Implications of recent advances in evolutionary theory

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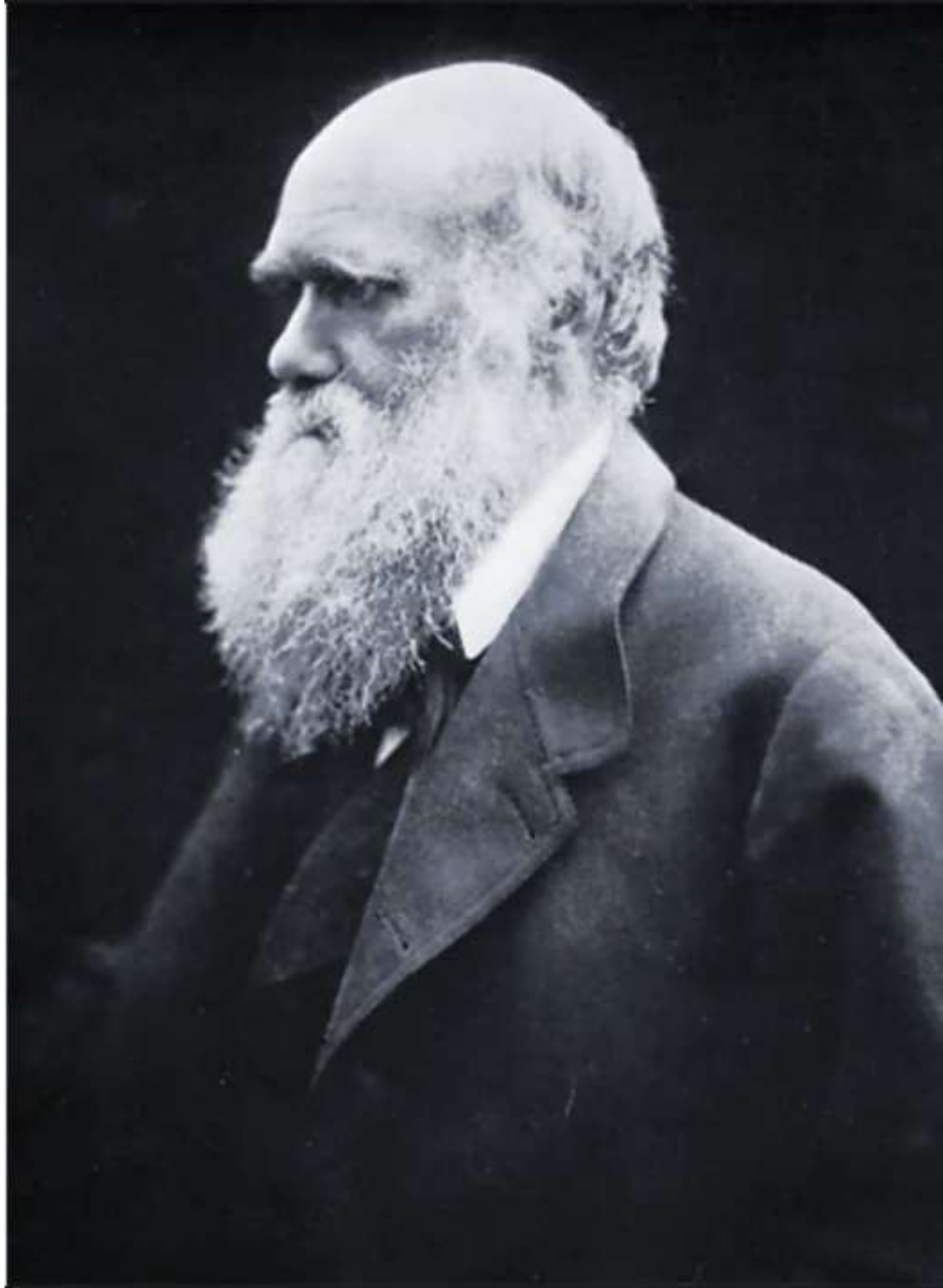
Darwin credited Malthus with his theory of natural selection

- For Darwin, competition for resources meant that “favourable variations would tend to be preserved, and unfavourable ones to be destroyed” (1859) – it was an economic theory inspired by Malthus.
- It only became a genetic theory in in the early 1930s when Darwinian natural selection was combined with Mendelian genetics, subsequently supercharged by the discovery of DNA in 1953.
- Thus, the “gene’s eye view of evolution”: "Like successful Chicago gangsters, our genes have survived, in some cases for millions of years, in a highly competitive world.” (Richard Dawkins “The Selfish Gene”, 1976)



The (Neo-)Darwinian synthesis: “adaptation view of nature”

Adaptation view of nature

Two differential equations:

dO/dt = f(O,E)

dE/dt = g(E)

where O is organisms, and E is environment.

- A causal linear model running from changes in the environment (dE) to changes in the organism (dO) facilitated by those changes in the organism’s genetic code (O) which “tend to be preserved”.
- Organisms can alter the environment but not in a way which has causal significance to evolution.
- Hence the dichotomy between “developmental ecology” (ie study of organism life cycles) and “evolutionary biology” (study of changes in organisms over evolutionary time); a dichotomy that hardened progressively after 1945.
- A corollary was the emphasis on information over energy: ”Crick and Watson ushered in the hegemony of DNA and information… but considering replication and the origins of natural selection in near isolation has distracted attention from the importance of other factors, notably energy" (Lane p90-1)

While this perspective remains the dominant view, it has been increasingly challenged since the 1970s:

- A deeper understanding of the fossil record, especially Gould-Eldridge model of "punctuated equilibrium" (1972/77): long periods of stasis in the fossil record were sharply broken by waves of new species, contrary to the conventional 'slow and steady' view.
- Likewise, several global-scale changes such as the "Great Oxidation" of the atmosphere were first understood robustly in the 1970s and 1980s.
- The systematic field study of natural selection in the wild only commenced in 1970s (eg the Grants' 40-year study of finches in the Galapagos Islands from 1973 – natural selection can work very quickly!)
- Dramatic improvements in molecular biology, revolutionising the understanding of how gene expression depends on input outside the cell and/or experience of the whole organism (eg transfer of maternal behaviours in rats down the generations)
- Landmark contributions such West-Eberhard's *Development Plasticity and Evolution*: organismal needs generate changed traits and gene changes follow to stabilise those traits (eg Chaves 2016 demonstrating the negligible impact of gene changes in initiating changes to Galapagos finch beaks)

Hence, a major rethink is emerging: “construction view of nature”

Construction view of nature

Two differential equations:

$dO/dt = f(O,E)$

$dE/dt = g(O,E)$,

where O is organisms, and E is environment.

- “Offspring receive both genetic and ecological inheritances from their parents, and these two inheritance systems interact with each other in descendent populations. a non-linear causal process … acting reciprocally” (Odling-Smee, p70)
- “Development is not “programmed” but rather “constructive”, with organisms continuously responding to, and altering internal and external states to shape their own developmental trajectories. … Natural selection is not something that just happens to organisms: their activities and behaviours contribute to whether and how it happens” (Lala, p228)

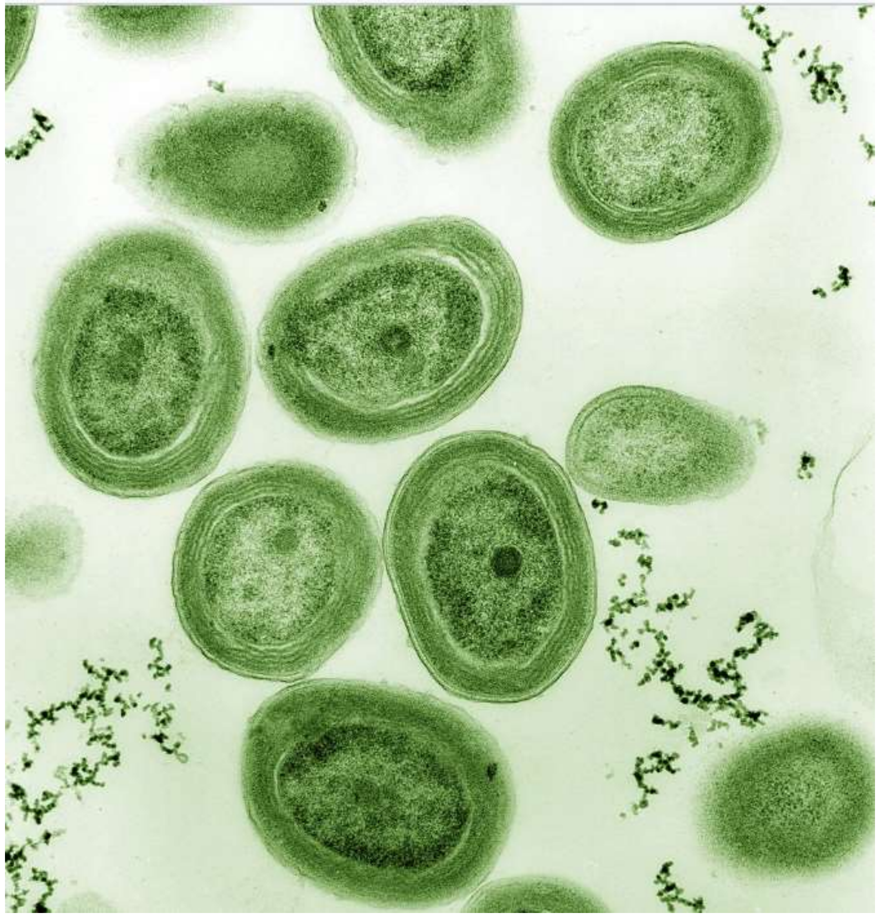
There is a particular focus on the *construction* on new niches, not just the traditional view of partitioning of a given environment into new niches.

Pilotfish (Naucrates Ductor)

"It seems hard to conceive of this tooth-cleaning niche as existing before the emergence of a relatively large swimming animal with teeth…Rather, the niche emerged together with shark teeth. The shark's evolutionary arrival brought with it multiple niches that cannot plausibly be thought of as existing previously". (Cazzolla Gatti p111)

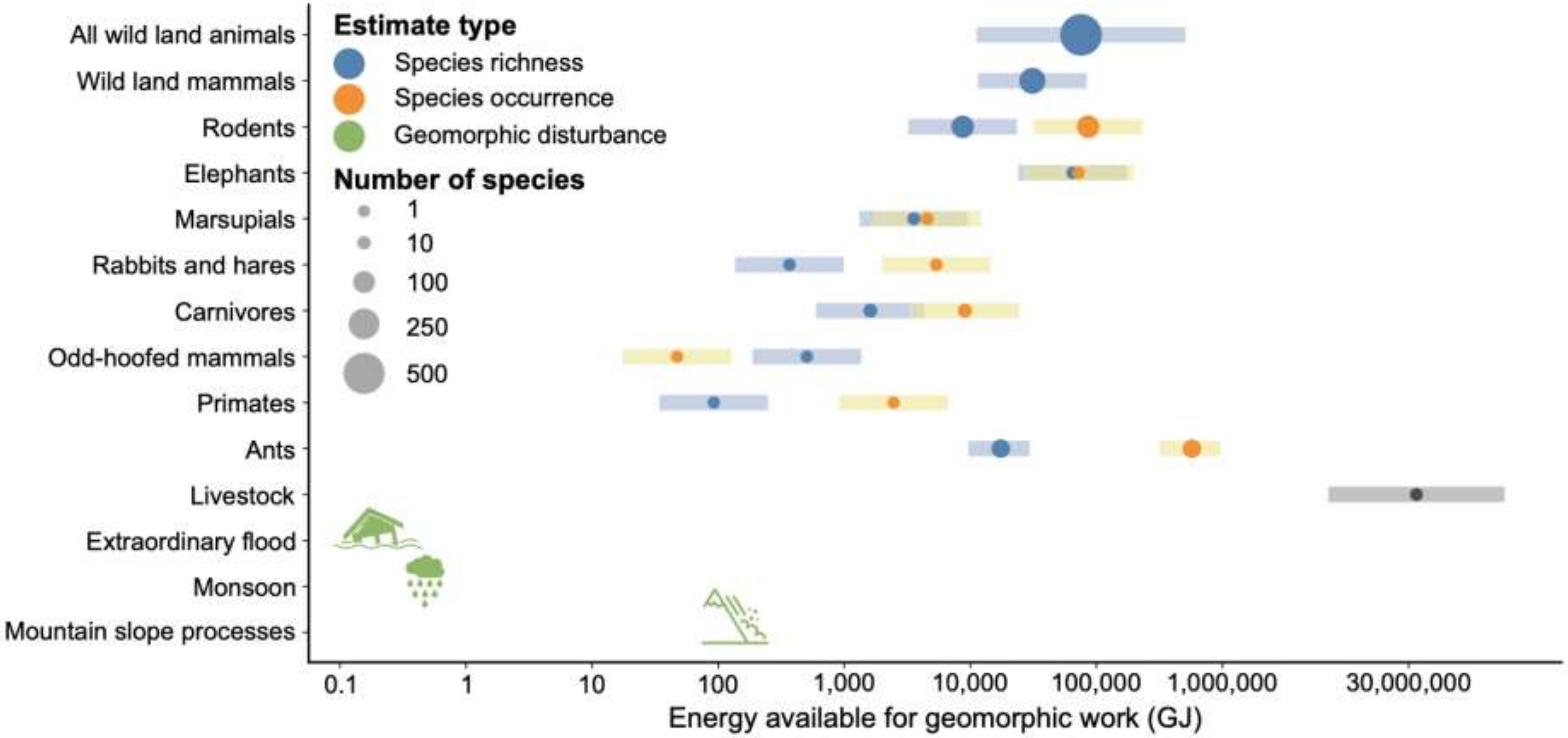
The Great Oxidisation as Organism-Environment coevolution

- Cyanobacteria ("blue-green algae") evolved c. 2.7b ybp – the first organisms known to have produced oxygen, a by-product of their photosynthesis. Oxygen is an extremely rich source of energy (exceeded only by FL & CL).
- This generated the Great Oxidisation (2.45-2.32b ybp), and in turn the emergence of eukaryotic ("good kernel") cells (c 1.8b-1.2b ybp). All life other than bacteria is eukaryotic.
- By the start of the Cambrian era (541m ybp) atmospheric oxygen was on a path to today's concentrations, and with it came the rapid diversification of organisms: the "flesh epoch" with the emergence of the hunting and eating by one life form of another.
- Oxygen as the ultimate "positive-spillover" technology (ie. non-rivalrous and non-excludable). Also highlighting the fundamental importance of new sources of energy for change and evolution.



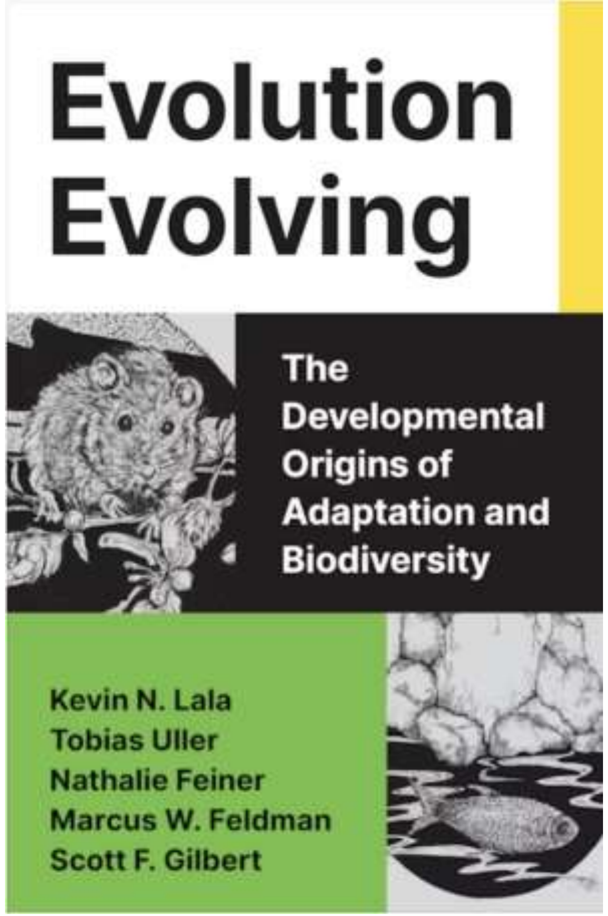
Prochlorococcus, a marine cyanobacterium which produces much of the world's oxygen.
https://en.wikipedia.org/wiki/Cyanobacteria

This is the first global estimate of the annual geomorphic impact of animals : equivalent to "hundreds of thousands of extreme floods" (PNAS, Feb-25)



https://www.pnas.org/doi/pdf/10.1073/pnas.2415104122

While the adaptation view remains dominant, much greater prominence is being given to the construction view



(Princeton UP, 2024)

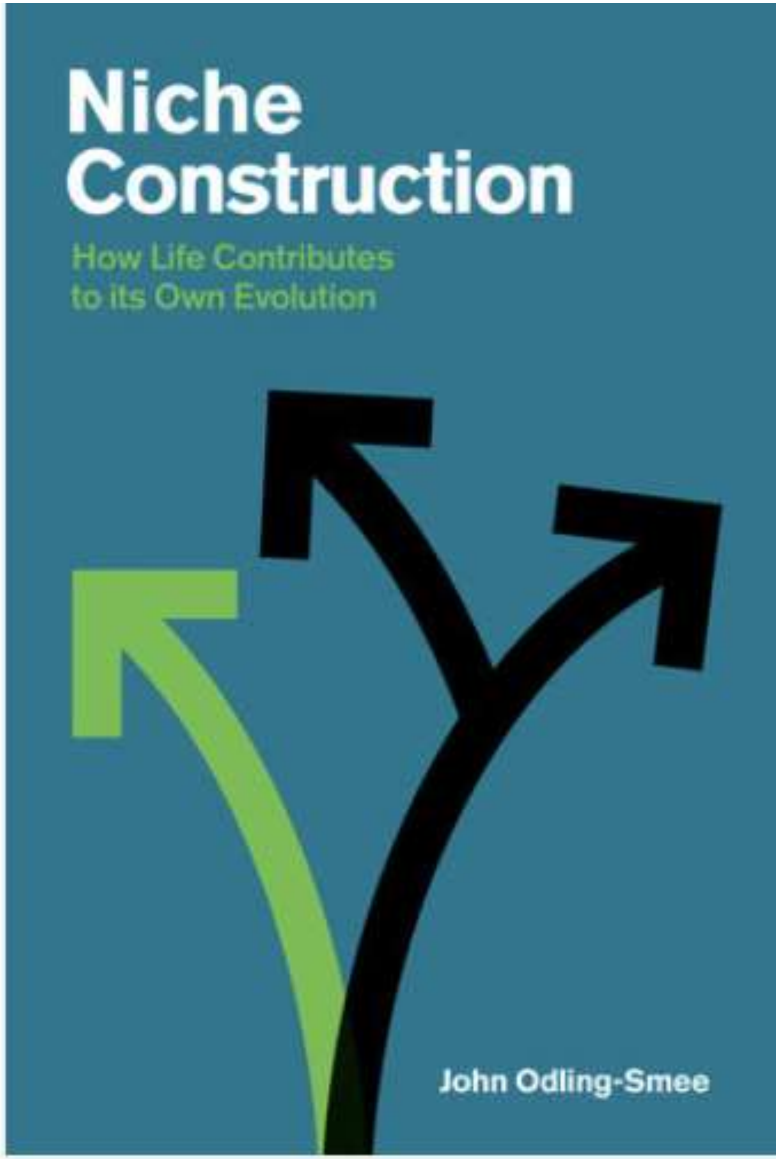
"the principal thesis: developmental processes do more than impose constraints on selection: they also help explain adaptive evolution and they do so in every bit as fundamental a sense as the far-better-established converse assertion that evolutionary processes explain developmental mechanisms" (p.x)

In summary, their intent is to move evolutionary theory from a linear causal process to a non-linear reciprocal process.

I think we can be confident that AI will play a role in unpicking precursors of human language.

- AI can now detect specific vocalisations and predict whether they are arguing about food, roosting position, or sex.
- There are also specific vocal signatures – the speculation is that they are about social status not names.
- Another project is feeding human language & music along with animal recordings into AI – early promising results.

15,000 vocalisations and videos of these fruit bats at Tel Aviv University used in AI analysis to date



(MIT Press, 2024)

2LoT imposes on *all* organisms the imperative of purpose – ie maximizing behaviours – and hence the imperative for them to generate know-how to achieve that purpose (ie to survive).

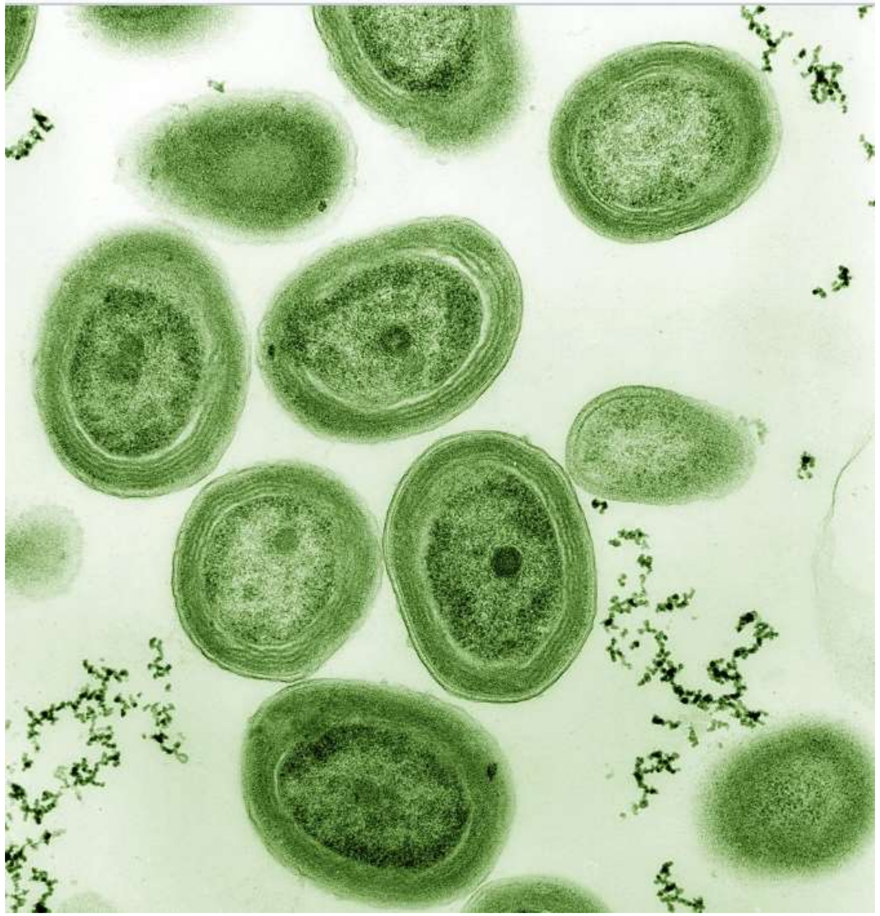
The *availability* of energy (R_p) is not sufficient; organisms must have the adaptive know-how (R_i) to be able to *access* it.

There are three levels of R_i:
- genetic code (capturing past selective pressures)
- learning by the individual organism (there is increasing scientific confidence that at least some of that learning can be transmitted to offspring)
- sociocultural learning and traditions (from bubble net feeding by humpback whales to human legal systems and technologies).

The dilemma is that nothing is free: R_i can't exist without R_p. How does nature jump this "impossibility barrier"?

The Great Oxidisation as Organism-Environment coevolution

- The emergence of atmospheric oxygen as cyanobacterial waste was an energy-rich R_p but, because all organisms then were anaerobic, that R_p was inaccessible to them – they did not have the necessary R_i to utilise it ("maladpted").
- The process of adaptation required organisms to generate R_i (via genetic change) to access this new R_p – this is precisely why R_i is "adaptive know-how".
- "The emergence of the ability of living organisms to use oxygen as an energy source is shrouded in at least as much mystery as the emergence of cyanobacteria." (Judson, 2017, p2)
- Only when this "impossibility barrier" was crossed could oxygen become the ultimate "positive-spillover" technology we now rely on.



Prochlorococcus, a marine cyanobacterium which produces much of the world's oxygen.
https://en.wikipedia.org/wiki/Cyanobacteria

To quote Odling-Smee:

"The purposes of organisms in their environment ultimately stem from the universal requirements of all living organisms to oppose the 2LoT without violating it. This fundamental need arises from the improbability of the internal environments of organisms relative to their external environments, and their far-from-thermodynamic-equilibrium status. A fundamental need of all organisms is to control a flow of energy and matter between themselves and their external environments that opposes the flux of energy and matter favoured by the second law. If they fail, the flux would destroy them…But organisms cannot oppose the second law by chance. Survival and reproduction require organisms to acquire sufficient adaptive know-how (R_i) about their local external environments to persist, using whatever knowledge-making processes are available to them, including the learning process in animals." (p43)

A corollary of the emphasis on purpose is an emphasis on control

- The argument: if organisms really are purposeful, then natural selection will favour those which can use knowledge-generating processes (R_i) to exert some control over their environment to cope with an “unknowable but not wholly unforecastable future” (Waddington’s famous phrase from 1969)
- Further: because natural selection works by selecting between variants, the early evolutionary response to seek potential control is to generate greater variation. The formal construct is Ashby’s (1956) “law of requisite variety” describing interactions between two systems – “only variety can destroy (or drive down) variety”.

Two final quotes:

- “natural selection will favour individual organisms that inherit at least a minimal capacity for self-control of their own inductive gambles [about the future]. ...By enabling individual organisms to be self-controlling, evolving populations should increase their amount of variance that is available to natural selection. Hence natural selection may also favour supplementary information-gaining processes in individual developing organisms. The evolution of immune systems, epigenetic processes, learning in animals, and eventually human cultural processes allows organisms to go beyond the relatively coarse-grained control of their adaptations granted to genetic predetermined organisms in order to allow additional fine-tuning of this control” (Odling-Smee, pp87-88)
- “Variation and selection are reciprocal causes of each of other, and it is because of this interdependence that evolution is evolving.” (Lala, p195)

Discussion starters:

1. Purpose in all organisms as an actuality, not simply a metaphor: economists are right to focus on maximising behaviours!
2. The need to "resist but not violate" 2LoT drives purpose: economists could reflect on this!
   "Energy's exclusive right to rank along space and time is founded on the fact that, besides energy, no other general concept finds application in all domains of science…In the last analysis everything that happens is nothing but changes in energy." (Nobel Laureate Wilhelm Ostwald, 1892)
3. Solow (1956) was a bit like Crick and Watson (1953) – thereafter information swamped physical resources in growth theory: should we follow the constructionist view in rebalancing this? R_p and R_i are inextricably interrelated.
4. Don't throw the baby out with the bath-water: Romer's instinct and conclusion on the importance of non-rivalrous spillovers is critical, as the Great Oxidisation shows.
5. The flip-side of purpose is agency and control – concepts which need greater prominence in economics.   After all, the most basic of all humanity's technologies, fire, is not a technology if its out of control.

I prefer this definition of technology:

Technology is *the ability to do or use something to achieve an outcome in a controlled manner*.

- *outcome* relates to having a purpose in mind
- *controlled* means some reasonable expectation of achieving that purpose.

A **peril** is *a former technology which is in no longer under control*.

→ There is much more to technology than just instructions

→ Technology is the human subset of the third level of adaptive know-how (R_i) (ie sociocultural learning)

Discussion starters:

6. Control is also fundamental to corporate/producer competitive strategy: indeed, there is a more-than-plausible hypothesis that maximising control (subject to what the relevant market allows) is the primary strategic objective, and profit performance is the measure of that success. "A profit opportunity available to all is a profit opportunity available to none". (Richardson, 1960).

7. The phrase "unknowable but not wholly unforecastable future" rings true in so many economic situations: do we focus enough on that sort of uncertainty?

8. Hayek's *Competition as a Discovery Process (1968):*
"competition [is] a procedure for the discovery of … facts…competition is valuable *only* because, and so far as, its results are unpredictable…equilibrium [is] a somewhat unfortunate term because such an equilibrium presupposes that the facts have already all been discovered and competition has therefore ceased. The concept of an 'order'…I prefer to that of equilibrium".

9. Niches are increasingly being seen by the biologists as sword just as much as shield. How could that translate into economics? (One application is the concept of affordances)

10. Would a major transition in evolutionary theory from *linear, causal* to *non-linear, reciprocal* have a material impact on the body of economic knowledge?

Well worth a read:

" I believe the transformative moment that gave rise to the genus Homo, one of the great transformations in the history of life, stemmed from the control of fire and the advent of cooked meals. Cooking increased the value of our food. It changed our bodies, our brains, our use of time, and our social lives. It made us into consumers of external energy and thereby created an organism with a new relationship to nature, dependent on fuel" (2010, p2)

British PM Winston Churchill inspecting House of Commons, after the biggest WW2 air-bombing of London, 10-11 May 1941

“We shape our buildings; thereafter they shape us”

- British PM Winston Churchill in his speech to the House of Lords, October 28, 1943, requesting that the House of Commons (bombed out in May 1941) be rebuilt exactly as before.
- Hence Marshall McLuhan: "We shape our tools and thereafter our tools shape us"

- Epigenetic example
- History of competition point
- Affordances
- Profit point
- Bob Gregory on uncertainty
- Lamarkian
- 2.7b yrs
- the use of oxygen as an electron acceptor releases more energy per electron transfer
- Richardson 1960
- 76 passengers who boarded AA11 on 9/11 the purpose was to get from Boston to LA:

Even non-toxic cyanobacterial blooms can still kill fish by causing **oxygen levels to crash** in the water.

- During a bloom, algae multiply rapidly.
- When the bloom collapses (e.g. due to lack of nutrients or sudden temperature change), **huge amounts of algae die**.
- Decomposing algae are broken down by bacteria, which **consume large amounts of oxygen**.
- This leads to **hypoxia** (low oxygen) or **anoxia** (no oxygen), and fish suffocate.

Epigenetic – literally above the gene - Epigenetics involves genetic control by factors other than an individual's DNA sequence. Epigenetic changes can switch genes on or off and determine which proteins are transcribed.   BEST EG IS DUTCH HUNGER WINTER – impact of starvation not just on 2nd generation but 3rd generation too.