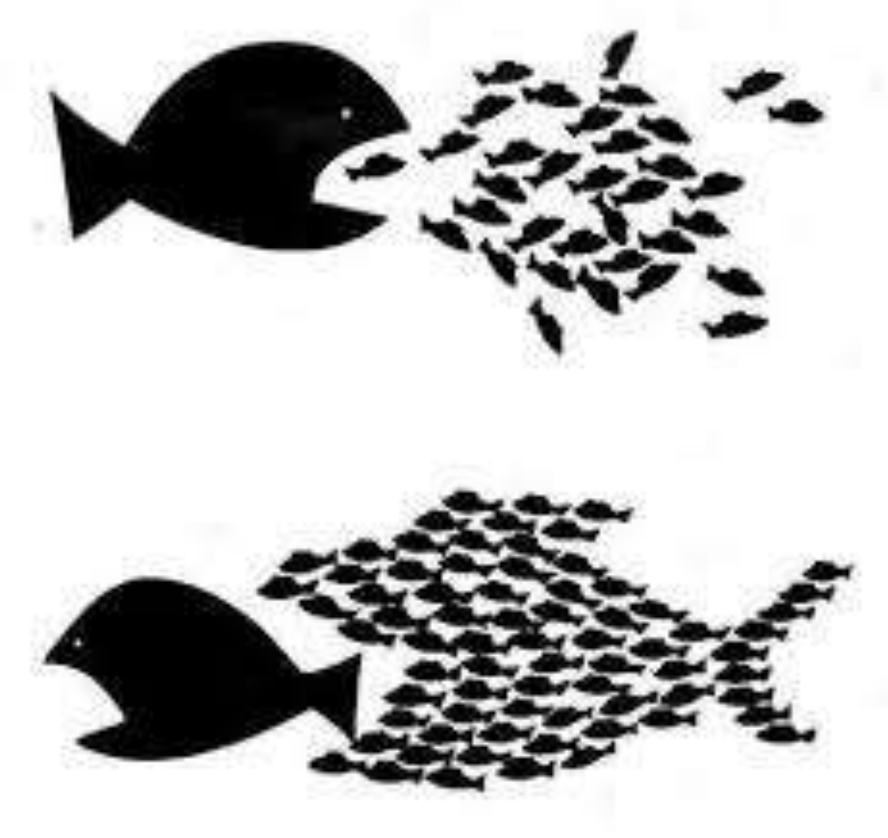
Collective motion, collective action, and collective decision-making



http://www.denizsozluk.com

Simon Levin

SESYNC2016

With thanks to

VET TES EN NOV TAM TVM

GRAND
ENERGY DEVELOPMENT HEALTH
CHALLENGES

CICS
Cooperative Institute
for Climate Science

SCIENCE TO SHAPE THE FUTURE OF THE ARMY
ARMY RESEARCH OFFICE
1951

BRIDGING THE GAP
DARPA
POWERED BY IDEAS

NATIONAL INSTITUTES OF HEALTH

NSF

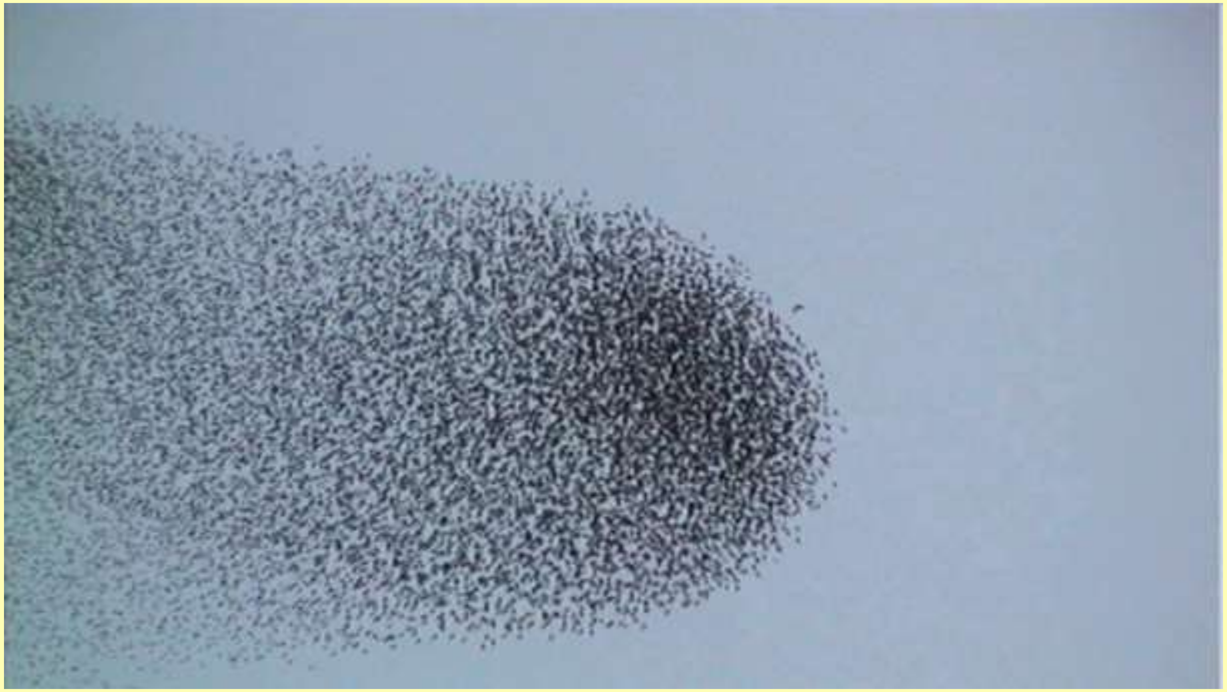
U.S. DEPARTMENT OF HOMELAND SECURITY

THE ANDREW W. MELLON FOUNDATION

John Templeton Foundation

norden
NordForsk

From microbial systems to socioeconomic systems, macroscopic patterns *emerge* from microscopic interactions

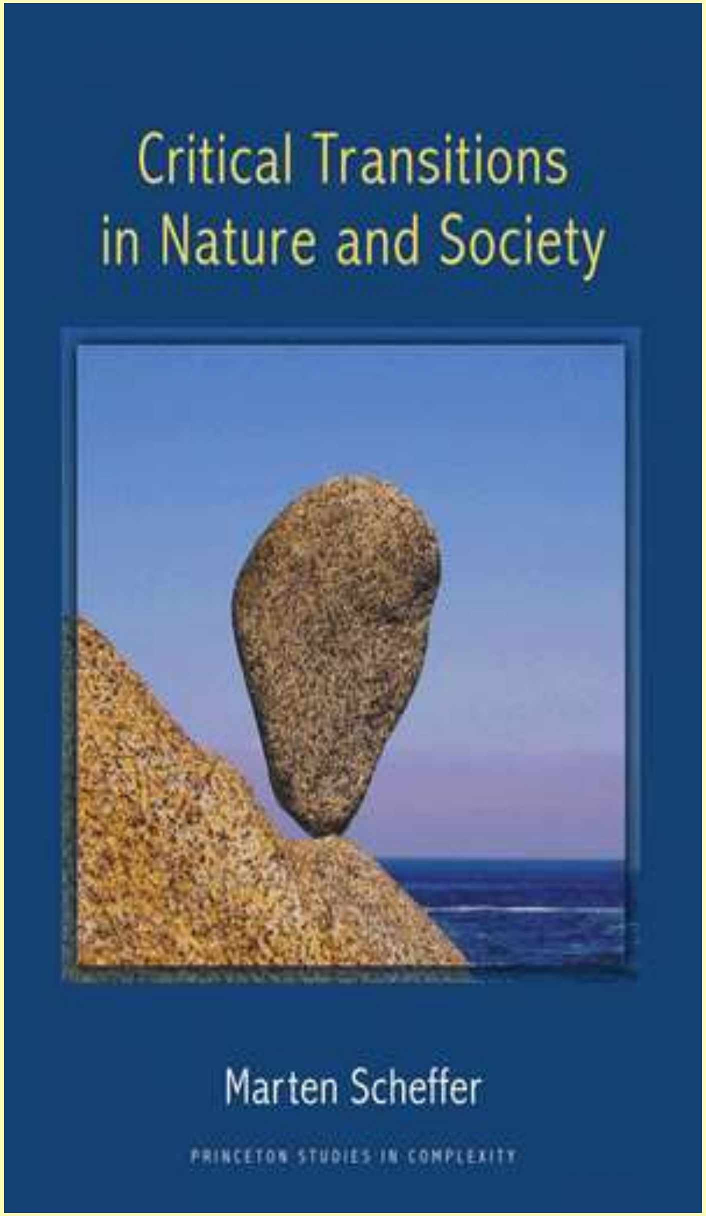


Claudo Carere
StarFLAG EU FP6 project

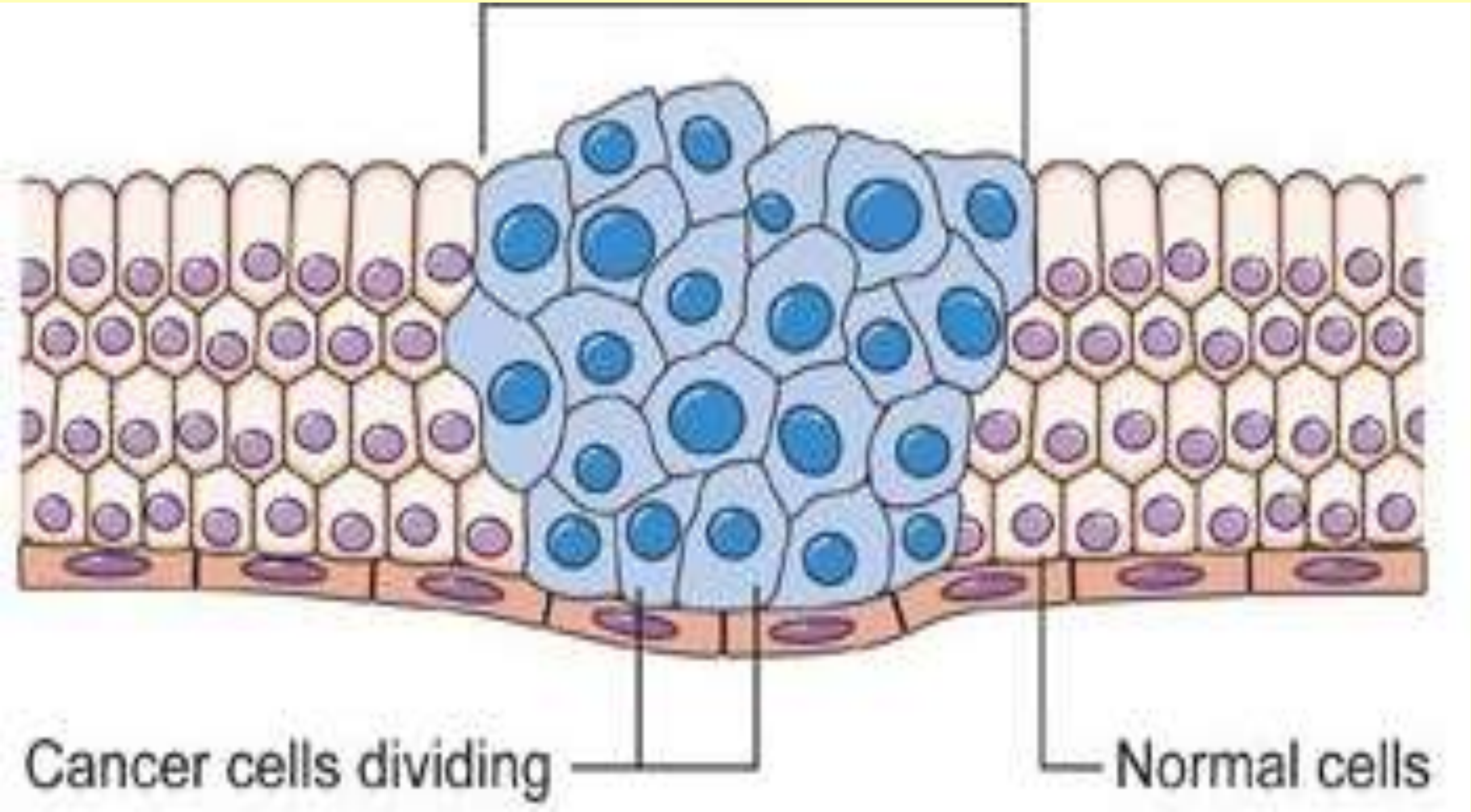
Phil Anderson: More is different.
Science 1972

Photo by Amaris Hardy, Office of Communications, Princeton

Emergence can lead to sudden shifts



..and inescapably to conflicts between levels



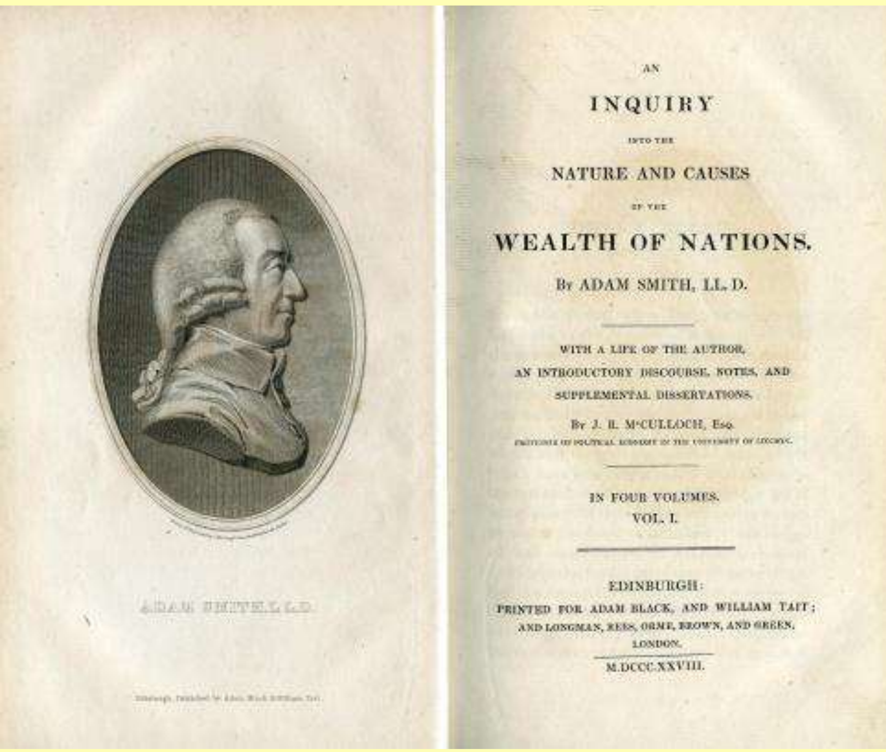
http://www.cancerresearchuk.org/

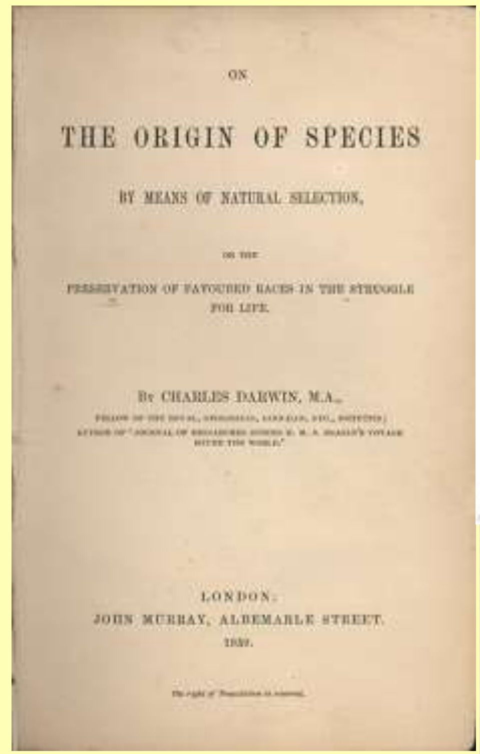
Public goods problems are widespread in socio-economic and ecological contexts, and share common features

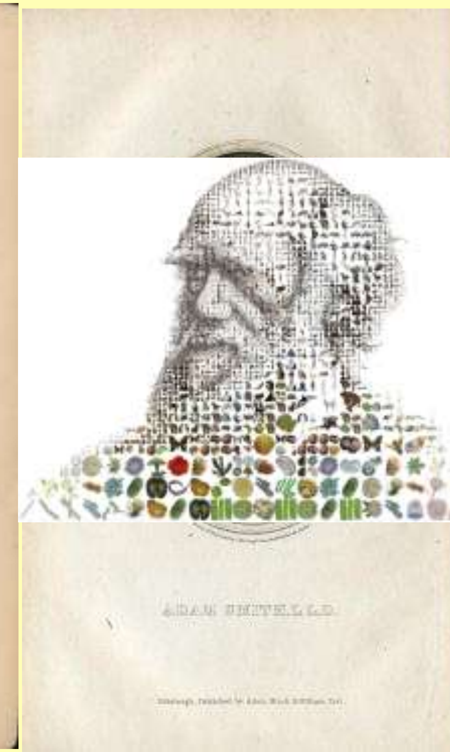
Patrick Semansky/AP

Carole Levin

Hence, economic perspectives can inform evolutionary questions, and vice versa

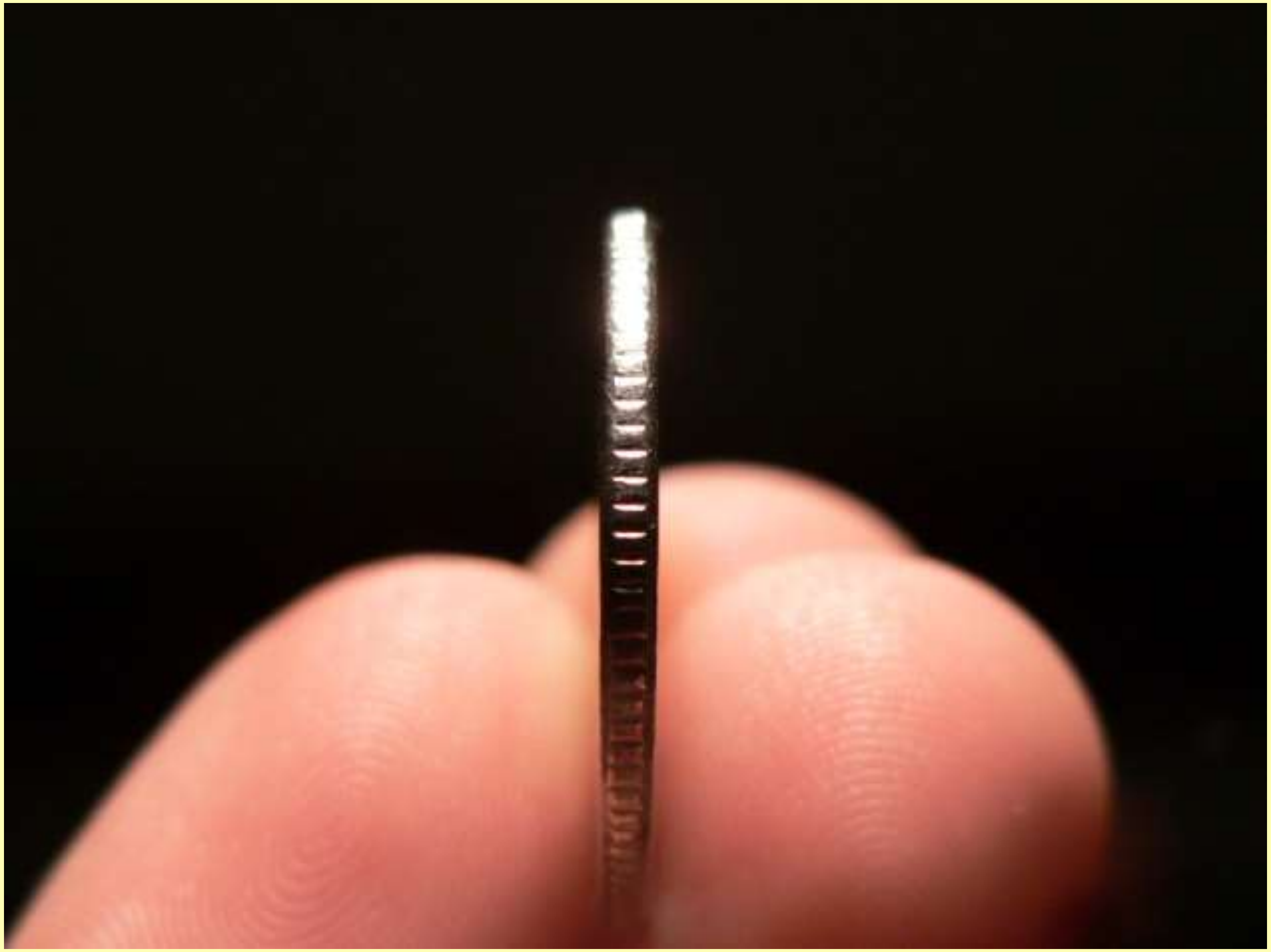






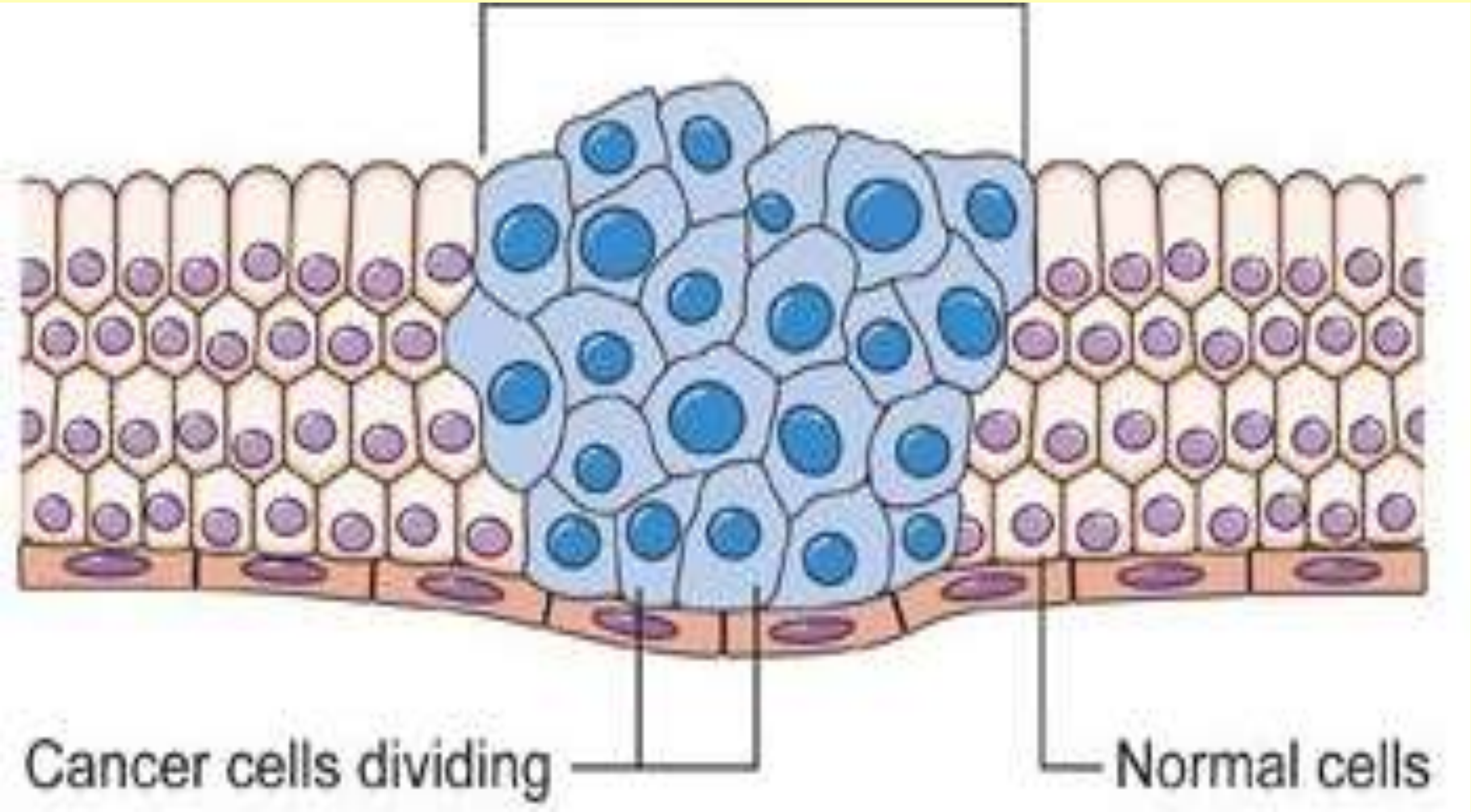
www.neoformix.com

Indeed, ecology and economics are two sides of the same coin



http://ecoopportunity.net/2013/07/sustainability-and-innovation-two-sides-of-the-same-coin/

Tumors show breakdown of public goods



http://www.cancerresearchuk.org/

But rely on public goods as well: Selecting for cheaters to fight cancer, with

http://www.cienciahoje.pt/index.php?oid

David Dingli

http://sweet.ua.pt/sdorogov/photos-networkers.html

Jorge Pacheco

http://www.the-scientist.com/

Corina Tarnita

There are precedents

Evolutionary Applications
Open Access

Evolutionary Applications ISSN 1752-4571

ORIGINAL ARTICLE

Drugs that target pathogen public goods are robust against evolved drug resistance

John W. Pepper[1,2]

1 Division of Cancer Prevention, National Cancer Institute, Bethesda, MD, USA
2 Santa Fe Institute, Santa Fe, NM, USA

Keywords
biomedicine, cancer medicine, contemporary evolution, disease biology, evolutionary medicine, evolutionary theory, experimental evolution, microbial biology, natural selection.

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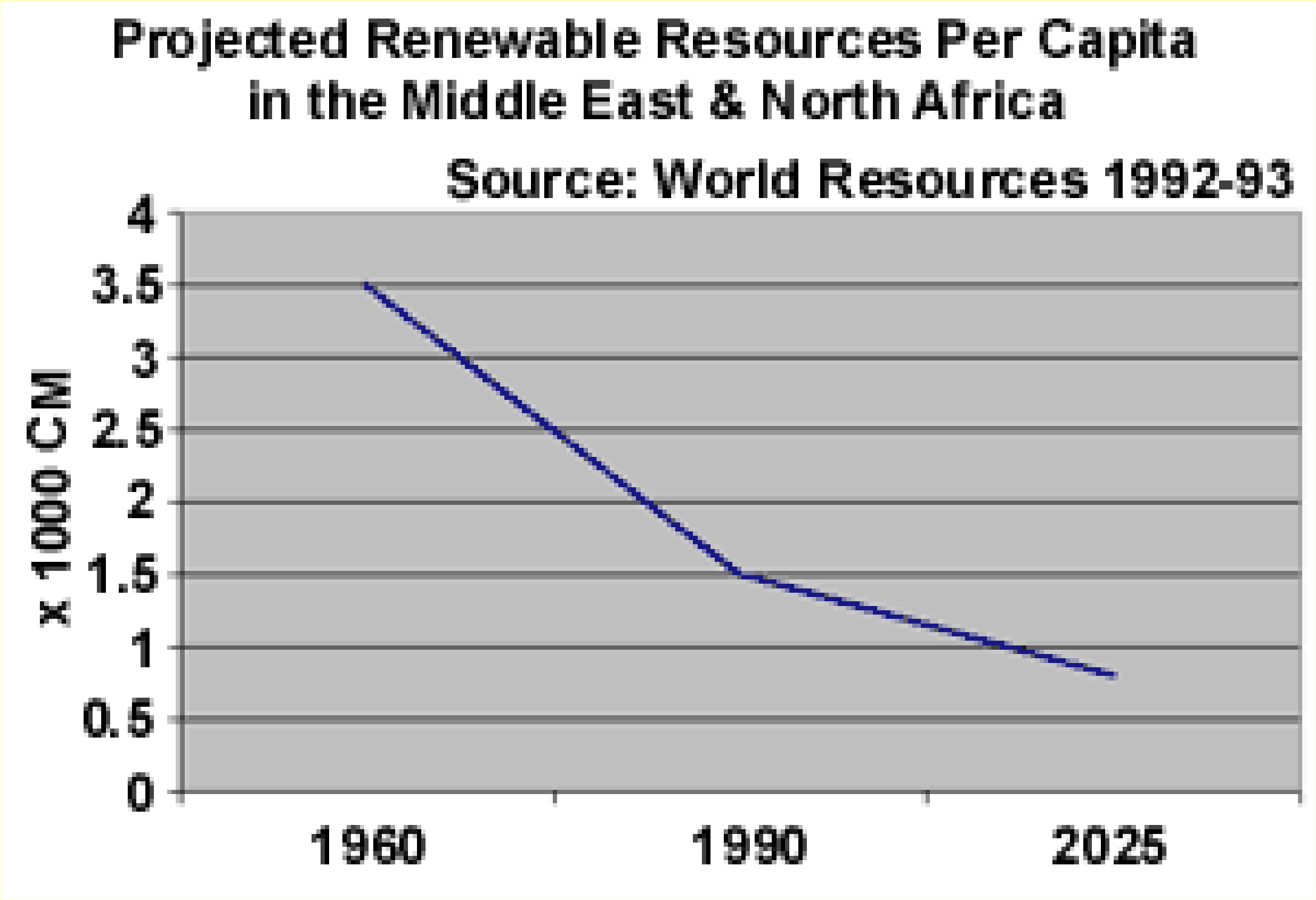
Tel.: 301-296-7477;
fax: 301-402-0816;
e-mail: pepperjw@mail.nih.gov

Abstract

Pathogen drug resistance is a central problem in medicine and public health. It arises through somatic evolution, by mutation and selection among pathogen cells within a host. Here, we examine the hypothesis that evolution of drug resistance could be reduced by developing drugs that target the secreted metabolites produced by pathogen cells instead of directly targeting the cells themselves. Using an agent-based computational model of an evolving population of pathogen cells, we test this hypothesis and find support for it. We also use our model to explain this effect within the framework of standard evolutionary theory. We find that in our model, the drugs most robust against evolved drug resistance are those that target the most widely shared external products, or 'public goods', of pathogen cells. We also show that these drugs exert a weak

Problems of public goods and common-pool resources are central to the future of humanity



Yet we are eroding our public goods

http://www.marketplace.org/topics/sustainability/what-would-your-city-look-beijings-air-smog-simulator

We discount

- The future

www.elements4health.com

We discount

- The future
- The interests of others

Moreover, we live in a global commons, in which

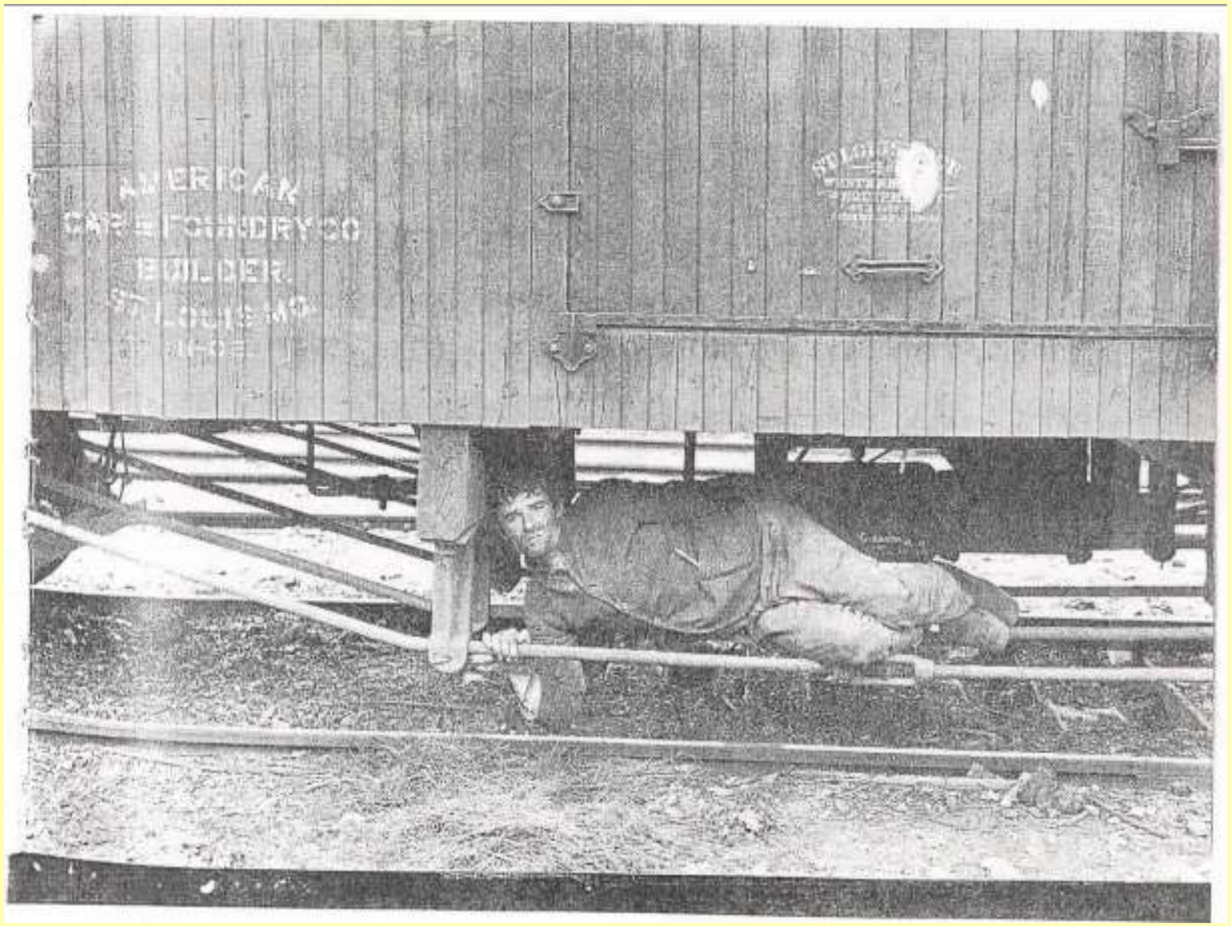
- Individual agents act largely in their own self-interest

Credit: JIRAPONG BOONPONGHA

Moreover, we live in a global commons, in which

- Individual agents act largely in their own self-interest
- Social costs are not adequately accounted for

The problem: Free-riders



www.americanpopularculture.com

Overuse of the Commons

William Forster Lloyd (1832)

Aelbert_Cuyp

The tragedy of the (unregulated) Commons

Garrett Hardin

http://www.physics.ohio-state.edu/~wilkins

The solution (Hardin)

"Mutual coercion, mutually agreed upon"

http://www.physics.ohio-state.edu/~wilkins

The maintenance of cooperation in small societies depends on shared and mutually agreed-upon norms

Lin Ostrom

Intertemporal social welfare poses similar problems

JSTOR: The Journal of Economic Perspectives, Vol. 18, No. 3... http://www.jstor.org/stable/3216811

Journal of Economic Perspectives—Volume 18, Number 3—Summer 2004—Pages 147–172

Are We Consuming Too Much?

Kenneth Arrow, Partha Dasgupta,
Lawrence Goulder, Gretchen Daily, Paul Ehrlich,
Geoffrey Heal, Simon Levin, Karl-Göran Mäler,
Stephen Schneider, David Starrett and
Brian Walker

Is humanity's use of Earth's resources endangering the economic possibilities open to our descendants? There is wide disagreement on the question. Many

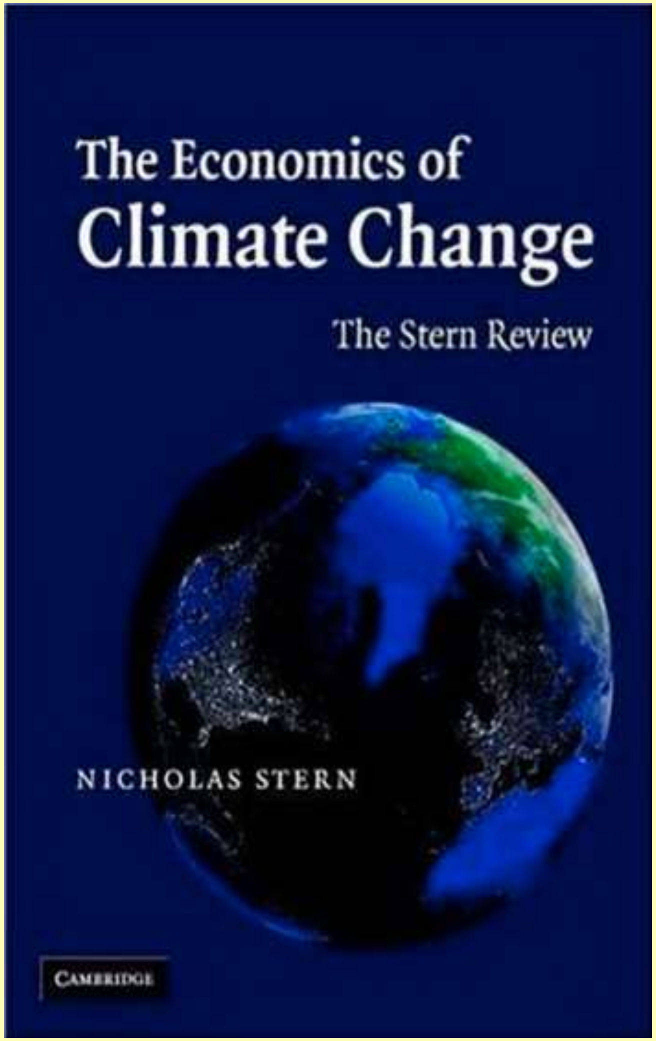
Intertemporal social welfare

$$V(t) = \int_t^{\infty} U[C(s)]e^{-\delta(s-t)}ds$$

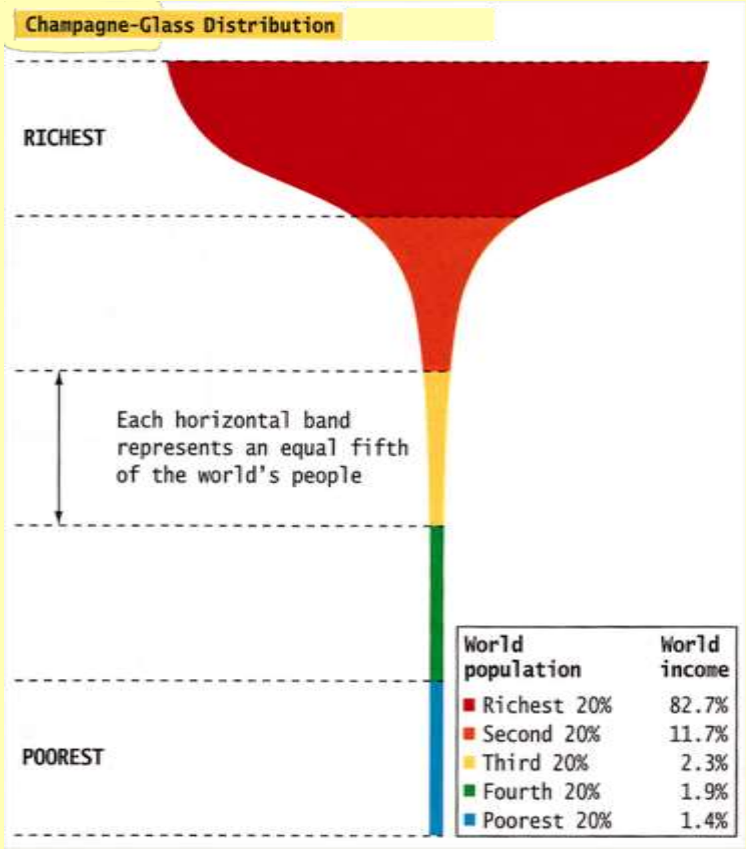
C=Consumption

U=Utility

Discounting and sustainability



World distribution of wealth is growing more distorted



Conley, D. (2008) You may ask yourself: An introduction to thinking like a sociologist. W.W. Norton and Company. p.392., after UNDP Human Developmnet report 1992. Oxford University Press.

Intergenerational resource transfers with random offspring numbers

Kenneth J. Arrow[a] and Simon A. Levin[b,1]

[a]Department of Economics, Stanford University, Stanford, CA 94305-6072; and [b]Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544-1003

Contributed by Kenneth J. Arrow, May 26, 2009 (sent for review March 29, 2009)

A problem common to biology and economics is the transfer of resources from parents to children. We consider the issue under the assumption that the number of offspring is unknown and can be represented as a random variable. There are 3 basic assumptions. The first assumption is that a given body of resources can be divided into consumption (yielding satisfaction) and transfer to children. The second assumption is that the parents' welfare includes a concern for the welfare of their children; this is recursive in the sense that the children's welfares include concern for their children and so forth. However, the welfare of a child from a given consumption is counted somewhat differently (generally less) than that of the parent (the welfare of a child is "discounted"). The third assumption is that resources transferred may grow (or decline). In economic language, investment, including that in education or nutrition, is productive. Under suitable restrictions, precise formulas for the resulting allocation of resources are found, demonstrating that, depending on the shape of the utility curve, uncertainty regarding the number of offspring may or may not favor increased consumption. The results imply that wealth (stock of resources)

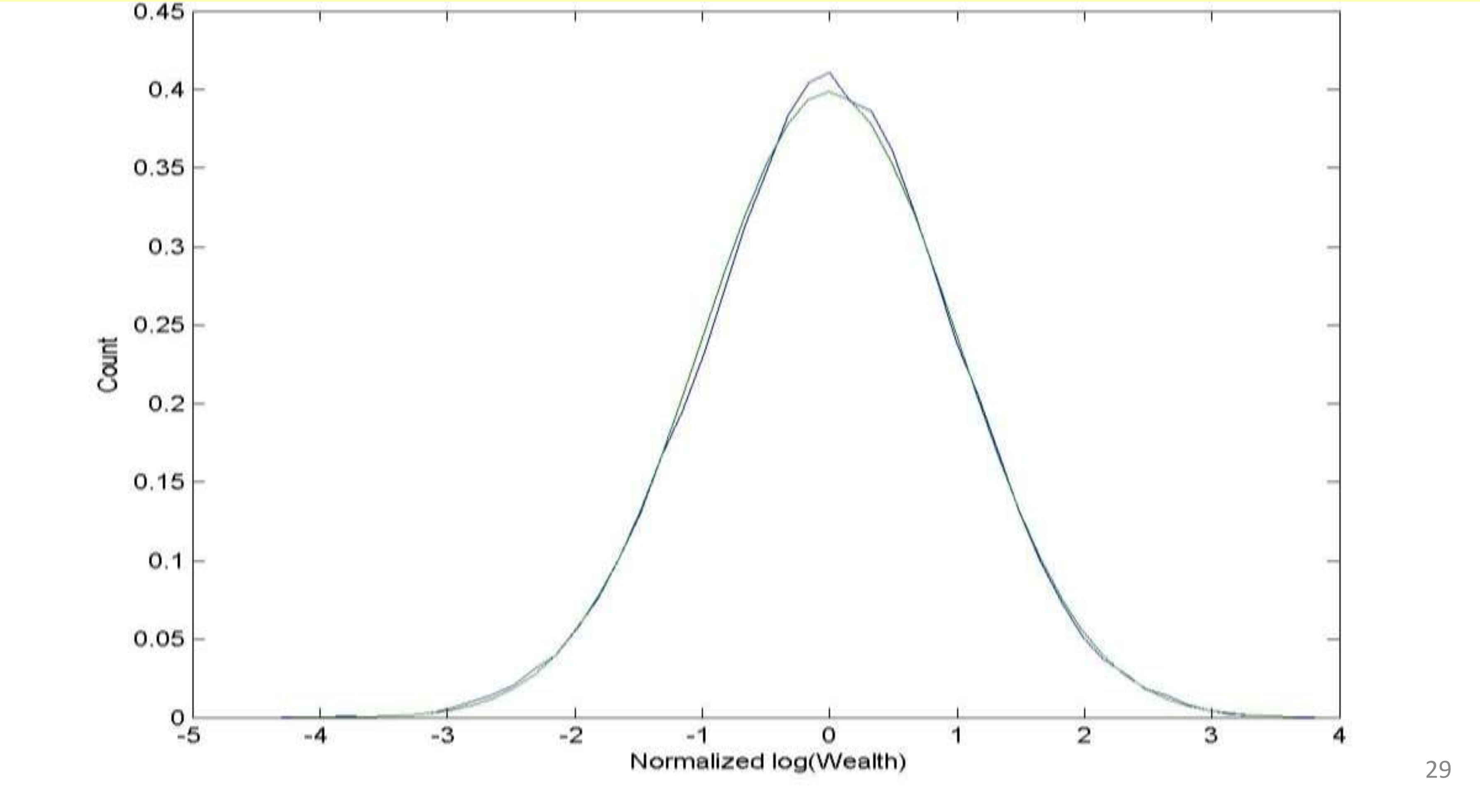
ping generations, offspring produced early in life are more valuable than those produced later because those offspring can also begin reproduction earlier. This is analogous to the classic investment problem in economics, in that population growth imposes a discount rate that affects when one should have offspring. The flip side is that early reproduction compromises the parent's ability to care for its children, and that increased number of offspring reduces the investment that can be made in each. Again, the best solution generally involves compromise and an intermediate optimum.

A particularly clear manifestation of this tradeoff involves the problem of clutch or litter size—how many offspring should an organism, say a bird, have in a particular litter? (11) Large litters mandate decreased investment in individuals, among other costs, but increase the number of lottery tickets in the evolutionary sweepstakes. This problem has relevance across the taxonomic spectrum, and especially from the production of seed by plants to the litter sizes of elephants and humans. Even for vertebrates, the evolutionary resolution shows great variation: The typical

ECONOMIC SCIENCES

Dynamic programming solution: Wealth converges to a log-normal distribution with spread determined by uncertainty

Arrow and Levin, PNAS



Extensions (with Sarah Drohan, Ricky Der)

- Modify assumptions to try to produce Pareto tail
  - Number of offspring contingent on wealth
  - Wealthy have higher return on investment
  - Other sources of uncertainty

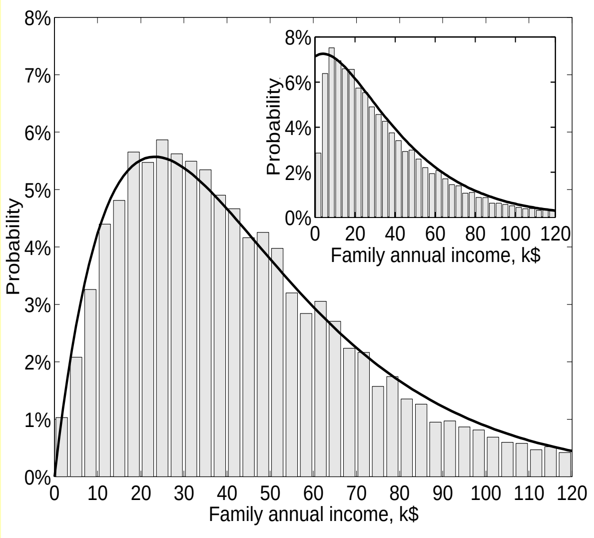


Fig. 4. Histogram: Probability distribution of income for families with two adults in 1996 [11]. Solid line: Fit to equation (5). Inset histogram: Probability distribution of income for all families in 1996 [11]. Inset solid line: $0.45P_1(r) + 0.55P_2(r)$.

Eur. Phys. J. B **20, 585{589 (2001) THE EUROPEAN PHYSICAL JOURNAL B**
Evidence for the exponential distribution of income in the USA
A. Dragulescu and V.M. Yakovenko

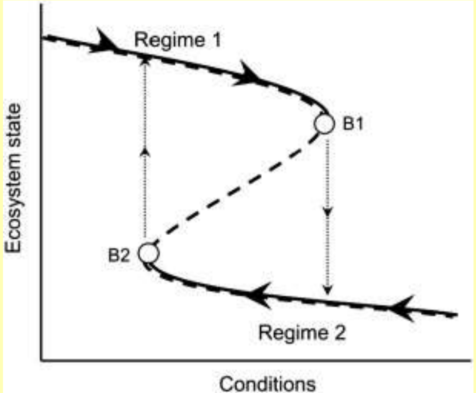
Ecosystems and the Biosphere are Complex Adaptive Systems

Heterogeneous collections of individual units (agents) that interact locally, and evolve based on the outcomes of those interactions.

NOAA

Challenges of managing CAS

- Multiple spatial, temporal and organizational scales
- Self-organization, emergence and consequent unpredictability
- Multiple stable states, path dependence, hysteresis
- Contagious spread and systemic risk
- Potential for destabilization and regime shifts through slow-time-scale evolution



Crepin et al, Ecol Econ, 2012

2008

Vol 451|21 February 2008

nature

NEWS & VIEWS

COMPLEX SYSTEMS

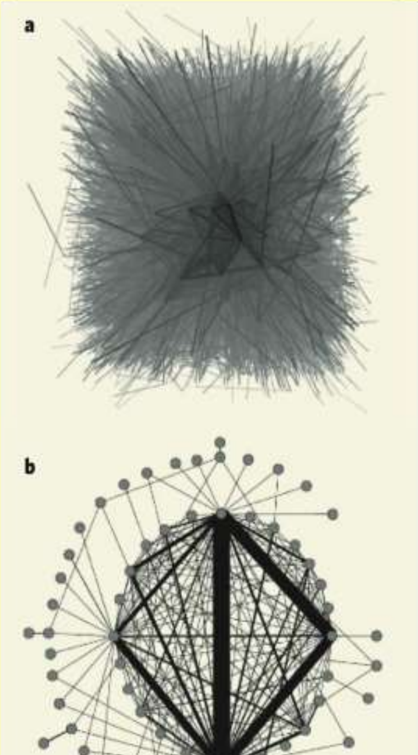
Ecology for bankers

Robert M. May, Simon A. Levin and George Sugihara

There is common ground in analysing financial systems and ecosystems, especially in the need to identify conditions that dispose a system to be knocked from seeming stability into another, less happy state.

'Tipping points', 'thresholds and breakpoints', 'regime shifts' — all are terms that describe the flip of a complex dynamical system from one state to another. For banking and other financial institutions, the Wall Street Crash of 1929 and the Great Depression epitomize such an event. These days, the increasingly complicated and globally interlinked financial markets are no less immune to such system-wide (systemic) threats. Who knows, for instance, how the present concern over sub-prime loans will pan out?

Well before this recent crisis emerged, the US National Academies/National Research Council and the Federal Reserve Bank of New York collaborated[1] on an initiative to "stimulate fresh thinking on systemic risk". The main event was a high-level conference held in May 2006, which brought together experts from various backgrounds to explore parallels between systemic risk in the financial sector and in selected domains in engineering, ecology and other fields of science. The resulting report[1] was published late last year and makes stimulating reading.



spent on studying systemic risk as compared with that spent on conventional risk management in individual firms? Second, how expensive is a systemic-risk event to a national or global economy (examples being the stock market crash of 1987, or the turmoil of 1998 associated with the Russian loan default, and the subsequent collapse of the hedge fund Long-Term Capital Management)? The answer to the first question is "comparatively very little"; to the second, "hugely expensive".

An analogous situation exists within fisheries management. For the past half-century, investments in fisheries science have focused on management on a species-by-species basis (analogous to single-firm risk analysis). Especially with collapses of some major fisheries, however, this approach is giving way to the view that such models may be fundamentally incomplete, and that the wider ecosystem and environmental context (by analogy, the full banking and market system) are required for informed decision-making. It is an example of a trend in many areas of applied science acknowledging the need for a larger-system perspective.

2008

COMPLEX SYSTEMS

Ecology for bankers

Robert M. May, Simon A. Levin and George Sugihara

There is common ground in analysing financial systems and ecosystems, espe[…] conditions that dispose a system to be knocked from seeming stability into an[…]

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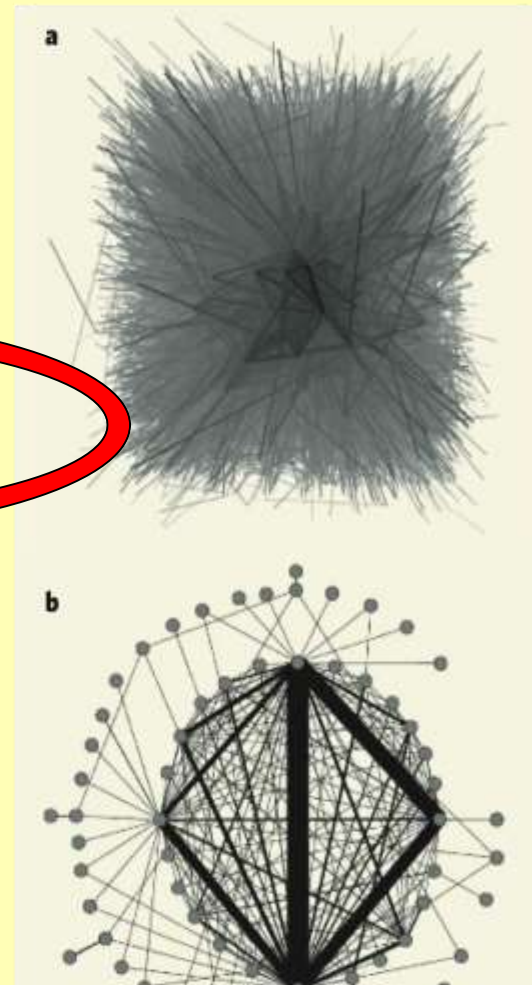
Catastrophic changes in the overall state of



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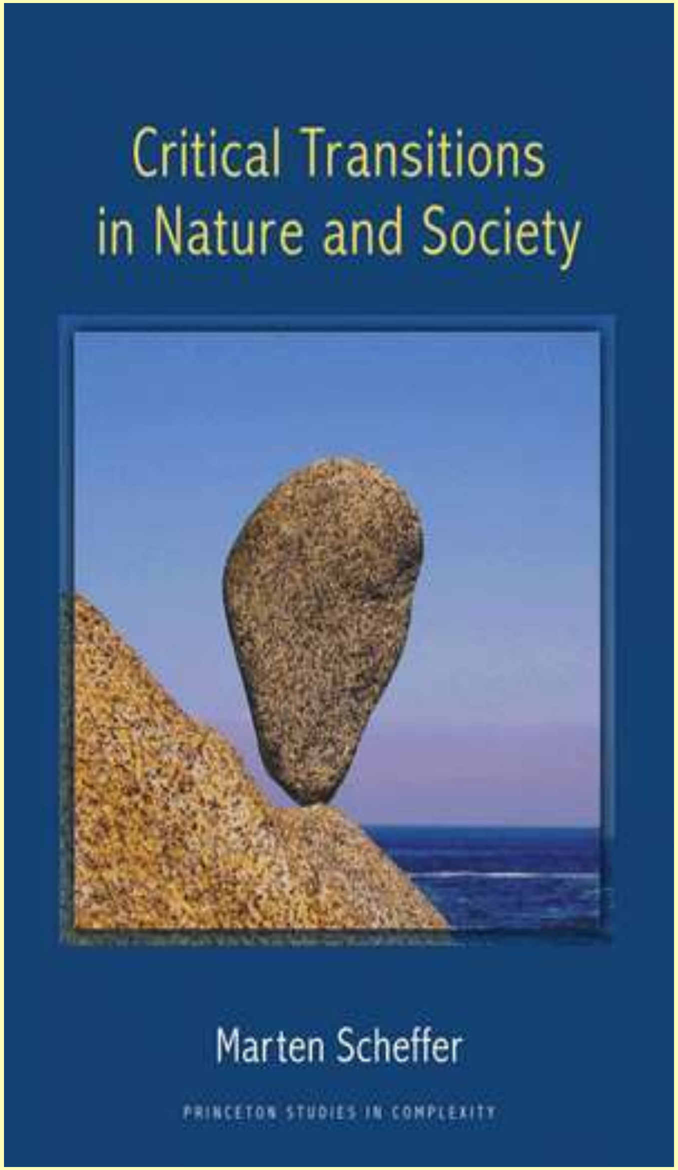
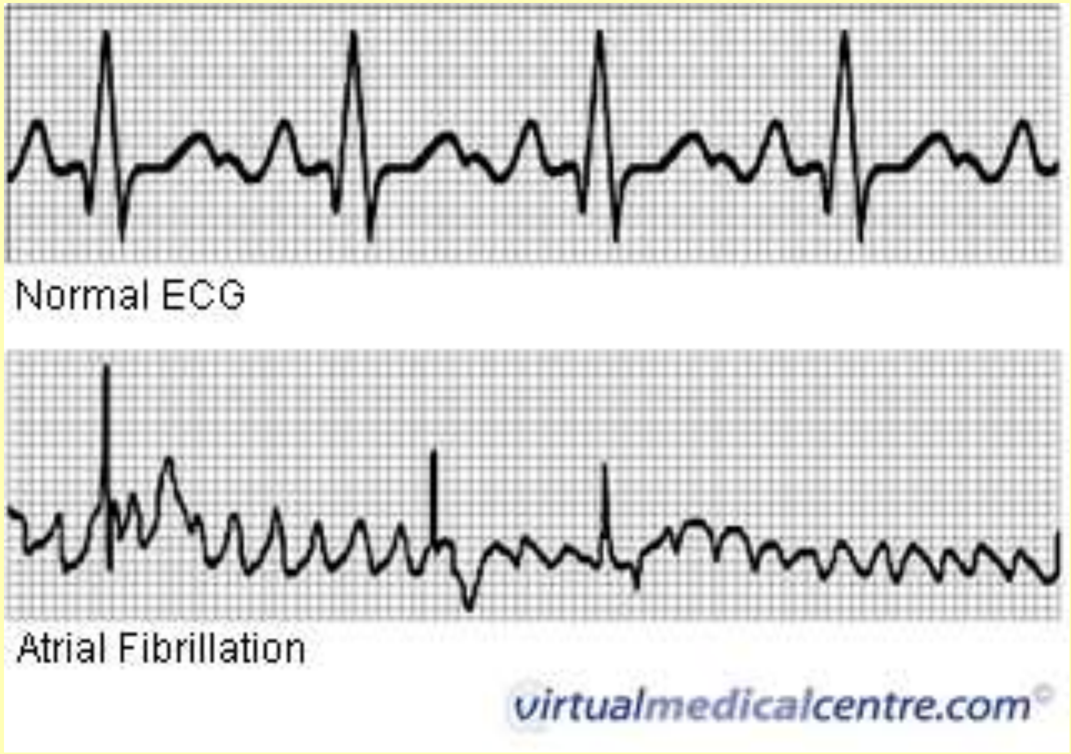
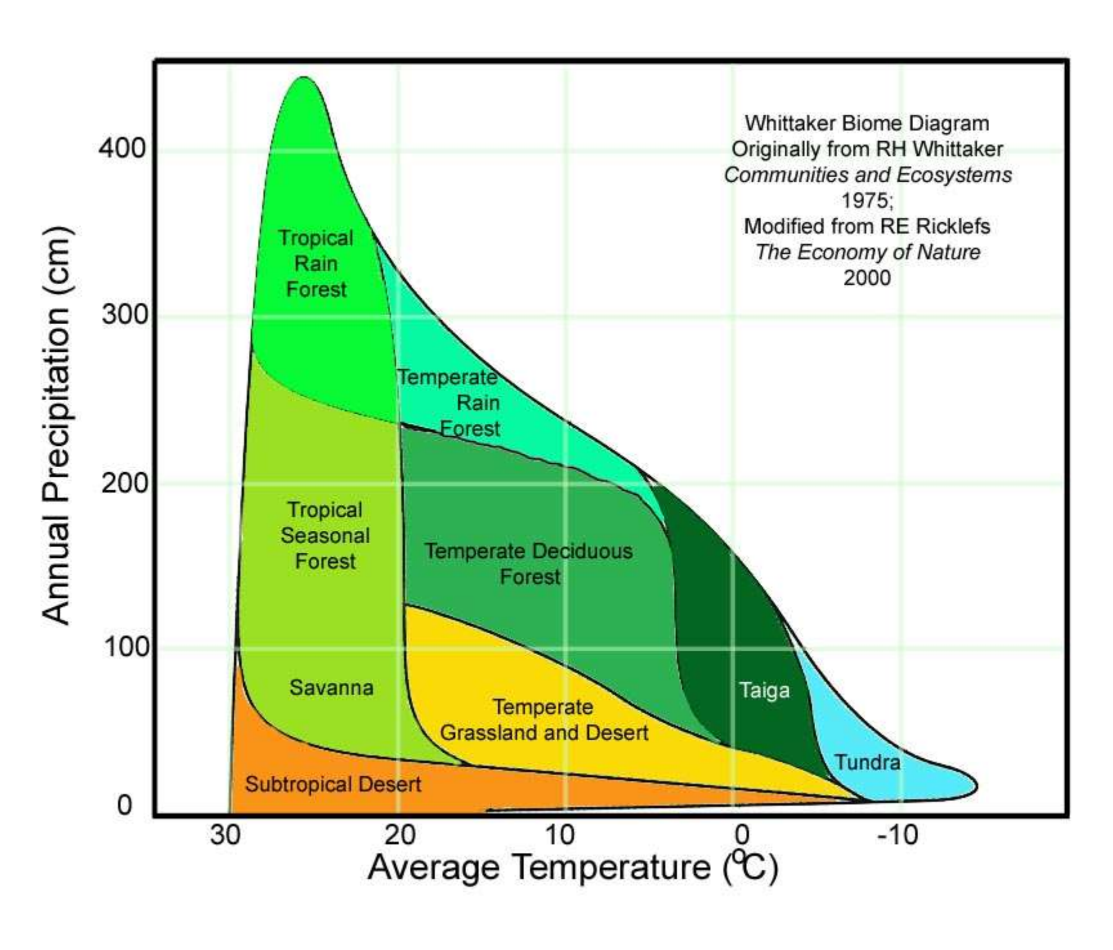
Such transitions are widespread

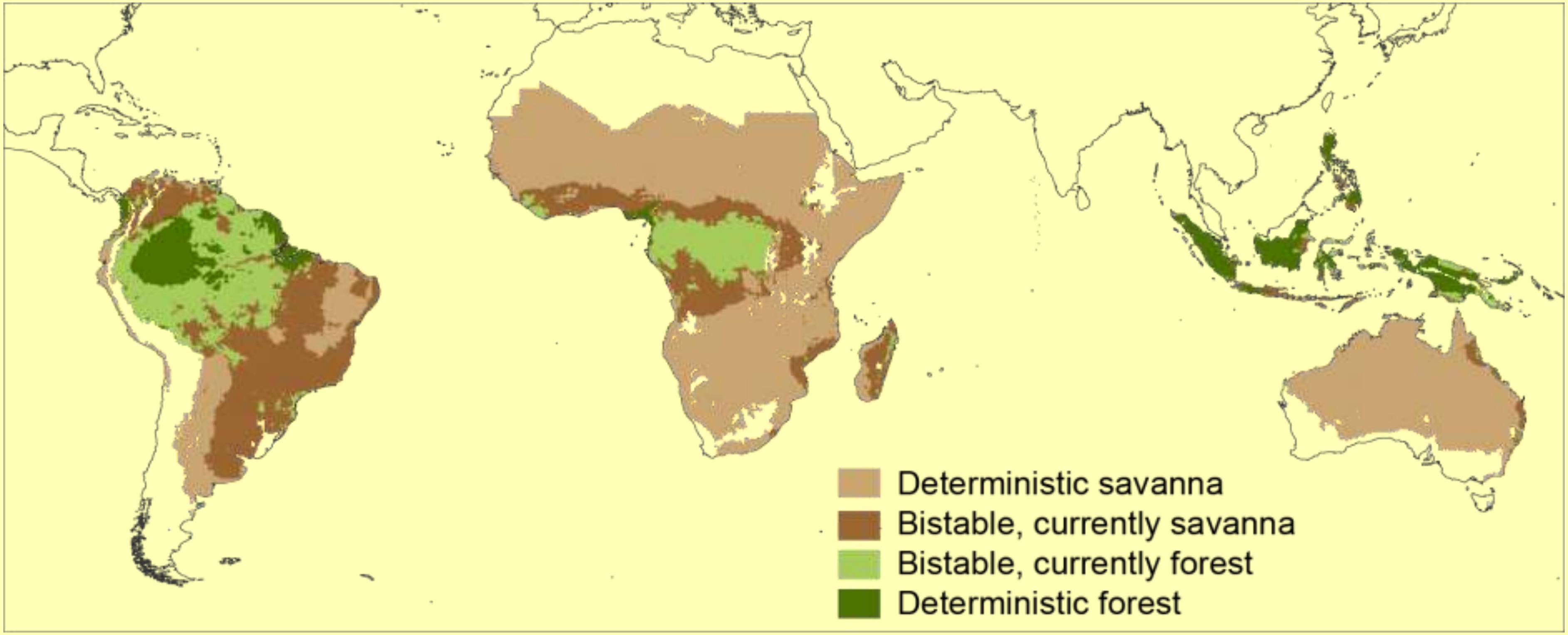




Much ecological pattern is exogenous: tracks environmental pattern

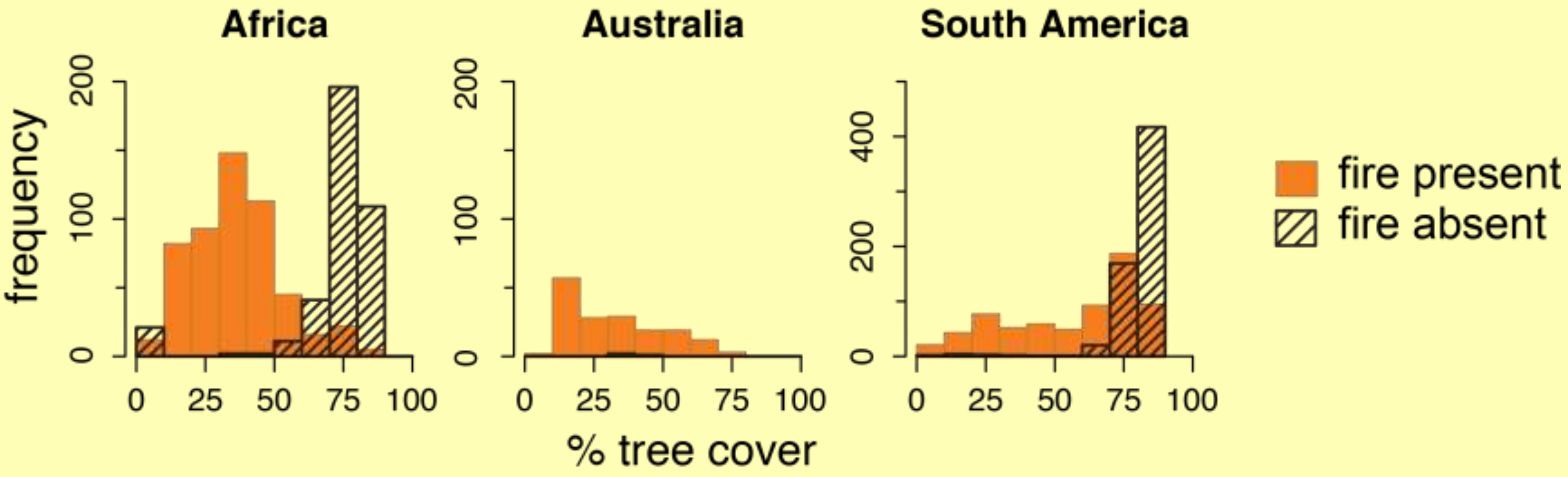


But, there are limits to predictability: Alternative stable states
Bistability characterizes global distributions



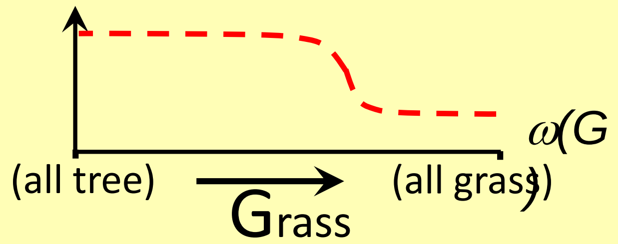
Staver *et al.* 2011 (*Ecology* and *Science)*

Fire separates savanna from forest within the intermediate climate envelope.



Staver *et al.* 2011 (*Ecology* and *Science)*

Savanna/Forest Distributions



Grass $$\frac{dG}{dt} = mS + nT - bGT$$

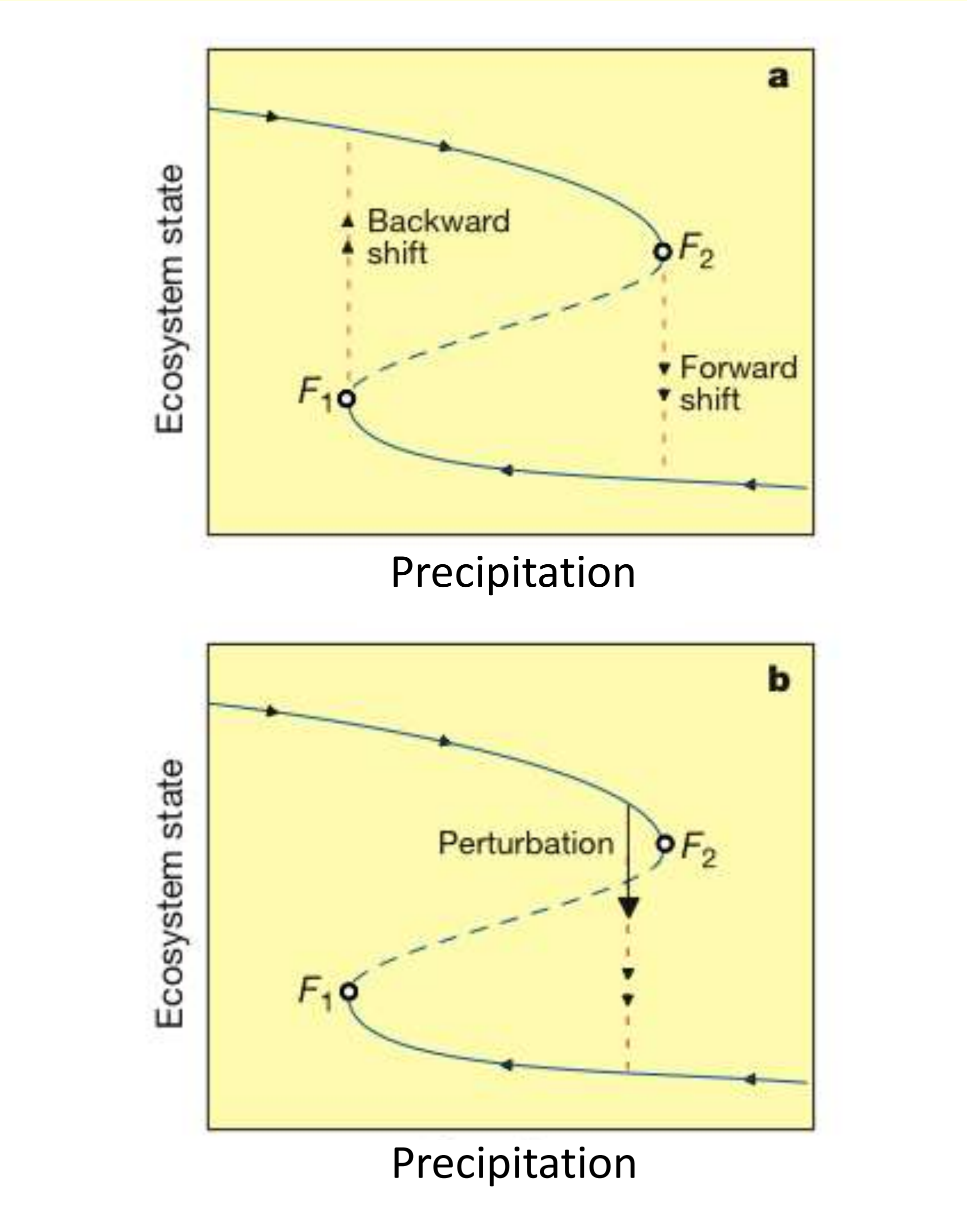
Saplings $$\frac{dS}{dt} = bGT - w(G)S - mS$$

Savanna Trees $$\frac{dT}{dt} = w(G)S - nT$$

$$G + S + T = 1$$

Staver *et al.* 2011 (*Ecology*) and Staver & Levin 2012 (AmerNatur)

Savanna/Forest Distributions



- Responses to changes in rainfall status will be rapid, threshold transitions
- Changes will not be easy to reverse
- Similar phenomena observed for other systems
  - Shallow lakes
  - Pest populations
  - Circulation patterms?

Modified very slightly from Scheffer *et al.* 2003, Nature

There has been much recent attention to critical transitions

REVIEW

Anticipating Critical Transitions

Marten Scheffer,[1,2*] Stephen R. Carpenter,[3] Timothy M. Lenton,[4] Jordi Bascompte,[5] William Brock,[6] Vasilis Dakos,[1,5] Johan van de Koppel,[7,8] Ingrid A. van de Leemput,[1] Simon A. Levin,[9] Egbert H. van Nes,[1] Mercedes Pascual,[10,11] John Vandermeer[10]

Tipping points in complex systems may imply risks of unwanted collapse, but also opportunities for positive change. Our capacity to navigate such risks and opportunities can be boosted by combining emerging insights from two unconnected fields of research. One line of work is revealing fundamental architectural features that may cause ecological networks, financial markets, and other complex systems to have tipping points. Another field of research is uncovering generic empirical indicators of the proximity to such critical thresholds. Although sudden shifts in complex systems will inevitably continue to surprise us, work at the crossroads of these emerging fields offers new approaches for anticipating critical transitions.

About 12,000 years ago, the Earth suddenly shifted from a long, harsh glacial episode into the benign and stable Holocene climate that allowed human civilization to develop. On smaller and faster scales, ecosystems occasionally flip to contrasting states. Unlike gradual trends, such sharp shifts are largely unpredictable (*1*–*3*). Nonetheless, science is now carving into this realm of unpredictability in fundamental ways. Although the complexity of systems such

emerging research areas and discuss how exciting opportunities arise from the combination of these so far disconnected fields of work.

The Architecture of Fragility

Sharp regime shifts that punctuate the usual fluctuations around trends in ecosystems or societies may often be simply the result of an unpredictable external shock. However, another possibility is that such a shift represents a so-called critical

points. The basic ingredient for a tipping point is a positive feedback that, once a critical point is passed, propels change toward an alternative state (*6*). Although this principle is well understood for simple isolated systems, it is more challenging to fathom how heterogeneous structurally complex systems such as networks of species, habitats, or societal structures might respond to changing conditions and perturbations. A broad range of studies suggests that two major features are crucial for the overall response of such systems (*7*): (i) the heterogeneity of the components and (ii) their connectivity (Fig. 1). How these properties affect the stability depends on the nature of the interactions in the network.

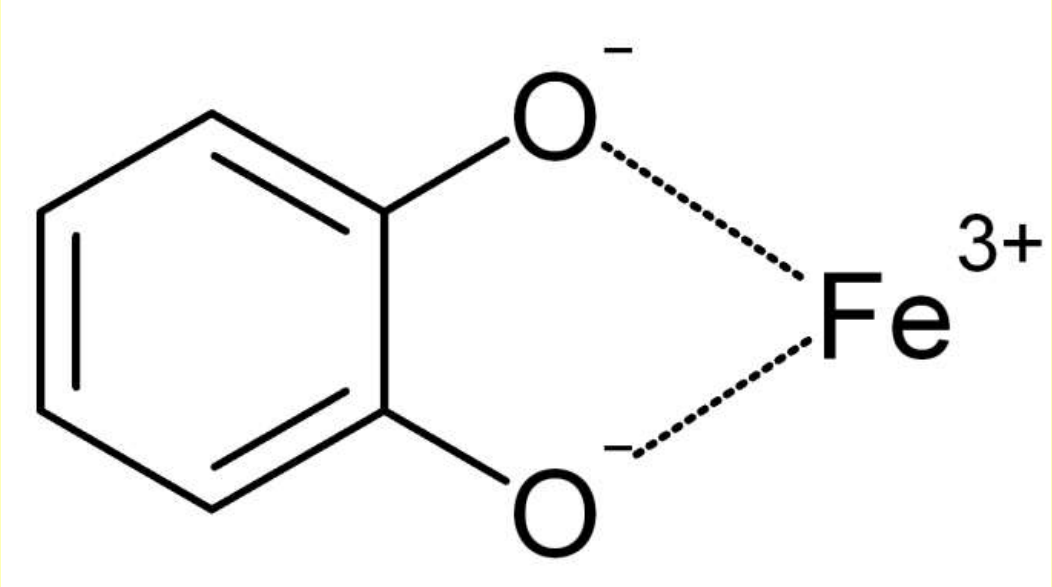
Domino effects. One broad class of networks includes those where units (or "nodes") can flip between alternative stable states and where the probability of being in one state is promoted by having neighbors in that state. One may think, for instance, of networks of populations (extinct or not), or ecosystems (with alternative stable states), or banks (solvent or not). In such networks, heterogeneity in the response of individual nodes and a low level of connectivity may cause the network as a whole to change gradually—rather than abruptly—in response to environmental change. This is because the relatively isolated and different nodes will each shift at another level of an en-

Lecture outline

- Critical transitions
- Conflict and public goods
- Collective action and collective decision-making

Public goods and CPR problems are central in ecology

- Information
- Tumors
- Chelation and siderophores



wikipedia

Public goods and CPR problems are central in ecology

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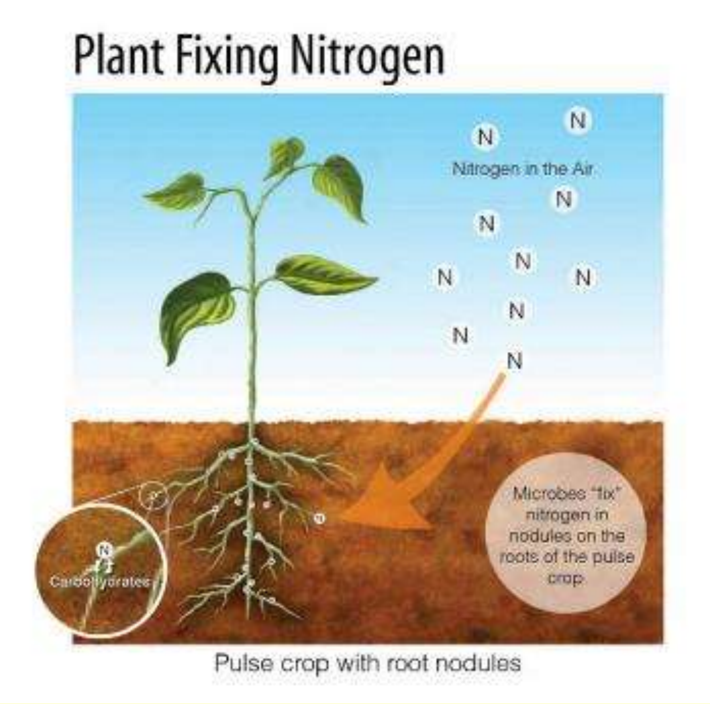
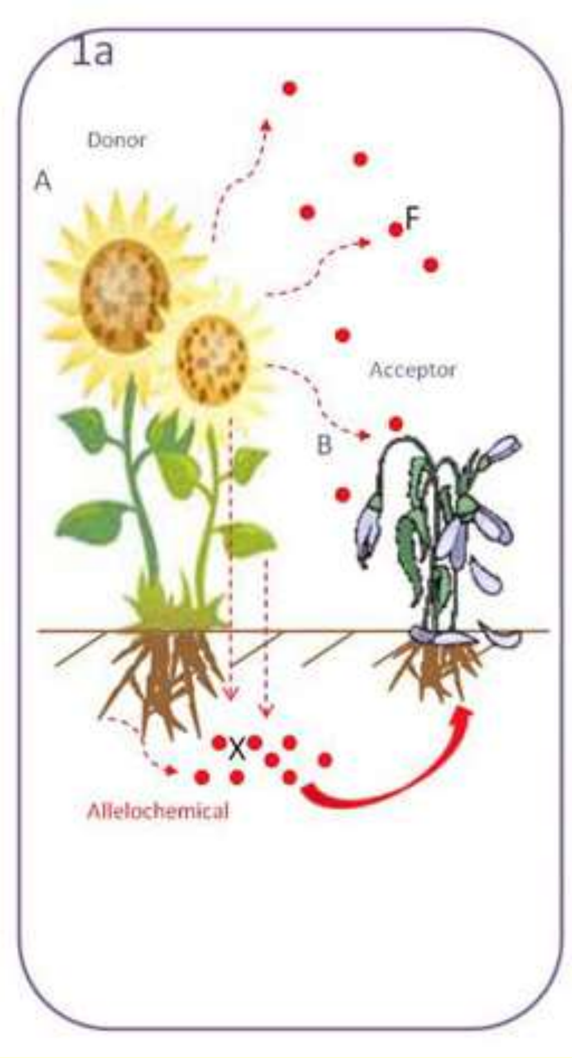
- N fixation



http://www.permaculture.co.uk/articles/nitrogen-fixing-plants-microbes

Public goods and CPR problems are central in ecology

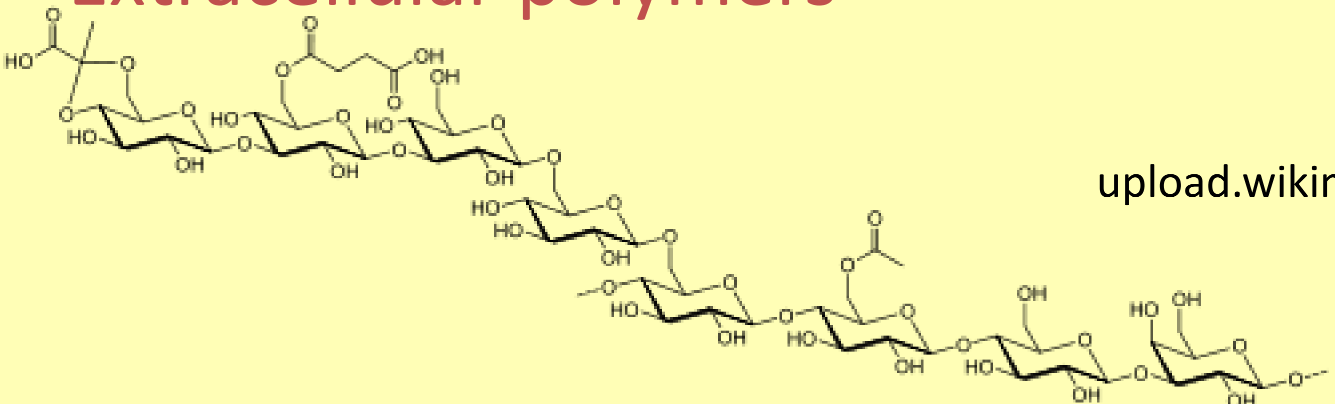
- Information
- Tumors
- Chelation and siderophores
- N fixation
- Antibiotics



http://www.intechopen.com/

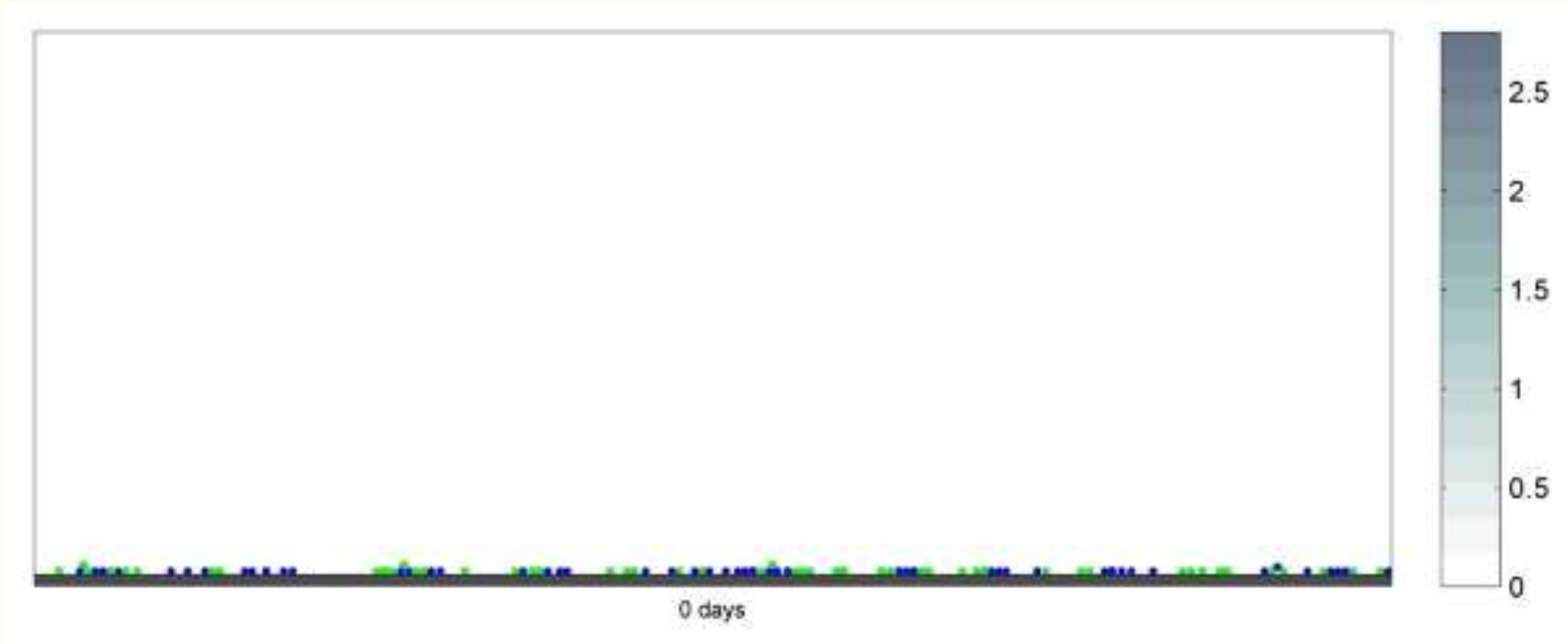
Public goods and CPR problems are central in ecology

- Information
- Tumors
- Chelation and siderophores
- N fixation
- Antibiotics
- Extracellular polymers



upload.wikimedia.org

Biofilm public goods production:
Local interactions important



Constitutive Slime-producer

QS Strain (below quorum)

Slime

QS Strain (above quorum)

Nadell, Xavier, Levin, Foster

In societies, collective action: Insurance agreements spread risks

http://dritoday.org/feature.aspx?id=31

Pastoralism and sharing of grazing grounds

- With Avinash Dixit and Daniel Rubenstein

In herder societies, kinship and prosociality can be important

http://gordonkilgore.com/gallery/countries-h-m/kenya/

E. Fehr

Social norms can sustain and enhance prosocial behavior

- Humans will punish others who deviate from social norms, at cost to themselves
- Punishment itself is a norm, and can evolve from repeated interactions
- Norms are important to understand much prosocial behavior
- Norms become formalized into rules and laws

Fairness norms can provide "mutual coercion, mutually agreed upon"

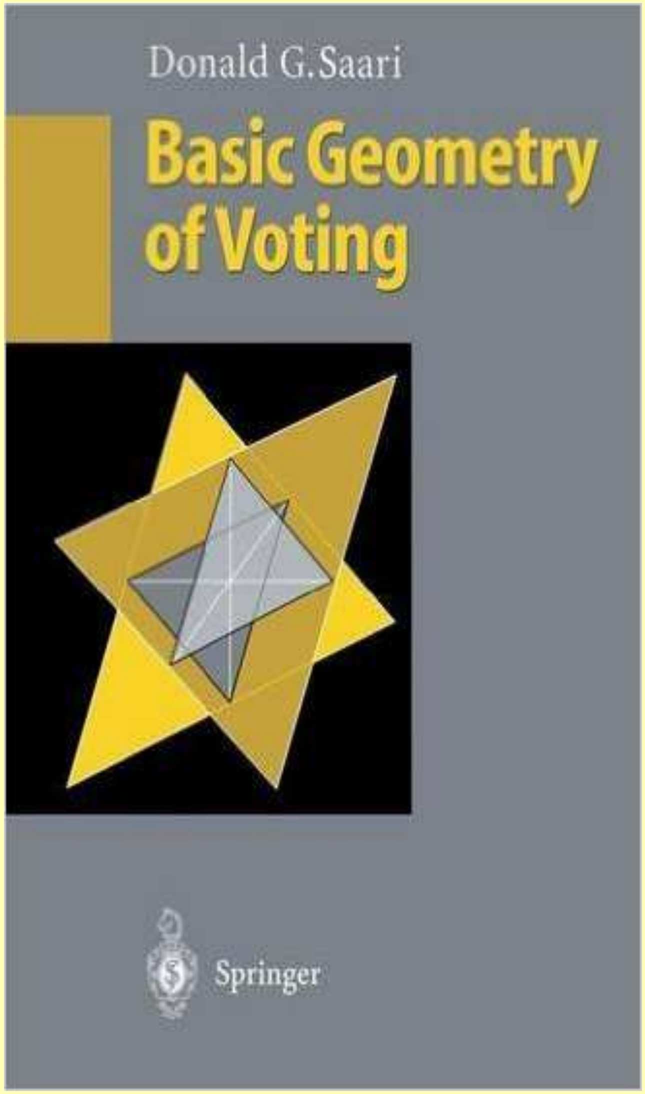
with Alessandro Tavoni and Maja Schlüter

http://geo.coop/node/654

Summary so far:

- Collective action can be effective if it includes enforcement
- Prosociality is an important contributor to the maintenance of public goods and common pool resources
- How are collective decisions made?

Voting theory and models of collective action



REPORTS

Uninformed Individuals Promote Democratic Consensus in Animal Groups

Iain D. Couzin,[1]* Christos C. Ioannou,[1]† Güven Demirel,[2] Thilo Gross,[2]‡ Colin J. Torney,[1] Andrew Hartnett,[1] Larissa Conradt,[3]§ Simon A. Levin,[1] Naomi E. Leonard[4]

Conflicting interests among group members are common when making collective decisions, yet failure to achieve consensus can be costly. Under these circumstances individuals may be susceptible to manipulation by a strongly opinionated, or extremist, minority. It has previously been argued, for humans and animals, that social groups containing individuals who are uninformed, or exhibit weak preferences, are particularly vulnerable to such manipulative agents. Here, we use theory and experiment to demonstrate that, for a wide range of conditions, a strongly opinionated minority can dictate group choice, but the presence of uninformed individuals spontaneously inhibits this process, returning control to the numerical majority. Our results emphasize the role of uninformed individuals in achieving democratic consensus amid internal group conflict and informational constraints.

Social organisms must often achieve a consensus to obtain the benefits of group living and to avoid the costs of indecision (*1–12*). In some societies, notably those of eu-

Consequently, for both human societies (*1*, *2*, *6*, *9*, *10*, *14*) and group-living animals (*6*, *13*), it has been argued that group decisions can be subject to manipulation by a self-interested

Science 2011

The dynamics of collective phenomena and collective decision-making

Claudio Carere
plus StarFLAG EU FP6 project

http://old.enciclopedia.com.pt/en/
articles.php?article_id=296

Role of leadership and collective decision-making

Couzin, Krause, Franks, Levin

Collective decision-making

1 informed individuals in group of 100.

Courtey Iain Couzin

Collective decision-making

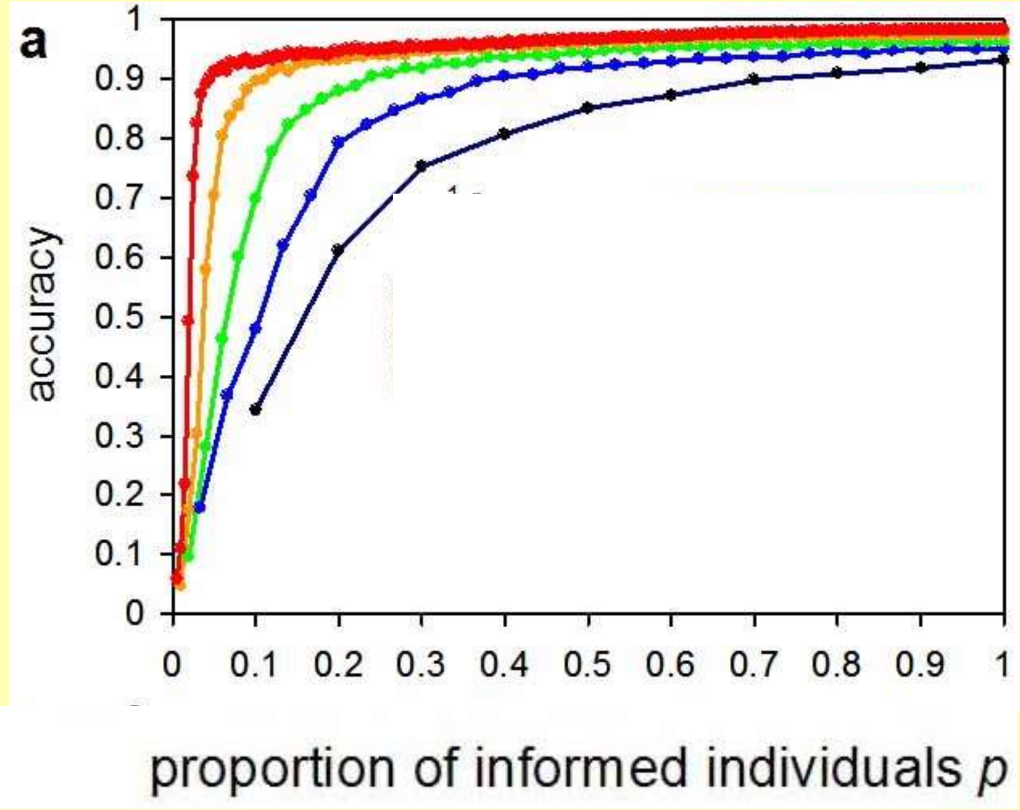
5 informed individuals in group of 100.

Courtey Iain Couzin

10 informed individuals in group of 100.

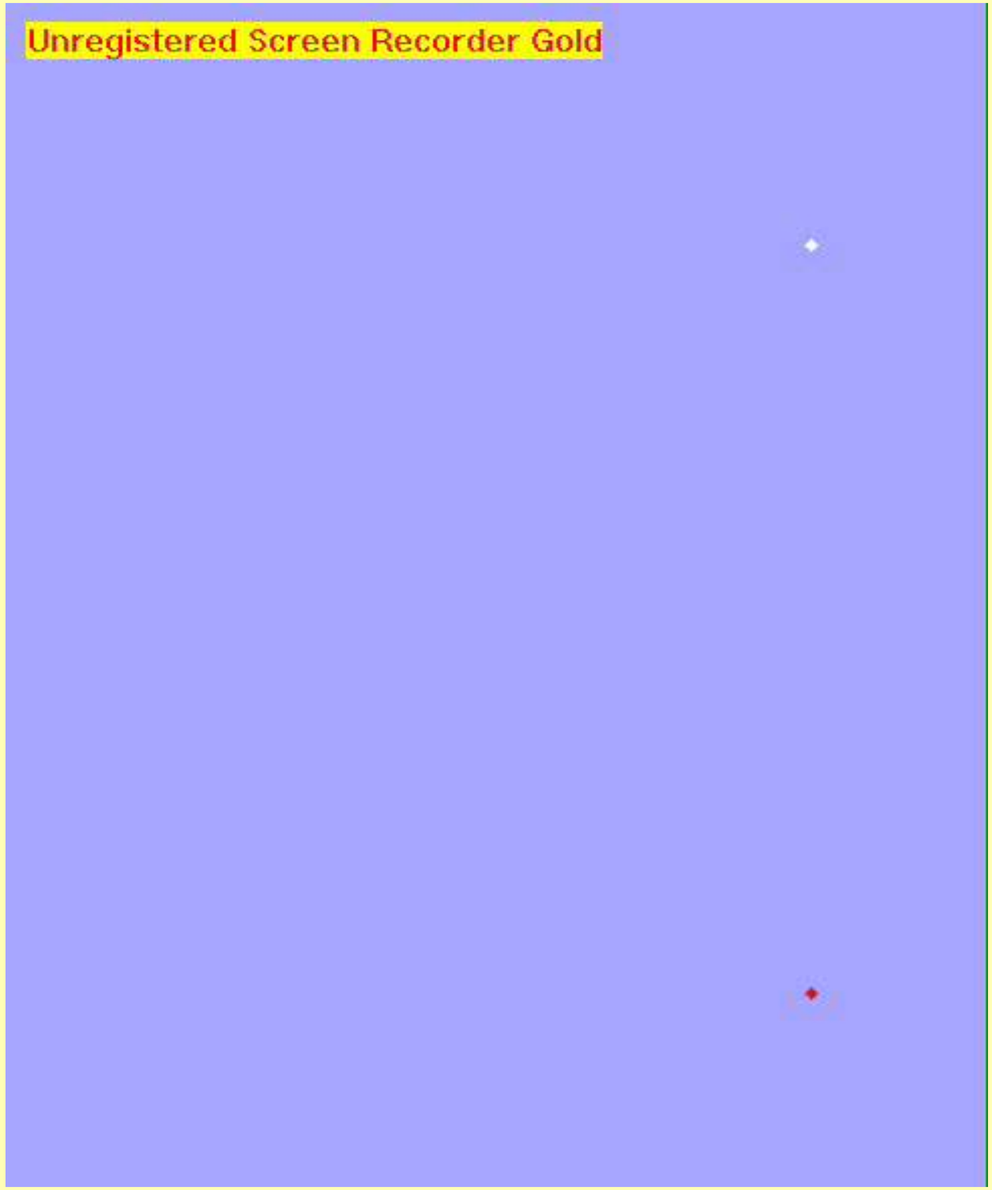
Courtey Iain Couzin

Animal groups may be led by a small number of individuals



From Couzin et al., 2005

Competition and consensus



Courtey Iain Couzin

Theoretically and empirically, unopinionated individuals are crucial to nature of consensus

http://motherjones.com/kevin-drum

Investigate from multiple angles

- Experimental studies with fish
- Simulation and analytical models of movement
- Models of human collective decision-making

REPORTS

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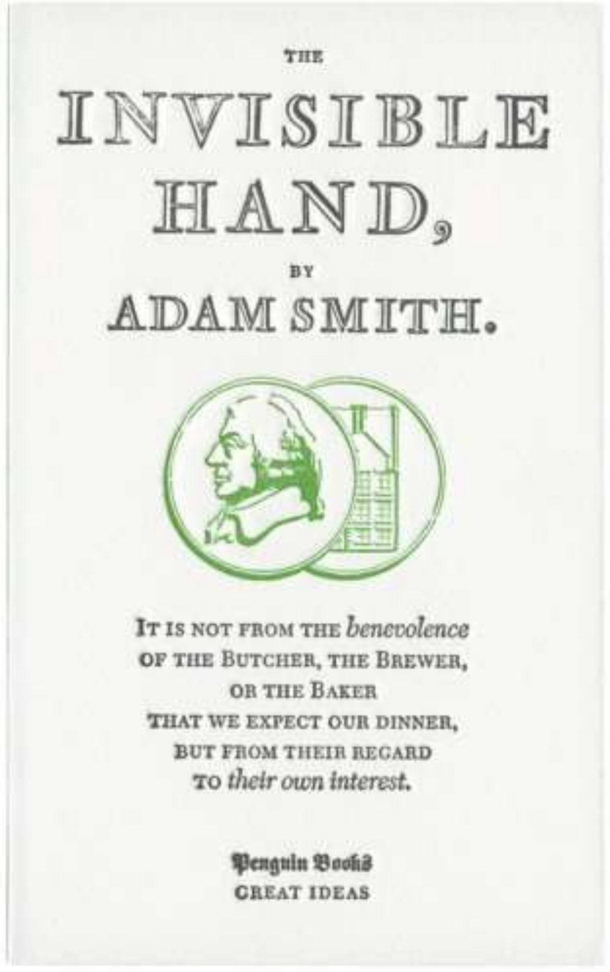
Attitudinal shifts affect action on issues like climate change

- In human societies as in animal groups, there may be few leaders and many followers
- Sudden shifts in attitudes given momentum by large numbers of followers (see also Lade et al.)
- Environmental action must take such potential volatility into account

Can cooperation be extended to the global level?

Adam Smith (1776)



"By pursuing his own interest he frequently promotes that of the society more effectually than when he really intends to promote it."

http://organizationsandmarkets.files.wordpress.com

The invisible hand does not protect society

Those lessons are magnified for ecological and environmental systems

There is no goddess Gaia merrymeet.today.com

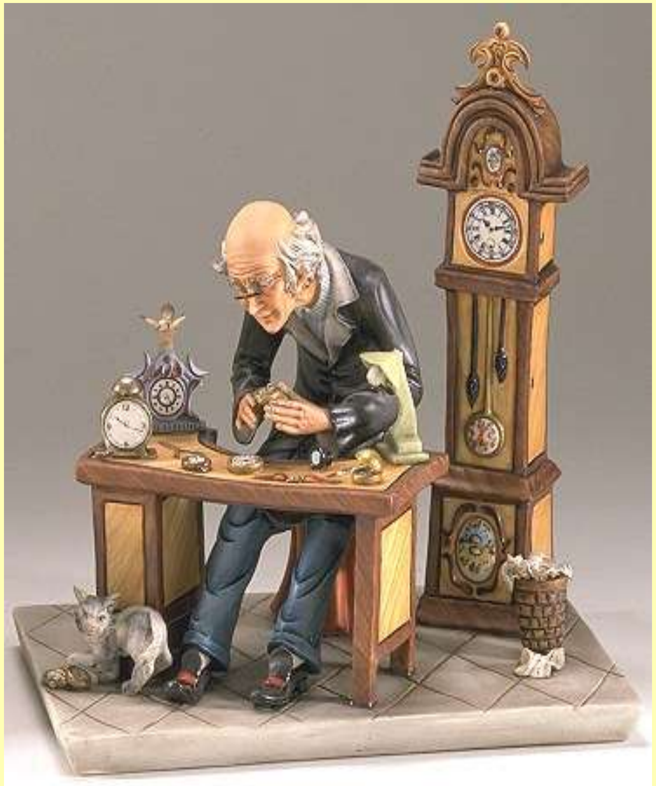
Finally

- Insurance arrangements
- Social norms
- Groups, modules and polycentricity

Groups

- Group structure creates modules for better cooperation
- Model for polycentricity and climate change

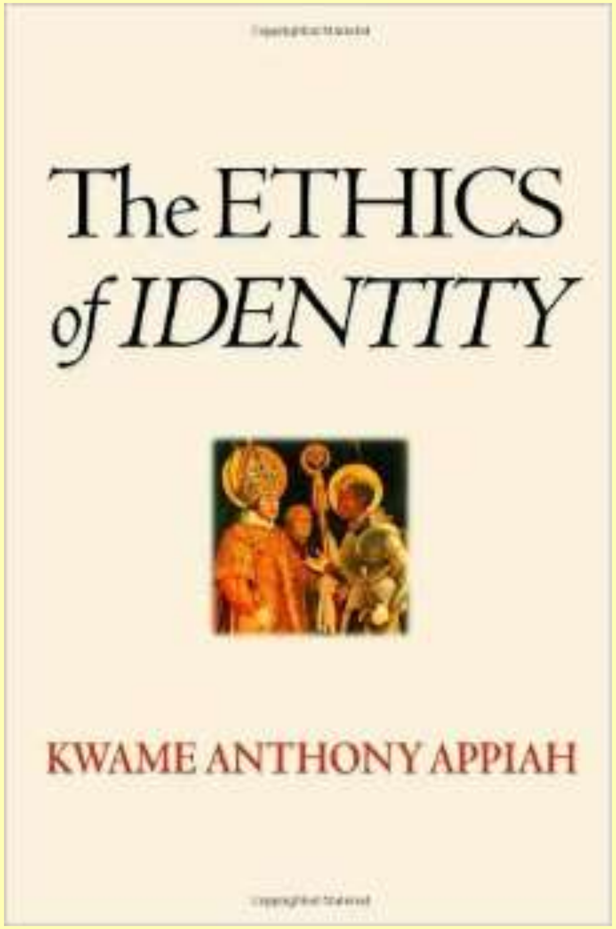
Herbert Simon: Modularity



kids4truth.com/watchmaker/watch.html

intart.org

Do systems "evolve" modularity?



From molecular to modular cell biology

Leland H. Hartwell, John J. Hopfield, Stanislas Leibler and Andrew W. Murray

NATURE
1999

Cellular functions, such as signal transmission, are carried out by 'modules' made up of many species of interacting molecules. Understanding how modules work has depended on combining phenomenological analysis with molecular studies. General principles that govern the structure and behaviour of modules may be discovered with help from synthetic sciences such as engineering and computer science, from stronger interactions between experiment and theory in cell biology, and from an appreciation of evolutionary constraints.

Although living systems obey the laws of physics and chemistry, the notion of function or purpose differentiates biology from other natural sciences. Organisms exist to reproduce, whereas, outside religious belief, rocks and stars have no purpose. Selection for function has produced the living cell, with a unique set of properties that distinguish it from inanimate systems of interacting molecules. Cells exist far from thermal equilibrium by harvesting energy from their environment. They are composed of thousands of different types of molecule. They contain information for their survival and reproduction, in the form of their DNA. Their interactions with the environment depend in a byzantine fashion on this information, and the information and the machinery that interprets it are replicated by reproducing the cell. How do these properties emerge from the interactions between the molecules that make up cells and how are they shaped by evolutionary competition with other cells?

Much of twentieth-century biology has been an attempt to reduce biological phenomena to the behaviour of molecules. This approach is particularly clear in genetics, which began as an investigation into the inheritance of variation, such as differences in the colour of pea seeds and fly eyes. From these studies, geneticists inferred the exis-

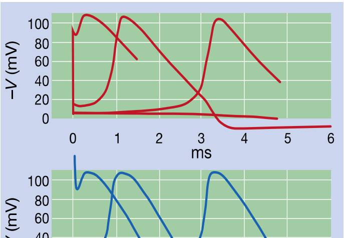
many components. For example, in the signal transduction system in yeast that converts the detection of a pheromone into the act of mating, there is no single protein responsible for amplifying the input signal provided by the pheromone molecule.

To describe biological functions, we need a vocabulary that contains concepts such as amplification, adaptation, robustness, insulation, error correction and coincidence detection. For example, to decipher how the binding of a few molecules of an attractant to receptors on the surface of a bacterium can make the bacterium move towards the attractant (chemotaxis) will require understanding how cells robustly detect and amplify signals in a noisy environment. Having described such concepts, we need to explain how they arise from interactions among components in the cell.

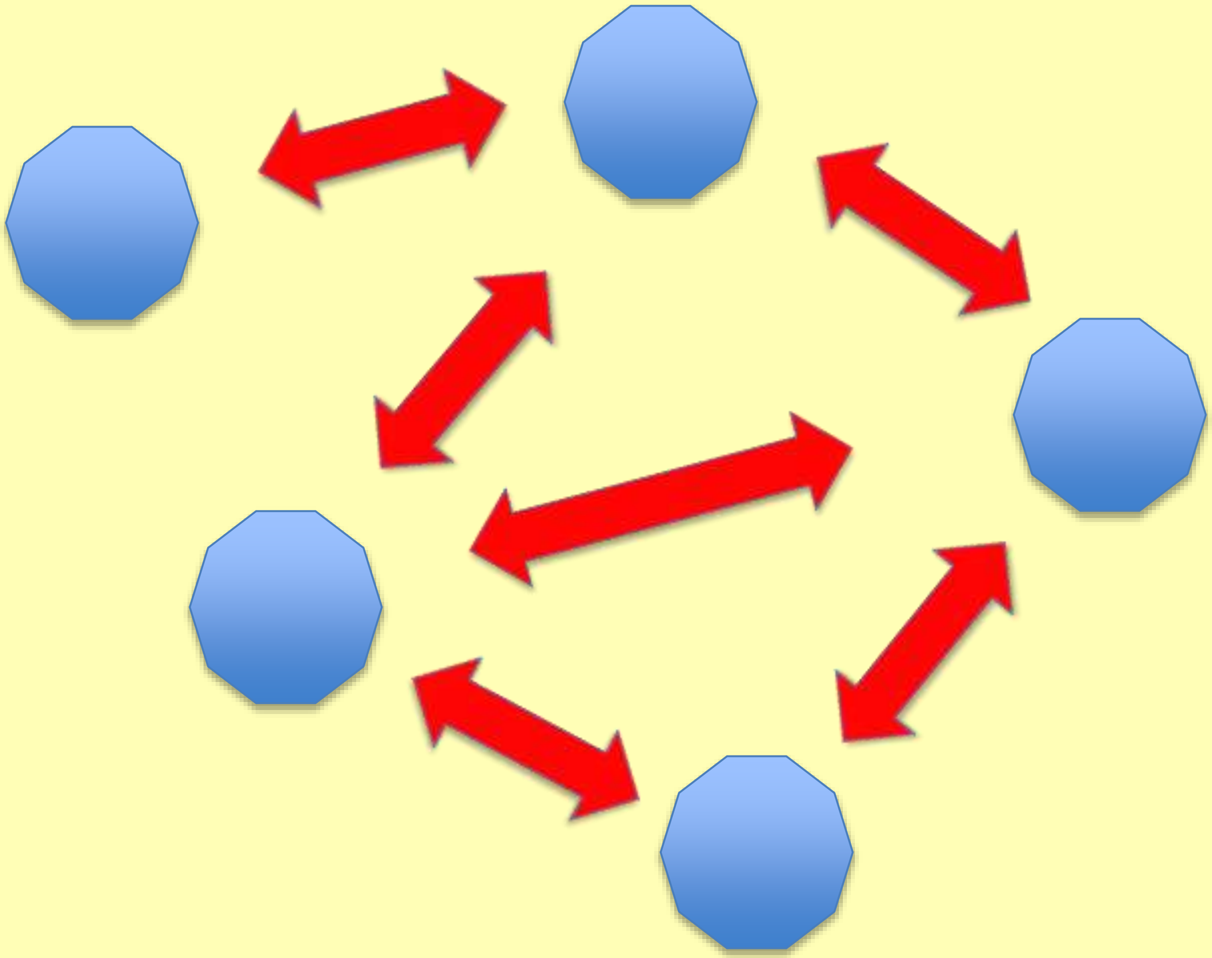
We argue here for the recognition of functional 'modules' as a critical level of biological organization. Modules are composed of many types of molecule. They have discrete functions that arise from interactions among their components (proteins, DNA, RNA and small molecules), but these functions cannot easily be predicted by studying the properties of the isolated components. We believe that general 'design principles' — profoundly shaped by the constraints of evolution — govern the structure and function of modules. Finally, the notion of function and functional properties separates biology

Box 1 Phenomenological analysis of action potentials in nerve cells

Action potentials are large, brief, highly nonlinear pulses of cell electrical potential which are central to communication between nerve cells. Hodgkin and Huxley's analysis of action potentials[29] exemplifies understanding through *in silico* reconstruction. They studied the dynamical behaviour of the voltage-dependent conductivity of a nerve cell membrane for Na^+ and K^+ ions, and described this behaviour in a set of empirically based equations. At the time,



Dixit-Levin
Contributions to public goods
Multiple groups



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Ostrom: Climate change

A Polycentric Approach for Coping with Climate Change

Elinor Ostrom

Indiana University

This paper proposes an alternative approach to addressing the complex problems of climate change caused by greenhouse gas emissions. The author, who won the 2009 Nobel Prize in Economic Sciences, argues that single policies adopted only at a global scale are unlikely to generate sufficient trust among citizens and firms so that collective action can take place in a comprehensive and transparent manner that will effectively reduce global warming. Furthermore, simply recommending a single governmental unit to solve global collective action problems is inherently weak because of free-rider problems. For example, the Carbon Development Mechanism (CDM) can be 'gamed' in

American Economic Review 2015, 105(4): 1339–1370
http://dx.doi.org/10.1257/aer.15000001

Climate Clubs: Overcoming Free-riding in International Climate Policy†

By William Nordhaus*

Notwithstanding great progress in scientific and economic understanding of climate change, it has proven difficult to forge international agreements because of free-riding, as seen in the defunct Kyoto Protocol. This study examines the club as a model for international climate policy. Based on economic theory and empirical modeling, it finds that without sanctions against non-participants there are no stable coalitions other than those with minimal abatement. By contrast, a regime with small trade penalties on non-participants, a Climate Club, can induce a large stable coalition with high levels of

Incomplete cooperation and co-benefits: Deepening climate cooperation with a proliferation of small agreements

Phillip M. Hannam[a,1], Vítor V. Vasconcelos[b,c,d], Simon A. Levin[d,e,f], Jorge M. Pacheco[g,b,h]

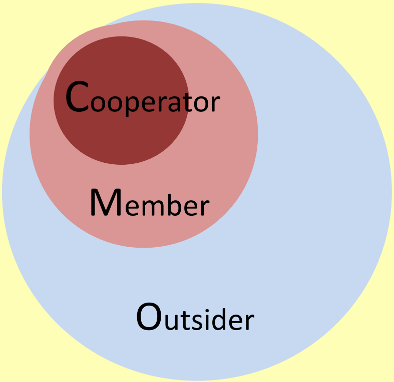
In press, Climatic Change

www.princeton.edu

https://pt.linkedin.com

http://www.cienciahoje.pt

Club approach



- Cooperators C (pay base +mitigation)
- Members M (pay base)
- Outsiders O (pay nothing)
- P=excludable share of public good that C produce (club good)
- χ=bonus portion of remainder available to members

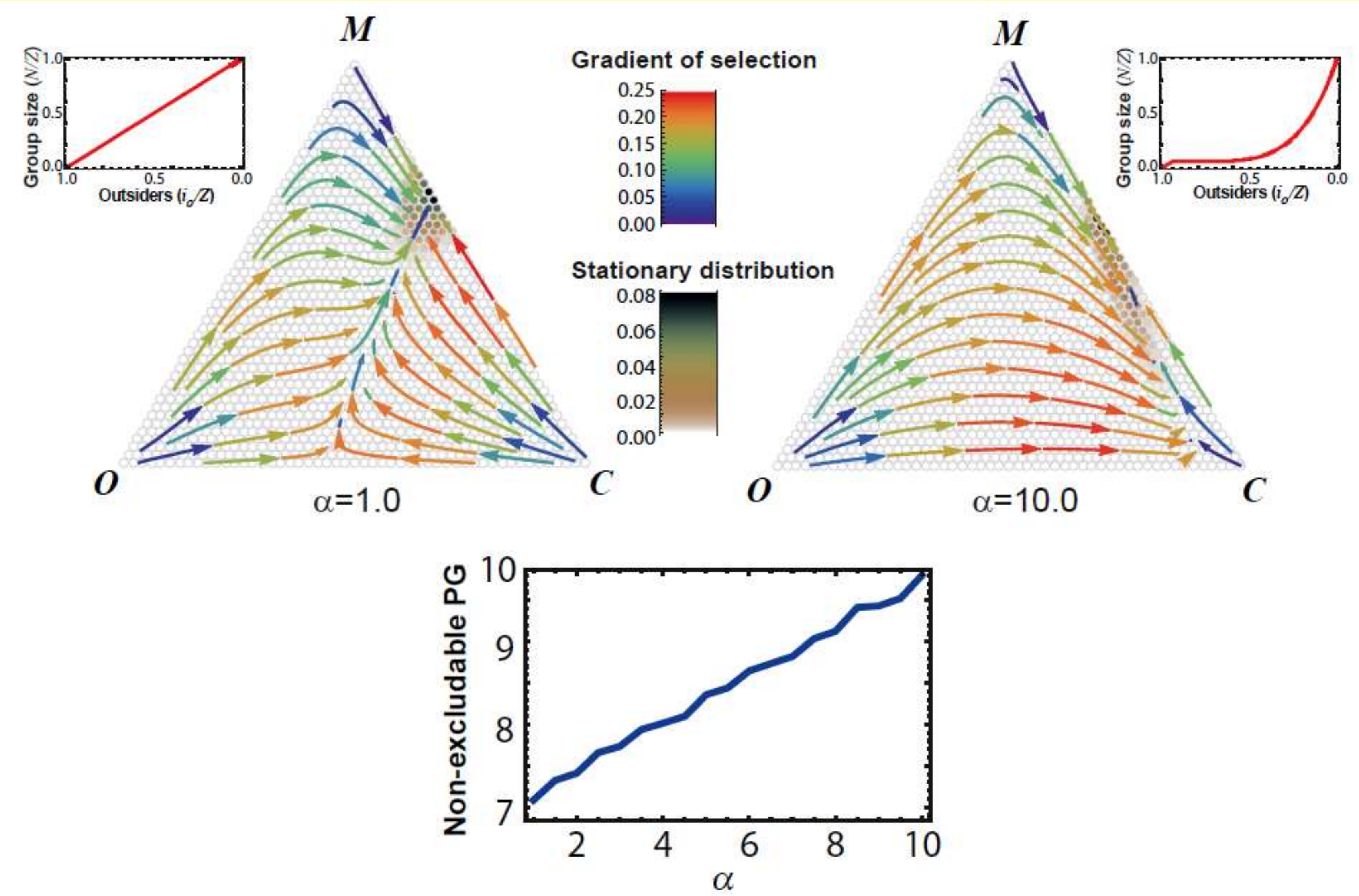


Figure 3: The public goods benefits of club size. Constraining the size of overlapping clubs increases the non-excludable public good produced within each. The top panels show the dynamics of the population. The arrows indicate the most probable direction of evolution at any given configuration, $\mathbf{i} = (i_C, i_M)$, known as the gradient of selection; the dots represent the

Managing the Commons is both an environmental and an evolutionary challenge

- In human societies: mutual coercion, mutually agreed upon
- Users self-organize, to develop norms and institutions, design sanctions (Ostrom 1990)
- To establish and maintain cooperation, i.e. individual restraint from short-sighted resource overexploitation

Ecological systems and socio-economic systems alike are complex adaptive systems

http://www.latinamericanstudies.org/maya

Interplay between

- Top-down mechanisms, like rewards and punishments
- Bottom-up mechanisms, like evolved prosociality and collective action
- This duality must inform the management of public goods and common-pool resources

Conclusions

- Public goods and common pool resource problems represent fundamental challenges in economics and in evolutionary biology
- Collective action can emerge from local interactions
- Multiple scales: Collective decisions can impose "mutual coercion, mutually agreed upon"
- Linking these is key to understanding the management of the Commons

Can cooperation be extended to the global level?

http://www.c2es.org/international/2015-agreement

Emergence of cooperation within groups is often for the benefit of conflict with *other* groups

http://www.twcenter.net/forums/showthread.
php?284308-RTR-AAR-Alexander-Reborn-A-Makedonian-AAR

In the global commons, there is no "other"

Walt Kelly

Understanding how to achieve international cooperation is at the core of achieving sustainability in dealing with our common enemy: environmental degradation

…so that we can achieve a sustainable future for our children and grandchildren

Thank you

Carole Levin