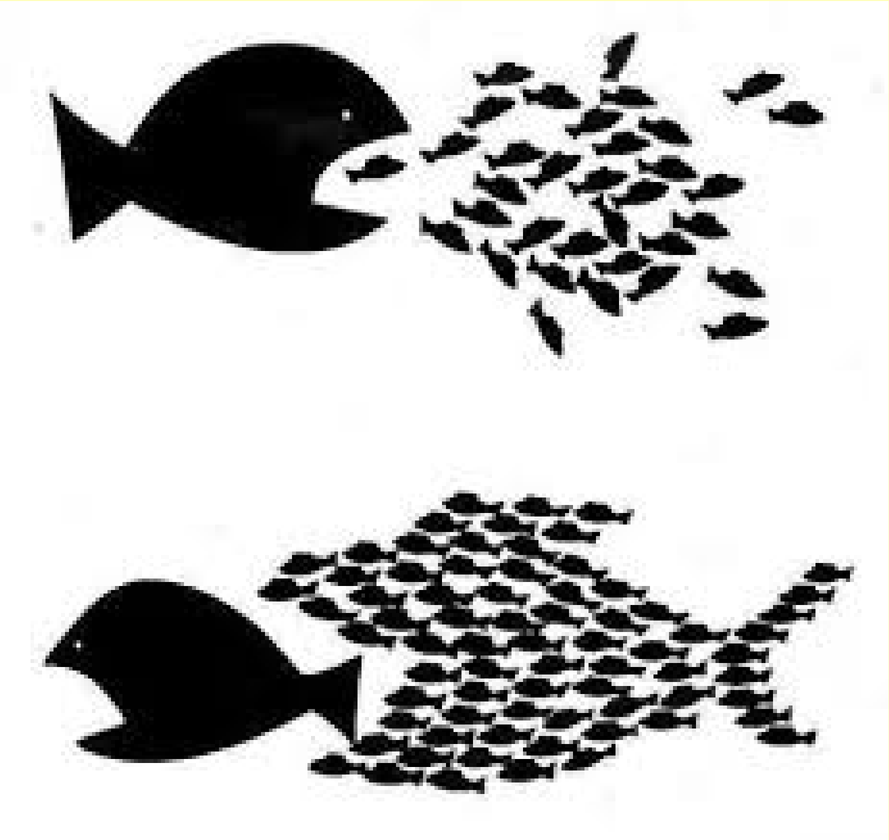
Dealing with public goods and common-pool resources in marine ecosystems



http://www.denizsozluk.com

Simon Levin

Brest2016

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

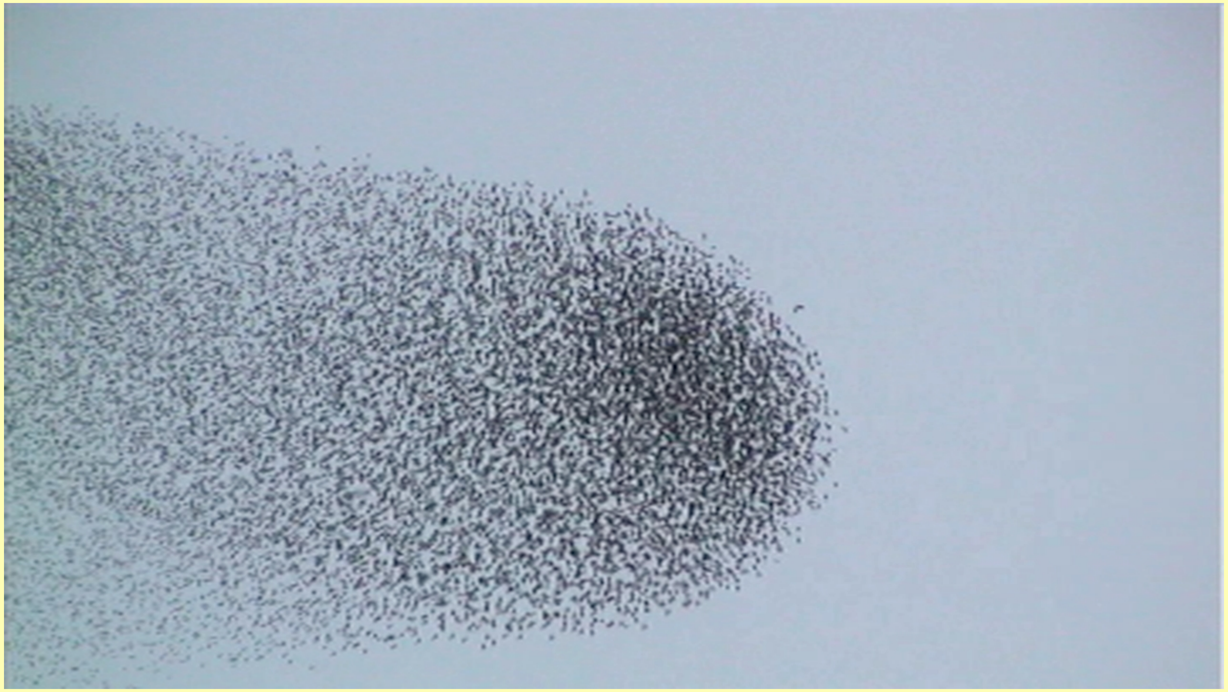
U.S. DEPARTMENT OF HOMELAND SECURITY

THE ANDREW W. MELLON FOUNDATION

John Templeton Foundation

norden
NordForsk

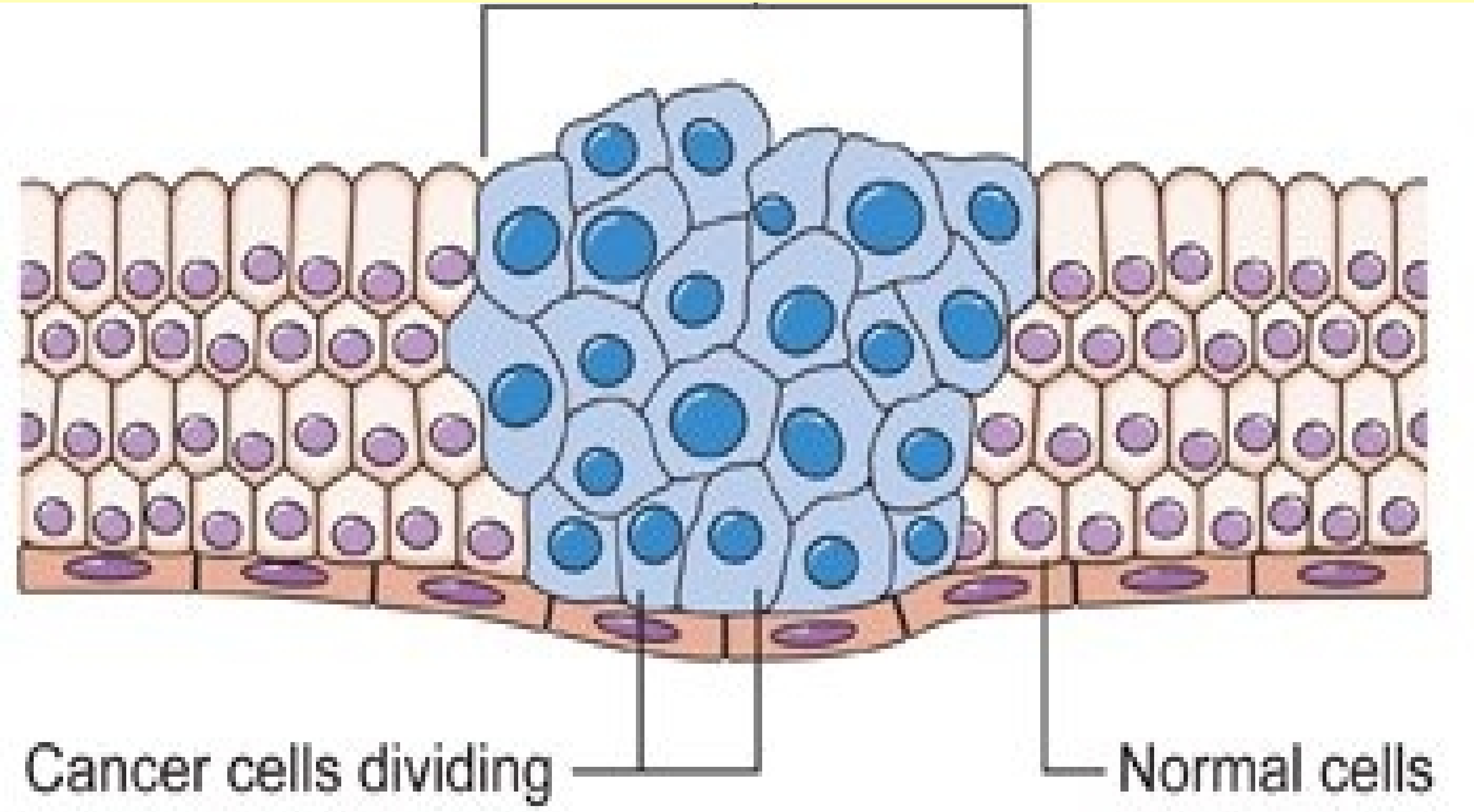
From microbial systems to socioeconomic systems, macroscopic patterns *emerge* from microscopic interactions



Claudo Carere
StarFLAG EU FP6 project

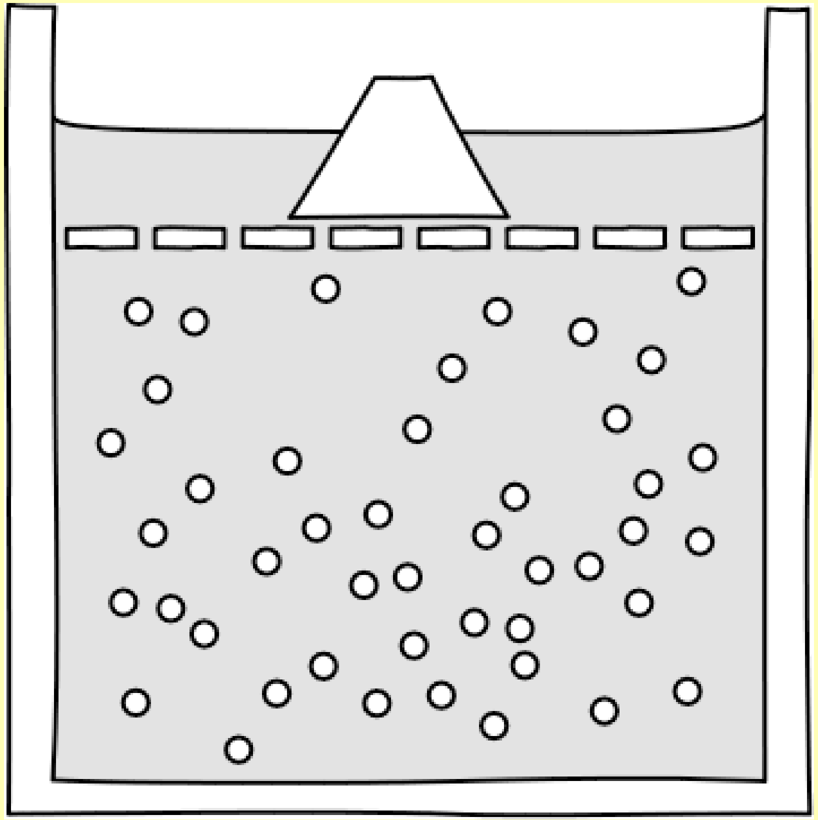
Just as collective actions arise from individual behaviors in human societies

This inescapably leads to conflicts between levels



http://www.cancerresearchuk.org/

And to the need for scaling, from individuals to ensembles



www.pitt.edu/~jdnorton

Lecture outline

- Conflict and public goods
- Scaling from microscopic to macroscopic
- Managing complex adaptive systems

Public goods problems are widespread in socio-economic and biological contexts

mashriqq.com/?p=1081

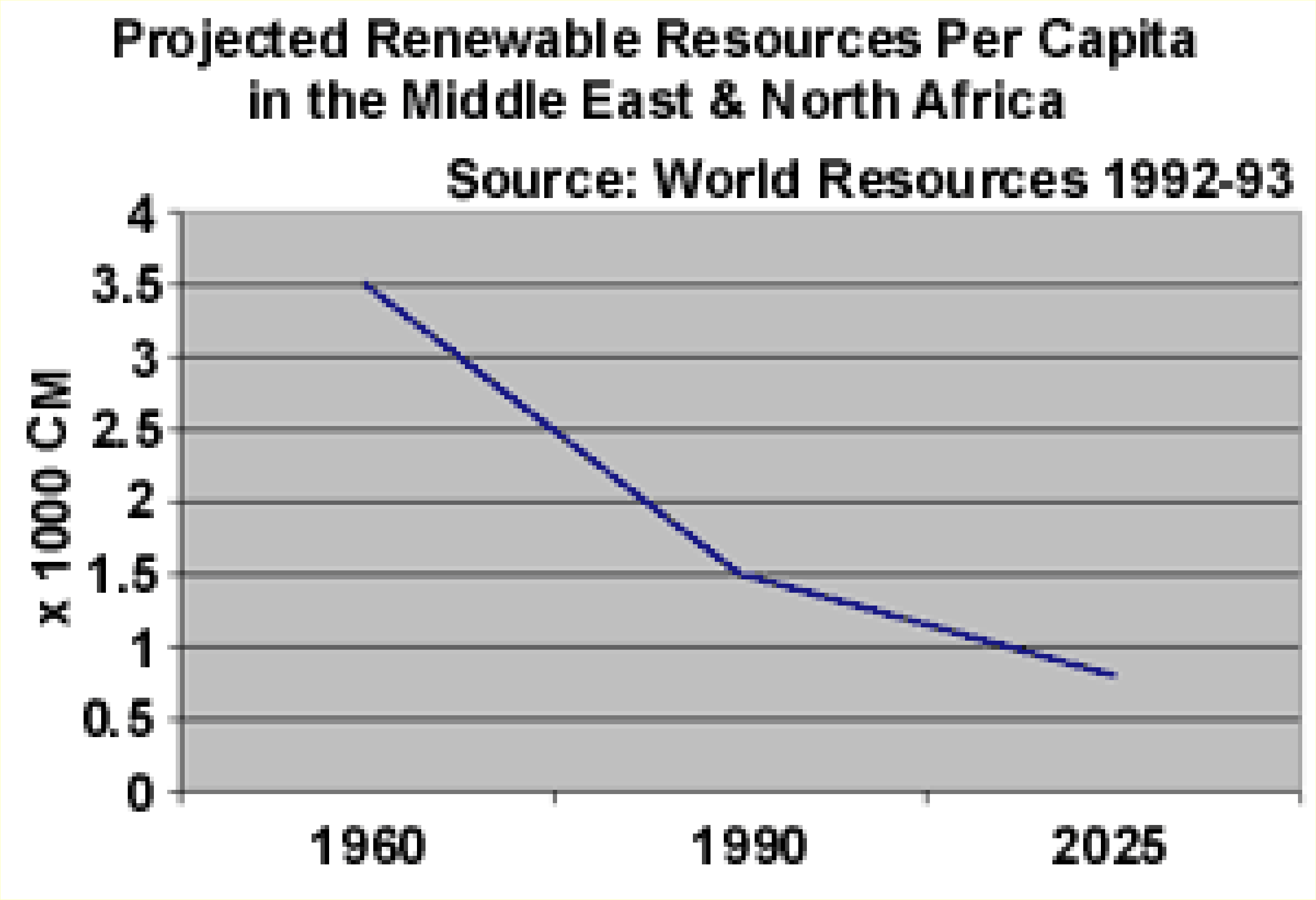
Carole Levin

This distinguishes them technically from common-pool resources

http://en.wikipedia.org/wiki/File:Traditional_fishery.JPG#file

- But for this lecture, I will lump them together

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

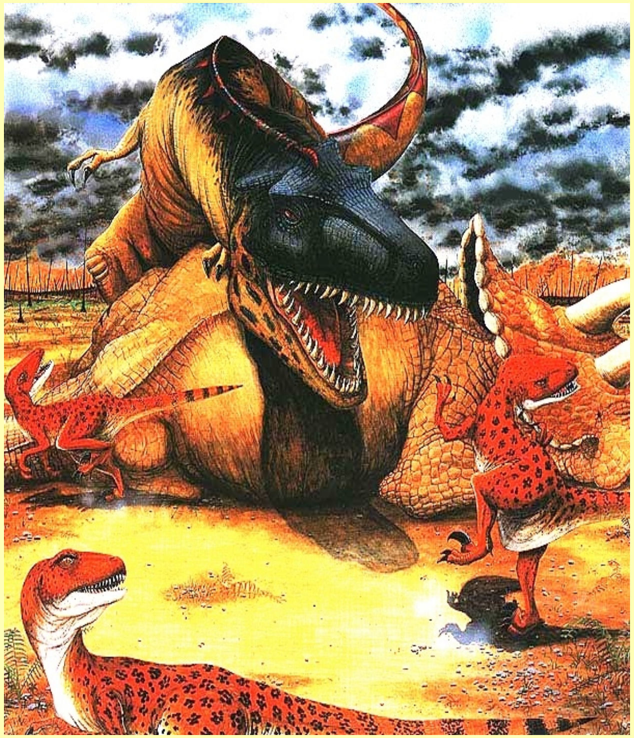
We discount

- The future
- The interests of others

info.acoustiblok.com

Moreover, we live in a global commons, in which

- Individual agents act largely in their own self-interest

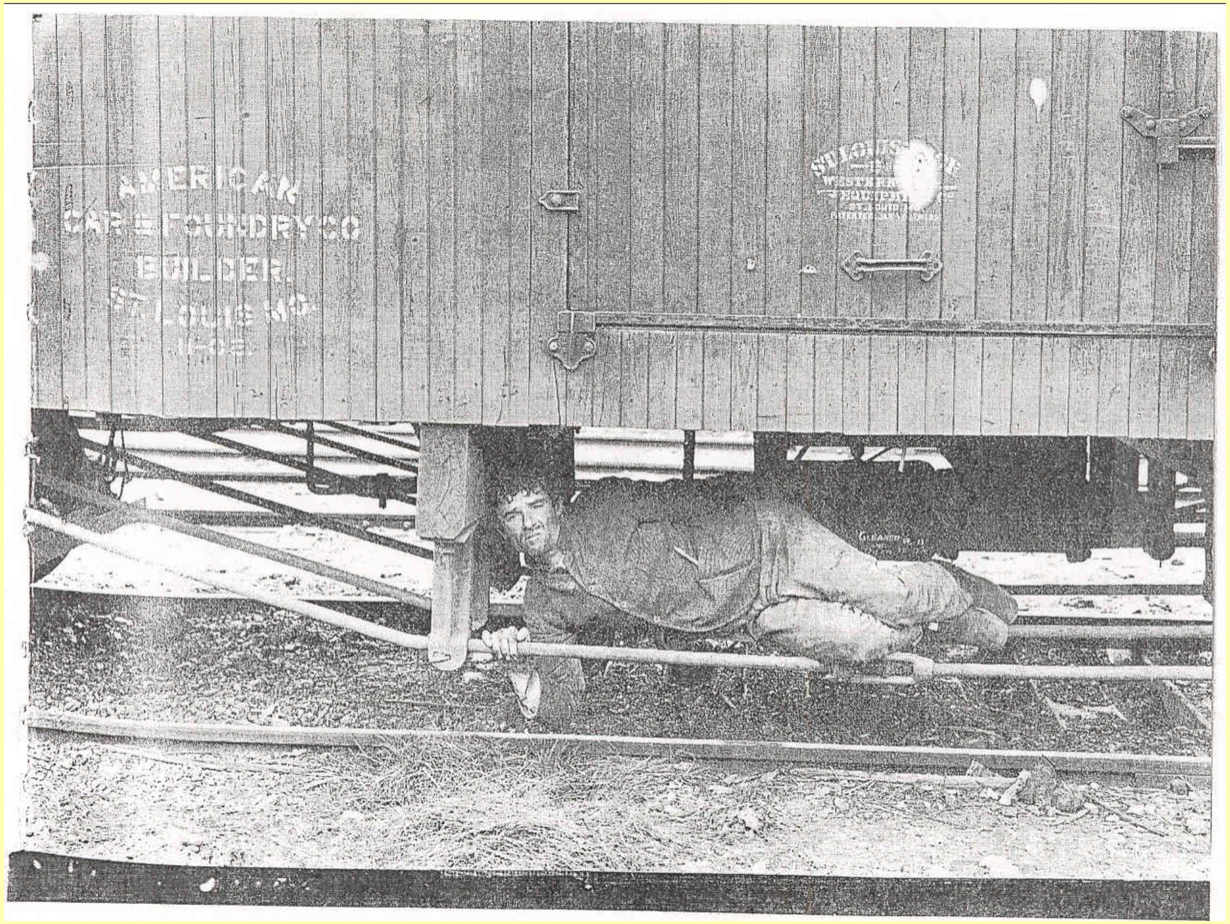


www.centerstage-musicals.com

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



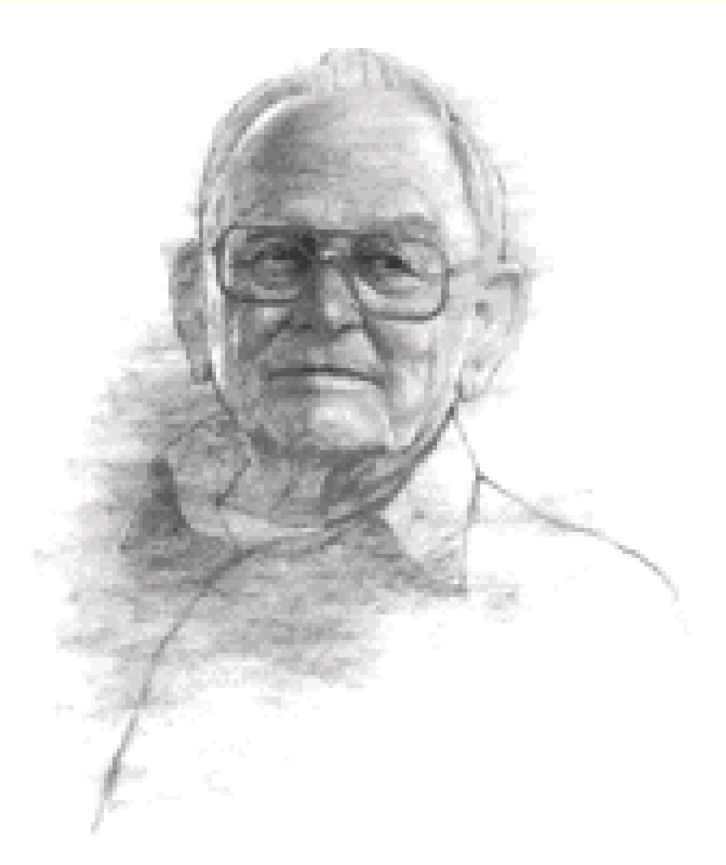
www.americanpopularculture.com

Overuse of the Commons

William Forster Lloyd (1832)

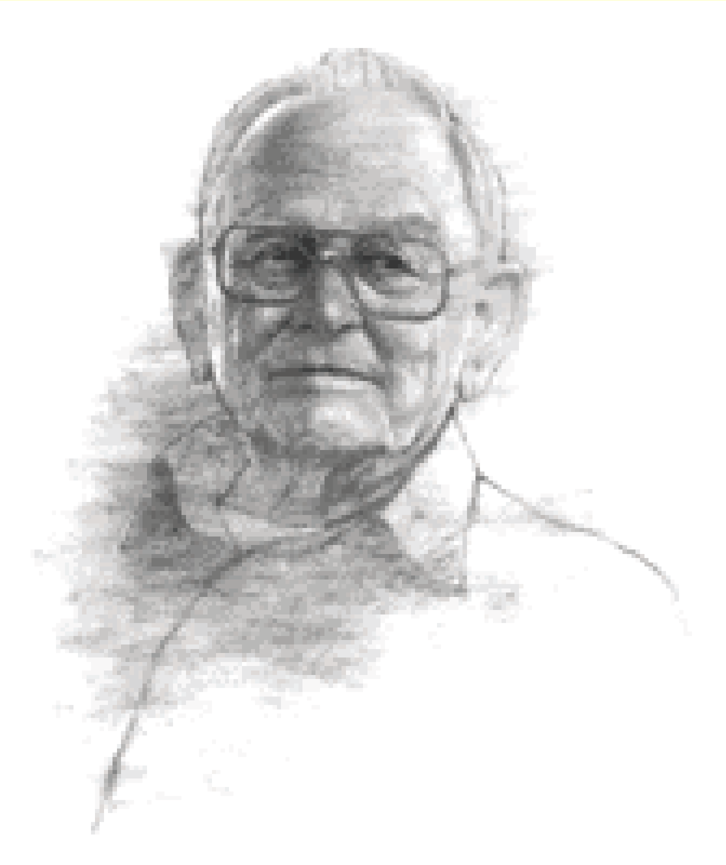
Aelbert_Cuyp

The tragedy of the (unregulated) Commons



Garrett Hardin

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

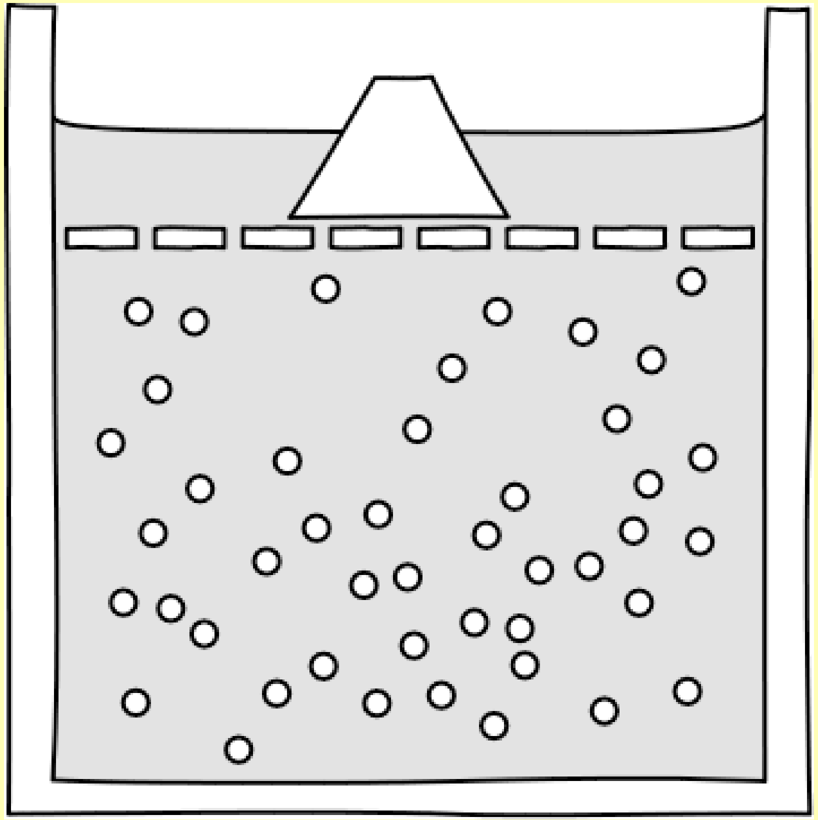
Lin Ostrom

Solutions to the commons problem requires interfacing individual incentives with systemic outcomes

http://www.philosophyofmoney.net/interdependence/

Lecture outline

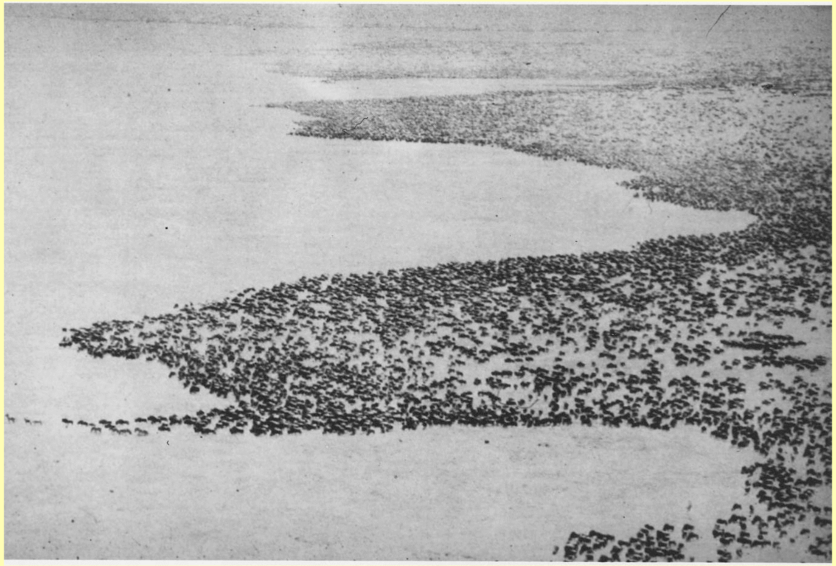
- Conflict and public goods
- Scaling from microscopic to macroscopic



www.pitt.edu/~jdnorton

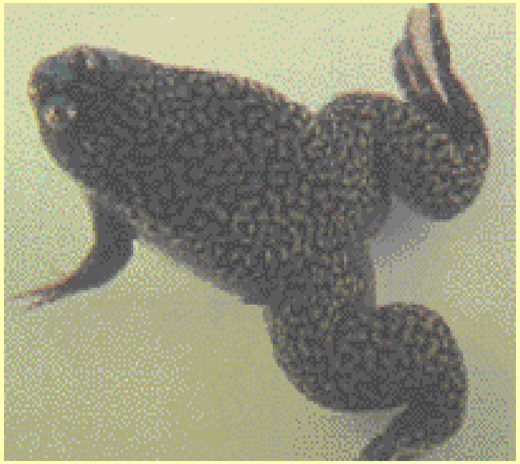
Problems of pattern formation exist for a wide range of organisms

- Bacteria
- Slime molds
- Insects
- Krill
- Birds
- Fish
- Ungulates



Aerial photograph of a large wildebeest herd, courtesy A.R.E. Sinclair (plate 3 from A.R.E. Sinclair, *The African Buffalo*).

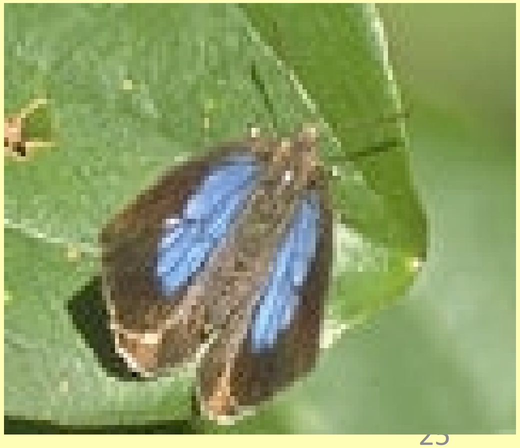
In development, highly differentiated structures self-organize from initially homogenous ensembles…multiple bifurcations must occur



http://worms.zoology.wisc.edu/frogs/mainme

Alan Turing (1912-1954)

Alan Turing posited the existence of two interacting chemicals (morphogens) in a homogeneous space



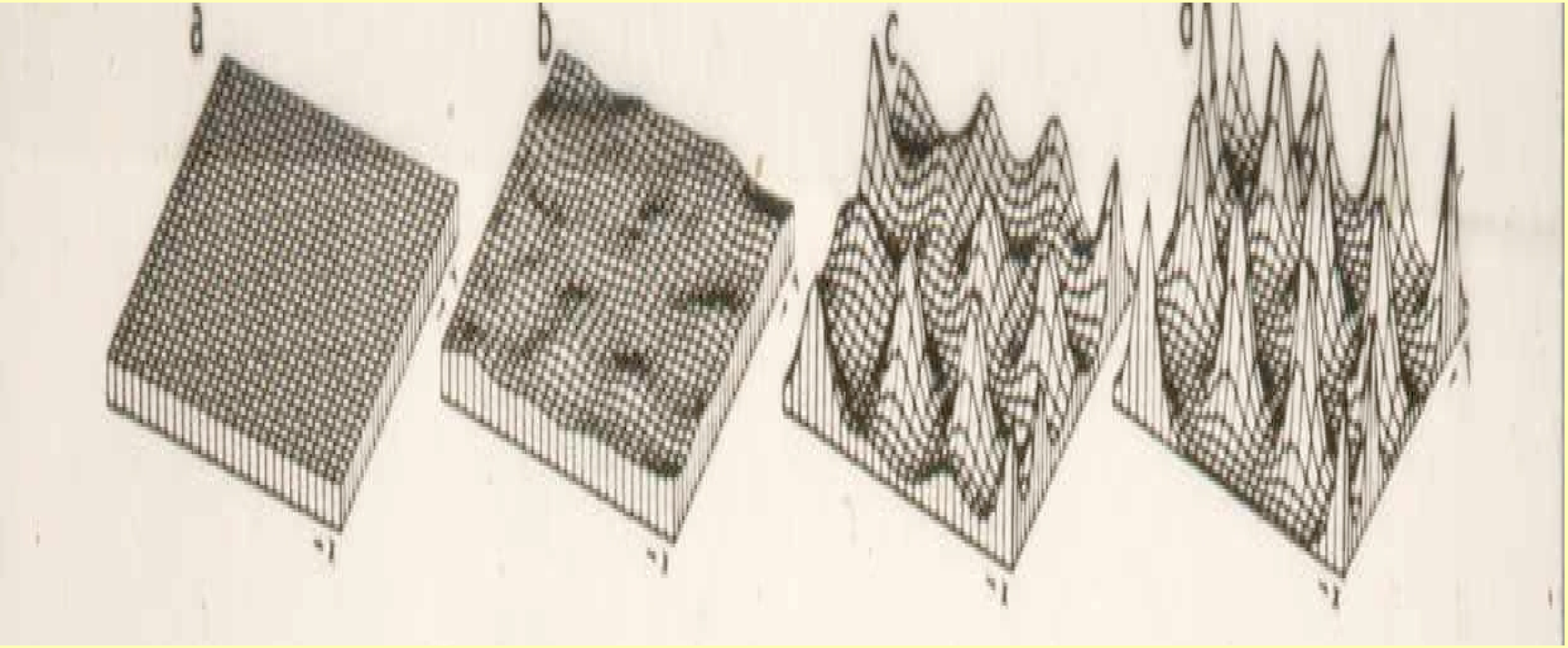
Turing instabilities:

$$\frac{\partial u}{\partial t} = F(u,v) + D_u \nabla^2 u$$

$$\frac{\partial v}{\partial t} = G(u,v) + D_v \nabla^2 v$$

uniform states can become unstable if *Dv/Du* is above some threshold.

Dissipative structures

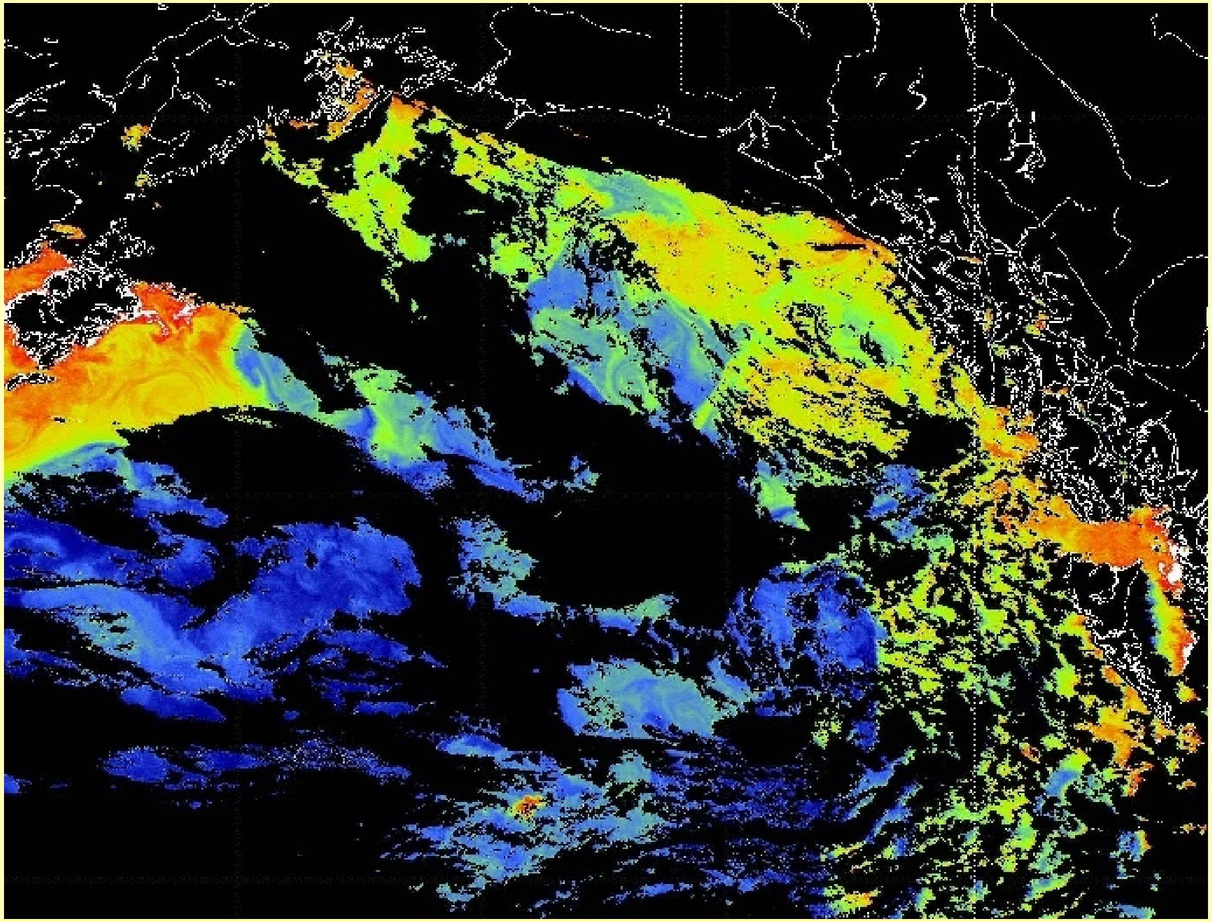


Meinhardt

Do such mechanisms underlie spatial patterns in ecology?

arts.monash.edu.au/ges/staff/ddunkerley

Plankton are patchy on almost every scale

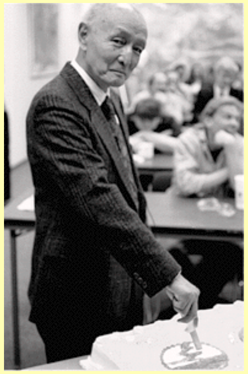


disc.sci.gsfc.nasa.gov

Could Turing apply to planktonic patchiness?

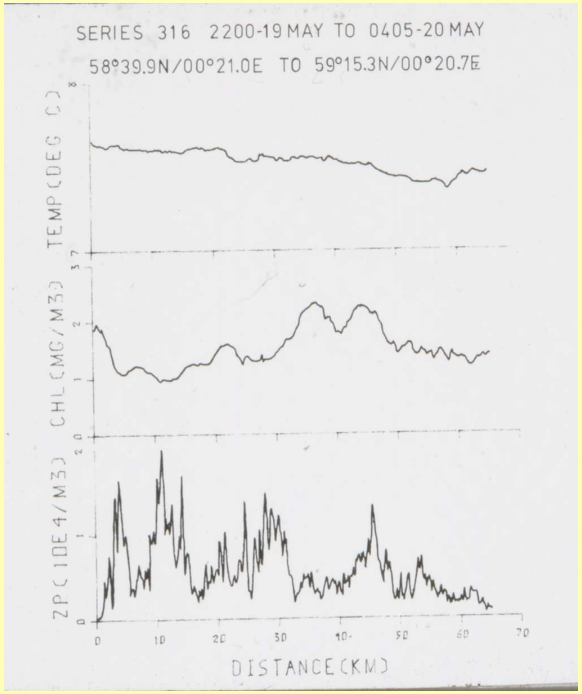
- Phytoplankton as "activators"
- Zooplankton as "inhibitors"

- Both Levin and Segel, and Okubo, independently proposed this



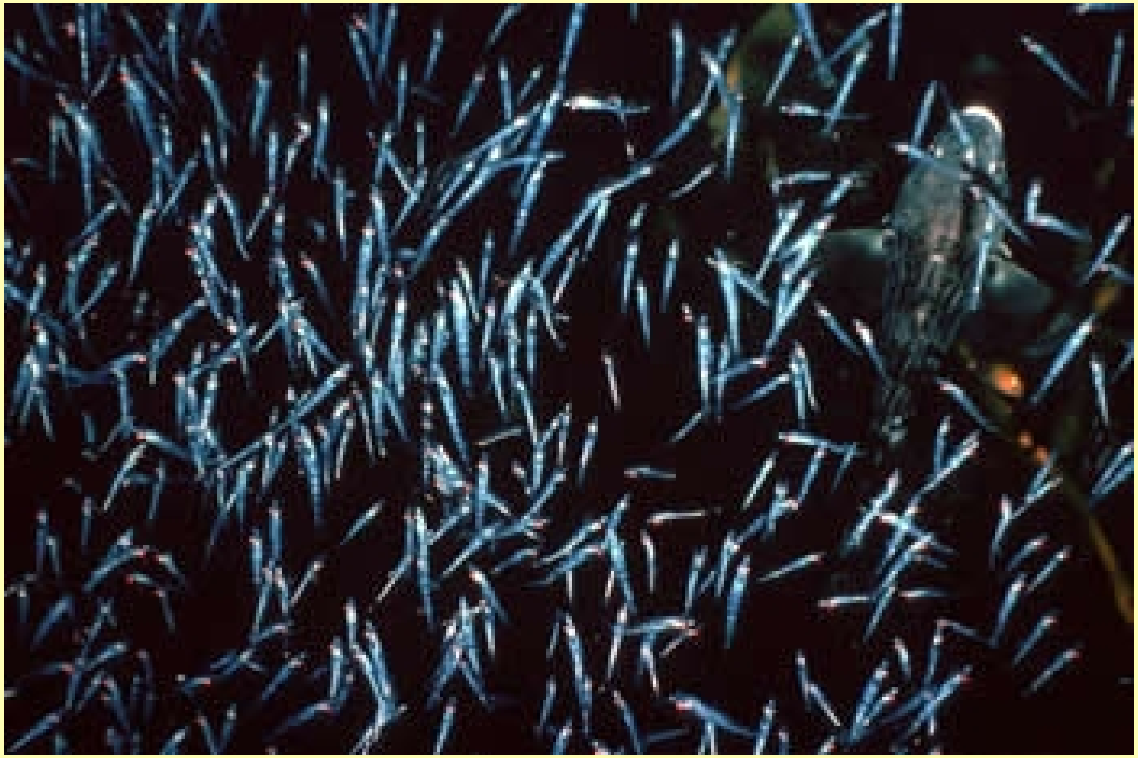
Turing mechanism didn’t work

Zooplankton are more patchily distributed



Mackas et al

Zooplankton don't move randomly, but aggregate



www2.le.ac.uk

Lagrangian-Eulerian connections

- Begin from microscopic (Lagrangian) rules

$$m\ddot{x} = F_1 + F_2 + F_3 + F_4$$

Random Directed Grouping Arrayal

If closures are good, such approximations work well

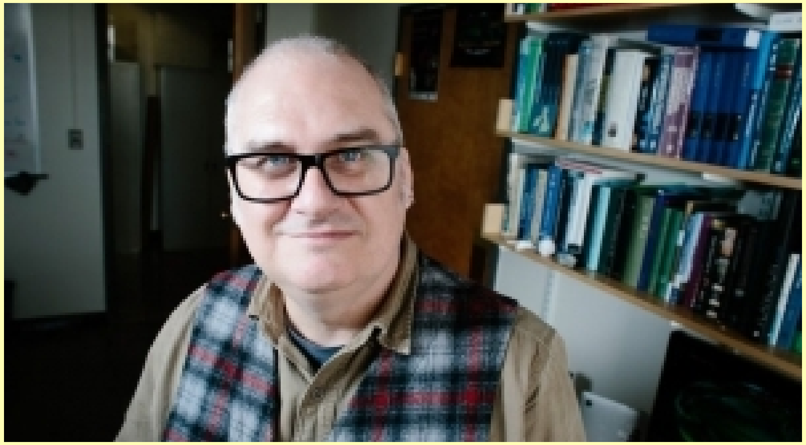
Flierl et al., JTB 1999

Otherwise, equation-free methods (Kevrekidis)

But real aggregations are heterogeneous assemblages of individuals

Will return to this problem later

Scaling to the ecosystem level (still without fish)



Science.mit.edu

Mick Follows

chisholmleb.mit.edu

Penny Chisholm

Ocean dynamics: The MIT-DARWIN Model

u and **K** from ECCO2 GCM — Phyto growth — Remineralization & other sources

$$\frac{\partial N_i}{\partial t} = -\nabla \cdot (\mathbf{u}\, N_i) + \nabla \cdot (K\, \nabla N_i) - \sum_j \mu_j P_j R_{ij} + S_{N_i}$$

Growth — Mortality — Grazing — Sinkin
g

$$\frac{\partial P_j}{\partial t} = -\nabla \cdot (\mathbf{u} P_j) + \nabla \cdot (K \nabla P_j) + \mu_j P_j - m_j^P P_j - \sum_k g_{jk} \frac{P_j Z_{k,i=1}}{P_j + k_j^P} - \frac{w_j^P \partial P_j}{\partial z}$$

$$\frac{\partial Z_{ki}}{\partial t} = -\nabla \cdot (\mathbf{u}\, Z_{ki}) + \nabla \cdot (K\, \nabla Z_{ki}) - m_k^Z Z_{ki} + \sum_k g_{jk} \frac{P_j R_{ij}}{P_j + k_j^P}$$

N/P/Z= nutrients/phytoplankton/zooplankton

C Wunsch & P Heimbach, *Physica D* **230**,197 (2007) MJ Follows *et al*, *Science* **315**, 1843 (2007)

Ecotypes, not species, are predictable

Follows, Dutkiewicz, Chisholm,

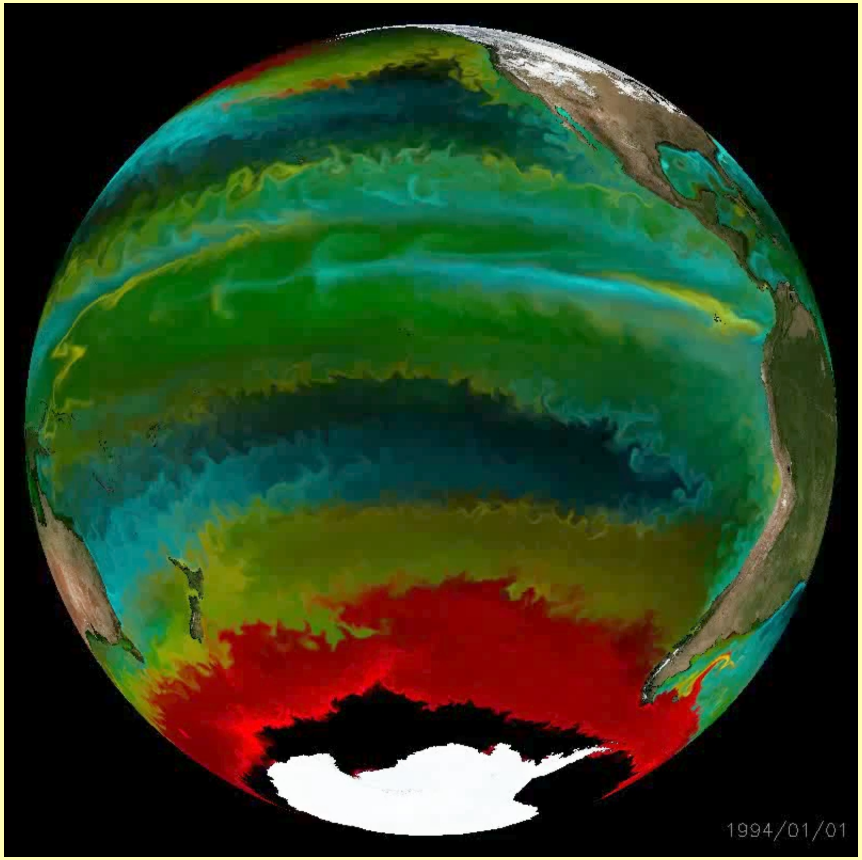
…

Prochlorococcus

Synechococcus

Diatoms

Large eukaryotes



Courtesy Follows and Dutkiewicz

Trait-based approaches

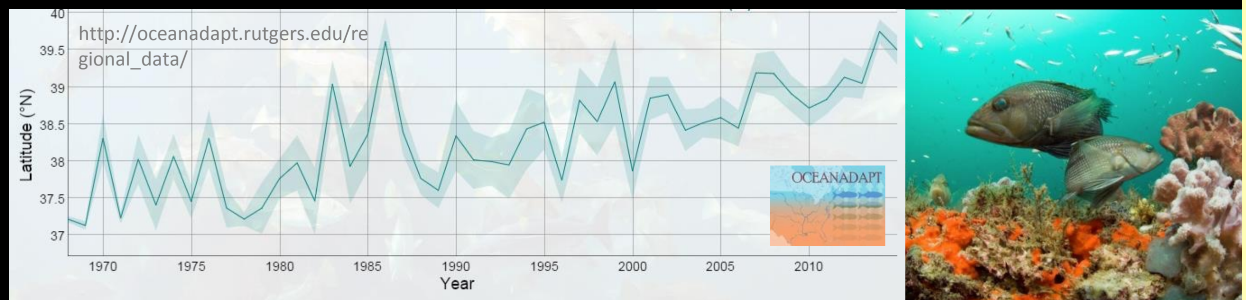
October 5-8, 2015
Waterville Valley, NH, USA

hors and Meeting Conveners: Andrew Barton (Princeton University, NOAA Geophysical amics Laboratory) and Stephanie Dutkiewicz (Massachusetts Institute of Technology)

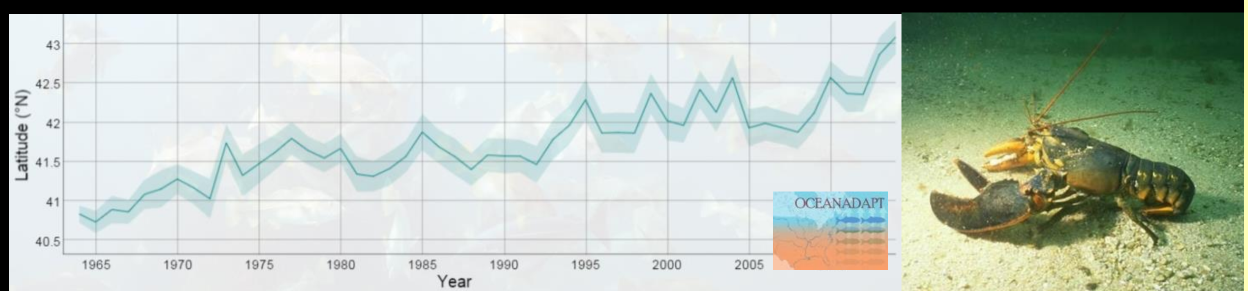
ommittee: Ken H. Andersen (Technical University of Denmark), Øyvind Fiksen (University), Mick Follows (Massachusetts Institute of Technology), Colleen Mouw (Michigan gical University), Nick Record (Bigelow Laboratory for Ocean Sciences), Tatiana (University of Rhode Island)

ay 2016

The human dimension:
As fish populations shift, so do fisheries…can we predict?



Black sea bass
and Lobster are also moving poleward



Pinsky et al. 2013 *Science*; http://oceanadapt.rutgers.edu/regional_data/

Courtesy Jane Lubchenco

NATURE CLIMATE CHANGE | PERSPECTIVE

Wealth reallocation and sustainability under climate change

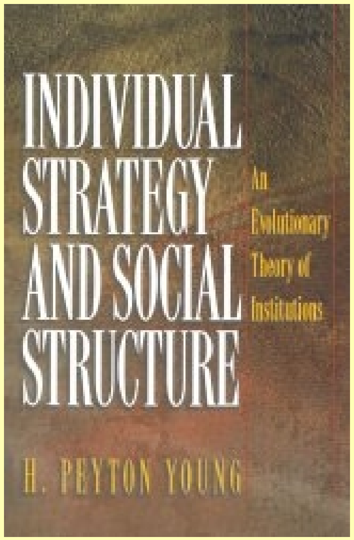
Eli P. Fenichel, Simon A. Levin, Bonnie McCay, Kevin St. Martin, Joshua K. Abbott & Malin L. Pinsky

Nature Climate Change **6**, 237–244 (2016) doi:10.1038/nclimate2871
Received 21 August 2015 Accepted 21 October 2015 Published online 24 February 2016

Abstract

Climate change is often described as the greatest environmental challenge of our time. In addition, a changing climate can reallocate natural capital, change the value of all forms of capital and lead to mass redistribution of wealth. Here we explain how the inclusive wealth framework provides a means to measure shifts in the amounts and distribution of wealth

Modeling emergent phenomena in human societies



Open access, freely available online

Essay

The Evolution of Norms

Paul R. Ehrlich, Simon A. Levin*

Over the past century and a half, we have made enormous progress in assembling a coherent picture of genetic evolution—that is, changes in the pools of genetic information possessed by populations, the genetic differentiation of populations (speciation) (see summaries in [1,2]), and the application of that understanding to the physical evolution of *Homo sapiens* and its forebears ([3]; e.g., [4,5]). But human beings, in addition to being products of biological evolution, are—vastly more than any other organisms—also products of a process of "cultural evolution." Cultural evolution consists of changes in the nongenetic information stored in brains, stories, songs, books, computer disks, and the like. Despite some important first steps, no integrated picture of the process of cultural evolution that has the explanatory power of the theory of genetic evolution has yet emerged.

Much of the effort to examine cultural evolution has focused on interactions of the genetic and cultural processes (e.g., [6], see also references in [7]). This focus, however, provides a sometimes misleading perspective, since most of the behavior of our species that is of interest to policy makers is a product of the portion of cultural evolution [8] that occurs so rapidly that genetic change is irrelevant. There is a long-recognized need both to understand the process of human cultural evolution per se and to find ways of altering its course (an operation in which institutions as diverse as schools, prisons, and governments have long been engaged). In a world threatened by weapons of mass destruction and escalating environmental deterioration, the need to change our behavior to avoid a

and humanely guided efforts to influence cultural evolution. While most of the effort to understand that evolution has come from the social sciences, biologists have also struggled with the issue (e.g., p. 285 of [10], [11–16], and p. 62 of [17]). We argue that biologists and social scientists need one another and must collectively direct more of their attention to understanding how social norms develop and change. Therefore, we offer this review of the challenge in order to emphasize its multidisciplinary dimensions and thereby to recruit a broader mixture of scientists into a more integrated effort to develop a theory of change in social norms—and, eventually, cultural evolution as a whole.

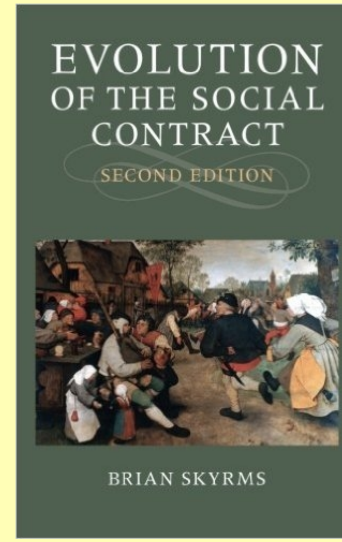
What Are the Relevant Units of Culture?

Norms (within this paper understood to include conventions or customs) are representative or typical patterns and rules of behavior in a human group [18], often supported by legal or other sanctions. Those sanctions, norms in themselves, have been called "metanorms" when failure to enforce them is punished [17,19,20]. In our (liberal) usage, norms are standard or ideal behaviors "typical" of groups. Whether these indeed represent the average behaviors of individuals in the groups is an open question, and depends on levels of conformity. Conformity or nonconformity with these norms are attributes of individuals, and, of course, heterogeneity in those attributes is important to how norms evolve. Norms and metanorms provide a cultural "stickiness" (p. 10 of [21]) or viscosity that can help sustain adaptive behavior and retard

argue that progress will depend on the development of a comprehensive quantitative theory of the initiation and spread of norms (and ultimately all elements of culture), and introduce some preliminary models that examine the spread of norms in space or on social networks. Most models of complex systems are meant to extract signal from noise, suppressing extraneous detail and thereby allowing an examination of the influence of the dominant forces that drive the dynamics of pattern and process. To this end, models necessarily introduce some extreme simplifying assumptions.

Early attempts to model cultural evolution have searched for parallels of the population genetic models used to analyze genetic evolution. A popular analogy, both tempting and facile, has been that there are cultural analogues of genes, termed "memes" [22,23], which function as replicable cultural units. Memes can be ideas, behaviors, patterns, units of information, and so on. But the differences between genes and memes makes the analogy inappropriate, and "memetics" has not led to real understanding of cultural evolution. Genes are relatively stable, mutating rarely, and those changes that do occur usually result in nonfunctional products. In contrast, memes are extremely mutable, often transforming considerably with each transmission. Among humans, genes can only pass unidirectionally from

Citation: Ehrlich PR, Levin SA (2005) The evolution of norms. PLoS Biol 3(6): e194.



Lecture outline

- Conflict and public goods
- Scaling from microscopic to macroscopic
- Managing complex adaptive systems

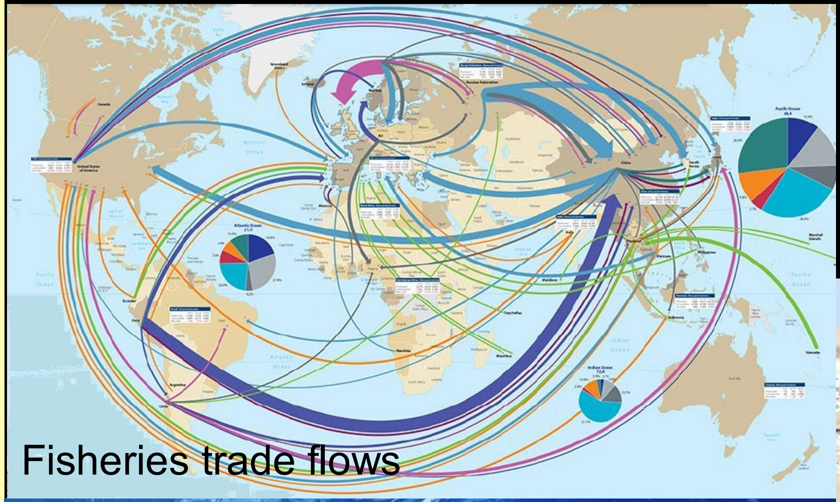
Ecosystems and the Biosphere are Complex Adaptive Systems

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

NOAA

So too are socio-economic systems

Coupled Human and Natural Systems



Fisheries trade flows

Interconnected ecological, social and economic systems

Food security, poverty alleviation

Complex Adaptive Systems

Courtesy Jane Lubchenco

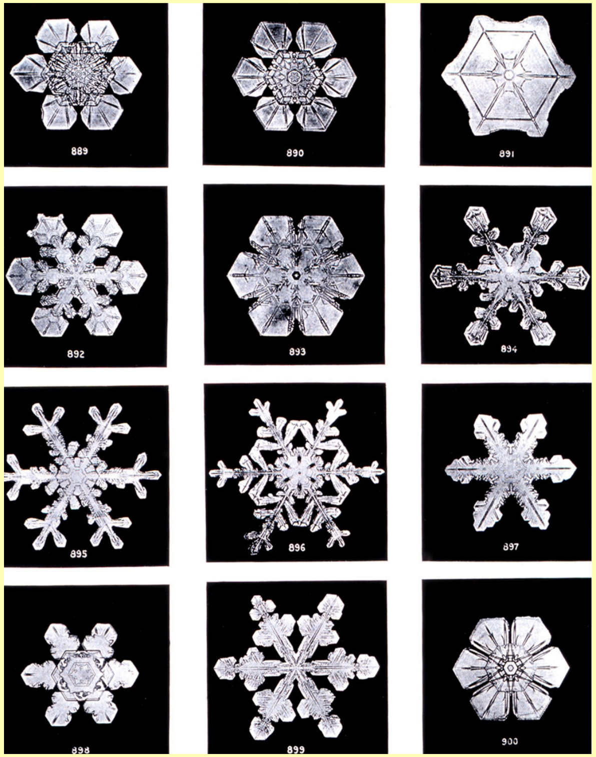
Challenges of managing CAS

- Multiple spatial, temporal and organizational scales

Arrow, Ehrlich, Levin 2014

Challenges of managing CAS

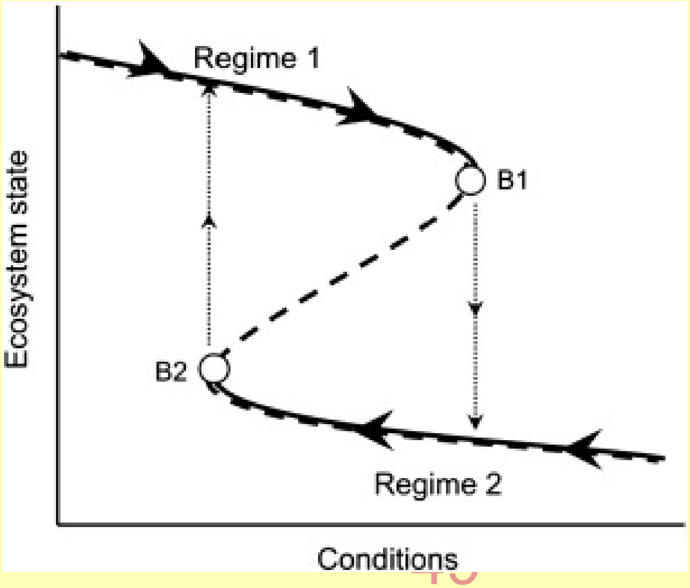
- Multiple spatial, temporal and organizational scales
- Self-organization, emergence and consequent unpredictability



https://en.wikipedia.org/wiki/Emergence#/

Challenges of managing CAS

- Multiple spatial, temporal and organizational scales
- Self-organization, emergence and consequent unpredictability
- Multiple stable states, path dependence, hysteresis



Crepin et al, Ecol Econ, 2012

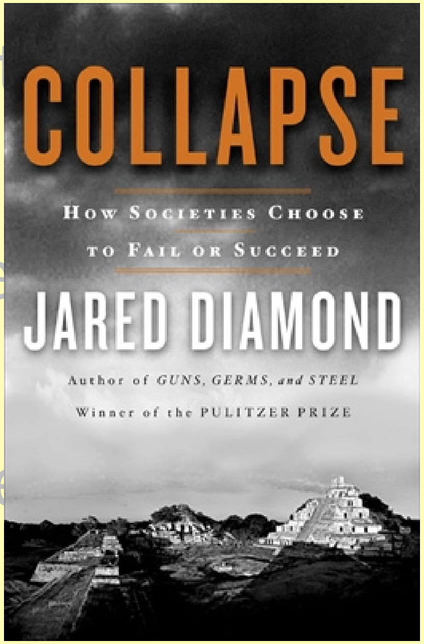
Challenges of managing CAS

- Multiple ... nizational scales
- Self-orga... onsequent unpredic...
- Multiple ... ence, hysteresi...
- Contagious spread and systemic risk

github.com

Challenges of managing CAS

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



2008

NEWS & VIEWS

COMPLEX SYSTEMS

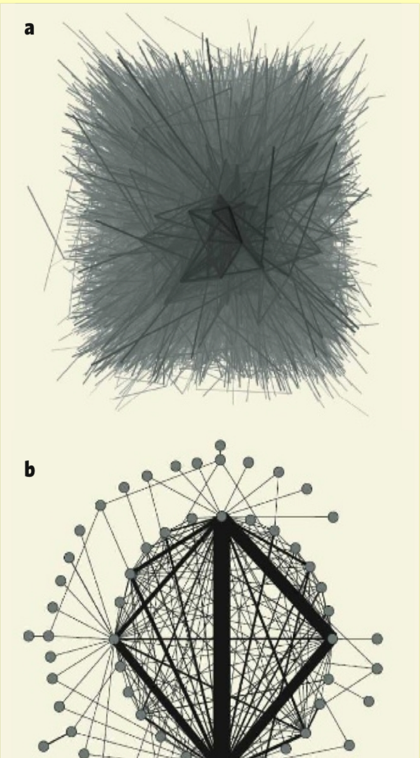
Ecology for bankers

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?

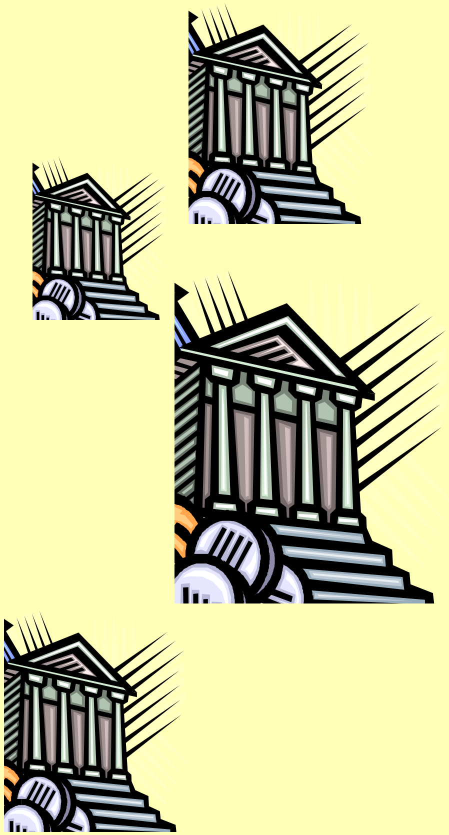
Well before this recent crisis emerged, the US National Academies/National Research Council and the Federal Reserve Bank of New York collaborated[1] on an initiative to "stimulate fresh thinking on systemic risk". The main event was a high-level conference held in May 2006, which brought together experts 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

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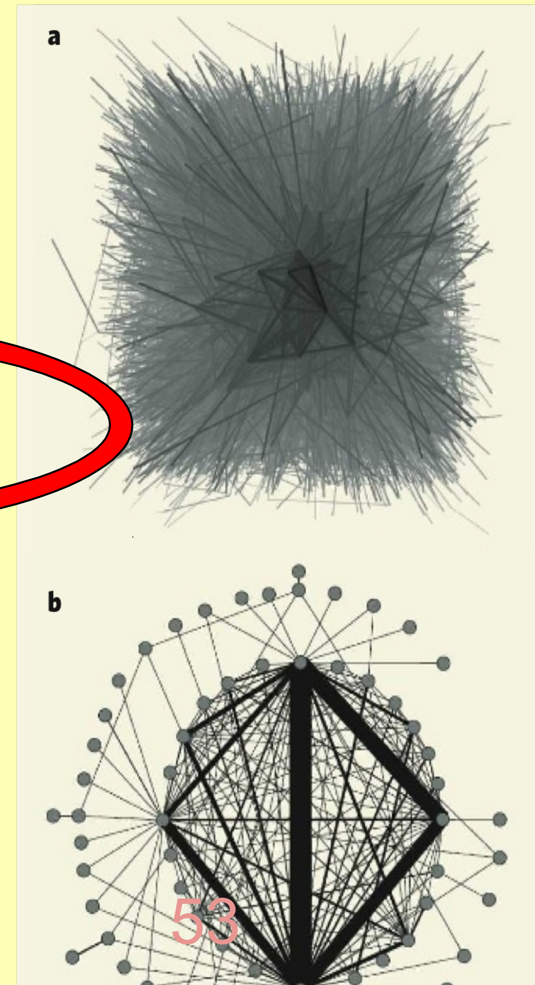
Catastrophic changes in the overall state of



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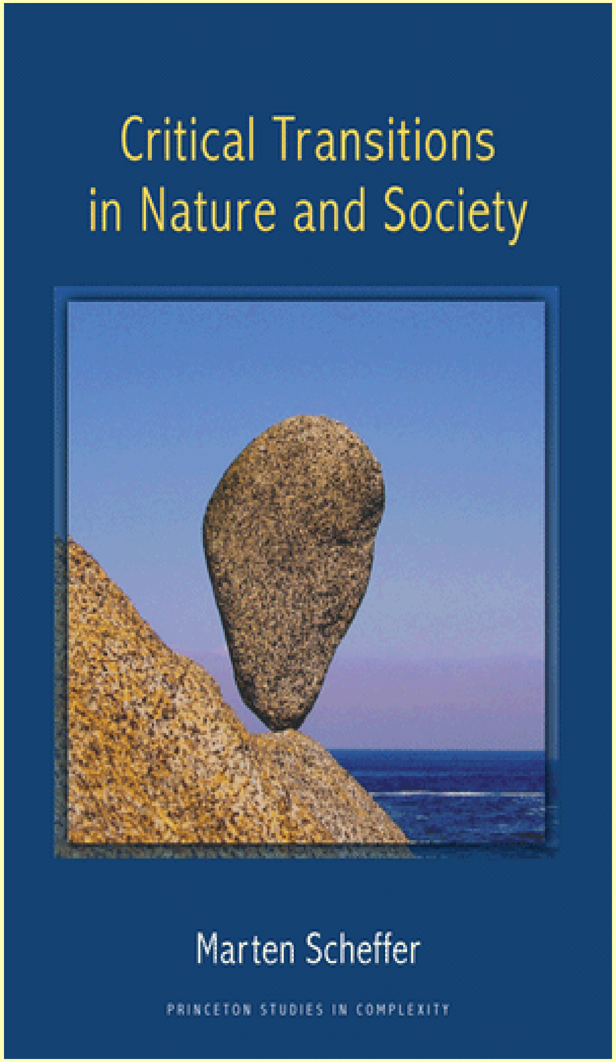
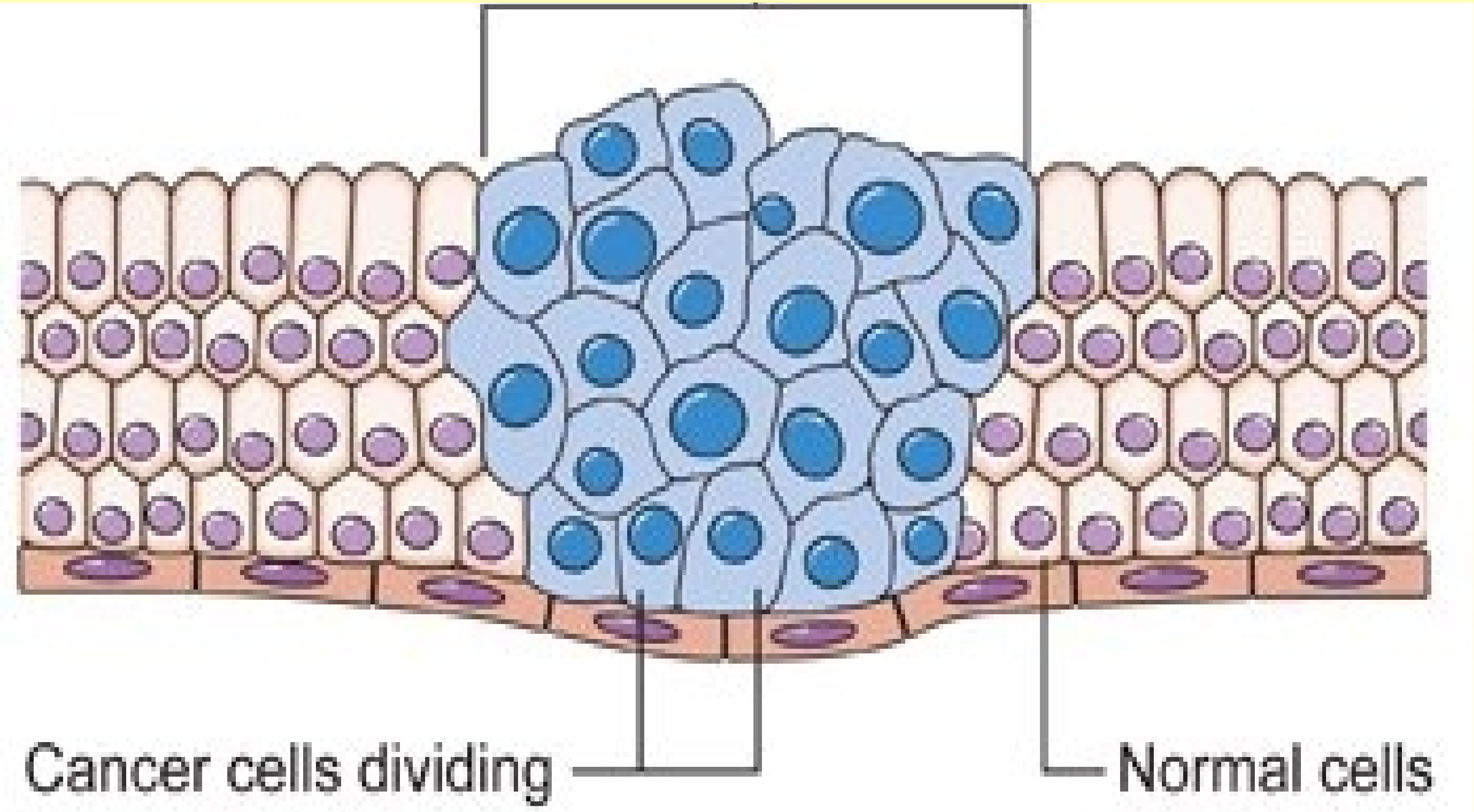
In complex adaptive systems, emergence can lead to sudden shifts



..and inescapably to conflicts between levels



http://www.cancerresearchuk.org/

Managing public goods and common-pool resources: Bridging levels

- Individual transferable quotas (ITQs)
- Territorial-use rights in fisheries (TURFS)
- Rights-based fisheries (RBFs)
- Social norms
- International agreements

E. Fehr

Social norms can sustain and enhance prosocial behavior

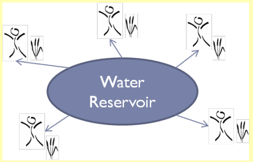
- Humans will punish others who deviate from social norms, at cost to themselves
- Punishment itself is a norm, and can evolve from repeated interactions
- Norms are important to understand much prosocial behavior
- Norms become formalized into rules and laws

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

with Alessandro Tavoni and Maja Schlüter

http://geo.coop/node/654

Equity-driven ostracism: Nash equilibria



- Agents that withdraw more than socially accepted are ostracized and refused help -> reduction in utility

$$U_C = \pi_C(e_C, R)$$

$$U_D(f_C) = \pi_D(e_D, R) - \omega(f_c)\frac{\pi_D(e_D, R) - \pi_C(e_C, R)}{\pi_D(e_D, R)}$$

Payoff from production

Ostracism function

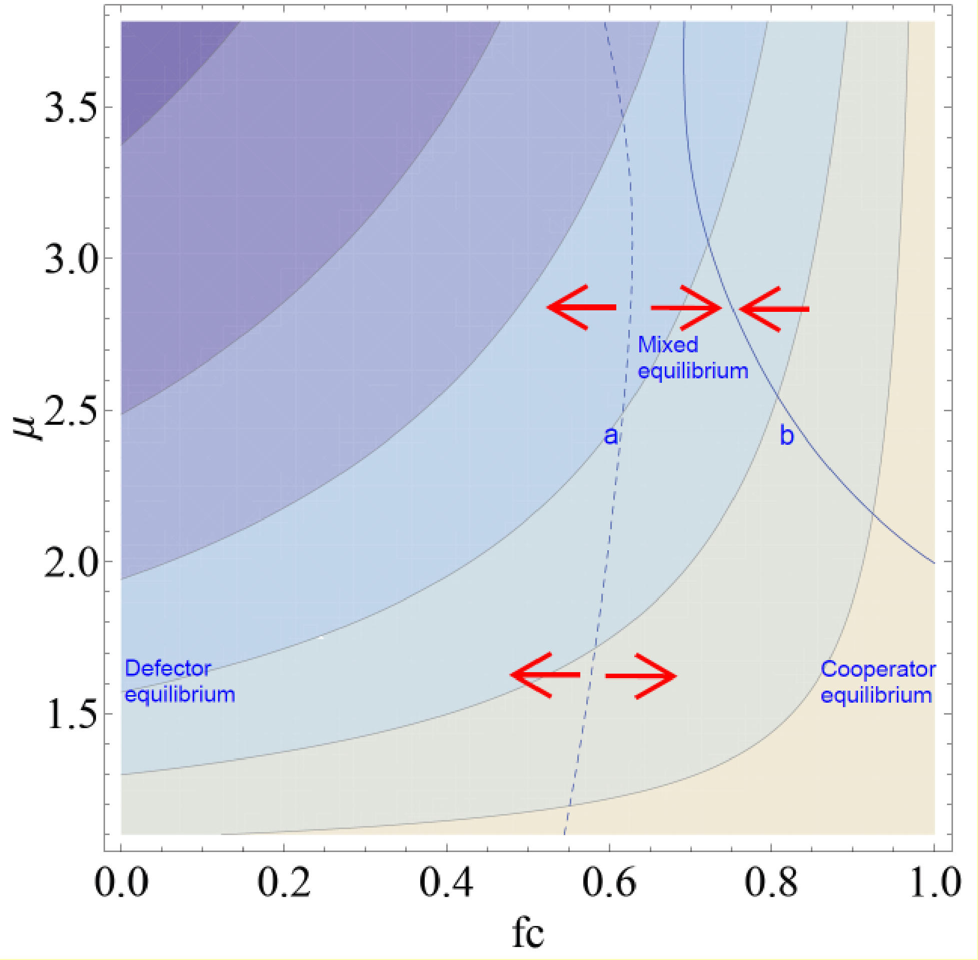
Intensity of defection (inequity)

RESOURCE LEVEL

$$\dot{R} = c - d(R / R_{\max})^k - qER$$

Tavoni, Schlueter, Levin
Coordination game

Selfishness



Frequency of cooperators

Journal of Theoretical Biology
Volume 299, 21 April 2012

The dynamics of collective phenomena and collective decision-making

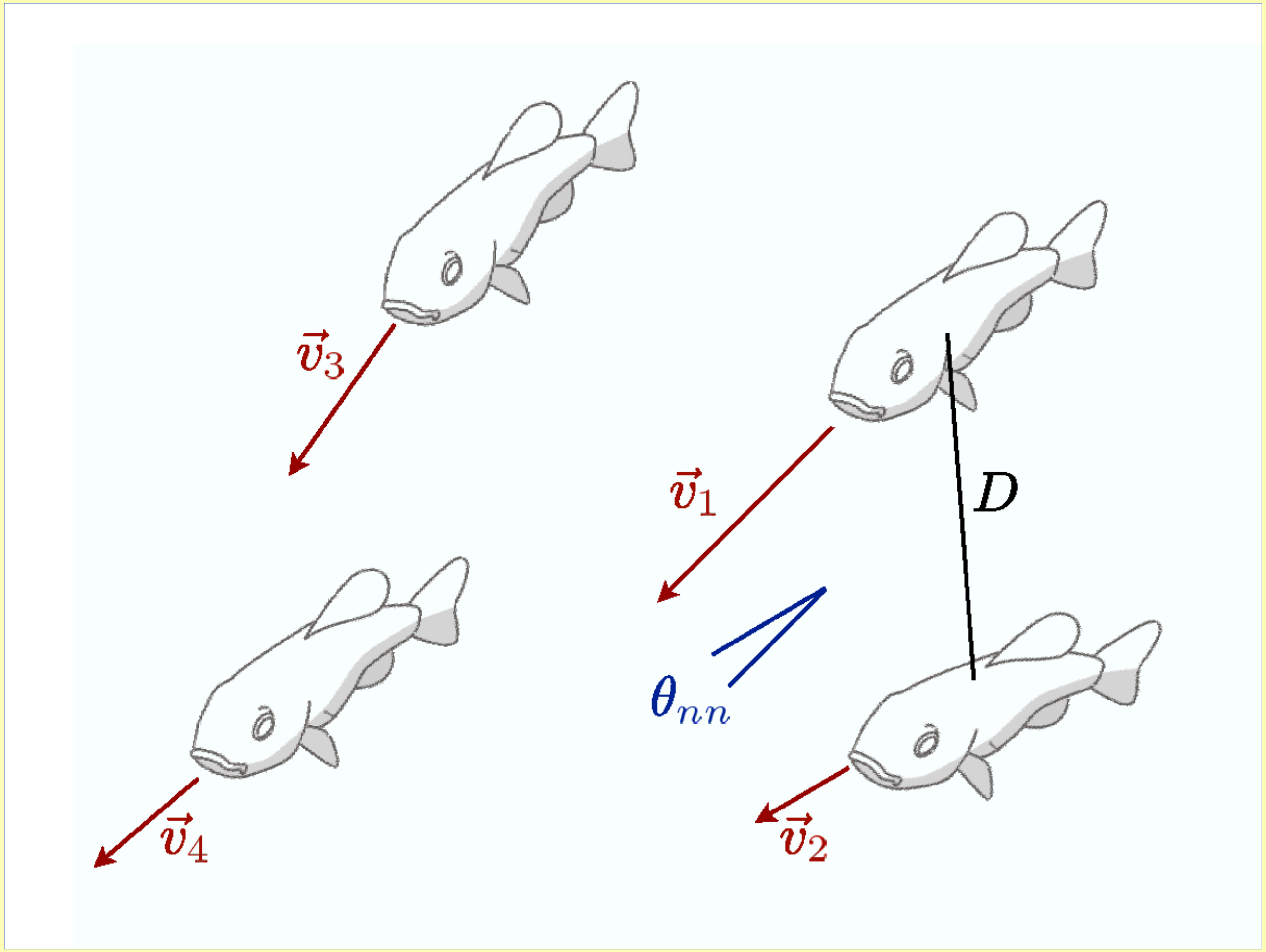
Claudio Carere
plus StarFLAG EU FP6 project

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



Courtey Iain Couzin

Collective decision-making

1 informed individuals in group of 100.

Courtey Iain Couzin

Collective decision-making

5 informed individuals in group of 100.

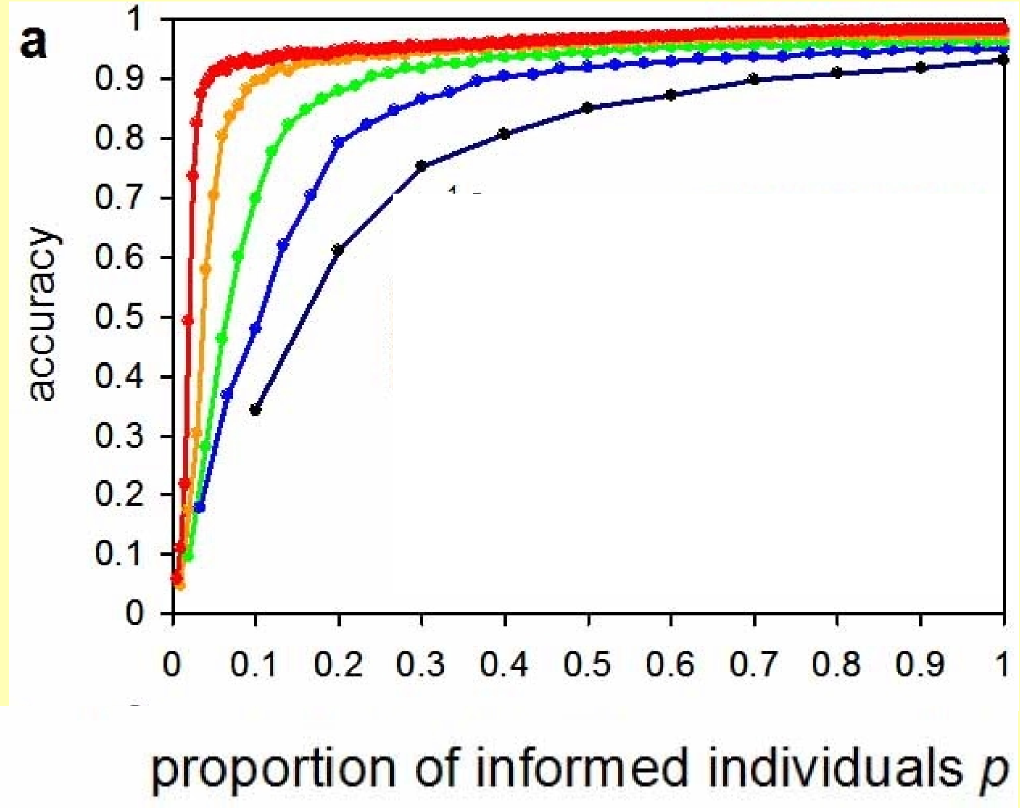
Courtey Iain Couzin

Collective decision-making

10 informed individuals in group of 100.

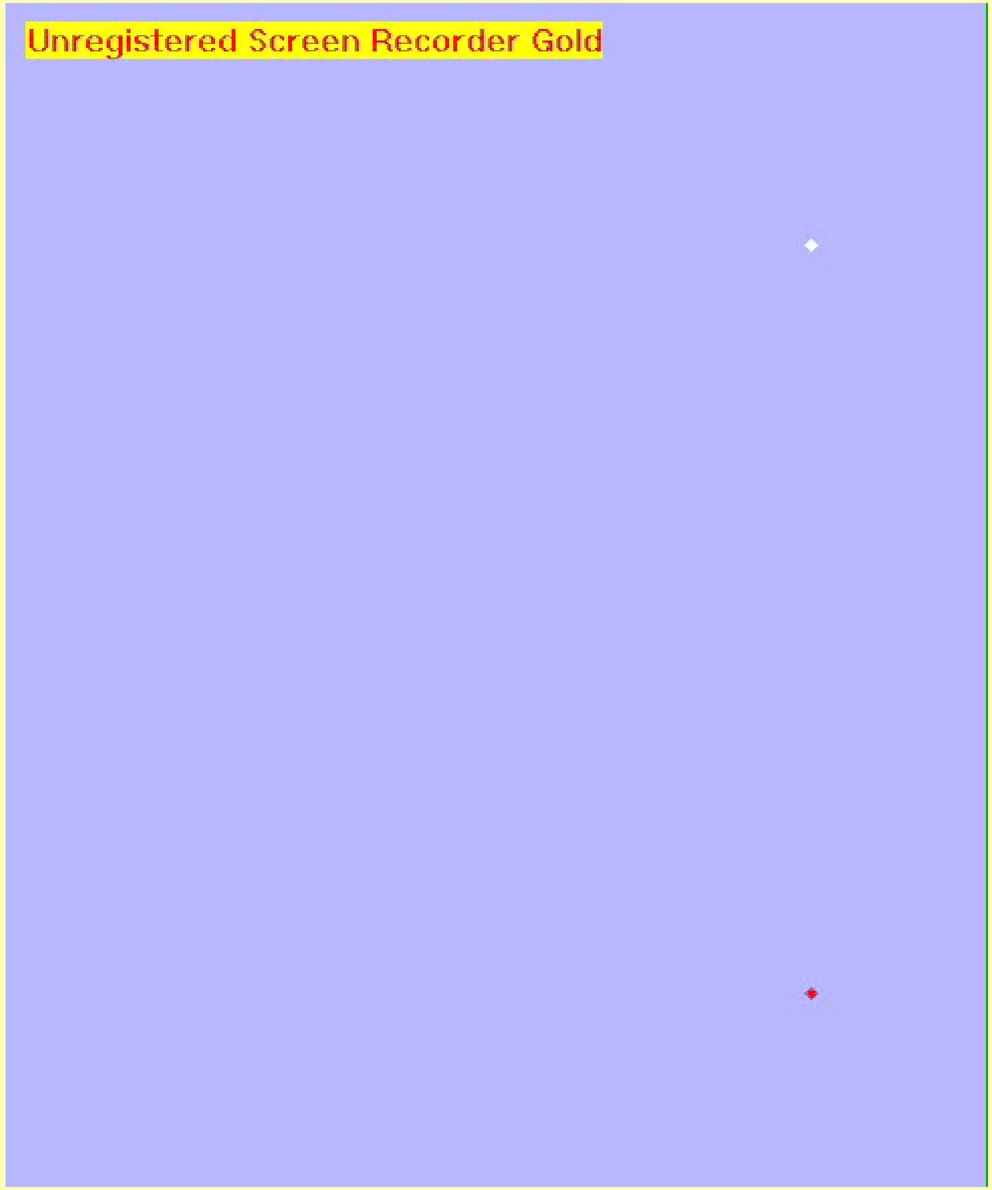
Courtey Iain Couzin

Animal groups may be led by a small number of individuals



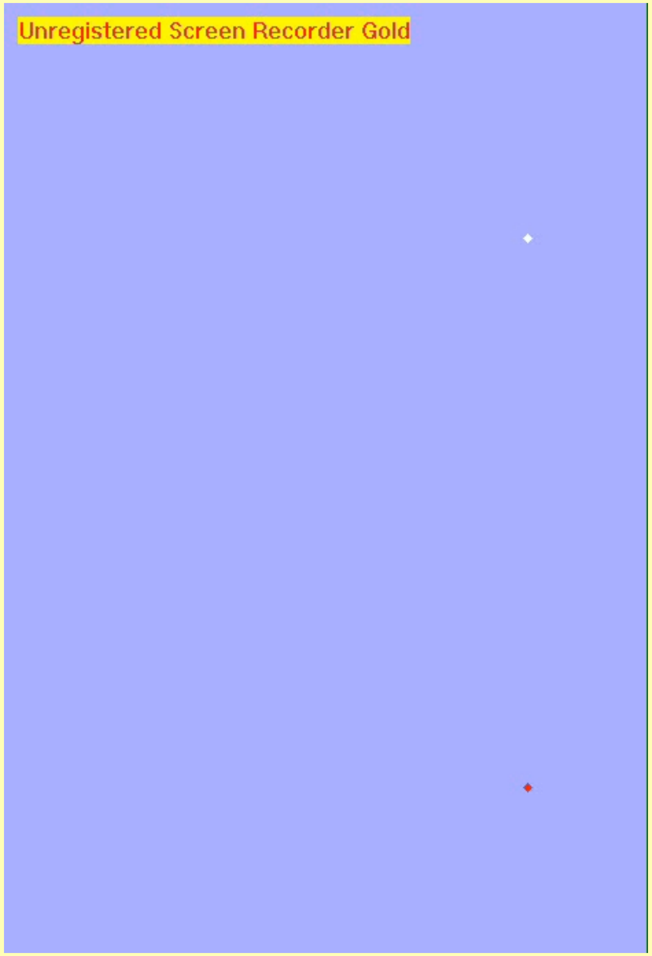
From Couzin et al., 2005

Competition and consensus



Courtey Iain Couzin

Competition and consensus



Courtey Iain Couzin

Extensions

- Complex spatial patterns (fish balls, tori)
- Evolution of local rules
- Role of unopinionated

Investigate from multiple angles

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

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

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

http://motherjones.com/kevin-drum

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?

ANNALS OF ECONOMICS AND FINANCE **15-1**, 97–134 (2014)

Ostrom: Climate change

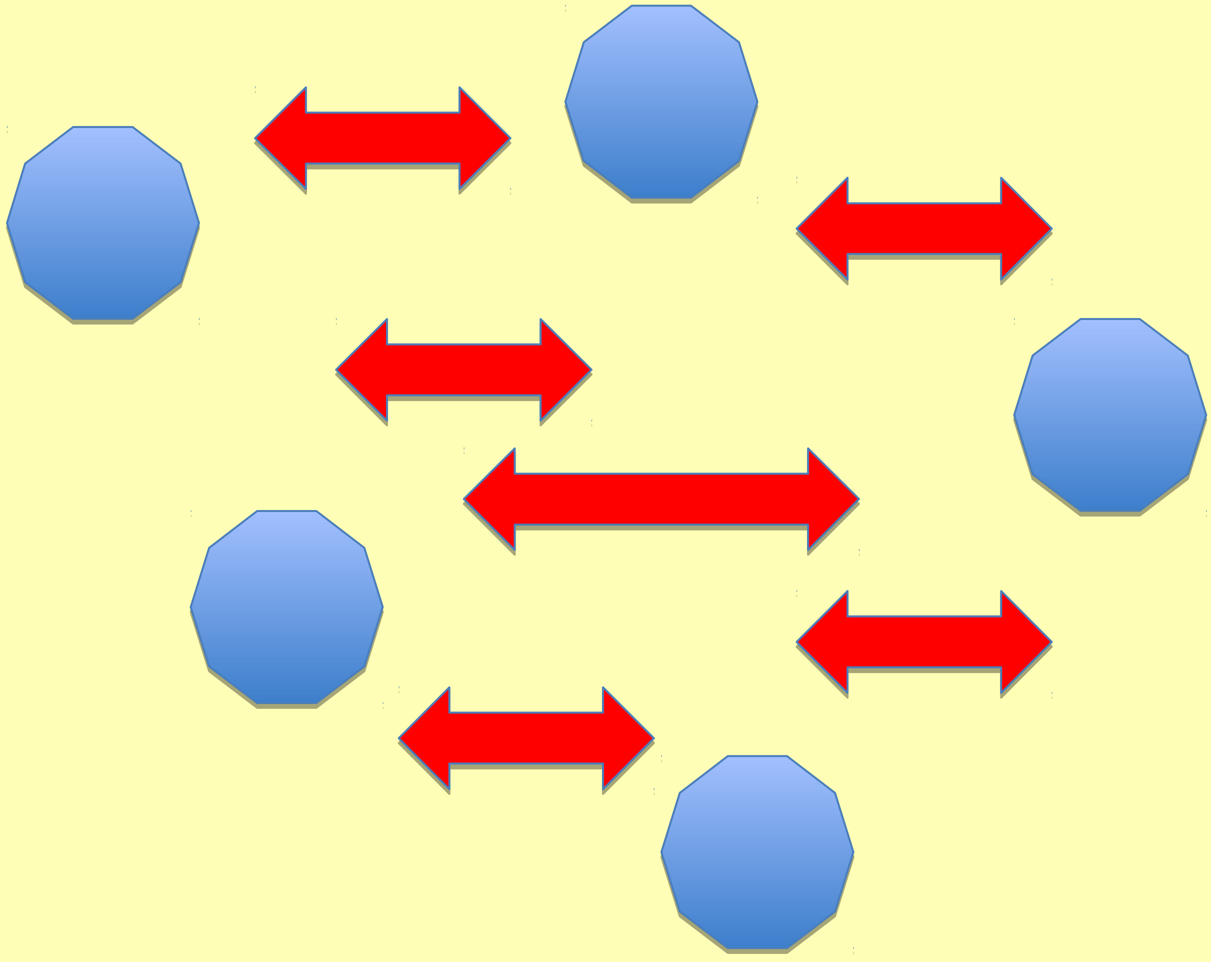
A Polycentric Approach for Coping with Climate Change

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

Dixit-Levin
Contributions to public goods
Multiple groups



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

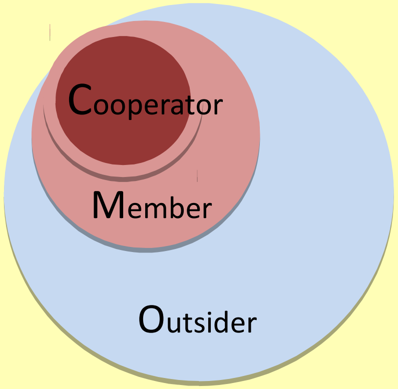
In press, Climatic Change

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

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

http://www.latinamericanstudies.org/maya

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