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Discussion

25. From steam engines to symphonies

In which—as an astonishing codicil to the laws we uncovered while building steam engines—we discover new ways to wonder about the wonders of life. Then a student suggests the purpose of life and it all gets glued together during an ocean passage on a small sailboat.

Have you ever wondered if something deep in our primordial brain attracts us to a manicured garden, a gracefully set out meal—most of all to music? Have you ever sensed that these experiences encapsulate the essence of being *alive*? Have you ever wondered, why?

In this article I'll succumb to my fascination with possible links between entropy and aesthetics. I imagine these links as a kind of metaphysical corpus callosum, connecting the left-brain ideas of 18th century steam-engine designers to the right brain's eternal question, "what is beautiful?" Let's explore this corpus callosum, searching for what might transcend from the ideas we learned from steam engines to Beethoven's Sixth or a dew-draped garden in the morning.

Having come this far, having completed our odyssey, plowed through the concepts of energy, entropy, exergy, and how these relate to life, living planets and designing better technologies, now is the time to keep the promise we made to ourselves—to climb that promontory so to relax in a little restaurant while we think back to our odyssey wondering what it all might mean. Let's lighten up. Let's cast-off the constraint of speaking only of things about which we can be pretty damn sure. Let's treat the caverns of our minds to some speculation—drift through a galaxy of intertwined ideas from aesthetics to baldness.

Our drifting can begin anywhere, so let's begin by wondering about our likes and dislikes. Since we know that to stay alive we must have sources of order and structure from which to graze, it is likely we're programmed to seek out highly structured foods and environments. Therefore it seems reasonable to ask:

- Is this why our enjoyment of dining is enhanced when the food is exquisitely arranged on a plate?
- Is this why we enjoy environments exuding orderliness and structure—like a formal garden, a forest, or an attractive office foyer—all manifestations of low-entropy order?
- Is this a fundamental reason we are repulsed by messes, like garbage dumps, sewage outfalls, or inner city decay?

Is this the reason we're troubled by children who, when bored, cantankerous and over-tired, take to stirring rather than eating the food on their plate? We admonish, "Don't mess up your food like that!" Whining, they rebut "But it all goes to the same place". We're frustrated, believe something is wrong, but don't quite know what. The "something wrong" may be that our reptilian brain is telling us the structured plate is somehow *better*.

- Does the child's messy food and the teenager's messy room mean that, as much as our reptilian brain seeks out order and structure, some aspects of creating or maintaining order must be learned?

The day after I wrote the preceding sentence, I chanced to read the following brief piece from *The Washington Post*: *The children of people who keep clean houses do better in later life than the children of people who let the dishes stack up in the sink, according to Rachel Dunifon, a researcher at the University of Michigan. Home cleanliness can predict a child's educational attainment and income more than 25 years later. Dr. Dunifon, of Michigan's School of Social Work and two collaborators at Northwestern University, examined a longitudinal study that has followed a representative sample of Americans since* 1968 …

Might this be research where social workers and thermodynamicists could collaborate? (But if I were the thermodynamicist I'd first need to understand what was meant by a "longitudinal study".)

Let's return to the relationships between low-entropy, structure and order. In "Entropy" [1] I wrote, "… structure and disorder are ways of *interpreting* low-entropy and entropy with everyday ideas. Alternatively, we can think of disorder and structure as *manifestations* of entropy and low-entropy. But equivalent they aren't".

That's an important warning—a warning that there are many nuances lying about. To help illuminate these nuances I can't do better than to quote from Schrödinger's wonderful book *What is Life* [2]:

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> *The difference in structure* (as manifested by low-entropy) *is of the same kind as that between an ordinary wallpaper in which the same pattern is repeated again and again in regular periodicity and a masterpiece of embroidery, say a Raphael tapestry, which shows no dull repetition, but an elaborate, coherent, meaningful design traced by the great master.*

To me, Schrödinger's comparison points to the difference between exquisite fine-structure and boring fine-structure. I'll appeal to mathematical ideas (but not equations) for help. It would be a simple matter to write a computer code for a plain white wall, marginally more demanding to write the code for repetitive wallpaper—but extremely demanding to write the code for Leonardo da Vinci's Mona Lisa. We can relate the complexity of these computer codes to the probabilities of various molecular distributions (within a container of gas) that we discussed in "Entropy" [2]. The white wall corresponds to molecules distributed uniformly throughout the container (high probability of occurrence and high entropy), while molecules distributed with a repeating density pattern (say, caused by a standing acoustic wave) would be slightly lower entropy (because there are fewer ways to distribute the molecules to realize the pattern). On the other hand, there would be *very few* ways to distribute the molecules so they were "seen" as Mona Lisa—which is why a Mona Lisa looking out at you from a container of gas would represent an extraordinarily low-probability, low-entropy, high-structure distribution of molecules.

When we speak of "structure" we mean structure with nuances. Walking a forest path, we see both its macro-structure *and* witness the fine-structure of stamens, caterpillar intestines, pollywogs and seeds. A formal garden exudes both fine-structure, like a forest, and also a macro-structure we enjoy at a different level. I hope this helps flesh out the idea that structure and disorder are ways of *interpreting* low-entropy and entropy with everyday ideas. Alternatively, we can think of disorder and structure as *manifestations* of entropy and low-entropy. Proxies they are. But equivalent they aren't.

These ideas *do* need a lot of marinating.

Returning to our likes and dislikes brings us face-to-face with aesthetics. The aesthetics of *settings* and the aesthetics of *processes*. Might, someday, the concepts of entropy help us better understand the fundamental reason we enjoy art?

Have you ever played with one of those dynamic toys made of five stainless-steel balls, each suspended by two strings from two cross bars (like parallel bars in a gymnasium)? Few of us can resist pulling one of the end balls up-and-away from its colleagues, and then releasing it to swing down hitting the others. We watch with joy as our dropping, accelerating ball strikes its neighbor to cause an *orderly*, sudden transfer of momentum from the original ball, through the next three balls, until the fifth ball swings up *almost* mirroring the trajectory of the ball we initially released. Once started, the process keeps *almost* repeating itself until, finally, the toy slows to a few spasmodic wiggles. Then we're saddened, would have liked it to be perfect, to have bounced back and forth forever.

- Is the root of our sadness because bouncing forever back and forth would be a zero entropy-production process? Yet we still like watching, even if disappointed when it doesn't go on forever.

- Is that because it's a low entropy-producing process?

Sometimes, on the first bounce it doesn't bounce at all. Rather all the strings get tangled and the motion twists itself to a quick stop. Then we're really pissed.

- Is our dismay because the tangling is rapidly destroyed orderly motion?

Continuing with entropy production processes:

- Is this why we find joy when an Indian rubber ball is thrown at the hard wall of, say, handball court, to ricochet off to the floor and to other walls, almost forever—but feel only disgust when an egg is thrown at that same wall where it goes splat?
- Could the ideas of entropy and structure be one way to separate good art from poor—one of the most subjective tasks of being human and therefore a task oft smothered in ponderous, artsy bafflegab?
- Could this be a way to separate the tastes of the perverted from the tastes of others?

Shortly after I moved to the West Coast of Canada, a Vancouver artist's unique form of "performance-art" was to tie live rats to concrete blocks. He then dropped another concrete block upon the tied rat so the rat, like the egg, went splat. I expect many folks, like me, felt repulsed. But I also expect we felt shackled, barred from passing judgment because who are we—who am I, a mere engineer—to judge the artistic value of anything, even a splattered rat? Might we now have a way to judge this nonsense? Rat splattering is a *strongly* entropy-producing process.

Goodness! Let's get away from splattered rats. Let's escape into music and poetry.

Is our desire for structure the reason we prefer music to noise? Is this why we enjoy Mahler's 2nd Symphony, "the Resurrection", or Beethoven's 6th Symphony, "the Pastorale", or the Beatles' "Lucy in the Sky with Diamonds", or Paul Simon's "Diamonds on the Soles of Her Shoes".

To me, the link between music and low-entropy is *the* wonderment of wonderments. We are born with its love, evolve our taste for its different forms through life until, lying abed, dementia wormholing our mind, a smile crinkles our face when we're hummed a childhood tune. Some part of music's magic must be rooted in music's nuanced structure.

Seems these questions lead to questions about language and poetry.

- Does negentropy lie at the root of our joy in poetry?
- Is this why Shakespeare gets through to us better than a legal description of the same idea?
- Is this why cadence is so important in writing and speech making, why it carries us along whether we understand the literal message or not?
- Is that part of the power and danger of cadence-speaking demagogues?

Of course we should acknowledge that sometimes it's not only low-entropy processes that we consider beautiful. Sometimes, high-entropy-producing processes are highlighted for their beauty—literally—like the spotlights that illuminate Niagara Falls at night. Still, the most mesmerizing part of Niagara is not the turbulent violence of the water's crashing entropy-producing turbulence below the falls, rather it's the ominous majesty of ordered, unruffled (high exergy) water sliding over the lip, turning down towards its exergy destroying doom. Stand, leaning over the railing, a few meters from that lip. You'll understand.

Let's wander back to the business of being alive. In "*Leitmotiv* of Living Planets" [1] we learned that, by shedding heat, animals have a wonderful mechanism for getting rid of entropy.

- Could this be another advantage of being warm-blooded?

We've also learned that the *amount* of heat shed is proportional to the *temperature difference* between the place giving off the heat and the place receiving the heat. This means that in very hot climates, because the human body is much closer to the environmental temperature, it's more difficult for people to employ heat rejection for entropy shedding. On the other hand, bitterly cold climates require an unusually large fraction of metabolic energy just to keep warm.

- Is this why the most vigorous societies seem to have arisen in what we (with body temperatures about 37°C) consider temperate climates—climates where most symphonies have been written, most inventions invented, most new political processes tried? [1]

Incidentally, the answer to this last question may reinforce Jared Diamond's suggestion—in his thoughtful book *Guns, Germs and Steel* [3]—that the East–West axis of Eurasia encouraged the more rapid spread of flora and fauna domestication, when compared with Africa and the Americas with their North–South axis. I observe that the East–West axis of Eurasia lies, throughout, within a relatively temperate zone above the tropic of Cancer. Yet equatorial regions slice the North–South axes of the two other major continental alignments.

We also know that every creature has two ways to shed entropy. The first, voiding entropic material suffers a key limitation: intermittency. Conversely, voiding entropic heat has the advantage that the *rate* of entropy shedding can be exquisitely matched to when it's produced. When you're fighting or running, it can be inconvenient—sometimes even dangerous—to call a "timeout!" to shed entropic material. But you can sure increase sweating, which speeds heat carrying entropy to the environment.

- Do these give warm-blooded creatures an advantage over cold-blooded creatures? [2]

The absence of hair can be a disadvantage to mammals not smart enough to make clothes, or set fires to keep warm. But if you *are* smart enough, being hairless has a great advantage when you want to shed entropy quickly during times of crises. (We sweat. Dogs don't. [3] More dogs die during Manhattan's dog days than do people.)

- Isn't it interesting that, among land-based mammals, people have so little hair?
- If we (the chattering class apes) are better off hairless, why are women more hairless than men?

Let's leave what keeps us healthy, wealthy and full of spunk, to think about what keeps our planet healthy, wealthy and full of delight.

It's obvious that life will want to migrate towards locations where there are conveyor belts to both deliver highly structured food and remove entropic waste. So we should ask:

[1] For those holding commissions in the politically-correct police, please note that this reflection is about the quality of thermal environment in which people live, not about the people.

[2] By providing the means to sustain regulated, high exergy consumption rates.

[3] Dogs pant, but sweating sheds entropy faster.

- Is it now even less surprising that life is so profuse within ocean upwellings, tropic and temperate rainforests, and tidal estuaries—those exuberant linkages between our atmospheric and oceanic conveyors?

If the temperature of Earth's epidermis increases, the entropy departing Earth will be reduced—because entropy transport is proportional to energy transport divided by temperature, that is $\mathbf{J}_s, \mathbf{J}_q/T$. That might give us another anxiety twinge about global warming. There are many unknowns in this "global warming" business—one reason I consider "climatic instability" a much better descriptor. And even if Earth's surface were warmer, it doesn't necessarily follow that the upper atmosphere (from which most of Earth's heat is rejected) would also be warmer. But it's likely. And so we should ask:

- Could global warming reduce Earth's ability to shed entropy?
- Might greenhouse gases constipate Earth's waste-product disposal?

Now I'd like to talk about something that seems very special about *people*.

Most residents of our biosphere take structure from their environment and put it *only* into themselves. The structure a tomato plant harvests from sunlight stays in the tomato plant—until it's eaten or oxidized. Some animals and birds put a portion of the structure they harvest back into the world around them, most often applying it to their nests. Beavers go further. A family of beavers puts structure into their home *and* their dam—thereby reconfiguring the landscape (for better or worse).[4]

What about people? Hunter-gatherer societies didn't (and still don't) go much further than beavers, when they built structure into tools, tents and weapons. But civilizations have poured immense negentropy into cathedrals, highways, railroads and canals—into the skyscrapers of Manhattan and Shanghai—into the Library of Congress—into the art treasures of the Louvre, the Tate, or the Metropolitan Museum of Art—into the temples of Ramses II at Abu Simbel—into manuscripts, compositions and encyclopedias—into equations—and more recently, into compact discs and hard drives. When you pause to think about it, it's absolutely amazing the amount of structure people have built *outside* their own bodies. In this way, we are absolutely unique among living species.

- Is this one reason to think better of ourselves?
- Is this one way to differentiate greater civilizations from lesser?
- When lying abed during the last few days of life, would it bring some peace to reflect on the amount of order and structure we've created and left behind—one way to measure if it was all worthwhile?

Pause! …

The mind wanders to Lenny Bernstein, Wolfie Mozart, Willie Shakespeare, to the great architects, to the builders of canals and railroads … and then … to the great destroyers.

Towards the end of my thermodynamics course for sophomore engineering students, I sometimes slide in a few ideas about how thermodynamics can be used not only to design steam turbines, but also to get more joy watching our living planet—perhaps even to suggest the dangers of highly entropic, anarchic societies. When walking back to my office after one of these tag-on lectures a student briskly overtook me from astern.

Somewhat breathless, he said, "You know I've always wondered about the purpose of life—now I think I know". Whoa! I thought. What am I in for? Although many of us might have asked these questions in our youth, most of us have given up that search, turning to more tangible things like families, fortune and fun. Then he repeated my slight modification to Grobstein's definition of life that we'd just discussed[5]—except changing one more word so "a" became "the"—and the revised statement became: *Life—…—constitutes the spreading center of order in an otherwise increasingly less ordered universe*.

For us more aged, jaded folks, this might be a bit much to import this as a purpose for *our* lives. But for this student, it was enough. He saw himself as one part of Earth's web of life—whose purpose was to be the spreading center of order in an otherwise increasingly disordered universe. So he hoped to pick a career that would, as directly as possible, allow him to assist the spreading—like in aerospace, fuelcell technologies, or hydrogen systems. Students can be idealistic. That's but one reason we need them.

I shuddered. For in some way, of course, he was right. During the latter half of the 21st century, these will be the technologies that speed Earthlet spores on their way to colonize the Universe—a colonization that will accelerate thereafter. But first, these same technologies must be employed to help put Earth's house-in-order during the first half of that same century.

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[4] Canada's animal symbol is a beaver, chosen because a beaver works hard—and chosen before North Americans gave much thought to what humans could do to the environment. It's interesting to look at the symbols chosen by different nations. Russia's symbol is a bear. Many nations have chosen and eagle, an aggressive raptor that sits atop both trees *and* the parasitic food chain from which they harvest structure from the flesh of their prey.

[5] That we reviewed in "*Leitmotiv* of Living Planets".

During the spring of 1996 my wife and I sailed our 11-m sailboat *Starkindred* from our home in Victoria on Canada's west coast to the Tahitian isles of the South Pacific. It's a great-circle passage of some 4000 nautical miles—a little further than the great-circle route from Victoria to London. [6]

Those night watches aboard *Starkindred*, during which I dreamily pondered entropy, life and our planet, were magical. The black ocean shushed past, a wake of phosphorescence marked our southerly course as night after night we imperceptibly sunk the North Star. Wonderful. Here we were, slip sliding along this profoundly important interface between Earth's two great conveyors of entropy and energy as they undulate in unison, seemingly making love.

From *Starkindred*'s log: 1996 May 28, 2350 h. N14°42′ W130°09′. Wind NE 18 knots, gusting 22. Broken clouds & waxing quarter moon to starboard, stars to port. Reefed mainsail and yankee. Full staysail. Boat speed 6.5 knots, surfing to 7.5. Waves 12–15 f, long wavelength. Beethoven's 6th from the Sony Walkman.

Here we are, more than a thousand nautical miles from the nearest land, sliding over a moonlit, silver-highlighted, black, rolling ocean. Skittering wavelets atop majestic seas that, having run a thousand miles, effortlessly lift *Starkindred* to pass unperturbed on their journey across oceanic immensity. Spectacular night sailing. The second movement of the 6th envelops my head, seems to fill the universe as I look to the masthead trilight and beyond to the stars. Although the symphony has been named the "Pastorale", interwoven cadences within the music's themes seem an impressionist rendering of the braided waves and wavelets—all in wondrous empathy with ocean passages in small sailboats.

And then! And then across the ocean, comes the largest pod of Pacific white-sided dolphins I could have imagined. They've come to play. More than fifty animals. Cutting across the bow. Coursing under the stern. Jumping. The phosphorescent wakes of dolphins and *Starkindred* intertwine. We're surrounded by living, silver torpedoes, filled with the joy of life, intimately connecting the ocean and sky with understanding I cannot hope to imagine. They stayed with us for more than an hour—through midnight—and so joined yesterday with tomorrow.

I'm struck, again, with the reality that every corner of our planet is *alive*. Listening to its own kind of music. Partaking of its own kind of joy. *Waiting*. Waiting to spread throughout the universe—waiting to beget order throughout an otherwise increasingly disordered universe.

This is the twenty-fifth in a series of articles by

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[1] Scott DS. Entropy. Int J Hydrogen Energy, 2002.
[2] Schrödinger E. What is life. Cambridge: Cambridge University Press, first published 1944, Canto edition, 2000.
[3] Diamond J. Guns, germs and steel. WW. Norton, 1999.

[6] A great-circle route is the shortest distance over the Earth's surface between to points on the surface. If the distances are significant, it can be much shorter than a rhumb-line course between the same two points, which crosses all meridians at the same angle.