Ecosystems as complex adaptive systems

Complex adaptive systems

- Many parts
- Many interactions

- Adaptive because feedback allows them to survive in fluctuating environment

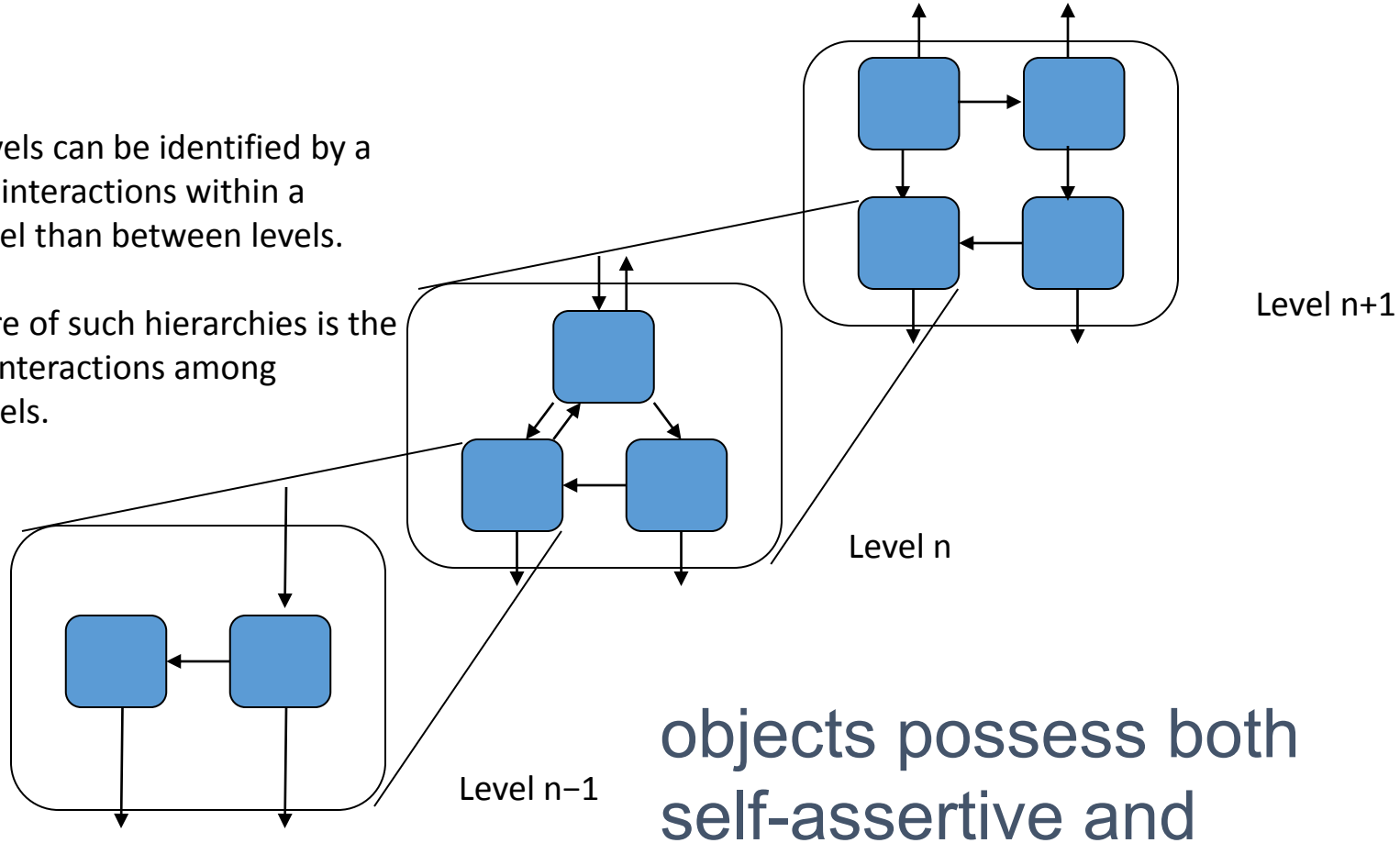
Systems

- Holistic view includes the relation between parts and the whole

Hierarchical Representation of Systems

Hierarchical levels can be identified by a stronger set of interactions within a hierarchical level than between levels.

A critical feature of such hierarchies is the asymmetry of interactions among hierarchical levels.



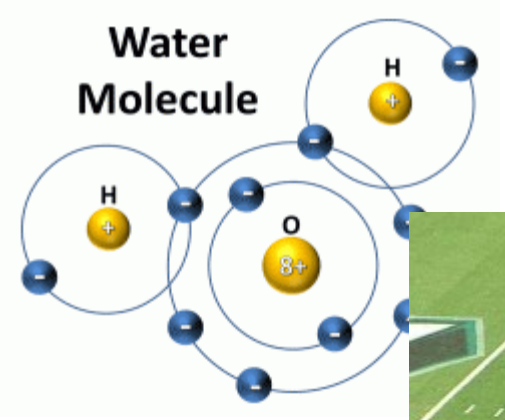
objects possess both self-assertive and integrative tendencies

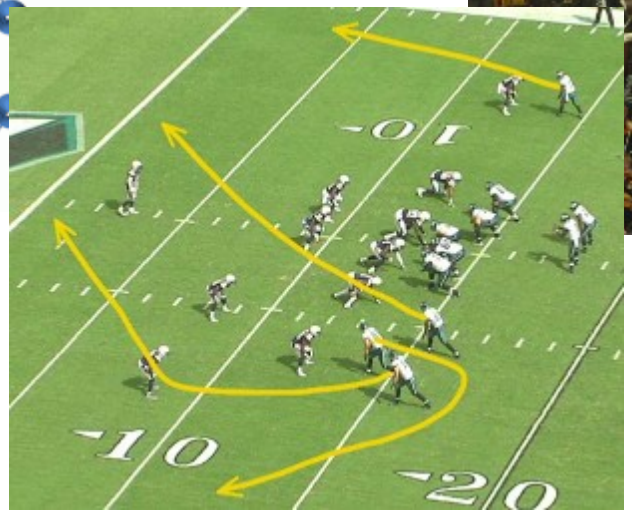
Systems

- It’s not just a random relation: “the whole exists for and by means of the parts and the parts exists for and by means of the whole.”
- – Stuart Kauffman
- (www.npr.org/sections/13.7/2011/08/08/139006531/the-end-of-a-physics-worldview-heraclitus-and-the-watershed-of-life)

Emergent Properties

- Function at higher order of organization that arises from behavior at a lower level
- Whole is more than the sum of the parts





Emergent Properties

- Self organization – increase complexity without being guided by outside force
  - Macroscopic structure from microscopic disorder

Within species organization

Among species organization

Among species with their environment

Among humans

Among humans and nature

Ecosystem Organization

Self-organizing processes in ecosystems make them awesomely complex

Some properties of sustainable systems

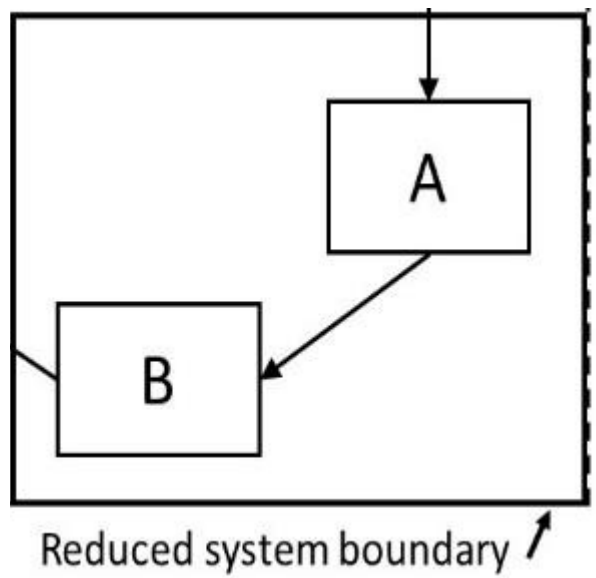
- How they organize
- How they are organized/designed – patterns that emerge
- How they stay functioning – homeostasis
- How they interact with adjacent systems - open with input-output flows
  - Natural Ecosystems
  - Agricultural Ecosystems
  - Urban Ecosystems

- Coadaptation
  - Fitting together
- Coevolution
  - Changing together

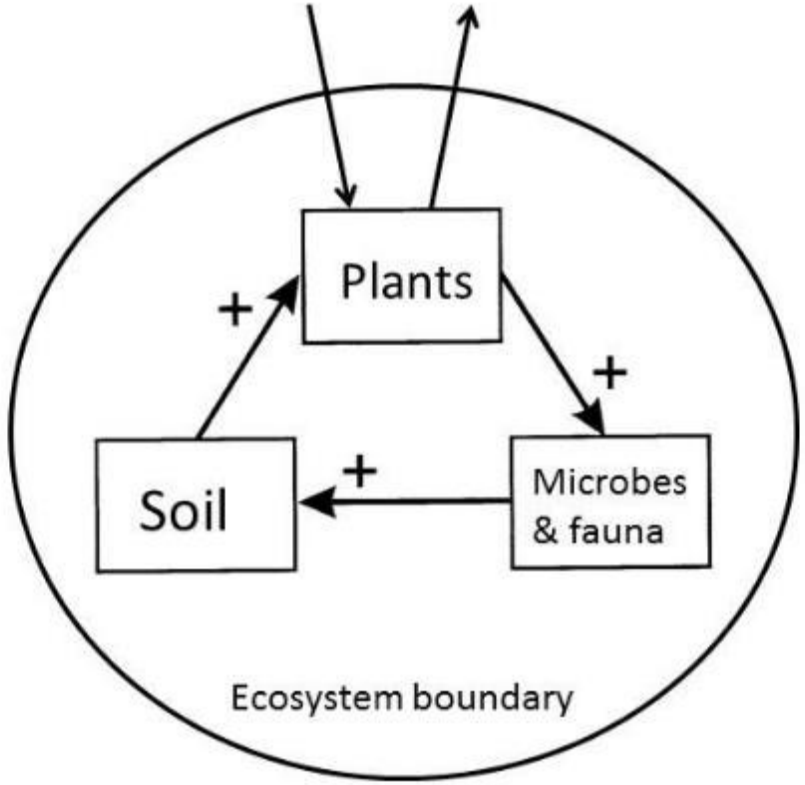
Ecosystem Design

- Redundancy – duplication
- Leads to Reliability and Resilience

- “The ecosystem ensures its survival be feedback mechanisms that regulate the biological populations within it.” p. 63


A
B
Reduced system boundary

Key design feature
Positive feedback in an autocatalytic Life—Environment system



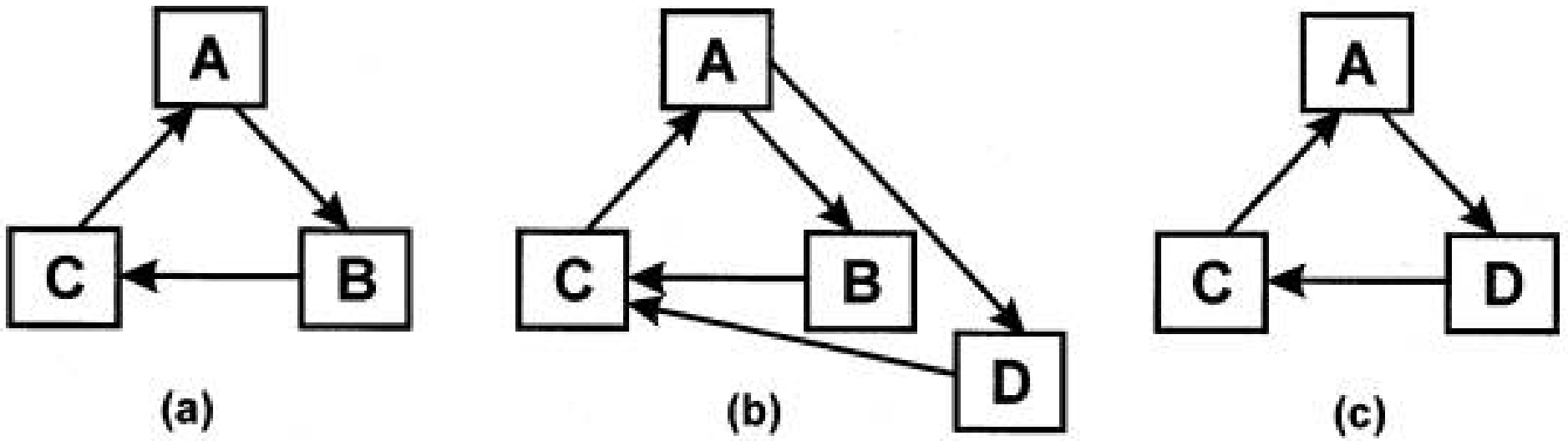
Everything operates as a web of interdependent co-developments

- The fittest panther in the jungle is a goner if its habitat goes. And what is habitat? It's an intricate, complicated web of interdependencies

- The ensemble itself made the environment rich by expanding.

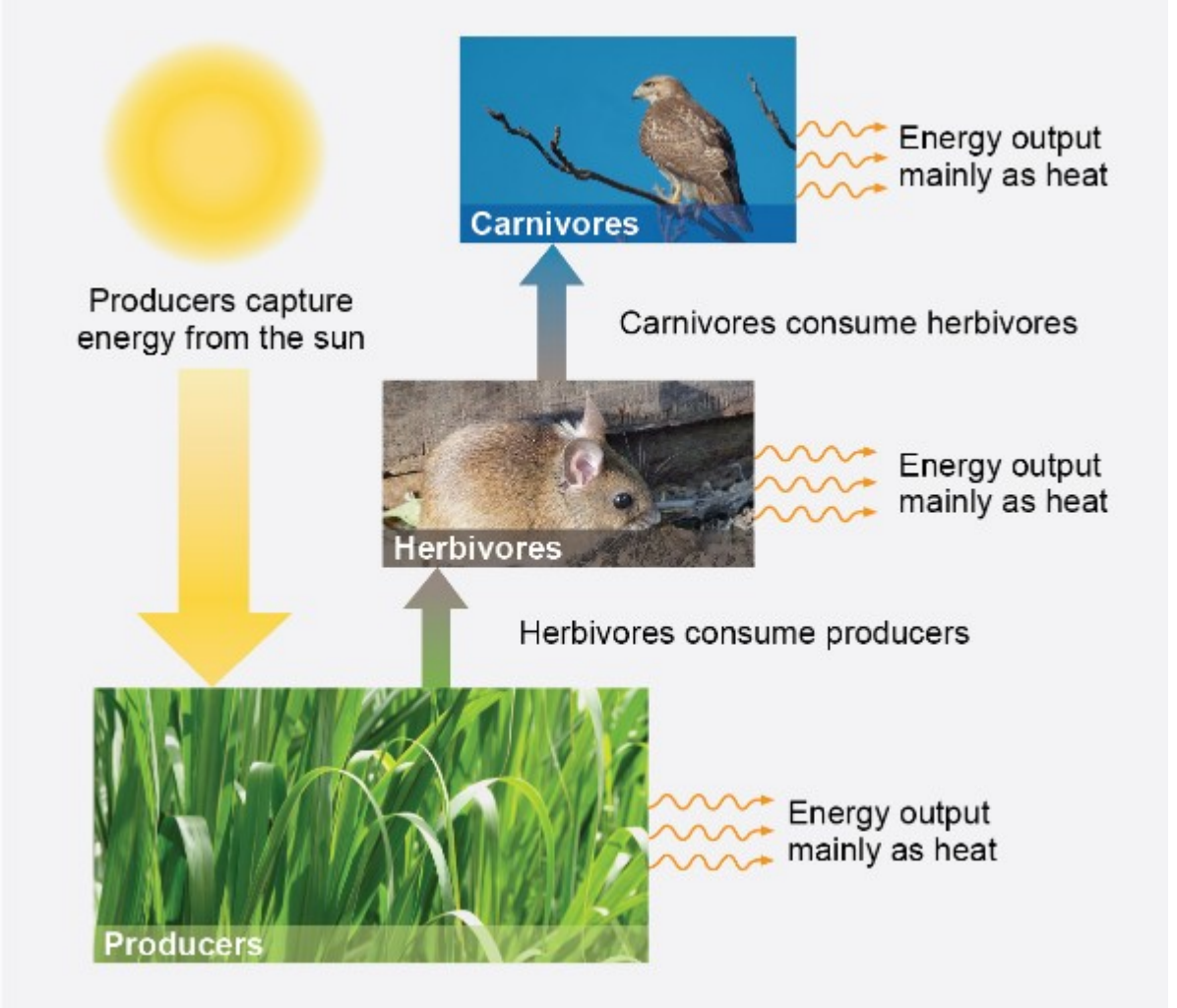
As the community assembly process forms a food web, it selects only species that fit into the existing web

Competition is occurring within a cooperative network



Open systems to energy flow

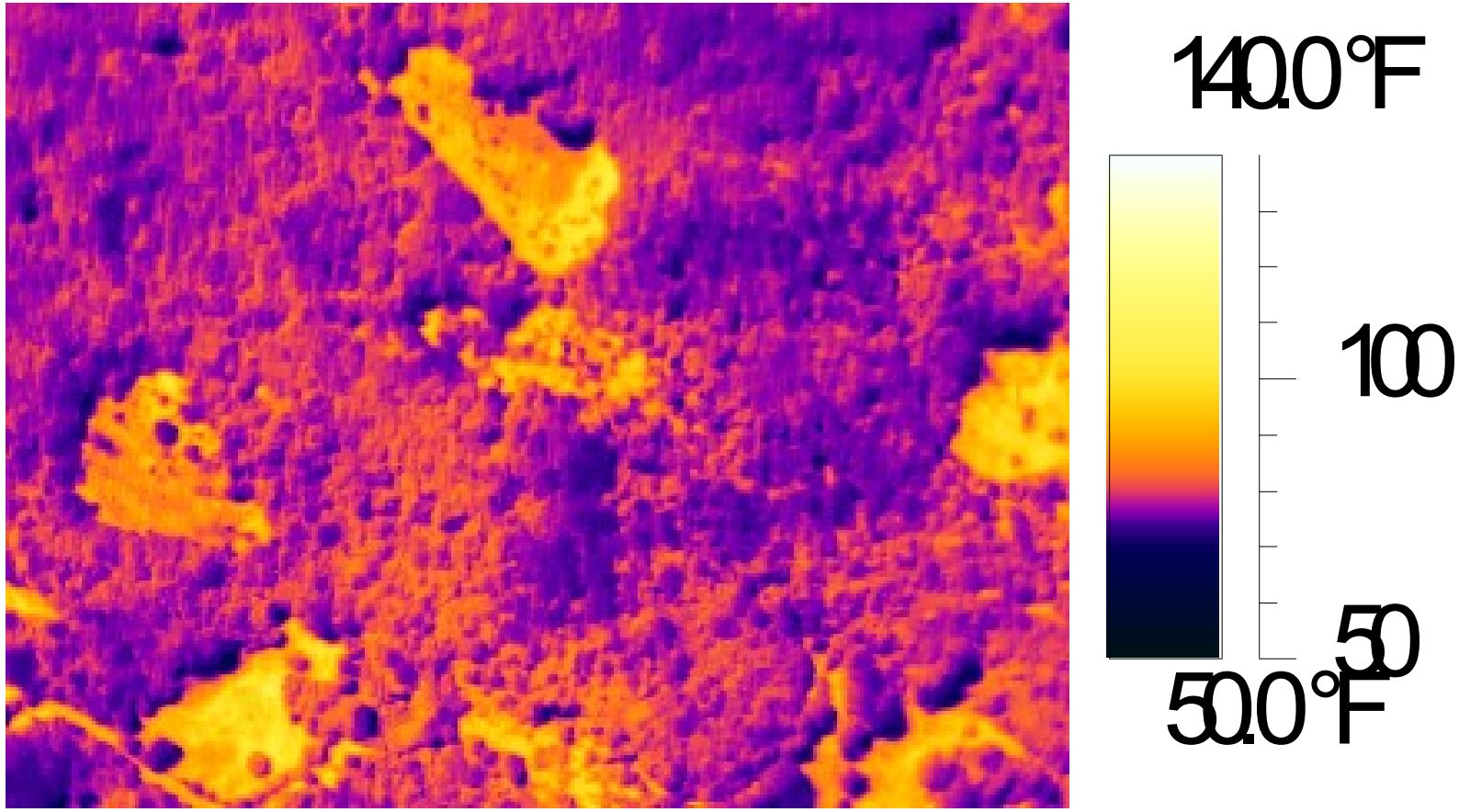
- A self-sustaining system needs infusions of energy from outside itself.
- The second half is energy discharge
- So an ecosystem can be thought of as a conduit through which energy passes, with many or few transformations of energy/matter during its trip through the conduit. The interesting question is what happens in the conduit.



Organization matters

- Desert – energy passage is swift and simple leaving little traces of its passage
- In the forest, energy flow is anything but swift and simple, because of the diverse and roundabout way that the system's web of teeming, interdependent organisms uses energy.

Thermal radiation from different biomes – the forest captures and utilizes more of the energy, with it creating complex and diverse structures.



Debeljak, 2004

One major barrier is the dominant idea in mainstream science now – to treat the fundamental working unit of Nature as a “mechanism” – we have turned the world into the machine we have pictured it to be.

The suite of systemic problems listed above – showing a world and natural life support ecosystems literally “running out of gas” and “breaking down” in myriad ways – is not typical behavior of natural living systems.

On the contrary, natural living systems normally self–organize continually and self–repair after disturbance. They grow, develop and improve in environmental quality over time (O_2 atmosphere, O_3 layer, soils, water purification, etc.)

These demonstrate the normal behavior of healthy Life systems is a win–win where life and environment both improve over time.

Life-environment interactions are self-organizing, self-regulating, and self-enhancing:

They make the overall conditions better for life as evidence in the greater complexity, diversity, and total energy utilization

Comparison of systems: Natural, Agriculture, Urban

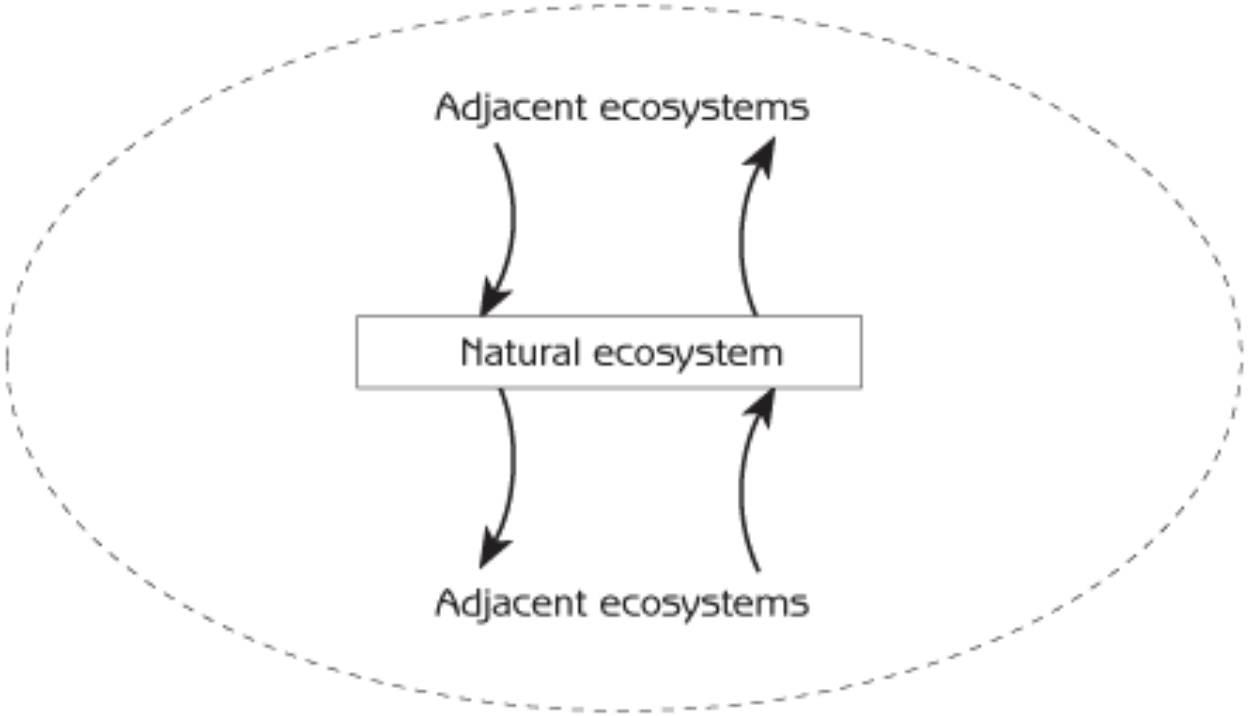
How big are the input-output flows?
Are the inputs renewable?
Are the outputs renewable (able to be used by others)?

Natural ecosystems are self-organizing, self-sufficient, and self-sustaining

Inputs are renewable

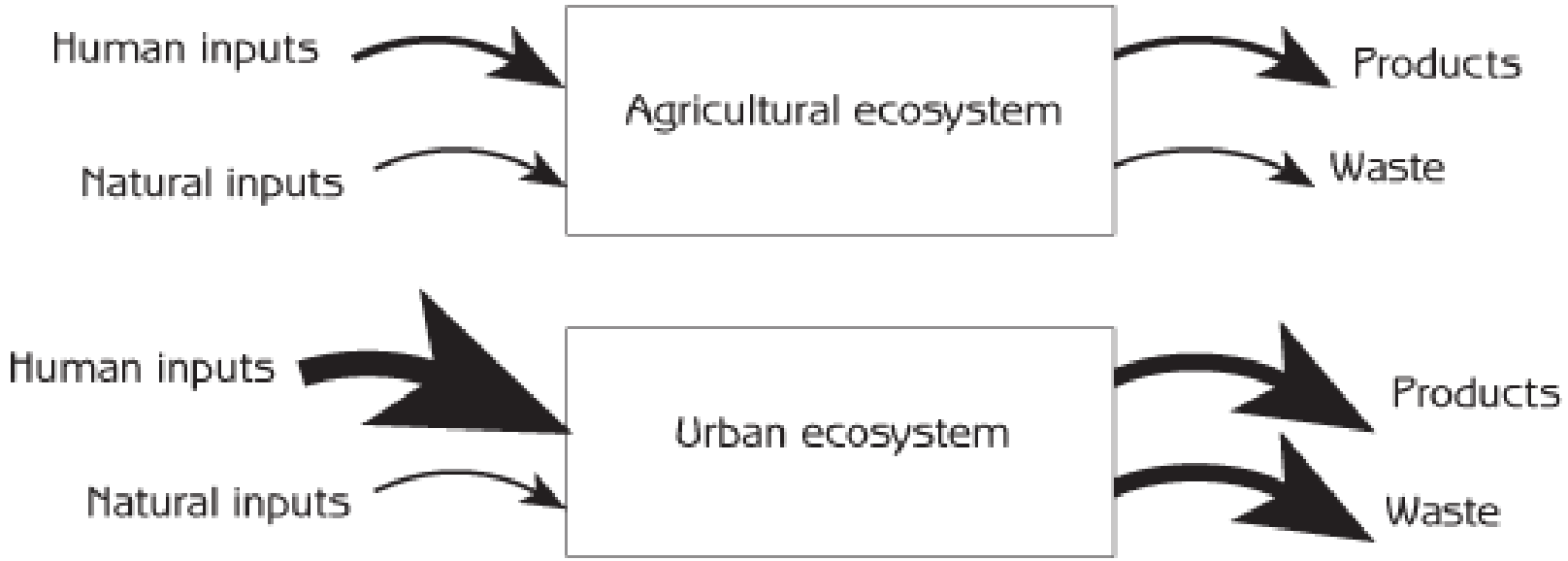
Inputs are small since the evolved mechanisms for holding onto materials

Outputs have use by others in the ecosystem



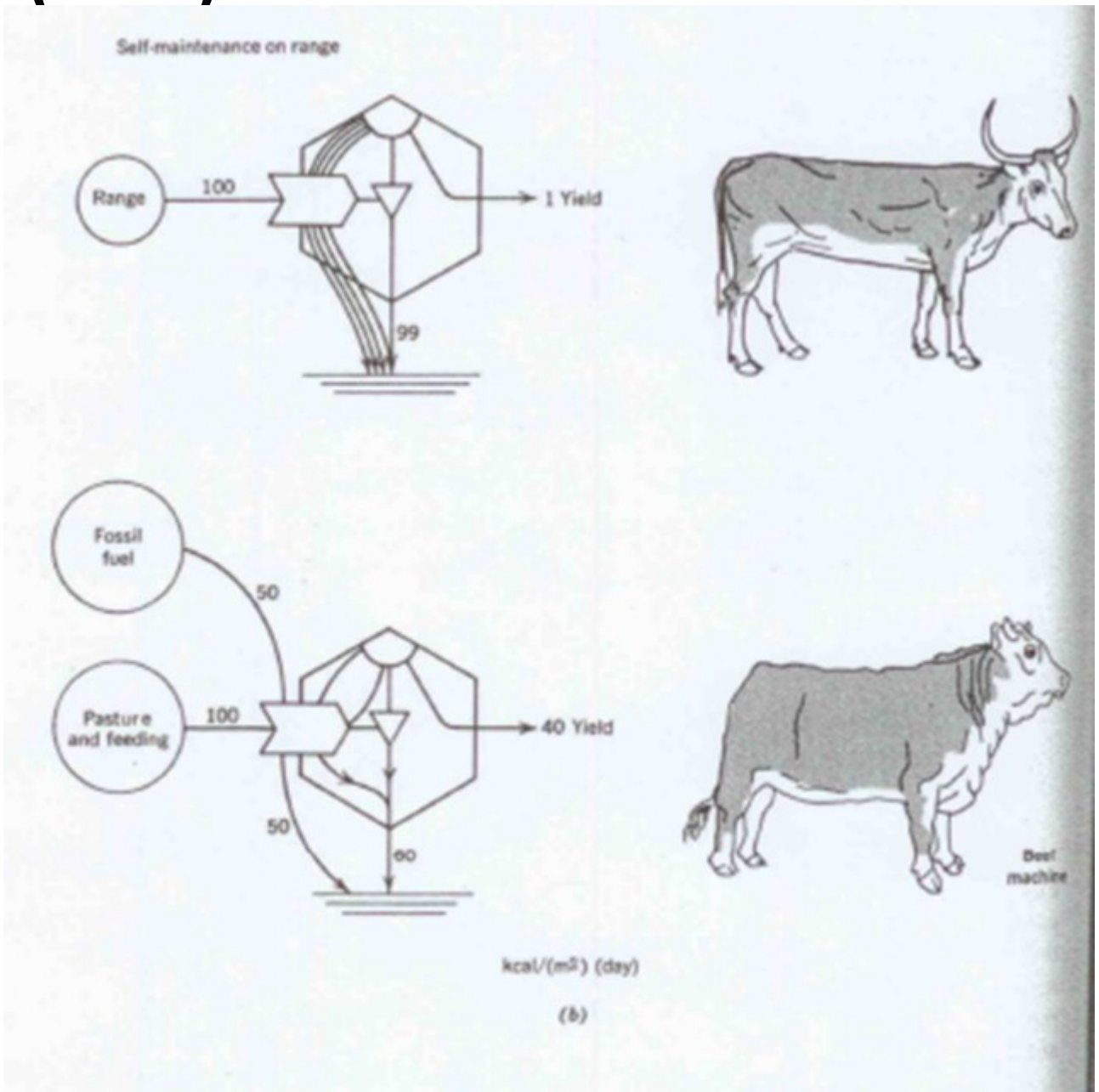
Agricultural and Urban are managed for specific purposes

Inputs are often largely nonrenewable
Inputs are large to meet the specific end
Outputs are large in terms of products and waste



Environment, Power, and Society (1971)
HT Odum

Role of thermodynamics and energetics in human society



Ways of farming meat

Pastureland

Ways of farming meat

Rangeland

Ways of farming meat

Factory farming

Google maps/satellite
Dalhart, Texas

URBAN SYSTEM BOUNDARIES

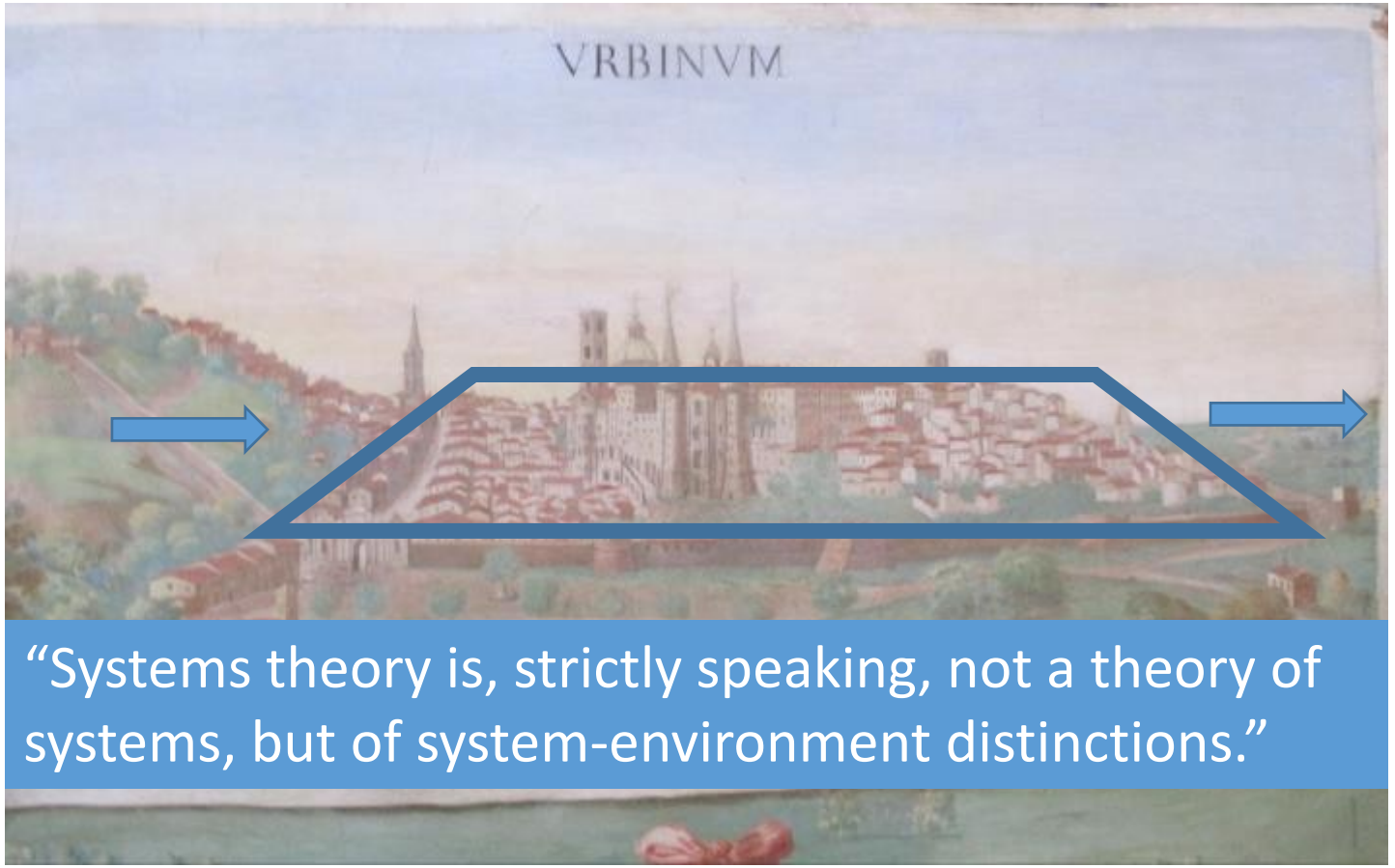
Open system with connections and dependencies on the countryside


59A
Jimbolia
S.C. Adient S.R.L.
59C
59A
59A
59A
Granični prelaz
Srpska Crnja
Srbija
Srbija
Srbija

A. City as system

Inputs: air, water, food, fuels, raw materials, people

Outputs: waste heat, finished goods, ideas, wastewater, solid wastes, air pollutants



"Systems theory is, strictly speaking, not a theory of systems, but of system-environment distinctions."

Environmental Science & Technology

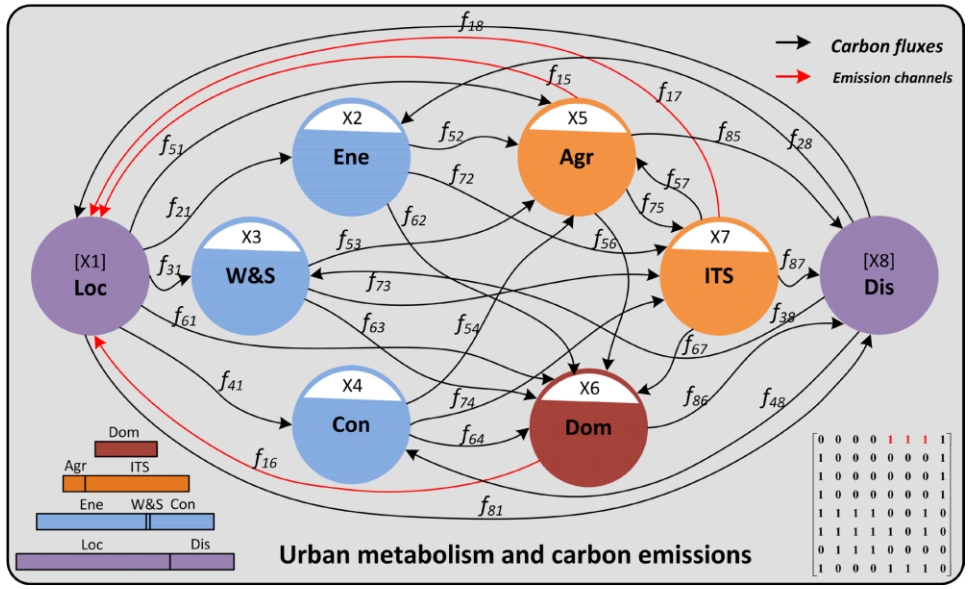
Article

pubs.acs.org/est

Network Environ Perspective for Urban Metabolism and Carbon Emissions: A Case Study of Vienna, Austria

Shaoqing Chen† and Bin Chen*,†

†State Key Joint Laboratory of Environmental Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing 100875, China



Metabolic Network tracking of carbon flows in Vienna, Austria is used to analyze that the major emission sectors (Agriculture, Domestic, and Industry) are most impacted by indirect transfer through the Energy and Construction sectors. This indirect flow analysis allows one to make more effective reduction strategies.

ITS – industry Dom – domestic Ene – energy production W&S – water and soil
Con – construction Agr – agriculture Loc – local environment Dis – distal environment

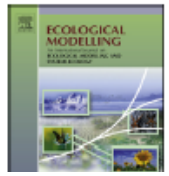
Chen S, Chen B, & Fath BD. 2014. Environmental Pollution 190, 139-149

Quantitative analysis of urban metabolism: nutrients and water

Ecological Modelling 337 (2016) 29–38

Contents lists available at ScienceDirect

Ecological Modelling



Science of the Total Environment 408 (2010) 4702–4711

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journal homepage: www.elsevier.com/locate/scitotenv

Modelling u
network an

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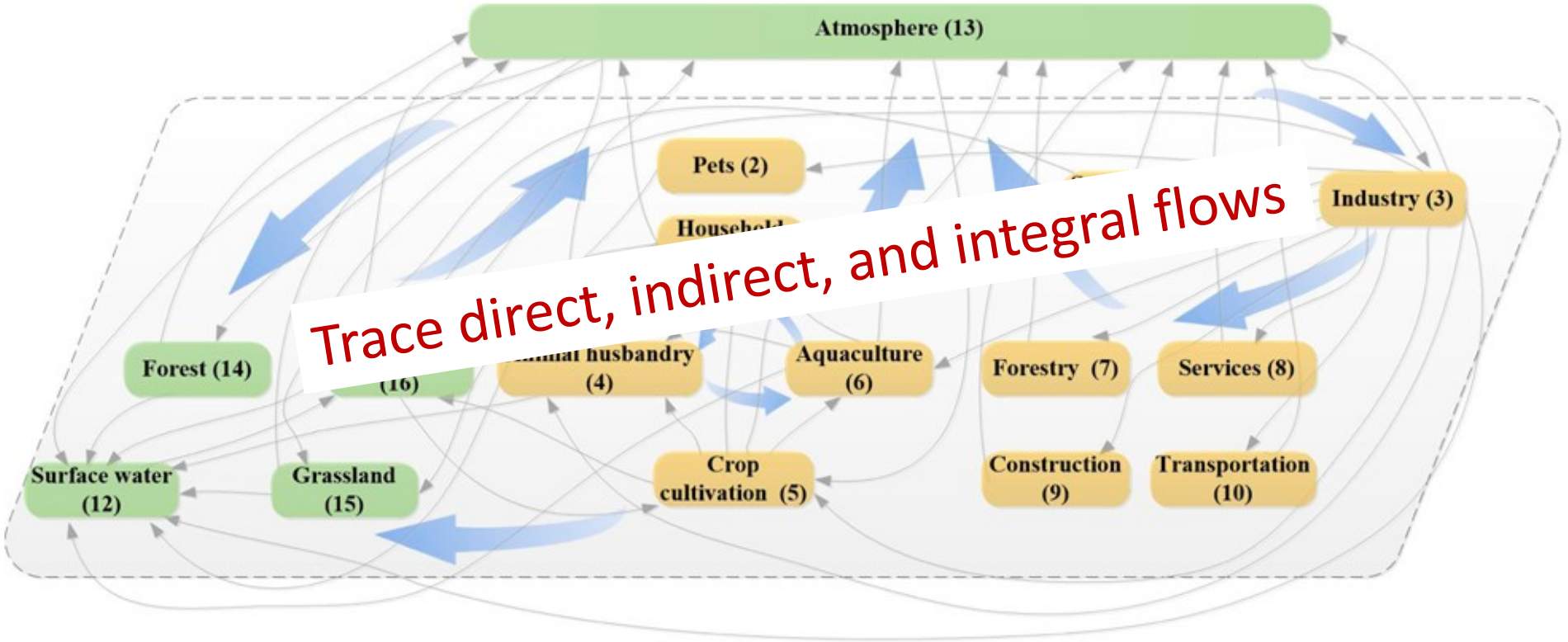
[b] Department of Biologic
[c] Advanced Systems Anal

Ecological network analysis of an urban water metabolic system: Model development, and a case study for Beijing

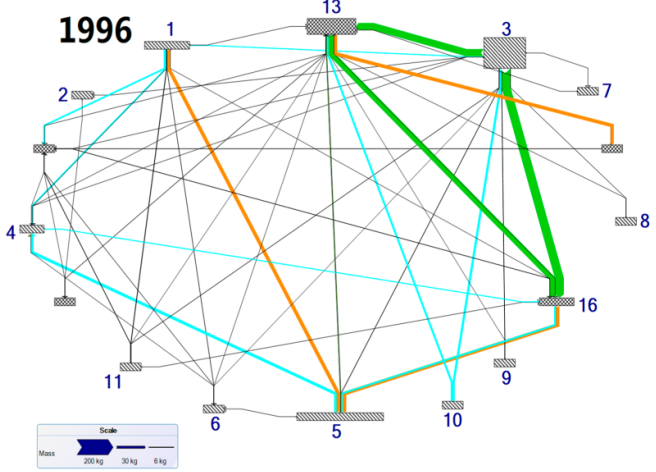
Yan Zhang [a], Zhifeng Yang [a,*], Brian D. Fath [b,c]

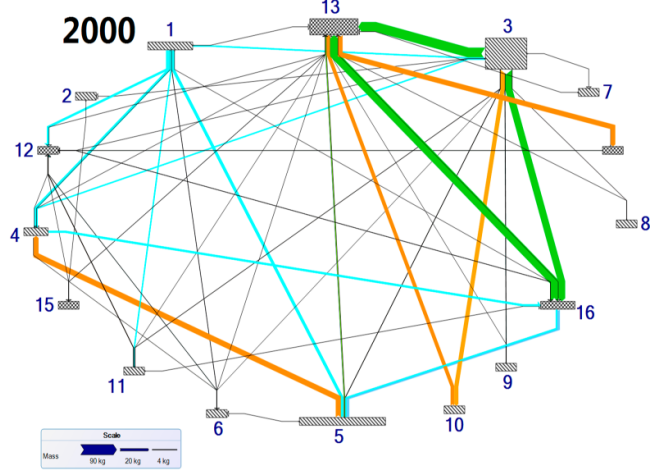
[a] State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing 100875, China
[b] Biology Department, Towson University, Towson, MD 21252, USA
[c] Dynamic Systems Program, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria

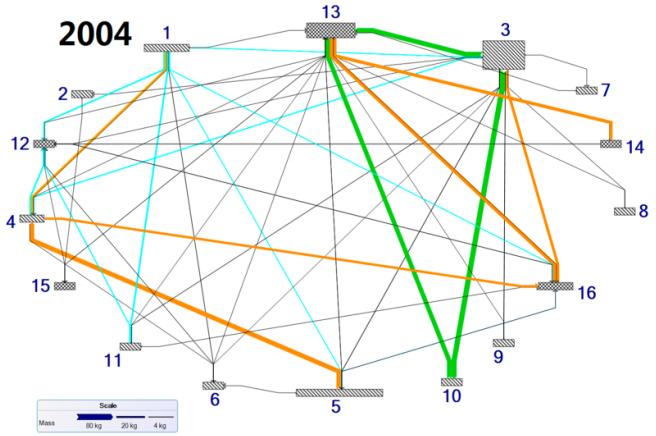
Urban Metabolic Nitrogen model of Beijing

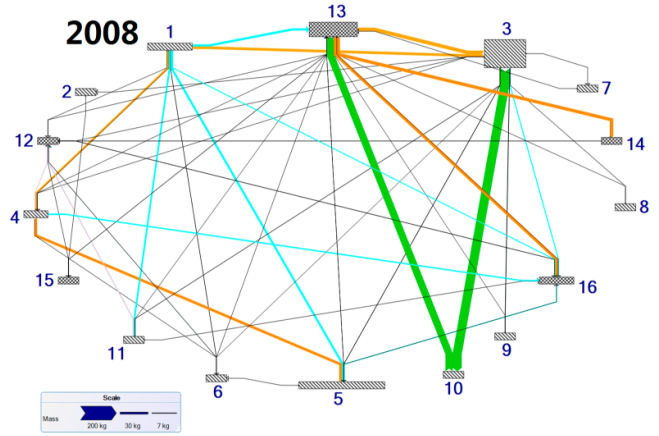


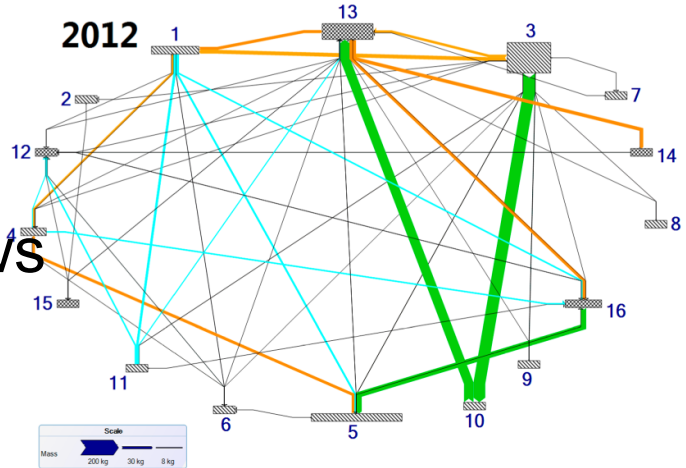
Network model of the nitrogen metabolic processes in Beijing's urban ecosystem



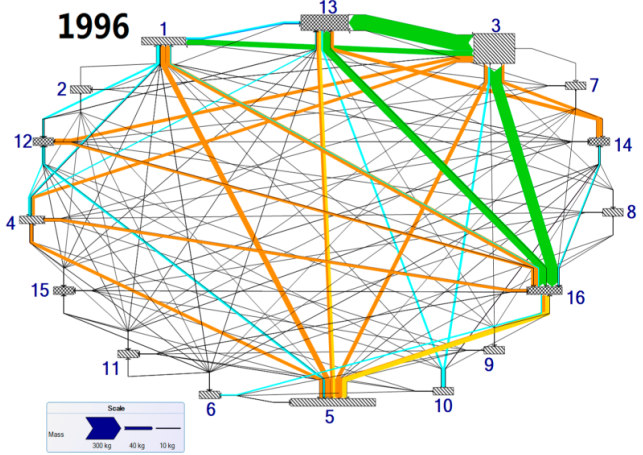


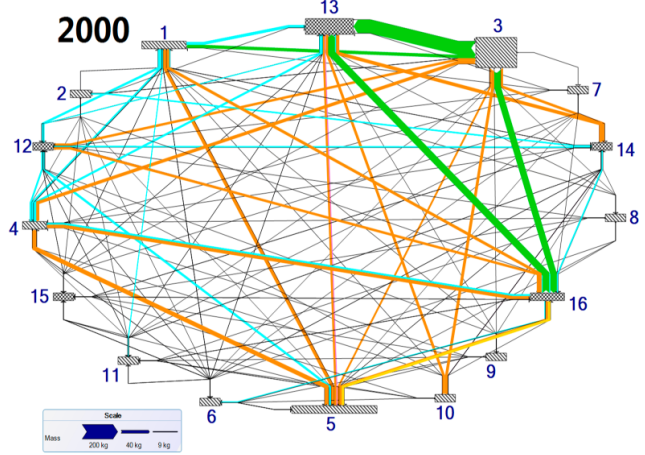


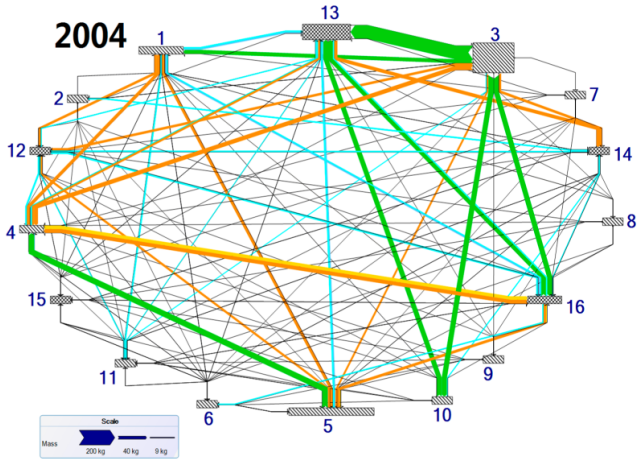


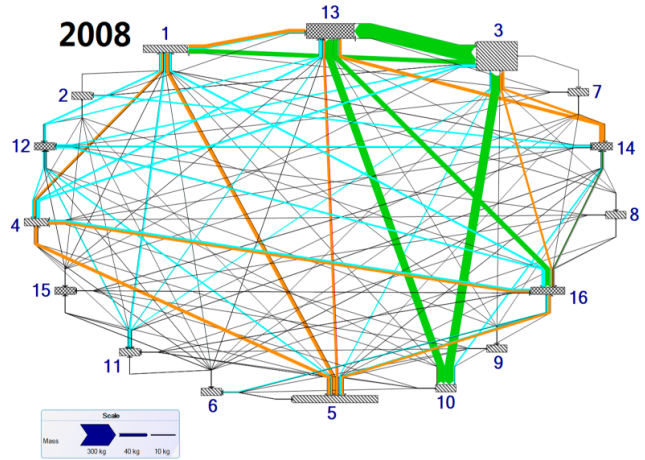


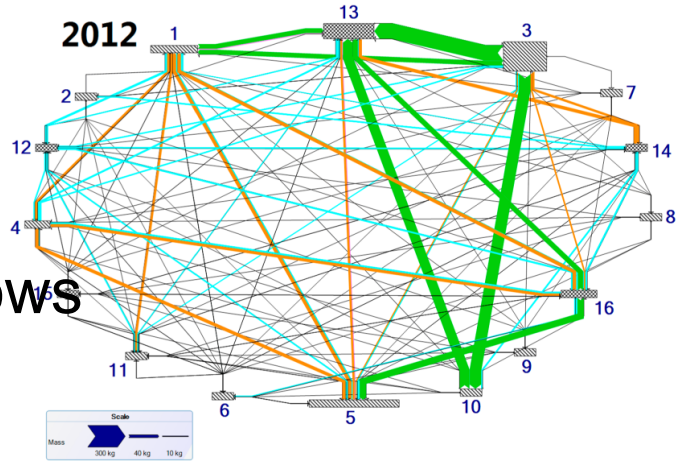
Direct Nitrogen Flows







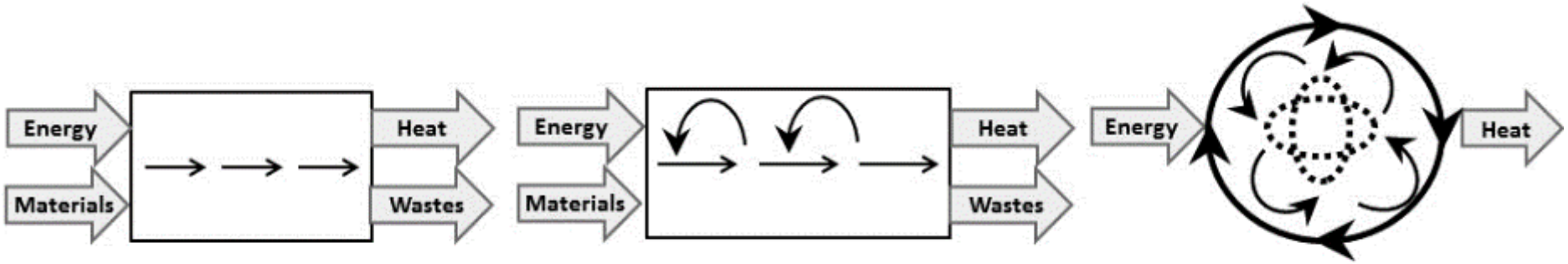




Indirect Nitrogen Flows

Conclusions from urban metabolism

- Cities, obviously, depend on exogenous energy resources
- Urban energetic trophic structure mostly inverted
- Additional energy recovery systems needed
- Households and industry always in competition for final demand energy
- Energy efficiency improvements can help but more importantly are how the energy networks are formed and maintained.



Key feature is forming and maintaining self-sustaining cycles