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Systems Ideas and Sustainability

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Systems Ideas and Sustainability

Martin Zwick

Systems Science & Social Sustainability Seminar

April 27, 2007

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Outline

- Introduction
- Some systems ideas about sustainability
 - From graph theory, game theory, thermodynamics, & from systems-oriented theories in ecology, sociology, & history
- Summary & conclusions

INTRODUCTION

- Systems ideas relevant to sustainability
- Descriptive/normative uses of these ideas
- What I mean by “sustainability”
- This talk
- Sources of systems ideas

Systems ideas are relevant to sustainability

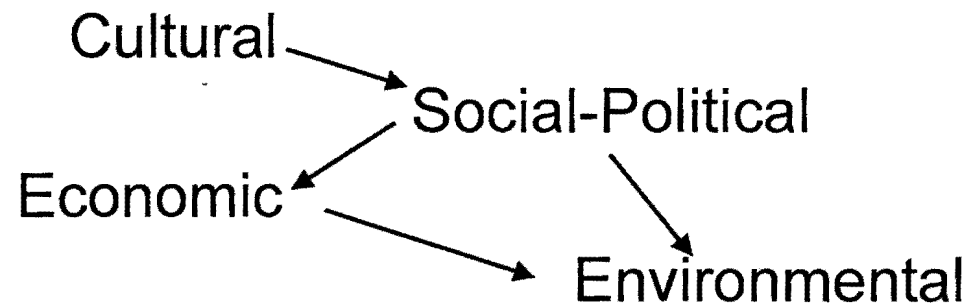
- Hawkins' *Ecology of Commerce*, referred to in documentary, *The Corporation*, uses systems ideas, but not explicitly
- This suggested looking at other systems ideas that might bear on sustainability.
- Web article, George Francis: "*Overview of Concepts & Insights from Complex Systems*" (Biosphere Sustainability Project) points to relevance of other systems ideas.

Descriptive/normative use of these ideas

- To understand the **causes** of sustainability problems
- To guide attempts to **solve** these problems

What I mean by sustainability

- Will emphasize *environmental* sustainability
- Other values (e.g., social justice) both bear on environmental sustainability & imply separate goals that must be simultaneously pursued.
- If *all* values are encompassed within 'sustainability,' the notion will lose its force.



This talk

- *A sampler* of systems ideas
- from a variety of sources,
- presented briefly & *abstractly*.

- (update of earlier CSS talk on this theme given in 04)

- *More detail* in SySc 510 “Systems Ideas & Sustainability”, *Fall 2007*.

Sources of systems ideas

- | | |
|--------------------------------------|-------------------|
| • Graph theory | Math |
| • Game theory | Social sciences |
| • Thermodynamics | Natural sciences |
| And theories from: | |
| • Ecology (Dynamics) | Natural sciences |
| • Sociology (Differentiation) | Social sciences |
| • History | “Social sciences” |

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GRAPH THEORY

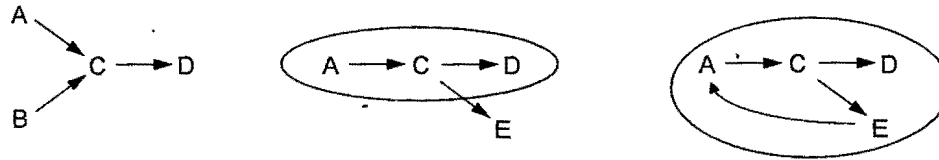
- Lineal, branching, & cyclic processes
- Branching processes → externalities
- Externalities & utility considerations

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Lineal, branching, cyclic processes



- **Lineal** (not “linear”) process is often assumed & “side” effects are ignored: **externalities** (E).
- **Most processes branch**
Herbert Spencer, “*the multiplication of effects*”;
Garrett Hardin, “*one can never do only one thing.*”

Sustainability requires:

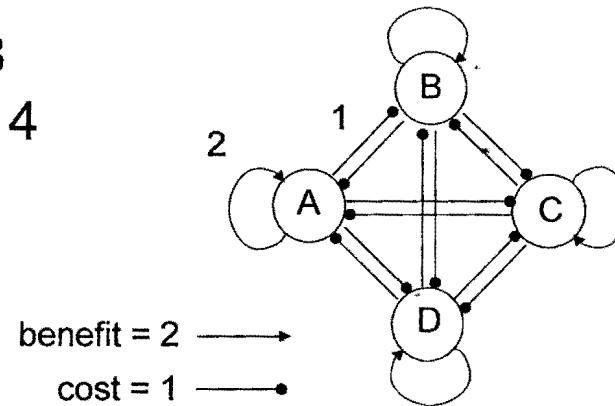
- internalizing externalities (bring E inside system)*
- closing circle (EA) on once-external effects*

About externalities ^{1/3}

- Externalities = effects not impacting agent (A,B,C,D) & not considered in its decisions
- “Utility” (U) from game theory; non-sustainable action produces costs as externalities

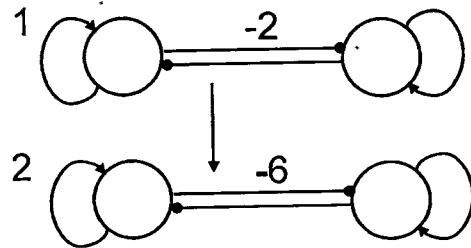
U_{total} w/o externalities = 8
with externalities = - 4

*Repeat: need to
internalize externalities*



About externalities ^{2/3}

- Meta-dynamics: competing agents try to increasingly externalize costs.

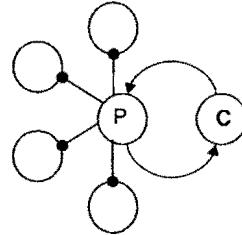


- Total utility = -2 → total utility = -8
Externalities are increasing

Sustainability requires removing incentives to increase externalities.

About externalities ^{3/3}

- Conventionally, “agents” are producers, but could include producer and consumer, since both benefit.



- In voluntary producer-consumer exchange (goods for money), both benefit, but effects on others may be negative.

Sources of systems ideas

- Graph theory
- **Game theory**
- Thermodynamics

And theories from:

- Ecology
- Sociology
- History

GAME THEORY

- Two games: PD & chicken
 - PD
 - Multiple effects, externalities, PD
 - Prisoner's Dilemma (2- & n-player)
 - PD can be solved
 - Chicken
 - Adding time to the PD model
 - Iterated PD
 - Temporal PD
 - Change of PD into Chicken

Two games: PD & Chicken

- *PD* models path that leads to collapse.
(‘Tragedy of commons’ = PD)
Example: species population decline
- *Chicken* models the final step of collapse.
Example: species extinction

*Sustainability requires avoiding PD traps
& Chicken dangers.*

Multiple effects → externalities → PD

- Branching processes (multiple effects)



- Externalities (esp. negative ones)



- Prisoner's dilemma (self-defeating action)

Prisoner's Dilemma (2-player) 1/3

C = cooperate = sustainable action

D = defect = non-sustainable action

Externalities: $(1,1) \Rightarrow (2,-1)$

	(1,1) C	(2,-1) D
(1,1) C	2,2	0,3
(2,-1) D	3,0	1,1

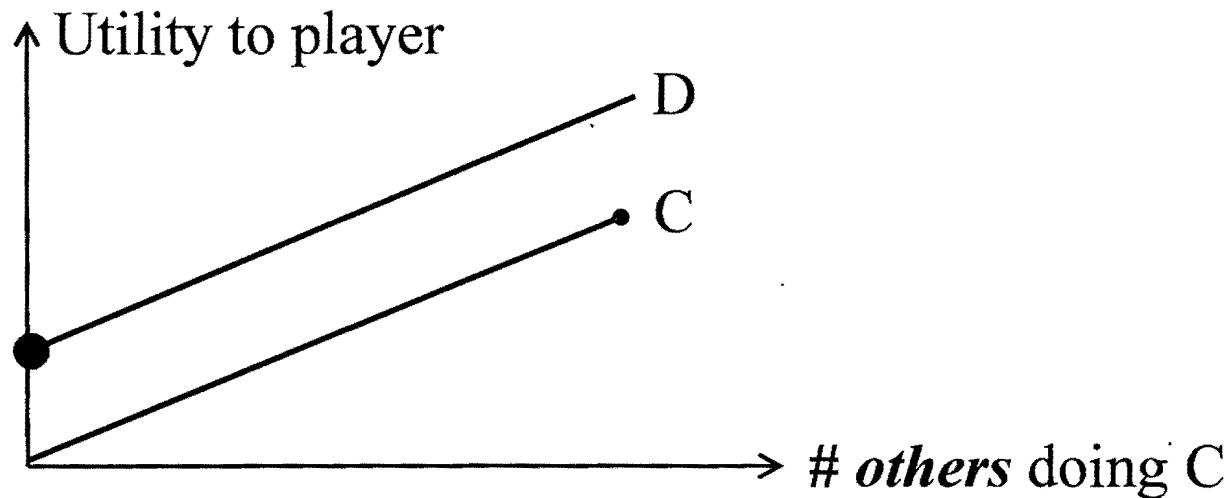
D is dominant strategy & stable

Prisoner's Dilemma ^{2/3}

- Large negative externalities produce PD.
- In PD, *individual rationality* leads to *collective irrationality*, i.e., net harm.
- What causes net harm is not sustainable.
- Market cannot solve PD because prices do not reflect *whole system* utility.

Sustainability requires non-market interventions.

Prisoner's Dilemma (n-player) 3/3



- D dominates C, so # doing C declines.
- Equilibrium point on left is deficient.

PD can be solved

- If payoffs changed by government intervention (Hardin: “mutual coercion mutually agreed upon”) or social action
- If payoffs changed by cultural values
- By competition between multiple systems (but *globalization* produces a single system).

Sustainability requires solving the PD.

Chicken (2-player)

C = cooperate = sustainable action

D = defect = non-sustainable action

	C	D	min
C	2,2	1,3	1
D	3,1	0,0	0
min	1	0	

	C	D
C	2,2	1,3
D	3,1	-1000, -1000

No dominant strategy.

C is *maximin* strategy but is **unstable**;
result is worst outcome (e.g., extinction).

Chicken & maximin strategy

(In Chicken) sustainability requires preferring security over the risky chance of greater gain.

Related issue in *decision theory*: should one use expected value rule or maximin rule?

	n_1	n_2	U_{expected}	U_{maximin}
C	2	1	2	2
D	3	-500	2.5	-500
	.999	.001		

Sustainability requires worst case rather than expected value decision making.

Adding time to the PD model

- Iterated PD
- Temporal PD
- Change from PD to Chicken

Iterated PD

IPD: game repeats with same parameters

- IPD can be solved without changing payoffs if future looms large (Axelrod)
- But future costs (temporal externalities) are discounted.

Sustainability requires making the future loom large.

Temporal PD

- PD not only in “space” (multiple agents), but in time: between (same) system at times t and $t+1$

*Collective irrationality is **temporal** irrationality (procrastination, addiction)*

		$t+1$	
		C	D
t	C	2	0
	D	3	1

- Externalities dumped on the system at a later time (future generations)

Sustainability requires internalizing the externality of the future.

Change of PD into Chicken

- Suboptimal result (PD) can degenerate into a worst case result (chicken)

	C	D		C	D
C	2,2	1,3	→	2,2	1,3
D	3,1	1+ ϵ , 1+ ϵ		3,1	1- ϵ , 1- ϵ

	C	D
C	2,2	1,3
D	3,1	-1000, -1000

Sustainability requires preventing traps from being transformed into dangers.

Sources of systems ideas

- Graph theory
- Game theory
- **Thermodynamics**

And theories from:

- Ecology
- Sociology
- History

THERMODYNAMICS

- Implications of the 2nd Law
- Open systems must live on input
- Money: inadequate measure of utility

Implications of 2nd Law

- Matter-entropy is different from energy-entropy (Georgescu-Roegen)
- Energy is potentially renewable: solar, wind, etc.; need energy accounting
- Matter-entropy may need unavailable energy resources to be overcome.
- Global warming the most severe energy-entropy problem (PD or chicken?).

Open systems must live on input

- Energy flow through system can organize it; higher flows allow greater complexity.
- Current growth generated by living off capital instead of income.
- But initial energy resources are one-time endowment, yolk for chick to develop & hatch, then live off income. *Living off endowment is plunder.*

Sustainability requires living on input.

Money: an inadequate measure of utility

- Prices are *information* not grounded in *matter-energy* (physical/biological) realities that are external to market.
- Exchange is only one aspect of value.
- Economically “efficient” may not be thermodynamically efficient, benign (e.g., activity that produces global warming), or reversible.

Sustainability requires prices being (thermodynamically) objective.

Sources of systems ideas

- Graph theory
- Game theory
- Thermodynamics

And theories from:

- **Ecology**
- Sociology
- History

ECOLOGY

- Patterns of growth (Holling, *Panarchy*)
- What is never sustainable
- Limits to exponential growth
- Catastrophe theoretic hysteresis

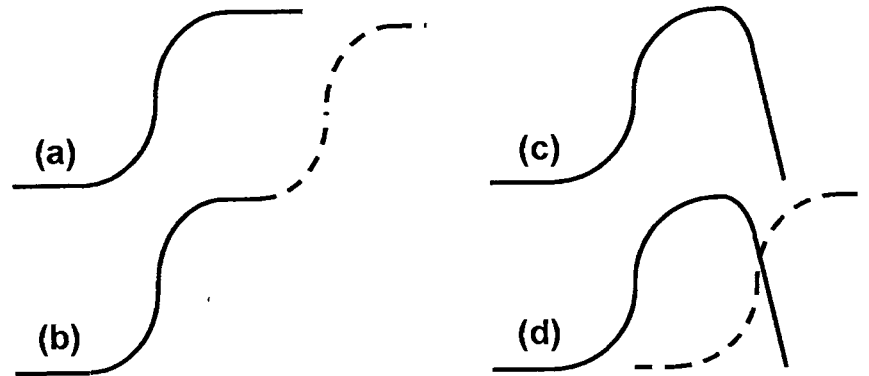
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Patterns of growth (Panarchy)

- (a) Logistic (S-shaped) growth to steady state
- (b) 2nd logistic growth on top of 1st
- (c) Growth, decline, & disappearance
- (d) Growth, decline, & replacement



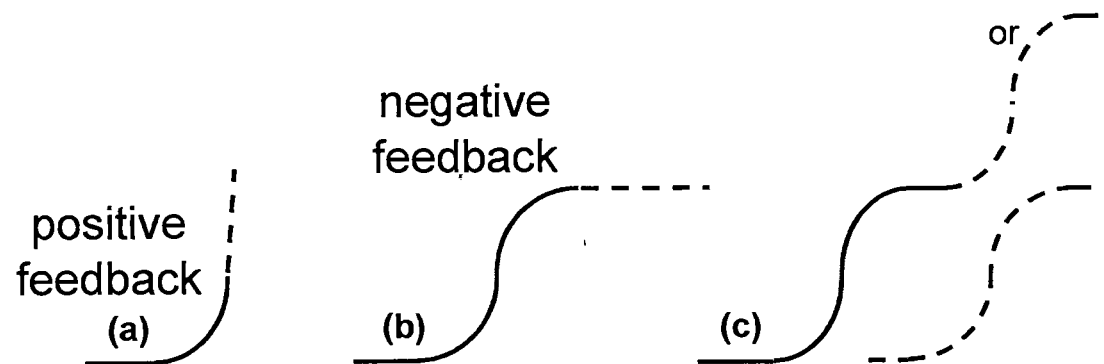
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What is never sustainable

- (a) Exponential growth is never sustainable
- (b) Steady state may not be sustainable
- (c) Continued progress or repeated replacement may not be sustainable



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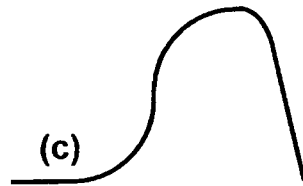
Limits to exponential growth

- Underlying temporal PD is expectation of indefinite exponential growth. But all systems are finite, and exponential growth invariably reaches limits.
- Systems in steady state need different organizing principles (OP) than systems in exponential growth (K- vs. r- selection).

Sustainability requires non-dependence on indefinite exponential growth.

Growth, decline, & disappearance

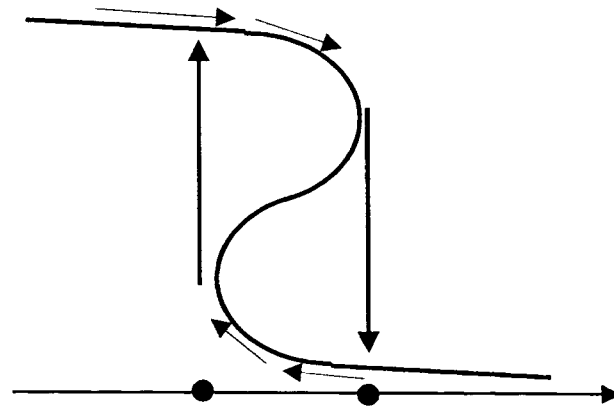
- Steady states not guaranteed to persist.
- Species extinction is forever.



*Sustainability requires long term
management & avoidance of extinctions.*

Catastrophe-theoretic hysteresis

- Reversing a cause that produced a sudden effect doesn't immediately reverse the effect.



Sustainability requires avoiding difficult-to-reverse crashes.

Sources of systems ideas

- Graph theory
- Game theory
- Thermodynamics

And theories from:

- Ecology
- **Sociology**
- History

SOCIOLOGY

- Externalities & societal differentiation
- Externalities & exploitation

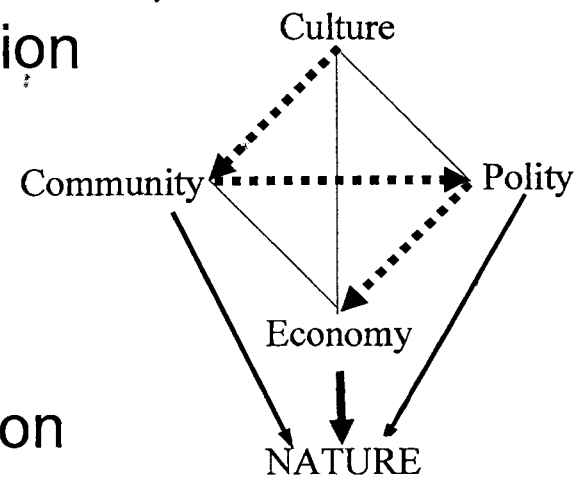
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Externalities & Societal Differentiation ^{1/3}

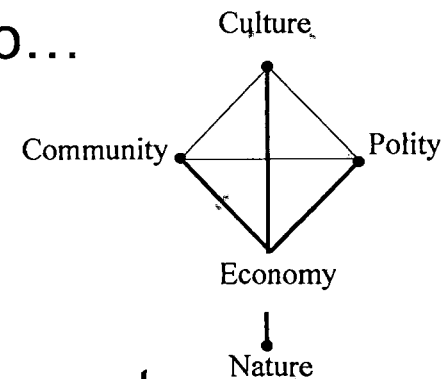
- Modernization = societal differentiation
- Differentiation not independence; requires necessary integration
- Parsons' "action" model of societal differentiation
- Externalities of economy imply improper differentiation



Sustainability requires right societal differentiation & integration.

Externalities & Societal Differentiation 2/3

Beyond benefits, economy causes present
& future negative externalities to...



- community: socializing human costs
- polity: corruption by special interests
- culture: dominance of commercial values
- nature: undermining support for life

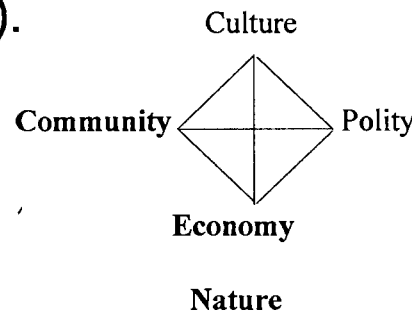
Externalities & Societal Differentiation ^{3/3}

Sustainability (reducing externalities) requires:

- *A polity that regulates the economy (allowing it to be autonomous within guiding infrastructure).*
- *Additional societal control of economy.*
- *Cultural values transcending commercial values.*

Externalities & multiple objectives

- Triple bottom line: cannot optimize *multiple* objectives w/o (a) converting to *one* using weights, or (b) treating some as constraints (decision theory).



- If *internalize* environmental & societal externalities by taxing them, objectives get encompassed within economy.

Sustainability requires satisfying multiple values.

Sources of systems ideas

- Graph theory
- Game theory
- Thermodynamics

And theories from:

- Ecology
- Sociology
- **History**

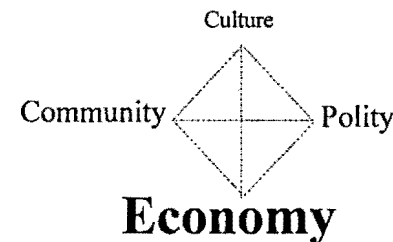
HISTORY

- **World systems analysis**
A view about globalization
(Wallerstein et al)
- **A speculative model of history**
Combining both 'materialist' & 'idealist' orientations
Putting the present in a macro-historical context

World systems analysis

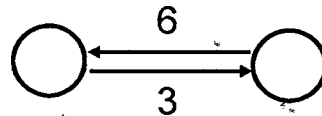
- International economy an integral 'world system' developed over past 100s of years; this now referred to as *globalization*.
- This system has developed/interacting *center* & developing/dependent *periphery* (N vs. S).
- International economy currently *unconstrained* by an international polity, community, values.

Sustainability requires the full development of international society.



Externalities and exploitation ^{1/2}

- In PD, players are equivalent & suffer equally, but if asymmetry between players, equity issues arise: *exchange can be unequal*



- Unequal exchange due to unequal development of systems.
- Problem shifts from *collective irrationality (PD)* → *exploitation*.

Externalities and exploitation ^{2/2}

- Ecological/thermodynamic analogy: *mature systems exploit immature systems* (Margalef).
- In World System: the organized exploits the unorganized, e.g., developed North (center) exploits developing South (periphery)

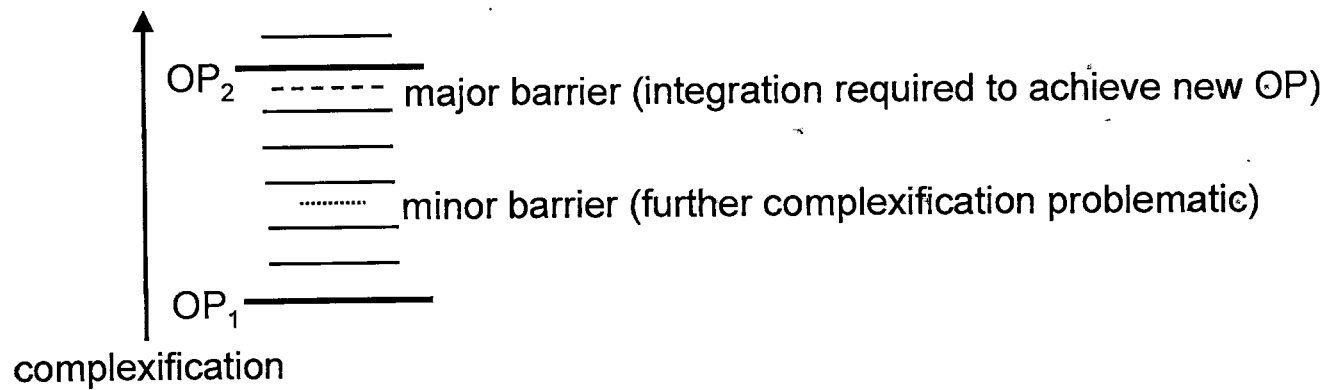
Sustainability requires ending exploitation & promoting socio-economic development.

A speculative process model ^{1/2}

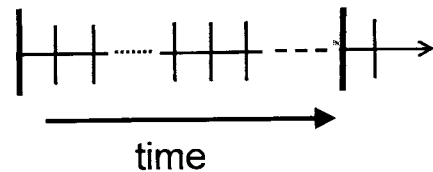
- Processes governed by a diachronic 'organizing principle' develop in stages.
- Transition to a new OP requires a major accomplishment of integration.
- There is a second difficult transition also associated with complexification.
- One process can facilitate the difficult transitions of another.

A speculative process model ^{2/2}

Complexification stages:



viewed diachronically:

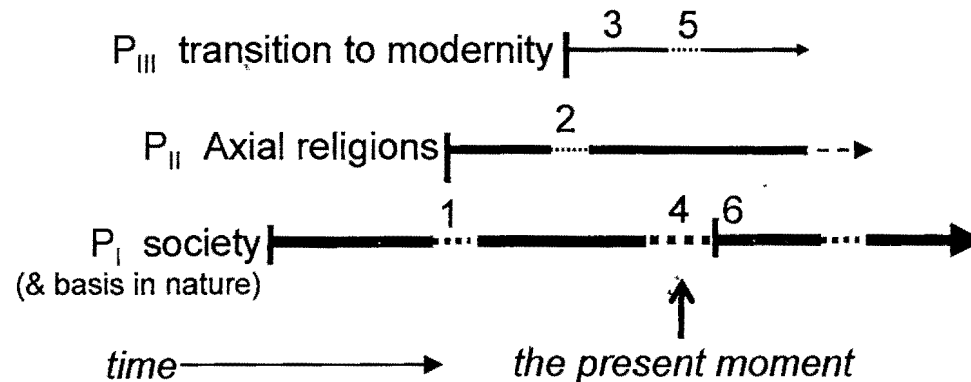


Applying the model to macro-history

Interacting global historical processes:

P_I nearly everywhere; P_{II} in several places; P_{III} in the West

- 1 Axial religions allow further societal complexification
- 2 Renaissance/Reformation/Enlightenment/Scientific Revolution
- 3 modernity (central challenge of differentiation)
- 4 the present planetary crisis (central challenge of integration)**
- 5 fragmentation of science (challenge of integration); uncontrolled technology
- 6 a new planetary unity (a new global societal 'organizing principle')**



Sustainability requires planetary integration.

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Summary

Ideas to understand/work for sustainability

- Lineal, branching, & cyclic processes
- Externalities; utilities
- Game/decision theory: prisoner's dilemma; chicken
- Implications of 2nd Law; open systems
- Thermodynamics of utility
- Patterns of growth
- Limits to exponential growth; hysteresis
- Societal differentiation; multiple objectives
- World system: integration- development
- Macro-history

Principles: sustainability requires ^{1/2}

GRAPH THEORY

- *Internalizing (negative) externalities.*
- *Closing the circle on external effects.*
- *Removing incentives to increase externalities.*

GAME THEORY

- *Avoiding PD traps (& solving PD) & Chicken dangers.*
- *Non-market interventions.*
- *Worst case rather than expected value decision-making*
- *Internalizing externality of future & making it loom large.*
- *Preventing traps from being transformed into dangers.*

THERMODYNAMICS

- *Living on input.*
- *Prices being (thermodynamically) objective.*

Principles: sustainability requires ^{2/2}

Theories from ECOLOGY

- *Non-dependence on exponential growth.*
- *Long-term management to prevent extinctions.*
- *Avoiding difficult to reverse crashes.*

Theories from SOCIOLOGY

- *Right societal differentiation & integration.*
- *Polity regulating economy.*
- *Additional societal control of economy.*
- *Cultural values transcending commercial values.*
- *Satisfying multiple values.*

Theories from HISTORY

- *Full development of international society*
- *Ending exploitation, promoting development.*
- *Planetary integration*

Advertisement for next Fall

- *More detail* in SySc 510 “Systems Ideas & Sustainability”, *Fall 2007*.

(an experimental modification of – and substitute for – SySc 521 “Systems Philosophy”)

Thank you.