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The Energetic Principle of Nature

Arto Annila
University of Helsinki

Background

When I was a young student, the profound question *what is life* inspired me to study biochemistry. So I learned how a bacterial virus can be assembled from synthetic constituents to an infective agent. Yet, how and when did the inanimate ingredients actually transformed into the living being remained unclear to me. One thing though became very clear to me, namely, I better complete also my engineering studies with physics major to be able to make my own living.

To know what life is, is of course also instrumental in our search for extra-terrestrial life. And as you know too well, we haven't found any clear-cut characteristic that would allow us to spot the signature of life in files of data. Since the profound problem *what is life* persists, despite much attention, could it be that we are asking a wrong question? Could it be that there is no life at all?

Now having said that, you surely wonder, whether I am all insane because it seems I even question whether I am alive myself. Please, postpone your grim diagnosis at least for a moment like a wise doctor would do when not yet acquainted with all symptoms. So, let me explain to you, why I doubt that there is no life at all.

Already at school teachers insisted, the same as professors later at the university on presenting any graph so that its axes are labeled and units are denoted. Otherwise, one could not possibly know what the graph represents. And here you see how right the teachers were.

Without labels there is no way of knowing that this sigmoid displays a growth of a colony of cells over a day and this sigmoid shows increasing oil production during the past 100 years. And this sigmoid shows the effect of drug dose on two sample populations, and this sigmoid shows inflation during the past 50 years. And surely, you recall that also evolution in its entirety proceeds in a sigmoid manner from one stasis to another.

Likewise, without labels there is no way of knowing that this skew distribution displays lengths of genes in two organisms and this distribution lengths of words in two languages. And this shows distribution of salaries and this photon flux vs. wavelength at different temperatures. And surely, you recall that also plant and animal populations are skewed with long, fat tails.

Moreover, without labels there is no way of knowing that this line follows the size of earthquake vs. frequency from numerous events and these lines follow the size of brain activation vs. frequency recorded from few individuals. And this line follows the distribution of galaxies across the sky and this line follows the distribution of cosmic ray flux across the energy scale. And surely, you recall that also the species-area relationship follows mostly a power law.

My point, by showing all this ambiguity to you, is that it is *us* who label the systems being either living or non-living. There is no such divide in the data itself. What is even more dramatic with these graphs is that they all display the one and the same thing. Namely, the functional form of a sigmoid or a skew distribution or a power-law line is the same, only its parameters, like the slope, vary from one system to another. Since the slope can be changed simply by stretching or shortening the unlabeled axes, all slopes display the one and the same thing. Moreover, it appears as if there are three types of graphs, but there is really only one graph because the skew distribution sums up along the sigmoid curve, and the sigmoid, in turn, when plotted on a log-log scale, follows mostly a straight line. So, all these graphs, when scale-free, display nothing but the one and the same pattern. It means that all natural systems behave the same way.

This universality implies to us that there is a universal principle without any divide between living and non-living or between microscopic and cosmic. It is this profound principle of nature that I want you to know.

The law of nature

Well, there is really nothing to it, since you already know this principle by heart. For example, you are not surprised to see an object falling straight down, but you would be if it instead went winding down. You are not surprised to see a brook running down along a hill's steepest slope, but you would be if it instead wandered uphill once in a while. You are not surprised to see aphids, snails or other pests to spread in a garden from one plant to another, but you would be looking for some reason if anyone shoot had miraculously escaped from the troubles.

So, things don't just happen, but they happen as soon as possible. If a process does not take the fastest way, the most effective means, surely another one will, and thereby consumes available resources. If a species is not able to take an advantage of a food supply, another one will soon come around and do so. If an individual does not take a change to succeed, another one will soon exploit the opportunity. If a company does not pursue with product development, a competitor will soon do so, and flourish on the market. Nature works just as Charles Darwin said *It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change.*

All systems are at the mercy of their surroundings, and hence they evolve to attain balance in their surroundings as soon as possible. Finally, when the balance has been attained, the system faces no forces that would impose further changes. This principle of least-time is common sense, and its theoretical form ought to be also common scientific knowledge.

Surely every one of you has held a textbook of physics in your hands. So you know there are many equations in those books. Surprisingly many, I'd say, when considering that all observations imply there is only one universal principle. So, which one among the many is the equation that states the universal principle? We will have a hard time in distinguishing the correct formula among the many inaccurate unless we first get acquainted with the reasoning that points toward the one universal principle.

Atomistic tenet

You probably recall that Isaac Newton expressed his gratitude to the previous thinkers by saying *If I have seen further it is by standing on ye sholders of Giants*. Undoubtedly among the giants were also the ancient Greeks. Newton developed differential calculus, but he ought to be acknowledged also for advocating the ancient atomism. Paradoxically, the very idea of a step, that can be divided forever, known as the differential, contradicts with the old idea that everything is composed of undividable basic building blocks.

So, how could Newton possibly reconcile in his head these two mutually exclusive ideas? Well, in a very simple way. Newton wrote Δ instead of d. Delta means a stepwise change whereas d stands for a continuous change. The fictitious but convenient continuity was first introduced by Leonhard Euler few decades after Newton.

Atomos is a Greek word. It means *cannot be cut*. This idea that everything is assembled of basic building blocks, that is, quanta, as we say today, was put forward by Democritus and his mentor Leucippus and little later perfected by Parmenides, who argued that also vacuum, the free space is not an empty void but also composed of quanta.

Indeed, the formula $E = mc^2$, made famous by Einstein, says that everything can be converted to quanta of light. So, we must conclude that everything is ultimately composed of photons. Being so, it is no wonder but only natural that everything follows the one and the same principle that gives rise to the ubiquitous scale-free pattern. Nevertheless, teachers and professors keep insisting on having labels and legends, and thereby disguising the one and same thing to look as if there were many different things in this Universe.

You surely recall that light takes always the path of least time. This old imperative by Pierre Fermat naturally applies to any other flow of energy, when everything is understood to be ultimately composed of photons. This generality was apprehended already by Pierre-Louis Moreau de Maupertuis. Maupertuis was once the president of the prestigious Prussian Academy of Sciences. He is rightfully credited for this discovery of the principle of least action. Nevertheless, his original formulation was shelved already before his death in 1759, because the equation did not meet the expectations of a computable law. In other words, the equation of nature could not be solved, as was expected, and hence a deterministic form of the principle, devised little later by Joseph-Louis Lagrange, became the textbook standard.

Lagrange followed Maupertuis as the leader of the Prussian Academy. He was mathematician. So solving equations must have been second nature to him. Maybe he did not even consider the possibility that an unsolvable equation could be the accurate account of nature. Since the correct equation was discarded, many approximate models of natural processes have been devised. Today these mathematical models inflate the textbooks.

If you have ever glanced through Newton's Principia, you must have been surprised to see how few equations there are. Nevertheless, Newton claims to cover everything. The opening words of Principia read as *Rational Mechanics will be the science of motions resulting from* any *forces* whatsoever *and of the forces required to produce* any *motions.* Newton did not consider only gravity, but everything. Undoubtedly Newton is highly praised, but apparently not highly enough.

Newton's second law of motion was subject to the same erroneous tampering as Maupertuis' principle to make it a deterministic law. Therefore, today we learn that $\mathbf{F} = m\mathbf{a}$ whereas Newton himself wrote that the force equals a change in momentum $d\mathbf{p}/dt$ which entails two terms $m\mathbf{a} + \mathbf{v}dm/dt$. The change in mass is most apparent in a nuclear reaction but also familiar to us from a chemical reaction where it corresponds, via $E = mc^2$, to dissipated heat.

When a covalent bond breaks, for instance, when a sugar molecule dissolves on our tongue, the change in mass is miniscule. It is only about 0.1 per mil (1/10 000) of the mass of an electron. However, if that change in mass is omitted, then corresponding dissipation is overlooked, and no reaction is understood properly. In fact, no change of state is understood, yet biology is all about changes, about evolution, development and maturation as well as decay from one state to another.

For this reason, physics, as it is taught to us, fails to describe even a simple chemical reaction, and hence it is no wonder that many a life scientist regards physics as an inept discipline to give an accurate account of life. And no wonder physicists themselves trouble with notions like emergence when not taking into account the photons from surroundings that couple to any synthesis. So, those of you who felt already at school that textbook equations of physics are incomprehensible, I can assure you, they are not merely incomprehensible but more importantly they depart from reality.

However, there is really nothing wrong with physics. The discipline only appears to us as flawed because the one-time deterministic expectations have not been eradicated but enforced in contemporary thinking. This state of affairs does not only compromise our understanding of how living systems work, but it deprives us from comprehending how any system works. No wonder that modern physics is also troubled with conceptual conundrums such as that of a cat being dead and alive at the same time.

Such an indeterminism, that is, randomness without reason, is no substitute for non-determinism that stems from interdependence. It is a characteristic of all natural processes. By the same token it is no wonder that the modern physics with its flawed models of changes has to resort to imaginary ideas such as dark energy and dark matter to account for observations from the evolving maturing Universe.

Equation of nature

The one-time bias for clock-work determinism and today's penchant for indeterminism, make it unlikely that we will find Maupertuis' non-deterministic least-time principle in today's textbooks. So it may happen that we have to derive the supreme law of nature by ourselves. Newton encourages us by saying that *You have to make the rules, not follow them.*

Also Gottfried Leibniz guides us by saying that *among all conceivable worlds the most probable is the actual*. Leibniz is basically saying that among all alternatives the most likely path will be naturally taken because that path is energetically the most rewarding. So runs a brook down along a hill's slope. It will vary its path and naturally select the one where water will run downwards in the least time.

Surely you recognized in my wordings Darwin's notions of variation and natural selection. Newton made no difference between of how a brook runs and of how a species evolves, neither did Leibniz nor Maupertuis. Why should we?

When speaking about evolution in terms of the profound principle there is no reason to highlight mutations in genes, because these particular molecular mechanisms, like any other mechanisms, are merely in service of natural processes, not in any command. Genes facilitate the probable processes, but they do not drive the processes. Therefore, also any other flow of energy than the flow of water will natural select the most probable, that is, energetically the most rewarding paths. This quest of least-time free energy consumption not only underlies cellular metabolism or nutrient circulation in ecosystems or turnover of money in economic systems but it also characterizes our behavior.

Now having said that, you must be about to conclude, that I present, if not incurable insanity, at least some severe form of cynicism. No, no, do not jump into conclusions. I am not denying the deep sensation that there is meaning in life, that we experience when falling in love, helping others, catching fish, drinking beer, or whatever you now might find as the most meaningful act. All I am saying is that also all pleasures just as all discontents just as everything else can be expressed by the most general concepts provided by physics, notably, in terms of consuming free energy in least time.

Leibniz' claim that probability invariably increases during all natural processes surely reminds you from the principle of increasing entropy. Indeed Ludwig Boltzmann understood entropy as a logarithmic measure of probability $S = k_B \ln P$, but he failed to include in his measure all terms of energy. Boltzmann insisted erroneously, in the spirit of determinism, that energy is conserved. Therefore he was lead to an equation for a steady-state free energy minimum where entropy is already at a maximum. As a result Boltzmann missed the full equation for an open system that is still on its way toward the free energy minimum. So did Boltzmann miss evolution, development, differentiation, maturation, proliferation, etc., all those processes that we find so meaningful.

In other words, Boltzmann obtained the equation for water in a calm pond, not for water in a brook running down. Perhaps it was too trivial for a sophisticated man to think that it is the running water that fills the pond, or that livestock grows up to its full size by consuming food and dissipating heat, or that gas expands by absorbing heat until in balance with forces imposed by a container, or that production of goods goes up by consuming returns until no more revenues can be earned. All systems change from one state to another by consuming free energy in the form of food, fuel and light until the steady state where all forces are in balance has been attained.

It may appear to you unbelievable that Boltzmann missed this apparent driving force of evolution, that is, the energy difference between the system and its surroundings. But I tell you when working with powerful theoretical concepts, like energy, in a closed closet one becomes easily detached from reality. For instance, the textbook statement that *In a closed system entropy can only increase,* is obvious nonsense. Nothing will happen in a thermos can. A good thermos will keep coffee hot. It is the very idea of the closed system that nothing will happen. Thus, a concept to have a true meaning, a genuine relation to reality, I must be able to touch it, or even better able to eat it. Indeed the proof of the pudding is in the eating.

Let me stress my point about correspondence between concepts and reality. Often one hears that high fat foods contain lots of energy which tends to turn one broad in the beam. However, this statement is not precisely correct. It is not energy in fat alone that matters but the energy *difference* between fat and surrounding atmospheric oxygen. Without the energy difference nothing will happen. Obesity is no problem on the Moon. When theorizing we tend to take the surroundings either for granted or as invariant. Either way, we will then miss, just like Boltzmann did, the driving force, that is, the energy difference between the system and its surroundings that powers all processes.

Entropy became confused with disorder because at the steady state the only dynamics that Boltzmann could think of was increasing disorder. But entropy does not equate with disorder. And I tell you, there is no irrefutably quest for disorder either. A system will become disordered when its surroundings is disordered. Conversely, the system will organize in an orderly manner when its surroundings displays order. Order or disorder is merely a consequence of consuming free energy in least time. Ingredients organize in orderly structures that we refer to as living beings in order to consume free energy available in their energy-rich surroundings. So organizes also water to ice to release heat to the cold surroundings. The ability to maintain order is no unambiguous signature of life. And to claim that entropy would be decreasing in a living system at the expense of increasing entropy in the surroundings is plain wrong.

Let us recall Leibniz' assertion, that life on this planet, or anywhere else, is not an improbable phenomenon. On the contrary emergence of life and its evolution are likely processes when entropy as a measure includes the free energy in high-energy insolation as well as in those ingredients, such as water and carbon, nitrogen, phosphor compounds that couple to the supply of energy. Conversely, when the system is cut off from its energy source or deprived from its vital ingredients of energy transduction, entropy will increase when the system decays and eventually dies to attain balance. In other words, entropy will always increase irrespective which way the energy difference between the system and its surroundings happens to be. It would violate conservation of quanta, that is, the number of basic building blocks in the whole Universe, if entropy of a system would decrease at expense of increasing entropy in its surroundings. It is the very same quanta, the photons that carry energy from the surroundings to the system and vice versa depending on which way the energy difference happens to be, for example, depending on day or night as well as whether it is summer or winter.

Thus the imperative of increasing entropy says that a change of state is driven by the consumption of free energy. The free energy can be partitioned to materials forms of energy, that is food or any other fuel, and to radiative forms of energy, that is light or any other form of freely propagating photons. This is the equation for the principle of least time as it was first written by Maupertuis. He already understood that it is the same equation as Newton's original second law of motion when multiplied with velocity and rearranged for changes in energy.

All processes obey this simple equation, but the simple equation cannot be solved. It cannot be solved because the motion affects its driving forces which in turn affect the motion. In other words, variables cannot be separated to solve the differential equation. For example, the number of cows on a field depends on the amount of grass which in turn depends on the number of cows eating it.

The rate of change in a population is proportional to free energy. The proportionality coefficient relates to the mechanisms of free energy consumption, such as teeth, stomach, etc., at the level of a cow, or to flora and fauna at the level of an ecosystem, or to factories, infrastructure, services etc., at the level of an economic system.

During an ecological succession pioneering species will pave the way for successors whose arrival, in turn, will affect both the pioneers as well as further immigrants. Likewise, technological innovations depend on previous innovations which, in turn, might become obsolete during the ensuing progress. Evolution of the entire biota affects conditions on the whole planet which in turn affects biota. Also, the rise of global economy affects local economies which in turn affect the global market. The expanding econosphere exert effects on biosphere, atmosphere and geosphere which in turn impose impact on the econosphere. When everything depends on everything else, no precise predictions are possible. On the contrary to common misconception, complexity or lack of knowledge is not the underlying reason of intractability. Non-determinism is in the nature of nature.

Scale-free patterns

Now that we have the basic equation of nature in hand we can analyze it to prove that it accounts for the scale-independent pattern. For example, it is easy to show that Newton's second law is a power-law by dividing the equation with momentum. Due to the quantized character of nature the straight line does not extend to infinity but curves toward a stasis when energy difference relative to the surroundings vanishes and punctuates almost exponentially when free energy source becomes first available.

Surely you recognize in my wordings the notion of punctuated equilibrium put forward by Stephen J. Gould and Niles Eldridge. Their description of evolution, like Darwin's tenet, is in many ways an accurate account on nature, yet now that we have the corresponding equation in hand we can describe evolution unambiguously and analyze it.

When the theory complies with reality, comprehension is intuitive and in concord with common sense. In Newton's words *Truth is ever to be found in the simplicity, and not in the multiplicity and confusion of things.*

Implications

What does this all-inclusive energetic principle of nature mean? It includes all those ordinary things that make sense to us, and it excludes all those extraordinary ideas that do not make sense. The value of having the common sense in the form of the natural law is that a layman's reasonable thought can be proven. Hence facts are no longer mistaken for opinions. For example, the natural tenet encourages us to pursue in transforming our economic systems to function in the same way as ecosystems where insolation powers circulations of ingredients, that is, to promote recycling.

From this perspective it is meaningless to ask, *What is life?*, but eye-opening to ask, for instance, what is an ecosystem and what is an economic system. The ecosystem is just like any other energy transduction system, say an economy. It develops, matures to attain balance in its surroundings in least time. Nowadays, surroundings of many an ecosystem is changing, and hence also the ecosystem is forced to change. As a result many animals and plants are learning to cope with urbanization and domestication as well as accompanied environmental degradation.

I noticed, for example, that a crow on our yard had become courageous enough, despite of us having a dog, to come inside from an open door apparently to search for the garbage bag that usually lies besides the front door waiting to be carried out. The crow was after free energy in her modern surroundings. Obviously not all species are equipped with means to cope with contemporary changes in surroundings, and will face extinction when flows of energy redirect via alternative mechanisms, such as via garbage collection. So, I am saying that species are merely mechanisms of energy transduction, just as are various molecular species in cells, and just as are cars, dishwasher, refrigerators, etc., in economic systems.

Also behavior, including our own despite being a versatile and complicated, can nevertheless be regarded merely as a mechanism to consume free energy in least time. Let me exemplify that the rate of a behavioral process is also proportional to the amount of free energy.

In the other day I noticed that my son should clean up his room. So I said that to him, but all I witnessed was some sluggish stretching that appeared to me anything but a least-time process. Well, couple of days later, he asked my wife for 20 euros to have his hair cut. And my wife replied to him *You have cleaned your room, haven't you?* It did not take him more than 20 minutes and the room was in a perfect shape, and my son was on his way to the barber shop. Now you might think that had I offered 20 euros right away, the job would have been done in no time. I have tried that. It does not work. My son is, to my regret, not interested in earning money, but spending it. And it is not about money but about getting hair fixed, and it is not about good-looks as such, it must be about going out on a date. I haven't seen the girl, but I judge from my son's least-time behavior, that the driving forces the assets associated with her are impressive.

When a young goes out on a date he might be looking eye to eye on returns that will be accumulating along a life time. Compared to that fortune my 20 euros are peanuts, and hence are hardly worth even getting up.

The holistic tenet says in some sense that there is no life on this planet, but equally well that this planet as a whole is living. All those processes we refer to as living by convenience are intimately coupled to those that we refer to as non-living. Of course for long we have known that geothermal processes, such as volcanic eruptions are vital for life in the long run by circulating necessary ingredients. Likewise, our economy depends tightly on numerous ecological processes, and today some life forms, like the crow on our yard, depend on economic processes. Everything depends on everything else just as we have thought all along, but now we know that this interdependency is the reason why we cannot make precise predictions.

What I find illuminating is that according to the natural law no particular process and no special phenomenon is either particular or special in any way. For instance, when we find a puzzle in an ecosystem, we should be able to find a corresponding phenomenon in another system, say in an organism or in an economic system where we easily understand the particular process. For example, we might wonder what habitant fragmentation might do for a species. It will mean the same trouble as dispersed patches of land are for a farmer. Business does not flourish when resources are consumed in mere earning.

We might also wonder how large natural reserves ought to be to maintain diversity. Obviously it is not the areal size as such but the available free energy that matters for the species in question. Correspondingly it is not of primary importance for a company of how many people there are in a market but how much purchasing power they have.

Diversity is no end in itself. Ecosystems will display great diversity when the multitude of species serves the least-time free energy consumption. However, many native ecosystems are relatively sparse in diversity. Think, for example, of a heath of pines. It is almost a monoculture, yet probably the most effective means to consume free energy in insolation at these latitudes.

We might also ponder upon why two seemingly similar species thrive in the same ecological niche despite the competitive exclusion principle. To make this puzzle a trivial one, I would only need to make a poll about those cellular phones you carry, to find out that two, three perhaps four major brands are populating the same niche, your pockets. And you surely know why. Minor differences meet minor preferences. Some of those preferences reflected in survival may not even be directly related to the species or gadgets themselves. Perhaps you prefer one kind of phone because it was recommended to you by someone. When everything depends on everything else, our overall sight becomes blurred when we focus only on one thing.

Now that we are struggling with global warming we should, in the first place, realize that the global system has evolved to maintain homeostasis, i.e., to maximize free energy consumption. Therefore, the stupidest thing to do is to demolish energy transduction machinery at the same time when perturbing the system with excessive carbon dioxide. We should not clear tropical forest which generates powerful cooling convection to the upper atmosphere. Instead we should allow tropics to expand as it would naturally do to counterbalance rising temperatures. So, what we are presently doing by clearing forest for oil plants is as crazy as it would be to hammer air conditioner to pieces when it is already too hot inside.

Conclusions

Do to my profession I represent expertize and specialty, yet I say that expertise and specialty are highly overvalued over common sense. Means of mankind have become by now so powerful that none of us should refrain from responsibility as if leaving it for experts by saying that one does not comprehend how nature works. Surely scholars foster myths of a mysterious nature, but how did we ever get the idea that the basic law of nature, namely that *energy differences of any kind will diminish in least time*, would be too difficult to grasp when a single photon knows its way just as a tiny ant knows its trail. Many mechanisms of consuming free energy are admittedly complicated, but the operational principle of a complex system is no different from a simple system.

Nowadays we are fed with data, but left unnourished when not comprehending it. So, we mistake a model that gives a good fit to data for an explanation because we are not even asking what gives rise to the data. Today when theorizing we no longer see the forest for the trees, but in the ancient Greek *theoria*, was just an everyday word that meant viewing or beholding. It is a high time to raise our eyes from the textbooks and it is a high time for us to abandon assortments of abstract notions, it is a high time for us to recognize and to reconcile reality in one law. In this holistic sense Alexander von Bunge, Tartu Ülikooli botaanikaprofessor said *To comprehend details of nature, one ought to understand nature in its entirety*.

Figures: http://prezi.com/fijlim5fxptj/principle/