The Science and Technology of Cooperation

Steve Omohundro, Ph.D.
Self-Aware Systems


How naturally cooperative are we?

The Ultimatum Game

- Proposer offers a split of $10

- Responder accepts or rejects
- If rejects, neither gets anything

Guth, 1982

Homo Economicus

As responder: Accepts any non-zero offer

"Something is better than nothing"

As proposer: Makes the minimum non-zero offer and expects responder to accept it

"Maximize profit"

What people actually do:

- 16% of offers are rejected
- Offers of <20% often rejected
- Asians reject more than US

- Average offer: 40%
- Most common offer: 50%
- Paraguay Ache and Indonesian Lamelara offer more than 50%
- Repeated play increases offers

Oosterbeek, 2004 *Camerer, 2003*

Why?

Reject a low offer?

- Promote fairness
- Punish selfish proposers
  "Moralistic Agression"
- Altrusim
- Self-image
- Develop reputation

Propose a high offer?

- Sense of fairness
- Altruism
- To avoid rejection

Neuroeconomics

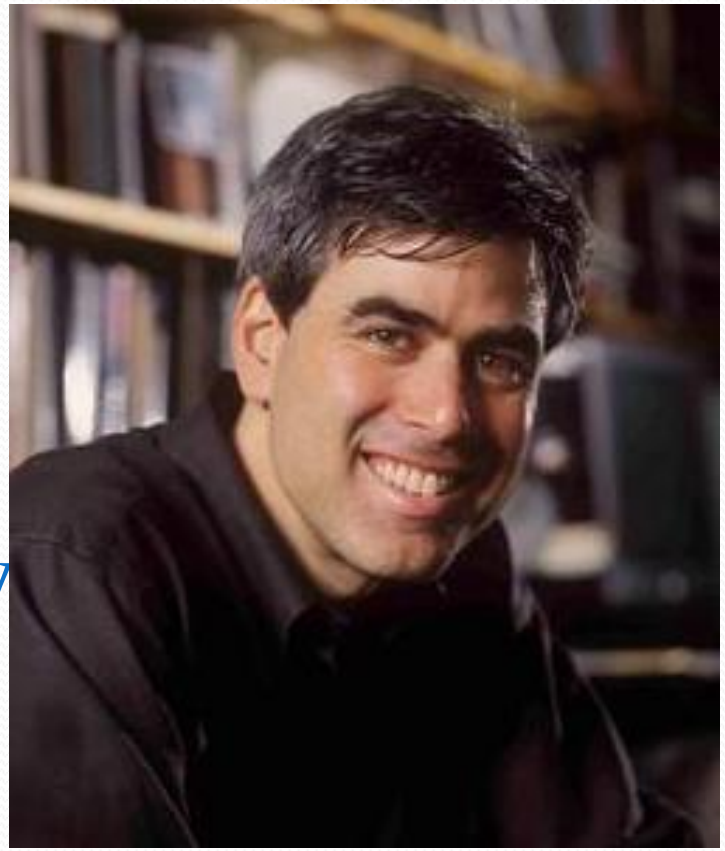
- Increased oxytocin leads to more generosity
- Low serotonin leads to greater rejection
- High testosterone leads to greater rejection
- Anterior insular cortex
- Twin studies find a genetic component
- Chimps accept low offers

Burnham, 2007 *Jensen, 2007*
Zak, 2007

Haidt: 5 Moral Emotions

- Non-harming
- Fairness

- Loyalty
- Respect for authority
- Purity or sanctity



Haidt, 2007

Kohlberg: 7 stages of morality

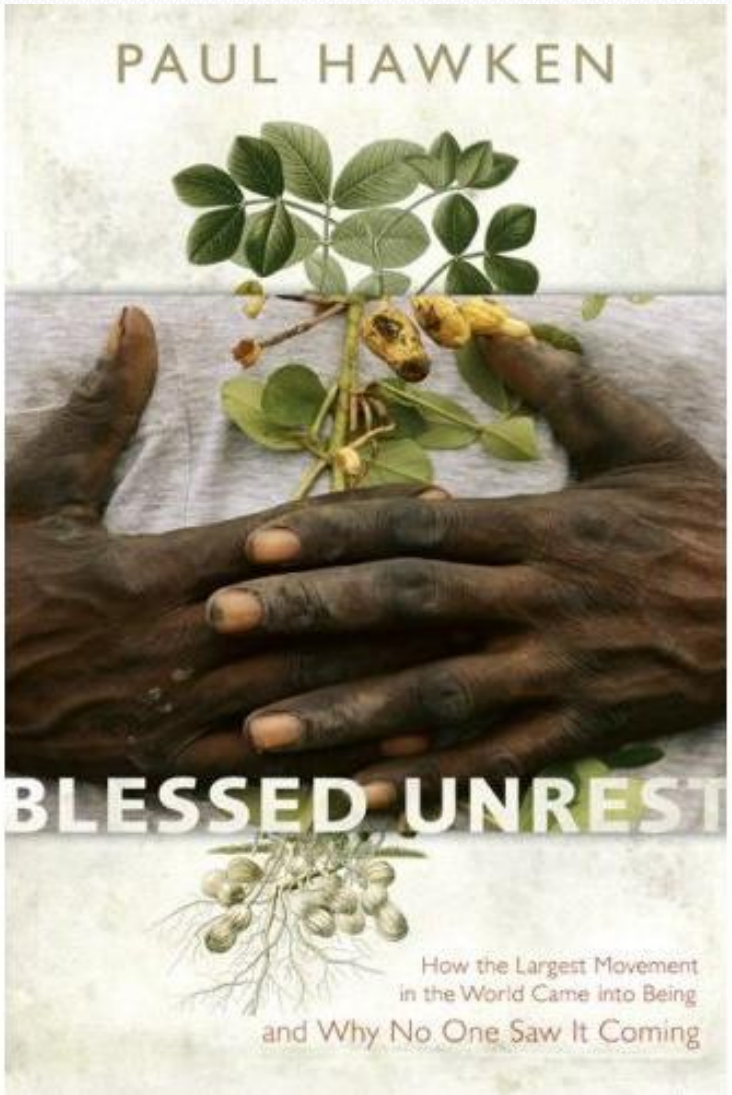
1. Avoiding punishment
2. What's in it for me?
3. Being a good boy
4. Obeying the law
5. Upholding the social contract
6. Universal ethical principles
7. Transcendental morality

Kohlberg, 1971

Human Moral Evolution

- Slavery
- Torture
- War crimes
- Women's rights
- Racial equality
- Animal rights
- Ecological movements
- Sustainability
- …

Hawken, 2007




How did
cooperation
arise in nature?

Physical Resources -> Competition

$$\mathcal{L}_{\rm SM} = \mathcal{L}_{\rm Dirac} + \mathcal{L}_{\rm mass} + \mathcal{L}_{\rm gauge} + \mathcal{L}_{\rm gauge/\psi} \ . \tag{1}$$

Here,

$$\mathcal{L}_{\rm Dirac} = i\bar{e}^i_{\rm L}\partial\!\!\!/ e^i_{\rm L} + i\bar{\nu}^i_{\rm L}\partial\!\!\!/ \nu^i_{\rm L} + i\bar{e}^i_{\rm R}\partial\!\!\!/ e^i_{\rm R} + i\bar{u}^i_{\rm L}\partial\!\!\!/ u^i_{\rm L} + i\bar{d}^i_{\rm L}\partial\!\!\!/ d^i_{\rm L} + i\bar{u}^i_{\rm R}\partial\!\!\!/ u^i_{\rm R} + i\bar{d}^i_{\rm R}\partial\!\!\!/ d^i_{\rm R} \ ; \tag{2}$$

$$\mathcal{L}_{\rm mass} = -v\left(\lambda^i_e \bar{e}^i_{\rm L} e^i_{\rm R} + \lambda^i_u \bar{u}^i_{\rm L} u^i_{\rm R} + \lambda^i_d \bar{d}^i_{\rm L} d^i_{\rm R} + {\rm h.c.}\right) - M^2_W W^+_\mu W^{-\mu} - \frac{M^2_W}{2\cos^2\theta_W} Z_\mu Z^\mu \ ; \tag{3}$$

$$\mathcal{L}_{\rm gauge} = -\frac{1}{4}(G^a_{\mu\nu})^2 - \frac{1}{2}W^+_{\mu\nu}W^{-\mu\nu} - \frac{1}{4}Z_{\mu\nu}Z^{\mu\nu} - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \mathcal{L}_{WZA} \ , \tag{4}$$

where

$$\begin{aligned} G^a_{\mu\nu} &= \partial_\mu A^a_\nu - \partial_\nu A^a_\mu - g_3 f^{abc} A^b_\mu A^c_\nu \\ W^\pm_{\mu\nu} &= \partial_\mu W^\pm_\nu - \partial_\nu W^\pm_\mu \\ Z_{\mu\nu} &= \partial_\mu Z_\nu - \partial_\nu Z_\mu \\ F_{\mu\nu} &= \partial_\mu A_\nu - \partial_\nu A_\mu \ , \end{aligned} \tag{5}$$

and

$$\begin{aligned} \mathcal{L}_{WZA} &= ig_2\cos\theta_{\rm W}\left[\left(W^-_\mu W^+_\nu - W^-_\nu W^+_\mu\right)\partial^\mu Z^\nu + W^+_{\mu\nu}W^{-\mu}Z^\nu - W^-_{\mu\nu}W^{+\mu}Z^\nu\right] \\ &\quad + ie\left[\left(W^-_\mu W^+_\nu - W^-_\nu W^+_\mu\right)\partial^\mu A^\nu + W^+_{\mu\nu}W^{-\mu}A^\nu - W^-_{\mu\nu}W^{+\mu}A^\nu\right] \\ &\quad + g_2^2\cos^2\theta_{\rm W}\left(W^+_\mu W^-_\nu Z^\mu Z^\nu - W^+_\mu W^{-\mu}Z_\nu Z^\nu\right) \\ &\quad + g_2^2\left(W^+_\mu W^-_\nu A^\mu A^\nu - W^+_\mu W^{-\mu}A_\nu A^\nu\right) \\ &\quad + g_2 e\cos\theta_{\rm W}\left[W^+_\mu W^-_\nu\left(Z^\mu A^\nu + Z^\nu A^\mu\right) - 2W^+_\mu W^{-\mu}Z_\nu A^\nu\right] \\ &\quad + \frac{1}{2}g_2^2\left(W^+_\mu W^-_\nu\right)\left(W^{+\mu}W^{-\nu} - W^{+\nu}W^{-\mu}\right) \ ; \end{aligned} \tag{6}$$

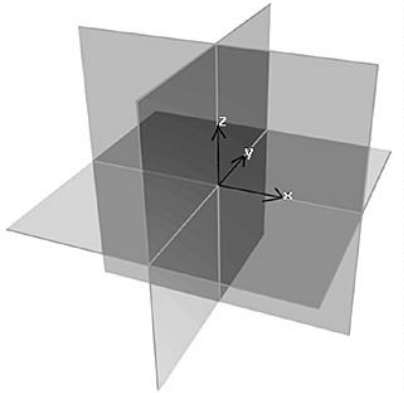
and

$$\mathcal{L}_{\rm gauge/\psi} = -g_3 A^a_\mu J^{\mu a}_{(3)} - g_2\left(W^+_\mu J^\mu_{W+} + W^-_\mu J^\mu_{W-} + Z_\mu J^\mu_Z\right) - eA_\mu J^\mu_A \ , \tag{7}$$

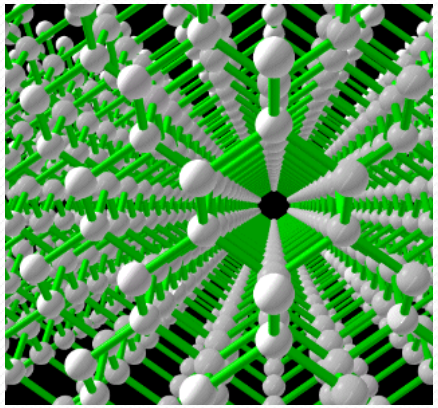
where

$$\begin{aligned} J^{\mu a}_{(3)} &= \bar{u}^i\gamma^\mu T^a_{(3)} u^i + \bar{d}^i\gamma^\mu T^a_{(3)} d^i \\ J^\mu_{W+} &= \frac{1}{\sqrt{2}}\left(\bar{\nu}^i_{\rm L}\gamma^\mu e^i_{\rm L} + V^{ij}\bar{u}^i_{\rm L}\gamma^\mu d^j_{\rm L}\right) \\ J^\mu_{W-} &= \left(J^\mu_{W+}\right)^* \\ J^\mu_Z &= \frac{1}{\cos\theta_{\rm W}}\left[\frac{1}{2}\bar{\nu}^i_{\rm L}\gamma^\mu\nu^i_{\rm L} + \left(-\frac{1}{2} + \sin^2\theta_{\rm W}\right)\bar{e}^i_{\rm L}\gamma^\mu e^i_{\rm L} + (\sin^2\theta_{\rm W})\bar{e}^i_{\rm R}\gamma^\mu e^i_{\rm R}\right. \\ &\quad + \left(\frac{1}{2} - \frac{2}{3}\sin^2\theta_{\rm W}\right)\bar{u}^i_{\rm L}\gamma^\mu u^i_{\rm L} + \left(-\frac{2}{3}\sin^2\theta_{\rm W}\right)\bar{u}^i_{\rm R}\gamma^\mu u^i_{\rm R} \\ &\quad \left. + \left(-\frac{1}{2} + \frac{1}{3}\sin^2\theta_{\rm W}\right)\bar{d}^i_{\rm L}\gamma^\mu d^i_{\rm L} + \left(\frac{1}{3}\sin^2\theta_{\rm W}\right)\bar{d}^i_{\rm R}\gamma^\mu d^i_{\rm R}\right] \\ J^\mu_A &= (-1)\bar{e}^i\gamma^\mu e^i + \left(\frac{2}{3}\right)\bar{u}^i\gamma^\mu u^i + \left(-\frac{1}{3}\right)\bar{d}^i\gamma^\mu d^i \ . \end{aligned} \tag{8}$$

Space



Time



Matter

Free Energy

Synergy -> Cooperation

Economies of Scale

eg. bird flocks for food finding and predator detection and protection

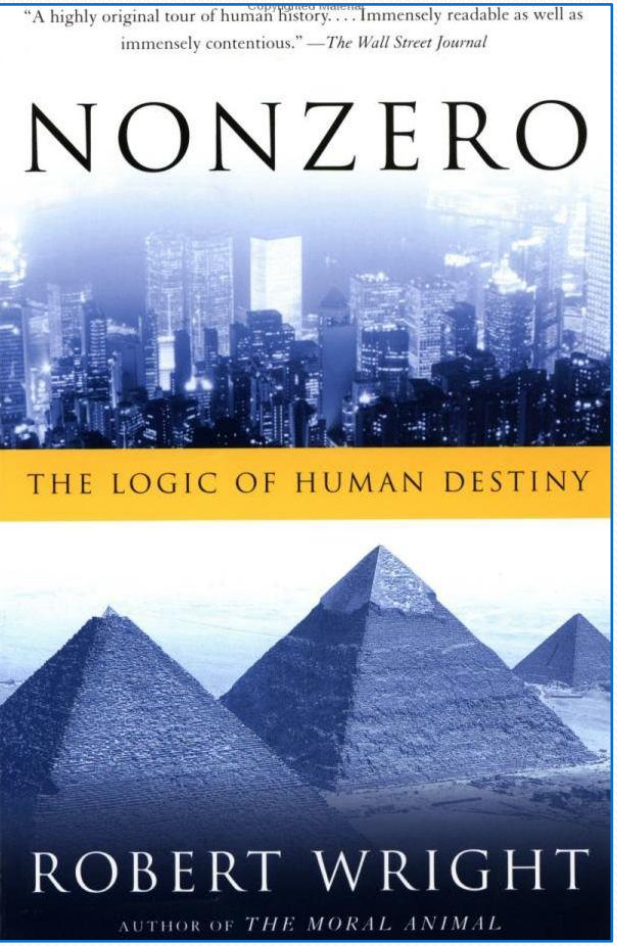
Complementary Needs

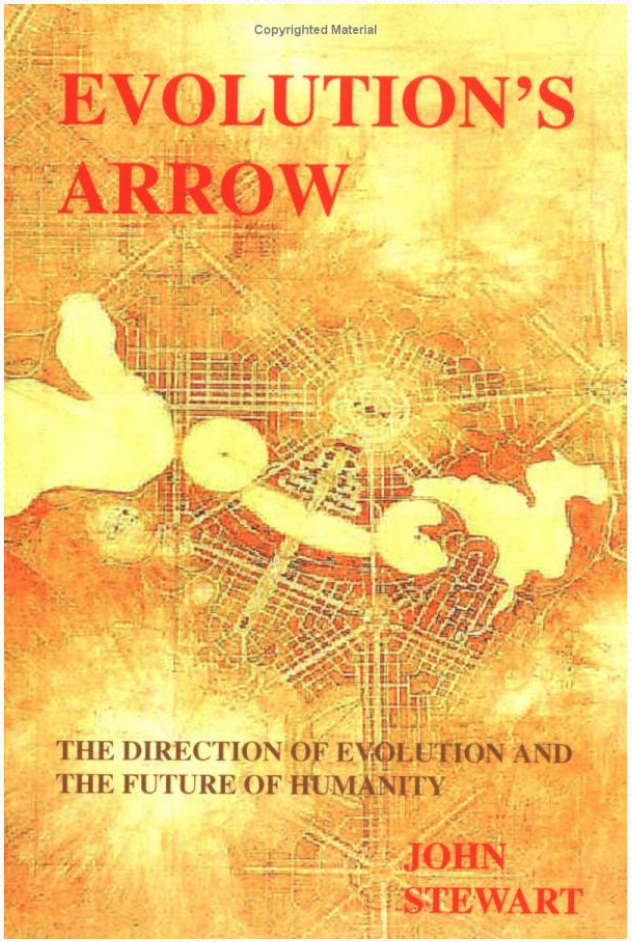
eg. Cleaner fish want food and hammerheads want clean skin

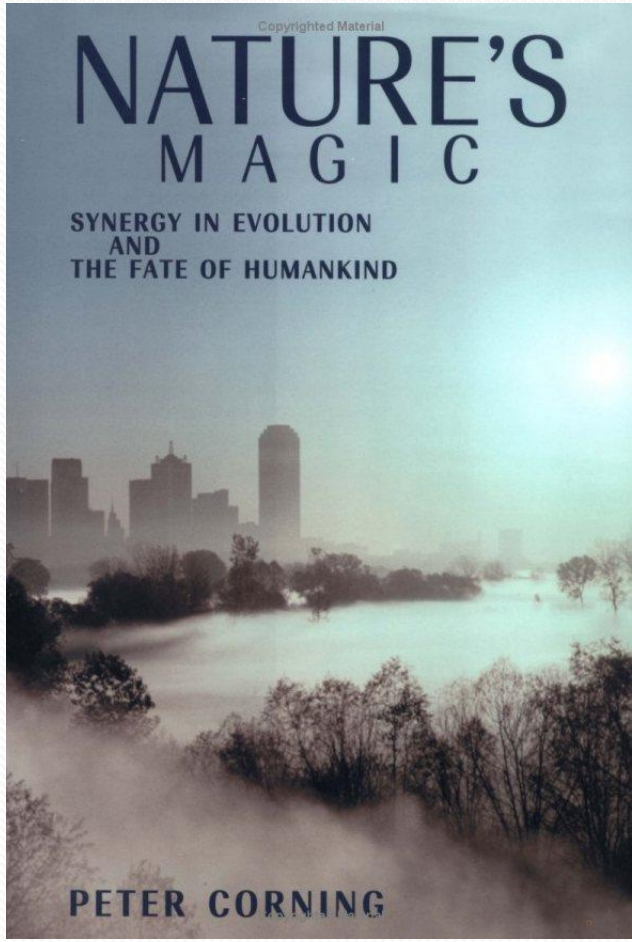
Complementary Abilities

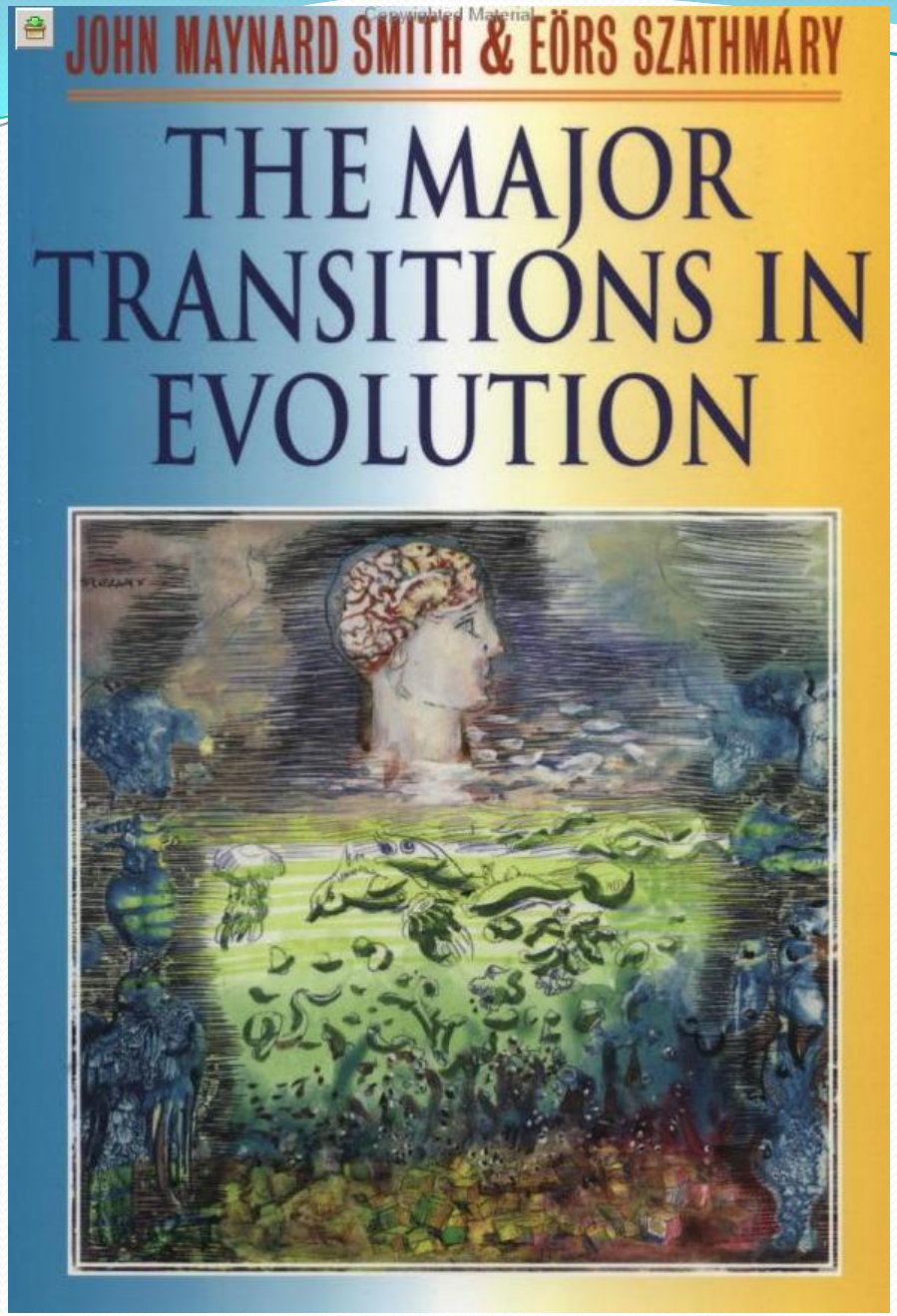
eg. In lichen, fungus provides water and support,algae provide photosynthesis

Synergy Gives Evolution a Direction





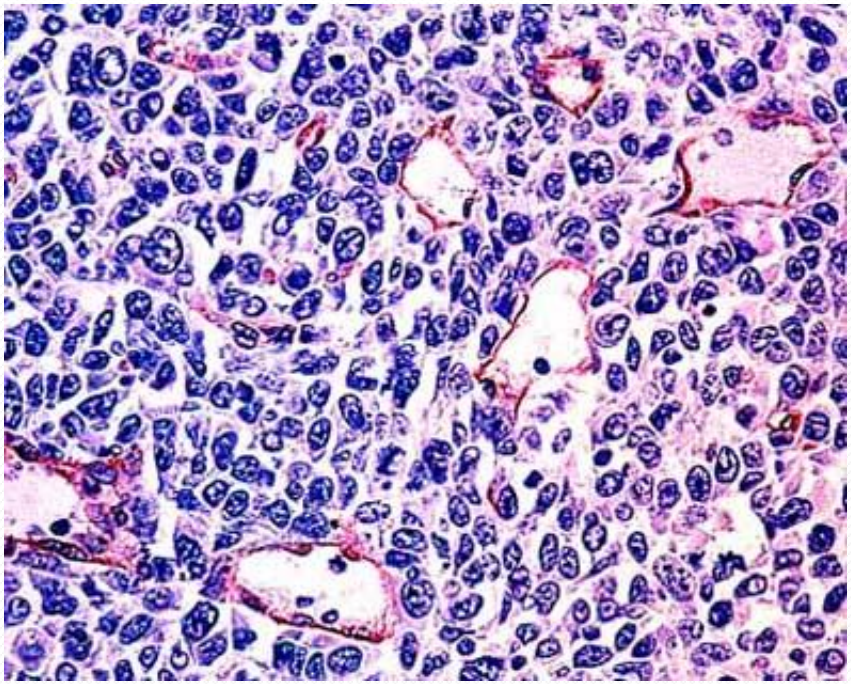




1. Replicating molecules -> Compartments
2. Independent replicators -> Chromosomes
3. RNA -> DNA + Protein
4. Prokaryotes -> Eukaryotes
5. Asexual clones -> Sexual populations
6. Protists -> Multicellular organisms
7. Solitary individuals -> Colonies
8. Primate societies -> Human language

Group Mechanisms to Ensure Cooperation Among Parts

Multicellular Organisms



Danger: Cancer

Solution: Immune System

Human Society

Danger: Criminals

Solution: Police and Courts

Social Insects

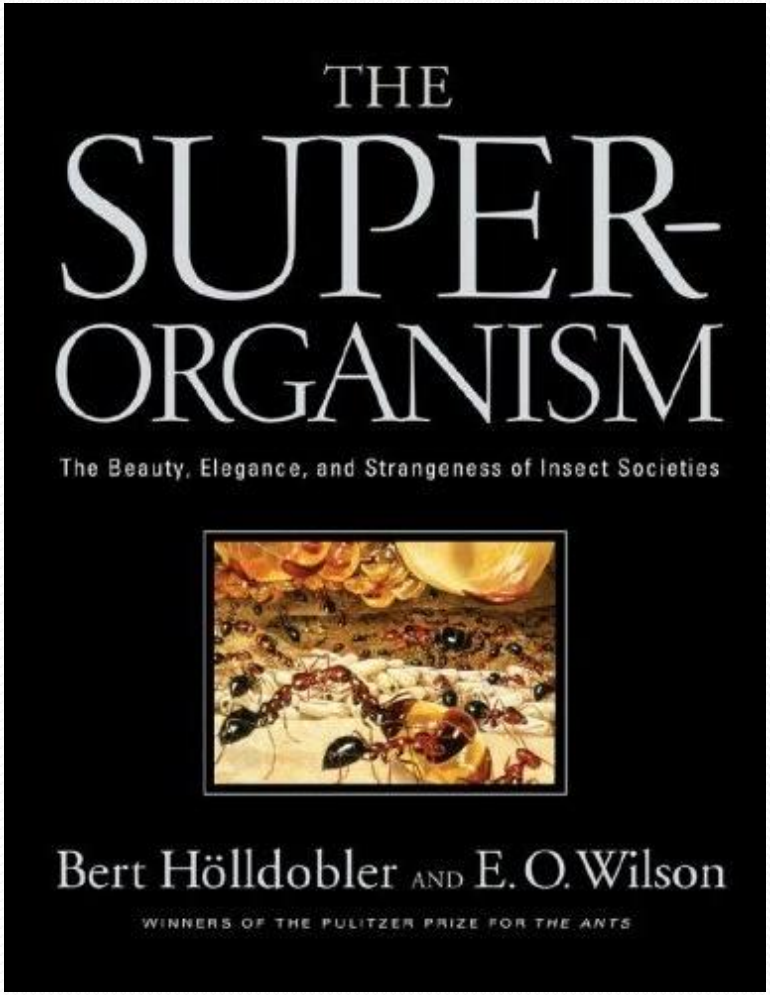
The Beehive is the Organism

Individual bees can't survive
Beehive is "warm blooded":
- Bees shiver if too cold
- Spread water if too warm

Castes are like organs
Queen is like ovaries
Bee type is like cell type
Decision making on response
Hive cognition
Reproduction like mitosis
Dance like neural firing

Groups and Individuals

- Group "wants" cooperation since competition is wasteful
- Group mechanisms evolve to reward cooperative individuals
- Individuals internalize "group mind" but only partially



Bee mind vs. Hive mind

Egoic mind vs. Social mind


Why does
cooperation
fail?

A Mountain Road in Italy

- Short one-lane section
- Cars from opposite directions were taking turns
- Until two drivers decided to try to outrun each other
- Each came to middle honking for the other to back up
- Other cars crowded in, also honking furiously
- It took authorities *three* days to clear the resulting traffic jam!

Fisher, 2008

BART or the Bay Bridge?

- Berkeley to San Francisco
- BART takes 40 mins.
- Bridge takes 20 minutes with no traffic
- Each additional 2000 cars adds 10 minutes
- 10,000 commuters
- 4K bridge, 6K BART: 40 minutes for everyone
- Best: 2K bridge, 8K BART saves 20K person minutes
- Bridge licenses, higher tolls, bridge ownership

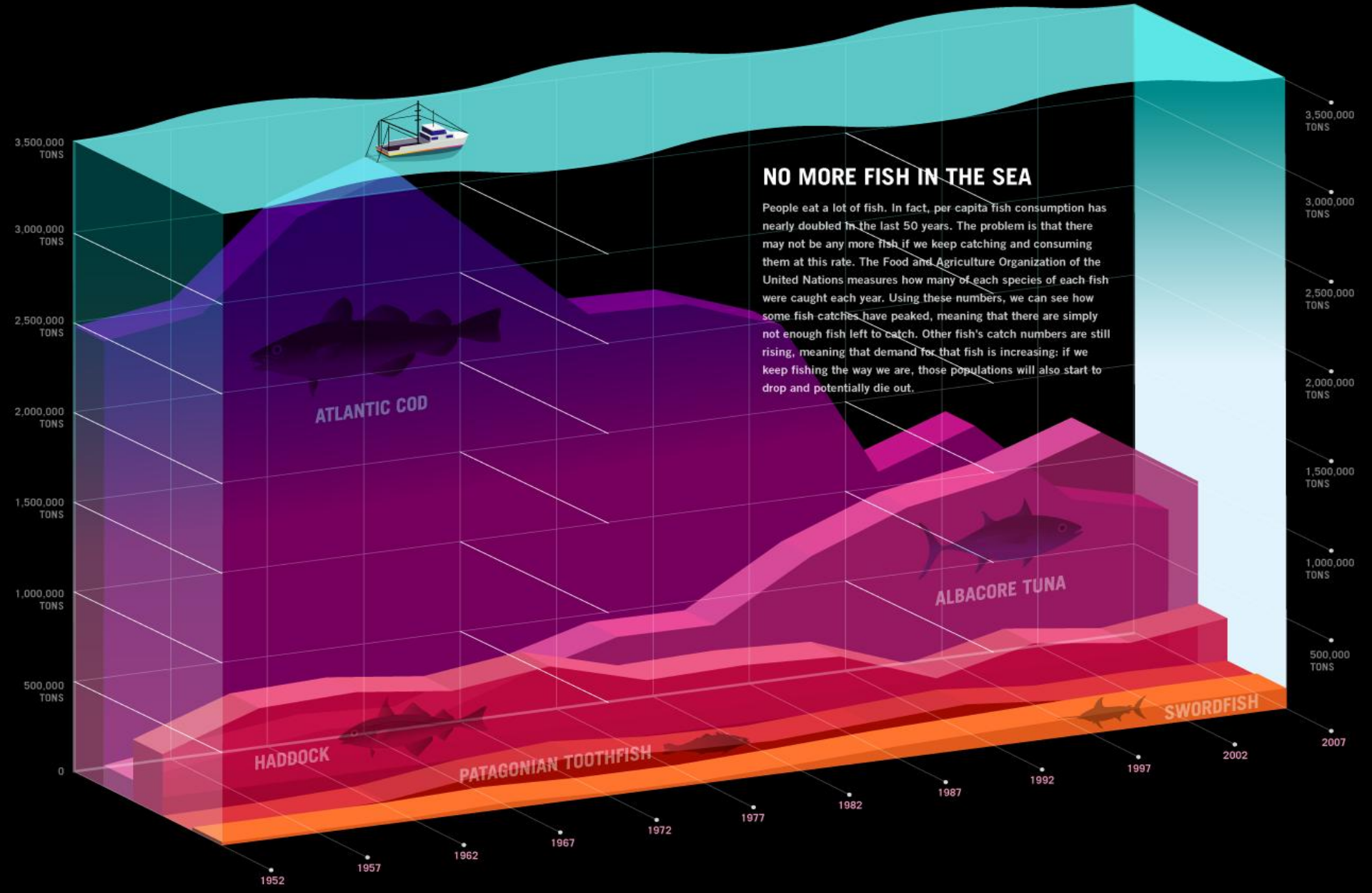
Dixit, 2008

Social Dilemmas

Situations which reward individual actions that lead to negative outcomes for everybody.

The Tragedy of the Commons

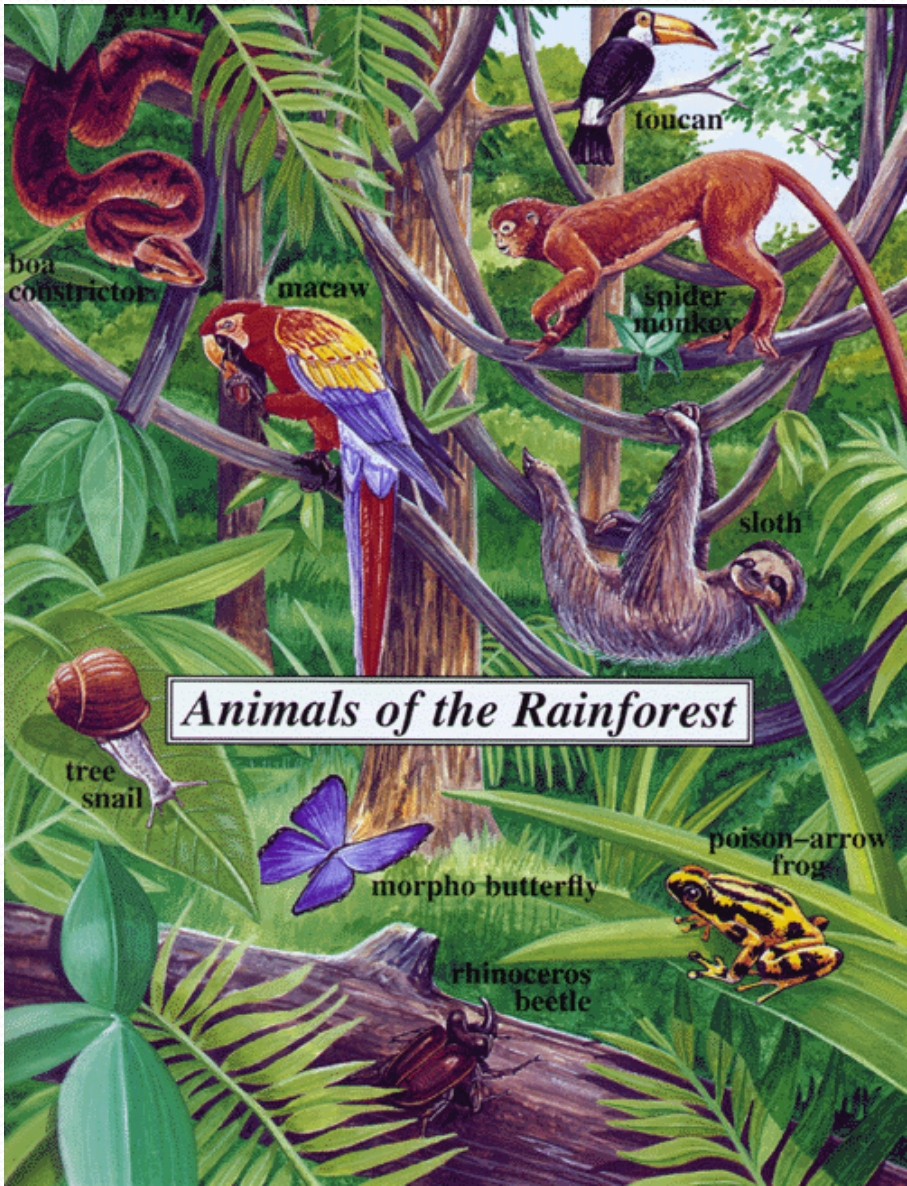
- Hardin, 1968
- Each herder sharing a common parcel has incentive to overgraze
- All herders are harmed
- Privatize: Inclosure Acts
- Doesn't work if renewal rate is less than risk-free interest rate
- Large fish
- Old-growth forests



SPECIES / YEAR	1952	1957	1962	1967	1972	1977	1982	1987	1992	1997	2002	2007
ATLANTIC COD	2,467,216	2,545,954	3,013,837	★3,201,009	2,727,559	2,271,320	2,254,716	2,070,596	1,185,017	1,375,079	903,211	774,188
ALBACORE TUNA	121,281	192,616	261,426	233,990	422,130	567,868	563,996	879,827	1,079,534	1,177,407	★1,359,704	1,009,628
HADDOCK	344,755	530,688	547,494	485,670	★552,866	404,303	423,103	397,894	207,815	334,105	270,299	339,230
PATAGONIAN TOOTHFISH *	0	0	0	0	0	1,178	1,153	8,641	39,836	30,175	★42,076	24,726
SWORDFISH	17,561	19,138	30,889	34,419	26,569	31,280	40,322	64,949	83,037	99,212	★109,707	109,271

Species Extinction

- 90% of all large fish are gone from the oceans
- Half of all species may be extinct in 100 years
- Elephants down 90% over past century
- African lions on the verge of extinction, 20,000 left
- All species of tiger on the verge of extinction
- Greatest destruction of species in 65 million years



World Problems

- Overpopulation
- Energy Shortage
- Global Warming
- Inequality
- Pollution
- Financial Instability
- War and Terrorism

Human Suffering

- 1% of population owns 40% of wealth
- 13% are hungry and seriously malnourished
- 18% don't have safe drinking water
- 43% don't have basic sanitation
- 18% of adults illiterate
- 97% have no internet connection

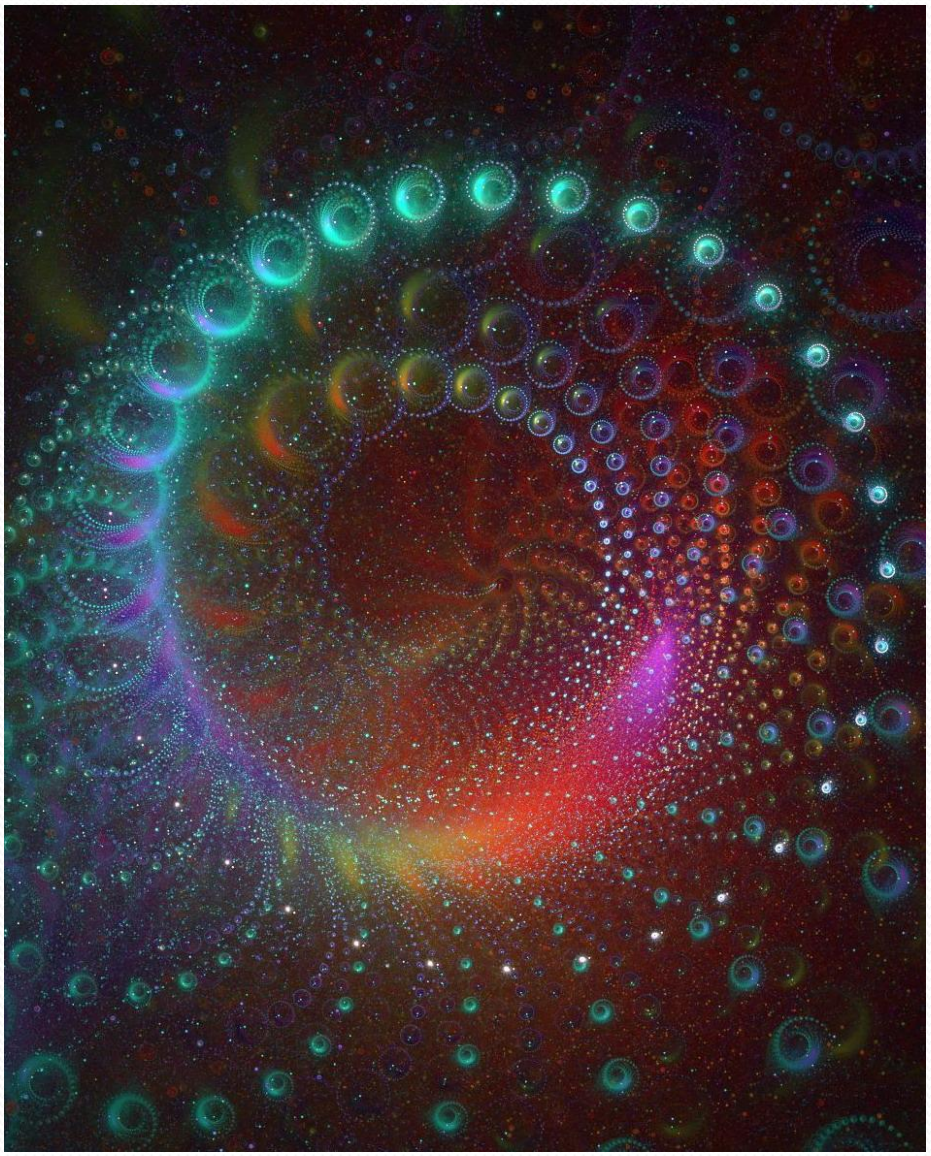
U.S. Problems

- Over 50% of marriages end in divorce
- Lung and breast cancer rates doubled over 30 years
- Obesity rate increased from 13% to 32% over 40 years
- 27% suffer from mental disorders
- 30% students involved in bullying
- 75% stressed, 35% experience job burnout


How can we create cooperation?

Internalize Externalities

- Individuals feel the effects of their actions on others
- Both positive and negative
- Pollution taxes
- Cigarette taxes
- Junk mail taxes
- Clean energy credits
- Per-mile car insurance
- HMO's and life insurance



Nalebuff, 2006

Interrupt Vicious Cycles Early

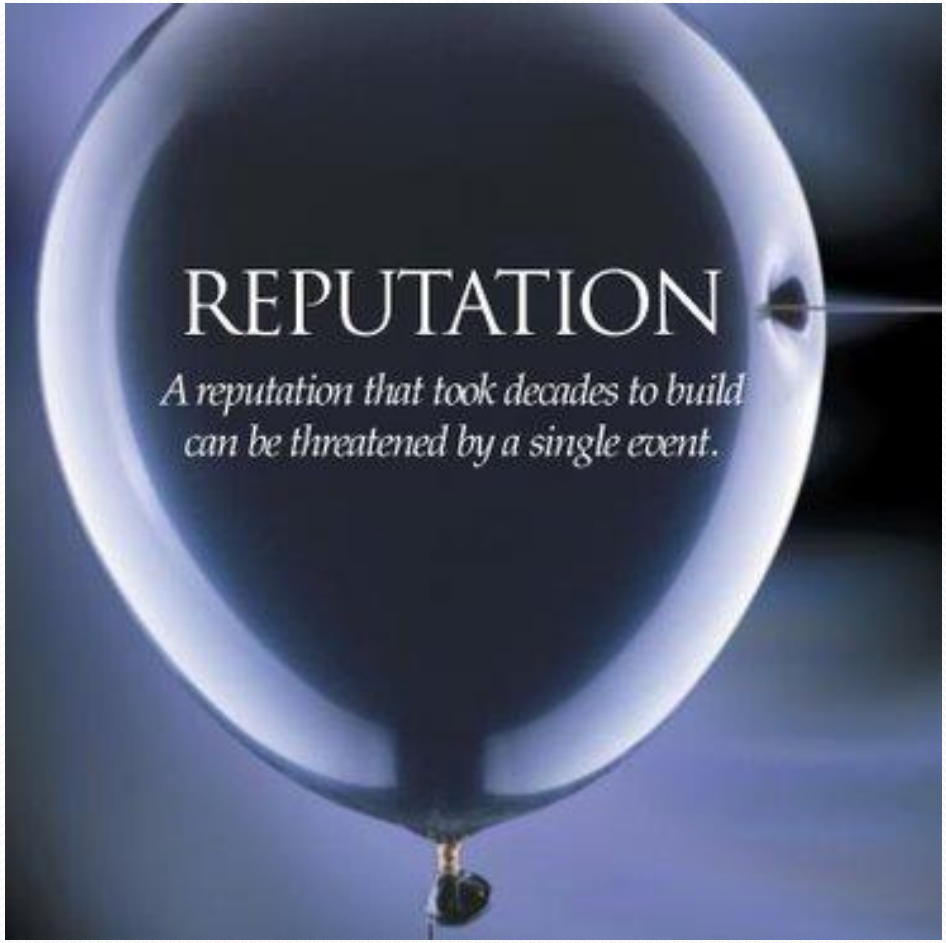
- Feuds, war
- Gridlock
- Runs on banks
- Crashing housing prices
- Home Equity insurance
- 1.5% one-time fee, Equity Headquarters, Syracuse
- Insurance breaks cycle
- Reduces risk of asset!

Nalebuff, 2006

Increase Accountability

- Flame wars
- Spam
- Cyber-bullying
- Road-Rage

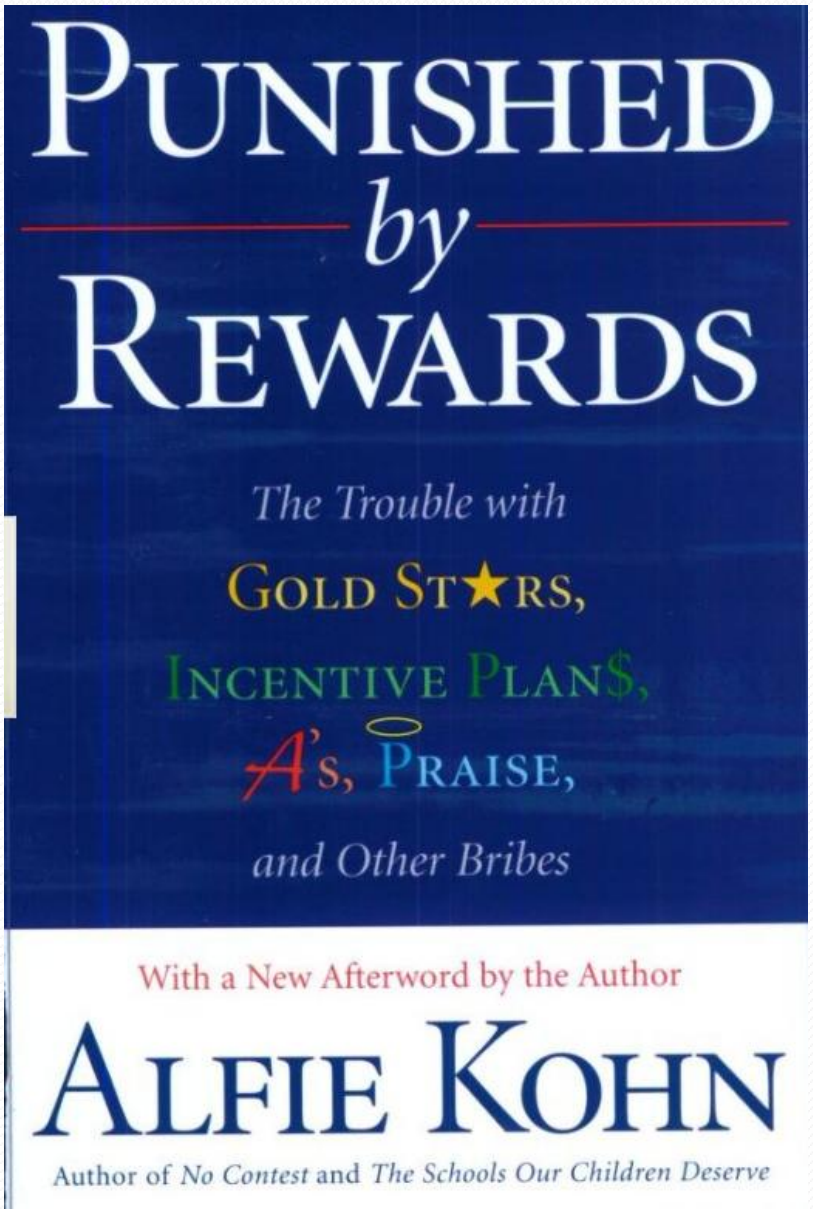
- Eliminate anonymity
- Slashdot Karma
- Ebay and Amazon ratings



Measure What You Care About

- Bhutan: Gross National Happiness
- Grading on a curve
- Standardized tests
- Publish or perish
- Corporate bonus systems

  (eg. Enron fired bottom 10% each year!)
- Speeding laws



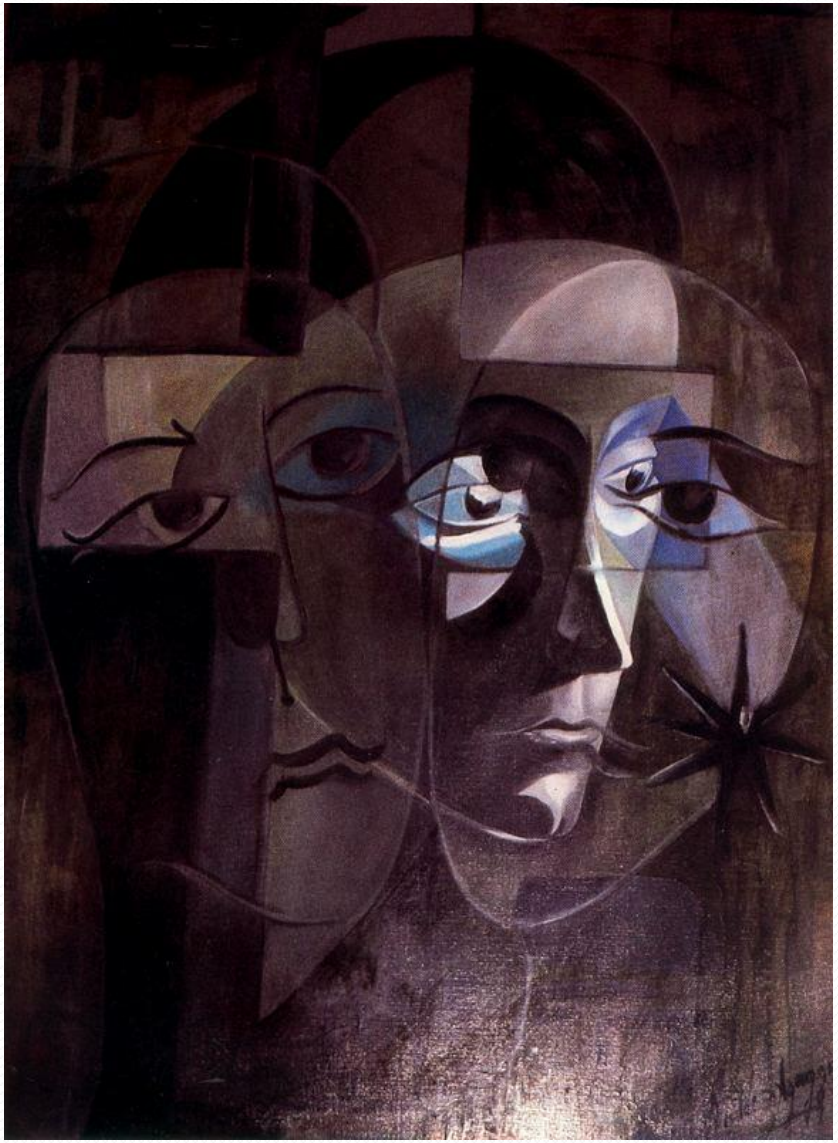
Separate Outcome from Strategy

- Politics looks one step ahead, economics many
- Hanson's Futarchy: Vote on desired outcomes, experts design strategies
- Use simulation to predict strategy results

Hanson, 2000

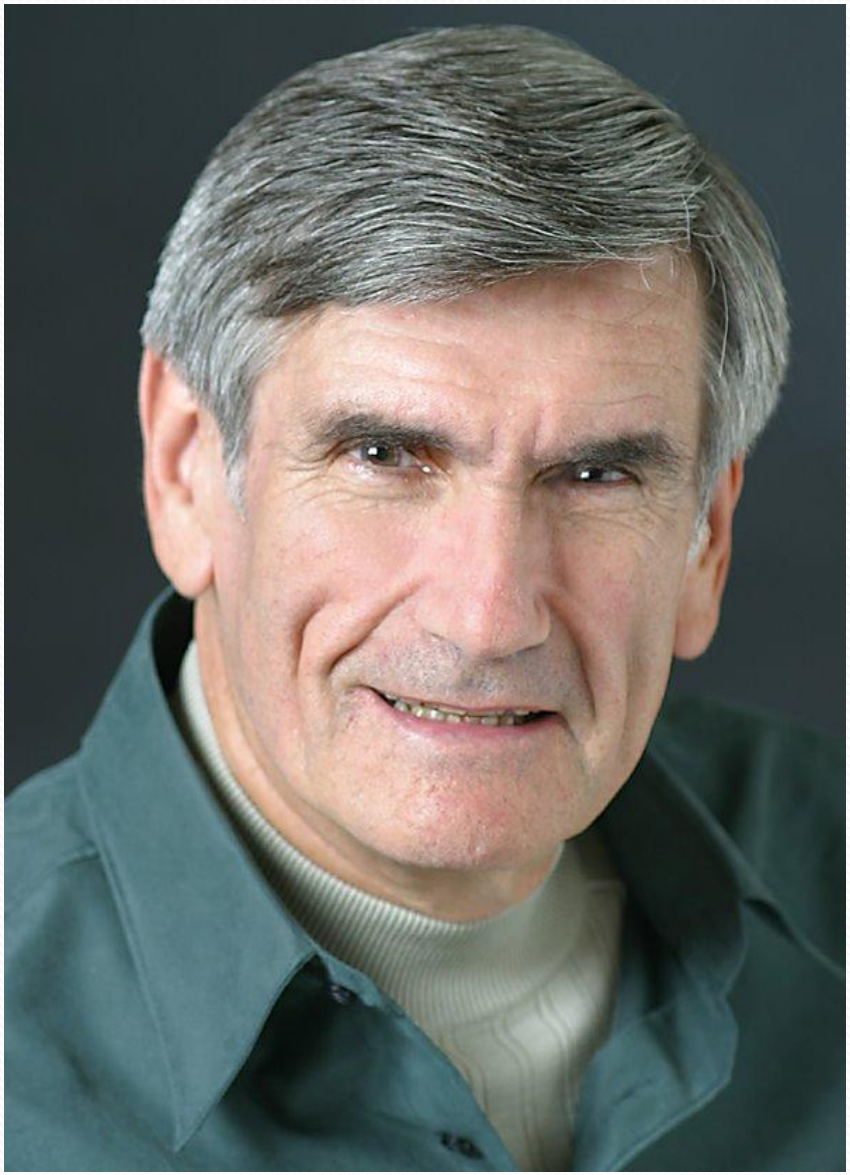
New Cooperative Business Models

- Reward cooperation
- Network Marketing
- Cooperative Networks instead of hierarchies
- Pair programming
- Group school projects
- Challenge Day
- CEO-Space



Improve Communication

- Marshall Rosenberg's Non-Violent Communcation
- Interupt vicious cycles of escalating violence
- Reflective listening
- Mediation
- Supportive win-win workplaces



Change the Dream

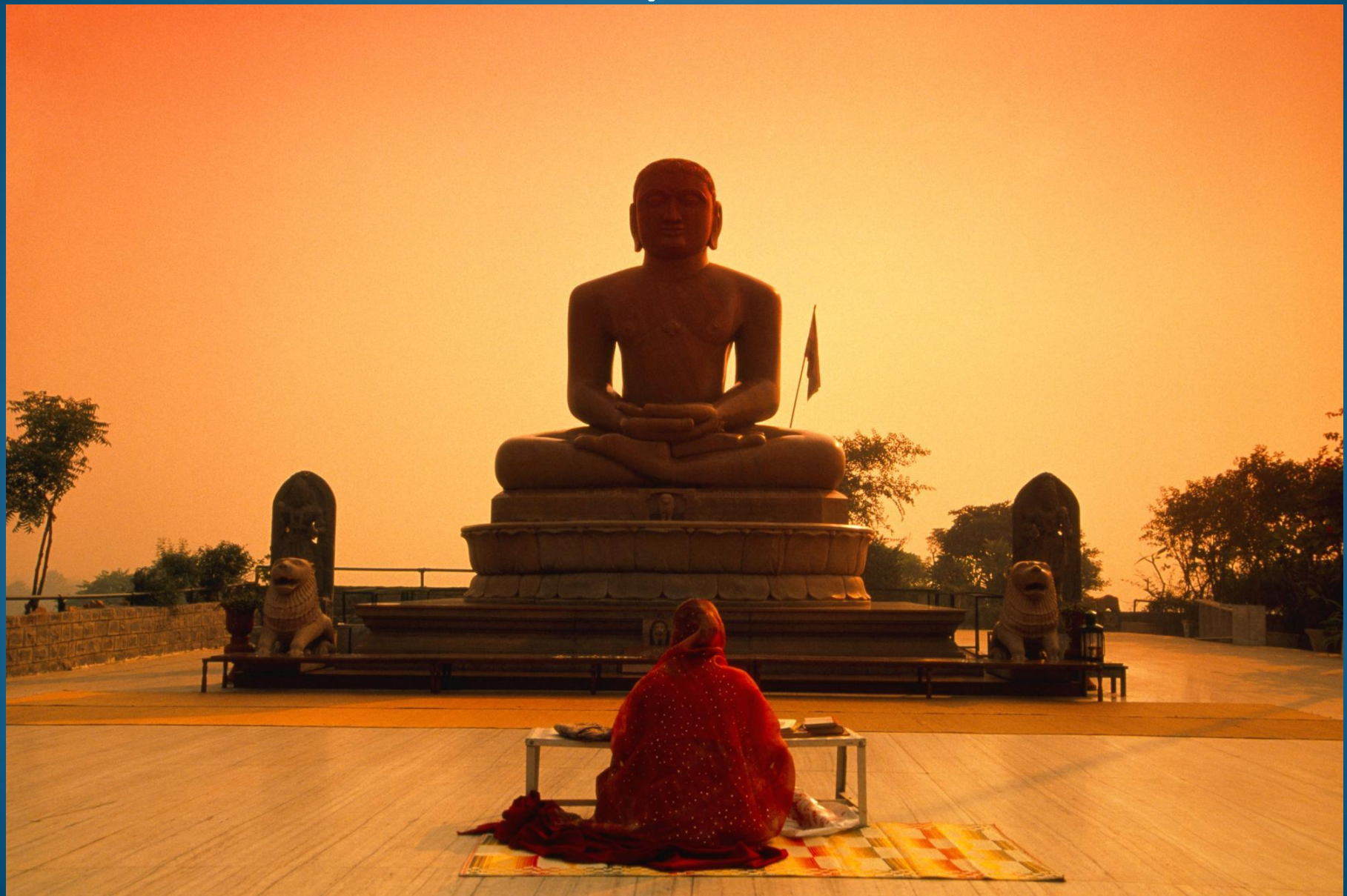
- Pachamama Alliance "Awakening the Dreamer, Changing the Dream" Symposium
- Create a new vision
- Cooperative and Sustainable Business
- Schools that inspire and encourage cooperation

THE PACHAMAMA ALLIANCE

Cooperative Technology

- Better incentive design
- Better strategy simulation
- Aggregation of desired outcomes: semantic voting
- Escrow mechanisms
- Commitment mechanisms
- Institution design
- Better monitoring
- Autonomous systems with designed utilities

Create a Cooperative Future



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