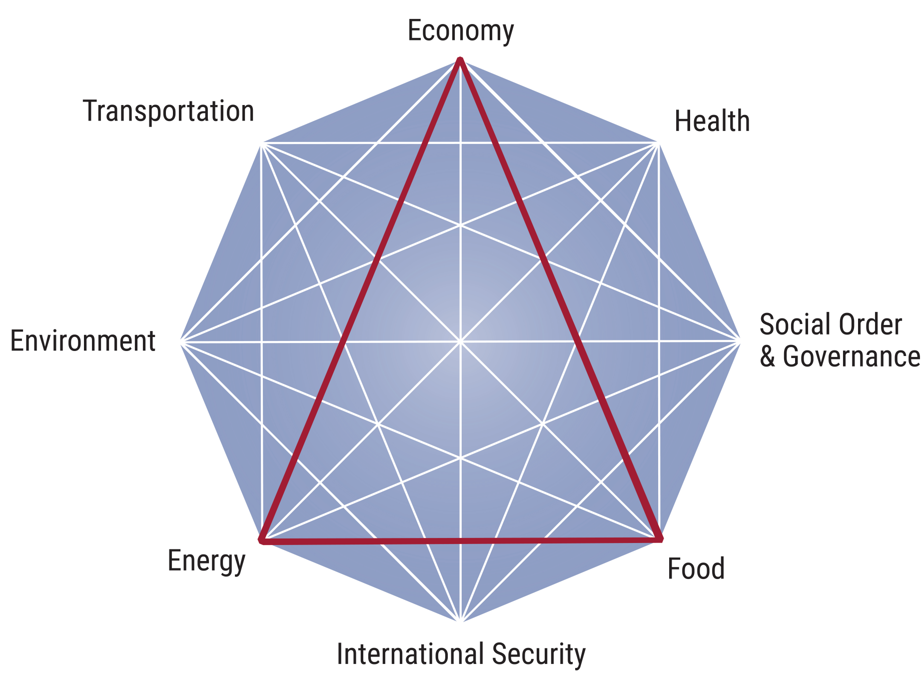
- Boolean causal loop analysis (BCLA)
- Cognitive affective mapping (CAM)
- Cross-impact balance analysis (CIB)
- State-space modeling
- Assemblage mapping

Cascade Institute: Research methods

Set-theoretic causal loop analysis	Integrates Boolean logic with standard causal diagraming to produce much clearer representations of feedbacks and interactive effects in complex social systems.
Cross-impact balance analysis	Formalizes qualitative descriptions of causation in complex social systems; allows for analysis of sudden nonlinear change in those systems.
Cognitive-affective mapping	Encodes positive/negative emotional intensity in concept maps of people’s worldviews.
State-space modeling	Represents distance between worldviews and possible pathways of change between them.
Assemblage mapping	Represents internalized or instrumentalized status of worldviews across individuals, identifying possibilities for worldview “tipping points” within groups.

Cascade Institute: Current Projects

1. MAPPING DANGEROUS INTER-SYSTEMIC CASCADES



ISC Project Briefs

Behind the mask: Anti-mask and pro-mask attitudes in North America

Scott Janzwood & Michelle Lee

September 15, 2020 • This Brief reviews the emerging scientific evidence on the effectiveness of masks for preventing the spread of COVID-19 and offers strategies for addressing persistent anti-scientific beliefs around masks, COVID-19 and other issues.

Read More →

Shocking global inequality

Michael Lawrence

August 25, 2020 • This Brief examines how the COVID-19 pandemic is interacting with entrenched structural inequalities between the wealthiest and the most marginalized segments of humanity.

Read More →

Evacuating communities affected by disasters during future COVID-19 waves

Scott Janzwood

July 7, 2020 • This Brief investigates the challenges of evacuating communities from natural disasters during possible future "waves" of COVID-19 cases.

Read More →

Cascade Institute: Current Projects

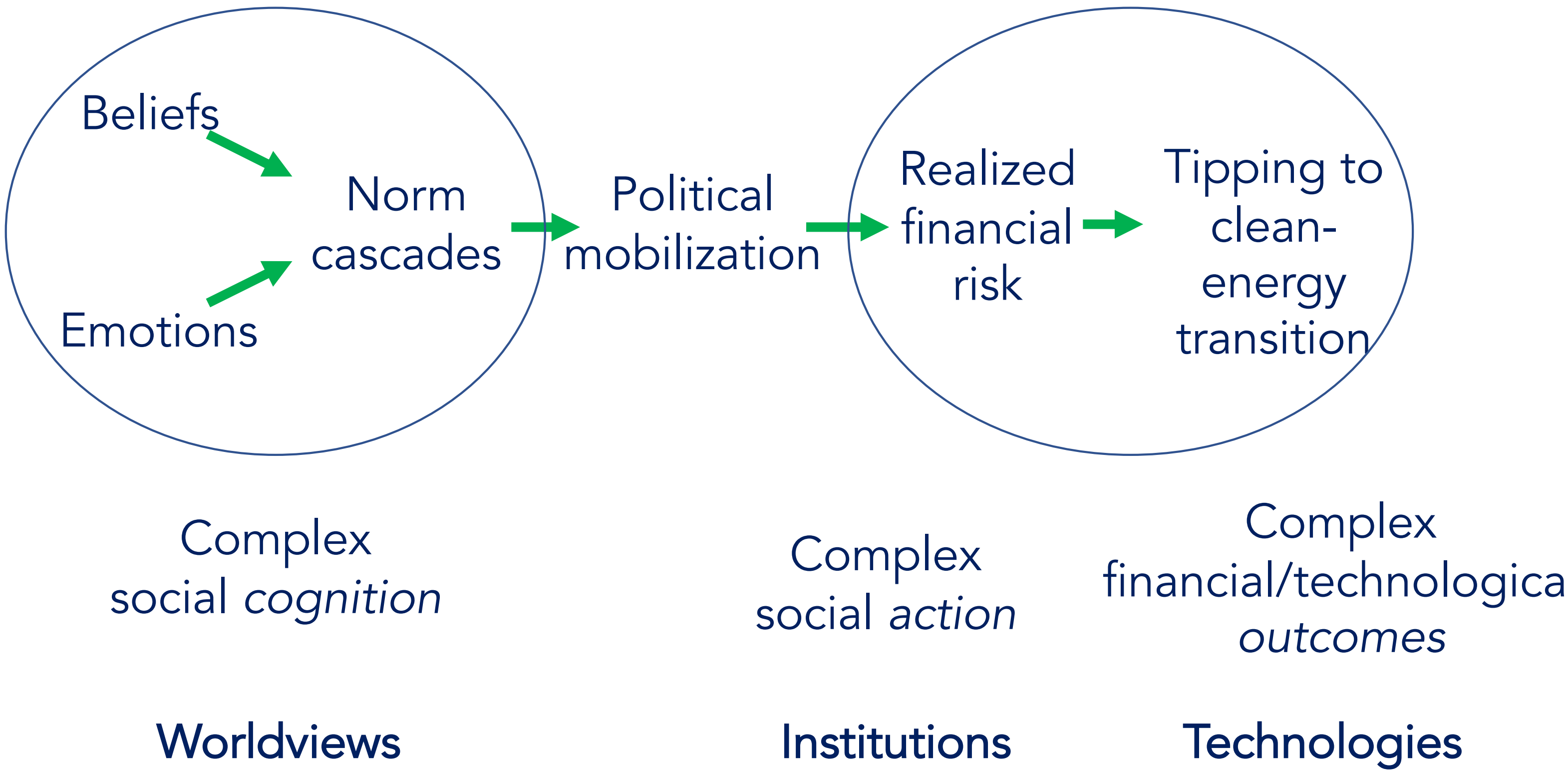
2. IDENTIFYING POSSIBILITIES FOR RAPID BELIEF AND VALUE CHANGE

CI Technical Paper (April 27, 2020)

The Social Distancing Norm Cascade:
The role of belief systems in accelerating normative change during the COVID-19 pandemic

Scott Janzwood

"Norm cascade" theory of change



Cascade Institute: Current Projects

3. PRODUCING EDUCATIONAL TOOLS TO IMPROVE YOUTH UNDERSTANDING OF, AND EFFECTIVE RESPONSES TO, COMPLEX NATIONAL AND GLOBAL PROBLEMS

Practical complex-systems curricular materials
Micro-credential programs
Emotional training