

Life, Universe & the 2nd Law

On fundamental systems...

Preamble: *I got to thinking recently during Lockdown. You know how it is. And those thoughts may seem to be right up there with current concerns for global warming, rising sea levels, and other apocalyptic notions. However, there are always other ways of looking at things. Especially when you get into fundamental systems-science notions... N.B. Bit 'scientific-ie,' this one—don't let that put you off.*

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As we should, no doubt, have been taught in school, the **Second Law of Thermodynamics**, is a cornerstone of physics. It comes in many forms including, perhaps, the simplest:—

*The processes most likely to occur in an isolated
system¹ are those in which the entropy² either
increases or remains constant.*

Physicists use this proposition to predict that the Universe will eventually become cold, inert and lifeless in some far off future...

¹ So, does that mean that the 2nd Law is a cornerstone of systems, too? Back in the 1860s?

² The degree of disorder or randomness in a system

All the more surprising, then, is the recent discovery of a galaxy, less than 100 million years old, in which *new stars* are forming, i.e., **entropy** is apparently *reducing*. How can this be consistent with the **Big Bang** and the Second Law? Well, of course, the Second Law is statistical. *If* the Universe is an isolated system, and *if* the average entropy throughout the Universe is still increasing or remaining constant, then local reductions in entropy need not confound the Law, provided there are equivalent increases elsewhere. But, *they still take some explaining...*

Which brings into question, just how useful is the Second Law in everyday life? Life appears to confound it: as we are born, develop, grow and mature, so our bodies become more ordered. Eventually, decay sets in and entropy wins, ‘dust-to-dust,’ but not before life has gained considerable ground. Civilisations are even more of a challenge to the Second Law. They emerge from social chaos, grow, develop, refine, evolve, morph, fluctuate and endure, sometimes—like ancient Egypt—for thousands of years. Eventually, they too decay, often with a resounding collapse, only to be replaced by another, and another.

This observation has given rise to the ***organismic analogy***, in which entities such as organisations, governments and civilisations, which are clearly not organisms, are observed to behave in ways *analogous* to organisms. That is, they comprise ‘*complementary, interacting parts, synthesizing a complex, organized whole of material and/or immaterial things*’³ and they have a life-cycle, at the end of which they terminate; often with a sudden, collapsing end.

The ‘organismic analogy’ is not universally appreciated...‘a load of old *tosh*,’ as one self-styled intellectual put it! Don’t you just love them...?

The Second Law refers to **isolated systems**. Looking around us in the real world, it is difficult to find an isolated system. If a system were truly isolated, it would receive no inputs and give no outputs. That would include energy, so presumably there would be no way of detecting an isolated system.

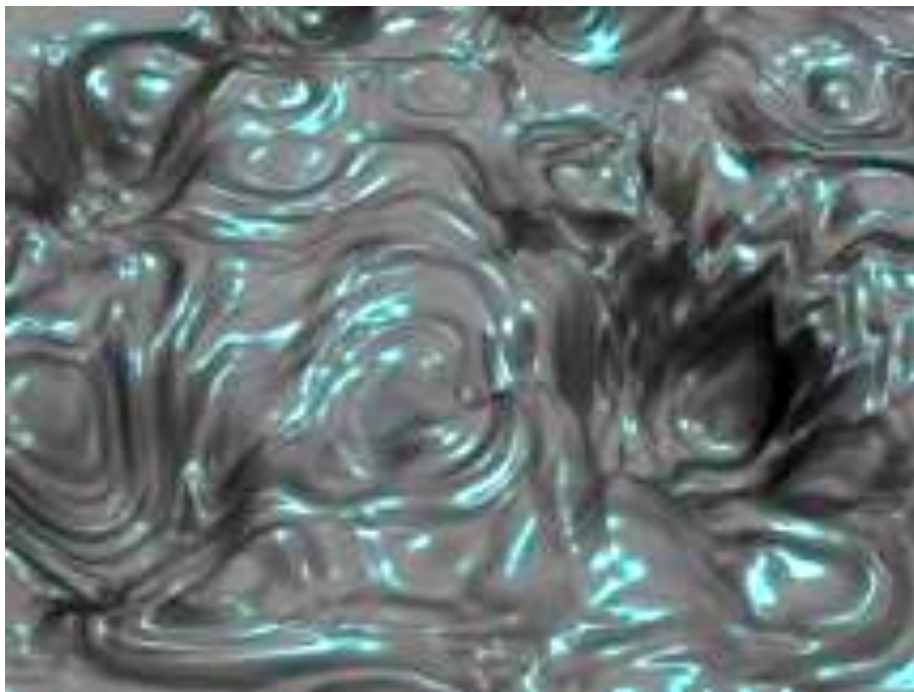
³ Necessary and sufficient definition of a system...any system. An organism is a system.

Stephen Hawking has famously determined that **black holes** can release information: they are, therefore, not totally isolated systems and may be detectable.

The idea of **open systems** was developed last century to accommodate observations that life, civilisations, weather, our Sun, indeed everything that we observe does not, *de facto*, appear to increase its entropy with time.

It is not so much that the Second Law is wrong; more that it does not apply. Instead of increasing entropy, we see “entropic cycling,” as complex⁴ systems form (reducing entropy), mature, age and decay/collapse in an entropic ‘outburst.’ The many parts subsequently come together with other parts to form new complex systems and the energy-driven cycle repeats endlessly—see the Lifecycle Map below. This entropic cycling appears everywhere we look in the real world about, below and above us, in the galaxies and in our weather maps.

Notional Entropy Surface Map.

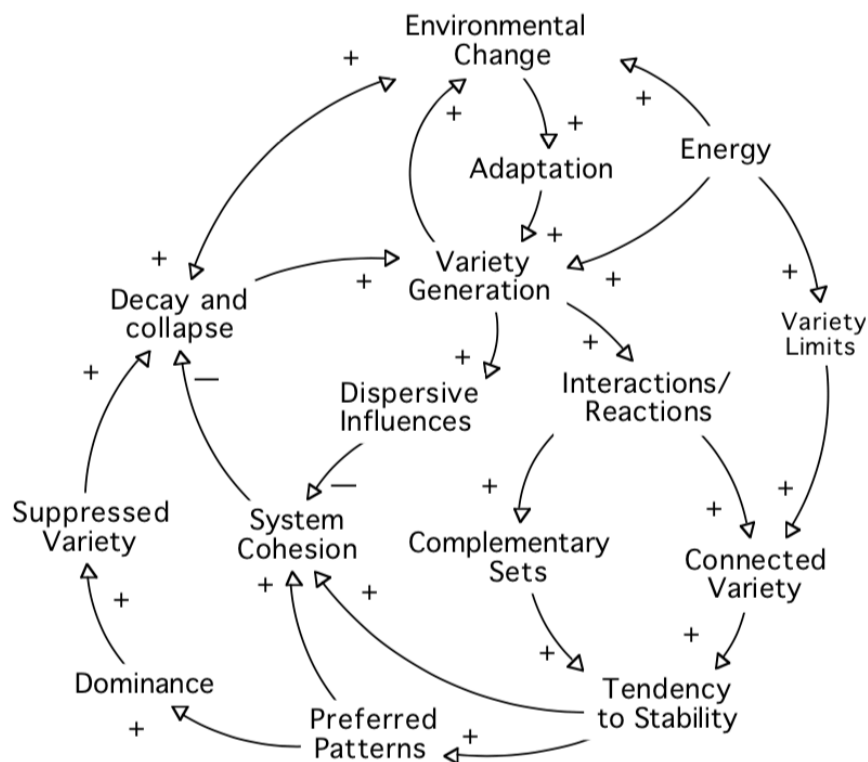


Systems appear as ‘dents’ in the
fabric of entropy

⁴ Complex: not simple and straightforward; with at least three parts, so able to exhibit non-linear behaviour...see Reference C

A mental model might consider a submerged pump pushing water upwards to the surface of a pond. The up-thrust causes vortices, whorls and ridges to form on the surface in close analogy to a weather/entropy map. The patterns fade towards the edge of the pond, being replaced in a continuous process by newly formed patterns emerging from the centre. I.e., energy causes entropy to reduce/open systems to form, as evidenced by these dynamically stable, yet short-lived, patterns in the water. Some patterns coalesce, either combining their energies or cancelling each other out. Other patterns fade as their energy dissipates into the surrounding water. More energy from the pump results in larger, deeper patterns, each with more energy and therefore tending to last longer and spread out further before eventually dissipating.

The ***Lifecycle Map*** below follows the fortunes of open complex systems as they continually form, stabilise, decay and reform.



The Lifecycle Map.....Reference A

Causal Loop Model showing energy-driven formation, co-existence and breakdown of *open, interacting complex systems*, forming a conceptual *ecosystem*...Basis for a 'systems dynamics' simulation.

Open complex systems are formed of diverse, interacting, complementary parts. Interactions between the parts sustain each other by the exchange of energy, substance and information. The whole is therefore internally dynamic, and work is done (energy dissipated) to maintain the reduction in local entropy.

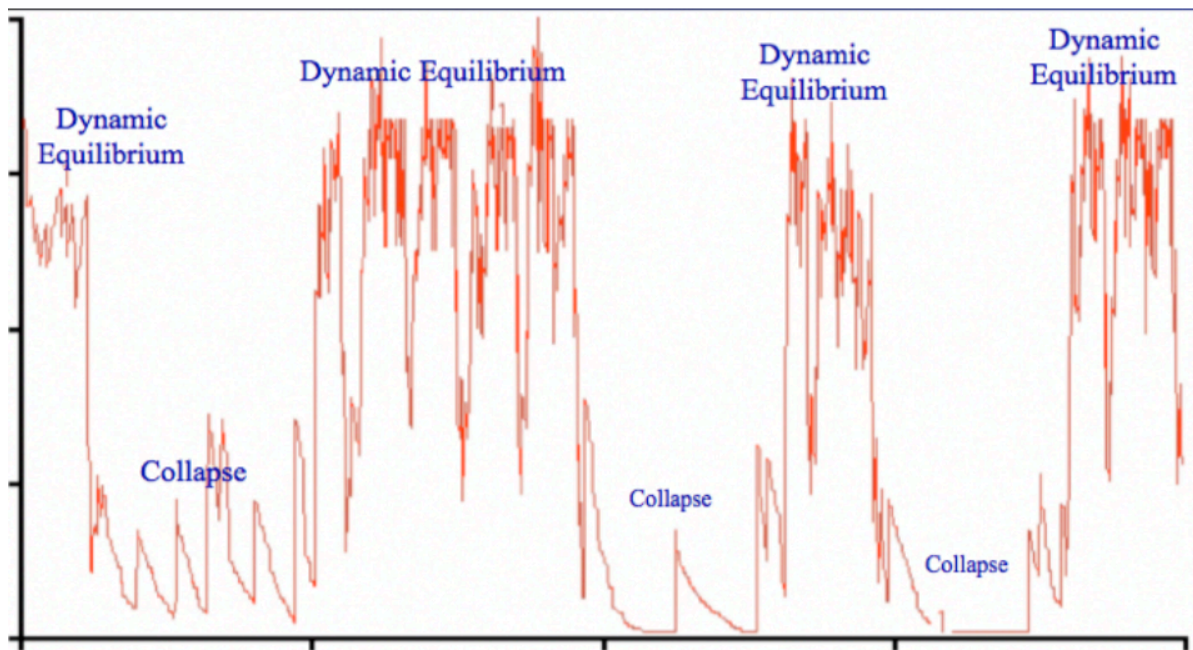
An open system can be dynamically stable, provided the mean inflow (again, energy, substance & information) equals the mean outflow over some arbitrary period. As a consequence, open system stability occurs, not at *low* energy, but at relatively *high* energy levels. This view of open complex systems starts to rationalise some observed phenomena with which some purists may be uncomfortable. For instance, Bak & Chen's *self organized criticality* may be observed when a flow is restricted, as may be the case in the interchanges between parts.

Organisms—and by extension, things analogous to organisms—display ‘rhythmic behaviour.’ There are many rhythms: diurnal rhythms in sync with the energy from the Sun; monthly, in sync with the rotating Moon, such as menstrual cycles, reproductive cycles, etc; seasonal cycles as in many botanical species;⁵ annual cycles as in mammals and many organizations and economies; and even longer cycles, e.g. in the 4 or 5 year planning cycles favoured by some communist states, and the case of the cicadas’ 13 or 17 year lifecycle...(And, no, it appears that cicada *cannot* count up to seventeen after all. How disappointing...)

Organisms, it seems, form, develop, mature and die rhythmically. Is that because life developed here on Earth with its fundamental rotating rhythms? And do we humans, consciously or unconsciously, reflect these rhythms in our human-activity, social and socio-technical systems?

The graph of entropic cycling derives, as above, from a simulation of archetypal open, interacting systems, forming a notional *ecosystem*; this kind of behaviour, with (negentropic) plateaux interspersed with unexpected change, seems to be typical of close-coupled open complex systems. Note the rhythmic pattern of

⁵ Surprisingly, fires caused by lightning every 40 years in parts of Yellowstone Park—see Reference B, by Romme & Despain, which was the inspiration for the Lifecycle Map



Nominal Run of Lifecycle Map: Dynamic Simulation

Typical simulation run, showing lifecycle behaviour of complex, interacting systems. At peak, they are dynamically stable, with continual variations about some mean.

Unexpectedly, they may collapse, only to reform in a different pattern...

...this is 'cyclic progression,' or 'entropic cycling,' STELLA™

build-up and sudden collapse, repeated continually, but never in quite the same way.

Such patterns may reflect the behaviour of a whole, extensive ecosystem, but may also arise in different locales within an ecosystem at different times, such that—to an external observer of the whole—there would be little, if anything, of these 'internal goings on' to see...

And, according to the nature of the ecosystem, a 'locale' could mean: a neighbourhood or suburb in a city; a relatively confined area in a jungle; groups within divisions of an organization...

With open systems, weak chaos, self-organized criticality, chaos⁶, catastrophe, open systems and so on, we might be forgiven for wondering if there is an alternative *behavioural paradigm* both in the heavens and here in the real world; a 'physics' specific to open complex systems, perhaps, with a *Law of Entropic Cycling*. Observation would suggest

⁶ See Reference C, *Systems and Systems Engineering: Chaos & SE!*

that there might, indeed be such a paradigm, and such a law, which might be tentatively stated as follows:

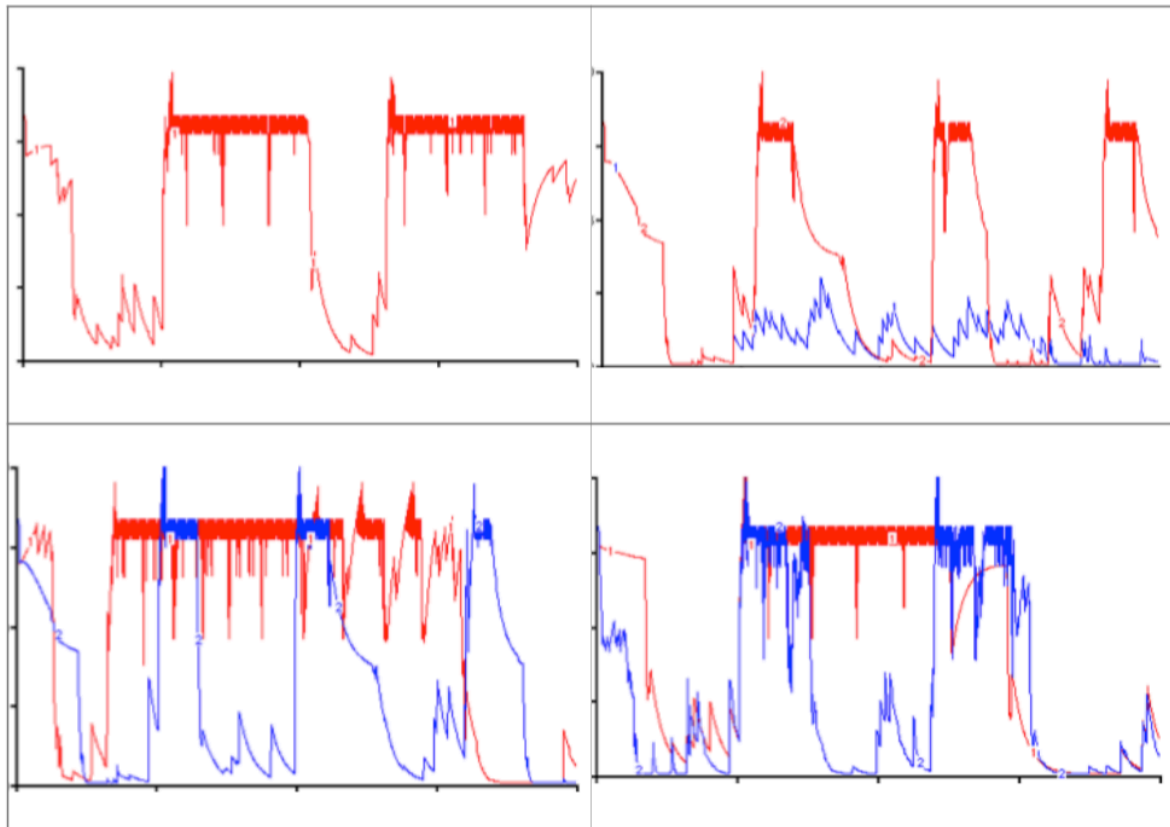
Unified Systems Theory (UST) ‘...that open interacting complex systems form, develop, sustain, collapse/decay and reform continually in a process that may be called “cyclic progression,” or “entropic cycling.”

Law of Entropic Cycling.

Open, interacting systems' entropy cycles continually at rates and levels determined by available energy

It is straightforward to vary the parameters of the Lifecycle Systems Dynamics Model, so generating different behaviour of putative interacting open systems, or ‘ecosystems.’ Results are shown in the table of graphs below:

- The upper left diagram, a) is a graph representing nominal behaviour of the ecosystem (or parts of the ecosystem); this may be used as a reference with which to compare the other three graphs.
- The upper right graph, b), shows the effect of varying the degree of variety/diversity in the ecosystem from very low (line 1), bumping along the bottom, to moderate in line 2. The results suggests that with insufficient variety there is little prospect of reaching a state of dynamic equilibrium
- The graph at lower left, c), shows the effect of varying the available energy in the system from low, line 2, to high in line 1: the result of higher energy is longer periods of stability and fewer, briefer collapses.
- Lower right, d), shows the result of varying the proportion of “dispersives,” i.e., influences to disrupt the ecosystem such as fires, pathogens, storms, etc. A low proportion of “dispersives” results, not surprisingly, in longer equilibrium, line 1, with less turbulence, and vice versa.



- a) Upper left: nominal/reference behavior.
 b) Upper right: varying variety/diversity; low line 1, moderate line 2.
 c) Lower left: varying available energy; low line 2, higher, line 1.
 d) Lower right: varying dispersives; moderate dispersives, line 1, high dispersives line 2.

Varying Dynamic Behaviour

Line 1 is Red; Line 2 is Blue

The tentative Law of Entropic Cycling is consistent with some widely observed and quite disparate natural and social behaviours:

- *Revolution.* The domino-collapse of Soviet Union is an example of the positive feedback that reinforces a collapse, once underway. (See UST Lifecycle Map: decay & collapse › variety generation › dispersive influences › system cohesion › and, back to › decay & collapse: a positive feedback loop.)
- *Politics:* continual switching between left wing and right wing governments in a democracy constitutes a state of dynamic equilibrium...

- *Dominant leader* who expels dissidents ('wets') from their cabinet, reduces necessary variety/diversity in that cabinet, so heralding sudden collapse of both leader and cabinet.
- *Multicultural societies* where one of the 'cultures' neither complements, nor cooperates with, the others, thereby becoming a societal 'pathogen,' prejudicing dynamic stability of the whole⁷.
- *International economic cycles* (e.g. Kondratieff cycles) that rack world economics periodically.
- *Bureaucracies* that "exist, like aircraft carriers, mainly to defend themselves" exemplifying preferred patterns in the process
- *Accountants* who inadvertently destroy companies by shedding variety/ diversity in attempts to to survive economic winters.
- *Civilizations* such as Ancient Egypt, which 'cycled' through 3 epochs (Old Kingdom, Middle Kingdom and New Kingdom) with 'intermediate' periods of relative disorder...
- *Large-scale 'Social' IT Systems*, such as those for health, security, finance, etc., which appear inordinately difficult to build and which are prone to apparent breakdown, discontinuity, and potential intrusion, with no apparent cause...
- *Periodic extinctions*, with the loss of many species on Earth. Such extinctions have been attributed to external "dispersives," notably meteor strikes, but these appear to be neither necessary nor sufficient to account for such major collapses of life, nor indeed for its selective nature:
 - For instance, the strike that supposedly "wiped out" the dinosaurs globally on land and in the seas some 64MY ago did *not* wipe out sharks, crocodiles, turtles, early mammals, bees, ants, etc., etc., which existed before, during and after the strike, yet apparently eliminated all dinosaurs including those in the seas, but possibly excluding some flying varieties. Why this curious inconsistency?

⁷ Diversity, taken by some as an end in itself, appears to be of value only when the diverse elements are complementary and interact positively, resulting in enhanced properties, capabilities and behaviours of the whole.

What can we make of these notions of open complex systems and entropic cycling? Parallels may be drawn between galaxies and weather patterns here on Earth. Elliptical galaxies, for instance, superficially resemble the isobar patterns of cyclones marked on weather maps. Like galaxies, cyclones and other weather features represent a reduction in entropy as evidenced by their regular patterns.

Weather systems self organize to stretch continuously around the world, driven by energy from the Sun and the Earth's rotation, configured around and above seas and landmasses. Moreover, the various structures within the overall weather system, that we might loosely call the weather subsystems, mutually interact in a complex, even chaotic, way.

While there may be arguments about the cause, it seems that the mean surface temperature of Planet Earth is rising at present. Weather patterns are changing. Storms are becoming more severe, rainfall heavier, periods of sunshine hotter and more prolonged...

As the real world in which we live is made up from networks of open, interacting systems; economic, political, environmental, ecological, social, etc. - the Law of Entropic Cycling should be universally applicable. The value of any law lies in its ability to make predictions. In this case, we could make predictions about the weather, as it will be affected by global warming. The prediction would be directly analogous to the pond model above:-

The energy of global weather systems will increase with mean temperature, as will the rate of energy dissipation, and the degree of interaction between weather systems. With more energy in the atmosphere, there will be more weather features such as cyclones and anti-cyclones, troughs and fronts. These will be more intense and will endure for longer, before fading and being replaced, degrading their energy as they do so.

The thought does occur, however: what if global temperatures are changing as part of some cyclic progression in the interactive network of Earth's many systems? Or perhaps there is a continual cycle between the Sun and its planets, including Earth, which we currently detect as rising global temperatures. Such notions raise different spectres. Perhaps we humans are not, after all, the sole cause of global warming, any more than we caused the last Ice Age, *from*

which Earth may still be recovering... If so, then should we not be preparing to survive in a changing world as well as trying—and not inconceivably *failing*—to prevent that inevitable change?

Meanwhile, back at the ranch, what is happening to encourage the formation of infant stars in that “new” galaxy, mentioned at the outset? Is that region open, receiving unseen energy and substance from other regions? Are gravitational waves, perhaps, making local dark matter clump as in a galactic-scale Kundt’s Tube or Chladni’s Plate experiment? Is new material being spewed into that region of space through a wormhole connected to some distant black hole? Are we glimpsing a rift in some multi-verse? However exotic the explanation, it seems reasonable to suppose that the new star formations are not an isolated system, vis-à-vis the Second Law of Thermodynamics.

One notion is to consider the star group as a *system*, made up from dynamic, interacting stellar *subsystems*, together with indeterminate interstellar material. This is redolent of the **organismic analogy**, i.e., that the star group is made up from separate parts which act together as a complex, self organizing whole, bound together by gravity, and exchanging energy and substance. The whole has a repeating life-cycle, which it has just re-started. It will develop, evolve, mature and eventually decay/collapse.

So, if the Law of Entropic Cycling is to be believed, then what we could be seeing in this new galactic nursery may be not so much a totally new system, but a resurgence, another phase in a never-ending cycle of birth, decay, death and, just at present, rebirth... On the other hand...

And, back on Earth, if the tentative Law is to be believed, post-Lockdown we are in for ever-worsening weather, floods, droughts, etc., and major social upheavals, too, as our various human societies around the globe interact ever more frenetically through antisocial media—with its antisocial positive feedback driving us toward dynamic extremes... This is the progressive development of the human monoculture into a world-wide colony—a veritable super-organism and, potentially, largely eusocialized like the others of that ilk, such as the Hymenoptera...

Wow! Why didn't we see that coming... the signs are everywhere about us...However, not to worry—the Law of Entropic Cycling seems destined to apply to our conceptual, nay *evolving*, worldwide monocultural ecosystem, too. The suggestion must be that, like the surface of the pond above, a continual process will develop of new and deeper social structures/systems forming, which will interact with each other such that some will endure while others subside, before reforming as reinvigorated social systems.

Such patterns of behaviour might, perhaps, look to an independent observer like mob⁸ rule, only there won't be any such observer—all will be engaged in the eusocial revolution. This suggests that current national boundaries, forms of government, control and culture may be prejudiced—and that will presumably apply across the globe, to countries that are presently dictatorships and to democracies alike...

There is one glint of light on the horizon...all of this dynamic turbulence is driven by energy. No energy? No turbulence. No networked technologies? No socially disastrous failures. Indeed, no interactions between disparate social groups? Little or no entropic cycling...

So, what is the energy that drives human societal interaction, growth and turbulence? As those ancient Egyptians knew well, all life derives ultimately from the Sun. Which, in the case of humanity at large, drives food production, both animal and vegetable. In a warming world, with rising sea levels causing mass human migrations and reduced land for food culture, food may be harder to grow, farming may be harder to conduct, and food may be harder to come by. What food there will be is liable to become the province of the powerful, whether powerful through money or, more likely powerful through force—perhaps the irresistible force of the mob...largest mob wins? All of which is suggestive of a dystopian future of epic proportions. Does it have to be that way?

Probably. It is difficult to see any way out of humanity's current dilemma. Unless, of course, you are prepared to think outside the box...

⁸ Mob. abbreviation of archaic Latin *mobile vulgus*, "excitable crowd."

F'rinstance. What if, Man's contemporary obsession with ever more advanced and extensive technology, with its commensurate worldwide industrial pollution, could be halted? After all, we don't actually *need any of it!* You only have to go back to 1930s to find a happy healthy world emerging from the Spanish Flu pandemic of 1918 and the Great Depression of 1929. No digital world, no digital computers, no cell phones, no satellites, no 'web.' Actually, no problem, either.

Don't believe it? You only have to look at those old 1930s Fred Astaire and Ginger Rogers movies to see a very comfortable, interesting world of people socialising in splendid surroundings, living in houses with all mod. cons. And they had social and antisocial media, too: t.v., newspapers, telephones, etc. And, post WWII, life had become good once again in the 50s and 60s. Much happier than today, if you ask any 'oldies.' But, what do we know... *ga-ga, racist and past it!*

But no, you are probably right, humanity is not about to give up its technological obsession. Yet, still thinking outside the box, could there be another way? By making use of that advanced technology? Perhaps... Earth's periodic Ice Ages are understood to have been caused by clouds of interstellar dust, in galactic spiral arms: as the solar system passes through these dust clouds, the Sun's energy is scattered by the dust particles, so reducing the solar energy reaching Earth. Hence a temporary Ice Age.

So, could we, with great care and caution, generate a dissipating dust cloud of our own at the Lagrangian Point directly between Earth and Sun, so scattering the IR radiation from the Sun? Such a cloud would, even after several repetitions, have only a minor effect, but could reduce the mean surface temperature of Earth to, say, pre-Industrial levels? Good idea? Reads well, doesn't it?

Nah! That would simply give the polluters a "Get out of Jail Free" card. Which would subsequently encourage even more technological development and more environmental pollution...and that would be, uh, as military folks might say, SNAFU. Right? Right!

Earth? We have a problem...

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