Biophysical Limits to Growth

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Questions?

- How does positive feedback induce system change?
- How does negative feedback restrain further system change
  - Give an example of positive and negative feedback

- Explain hierarchy and how it plays a role in establishing a system boundary

- Which solidarity type (individualist, egalitarian, hierarchist, fatalist) was most likely to use the precautionary principle? Which type believes environment is most resilient?

We witness unsustainable human-ecosystem interactions

- How could people make such serious mistakes in the past and why does society continue to repeat such mistakes today?

- Is it inevitable that the environment must be degraded to satisfy human needs?

Drivers of Unsustainability

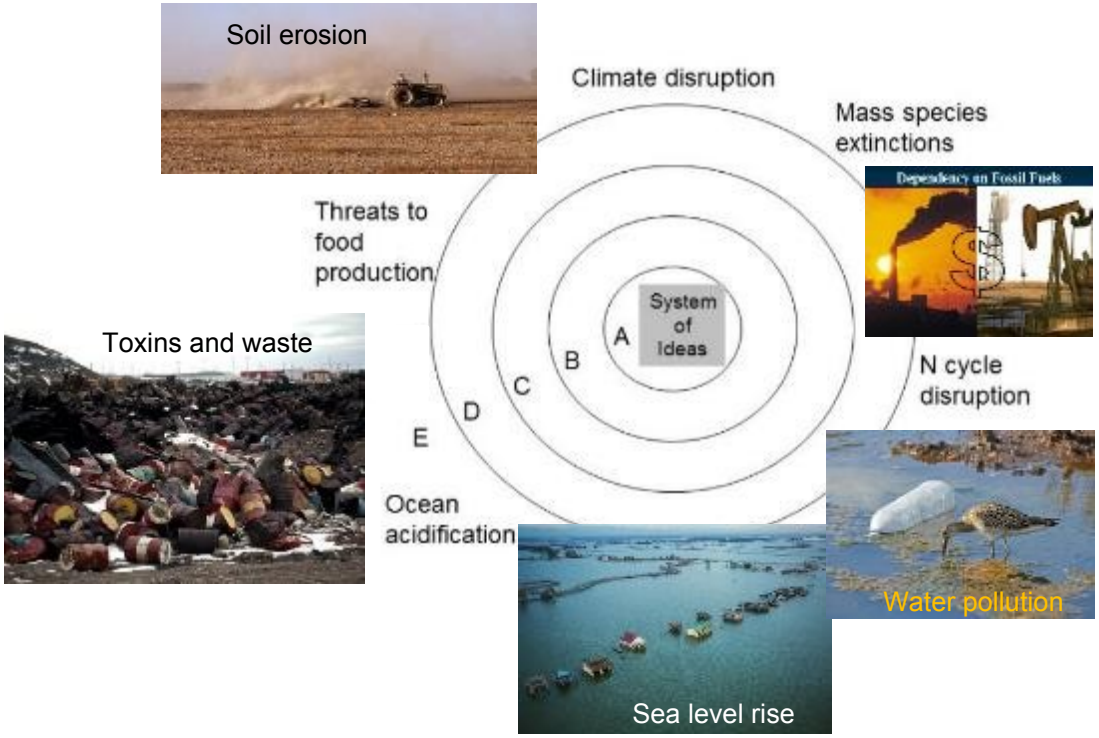
- HUMAN POPULATION INCREASE
  - Agriculture
  - Shelter
  - Mobility
  - Stuff

Use Energy and Material Resources causes
- Land use change
- Habitat loss
- Deforestation
- Alter biogeochemical cycles

Leads to

Climate Change
Eutrophication
Acid precipitation
Ozone Depletion
Smog
…

Environmental (and Social) problems are symptoms of deeper failures

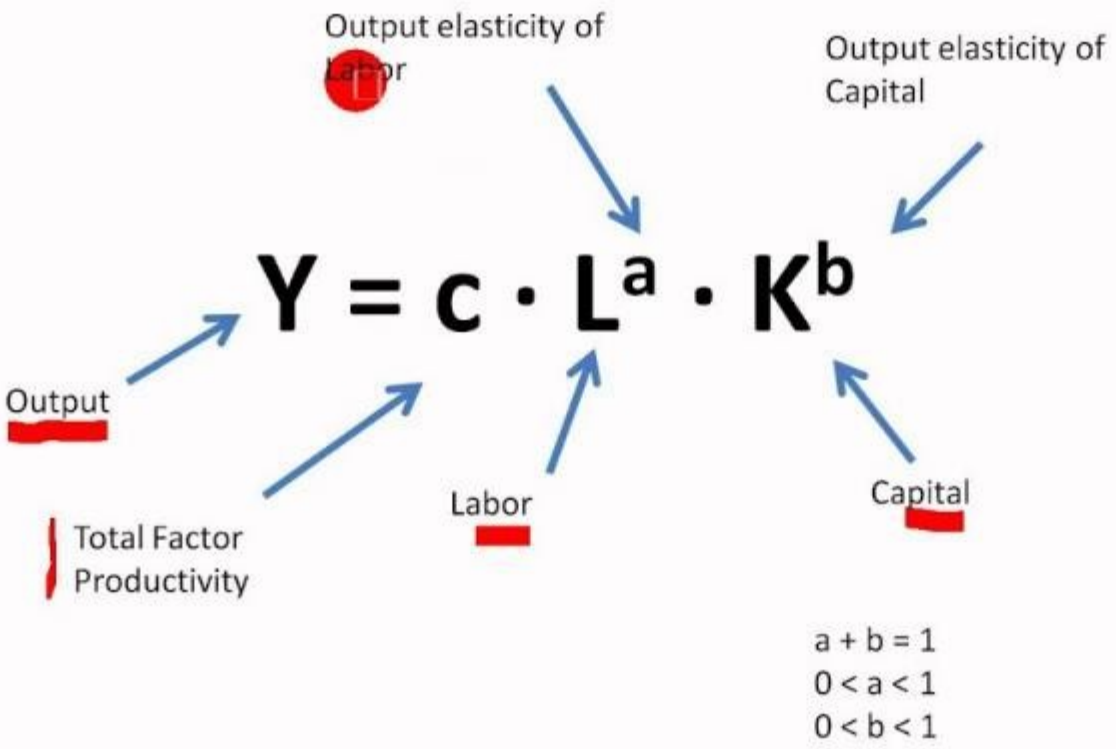


Economics

- Economics is one the main organizing forces in society
- Many decisions are made based on cost-benefit analysis but true costs (direct + indirect) to individual, society, or environment are often not known

Economic Growth Models

Cobb-Douglas Production Function



WHERE IS ENVIRONMENT?

The New York Times

TheUpshot

ECONOMIC TRENDS

We're in a Low-Growth World. How Did We Get Here?

Neil Irwin @Neil_Irwin AUG. 6, 2016

One central fact about the global econo… …e year's remarkable headlines: Eco… …ed nations has been weaker for lon… …ifetime of most people on earth.

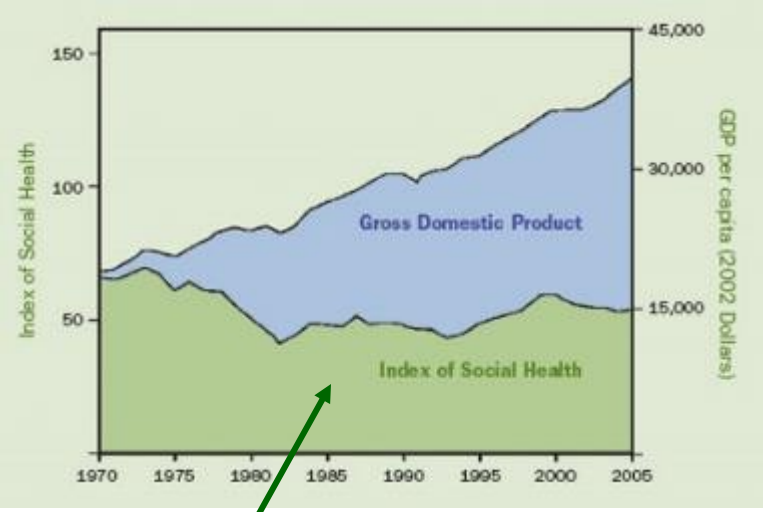
No mention of natural resources or environment

…t increasingly looks as if something fundamental is broken in the global growth machine — and that the usual menu of policies, like interest rate cuts and modest fiscal stimulus, aren't up to the task of fixing it (though some well-devised policies could help).

www.nytimes.com/2016/08/07/upshot/were-in-a-low-growth-world-how-did-we-get-here.html?hp&action=click&pgtype=Homepage&clickSource=story-heading&module=first-column-region&region=top-news&WT.nav=top-news&_r=0

What is the purpose of growth?

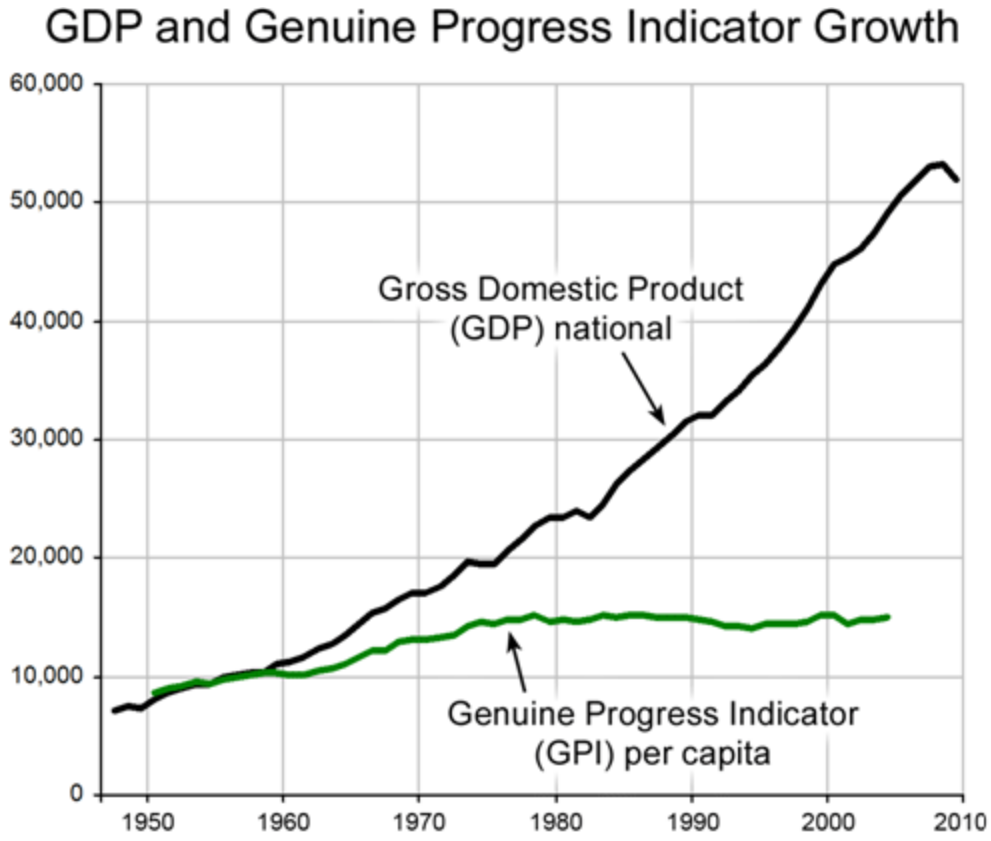
We know that bigger does not always mean better, nor more happiness



'STILL NOT HAPPY'

Alternative well-being indicators tell a different story

How we measure progress matters

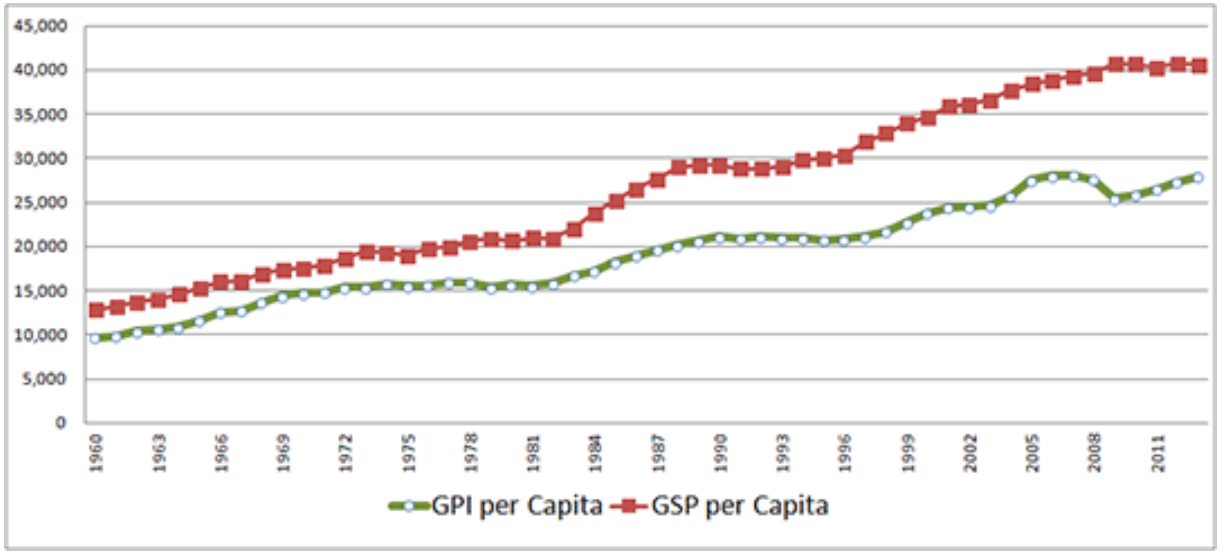


GPI accounts for 26 indicators including economic, environmental, and social factors to determine if we are well off.

GDP measures the circulation of money

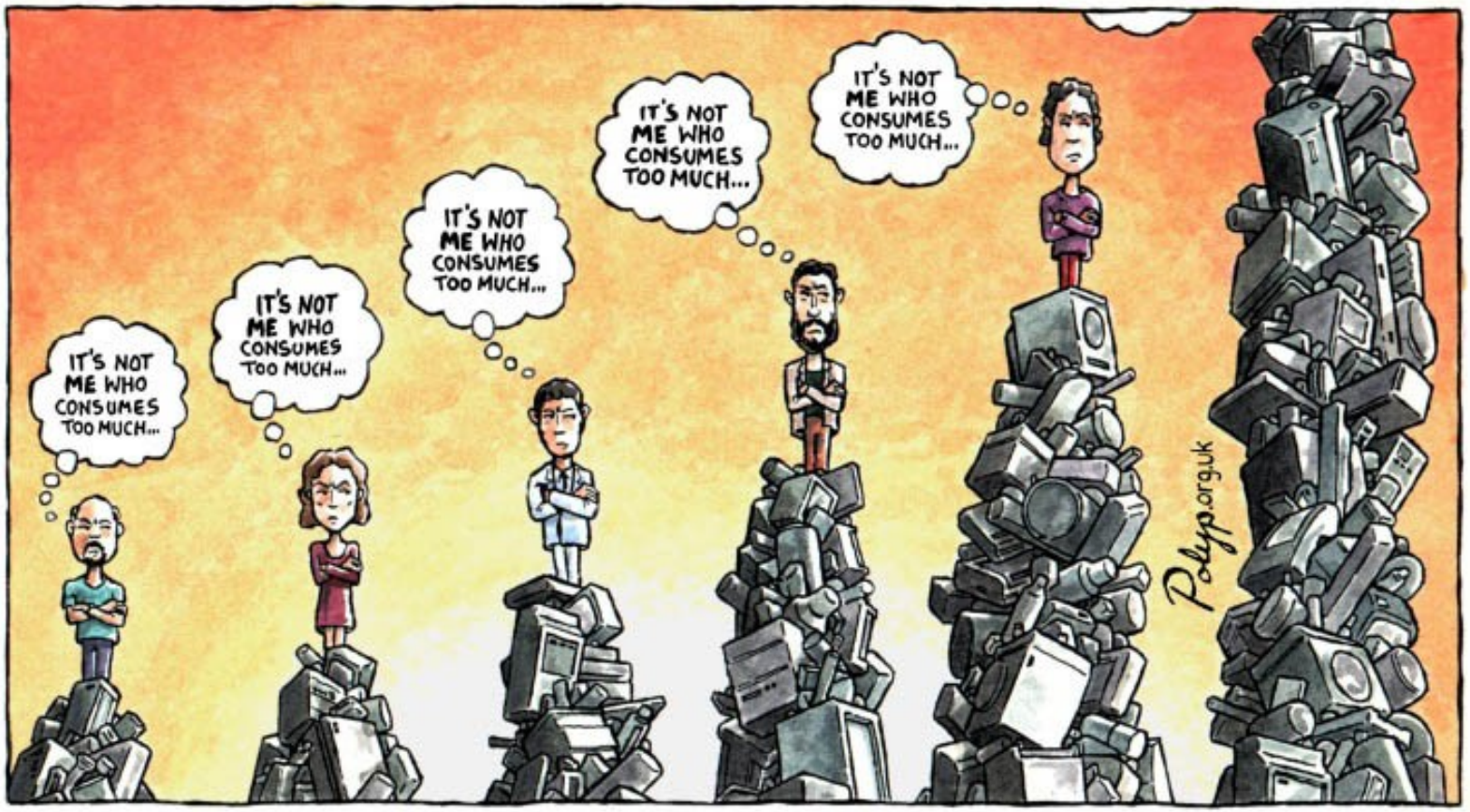
Maryland was first state to adopt GPI as official indicator

Maryland's Genuine Progress Indicator compared with Gross State Product



Memetic rivalries: Rene Girard

Our wants are socially constructed in competition (for status) with others. We measure in terms of others, not absolutes



'IT'S NOT ME'

Sustainable Development

- Sustainable Development: “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” – *Our Common Future*/ Brundtland Report, 1987

What are “our needs”?

The challenge is “To live undestructively in an economy that is overwhelmingly destructive…” p. 20

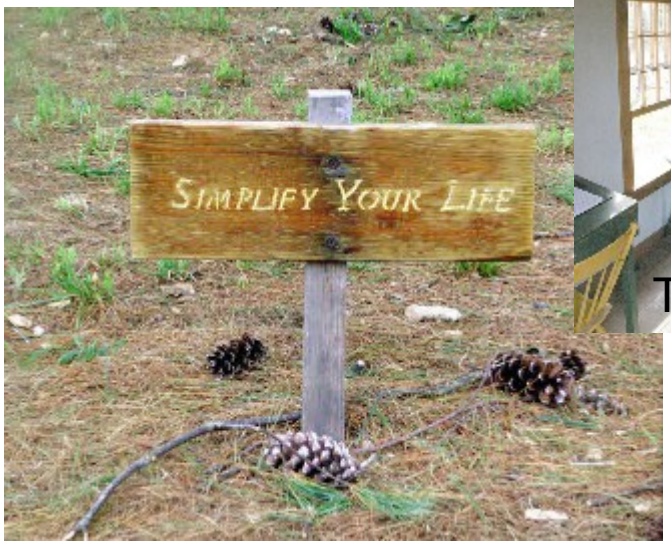
“The responsible consumer slips out of the consumer category altogether.” P. 27

Wendell Berry, The Unsettling of America 1977


We help the environment by consuming less
We help the environment by consuming lots of environmentally safe products

Early social customs actually blocked consumerism

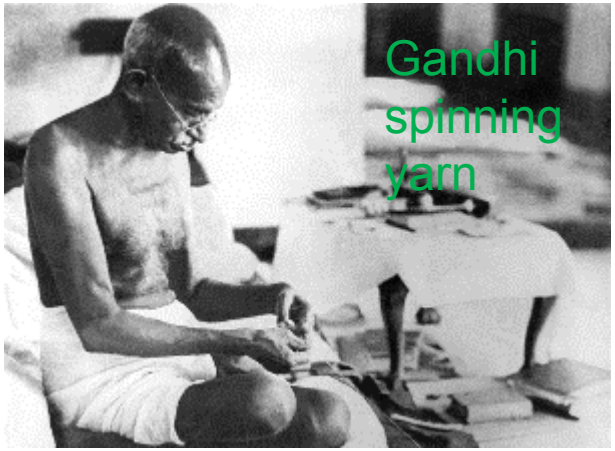
Religion
Fasting
(Lent, Ramadan)
Poverty
Simple living




Thoreau's bedroom

Limited credit
Preference for leisure time

How can we regain control over consumerism?


Gandhi spinning yarn

Measuring environmental impact

- I=PAT
- Impact = Population * Affluence * Technology

- Affluence ~ consumption per person
- Technology ~ impact per consumption

Ecological Footprint

- the impact of human activities measured in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated.

1) Transportation,
2) Diet,
3) Household/lifestyle choices

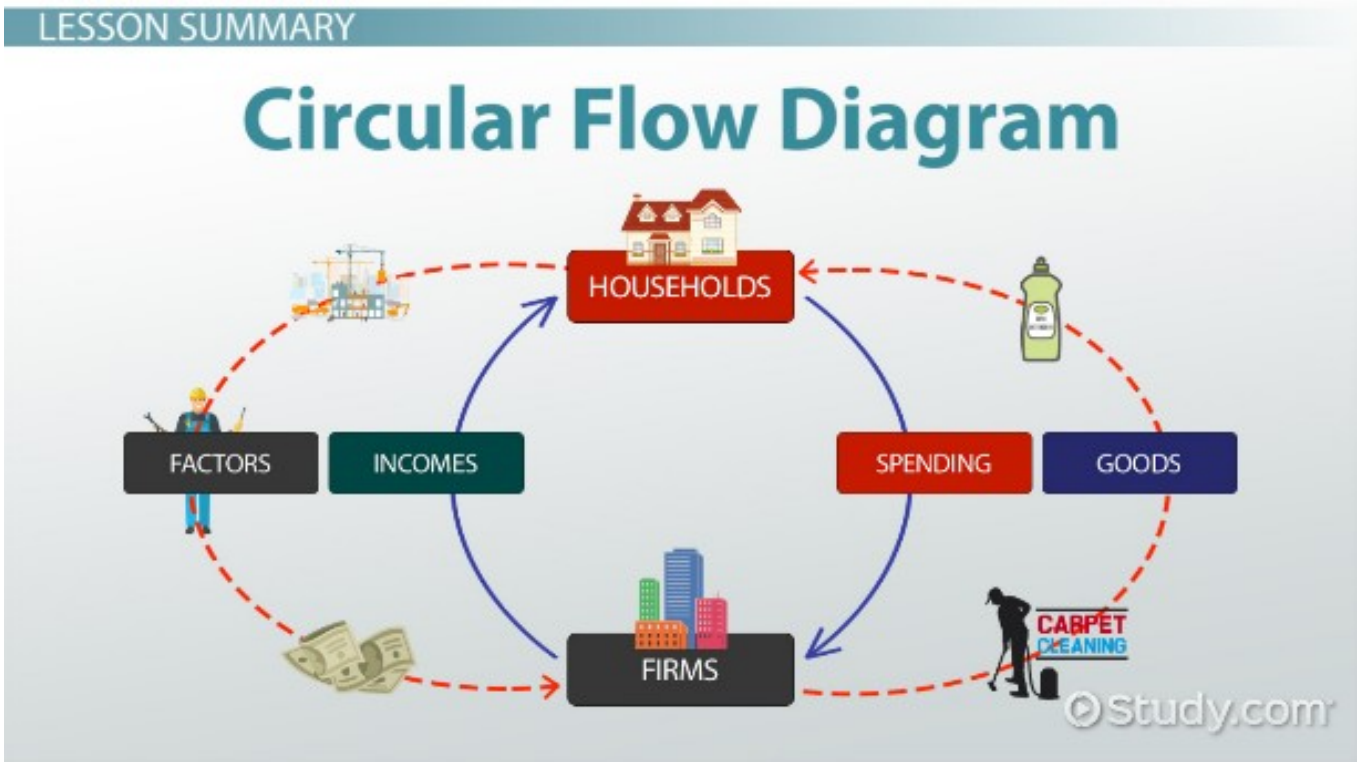
Ecological Footprint Calculator

- https://www.footprintcalculator.org/

world-average ecological footprint in 2012 was 2.84 global hectares per person. world-average biocapacity of 1.73 global hectares per person

Assumption error:

Economy as an isolated system



A better model:
Economy as an open system

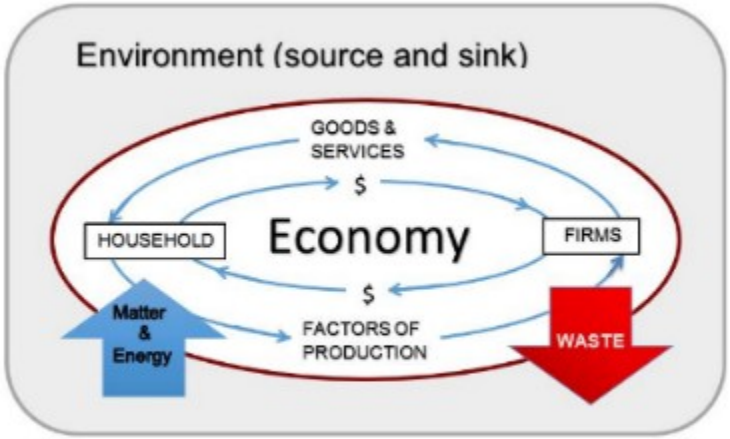
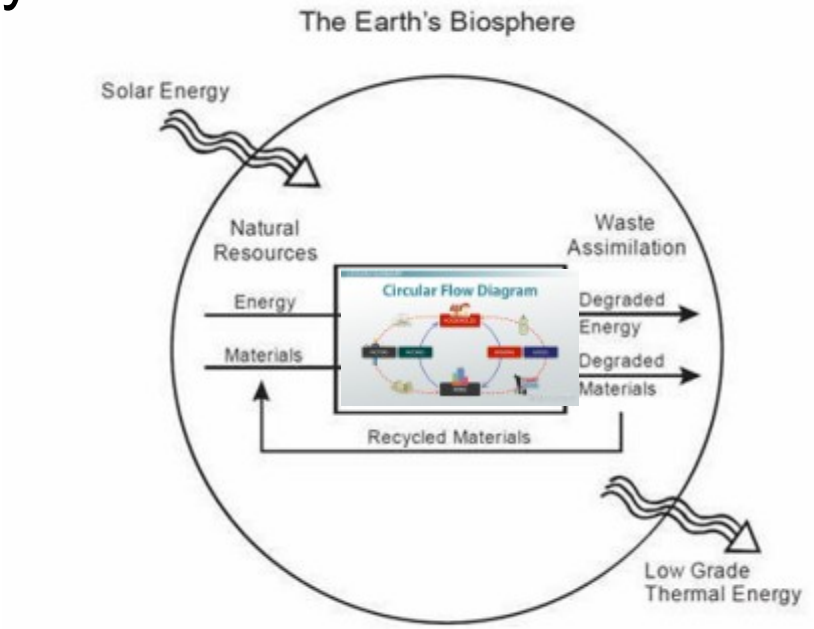


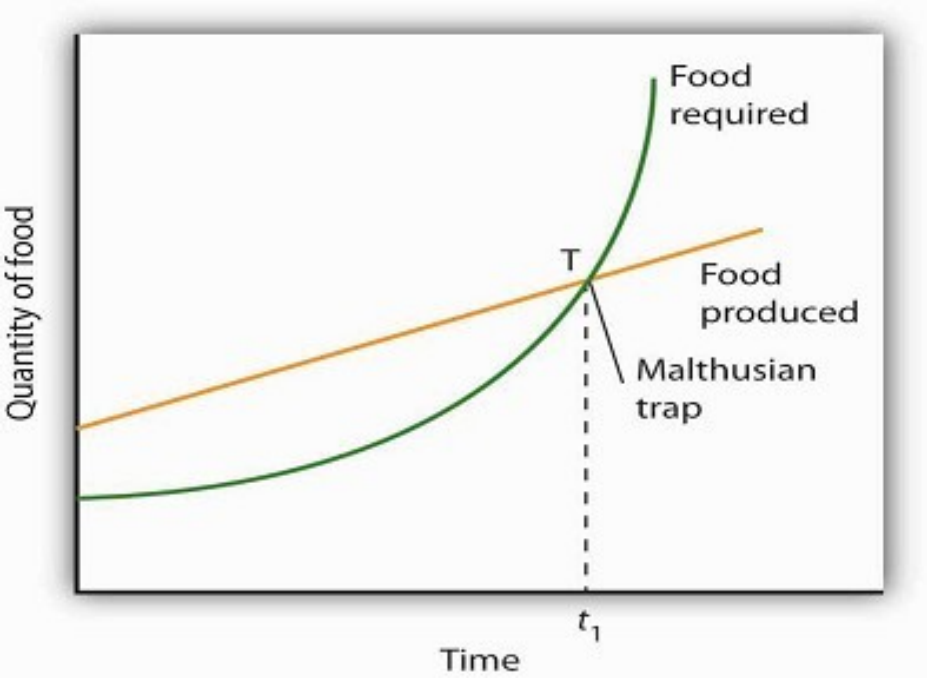
Fig. 2. Thermodynamic throughput model. Note the addition

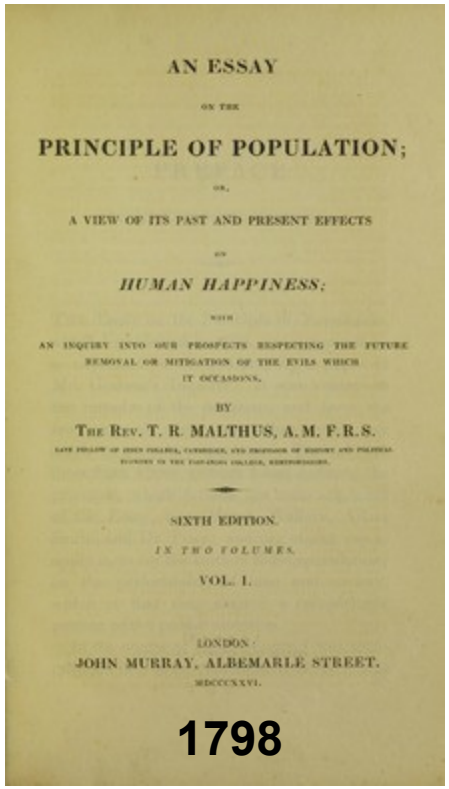


A look back at the history recognizing limits

Thomas Malthus

- Predicts eventually food and resources will run out as populations explode




AN ESSAY

ON THE

PRINCIPLE OF POPULATION;

OR,

A VIEW OF ITS PAST AND PRESENT EFFECTS

ON

HUMAN HAPPINESS;

WITH

AN INQUIRY INTO OUR PROSPECTS RESPECTING THE FUTURE REMOVAL OR MITIGATION OF THE EVILS WHICH IT OCCASIONS.

BY

THE REV. T. R. MALTHUS, A.M. F.R.S.

SIXTH EDITION.

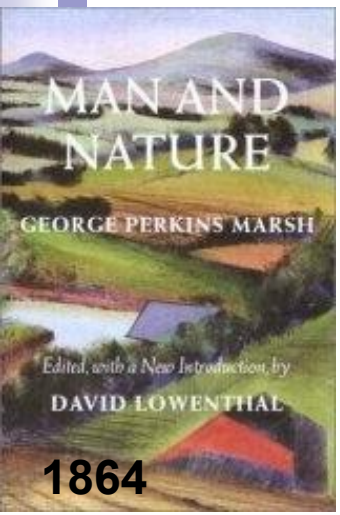
IN TWO VOLUMES.

VOL. I.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1798

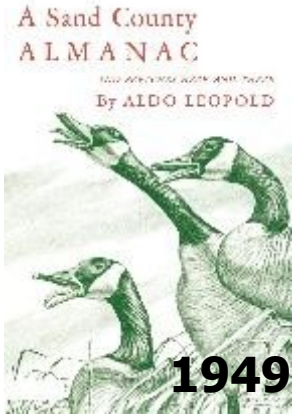


George Perkins Marsh

- "A certain measure of transformation of terrestrial surface, of suppression of natural, and stimulation of artificially modified productivity becomes necessary. This measure man has unfortunately exceeded."

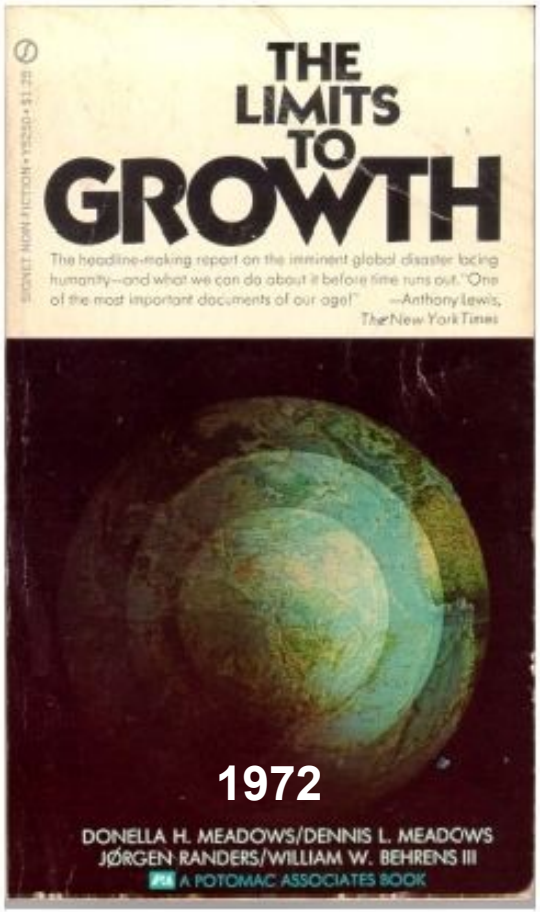
- "The ravages committed by man subvert the relations and destroy the balance which nature has established…; and she avenges herself upon the intruder by letting loose her destructive energies…"

Aldo Leopold

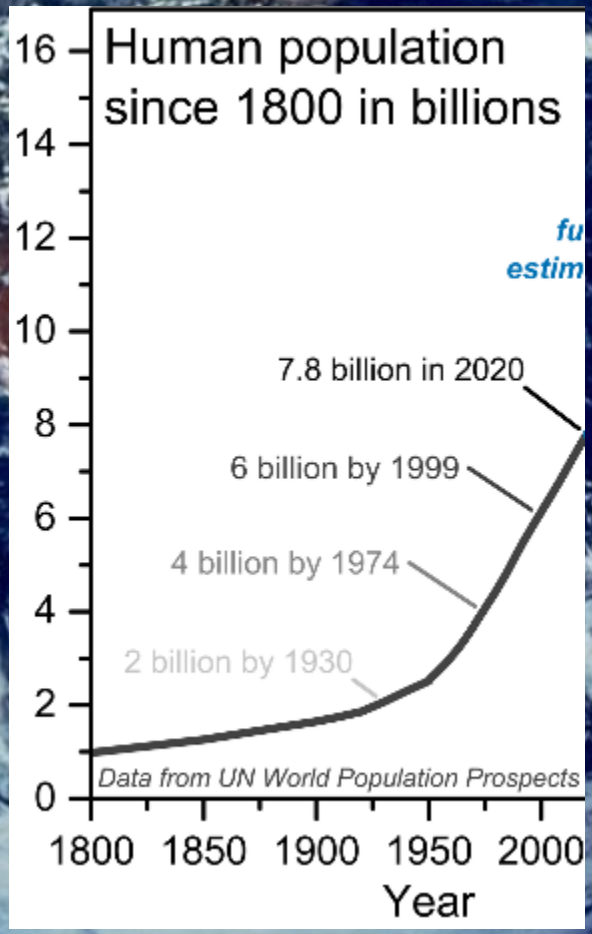


- A Sand County Almanac – regarded as the most influential book on conservation ever written.
- The land ethic:
- "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."
- Enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land.

Donella Meadows and Club of Rome



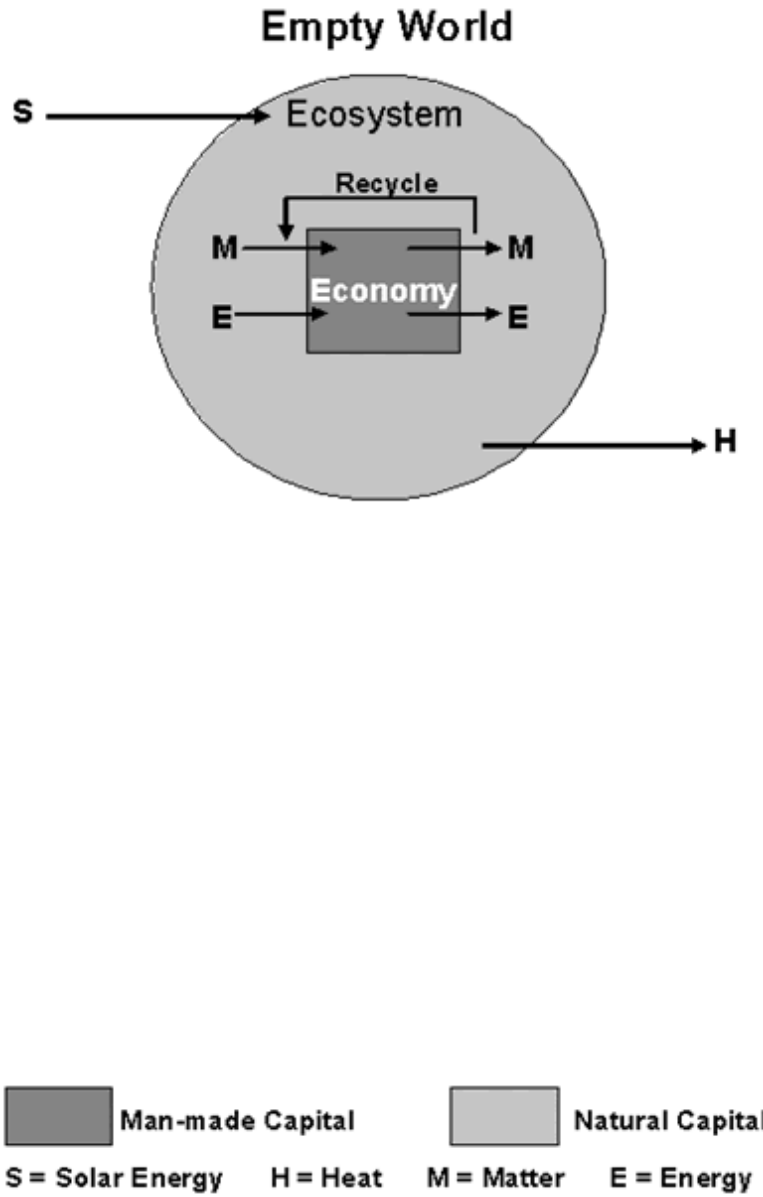
Importance of scale



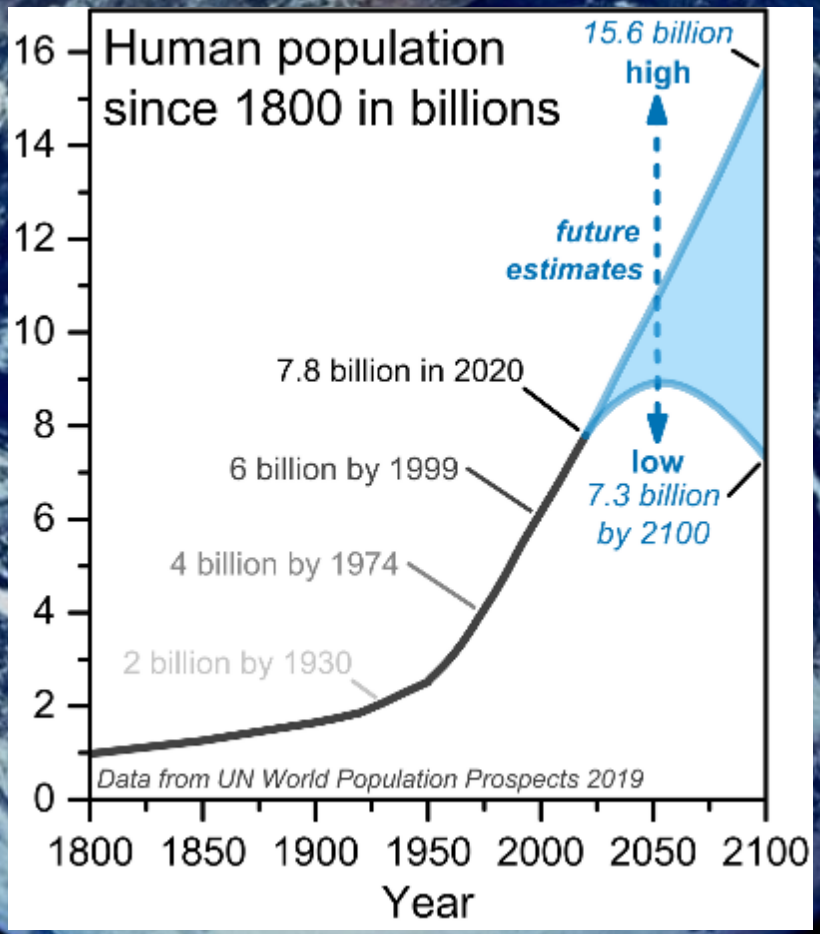
Emergence of humans, from a minor component of natural system to predominant occupant

Scale of humanity has increased greatly putting pressure on all natural resources

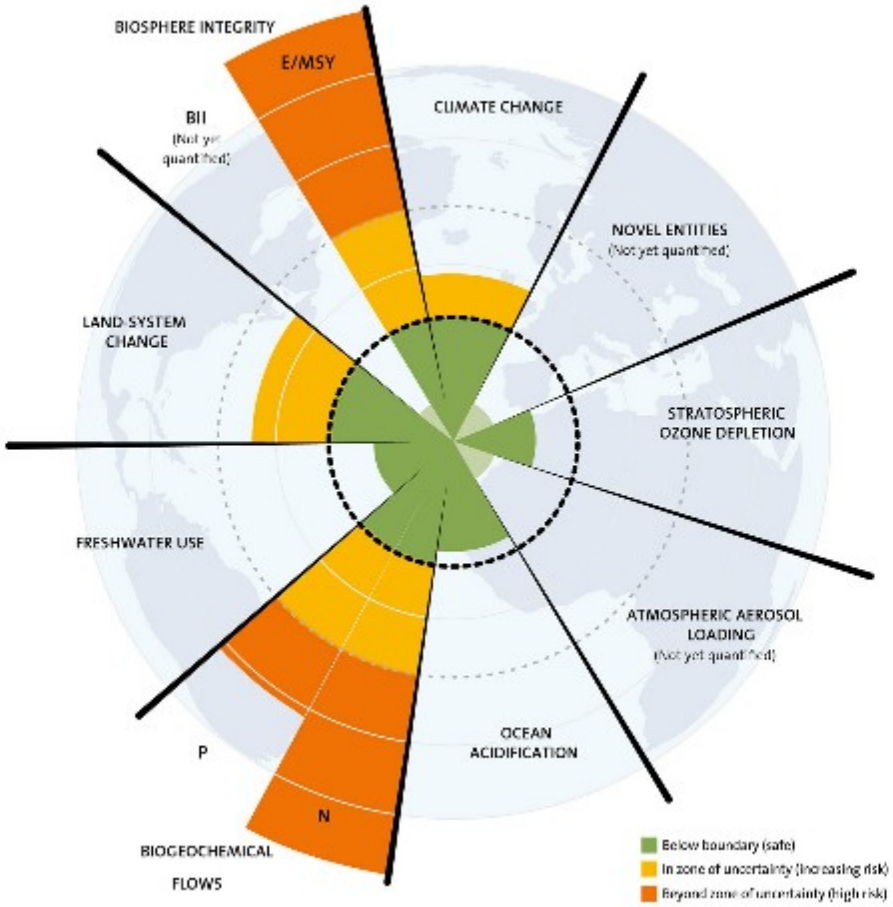
The changes have come so fast our customs ethics, and religious patterns may not have adapted to them.



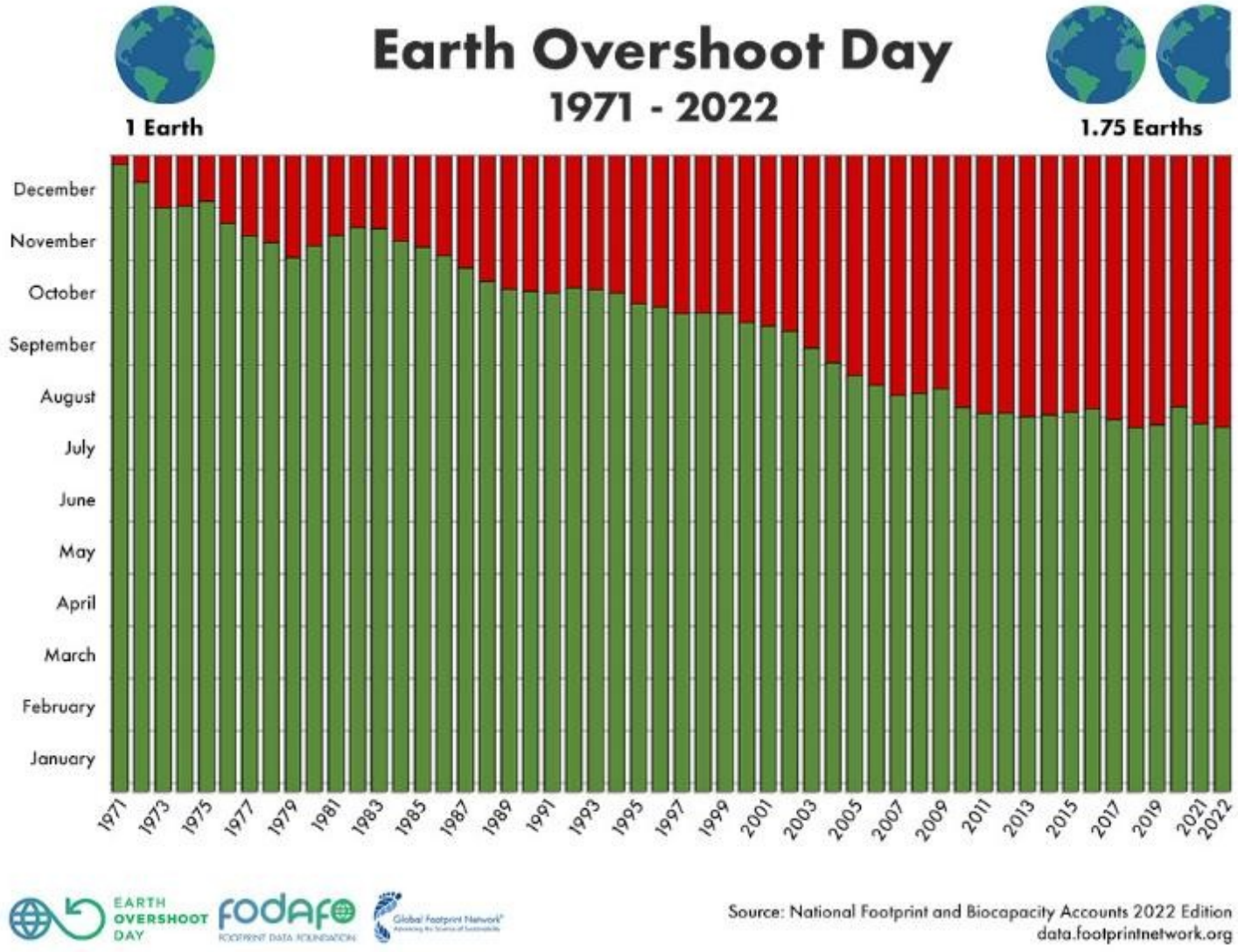
Importance of scale



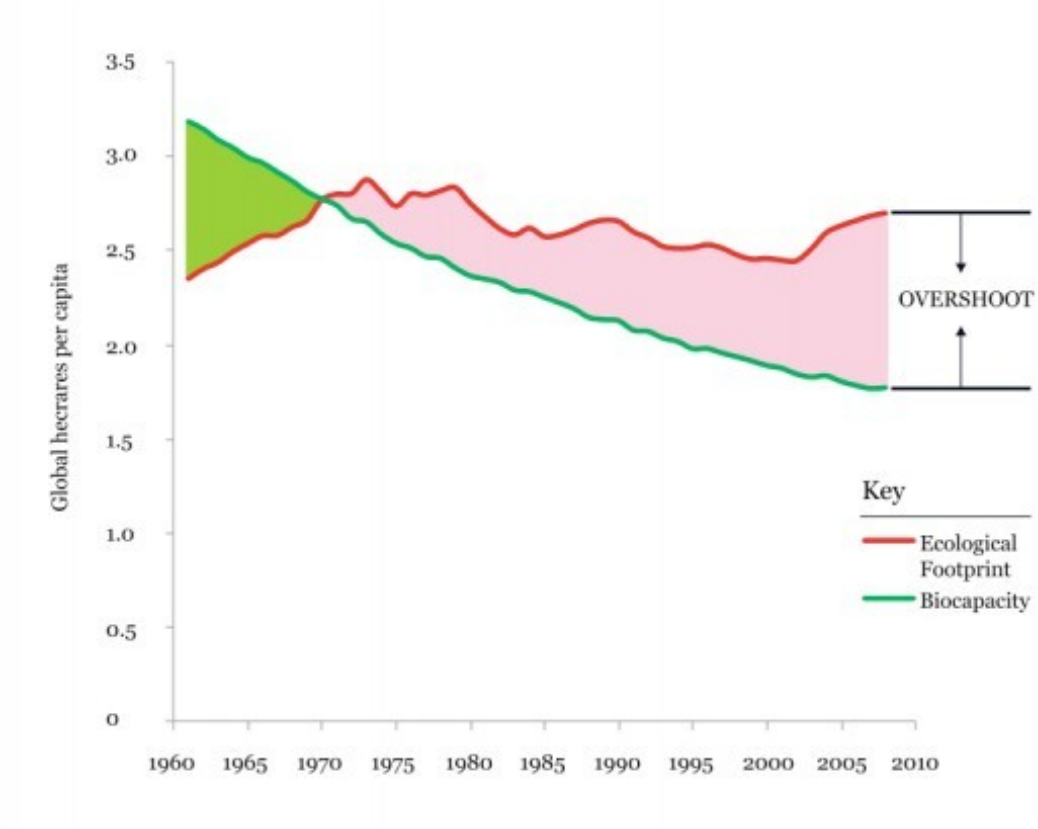
Planetary Boundaries – Stockholm Resilience Centre

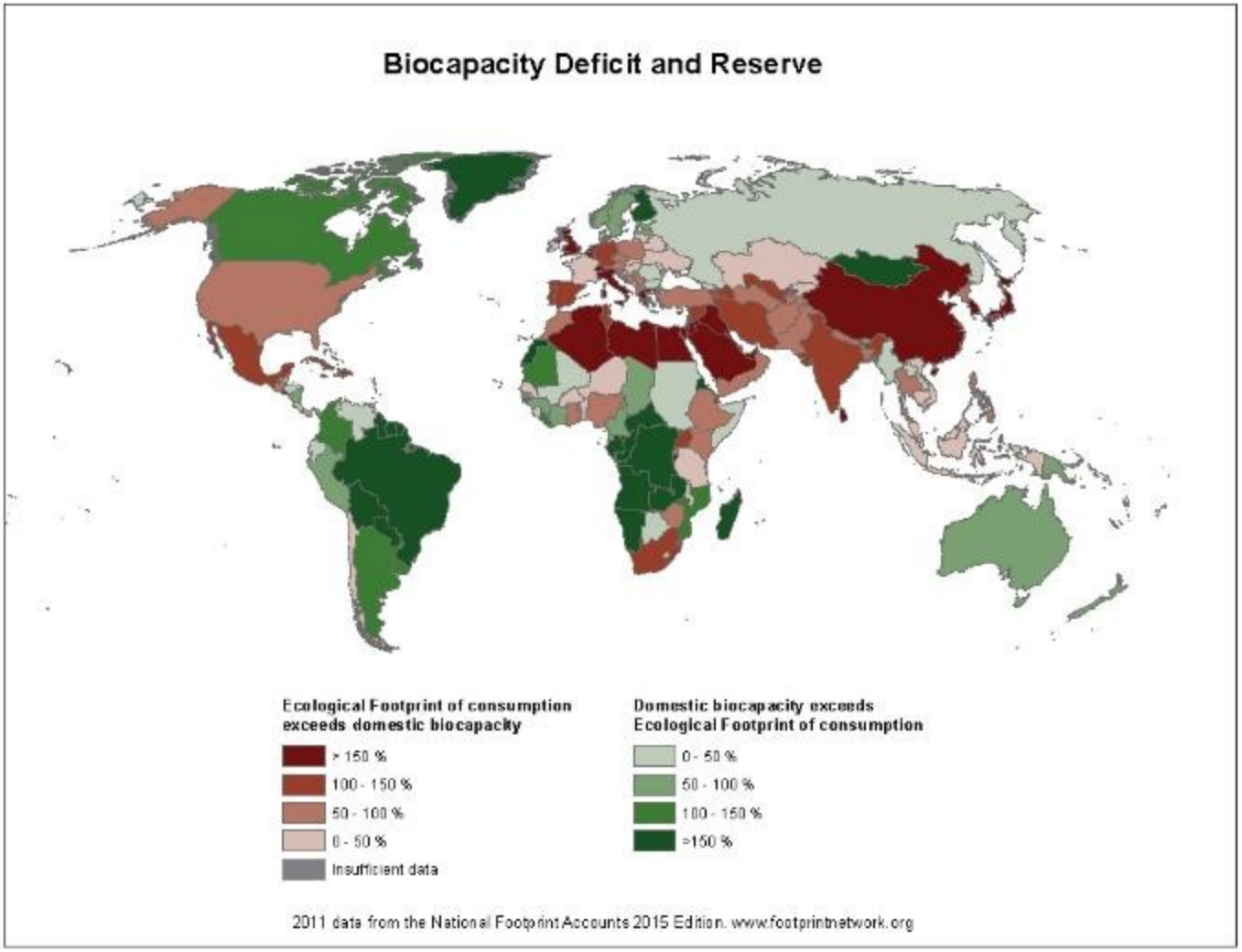


Overshooting the limits – July 28, 2022

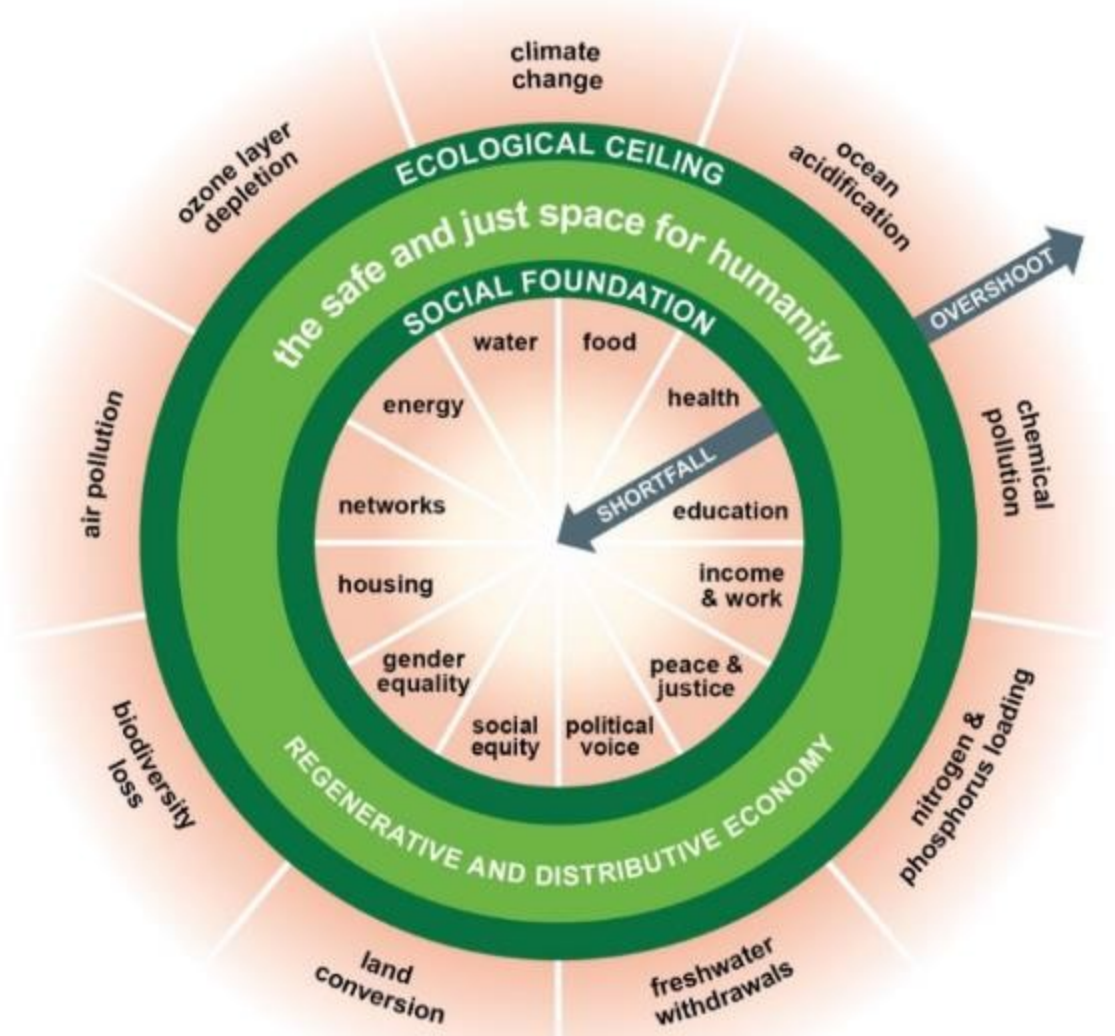


Overshoot!


Global hectares per capita
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
OVERSHOOT
Key
Ecological Footprint
Biocapacity

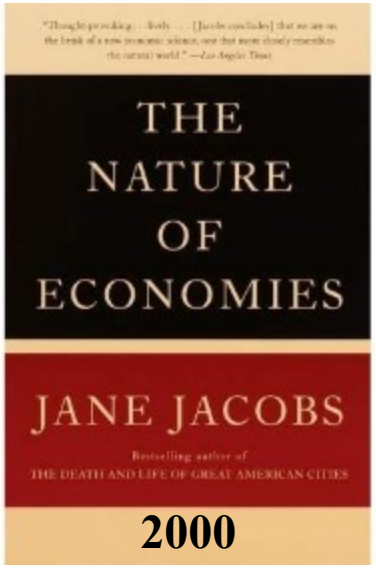

Biocapacity Deficit and Reserve
Ecological Footprint of consumption exceeds domestic biocapacity
> 150 %
100 - 150 %
50 - 100 %
0 - 50 %
Insufficient data
Domestic biocapacity exceeds Ecological Footprint of consumption
0 - 50 %
50 - 100 %
100 - 150 %
>150 %
2011 data from the National Footprint Accounts 2015 Edition. www.footprintnetwork.org

Ceilings and Floors
Donut Economics – Kate Raworth



Limits to Growth

- ***"Natural principles of chemistry, mechanics and biology are not merely limits. They're invitations to work along with them."***

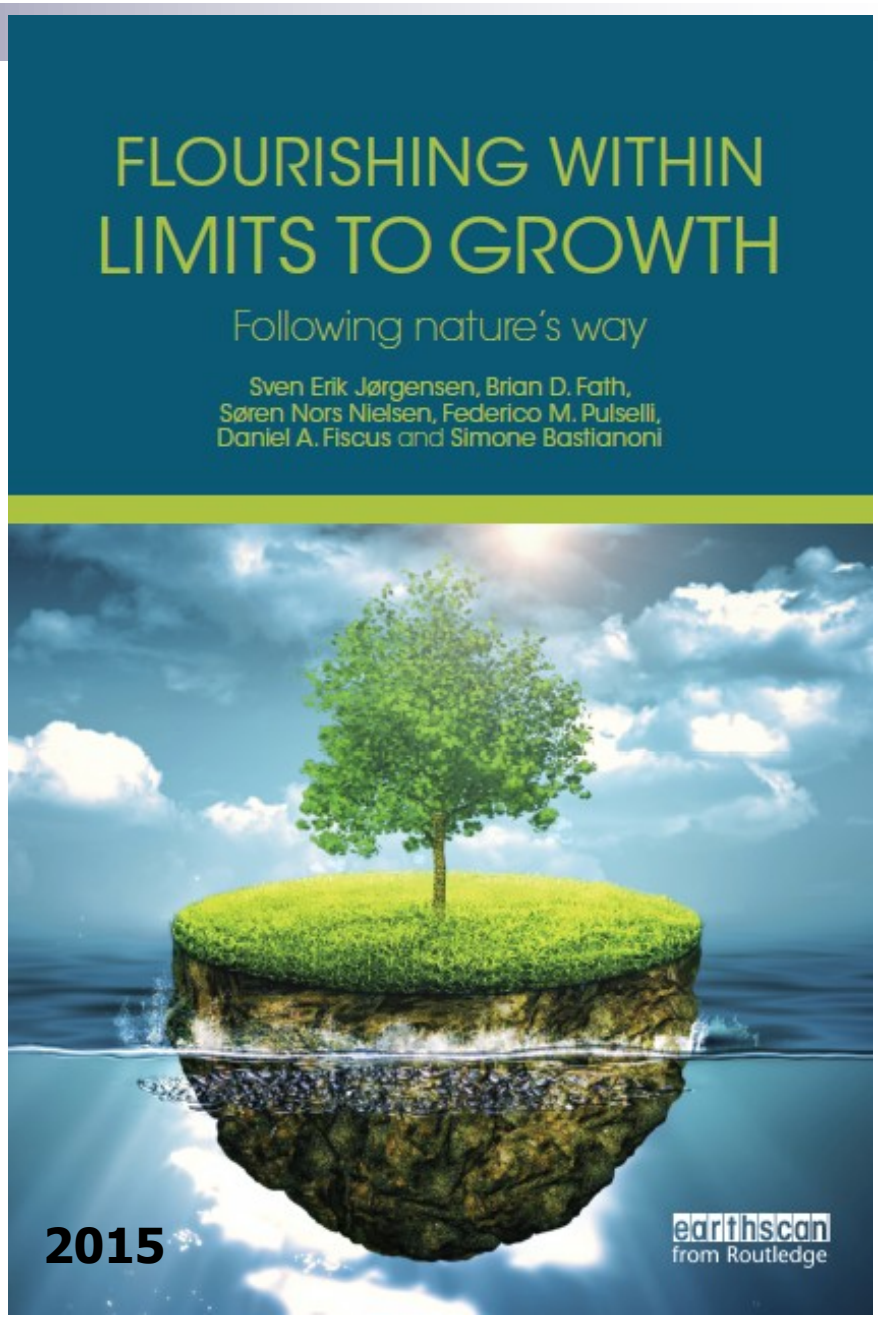


Jane Jacobs

- ***"There are limits. Let's celebrate the limits, because we can reinvent a different future."***

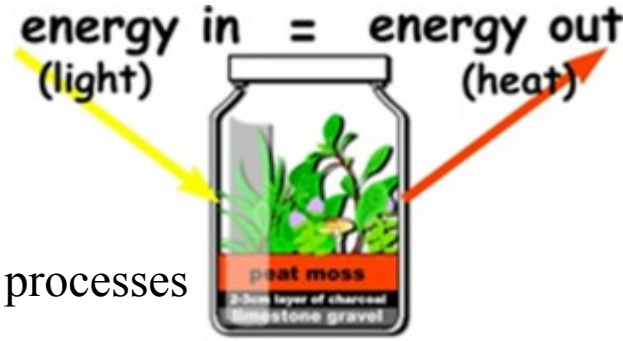
Sunita Narain
This Changes Everything 2015

Ecosystems do quite well under constraints, let's learn from them



clubofsiena.eco-soft.dk

9 properties of ecosystems



Material constraints

1) Ecosystems conserve matter and energy – 1st law
2) All processes are dissipative – 2nd law
3) All life uses largely the same biochemical ients and processes

Ontological properties

4) An ecosystem uses surplu away from thermodynamic equ ven biological aspect) – centripetality
5) Ecos dapt to prevailing conditions (biologically et)

Phe al properties

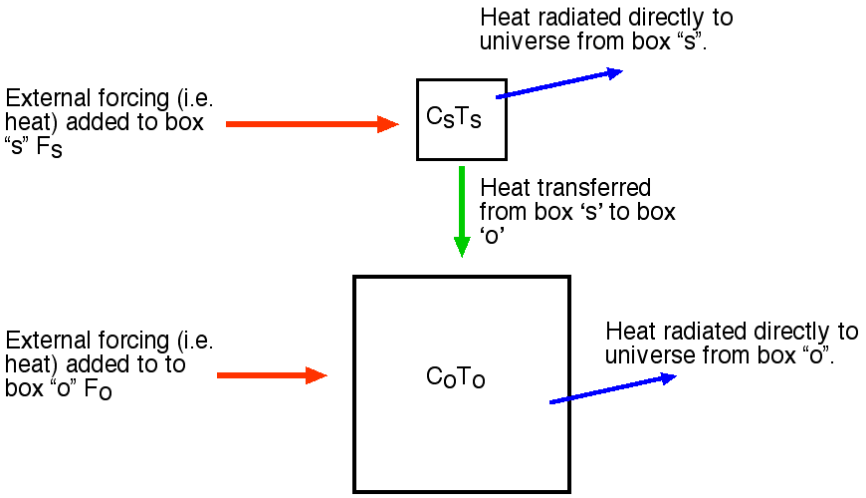
6) E stems have diversity of structure and function
7) Ecosystems work together in networks that improve the resource flow utilization
8) Ecosystems are emergent hierarchically
9) Ecosystems have an enormous amount of genetic, biochemical, and process information

Understand these and apply to socio-economic systems

1. Ecosystems conserve *matter and energy*

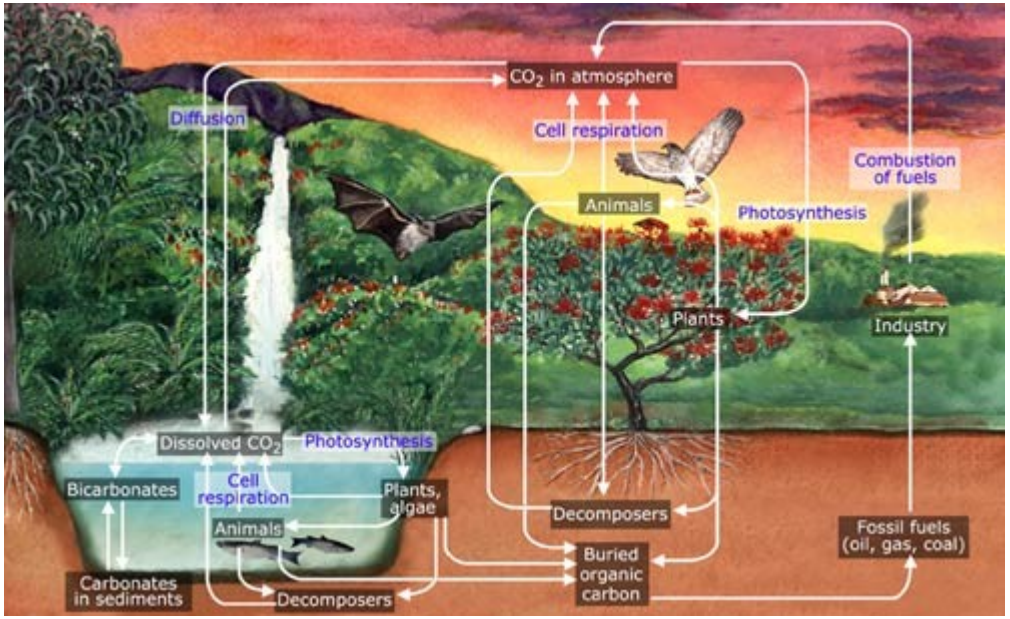
This principle allows one to write balance equations, such as: accumulation = input – output.

General Two Box Energy Balance Model.

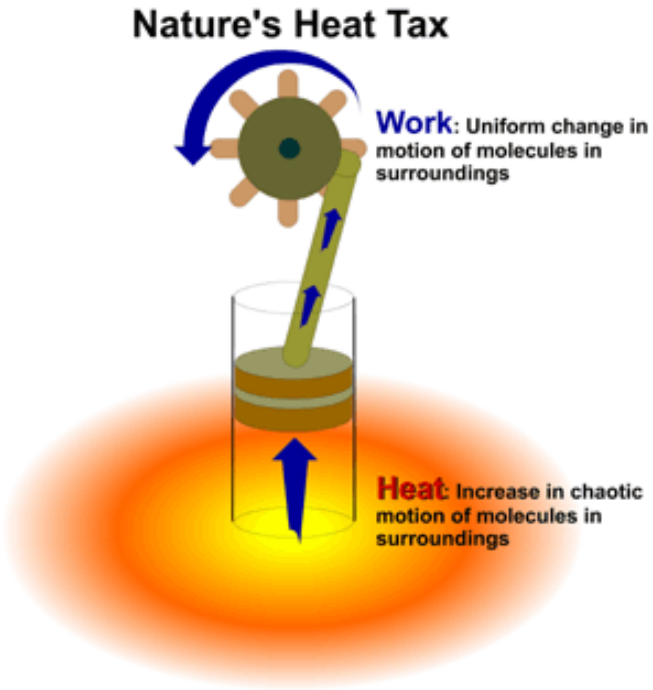


1.1. *There are no trash cans in nature*

Material is reused again and again through functional couplings

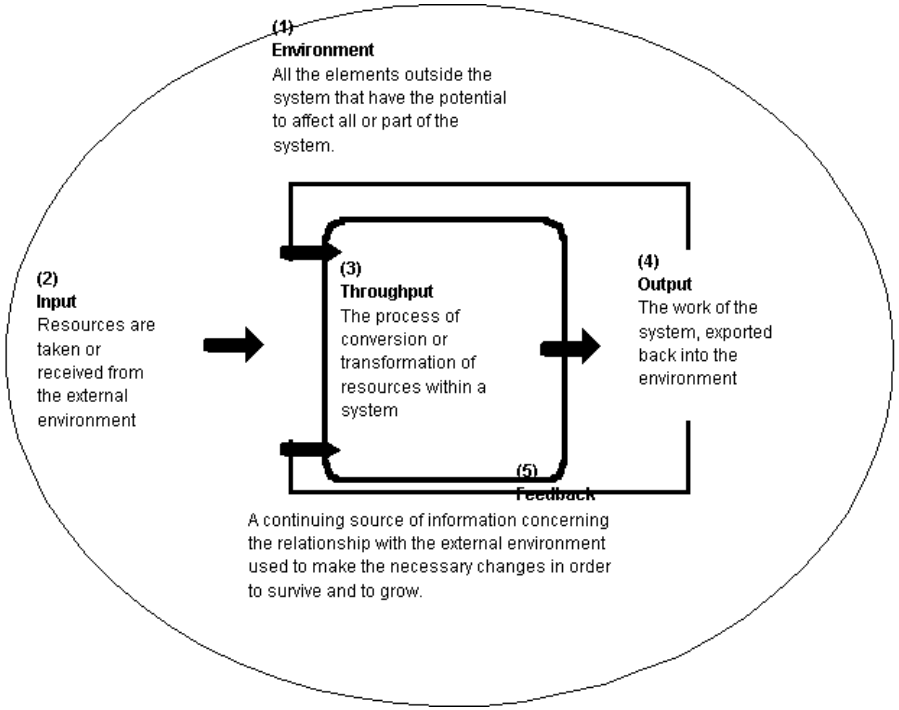


2. *All processes are dissipative (irreversible)*
(useful way to express the 2nd Law in ecology).



2.1. *Ecosystems are open systems* ***and require an input of work energy*** *to maintain their function*

From a thermodynamic point of view, this principle is a prerequisite for ecosystem processes. If ecosystems were isolated in the physics' sense, then they would inevitably go to thermodynamic equilibrium without gradients and without life.



Ecological Cycles

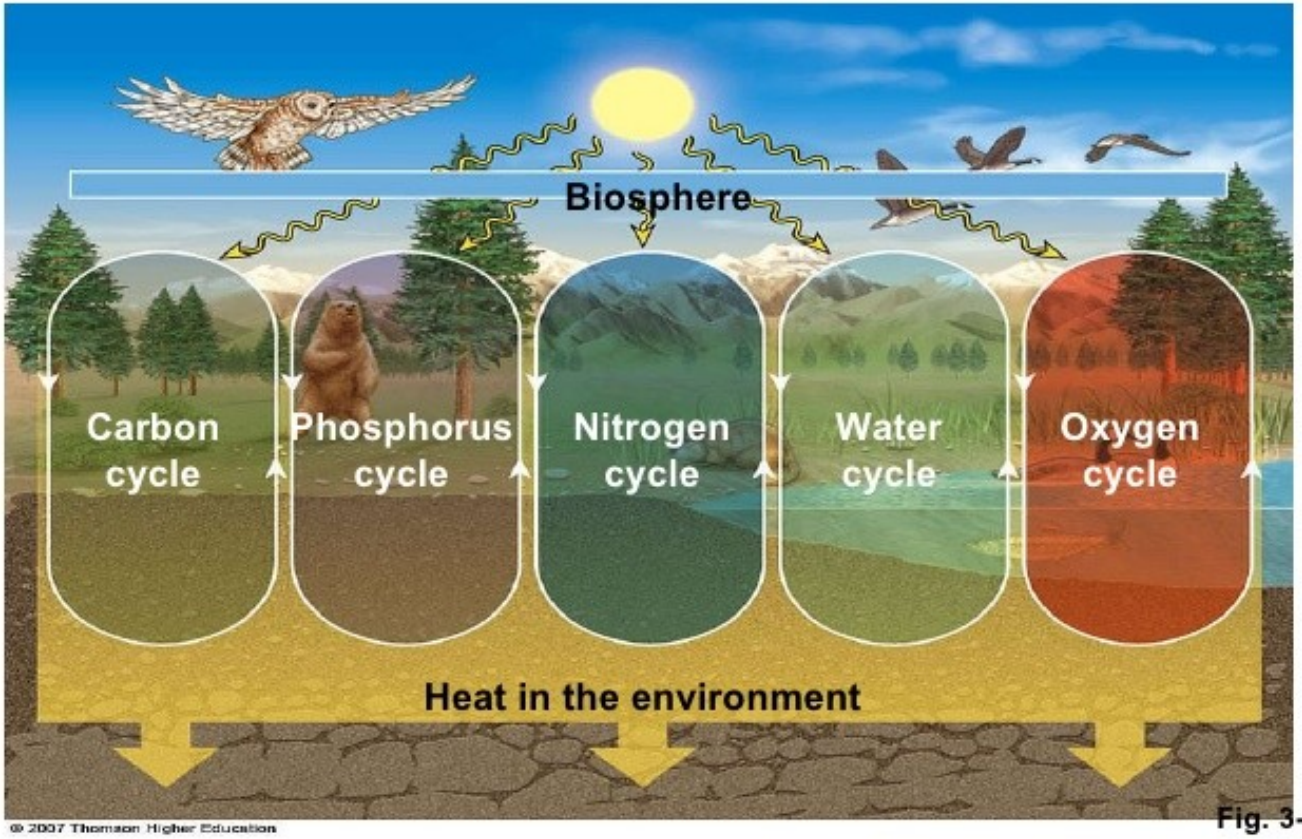


Fig. 3-7, p. 55

3. *All life uses largely the same biochemical constituents and processes*

Biochemical compounds found in all living organisms are derived from about 25 elements.

The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Yellow Boxes = Top 5 Elements present in the human body

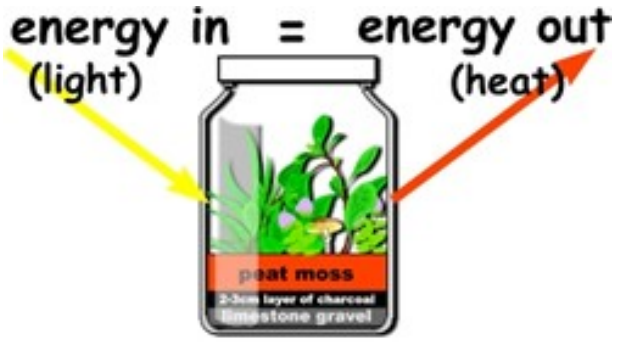
Green Boxes = Second 5 Top Elements present in the human body

Blue Boxes = Trace elements that are required by the human body

Violet Boxes = Elements that are deleterious to the human body.

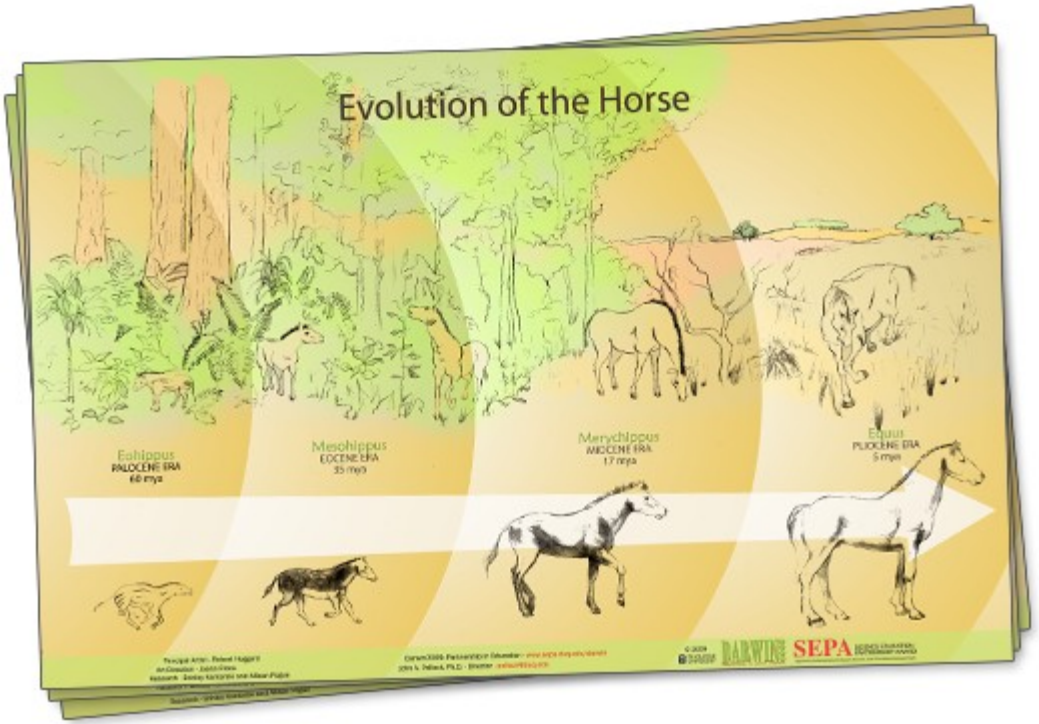
4. *An ecosystem uses surplus energy to move further away from thermodynamic equilibrium*

This is just another way of expressing that ecosystems can grow – progressive, directional change



5. *An ecosystem co-evolves by adapting to and modifying its environment*

Evolution is a step-wise development that is based on previous configurations for survival in a changeable and very dynamic world.



7. Ecosystems work together in networks that improve the resource flow utilization

Connectivity is a basic property that, through transactions and relations, binds ecosystem parts together as an interacting system.

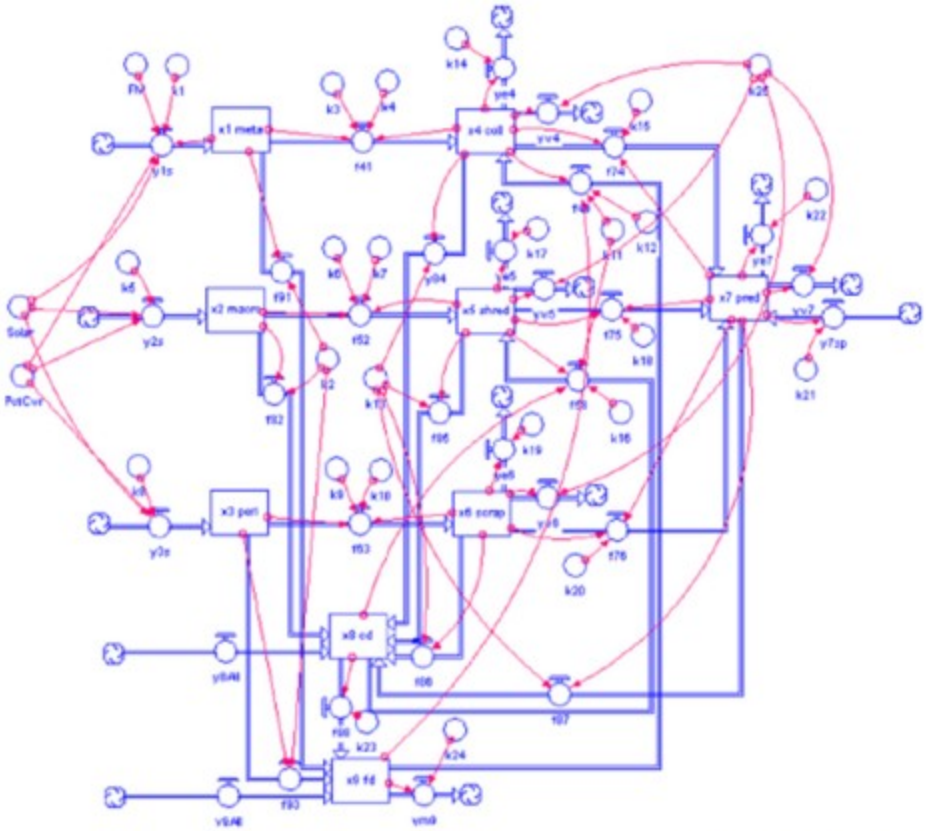
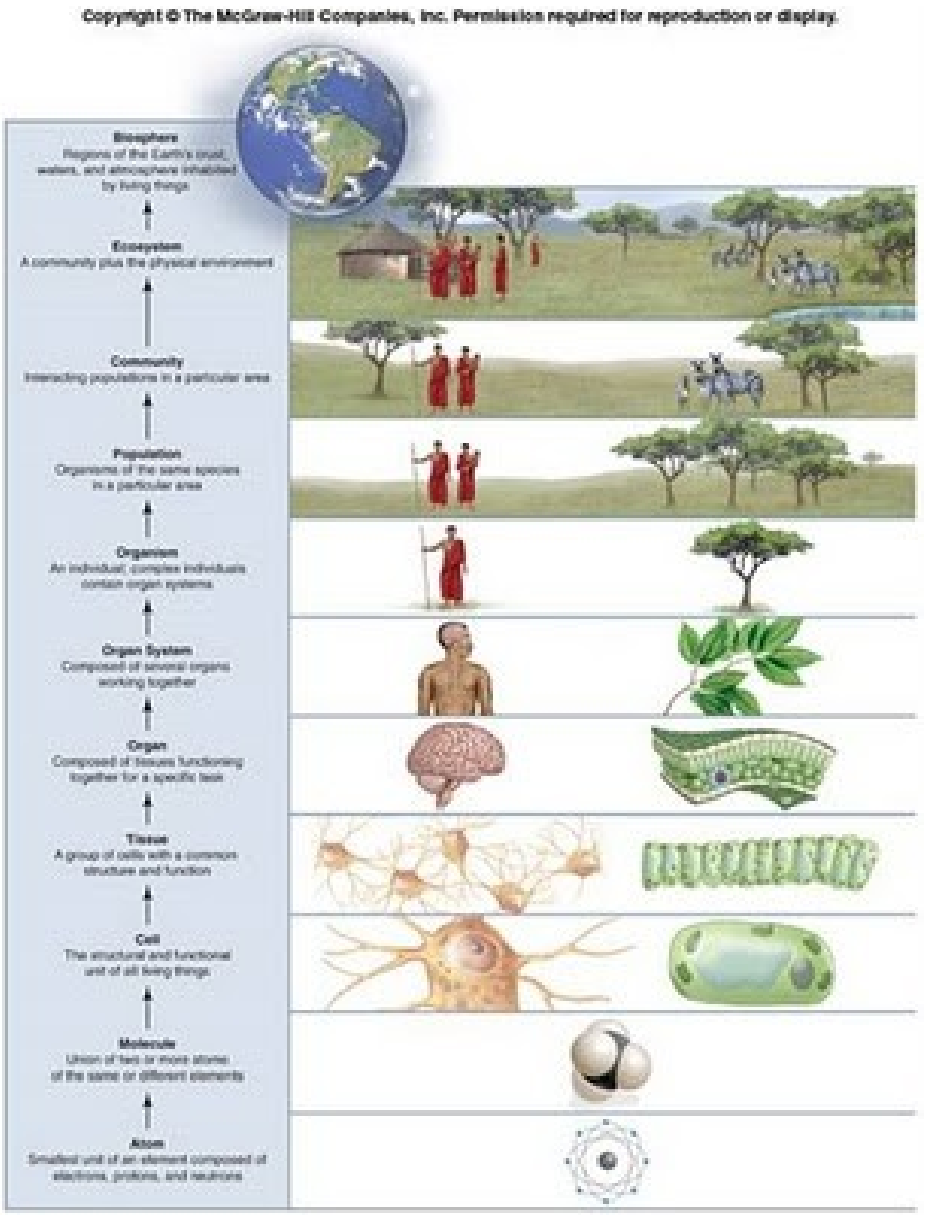


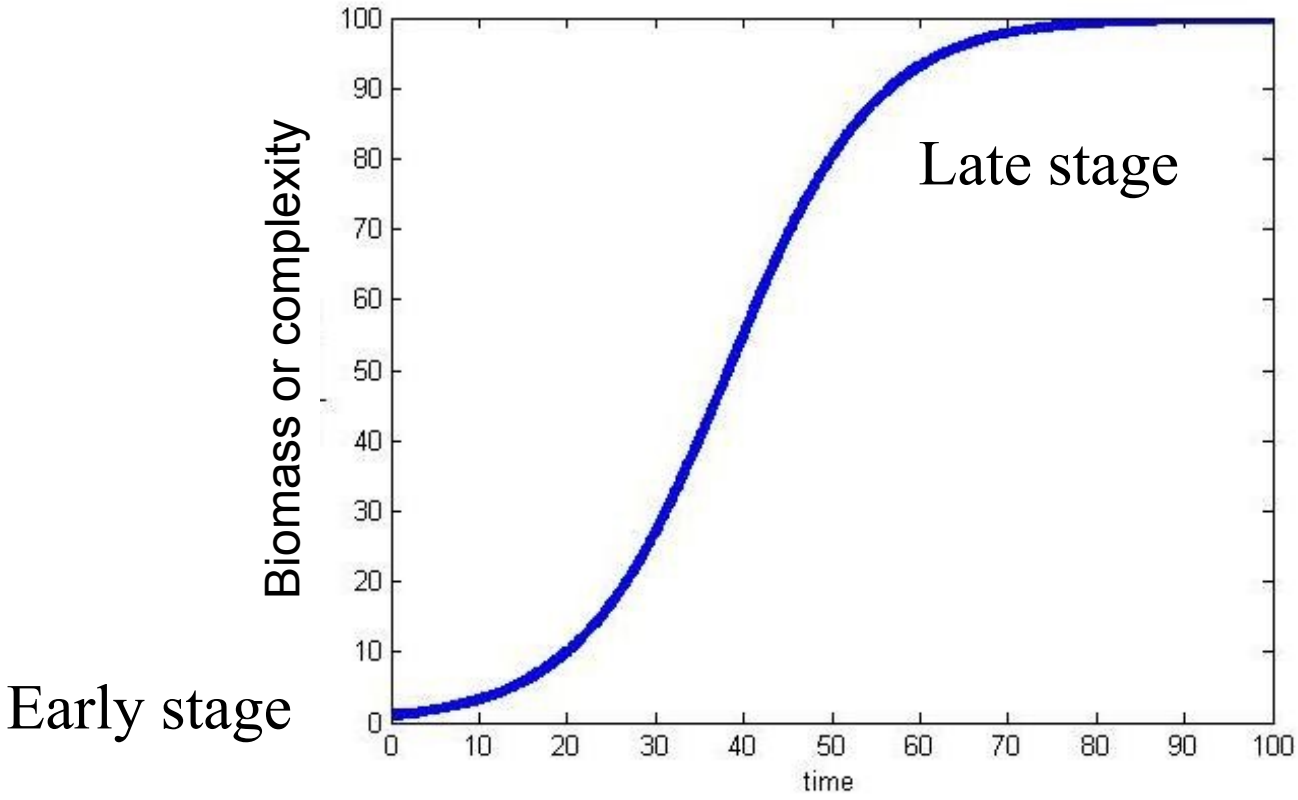
Fig. 1 – Trophic model of Olentangy Wetland in STELLA (recreated from Spieles and Mitsch, 2003).

8. *Ecosystems are emergent hierarchically*

Ecosphere
Ecosystems
Communities
Populations
Organisms
Organ systems
Organs
Tissue
Cells
Molecules
Atoms

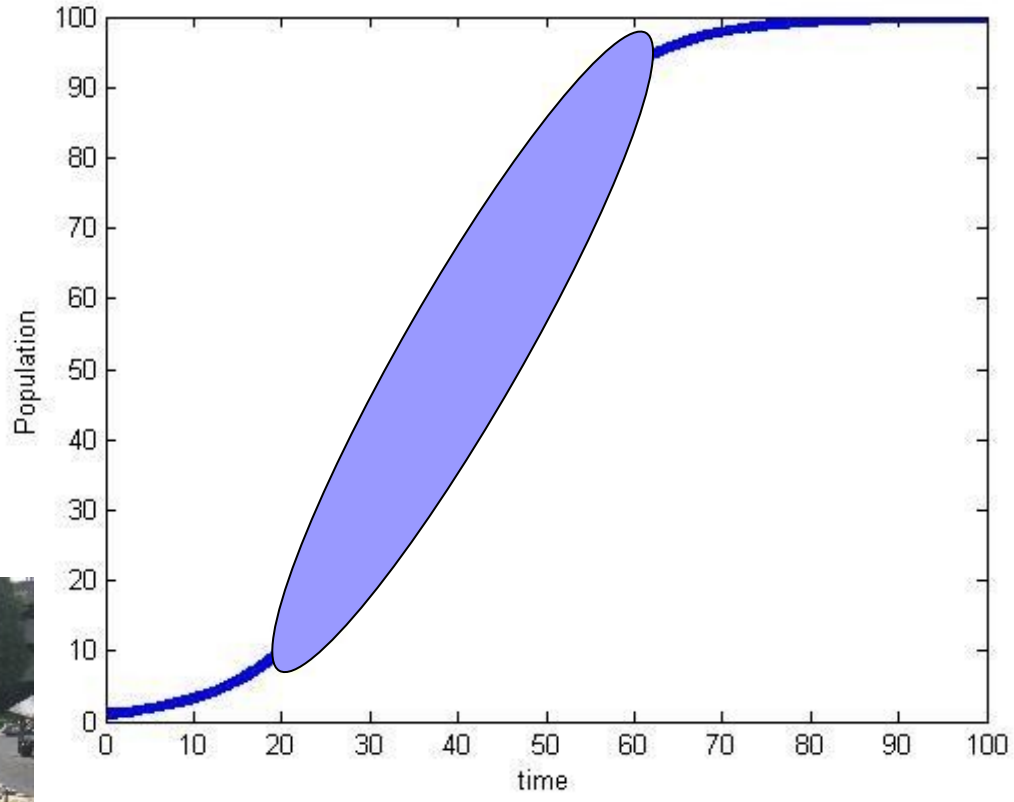


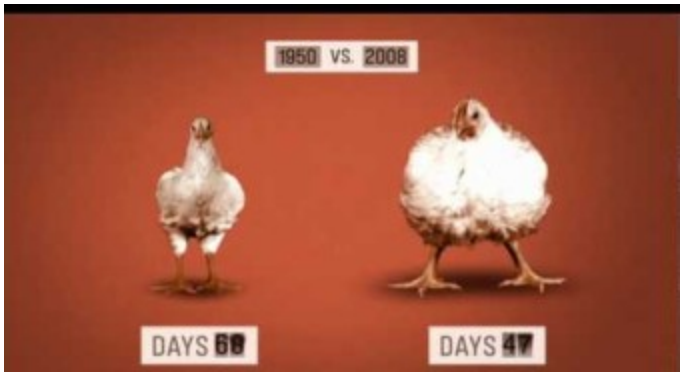
Ecosystem growth and development follows a logistic curve from early to late successional stages



Ecosystem services are extracted to exploit growth phase

Human induced succession –deforestation, agriculture– moves the system back to earlier stage.





Bioenergetic model of succession

In early stages of succession, P≥R and excess is channeled into growth and accumulation of biomass.

In late stages of succession, P=R as maintenance costs increase respiration (network, feedback, cycling).

Negative feedback maintains steady state, with little or no change in biomass

Increase capacity and complexity of the energy storage compartments (total biomass of all species and trophic levels) as well as the complexity of energy transfer pathways.

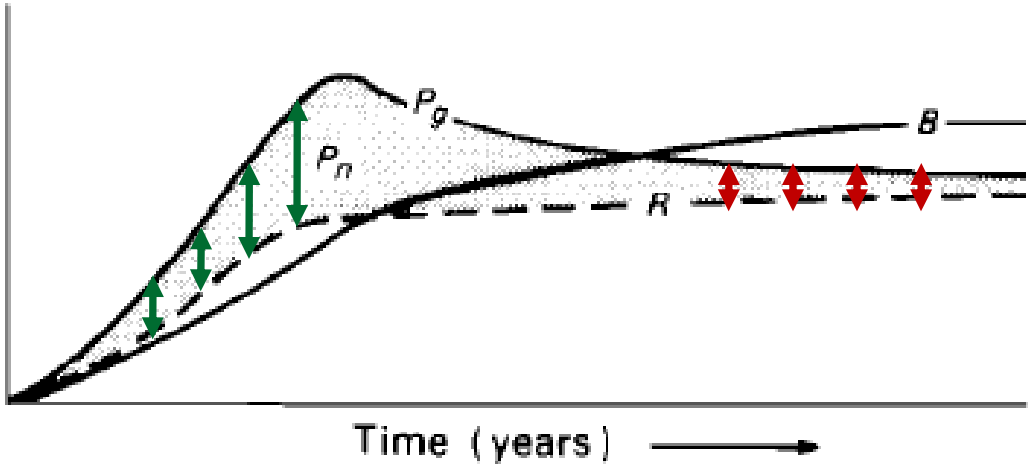
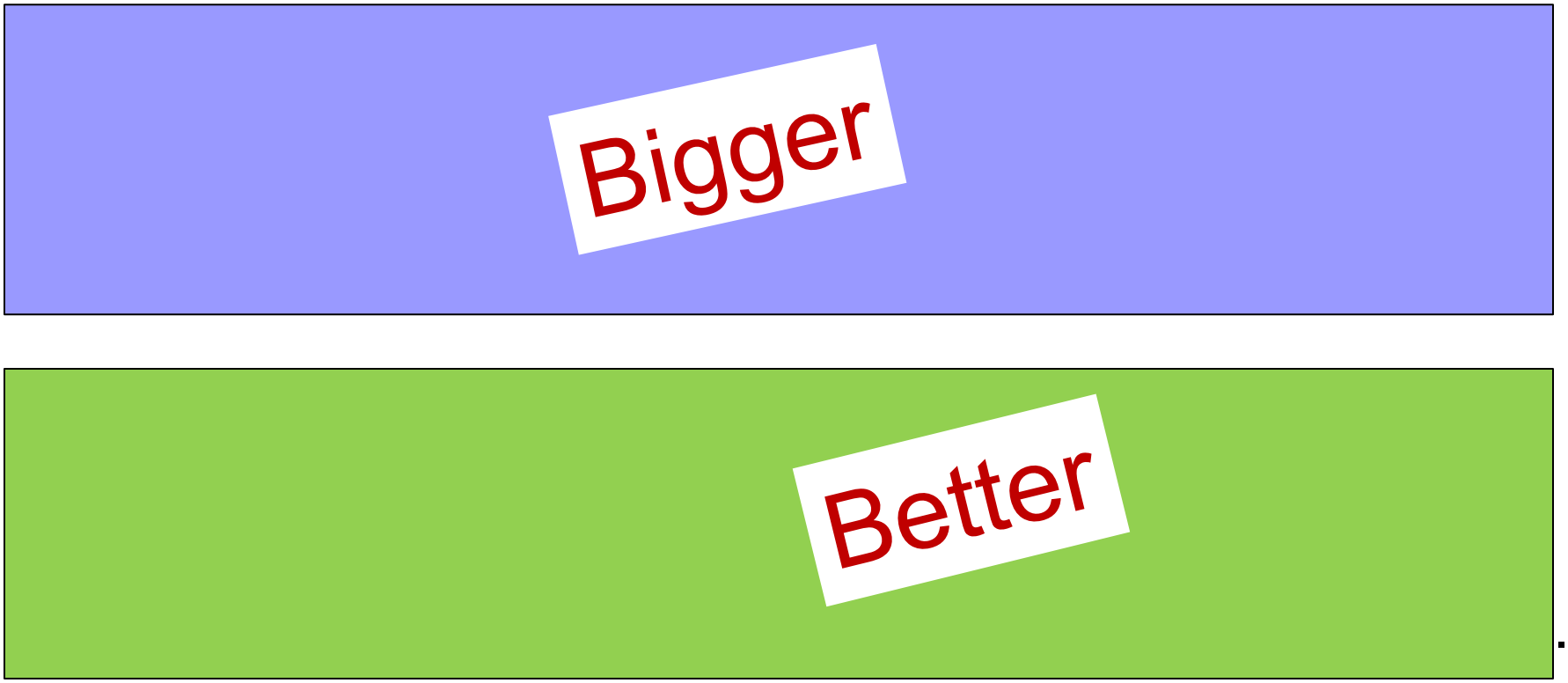


Fig. 25.17 Changes in gross (P_g) and net (P_n) production, respiration (R) and biomass (B) through succession.

Four types of Ecosystem Growth and Development



Fath BD, Jørgensen SE, Patten BC, Straškraba M. 2004. Biosystems 77, 213–228.

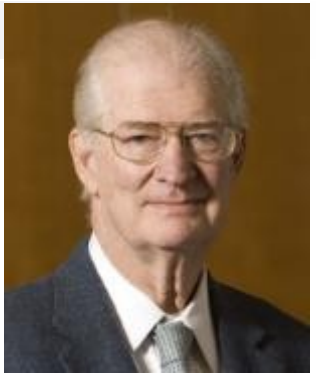
Growth → *Quantitative* increase
Development → *Qualitative* increase

"We must realize that growth and development are two very different things. You can develop without growing and vice versa.“

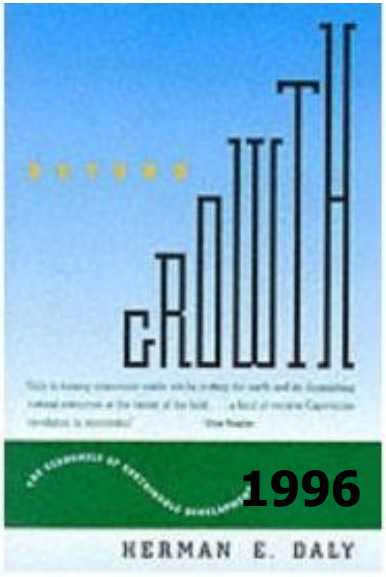
Tibor Vasko, 2009, www.solon-line.de/interview-with-tibor-vasko.html

Alternative Economic Systems…

Herman Daly



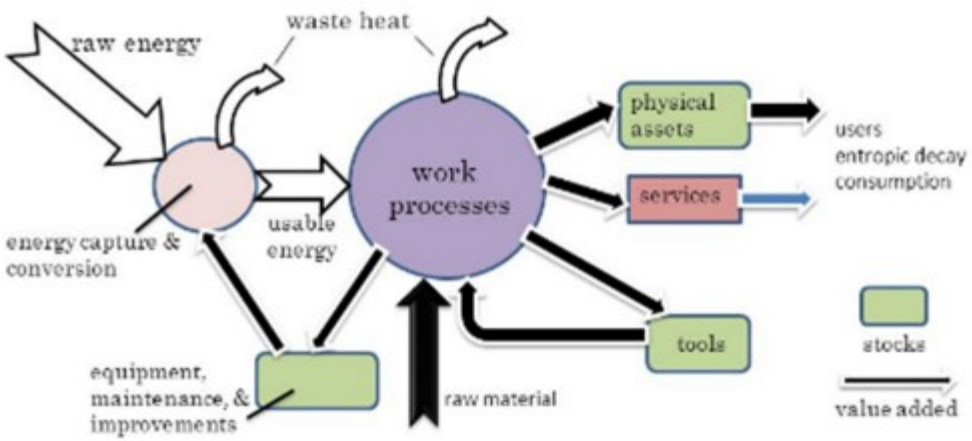
- **Beyond Growth: the economics of sustainable development**
  - The first and second laws of thermodynamics must be the starting point of economics
  - Neither the sources of useful inputs nor the sinks for polluting waste outputs are infinite.



Nicolas Georgescu-Roegen

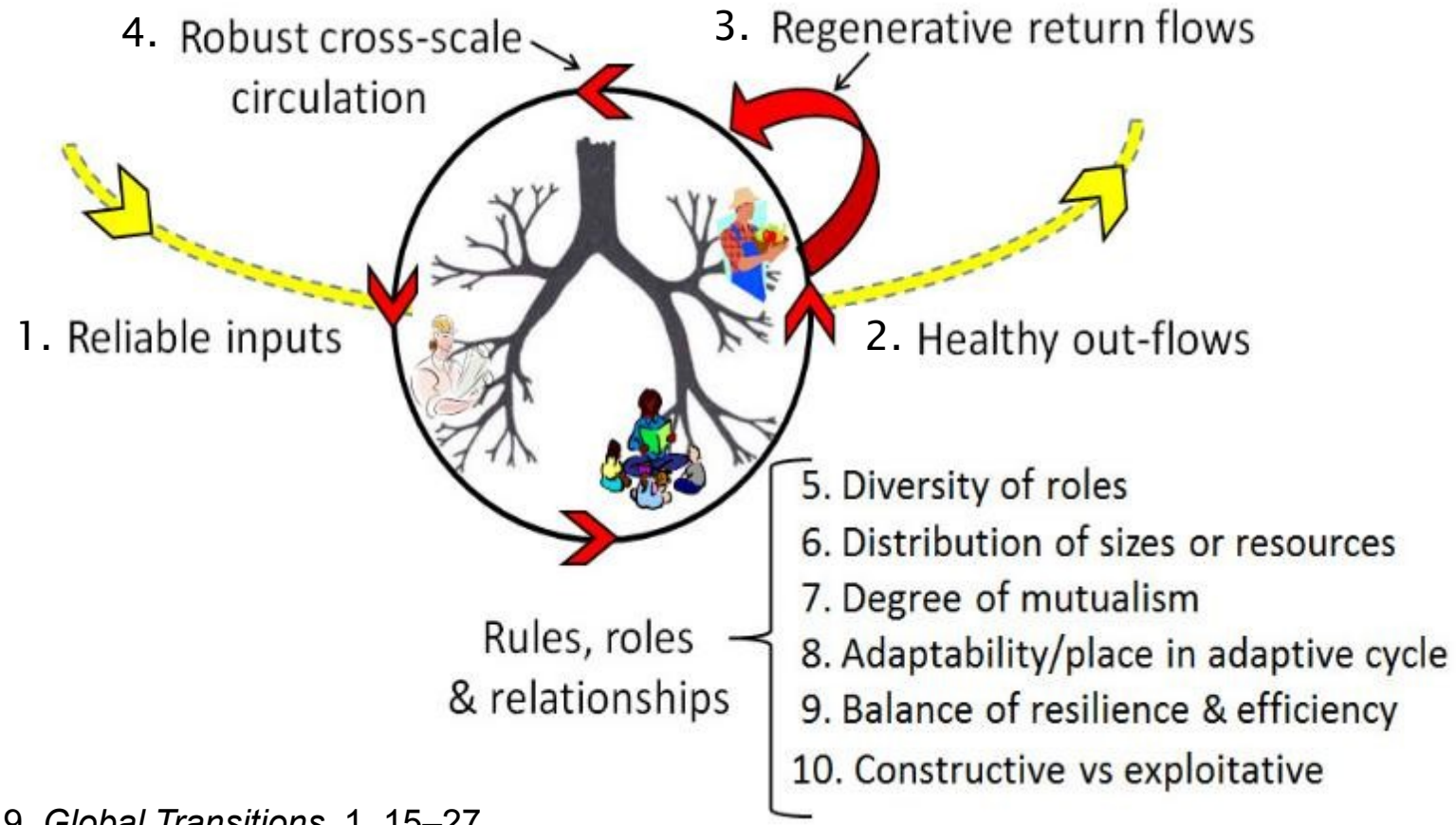
- *The Entropy Laws and the Economic Process* (1971)
  - Wealth is an open system, a structure maintained in the midst of throughput
  - It begins with the depletion of useful matter/energy and ends with the return of an equal quantity of spent matter/energy back to the environment.

- The Economy: Energy, work, and goods/services



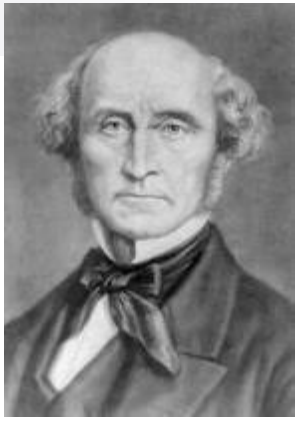
Regenerative economy

Input, Output, and System Dynamics



Fath et al. 2019. *Global Transitions*. 1, 15–27.

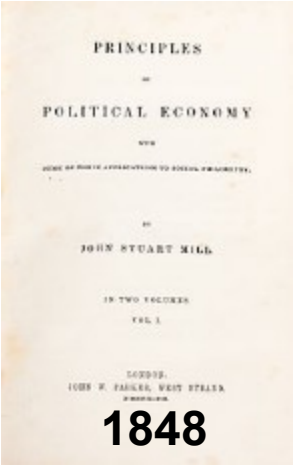
John Stuart Mill



- British philosopher, political economist and civil servant (1806-1873)
- Considered “the most influential English-speaking philosopher of the nineteenth century"

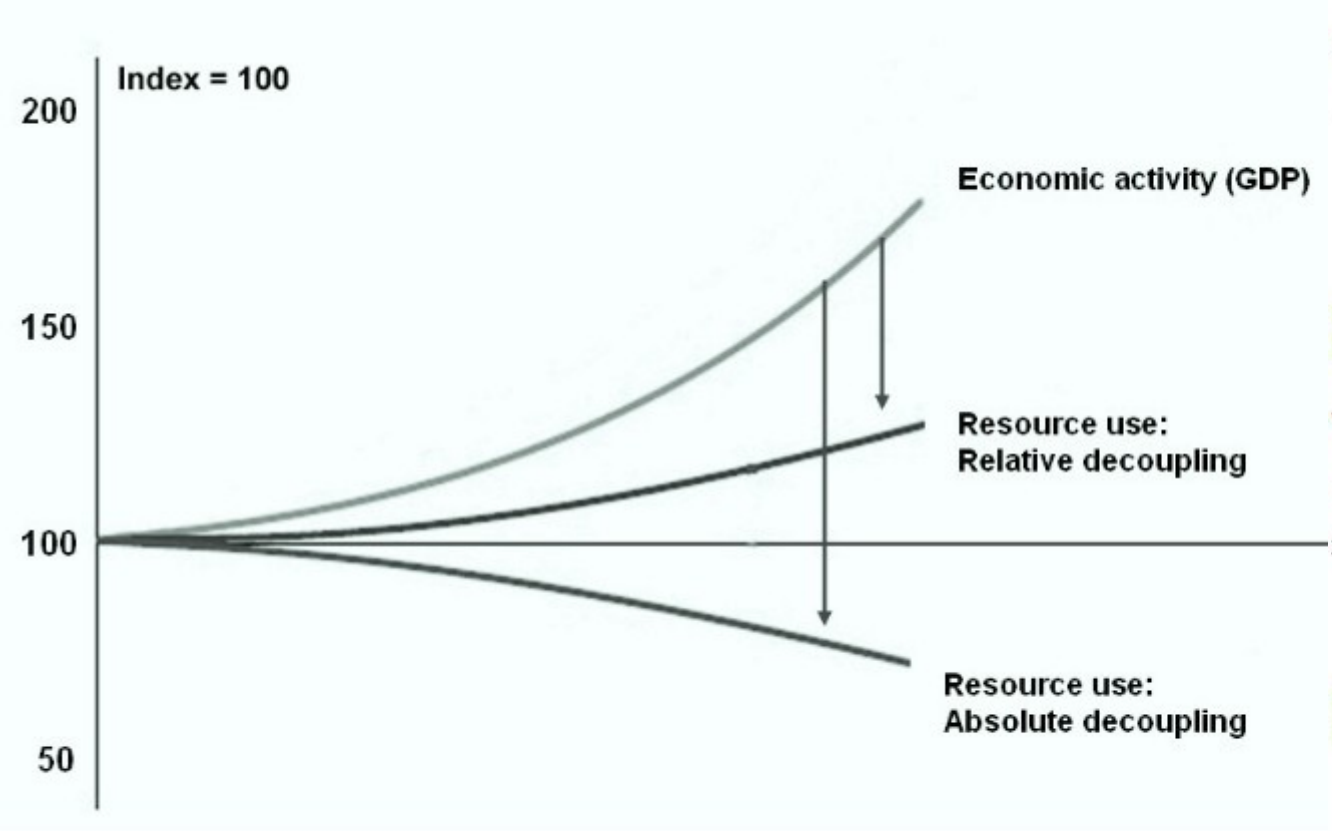
“Perpetual growth in material well-being is not possible or desirable.”

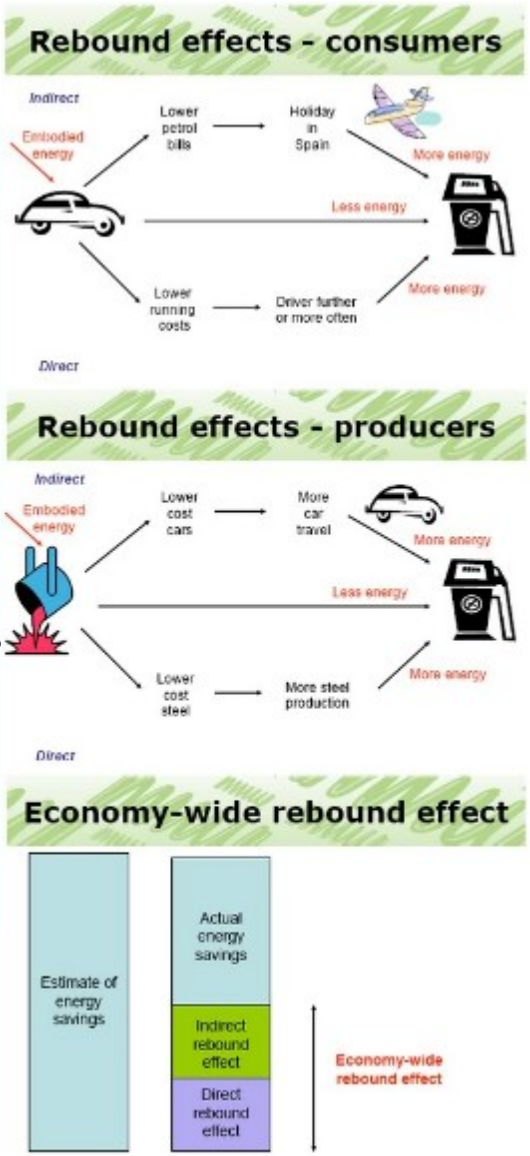
Mill argued that the logical conclusion of unlimited growth was destruction of the environment and a reduced quality of life. He concluded that a stationary state could be preferable to unending economic growth



WHY HAVE WE NOT LEARNED THIS LESSON?

Decoupling –greater resource efficiency



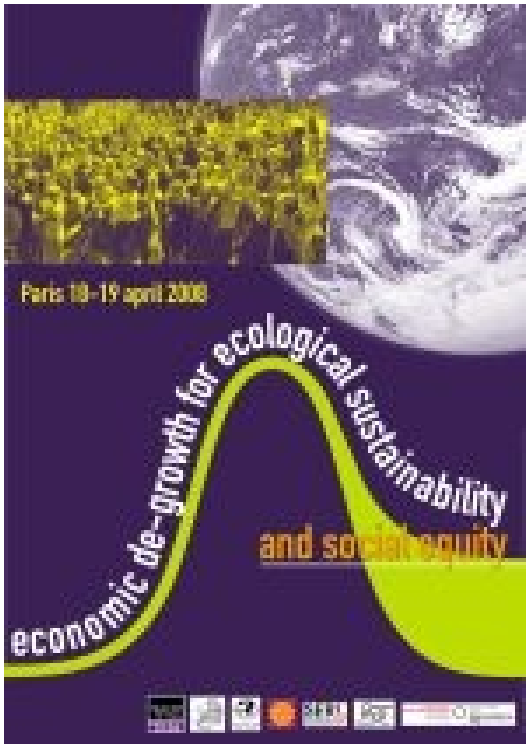


Do more with less

degrowth

- Reduce scale to fit within planetary boundaries

'THE SAME BOAT'



Do less

Discussion questions

- Should biophysical limits be considered in economics?
  - How?
- Is it mostly a matter of getting the prices right – internalize extranalities?
- How to differentiate between productive work and exploitative work?
- How to move away from growth as a goal function?
- Give an example of increased efficiency leading to increased consumption. How can we account for this in reducing environmental impacts?

Thank you for your attention!