Complex Social Systems:
a guided exploration to concepts and methods

The potential contributions of complexity science to development

Martin Hilbert (Dr.; Ph.D.)
MartinHilbert[at]gmail.com

Historical context of Complexity

Weaver W. **Science and Complexity**. *American Scientist*. 1948;36:536–544.

1. Problems of simplicity:

"*…science before 1900 was largely concerned with **two-variable problems***"
temperature & pressure; population & time; production & trade, etc.

2. Problems of disorganized complexity:

"*…subsequent to 1900… scientists… developed powerful techniques of **probability theory** and of **statistical mechanics** … each of the many variables has a behavior which is individually erratic.*"
billiard balls & air molecules; normal distributions; etc.

"regression" and "science of averages" requires assumptions

3. Problems of organized complexity:

"*…dealing simultaneously with a sizable number of factors which are **interrelated** into an organic whole… **cannot be handled with the statistical techniques so effective in describing average behavior**… "*

Science must, over the next 50 years, learn to deal with these problems of organized complexity"
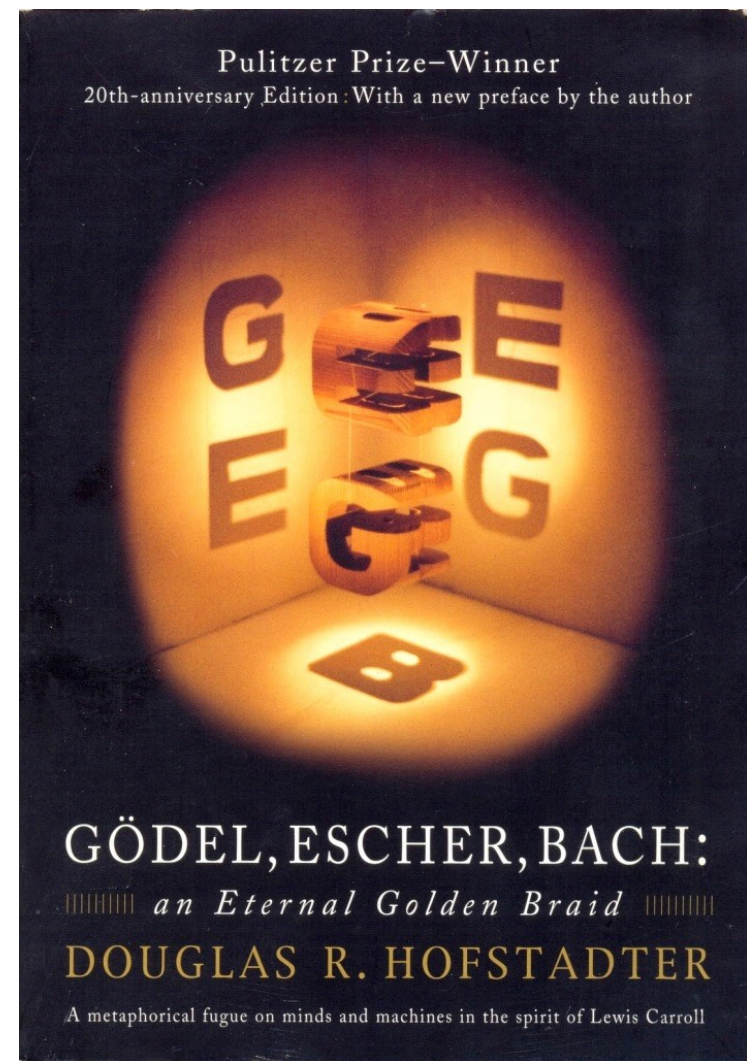
…said Weaver over 65 years ago…

"On what does the price of wheat depend?"

"How can one explain the behavior pattern of an organized group of persons?"

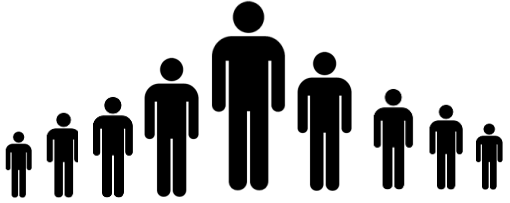"economic control… to prevent the wide swings from prosperity to depression?"

"selfish interest… contribute to a stable, decent and peaceful world?"

Examples of Complex systems 1

Pulitzer Prize–Winner
20th-anniversary Edition: With a new preface by the author

GÖDEL, ESCHER, BACH:
an Eternal Golden Braid
DOUGLAS R. HOFSTADTER
A metaphorical fugue on minds and machines in the spirit of Lewis Carroll

Anteater: *"…all the ants in Aunt Hillary are as dumb as can be… there are teams on higher levels whose members are not ants, but teams on lower levels… all these layers of structure are necessary for the storage of the kinds of knowledge which enable an organism to be 'intelligent' in any reasonable sense of the word… the thoughts in Aunt Hillary emerge from the manipulation of symbols composed of signals composed of teams composed of lower-level teams, all the way down to ants…"* (pp. 311-336)
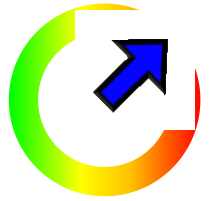
Examples of Complex systems 2

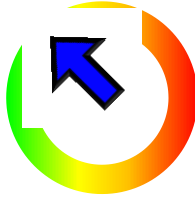...i.i.d.?   ...or:

Summary of _characteristics_ and (selected)
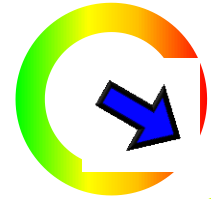
analytical _tools_ of Complex Systems
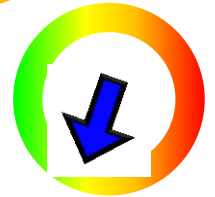
➢ **Connected**: social network analysis
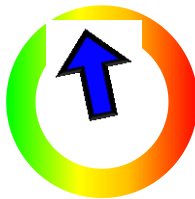
➢ **Interdependent**: dancing landscapes

➢ **Diverse**: entropy and differences

➢ **Adaptive**: information processing

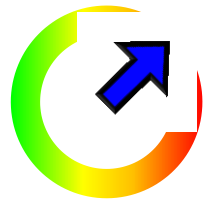➢ **Path-dependent**: dynamics & chaos

➢ **Emergent**: agent-based models

"...the interesting in-between...!"

Summary of _characteristics_ and (selected)

analytical _tools_ of Complex Systems

➢ **Connected:** social network analysis

➢ Interdependent: dancing landscapes

➢ Diverse: entropy and differences

➢ Adaptive: information processing

➢ Path-dependent: dynamics & chaos

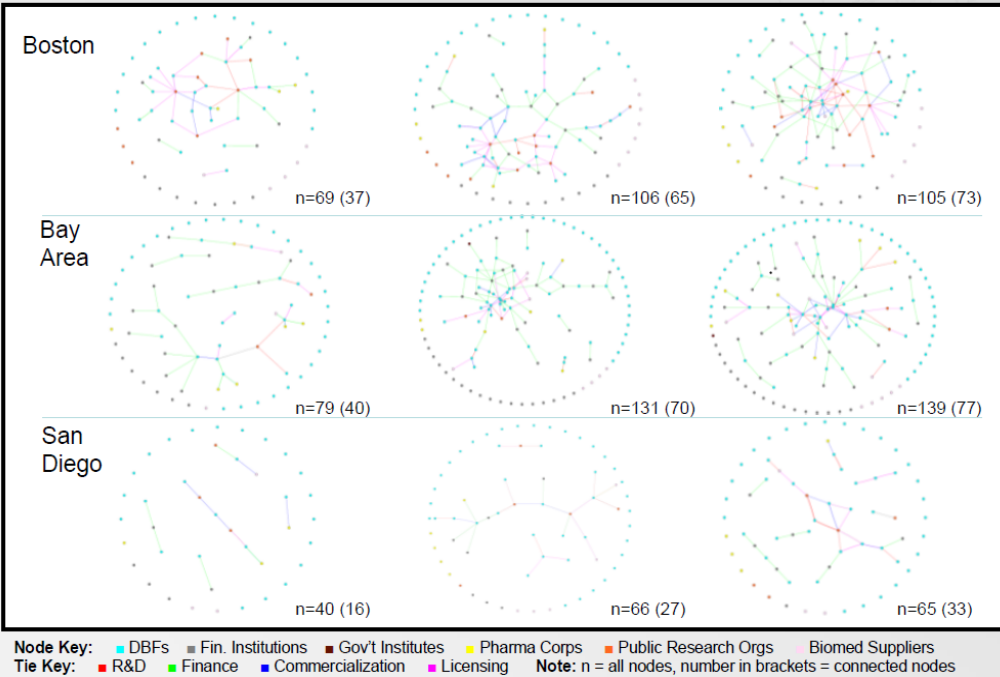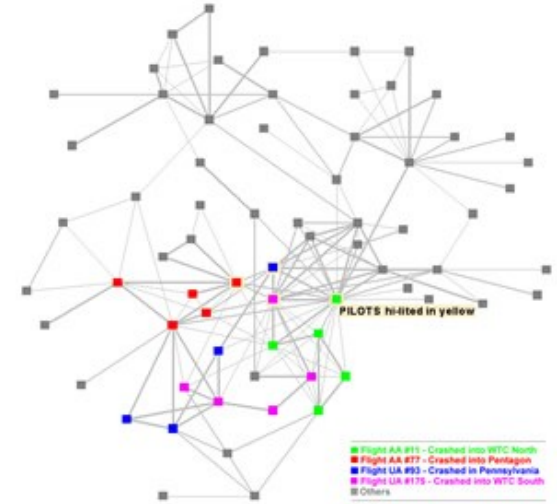➢ **Emergent:** agent-based models

" ...the interesting in-between...!"

Innovation & Industry

Social = network

Boston, Bay Area and San Diego, 1990, 1996, and 2002

Boston: n=69 (37), n=106 (65), n=105 (73)
Bay Area: n=79 (40), n=131 (70), n=139 (77)
San Diego: n=40 (16), n=66 (27), n=65 (33)

Node Key: ■ DBFs ■ Fin. Institutions ■ Gov't Institutes ■ Pharma Corps ■ Public Research Orgs ■ Biomed Suppliers
Tie Key: ■ R&D ■ Finance ■ Commercialization ■ Licensing Note: n = all nodes, number in brackets = connected nodes

9/11 Terrorist Network

Friendship by race

Food Network

Food Web in a Forest

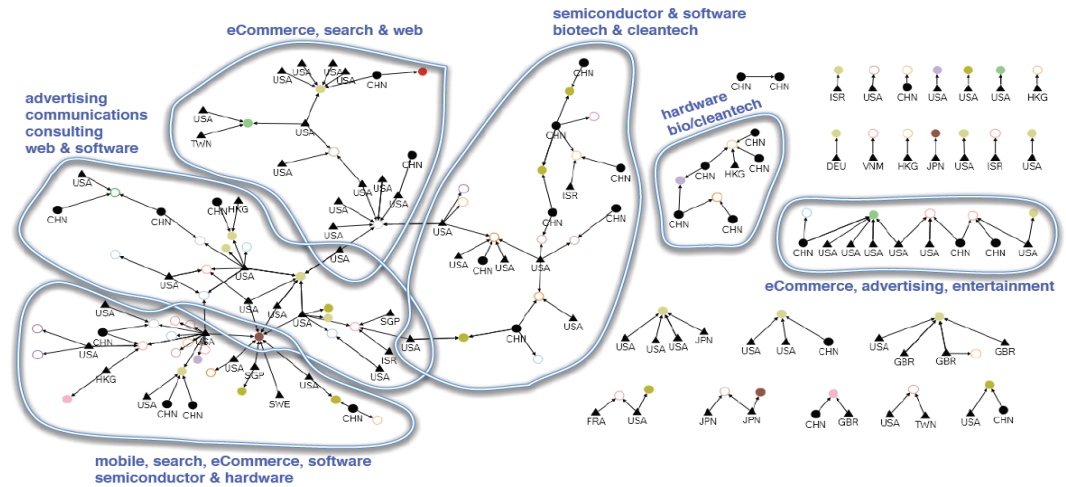Source: http://www.visualcomplexity.com/vc/; Powell et.al. (2010);
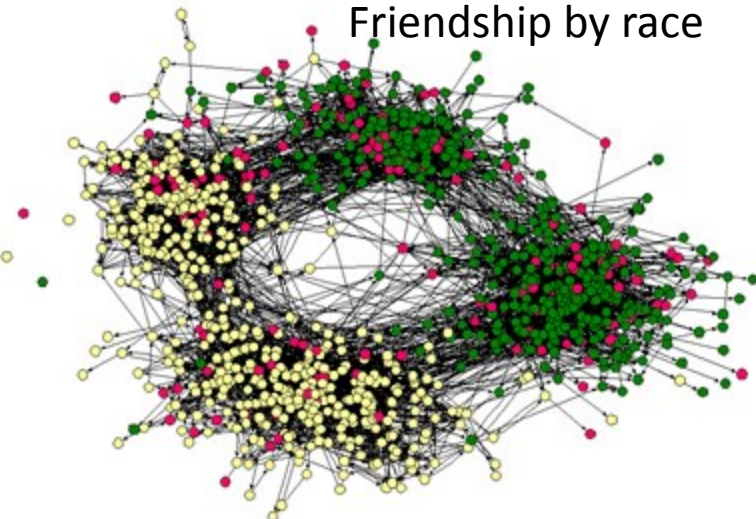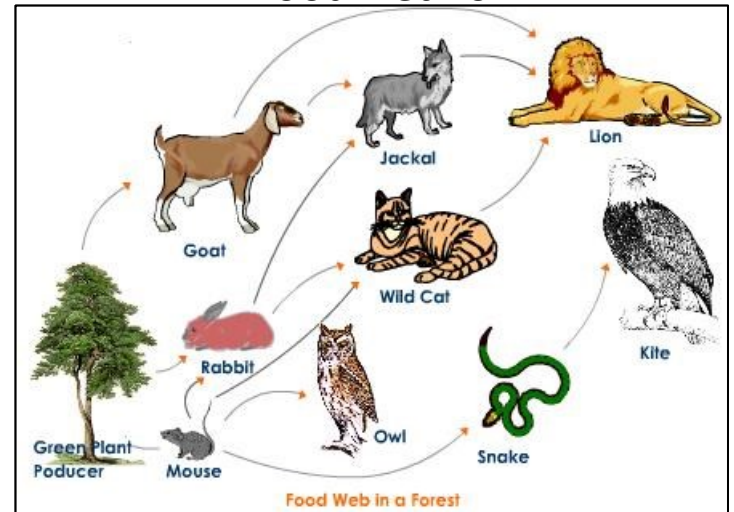
Political integration and cooperation
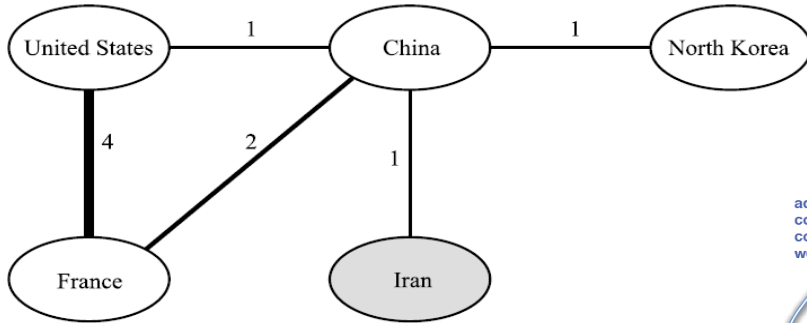
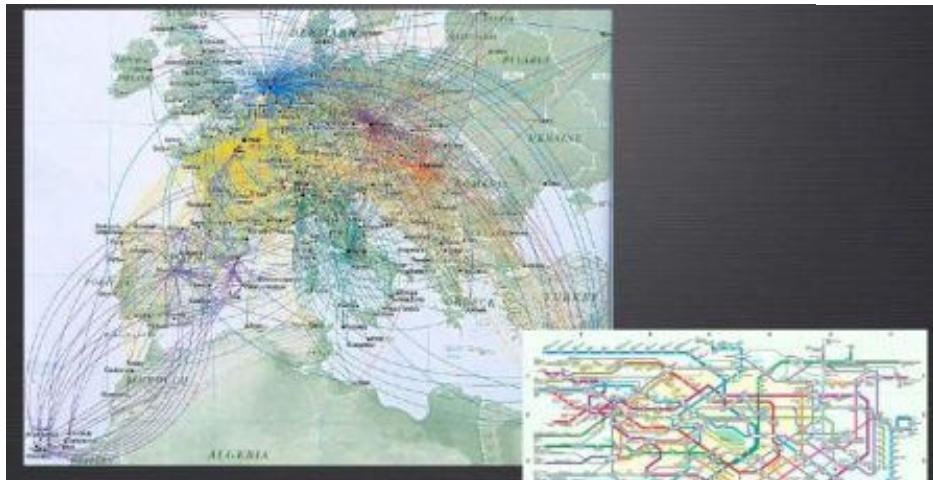# Social = network

Investments
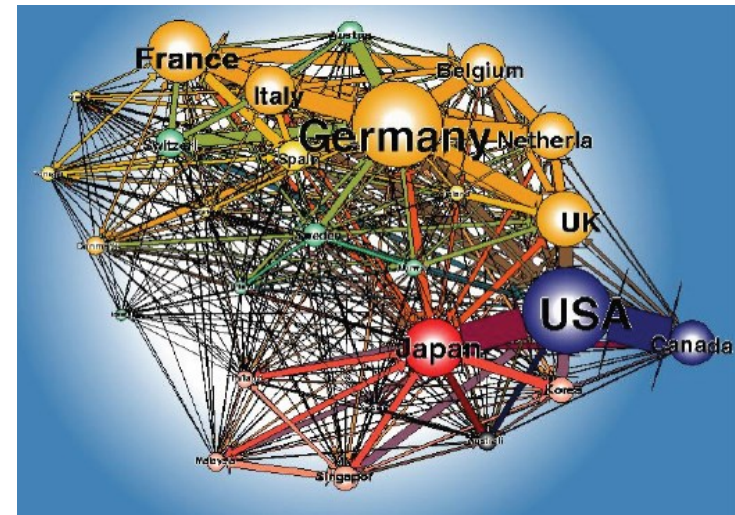

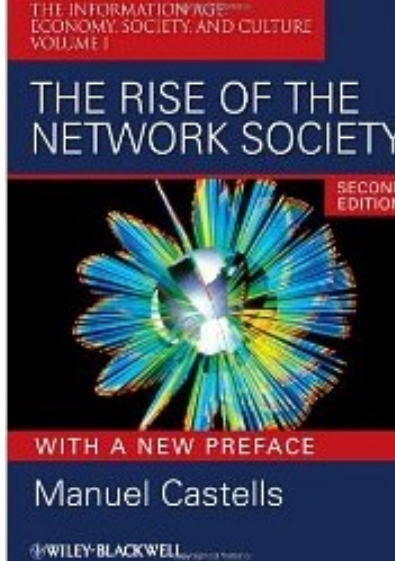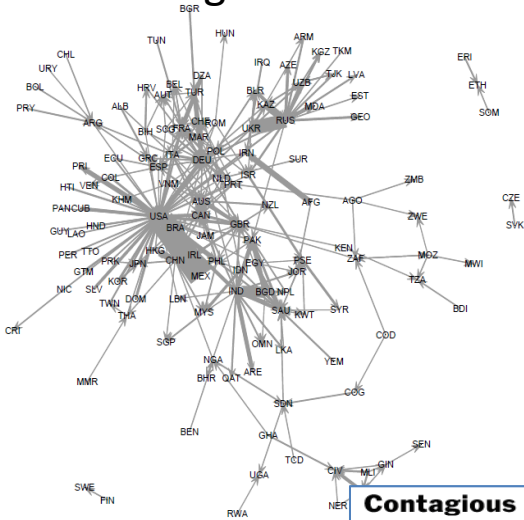Figure 10. Emerging Chinese business clusters linked by investment firms as resource routers.

Transport

International trade

Sources: Hafter-Burton, et.al. (2009), Maoz, et.al. (2003); Serdült y Hirschi; ASNA 2011;

Social = network

Migration

Sustainable Development

THE RISE OF THE NETWORK SOCIETY

Manuel Castells
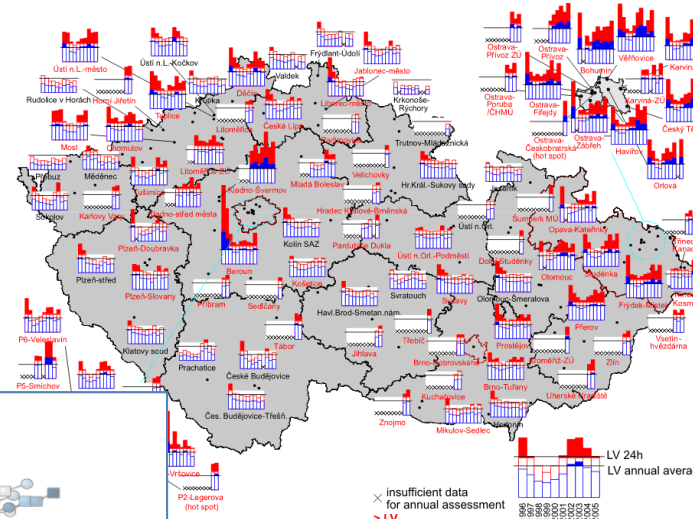
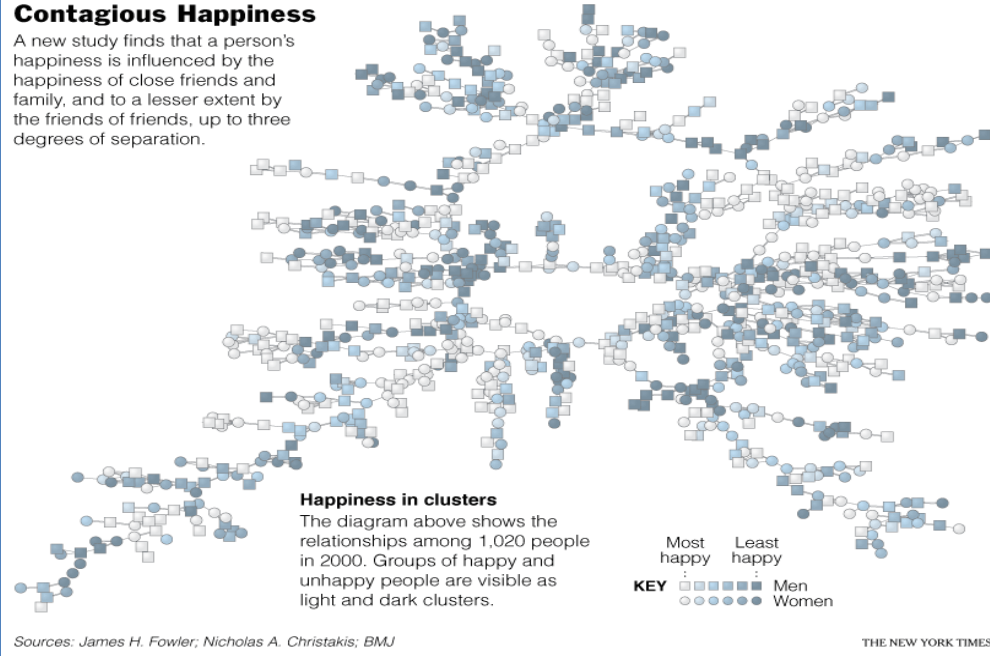Business and

Contagious Happiness
A new study finds that a person's happiness is influenced by the happiness of close friends and family, and to a lesser extent by the friends of friends, up to three degrees of separation.
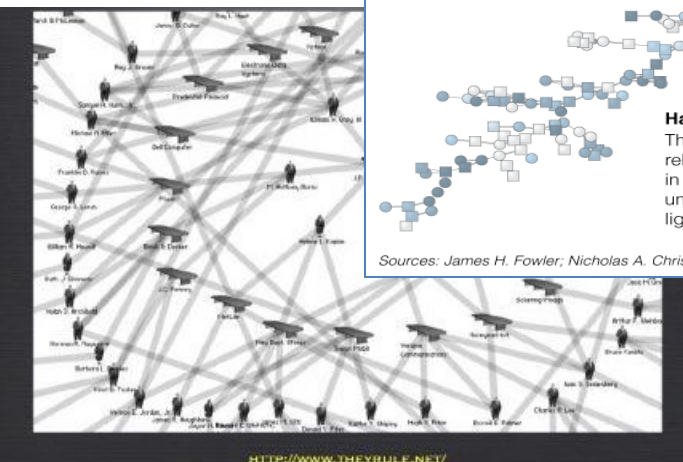
Happiness in clusters
The diagram above shows the relationships among 1,020 people in 2000. Groups of happy and unhappy people are visible as light and dark clusters.

Most happy   Least happy
KEY   ■ Men   ○ Women
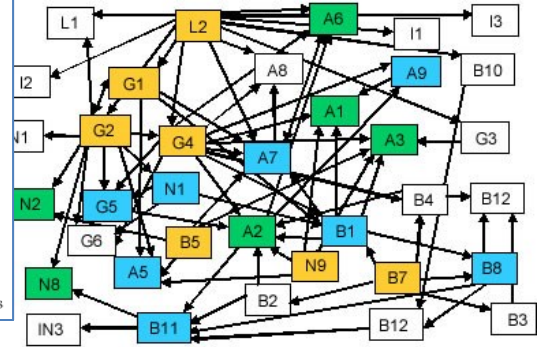
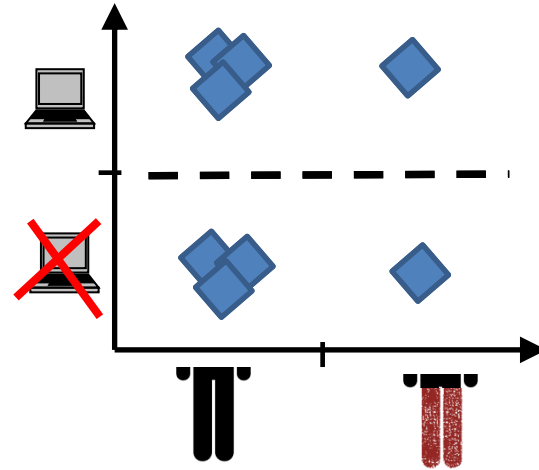Sources: James H. Fowler; Nicholas A. Christakis; BMJ

THE NEW YORK TIMES

Democratic governance

We provide financial support to them
We receive financial support from them
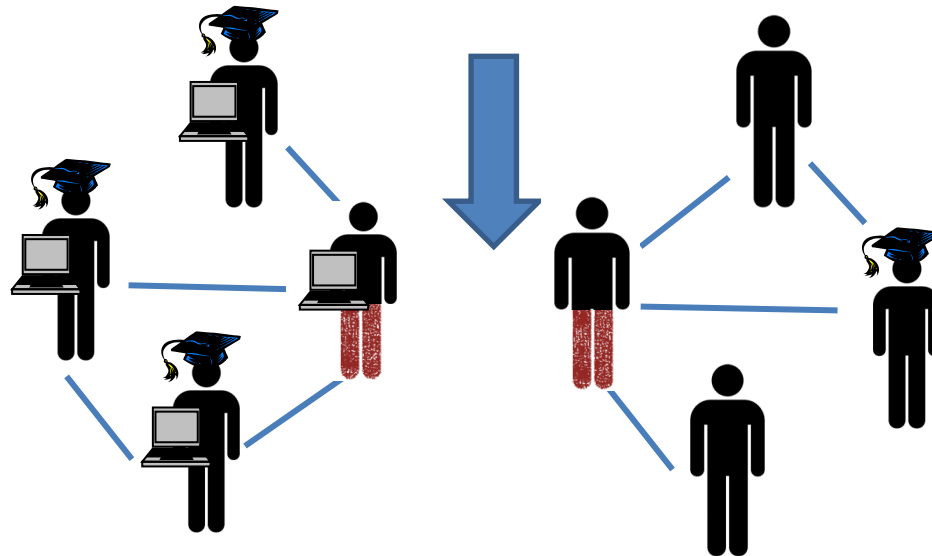We provide and receive financial support

Social Networks

Because society is as much about WHO your are, as WITH WHOM you are
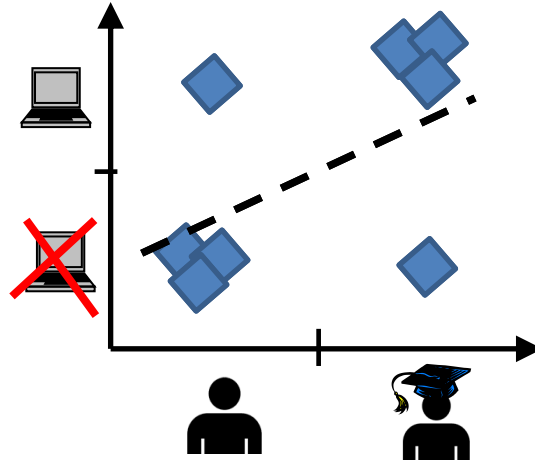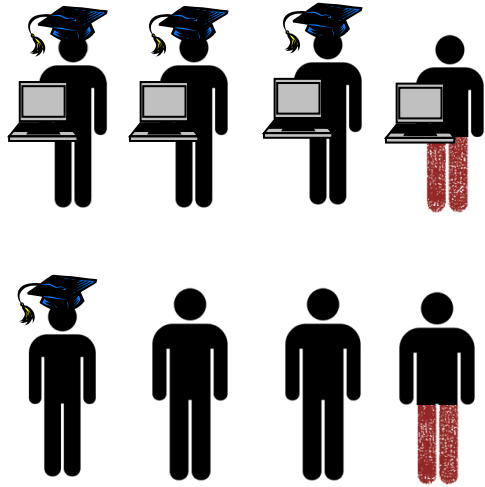
=> Policy on education!

...certainly not on red pants...

=> Policy on agents of change!

...the ones with the red pants...!

It'll hit some of us first!

...homophily can confound underlying network mechanism...

What is needed?

Traditional database of attributes

	Gender	Location	Income	Educat.	...
Jorge	M	Urban	700	Tertiary	...
Maria	F	Urban	500	Second.	...
Juan	M	Rural	300	Primary	...
Magda	F	Rural	200	---	...
...	...	...	...	...	...

Network database of links

	Jorge	Maria	Juan	Magda	...
Jorge	Self	↱	---	↱	...
Maria	↱	Self	---	↱	...
Juan	---	---	Self	---	...
Magda	---	↱	↱	Self	...
...	...	...	...	...	...

Social Emergence

Adam Smith (1723 – 1790)
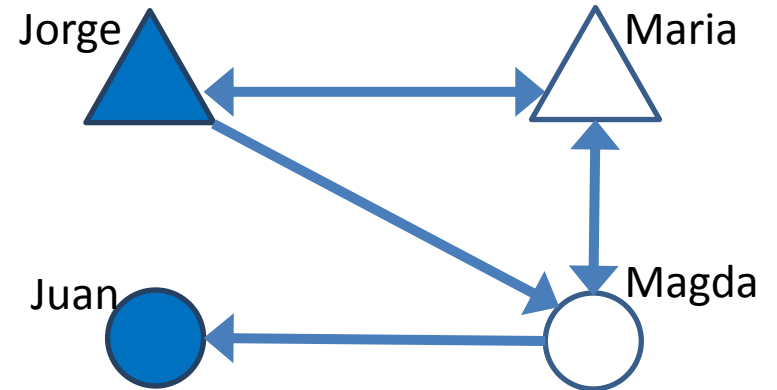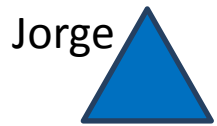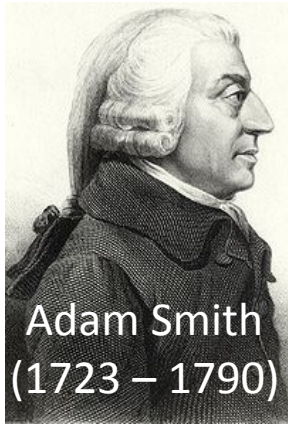
*"…he intends only his own gain, and he is in this, as in many other cases, led by an **invisible hand** to promote an end which was no part of his intention… By pursuing his own interest he frequently promotes that of the society more effectually than when he really intends to promote it…"*
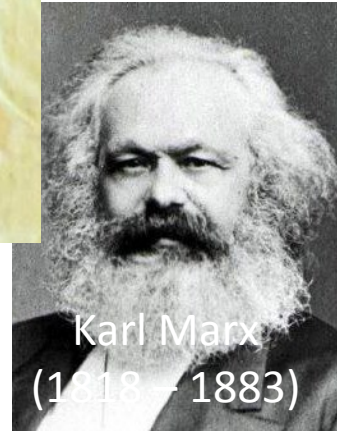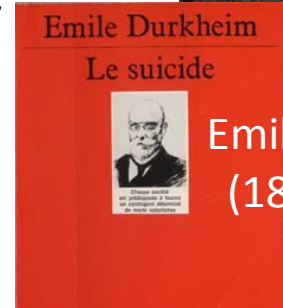
*"Therefore there is not one of all the single centers of consciousness who make up the great body of the nation, to whom the **collective current** is not almost wholly exterior, since **each contains only a spark** of it…"*

Emile Durkheim (1858 – 1917)

Karl Marx (1818 – 1883)

*"…merely **quantitative differences** beyond a certain point pass into **qualitative changes**"*
(+ Hegel and Engels =>
"basic metaphysical principle of Dialectics"!

Self-organization

Σ [***volonté particuliére***] =

= [***volonté de tous***] $\neq$

$\neq$ [***volonté générale***]

Jean-J. Rousseau (1712 –1778)

Schelling's segregation model
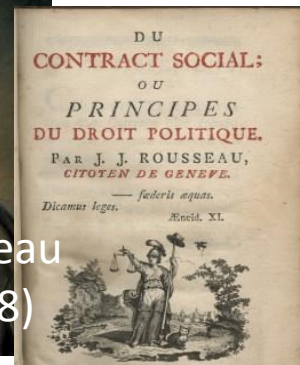

2400 agents:
- ➤ 50 %
- ➤ 26 % & 25 % => ?
- ➤ 75 % & 76 % => ?

http://www.plataformaurbana.cl ; http://globedia.com Wilensky, U. (1997). NetLogo Segregation model. http://ccl.northwestern.edu/netlogo/models/Segregation. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Schelling's segregation model

Empirical data from Los Angeles, Milwaukee, Cincinnati, Omaha, & Kansas City show *"that the Schelling description of preferences is broadly correct but that the empirical curves are less regular than those posited by Schelling…"*
Clark (1991). Residential Preferences and Neighborhood Racial Segregation: A Test of the Schelling Segregation Model. *Demography*, *28*(1), p.17

Tolerance

Mixed Society

Separation / / Polarization

Extremism

GRUPO SOCIOECONÓMICO PREDOMII

GRUPOS SOCIOECONÓMICOS

SIN INFORMACIÓN   PREDOMINANTE C2
PREDOMINANTE E   PREDOMINANTE ABC1
PREDOMINANTE D   ÁREA URBANA
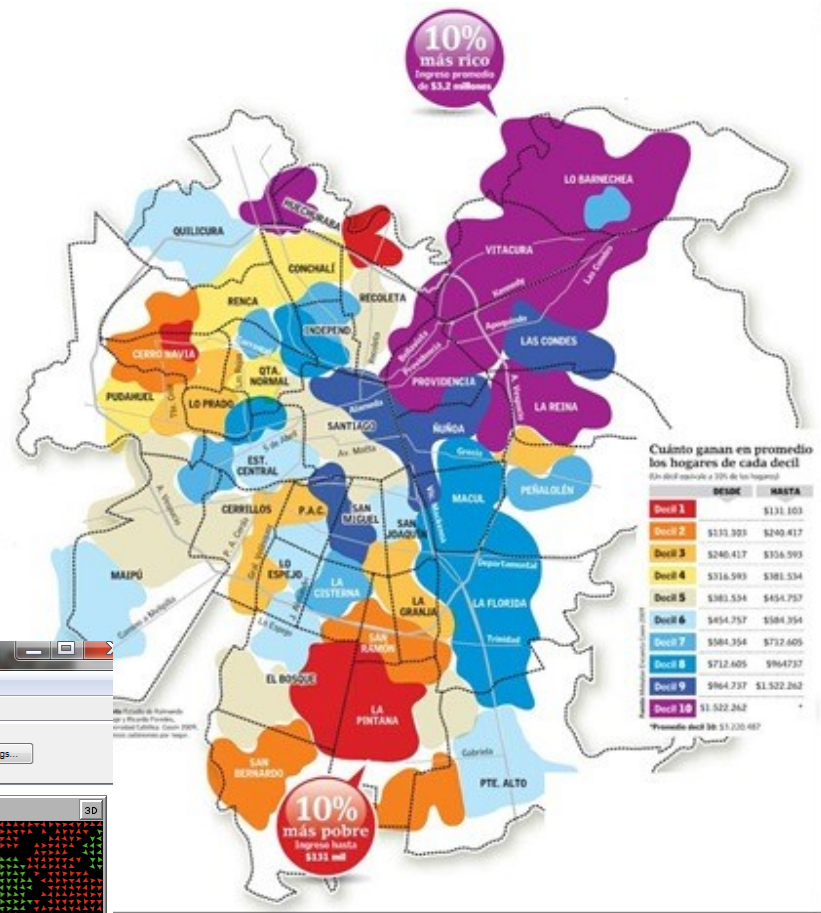PREDOMINANTE C3

FUENTE: ELABORACIÓN PROPIA OCUC EN BASE A SIDICO SEREMI MINVU

setup   go

%-similar-wanted   60 %

Percent Similar
100

%

0
0   time   36.3

% similar
96.7

Percent Unhappy
100

%

0
0   time   36.3

% unhappy
0

2400 agents:
➢ 50 %
➢ 26 % & 25 % => ?
➢ 75 % & 76 % => ?

➢ Total is different than sum of parts
(total racists lead to mixed society…)
➢ Phase transitions
➢ Dependence on initial conditions
➢ Invariant Distribution

http://www.plataformaurbana.cl ; http://globedia.com Wilensky, U. (1997). NetLogo Segregation model. http://ccl.northwestern.edu/netlogo/models/Segregation. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Alternative Approaches

DYNAMIC MODELS OF SEGREGATION

Fig.8

MICRO**MOTIVES** AND
MACROBEHAVIOR

THOMAS C. SCHELLING
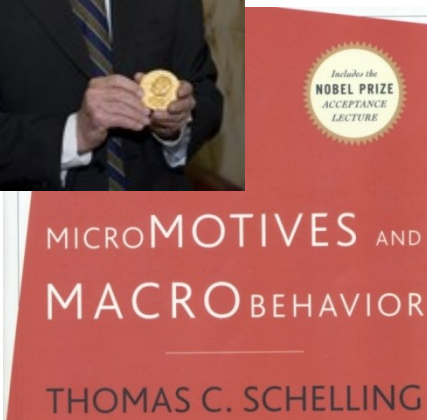
"I cannot too strongly urge you to get the dimes and pennies and do it yourself… there is nothing like tracing it through for yourself and seeing the thing work itself out. In an 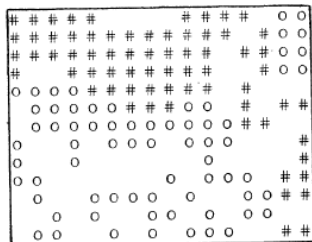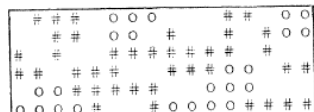hour you can do it several times and experiment with different rules of behavior, sizes and shapes of boards, and (if you turn some of the coins heads and some tails) subgroups of dimes and pennies…" (p. 150)
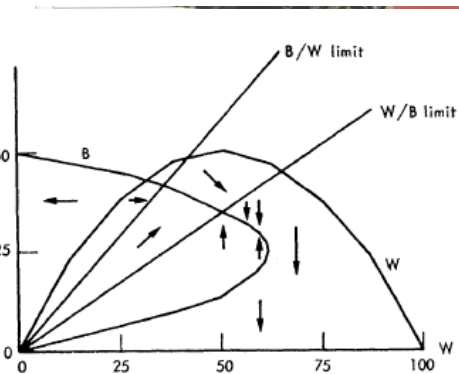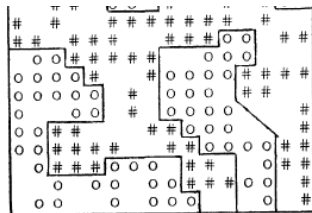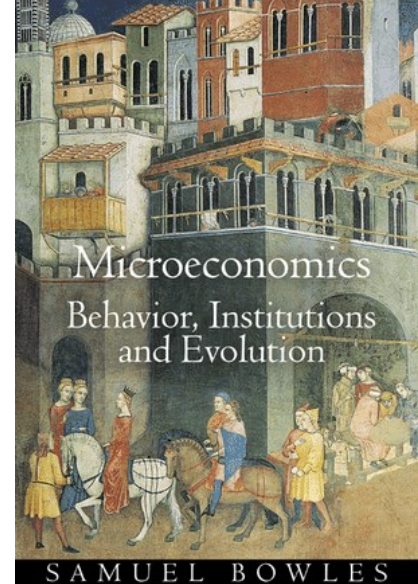
Fig.29

Fig. 10

Schelling, T. C. (1971). Dynamic models of segregation.
The Journal of Mathematical Sociology, *1*(2), 143–186.

Microeconomics
Behavior, Institutions
and Evolution

SAMUEL BOWLES

$$f' = f - \alpha f(1 - f)\rho_b\beta(p_b - p_g) + \alpha(1 - f)f\rho_g\beta (p_g - p_b) \quad (2.2)$$

where $\rho_b = 1$ if $p_b > p_g$ and is zero otherwise, and $\rho_g = 1$ if $p_g \geq p_b$ and is zero otherwise. (Obviously, $\rho_b + \rho_g = 1$.)

term). The second term on the right hand side, for example, is the loss of greens through sales to blues; αf is the number of greens seeking to sell, of these $(1 - f)$ will be matched with a blue, and if the blue's price exceeds the greens' price, the sale will take place with probability $\beta(p_b - p_g)$. The third term may be interpreted analogously, in the case that green prices exceed blue prices, in this case blues selling to greens.

$$\Delta f = f' - f = \alpha f (1 - f)\beta(p_v - p_a) \quad (2.3)$$

$$\Delta p = \omega p \beta(b_x - \underline{b}) \quad (2.6')$$

$$\frac{db_y}{dp} - \frac{db_x}{dp} = \pi(y, x) - \pi(y, y) - \pi(x, x) + \pi(x, y) > 0 \quad (2.8)$$

Rebellion model
Civil violence, genocide, revolution, security...

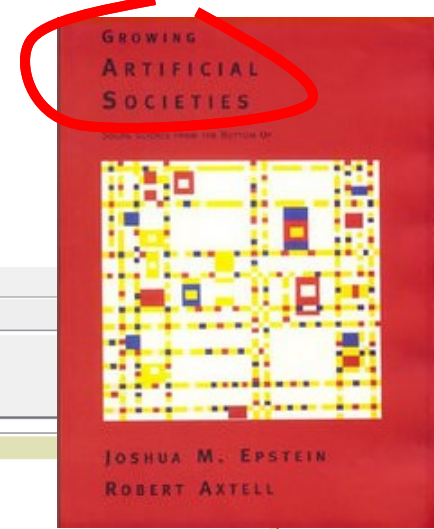http://blogs.tribune.com.pk/story/6702/arab-spring-what-now/

pccua.edu/keough/Wc%202/french_revolution.ht

The population wanders around randomly. If their level of grievance against the central authority is high enough, and their perception of the risks involved is low enough, they openly rebel. A separate population of police officers ("cops"), acting on behalf of the central authority, seeks to suppress the rebellion. The cops wander around randomly and arrest people who are actively rebelling
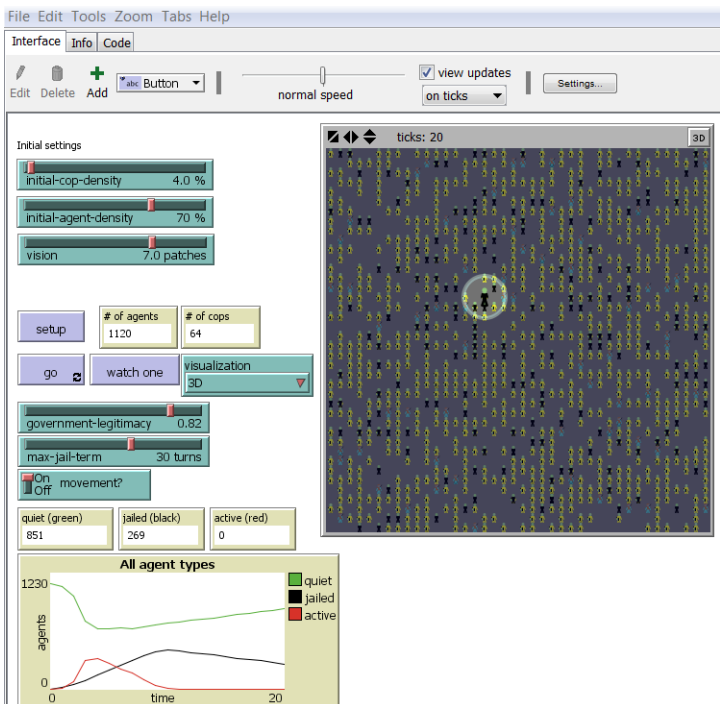
➢ Individuals with different propensity for revolt (red) get jailed when cops are close
   ➢ Individual: hardship & risk aversion & vision & jail-term
   ➢ Global: government legitimacy & cop density
➢ Move government-legitimacy slowly down to 0
➢ Start government-legitimacy at 90 and move suddenly to 55
➢ Double (8%) & triple (12%) number of cops

Joshua M. Epstein, "Modeling **civil violence**: An agent-based computational approach", Proceedings of the National Academy of Sciences, Vol. 99, Suppl. 3, May 14, 2002
Wilensky, U. (2004). NetLogo **Rebellion model**. http://ccl.northwestern.edu/netlogo/models/Rebellion. Center for CL&C-BM, Northwestern University.

…just one of a couple of dozen of **Sugarscapes**

- Fine-tuned capability diversity
- Foresight and planning
- Seasons
- Migration patterns
- Off-springs and inheritance
- Sugar & Spice
- Trade and price
- Lending and interest rates
- Pollution of resource extraction
- Disease
- Cultural belonging
- …

Iain Weaver (2009) The Sugarscape; http://ccl.northwestern.edu/netlogo/models/community/Sugarscape
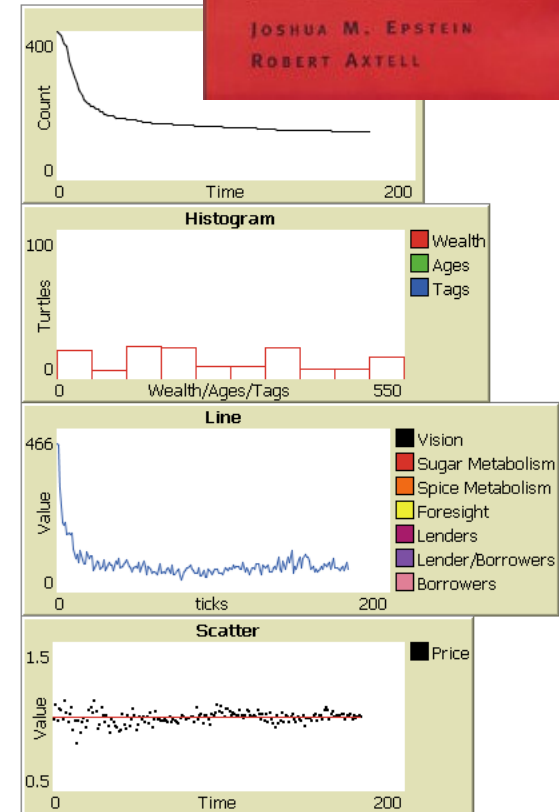
…more realistic / complex models of society:
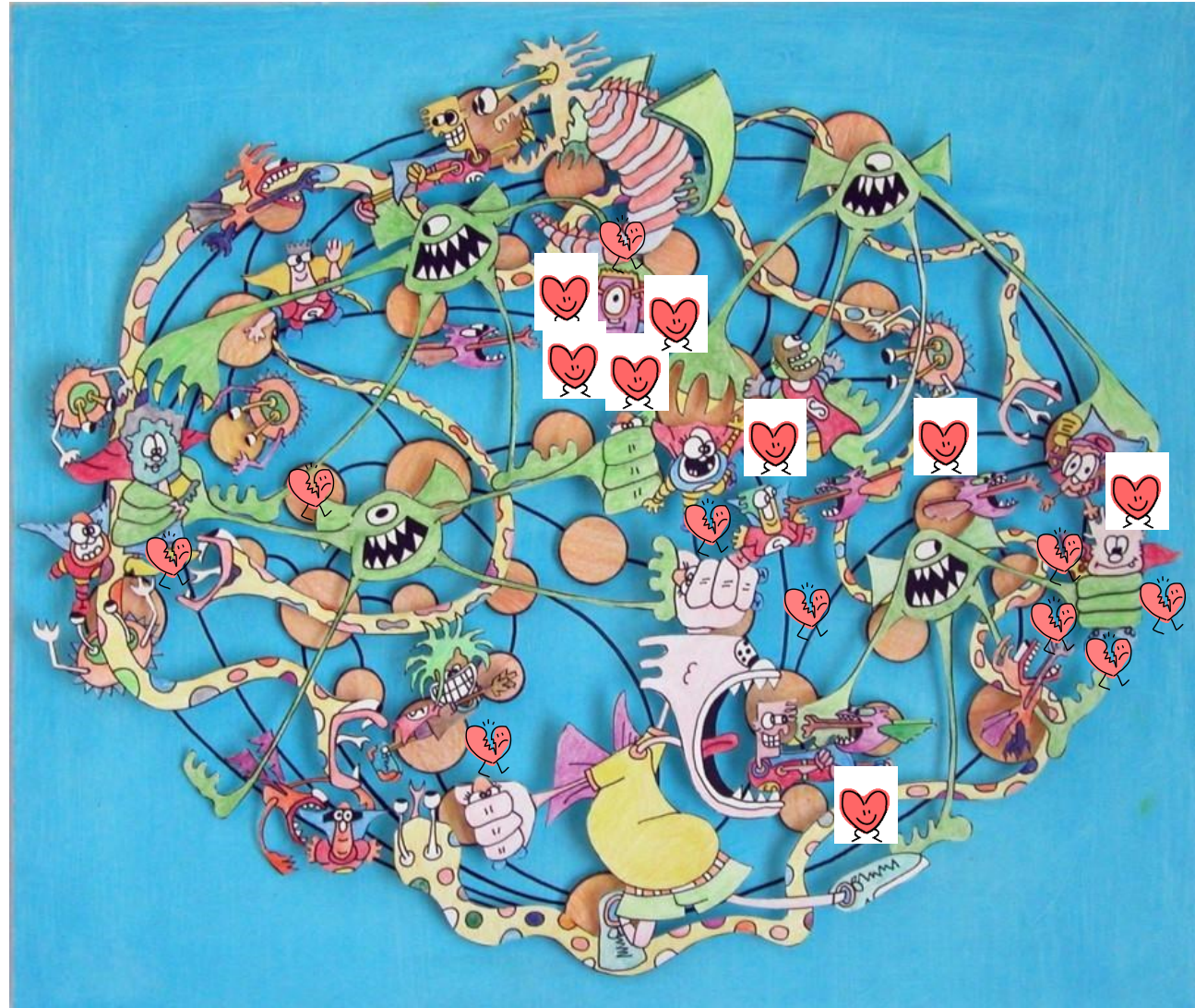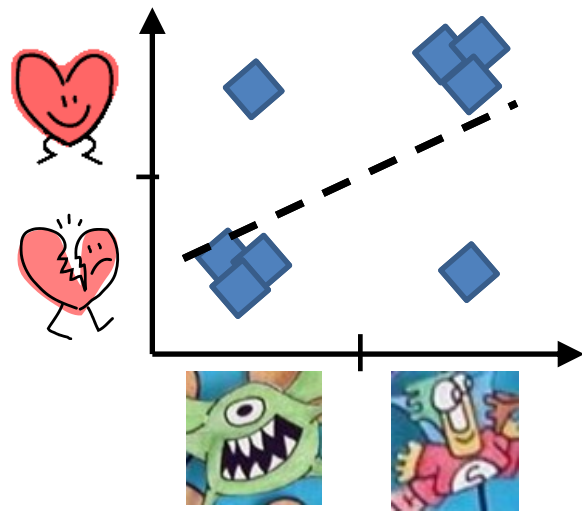
Complex Challenges

Macro can be surprising

Schelling (1969). Model̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ian Econ. Review, 59(2), p.488

"Economists are f̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ to aggregate results t̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ needs to be aware ̲o̲,̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ recognizable counterpart at the i̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ …savings decisions cause depression or inj̲ ̲ ̲ *interplay of individual choices*… is a complex system with collective results that bear no close relation to the individual intent."

Micro can be surprising

Epstein & Axtell (1996). Growing Artificial Societies. Bradford; pp. 51-52.

"…upon first exposure to these familiar social, or macroscopic, structures – be they migrations, skewed ̲w̲ealth distributions… – some people say, "Yes, that looks ̲ ̲ ̲ ̲ ̲'̲ve seen it before. What's the surprise?" The ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ in the emergence of familiar ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ from **simple local** ̲he social, or collec̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲, it is not the emergent macrosc̲ ̲ ̲ ̲ ̲ ̲ ̲ ̲ surprising, but the generative sufficiency of the s̲ ̲ ̲ rules."

The generativist motto: "If you didn't grow it, you didn't explain it!"

Descriptive / bottom-up / micro => macro:

Given (change in) *individual rules*, what is the *global behavior*?

Interventionist / top-down / macro => micro:

Given (desired) *global behavior*, what should be the *individual rules*?

"Designing self-organization"…(!)

"The **new science of artificial societies** suggests that real ones are both more predictable and more surprising than we thought. …computers will probably never enable us to foresee the future in detail—but we might learn to anticipate the kinds of events that lie ahead, and where to look for interventions that might work".

*Rauch, J. (2002). **Seeing Around Corners**. The Atlantic, (April), p. 35*