Networks: ontologies, modeling, and ethics

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Outline

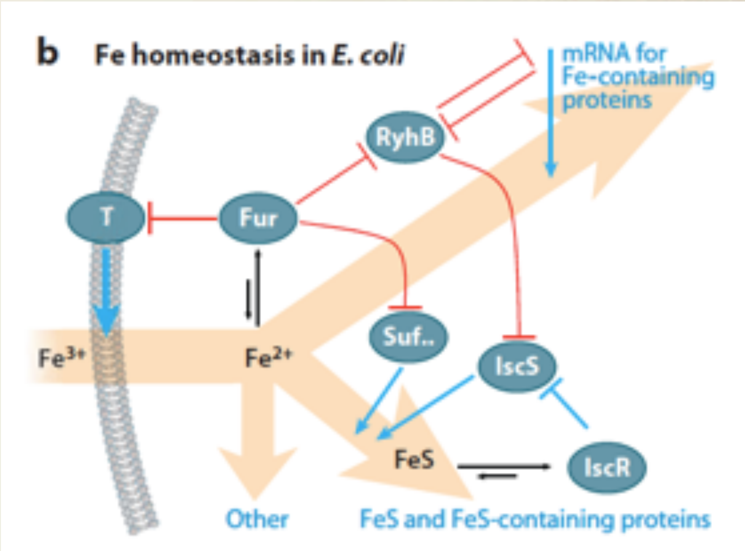
1. what is at stake?
2. *general networks*: the statistics of topology
3. *biological networks*: the function of dynamics
4. *philosophy of science*: conflict or synthesis of perspectives?

1. WHAT IS AT STAKE?

Ontologies

* WHAT IS THE ... OF A NETWORK?

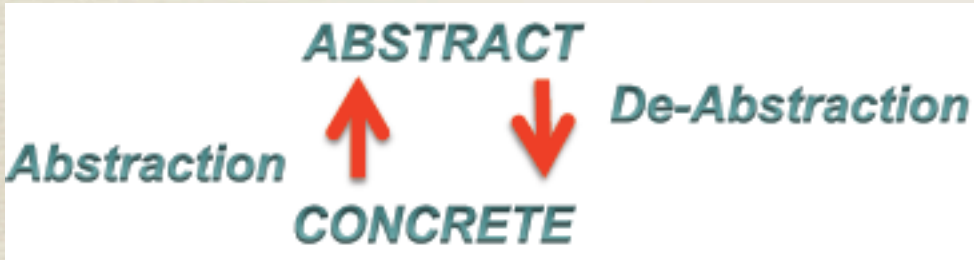
1. Set of nodes & links?
2. Relevant field?
3. Structure, topology, and "morphology"?
4. Function, dynamics, and "physiology"?
5. Evolution?
6. Individuation?



Sneppen et al. 2010

Modeling

- *Simulation* (abstract modeling) techniques and aims?
- *Experiment* (concrete modeling) techniques and aims?
- Promises and limits of *in silico* and *in vivo* modeling? "assumption archeology" and "pernicious reification"



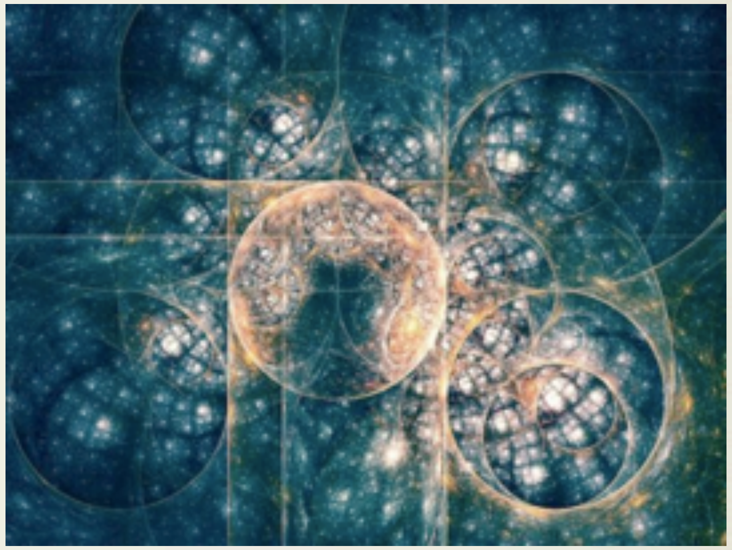
"The problem for science is to understand the proper domain of explanation of each abstraction rather than become its prisoner." (Levins and Lewontin 2006, p. 150)

Ethics & Metaphor

- **atomism** (averaged/ single/major effects)

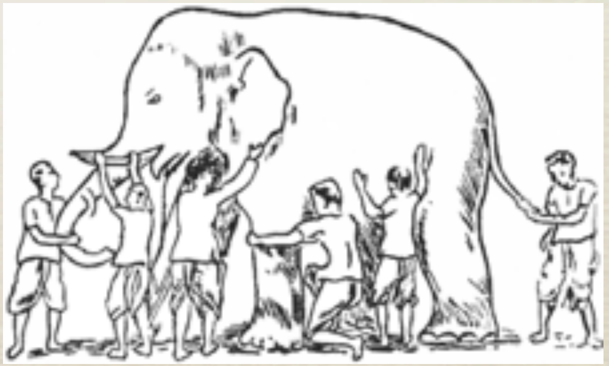
vs./and?

- **holism** (interactive/ emergent effects)



- **monoperspectivalism**

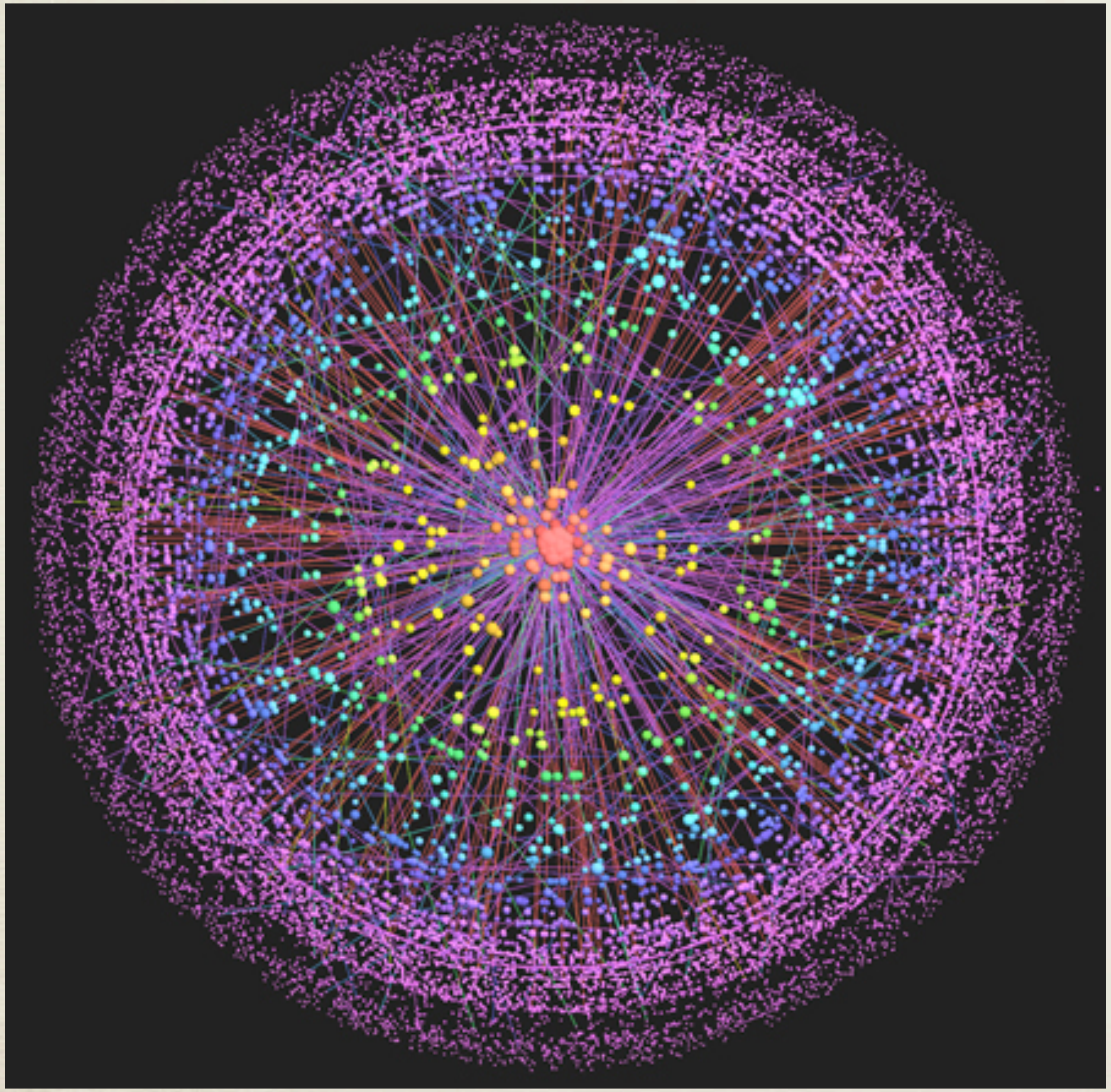
- **pluriperspectivalism**



an ethics of connectivity?

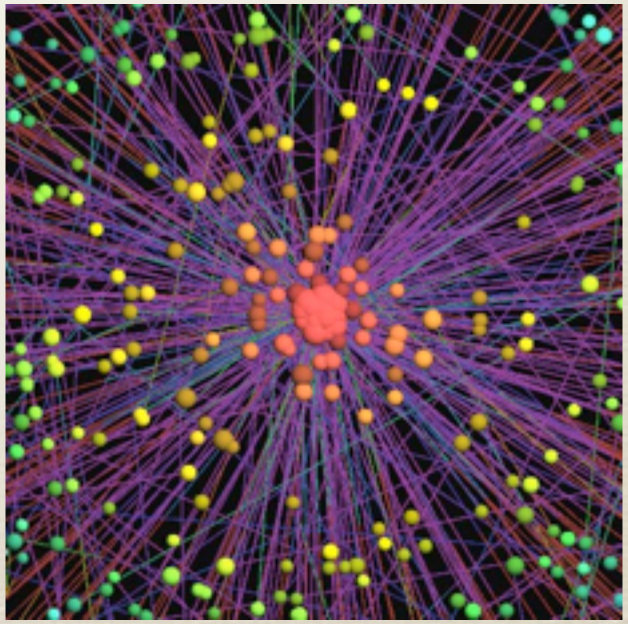
2. *GENERAL NETWORKS*:
THE STATISTICS OF TOPOLOGY

Internet

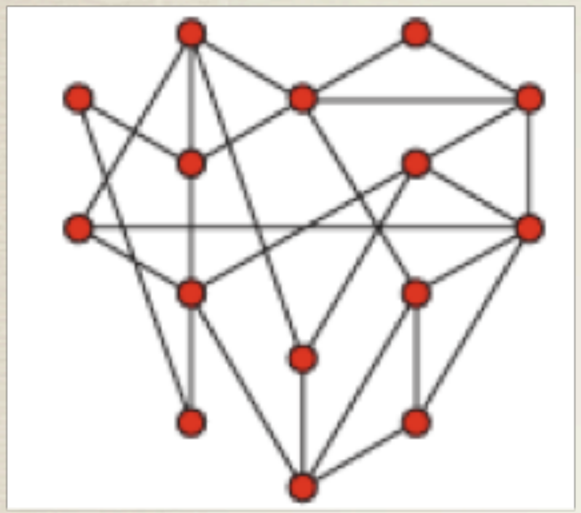


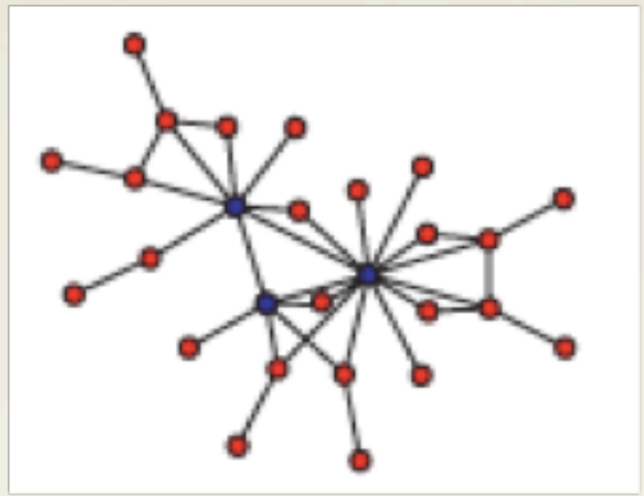
Carmi et al. 2007

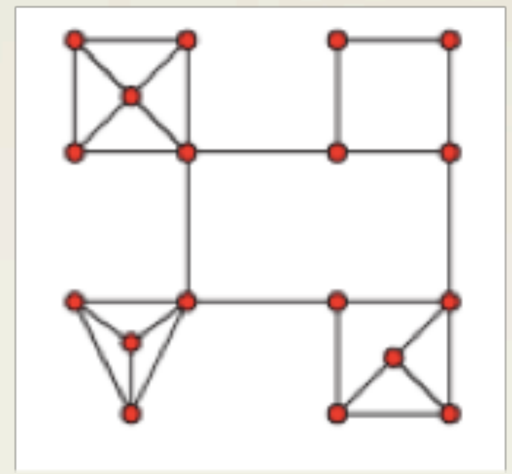
If it can't be quantified, it doesn't exist!

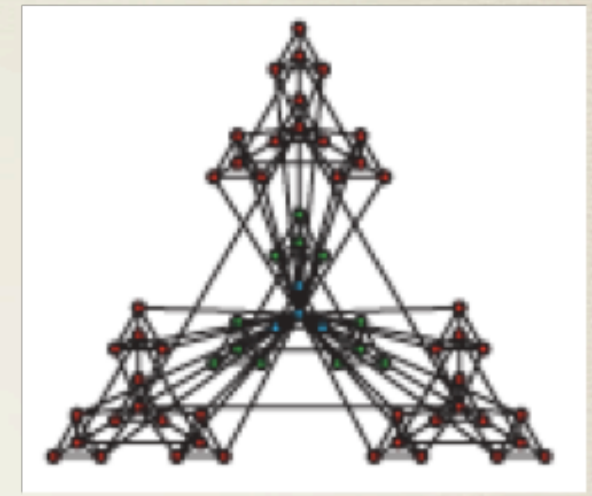


Network Topologies: Images







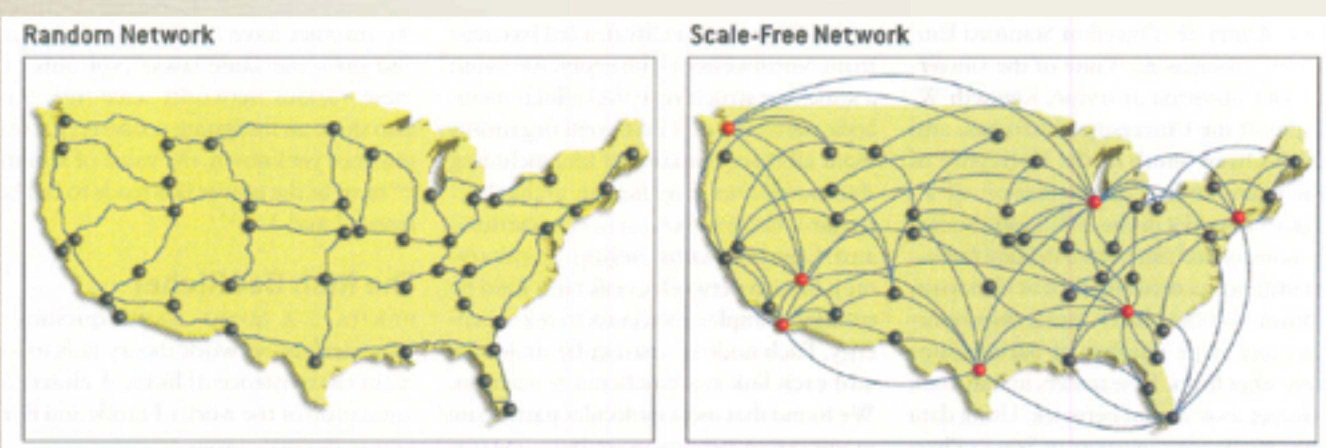


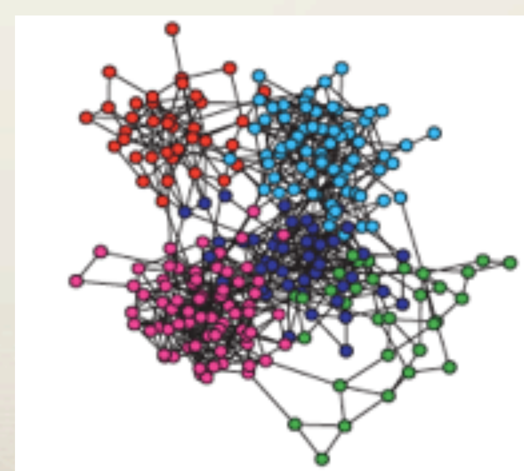
random
(Erdős & Rényi 1959)

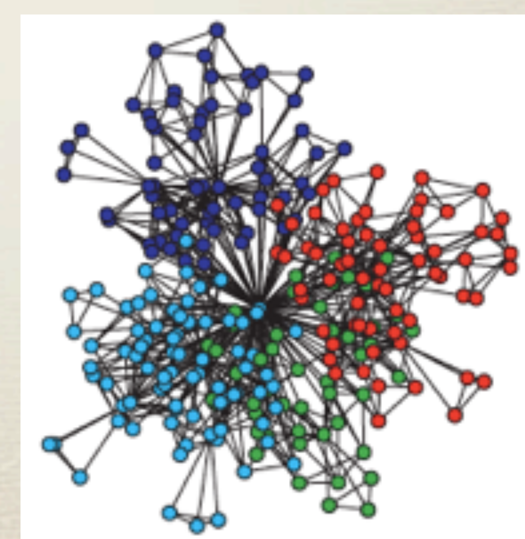
scale-free
(Barabási & Albert 1999)

modular
(Simon 1962)

hierarchical
(~Ravasz et al. 2002)







Network Topologies: Properties

	random	scale-free	modular	hierarchical
Degree distribution function?	$K^k e^{-K} / k!$	$\sim k^{-\gamma}$	$f_m(k)$	$f_h(f_m(k), k^{-\gamma})$
Modularity?	low	low	very high	high
Small-world?	yes	yes	need not	yes
Growth mechanism?	random	preferential	tight module	cloning

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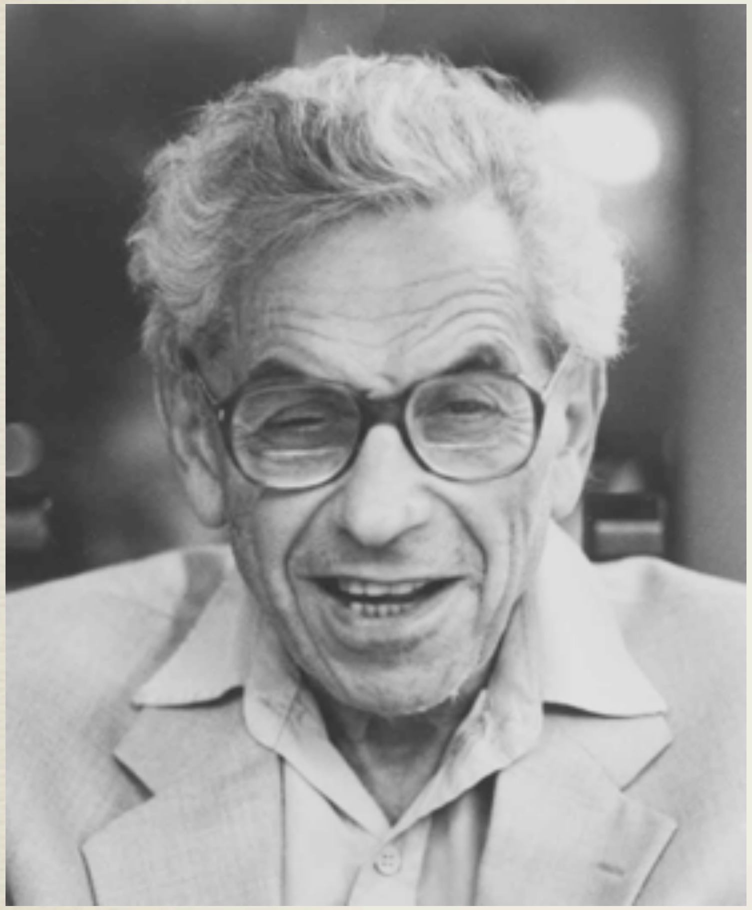
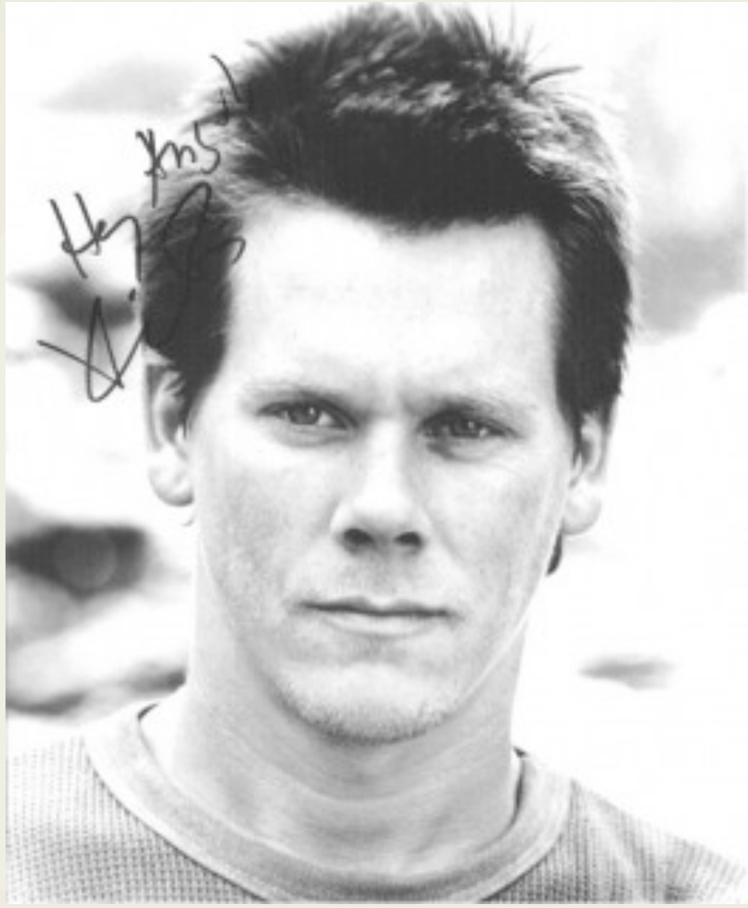
A Network Property: Small World



Paul Erdős
1913-1996

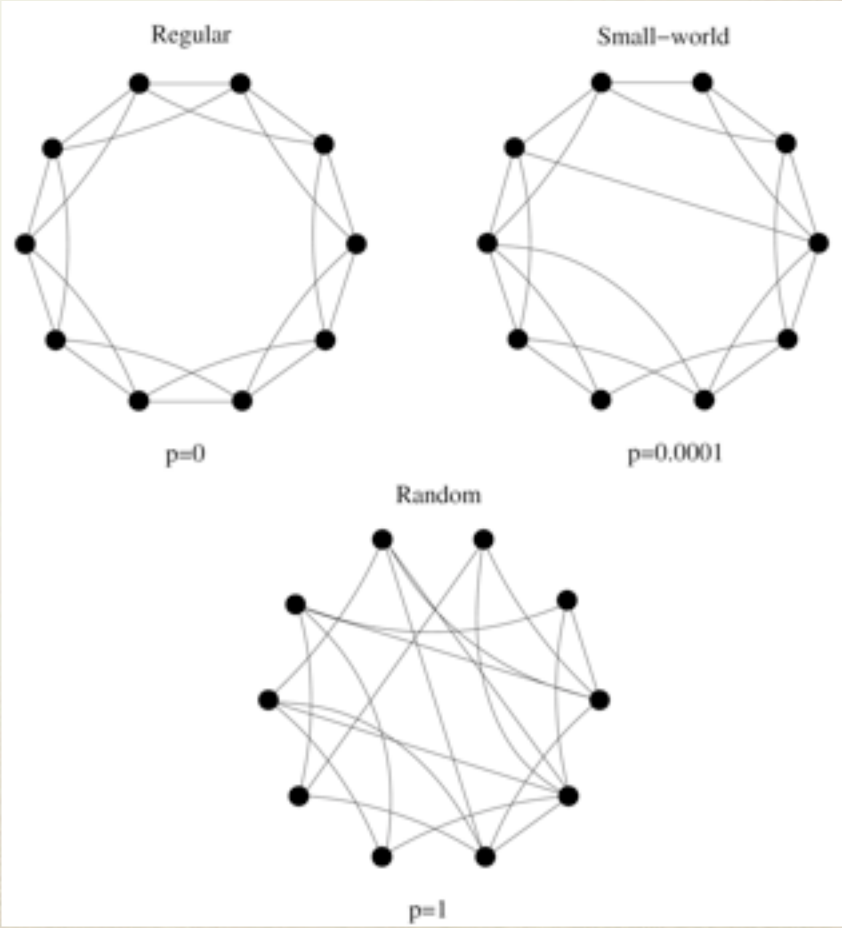
1475 articles
511 collaborators



Kevin Bacon
b. 1958

Animal House, Footloose, Flatliners, A Few Good Men, Apollo 13, Mystic River, The Woodsman, Friday the 13th, Hollow Man, and Tremors

Erdős-Bacon numbers?



Network Topologies: Types

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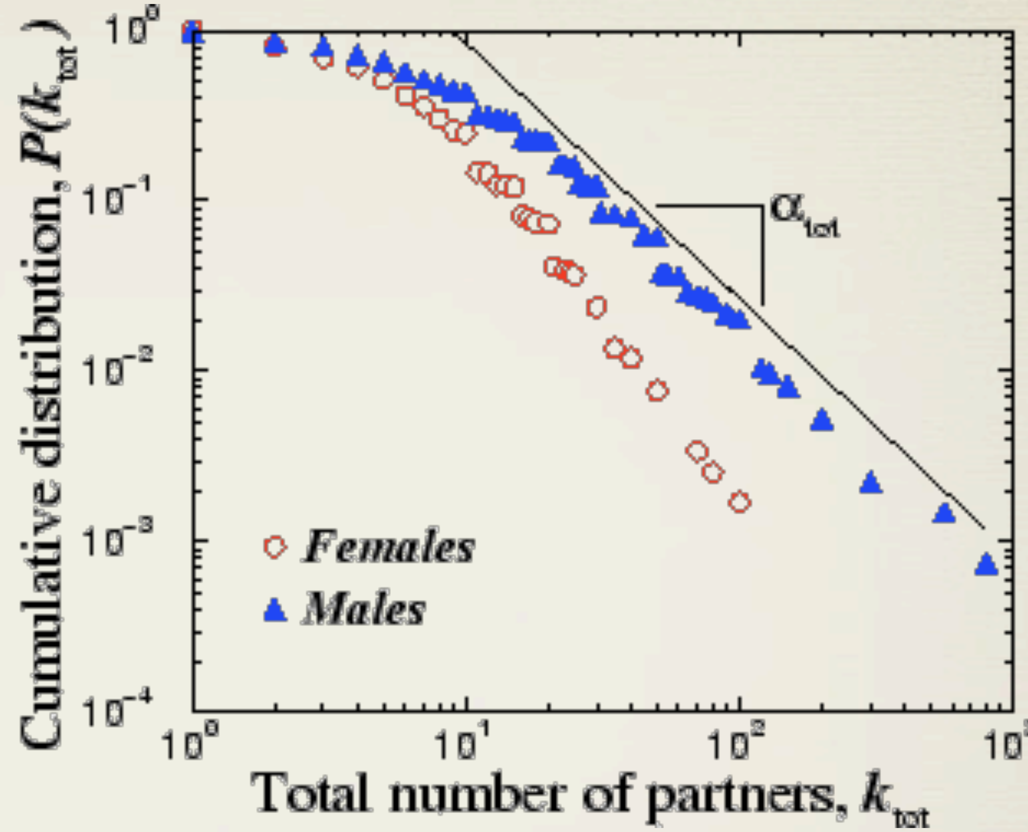
Swedish Sex-Web: A Scale-Free Network

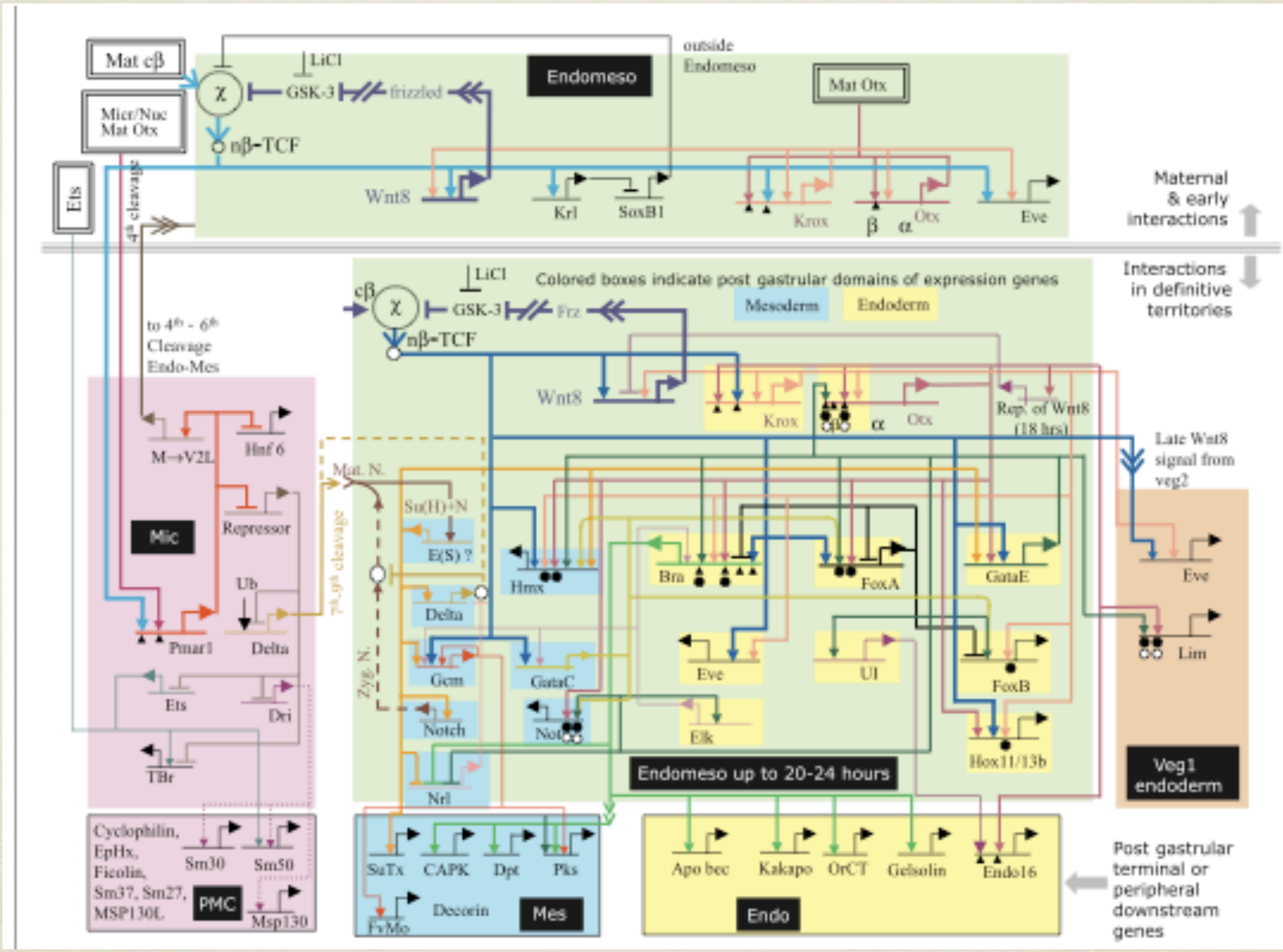


Nodes: people
Links: sexual relationships

4781 Swedes, 18-74 yoa
59% response rate
Lijeros et al. *Nature* 2001

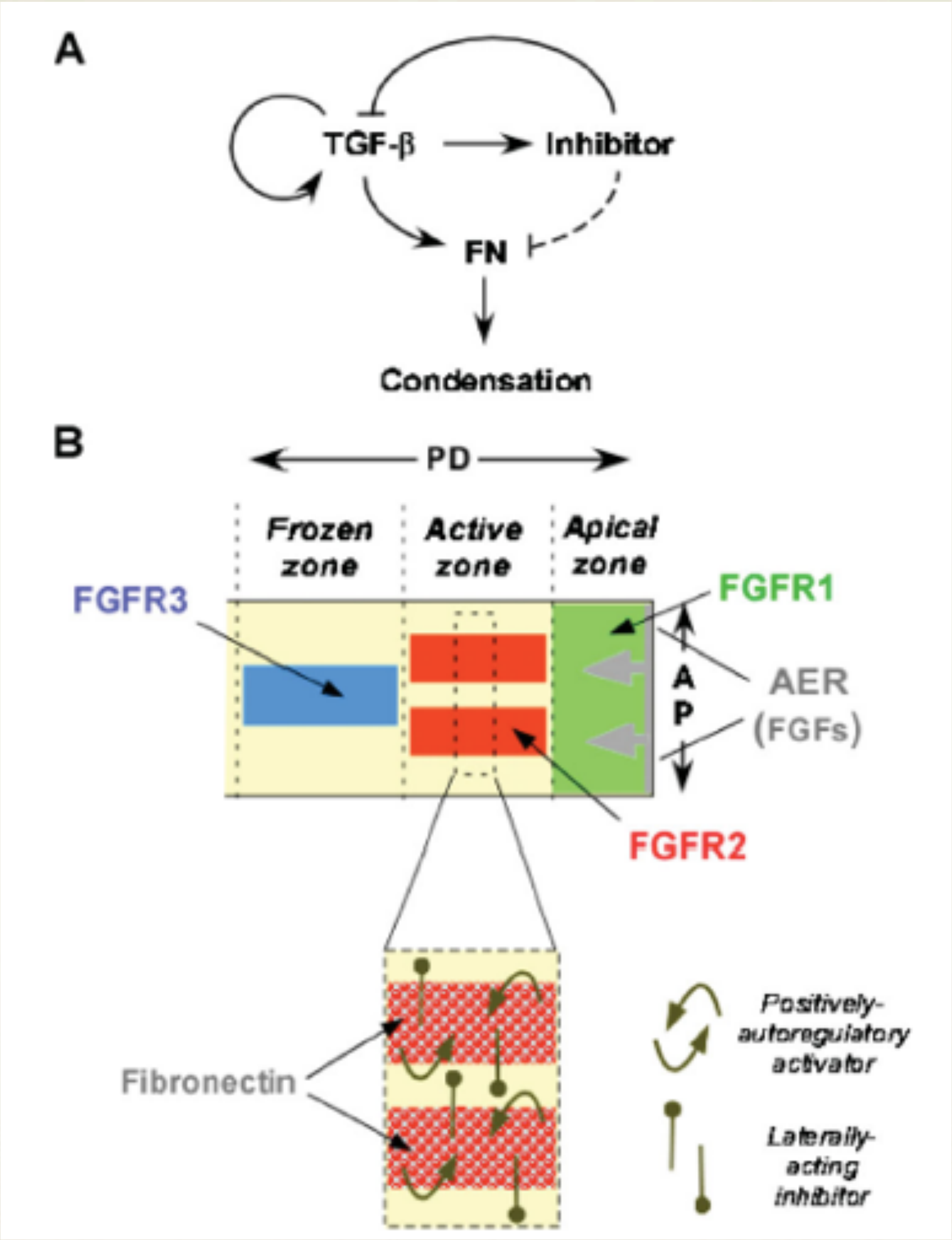
3. *BIOLOGICAL NETWORKS*: THE FUNCTION OF DYNAMICS

Gene Networks



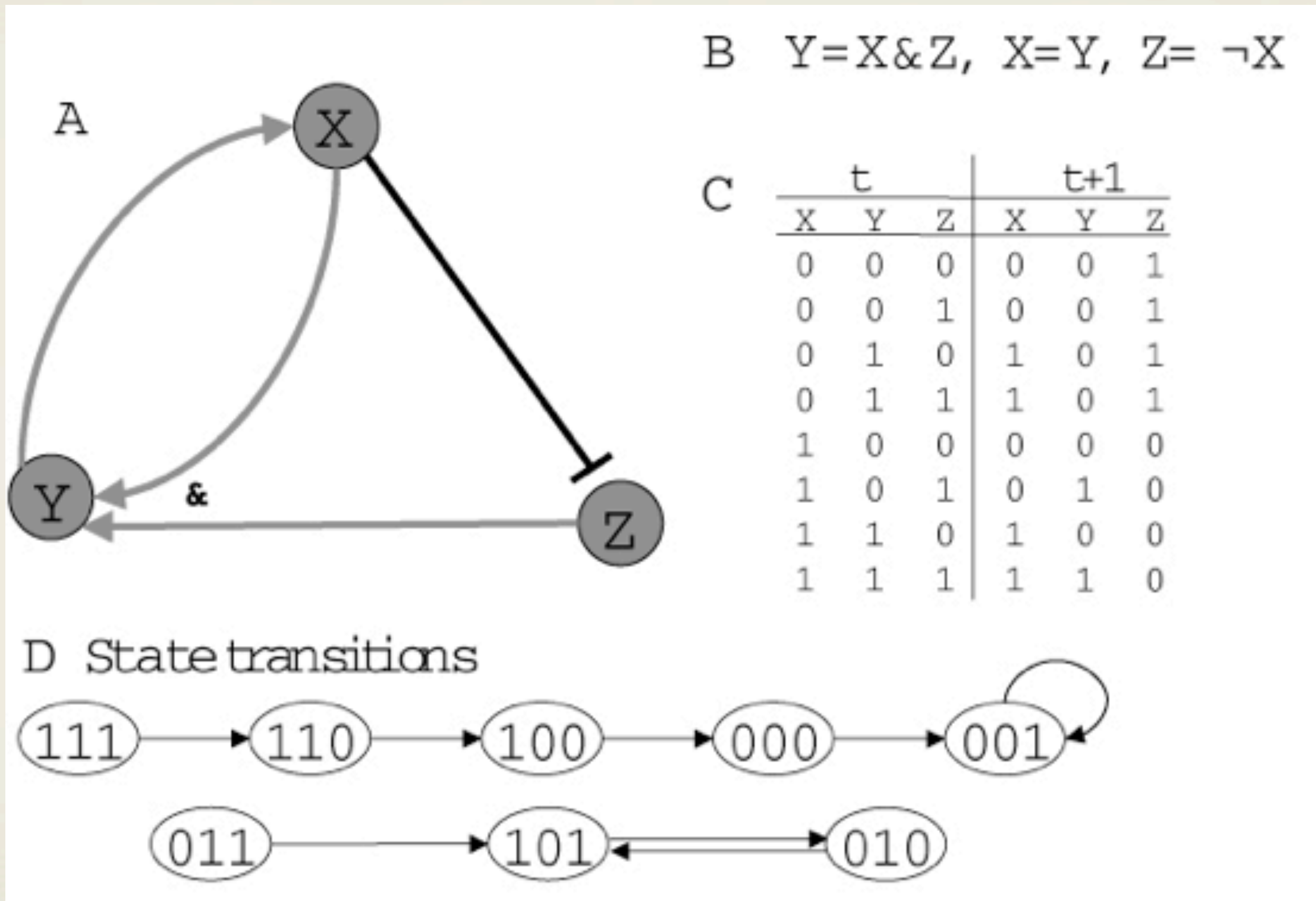
We must understand the biology of the system!

Pattern(ing) Networks



Winther 2009, “Part-Whole Science”

Gene Network Modeling: Boolean Logic



Example for a small Boolean network consisting of 3 genes X, Y, Z. There are different ways for representing the network: A as a graph, B Boolean rules for state transitions, C a complete table of all possible states before and after transition, or D as a graph representing the state transitions. Reproduced from [2].

Schlitt and Brazma *BMC Bioinformatics* 2007 **8**(Suppl 6):S9 doi:10.1186/1471-2105-8-S6-S9

Gene Network Modeling: Differential Equations

$$\frac{dx_i}{dt} = f_i(\boldsymbol{x}), \quad 1 \le i \le n,$$

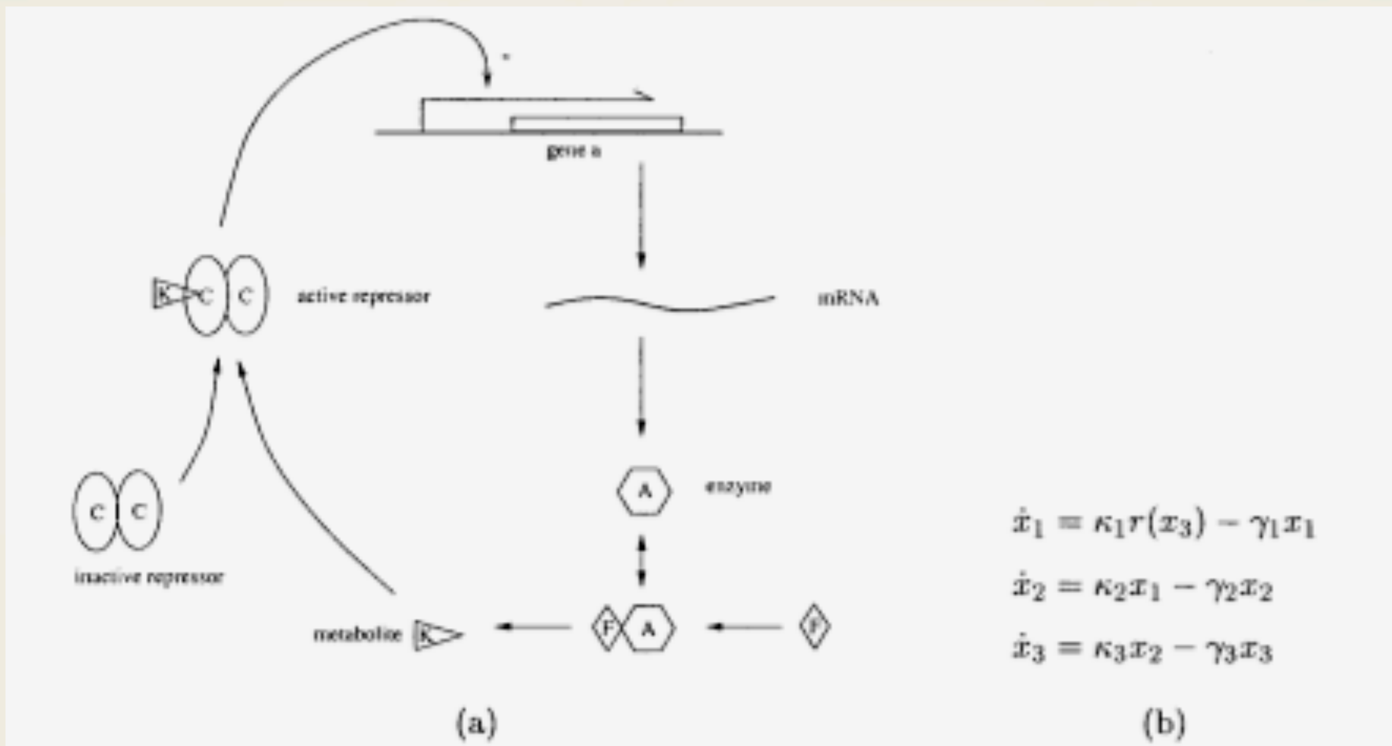
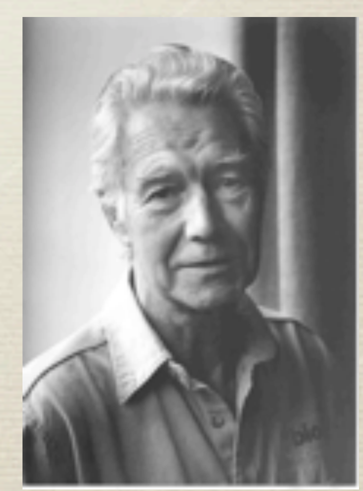


FIG. 7. **(a)** Example of a genetic regulatory system involving end-product inhibition and **(b)** its ODE model (adapted from Goodwin [1963, 1965]). A is an enzyme and C a repressor protein, while K and F are metabolites; x_1, x_2, and x_3 represent the concentrations of mRNA a, protein A, and metabolite K, respectively; $\kappa_1, \kappa_2, \kappa_3$ are production constants, $\gamma_1, \gamma_2, \gamma_3$ degradation constants, and $r : \mathbb{R} \rightarrow \mathbb{R}$ a decreasing, nonlinear regulation function ranging from 0 to 1.

de Jong 2002

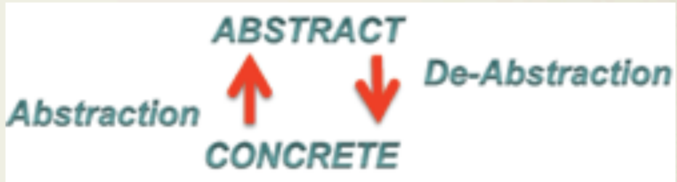


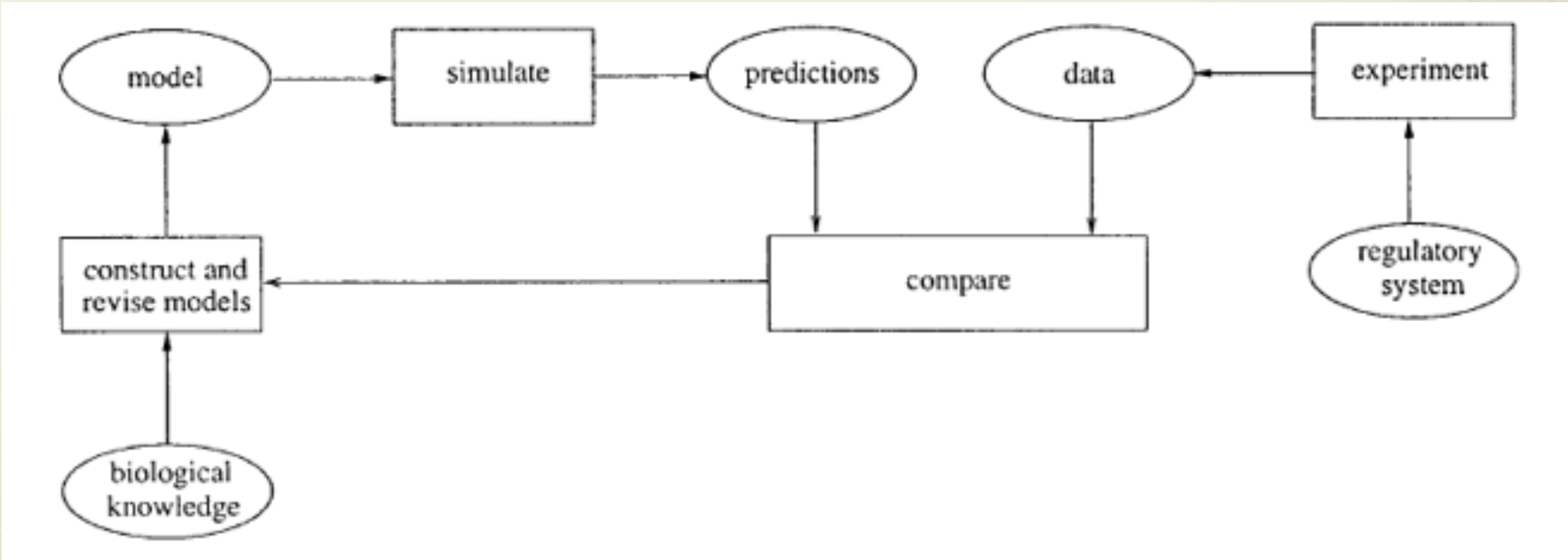
Winther 2009, "Schaffner's Model of Theory Reduction: Critique and Reconstruction"

Assumptions and Reification

	Boolean Networks	ODEs
single-gene causation	binary	continuous
multiple gene causality?	simultaneous	distributed
thresholds?	with difficulty	yes

"In any case in which the Guide and reality are at odds, it is reality that is wrong" (Adams)





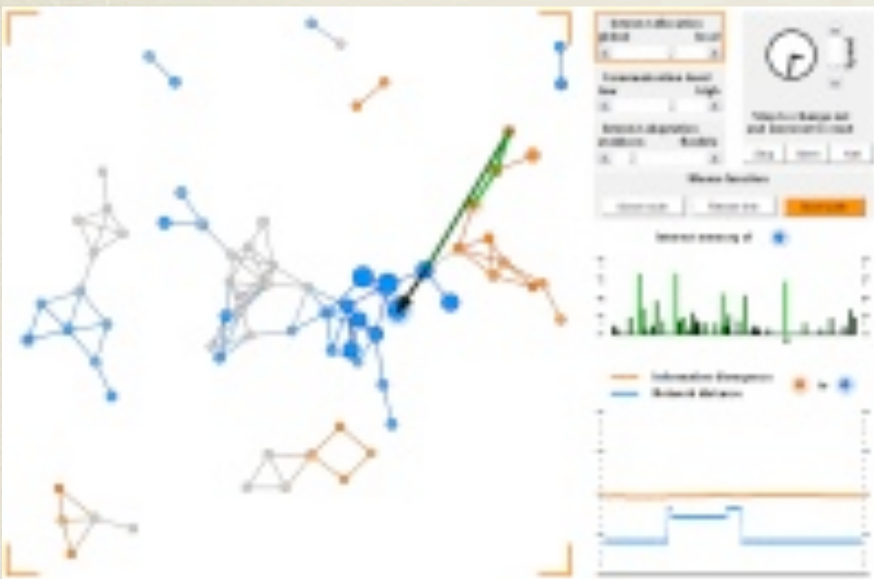
de Jong 2002

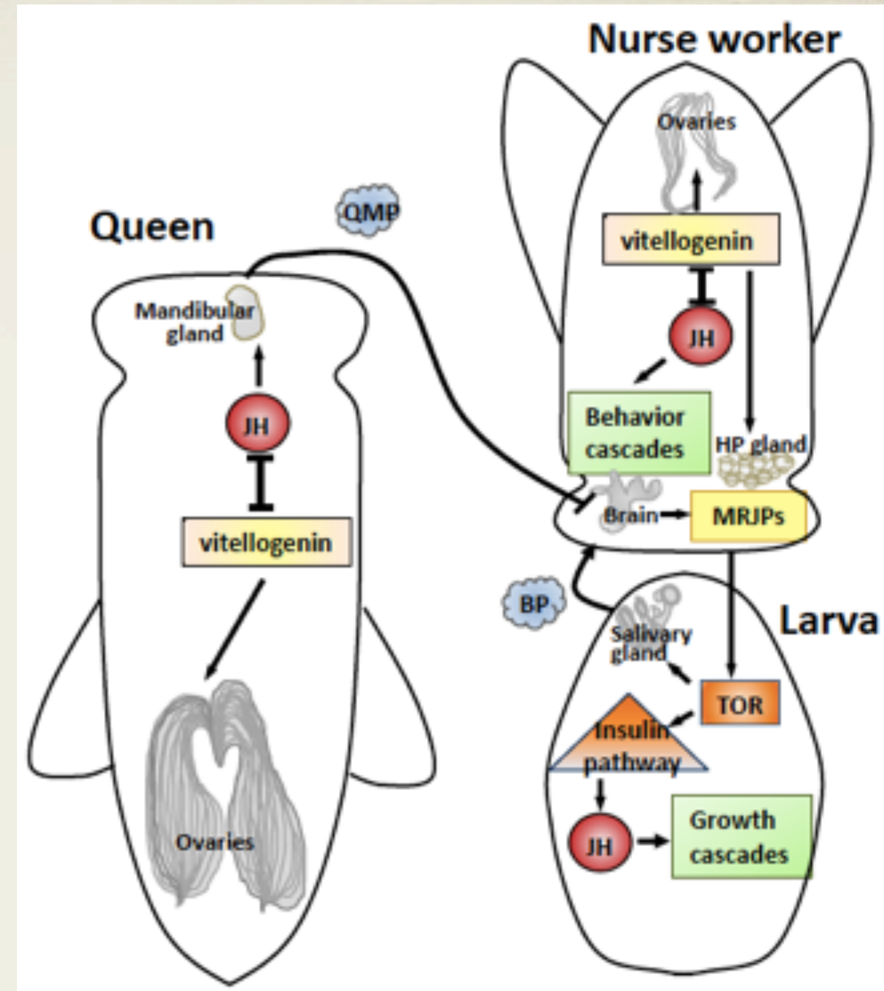
4. *PHILOSOPHY OF SCIENCE*: CONFLICT OR SYNTHESIS OF PERSPECTIVES?

Conflict or Synthesis?

- Perspective? 
  - topology or dynamics?
  - evolution or synchronic?
  - Boolean logic or ODE?
- (risks of) reification, narrowness, and imperialism
- How to synthesize? Division of theoretical labor: hedgehog vs. fox.

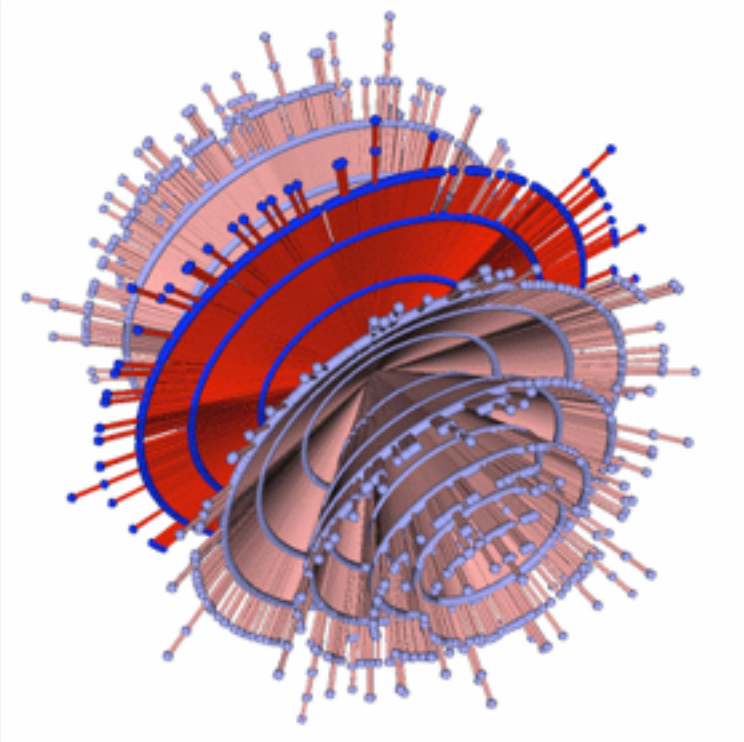
The Proof is in the Pudding





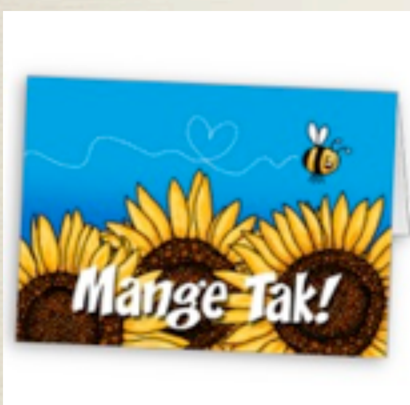
http://cmol.nbi.dk/javaapp.php

an ethics of connectivity?



- networks emphasize:
  - connection and flow of information/matter
  - competition/cooperation shifting balance
  - change and vulnerability of control
- revising metaphors
- ethics of interaction, responsibility, attention...

Acknowledgements



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- ✓ Amir Najmi
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- ✓ Kim Sneppen
- ✓ Michael Wade
- ✓ Günter Wagner