4-15-2011

Systems Views of the Economics of Sustainable Development

Joshua Hughes
Portland State University

SYSTEMS VIEWS
OF THE
ECONOMIC$
OF
SUSTAINABLE DEVELOPMENT

Joshua Hughes
Systems Science Graduate Program
Portland State University

Systems Science Seminar Series
April 15, 2011

THE ECONOMICS OF SUSTAINABLE DEVELOPMENT

- What is economics?
- What is “traditional” economic theory, and what's wrong with it?
- Why markets exist, why they are good, and why they are not so good
- How can we make microeconomics more realistic?
- How can we make macroeconomics more realistic? (The BIG Picture)
- What does this all mean for sustainable development?

What is economics?

- the study of the allocation of scarce resources
- the relative importance of particular things
- rational behavior and planning regarding these things

- wealth, production, trade
- *trade-offs:* winners, losers (rich, poor) – in terms of both populations and environments

What is “traditional” economic theory?

mathematics

- Adam Smith (1776) – human self-interest (“the invisible hand”) drives markets to a balance (stable state) that is the best possible outcome for society as a whole
- Leon Walras (1872) – this balance is an equilibrium point that can be mathematically calculated (general equilibrium)
- William Stanley Jevons (1871) – people maximizing their differing utilities (how much something is worth to them) will trade their way to this equilibrium (partial equilibrium)
- Vilfredo Pareto – people will only engage in “win-win” or “win-no-lose” trades, i.e., trades that increase welfare
- Alfred Marshall – combined the work of Jevons and Walras, drew the crossed supply and demand curves

What is “traditional” economic theory?

mathematics

- Adam Smith (1776) – human self-interest (“the invisible hand”) drives markets to a balance (stable state) that is the **best** possible outcome for society as a whole
- Leon Walras (1872) – this balance is an equilibrium point that can be mathematically calculated (general equilibrium)
- William Stanley Jevons (1871) – people **maximizing** their differing utilities (how much something is worth to them) will trade their way to this equilibrium (partial equilibrium)
- Vilfredo Pareto – people will only engage in **“win-win”** or “win-no-lose” trades, i.e., trades that increase welfare
- Alfred Marshall – combined the work of Jevons and Walras, drew the crossed supply and demand curves

What is “traditional” economic theory?

more mathematics

- Paul Samuelson (1941) – people's preferences (~utility) are revealed through the choices they make

  You are given a choice between an apple and an orange.
  → You choose the apple.

  Now you are given a choice between an apple, an orange, and a banana.
  → You *will not* choose the orange.

- Kenneth Arrow and Gerard Debreu – prices transmit signals about supply and demand; people's reactions to those signals drive the economy to equilibrium

What is “traditional” economic theory?

more mathematics

- Paul Samuelson (1941) – people's preferences (~utility) are revealed through the choices they make

  You are given a choice between an apple and an orange.
  → You choose the apple.

  Now you are given a choice between an apple, an orange, and a banana.
  → You *will not* choose the orange.

- Kenneth Arrow and Gerard Debreu – prices transmit signals about supply and demand; people's reactions to those signals drive the economy to equilibrium

What's *wrong* with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)

What's wrong with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)

In addition to whatever you own, you have been given $1,000. You are now asked to choose between:

A) 50% chance of gaining $1,000

B) $500

What's wrong with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)

In addition to whatever you own, you have been given $1,000.
You are now asked to choose between:

A) 50% chance of gaining $1,000

B) $500

In addition to whatever you own, you have been given $2,000.
You are now asked to choose between:

C) 50% chance of *losing* $1,000

D) a $500 *loss*

What's wrong with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)

In addition to whatever you own, you have been given $1,000.
You are now asked to choose between:

A) 50% chance of gaining $1,000 16%

B) $500 84%

In addition to whatever you own, you have been given $2,000.
You are now asked to choose between:

C) 50% chance of *losing* $1,000 69%

D) a $500 *loss* 31%

What's wrong with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)

In addition to whatever you own, you have been given $1,000.
You are now asked to choose between:

A) 50% chance of gaining $1,000 = $500 *expected value*

B) $500

In addition to whatever you own, you have been given $2,000.
You are now asked to choose between:

C) 50% chance of *losing* $1,000

D) a $500 *loss*

What's wrong with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)

In addition to whatever you own, you have been given $1,000.
You are now asked to choose between:

A) 50% chance of gaining $1,000 = $500 *expected value*

B) $500

In addition to whatever you own, you have been given $2,000.
You are now asked to choose between:

C) 50% chance of *losing* $1,000 = -$500 *expected value*

D) a $500 *loss*

What's wrong with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)

In addition to whatever you own, you have been given $1,000.
You are now asked to choose between:

A) 50% chance of gaining $1,000 = $500 *expected value*

B) $500 = $500 *expected value*

In addition to whatever you own, you have been given $2,000.
You are now asked to choose between:

C) 50% chance of *losing* $1,000 = -$500 *expected value*

D) a $500 *loss* = -$500 *expected value*

What's wrong with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)

In addition to whatever you own, you have been given $1,000.
You are now asked to choose between:

A) 50% chance of gaining $1,000 = $500 *expected value*

B) $500 = $500 *expected value*

In addition to whatever you own, you have been given $2,000.
You are now asked to choose between:

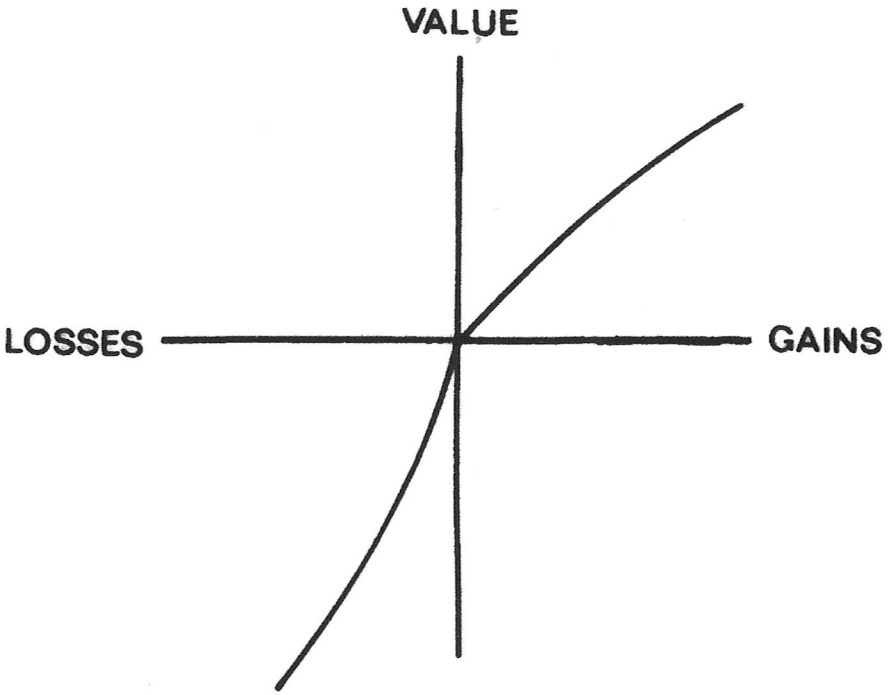
C) 50% chance of *losing* $1,000 = -$500 *expected value*

D) a $500 *loss* = -$500 *expected value*

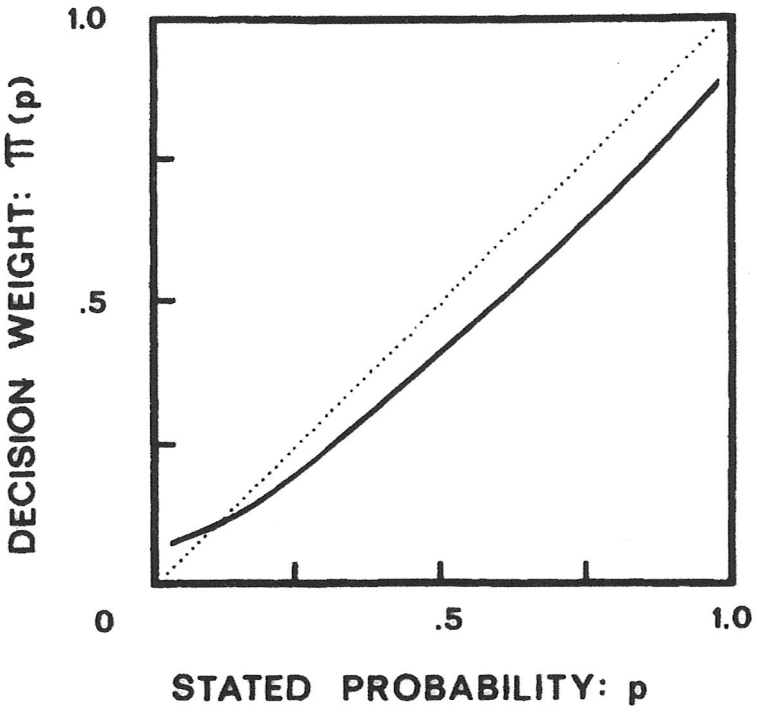
A = B = C = D = $1,500 *expected value*.

What's wrong with traditional economic theory?

Prospect Theory – Kahneman and Tversky (1979)



value function



weight function

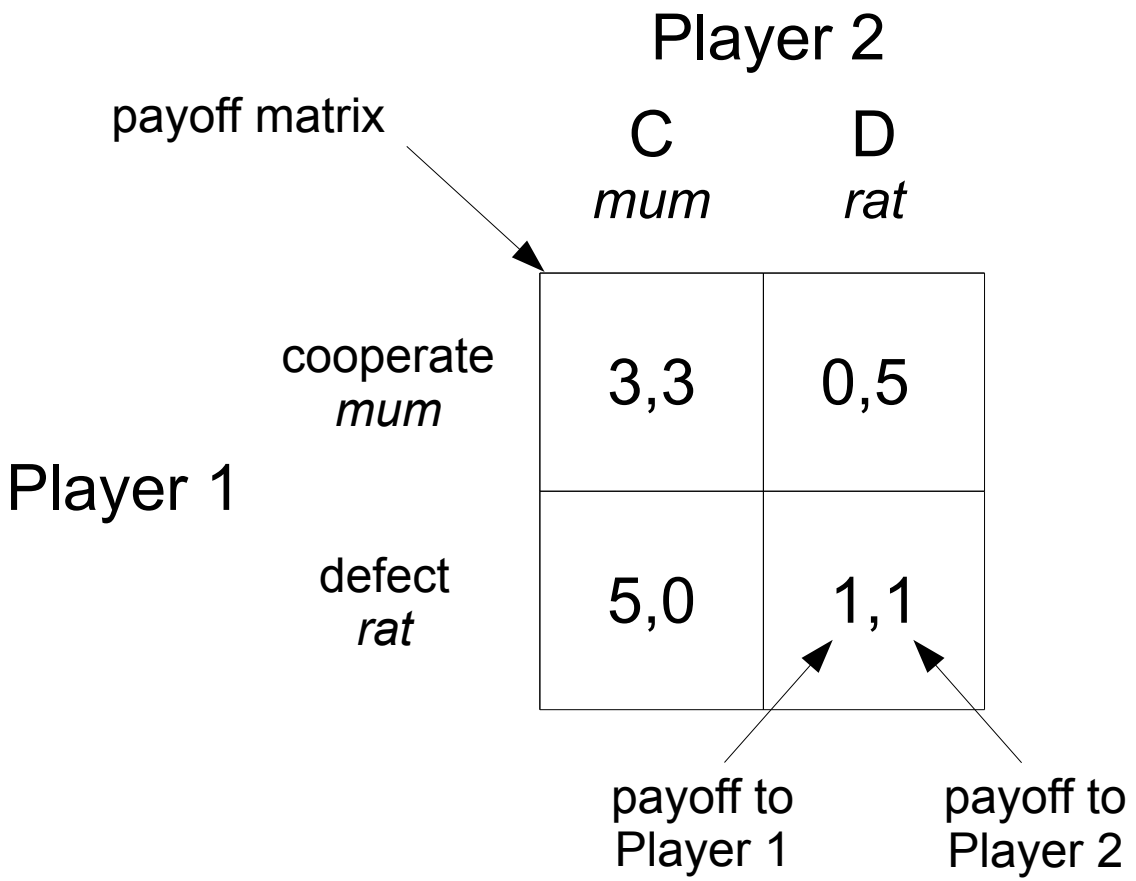
What's wrong with traditional economic theory?

Game Theory – von Neumann and Morgenstern (1953)

What's wrong with traditional economic theory?

Game Theory – von Neumann and Morgenstern (1953)

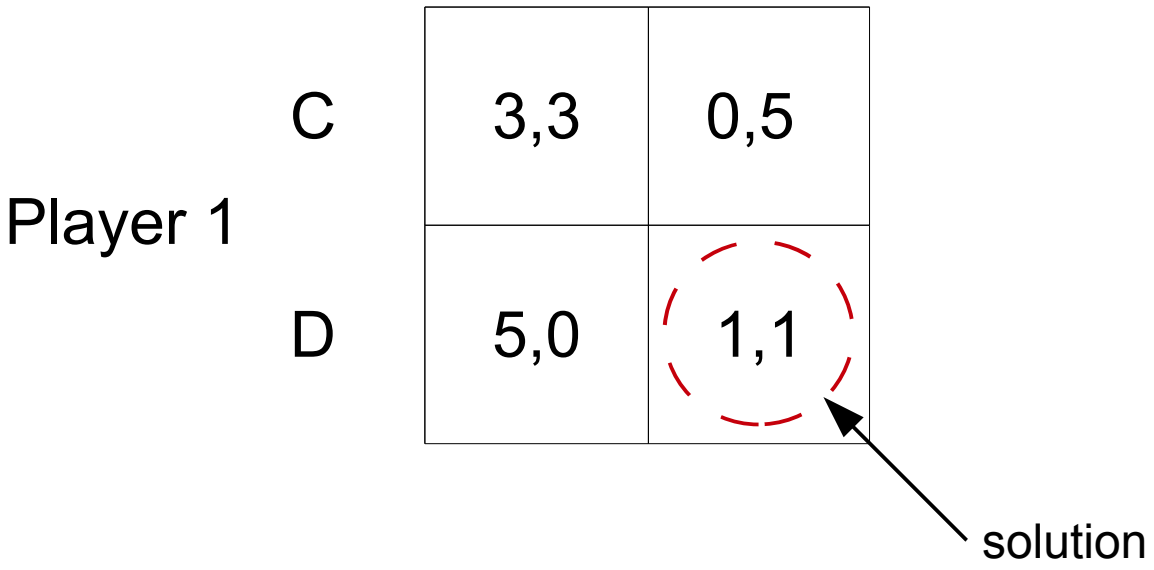
Prisoner's Dilemma (PD)



What's wrong with traditional economic theory?

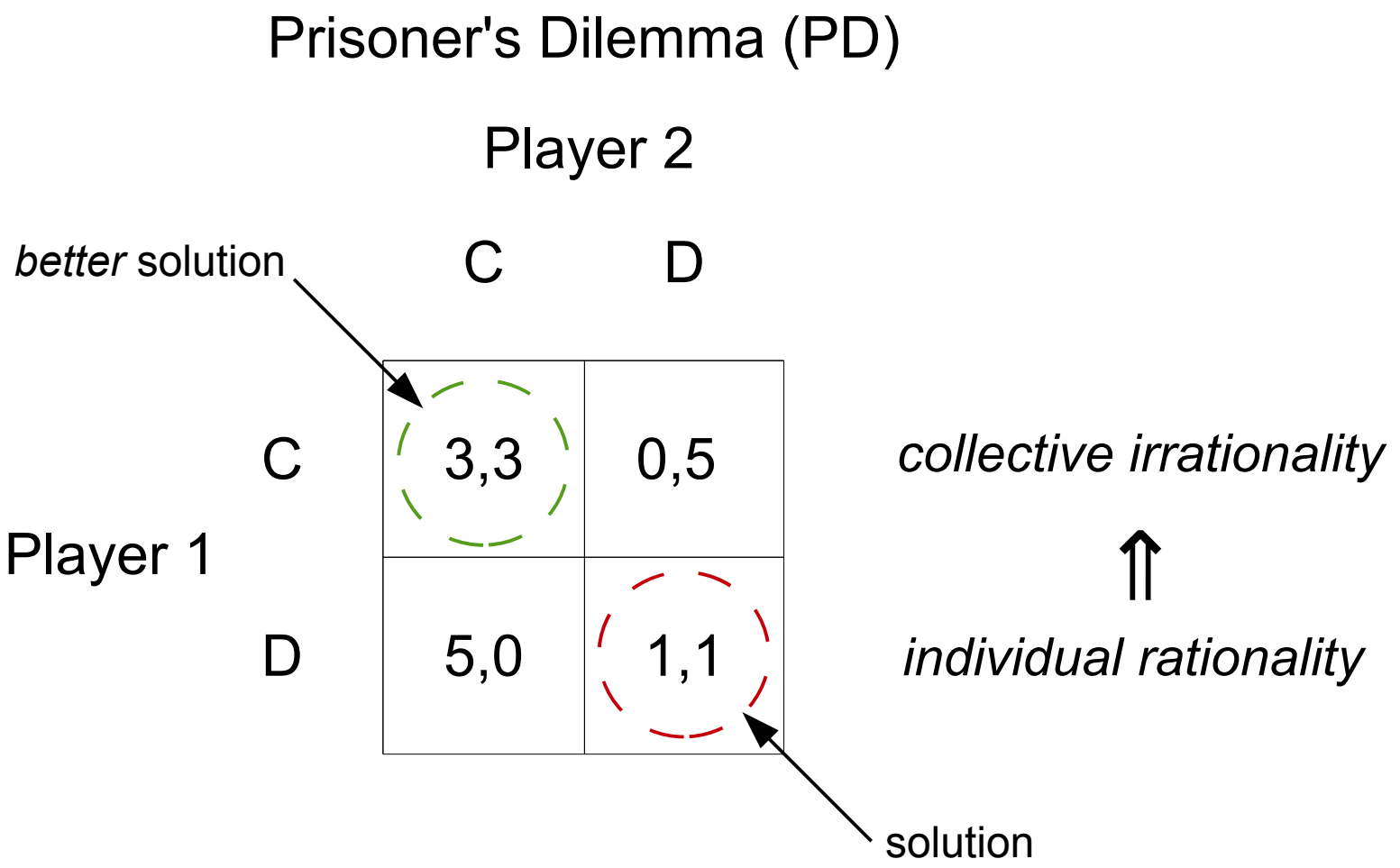
Game Theory – von Neumann and Morgenstern (1953)

Prisoner's Dilemma (PD)



What's wrong with traditional economic theory?

Game Theory – von Neumann and Morgenstern (1953)



What's wrong with traditional economic theory?

The Ultimatum Game

You have $100 to share between yourself and another person. You can offer the other person any portion of that $100.

If the other person accepts your offer, he or she gets what ever you offered, and you get the remainder.

If the other person rejects your offer, you both get nothing.

What's wrong with traditional economic theory?

The Ultimatum Game

You have $100 to share between yourself and another person. You can offer the other person any portion of that $100.

If the other person accepts your offer, he or she gets what ever you offered, and you get the remainder.

If the other person rejects your offer, you both get nothing.

Utility theory says you should take whatever you are offered, *but people reject offers that they think are* ***unfair***.

→ *costly punishment*

What's wrong with traditional economic theory?

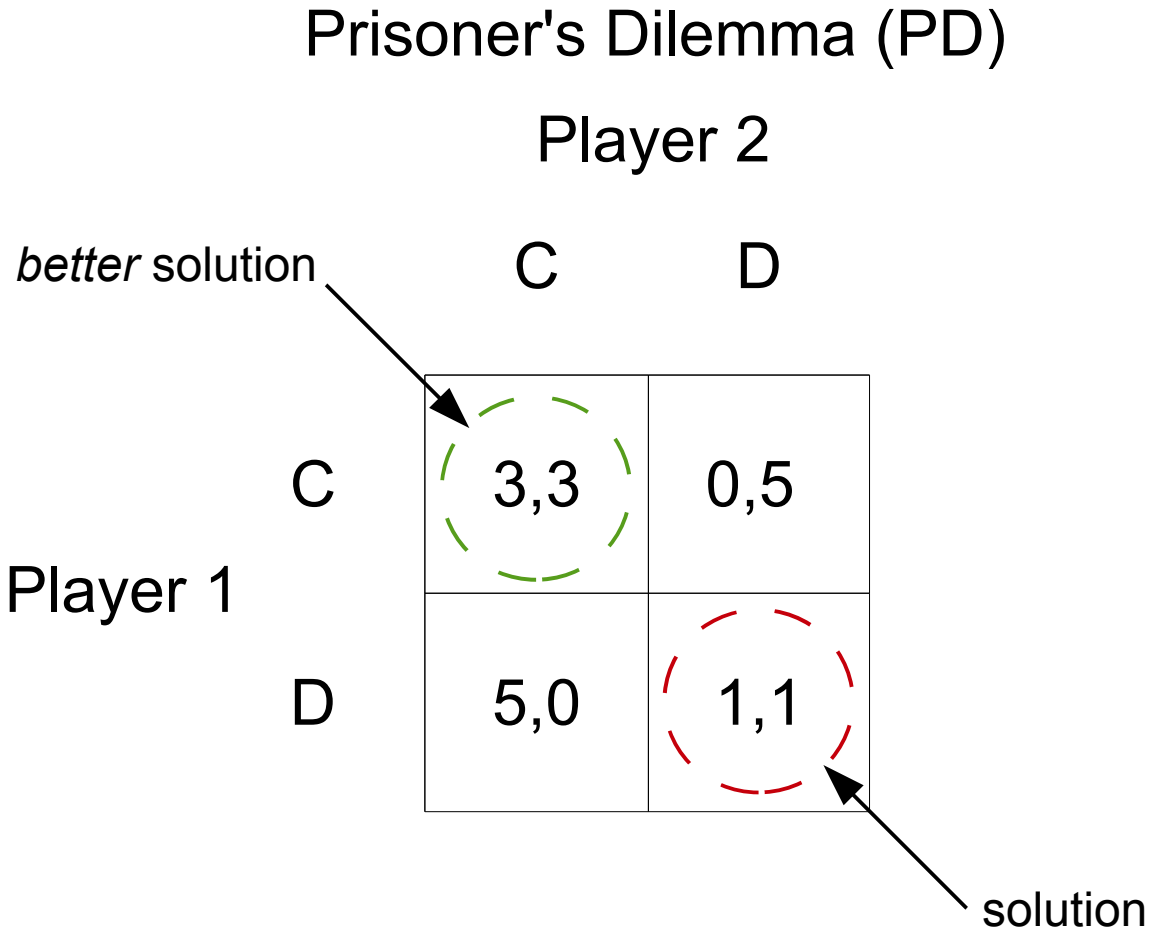
Iterated Prisoners Dilemma – Axelrod (1984)

First Tournament: Players asked to submit strategies to play the PD repeatedly against all other strategies. Winner based on total payoff for all games.

What's wrong with traditional economic theory?

Iterated Prisoners Dilemma – Axelrod (1984)

Prisoner's Dilemma (PD)



What's wrong with traditional economic theory?

Iterated Prisoners Dilemma – Axelrod (1984)

First Tournament: Players asked to submit strategies to play the PD repeatedly against all other strategies. Winner based on total payoff for all games.

- Winning strategy was “Tit for Tat” – start with cooperation and then do whatever the other player does.

  1) nice 2) *punishes* 3) *forgives*

→ Does not win against all strategies (can be exploited) but does well *overall*.

What's wrong with traditional economic theory?

Iterated Prisoners Dilemma – Axelrod (1984)

First Tournament: Players asked to submit strategies to play the PD repeatedly against all other strategies. Winner based on total payoff for all games.

- Winning strategy was "Tit for Tat" – start with cooperation and then do whatever the other player does.

  1) nice 2) *punishes* 3) *forgives*

→ Does not win against all strategies (can be exploited) but does well *overall*.

Second Tournament: All players are aware that "Tit for Tat" won the first tournament when they submit their strategies.

"Tit for Tat" wins again.

What's wrong with traditional economic theory?

Cooperation – Poteete, Marco, and Ostrom (2010)

People cooperate when...

- they have repeated interactions within a group,
- they are able to communicate, and
- they punish defectors.

Groups self-organized to manage common resources when organizations were created when the group was small, close to, and dependent on a common resource and when coordination and management were necessary for simultaneous and sequential use by different groups.

* Groups with mostly cooperators can do “better” than groups with mostly selfish individuals;
  however, the selfish individuals still do better than the cooperators *within* the groups

*What is “traditional” economic theory?

“The Use of Knowledge in Society” – Hayek (1945)

- science is not the only kind of knowledge that is relevant; “there is beyond question a body of very important but unorganized knowledge which cannot possibly be called scientific in the sense of knowledge of general rules: the knowledge of the particular circumstances of time and place”
- “economic problems arise always and only in consequence of change” – “the economic problem of society is mainly one of rapid adaptation to changes in the particular circumstances of time and place”
- “prices *can* act to coordinate the separate actions of different people in the same way as subjective values help the individual to coordinate the parts of his plan”

*What is “traditional” economic theory?

“The Use of Knowledge in Society” – Hayek (1945)

- science is not the only kind of knowledge that is relevant; “there is beyond question a body of very important but unorganized knowledge which cannot possibly be called scientific in the sense of knowledge of general rules: the knowledge of the particular circumstances of time and place” → ***local***
- “economic problems arise always and only in consequence of change” – “the economic problem of society is mainly one of rapid adaptation to changes in the particular circumstances of time and place” → ***adaptive***
- “prices *can* act to coordinate the separate actions of different people in the same way as subjective values help the individual to coordinate the parts of his plan” → ***information***

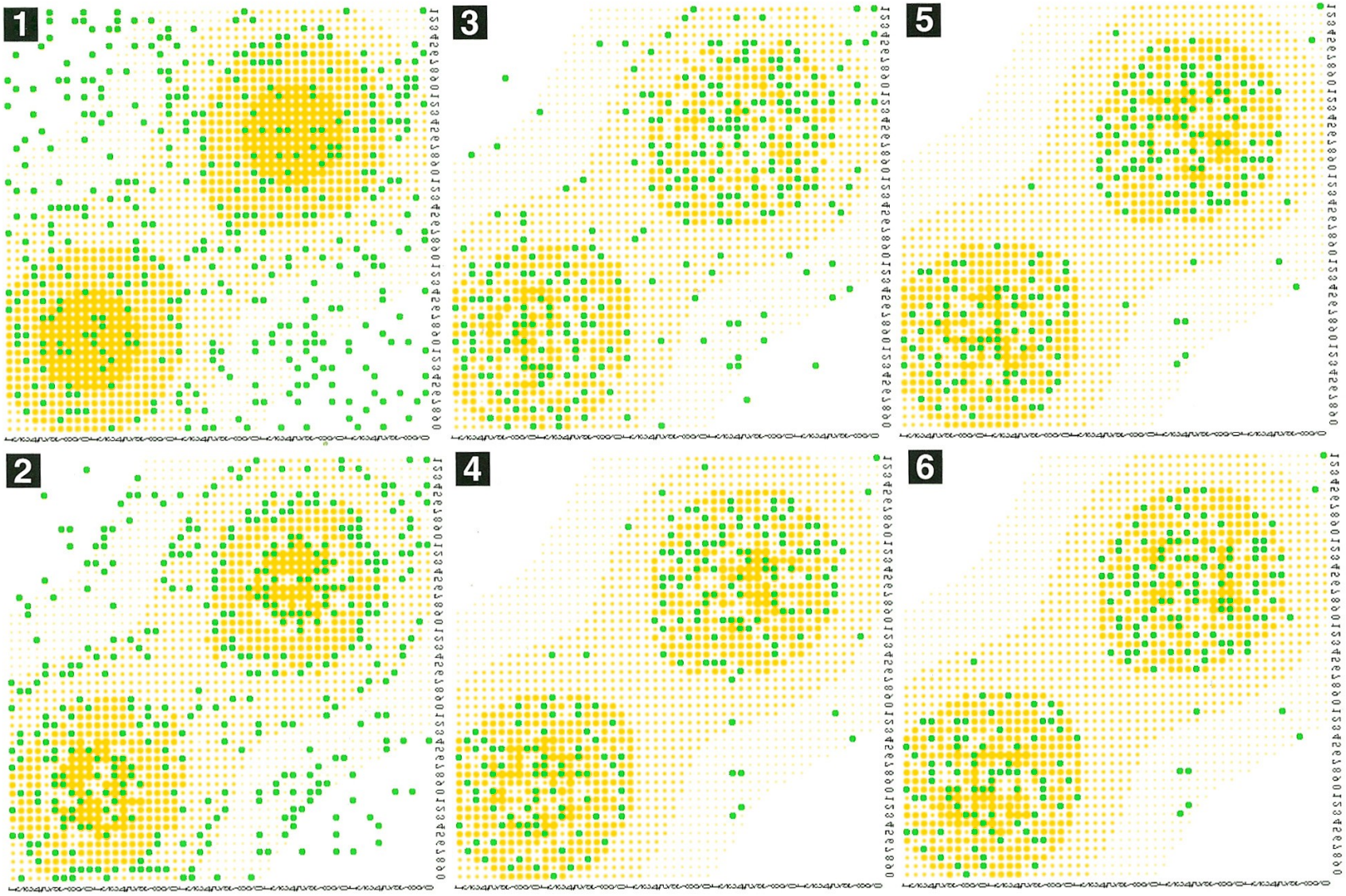
What's wrong with traditional economic theory?

Sciences of the Artificial – Simon (1969)

traditional* (neoclassical)	*behavioral* *
• rational agents	• *bounded* rational agents
• perfect information	• *imperfect* information
• all alternatives known	• *selected* alternatives known
• optimize	• *satisfice* (“good enough”)
• selfish	• *cooperative*
• “free” markets	• markets *embedded* in ecosystems and society
• equilibrium	• *disequilibrium*

How can we make microeconomics more realistic?

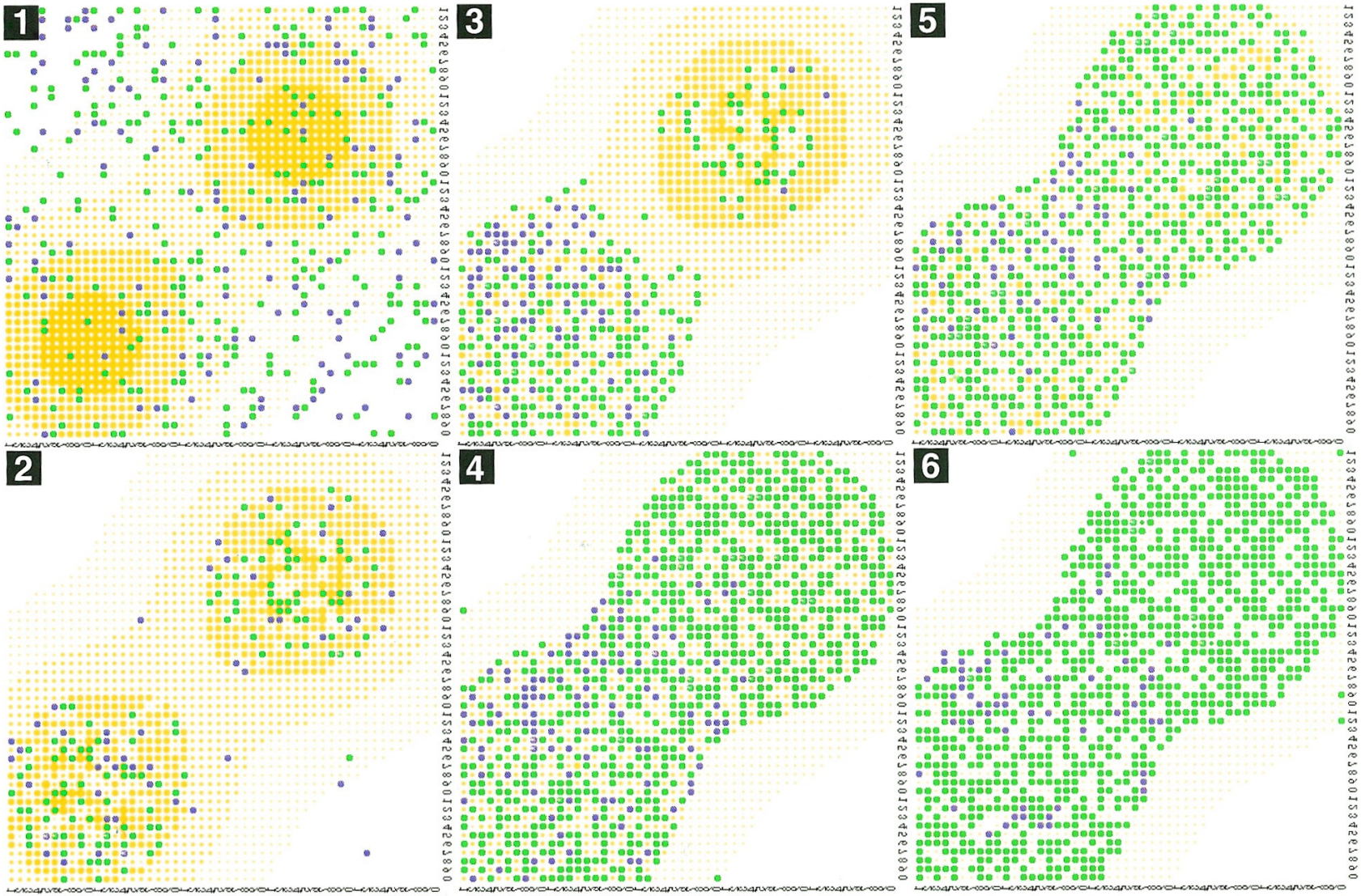
Agent-Based Simulation: *Sugarscape* – resource-seeking



Epstein and Axtell (1999)

How can we make microeconomics more realistic?

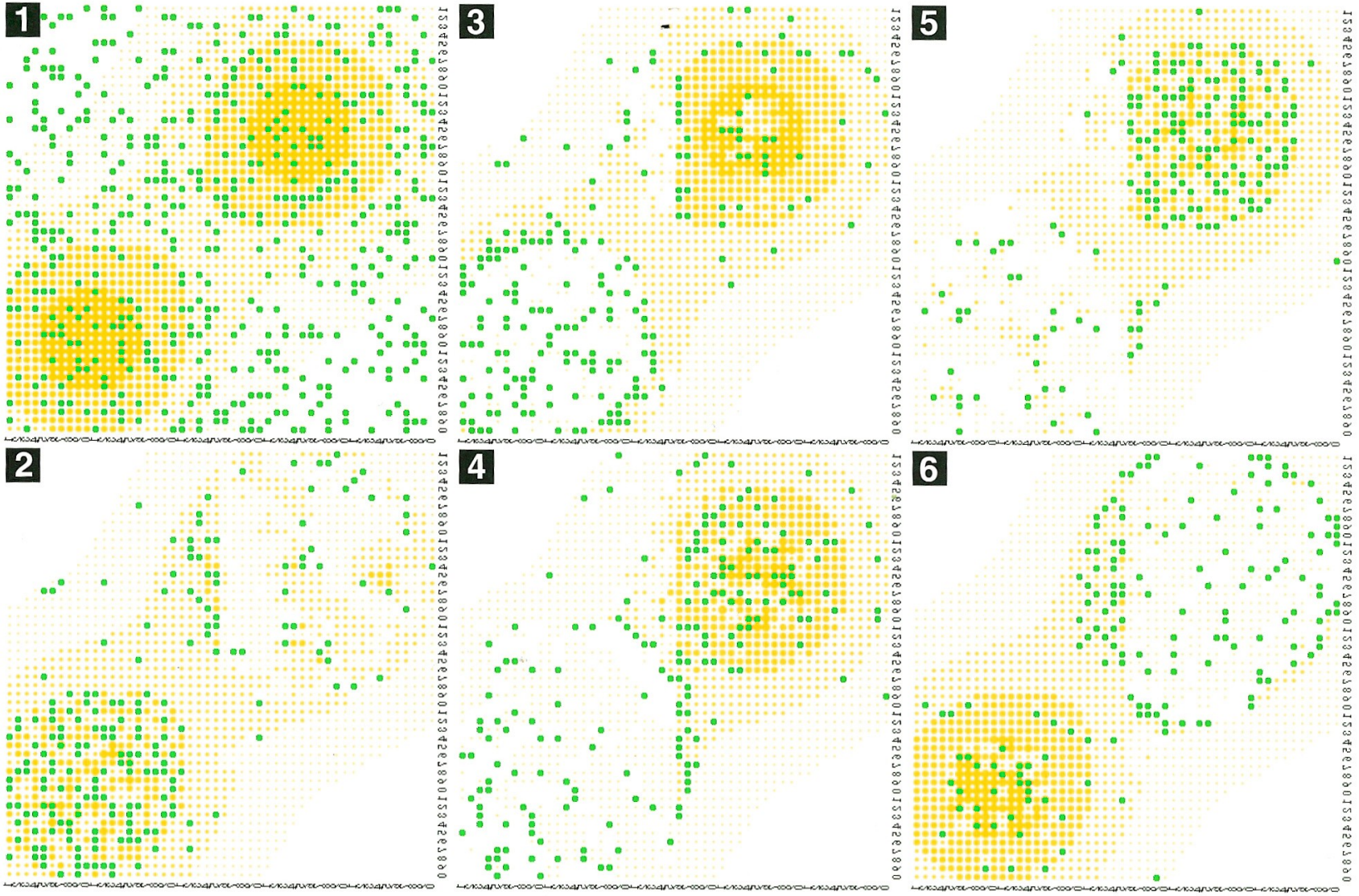
Agent-Based Simulation: *Sugarscape* – selection



Epstein and Axtell (1999)

How can we make microeconomics more realistic?

Agent-Based Simulation: *Sugarscape* – migration/hibernation



Epstein and Axtell (1999)

Why markets exist

- **evolution** – evidence of of trade and cooperation in societies of *Homo habilis* and Homo *erectus*
- **necessity** – societies often must supplement their natural resources and skills with the resources, skills, and products of others
- **desire** – individuals have diverse wants; complex economic systems develop even in environments that have no production such as P.O.W. camps and prisons
- **alternative** – centralized control of economic systems have been disastrous (e.g., U.S.S.R. under Stalin, China's “Great Leap Forward”, North Korea today)

Why markets are good

- efficient solution to the allocation of resources
- competition leads to innovation
- “free”
- increases people's wealth
- prices signal costs

Why markets are *not so good*

- *exploitive* solution to the allocation of resources
- competition leads to *monopolies*
- *distorted*
- increases people's wealth *inequality*
- **prices *hide* costs**

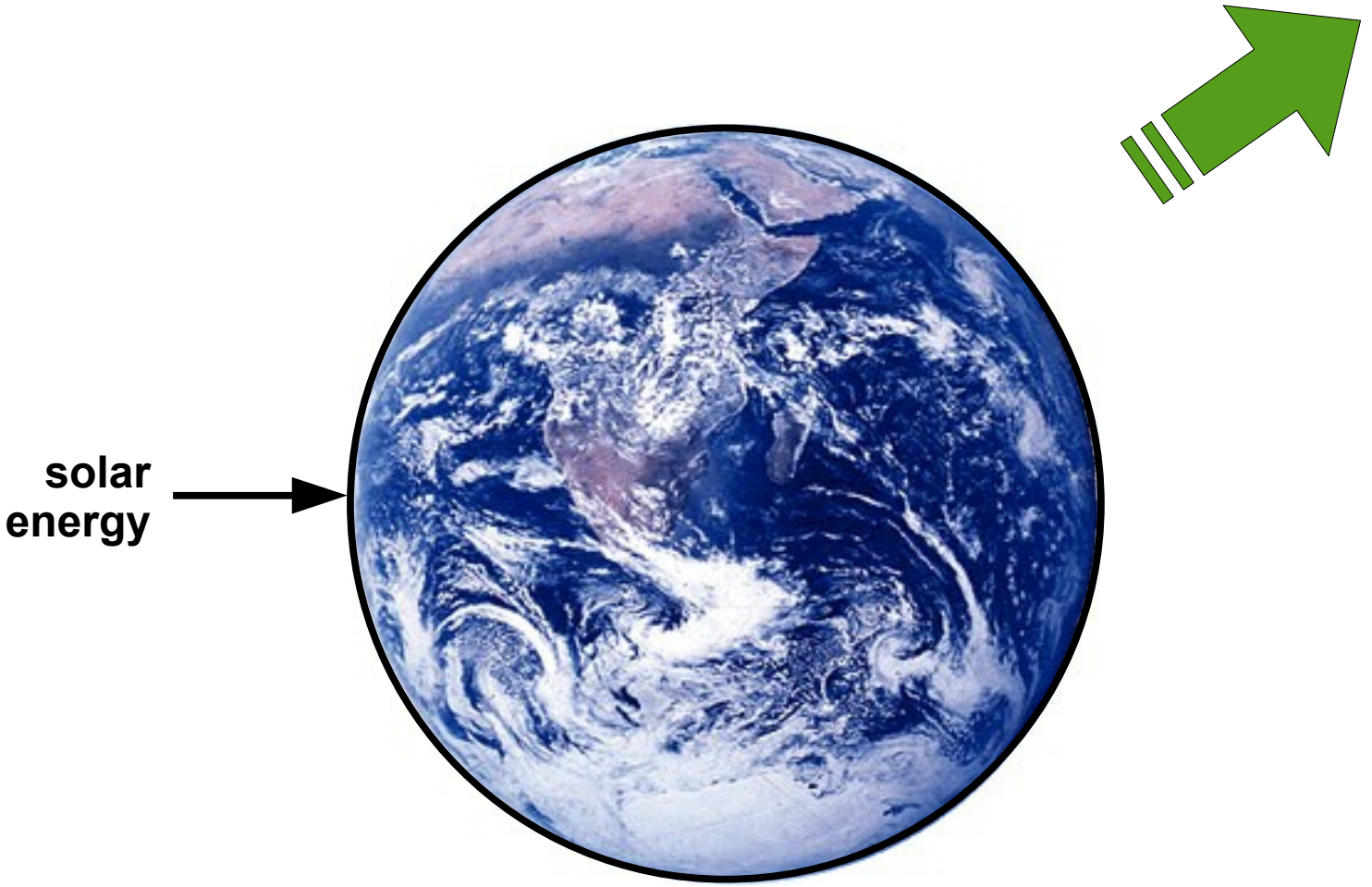
THE **BIG** PICTURE

(systems ideas for macroeconomics)

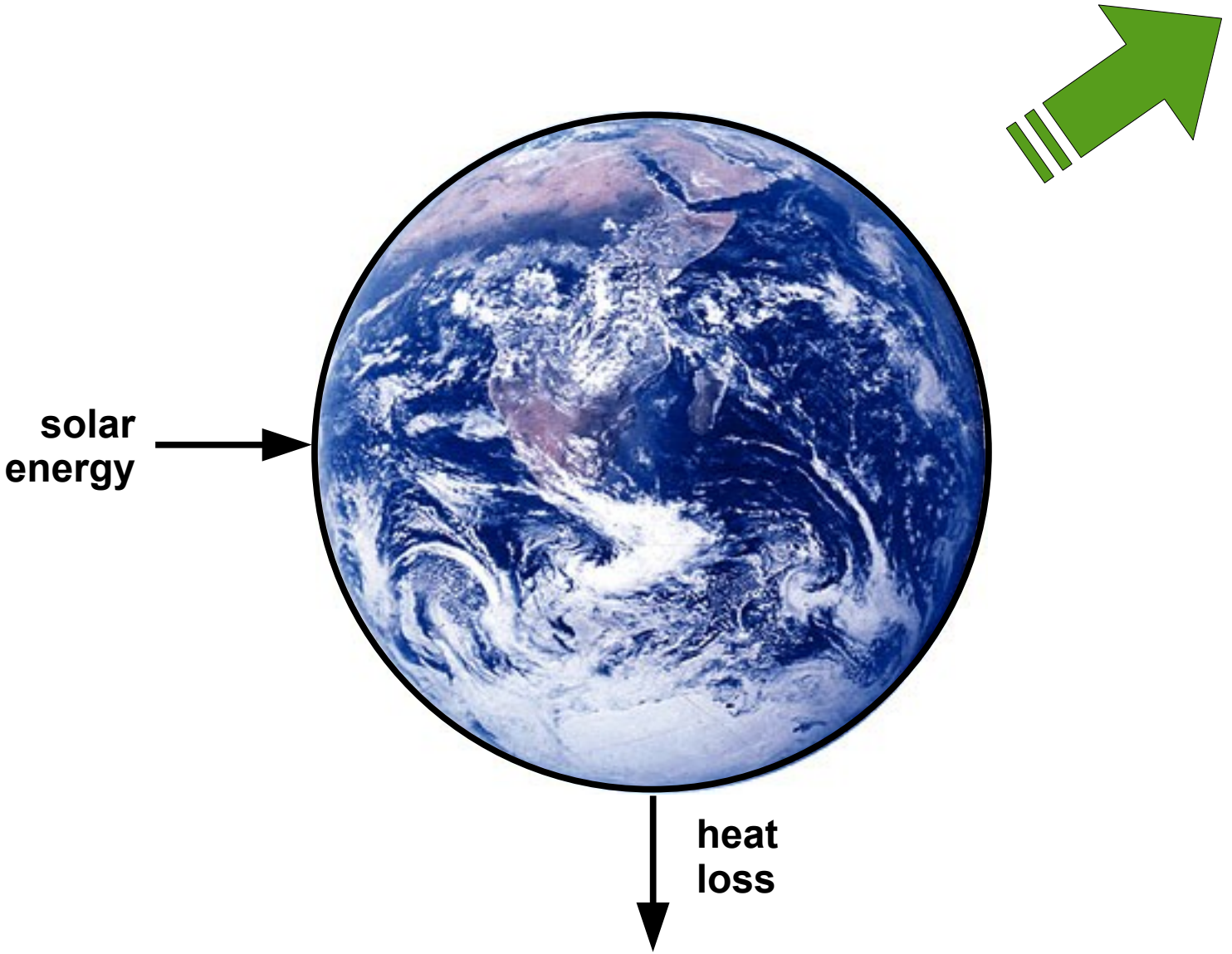
Earth

Spaceship Earth

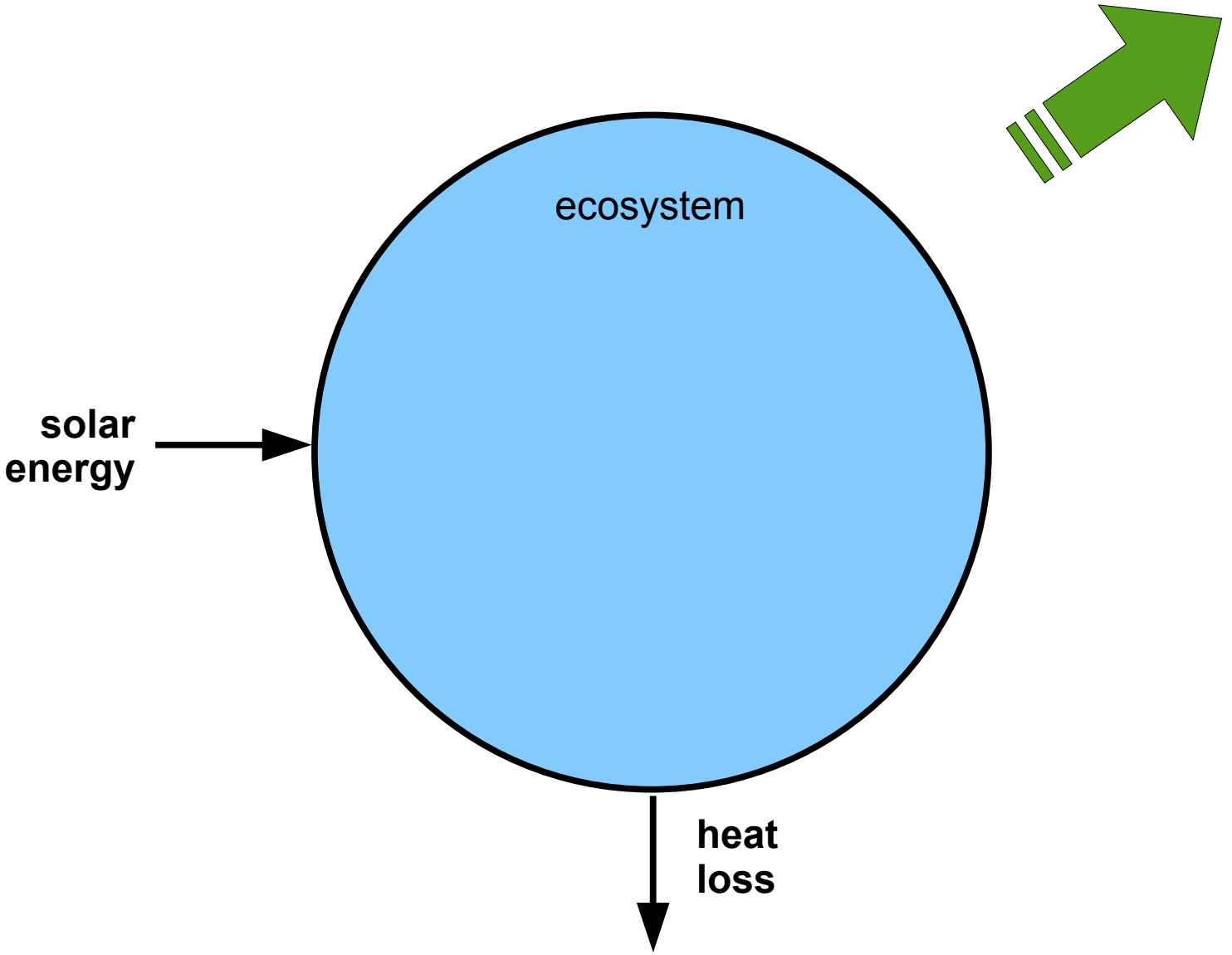
Spaceship Earth



Spaceship Earth

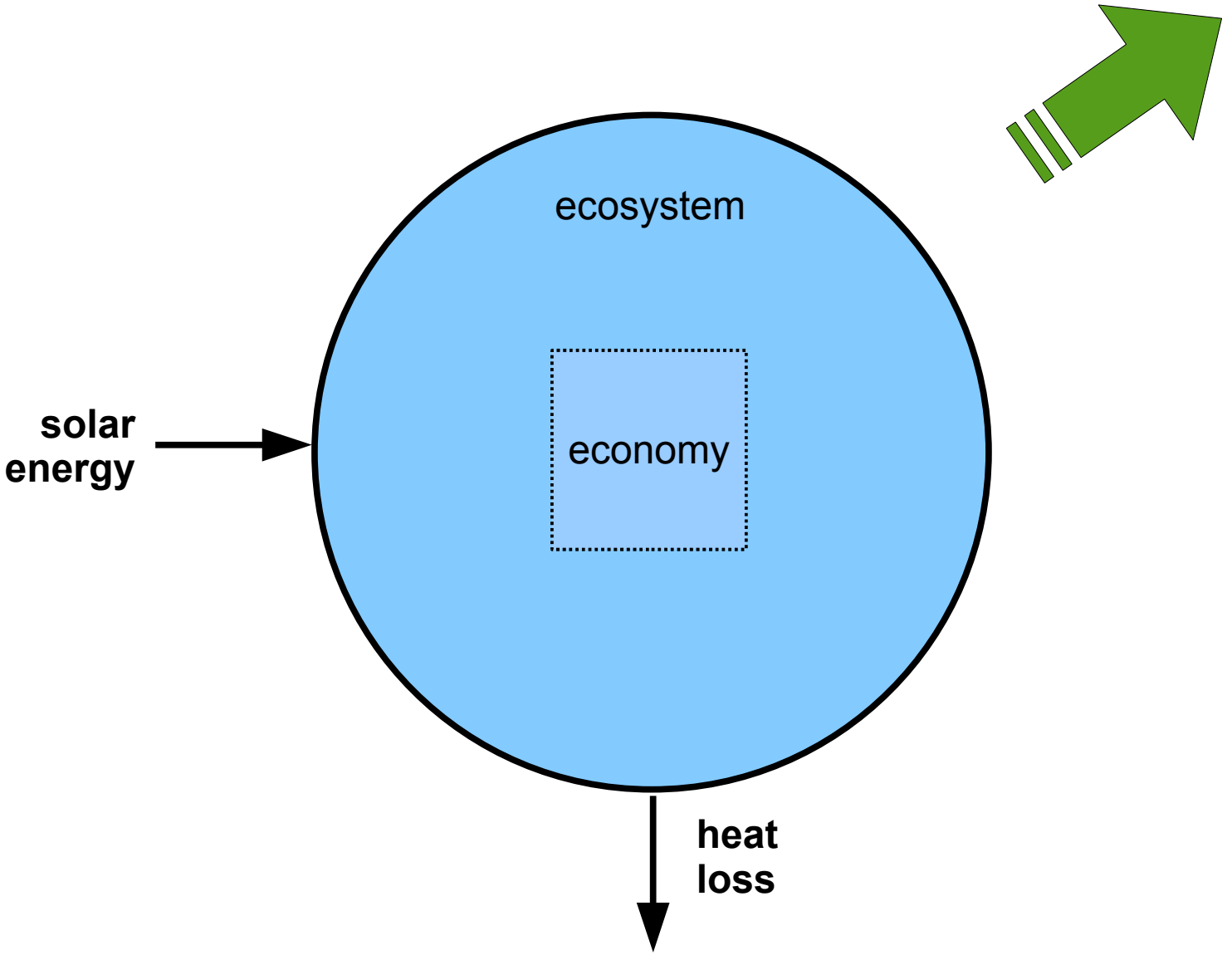


Spaceship Earth



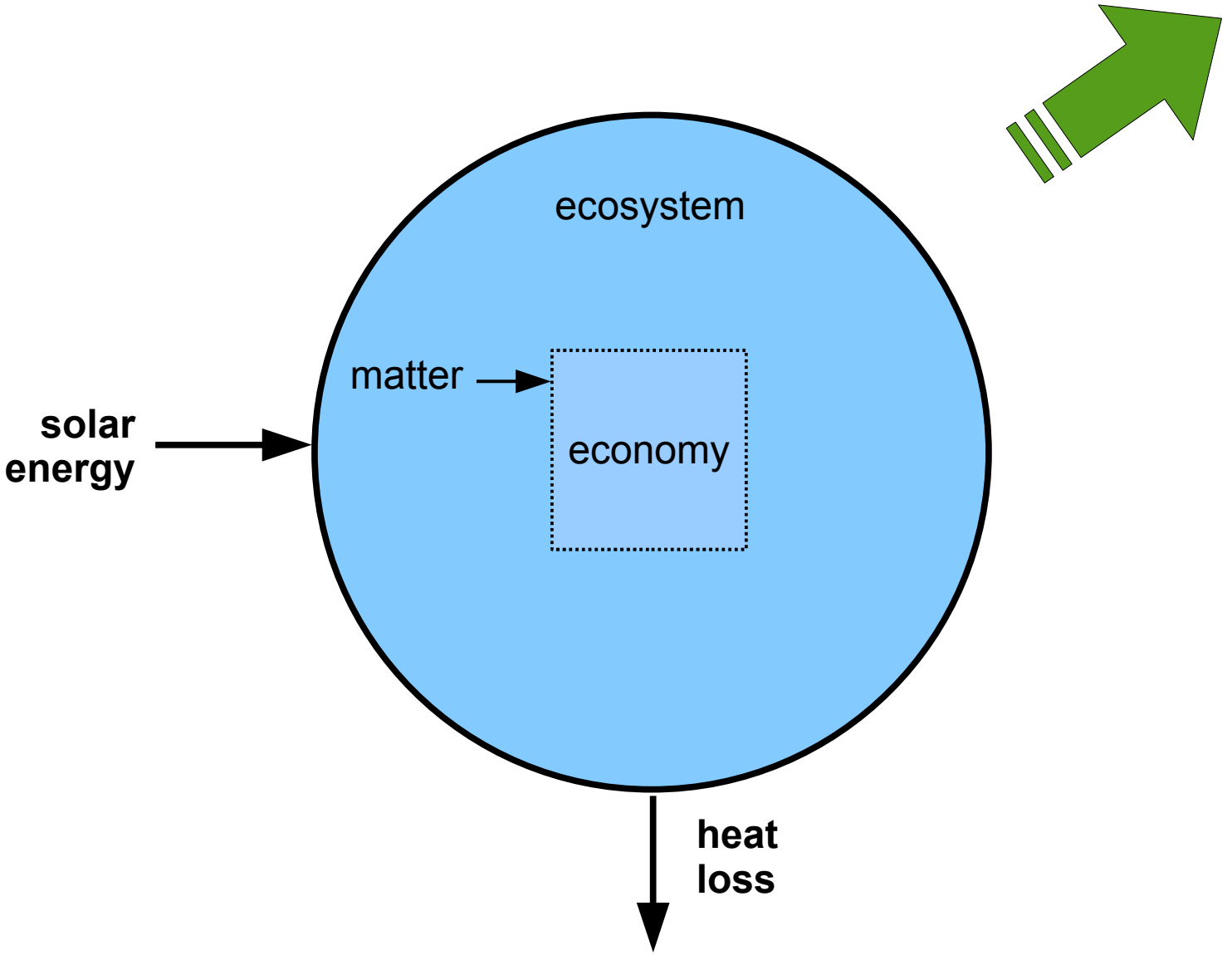
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



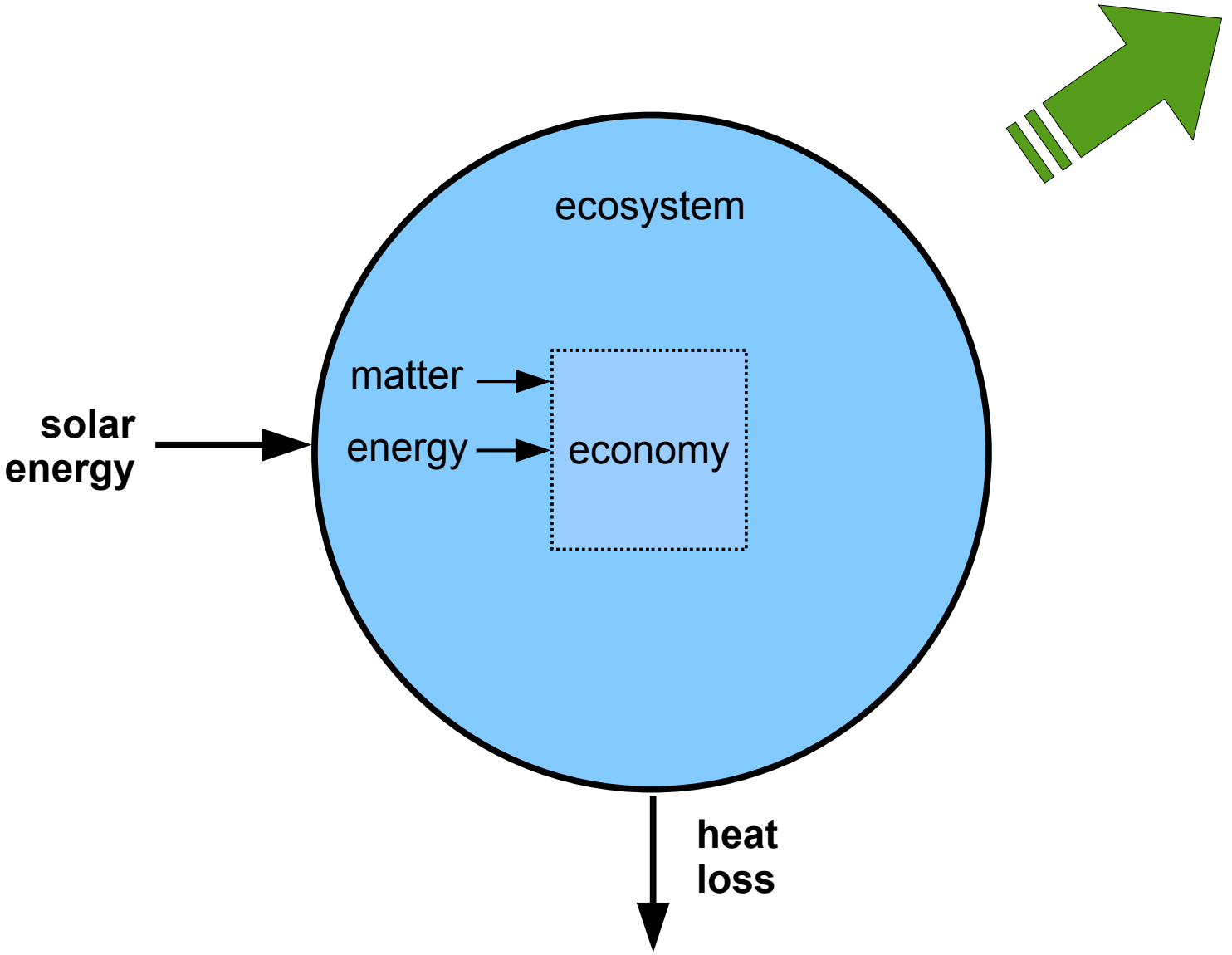
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



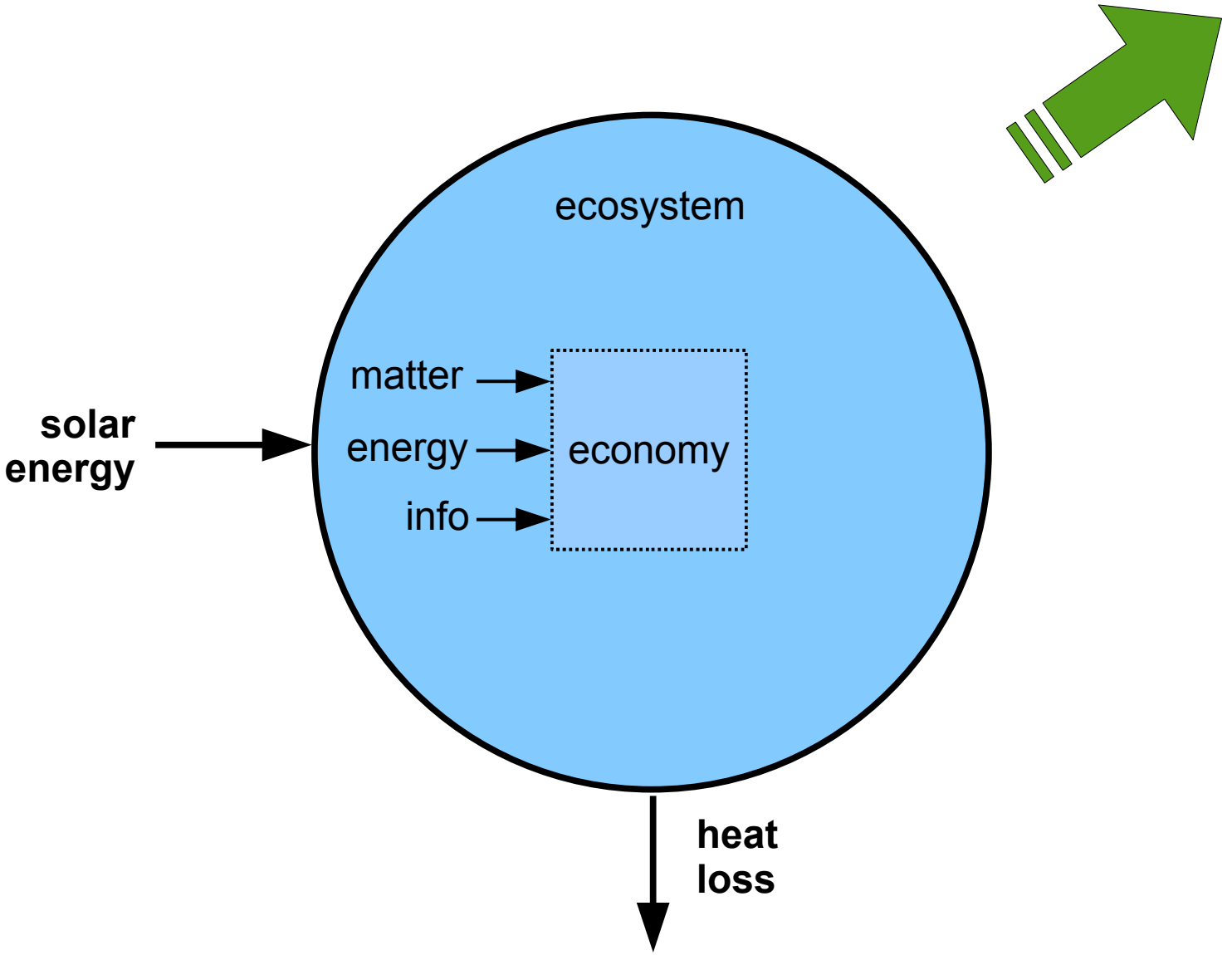
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



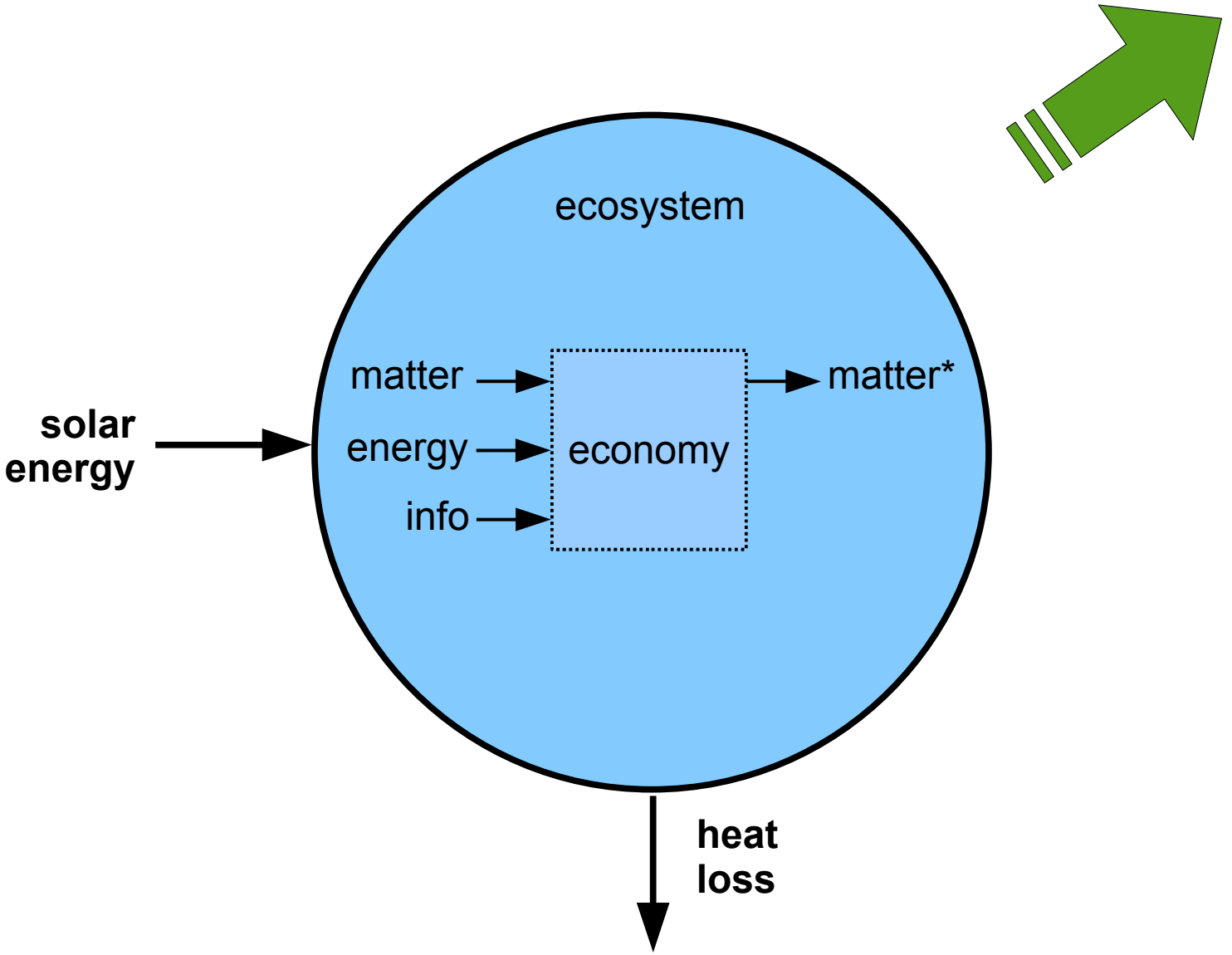
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



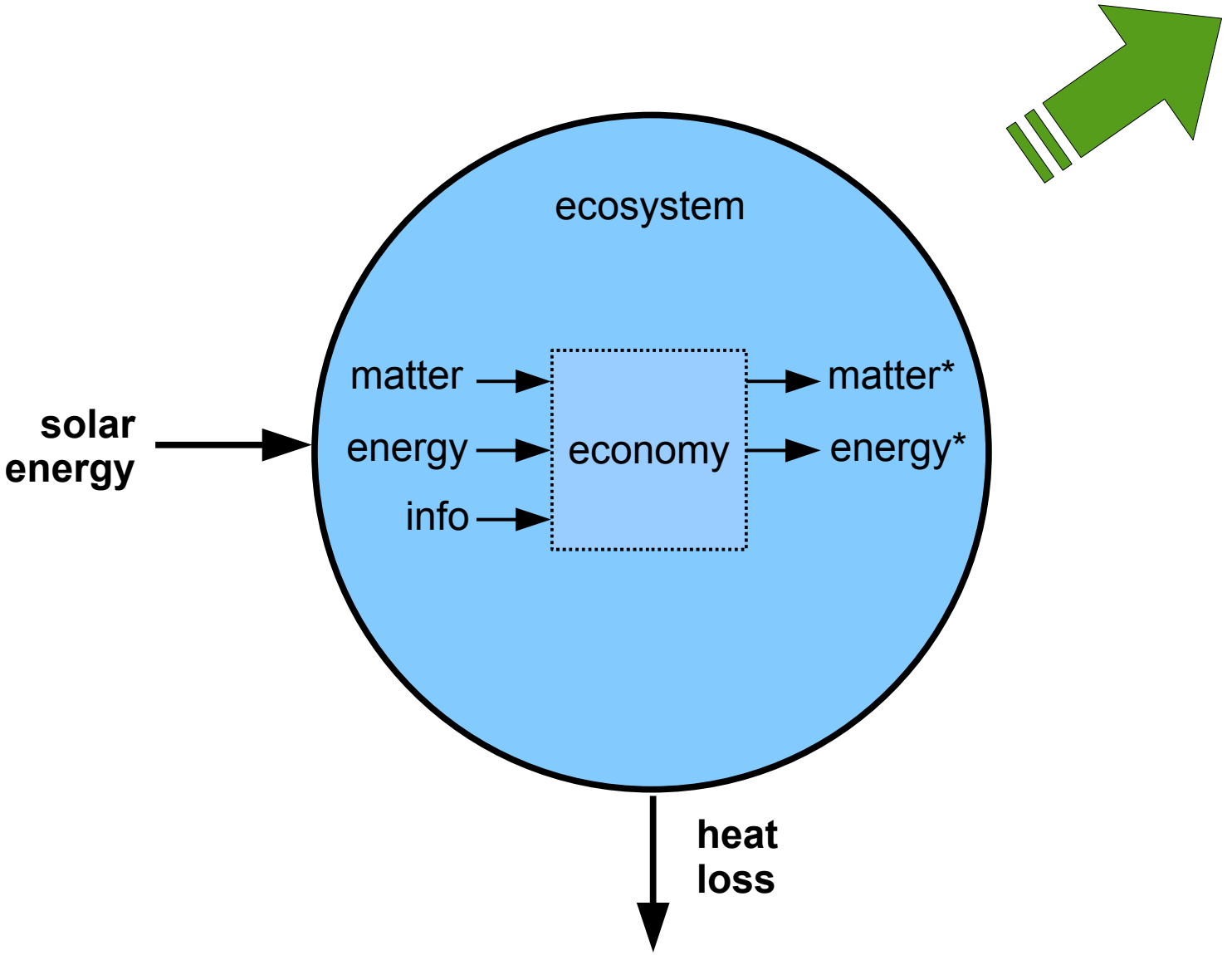
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



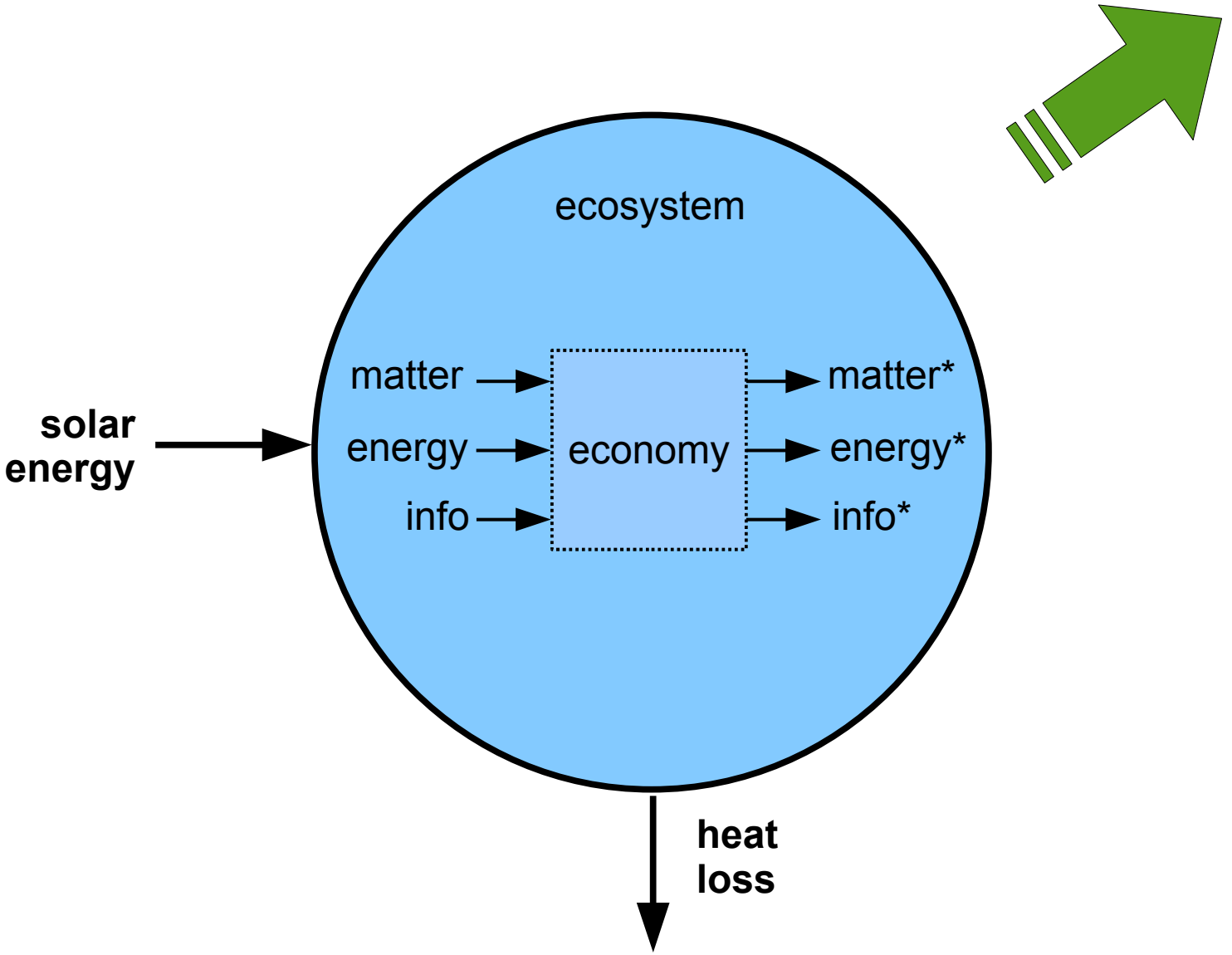
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



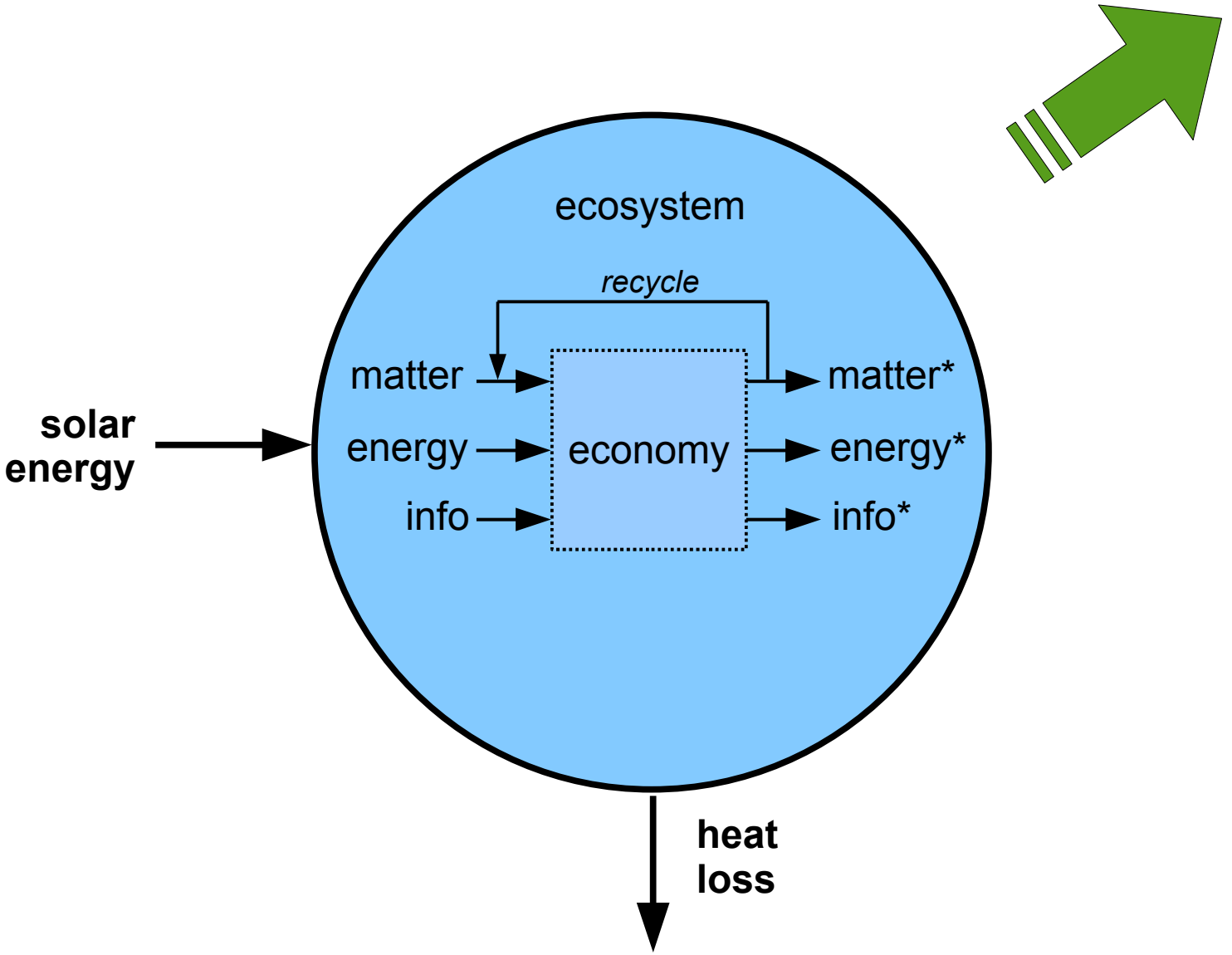
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



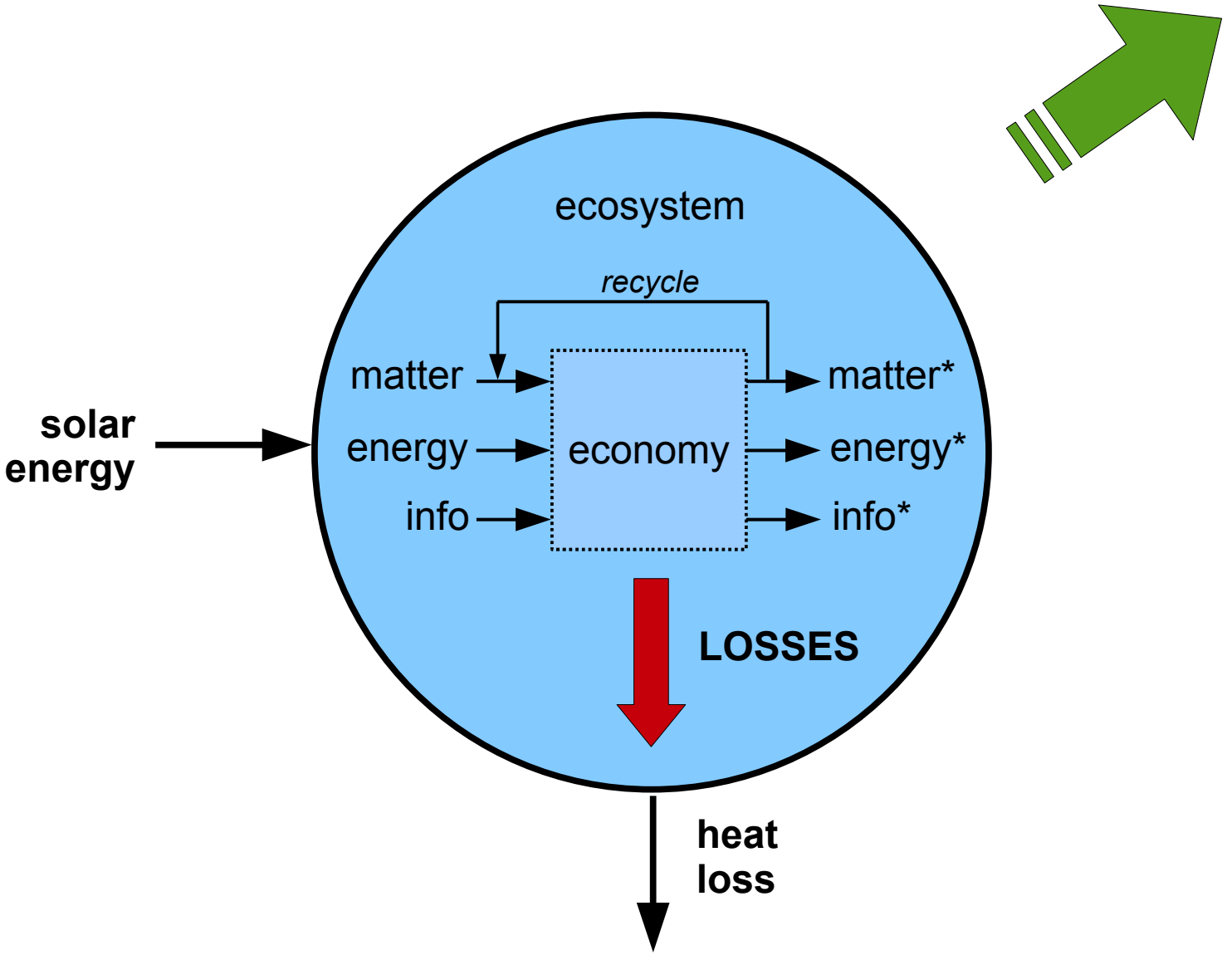
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



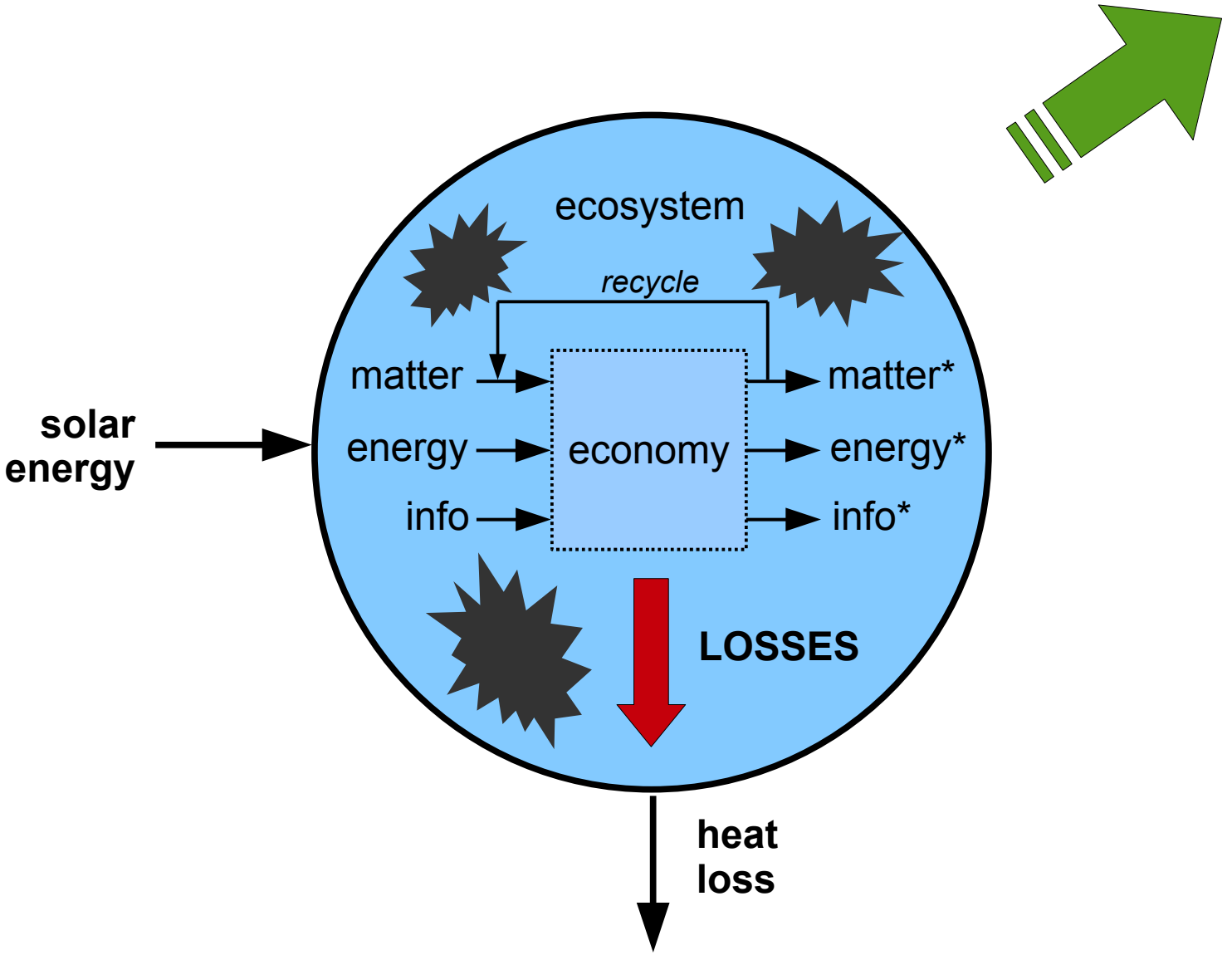
adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



adapted from Prugh, Constanza, and Daly 2000

Spaceship Earth



adapted from Prugh, Constanza, and Daly 2000

The Cowboy and the Spaceman

"The Coming Spaceship Earth" – Boulding (1966)
"Selected Growth Fallacies" – Daly (2003)

Cowboy Economy	**Spaceman Economy**
young	mature
limitless	limited
production and consumption	quality and complexity
use capital (stock) to produce throughput (flow)	use throughput (flow) to maintain capital (stock)
growth is positive	growth has negative effects

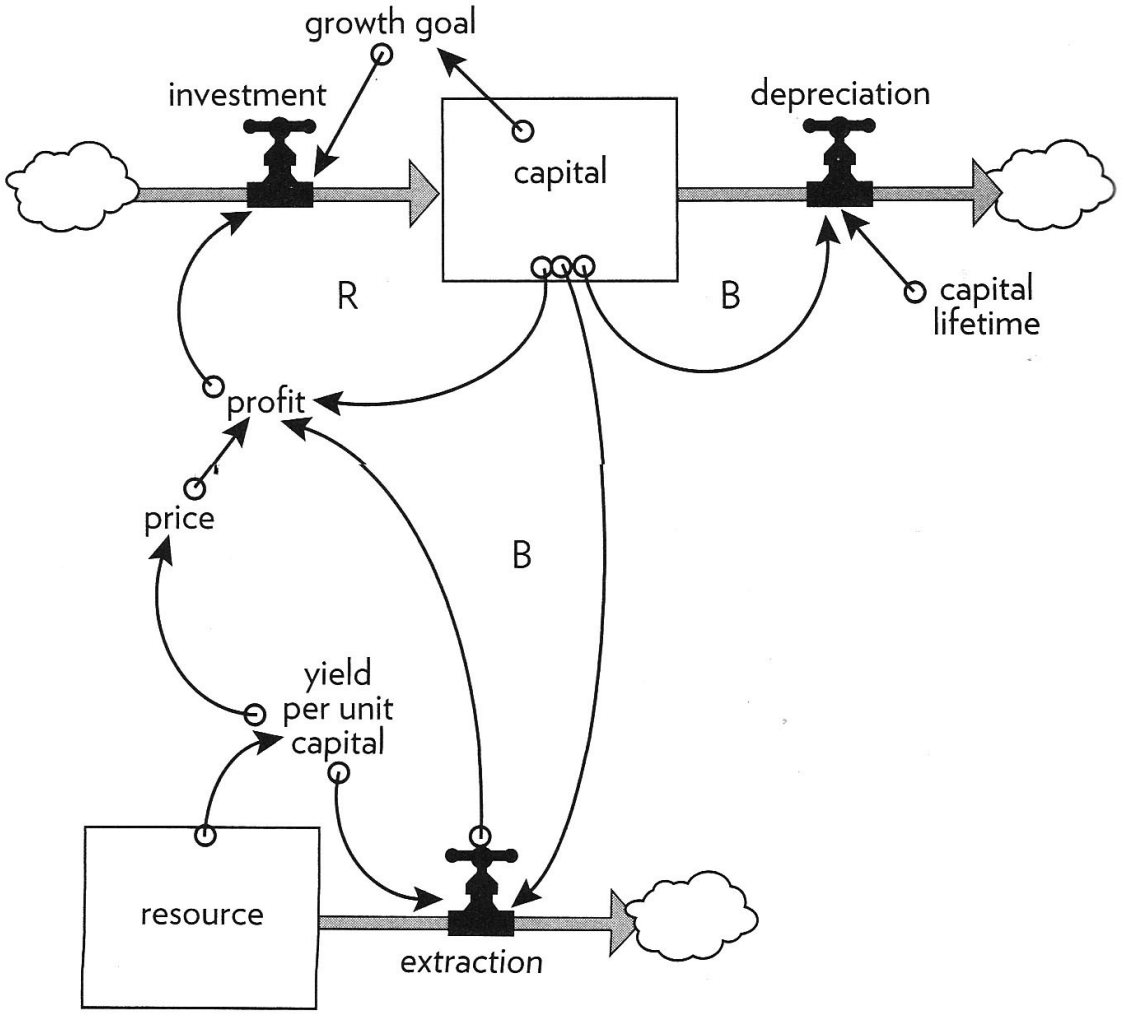
System Dynamics

Meadows (and Meadows), Forrester, Senge, et al.

- the structure of the system determines its behavior (focus on endogenous rather than exogenous variables)
- inclusion of feedback loops generates behavior more complex than simple cause-and-effect
- exact or specific predictions are less important than overall dynamics and trends
- examples: Limits to Growth, Industrial Dynamics, World Dynamics, Urban Dynamics, “the Beer Game”

System Dynamics

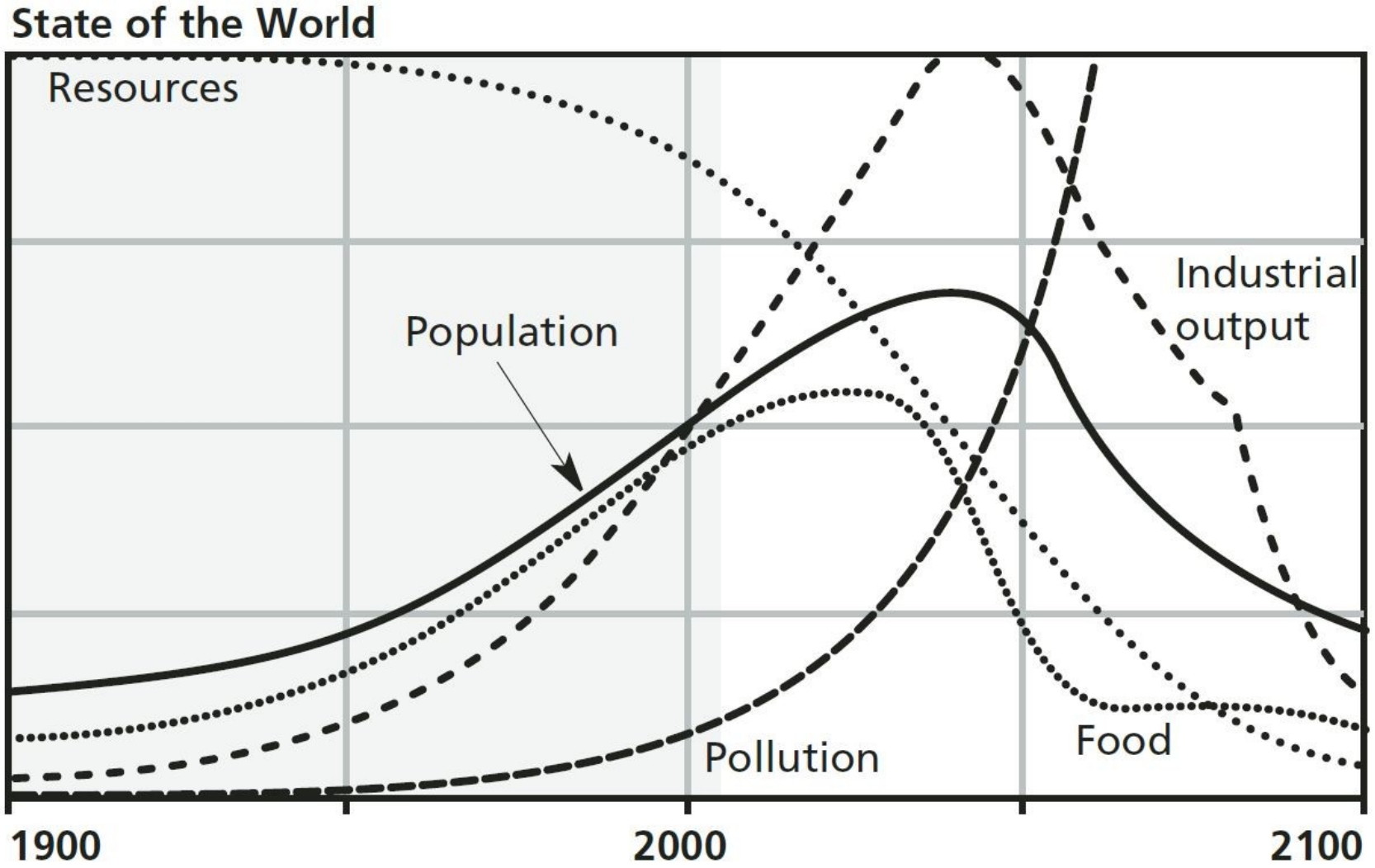
Meadows (and Meadows), Forrester, Senge, et al.



Meadows (2008)

System Dynamics

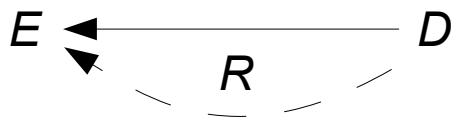
Meadows (and Meadows), Forrester, Senge, et al.



Meadows, Ranger, and Meadows (2004)

Regulation

The Law of Requisite Variety – Ashby (1963)



$$H(E) \geq H(D) + H_d(R) - H(R)$$

$H_d(R) = 0$ when R is a determinate function of D

$$H(E) \geq H(D) - H(R)$$

the variety in the essential variables
will be greater than or equal to
the variety in the disturbances
minus
the variety in the regulators

Regulation

The “Good” Regulator – Conant and Ashby (1970)

“Every good regulator of a system must be a model of that system.”

$H_d(R) \rightarrow 0$ as R gets better (more determinate)

for $H_d(R) = 0$ we need a perfect model

Our “image” of a system is our model of that system.

Society's image of a system is a collection of the individual images of its members. (Boulding, 1964).

Regulation

The Law of Requisite Variety – Ashby (1963)

sustainability example

E = {*people live well*, *nature is not run down*}

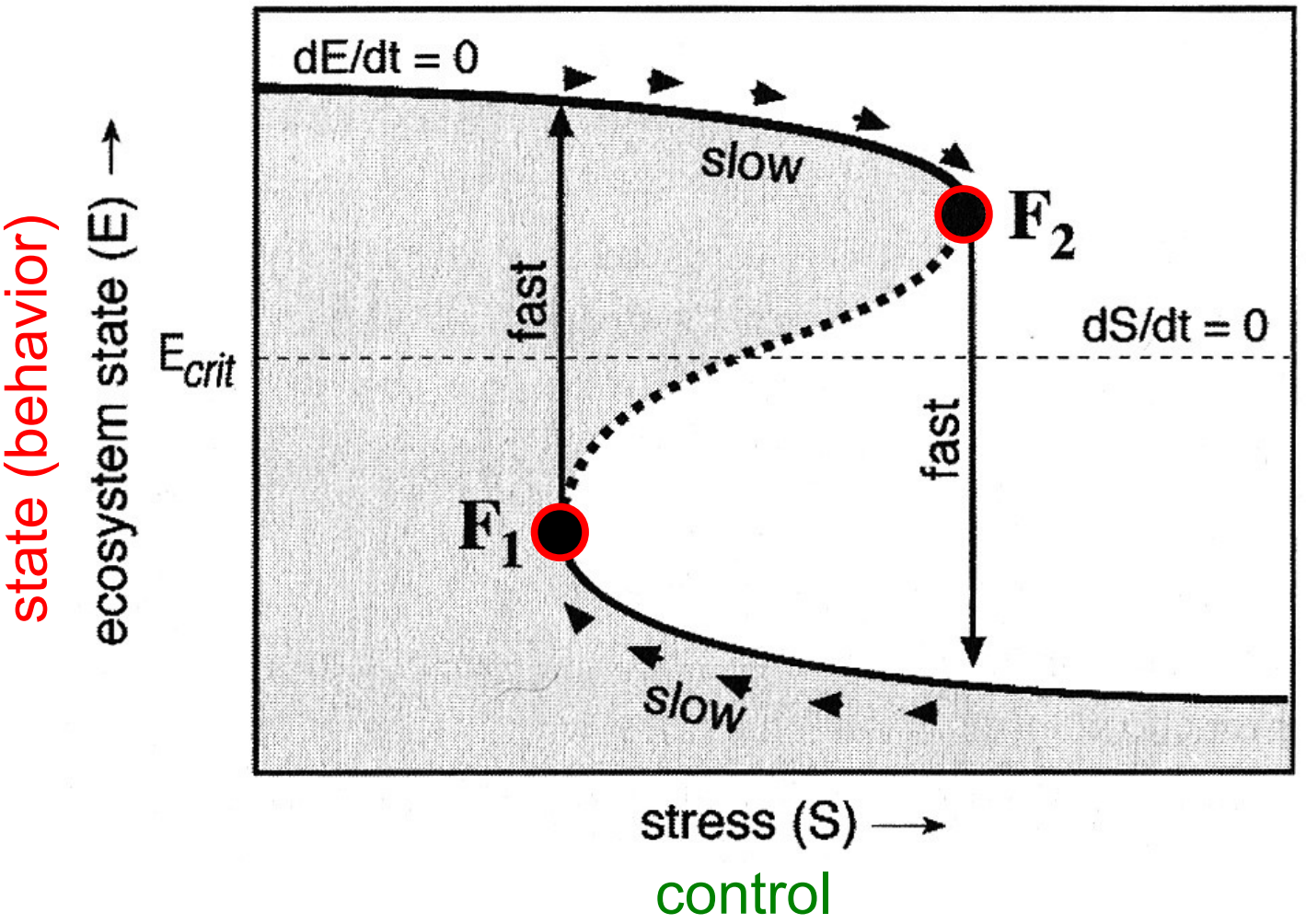
$$H(E) \geq H(D) - H(R)$$

<u>options</u>

1) *do nothing* – essential variables are controlled by disturbances
2) *lower standards* – allow more variety in *E*
3) *increase regulation* – new laws, renewable resources
4) *discover disturbance patterns* – learning structure (constraints) of disturbances reduces variety in *D* and *can* lead to the creation of better models

the cusp catastrophe

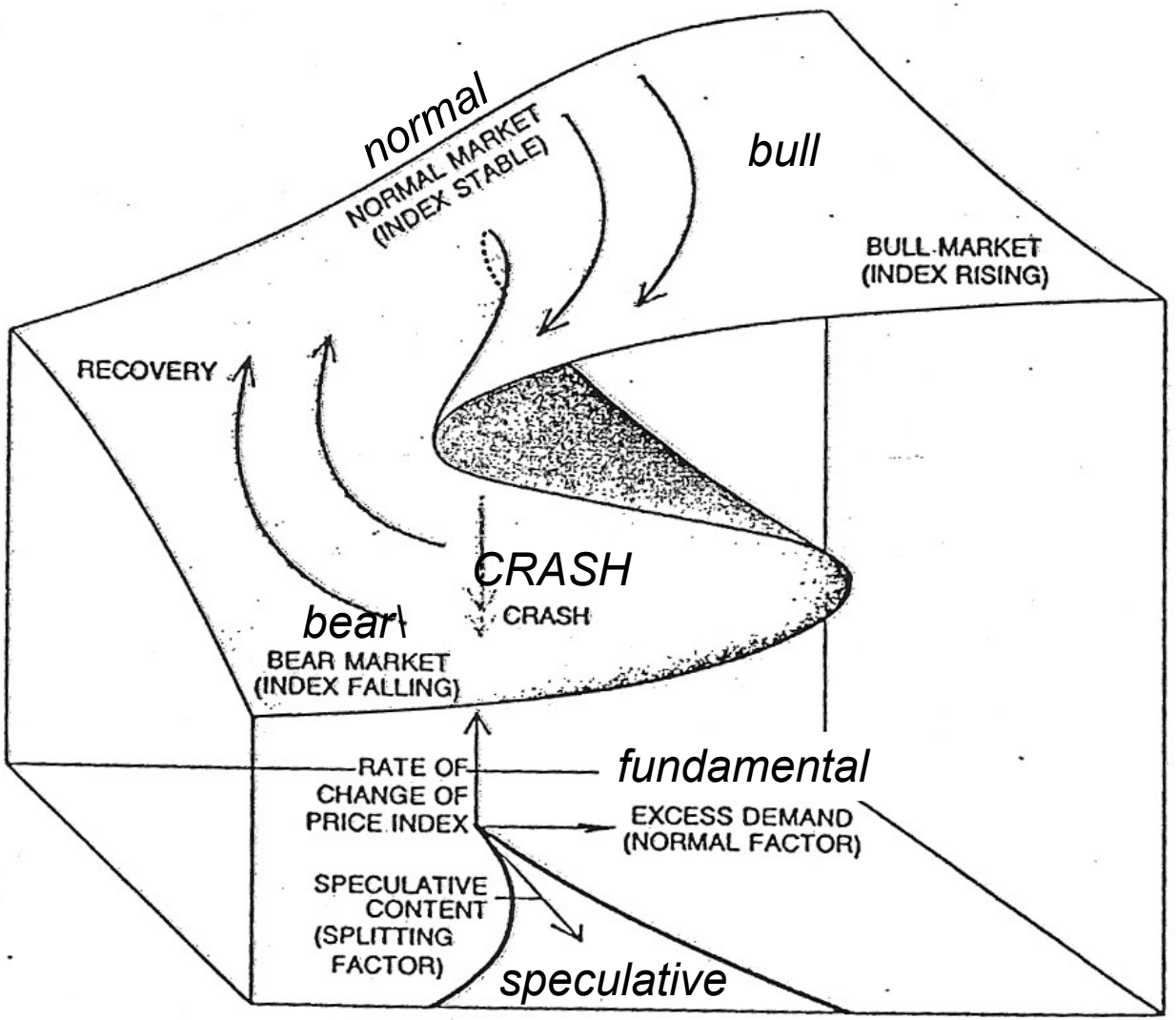
2-D cross-section of cusp catastrophe



Gunderson and Holling (2002)

the cusp catastrophe

example: stock market



Zeeman (1976)

the panarchy adaptive cycle

Panarchy – Gunderson and Holling (2002)

Purpose: a theory to guide sustainability efforts

- Humans have increased the amount and intensity of stress on the environment.
- Attempts to control nature lead to unintended consequences, including slow erosion and/or fast collapse of environments.
- Sustainability efforts are often too rigid and myopic and do not transcend disciplines.

The world is ***complex*** and ***dynamic***, so we must ***conserve*** the ability to ***adapt***.

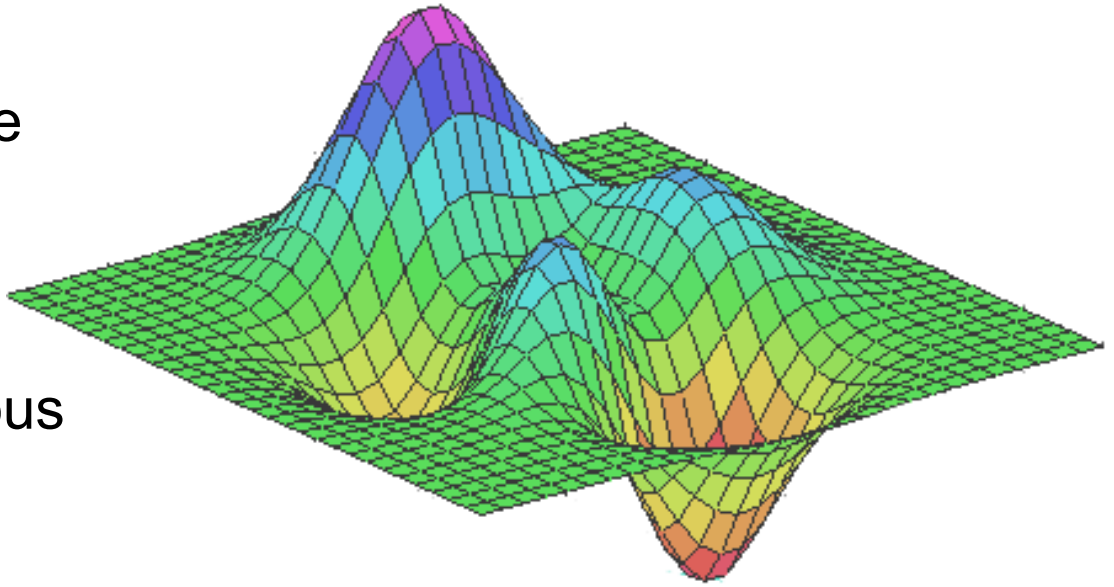
the panarchy adaptive cycle

general theory (model) for living systems

Nature is *evolving*...

- innovation and emergence
- stasis ↔ change
- simple ↔ complex
- continuous ↔ discontinuous

* multiple shifting attractors



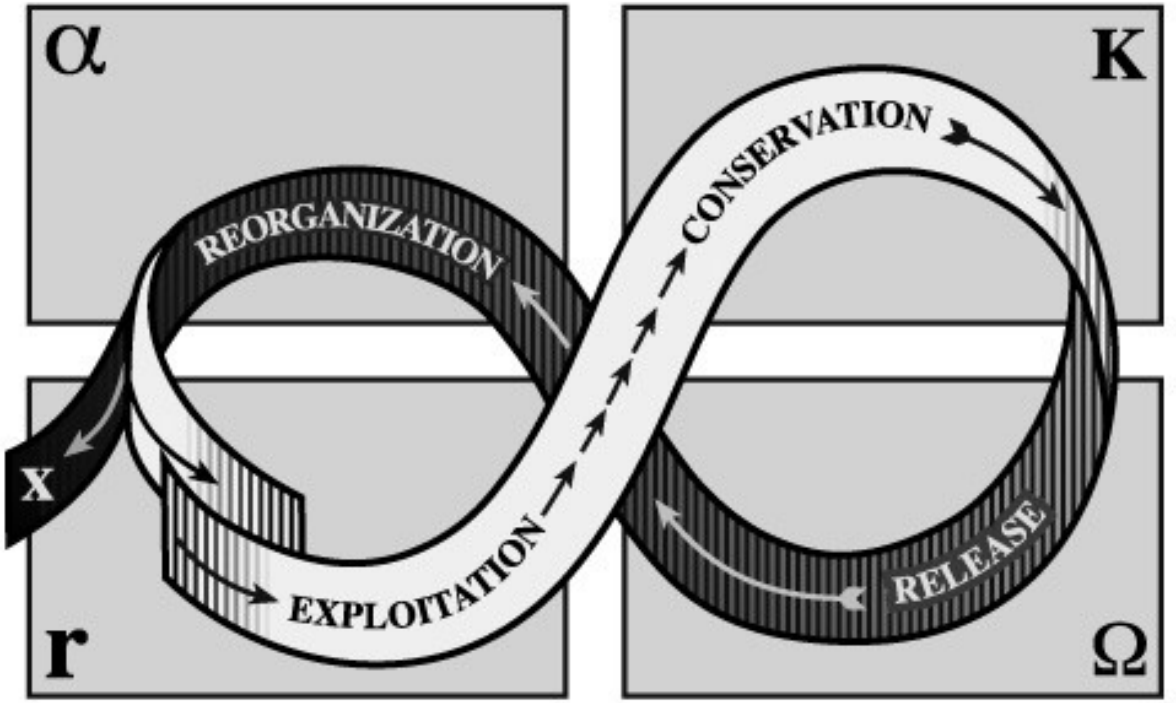
What we know:

- Novelty emerges by interaction between scales and is either embraced or suppressed.
- Adaptation is needed to deal with unpredictability.

→ ***Humans must continually adapt.***

the panarchy adaptive cycle

exploitation (r) → conservation (K) →
release (Ω) → reorganization (α) →



Gunderson and Holling (2002)

the panarchy adaptive cycle

exploitation (r) → conservation (K) →
release (Ω) → reorganization (α) →

r → **K**	survival of the fastest / scramble (**r** adapts) self-organization, relations develop increasing connectedness, environment stabilizes, and diversity peaks (**K** controls)
K → Ω	system is rigid, disturbance causes crash
Ω → α	explosive increase in uncertainty and chaos connections are broken / weak interactions
α → **r**	novelty and experimentation many experiments fail, potential leaves system

the panarchy adaptive cycle

front loop and back loop

FRONT (r + K)

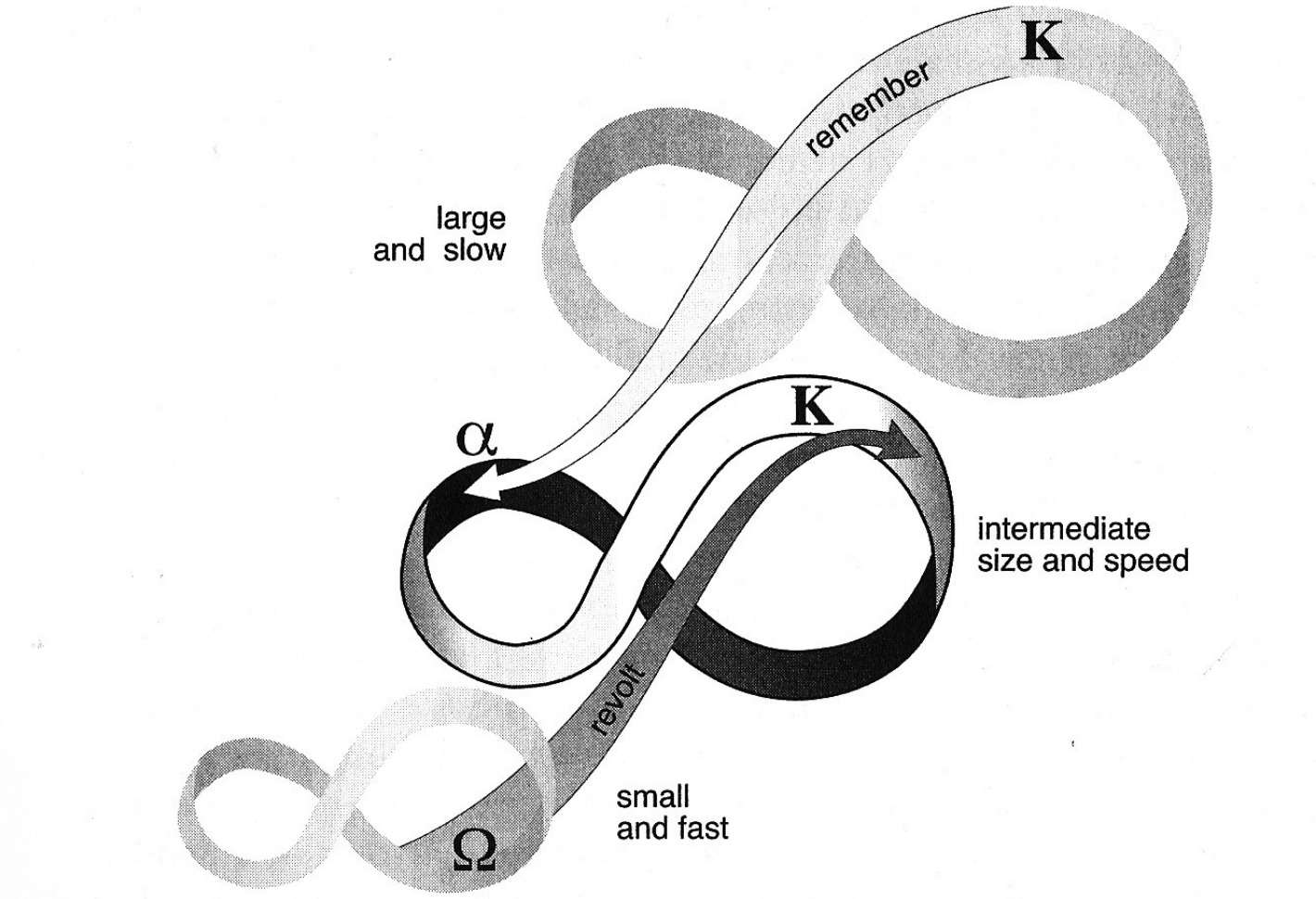
- production
- accumulation
- slow
- predictable
- stable

BACK (Ω + α)

- invention
- reorganization
- fast
- unpredictable
- unstable

the panarchy adaptive cycle

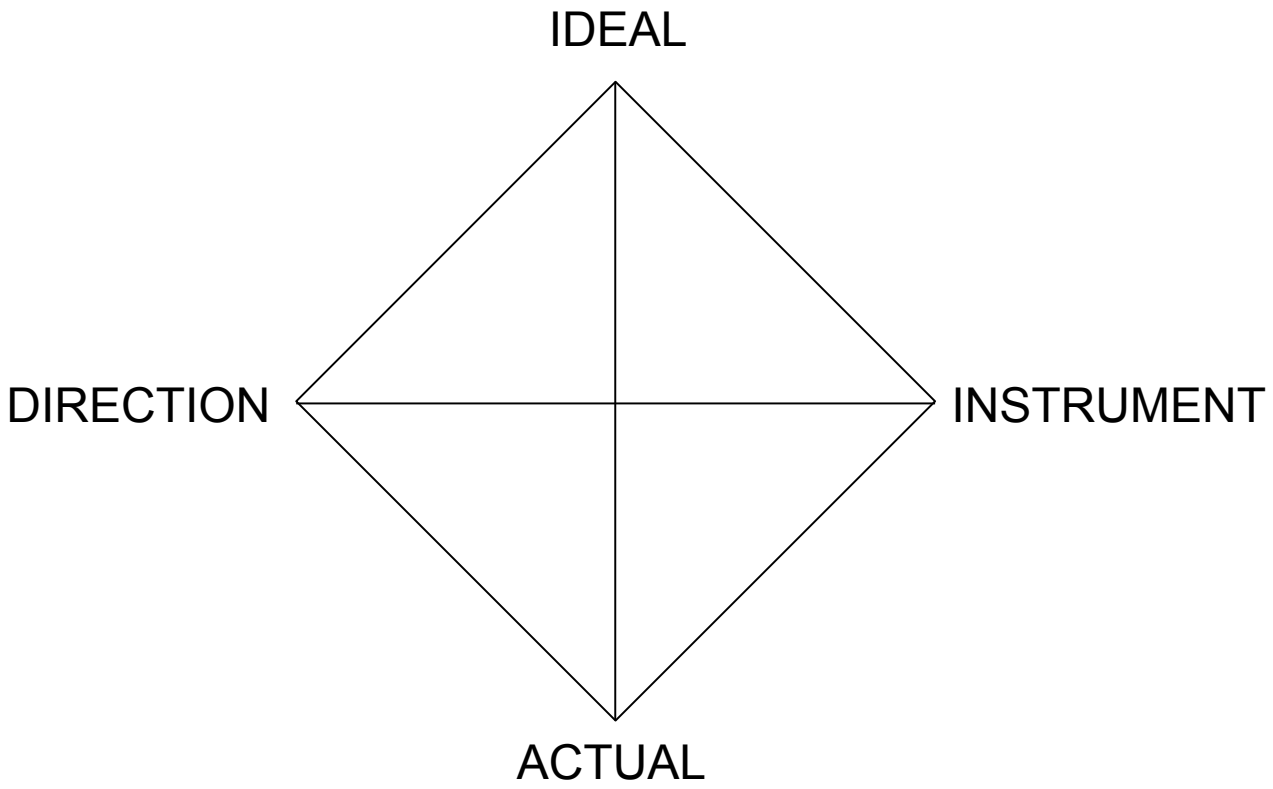
“revolt and remember”



Gunderson and Holling (2002)

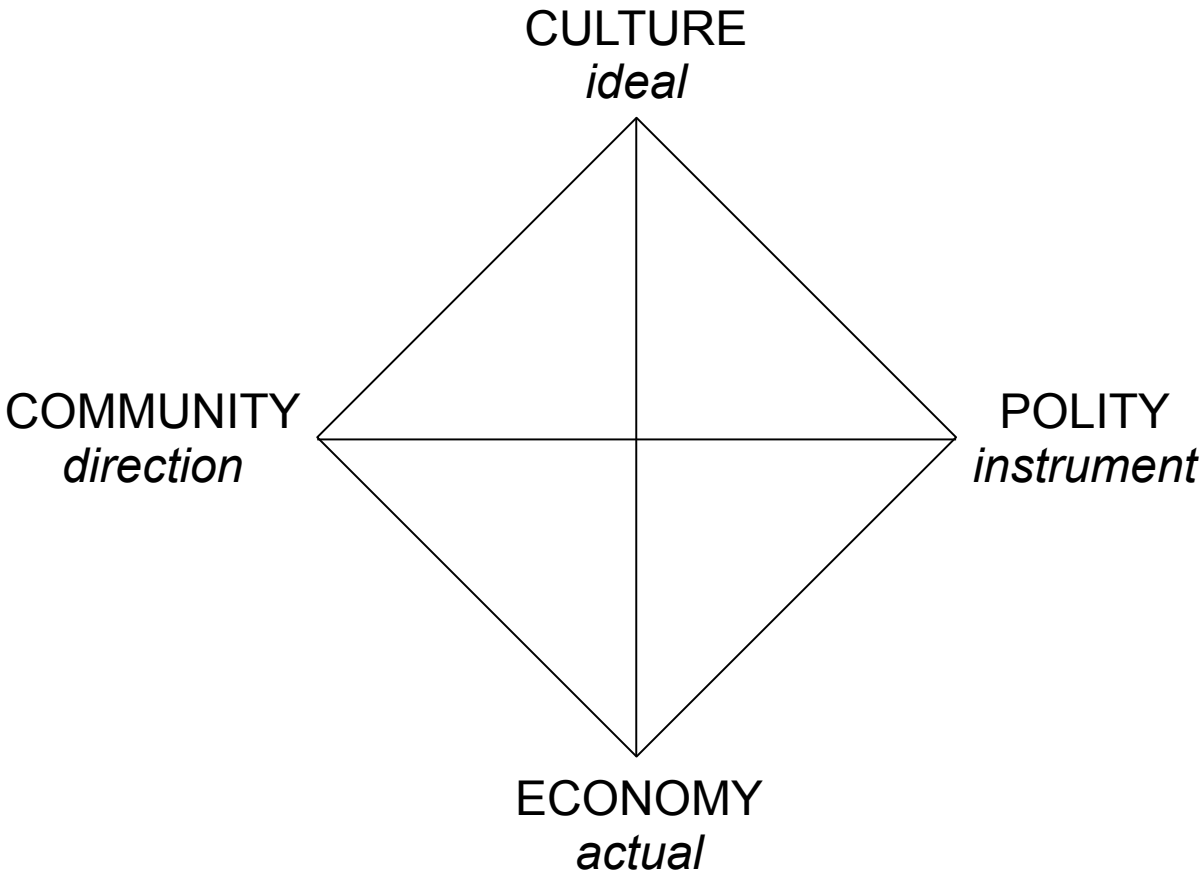
The Tetrad of Purposeful Action

"What is happening here and why?"



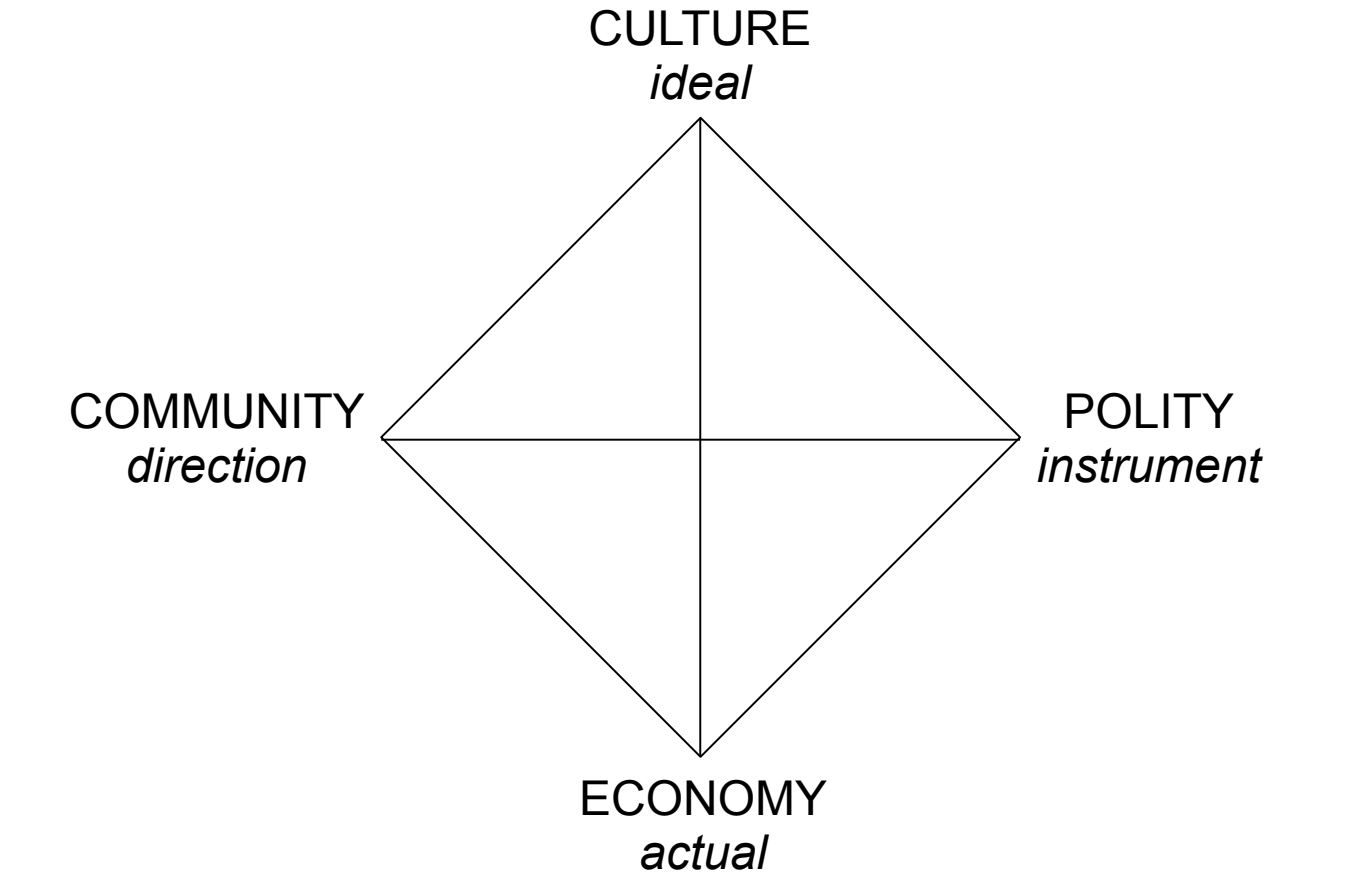
J.G. Bennett (1966)

The Societal System

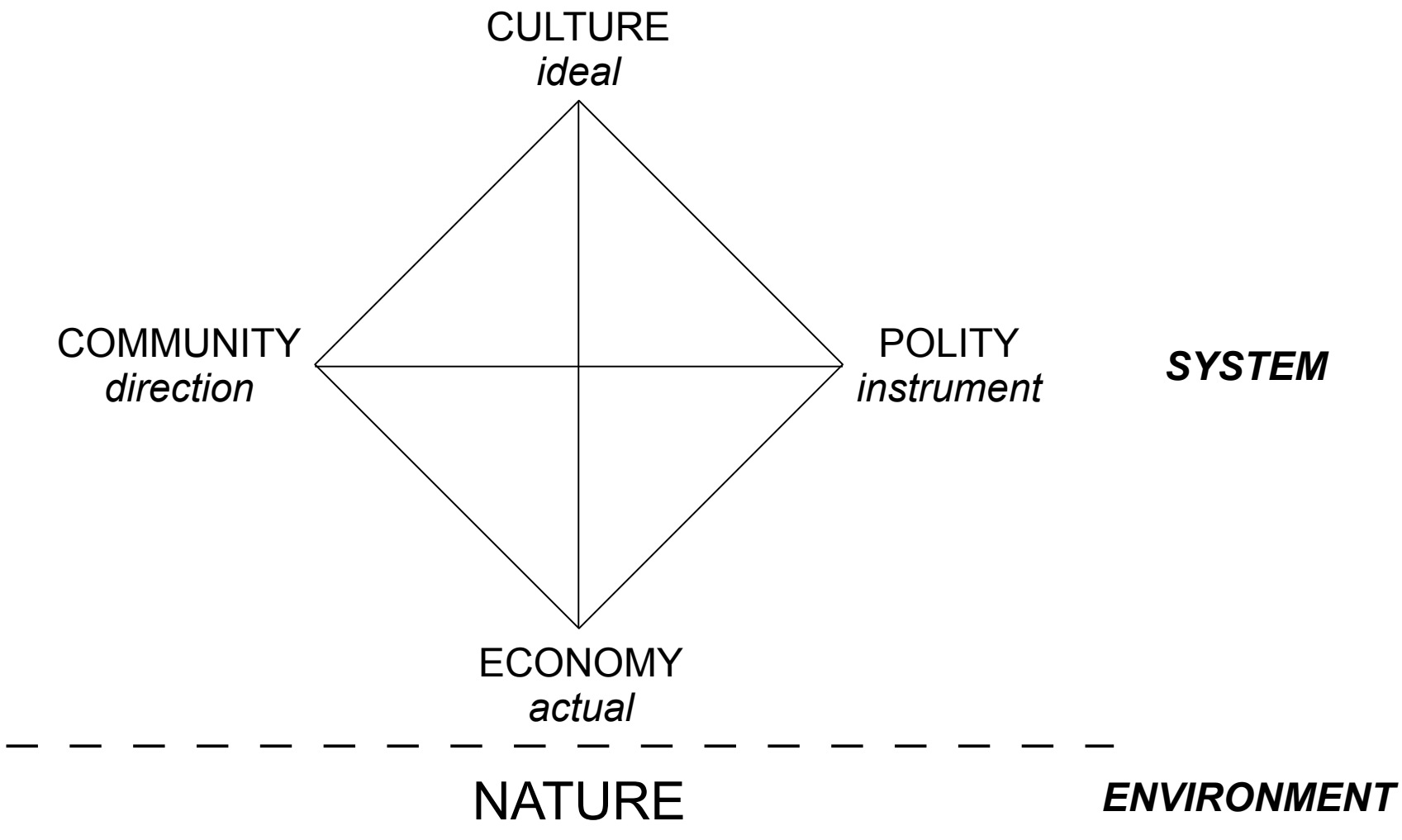


Talcot Parsons (1971), Martin Zwick (2008)

The Societal System

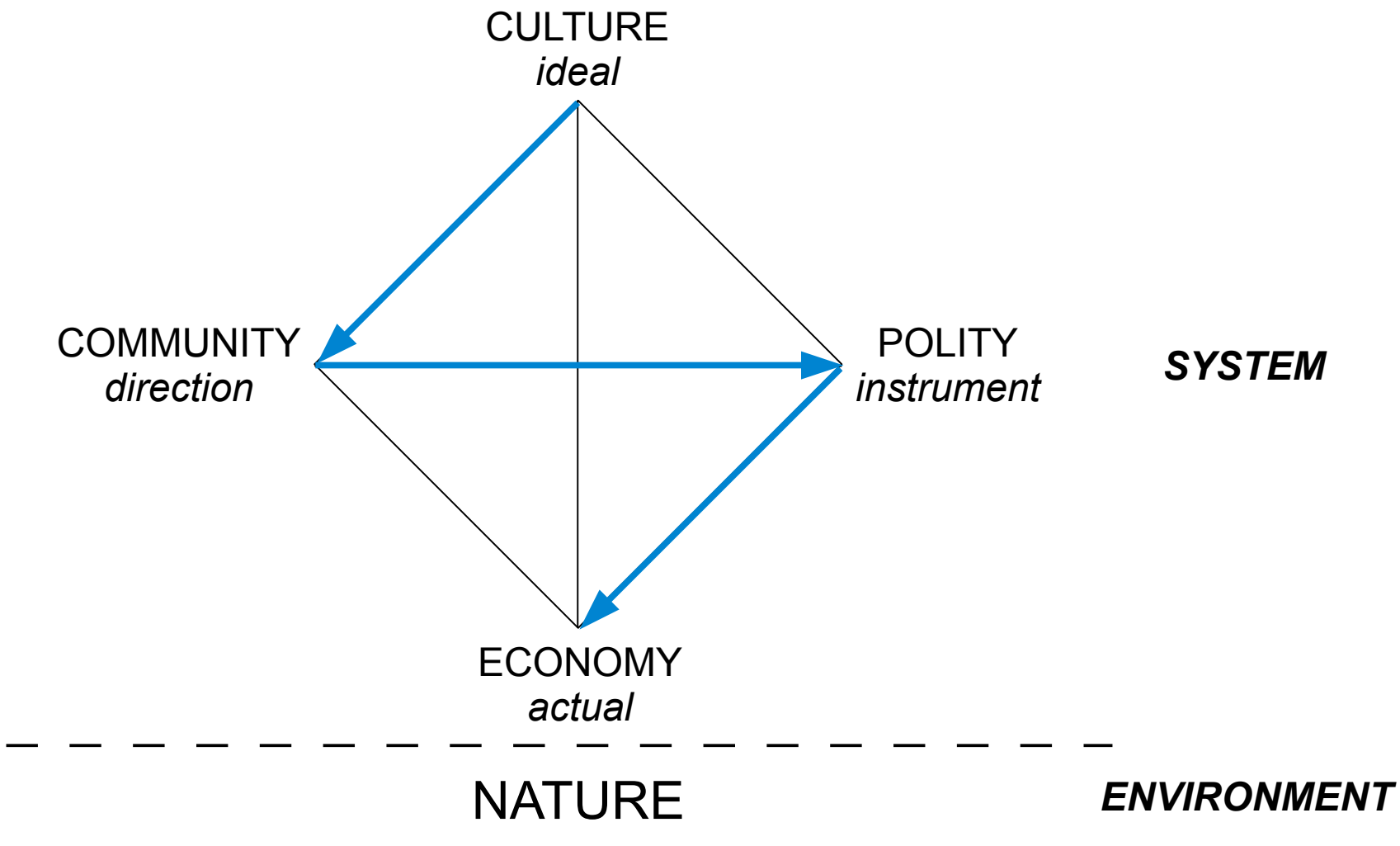


The Societal System



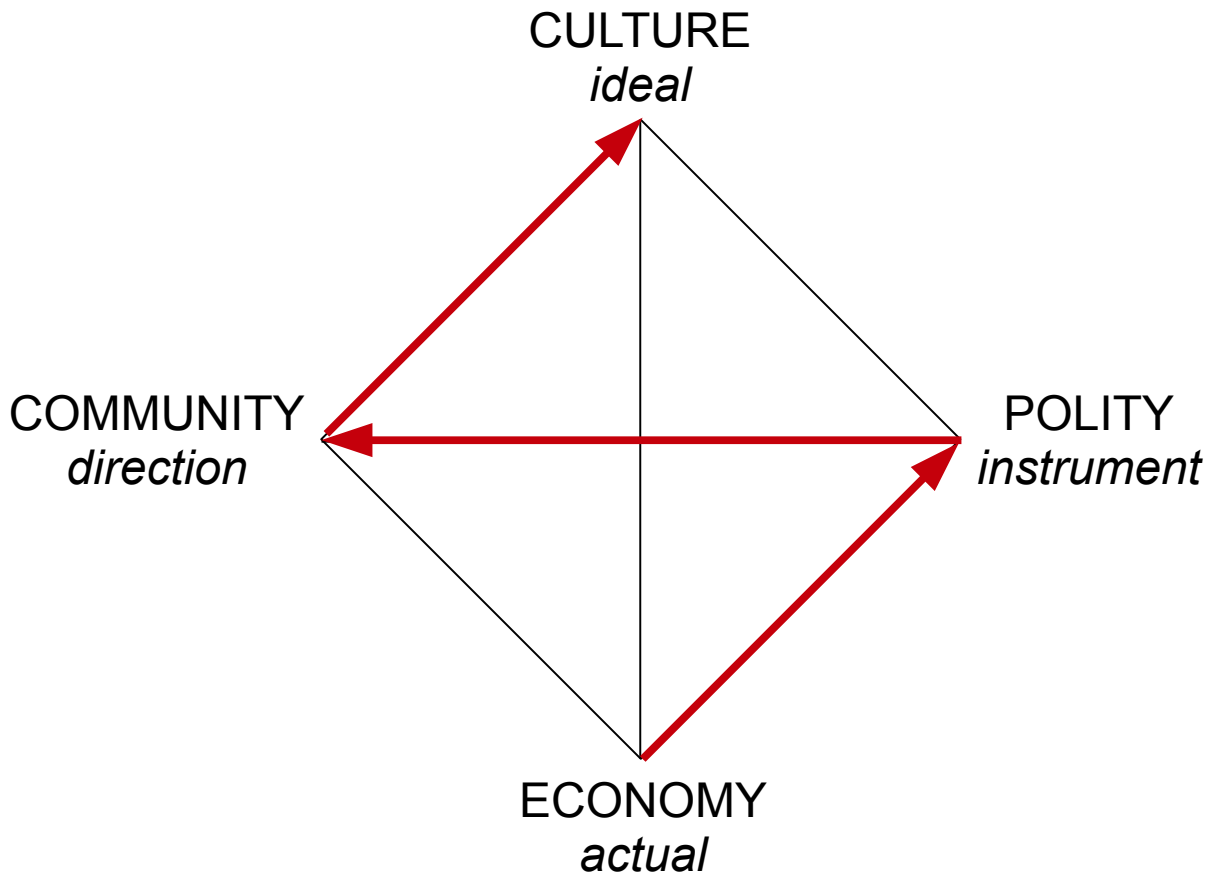
The Societal System

How it should work



The Societal System

How it seems to work (*at least sometimes*)



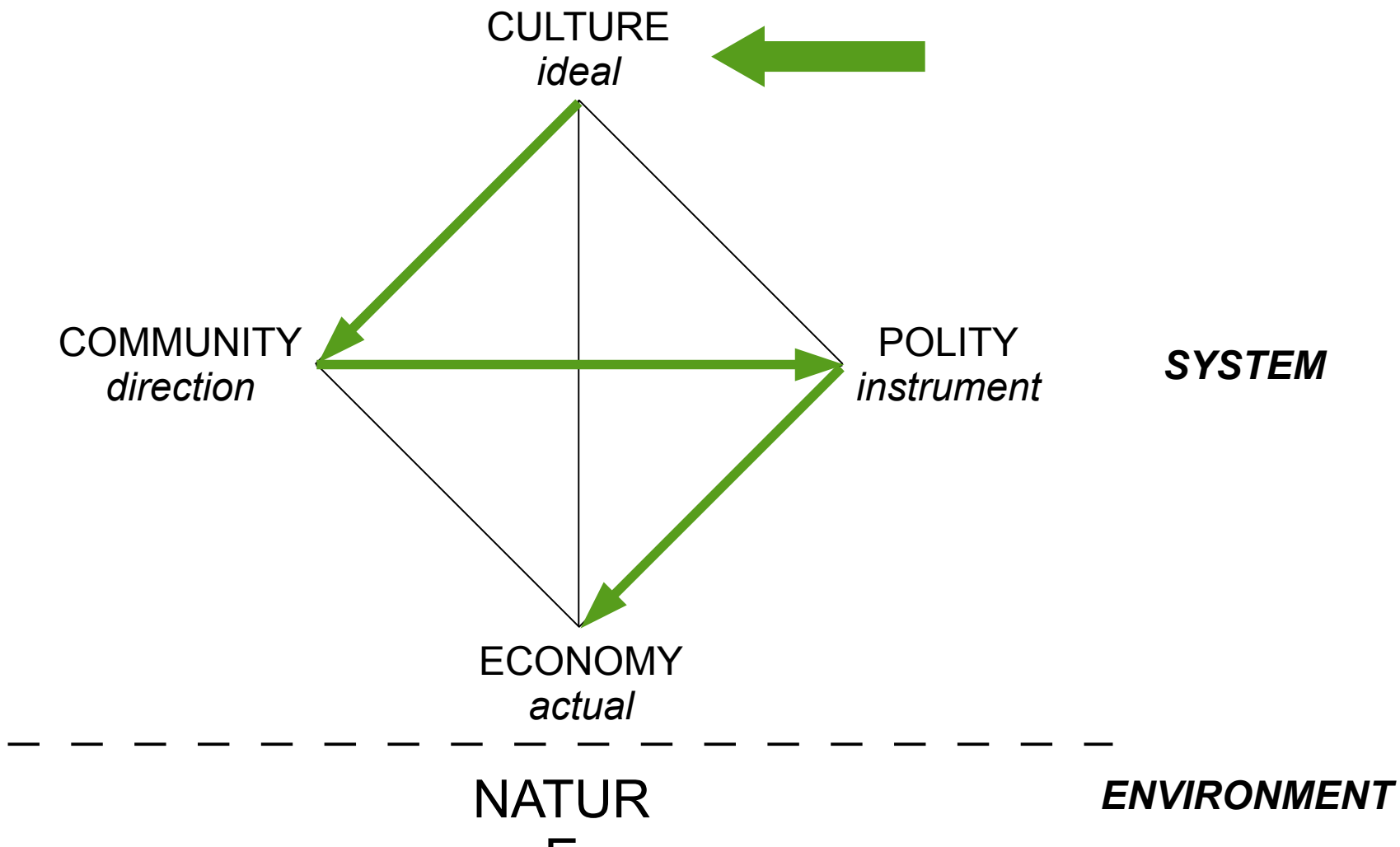
SYSTEM

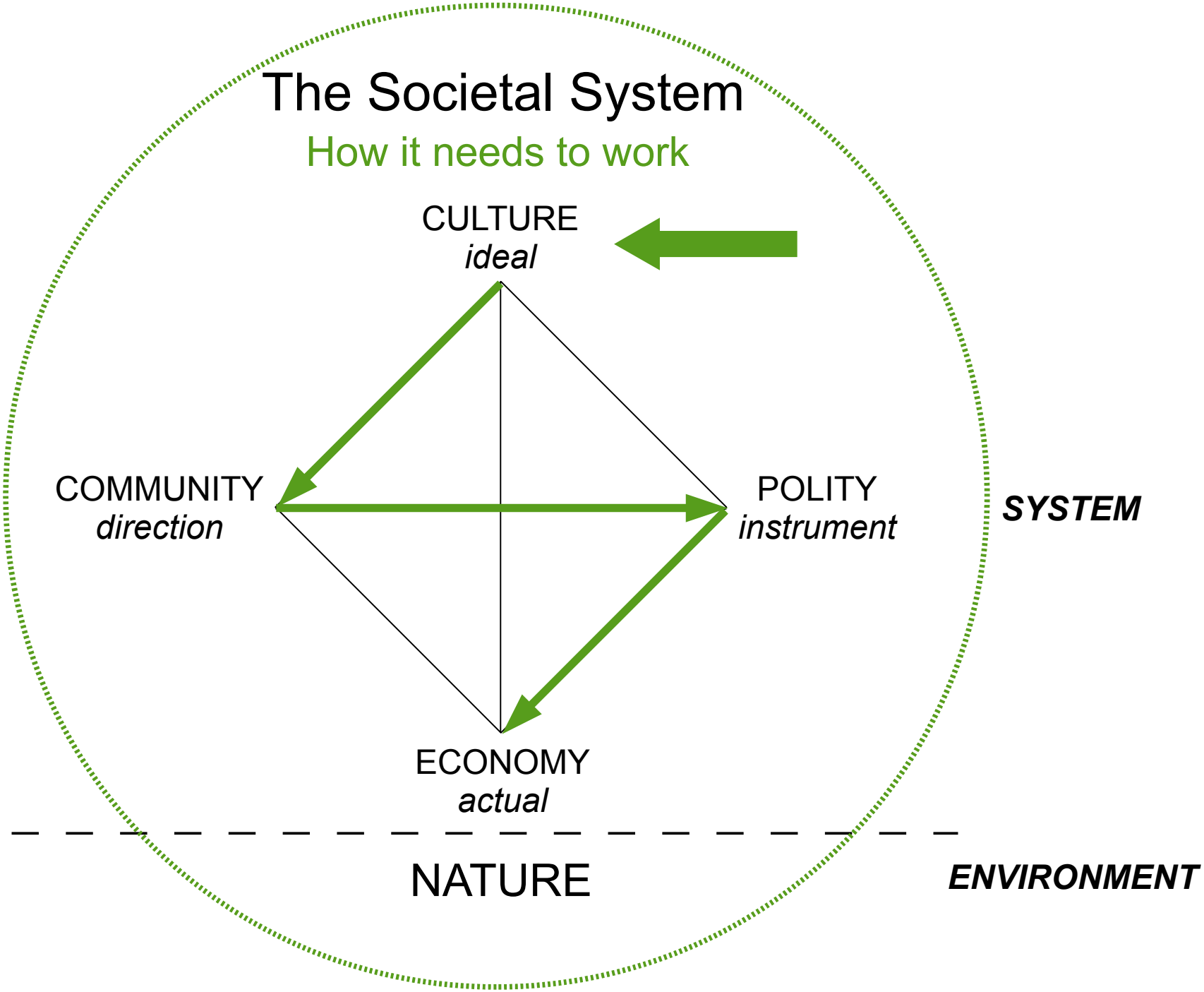
NATURE

ENVIRONMENT

The Societal System

How it needs to work




The Societal System
How it needs to work
CULTURE
ideal
COMMUNITY
direction
POLITY
instrument
ECONOMY
actual
SYSTEM
NATURE
ENVIRONMENT

Paul Krugman (1998, 2008)

- “As geologist Nathan Winslow puts it in a gently skeptical review on self-organized criticality, 'A theory can, once in the pop science regime, acquire a level of acceptance and momentum that may or may not be warranted by its actual scientific credibility.' And the track record of pop science enthusiasms is uniformly dismal. Does anyone remember cybernetics or catastrophe theory?” [1]

- “Occasionally, I have a nightmarish vision in which the Santa Fe Institute, that temple of 'complexity theory' (whose heavy hitters include Bak, biologist Stuart Kauffman and, yes, economist Brian Arthur) actually starts having direct input into major policy decisions. Now that would be scary.” [1]

- “As a result, the study [*World Dynamics*] was a classic case of garbage-in-garbage-out: Forrester didn’t know anything about the empirical evidence on economic growth or the history of past modeling efforts, and it showed. The insistence of his acolytes that the work must be scientific, because it came out of a computer, only made things worse.” [2]

[1] “Algorithms: Probing the vice president's thought processes,” *Slate*, Friday, Feb. 13, 1998.

[2] “Limits to growth and related stuff,” *The New York Times*, April 22, 2008.

Conclusions (I)

- people do not behave the way traditional economics predicts they will – people have *bounded rationality, satisfice* rather than optimize, and are loss averse
- people *cooperate* under certain conditions (and do not under others)
- markets are useful, but *markets are embedded* within society and ecosystems
- we cannot live indefinitely off of our stocks: we must learn to *live off flows*
- ecosystems—and therefore economics—are inherently *unpredictable*, so we must *conserve* the ability to *adapt*
- the key to sustainable development is *culture*

Conclusions (II)

- systems theories, methods, and ideas can make important contributions to economics, especially with regard to sustainable development
- more work (experiments, analyses, etc.) is needed to validate systems models of economic activity
- validation is needed if systems ideas are to be adopted for policy decisions
- “Unless our images conform to the real world which surrounds us and of which we are a part, we are doomed to eventual destruction in the fires of illusion.” (Boulding, 1981)