Sustainability: What It Would Take

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As the icecaps melt and biodiversity melts away it may seem almost fatuously optimistic to speak of sustainability, let alone sustainable development. The latter phrase is indeed oxymoronic, if "development" means anything like "business as usual". There is no question that humanity is in for a very rough ride in the decades to come. However, I will argue that there are grounds for judiciously tempered optimism so long as we grasp that sustainability can be understood in terms of the biophysics of symbiosis, and that humans, with their unique neurological capacities, are potentially capable of contributing to such a planetary-scale symbiotic state in constructive ways. I will explain how this could follow from a general understanding of symbiosis from an evolutionary point of view, and sketch some of the requisites, physical, technological, and ethical, for such a hopeful transformation.

Are Microbes More Intelligent Than Humans? Two Case Studies

- Parasitical bacteria accidentally introduced into a culture of *Amoeba* nearly wiped out the host culture.
- However, after many generations, the bacteria became *obligate endosymbiotes* (organelles) of the *Amoeba*.
  - (Jeon & Jeon, *Journal of Cell Physiology,* 1976; reported in Margulis & Sagan, *What Is Life?,* 1995.)
- What seems to be crucial in this case was the finitude of the environment (a Petri dish).

- Myxomatosis virus was introduced to Australia to kill rabbits (*also* introduced) which were multiplying without control.
- The virus killed many rabbits, but then a quasi-stable balance was reached.
- The rabbits unsurprisingly acquired resistance to the virus.
- Surprisingly (from the conventional view) the *viruses* evolved to become less virulent—thus in effect ensuring a more sustainable supply of hosts.
- Viruses thus show that they can solve the Tragedy of the Commons!
  - (See Sober & Wilson, *Unto Others*, 1998.)

Sustainability In General

- First stab: a process is sustainable if it can go on indefinitely.
  - But this is too general to be interesting; it includes gravity, for instance.
- Classic example: an investment.
  - If I only spend the interest on an inheritance, the process is sustainable.
  - If I dip into the principal, I might live very richly for a short while, but the process is unsustainable because sooner or later I will squander the inheritance and have nothing left.
- This example is so obvious that even economists can understand it.

There are three possibilities:

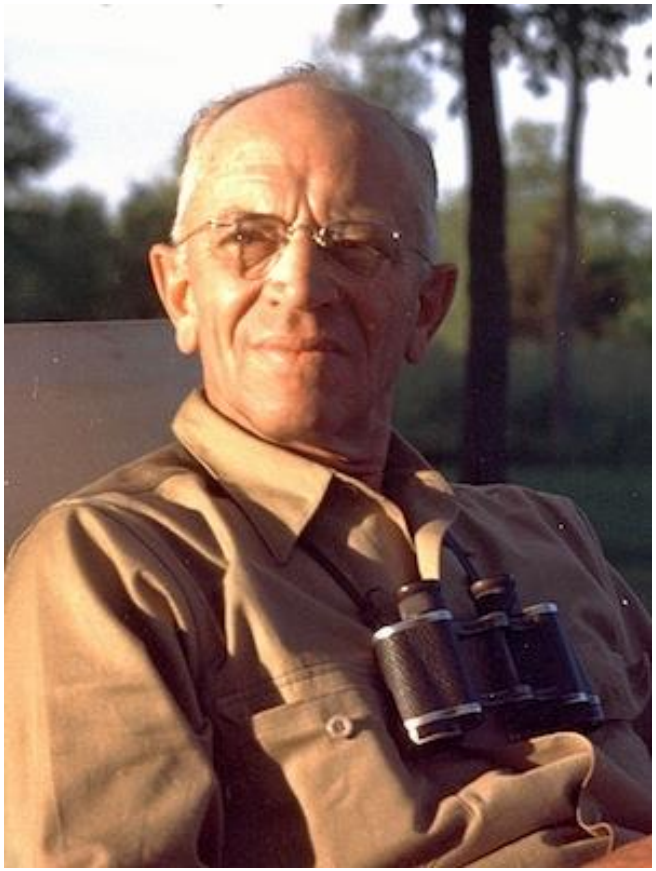
- I could squander the inheritance.
- I could live passively off the interest.
- I could actively reinvest some of the interest or principal in a way that increases the total principal and/or the flow of interest.
    - (I might have to do this in order to maintain a given flow of interest as well—investors often have to move their money around.)

The General Picture

- Sustainable processes are driven by external flows of matter and energy.
- They are self-supporting, in the sense that some of the energy flowing through the system is *fed back* in such a way as to help maintain the structure and coherence of the system.
- A sustainable biological system is thus an example of a *dissipative structure*—a far-from-equilibrium ordered structure maintained by feedbacks within flows of energy (Prigogine).
    - Favoured thermodynamically because they are the quickest way to generate entropy.

Aldo Leopold: The Symbiotic Vision

- How do we apply this general notion of sustainability to the human/Earth-system relationship?
- Leopold ("The Land Ethic") sketched a provocative picture of a sustainable human-land relation as *symbiotic*.
- He saw ethics as an essential part of the human way of being symbiotic.



Symbiosis: The Scientific Picture

- But is the notion of a human-land (or human-Earth) symbiosis anything but a feel-good (and highly improbable) metaphor?
- I went from Leopold to the literature on symbiosis to try to answer this question.

Discovery of Symbiosis

- Simon Schwendener (1868) proposed “dual hypothesis”:
  - Lichen are an association of fungi and algae.
  - This radical view was received with shock and disapproval; of course, we now teach it in high school biology.
- A. B. Frank, Anton de Bary (1877, 1888) introduced term “symbiosis”:
  - The “living together of unlike named organisms.”
- Joseph van Beneden (1873) introduced “mutualism” or “mutual aid.”

Further History

- Numerous biologists worked on symbiosis and mutualism in late 19th, early 20th century; several Russian scientists were prominent (Famintsyn, Kropotkin, Merezhkovskii).
  - Suggestion has been made that Russians, as political collectivists, preferred the symbiotic model, while Western thinkers, as rugged individualists, preferred the competitive model.
  - In fact, many symbiosis biologists were not Russian!
    - (Jan Sapp, *Evolution by Association: A History of Symbiosis*, 1994)

Kropotkin & Mutual Aid

- Petr Kropotkin (1842-1921) wrote an influential book, *Mutual Aid* (1902) arguing in detail that cooperation is as important as competition in nature.
- Argued that the best political systems would be those that were based on human cooperation.
  - Thus, he had to flee Russia.

Key Case of Symbiogenesis

- Several biologists (1890s to 1920s) explored the idea that eucaryotic cells are obligate symbiotic associations of procaryotes.
  - This is called *serial endosymbiosis*.
  - Up to the 1960s, this was regarded as fanciful speculation.
  - The tools did not exist to test the idea.

- This idea was revived by Lynn Margulis (1938—2011).
- It can now be demonstrated using modern techniques of biochemistry, molecular biology, and electron microscopy.
  - (Margulis, *Origin of Eurcaryotic Cells,* 1970.)

- A fascinating and beautiful idea.
  - By now, SET is well-established, but some cell biology texts still skate cautiously around it.

Scale of Symbiosis

- Pathogenic parasitism
- Chronic parasitism/predation
- Commensalism
- Mutualism (mutual benefit)
  - (Note: this includes many predator-prey relations; it's not simple!)
- Symbiogenesis
  - Fusing of distinct branches of Darwin's tree into new kind of species.
  - Margulis: this is very important in evolution.

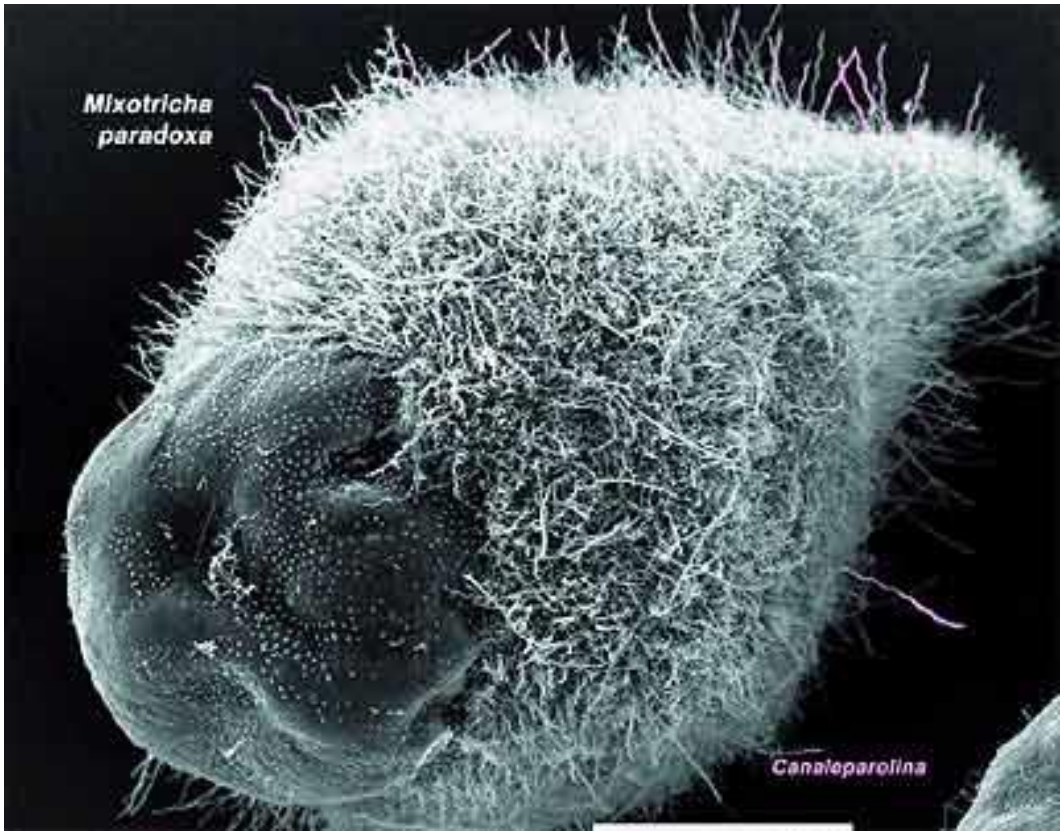
- Parasite: takes resources from host in such a way as to degrade the viability of the host.
- Commensal: neutral; has no impact on host.
  - E.g., *Demodex* sp. (forehead mites).
- Mutualist: co-operates with partners in such a way that the viability of all is maintained or enhanced.

The Symbiotic Transition

- Associations of organisms can move up and down the scale, often rapidly.
  - Jeon & Jeon's amoeba-bacteria system is an example of an association that went from pathogenic to symbiogenic in a few cell generations.
  - It can go the other way as well (arguably in cancer, for instance).
- Crucial fact: it is not uncommon for emergent parasites to become mutualistic symbiotes when ecological constraints are such as to favour cooperation.

A Beautiful Example of Symbiosis

- *Myxotricha paradoxa*, a protozoan living in the gut of termites.



Can We Talk?

- Evolutionary biologists and symbiosis biologists (need a term here) often do not talk well to each other.
- Most philosophy of biology conducted on the assumption that Darwin is *all* there is to understanding the evolution and development of life.
- My view: you need de Bary and Margulis also!
  - This is still a frontier area; stay tuned!

Competition, Cooperation, or Both?

- Question: the orthodox view is that even when organisms appear to cooperate, they are actually competing.
  - Is this correct?
- What could "cooperation" mean at deep biological level (e.g., between micro-organisms)?
- It does *not* involve intentionality!
  - Intentionality helps to explain how *humans* (with complex neurosystem) cooperate (when they do).

Thermodynamic Analysis of Symbiosis

- T. Lenton (1998): basic “currency” of nature is free energy –
  - Which can be transduced in innumerable forms.
- From a physical viewpoint, the most general sense in which members of a symbiome “benefit” each other is that they share free energy in a way that maintains or enhances the coherence of the symbiome upon which their survival depends.

Cooperation in *M. paradoxa*

- The myriad symbiotes in *M. paradoxa* co-operate to maintain the functioning of the whole.
  - Obviously, no intentionality involved!
- Key feature of symbiosis: there is a complex association of various organisms which functions as a coherent whole.
  - It will be in general *multigenomic*—the genome of *M. paradoxa* comprises not only the nuclear DNA of the host cell, but the genomes of the symbiotes.

Humans as Symbiomes

- Humans are comprised of trillions of clones of a fertilized zygote.
  - All our cells contain mitochondria, symbiotic bacteria.
  - These contain about 2% of our DNA.
  - We get our mitochondria from our mothers, since only the sperm's head is absorbed into the egg.
- We also carry thousands of species of symbiotic micro- and meso-organisms (including forehead mites!)—2 to 6 lb. in normal adult.
- *We* are symbiotic colonies!
  - Whitman: "I contain multitudes…"

Obligate vs. Facultative Symbiosis

- Sometimes species become so closely adapted to each other in a symbiome that they cannot function independently.
  - E.g., mitochondria lost their redundant DNA and cannot be cultured independently.
  - This is one of the things that makes symbiosis difficult to study.
  - The symbiome can no longer be considered to be made up of independent organisms.
    - (Obligate: cannot live separately.)
    - (Facultative: symbiosis is to some degree 'optional.')

Cooperation vs. Competition

- Deep philosophical issues which we can only sketch here.
- However, it does not make clear sense to say that the symbionts in an obligate symbiosis 'compete' with each other *because there is no longer such a thing as 'each other'*!
- Symbiogenesis: formation of *new type* of organism due to highly obligate symbiosis being amplified by natural selection.

The Symbiotic Transition Again

- Jeon & Jeon observed a transition from pathogenic parasitism to obligate mutualism.
- A key feature is the finitude of the environment (a small Petri dish).
- Possibly, in a much larger environment, it would have been possible for the bacteria to continue their predatory/parasitical ways without threatening their own survival.
- Example of a fairly common pattern: the endosymbiotic bacteria in our own bodies (mitochondria) which probably started out as predatory invaders of some host bacteria.

Back to the Symbiotic Scale

- Pathogenicity often occurs when an organism is introduced into a new environment (emergent disease, such as HIV and Ebola).
  - Also, when symbiotic checks and balances break down (as in aging, stress).
- Often (but no guarantees!) a symbiotic accommodation will evolve between host and parasite.
  - Example: myxomatosis virus introduced to control rabbits in Australia; became endemic, a tolerated commensal.

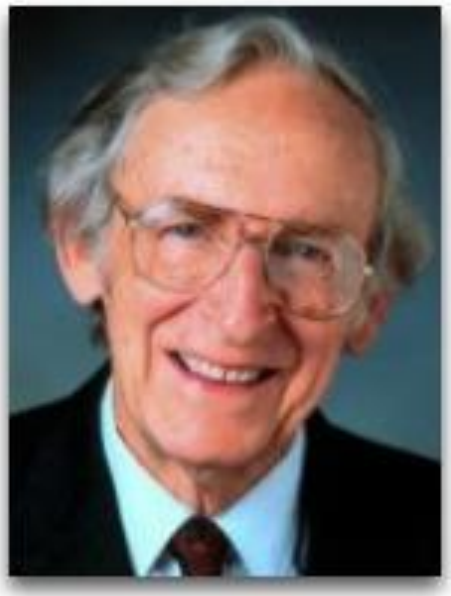
Kropotkin's Analysis….

- Mutualism is favoured in highly constrained physical environments, where there is a strong survival advantage in cooperation.
- Predatory competition may be favoured, at least for a while, in abundant environments where the short term advantages of "grabbing it all" can out-weigh its long-term disadvantages (threatening the supply of prey).

Implications for Humans

- Human status as planetary macroparasites:
- William McNeill (*Plagues and Peoples*, 1976)*:*
  - "It is not absurd to class the ecological role of humankind … as a disease. Ever since language allowed human cultural evolution to impinge on age-old processes of biological evolution, humankind has been in a position to upset older balances of nature [using language and technology] in quite the same fashion that disease upsets the natural balance within a host's body. … Looked at from the point of view of other organisms, humankind therefore resembles an acute epidemic disease, whose occasional lapses into less virulent forms of behavior have never yet sufficed to permit any really stable, chronic relationship to establish itself."

Eugene Odum



- Distinguished American ecologist (1913—2002) argued for “symbiotic transition” for humanity:
  - “Until now man has generally acted as a parasite on his autotrophic environment… Obviously it is time for man to evolve to the mutualism stage in his relations with nature since he is a dependent heterotroph… If man does not learn to live mutualistically with nature, then, like the ‘unwise’ or ‘unadapted’ parasite, he may exploit his host to the point of destroying himself.”

Is ‘Win-Win’ Possible?

- Odum again:
  - “…if understanding of ecological systems and moral responsibility among mankind can keep pace with man’s power to effect changes, the present concept of ‘unlimited exploitation of resources’ will give way to ‘unlimited ingenuity in perpetuating a cyclic abundance of resources’” …
- This would entail that a *major preoccupation* of our species from now on must be ‘planetary care.’

Ingenuity: Its Care and Feeding

- Human ingenuity (creativity) is a factor by which *new things* come into the world.
- Ecological and evolutionary possibilities are expanded by ingenuity.
- One of the most important things we can do in order to see ourselves through our present tough patch is to enhance those social conditions that conduce to the exercise of human ingenuity.
  - IMHO, this is more important than promoting any one *specific* innovation.

A Glimmer of Hope

- It is not out of the question that, like the microbes studied by Jeon and Jeon, humanity might undergo a "symbiotic transition" when pressed up against the walls of the planetary petri dish.
  - The *general principles* of symbiotic biology seem to allow for this!
  - This would be a truly 'sustainable' ecological relationship between humans and the Earth system.
- But with CO_2 already at 400 ppm (Pliocene levels), do we have time to figure this out?