

# Towards a Complex Systems Science

Paul Bourgine

National Network of Complex Systems, Paris

Complex Systems Institute of Paris

# What are complex systems ?

Two points of view : extension/intention

- **Complex objects**

- cells,
- multicellular organisms,
- cognition,
- law,
- economy,
- road traffic,
- telecom systems,
- Internet
- the web,
- society,
- Ecosphere
- .....

## Questions/properties :

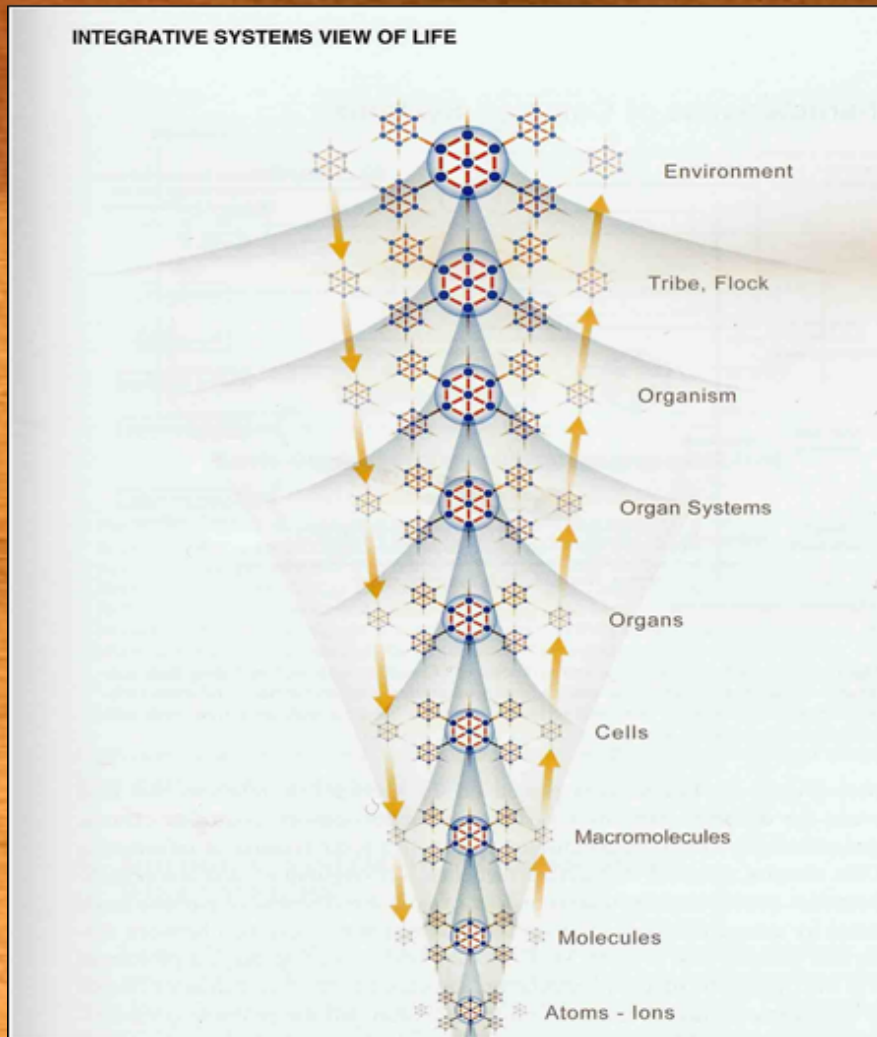
- Large network of entities
- Network of networks
- Emergence
- Reconstruction
- Prediction
- .....
- Self-organization
- Robustness and Stochasticity
- Autonomy
- Viability and Resilience
- Adaptation
- Governance
- .....

# Two types of interdisciplinarity :

## Starting from an Object OR from a Question

	Cell	Multicellular Organism	Cognition	Ecosystem	Society	...
Multi-scale Reconstr./Predict.		MORPHEX Embryomics Mechanical Induction			EVERGROW DELIS ERG 4 TiGrESS	
Large interaction network		Plurigenesis BioEmergences Mechanical Induction				
Collective phenomena		Morphoscales BioEmergences Mechanical Induction		STARFLAG	STARFLAG ISCOM	

# Reconstructing multi-scale dynamics

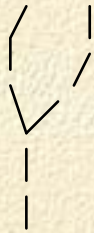


- Reconstruction from multi-scale data and « first » principles of
  - Multiscale dynamics,
  - micro-macro & macro-micro function
- Multiscale Protocols
  - For observing complex systems *in vivo*,
  - Designed by theoreticians & experimentalists
- Open science - Science Commons
  - open data
  - open software

# L-Systems

A. Lindenmeyer  
P. Prusinkiewicz

Example :



$n = 1, \delta = 22.5^\circ$

F (axiom)

$F \rightarrow FF- [-F+F+F] + [+F-F-F]$

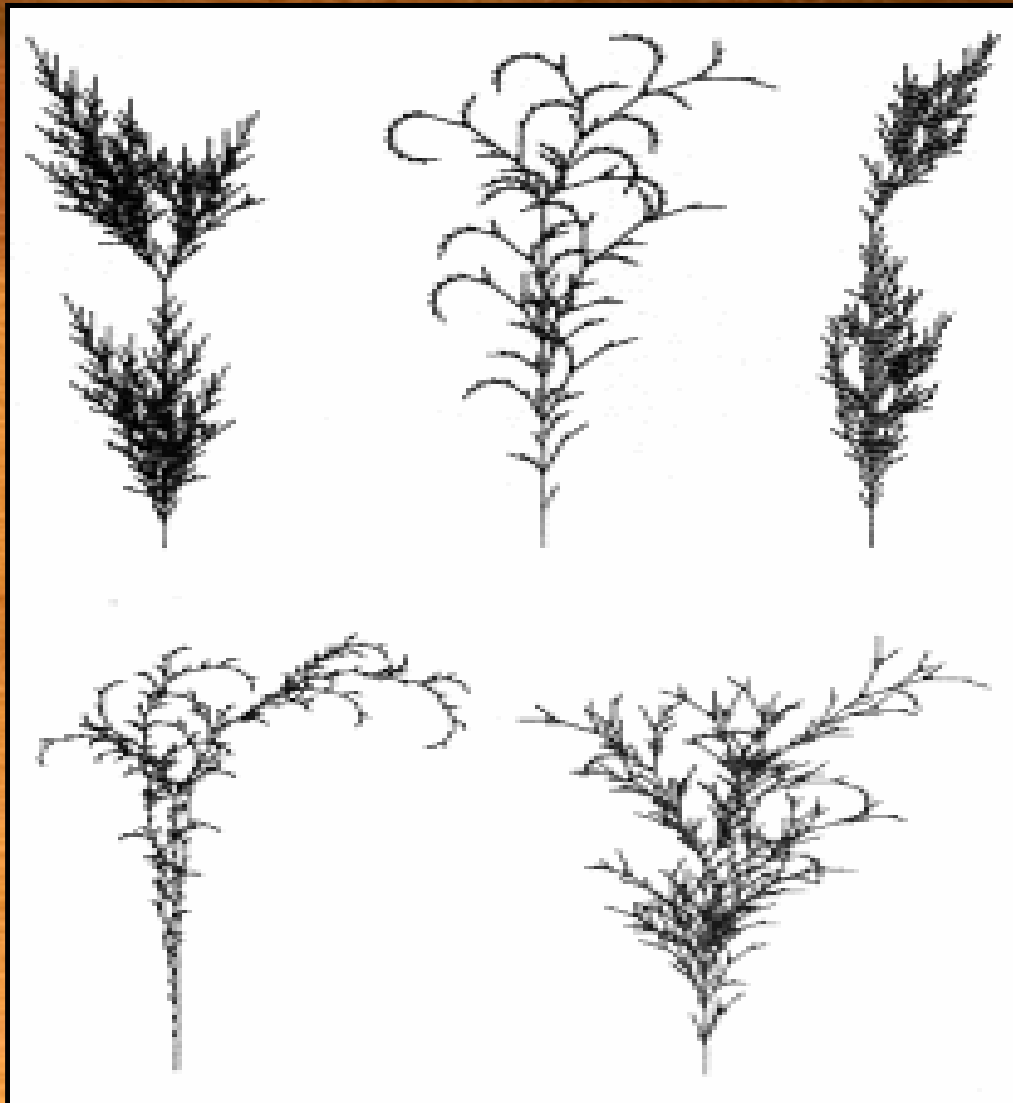
with F = "go ahead 1step"

+ = "rotate by +  $\delta$ "

- = "rotate by -  $\delta$ "

# Simulating L-Systems

After P. Hogeweg & B. Hesper



# Orchidea Reconstruction

QuickTime™ et un  
décompresseur TIFF (non compressé)  
sont requis pour visionner cette image.

5000 polygons

# Measuring Sophisticated Data

AMAP-mod: Liama (franco-chinese), Ci

QuickTime™ et un  
décompresseur TIFF (non compressé)  
sont requis pour visionner cette image.

# Phenomenological reconstruction

<http://www.cirad.fr/presentation/programmes/amap/themes/r>

QuickTime™ et un  
décompresseur TIFF (non compressé)  
sont requis pour visionner cette image.

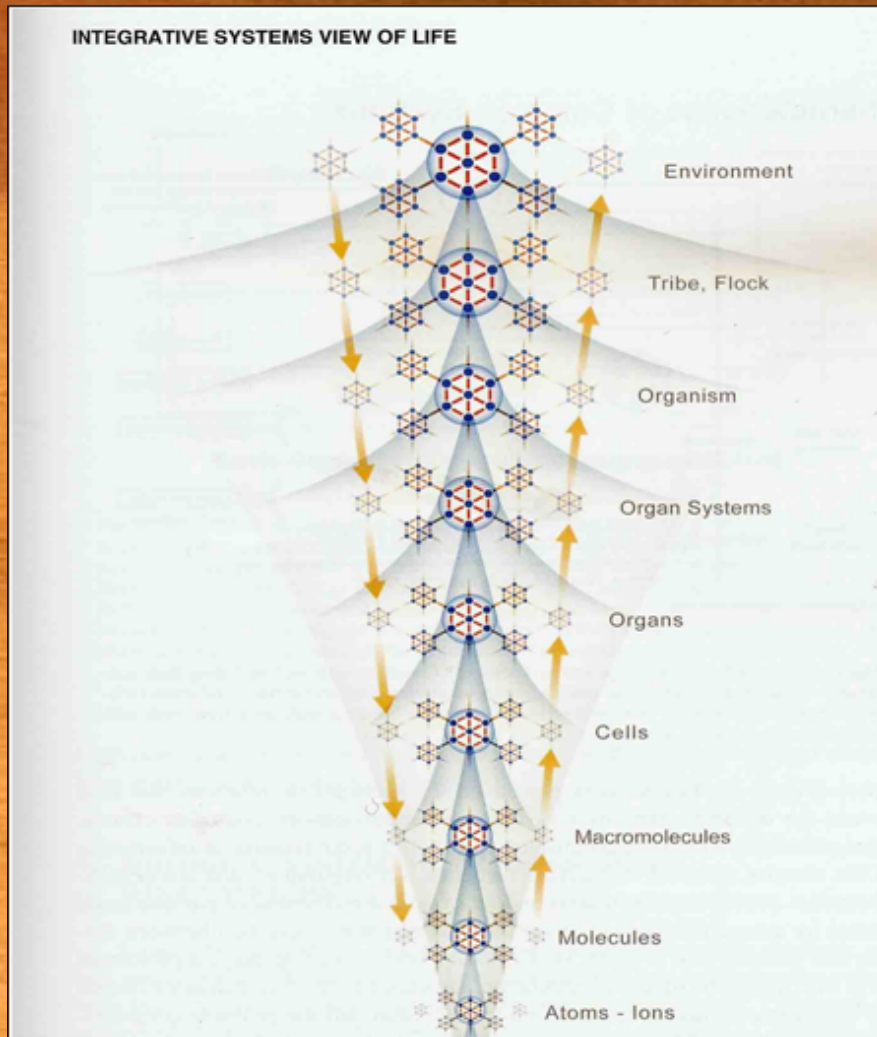
# Reconstruction/Simulation

- Reconstruction is an "inverse" problem of simulation :
  - 'Simulation' : given a program  $A$ , obtain  $\text{Result}(A)=B$
  - 'Reconstruction' : given  $B$ , search  $A$  for  $\text{Result}(A)=B$
- Reconstruction are under-determined by the facts (Quine)
  - Occam's razor, Kolmogorov complexity = Length of smallest  $A$
  - Modelling from first principles, with (new) elegant formalism,...

# Reconstruction /Prediction

- Reconstruction up to a noise (Crutchfield)
  - ex. of pure disorder : a long random series of 0/1
  - Bernouilli machine, Stochastic L-systems, Stochastic partial differential equation, ...
  - Take the model with the best predictive performance (e.g. Vapnik statistical theory)
- Probabilistic Prediction Paradigm :
  - "Predict not what will happen BUT what can happen" (Prigogine, Nicolis)

# Universalization of dynamics (and of phase transition)



- Heat Equation
- Navier-Stokes Equation
- ? Do the same for :
  - Biomechanics
  - Reaction/Diffusion Processus in Biology/Social
  - Etc...