Review of: "On the statistical arrow of time"

Peter Verheyen

Potential competing interests: No potential competing interests to declare.

The article is well substantiated, structured and argumentated.

I agree with the author, although, in stead of '… unless the choise is made to take the philosophical standpoint that it is the act of measurement by an ignorant observer which creates the apparent directionality in time', the proper characteristics of life itself may be involved in the 'subjective flow of time'.

1.Entropy, information and life.

Entropy is the cause for a bustling universe where life such as ours can arise. A basic property and characteristic of living matter, is to keep its entropy low, allowing information and matter, atoms, to get their biochemistry done. Like a bowl of soup never cooling down or an ice cube never melting outside of the fridge. James Lovelock 'Life is creating order out of chaos. Decreasing entropy is an overall property of life. Living things use energy out of their environment and through their metabolism, they succeed in surviving as islands of low entropy'. Although superefficient, thermodynamics tell us that an efficiency of 100% is not possible, even not for complex life. Studying dissipation in cellular processes is a brilliant idea, though extremely difficult to accomplish. Microtubules are nanotube proteins. They are found in fast amounts in every living cell. They form the skeleton of the cell, can move around, transport material within the cell and can even cooperate to get a tough job done while consuming energy. They can be considered as biological mini steam engines, obeying the laws of thermodynamics. Studying their dissipation can teach us a lot about life and the cellular machinery. Likewise, also latest research, that on the nanoscale of life, time can run backwards, 'Reversing the arrow of time'. On the micro scales of the cellular machinery, energy can flow from low energy regions to higher energy regions, violating the second law of thermodynamics. On a macroscale and on average, the second law takes over.

The entropy of a system represents its microscopic complexity. Entropy represents the probability of a certain condition, and the universe urges up to ever more probable outcomes. But the number of ways to create life as we know it, is extremely small: everything must fit perfectly together, demonstrating a state of low entropy.

An average human body consists out of approximately 37.000 billion cells. Every day, about 3 billion cells are renewed, meaning, every second 35.000 new cells are created in your body, and yet, this is only $1/12{,}000^{th}$ of your total amount. While every second, in all those other cells , billions of other biochemical actions and interactions occur. Microscopically, we are a tremendous volcano of activity, yet, macroscopically, we appear as a consistent whole. And life succeeds in keeping this all extremely energy efficient. Moreover, the brain has only $1/50^{th}$ of the mass of a body yet consuming 20% of its energy, while this represents only the energy use of a 20-Watt light bulb, meaning the brain executes about 6 million times more energy efficient compared to a regular computer. An axon only fires when it reaches a certain critical potential.

Every single dendrite of a neuron can execute complex computation and information processing, that takes a neural network made up of at least 2 layers of many artificial spiking neurons to replicate. And a single neuron' s computation capability and information processing need at least 5 to 8 of those layers, latest Israelian research shows.

Before the human genome was mapped, one was expecting several hundred thousand of genes. The outcome back then was only 40,000, recently even reduced to 20,000. With this small amount, the complexity of the brain activity could not be explained. Latest theory, Infotropy, information & entropy deals with this. Like plants search for sunlight and bacteria search for sugar, the brain searches for information. The brain uses its environment to shape itself, it can only develop through a constant information supply. The neural circuits need interaction with the outside world enabling them to develop in the right way. 'Livewired, the ever changing and adapting neural circuits in the brain', David Eagleman. Out of this, a child only develops self-awareness from an average age of 3 years, when they start to say 'That' s mine'.

Infotropy: the universe urges for the most probable outcomes, meaning an ever increase in entropy. As in computer terms, serials of roughly equal amounts of zeros and ones, are the most probable, having therefore a higher entropy and contain the most information. Information and entropy seem like 2 sides of the same coin.

Andreas Wagner 'Organisms live and die by the amount of information the acquire about their environment'.

Paul Davies 'The thing that separates life from non-life is information and the possibility to store and process information in an organized manner. Life is matter + information. The DNA in every human cell contains 2 terabytes of information, and this is only an vey small portion of the total information content of a cell. This shows how deeply life is invested in information'. 1 mm^3 of the brain can contain 2 petabytes of information, the whole brain approximately 200 exabyte. Neurons can fire at a frenetic rate of 15 pulses per second. The brain is able to execute about 10 to the 15^{th} logical operations per second.

Our computers use only 2 signs, 0 and 1, to describe the whole universe. DNA and RNA use 4 signs, nucleobases, for their information processing and storage, AGCT and AGCU. And the proteins they construct, use 20 signs or amino acids for their information processing and storage and their 3D structure, which is essential for their biological activity. After denaturation of ribonuclease, the information in its amino acid sequencing enabled it to fully reconstruct its 3 D structure and regain its biological activity, Nobel Prize physiology 1961.

Some scientists start to look at information as the 5^{th} state of matter. Ralf Landauer calculated the energy content of an information bit as to 3 x 10-21 J. Lucas Céleri found a huge difference in the energy content of a qubit, with an average of 2,8 x 10-21 J. A rough calculation gives a mass of about 3,1 x 10-34 kg.

2.Entropy, life and time.

Entropy, life, and time are somehow closely connected.

Carlo Rovelli 'We have a classical world and a fundamental world, and on a fundamental level, time doesn't exist'. To him, time appears when a quantum state collapses into a classical reality.

Paul Davies ‘Wave function collapse is projection into a single concrete reality’.

To Carlo Rovelli, the fact that the collapse and outcome is not repeatable, these facts/happenings create time.

The very first life needed a notion or awareness of the environment to survive, with the creation of a primitive reality and of time.

From cyanobacteria, showing up 2.4 billion years ago, we know that they had back than already a biological clock. Before sunset, their biochemical machinery/metabolism, entropy driven, starts to produce the molecules, necessary to make their photosynthesis as efficient as possible once the sun arises.

Eucaryote, multicellular life and growing complexity, needed an ever-improved agenda.

Growing complexity urged for an ever-better organization. Organization is planning. Planning involves time , getting the actions done in the right sequence. The necessary biological clock, ever evolutionary improving.

Oak trees restart their metabolism when temperature increases. Beech trees, when days grow longer.

The human biological clock is extremely complex: complex brain activity guiding the regulating hormones.

From childhood to puberty to adultness to growing old and dying. Our brain knows exactly when it is time to carry out that precise, specific action. Even every single cell in in our body. But cells have an expiration date. Nerf cells and muscle cells don’t divide , so at a certain point the waste regulation starts to fail, as well as the cellular machinery. Entropy cannot be kept low, resulting in more equal energy and matter distribution, and failing interactions. Cells with mitosis, their division is limited as to approximately 50, due to the telomere extends at their DNA/chromosome ends, shrinking with every division. At a certain length, the DNA gives the cell the signal that it is time to pile up.

Expiration date is a perfect invention of evolution: constantly renewing with beneficial errors creates the highest chances on survival and improvement, survival of the fittest.

As to our consciousness and time. I don’ t know how it feels to be a bat neither a dog. I know that my dogs greet me in the same spectacular manner when I left for only 5 minutes or return after 5 days. So, I don’ t know how they experience time. Joseph Ledoux gives a great insight: human complex brains create an auto-noetic consciousness with increased and sophisticated time perception, dogs have a noetic consciousness. They need their rabies vaccine boost, jump that happy in your car and while reaching the doctor’ s place, they start to tremble and getting very nervous. Our auto-noetic consciousness, surely if we are afraid for a doctor’ s visit, makes us crazy already several days before the appointment.

Huwe Prince ‘If physics tells us that time doesn’t exists on a fundamental level, perhaps we can only understand time if we connect physics with cognitive science’.

A happening, what-where-when. The brain makes a logical story out of it and creates an illusion of time. When you are having fun, time flies. Time flies, when you are having fun.

A lot of what-where-when, means a lot of information and our brain is occupied, it needs and consumes information. A lack of it, and our brain gets bored. Must wait for something the brain excites, makes it crazy, desires.

Time is not a basic property of the universe, but entered the classical world together with entropy and life. Our time is arbitrary, based on a 1/86,400ste of an Earth rotation, which also can be regarded as facts/happenings in a regulated sequence. When there were aliens out there, we were not able to date them as they could nut understand our notion of time. Something as a second, doesn't exist in the universe, it is an 'Earth life invention', the universe doesn't need it.

The more precise we try to make 'our' clocks, the more energy they consume, the higher their entropy, the arrow of time, running only in 1 direction for living organisms. In space, we can move (more or less) freely in 3 dimensions. Entropy and 'our' time lock us up in an eternal present, allowing us only to move from past to future.