From complexity theories to value creation in cities

A one-week seminar for PhD students
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The seminar

The last decades have witnessed the emergence of complexity theories of cities (CTC) – a domain of research that applies the various theories of complexity to the study of cities, their dynamics, planning and design [1-4]. The last decades have further witnessed the 4th industrial revolution [5] that by means of its information and communication technologies (ICT) gave rise to the so-called smart machines and smart cities [6]. Finally, the unprecedented urban growth of the last decades has recently culminated in the "age of cities": as from 2008, for the first time in human history, more than 50% of human population live in cities; according to the UN World Urbanization Prospect by 2050 some 68 % of the world's population will live in urban areas [7]. The aim of this one-week seminar is to explore the interrelations between these developments and their implications to value creation in cities [8,9].

The lectures

1. General introduction
2. Complexity theories.
3. CTC—complexity theories of cities.
4. Complexity, cognition and the city.
5. Inter-representation and information adaptation
6. The smartification of cities
7. Value creation in cities
8. Students' presentations and conclusions

References

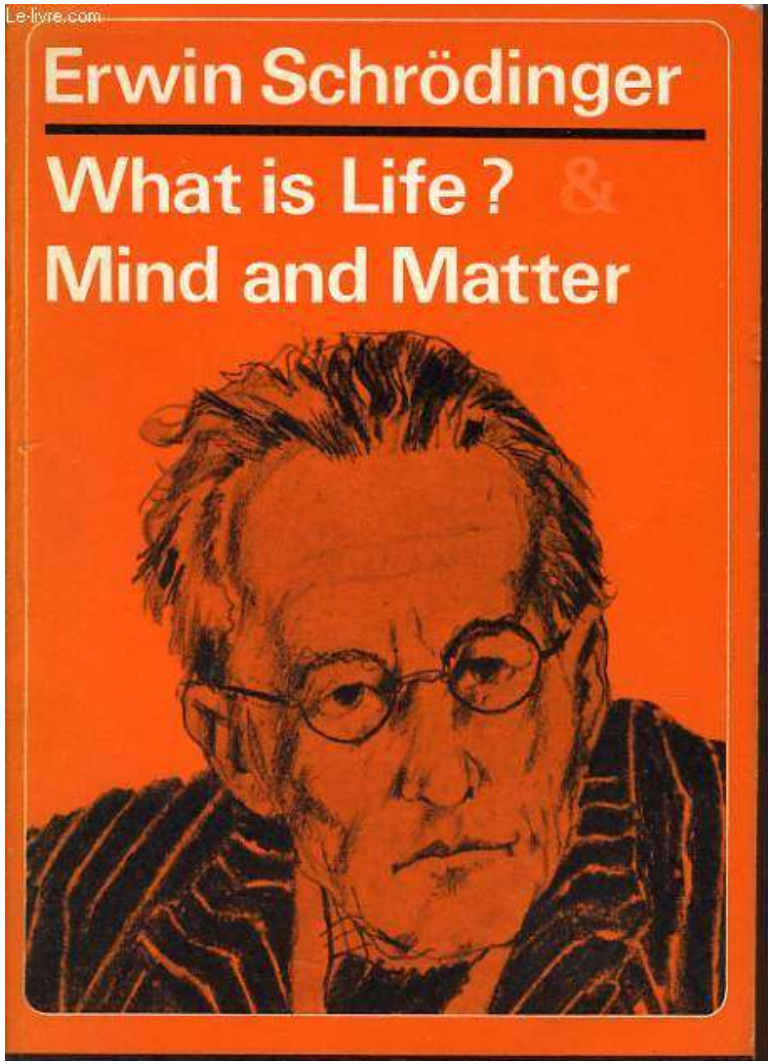
1. Portugali, J. 2000. *Self-Organization and the City*. Springer, Heidelberg.
2. Portugali, J. 2011. *Complexity, Cognition and the City*. Springer, Heidelberg.
3. Batty, M. 2005. *Cities and Complexity*. MIT press, Cambridge Mass.
4. Batty, M. 2013. *The new Science of Cities*. MIT Cambridge Mass.
5. Schwab, K.2016. The Fourth Industrial Revolution, Kindle edn. World Economic Forum, Switzerland
6. Haken H and Portugali J. 2017. Smart cities: distributed intelligence or central planning? In: Rassia S. and Pardalos P.M (Eds.). *Smart City Networks: Through the Internet of Things*. Springer, Heidelberg
7. The UN World Urbanization Prospect https://population.un.org/wup/
8. Dameri R.P and Rosenthal-Sabroux C. 2018. Smart City and Value Creation. In Dameri R.P and Rosenthal-Sabroux C.E (Eds.) *Smart City: How to Create Public and Economic Value with High Technology in Urban Space.* Springer, Heidelberg
9. Tokoro N. 2016. The Smart City and the Co-creation of Value. SpringerBriefs in Business. Tokyo, Heidelberg.

Complexity Theory

An umbrella name to a set of theories about **open** and **complex** systems that achieve their order spontaneously=by means of self-organization

Before complexity

What is Life?



Entropy: a property of matter

vs.

Negative entropy a property of life

(Negentropy) 1944

"How would we express the marvellous faculty of a living organism, by which it delays the decay into thermodynamical equilibrium (death)?".

"It feeds upon negative entropy, attracting … a stream of negative entropy upon itself, to compensate the entropy increase it produces by living and thus to maintain itself on a stationary and fairly low entropy level."

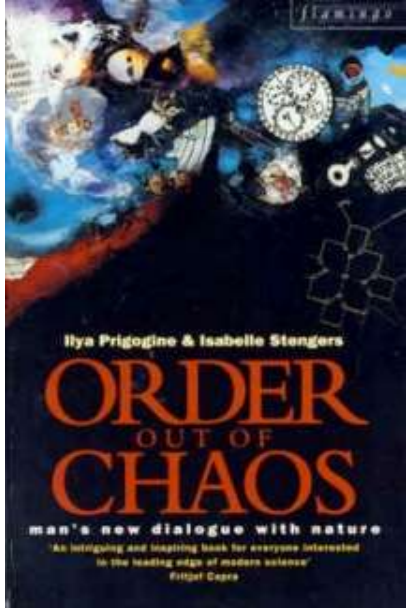
"Organization is maintained by extracting 'order' from the environment"

Anticipation of complexity theory

Order out of Chaos

3 decades later

Nobel lecture December 8, 1977: Dissipative structures Prigogine's entropy



The classical formulation [of entropy] due to Clausius refers to isolated systems exchanging neither energy nor matter with the outside world. […]. It is easy to extend this formulation to systems which exchange energy and matter with the outside world. (see fig. 2.1). We have then to distinguish in the entropy change dS two terms: the first, deS is the transfer of entropy across the boundaries of the system, and the second diS, is the entropy produced within the system. … (ibid, p 264-5)

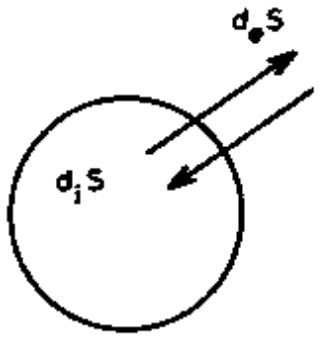
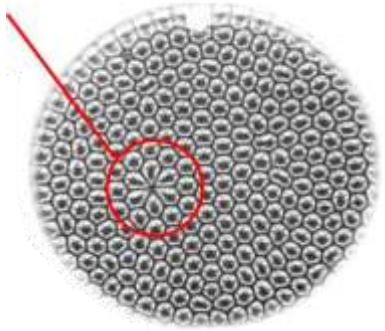


Fig. 2.1. The exchange of entropy between the outside and the inside.

$$dS = d_eS + d_iS$$

Canonical experiments/examples

Benard 1904



Prigogine's dissipative structures

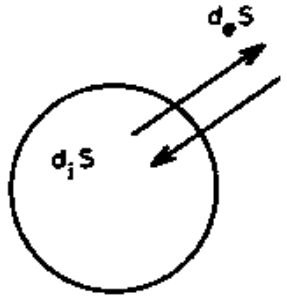
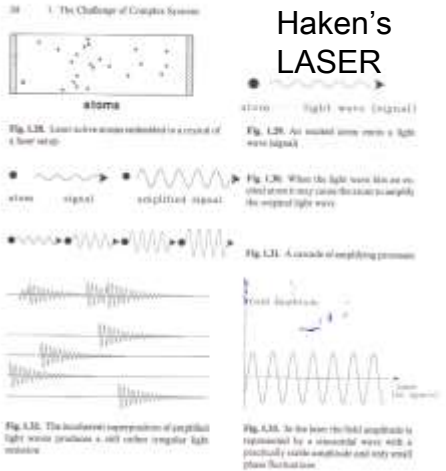
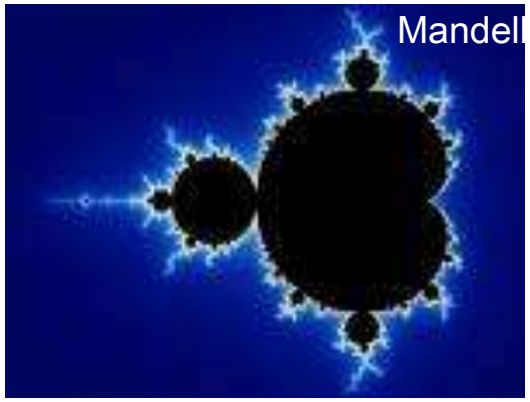
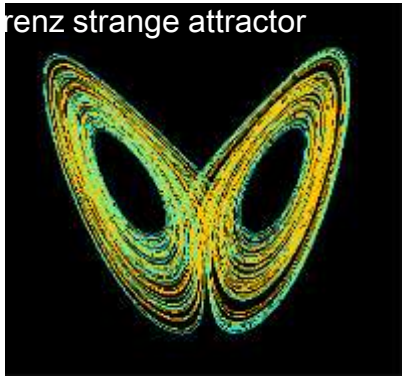


Fig. 2.1. The exchange of entropy between the outside and the inside.

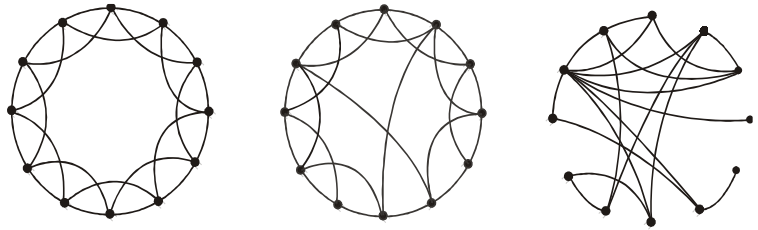
Haken's LASER





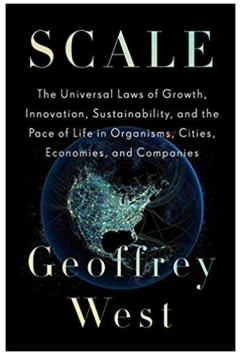


Bak's SOCriticality



Regular network | Small-world network | Random network

Milgram → Watts, Barabasi



West

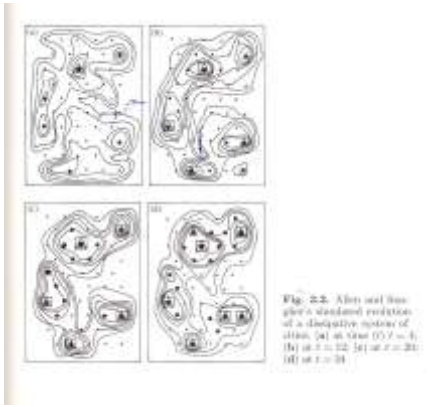
The link to towns and cities

accompanied complexity theory from the start.
Already in his Nobel lecture Prigogine (1977) says/writes:

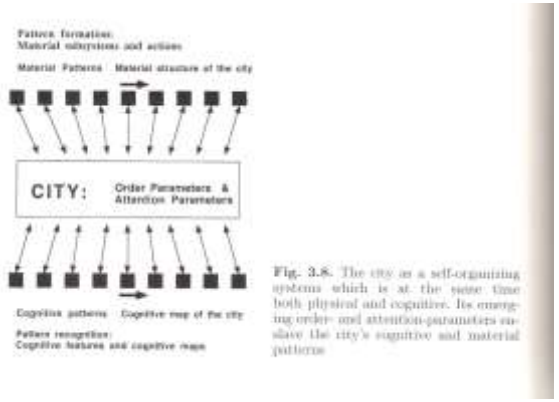
Are most types of ‘organizations’ around us of this nature?”, [that is, characterized by thermodynamic equilibrium?]. […] the answer is negative. Obviously in a town, in a living system, we have a quite different type of functional order. To obtain a thermodynamic theory for this type of structure we have to show that non-equilibrium may be a source of order.

All theories/mthodologies of complexity have been applied to cities with the implication that we now have a family of CTC (Complexity theories of cities):

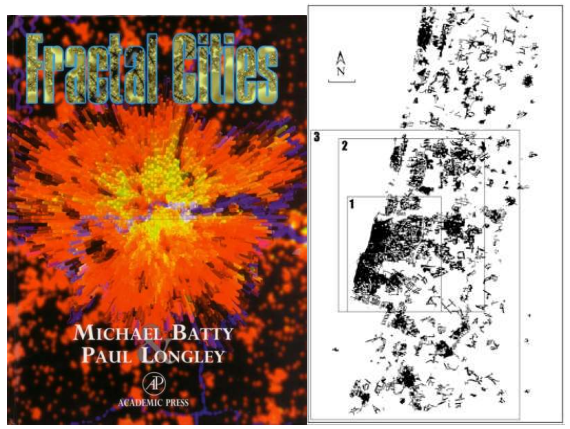
Dissipative cities (Allen)



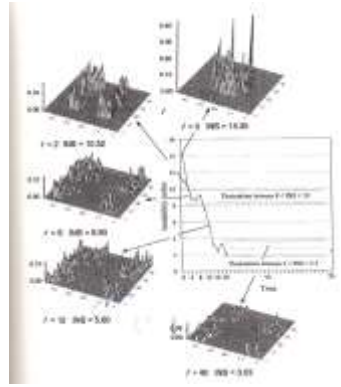
Synergetic cities (Weidlich Haken&Portugali)

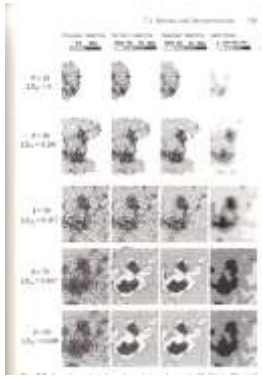


Fractal cities (Batty&Longely)



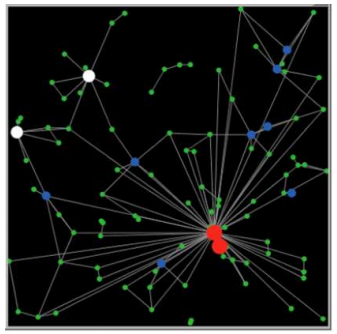
CA Cities



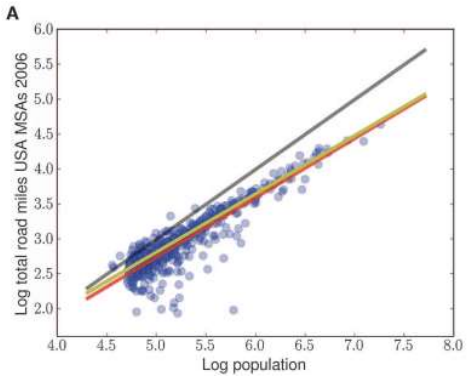


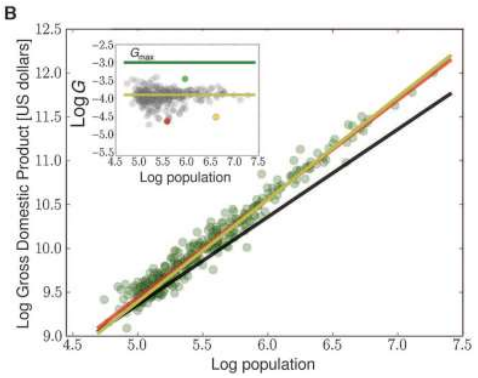
AB/FACS Cities

Sandpile Cities



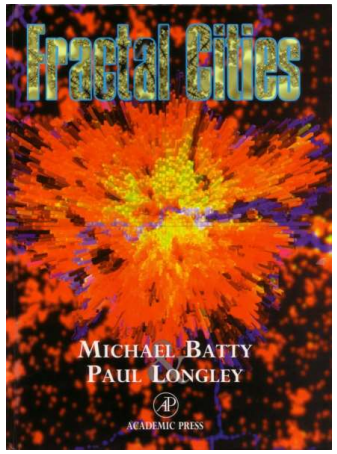
Network Cities

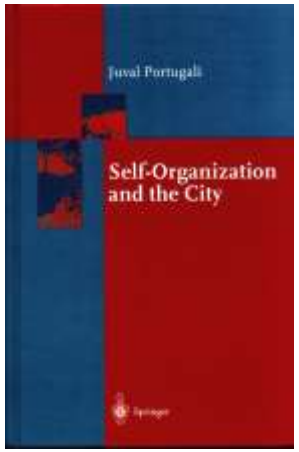


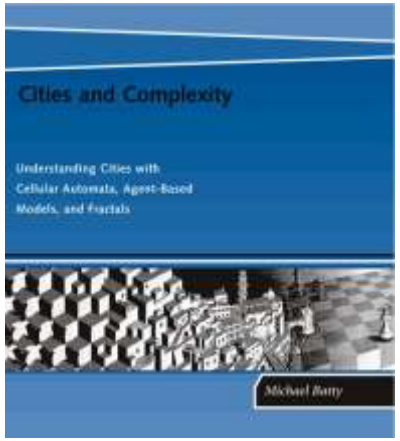


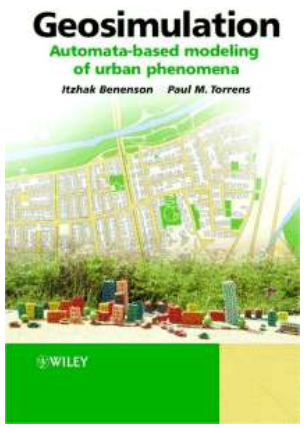
Allometreic cities (Bettencourt et al)

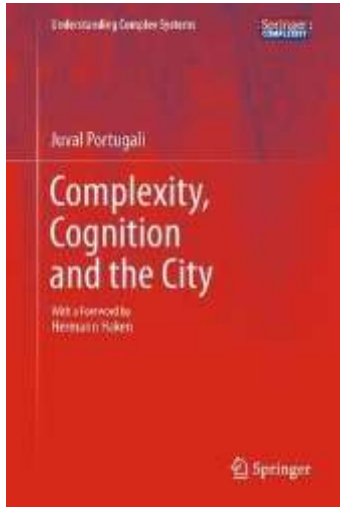
Many papers and a few books

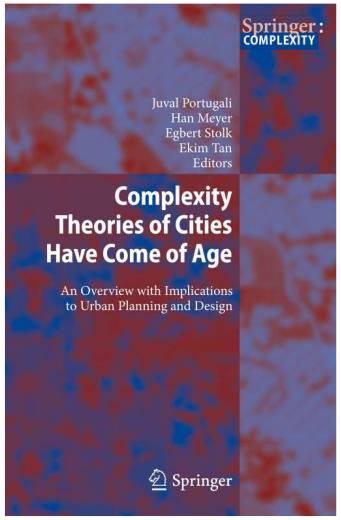












Each CTC emphasizes a different property of the complexity of cities and a different aspect of urban transformation:

Prigogine's dissipative structures:
interaction with the environment
The role of fluctuations

Haken's synergetics:
bottom-up emergence and top-down slaving
The play between control and order parameters

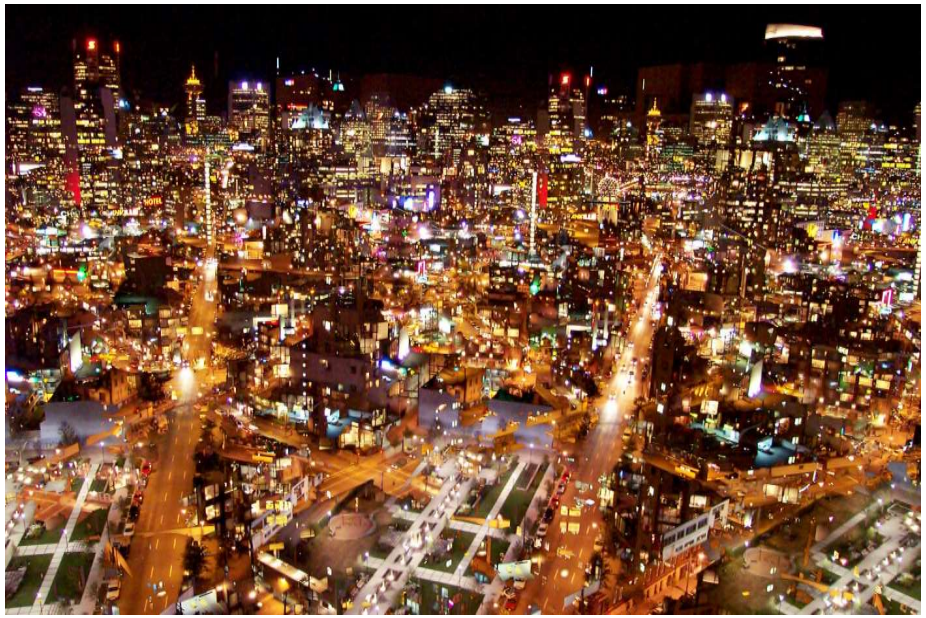
Mandelbrot's fractals:
self similarity

Lorenz' Chaos – unpredictability and non-linearity

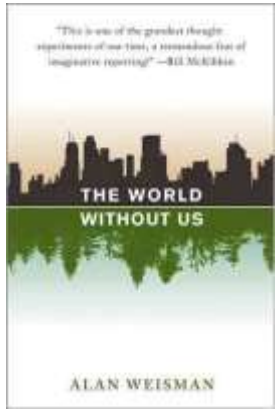
Etc.

Interaction with the environment

Prigogine (*The End of Certainty*, 1997, 62): “A crystal … can be maintained in a vacuum, but if we isolate the town, it would die…”
If you put a city in a vacuum it will disintegrate



The world/cities without us urban agents



NY becomes part of its env. But looses its self identity

Simple systems are subject to the 2nd law of thermodynamics and the process of *entropy*

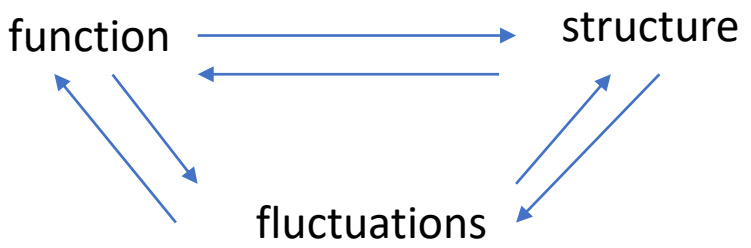
Complex systems are subject to *negetropy* and evolution

The role of fluctuations

TIME, STRUCTURE AND FLUCTUATIONS

Nobel Lecture, 8 December, 1977

By ILYA PRIGOGINE



"There are three aspects which are always linked in dissipative structures: the **function** as expressed by the chemical equations, the space-time **structure**, which results from the instabilities, and the **fluctuations**, which trigger the instabilities. The interplay between these three aspect leads to most unexpected phenomena, including "**order through fluctuations**" which we shall analyze in the next sections"

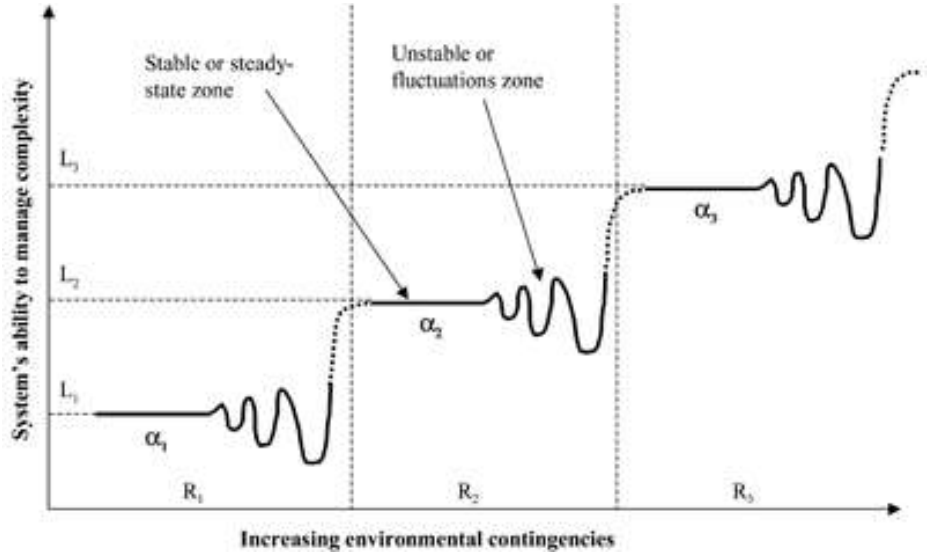
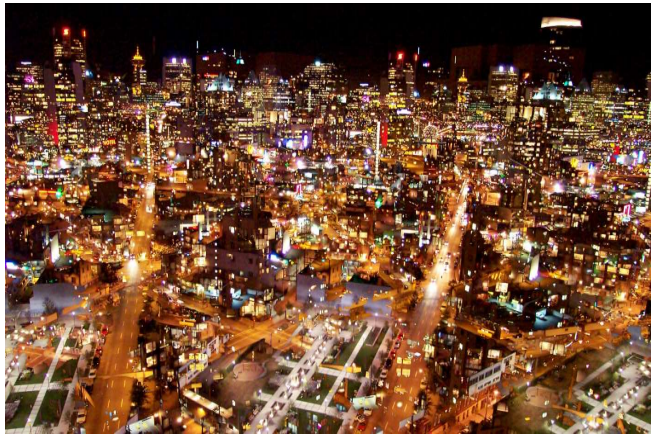


Figure 11.6. System transformation and production of macroscopic order.

Synergetic cities:
bottom-up emergence, top-down slaving

Up

Top



Emergence

Slaving

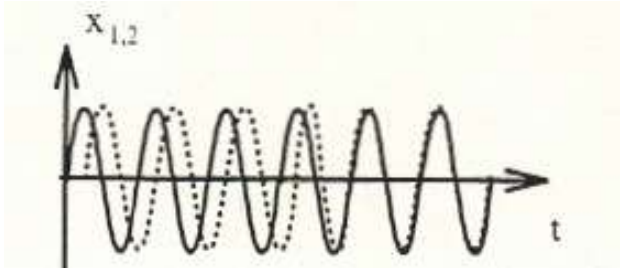
Bottom

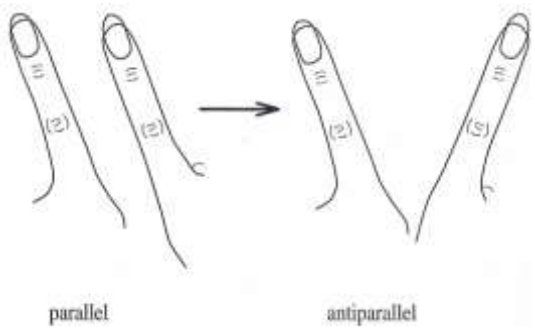
Down

The play between control parameter and order parameter

HKB (Haken, Kelso Buntz)
Finger movement paradigm

The speed of the metronome as control parameter





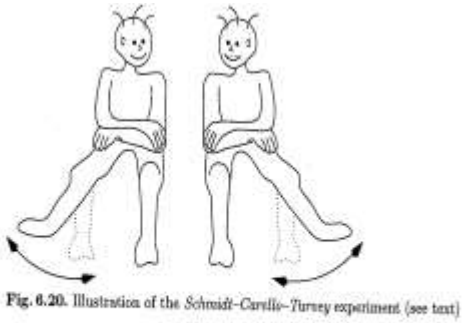
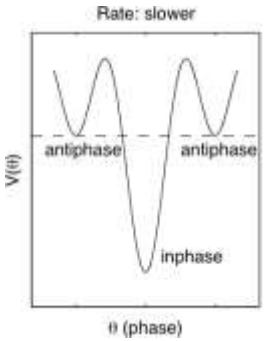
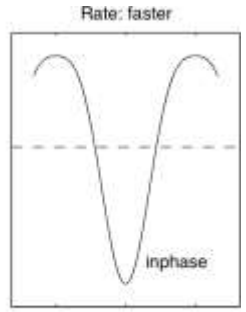


Fig. 6.20. Illustration of the *Schmidt–Carello–Turvey* experiment (see text)



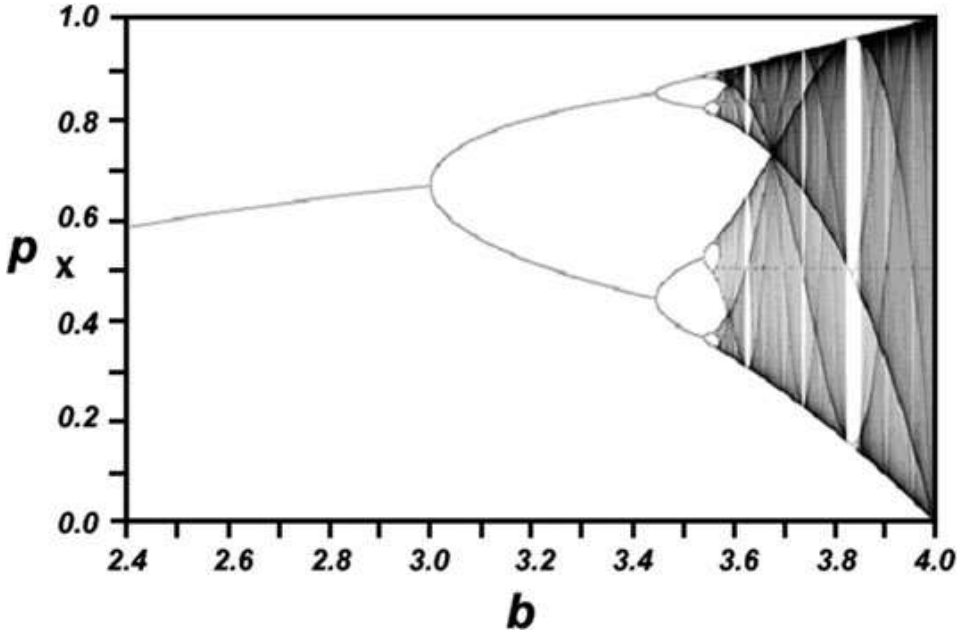
Choice of 2 Ops



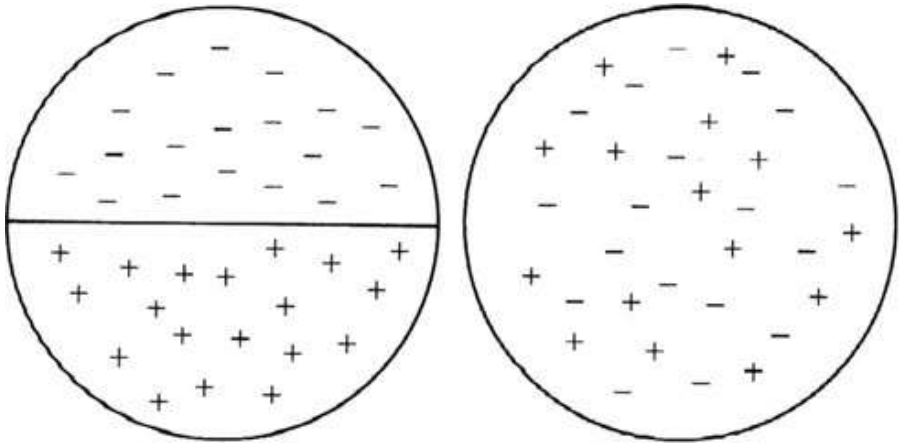
One OP (no choice)

Pedestrians walking speed as control parameter

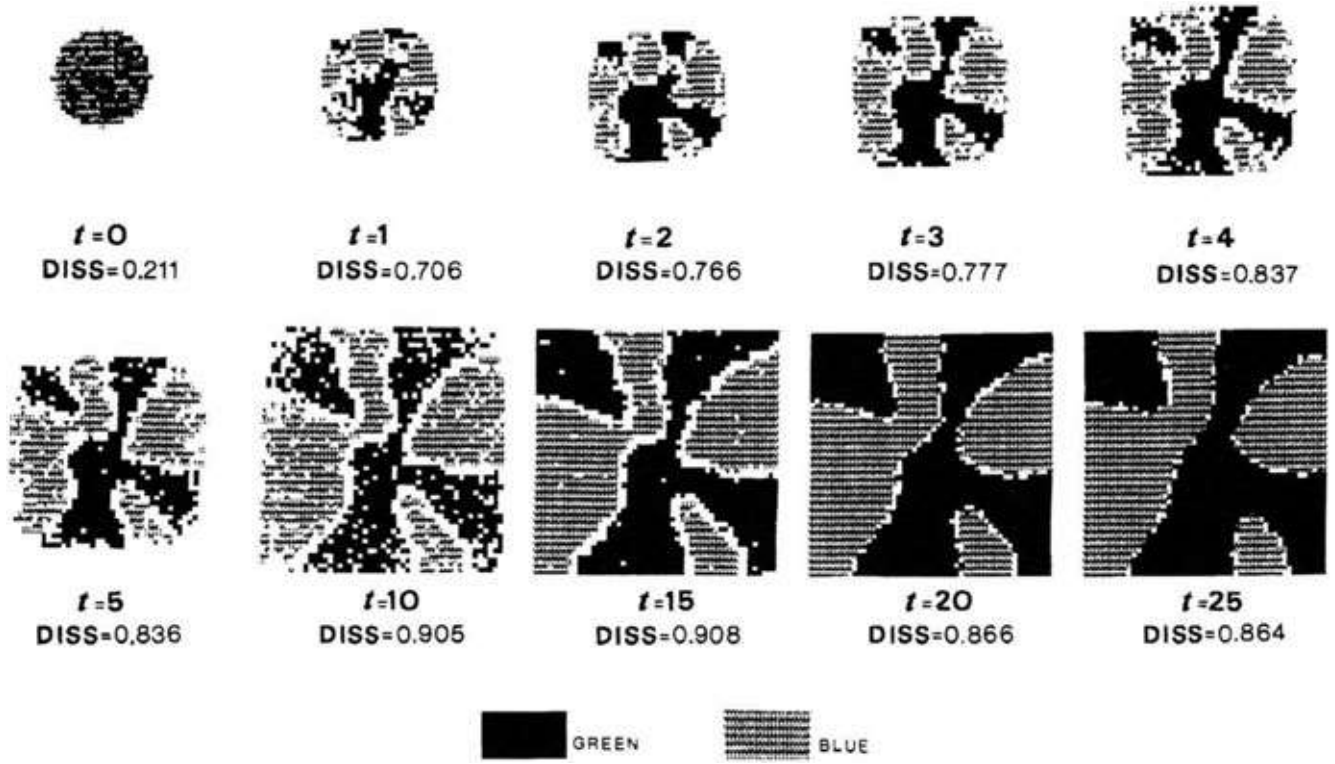
Two famous notions associated with Lorenz's work: Left: Photograph of a butterfly as a reference to his "butterfly effect". Right: Trajectories of Lorenz's strange attractor. While the two notions refer to quite different phenomena, the "butterfly effect" is internally related to the strange attractor



The way to chaos. A simple population dynamics can be described by: P(nß1) . b.P(n), that is, population P at year nß1 is P at year n, multiplied by b – the rate of population growth. According to Pierre Francüois Verhulst's (1845) this equation can be normalized to P(nß1) . b.P(n)(1–P(n)). Now, when b is small, say 1.00, this equation yields one attractor; when b . 3.0 ! 2 attractors; b . 3.44 ! 4 attractors; b . 3.56 ! 8 attractors; b .. . . ; but then when b . 3.56999 ! infinity of attractors, that is to say, chaos



Left: A stable dynamical system in which “the motions denoted as + or – lie in distinct regions of phase space”. Right: An unstable dynamical system in which “each motion + is surrounded by – and vice versa”. (Prigogine with Stengers ibid p 36, Figs. 1.5 and 1.6)



Time evolution of segregation in a city with two cultural groups (Portugali 2000, Fig. 5.2)

Self-organized criticality

Chaotic cities

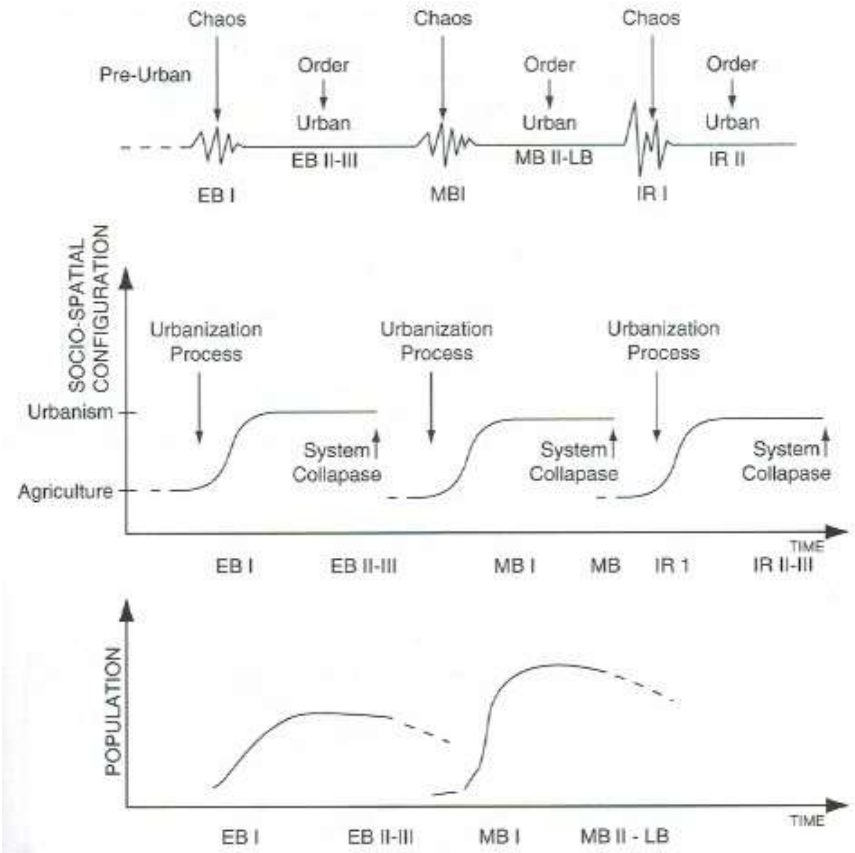


Fig. 4.15 Ancient urbanization and chaos. *Top*: The evolution of the settlement system in Palestine, from the Early Bronze Period to the Iron Age, exhibits long periods of urban steady state that are interrupted by short, nonurban periods characterized by system collapse, nomadization, strong fluctuations and chaos. *Center*: A description of the process as a rhythm between agriculture and urbanism, interrupted by global collapses of the urban system. *Bottom*: The above rhythm between urban steady state and nonurban chaos shows itself also in the calculated population changes (by Gophna and Portugali 1988) in the Early Bronze and Middle Bronze periods. Adapted from Portugali 2000, Fig. 15.8

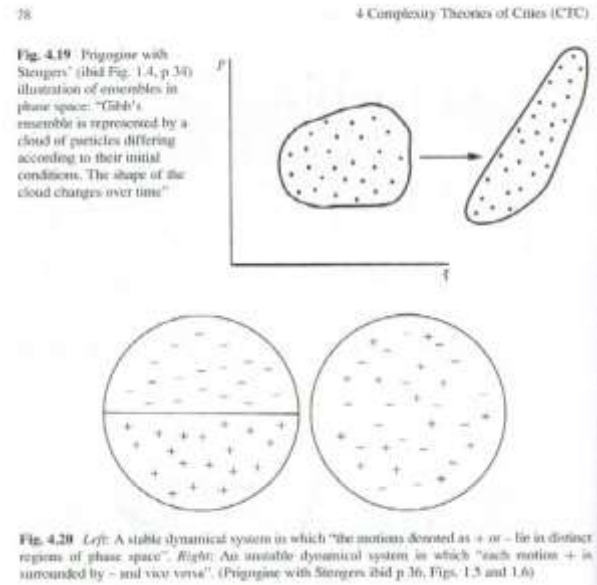
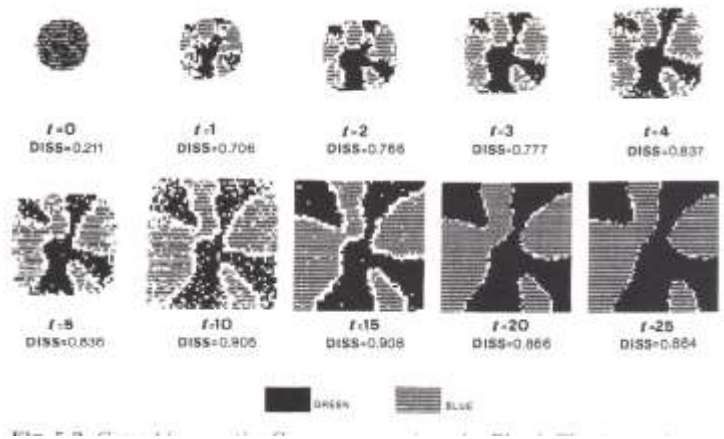
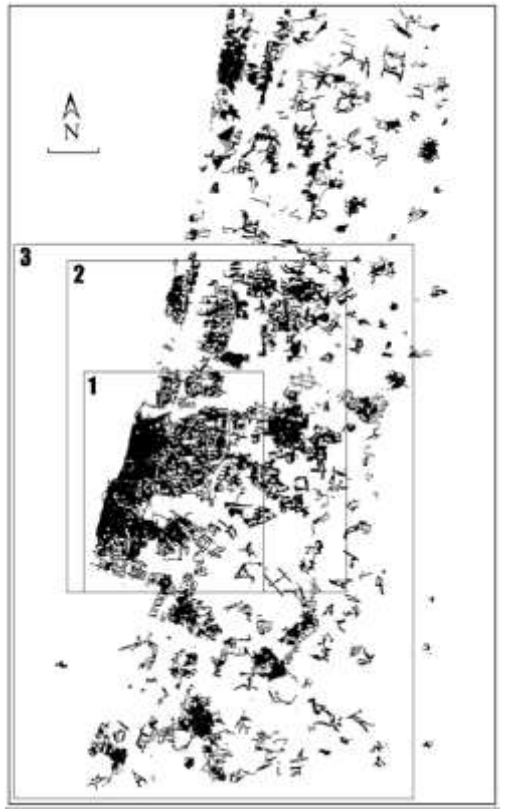


Fig. 4.20 *Left*: A stable dynamical system in which "the motions denoted as + or – lie in distinct regions of phase space". *Right*: An unstable dynamical system in which "each motion + is surrounded by – and vice versa". (Prigogine with Stengers ibid p 36, Figs. 1.5 and 1.6)



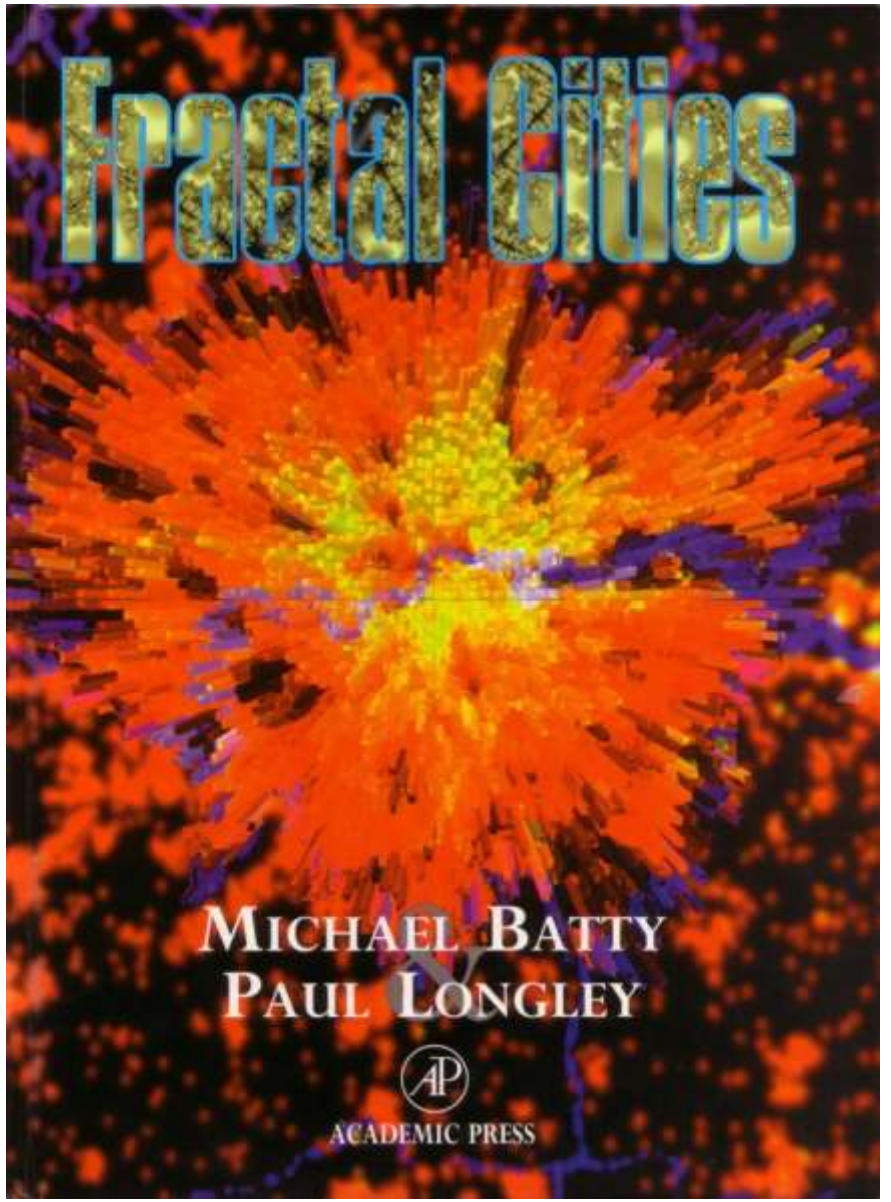
Fractal cities

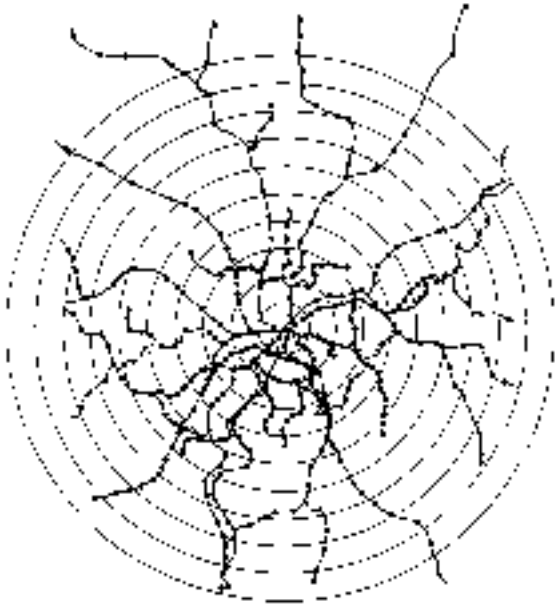
Self similarity



“When and where a city is fractal?”

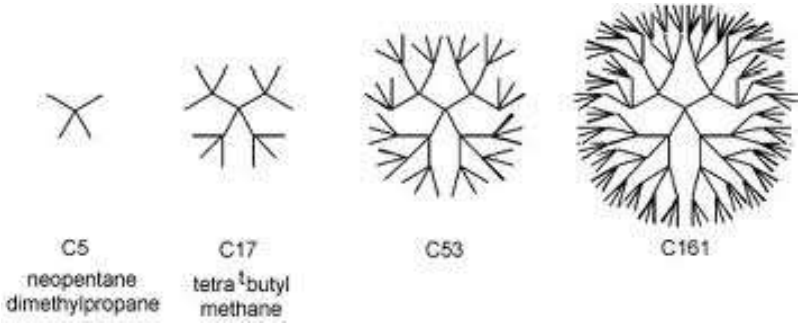
Benguigui, Czamanski., Marinov, & Portugali,



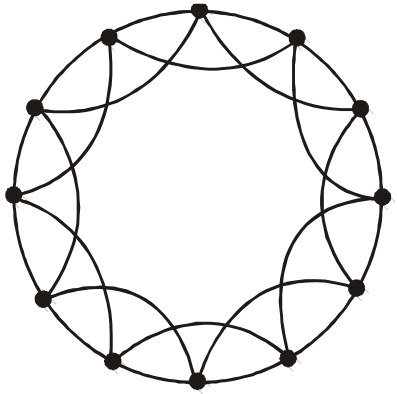


Paris' metro as a branched net

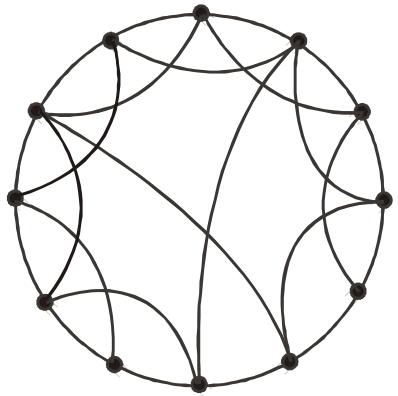
Infrastructures are often self-similar with specific fractal dimension. Paris metro (+suburban net) is a branched fractal with dimension =1.47 (Benguigui)



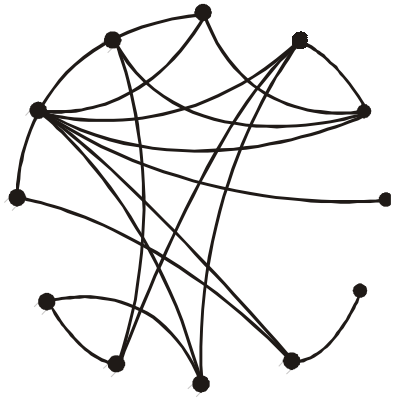
Branching



Regular network



Small-world network



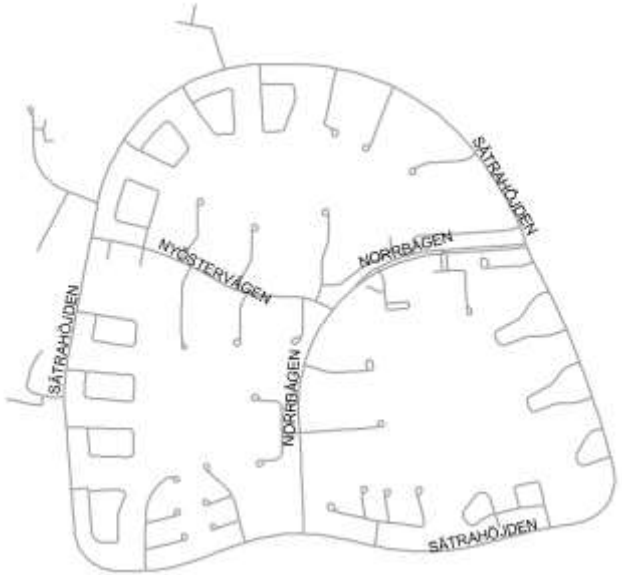
Random network

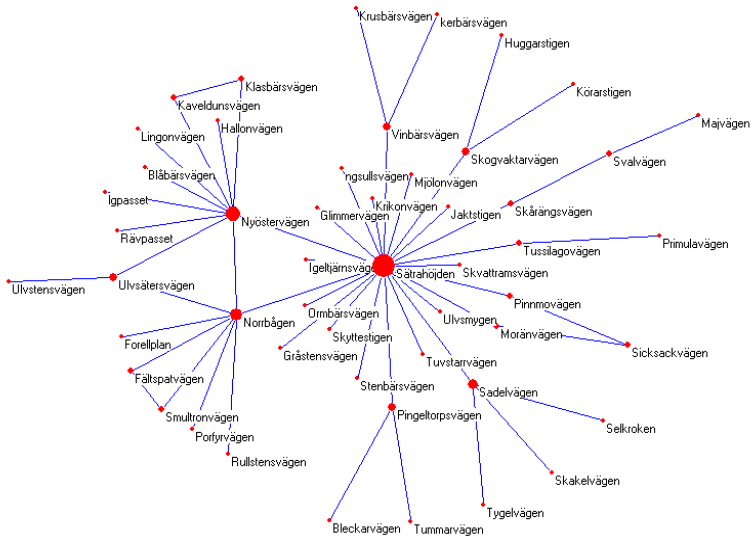
Small world

Cities

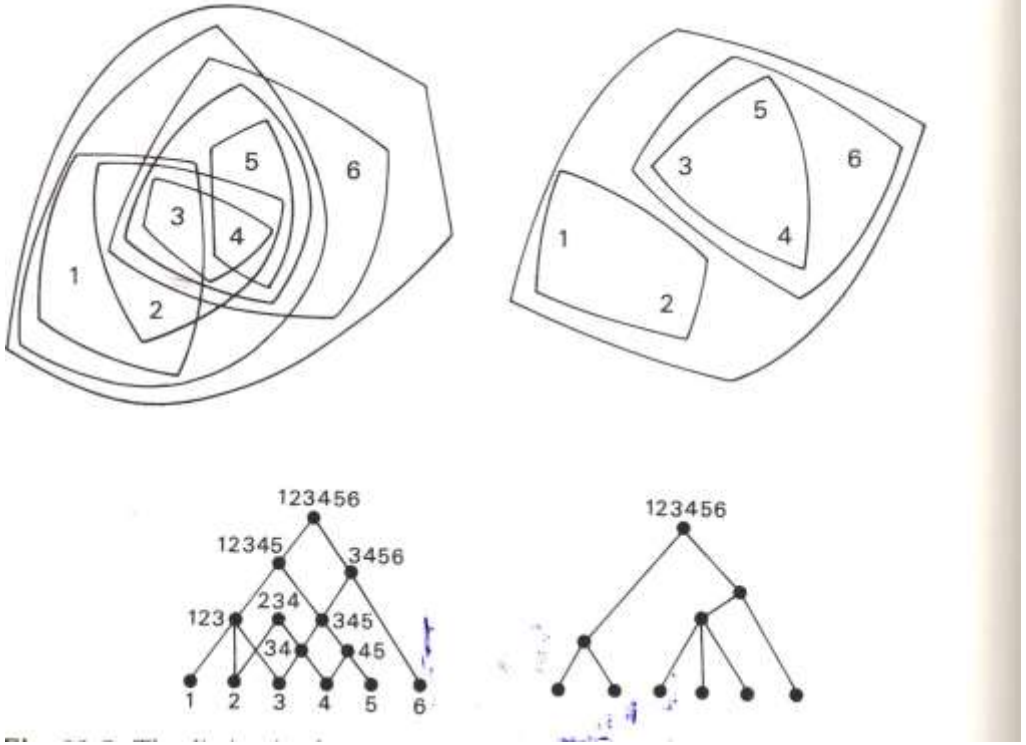
Power law

Jiang





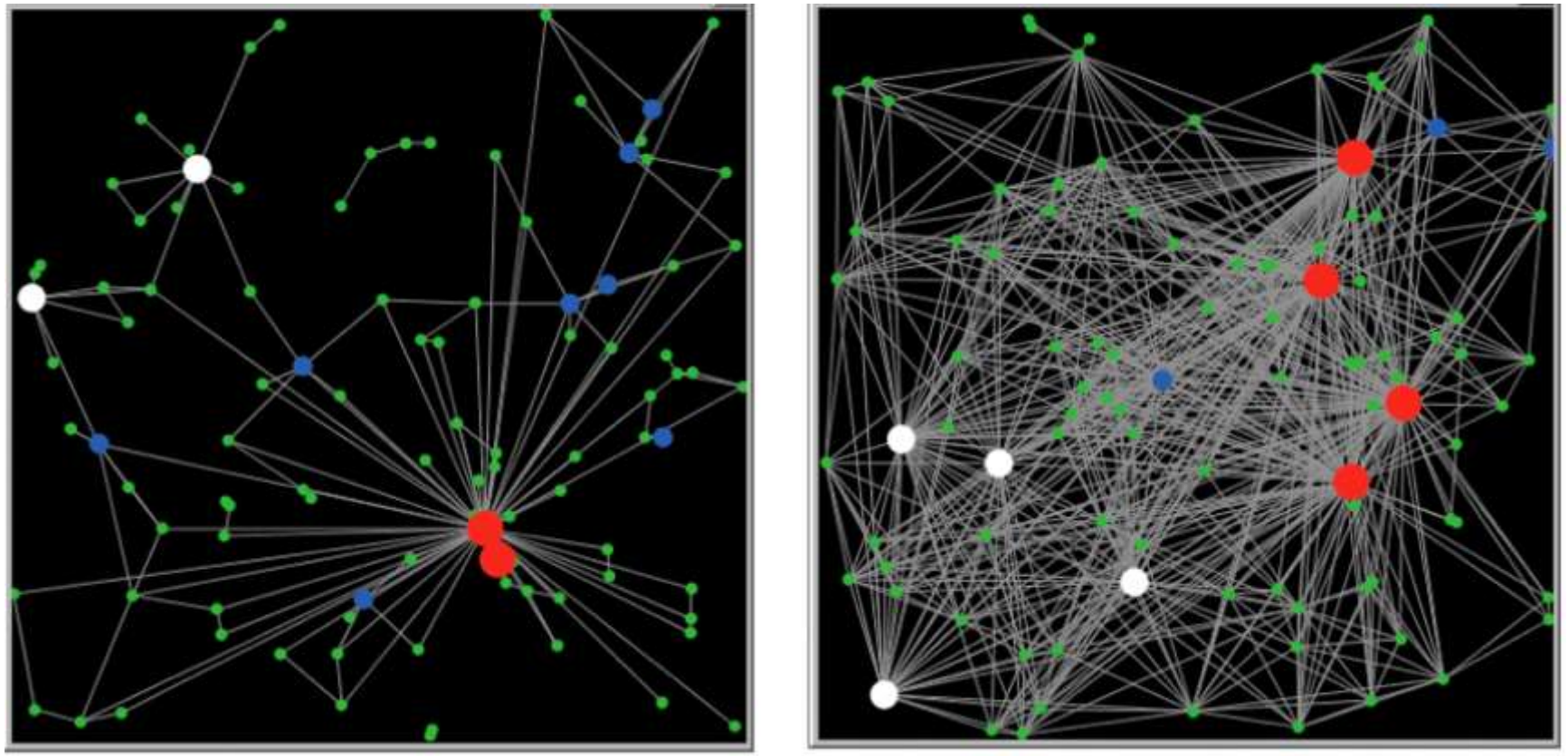
בין יאנג -- יבלה



Reminder --

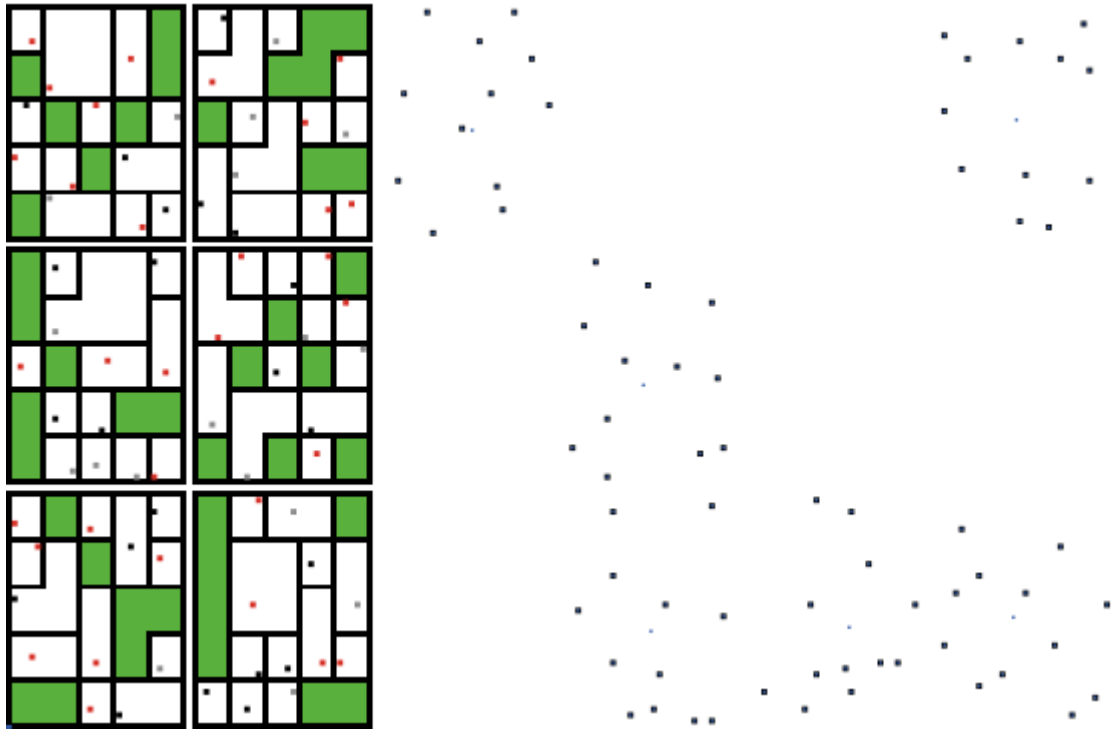
Christopher Alexander:

“A city is not a tree”



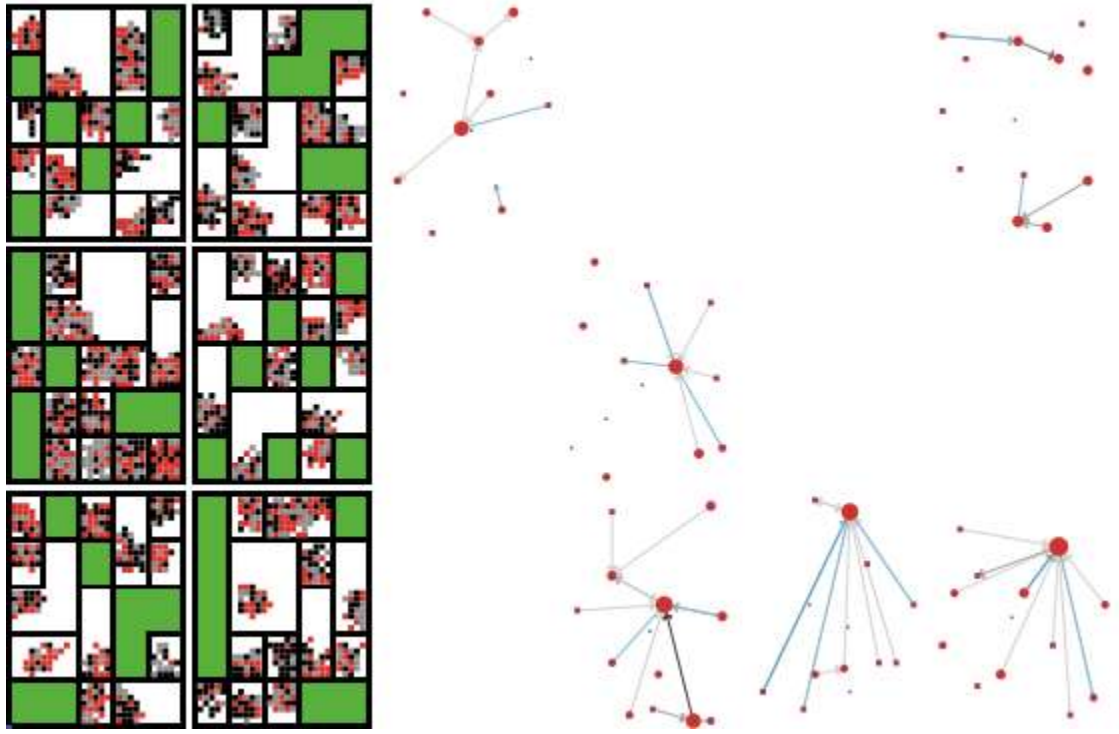
Two examples for urban commuting networks, resulted from the model. The sizes and colors of the nodes represent different sizes of urban economic centers (Blumenfeld and Portugali, forthcoming)

Multi scale urban networks

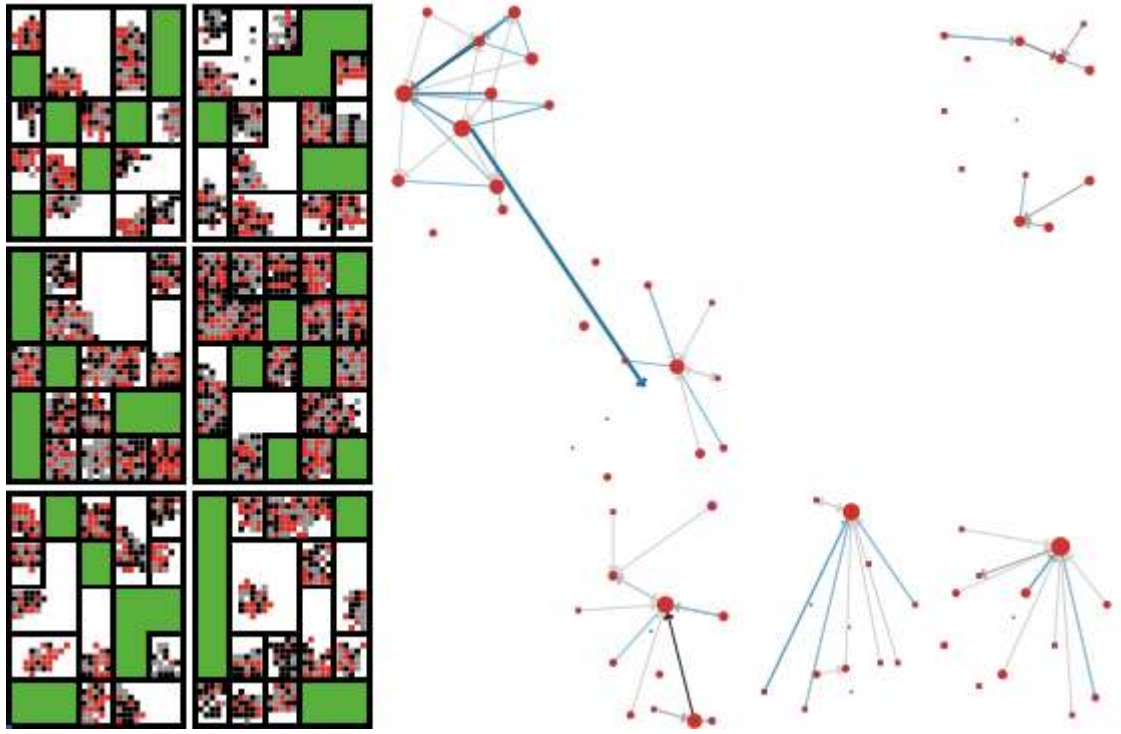


Stage two: Cities extend beyond national boundaries

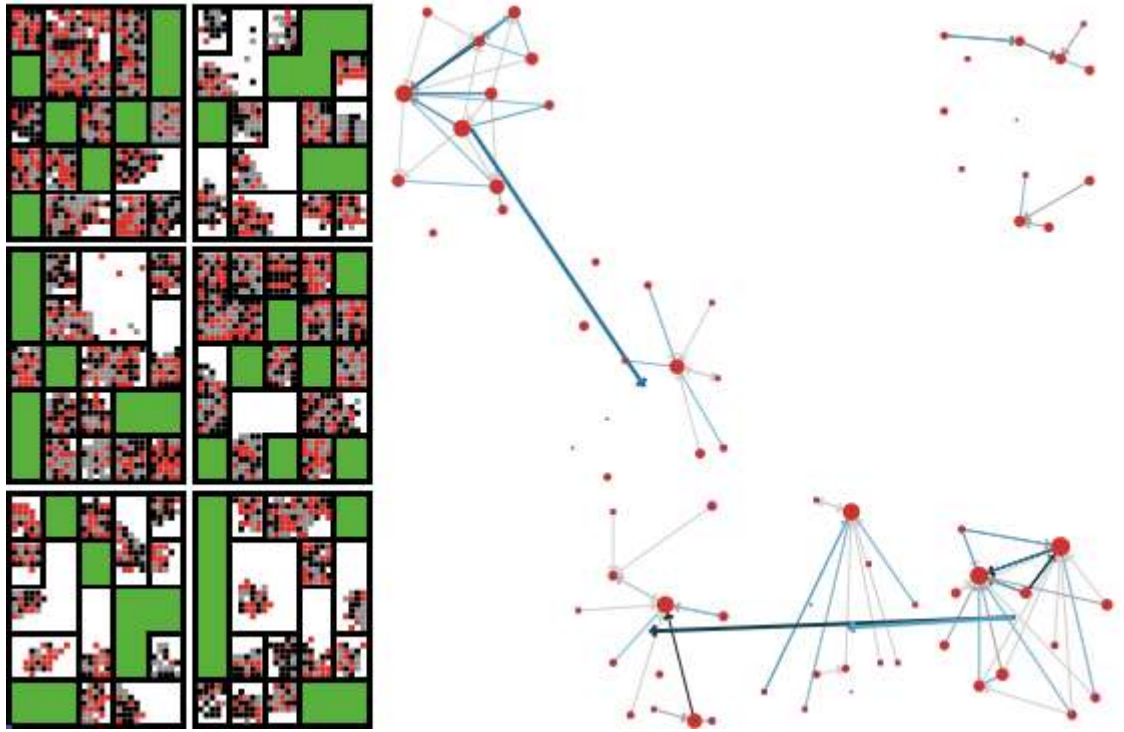
Multi scale urban networks



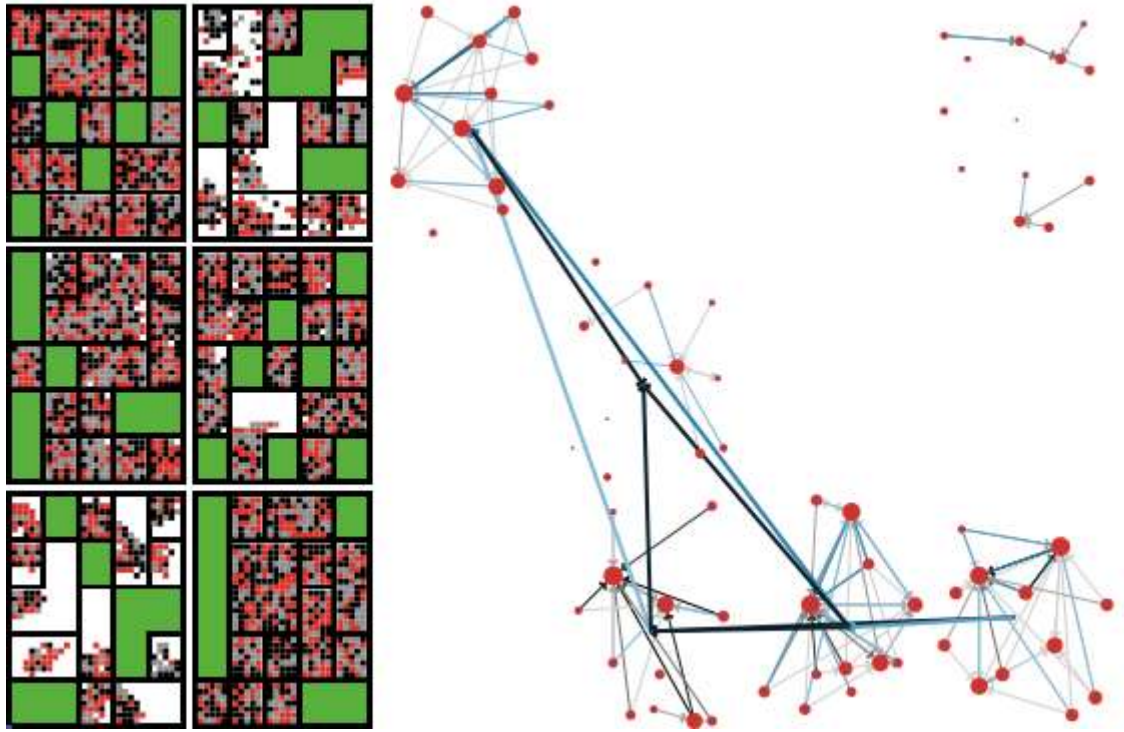
Multi scale urban networks



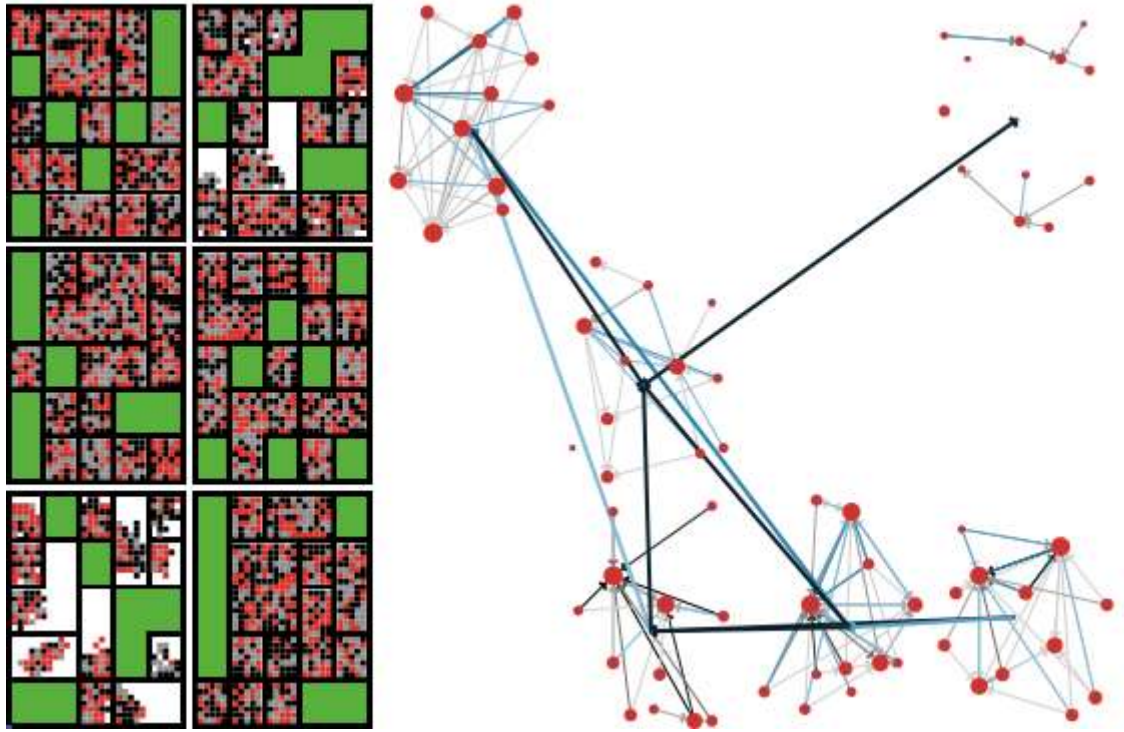
Multi scale urban networks



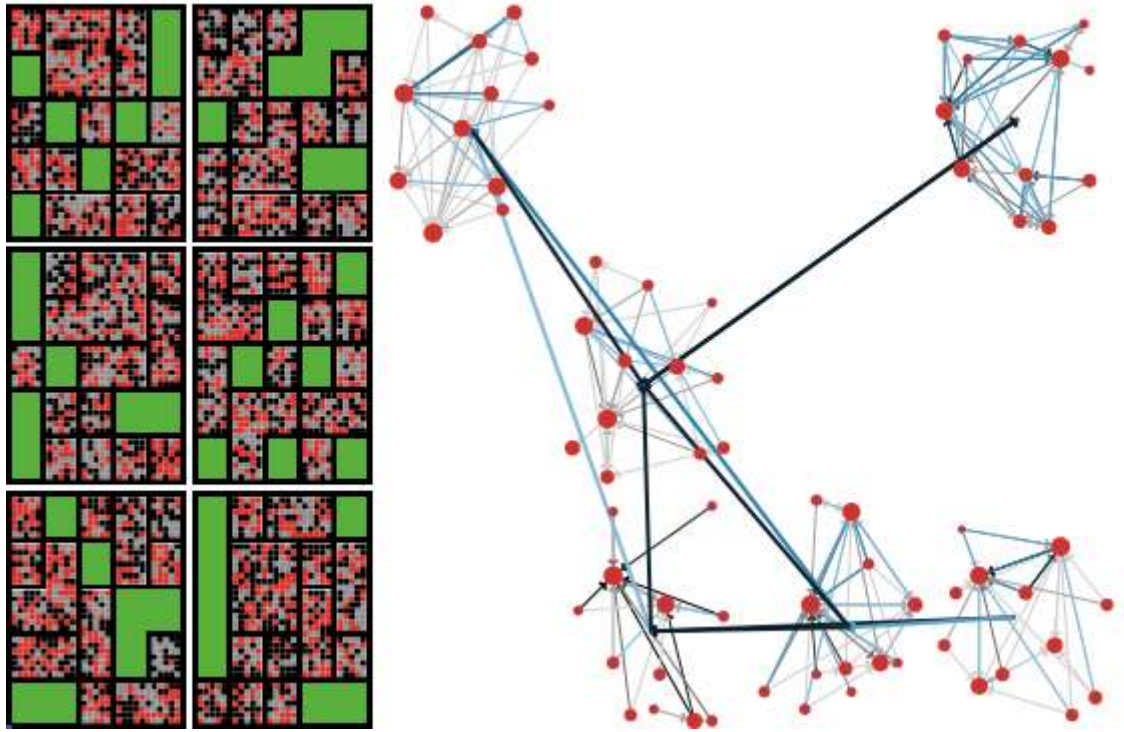
Multi scale urban networks

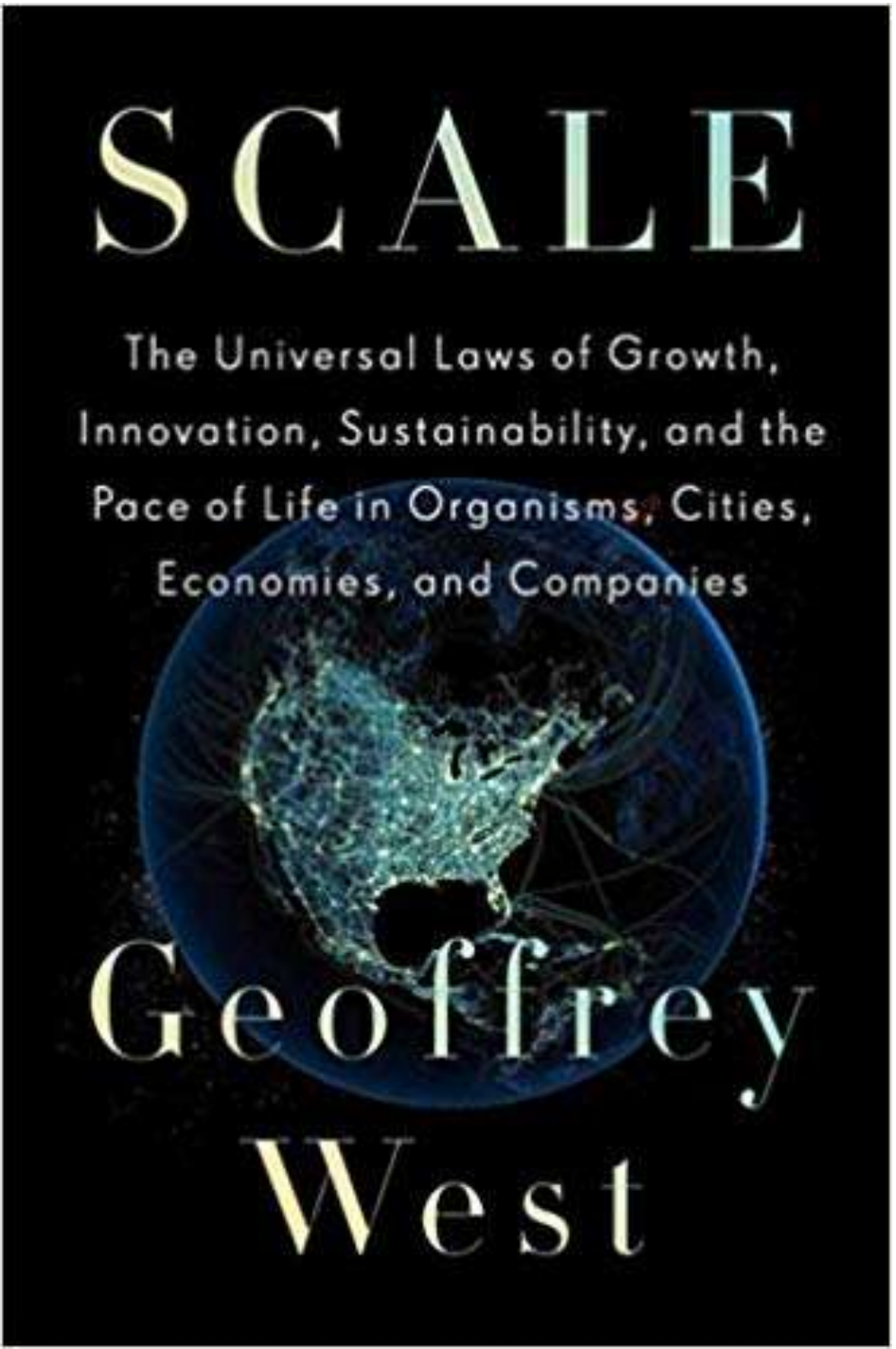


Multi scale urban networks



Multi scale urban networks

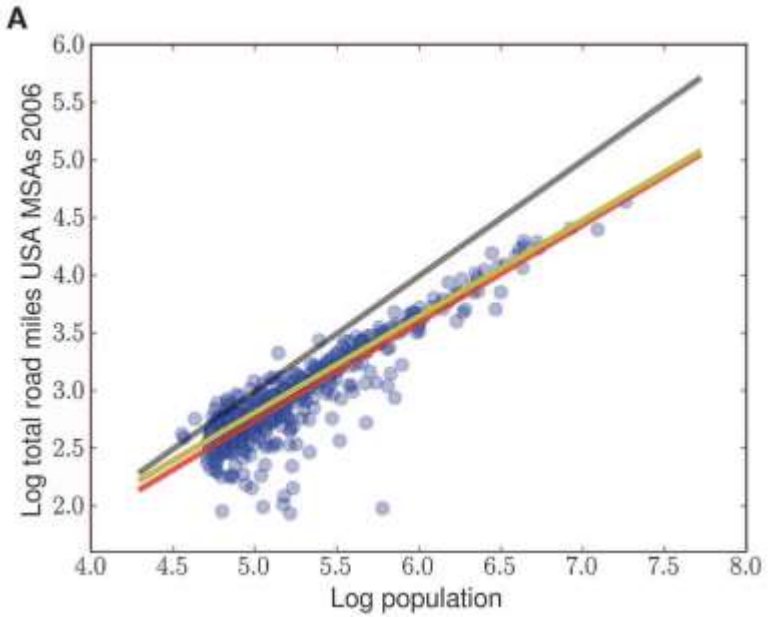


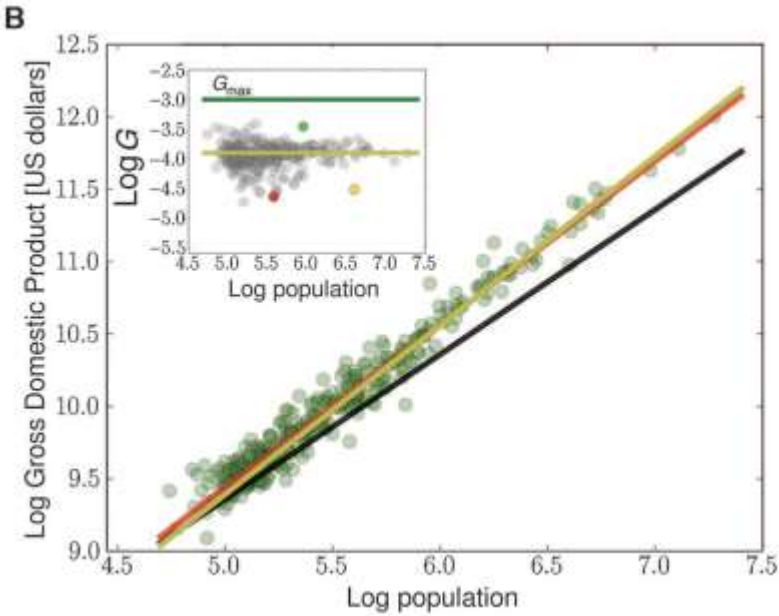


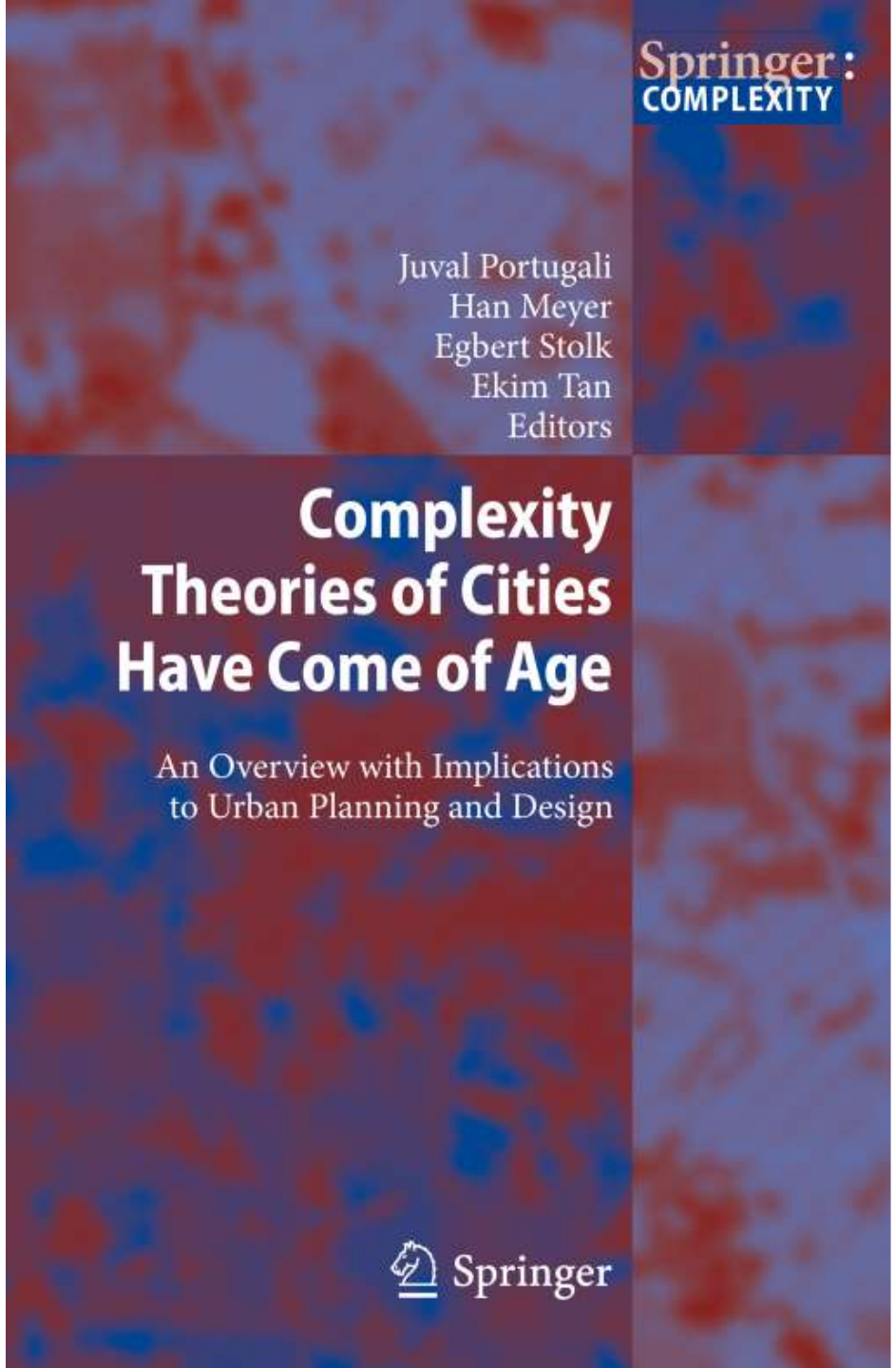
Allometry cities

$$Y(t) = Y_0(t)N(t)^{\beta},$$

where $Y(t)$ stands for a given urban indicator, $N(t)$ is the population size of a city at time t, and $Y_0(t)$ is a time-dependent normalization constant. β that characterizes the various urban indicators, can take three universal forms: $\beta<1$, a ***sublinear*** *regime* …,,; $\beta \approx 1$, a ***linear*** *regime* …. and $\beta > 1$, a ***superlinear*** *regime* associated with outcomes from social interactions …







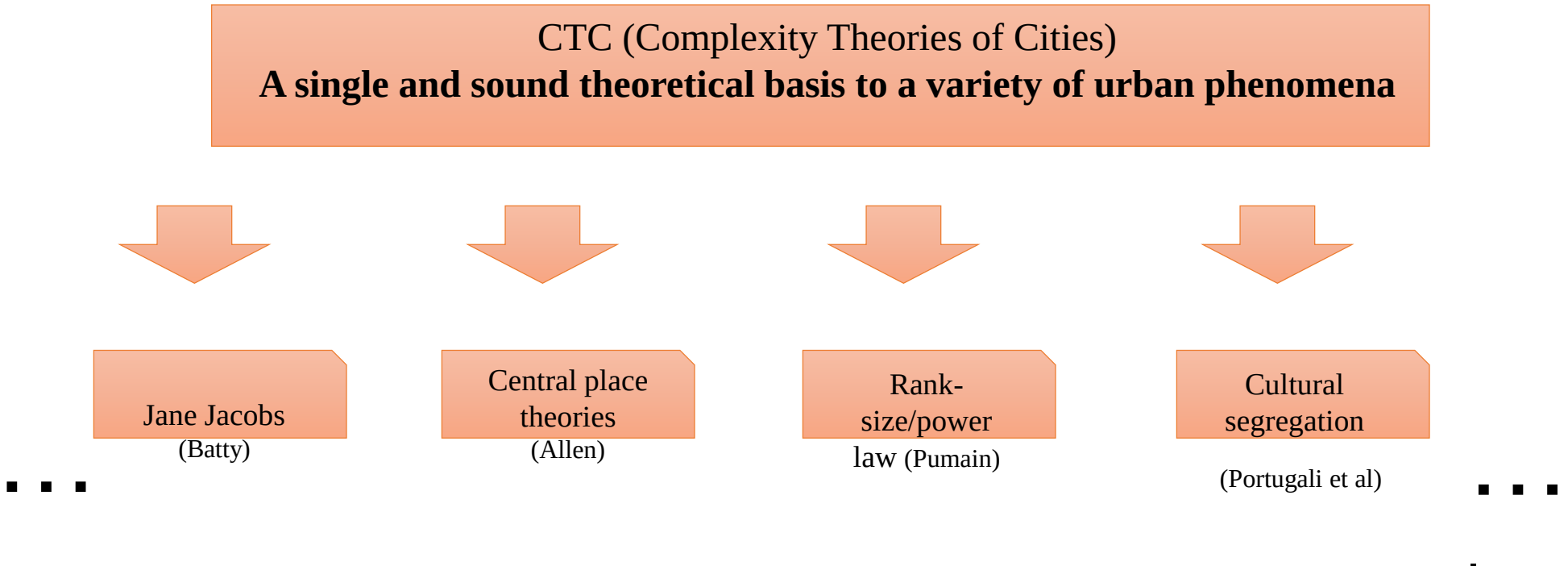
Complexity theories of cities (CTC) have come of age

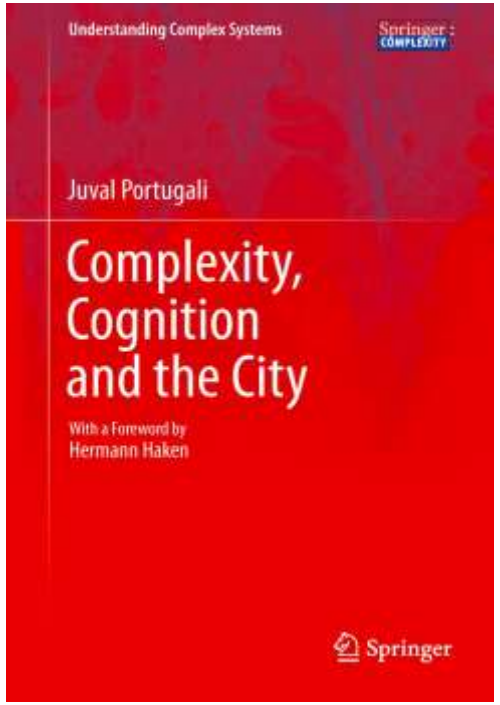
From a narrow stream of studies – written mainly by physicists applying theories from physics – it has now become not a flood but an established interdisciplinary research domain engaging urbanists, geographers, planners, urban designers, regional scientists, mathematicians and physicists among others.

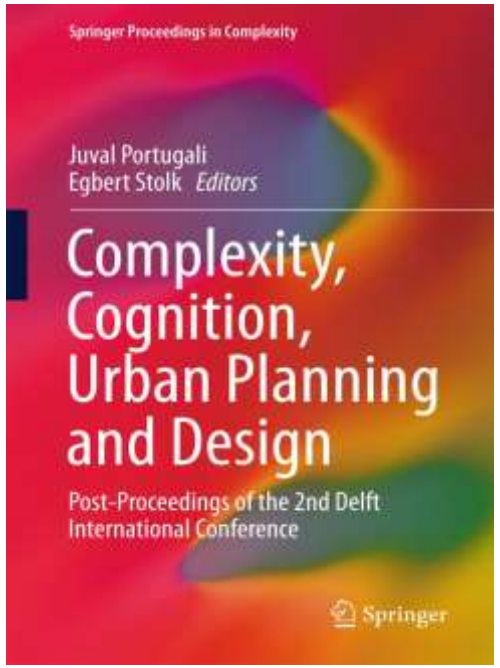
Achievements

Michael Batty:

In the past 25 years, our understanding of cities has slowly begun to reflect Jacobs's message. Cities are no longer regarded as being disordered systems. Beneath the apparent chaos and diversity of physical form, there is strong order and a pattern that emerges from the myriad of decisions and processes required for a city to develop and expand physically.







Why Cognition?

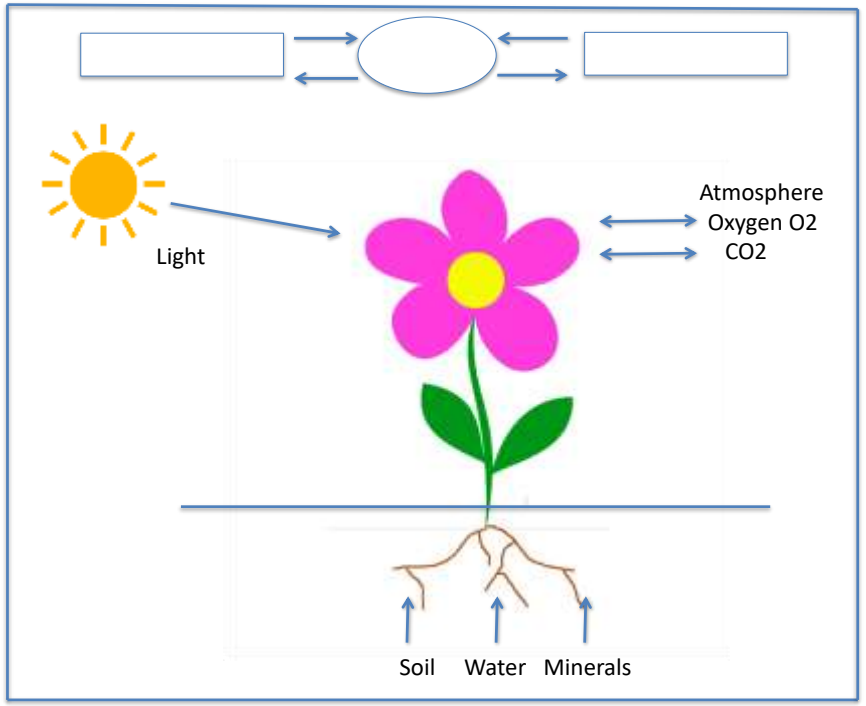
A: Because human systems differ from both material and organic systems, that is, they differ from natural systems:

Natural organic systems are subject to one evolutionary process – Darwinian evolution
Humans are subject to two evolutionary processes
- Darwinian and cultural

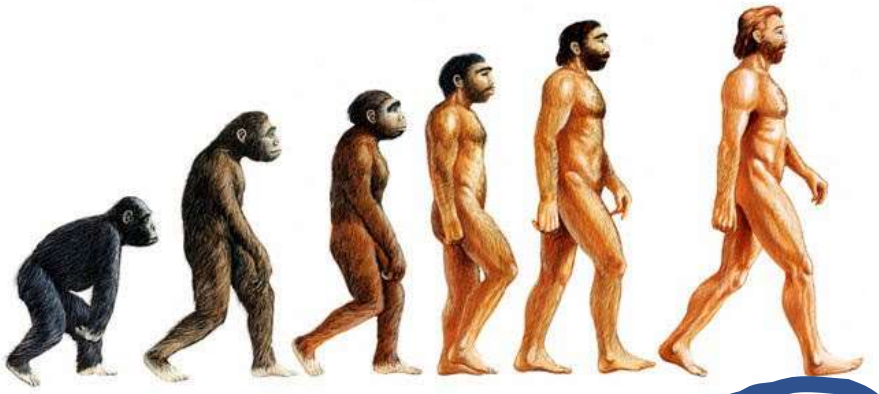
Cities are dually complex systems=
They are HYBRID CS

B: The Quark, the jaguar and the City:
What can the city add to Complexity theory?

To understand human behavior in cities we need to make a link to cognitive science



CAS are subject to one evolutionary process: natural Darwinian Evolution

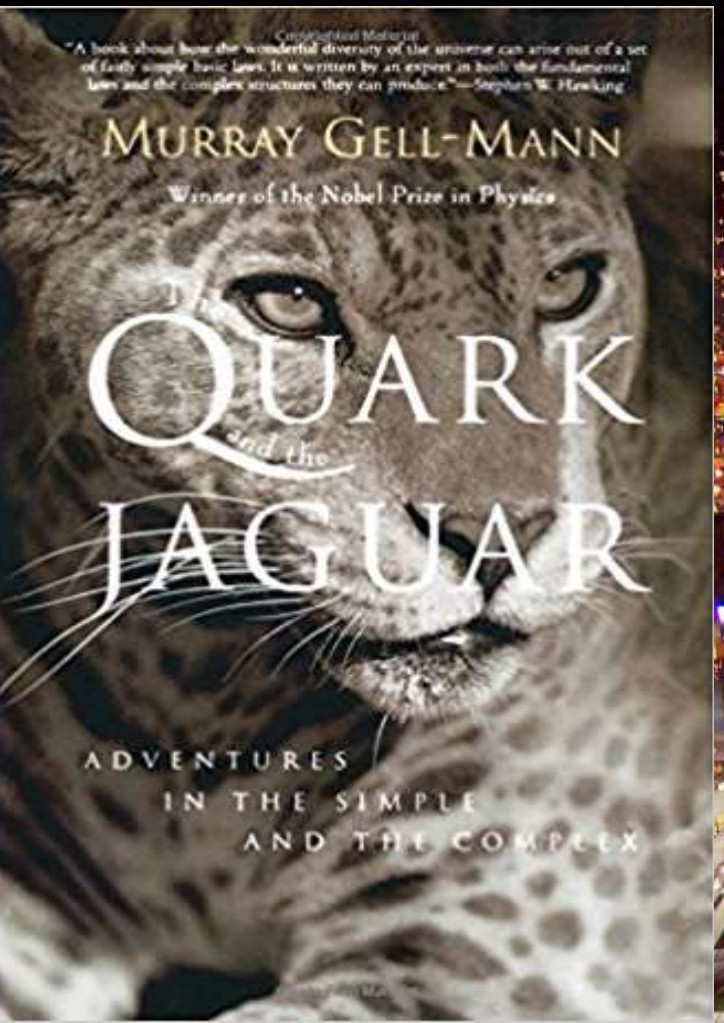


Hybrid complex systems are subject to two evolutionary processes: natural and artificial/cultural

The Quark, the jaguar and the City

"The world of the quark has everything to do with a jaguar circling in the night".
Arthur Sze, a Chinese-American poet.

From CAS to Hybrid CAS (H-CAS)



To understand human behavior in cities we need to make a link to cognitive science!

What can the link to cognition tell us about cities?

Cognitive maps: People behavior in the city is determined by their (often systematically distorted) cognitive map of the city

Image of the city: Urban morphology affects legibility/imageability

Mental maps studies: People perception of the environment depends on (determined by) their location in space.

Embodied cognition: People perceive environmental affordances

Brain studies/neurology: The hippocampus as a cognitive map;
Brain plasticity: memorizing a city affects human brain
Place cells, grid cells, edge/border cells, head direction cells

Human memory is chronesthetic, capable of mental time travel (MTT)

The brain is the ultimate complex system

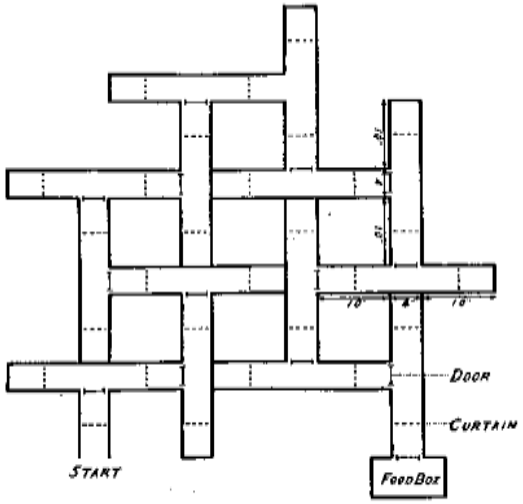
But, CS disregard artifacts

Cognitive maps (CM)

Tolman (1948) Cognitive maps in rats and men

S → CM → R

Environment

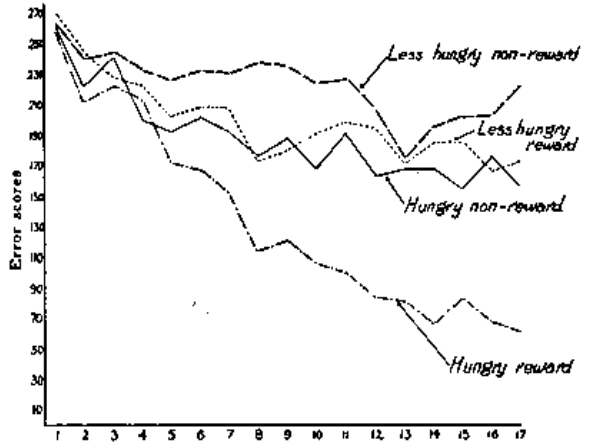


Plan of maze
14-Unit T-Alley Maze

FIG. 1

(From M. H. Elliott, The effect of change of reward on the maze performance of rats. *Univ. Calif. Publ. Psychol.*, 1928, 4, p. 20.)

Behavior

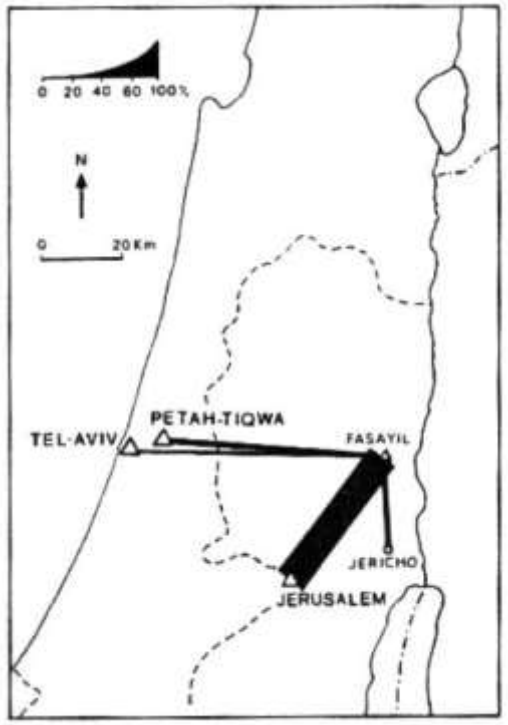


Error curves for four groups, 36 rats.

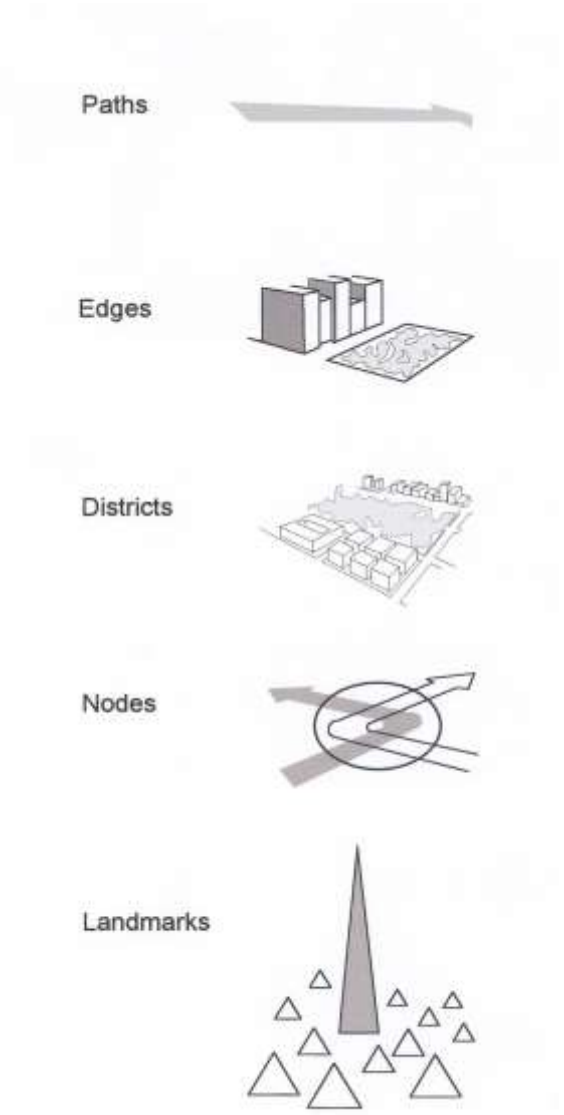
FIG. 3

(From E. C. Tolman and C. H. Honzik, Degrees of hunger, reward and non-reward, and maze learning in rats. *Univ. Calif. Publ. Psychol.*, 1930, 4, No. 16, p. 246. A maze identical with the alley maze shown in Fig. 1 was used.)

Cognitive maps are often systematically distorted



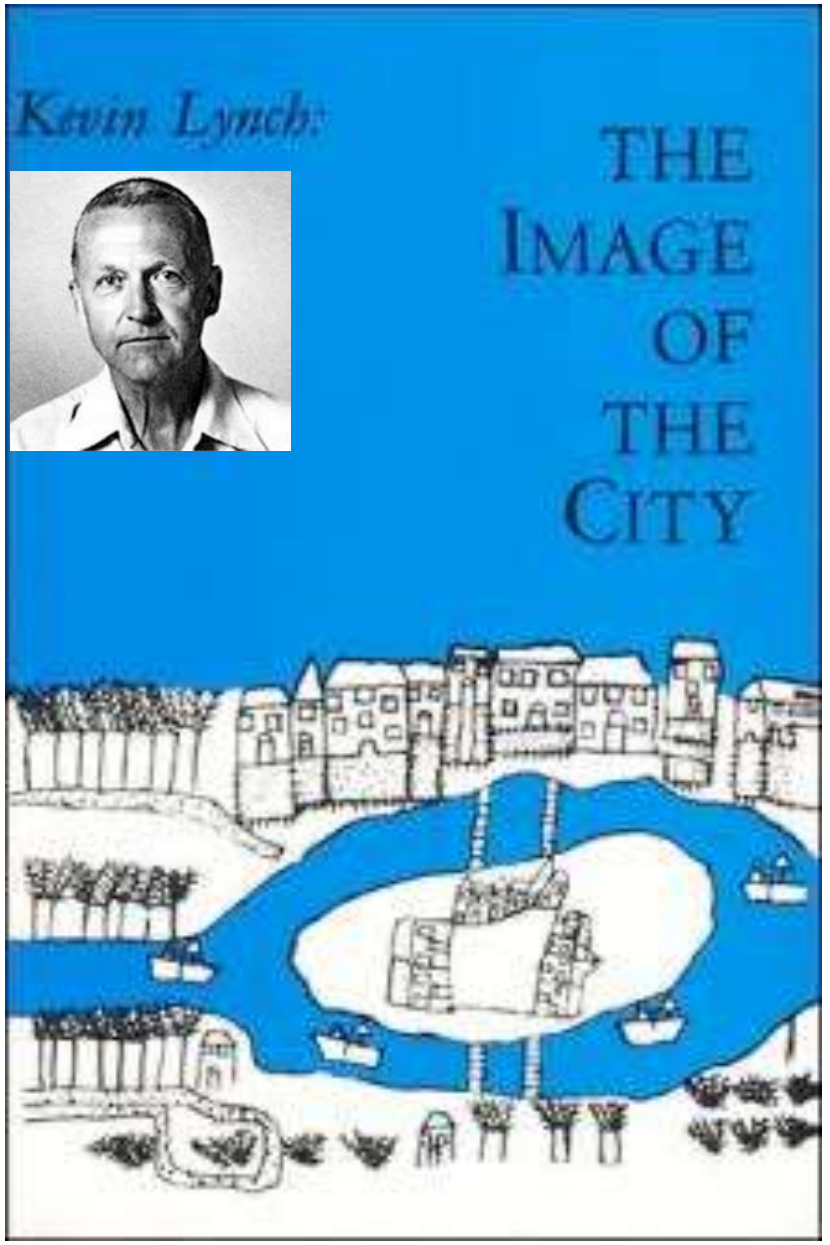
5 Elements



Boston, Jersey city, Los Angeles

Legibility

קריאות



Mental maps

Behavioral geography

Mental maps of school leavers responding to the question “If you had a free choice, where would you like to live?” (Gould and White, 1974, 69): *Left*, from Bristol. *Middle,* from Aberystwyth. *Right*, from Liverpool. Source, ibid, Figs. 3.1 3.3, 3.4.

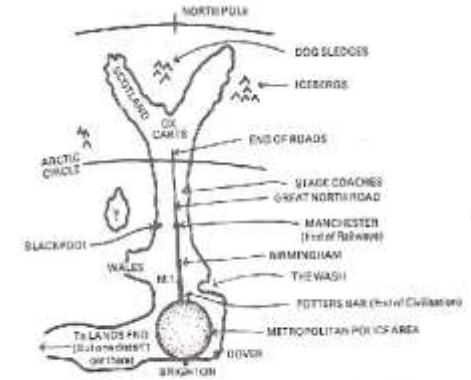
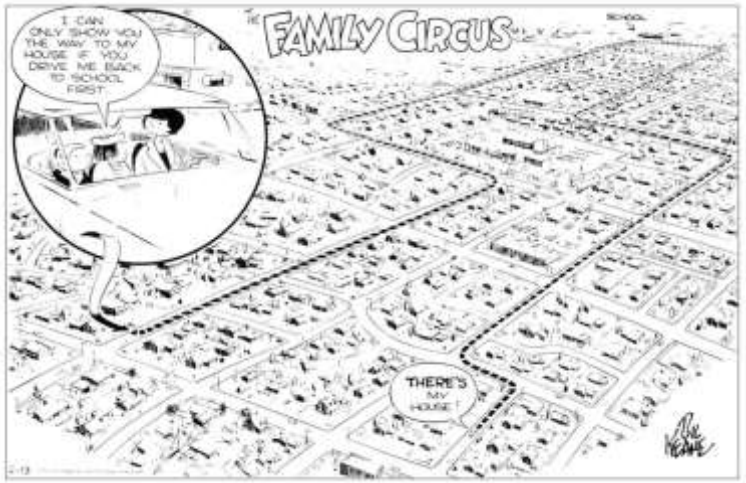
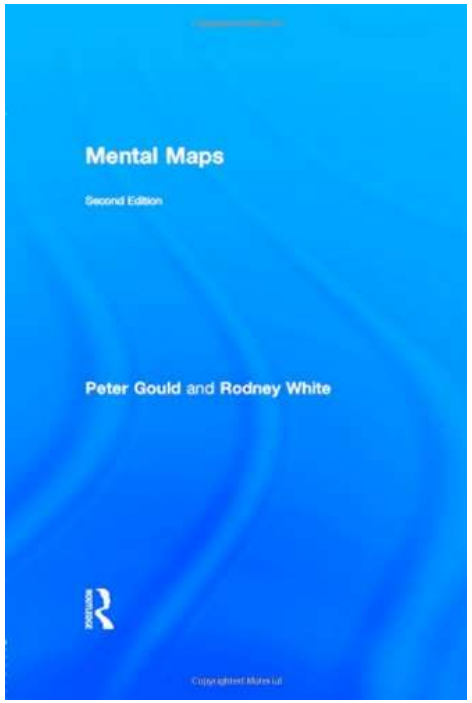
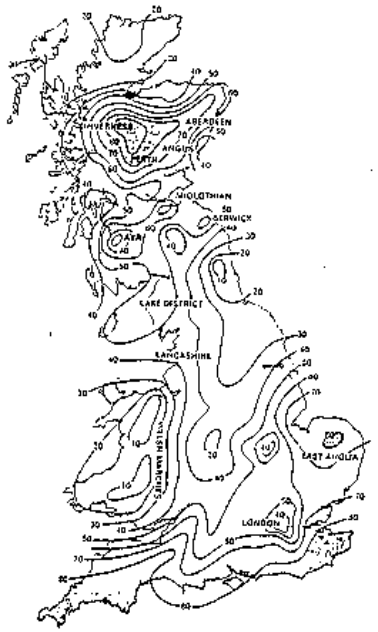
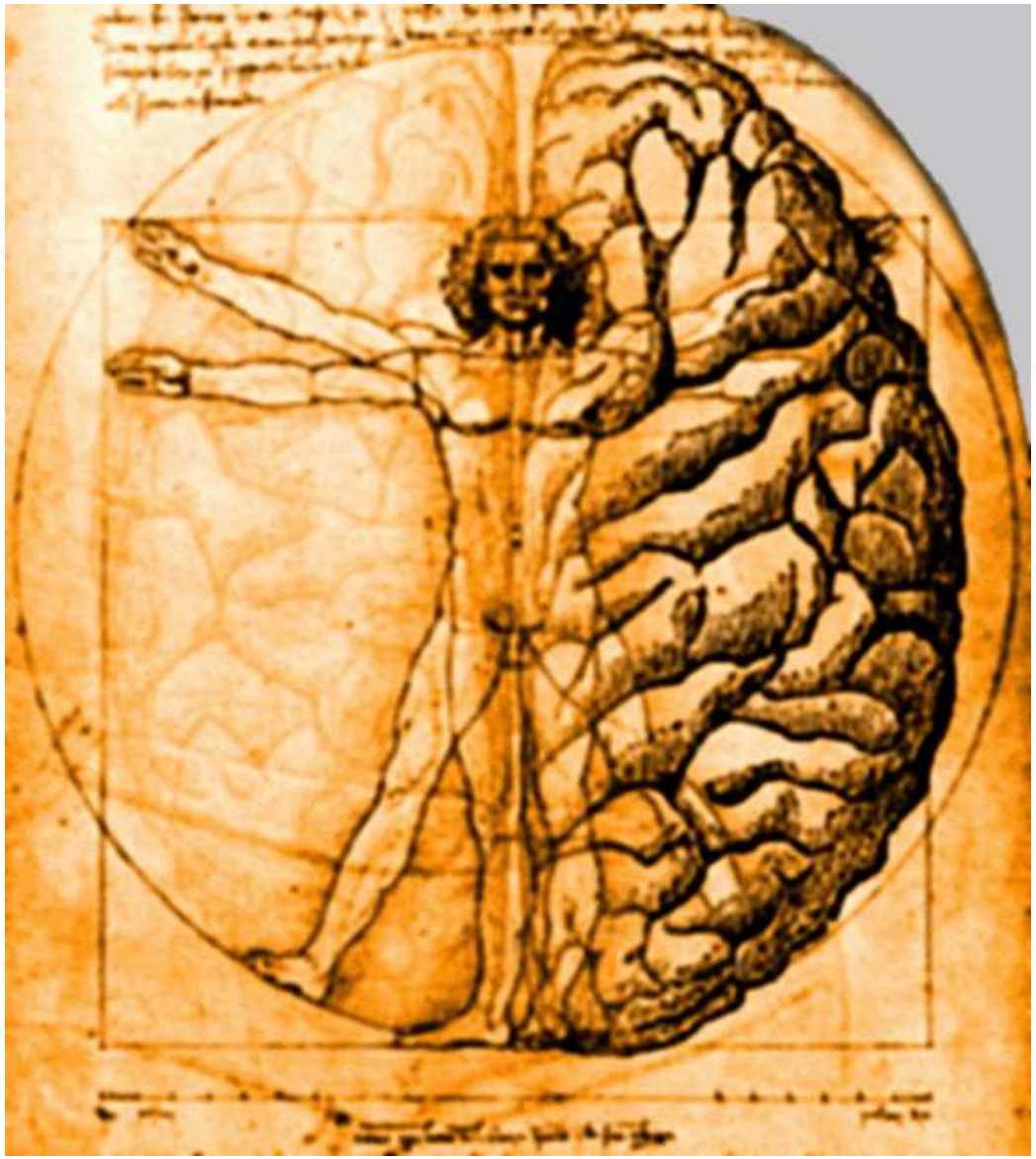


Figure 1.10 How Londoners see the North – at least, according to the Doncaster and District Development Council.









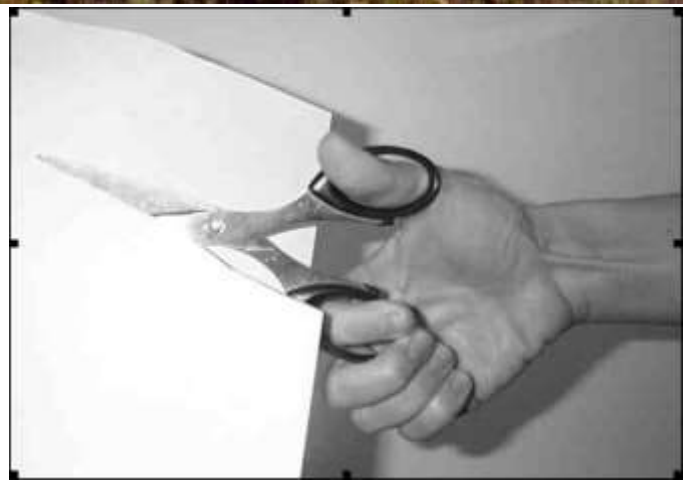
Embodied cognition

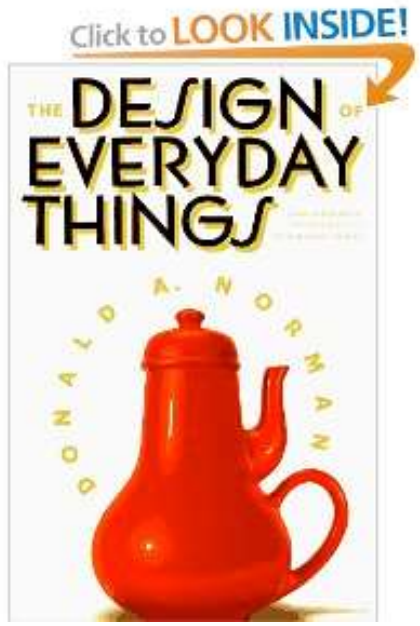
The mind/brain, the body and the environment form a single interacting system

A) *Perception*

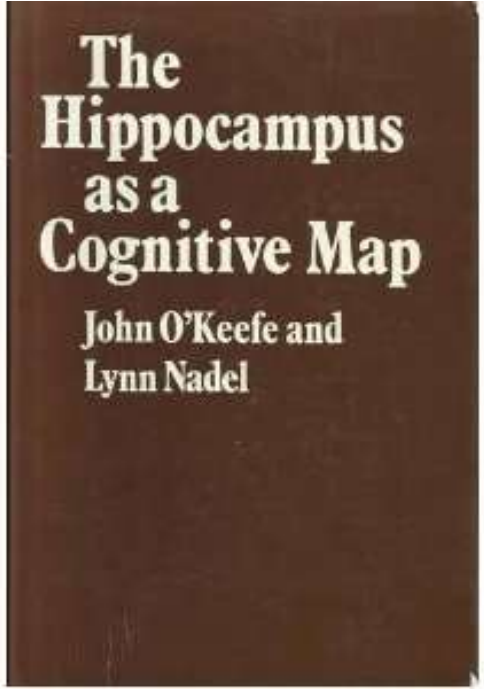
B) *Perception* —— *Action*

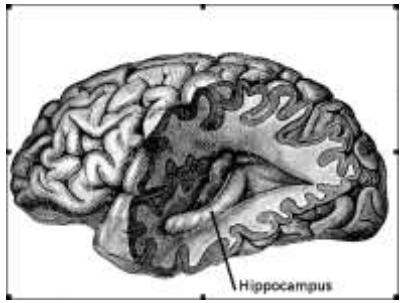
Gibson's (1986) ecological approach to visual perception: organisms perceive environmental affordances

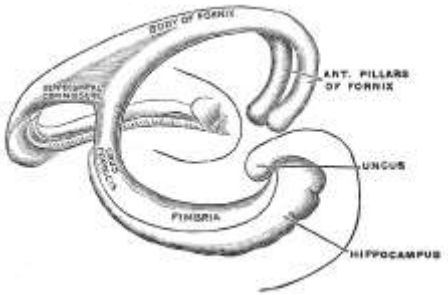


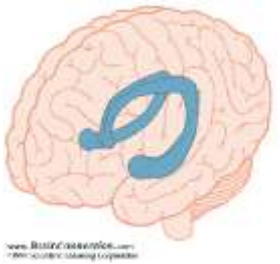


Donald Norman 1988/2002, ***The Design of Everyday Things*** (originally entitled The Psychology of Everyday Things): Gibsonian affordances are part of nature. **Artifacts' affordances** are part of culture = specifically designed to fit (adapt to) humans' bodily and cognitive capabilities.



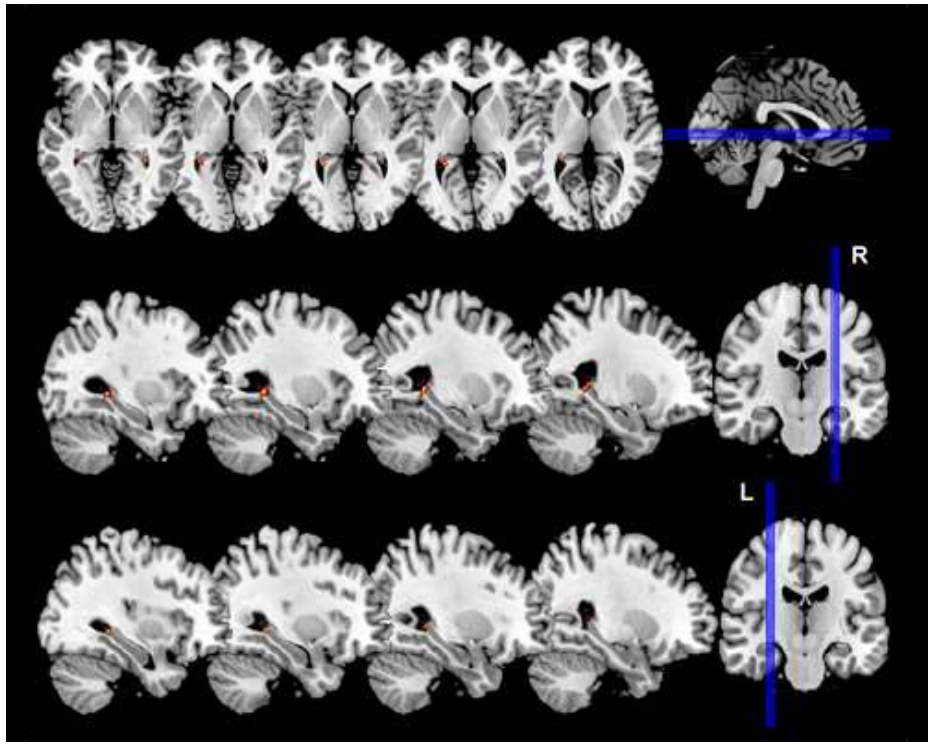






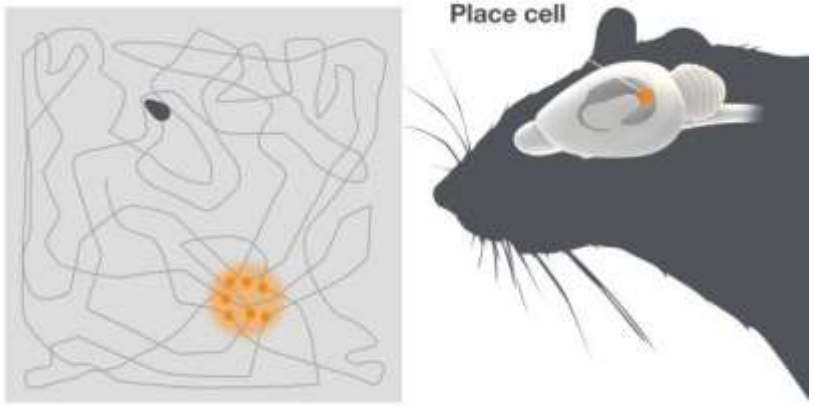
The neurological basis

The Knowledge: drivers' navigational knowledge of London's streets and points of interest.

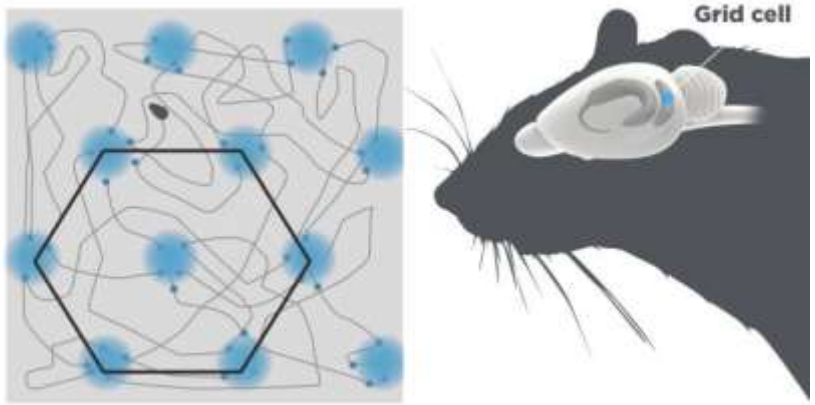


The Nobel Prize in Physiology or Medicine 2014

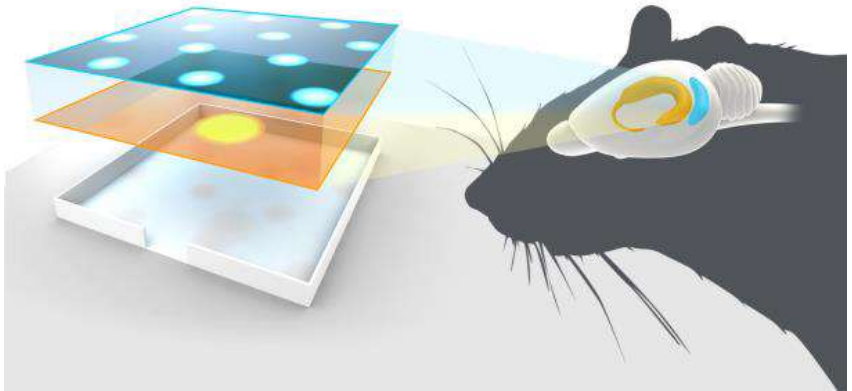
John O'Keefe **May-Britt and Edvard I. Moser**



Place cells. *To the right is a schematic of the rat. The hippocampus, where the place cells are located is highlighted. The grey square depicts the open field the rat is moving over. Place cells fire when the animal reaches a particular location in the environment. The dots indicate the rat's location in the arena when the place cell is active. Different place cells in the hippocampus fire at different places in the arena.*



Grid cells. *The grid cells are located in the entorhinal cortex depicted in blue. A single grid cell fires when the animal reaches particular locations in the arena. These locations are arranged in a hexagonal pattern.*

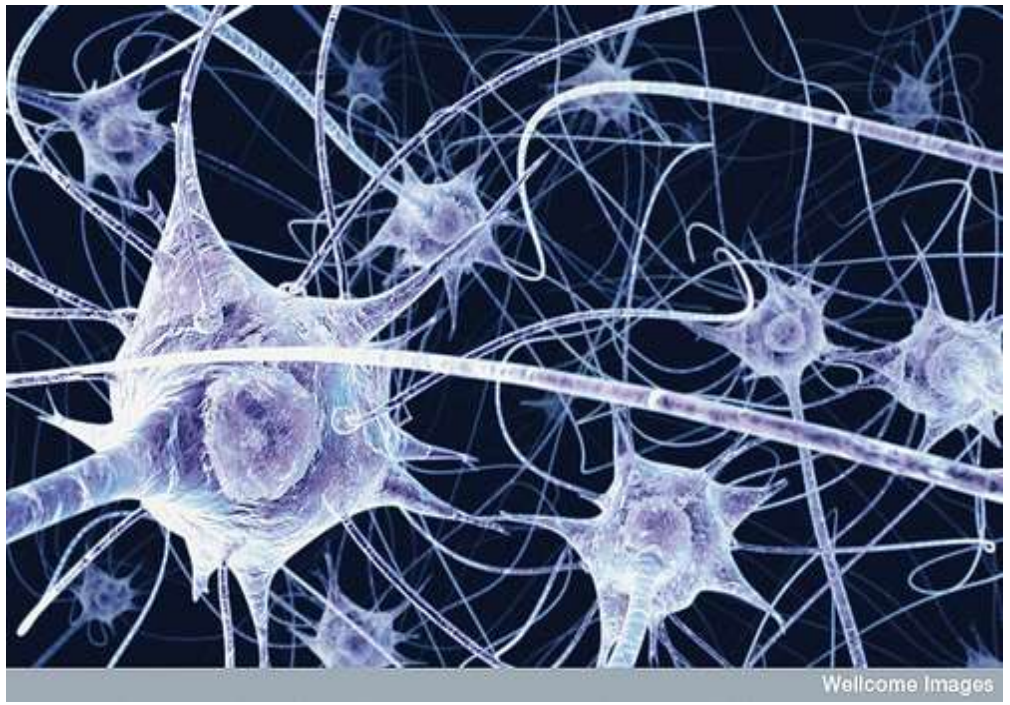


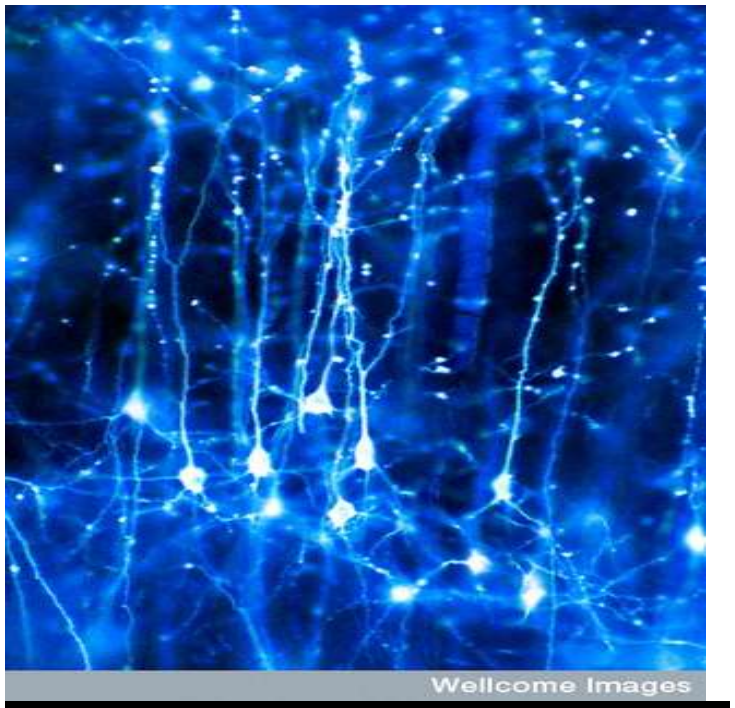
A schematic showing grid cells (blue) and place cells (yellow) in the entorhinal cortex and hippocampus, respectively.

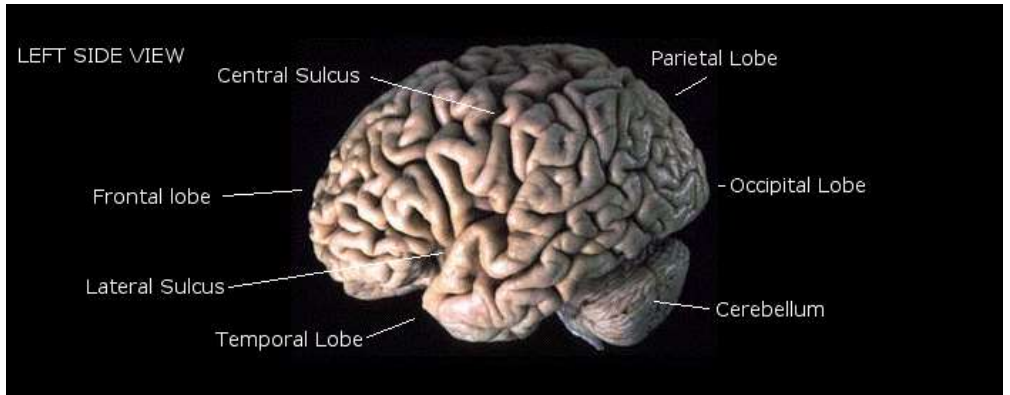
Together with head direction and border cells: the neurological basis of spatial behavior

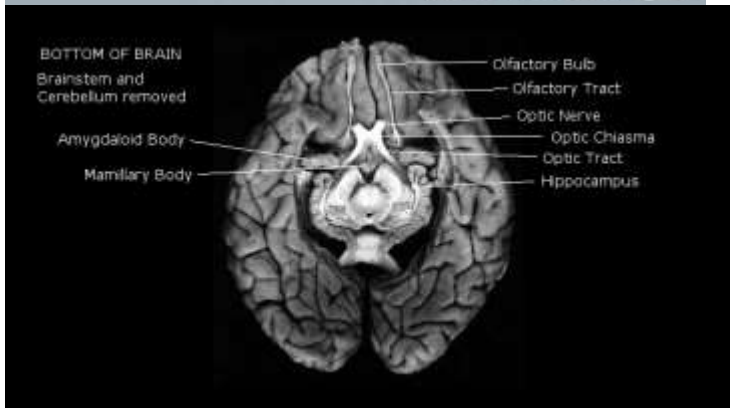
Complexity, self-organization and cognition

The brain with its about 100 billion (10^{11}) neurons each with about 10^4 connections is often mentioned as the ultimate example of a complex system.



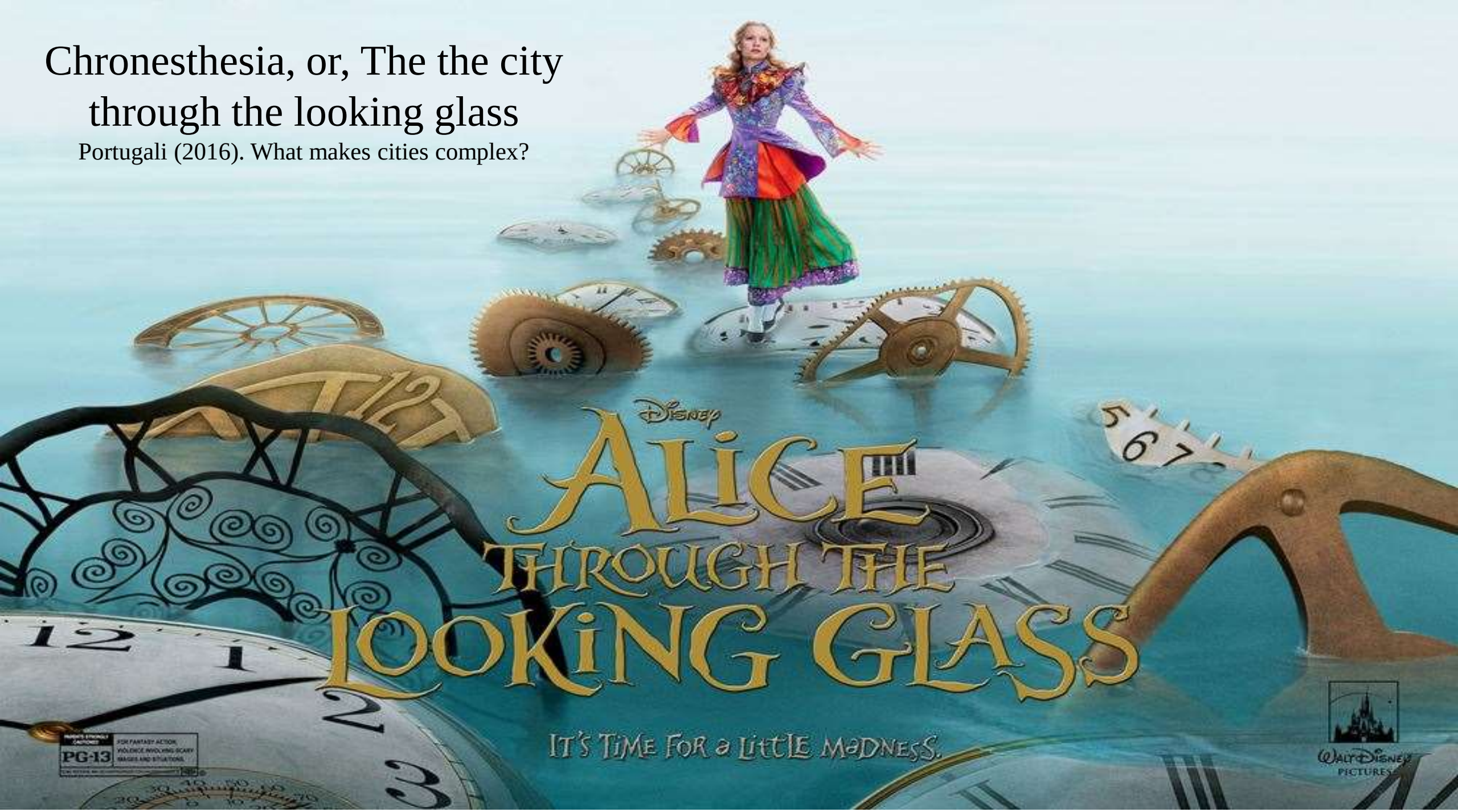






Chronesthesia, or, The the city through the looking glass

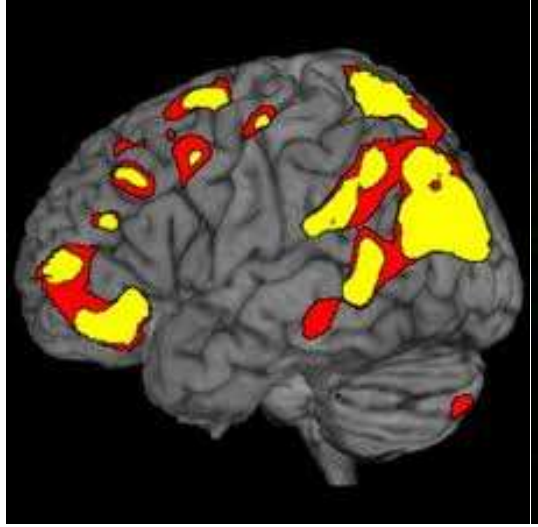
Portugali (2016). What makes cities complex?



Alice and the White Queen in **Through the Looking Glass** by Lewis Carrol:

I don't understand you,' said Alice. `It's dreadfully confusing!'
`That's the effect of living backwards,' the Queen said kindly:
`it always makes one a little giddy at first --
`Living backwards!' Alice repeated in great astonishment. `I never heard of such a thing!'

` -- but there's one great advantage in it, that one's memory works both ways.'
`I'm sure *mine* only works one way.' Alice remarked. `I can't remember things before they happen.'
`It's a poor sort of memory that only works backwards,' the Queen remarked.



fMRI Chronesthesia

Back to the future

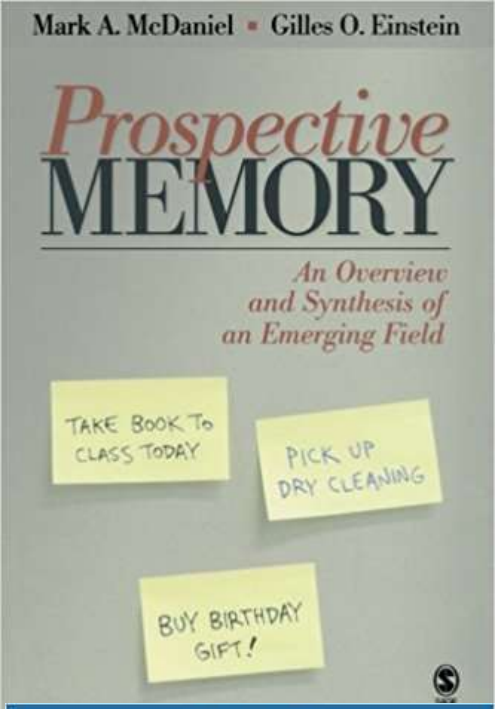
Piolino P. Prospective memory

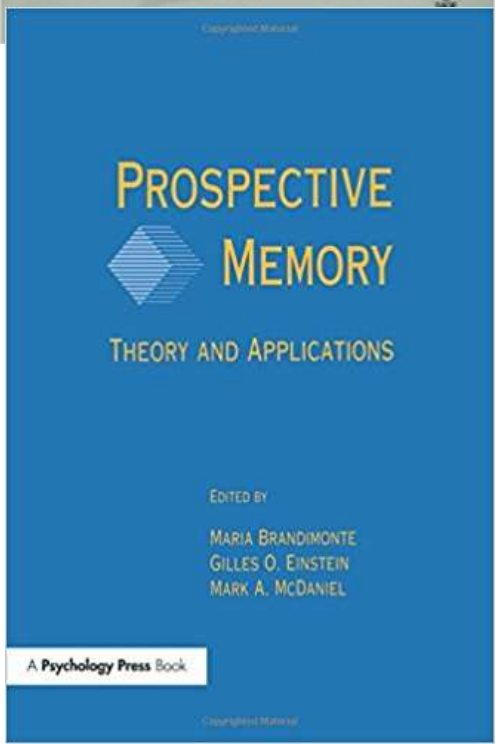
Chronesthesia,' or mental time travel (MTT)
The brain's ability to think about the past, present, and future

Lars Nyberg; Reza Habib, Alice S. N. Kim, Brian Levine, and **Endel Tulving**, *Proceedings of the National Academy of Sciences***.**

"…. certain regions in the left lateral parietal cortex, left frontal cortex, and cerebellum, as well as the thalamus, were activated differently when the subjects thought about the past and future compared with the present. *Notably, brain activity was very similar for thinking about all of the non-present times (the imagined past, real past, and imagined future).*

Forms of Chronesthesia/ MTT: Prospective memory (Cue dependent and time dependent) **and Cognitive planning**





Forms of Chronesthesia/ MTT:
Prospective memory (Cue dependent and time dependent)
and
Cognitive planning

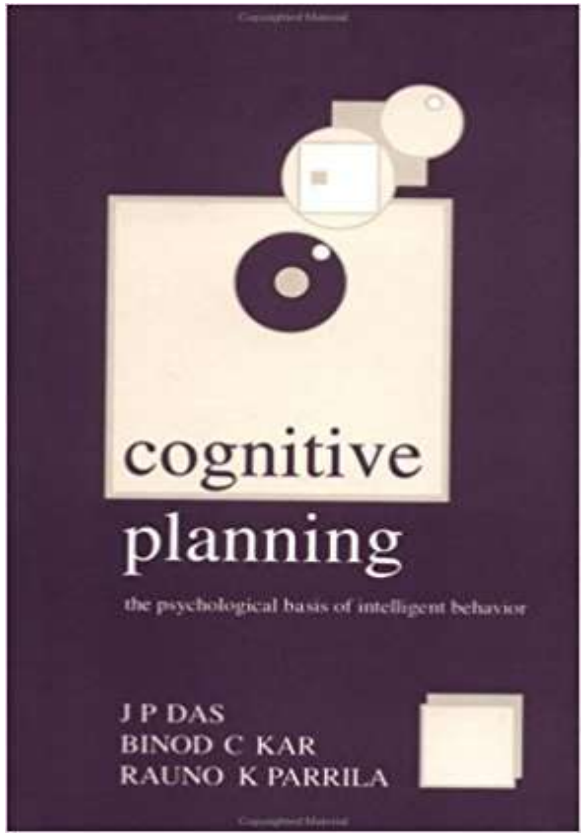
Cognitive Processes (2005) Jun;6(2):87-97.

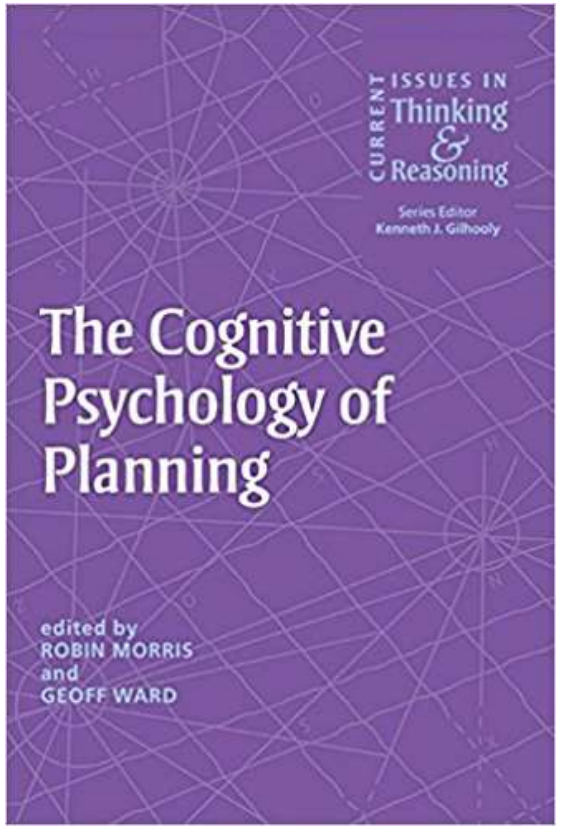
A synergetic interpretation of cue-dependent prospective memory.

Haken H, Portugali J.

Abstract

In this paper, we make a preliminary attempt to approach the phenomenon of prospective memory (PM) from the point of view of Haken's theory of synergetics that refers to complex, self-organizing systems, in general, and to brain functioning and cognition, in particular. In the following, we consider one form of PM only-the so-called event- or cue-dependent PM. We first interpret cue-dependent PM in terms of synergetics and then applythe mathematical formalism of synergetics.





Human tend to mentally travel in time – back to the past as well as forward to the future

It takes a lot of mental effort to meditate in order to be for a while in the here and now

Suggestion:
Planning and design are direct manifestations of humans' chronesthetic and constructive memory

Humans are, therefore, natural planners and designers

Not only that humans have the ability for MTT, but,
they cannot not mentally travel in time – back to the past as well as forward to the future.

Urban agents as natural planners and designers
cannot not plan or design

Suggestion:

From the above follow
two new forms of human behavior:

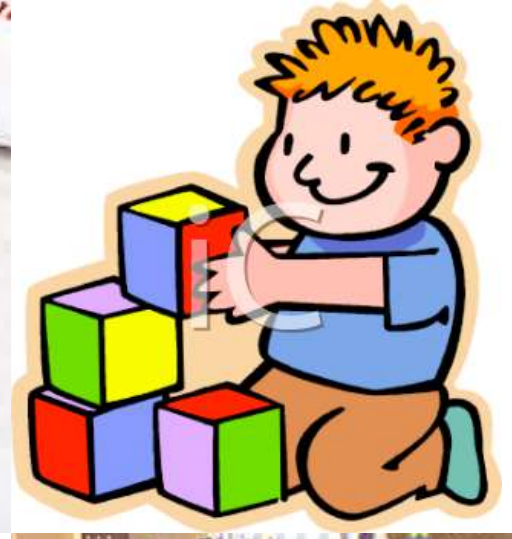
Planning behavior (Portugali 2011)

And

Design behavior

One is behaving and acting in response to a plan
or design, that is,
in response to a reality that doesn’t yet exist and
might never exist

Born to plan -- Planning behavior



Born to design – design behavior

Urban dynamics implications

Suggestion: two new forms of behavior:

Planning behavior

And

Design behavior

Urban agents are behaving and acting in
response to plans or designs,
that is,
in response to a reality that doesn’t yet exist and
might never exist

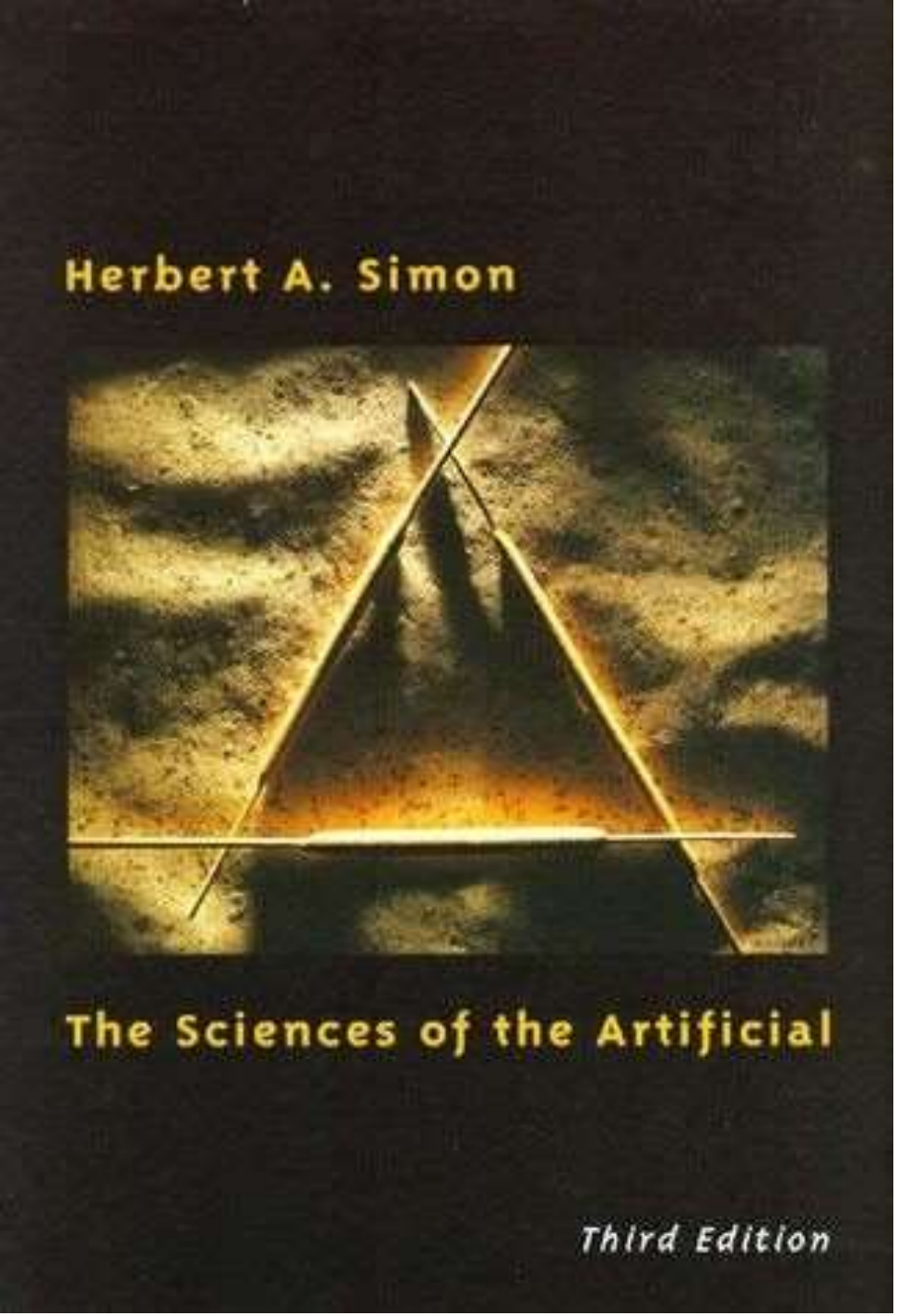
In response to invisible cities

Urban planning implications

Every person or urban agent is a planner at a certain scale

In the city we therefor have two forms of planning:

Institutional planning
executed by professional planners usually in the name of the authorities
Versus
Cognitive planning
executed by every person/urban agent



The link to cognitive science thus tells us a lot about human behavior in cities but it also created a problem:

A methodological barrier between cognition and the city.
The reason:
Cognitive science disregards artifacts.

To use Herbert Simon's phrase in his 1969 *The Sciences of the Artificial*,
"the term 'artificial' has a pejorative air about it"

Yet a city is (at least partly) **an Artifact**

A case is point is Chomsky (1983, 26-7) in his *Knowledge of Language: Its nature, origin and use*.

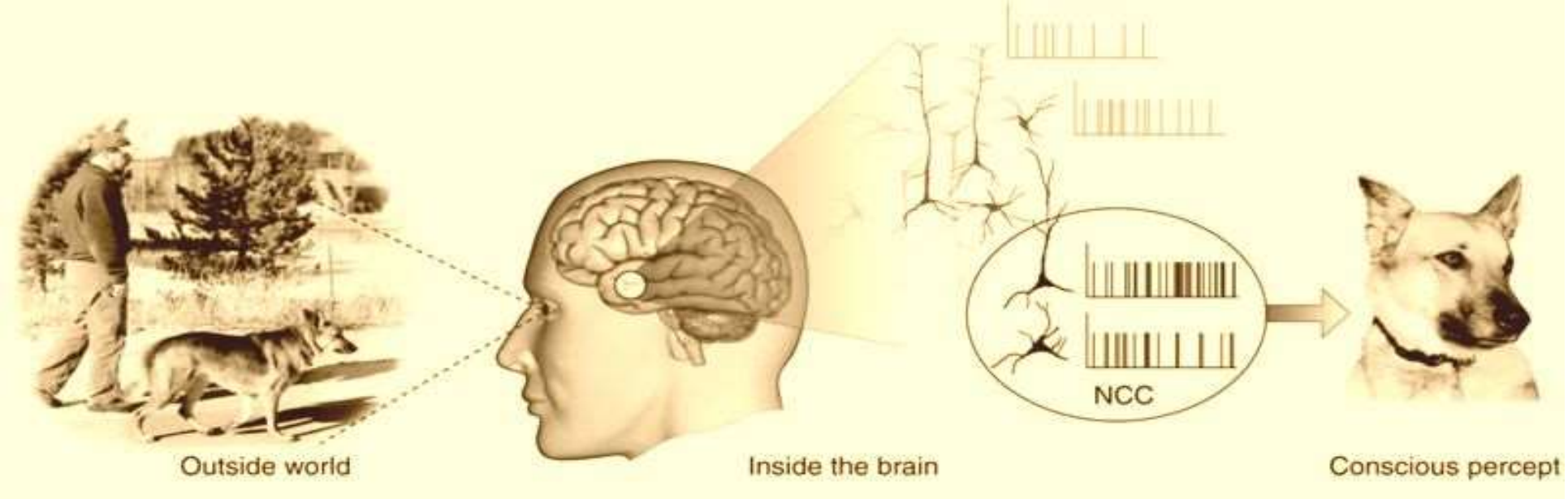
N. Chomsky (1983, 26-7) in his

Knowledge of Language: Its nature, origin and use.

The notion of E-language has no place in this picture. There is no issue of correctness with regard to E-languages, however characterized, *because **E-languages are mere artifacts**. . . the concept appears to play no role in the theory of language*. . . The technical concept of E-language is a dubious one in at least two respects. In the first place ... ***languages in this sense are not real-world objects but are artificial***, somewhat **arbitrary**, and perhaps **not very interesting** constructs. In contrast ... statements about I-language ... are true or false statements about something real and definite, about actual states of the mind/brain and their components ... (italics added).

The outcome is a paradoxical situation:
On the one hand, cognitive science tells us
(in the words of Kandel, 2012, p.284, about vision), that

"Thus, we live in two worlds at once, and our ongoing visual experience is a dialogue between the two: the outside world that enters through the fovea and is elaborated in a bottom-up manner, and the internal world of the brain's perceptual, cognitive and emotional models that influences information from the fovea in a top-down manner."



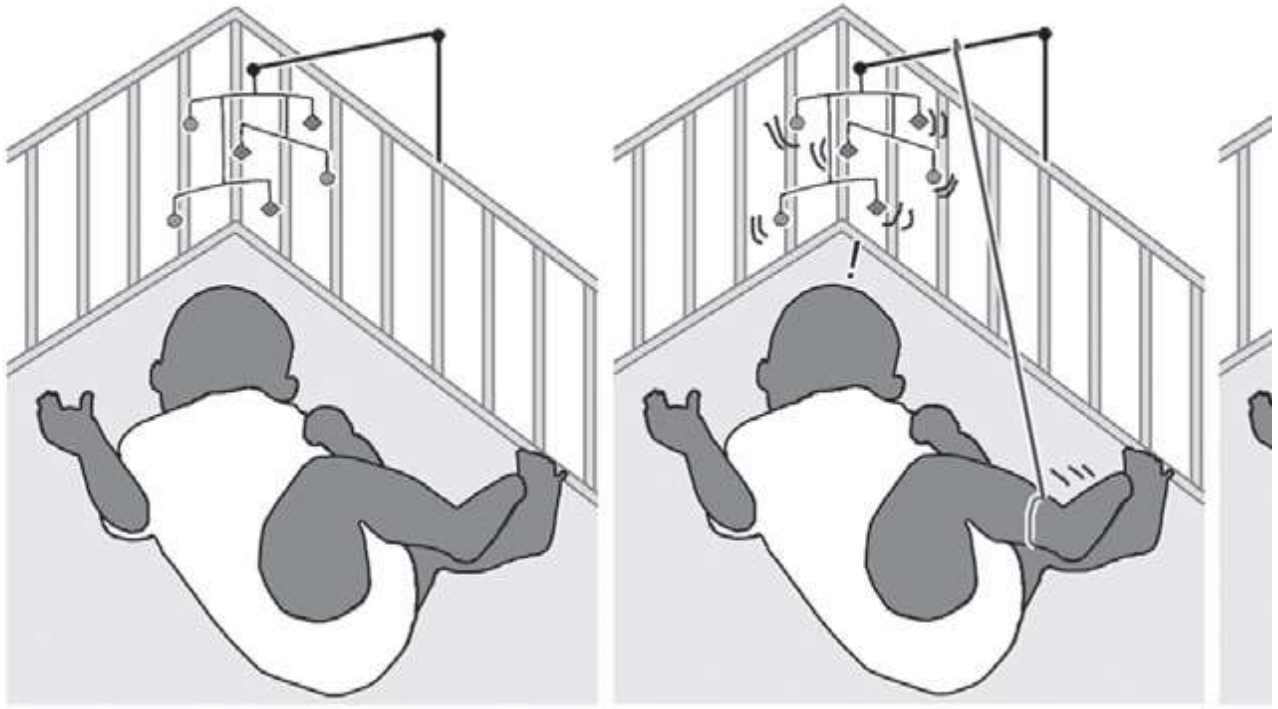
On the other hand, it tells us (in the words of Chomsky) that the external world, that is, the world of artifacts, is
"somewhat **arbitrary**, and perhaps **not very interesting** …."

This anti-artifacts tendency had an effect also on studies related to cognition and the city. For example, Lynch's main interest in the 'image of the city' was the city itself—its morphology and urban landscape.

However, in the context of behavioral and cognitive geography the interest shifted from the city to behavior in space and then to spatial cognition.

The city itself became just a passive environment by means of, and within which, behavior and cognition can be studies;

very much in line with the role of the external environment in cognitive science in general.



In the latter, the focus of interest was and still is one-sidedly on the details of the inner world, even in the above noted ecological-embodied-extended mind approaches.

"… to my knowledge,"
writes Scott Kelso (2016 , 5) in a recent study about the emergence of agency in a human infant out of the interaction between the infant and a mobile in the environment,

"not a single study has recorded the motion of the mobile, thereby obviating the possibility of obtaining any information about its relation to the baby's movements."

[Note that for urbanists the mobile is the city]

Chomsky is thus right: E-languages are artifacts.
But he is not right in saying that they are not interesting;
they are and for several reasons.

1. They are complex, self-organizing artificial systems

1. They are one example of a special kind of complex systems:
hybrid natural-artificial complex systems

3. Another example is cities: Similarly to languages,
cities too are hybrid natural-artificial complex systems

4. In the dynamics of hybrid natural-artificial complex systems

artifacts are integral part of cognition!

SIRN

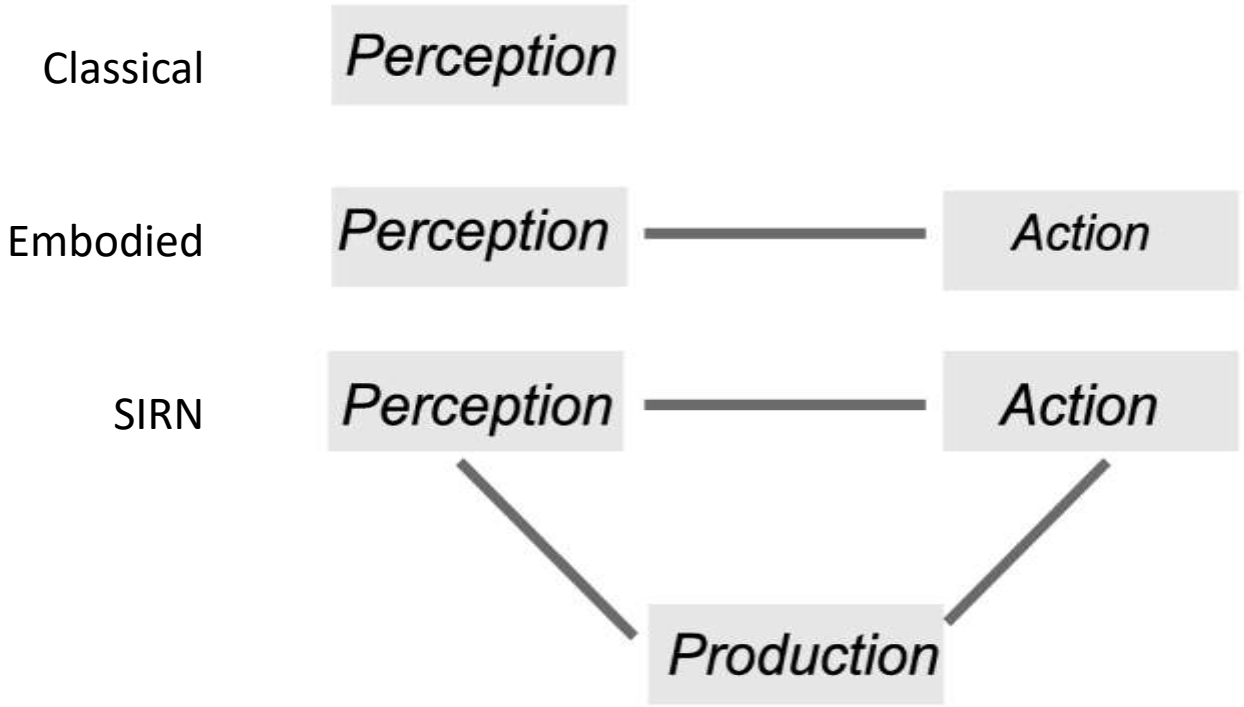
Synergetic Inter-Representation Networks

(Portugali 1996, 2011; Haken and Portugali 1996)

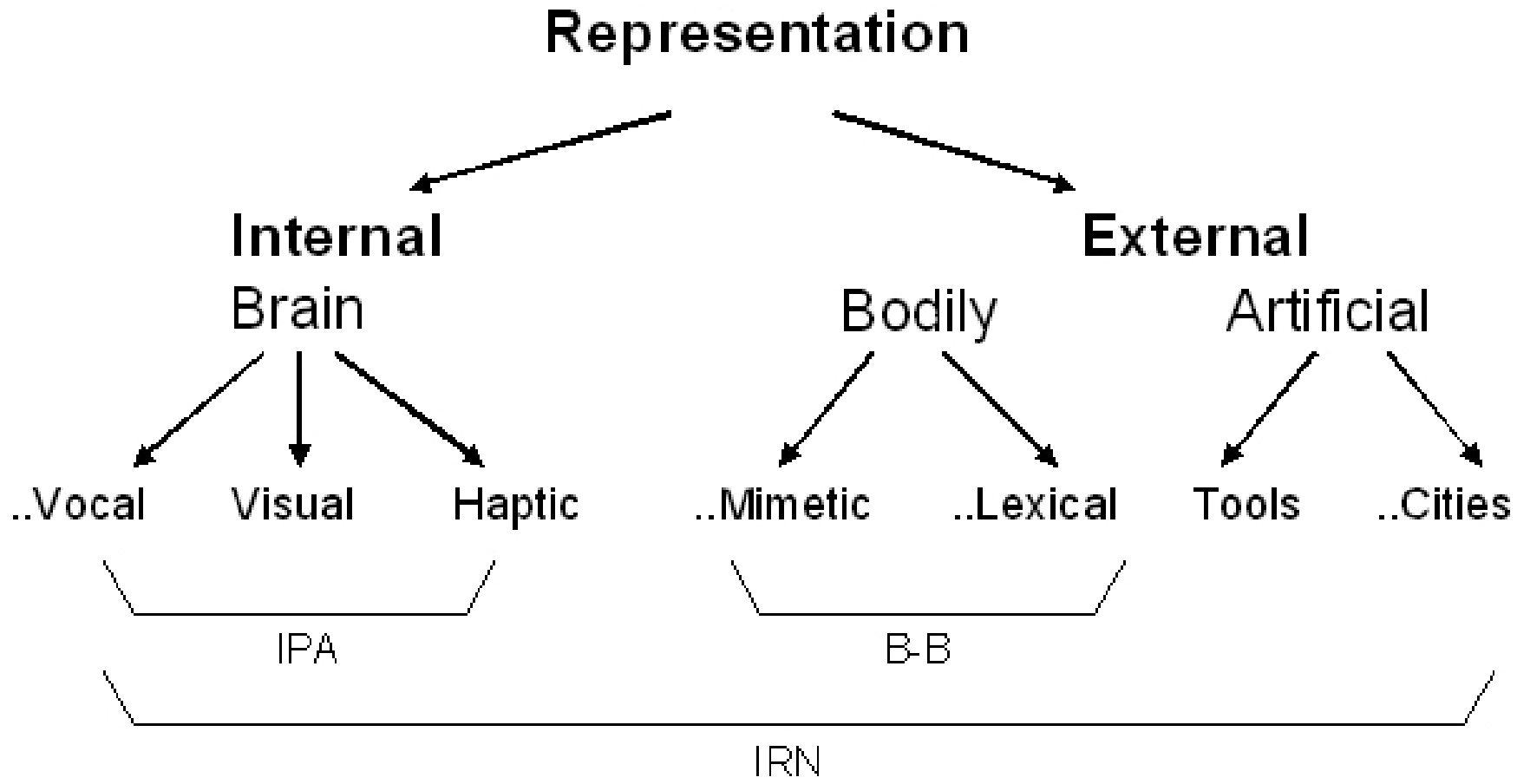
A theory that starts from the notion that
artifacts are integral part of cognition!

SIRN starts from the notion that

artifacts are integral part of cognition!



Humans come to the world with
two kinds of representation capabilities:



IRN (Inter representation networks)

Many cognitive processes evolve as an on going interaction between internal representations created in the mind/brain and external representations created in the world.

In this process we can identify two kinds of IRN processes:
Technical processes such as the multiplication of, say, several digit numbers:

2x3=6 Easy 3x12=36 Easy 476x53=????? Problem	→	476 53 1428 2380- **25228**	→	Int: 3x6=18 Externalize 8, memorize 1 Int: 3x7=21 ……

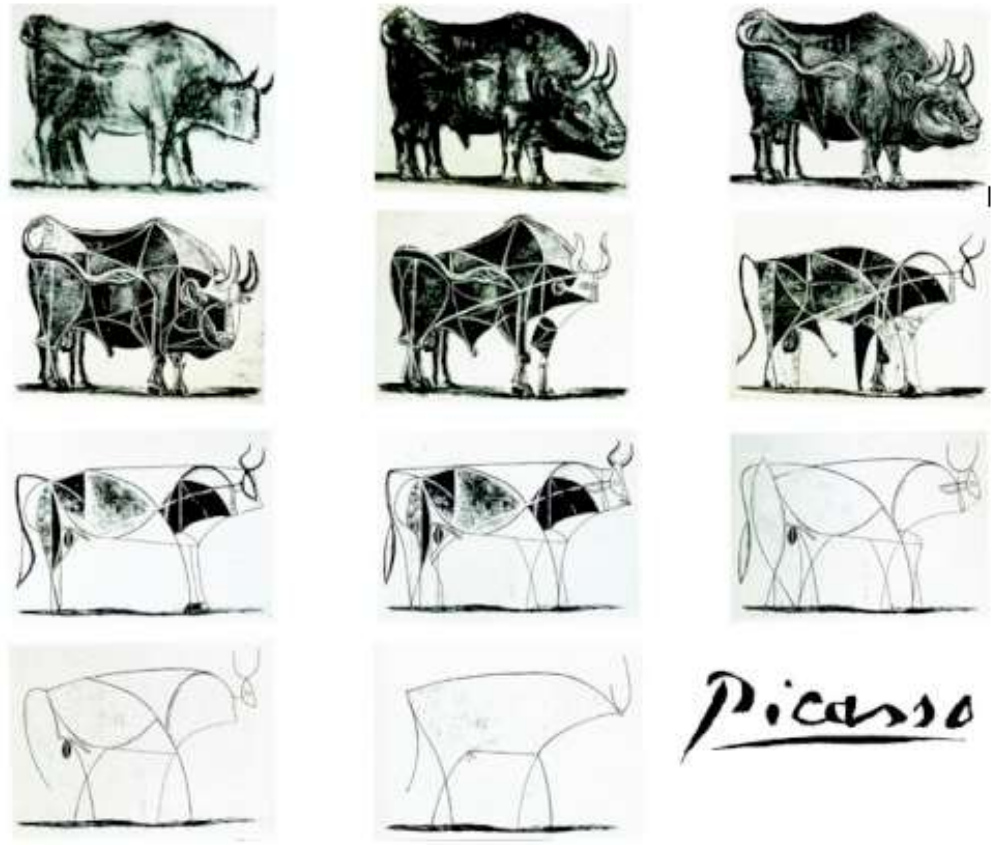
Creative processes such as painting, sculpturing, developing an idea by means of writing, and so forth.

It is here where Synergetics – Haken's theory of complex, self-organizing systems – enters and the process becomes
SIRN (Haken & Portugali, 1996)

SIRN in Art

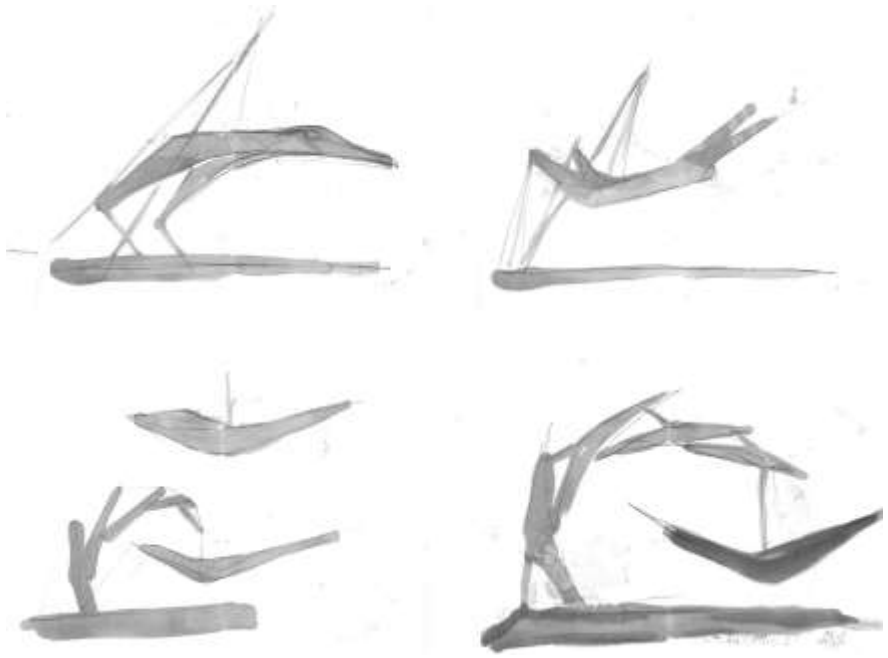
Brancusi: Kiss

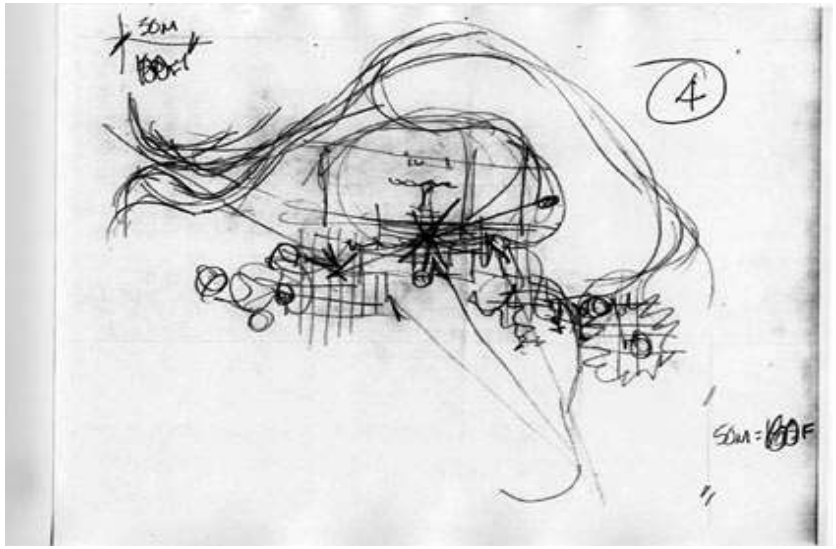
Picasso: Bull



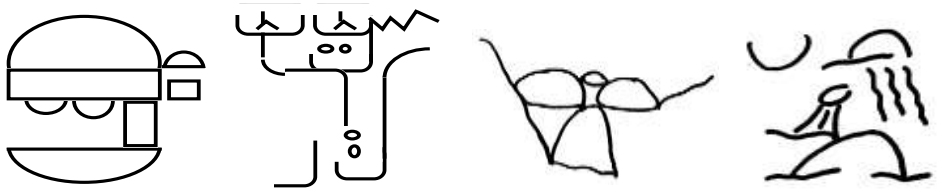
Pablo Picasso, Bull (plates I - XI) 1945

Santiago Calatrava





Externally represented sketches (“massy lines”) as thinking devices (B. Tversky)

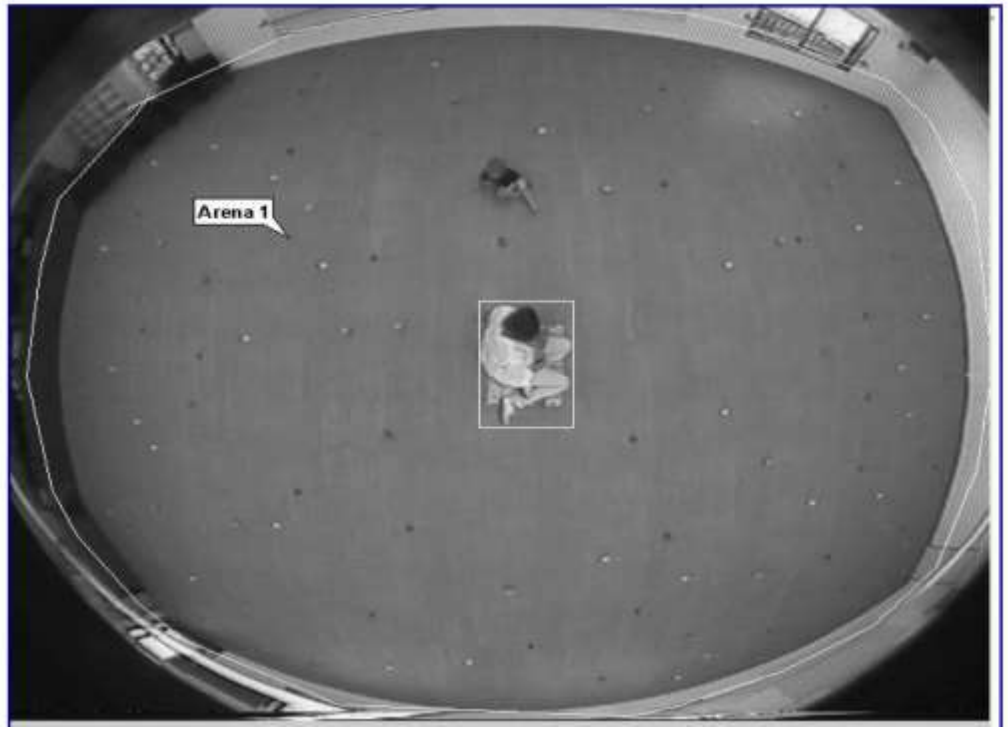


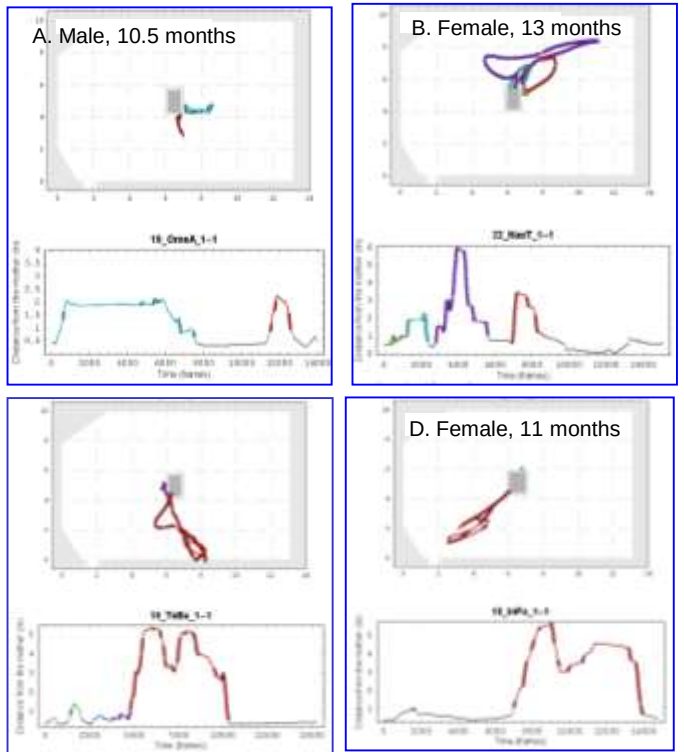
The inspiration: Bartllet's scenarios of serial reproductions

0. When the sun rose he fell down. Something black came out of his mouth. His face became contorted.
1. When the sun rose he fell down. And he gave a cry, and as he opened his mouth a black thing rushed from it.
2. When the sun rose he suddenly felt faint, and when he would have risen he fell down, and a black thing rushed out of his mouth.
3. He felt no pain until sunrise the next day, when, on trying to rise, a great black thing flew out of his mouth.
4. He lived the night, and the next day, but at sunset his soul fled black from his mouth.
5. He lived during the night and the following day, but at sunset his soul fled black from his mouth.
6. He lived during the night and the next day, but died at sunset, and his soul passed out from his mouth.
(Before the boat got clear of the conflict), the Indian died, and his spirit fled.
(Before he could be carried back to the boat), his spirit had left this world.
His spirit left the world.
(''Nonsense'', said one of the others, ''you will not die.'') But he did.

Exploratory behavior of rats

Exploratory behavior of human babies

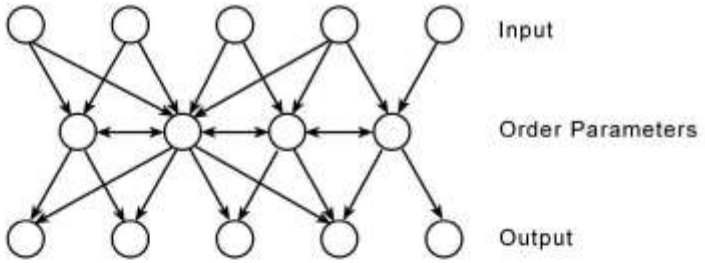


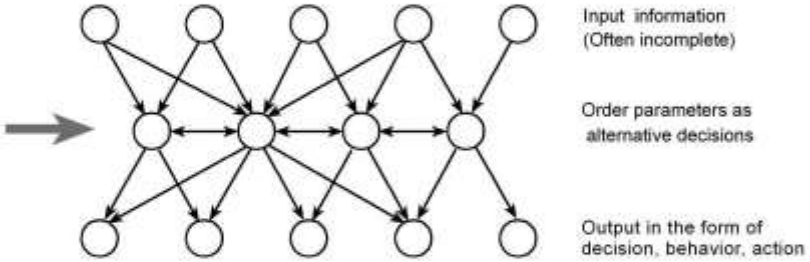


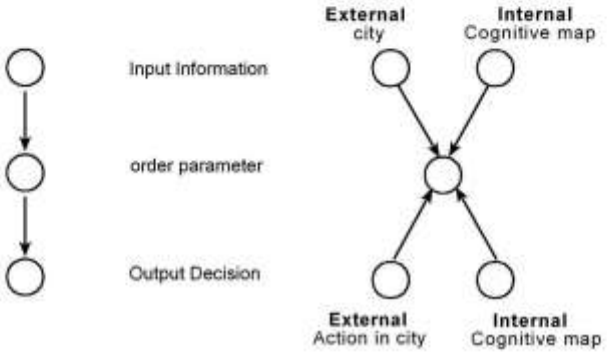
Nature

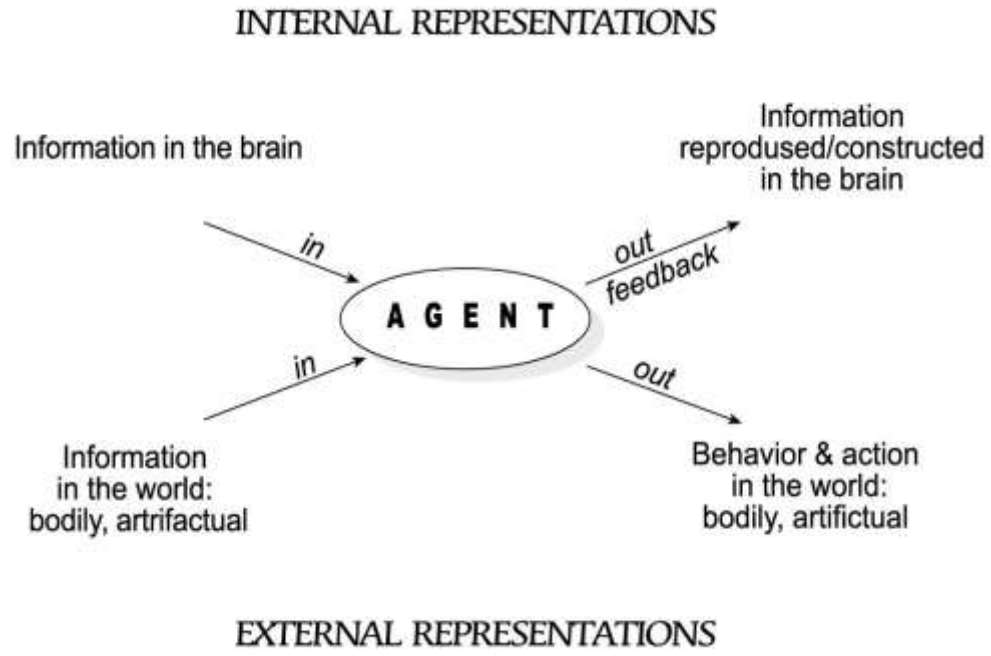
The spider is producing the environment on which it moves

Formalism:
From the Synergetic computer to SIRN









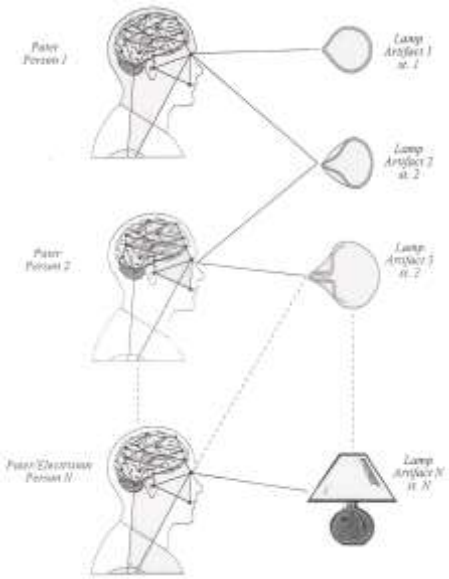
In developing SIRN, we have identified three types of processes: intra-personal, inter-personal and collective.

The first refers to an SIRN process as evolving by a single person. The second refers to a sequential interaction between several persons, and the third to a collective process in which several persons are acting simultaneously and interact via a collective (emerging) medium, for example, a city.

The Kiss by Brabkusi

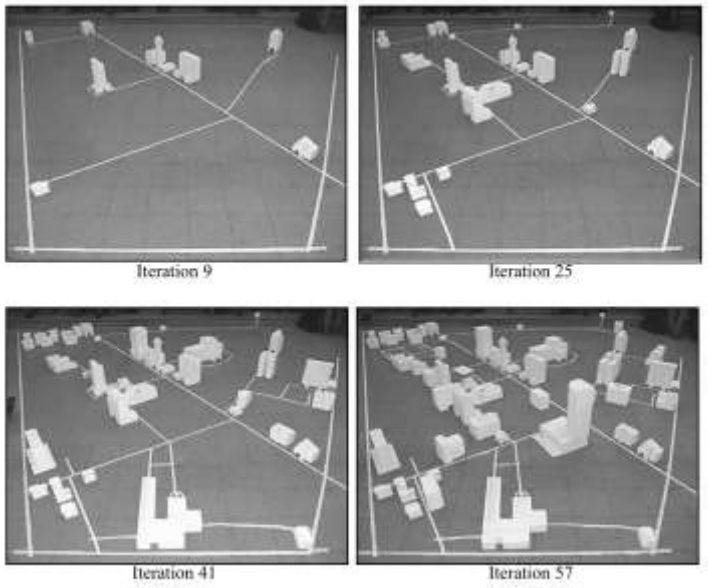
Intrapersonal

Lamps' production



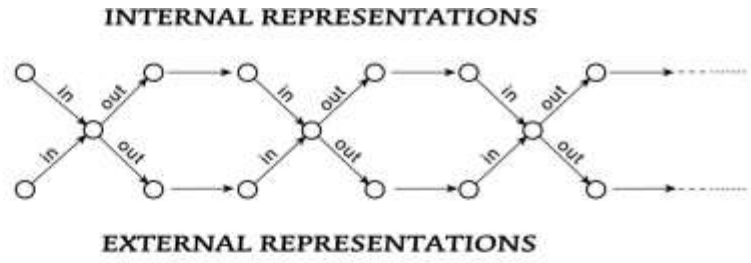
Interpersonal

Urban dynamics

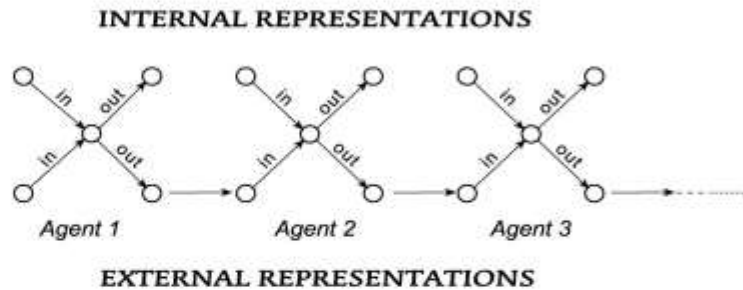


Collective

A single agent



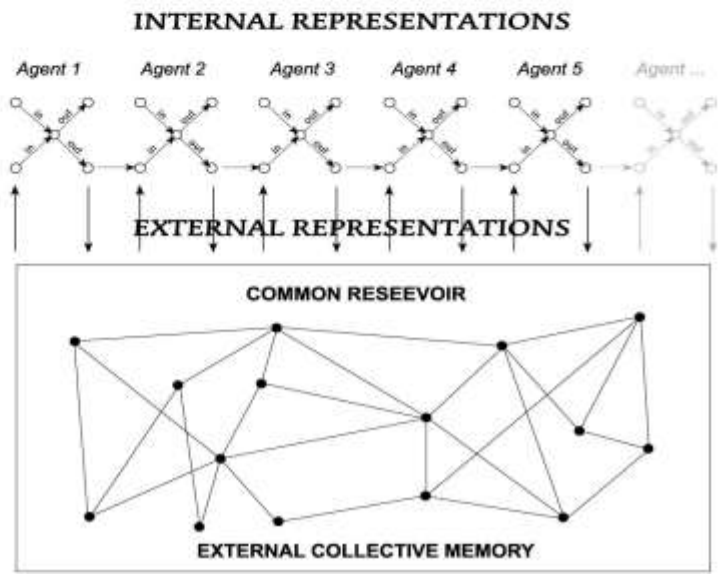
Several agents in a sequence



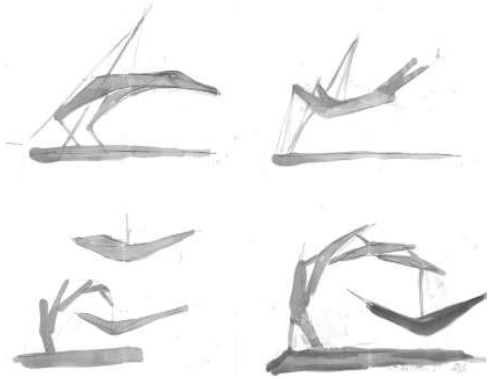
Many individual agents acting simultaneously; each is a local self-orgenizing system

Affordances, Legibilities

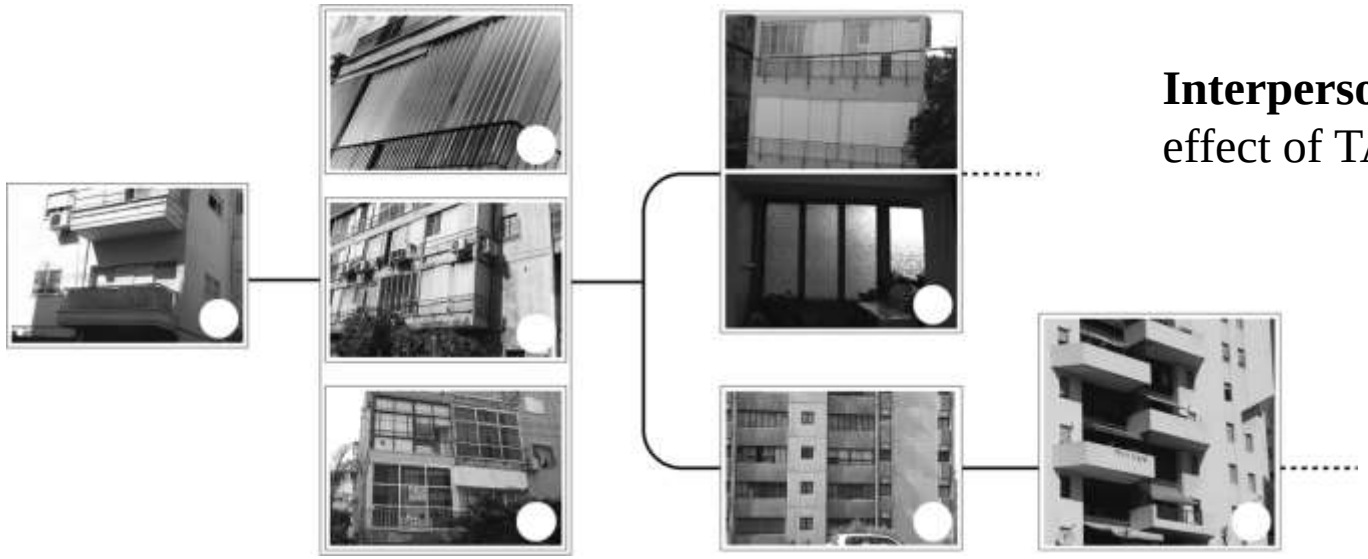
The common reservoir as a global self orgenizing system and external collective memory



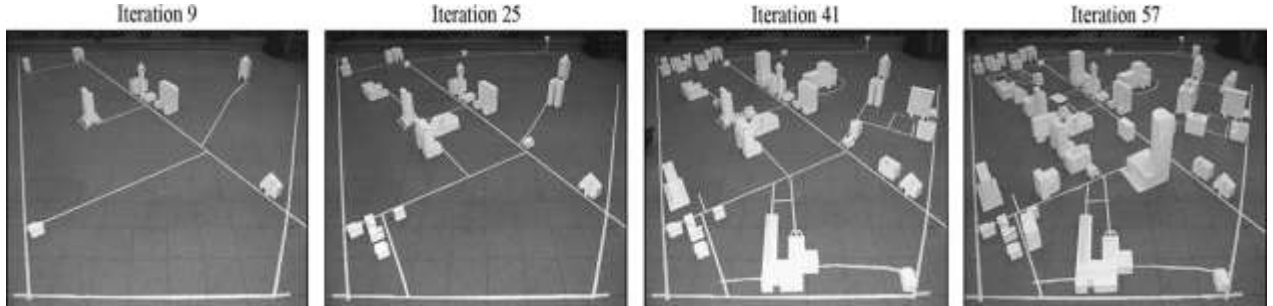
SIRN design models



Intrapersonal: Sequence of sketches from Calatrava's notebook

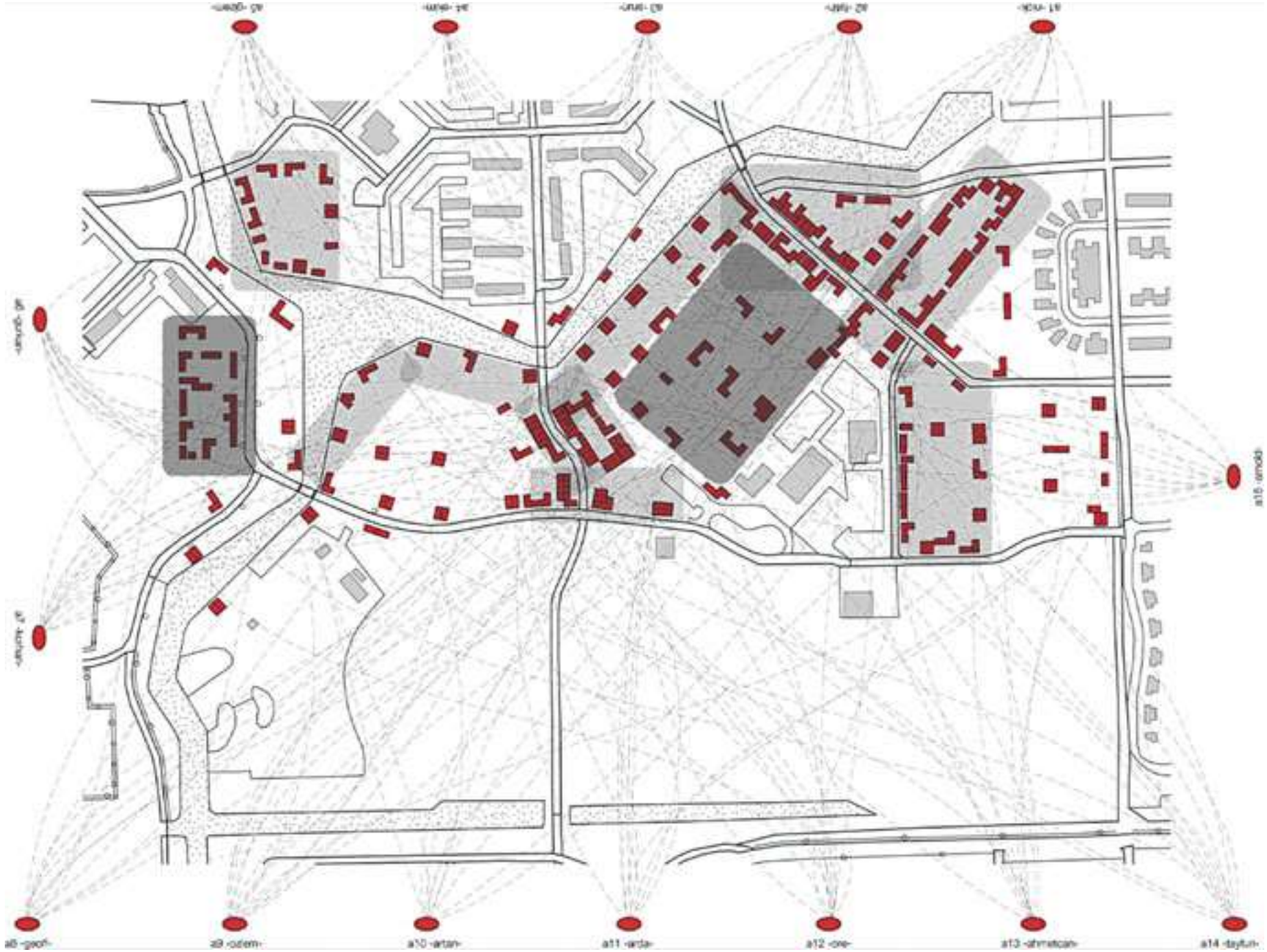


Interpersonal, the butterfly effect of TA balconies



The interpersonal–simultaneous: City game

SIRN as collective design (Tan and Portugali 2012; Tan 2016 “play the city”)


a8 -geof-
a9 -otem-
a10 -artan-
a11 -arda-
a12 -ore-
a13 -ahmetcan-
a14 -tayfun-
a15 -emre-

From SIRN → to Information

SIRN is based on the interaction between internal and external representation

Q: What are internal and external representations?

A: Representations are entities that convey information

Q: But then, what is information?

First answer: Information as defined by Shannon's information theory

Second answer: Semantic and pragmatic information

Shannon’s information theory

Information theory as developed by C. Shannon deals with the capacity of information channels. This capacity depends on statistical properties of the signals, **but not on their meaning**, be it the contents of the text in some language, a melody, or a picture. In this sense channel capacity is a fixed physical quantity in each specific case.

“Frequently”, writes Shannon (1948, 1):

“the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. **These semantic aspects of communication are irrelevant to the engineering problem**. … “

Shannon has suggested several notions of information quantity. The most common one is Shannon's *information bits* (Shannon and Weaver, 1949). One way to define it is as follows:

$$I = \log_2 Z$$

when Z is the number of possible states the system can take.

For example, in the case of rolling a dice, Z=6 and *I* – the quantity of Shannonian information enfolded in the process of rolling of a dice – is about 2.5 bits.

As can be seen from this definition, Shannonian information is:

1. Not related to any meaning
2. Refers to a future state,
to what might be when one is rolling a dice

The more general definition of information bits is Shannon's famous formula

$$s = -\sum_j p_j \log_2 p_j$$

$$\sum_j p_j = 1 \qquad P_i = \text{relative frequency of occurance of event } j$$

that allows us to calculate the (information) entropy of any signal with a known relative frequency (or probability) distribution of symbols distinguished by the index ***j***.

A well-known example is the Shannon (information) entropy of the English language, where *j* labels the individual letters and p_j is the relative frequency of their occurrence in a sufficiently long and representative text.

It is hard to exaggerate the importance of Shannon Information theory.

the theory is still valid, still providing the foundation to any discussion of information,

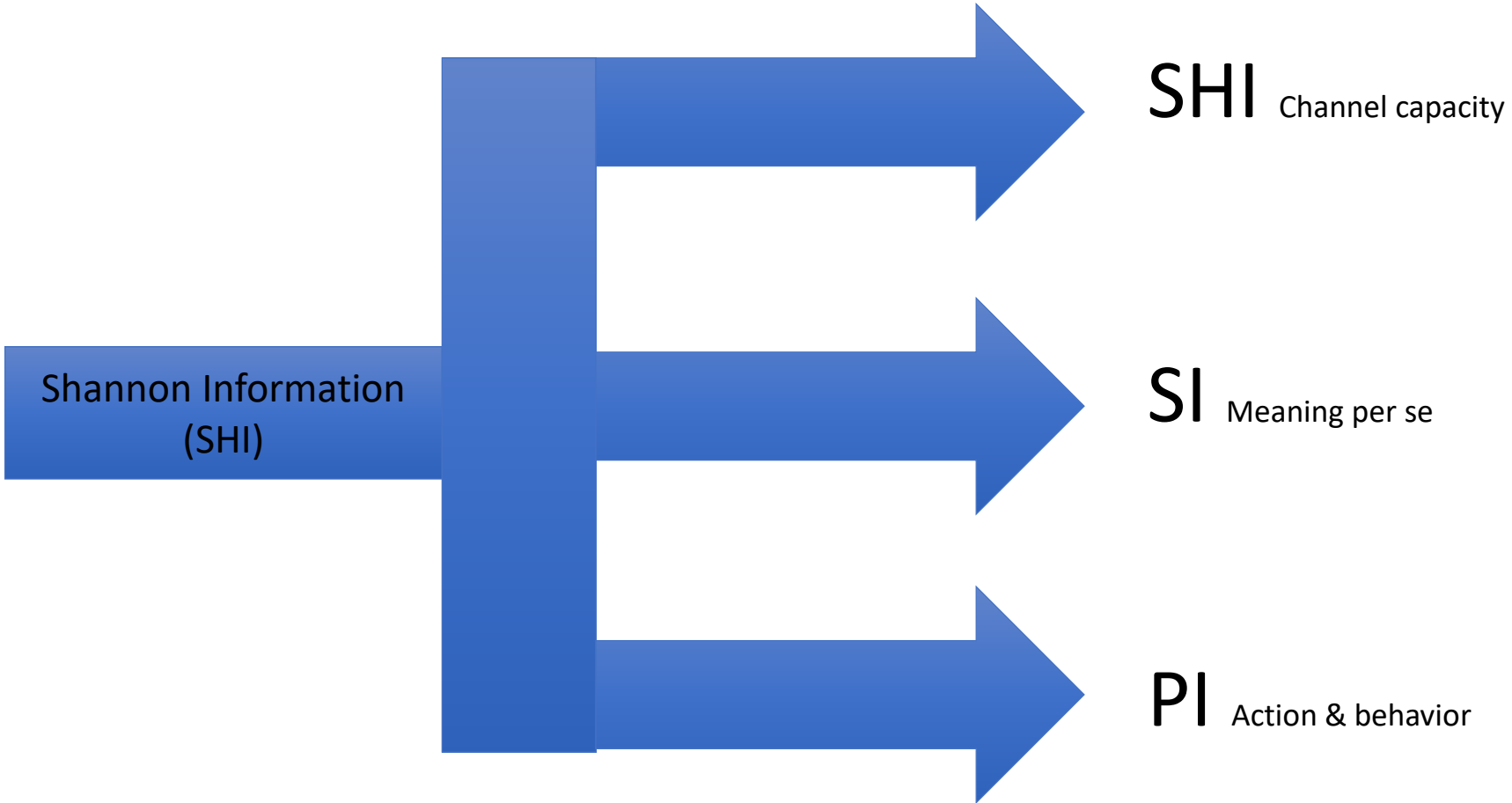
still central to the development of computer technology and science, communication and information sciences and also

cognitive sciences.

Following Shannon there have been attempts to develop alternative conceptions and measures of information:

Bar-Hillel and Karnap (1953), Floridi (2011) – **Semantic information (SI)**
Weizsäcker and Weizsäcker (1972), Gernert (2006) **--- Pragmatic information (PI)**

The result: 3 **parallel** currents (with little/no links between them)

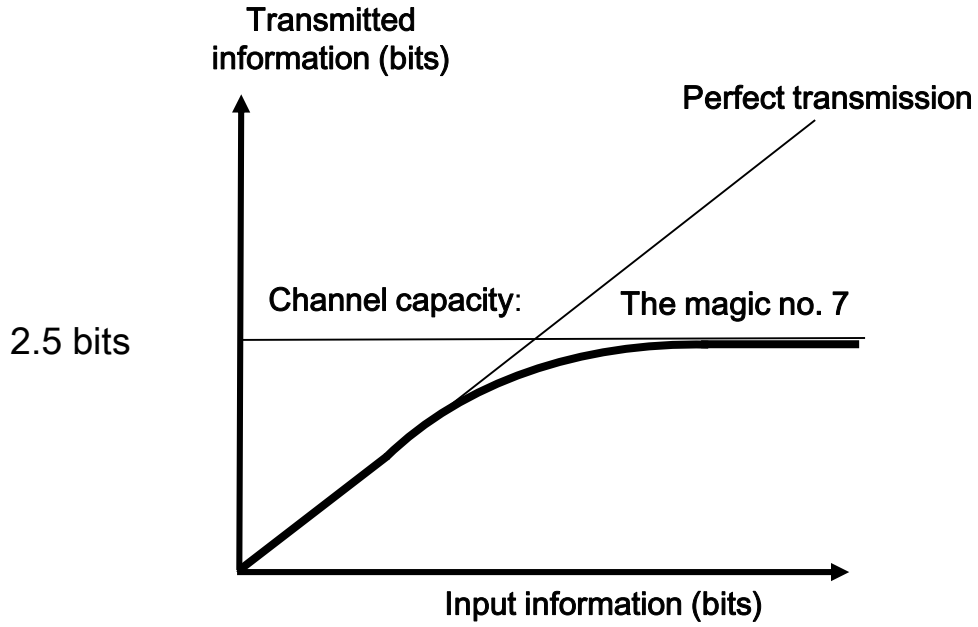


Applications to cognition

One cognitive application is:

Miller (1956) "The magic number seven plus or minus two: Some limits on our capacity for processing information".

As the title of Miller's study indicates, he brings evidence demonstrating that there is a limit to humans' capacity to process information in short term memory. Namely, it is about 2.5 bits.



A second cognitive application

Gestalt's 'figurative goodness' that entailed an intriguing conclusion:

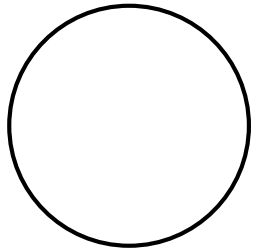
Different (abstract or specific) forms transmit different quantities of information. These quantities can be measured by means of Shannon's bits.

"The *good gestalt* is a figure with some high degree of internal redundancy" (Attnive 1958, 186) – little information.

"information is a function not of what the stimulus is, but rather of what it might have been" (Garner, 1974, p. 194)

Example (By D Algom): rotation of a circle vs. "L" shape.

i is Low



i is high

High redundancy, Good gestalt, High certainty Little information

High uncertainty High information

Applications to the city:
Shannon information, cognition and the city

“The face of the city is its information”

(Haken and Portugali, 2003, *Journal of Environmental Psychology* 23, 385-408; Chaps. 8, 9 in Portugali 2011):

1. Shannon information and the city

Employing Shannon’s information theory and its applications to cognition, Haken and Portugali show that:

1.Different elements in the city afford different levels of information.

2. The Shannonian information afforded by the various urban elements can be measured by means of Shannon’s theory of information.

Shannonian Information II: Applications

When all buildings are similar ***i is low***

When they are different ***i is high***

but hard to memorize (+-7 …)

When landmarks are added apart from each other, ***i is high***

When they are grouped, ***i is low***

When all buildings are similar ***i is low***

When they are different ***i is high .. But ..***

The tower house at Piazza del Campo, Siena,

When landmarks are added apart from each *I is high*

The tower houses of San Gimignano

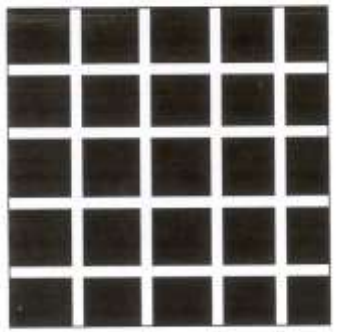
When they are grouped, ***i is low***

j1, 8 strs.

j1,1st str., j2, 2 nd.st. Etc.

j1, Avs.; j2, strs.

a



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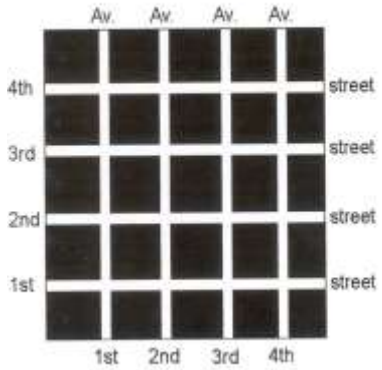

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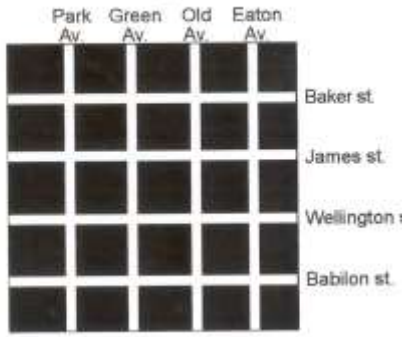

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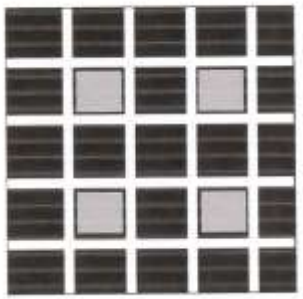


The surprising finding of our 2003 paper was that **Semantic information enters in disguise** (into the Shannonian definition) via the choice of the index *j*:

$$s = -\sum_j p_j \log_2 p_j$$

j implies a certain categorization of the urban elements such as buildings into, say, buildings' style (modern, postmodern …) and/or function (residential, offices, industrial …)

Categorization implies giving **meaning** to different urban elements or in other words, ***that we are using SI/PI***

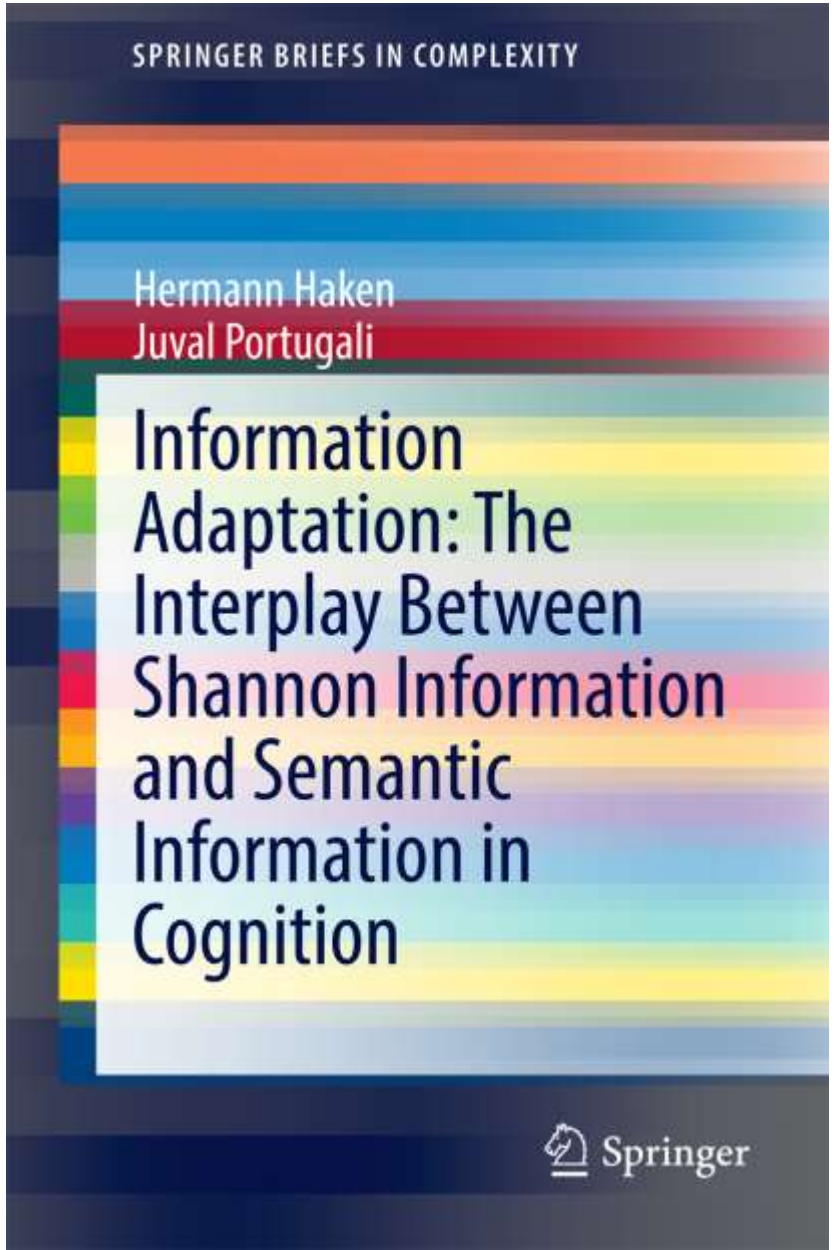
At first sight this finding sounds rather innocent. But it has far reaching consequences on cognition because, as we shall see below in connection with our *Information Adaptation* approach, Shannon information acts in turn as driving force for SI/PI.

That is, the IA process is two directional:

Not only SI/PI determine SHI,

but also SHI affects SI/PI by triggering it

A new book



Information

In this book (Haken and Portugali 2015) we explore the relations between two main forms of information:

Shannon information **(SHI)** that refers to the quantity of information conveyed by an information source, irrespective of its meaning, and information with meaning that can take two forms:

Semantic information **(SI)** referring to meaning per se and

pragmatic information **(PI)** referring to action.

We show that SHI and the two forms of information with meaning (SI, PI) are two aspects of a process of

information adaptation

in which SHI triggers SI/PI while the latter determines SHI.

Our canonical example is vision

Example 1: Vision as Information Adaptation:
Bottom-up

Hubel and Wiesel (1959, 1962, 1965): The brain's processing of optical information **starts bottom up** in the retina …. The optical fiber transports the signal …to the neurons of the visual cortex (Fig.) with its Areas V1-V4. …

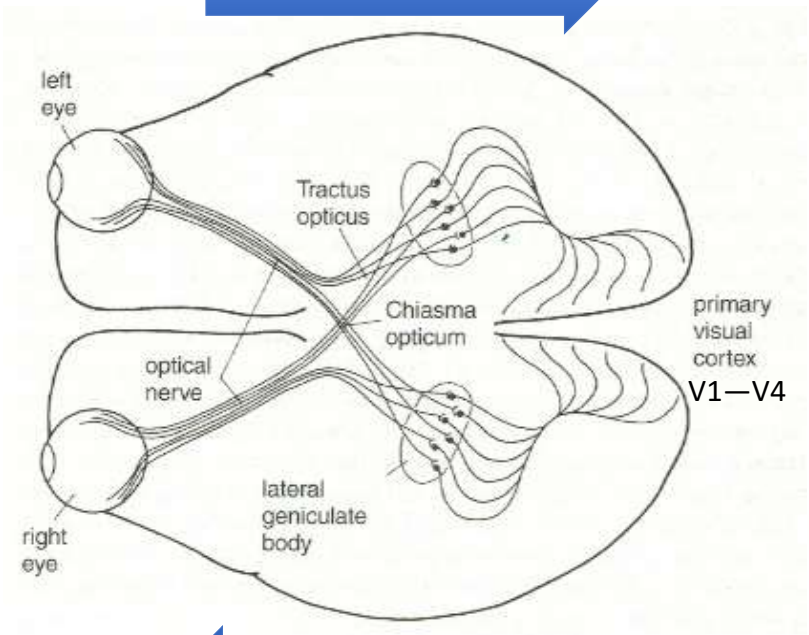
and top down

Then, at higher levels, **top down** neurons getting inputs from lower areas, react to specific orientations of lines, corners. **Livingstore 2009, Freiwald and Tsao 2010; Kandel 2012:** The process of reconstruction/synthesis is implemented by the brain's semantic (meaning giving) capabilities

Bottom-up

Data from the environment is bottom-up transformed into local information features (lines, corners);

their interaction generates order parameter(s) that top-down determines vision as global information

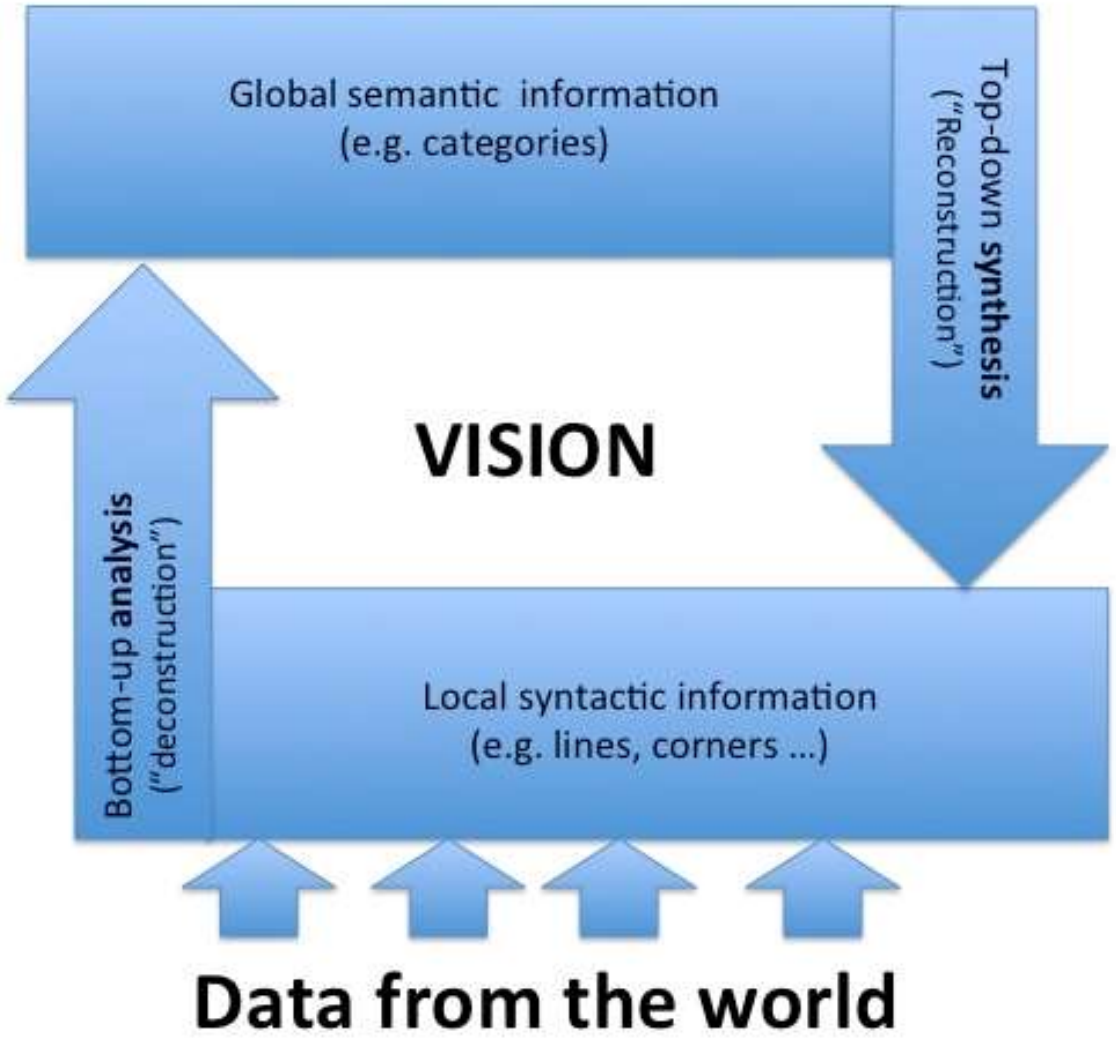


Schematic representation of the visual pathway of a human

Top down

schematic description of the process of vision:

data from the world is first analyzed ("deconstructed" in Kandel's words) by the mind/brain, in a bottom-up manner, into local information of lines, corners etc.



This local information triggers a top-down process of synthesis ("reconstruction" in Kandel's language) that gives rise to global information, that is, to seeing and recognition.

(For more details see Haken and Portugali 2015.}

To an extent, vision is like doing a puzzle

Bottom-up: Take a whole picture, cut it into pieces, categorize them into edge pieces **color** groups (such as blue sky pieces, green grass pieces, red/yellows, etc.) …

Top-down: Now start to assemble the edge pieces, to complete the different color groups of the puzzle/ Place completed sections in the rough location where they seem to go/ Continue "filling in the gaps" of the puzzle/ you will eventually get to the stage where you can see the end of the project/ Continue on until you complete the puzzle.

Arrange pieces into form and color groups

Assemble the edge pieces

complete the different color groups

Place completed sections in the rough location where they seem to go

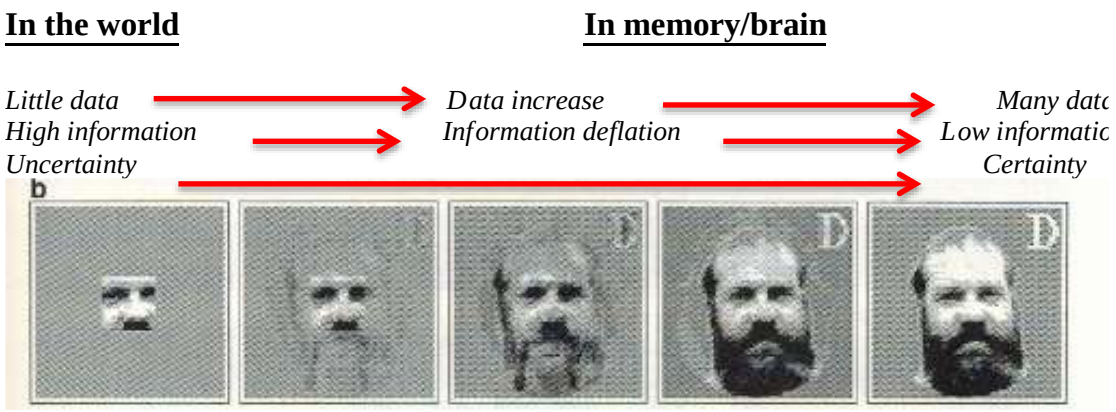
Continue "filling in the gaps" of the puzzle

you will eventually get to the stage where you can see the end of the project

Continue on until you complete the puzzle

Why?

Why to deconstruct – reconstruct?
Because the visual data that comes from the environment is very often incomplete, while in some cases superfluous. Vision is thus interpretation of data based on learned information.
E.g. Pattern recognition



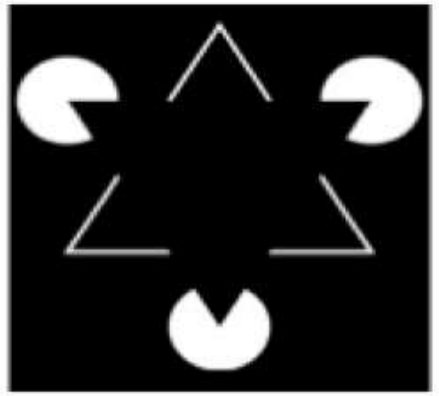
The result:
Information adaptation by means of information inflation – deflation

Information adaptation in cognition

the cognitive process of information adaptation is implemented by **inflation** or **deflation of SHI**:

In some information adaptation cases the brain adds data that doesn't exist in the row data/information (*left*), while in other cases the brain implements adaptation by the exact opposite - by ignoring data/information that exists in the row information (*center* and *right*).

The Kaniza triangle illusion: **the MBB adds data**

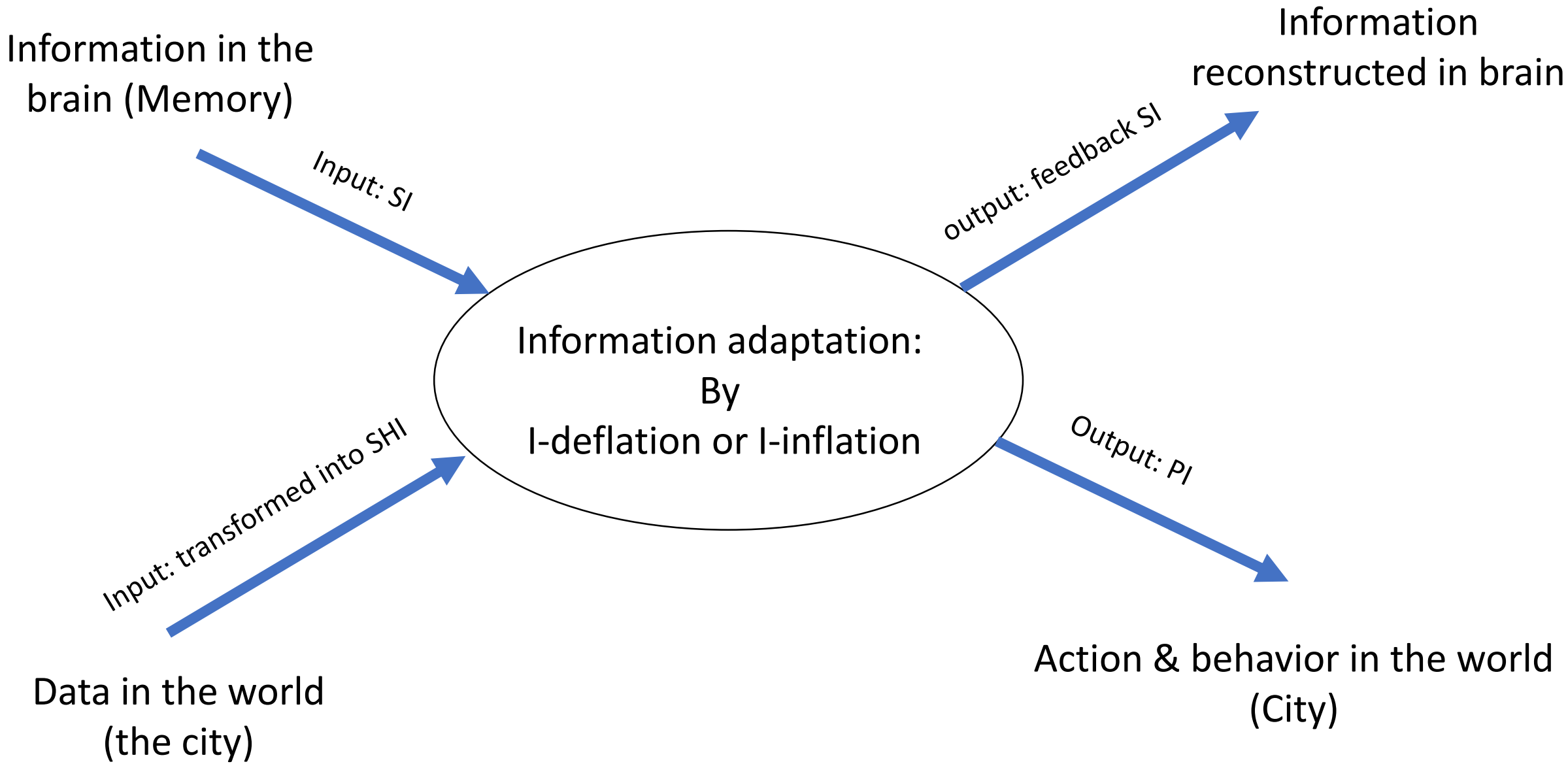


The "Olympic rings" illusion

The gorilla illusion: When the observers' attention is directed to the ball and players, 50% of them do not see the gorilla**:** **the MBB extracts data**

SIRNIA:
A conjunction between SIRN and IA

SIRNIA: A conjunction between SIRN and IA



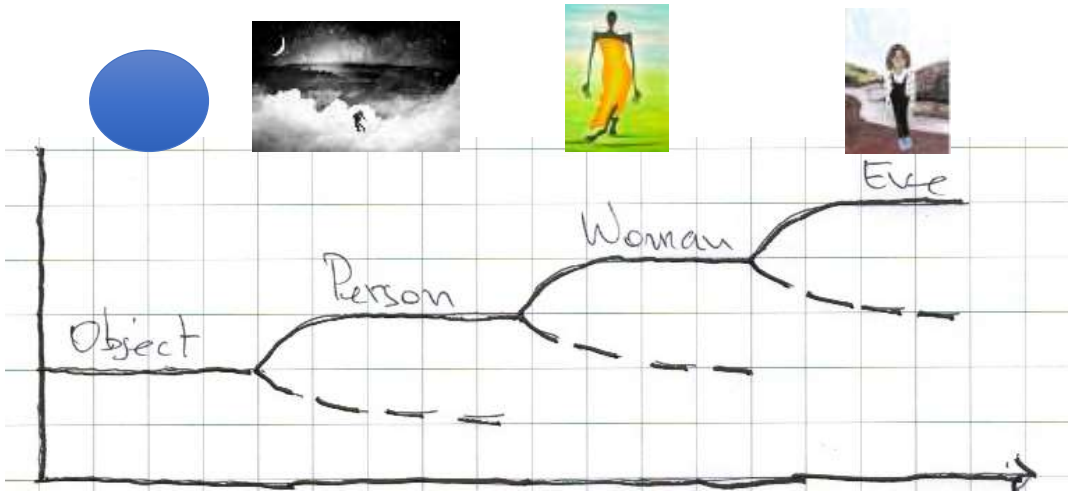
Example: Sequential IA by “Punctuated pattern recognition”

Imagine the following scenario: You stand in an open area and you observe at the horizon an object moving towards you. At this stage there is little data and the object can be anything and thus the information (uncertainty) is high.

As the object gets closer, more data are added and you realize that it is a person, that is, your MBB adapts to the incoming data by deflating the information (uncertainty) and by pattern recognizing the moving object as a the SI category ‘person’.

As this person gets still closer …, you realize that it is the SI ‘woman’ – …

Finally, as this woman gets even closer you realize that this is Eve – …



The time-space evolution of the process of information adaptation is not linear and smooth but rather it evolves in punctuations. While data increases continuously, the pattern recognition process of information adaptation is abrupt and thus discrete: a moving object, person, woman, Eve.

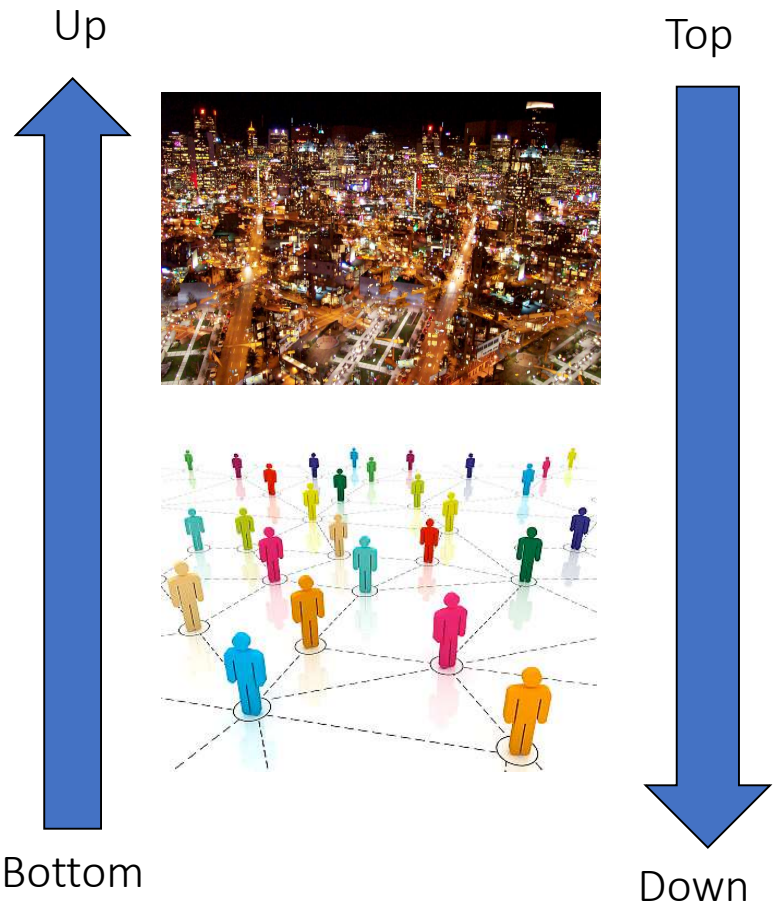
At these points of punctuation, in each case a **phase transition** connected with the **emergence** of a new “**category**” (or the reverse) happens.

Implications to urban scaling

Based on
Portugali and Haken (in evaluation) “Information Adaptation, SIRN and urban allometry

Synergetic cities

bottom-up emergence, top-down slaving



The result: **Circular causality** that ensures urban structural **reproduction**.

1. Synergetics

In line with synergetics, cities emerge bottom-up out of the interaction between their part. This interaction gives rise to an OP that enslaves the parts and so on in circular causality

2. SIRNIA
Information production

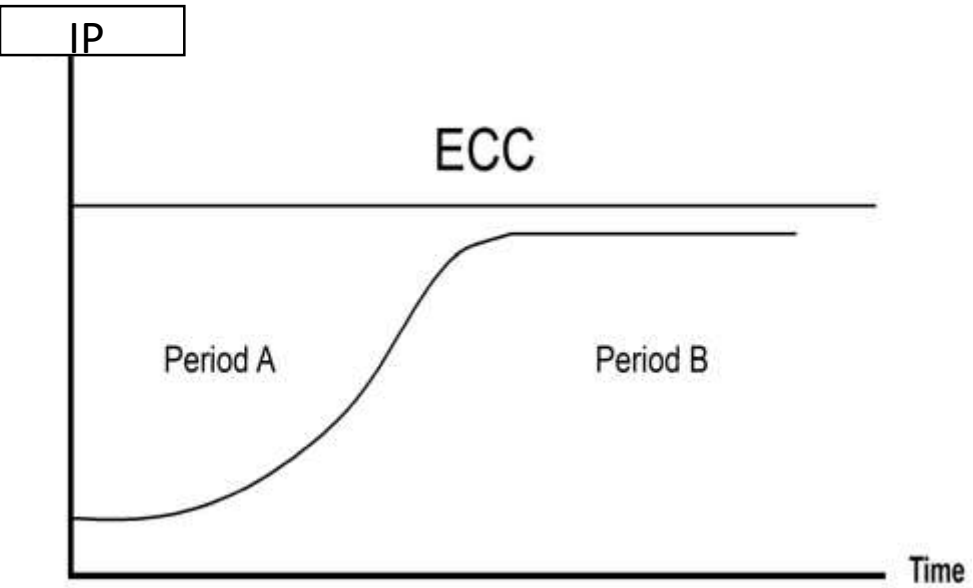
In line with SIRNIA, **Urban dynamics is a kind of production process** – producing artifacts of all kinds, ranging from buildings, parks and roads to many other kinds of commodities, but also socio-cultural entities/products such as cultural areas (neighborhoods) and so on.

These **artifacts convey data** from which urban agents extract SI and PI with their entailed SHI; then, on the bases of, or in response to, the extracted information urban agents behave and act in the city. We term this SIRN-IA process the **City's *information production* (IP).**

This IP process can be seen as, or gives rise to, the city's OP that affords a certain urban routine in all aspects of city life: ranging from commuting routinized patterns, to a steady production of residential, commercial, cultural and other goods and services.

Once emerged, an order parameter has a certain carrying capacity. That is, it enables “freedom of choice” (measured by SI or PI determined SHI) to the city’s urban agents.

As long as this carrying capacity is not exhausted (Period A), the order parameter is capable of “enslaving” the parts, a process of circular causality and structural reproductions occurs, the system is stable and resilient against internal and external perturbations.



However, once the carrying capacity of the order parameter is for some reason exhausted (Period B), the system becomes unstable and looses its resilience, and thus vulnerable to internal or external fluctuations.

Fluctuations

Complex systems are subject to on-going random fluctuations of various kinds, some of which are internally determined by the action and behavior of the parts of the system.

Fluctuations are creative acts of urban agents that do not conform with the city' s routinized dynamics determined as it is by the city's OP

They are direct consequence of the SIRNIA process: An urban agent is ongoingly interacting with the city and adapts to its data/information. Some agents adapt to the information conveyed by the city by conforming with its OP (slaving); others adapt to the information conveyed by the city by non-conformist creative acts.

Example: the stories of NY Lofts and and TA balconies

1

Information adaptation: Behavior in the city as a play between Cognitive vs Institutionally determined pragmatic information

1. Every urban element conveys *syntactic* SHI referring to its possible states/uses **as defined by institutional planning**. For example, a given element in the city is legally defined (by city plan) as a warehouse; its SHI is thus 0 bits:

$$I = \log_2 1 = 0 bits$$

2. Every urban element conveys/affords *subjective* PI determined SHI, referring to its possible use as perceived by each urban agent as a cognitive planner. For example, for an urban agent (=cognitive planner), say a poor artist desperately looking for a place to live and to work, the above very warehouse conveys/affords different meanings and as a consequence different potential uses: it can be an apartment, a studio and a little shop. Its pragmatically determined SHI will now be about 1.5 bits:

$$I = \log_2 3 \approx 1.5 bits$$

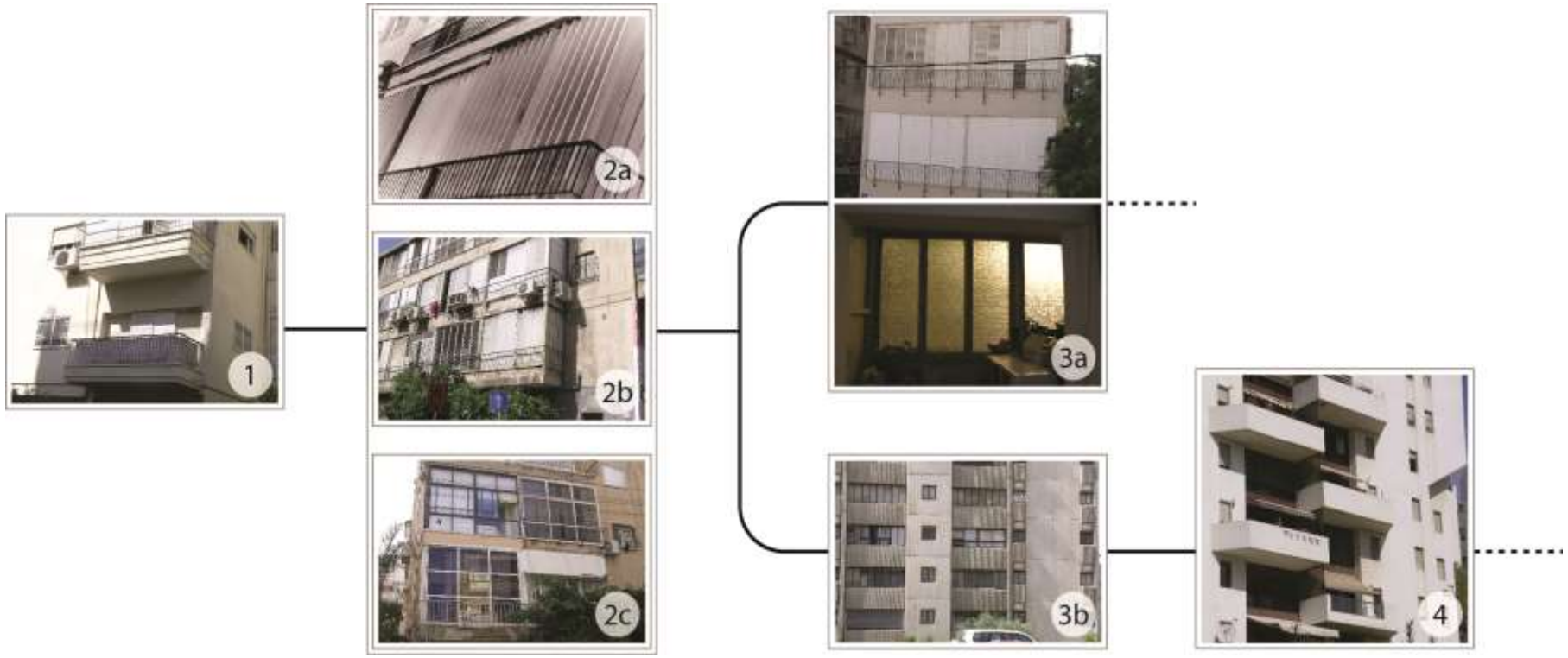
The above is, of course, the background to story of lofts in New York, London and other big cities around the world.

In NY the “ad-hoc conversion of lofts in SoHo [by individual cognitive planners] began in the 1960s, illegally and in contravention of both the New York City Zoning Resolution and Multiple Dwelling Law. Subsequently, this ad hoc activity was legitimized by revisions to both sets of regulations in 1982” (Kwartler 1998).

In NY after some 20 years, institutional planning adapted itself to the actions of cognitive planners

2

A similar scenario took place in Tel Aviv in “The butterfly effect of Tel Aviv balconies”. Here the struggle between cognitive and institutional planning has transformed the urban landscape of Tel Aviv from open balconies, to closed balconies, to no-balconies, to jumping balconies and recently once again to open balconies



1) Open balcony. 2a) Closed by asbestos shutters. 2b) Closed by plastic shutters. 2c) Closed by glass windows. 3a) From the outside it looks as a balcony; from the inside part of the living room or a kitchen. 3b) No balconies. 4) “Jumping balconies”. (Portugali 2011, Portugali and Stolk 2013)

Fluctuations (Con’t)

As long as the system is in a structurally stable steady state with a high level of carrying capacity, random fluctuations of the individual parts of the system (creative acts as in the cases of lofts and balconies) have no significant effect on the overall/global evolution and behavior of the system.

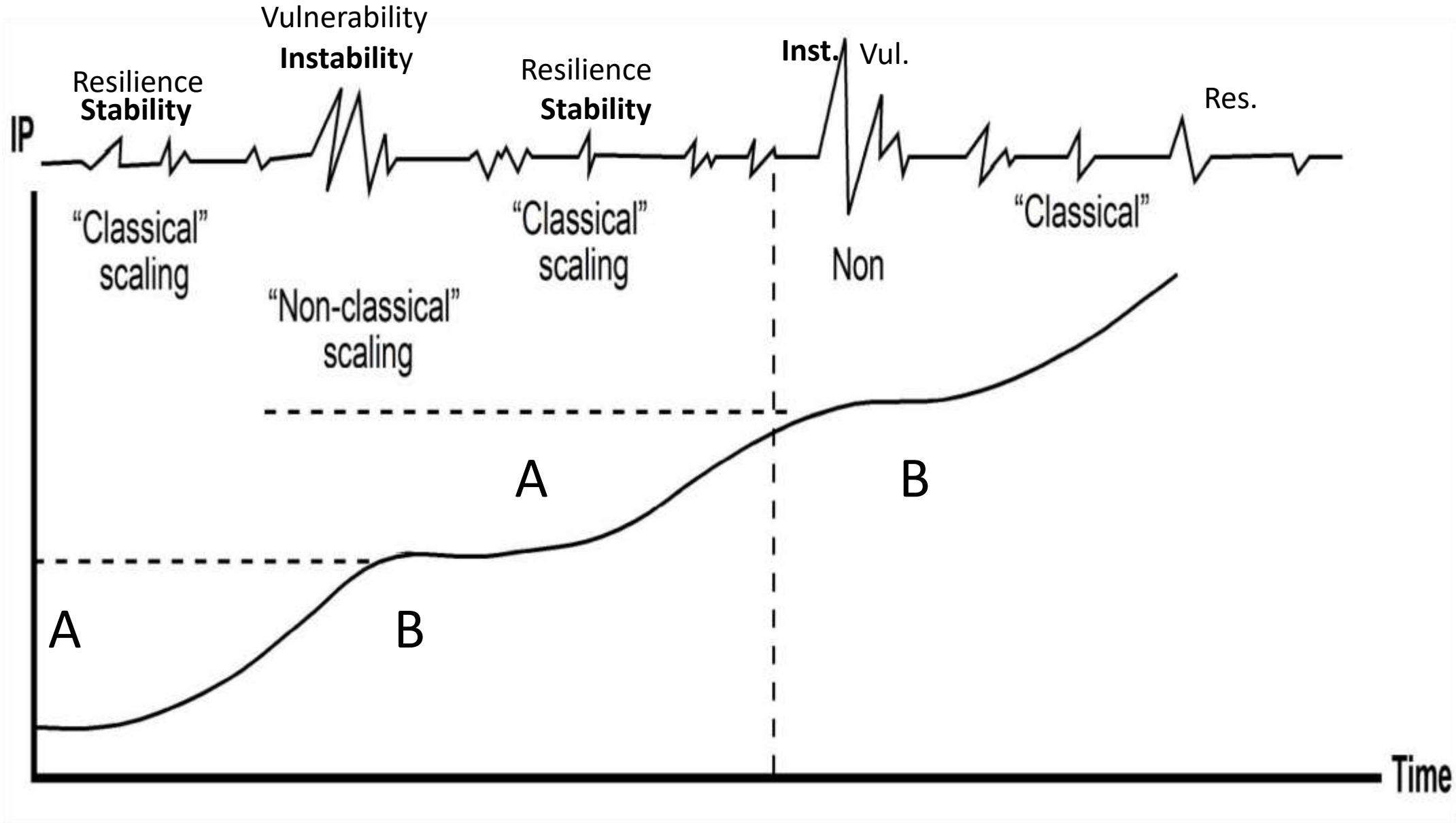
However, when the system enters an instable state (e.g. due to exhausted carrying capacity or any other reason) it loose its resilience and becomes vulnerable to such local fluctuations.

At this stage, the system is specifically typified by non-linear (“butterfly”) effects in which a minor local perturbation might lead to a global phase transition.

The result is that the *longue durée of cities* evolves as a stepwise sequence of Verhulst's S-curves, driven by Spencerian innovations (Fig. 7).

That is, long periods of steady state during which the city is resilient and thus enslaves local disturbances, followed by short chaotic periods during which the property of nonlinearity prevails (Fig. 7) so that a minor-scale local event might bottom-up give rise to a global phase transition and a large-scale global change.

Stability, instability and fluctuation in the longue durée of complex systems and of cities as complex systems. In periods A, the city's OP conveys high SHI with high freedom of choice; in periods B, little or no SHI/choice.



Implications

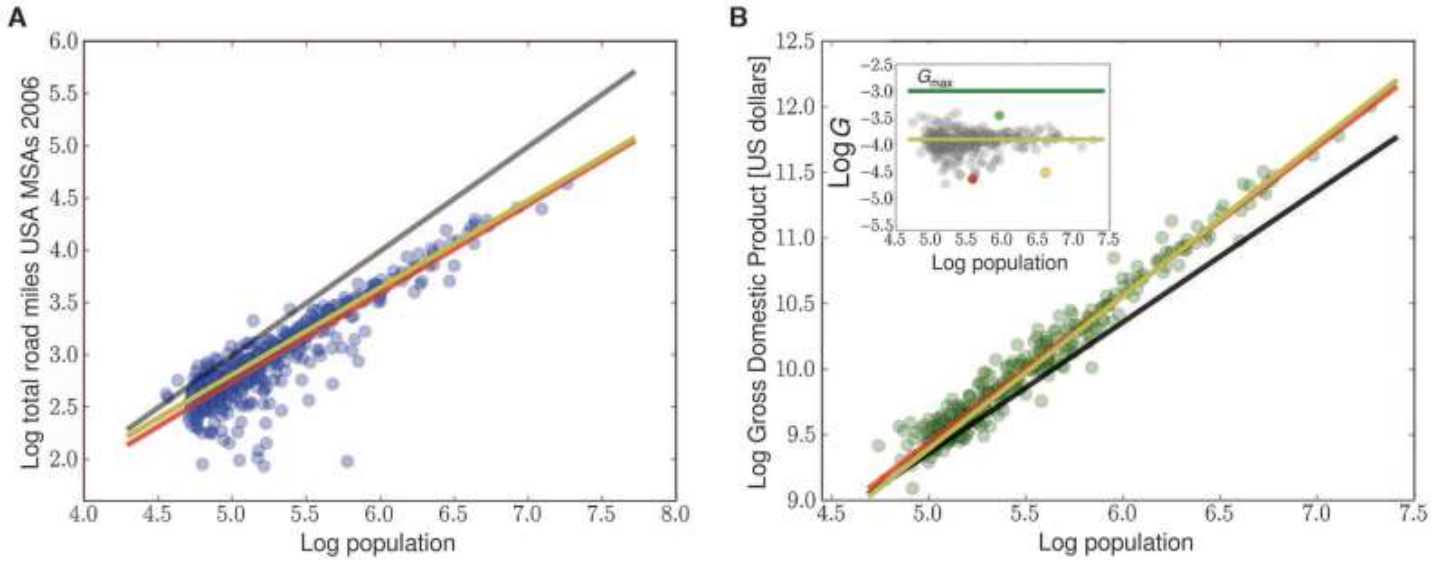
Big data ~ small data

As a complementary pair

Guy M. Ross and Juval Portugali (2018) “Urban regulatory focus: a new concept linking city size to human behavior”. Royal Society open science 5: 171478.

Haken and Portugali (In preparation). “A synergetic perspective on Urban scaling, URF and their interrelations”.

By means of rich **("big")** statistical data, recent studies on urban scaling (allometry) suggest that many urban properties scale with city size in universal ways (e.g. Bettencourt et al 2007).



What such statistical findings show is that these scale relations result from the fact that **citizens behave differently in small and large cities, yet they do not explain why**.

In a recent paper based on "**small data**", we (Rose and Portugali, 2018) have suggested that an answer can be found by extending the principles of Higgins' (1977) *regulatory focus theory* (RFT) regarding human individuals' motivational system, to the context of cities.

Regulatory Focus Theory

Higgins, E. T. (1997). Beyond pleasure and pain. American Psychologist, 52, 1280-1300.

For centuries, **the hedonic principle** that people approach pleasure and avoid pain has been the dominant motivational principle for many disciplines and across all areas of psychology. Even when Sigmund Freud discussed the need to go beyond the pleasure principle because people were controlled by the reality principle—environmental demands—he was simply modifying the pleasure principle such that avoiding pain became almost equal in importance to approaching pleasure. But is that the end of the story of motivation? **How does the hedonic principle itself work? Might not there be different ways** to approach pleasure and avoid pain **that tell us something about motivation beyond the hedonic principle per se? Regulatory focus theory was developed in response to these questions.**

According to RFT, "… goal-directed behaviour is regulated by two motivational systems, **promotion** and **prevention**. Individuals motivated by promotion goals … focus on winning and tend to take risks, whereas those driven by prevention goals … focus on not losing and try to avoid risk."

A person's motivational system is composed of both tendencies; yet some are more **promoters** while others **preventors.**

Subsequent studies elaborated the collective aspects of RFT. In particular "Faddegon et al. (2008) proposed that the **collective regulatory focus** is a psycho-social mechanism operating at the group level via social identity and through social categorization.

"In this conceptualization, the likelihood of one's behaving in a promotion or prevention way depends not only on one's personal regulatory focus but also on the collective regulatory focus of the group (or groups) one belongs to. "

Guy M. Ross **Urban Regulatory Focus,** PhD, TAU 2016

Based on several sets of laboratory experiments (small data) Ross has taken the collective aspect of RFT one step up the scale by demonstrated that the city functions as a strong regulatory system. More specifically, that urban context of large, fast-paced cities and that of small slow-paced cities encourage two distinctively different motivations on the part of their inhabitants. These motivational differences show up in their behavior in the city as well as In their residential location choices

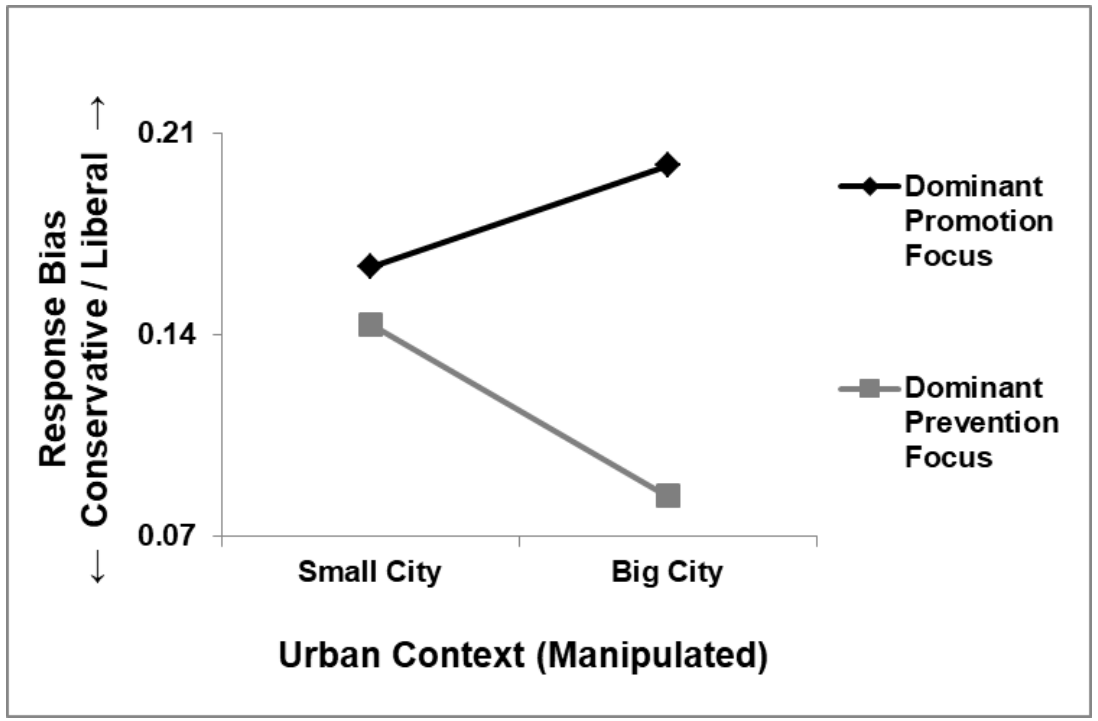
Urban promotion context – large city, high-rise luxury towers. …

busy streets full of people

Urban prevention context – small city, small buildings, sparse traffic. …

– slow-paced city.

In a subsequent paper we* have related RFT&URF to urban allometry, showing that under the context of a small city, participants with a dominant promotion focus showed a response pattern as conservative as shown by those with a dominant prevention focus. However, the change in context from a small city to a big city made participants with a dominant promotion focus display an extremely liberal bias, while those with a dominant prevention focus displayed an extremely conservative bias.



* Guy M. Ross and Juval Portugali (2018) “Urban regulatory focus: a new concept linking city size to human behavior”. Royal Society open science 5: 171478.

The situation

Urban allometry studies show that that many urban properties (resulting from citizens' behavior) scale with city size in universal ways (e.g. Bettencourt et al 2007).

Urban RF studies show that City size has an effect on individuals' promotion/prevention tendencies and as a consequence on their behavior in the city.

What remains an open question following these studies, however, is the way these motivational-behavioral reactions are related to the dynamics of cities as complex, adaptive, self-organization systems.

In a new paper we* are currently attempting to 'close the circle' and answer this open question.

We do so from the theoretical perspective of Synergetics – Haken's theory of complex self-organization systems—and its application to the domain of CTC (complexity theories of cities) by means of the notions of SIRN (synergetic inter-representation networks), IA (information adaptation) and their conjunction (SIRNIA).

From this perspective the following takes place:

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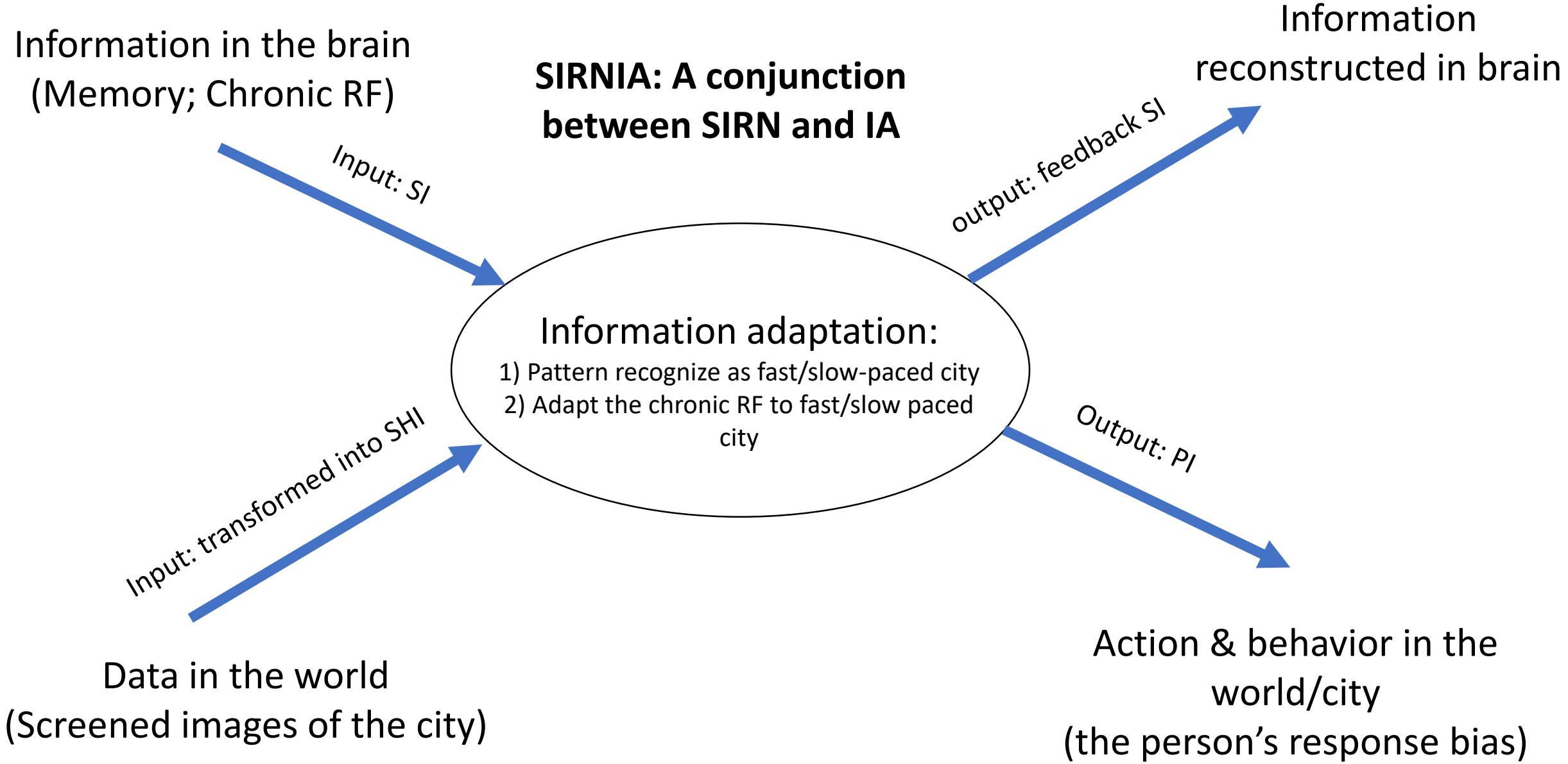
*Haken and Portugali (In preparation). "A synergetic perspective on Urban scaling, URF and their interrelations":

At the level of the individual urban agent:

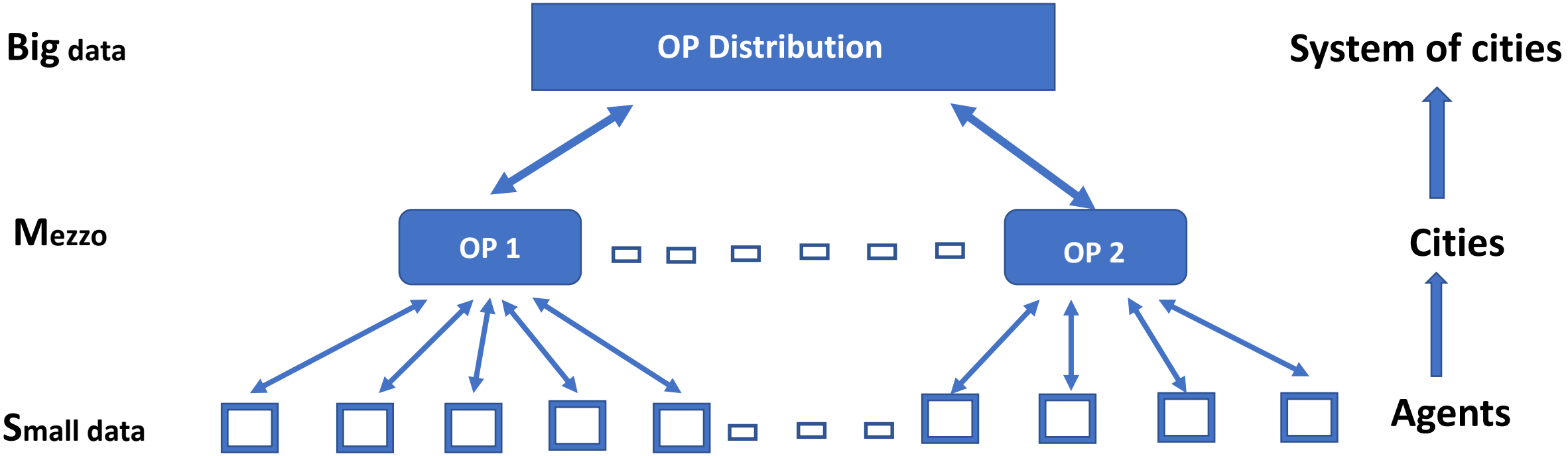


At a collective level

Urban agents with their chronic promotion-prevention tendencies interact with each other and give rise to the city with its specific pace of life, which in its turn affects the promotion-prevention tendencies of the agents, which once again affect the city's pace of life, and so on in circular causality.

In R&P experiments and paper, this circular process and its effect of the motivational tendencies of the urban agents is measured by the agents' response bias.

This response bias it taken as the city's OP that emerges out of the interaction.



P A R T S (Agents' promotion-prevention tendencies)

Hierarchical Organization of Conceptual Categories

- **Superordinate Level** - the most general form of concept (animal, vehicle, fruit, utensil)
- **Basic Level Categories** - an example of a type of concept around which other similar concepts are organized (dog, car, pear, knife, table)
- **Subordinate Level** - the most specific category of a concept such as a very specific example (German Shepard, Honda, Bradford pear, steak, card table)

Superordinate: **vehicle**

Basic-level: **car**

Subordinate: **ford_mustang**

Superordinate: **animal**

Basic-level: **bird**

Subordinate: **palm_cockatoo**

A reference to Cognitive theories of categorization (following E. Rosch 1973, 1975, 1978),

Superordinate level

Preferred level
BASIC LEVEL

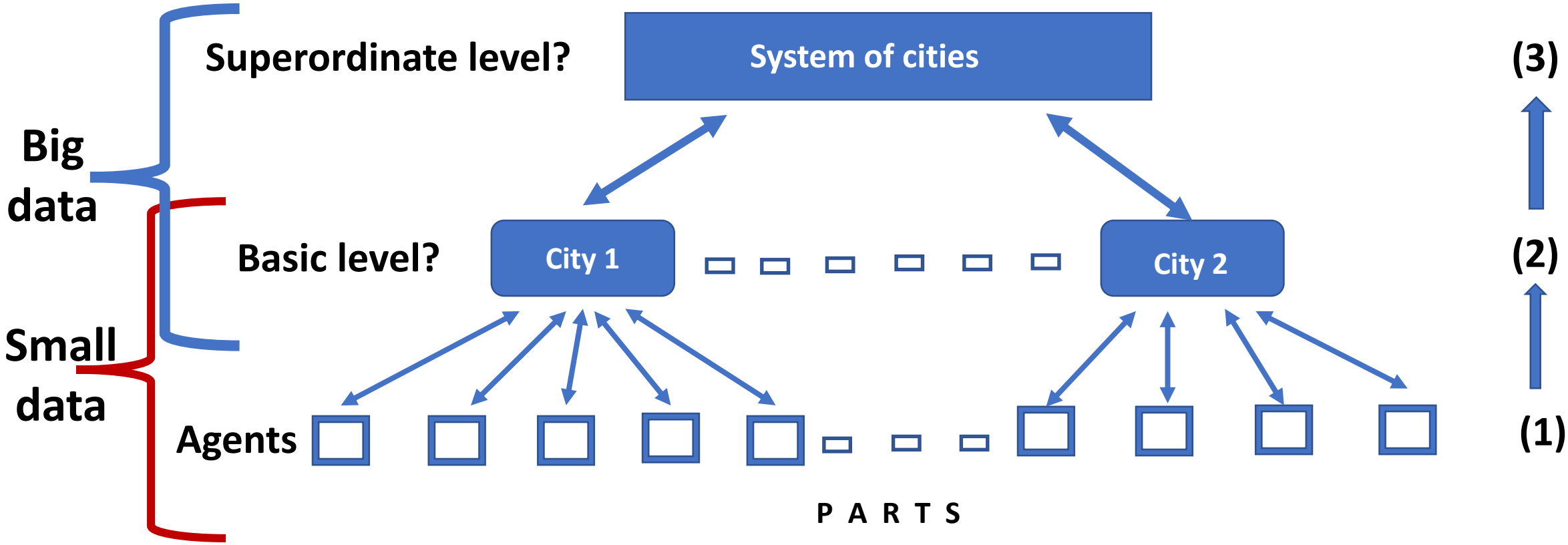
Subordinate level

$$\mathcal{F} = [\underbrace{* \cdots *}_{\text{Superordinate}} \; \underbrace{* \cdots *}_{\text{Basic-level}} \; \underbrace{* \cdots * 0 \cdots 0}_{\text{Subordinate}}]$$

Semantic process: semantic classifiers φ^S

Visual process: binary classifiers φ^V

CAN WE SAY THAT:



Small data domain: interaction between urban agents (driven by their cognitive behavioral tendencies) with the city as their Basic-level, experiential, category?

Big data domain: Allometric conceptualization of the interrelation between cities' global (e.g. size) and local (e.g. patents) properties

Thank you

Photo: Amir Pas https://www.flickr.com/photos/amirpaz