

# Computational models in complex systems

2009

Lecture 1: Introduction, evolutionary systems, complexity

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# Lecture topics 1

1. Course introductory, complexity in nature and social systems.  
Aim of the course.
2. About science, it's history and philosophy, purpose and expectations.
3. Information systems, Shannon entropy of information.
4. Emerging systems and self-organization, power laws.
5. The logistic equation, introduction to chaos theory, attractors, strange attractors.
6. Bifurcation and stability in chaotic systems, Lyapunov-exponent.

# Lecture topics 2

7. Fractals, the geometry of living nature. Practical examples.
8. Models of growth (Malthus, Lotka-Volterra). Predator-prey models.
9. System dynamics, models for competing agents (wolf-lamb), epidemics and global resource management.
10. Introduction to the philosophy of mind, the human brain, consciousness.
11. Artificial intelligence, artificial neural networks.
12. Game theory. Prisoners dilemma, decision-making strategies.

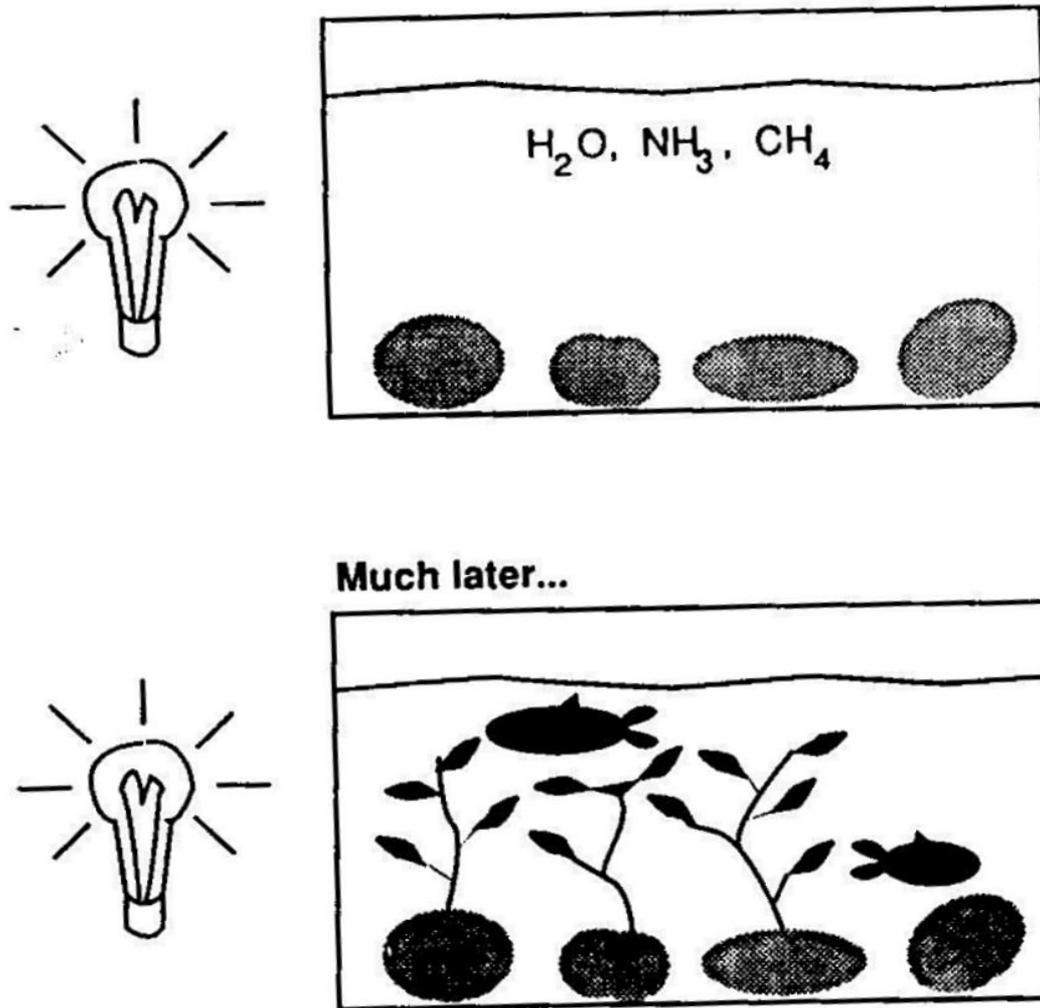


FIGURE 1 What is complexity? What causes it to increase? Is there a limit to its increase?

Source: Zurek et al.

# 1. Order and disorder

## Disorder

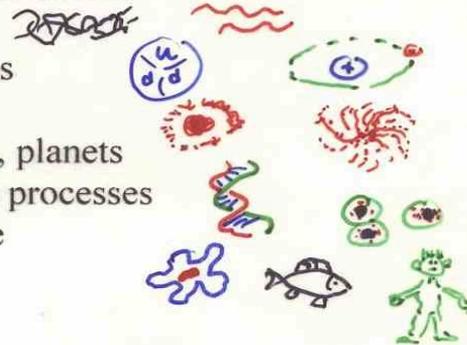
Chaos, utmost disorder, no laws, zero computability.

"Big bang" the only real known chaos.

Edge of chaos: complexity.

## Formation of patterns and organisation

- strings, photons
- quarks, protons, electrons, atoms
- stars, galaxies
- exploding stars, heavy elements, planets
- amino acid molecules, early life processes
- cells, development of higher life



## Order

- patterns, regularities
- Laws of Nature: Newton, Maxwell, etc.
- the Periodic System
- provides predictability
- order seems to be a static property

## Organization

- dynamics of an ordered system
- a coordinated time process
- distributed activities against a common goal (ants)

Source: J-T Eriksson

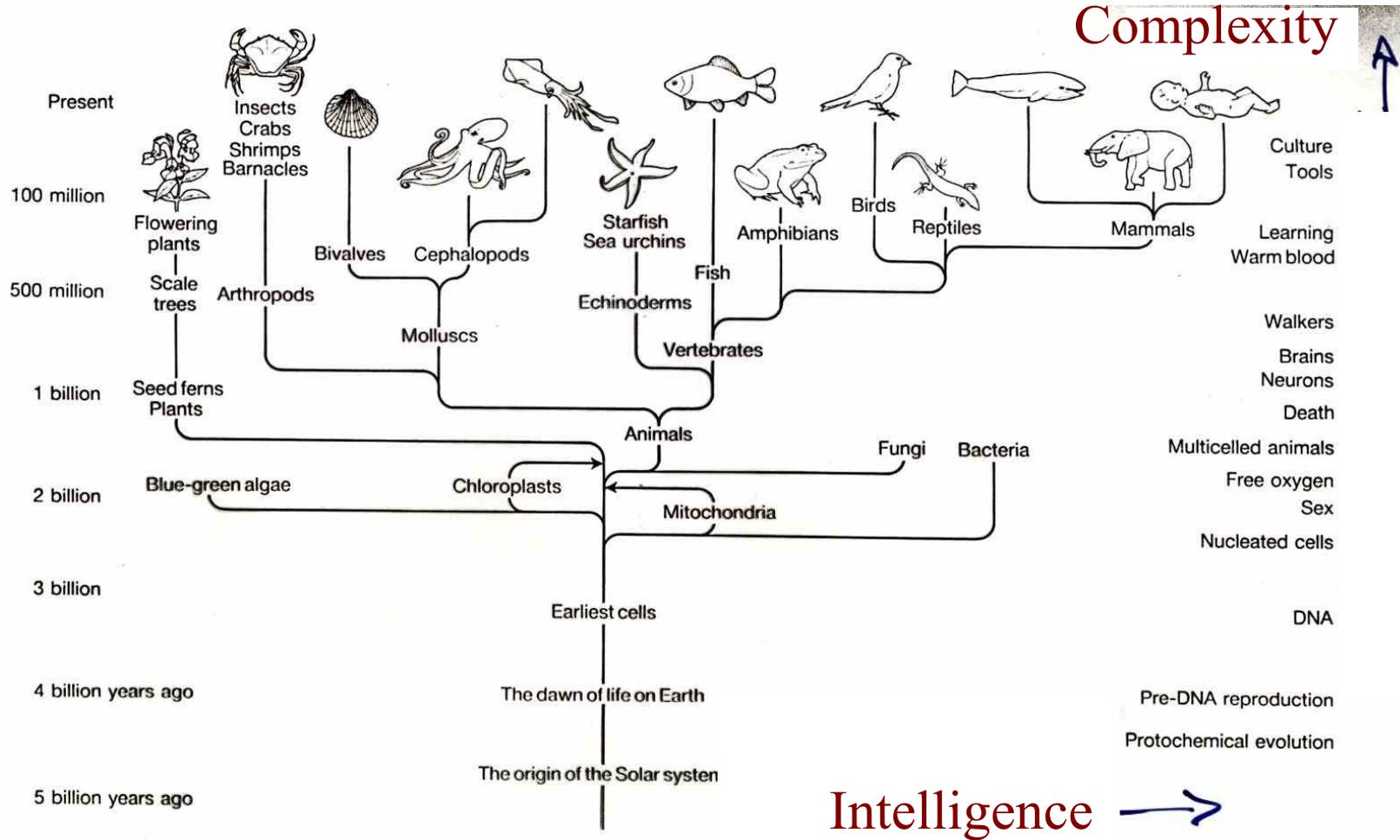
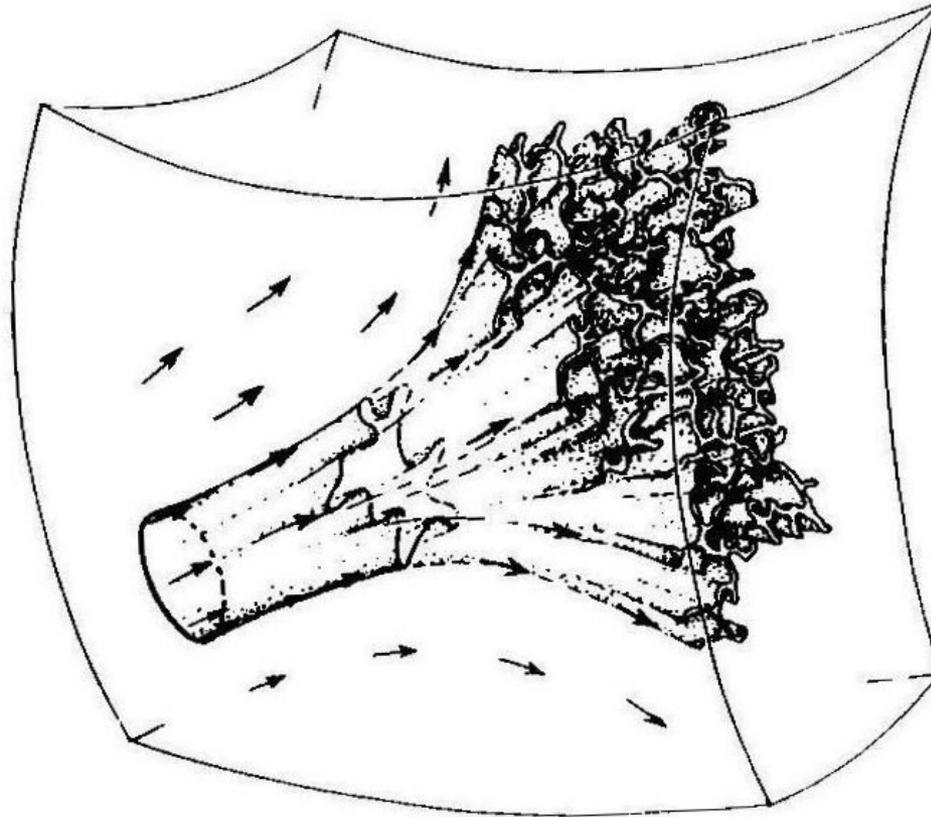
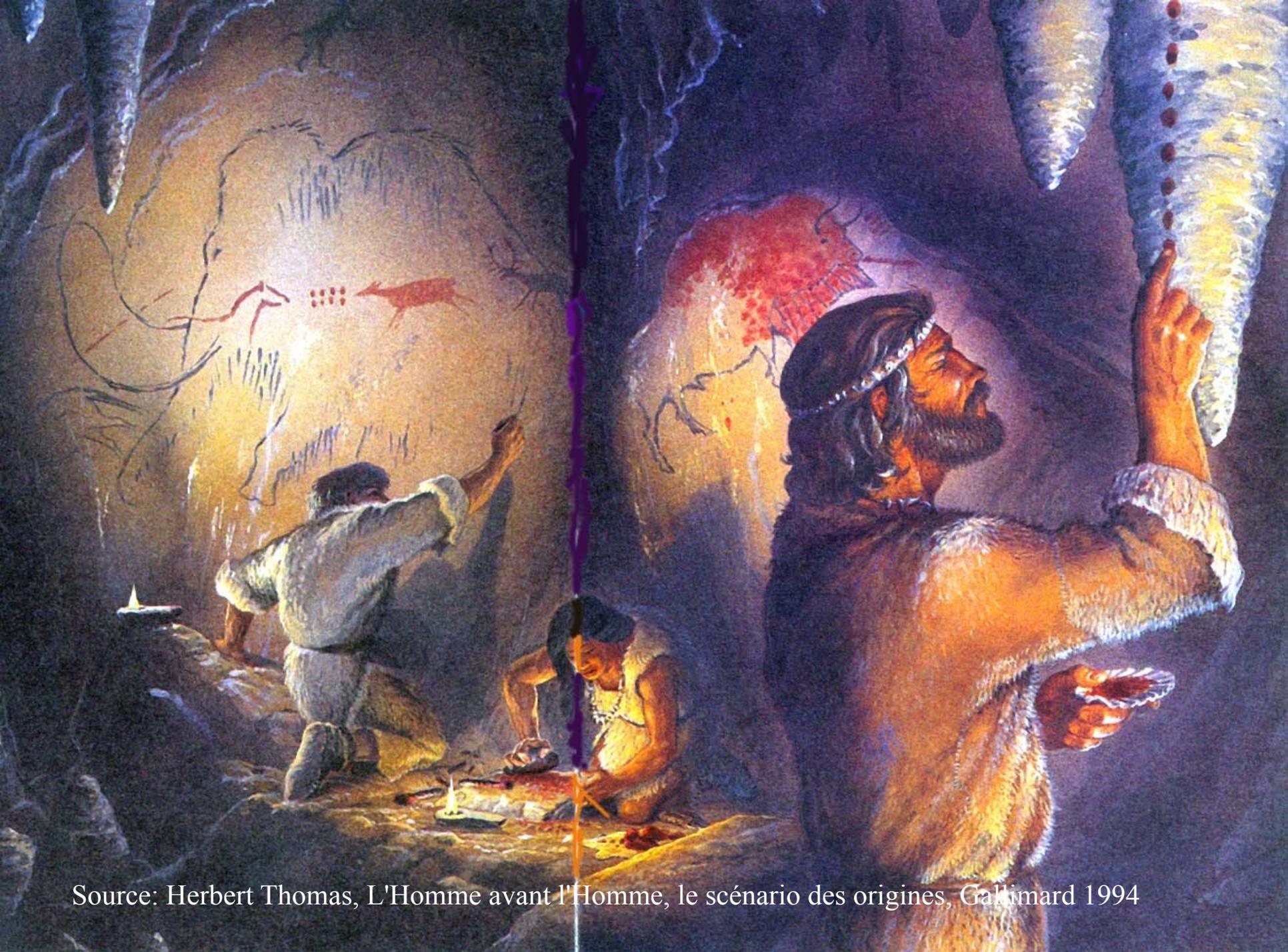


Figure 7.2 The evolutionary pathways of known animal lineages showing the common ancestors of each branch. There is a suggestive parallel between the mobility of each life-form and its intelligence. Humans are distinguished further by the highly effective way in which they have pooled the individual intelligence of single individuals to produce a collective intelligence that greatly outweighs the capability of any single individual.



**Fig. 5.14.** Despite the fact that Liouville's theorem tells us that phase-space volume does not change with time-evolution, this volume will normally *effectively* spread outwards because of the extreme complication of this evolution.

Source: Roger Penrose



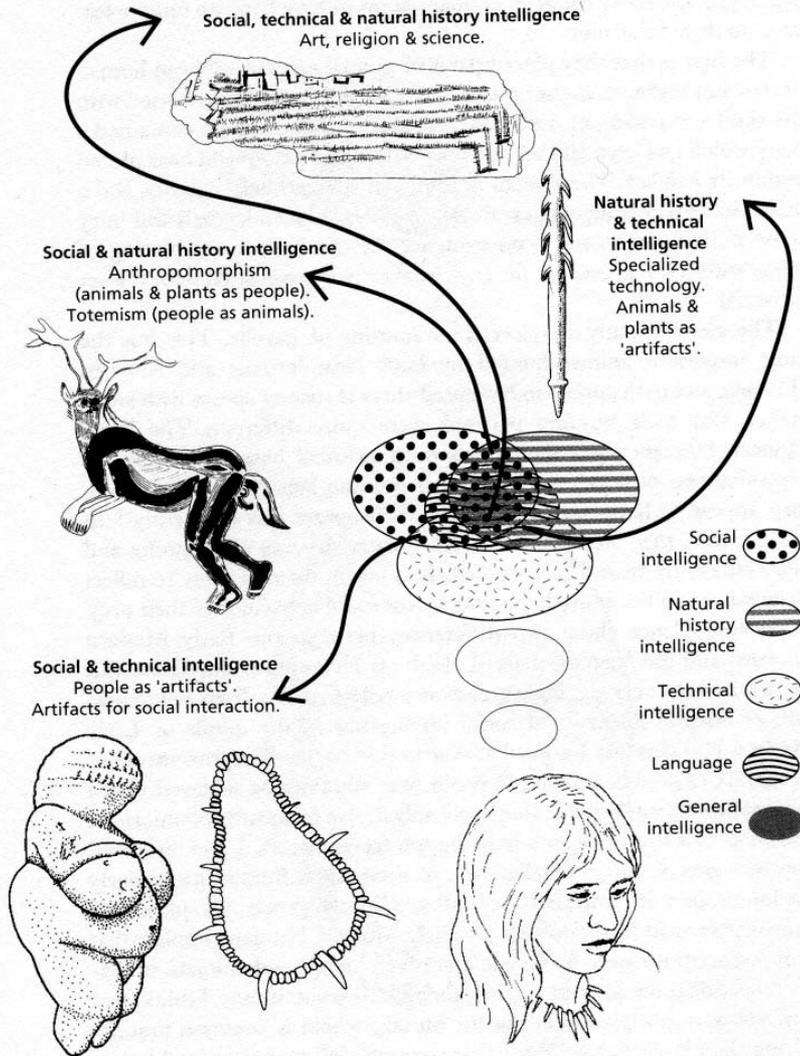
Source: Herbert Thomas, *L'Homme avant l'Homme*, le scénario des origines, Gallimard 1994

Intellectual skills were distributed into different brain areas in the primitive human being. Areas did not communicate.

The development of language facilitated cognitive thinking.

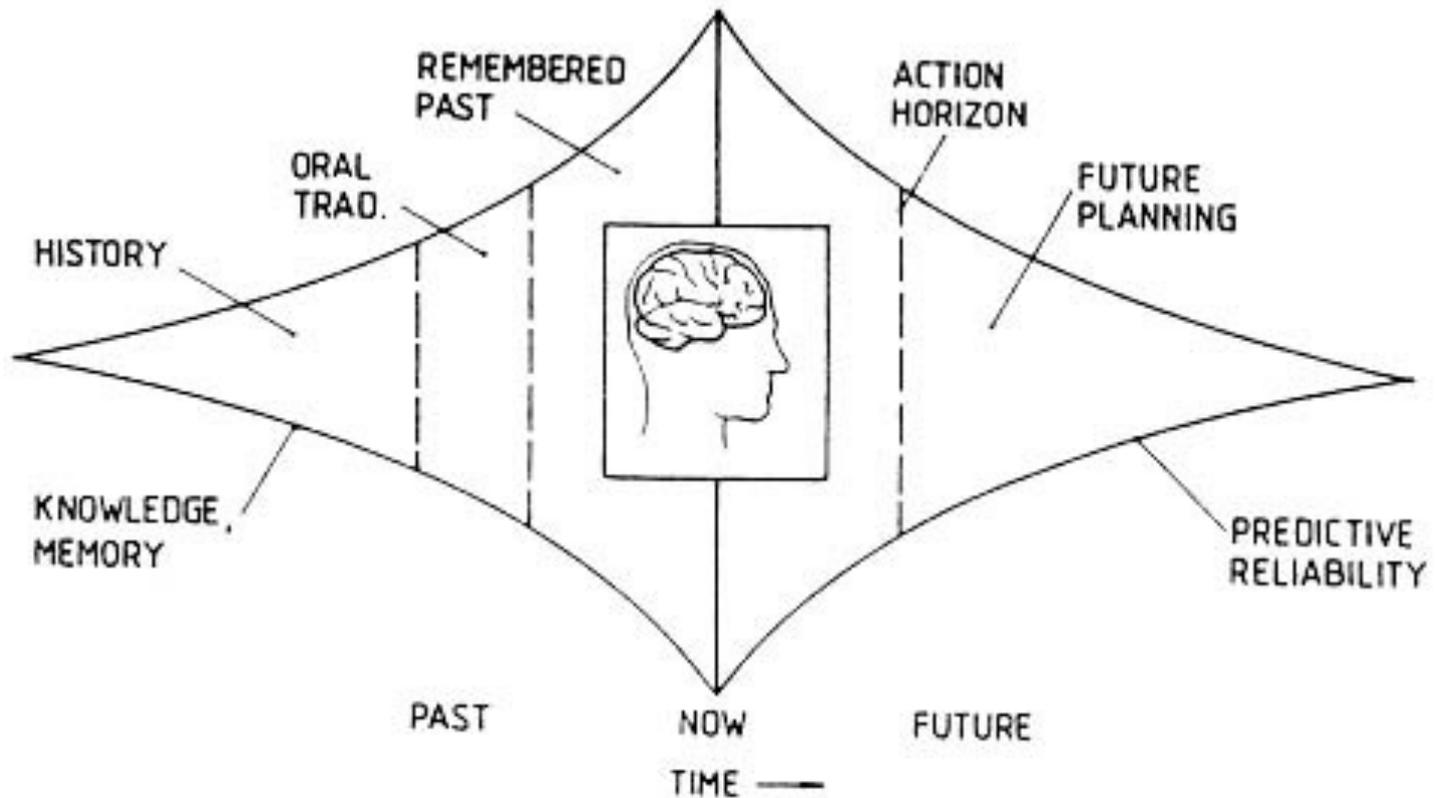
30.000 years ago a giant developmental leap in brain function:

Fantasy removed the human being from a stiff anchoring to the instant of reality.



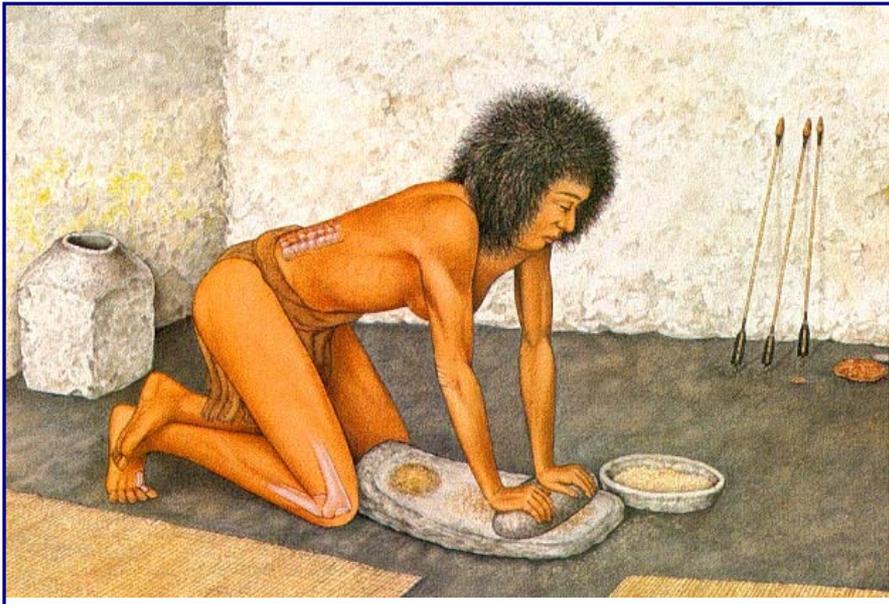
Source: Steven Mithen, *The Prehistory of the Mind*

25 *The cultural explosion as a consequence of cognitive fluidity.*



Only humans are able to make time travels in their fantasy.

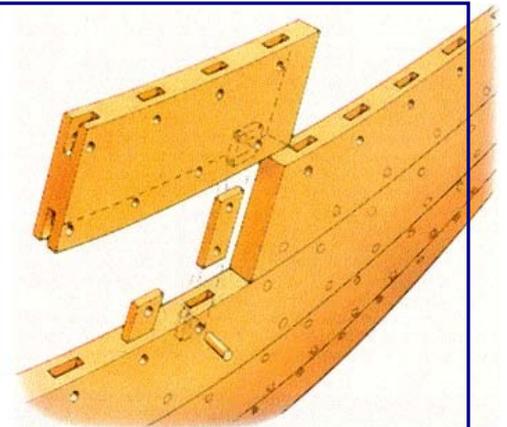
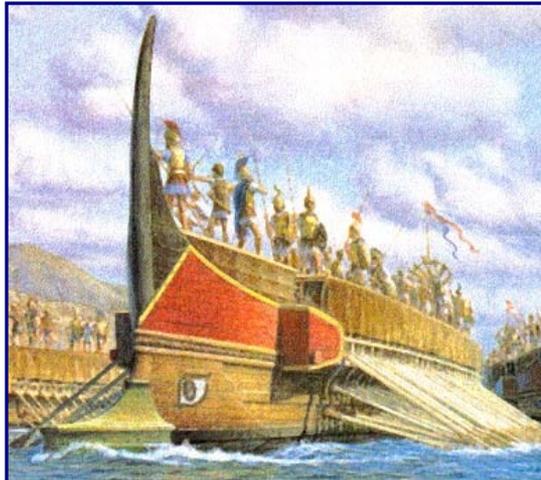
Source: J-T Eriksson



## Reasons for settling 7000 year ago

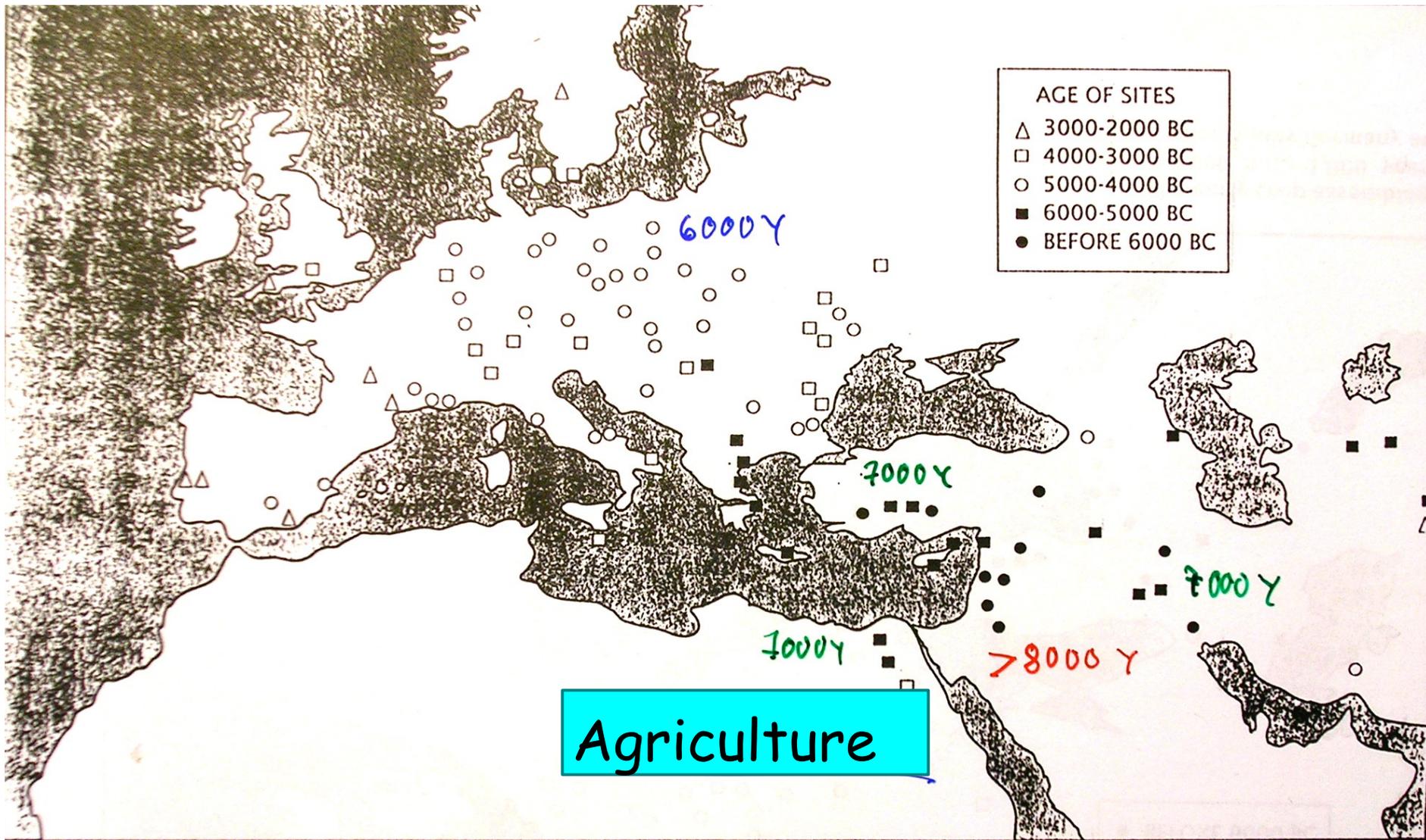
1. Hunting grounds for family tribes becoming too small.
2. Climate changes supported primitive farming.
3. Social status differentiation due to an increasing amount of artefact items.
4. The growth of tribes created hierarchies of power and wealth.

**Already 3000 years ago humans were very skillful in handicraft work.**



Source: Scientific American

**Greece shipbuilding 350 BC**



# The propagation of modern man

Dna johdattaa Eevaan ja Aatamiin



**5.** Mutaatio **M9** syntyi Lähi-idässä ja siirtyi itään päin. Sieltä jotkin heimot kuljivat Intiaan (**M20**) ja Kiinaan (**M175**). **M45** siirtyi pohjoiseen ja siitä polveutuu suurin osa Euroopan, Siperian ja Amerikan ihmisistä.

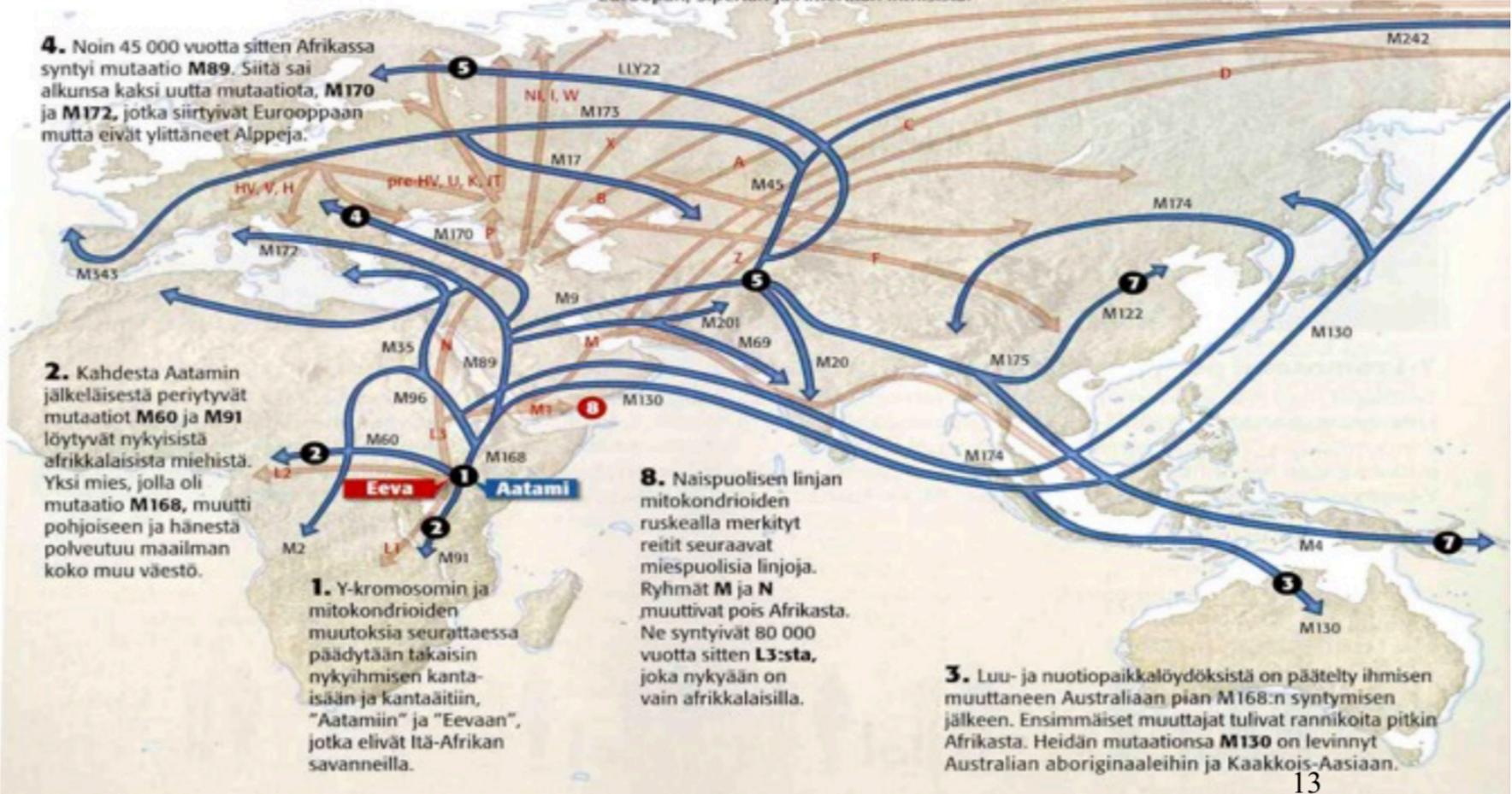
**4.** Noin 45 000 vuotta sitten Afrikassa syntyi mutaatio **M89**. Siitä sai alkunsa kaksi uutta mutaatiota, **M170** ja **M172**, jotka siirtyivät Eurooppaan mutta eivät ylittäneet Alppeja.

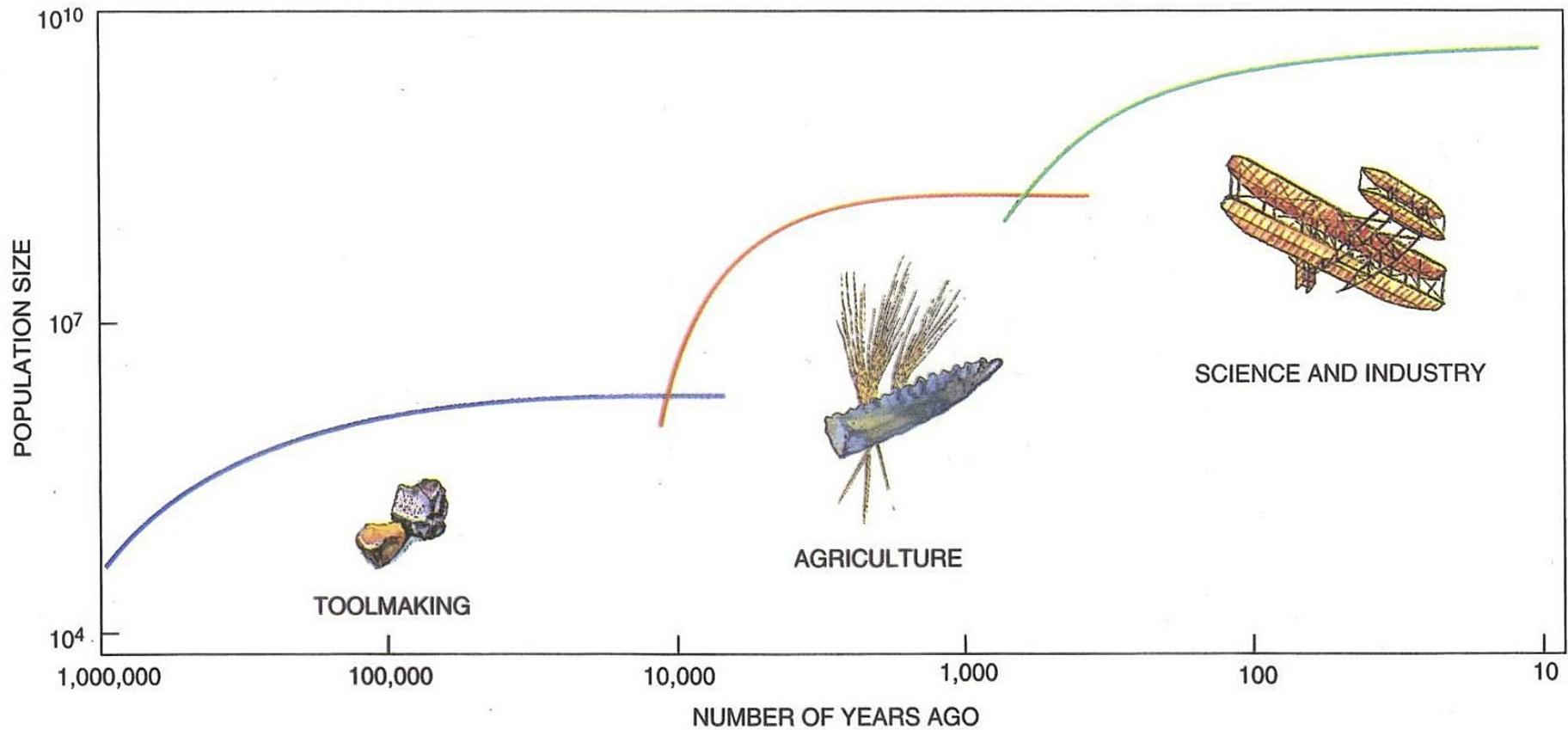
**2.** Kahdesta Aatamin jälkeläisestä periytyvät mutaatiot **M60** ja **M91** löytyvät nykyisistä afrikkalaisista miehistä. Yksi mies, jolla oli mutaatio **M168**, muutti pohjoiseen ja hänestä polveutuu maailman koko muu väestö.

**1.** Y-kromosomin ja mitokondrioiden muutoksia seurattaessa päädytään takaisin nykyihmisen kanta-isään ja kantaäitiin, "Aatamiin" ja "Eevaan", jotka elivät Itä-Afrikan savanneilla.

**8.** Naispuolisen linjan mitokondrioiden ruskealla merkityt reitit seuraavat miespuolisia linjoja. Ryhmät **M** ja **N** muuttivat pois Afrikasta. Ne syntyivät 80 000 vuotta sitten **L3:sta**, joka nykyään on vain afrikkalaisilla.

**3.** Luu- ja nuotiopaikkalöydöksistä on päätelty ihmisen muuttaneen Australiaan pian **M168:n** syntymisen jälkeen. Ensimmäiset muuttajat tulivat rannikoita pitkin Afrikasta. Heidän mutaationsa **M130** on levinnyt Australian aboriginaaleihin ja Kaakkois-Aasiaan.

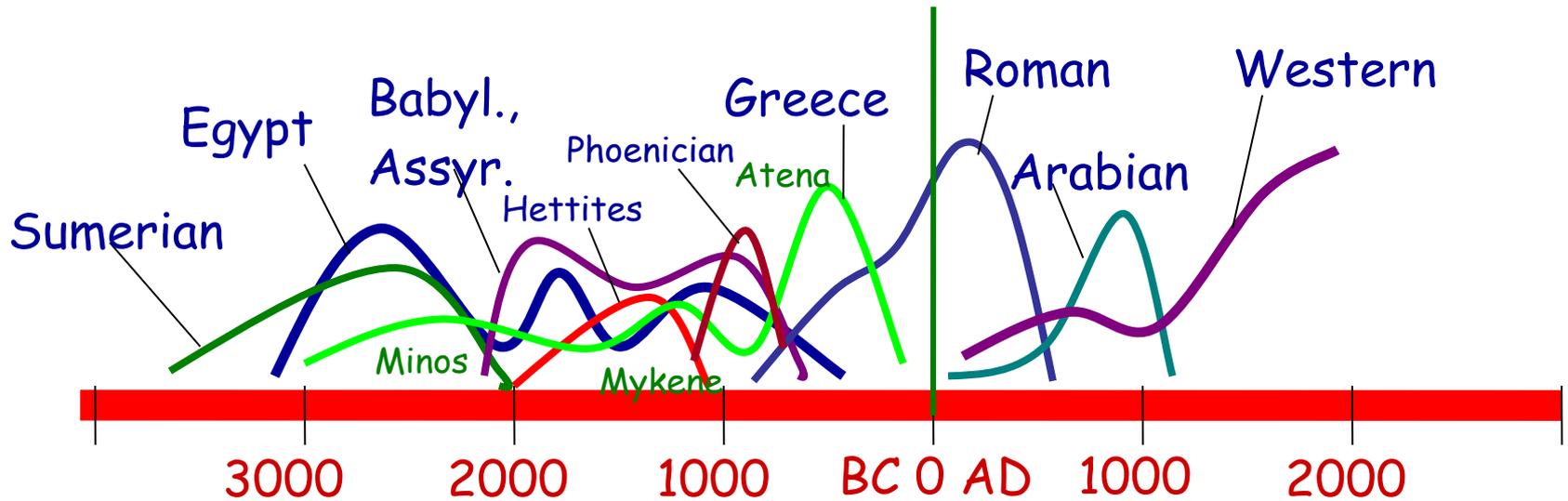




Cultural evolution based on mental intervention.

Source: Scientific American

# "Roots of the Western Culture"



Developmet  
of the use of  
Metals

Copper



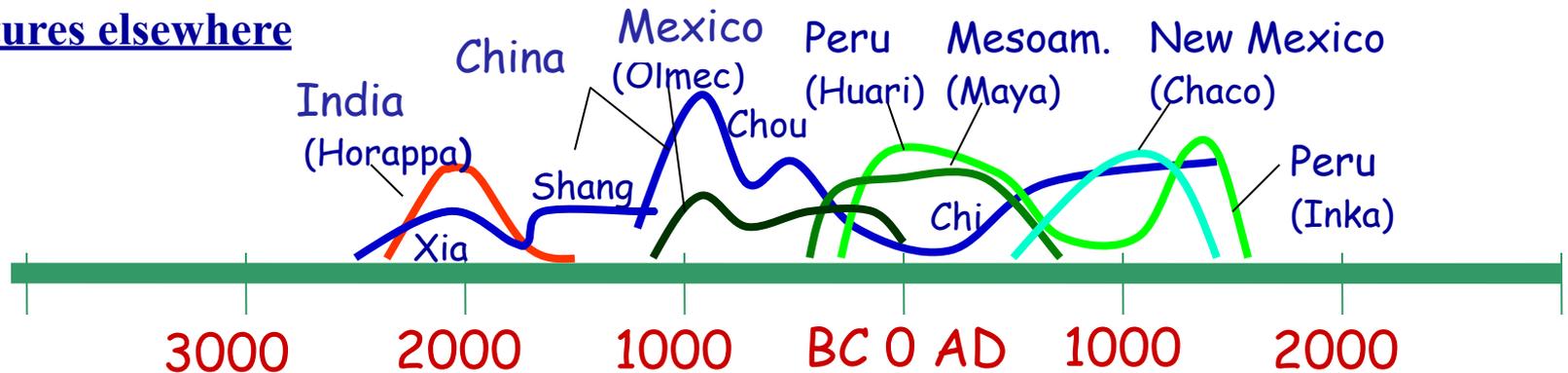
Bronze



Iron



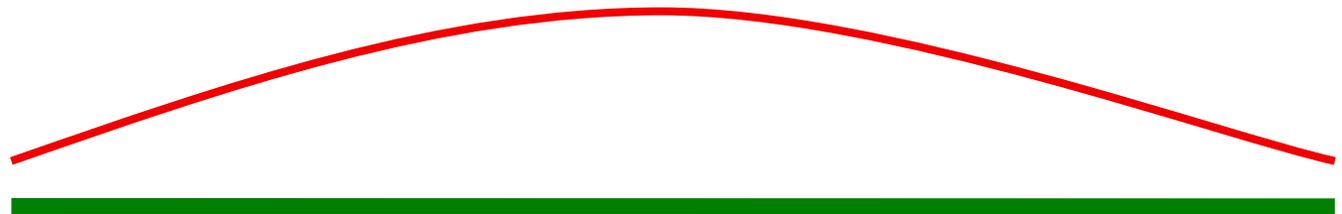
## Cultures elsewhere



Source: J-T Eriksson

# The 4 seasons of cultural development

(Oswald Spengler)



	<b>Spring</b>	<b>Summer</b>	<b>Fall</b>	<b>Winter</b>
<b>Mentality</b>	Joy of life, naiveness	Growing self-confidence	Maturation, consideration	Stiffness, civilization
<b>Culture</b>	Idealistic, hero stories	Religion dominated	Enlightment philosophy	Mass culture,
<b>Classic</b>	Odysseia, Illia	Thales, Pythagoras	Aristoteles	Zenon
<b>Western</b>	Knight tales, sagas	Galilei, Luther	Voltaire, Kant	Marx, Nietsche
<b>Art</b>	Naive religious	Artist central romantic	Realistic, naturalistic	"modern" non-figurative
<b>Politics</b>	King, nobility priests	growing bourguise	power of the bourg. class	metropolitan gowernance

# Complexity and culture

1. **Humans are problem-solving survivors**
2. **A society aims at strengthening the surviving force**
3. **A society is maintained by the continuous flow of resources and information**
4. **Distribution of resources is conditioned by a socio-political system**
5. **Stability requires harmonic involvement of sociopolitical institutions**

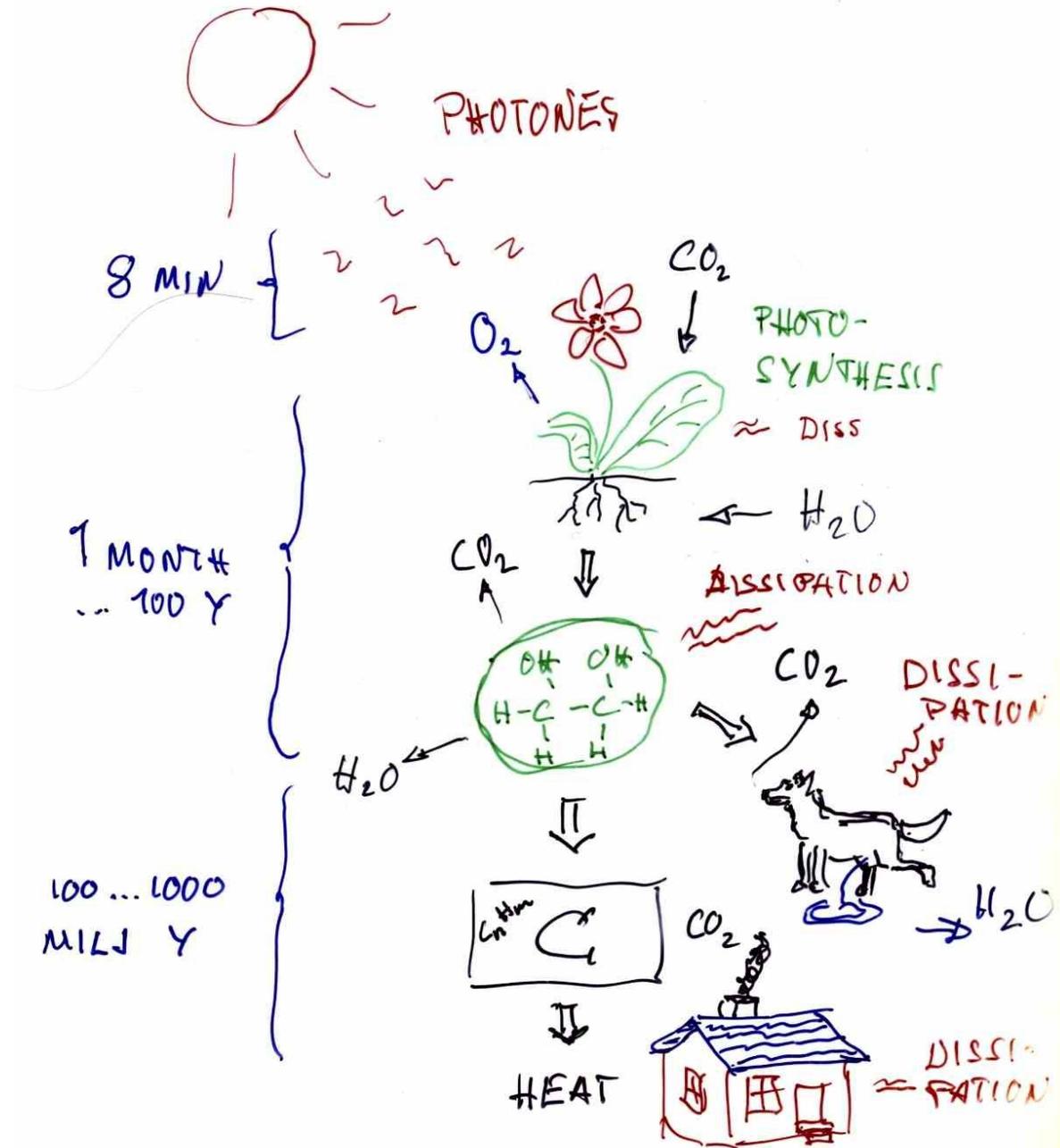
1. **Complexity offers a solution to perceived problems**
2. **Complexity is the response to social needs**
3. **Investment in complexity results in benefits for the society – up to a certain point**

# Complexity and culture

## Why cultures collapse?

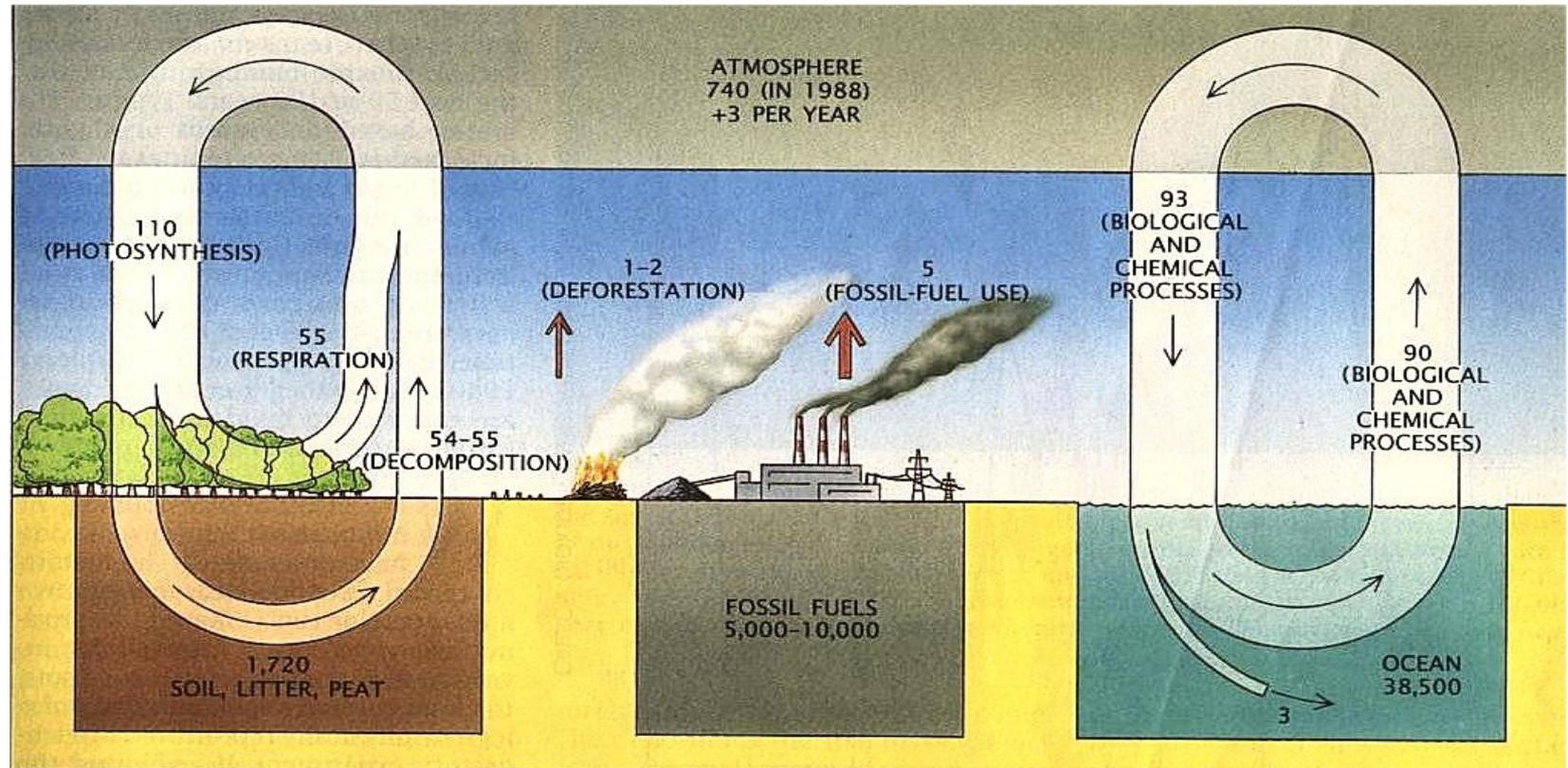
1. **Less over-all coordination.**
2. **Less flow of information.**
3. **Less trading and redistribution of resources.**
4. **Less investment in cultural attributes.**
5. **Less economical and occupational specialization.**

# Spatial and temporal interconnection in the biological cycle.



Source: J-T Eriksson

# Carbon circulation in the biosphere

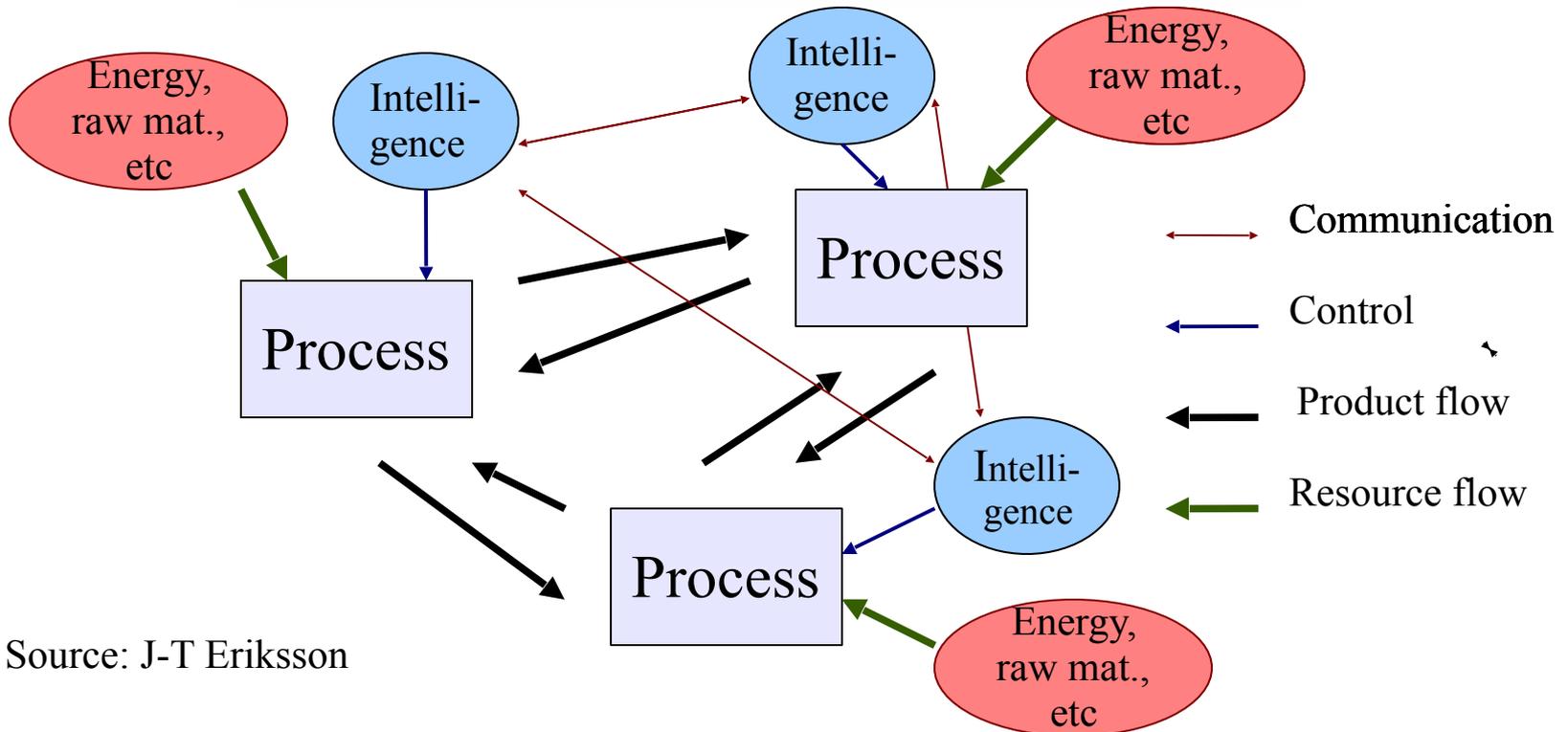


Influence of human activity on atmospheric  $\text{CO}_2$  content. Numbers in 1000 million tons.

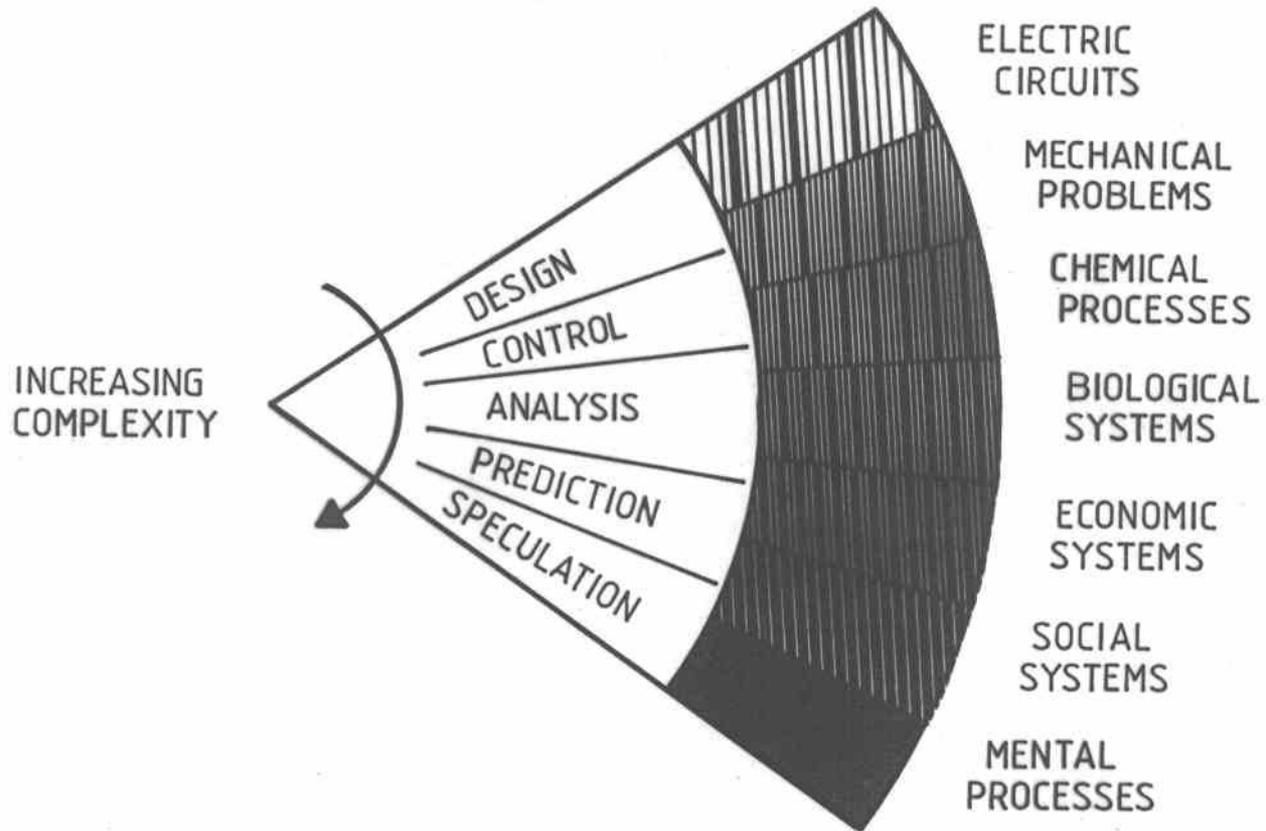
Source: Scientific American

## Characteristics of a Complex system

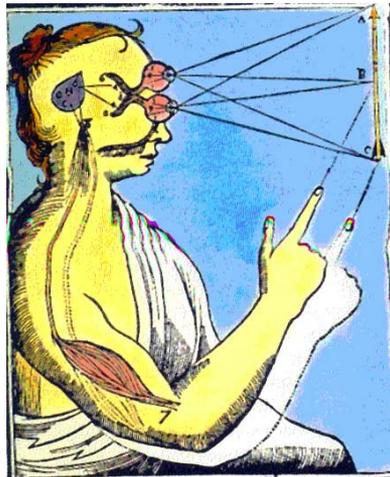
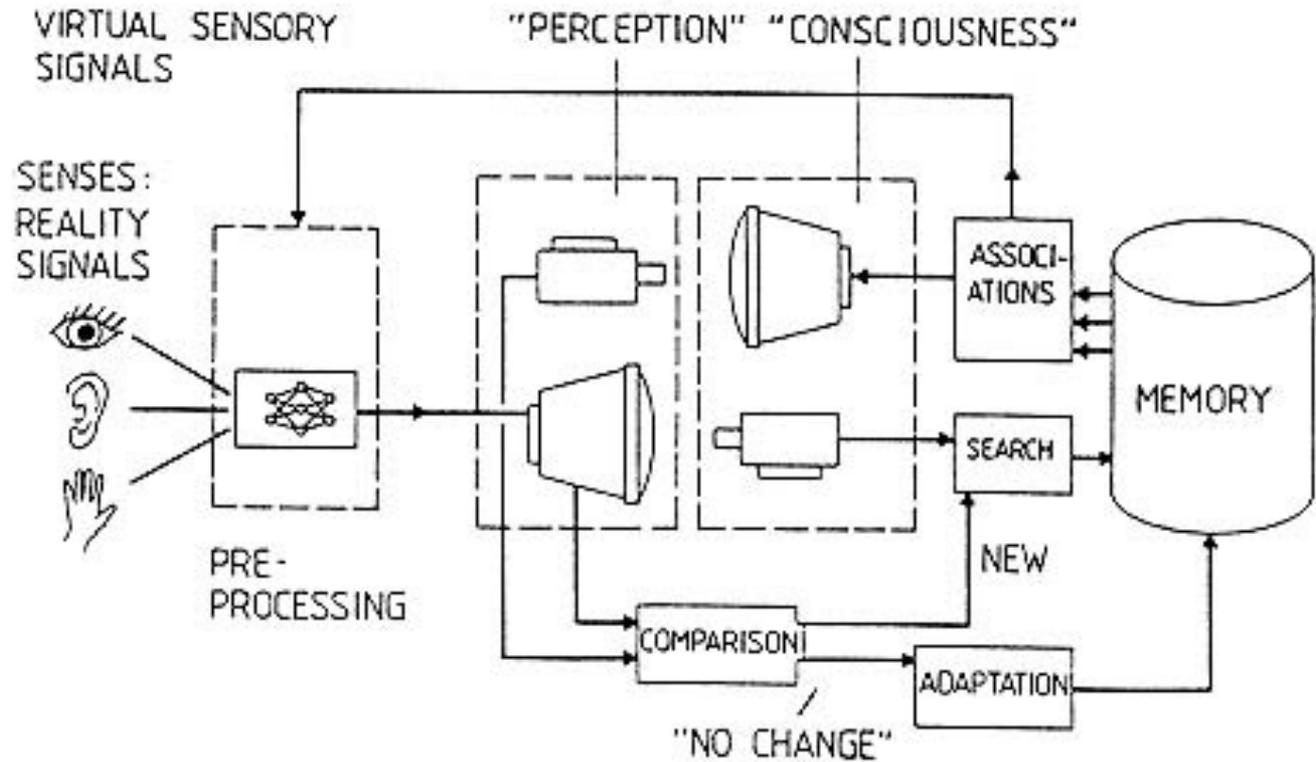
- the system consists of a network or is continuously distributed in space
- centers for consumption or production of resources, energy etc.
- flow of energy and resources
- flow of information
- coherence between the two types of flows
- energy through flow, dissipation
- delays and different time scales for separate processes



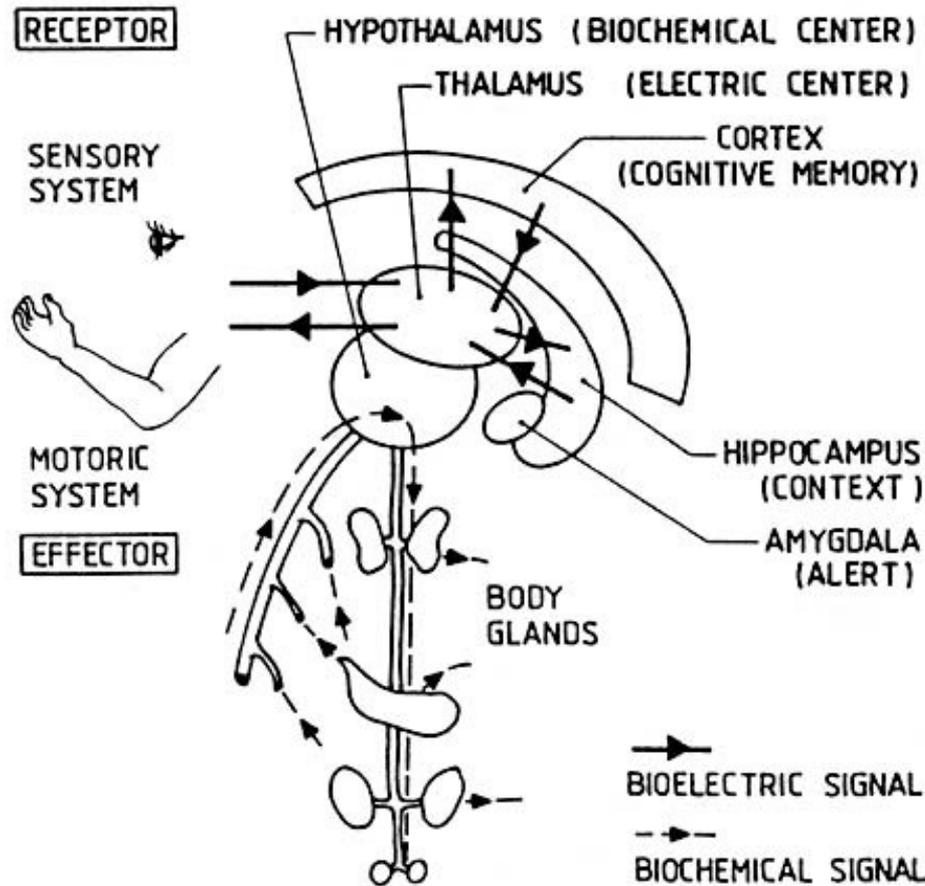
Source: J-T Eriksson



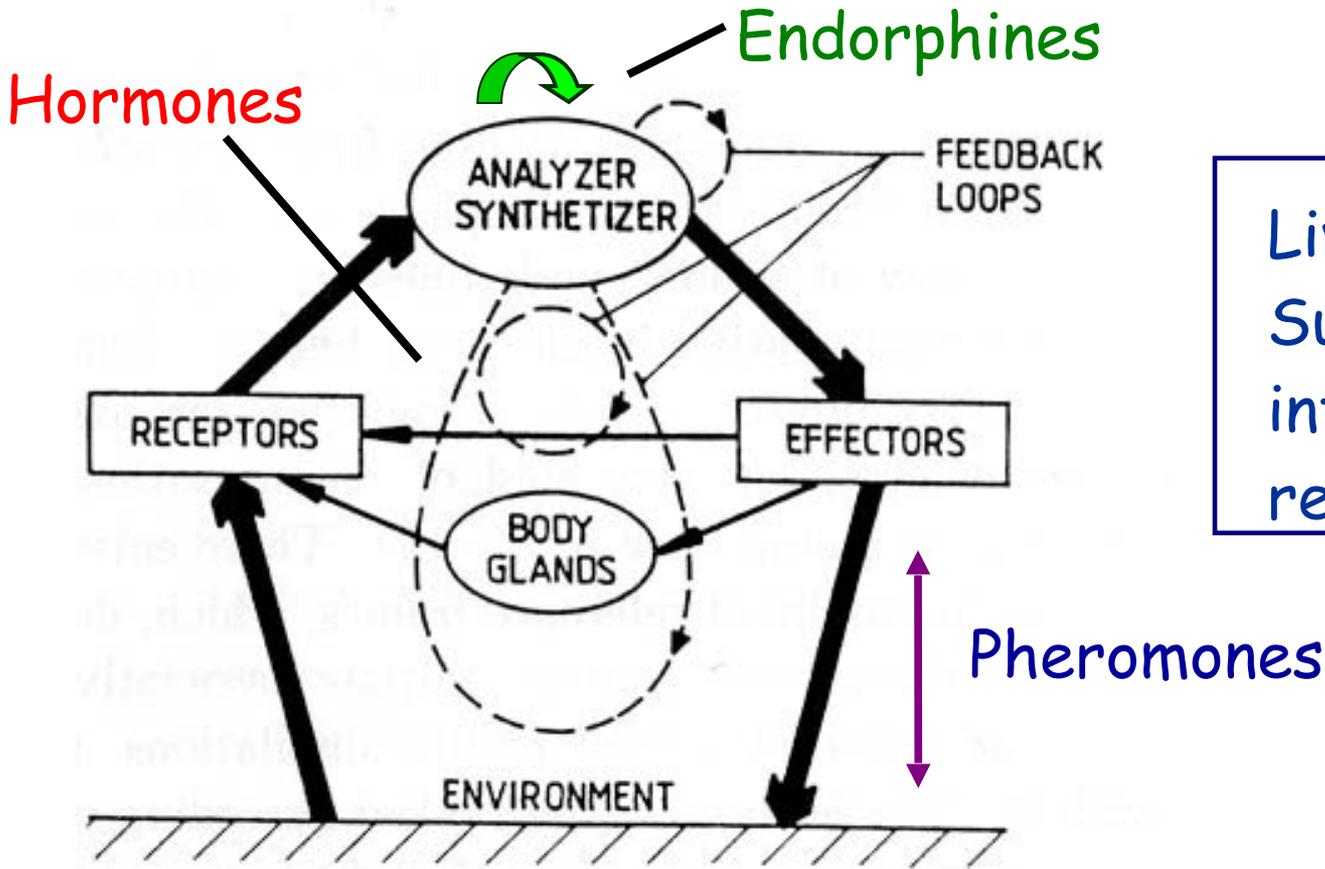
COURTESY :  
WALTER KARPLUS



What humans see or sense is not projected on an "inner film screen", but has to be recognized by the memory. The conscious mind builds a representation of the experienced real world.

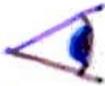
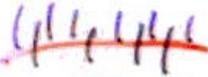


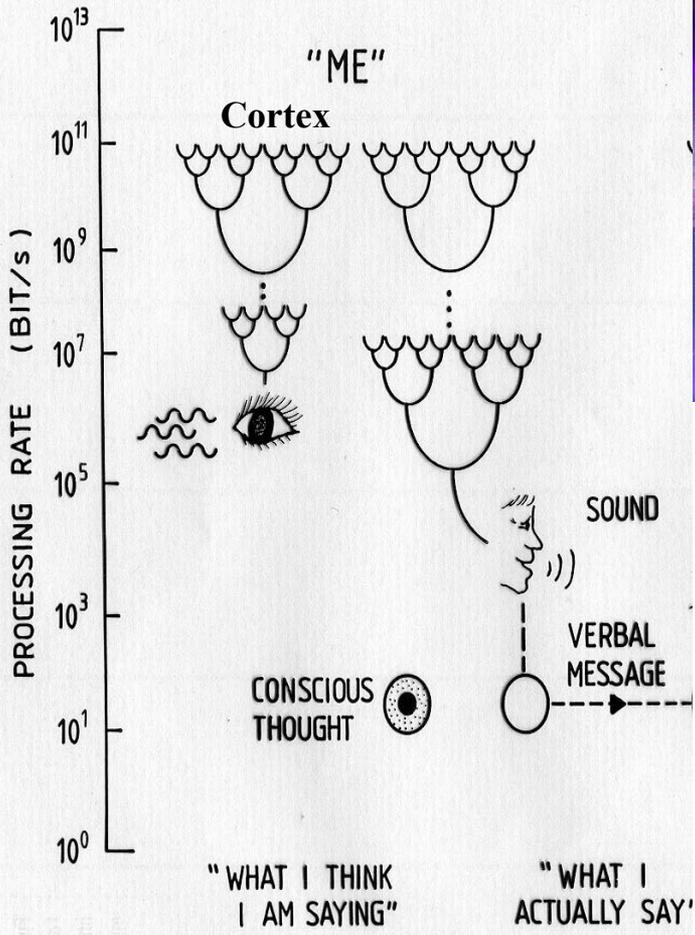
## Signal systems of the human body



Living creature -  
Survivor through  
interaction with  
real world.

# Sensory inputs

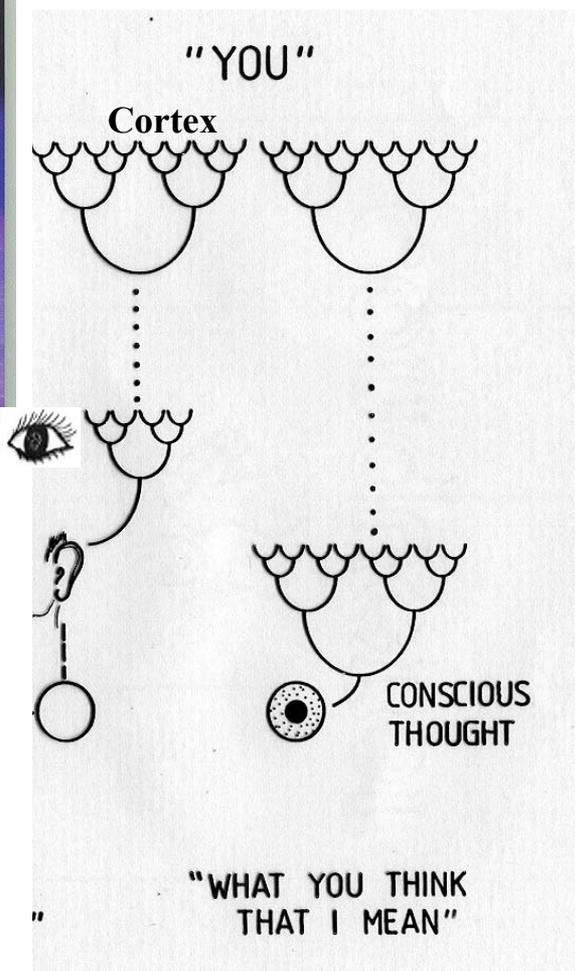
	Vision	$10^7$ bit/s
	Sensing (skin)	$10^6$ bit/s
	Hearing	$10^5$ bit/s
	Smelling	$10^5$ bit/s
	Tasting	$10^3$ bit/s



Multimedia-communication  
10 Mbit/s



Speechcomm  
40 bit/s



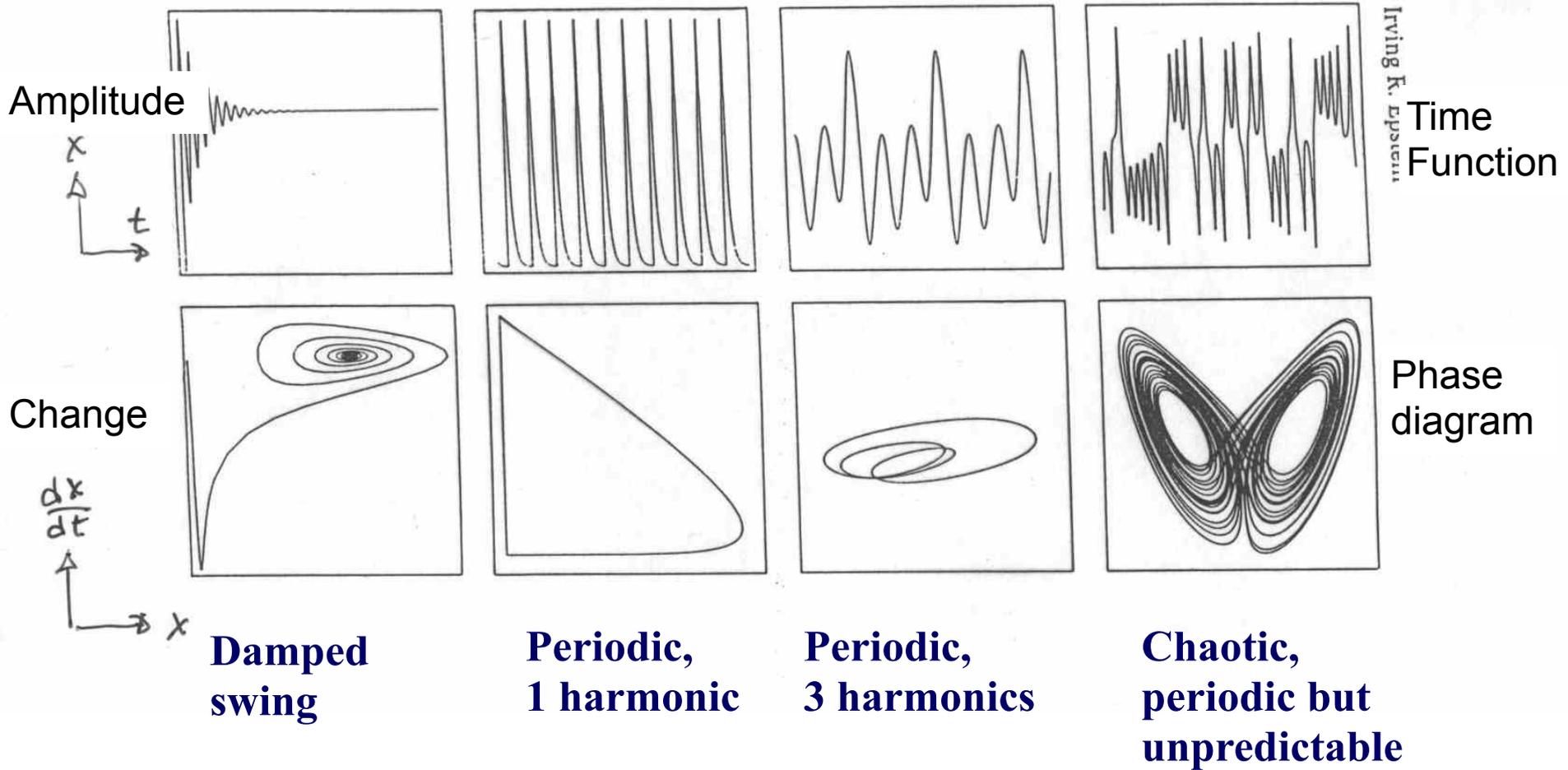
# Leonardo da Vinci creating mental models of turbulence



The complex phenomena of Nature have to be studied and mentally processed before generalizing theories or mathematical models can be formulated

Source: Leonardo da Vinci

# Chaos theory



# Game theory



		Player 2	
		YHT Cooperate	KILD Defect
Player 1	YHT Cooperate	R=3 3	S=0 5
	KILD Defect	T=5 0	P=1 1

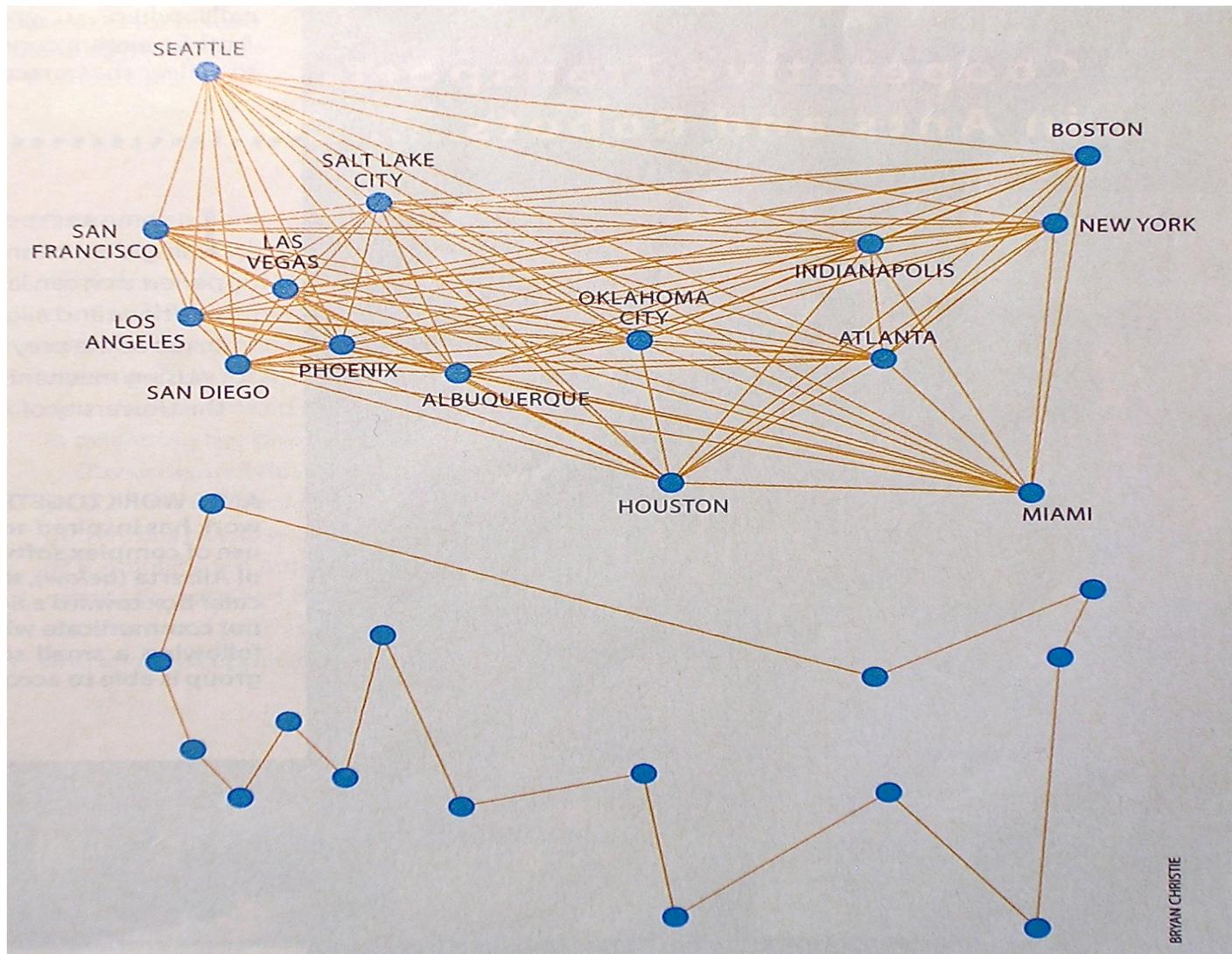
The Prisoner's Dilemma is everywhere. Two players (for instance riders on a tandem) can each decide whether to cooperate or defect. The matrix shows that player 1 gains more by defection not only when player 2 cooperates (5 instead of 3 points) but also when player 2 defects (1 instead of 0 points). Because this is true for either player, both will defect and end up with 1 point each although they could have gained 3 points each if they had cooperated. Hence the dilemma (and the reason why tandems have never become very fashionable).

Source: Scientific American

# A Complexity Toolbox Sampler

- Genetic algorithms take their cue from natural selection, creating “mutations” and “crossovers” of the “fittest” solutions to generate new and better solutions.
- Intelligent agents are autonomous programs that can modify their behavior based on their experiences.
- Neural networks mimic biological neurons, enabling them to learn and making them ideal for recognizing patterns in speech, images, fingerprints and more.
- Cellular automata consist of a checkerboard array of cells, each obeying simple rules, that interact with one another and produce complex behavior.
- Ant algorithms use a colony of cooperative agents to explore, find and reinforce optimal solutions by laying down “pheromone” trails.
- Fuzzy systems model the way people think, approximating the gray areas between yes and no, on and off, right and wrong.

Source: Scientific American



The traveling salesman problem can be solved utilizing the ant algorithm.

# Developing the understanding of complex systems

- Cross-disciplinary education.
- Awareness of methodological diversity.
- Individual focus on specific methods.
- Cooperative networking acting like the brain of the individual.