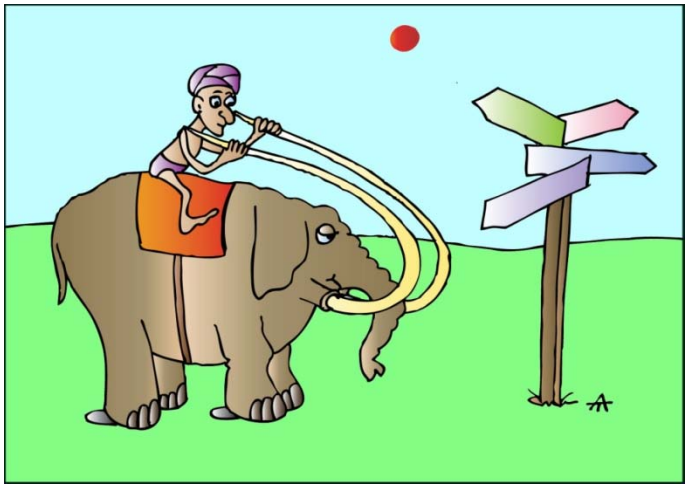
Big History: Earth, Life, and Sustainability



Raghu Murtugudde

EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER

INDIAN INSTITUTE OF TROPICAL METEOROLOGY

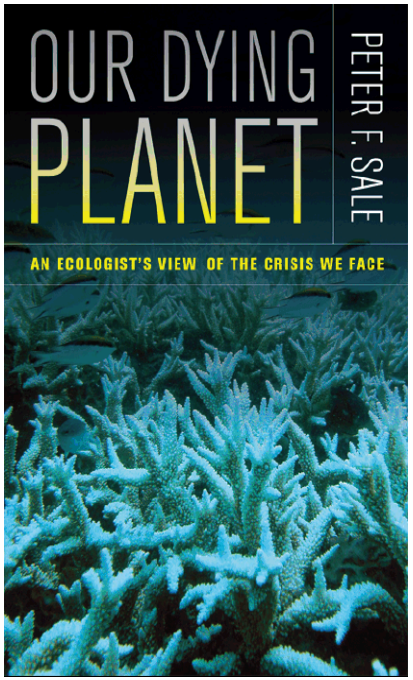
(An Autonomous Body under the Ministry of Earth Sciences, Govt. of India)

Atmospheric and Oceanic Science

UNIVERSITY OF MARYLAND

Red Hot Lies: How Global Warming Alarmists Use Threats, Fraud, and Deception to Keep You Misinformed

State of Fear



Climate Cover-Up: The Crusade to Deny Global Warming

NASA Global Warming Alarmist Endorses Book That Calls For Mass Genocide

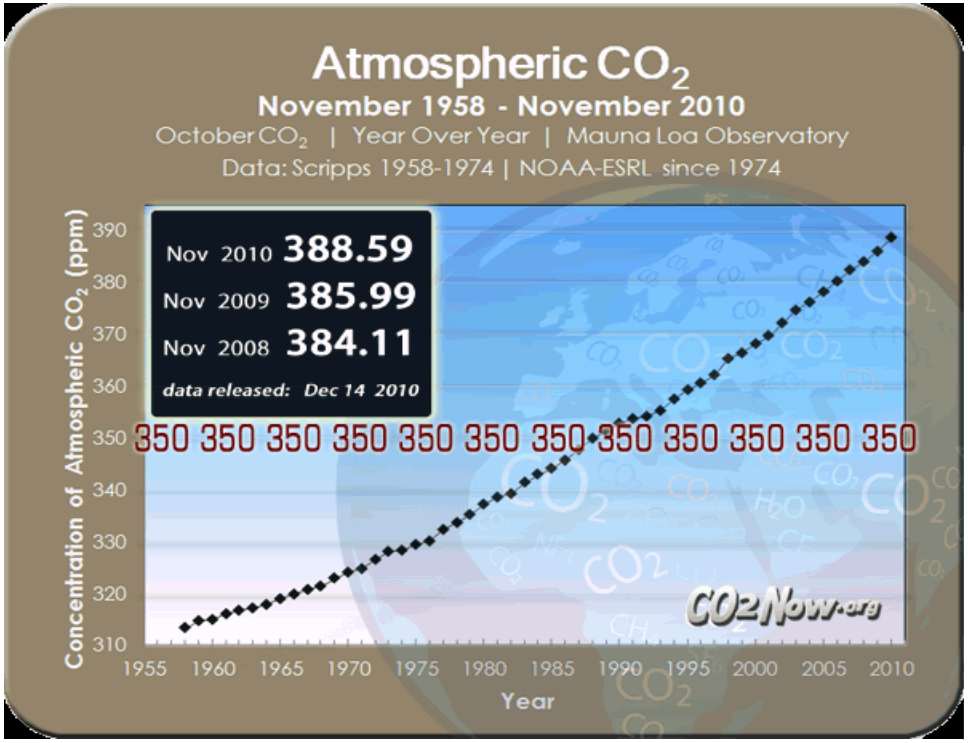
Dr James Hansen: Eco-fascist author who wrote that industrial civilization should be destroyed "has it right"

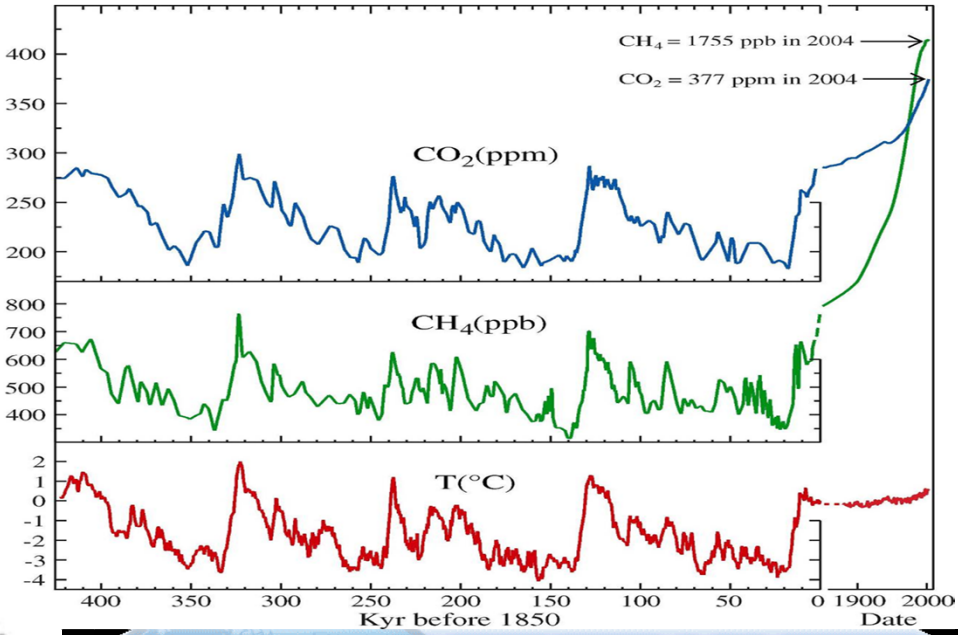
Storms of My Grandchildren: The Truth About the Coming Climate Catastrophe and Our Last Chance to Save Humanity

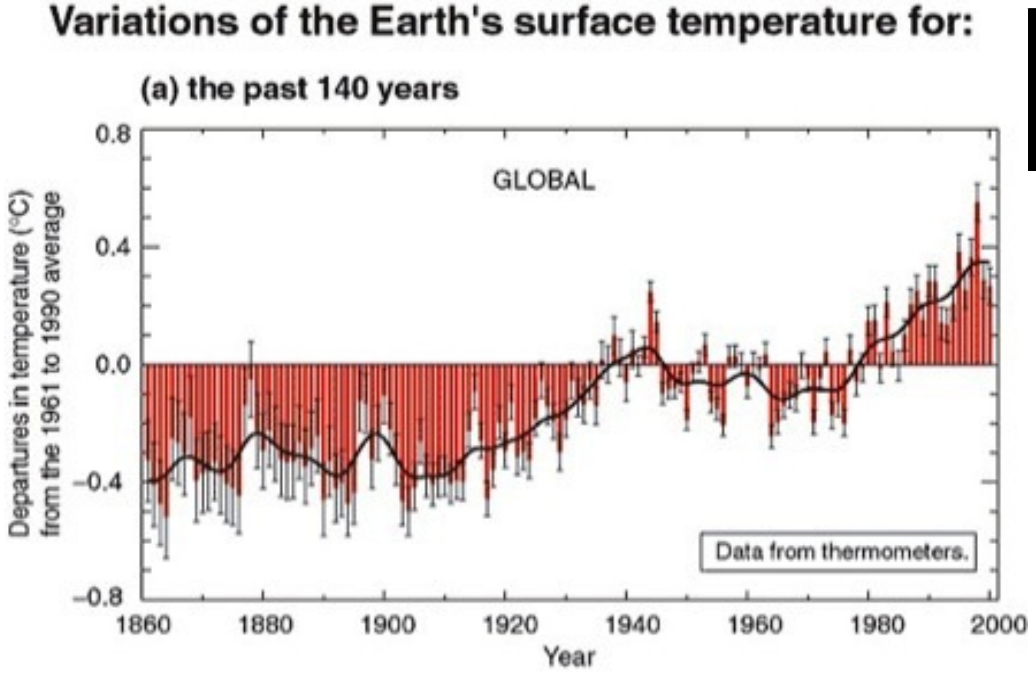
"Unfortunately, people often have flawed intuitions regarding how well they communicate, typically exaggerating their success. In ordinary conversation, people receive feedback, allowing them to refine their imperfect communications. Scientists, though, often have little direct contact with the public. As a result, they can not tell how well they are doing or how to do better. Without evidence to moor them, science communication can lurch from one well-intended initiative to the next. A scientific approach to communicating science requires the systematic feedback provided by empirical evaluation."

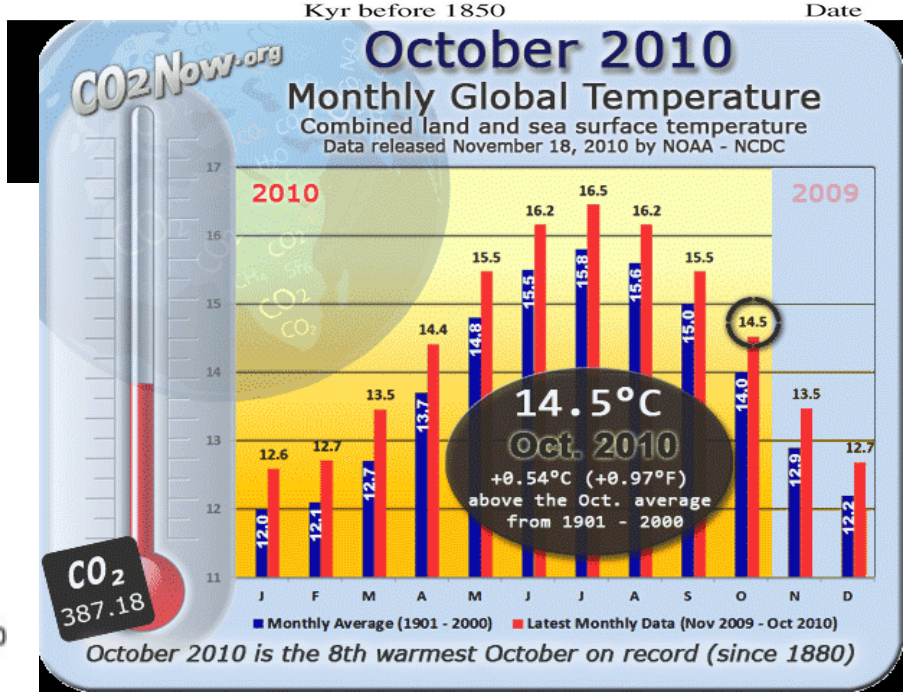
Pidgeon and Fischoff, Nature CC 2011.

There is very accurate and reliable data for atmospheric CO_2 and temperatures









CLIMATE VULNERABILITY IN NUMBERS

UN Report

Facts are uncertain, values are in dispute, stakes are high, and decisions are urgent. **Funtowicz, S.O. and J.R. Ravetz 1990**

Nearly
1 MILLION CLIMATE CHANGE DRIVEN DEATHS* ESTIMATED EVERY SINGLE YEAR FROM 2030 IF ACTION IS NOT TAKEN

Some
5 MILLION CLIMATE DEATHS ESTIMATED OVER THE NEXT TEN YEARS IN ABSENCE OF AN EFFECTIVE RESPONSE

Already
350,000 CLIMATE DEATHS ESTIMATED EACH YEAR TODAY

Almost
80% OF ALL CLIMATE DEATHS ARE REGISTERED ONLY AMONG CHILDREN LIVING IN SOUTH ASIA OR SUB-SAHARAN AFRICA

Over
99% OF ALL MORTALITY OCCURS IN DEVELOPING COUNTRIES

Close to
10 MILLION PEOPLE ESTIMATED TO BE LIVING UNDER THREAT FROM CLIMATE DRIVEN DESERTIFICATION BY 2030, UP FROM 2.5 MILLION TODAY

Around
150 BILLION DOLLARS IN LOSSES TO TODAY'S ECONOMY ESTIMATED TO BE CAUSED BY CLIMATE CHANGE

More than
HALF OF THE TOTAL ECONOMIC LOSSES TAKE PLACE IN INDUSTRIALIZED COUNTRIES

More than
50 COUNTRIES ACUTELY VULNERABLE TO CLIMATE CHANGE TODAY ARE IN URGENT MOST NEED OF SUPPORT

Some
170 COUNTRIES -- OR MOST OF THE WORLD -- HAVE HIGH VULNERABILITY TO CLIMATE CHANGE IN AT LEAST ONE KEY IMPACT AREA ALREADY TODAY

Over
50 HIGHLY EFFECTIVE MEASURES INCLUDED IN THIS REPORT ARE READILY AVAILABLE TO LIMIT VIRTUALLY ALL HARM CAUSED BY CLIMATE CHANGE -- JUST A GLIMPSE OF THE MANY MORE OPTIONS AVAILABLE

Irreducibel uncertainties: what we know that we know, what we know that we don't know, what we don't know that we know, what we don't know that we don't know.

High quality ≠ low uncertainty

Risk perception

Relevant, Reduced-Complexity, Timely

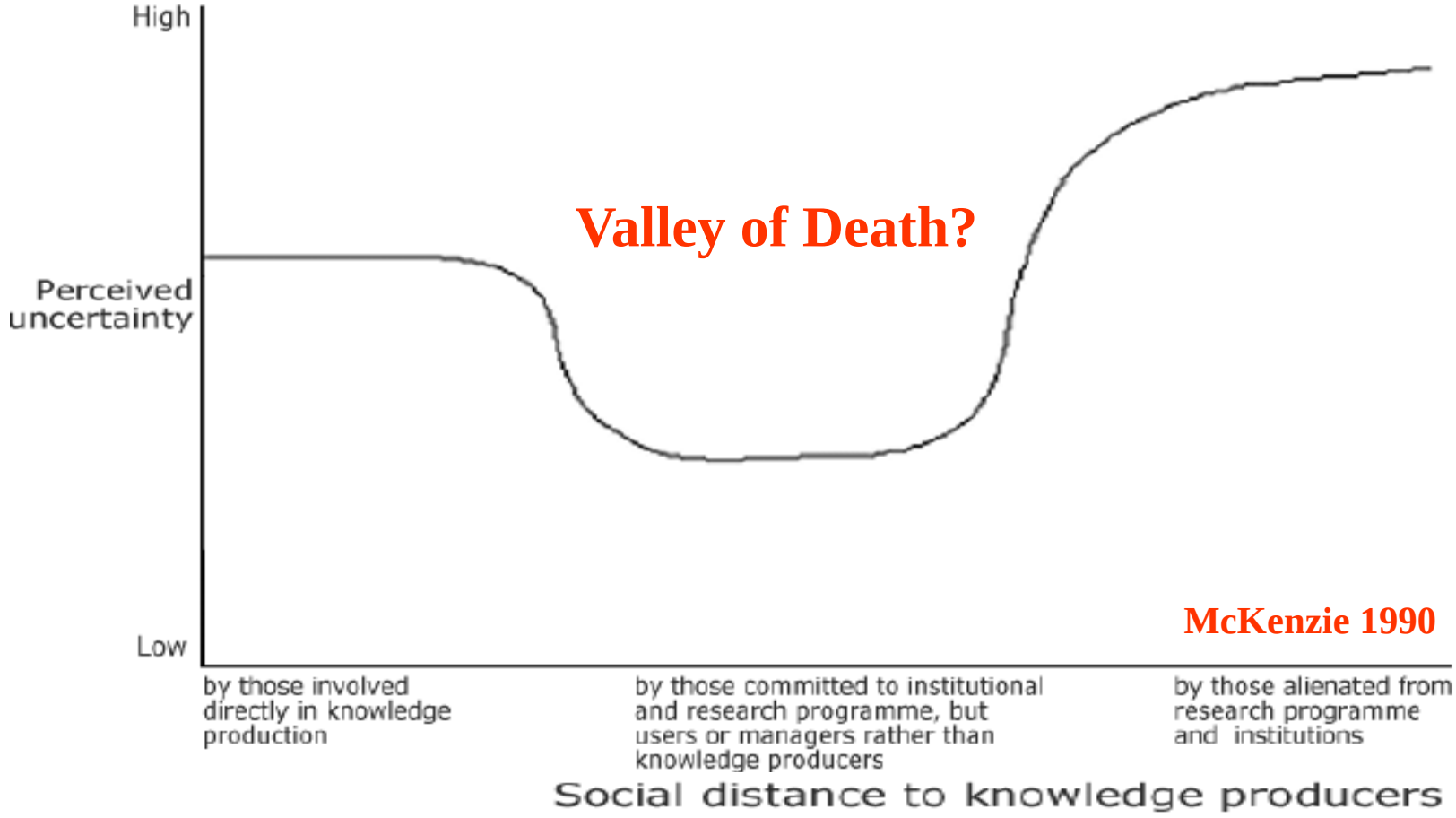


Figure 1. The certainty trough (MacKenzie, 1990)

Sustainability

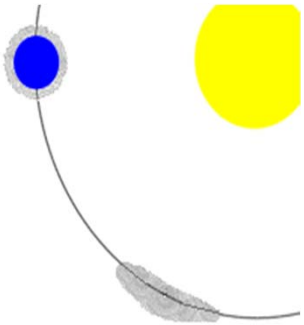
Ability of one generation to exploit resources without jeopardizing the ability of future generations to exploit the same resources.

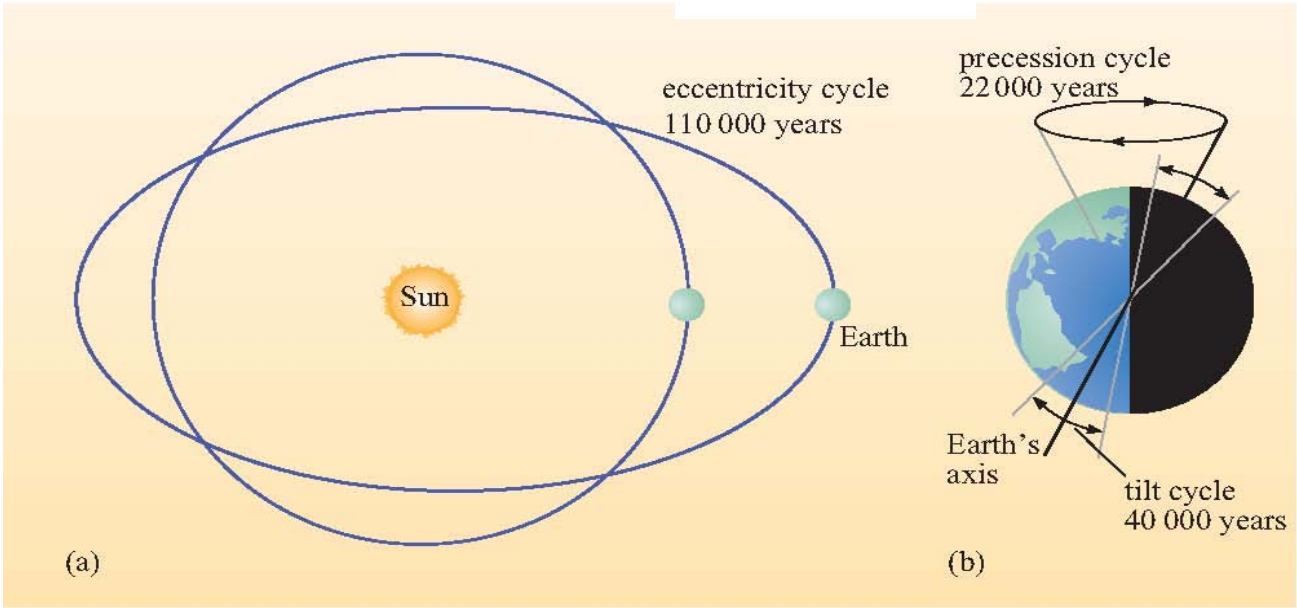
Who makes decisions? How?

How did we Evolve? What is unique about our planet?

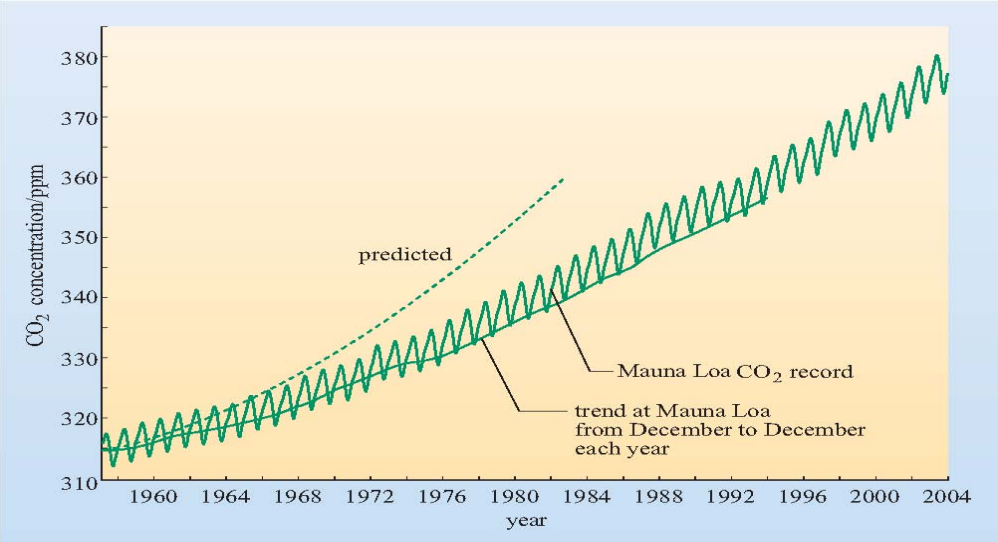
GOLDILOCKS PLANETS

Temperature	-50°C	+15°C	+450°C
Greenhouse Effect	a few degrees	~30°C	~470°C



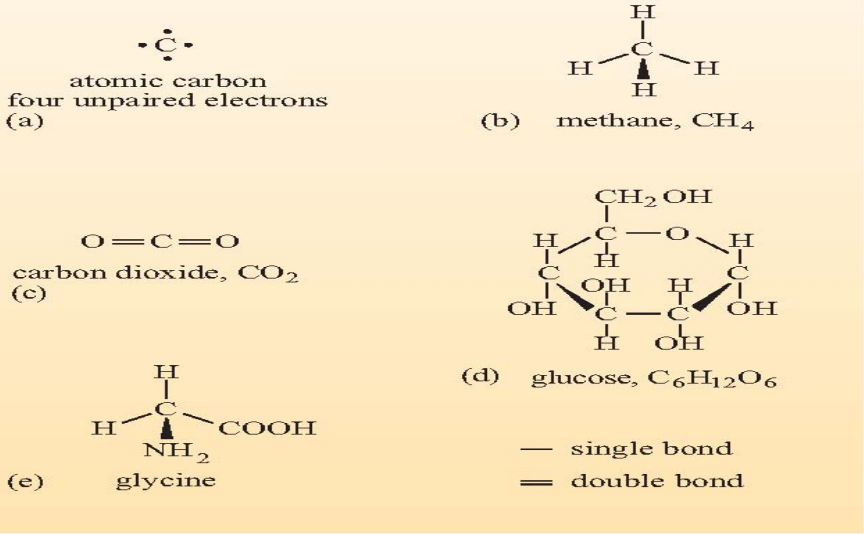


Stuff life is made of: Water and Carbon

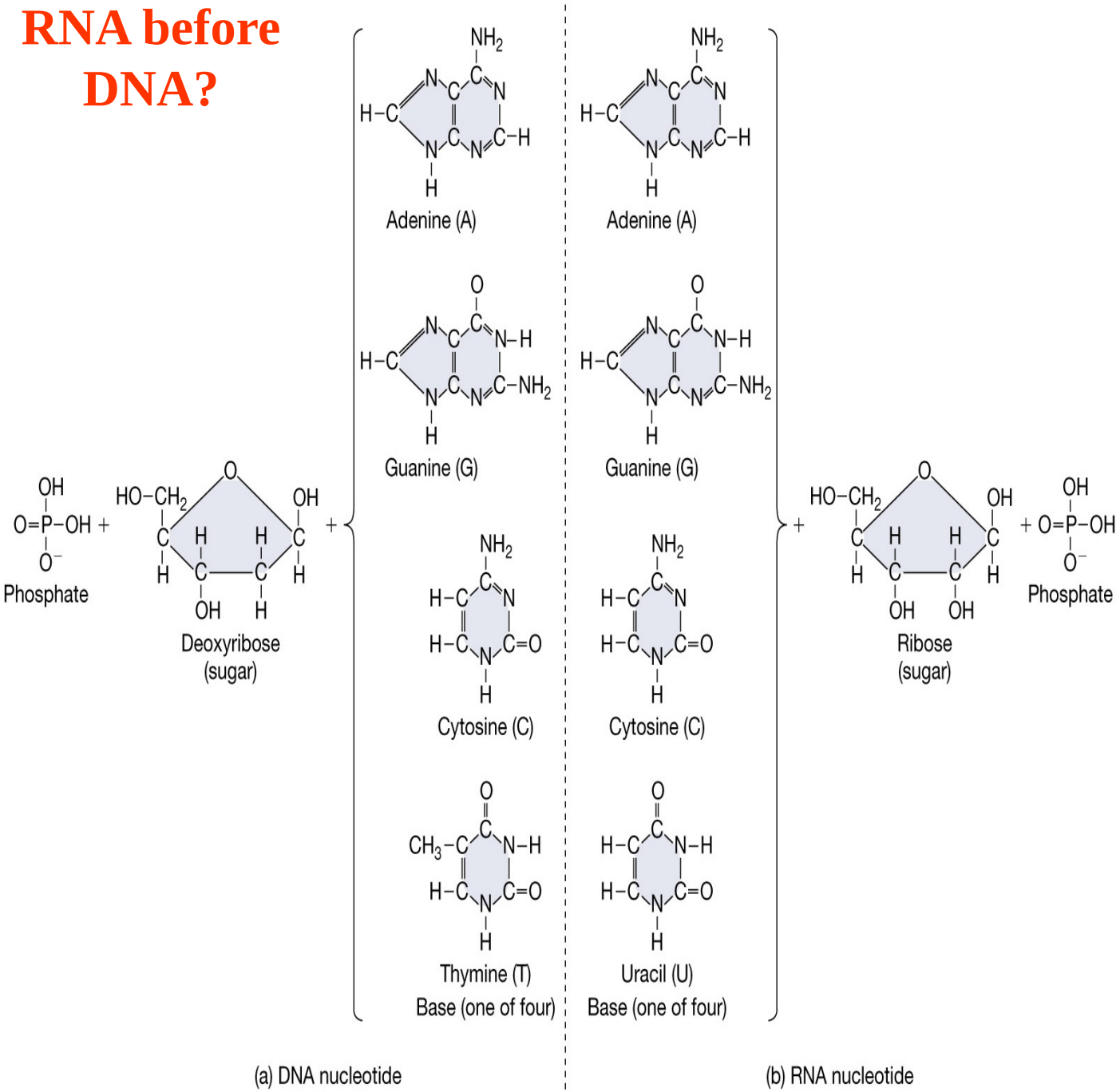


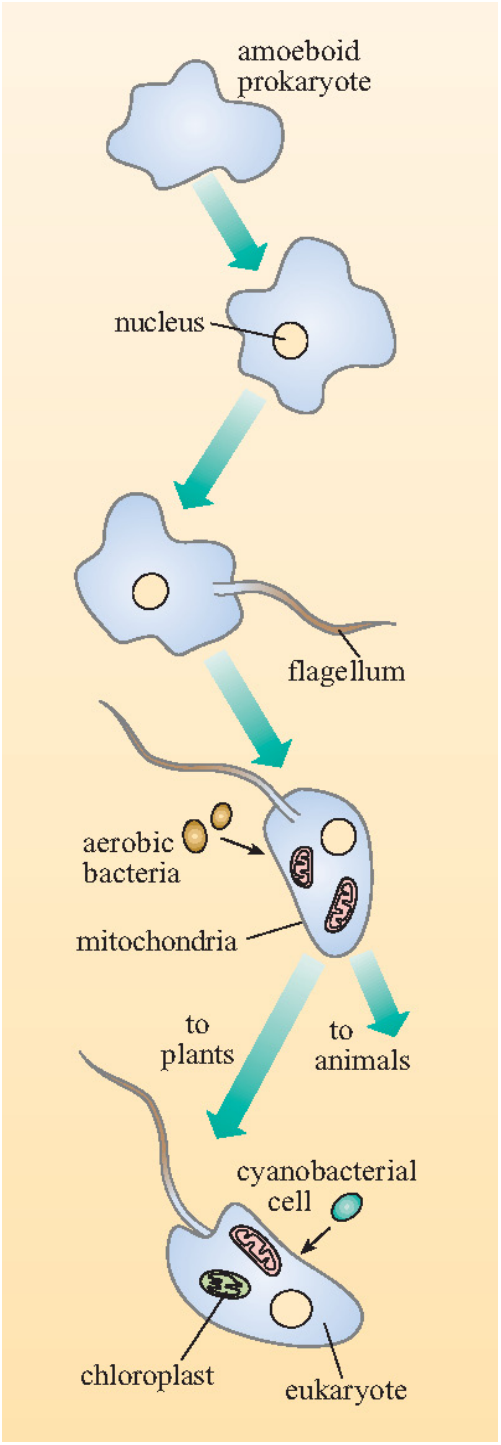
Where did life originate?

Geothermal ponds, like this one in Yellowstone National Park, could have been where the first cells evolved.

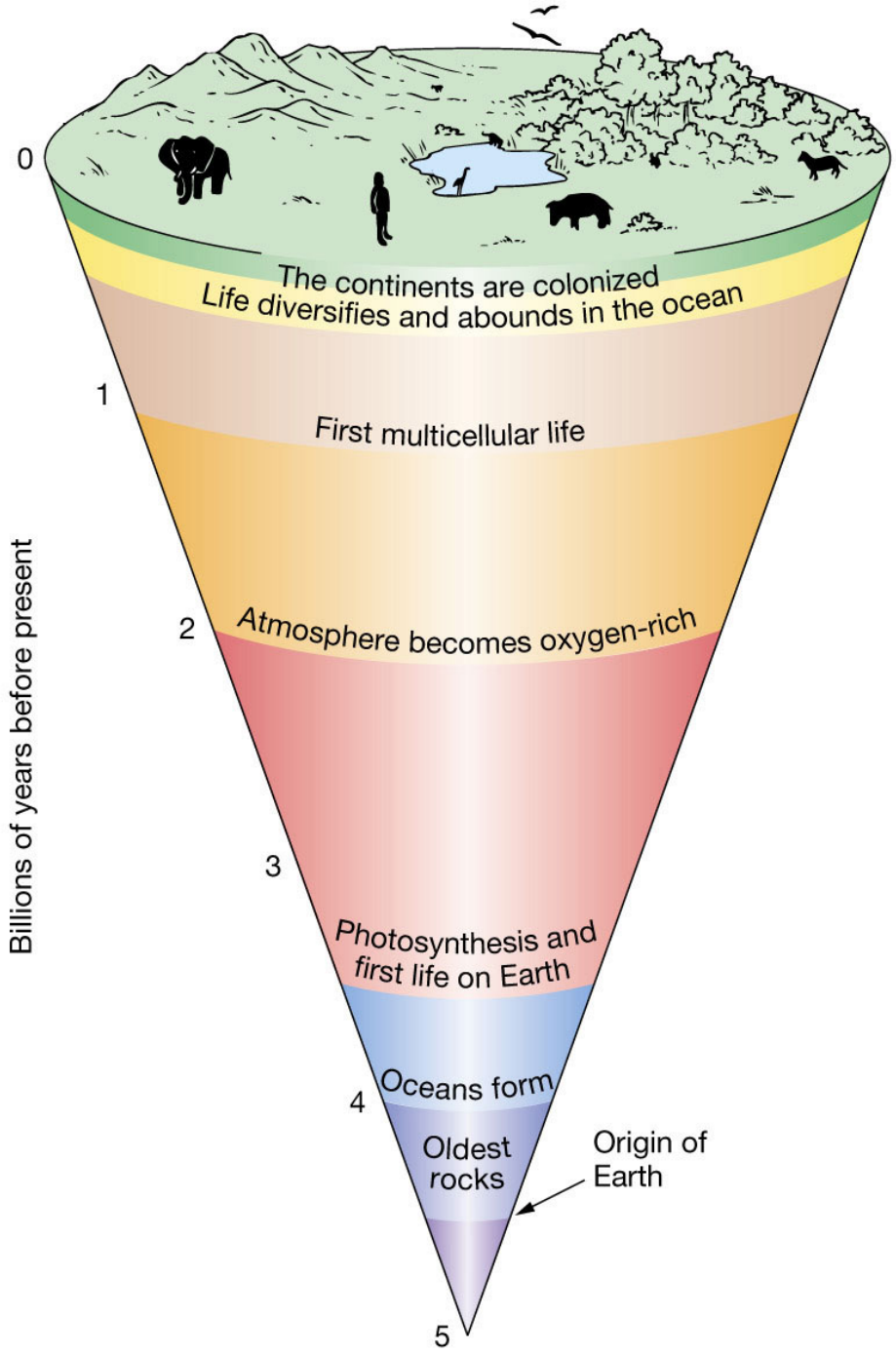


RNA before DNA?

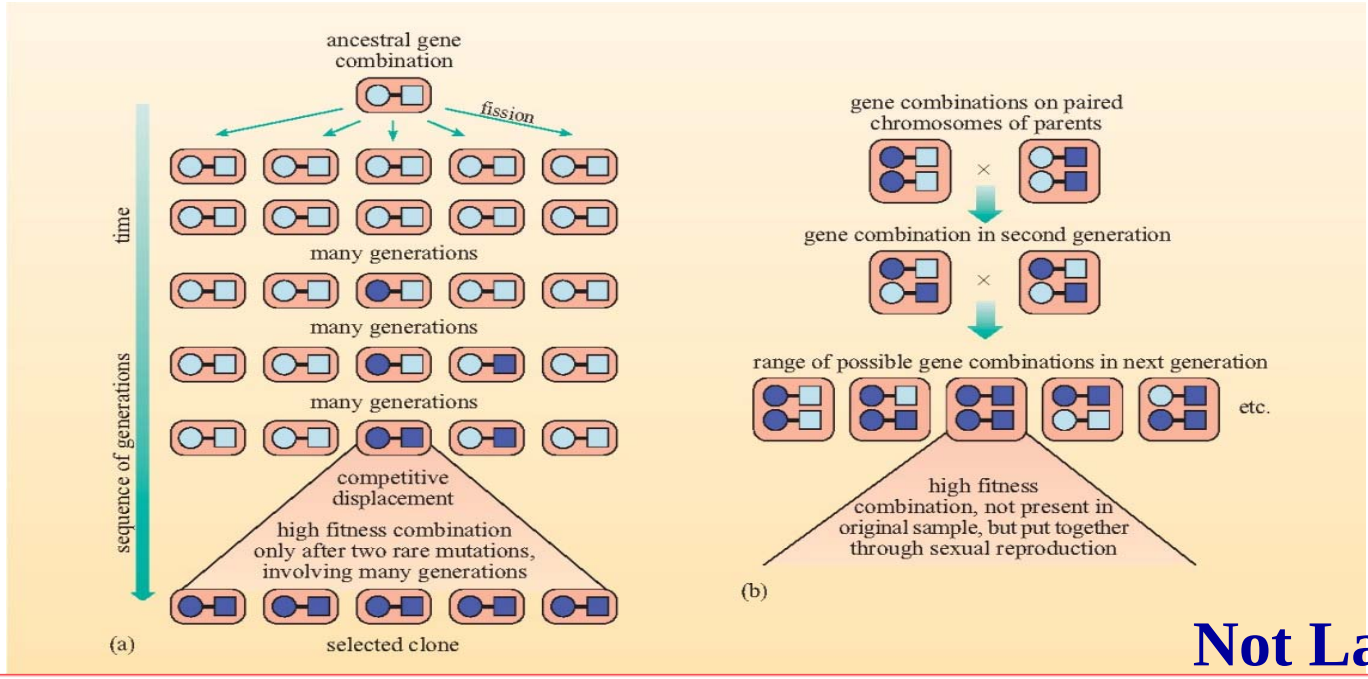




Spineless Penis and a Big brain!



Epoch		Development of Plants and Animals
olocene	0.01	Humans develop
istocene	1.6	
iocene	5.3	
iocene	23.7	"Age of Mammals"
gocene	36.6	
ocene	57.8	
leocene	65.0	
Age of eptiles"		Extinction of dinosaurs and many other species First flowering plants First birds Dinosaurs dominant
Age of phibians"		Extinction of trilobites and many other marine animals First reptiles Large coal swamps Amphibians abundant
Age of ishes"		First insect fossils Fishes dominant First land plants
Age of rtebrates"		First fishes Trilobites dominant First organisms with shells
		First multicelled organisms First one-celled organisms Age of oldest rocks Origin of Earth



Not Lazy

Lazy?

EVOLUTIONARY BIOLOGY

Lice in hiding

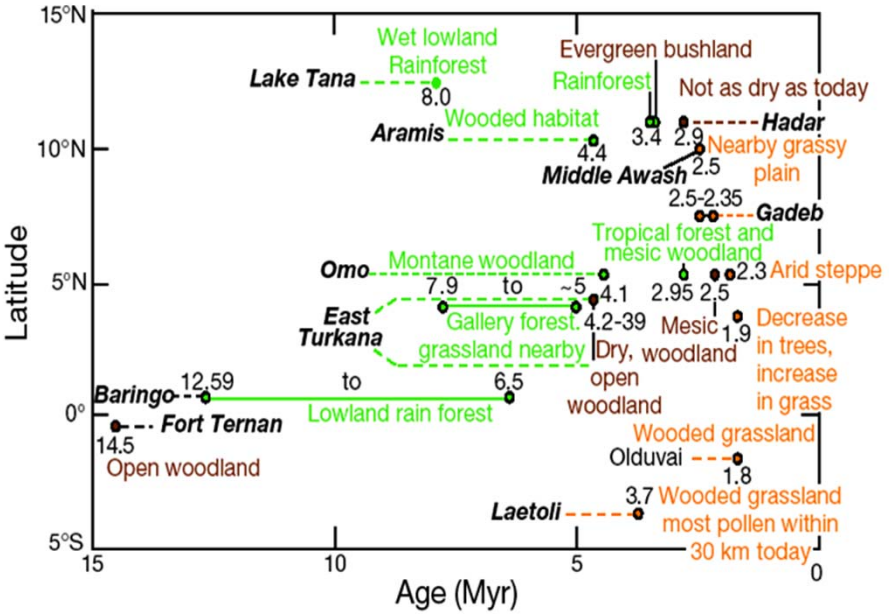
Am. Nat. doi:10.1086/656269 (2010)

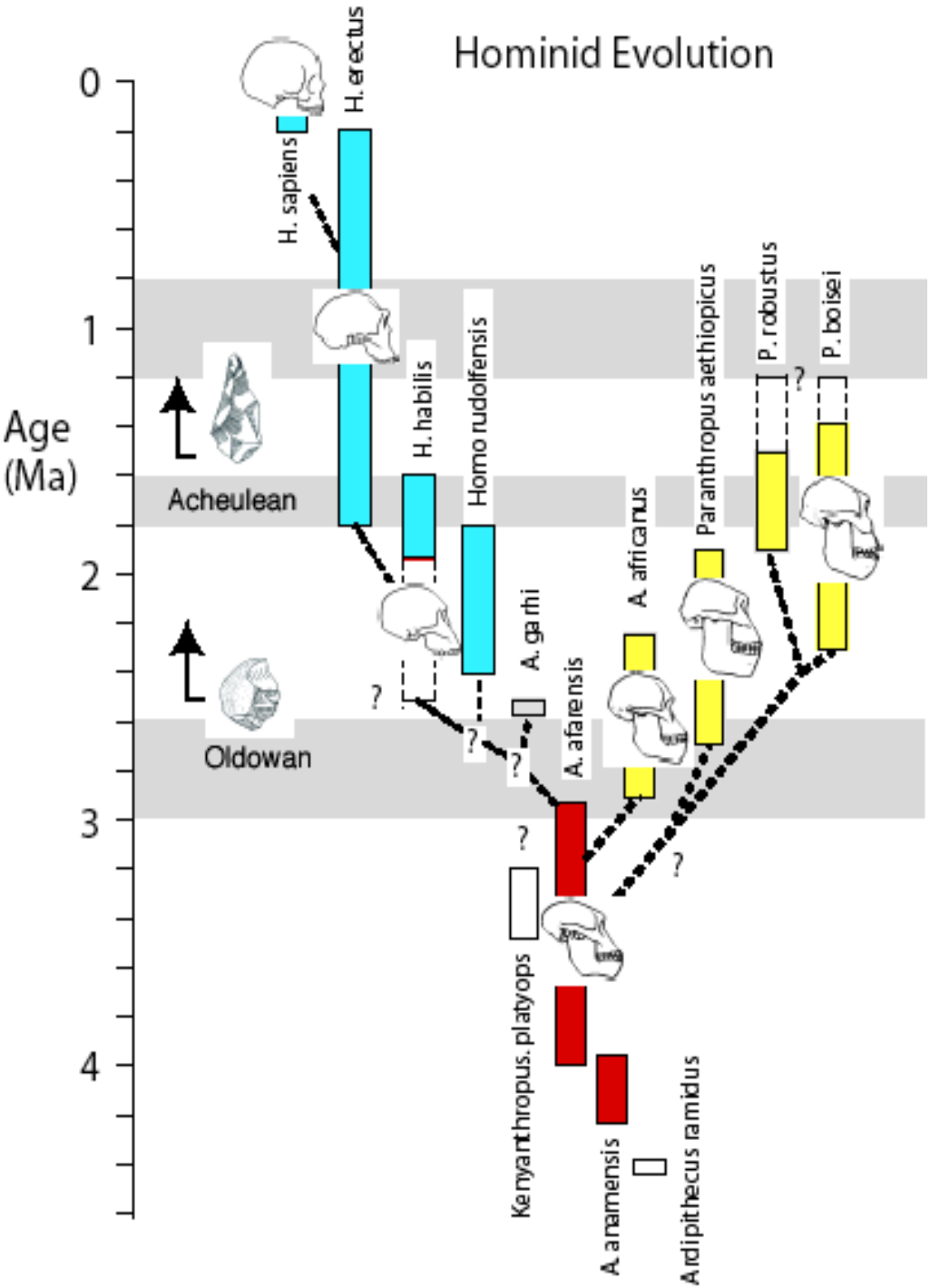
Bird lice reduce their chances of being picked off by their hosts by evolving to match the colour of the birds' feathers.

Camouflage has been well documented in predator–prey relationships. Sarah Bush and her colleagues at the University of Utah in Salt Lake City now report that the same evolutionary trend exists between parasites and their hosts.

By comparing lice from species of dark- and light-coloured birds (pictured), the researchers found that 'feather' lice — which live on a bird's body — match the colour of their host's plumage (insets). However, 'head' lice do not necessarily blend in. This suggests that bird preening drives lice-colour evolution: birds cannot see or groom their heads, so there is no selective pressure for head lice to be camouflaged.

Are we really trying to stop climate change?





- **Cranial Activity: Encephalization - Baldwinian evolution? Feedback with tool making from the Paleolithic to the Holocene?**

- **Symbolic language – cultural learning**

Birds with beauty — and brains

Some birds have it all. Male siskins with brighter, more attractive plumage are better at finding food than their less eye-catching counterparts.

Fernando Mateos-Gonzalez and his team at the Natural History Museum of Barcelona, Spain, measured the length of a yellow stripe on the wings of male siskins (*Carduelis spinus*; **pictured**). Females are known to pick mates on the basis of the length of this stripe. The researchers challenged hungry males to unlock a cache of pine seeds blocked by toothpicks.

Birds with longer yellow
ved the problem
ckly than those with
ripes. The authors
age, size and social
ce as possible
ory factors, and
that fancier feathers
p discerning females
nates that are not
r, but also smarter.
loi:10.1098/
0163 (2011)

Probing Pronghorn Mating Preferences

Pronghorns, the American antelope, are the fastest animals on the North American continent, yet coyotes still kill many of the fawns, catching them before they develop the quickness to run away. Animal behaviorist John Byers of the University of Idaho, Moscow, has shown, however, that if a female pronghorn picks the right male, her fawns will grow faster than normal and have a much better chance of surviving. Since 1981, he and colleagues have tracked six pronghorn generations at the National Bison Range in Montana.

Byers suspects that female pronghorns, which he found favor males best able to fight off other males, are actually choosing mates with the lowest burden of so-called deleterious mutations. Byers hasn't had a good way to prove his theory, but thanks to the growing availability of next-generation DNA sequencing, he may finally have a chance. He and his colleague have over the years collected tissue samples from 835 pronghorns across the generations, and they now plan to genetically profile each animal to determine whether female pronghorns do indeed pick genetic studs. "I think it's going to be ultracool," Byers says. **–E.P.**

ECOLOGY

Hidden in plain sight

Some species elude predators by masquerading as common, inedible objects. But far from being a passive disguise, such camouflage also involves specific changes in prey and predator behaviour, say John Skelhorn at the University of Exeter, UK, and his colleagues.

In lab experiments, the researchers exposed twig-like *Selenia dentaria* caterpillars (**pictured**) sitting among real twigs to domestic chicks trained to attack them. Not only did the chicks take longer to spot their prey when twig density was higher, but caterpillars also preferred branches with more twigs. During the day, caterpillars opted for twig density over leaf availability; however, at night, when predators are no longer on the prowl, the insects were found on branches with abundant leaves to eat.

High twig density further protects caterpillars by dashing predators' hopes. Repeated exposure to branches with many twigs and no caterpillars made chicks less motivated to hunt for prey than birds less frequently exposed to this situation.

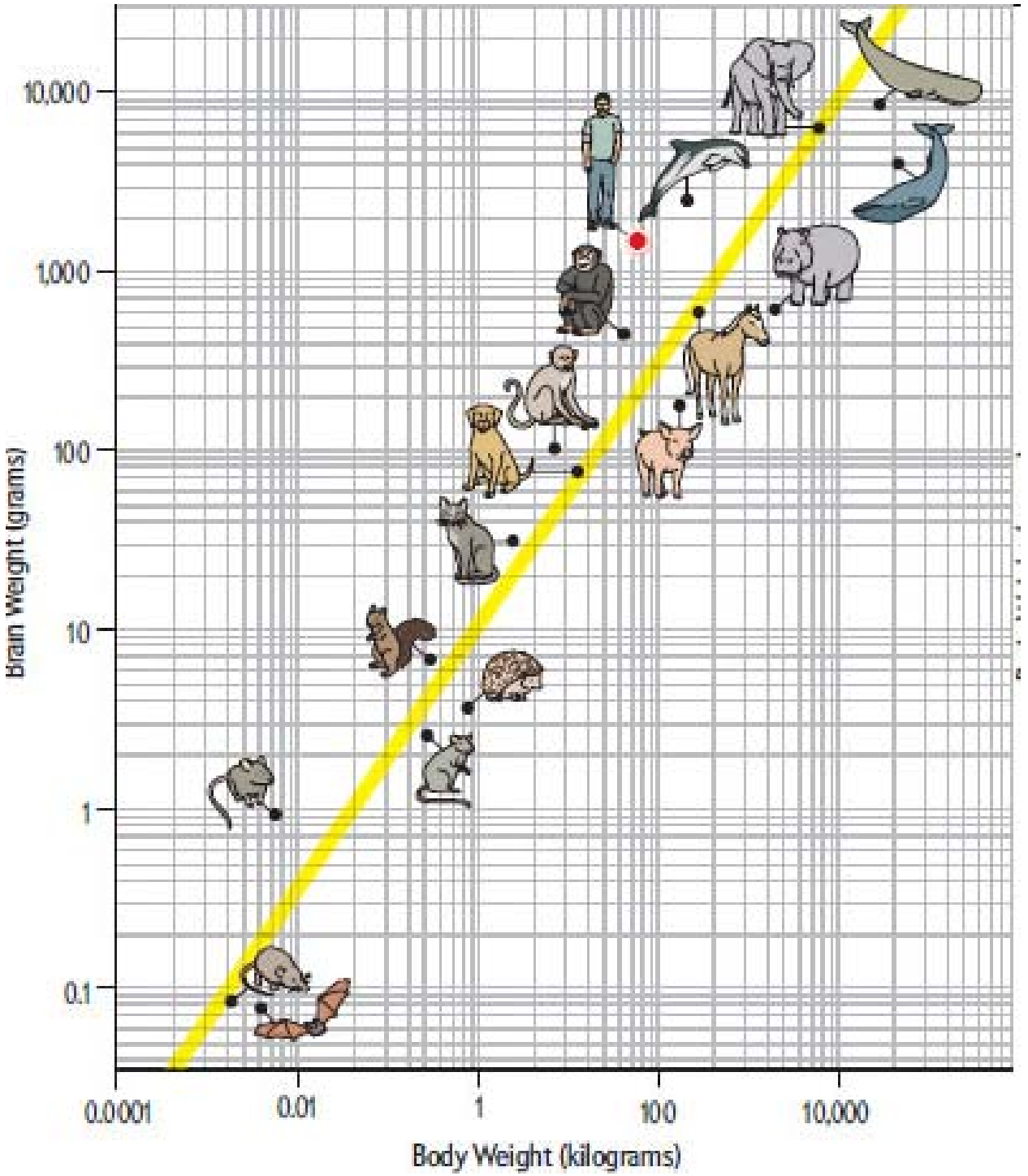
Proc. Natl Acad. Sci. USA **doi:10.1073/pnas.1014629108 (2011)**

Intelligence is NOT needed

Are we the ONLY Nonzero species?

Brain Size Outliers

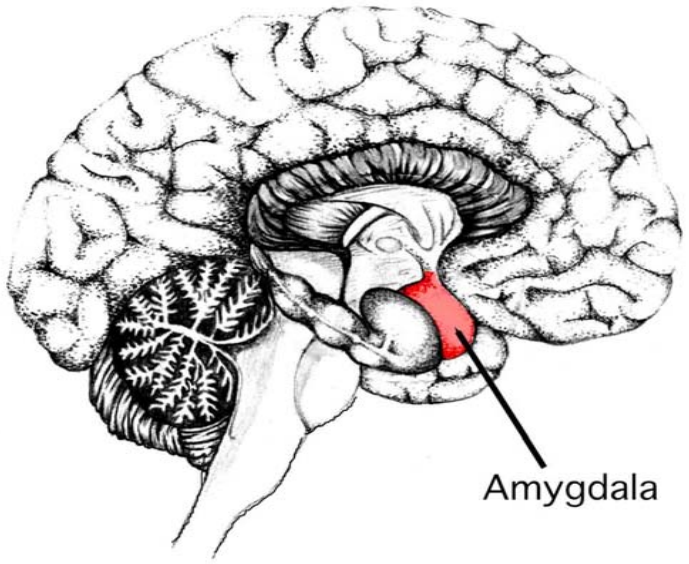
Whether they are smarter or not, larger animals typically have larger brains, although brain size grows not as a fixed percentage but as the 3/4th power of body mass. Unusually smart animals then are those that deviate from this power law and place further up than the line; humans beat the law by a factor of 7.5, the best of any species. Beyond a point, however, increasing brain size brings diminishing returns.



Are we the smartest of all creatures? Social behavior, brain size, intelligence

Box 1
Selected traits that distinguish humans from other apes[6–7]

- Body shape and thorax
- Cranial properties (brain case and face)
- Relative brain size
- Relative limb length
- Long ontogeny and lifespan
- Small canine teeth
- Skull balanced upright on vertebral column
- Reduced hair cover
- Elongated thumb and shortened fingers
- Dimensions of the pelvis
- Presence of a chin
- S-shaped spine
- Language
- Advanced tool making
- Brain topology



The parasite T. gondii, seen here, may be changing connections between our neurones, altering how we act and feel. (Dennis Kunkel Microscropy, Inc./Visuals Unlimited/Corbis Images)

Competing inputs. A typical moment in the life of a typical *Science* reader, who is simultaneously processing various sensory inputs with his eyes, ears, nose (the smell of the food), skin touch receptors (the friend's handshake, the briefcase being held), and proprioreceptors (the cramp in his leg), and having competing thoughts. Depending on the circumstances, any one of those stimuli or thoughts may warrant full attention. Recent studies suggest that multilingual people may have an advantage over monolinguals in sifting and managing these distracting stimuli.

Love Potion Number 10: Oxytocin Spray Said to Increase Attraction

Is Oxytocin the Body's Own Love Potion?

Oxytocin Hormone: The Cuddle Hormone

Van Veelan and Nowak 2011

Figure 1 | Float like a butterfly, sting like a bee. Muhammad Ali saw himself as "the king of the world". His supreme confidence helped him to win many fights. Johnson and Fowler[11] report that overconfidence can confer an evolutionary advantage.

Altruism: May be we have it in us!

Examples of favouring kin are widespread: Japanese macaques spend more time grooming their closer relatives and meerkats share feeding and guard duties.

Eciton burchelli army ant workers can form living bridges for other colony members to cross. Older moorhen chicks sometimes help feed their young siblings.

Altruism
Behaviour that is costly for an animal to perform but benefits others. Costs and benefits are measured in terms of reproductive success.

Inclusive fitness
A generalization of Darwinian fitness, which takes into account the effect of an individual's actions on the reproductive success of their relatives, as well as on their own.

Kin selection theory
The idea that natural selection shapes individuals' behaviour according to the effect it has on relatives.

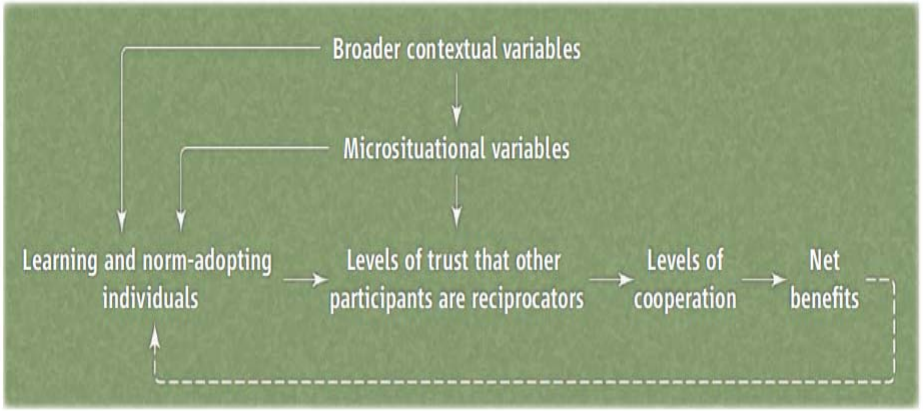
Group selection
The idea that natural selection favours traits because they benefit whole groups, rather than individuals.

Multi-level selection theory
The idea, closely related to group selection, that natural selection can operate on more than one hierarchical level, for instance at the level of the individual, group or species.

Social evolution
Darwinian theory as applied to an animal's social behaviour, that is behaviour affecting other individuals in the population.

…Individual knowledge is obtained experientially as part of the development process, through parents, societal interactions (e.g., early childhood play, storytelling, and interactions with elders), and through cultural (tribal) rituals (e.g., religion, political structure). Because it is learned, it can be taught –and hence can rapidly pervade human society – but it can be lost just as rapidly.

Are we doomed because of the Tragedy of the Commons? Is it an evolutionary trait? Is it stable?



Trust me. "Microsituational" and broader contextual variables can influence levels of trust and cooperation in managing common resources such as forests. [Adapted from (*18*)]

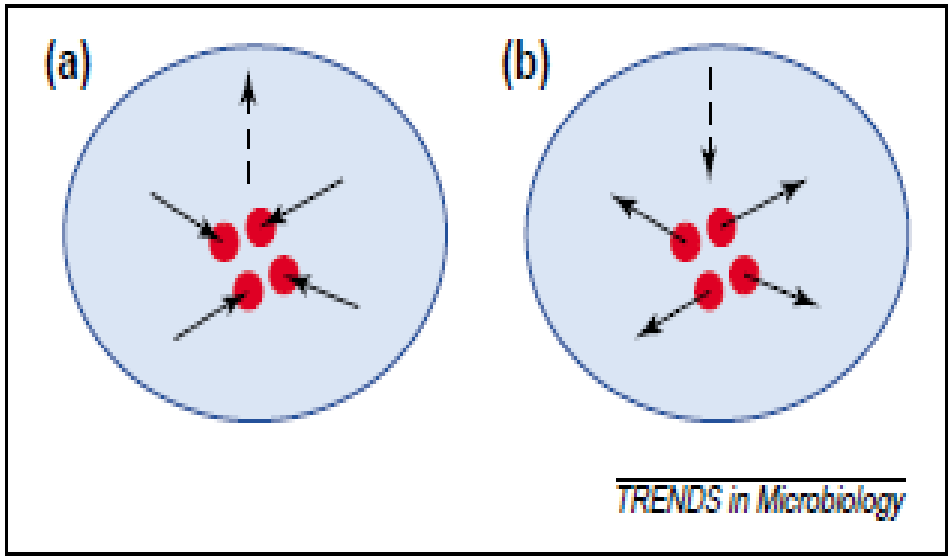
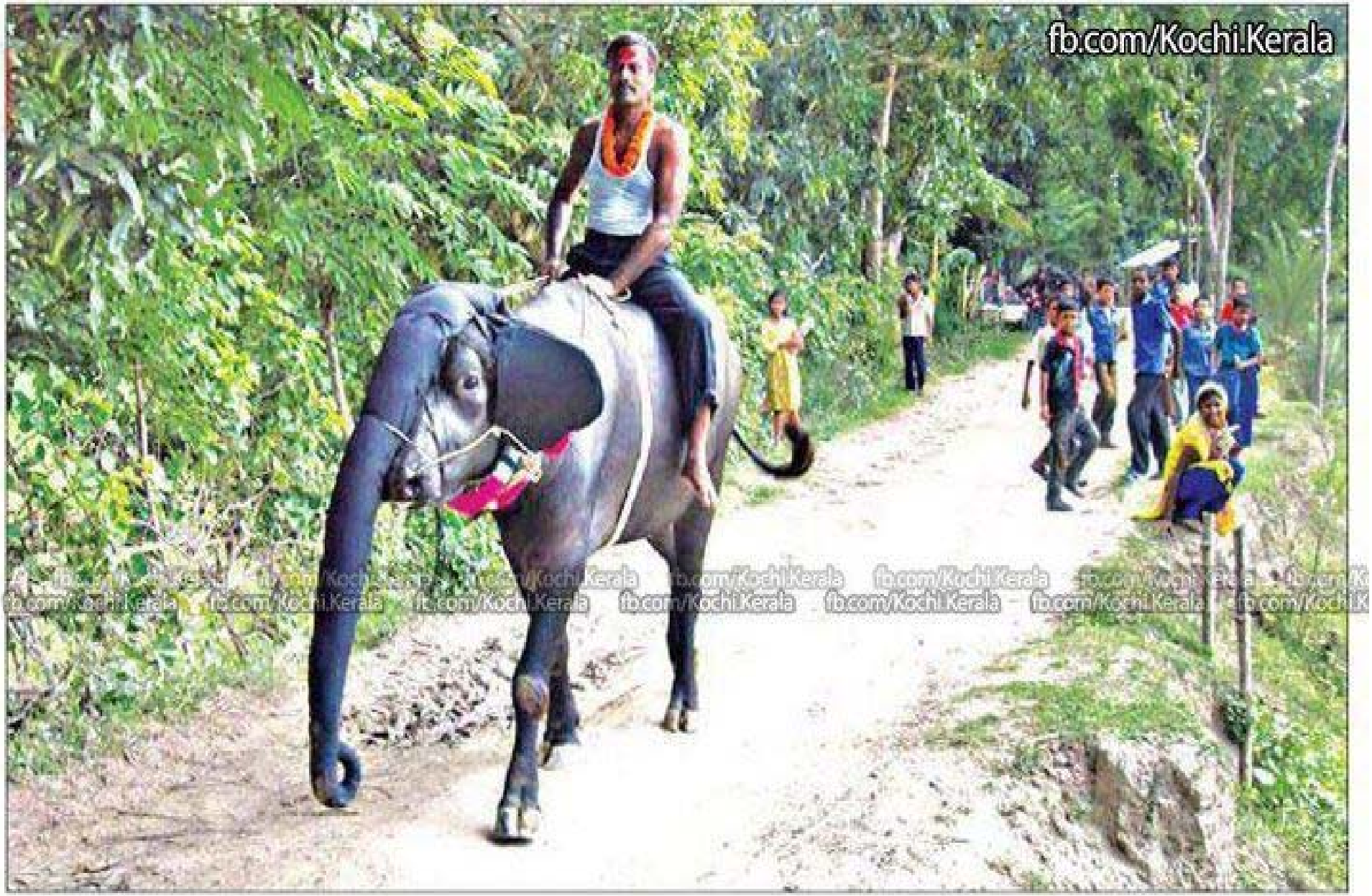


Fig. 1. A schematic diagram of 'tragedy of the commons' (a) and 'collective action' (b) parasite traits. Red dots represent parasites, the large blue circles represent hosts. Arrows represent the flow of energy or value with respect to the parasites. Solid arrows represent individual traits, dotted arrows represent group-level traits. (a) Tragedy of the commons: individual benefit, group costs. The individual benefit is derived from direct exploitation of a readily available common resource, the devaluation of which presents a collective cost of exploitation. (b) Collective action: individual cost, group benefits. Here, the individual benefit is derived by exploitation of a socially constructed or emergent common resource, the construction of which requires individual contributions to the common good.

Quantitative measures must always be related to human welfare

Data sourced from:
Global Footprint Network
2008 report (2005 data)
UN Human Development
Index 2007/08

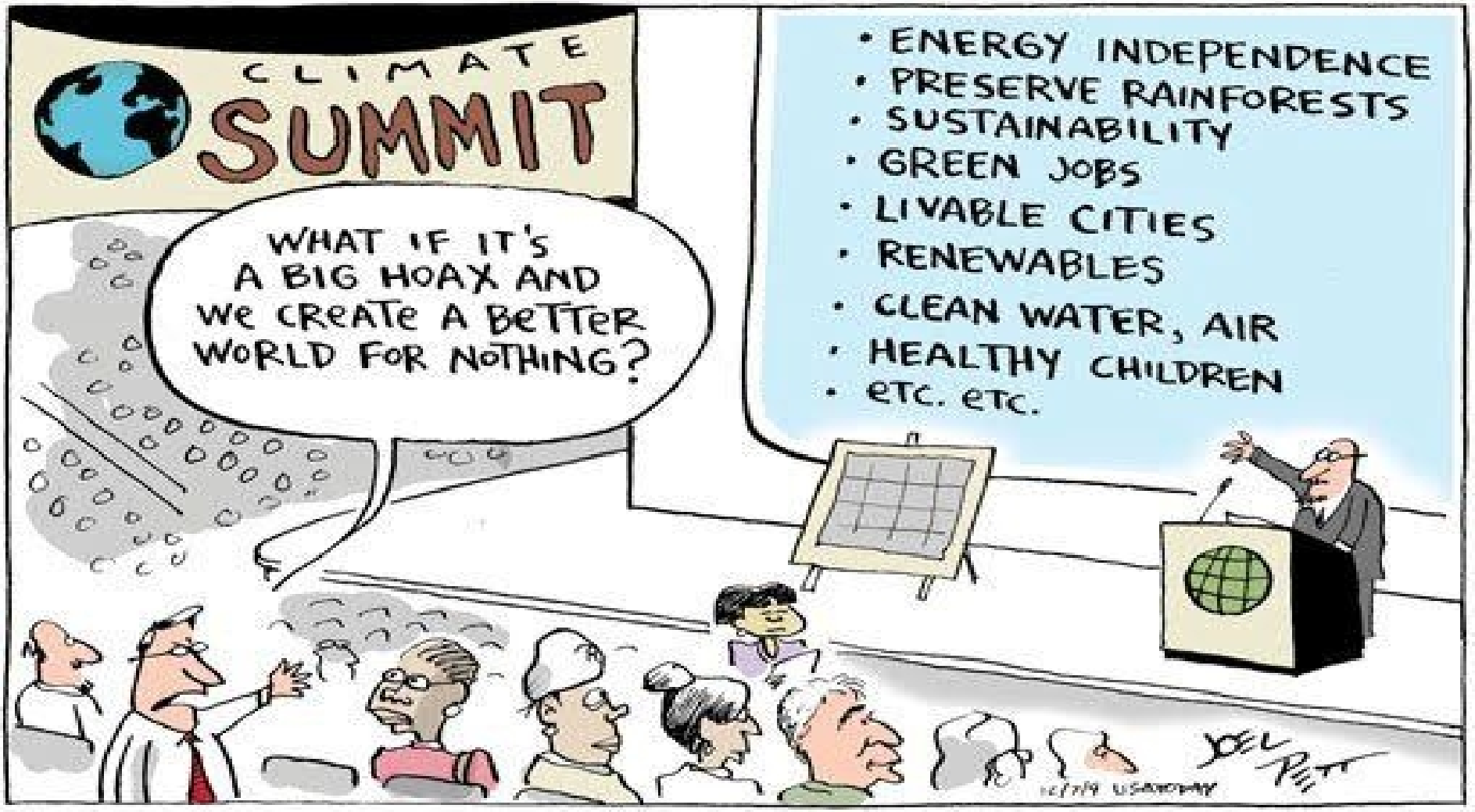
Trying to fool the elephant will lead to a disaster!


fb.com/Kochi.Kerala

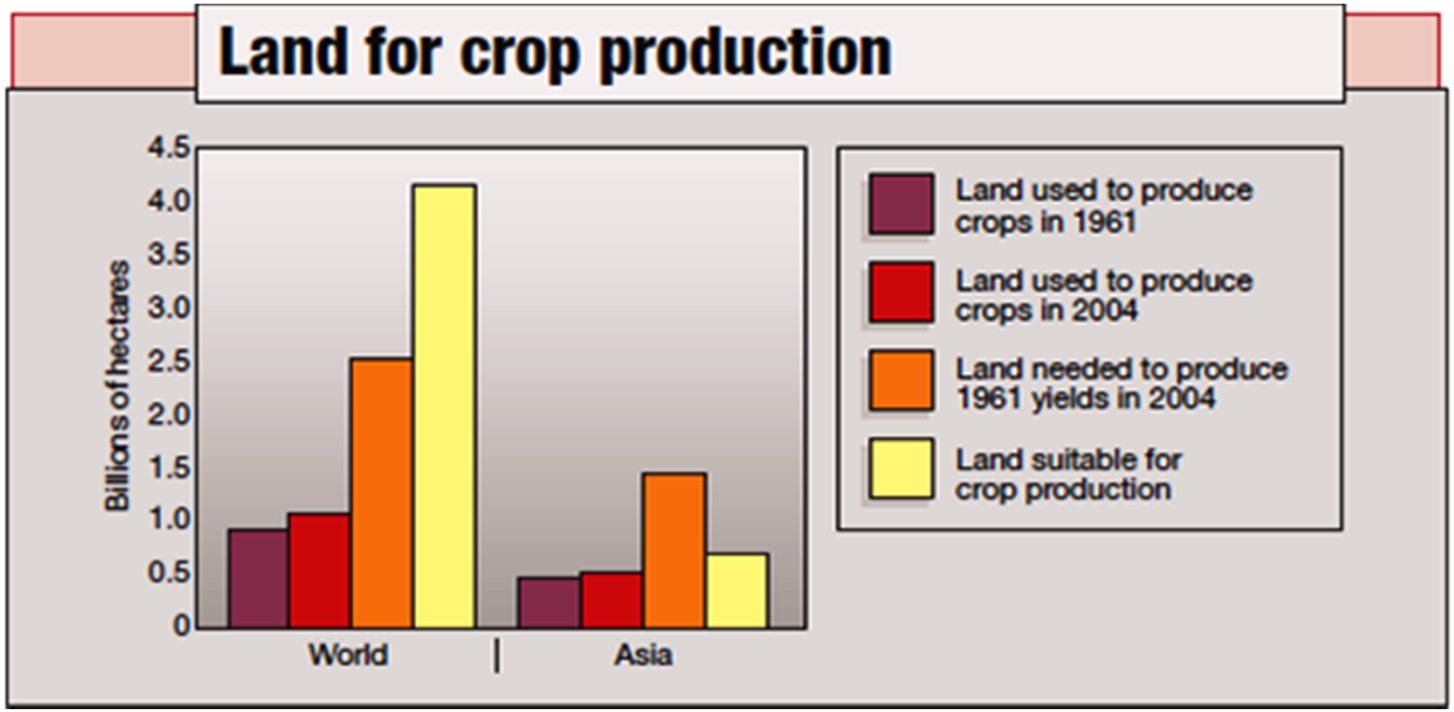
Earth is a spaceship and just like an airplane, the first class can not be made safer than economy!

So we must avoid the tragedy of the commons especially for those species who have no control over their destiny!!

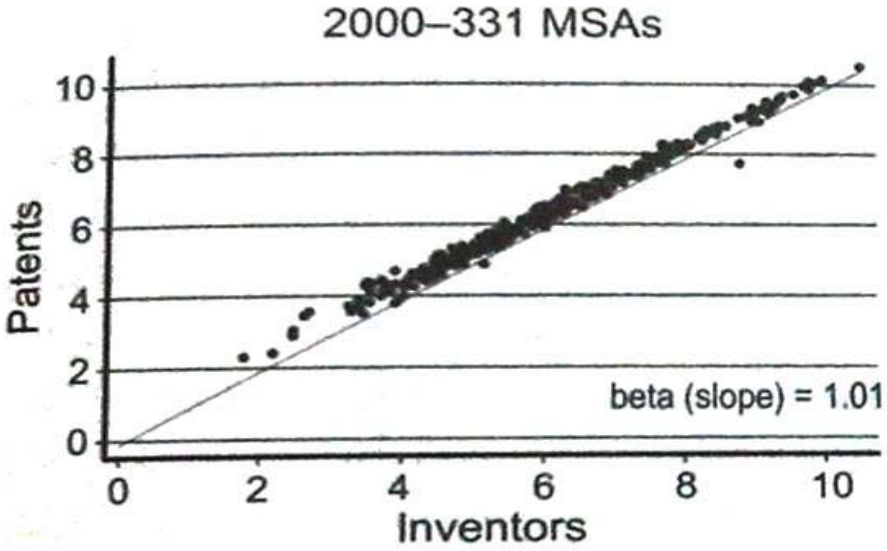
Behave as if you are here to stay!

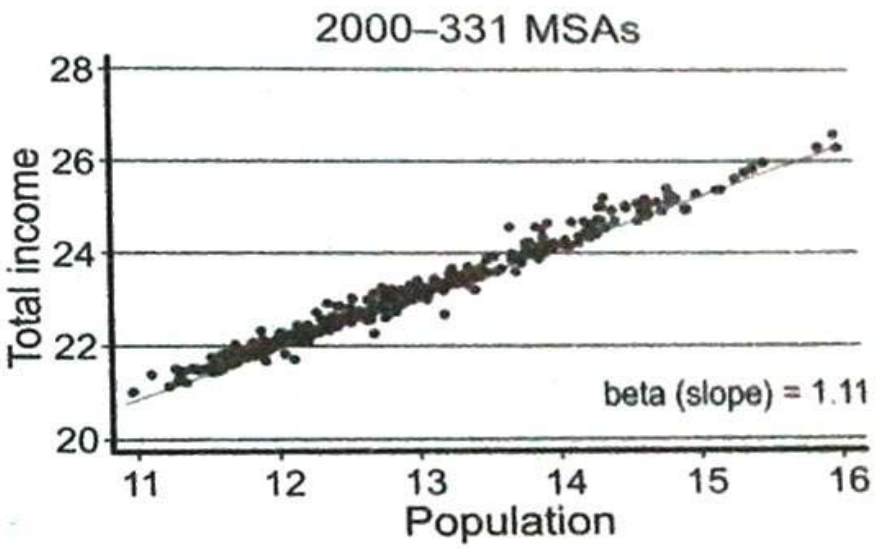


Have humans escaped Red Queen??



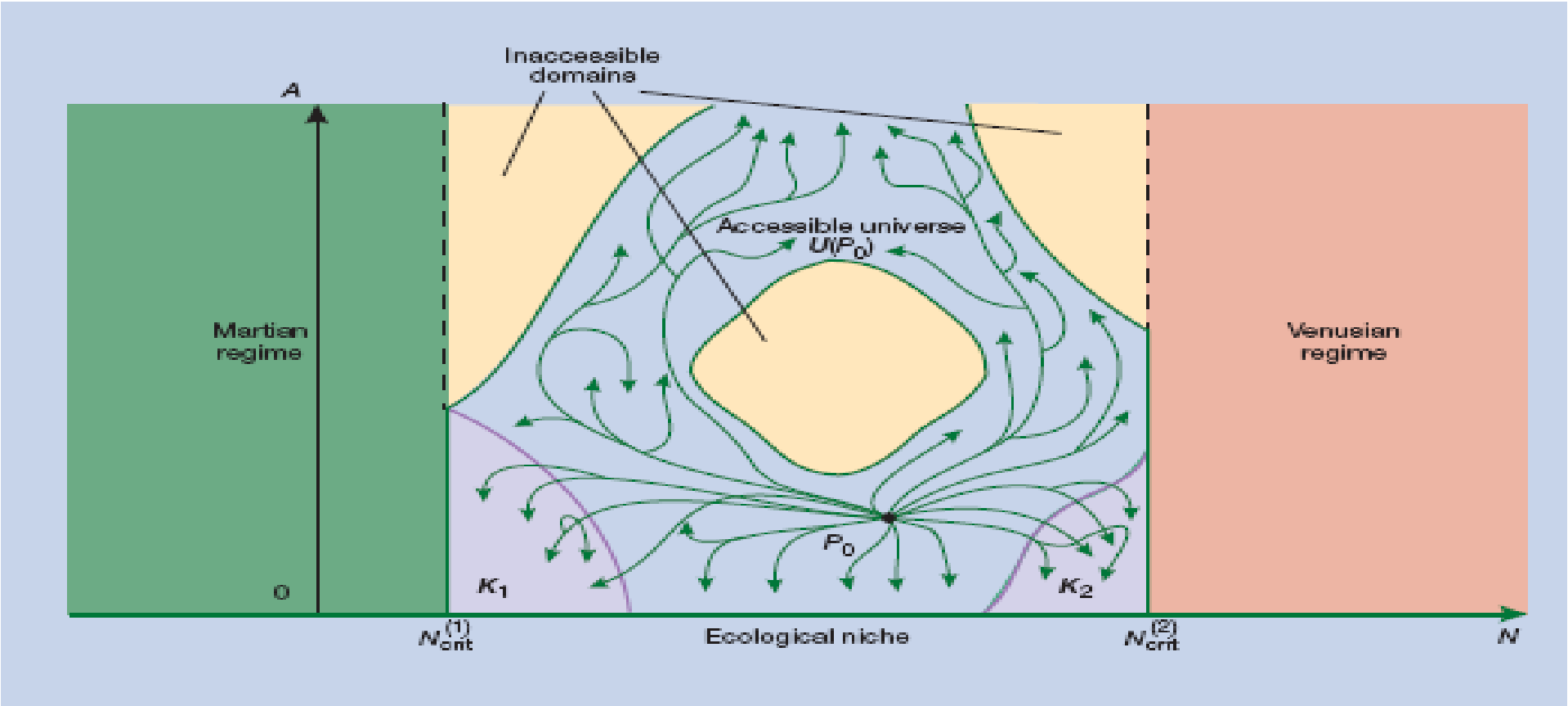
Is population a problem?





GOLDILOCKS PLANETS

Temperature	-50°C	+15°C	+450°C
Greenhouse Effect	a few degrees	~30°C	~470°C

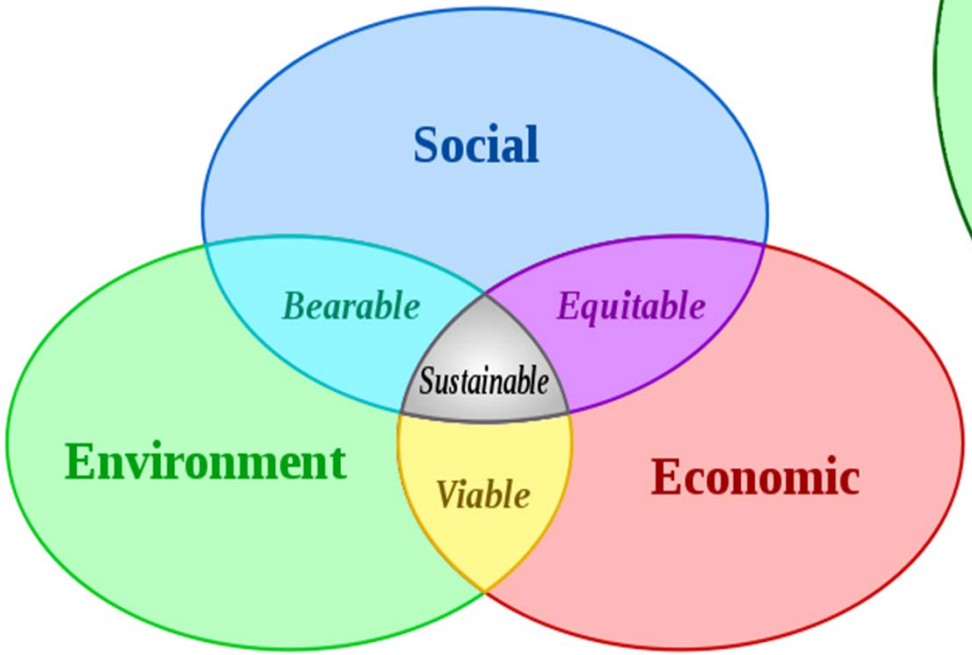


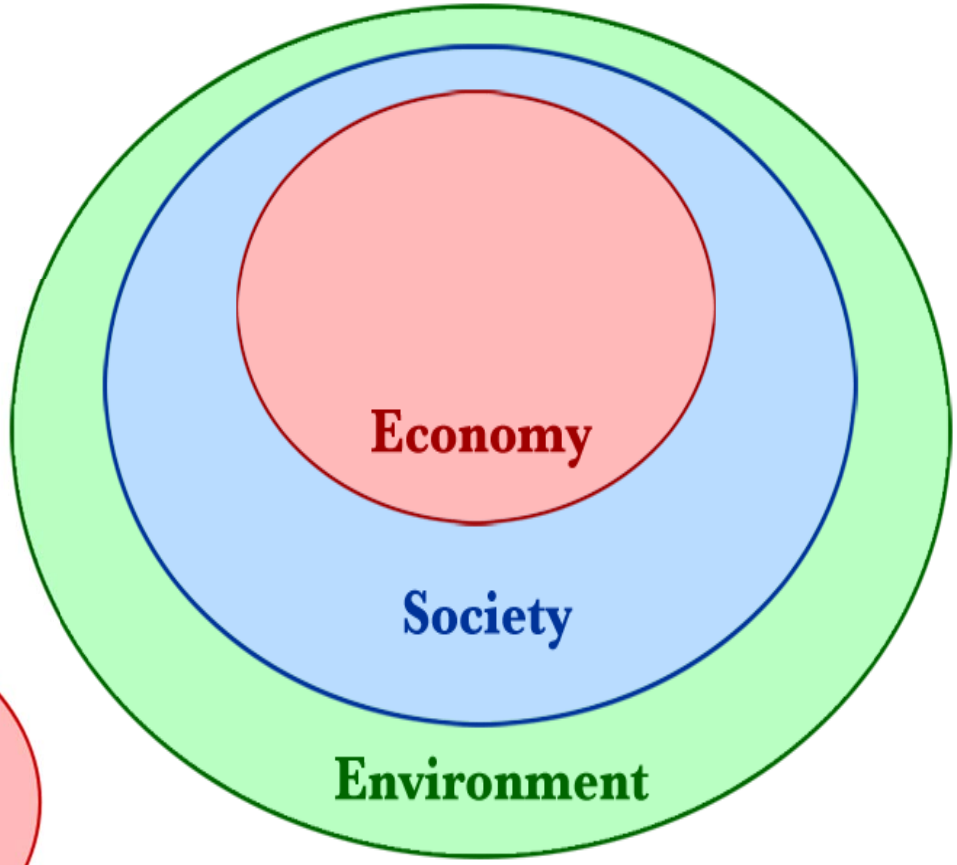
Standardization, optimization, pessimization, Equitization, and Stabilization

Schellnhuber 1999

Mahatma Gandhi:

“If it took half the resources of the world to make England so rich, how many worlds would India need?”





Extreme Sustainability?

Herman Daly, 1990: "Commentary: Toward some operational principles of sustainable development." *Ecological Economics* 2(1990): 1-6.

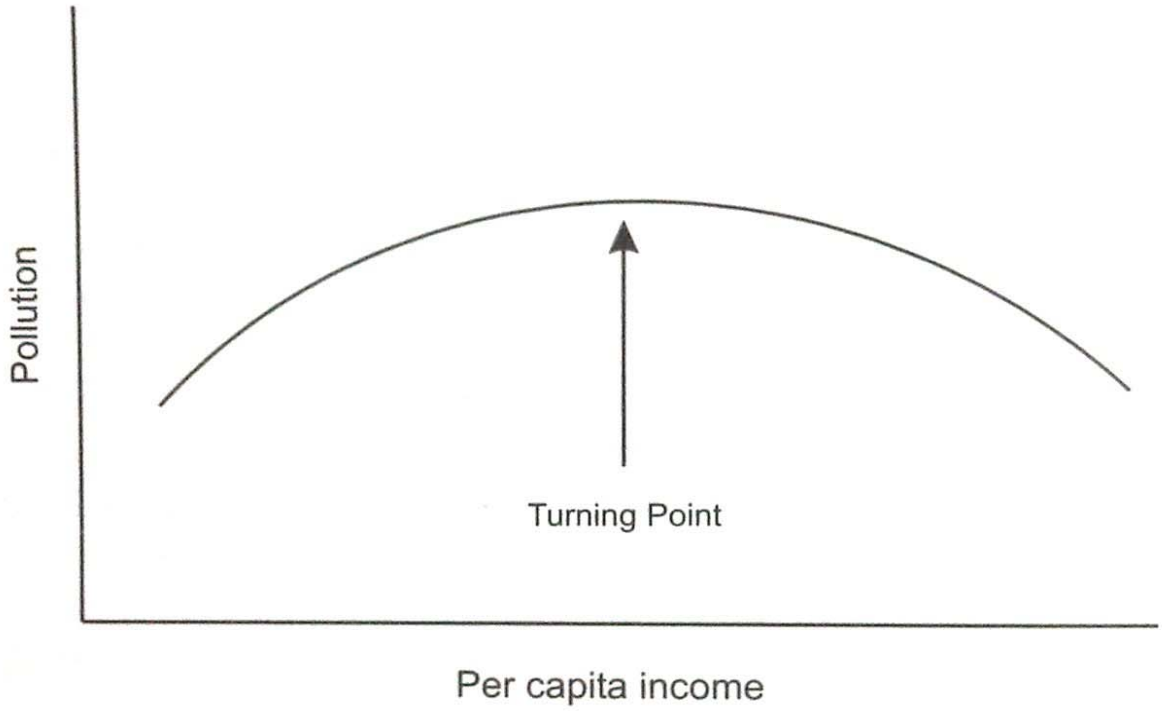
"Since the human economy is a subsystem of a finite global ecosystem which does not grow, even though it does develop, it is clear that growth of the economy cannot be sustainable over long periods of time"

Sustainable development requires that

(1) harvest rates should equal regeneration rates and

(2) waste emission rates should equal the natural assimilative capacities of the ecosystems into which the wastes are emitted

(3) reduction rate of any non-renewable resource must not exceed the rate of substitution by a fully-equivalent renewable resource



Kuznet's curve

Can we wait for every nation to reach the top of its Kuznet's curve?

How to avoid the Tragedy of the commons?

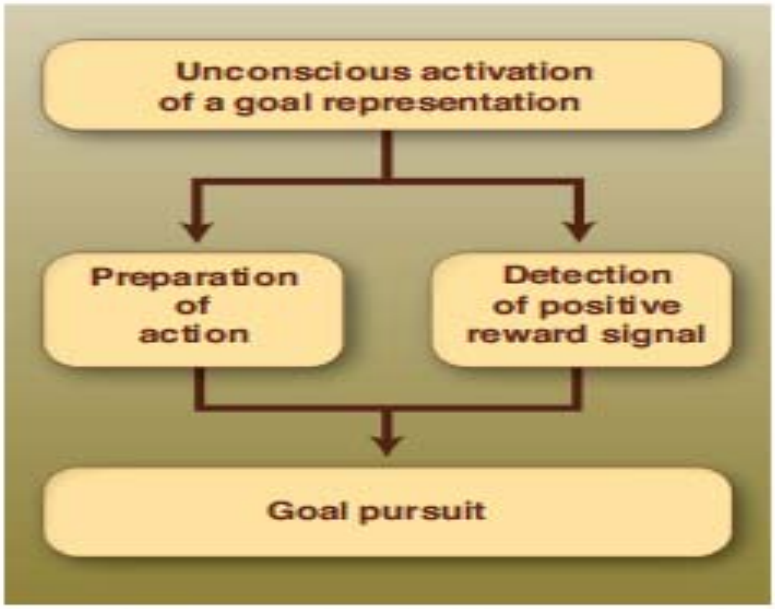


Fig. 2. The proposed mechanism for unconscious goal pursuit.

Are there random events or inventions that lead to unpredictable cascades with unknown consequences?

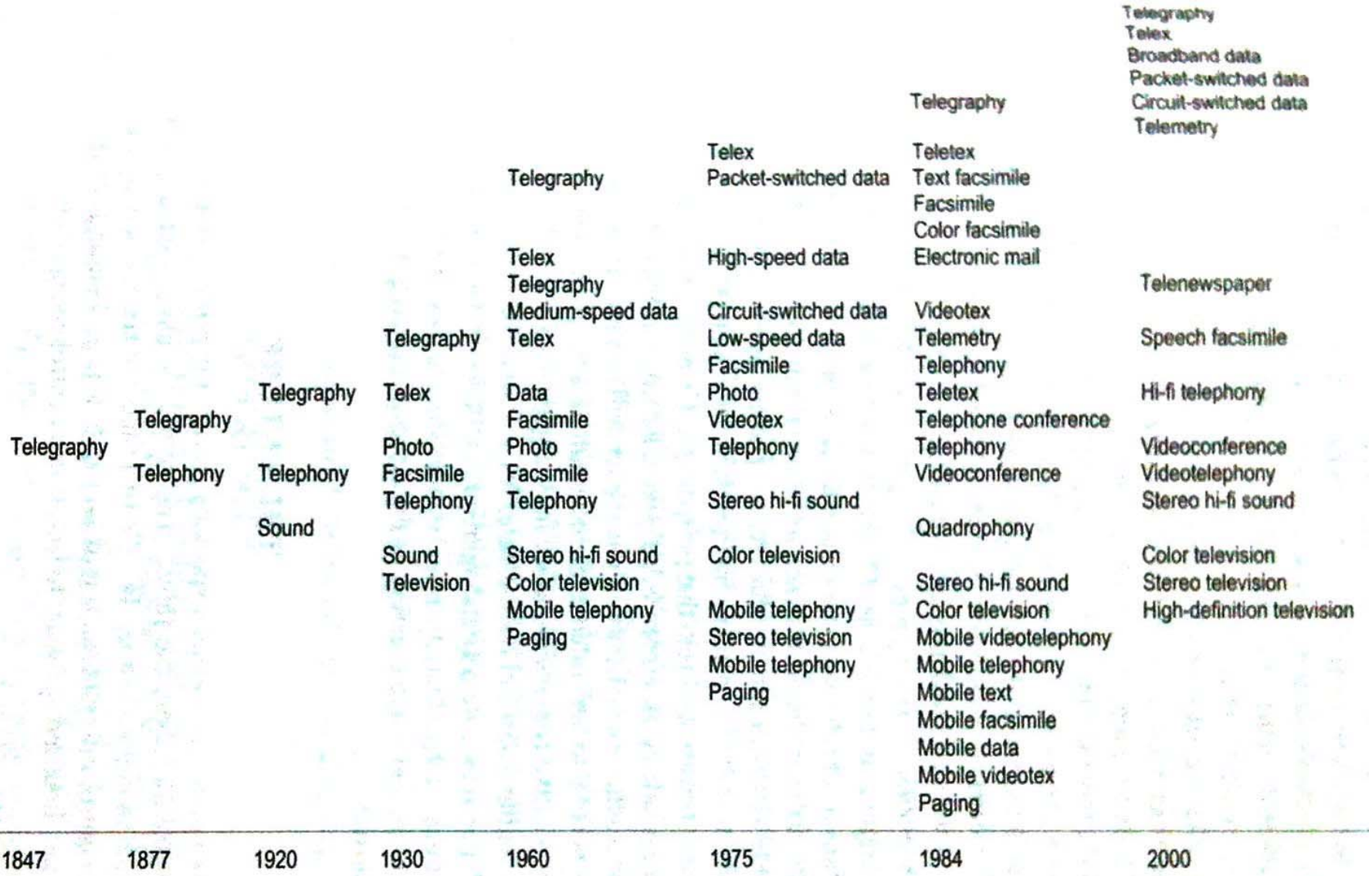


Figure 13.5 Chronology of the innovation cascade triggered by the invention of the telephone.

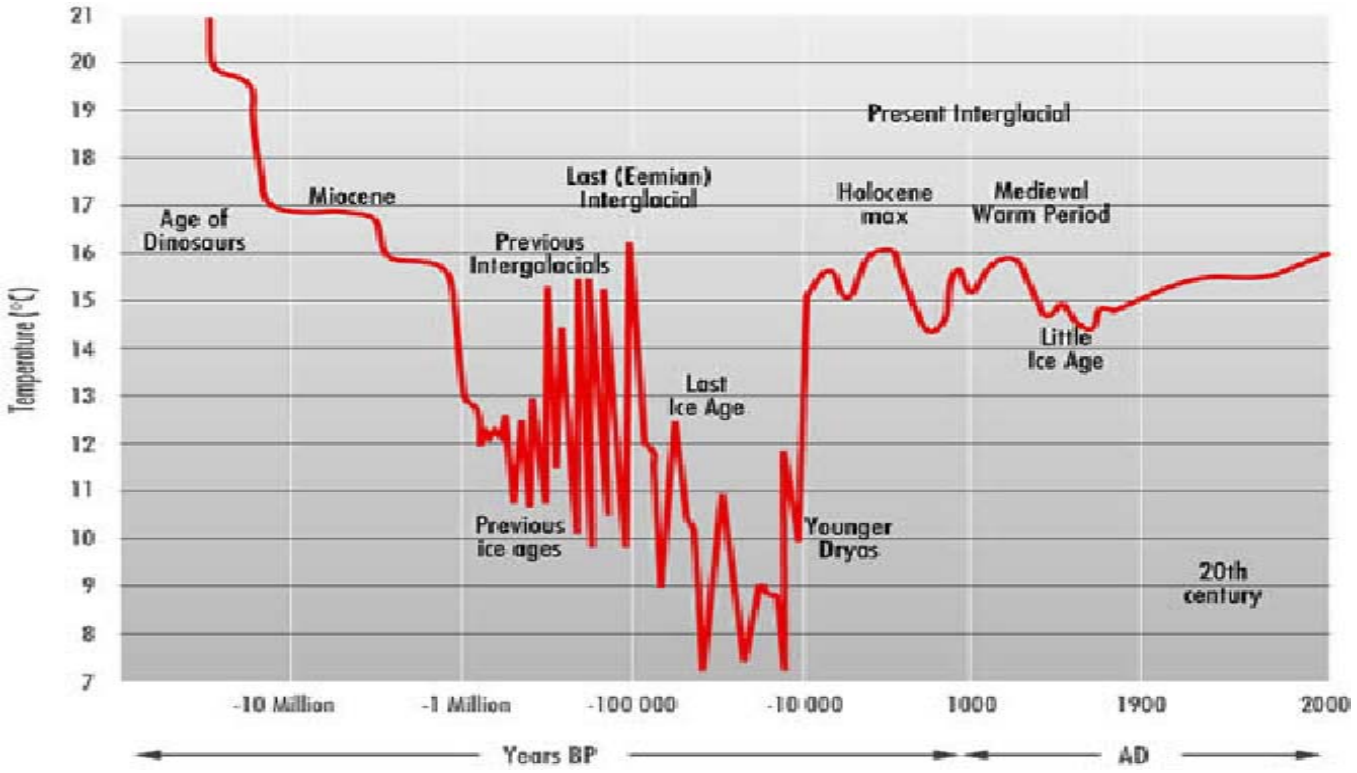
Table 1. Potential wedges: Strategies available to reduce the carbon emission rate in 2054 by 1 GtC/year or to reduce carbon emissions from 2004 to 2054 by 25 GtC.

Option	Effort by 2054 for one wedge, relative to 14 GtC/year BAU	Comments, issues
	Energy efficiency and conservation	
Economy-wide carbon-intensity reduction (emissions/$GDP)	Increase reduction by additional 0.15% per year (e.g., increase U.S. goal of 1.96% reduction per year to 2.11% per year)	Can be tuned by carbon policy
1. Efficient vehicles	Increase fuel economy for 2 billion cars from 30 to 60 mpg	Car size, power
2. Reduced use of vehicles	Decrease car travel for 2 billion 30-mpg cars from 10,000 to 5000 miles per year	Urban design, mass transit, telecommuting
3. Efficient buildings	Cut carbon emissions by one-fourth in buildings and appliances projected for 2054	Weak incentives
4. Efficient baseload coal plants	Produce twice today's coal power output at 60% instead of 40% efficiency (compared with 32% today)	Advanced high-temperature materials
	Fuel shift	
5. Gas baseload power for coal baseload power	Replace 1400 GW 50%-efficient coal plants with gas plants (four times the current production of gas-based power)	Competing demands for natural gas
	CO_2 Capture and Storage (CCS)	
6. Capture CO_2 at baseload power plant	Introduce CCS at 800 GW coal or 1600 GW natural gas (compared with 1060 GW coal in 1999)	Technology already in use for H_2 production
7. Capture CO_2 at H_2 plant	Introduce CCS at plants producing 250 MtH_2/year from coal or 500 MtH_2/year from natural gas (compared with 40 MtH_2/year today from all sources)	H_2 safety, infrastructure
8. Capture CO_2 at coal-to-synfuels plant	Introduce CCS at synfuels plants producing 30 million barrels a day from coal (200 times Sasol), if half of feedstock carbon is available for capture	Increased CO_2 emissions, if synfuels are produced without CCS
Geological storage	Create 3500 Sleipners	Durable storage, successful permitting
	Nuclear fission	
9. Nuclear power for coal power	Add 700 GW (twice the current capacity)	Nuclear proliferation, terrorism, waste
	Renewable electricity and fuels	
10. Wind power for coal power	Add 2 million 1-MW-peak windmills (50 times the current capacity) "occupying" 30×10^6 ha, on land or offshore	Multiple uses of land because windmills are widely spaced
11. PV power for coal power	Add 2000 GW-peak PV (700 times the current capacity) on 2×10^6 ha	PV production cost
12. Wind H_2 in fuel-cell car for gasoline in hybrid car	Add 4 million 1-MW-peak windmills (100 times the current capacity)	H_2 safety, infrastructure
13. Biomass fuel for fossil fuel	Add 100 times the current Brazil or U.S. ethanol production, with the use of 250×10^6 ha (one-sixth of world cropland)	Biodiversity, competing land use
	Forests and agricultural soils	
14. Reduced deforestation, plus reforestation, afforestation, and new plantations.	Decrease tropical deforestation to zero instead of 0.5 GtC/year, and establish 300 Mha of new tree plantations (twice the current rate)	Land demands of agriculture, benefits to biodiversity from reduced deforestation
15. Conservation tillage	Apply to all cropland (10 times the current usage)	Reversibility, verification

Estimated Free Energy Rate Densities

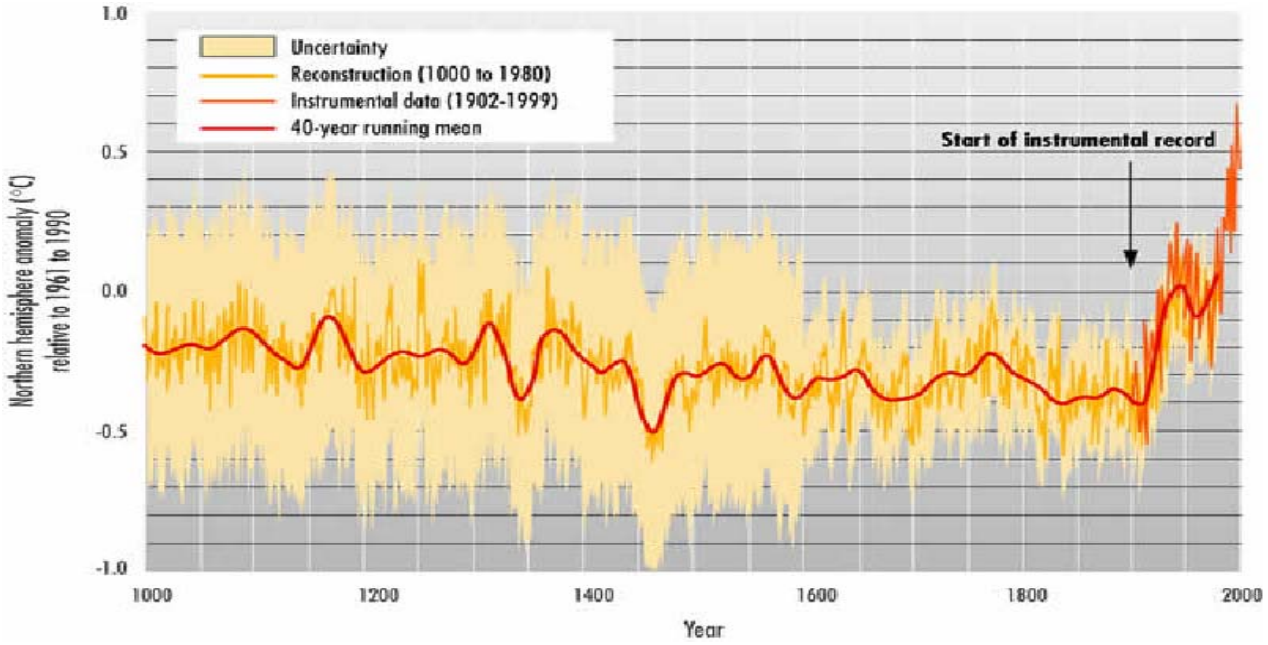
Chaisson, 2001: Cosmic Evolution

• Galaxies	1	erg s^{-1} g^{-1}
• Stars	2	
• Planets	75	
• Plants	900	
• Animals	20,000	
• Brains	150,000	
• Society	500,000	

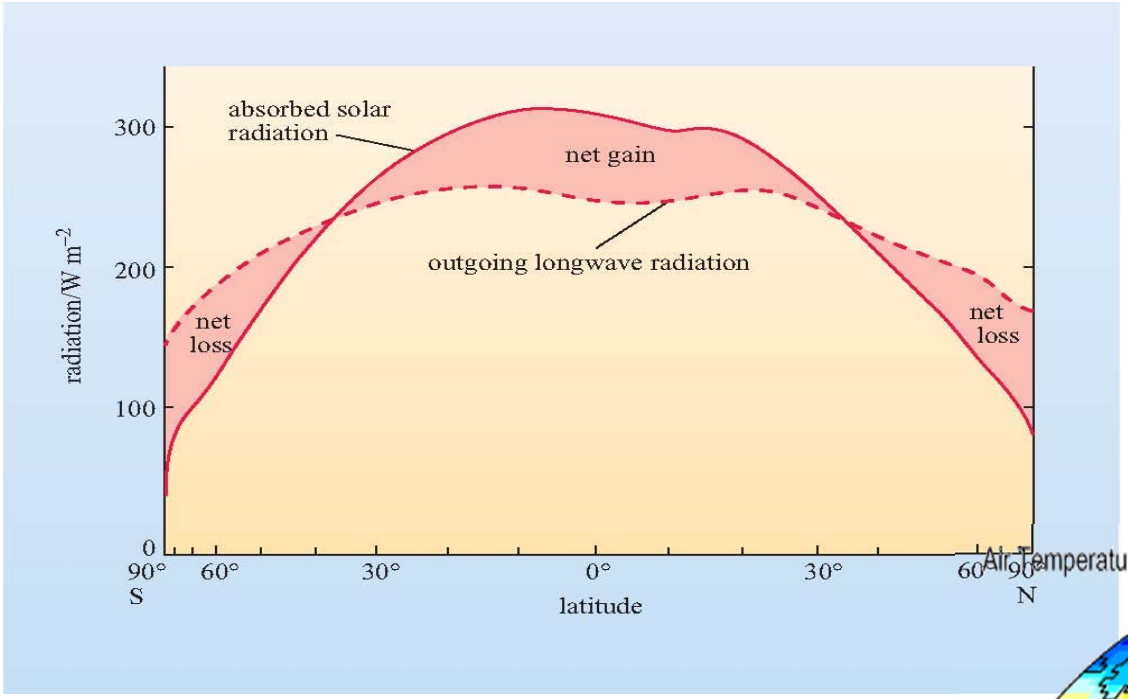


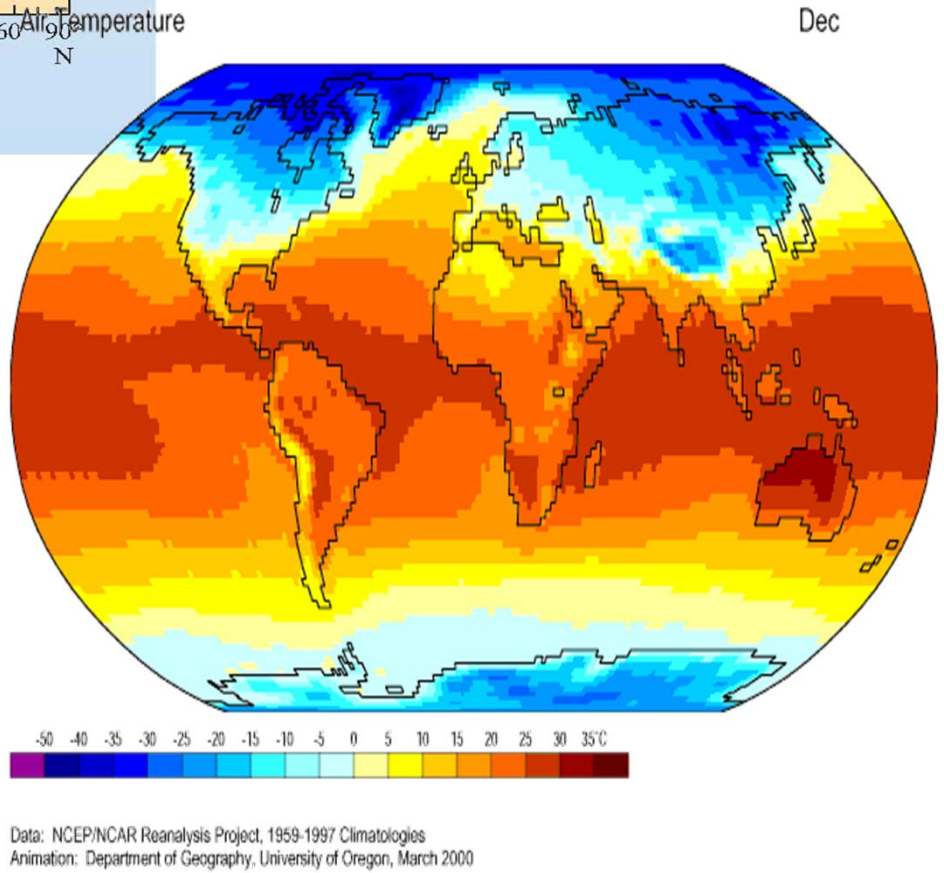
Earth has been warmer before. So why worry?

The rate of warming unprecedented?
Biological responses always depend on the rate of change.



Life and Climate





- **How does life cross the equator?**

- **Beluga Whales and Dusky Dolphins**

HOW TO MAKE A **SWITCH**

For things to change, somebody somewhere has to start acting differently. Maybe it's you, maybe it's your team. Picture that person (or people).

Each has an emotional Elephant side and a rational Rider side. You've got to reach both. And you've also got to clear the way for them to succeed. In short, you must do three things:

----➤ **DIRECT** the Rider

FOLLOW THE BRIGHT SPOTS. Investigate what's working and clone it. [Jerry Sternin in Vietnam, solutions-focused therapy]

SCRIPT THE CRITICAL MOVES. Don't think big picture, think in terms of specific behaviors. [1% milk, four rules at the Brazilian railroad]

POINT TO THE DESTINATION. Change is easier when you know where you're going and why it's worth it. ["You'll be third graders soon," "No dry holes" at BP]

1

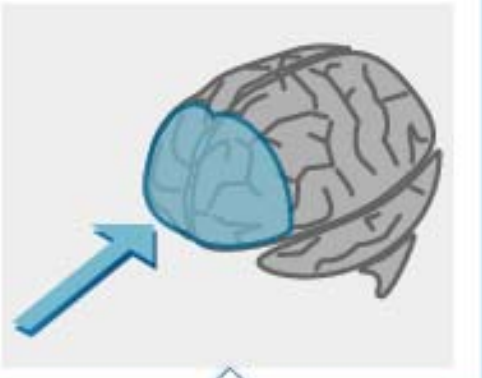
(from the book)

The Rider

The Rider loves to contemplate and analyze, doing so with a negative bias, almost always focusing on problems rather than solutions. The Rider is frustrated by uncertainty and easily exhausted.

is a metaphor for

(in your brain)



The rational mind

Typified by the prefrontal cortex, the area of the brain that looks for patterns, makes plans, predicts the future, monitors the self, and attempts to distinguish between and suppress animal instincts.

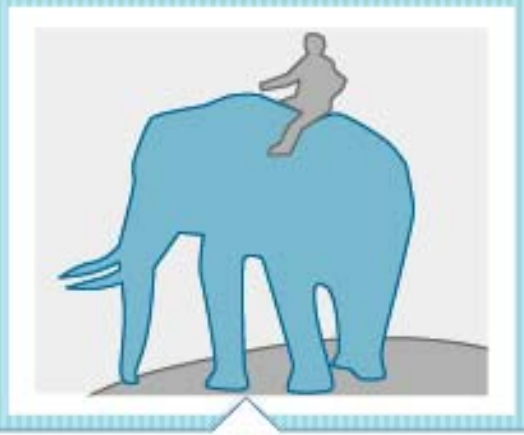
MOTIVATE the Elephant

FIND THE FEELING. Knowing something isn't enough to cause change. Make people feel something. [Piling gloves on the table, the chemotherapy video game, Robyn Waters's demos at Target]

SHRINK THE CHANGE. Break down the change until it no longer spooks the Elephant. [The 5-Minute Room Rescue, procurement reform]

GROW YOUR PEOPLE. Cultivate a sense of identity and instill the growth mindset. [Brasilata's "inventors," junior-high math kids' turnaround]

2



is a metaphor for

The Elephant

The elephant is eaily spooked and hates doing things with no immediate benefit. It is stubborn, needs reassurance, and is quickly demoralized. But it is powerful, tireless, and difficult to actively direct.

The emotional mind

Typified by the amygdala, the root of fear and trigger of the body's stress response. Negative emotion has a narrowing effect on range of thought. Positive emotion allows the mind to wander creatively.

SHAPE the Path

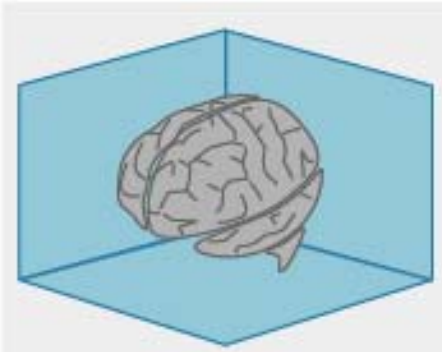
TWEAK THE ENVIRONMENT. When the situation changes, the behavior changes. So change the situation. [Throwing out the phone system at Rackspace, 1-Click ordering, simplifying the online time sheet]

BUILD HABITS. When behavior is habitual, it's "free"—it doesn't tax the Rider. Look for ways to encourage habits. [Setting "action triggers," eating two bowls of soup while dieting, using checklists]

RALLY THE HERD. Behavior is contagious. Help it spread. ["Fataki" in Tanzania, "free spaces" in hospitals, seeding the tip jar]

3

is a metaphor for



The Path

Even when the Rider and the Elephant cooperate, they must know what direction to head. Without a clear vision of the destination, change will not happen. The Elephant tends to follow the path of least resistance.

The environment

External stimuli make up the world that the mind consciously and unconsciously interprets and reacts to. Forces like convenience, distraction, and cognitive biases play a significant role in directing behavior.

Are there analytical analogs to Human-Natural System Interactions?

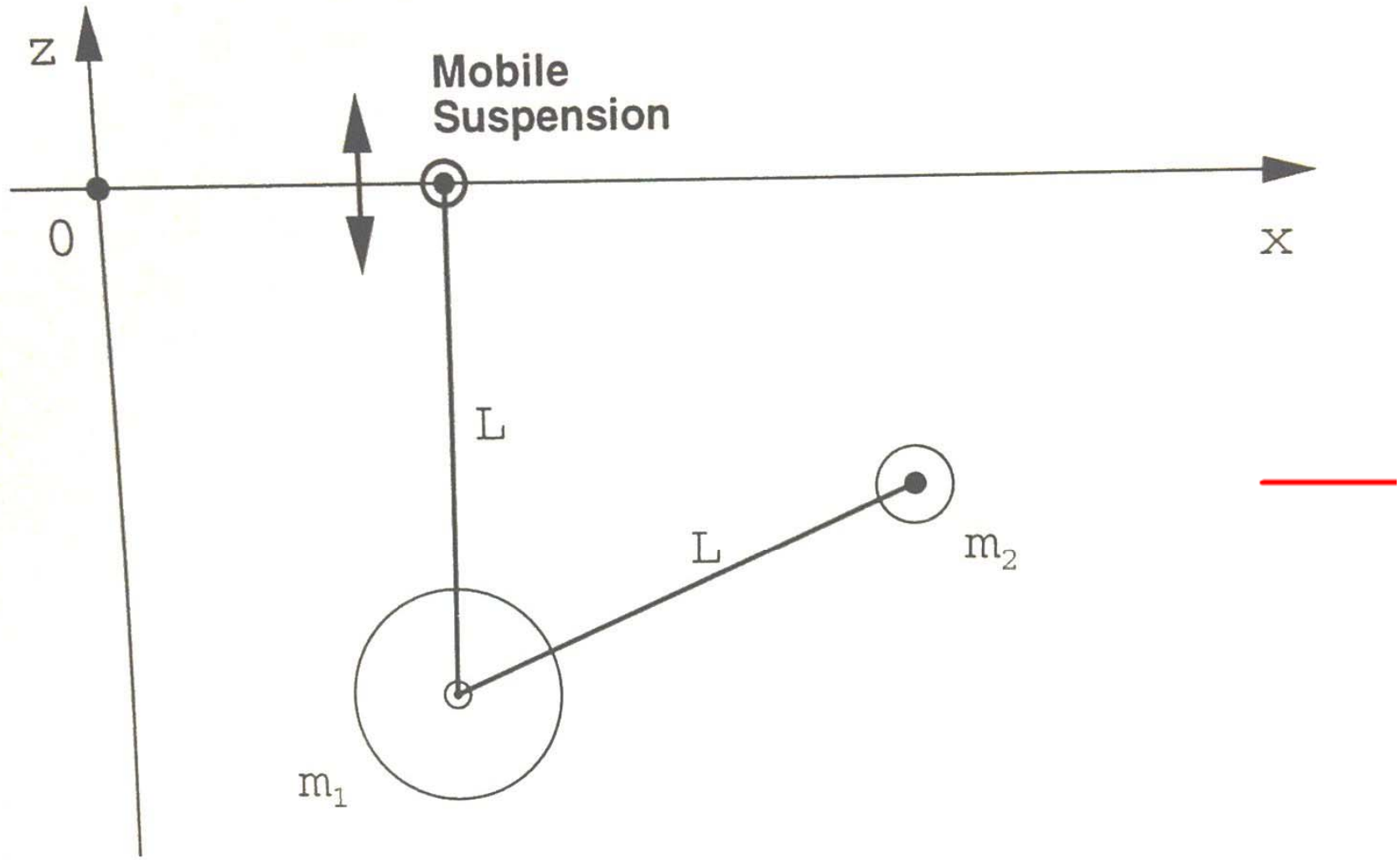


Figure 2. Planar double pendulum, moving under the combined influence of the gravitational forces $\mathbf{F}_i = -m_i g\hat{z}, i = 1, 2$, and a temporal modulation of the pivotal suspension. g denotes the constant acceleration due to the Earth's gravitational field, the two rigid links have identical length L. We initially assume that the first mass is clearly dominating the dynamics, i.e., $m_1/m_2 \gg 1$.

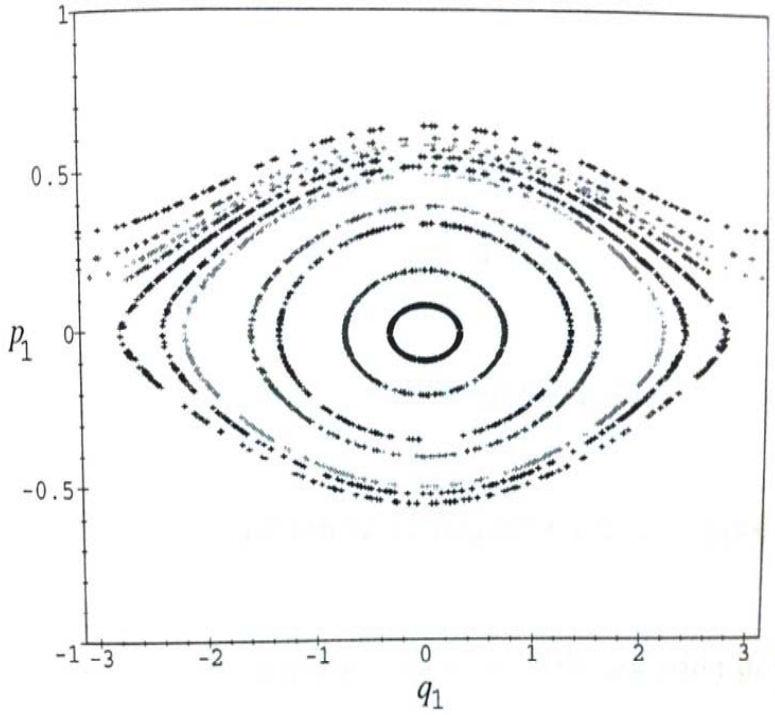


Figure 3. Phase space portrait for the motion of the (almost) unperturbed dominating mass in the double pendulum system depicted in Fig. 2. Each contour corresponds to a given (practically conserved) initial energy of the system component considered. The analyticity of the graph indicates the perfect regularity of the dynamic behaviour observed.

Are we doomed to produce a chaotic solution Or have we evolved a smart enough brain that will save us?

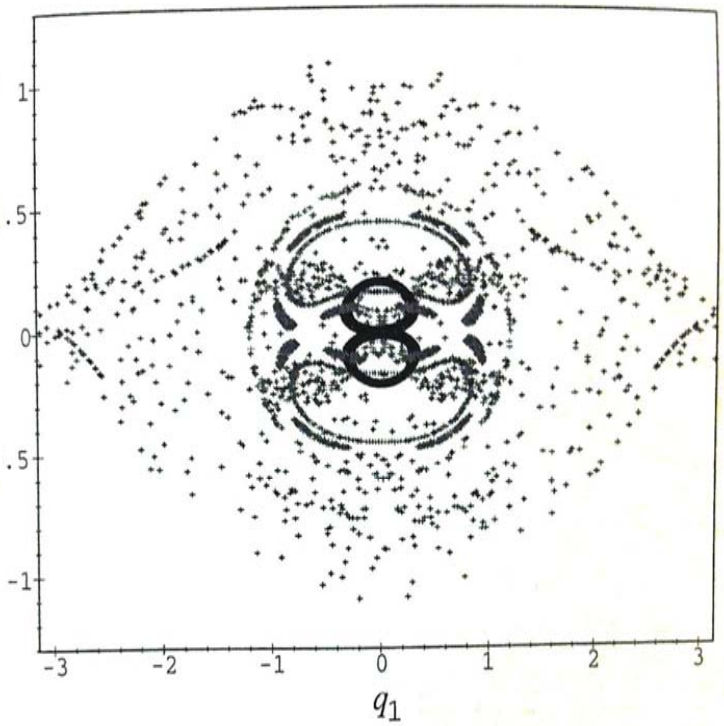


Figure 5. Phase space portrait for the motion of the first mass in the double pendulum system of Fig. 2 for the mass ratio $m_1/m_2 = 1$. Note that the qualitative character of the graph has changed completely in comparison with Fig. 3: the non-analytic texture now heralds chaotic dynamics.

We CAN seek global and local solutions for normative, strategic, analytic, and operational questions for a transition towards sustainability.