# THERE ARE TWO TWIN SHADOWS, BUT EINSTEIN IS ONE*

by

***Marko E. POPOVIĆ***

Faculty of Chemistry, University of Belgrade, Serbia

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*"The second law of thermodynamics holds, I think, the supreme position among the laws of nature. If someone points out to you that your pet theory is in disagreement with Maxwell's equations – then so much the worse for Maxwell's equations. If it is found to be contradicted by observation well, those experimentalists do bungle things up sometimes, but if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing to do but to collapse in deepest humiliation."*

*Sir A. S. Eddington*

*2011 is the international year of chemistry, and it is exactly 100 years past after the P. Langevin promotion of "twin paradox" problem. The hundred year old problem still demands its solution. Twin paradox, established by a physicist, has been representing a nightmare for philosophers, physicists, chemists, and biologists until these days. After a hundred years, it is time to try to close this page in long history of misunderstanding of the special relativity. This analysis has three main assumptions. First, biological systems are a part of physical world and therefore they behave in accordance to the physical laws according to Schrödinger. Second, according to Von Bertalanffy the biological systems are open thermodynamic systems. Because of that the approach of non-equilibrium thermodynamics was used for analyzing the twin paradox. Third, rise of entropy is according to Hyflick strongly connected with aging. Entropy can be taken as a measure of cell age or even human age according to Silva et al. and Gladyshev. So entropy invariance strongly suggests that both twins should be the same age, so there is a potential problem for twin paradox with the second law. The only possible influence of relativity on the chemical reaction rate is time dilatation. However time flow does not cause the aging process, so time dilatation cannot have any influence on it. So, after detailed analysis, it is concluded that there is no twin paradox in reality. Both twins will be exactly in same thermodynamic state and biological age. The traveler twin will notice time dilatation, but this relativistic effect has no influence on the aging process.*

Key words: *dissipative structure, twin paradox, entropy, aging, non-equilibrium thermodynamics*

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Author's e-mail: popovic.pasa@gmail.com

## Introduction

Origin of the now iconic unsolved story about twin paradox lay in words: ”If we placed a living organism in a box ... one could arrange that the organism, after any arbitrary lengthy flight, could be returned to its original spot in a scarcely altered condition, while corresponding organisms which had remained in their original positions had already long since given way to new generations. For the moving organism, the lengthy time of the journey was a mere instant, provided the motion took place with approximately the speed of light.“ [1] In 1911, a ”striking example“ is given by describing the story of a traveler making a trip at $v \rightarrow c$. The traveler remains in a projectile for one year of his time, and then reverses direction. Upon return, the traveler will find that he has aged two years, while 200 years have passed on Earth [2]. To be clear, this is the picture presented to the public: “Consider a space ship traveling from Earth to the nearest star system outside of our solar system: a distance $d$ = 4.45 light years away, at a speed $v = 0.866c$. The Earth-based mission control reasons in this way about the journey: the round trip will take $t = 2\ d/v$ *= 10.28 years in Earth time, i. e. everybody on earth will be 10.28 years older* when the ship returns. The amount of time as measured on the ship's clocks and the aging of the travelers during their trip will be reduced by the factor = $(1 - v^2/c^2)^{1/2}$, the reciprocal of the Lorentz factor. In this *case* $\varepsilon = 0.500$ *and the travelers will have aged only 0.500 × 10.28 = 5.14 years when they return“.*[*] So the logic behind this paradox is:

*Syllogism A*

(I) Time passes slower under relativistic conditions

(II) Time passing causes aging of living organism

→ Aging of a living organism is slower under relativistic conditions.

And second

*Syllogism B*

(I) Time pass usually under usual Earth condition

(II) Time passing causes aging of living organism

→ Aging of living organism is usual under usual Earth condition.

*Comparing the A and B*

(I) Aging of a living organism is slower under relativistic condition

(II) Aging of living organism is usual under usual Earth condition

Take us to the twin paradox problem. Traveler twin returns after trip and met his older twin brother. Physicists tried to solve twin paradox on the many different ways. ”It is pointed out that a complete resolution of the twin paradox demands that the travelling twin takes into account the gravitational effect upon the rate of time when he predicts the ageing of his brother“ [3]. So the problem is really complex and its solution demands multidisciplinary access. The year 2011 is the year of chemistry, and it is exactly 100 years past after the promotion of twin paradox. The aim of this paper is to revisit and reconsider the problem and shed more light on it.

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* Author’s remark: The marked text gives the logical connection between time flow and aging)

## Theoretical analysis

Is it just logic (or logical mistake) leading us to the conclusion that twin paradox appears as a consequence of the relativistic movement or the problem is more complex? At the beginning, second premise in both syllogisms is wrong, time passing does not cause the aging process. There is not such theory in biology or gerontology [4]. This is the first indication that whole construction of twin paradox may have some difficulties. To analyze twin paradox let us start from the definition of aging. There are plenty of them, but each of them is based on some of the morphological or biochemical observations linked with aging. One word is part of each of those definitions. For example ”Ageing is the accumulation of changes in an organism or object over time“ [5]. ”Ageing is the accumulation of damage (it means the change) to somatic cells, leading to cellular dysfunction“ [6]. ”Age changes can occur in only two fundamental ways: by a purposeful program driven by genes or by random, accidental events“ [7]. That word is change. Indeed, the change is the obvious and crucial phenomenon in aging process. It seems logical to add another word-consecutive. So aging is the consecutive change of the cell, tissue, or organism. “Therefore, the physical interactions between our system and others must, as a rule, themselves possess a certain degree of physical orderliness, that is to say, they too must obey strict physical laws to a certain degree of accuracy“ [8]. If so, then we can consider the cell, tissue or organism as a thermodynamic system. Previous works [4, 7-16] in this field allows us to analyze living cell as a thermodynamic system. So we may define aging as a consecutive change of (bio) thermodynamic system. We would like to add to this definition word spontaneous, since aging is spontaneous and irreversible process. Aging is spontaneous, consecutive change of the state of the biothermodynamic system that is driven by the tendency of entropy to increase. In that case the change of state of the system, and consequently aging, is caused by physicochemical laws, which is in accordance with Schrödinger [8]. Von Bertalanffy, as well as most researchers discusses living systems as open living systems, opposite to Gladyshev who considers them to be closed systems. These two approaches are not only of cosmetic nature, but they require two completely different kinds of thermodynamics. Other authors also consider living system as open thermodynamic system: “Life resides in the pattern of dynamic flows of matter and energy that somehow makes the organism alive, enabling it to grow, develop, and evolve. The whole does not refer to an isolated monadic entity. On the contrary, it refers to a system open to the environment [17]. It is closer for us to consider living systems as open thermodynamic systems, which requests the use of non-equilibrium thermodynamics, where the most important contributions were made by Prigogine [18]. Here we will offer a model of an open thermodynamic system, which should satisfy the following characteristics of biological systems:

(1) the exchange of substance and energy with its surroundings (open system),
(2) the property of growth which means that input of matter into the system is greater than the output,
(3) that the membrane is semipermeable,
(4) that the analyzed system requires energy from outside for its growth,
(5) that it continuously changes its state,
(6) that during the change of state errors happen which accumulate with time, and
(7) that there is a mechanism which repairs the errors but it is not perfect.

For simplification of the model we neglected that energy rich substances (glucose) enter the cell and that trough a cascade of chemical reactions they are converted into energy necessary to keep the biological system alive. It was replaced by an ideal pump with an external supply of energy, because it is all the same whether the pump is supplied by an energy supplier or by the Sun (glucose).

### *Model*

Let us consider an open system Sys2, which is inside system Sys1. Systems Sys2 and Sys1 are isolated from the surroundings, and can contact only with each other. The systems are divided by a semipermeable membrane M, which is impermeable for substances A, B, and C, and permeable for D. Substances A, B, C, and D have the same molarities on both sides of the membrane. The membrane is consists of an ABC polymer. Inside Sys1 there are pumps PA, PB, and PC, which are supplied by an infinite external supply of energy. The volume of Sys1 (surroundings) is much larger than volume of Sys2, and it can be approximated that it is infinite. From this we conclude that the quantity of substances A, B, C, and D are much greater in Sys1 then in Sys2. Inside Sys2 there is a catalyst which enables the following reactions to happen inside it:

$$A_{(g)} + B_{(g)} + C_{(g)} \rightarrow ABC_{(s)} \tag{1}$$

$$ABC_{(s)} + (ABC)_{n-1(s)} \rightarrow (ABC)_{n(s)} \tag{2}$$

These reactions produce *ABC* which by polymerization incorporates itself into the wall of the membrane, and makes the system grow. According to the Le Chatelier principle the synthesis and polymerization are favorised because the reaction is irreversible and *ABC* escapes the system by being incorporated into the membrane. Occasionally by accident another reaction happens:

$$A_{(g)} + B_{(g)} + C_{(g)} \rightarrow BAC_{(s)} \tag{3}$$

The Sys2 meets the requests given above, and represents a simple theoretical simulation of cell function.

### *Analysis of the model*

The total change of entropy in described system Sys 2 is given as:

$$\mathrm{d}S = \left( \frac{\mathrm{d}H_{\mathrm{in}}}{p\mathrm{d}V_{\mathrm{out}}} - 1 \right) R\mathrm{d}n_{\mathrm{g}} + (\Delta_{\mathrm{r}} S_1)\mathrm{d}n_{\mathrm{ABC}} + (\Delta_{\mathrm{r}} S_2)\mathrm{d}n_{(\mathrm{ABC})_{\mathrm{n}}} + (\Delta_{\mathrm{r}} S_3)\mathrm{d}n_{\mathrm{BAC}} \tag{4}$$

Or in a more generalized form, which is more adequate for a living system:

$$\mathrm{d}S = \left( \frac{\mathrm{d}H_{\mathrm{in}}}{p\mathrm{d}V_{\mathrm{out}}} - 1 \right) R\mathrm{d}n_{\mathrm{g}} + \sum_{i=1}^{N} \Delta_{\mathrm{r}} S_i \mathrm{d}n_i \tag{5}$$

From eq. (4) we see that there are two main contributions to the entropy of Sys2. The first is the system expansion represented by the first term on the right, it is positive. The second are the chemical reactions, their contribution is represented by second, third, and fourth term on the right. Their contribution decreases the entropy change in Sys2. We conclude that in this system there are two tendencies: one to increase the entropy and the other one to decrease it. This is supported by Hayflick: "Physiological reserve does not renew at the same rate that it incurs losses because molecular disorder increases at a rate greater than the capacity for repair" [12]. Having in mind eqs. (4) and (5) it can be concluded that time dilatation has no effects on entropy change of open biothermodynamic systems. Time simply plays no role in living processes. Parameters in eqs. (4) and (5) are entropy and enthalpy which both are state functions and are therefore Lorentz invariant, and pressure (also invariant according to Tolman [19] and Planck [20]), volume (apparent artificial phenomenon according to [21-28]) and quantity of substance (according to the conservation law also invariant) that are not related to a time, and R which is a physical constant. According to Bormashenko [29] Boltzmann constant is invariant. In that case $R$ is also invariant. Moreover it can be shown that first term in eq. (4) could be written as:

$$\mathrm{d}S = \mathrm{d}S_{\mathrm{in}} - R\mathrm{d}n + (\Delta S_1)\mathrm{d}n_{\mathrm{ABC}} + (\Delta S_2)\mathrm{d}n_{(\mathrm{ABC})_\mathrm{n}} + (\Delta S_3)\mathrm{d}n_{\mathrm{BAC}} \tag{6}$$

where $\mathrm{d}S_{\mathrm{in}}$ is the entropy brought into the system by pumping matter in. This equation shows that the total change of entropy caused by systems growth depends only on entropy brought into the system and corrective factor $R\mathrm{d}n_\mathrm{g}$ (both Lorentz invariant). So there is no way for the relativity to influence the behavior of open thermodynamic system. Since eqs. (5) and (6) are different forms of the same equation, and from eq. (6) we see that the first term on the right is Lorenz invariant, we can conclude that the argumentation for the eq. (4) is correct, because it supports it.

As we defined it earlier already, living systems are open thermodynamic systems. So we see that even with the effects of time dilatation the system will not change its entropy in different ways, depending on its state of motion. If entropy change is the cause of aging, according to [4, 7, 11-15], and its change does not depend on time, then relativistic time dilatation has no effect on aging. We can say this in different way entropy is a state function and it does not depend on neither the way nor the time it took to achieve the given state [4]. Now recall the definition of aging given above. Thermodynamic state is visible as age of the (bio) system. The Planck's theorem of entropy invariance [20] also supports the conclusions. At the end, time dilatation can have some influence on calculated chemical reaction rate, but has no influence on the state of the system and consequently age of the biological system. Reason for that is fact that time flow does not cause anything, especially not thermodynamic process, and consequently aging process, because aging is primarily thermodynamic process caused by the fundamental natural laws such as second law of thermodynamics.

## Conclusion

If living systems are open thermodynamic systems, and if the entropy change of the system characterizes aging in that case aging is independent of time passage, so the effects of relativistic time dilatation have no effect on the aging process. In that case there is no twin paradox.

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