Opinion

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On microgravity and its effects at the molecular level

Abstract

There are biological processes that could be directly related to physics and the shortening of telomeres is one of them. This fact is something well known and acts like a clock in the life of each living being, but the reason why they are extended in some cases is something not so understood, it is only known that it is directly connected with the activation of telomerase, but it does not know, in some cases, the exact reasons that produces it. I propose that the asymmetry of time is important to know the cellular world, and could even be related to the cause of telomerase activation and the consequent lengthening of telomeres, and microgravity could be part of the explanation.

Keywords: asymmetry of time, cells, molecular, gravitation

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Description

The concepts of entropy and information are related to each other, and the entropy of information theory is closely related to thermodynamic entropy. In an isolated system, the interaction between the particles tends to increase their dispersion, affecting their positions and their velocities, which causes the entropy of the distribution to increase with time until reaching a certain maximum, which is called the second law of thermodynamics.

In the theory of information, entropy is the measure of the uncertainty that exists before a set of messages, of which only one will be received. It is a measure of the information that is necessary to reduce or eliminate uncertainty. Thermodynamics defines the statistical behavior of many entities, since the fundamental laws of physics are at all times reversible, it can be argued that the irreversibility of thermodynamics must be of a statistical nature, which means that it must be very improbable, but not impossible.

Another way to understand entropy is as the average amount of information contained in the transmitted symbols, and the message will have relevant information and maximum entropy when all the symbols are equally likely.

In general terms, thermodynamics is a branch of physics that studies the effects of temperature, pressure and volume of physical systems at a macroscopic level. The amount of entropy of any thermodynamically isolated system tends to increase over time, which would indicate that time has a direction, a temporal asymmetry. But, as can be seen in previous works,[1-3] everything seems to be clear at a macroscopic level, however, on a microscopic scale it is more difficult to say that entropy is increasing and, as a consequence, time is going forward.

In the field of bio-nanotechnology, it is currently possible to study a single biological molecule, and one of the methodologies developed for this consists of the use of an instrument called optical clamp. This method requires that the biomolecule under study be previously bound to another type of molecule or to an artificial nanostructure, so that the larger size of this allows the biomolecule to be manipulated much more easily within the solution that contains it. The high sensitivity of the optical tweezers makes it possible to perform sub-nanometer displacements and rotations.

With these techniques, long ago Feng & Crooks,[4] created a method to accurately measure the temporal asymmetry at the microscopic level. They obtained a new measurement method, where they saw that time advances towards the future even when the entropy decreases. For this, they used experimental data[5] where they analyzed how an RNA molecule was folded and unfolded, and discovered that for some intervals, entropy may actually decrease, so that while general entropy increases on average, the time does not always have a clear direction.

To study time on this scale, they began by investigating the increase in energy dissipation in various distributions and showed that, at certain intervals, entropy actually decreased, so it can be said that while time advances in the macroscopic world, the direction of time becomes confused on the scale of a single molecule.

They worked with an RNA molecule given its versatility. They defined the temporal asymmetry as the Jensen-Shannon divergence[6] between the probability distributions of the trajectory of an experiment. They analyzed the folding and unfolding of an RNA molecule and used lasers to stretch and compress it. Initially, the RNA starts at thermal equilibrium, but as it is stretched and compressed in the turns, the total entropy of the RNA and its surrounding medium increases on average.

In these stretching experiments, a mechanical force is applied at both ends of an RNA molecule, and they generate important information that may not have been produced in any other way. Basically, the value of the applied force grows linearly until the molecule unfolds. If the process is reversed, relaxing the tension applied to the system, the molecule retreats again. The information obtained from these experiments is the force as a function of the end-to-end distance of the system.

The process is essentially temporary asymmetry. It was shown that this process generates a large average dissipation or increase in entropy, and a small temporal asymmetry, as intuitively expected due to the slow traction. This probability can describe temporal asymmetry more accurately than a simple measurement of average entropy, since the average entropy is affected by abnormal events, for example, if the RNA is entangled, it will resist deployment when the claws expand. The process is essentially temporary asymmetry.

If this same mechanism is associated with what happens to astronauts in space, where the effect of gravitation or the lack thereof, that is, microgravity, could be producing a mechanism equivalent to what was done by Feng and Crooks in the laboratory , and this could be the cause of the activation of the telomerase enzyme that would be the cause of the lengthening of telomeres as happened to astronaut Scott Kelly who spent 340 days in space, according to a study conducted by Susan Bailey and NASA. This could be an alternative explanation to explain what until now has no explanation, the cause of the lengthening of telomeres, because the other possible causes are almost discarded.

In addition, today we know a lot about how tumor cells stop their aging by lengthening telomeres,[7] as well as that cells that have undergone transformation usually show telomerase activity, which is repressed in adult cells and with each division the telomeres shorten. In a way, cancer cells find a way to avoid aging. Everything suggests that telomeres are involved in the differentiated cells have a limited number of cell divisions after which death occurs by senescence, ie that the shortening of telomeres is related to the replicative senescence of differentiated somatic cells lacking telomerase activity. This indicates that the telomeric shortening works like a clock that carries out the account of the cell divisions that are left to a certain cell.

The enzyme telomerase ensures that the telomeres of these cells remain fully in the next generation, but disappears after birth, which causes that, thereafter, the telomeres shorten and we begin to age. When telomerase reappears, the telomeres grow back, and this can be a problem if the process is not controlled. If the treated cells begin to divide they can become very dangerous, because in the process it is quite probable that a cancer develops.

It was assumed that the rigors of space should accelerate this decrease, and not the other way around. The most radical and fascinating transformation observed so far in the body of Scott Kelly is in his DNA, specifically as we said in the telomeres, that is to say at the ends of the chromosomes, whose main function is the structural stability of the same in the cells eukaryotes, cell division and lifespan of cell lines. As identical twins, Scott and Mark Kelly are very similar genetically; however, it has been found that while Scott was in orbit, the ends of his chromosomes grew to reach more length than his brother's, although they recovered their original length shortly after to return to Earth, the finding is completely unexpected.

Conclusion

Assimilating these experiments with the situations to which astronauts are subjected in space, it could be assumed that perhaps microgravity and its variations in space could be equivalent to the experiments cited, and perhaps, as experiments would indicate, this mechanism may be an eventual explanation of the lengthening of telomeres in space, since the other possible causes are practically discarded. These investigations are very interesting because to understand how space affects the telomeres is crucial to program future manned space travel.

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Conflicts of interest

Author declares that there is no conflict of interest.

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