Systems Thinking for Design

Session 4

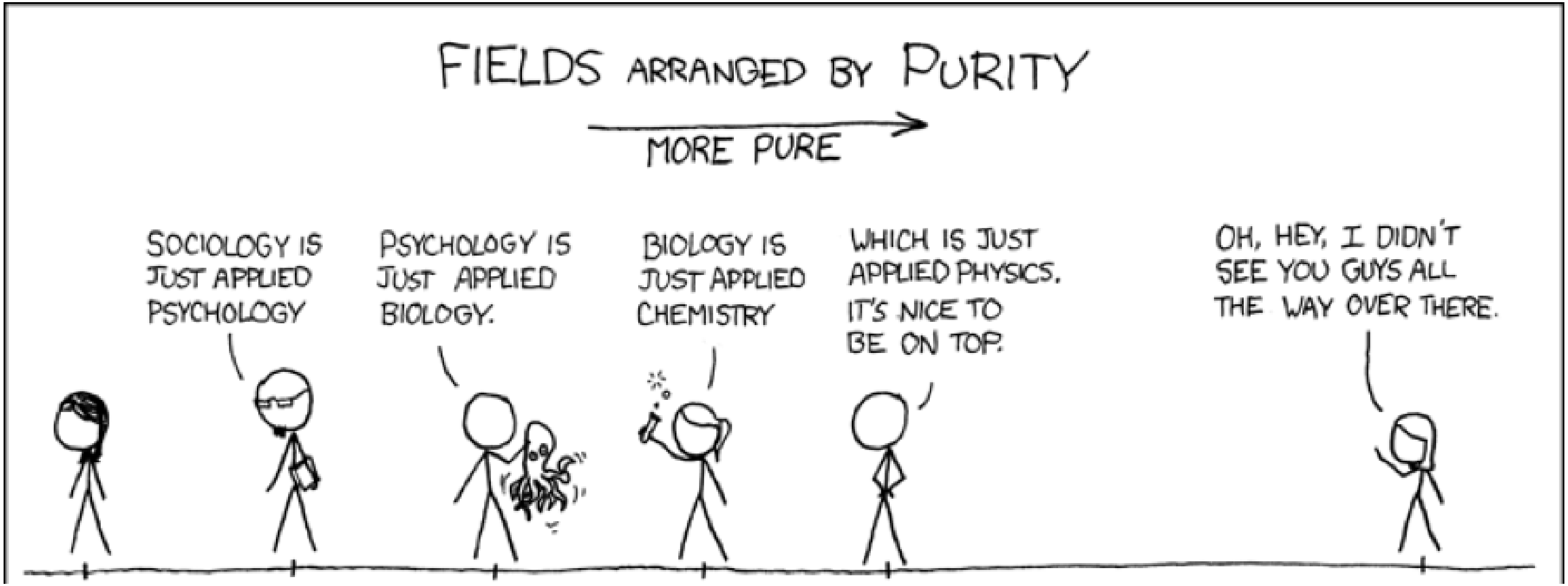
INDIAN INSTITUTE OF INFORMATION TECHNOLOGY, DESIGN AND MANUFACTURING, KANCHEEPURAM

Dr. Karthik Chandrasekaran
School of Interdisciplinary Design and Innovation (SIDI)

Session outline

Introduction to Systems Theory

Problem Structuring using Concept Maps

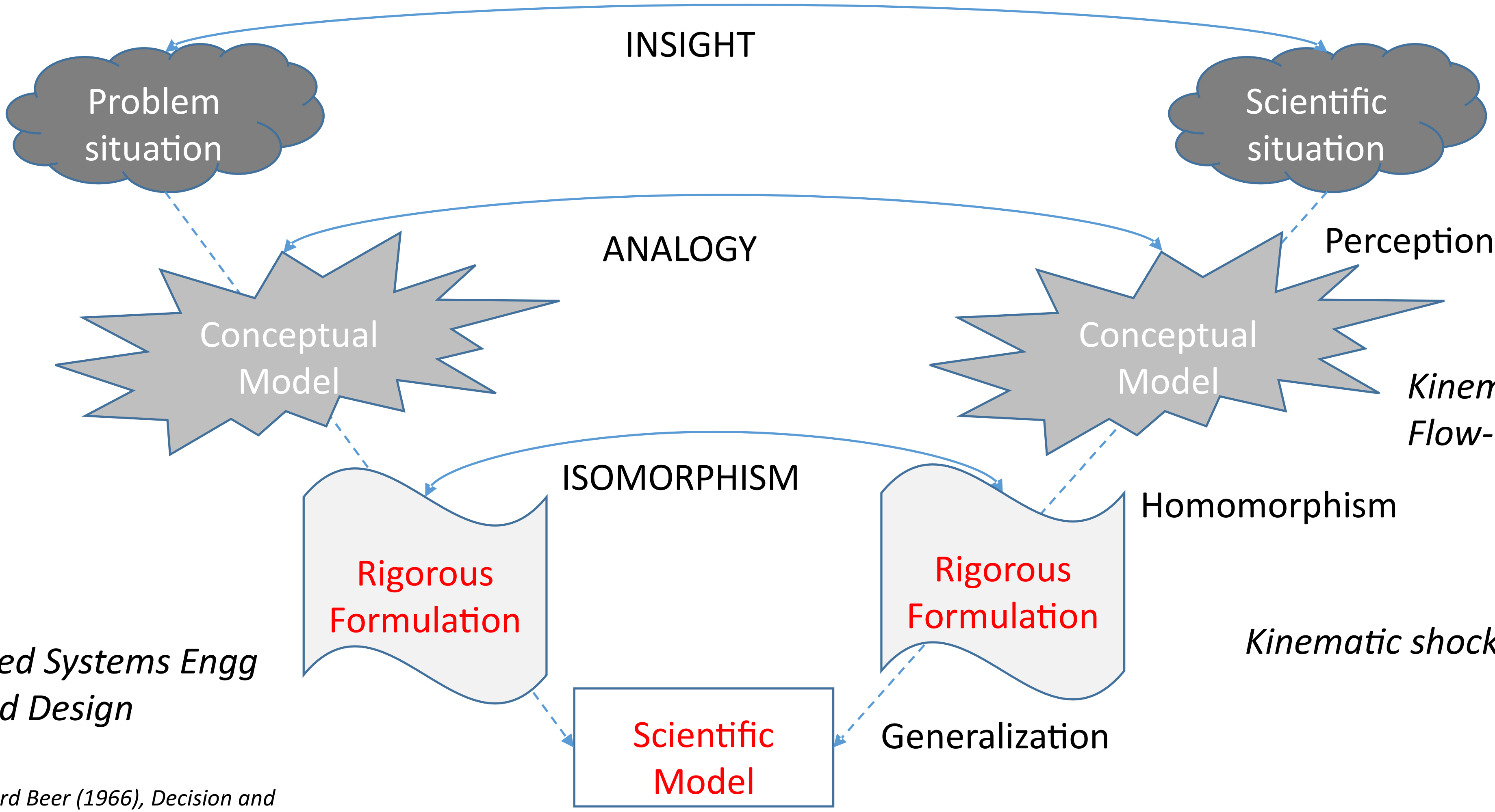


Source: Internet

Inter-disciplinary approach to problems

- The problem of reductionist thinking … limited/narrow disciplinary view
- The challenge of integrating disciplinary concepts … incommensurability
- Dealing with socio-technical problems … in search of common language

Fundamentals of Inter-disciplinary approach



Vehicle Traffic

Fluid Dynamics

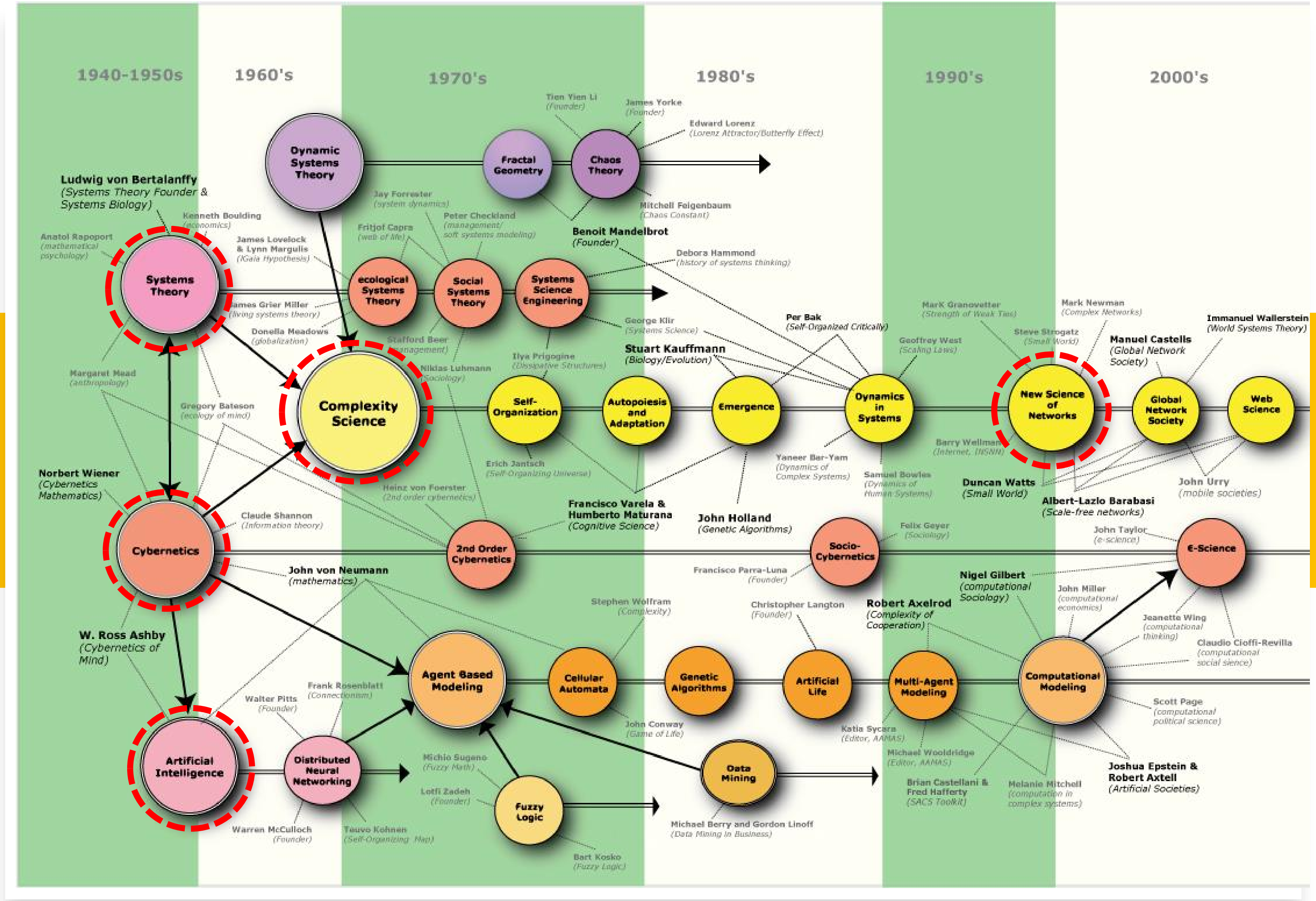
Kinematic model:
Flow-concentration curve

Deduction
Induction
Abduction

Kinematic shock-wave

Model based Systems Engg
Bio-inspired Design

Source: Stafford Beer (1966), Decision and Control

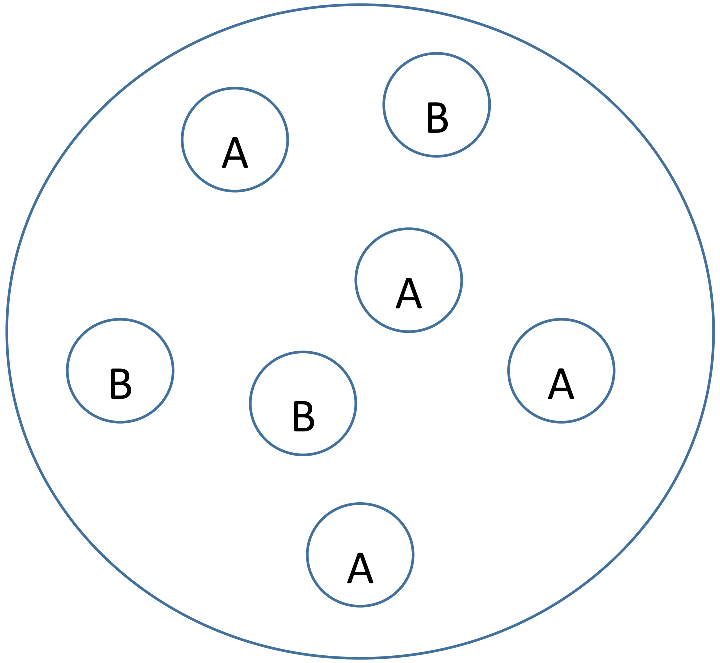


Advances in inter-disciplinary theories

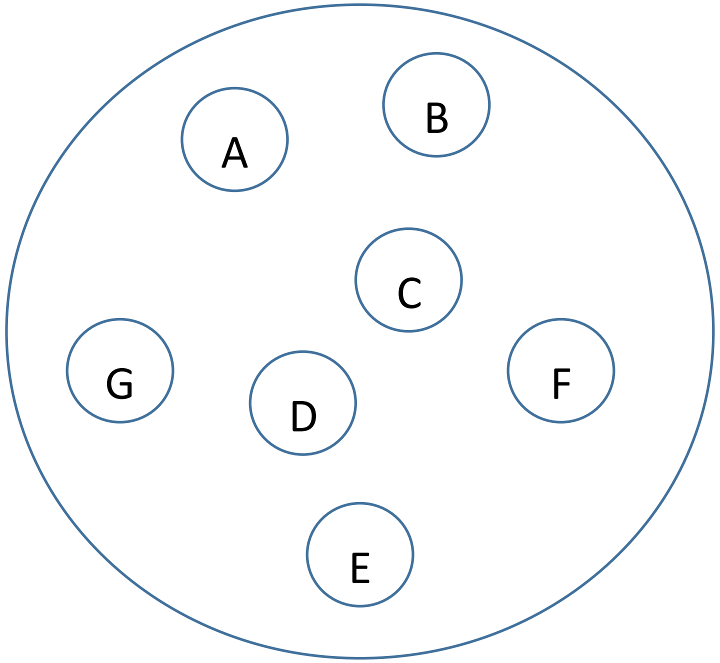
The language of systems … complexity

- Systems, Cybernetics and Complexity as inter-disciplinary concepts & languages
- System / Complexity as a key property of coherent, dynamic, adaptive phenomenon
- Most socio-technical problem situations have good and bad complexity
- Simplification should eliminate bad complexity, not good complexity
- Welcome to complexity!

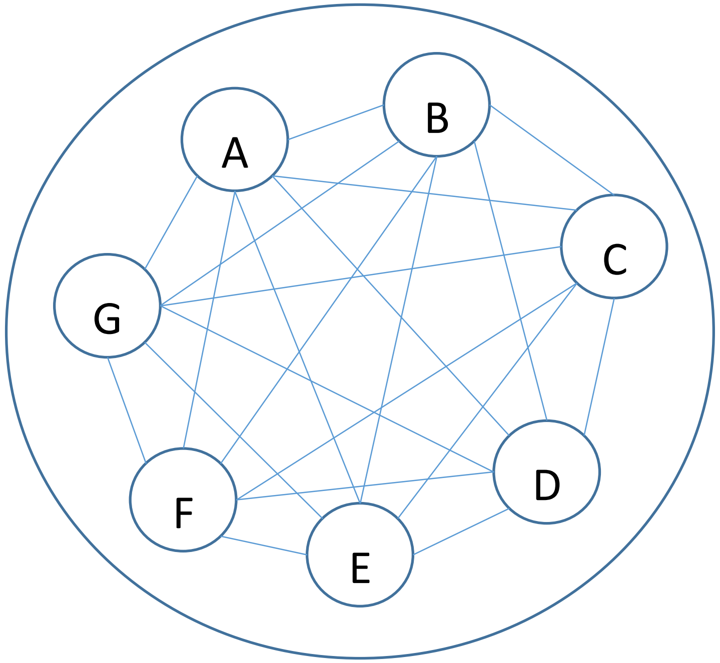
Variety as a measure of complexity (1/2)



A collection of partial similars
Variety=n=2



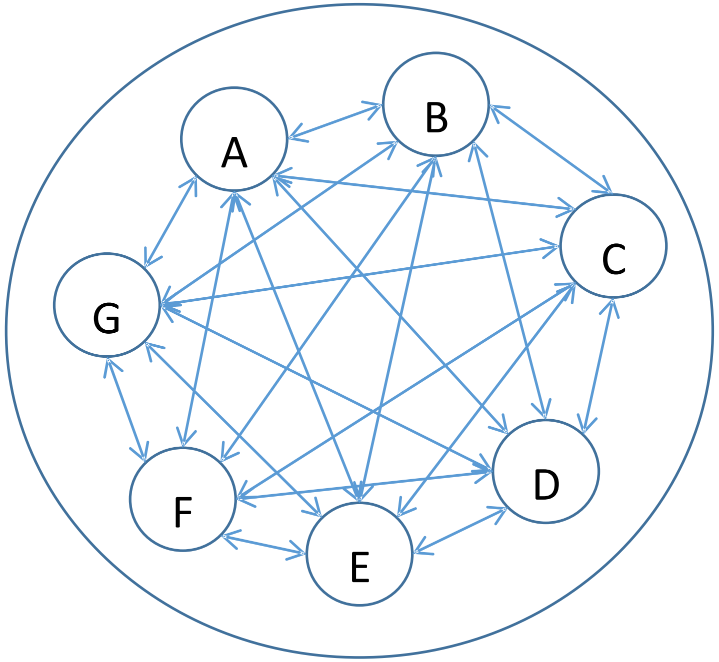
A collection of dis-similars
Variety=n=7



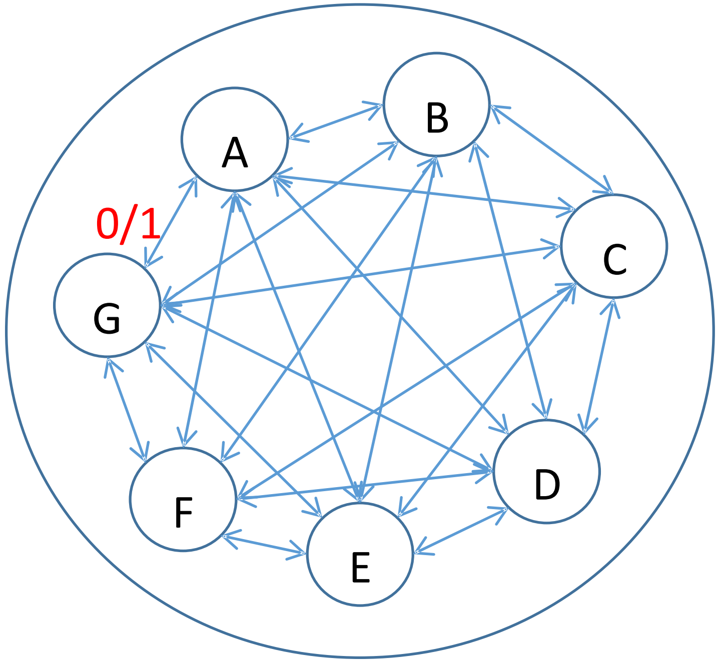
An assemblage of dis-similar (coherence), Variety=k=21 [n(n-1)/2]

Source: Stafford Beer (1956), Decision and Control

Variety as a measure of complexity (2/2)



A systematic assemblage of dis-similars
Variety=k=42 [n(n-1)]



A dynamic system
Variety=2 to the power k

Intelligent, adaptive, living systems ***need to have a high degree of complexity***

Source: Stafford Beer (1956), Decision and Control

Why systems for design and innovation?

System:
A pattern that is coherent and has emergent properties > than the sum of parts

Design:
A pattern that is distinctive, yet contextual – engaging & empathetic

Innovation:
A pattern that has become an attractor – dynamic & growing

Patterns differ in terms of the degree of complexity (a function of N,K,C)

The three concepts deal with different levels of complexity

High complexity

Society/Ecosystem

Organization

Product/System

Sub-system

Component

Low complexity

Weak Cause-Effect
Outcome based recognition

Strong Cause-Effect
Input based recognition

Innovation

Design Thinking

Systems Engineering

Engineering Discipline

Complexity Theor y

Aspects to be learnt	FORM	FUNCTION	BEHAVIOR	STRUCTURE	PROCESS	E&M	E&M
		Function	Behavior	Structure	Prototyping	Mobilizing	Leading
Social aspects	Form	Team forming & storming / Iterative	Team Norming / Interactive	Performing / Integrative	External Negotiation / pitch	Beyond a team… network	Paradox-Reflexive-Leadership
Mnf Industry Focus (Space, Auto, M/c Tools, Proc Industries)	Observe Product Sketches in these verticals / history	Understand emerging needs in these verticals	Understand desired product behaviors in these verticals	Understand structures in these verticals	Build prototypes relevant to these domains	Understand competition in these verticals	Understand ethical issues in these verticals
Why & How to achieve Inter-disciplinary Synthesis	Art-Part, narrative writing & Sketching for thinking & com	Simple -complex Systems as a common language	Technical-Social ANT, Network perspective, Semiot	Creative Synthesis of M/E/I Abductive / Metaphor	Product-Process (Design Manufacture)	Tech-Design-Business	Social-economic-ecological
Customer Focused		Stakeholder Analysis / Need Identification	Customer / unstated needs / user contexts	Customer/user perceptions of form – affordances/signs	User reviews & usability	Customer Value / Market Insight	
Product Level First	Exterior form	Product-Env (Deriving product level functions)	Defining product level behaviors / attributes	Product level structural decisions (Form-Beh-fn Fit)	Concept eval, MVP, prototyping choices – COTS/AM/SRP	Product-Enterprise fit	
Understanding patterns that hold the whole (System-Sub-system-Component-Part)	Unbundle and reassemble …	Derive Functional Hierarchy	Functional arch to support desired behaviors (smart)	Component / technical arch & Bs		Strategy-Orgn-Process/Fn	
Lifecycle perspective (Time)		Likely evolution of function-env over time	Likely evolution of behaviors over time - Reliability	Likely evolution of structure over time	Process Quality	Business plan	
Techniques and Tools	Concept sketch / 3D rendering / Physical realization	Issue map / SNAC / ISM / SysML–Fn	Ethnography / Rich Ps / VSM / SysML- Be	Biomimicry / Morphology / SysML-Str	PUGH / TRIZ / MVP/ Config Mgt / Prog Mgt, RP Tools	Porter's f/w, Lean startup, Cost & Financial Models	CSH?
Point of Passage	Notebook used to represent house	Cloth on table to create space	Core quality using form & fn	House using bamboo etc.	Working PoC – house with bricks	Seed customer	

Emergent Whole & Part (n)

- Anything is a whole which operates in quasi-independence of its environment. Example, a rock, a mammal, an apple, a committee
- Parts are the immediate basic factors into which wholes can be analyzed, and they are of a certain quantity… example, a rock analyses into parts as crystals, an apple into such parts as skin, flesh and seeds
- Sub-parts are the second level of analysis. They are immediate factors into which parts can be analyzed. Example, a crystal analyzes into molecules, apples flesh into cells
- Wholes can be parts of still larger wholes, and sub-parts can be analyzed into sub-sub-parts. Example, rocks are part of mountains, apples of the tree-system, and molecules can be analyzed into atoms, and apple cells into molecules
- Systems and Complexity differ in the way they view parts and wholes… in complexity wholes are emergent properties, whereas in systems wholes are treated as a level

Source: Emery (1969), Systems Thinking

Types of relations (k)

- Transitive: Relation of two parts through a middle part
- Symmetry: Where interchange of parts does not involve any change in the relation
- *Additional types of relations can be a combination of the above. For example, seriality is the relation which is transitive and asymmetrical*
- Correlation: A relation between two series such that for every part in one series there is a corresponding part in the other series
- Dependence: Relation in which the existence of one part is conditioned by some other, example, limb of an animal is dependent upon the circulatory system

Source: Emery (1969), Systems Thinking

System = Function of Parts, relations, content/rules

- The rules or principles according to which all relations fall together into one controlling order that makes an organization or a system. The level of complexity depends on the degrees of freedom of parts, relations and rules

- Systems and complexity theories differ in the way they treat the rules or principles. Complexity assumes that rules of interaction between parts (local) decides emergence … flight of geese, whereas systems looks for rules or principles in the purpose of the whole (macro)

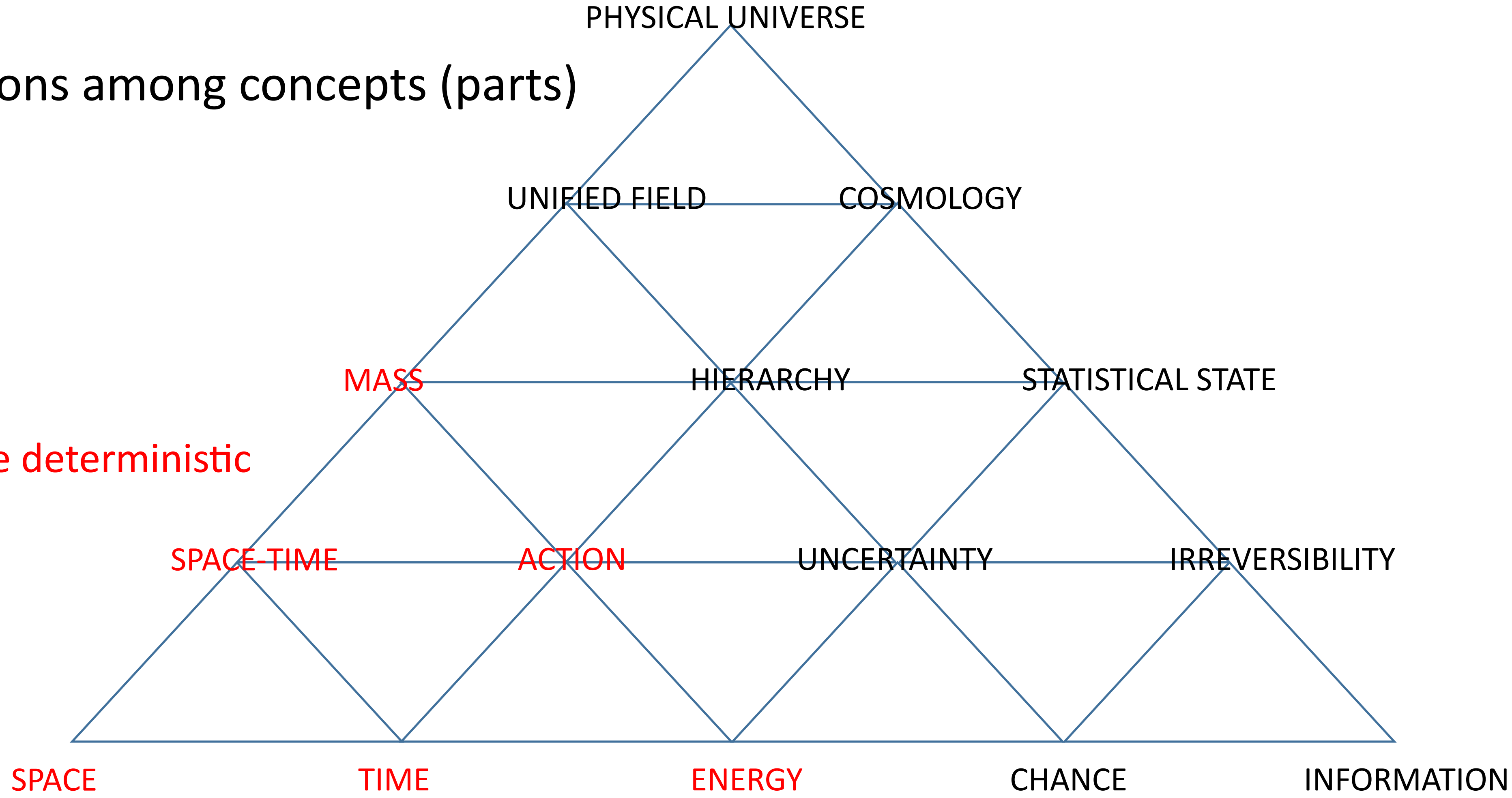
- Boundary, Environment, Closed and Open Systems
  - Boundary can allow/prohibit exchange of matter, energy, information with the environment
  - Boundary judgments (what is inside is sacred, what is outside is profane)

Source: Emery (1969), Systems Thinking

A Systems View of Physical Sciences

Relations among concepts (parts)

More deterministic

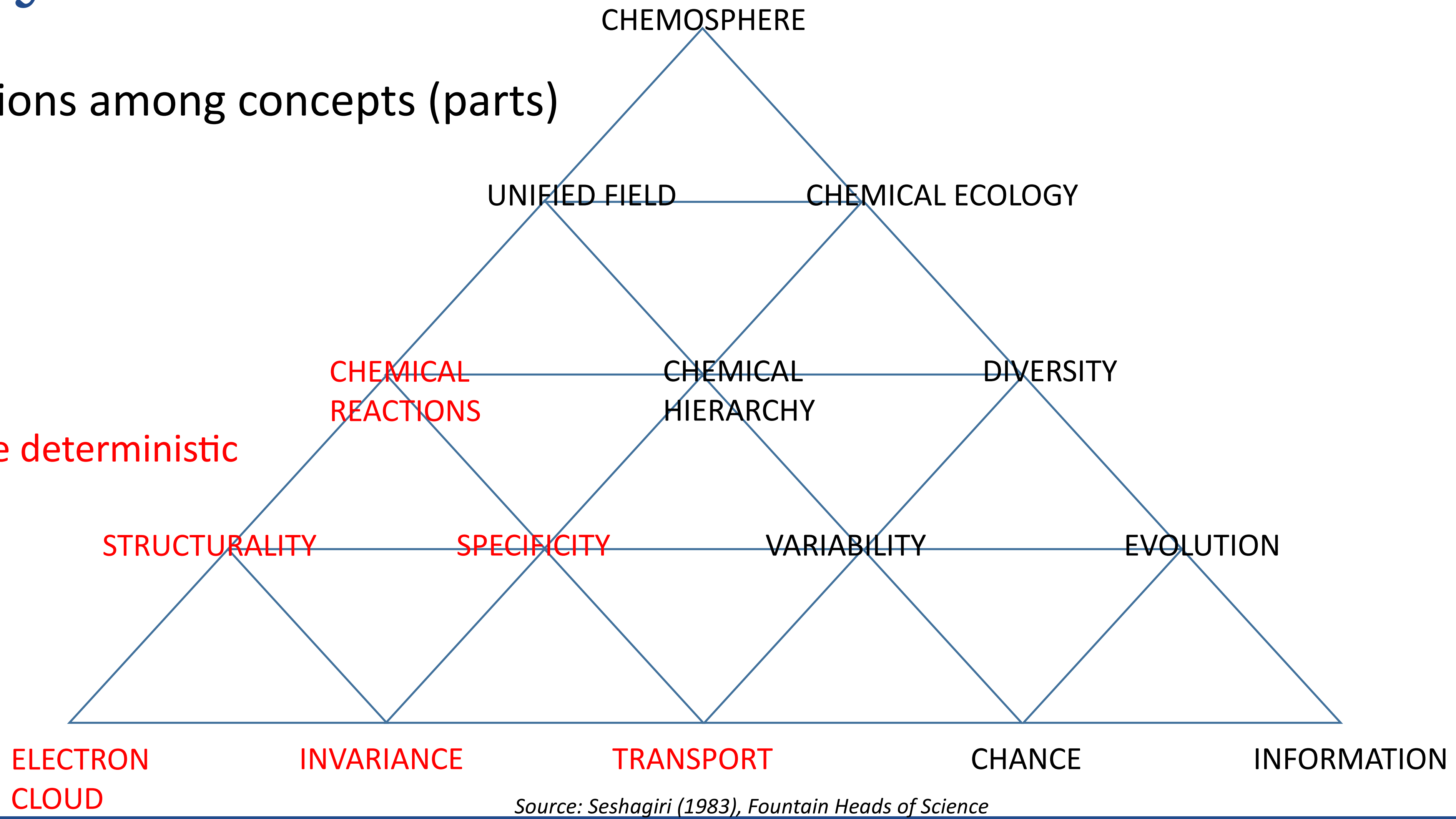


Source: Seshagiri (1983), Fountain Heads of Science

A Systems View of Chemical Sciences

Relations among concepts (parts)

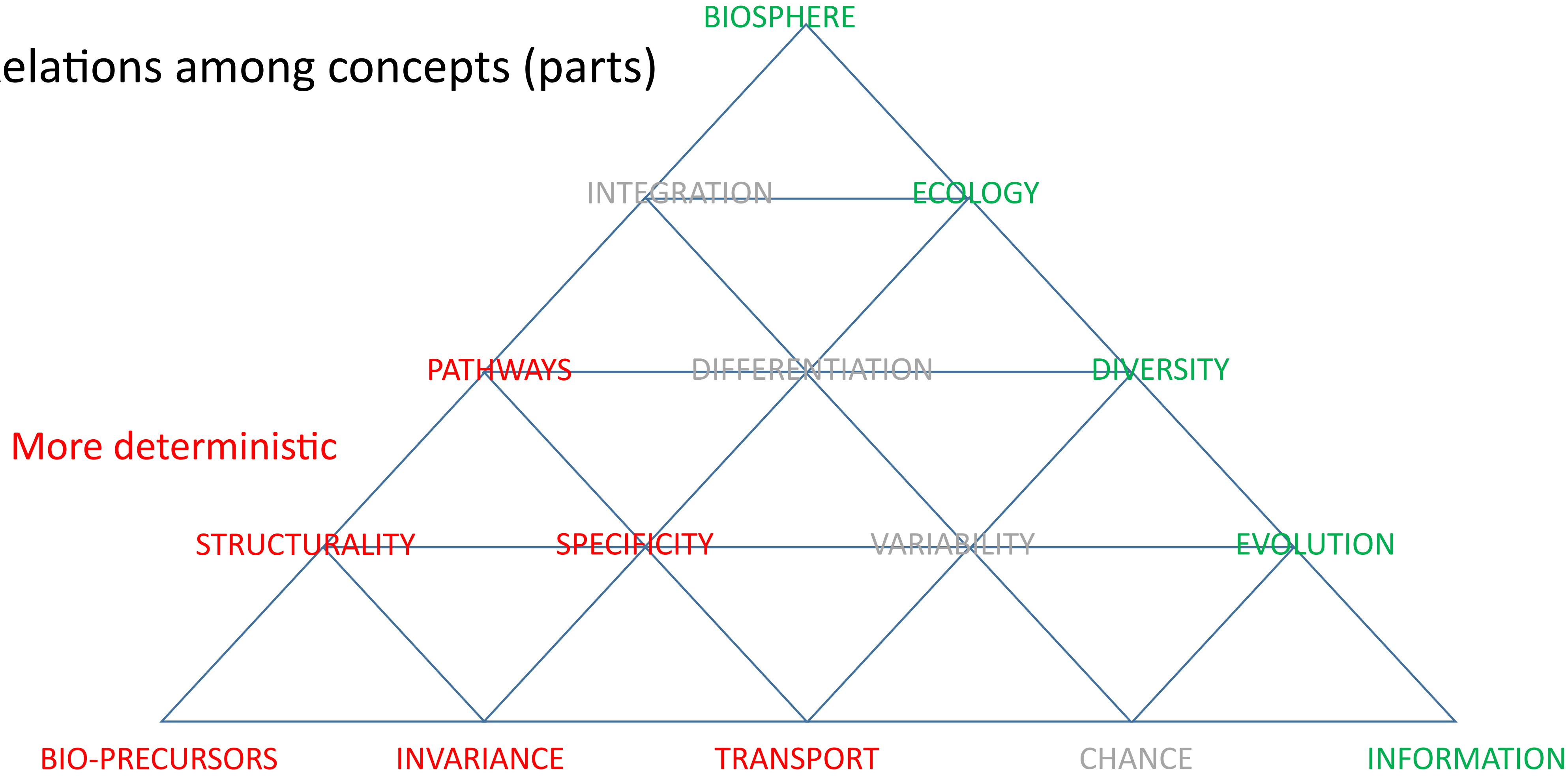
More deterministic



Source: Seshagiri (1983), Fountain Heads of Science

A Systems View of Biological Sciences

Relations among concepts (parts)



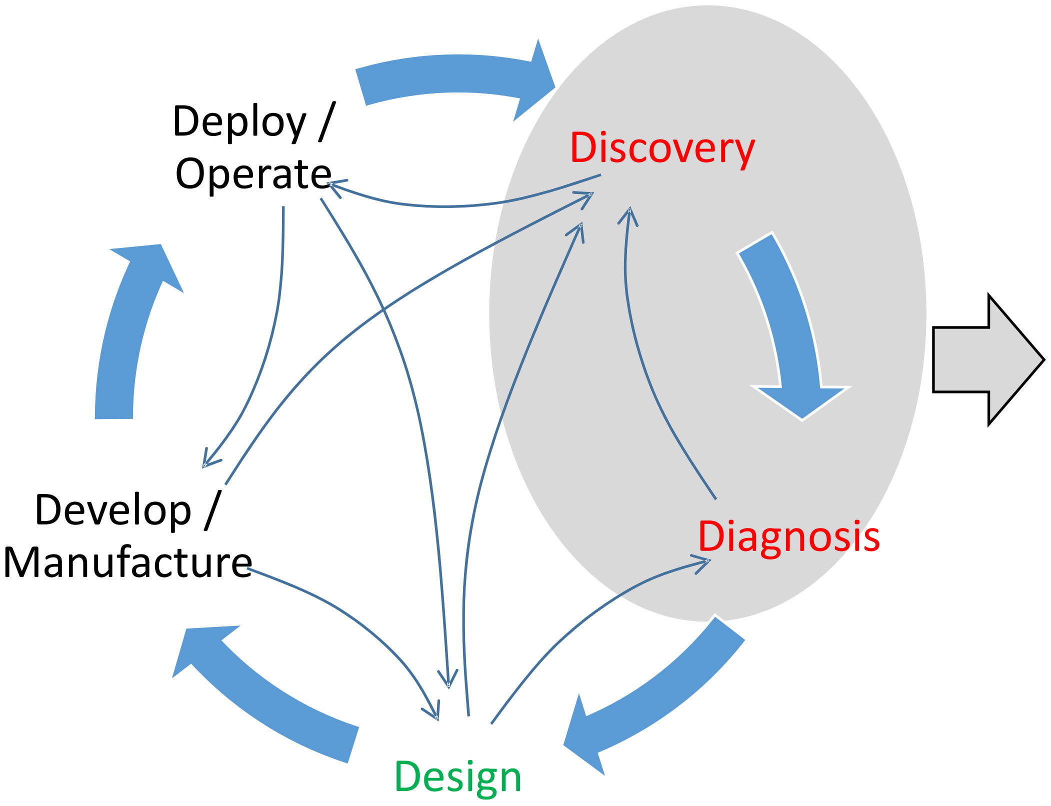
Source: Seshagiri (1983), Fountain Heads of Science

Session outline

Introduction to Systems Theory

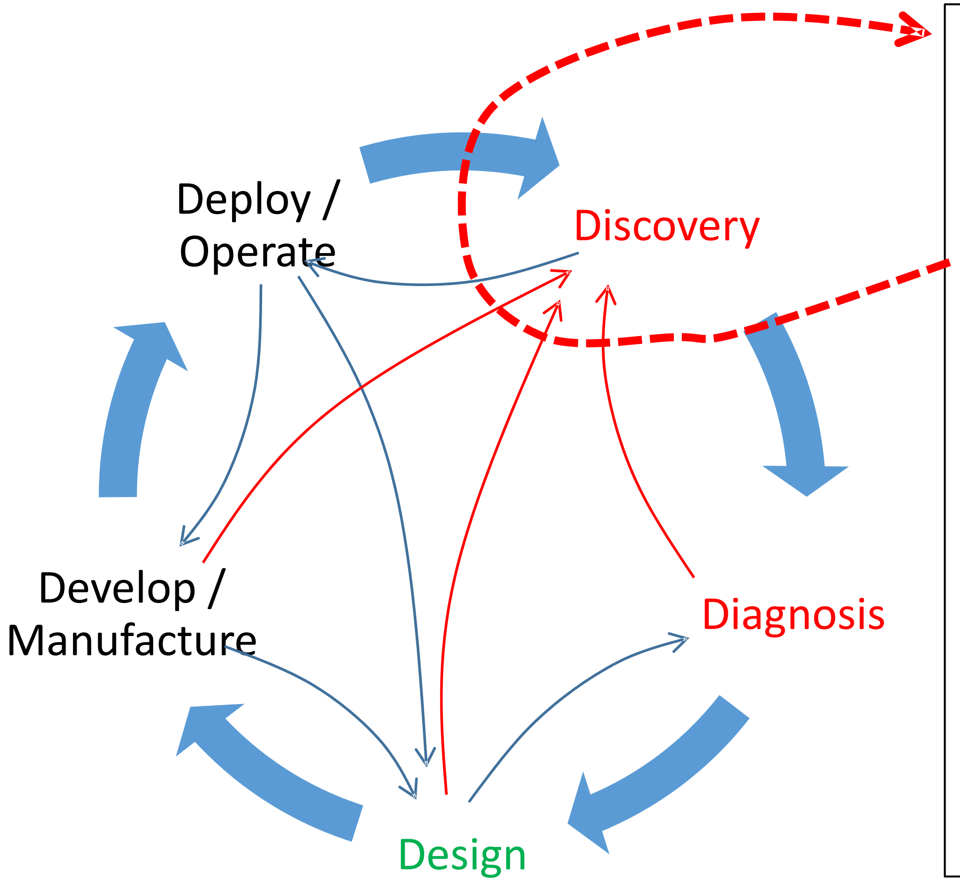
Problem Structuring using Concept Maps

Fuzzy front-end of product design



This is the fuzzy front-end (FFE) of product design (a chaotic phase with no clear cause-effect rules)

Data for discovery



All these influences are potential sources of data for discovering new product concepts

Usually involves people from different divisions, with different specializations and priorities

Important that whatever role you chose, you are sensitive to problem discovery

Data collection methods: should increase complexity for better problem understanding

Qualitative & Quantitative data from primary (observation, interview, group techniques) and secondary sources (research, reports, news items)

Images, Voice, Text, Data

Problem Description Document

(discovery matrix)

Multiple sources

Different Data types

Outcome of Discovery

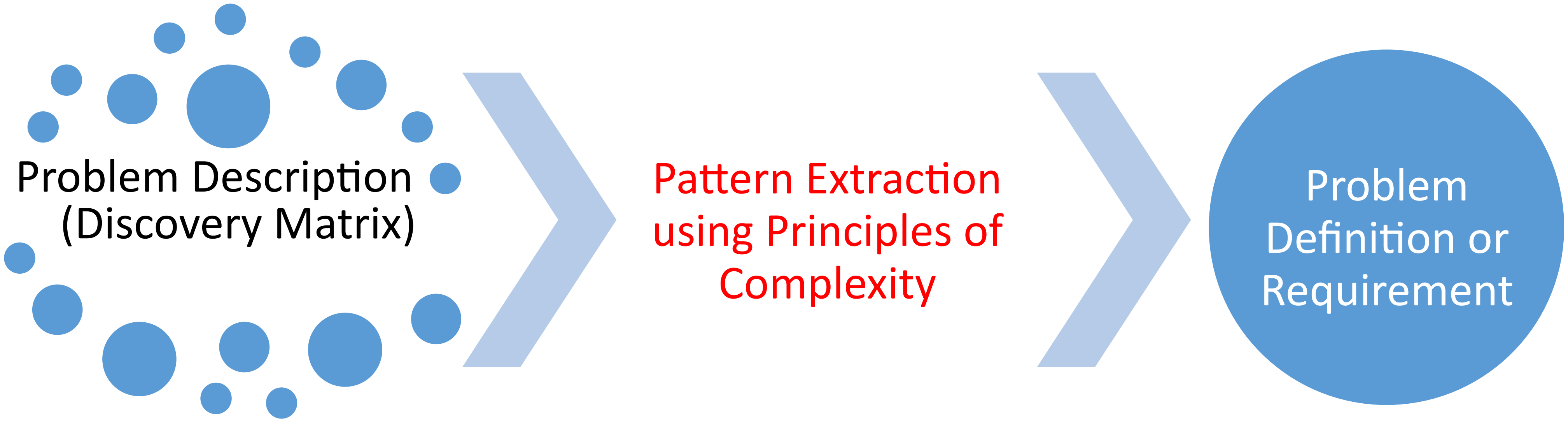
Tools like Nvivo support this entire process, largely in academic research

Discovery matrix: starting point for diagnosis (qualitative research)

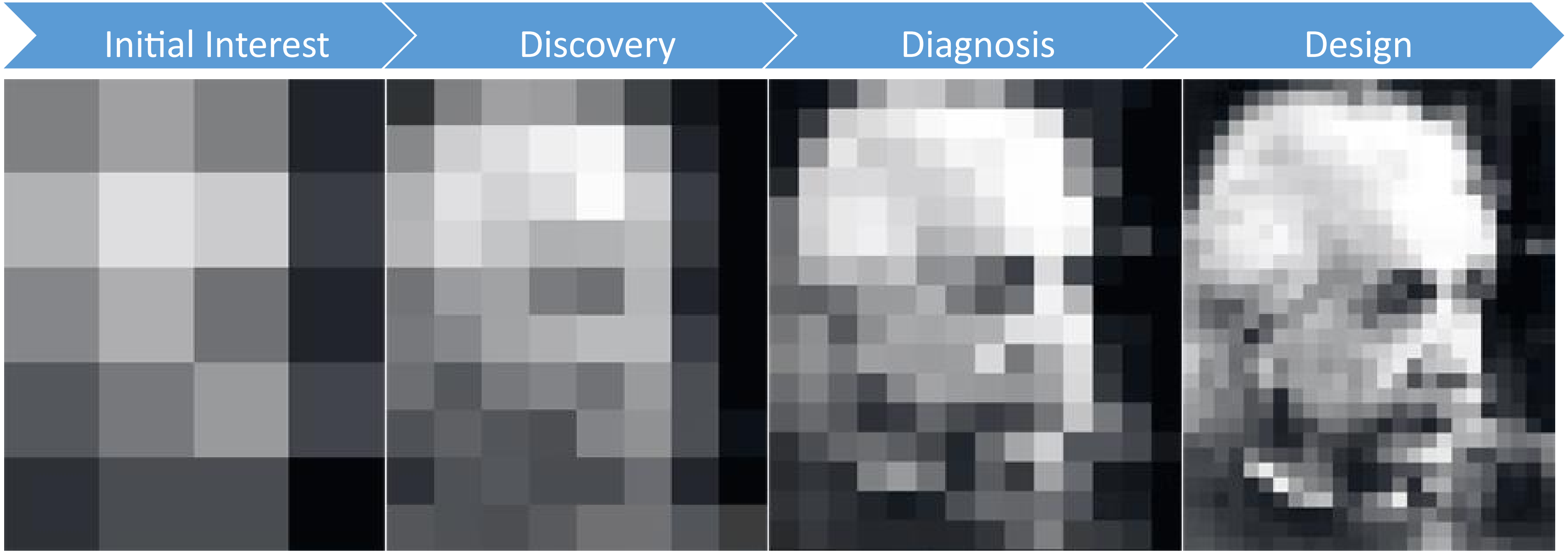
- Once we have represented a situation in the form of parts and relations, we can ask different questions about the situation
- Is the representation holistic? Are we missing any stakeholder perspectives? For instance, for the fuzzy front-end of product design (conceptual design) the stakeholders could be customers, competition, academic research, shareholders, management, engineering design, manufacturing
- Second, is there a pattern in this description? Is it biased or focused only on a few aspects? What are the critical points? Or patterns that cut across some elements?
- Some of these patterns could be extremely beneficial and represent the complex character of the phenomenon, while others could be detrimental and complicated

Parts (Key Elements)	1	2	3	4	5	6
1						
2						
3						
4						
5						
6						

Diagnosis: Using complexity principles to extract a more creative, holistic and rigorous problem definition / product concept



How order can emerge out of chaos?



12 inputs: nothing

80 inputs: general perimeter

238 inputs: product architecture

825 inputs: product design

Source: http://design.activeside.net/why-designers-should-seek-complexity

Does this follow the Golden Ratio?

Exercise 4.1 (30 min)

- Identify the parts and relations from the problem statement
- Abstraction is key to identify parts… ask why 5 times… restrict to 20-25 key elements
- Use a simple relation to start with – a *"is connected to"* to b
- Use a matrix to depict parts and relations (25 by 25)
- Complete the exercise during the week and bring the matrix for the next class

Example: Keywords from policy statement -“No Plan At Present To Have All Electric Car Fleet By 2030”

- Minister of state for heavy industries Babul Supriyo said in a written reply in the Lok Sabha, "There are, at present, no plans under consideration of the Department of Heavy Industry to make all vehicles in the country powered by electricity by 2030," This is in complete contradiction to what Goyal said last year. In fact after Goyal's statement there are more than a dozen car makers that have announced plans to introduce electrification technology or electric cars in India. In fact the Niti Aayog has been currently tasked with preparing a vision for electric cars and a policy document on EVs has defined a 15-year roadmap to attain complete electrification.

Extent of Electrification

Investments

Types of Vehicles

Clarity on Policy

EV Technology

Car makers → Automobile Industry

Think Tanks

Govt

Example: Keywords from opinion – “Electric Vehicles In India; What The Future Holds”

- The world is quickly adopting to electric vehicles. Where does India fit in the overall scheme of electric vehicles globally? A recent report prepared by Bloomberg New Energy Finance has some doubts on India being a big player the EV market. One of the biggest reasons for this is the very low average vehicle prices in India. For example, if we talk globally, people in US, EU would not mind spending around $35,000 on a new car. That figure is about $15,000 for people who buy a new car in China. But India, the average price of a car is less than $10,000. And therefore, people will be looking to buy an electric vehicle only when the prices of EVs will fall in that range.

Purchase behavior

Difference between avg price & EV price

Average vehicle prices

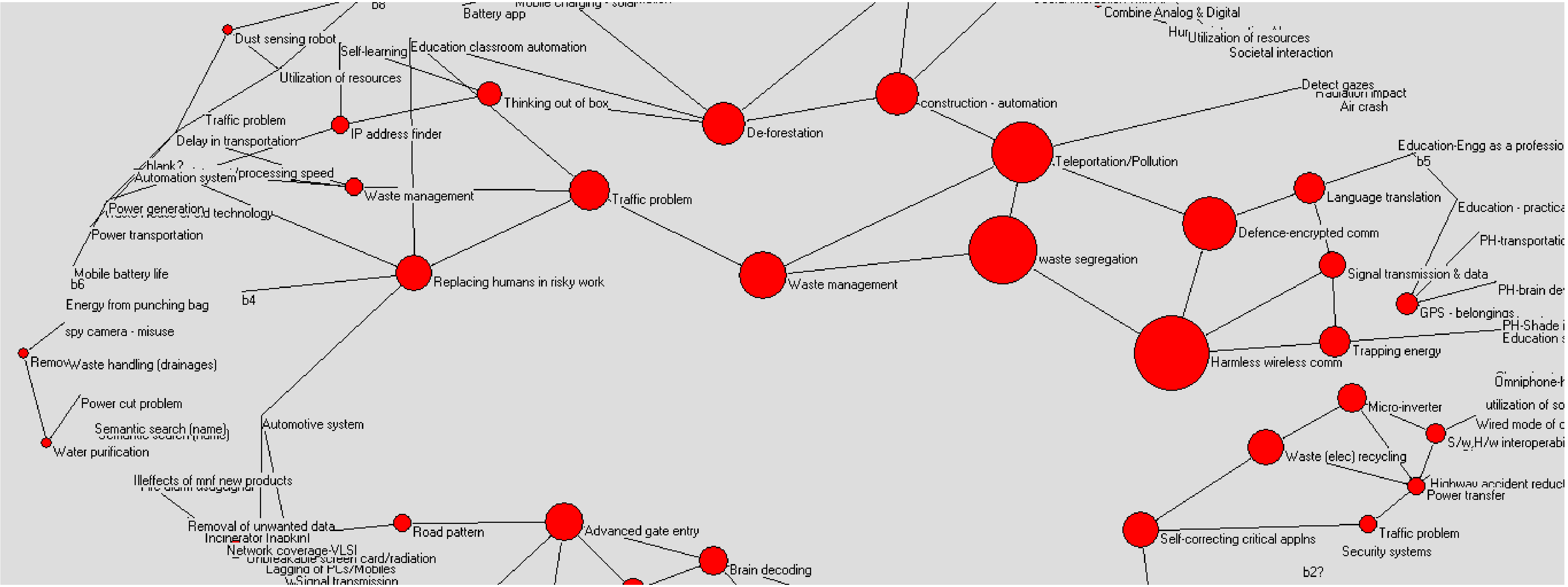
EV market growth in India

Rate of Adoption of EVs

Global Trend in EV

Example: Keywords from a counter view: “Electric vehicles don’t need a government push”

- The primary reason for the EV push is controlling carbon emissions. But something like an all-electric fleet of buses is an expensive solution to the problem. A **World Bank study** on the cost effectiveness of electric and hybrid buses in developing countries concluded that in order to tackle air pollution, the policy goal should be to incentivise more people to leave their cars at home. It is, therefore, clear that many of the gains against air pollution can be derived by enabling the modal shift, through improvements in the quality of public transport.
- Similarly, the government should avoid regulating the supply of infrastructure with arbitrary prescriptions and subsidies. While everyone agrees that charging infrastructure is essential to the success of EVs, whether there should be a charging station at every five kilometres or 10 cannot be known in advance. Factors such as the driving range of vehicles, private charging capabilities of users and charging speed will determine the number and location of charging stations. Similarly, shifts in technology—such as wireless charging, solid state batteries or a transition to hydrogen fuel cells—will have to be anticipated as these might render existing infrastructure obsolete.
- Given the amount of uncertainty, private players in a competitive framework will have the right incentives—the skin in the game—to acquire the necessary knowledge, and pursue their competing visions on how to meet future challenges. Choosing new technologies is the task of venture capitalists and entrepreneurs—not the government.



Discover underlying complexity