

Exogenous Mechanism of the Time Sensor of Biological Clock

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The problem of time sensor of a biological clock attracts interest of many scientists, and a great number of experiments are being conducted to study the influence of various physical and chemical factors on functioning of a biological clock. Analyzing publications and considering our own original results a physical exogenous mechanism of biological clock is formulated that adequately explains the obtained experimental data.

The problem of biological rhythms i.e. biorhythms (BR) with periodicity close to the periodicity of geophysical phenomena has been attracting interest of scientists for centuries. And a great number of experiments carried out on different organisms beginning from single-cell creatures and plants to animals and human beings confirm that biological organisms have the ability to measure time [1–6] and biological clocks (BC) really exist.

The central problem in this matter is explanation of how time sensor (TS) of a BC functions and of the very basic mechanism of TS. Attempts had been made to study the influence of different chemical and physical factors on the parameters of BC.

The most thoroughly studied rhythms are those with a period close to 24 hours. These are so called circadian rhythms (CR). Fewer works are devoted to lunar rhythms (LR) which are of periods around 29.53 and 14.77 days. A few works involve yearly rhythms, and there is information about a period of about 180 million years of the Earth's biosphere productivity [4].

In an attempt to determine the mechanism of TS influences of the following factors have been studied on the parameters of CR: illumination [7], light/darkness cycles [8], electrical and magnetic fields of the Earth [9, 10], and absence of such [11], temperature variations [12, 13], chemicals [14, 15]. There were experiments in constant pressure and temperature environments [17].

The main properties of BC obtained from experiments are presented in [16]. The noteworthy fact is that the study of BC had been carried out on biological objects using parameters, which are the last stages of long chains of complex biochemical reactions and processes. In fact, in biological experiments researchers observe the motion of the "hands" of BC. Naturally, such observations do not allow revealing the mechanism of BCTS that controls the "hands" of the clock. Thus, the study of biological objects makes it impossible to draw conclusions about the specific stages where one or another factor begins to affect the biochemical chain of reaction. This means, it is difficult to come to a single conclusion, that the observed effects were the result of the action of a single factor on the mechanism of time BCTS. And, as J. Gustings noticed it is impossible to give an example of an isolated and studied biochemical system, which possesses the properties that

would reveal the factor and the location of such factor's influence on CR [14].

The summarized conclusion coming from broad experimental data is that physical and chemical factors, whose influence on BC have been studied, do not have any relationship with the mechanism of BCTS, but only play a synchronizing role. Namely, the factor whose influence is studied only affects the "hand" of the clock by force shifting it one way or another without affecting the actual mechanism behind the "face" of the clock, i.e. without changing the period of CR.

As a result the conclusion is drawn that the period of BC, particularly of CR, is independent from external factors. And thus this period of the rhythms must be defined by organisms independently from external factors, periodic or non-periodic, of physical or chemical nature. This hypothesis is based on three well known facts:

- i. The difference of the period from 24 hours in experiments in constant conditions;
- ii. Ease of shifting the phase of the rhythms;
- iii. Stability of the rhythm period during latitudinal shifts, that followed by the change of all geophysical factors determined by place and time.

But none of these facts can be accepted as a definite proof as it is established in scientific world [17].

Overall experimental data from studies of BCTS mechanism do not permit to arrive to a single conclusion regarding the physical foundation of BCTS. Therefore, presently the hypothesis of endogenous mechanism of BCTS is generally accepted. Though there are facts that may support a combined exogenous-endogenous mechanism [7]. Such attempts encourage search for processes (of physical or simple chemical nature) that would allow identifying possibly a single simple mechanism of BCTS.

Circadian periodicity of evaporation of water from a thermostated essel*

Initial experiments were carried out in 1974. During one of experiments (see the footnote) it became necessary to obtain a stable flow of water vapor of low intensity (1.4×10^{-5} kg/s).

*These experimental data had been obtained in 1974 by a group of physicists headed by Prof. M. A. Asimov. The author of the present article was a responsible leader for the experiments.

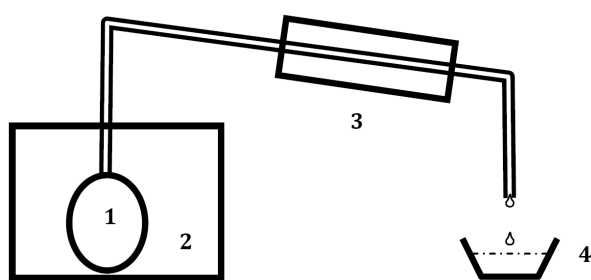


Fig. 1: (1) Container filled with distilled water; (2) Thermostated chamber with inside temperature of $103 \pm 0.1^\circ\text{C}$; (3) Cooling system; (4) Container where the water condensate was collected

For this, the experimental setup, schematics plotted on Fig. 1, had been assembled.

Container (1) with distilled water was placed into the thermostated chamber (2), where stable temperature at $103 \pm 0.1^\circ\text{C}$ was maintained. Water was boiling inside the container (1). The water vapor went through the cooling system (3) and precipitated into the container (4). The mass of the evaporated/precipitated water was measured every 15 min and a set of 4 measurements had been plotted on the Fig. 2a and 2b. The experiments were carried out uninterruptedly by a number of series of 1 to 7 days of duration.

In order to thoroughly investigate the rate of water vaporization power supply of the thermostat was carefully stabilized, all containers and tubes and connections were thermally insulated, mass was carefully measured and stability of the temperature was closely monitored. The data coming from the measurements strongly suggested the existence of CR in the physical process of distilled water evaporation from a thermostated container.

Measurements were repeated 2001. Due to the limited resources and financial restrictions, the measurements were conducted for only 24 hours. The data collected in 2001 is plotted on Fig. 2b.

Simultaneously, external parameters were monitored. In the Fig. 3, these parameters were plotted vs. time of the day. Namely, temperature of the thermostated chamber T_{hot} , temperature of the liquid in cooling system T_{cold} , ambient temperature T_{amb} , atmospheric pressure p in mm Hg, relative humidity η , and voltage of the power supply were plotted vs. time. As it is clear from Fig. 3, no significant correlation was observed between external parameters and the mass of the evaporated/precipitated water*.

Lunar rhythm in the reaction of vapor conversion of methanol

The stable vapor flow of low intensity was necessary for studying of chemical reaction of vapor conversion of metha-

*Experiment conducted in 2001 was made possible by generous technical assistance of Abdulaev Khikmat at the Biology Department of Tashkent State University.

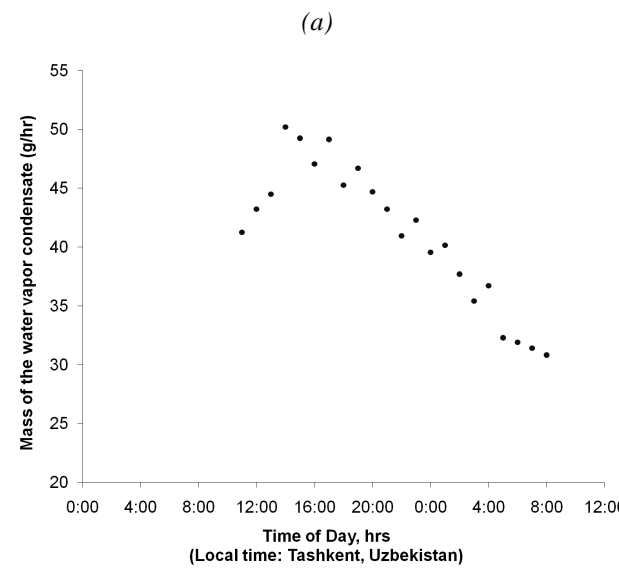
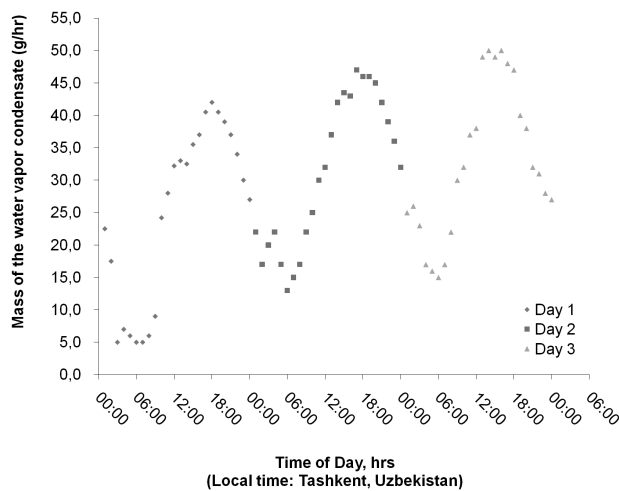
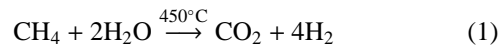


Fig. 2: Variation of the mass of collected water condensate vs. time of the day

anol. The reaction used in chemical industry to produce hydrogen is described by a formula:



To investigate time dependence of the reaction speed there were provided stable flows of gaseous CH_4 and water vapor (deviations were $\pm 0.3\%$ and $\pm 3\%$, respectively).

The experiment had been carried out for 540 hours in October and November of 1974. In Fig. 4 the experimental measurements were plotted, y axis shows the fraction of residual methane in the converted, dry gas at the output of the reactor.

Composition of the gas at the output was analyzed by the method of gas chromatography. Every 15 min three chromatographs were collected; results of 2-4 hour measurements

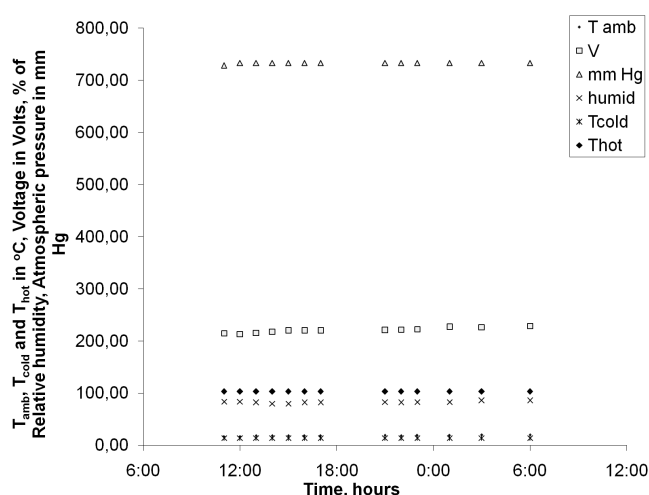


Fig. 3: Monitoring of external parameters of temperature of the thermostated chamber T_{hot} , temperature of the liquid in cooling system T_{cold} , ambient temperature T_{amb} , atmospheric pressure p in mm Hg, relative humidity η , and voltage of the power supply were plotted vs. time. Experiments were conducted in summer of 2001.

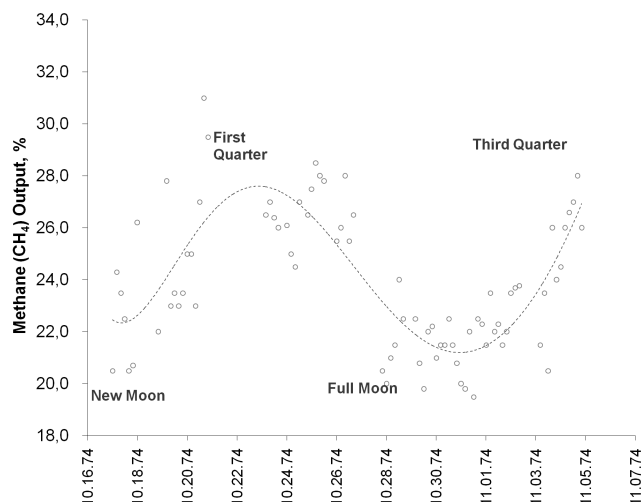


Fig. 4: Concentration of residual CH_4 in % in vapor conversion reaction output. (Experimental data presented in this figure were obtained in Tashkent State University, Uzbekistan by Docent M. A. Azimov's group, headed by Mr. Takhir R. Akhmedov in 1972–75)

were averaged and then plotted on the Fig. 4.

Results of these studies indicated on the existence of a lunar rhythm in the chemical reaction of vapor conversion of methanol at $T = 450^\circ C$. This temperature is noticeably higher than temperature of any known living organism.

Discussion

A sum total of published experimental data and mentioned above original results of revealing of CR in water evaporation from a thermostated vessel (at $T = 103^\circ C$), and LR in chemical reaction of vapor conversion of methanol (at $T = 450^\circ C$) allowed to conclude that the mechanism of BCTS has exogenous nature.

Let's analyze changing of kinetic and potential energy of atoms/molecule on the surface of the Earth. An atom/molecule on the surface of the Earth takes part in following motions:

1. Spinning of the Earth around its own axis with the surface speed $V_1 = 465 \times \cos \alpha$ m/s, where α – is latitude;
2. Revolving with the Earth around the Sun with a linear speed of $V_2 = 3 \times 10^4$ m/s;
3. Moving with the Solar system around the center of the Galaxy with a linear speed of about $V_3 = 2.5 \times 10^5$ m/s;
4. Moving with the Galaxy from the center of the Universe with a linear speed of about $V_4 = 6 \times 10^5$ m/s [18];

It's known that total mechanical energy is the sum of kinetic energy KE and potential energy U:

$$E_{total} = KE + U \tag{2}$$

And, if any of these components or both of them change according to a law, then the total energy will change according to the same law. And the change can be potentially affecting any physical, chemical or biological process.

The factors 1-3 cause changing of kinetic energy of atoms/molecules on the surface of the Earth with periods, respectively, 24 hours (CR), a year (year rhythm), 180 million years (the Galaxy "year" rhythm). The existence of the rhythms has been mentioned above. Analysis of the kinetic energy changing leads us to the following formula:

$$E_{max} - E_{min} = 2m \times V_T \times V_E \times \cos \alpha \tag{3}$$

where m – mass of an atom/molecule, V_T – thermodynamic speed of an atom/molecule, V_E – the orbital speed of the Earth's surface on the equator, α – latitude.

Formula (3) evaluates the change of kinetic energy of H_2O molecule caused by orbital spinning of the Earth. Calculations show that the change of the kinetic energy is equivalent to the temperature change in the order of $1^\circ C$, which in turn explains the existence of a minimum/maximum of water evaporation from a thermostated vessel at 6 a.m./6 p.m. of the local time. Similar changes of energy in biological objects naturally lead to emerging of CR in them.

It should be underlined, that the argument I (differ of CR period from 24 hours), interpreted in the favor of endogenous mechanism of BCTS, actually proves exogenous character of the BCTS mechanism [15]. The argument II – easiness of shifting of CR phase in biological objects is not related to the mechanism of functioning of BC, but is the result of response of bio-objects to the external environmental factors, and the response is of biochemical nature.

The argument III – conservation of the rhythm during latitudinal shift – naturally follows from the above offered interpretation of the mechanism of BCTS. As the speed of an atom/molecule on the surface of the Earth is described by a formula:

$$V = V_T + V_E \cos \alpha \quad (4)$$

And for a given time zone during latitudinal shifting the BC of a studied object conserves circadian periodicity. But the shifting can be followed by a change of the amplitude. CR of bio-objects should disappear on the Poles of the Earth and in space (space stations).

As it's known, an atom/molecule besides kinetic energy possesses potential energy. E_{poten} in (2) for atoms/molecules on the surface of the Earth changes with a period equal to lunar rhythm, that is caused by displacement of celestial bodies in the system Sun-Earth-Moon. And temperature equivalent of the effect is of order of 10-20°C for the researched chemical reaction. The same mechanism of the energy changing may cause changing of daily global temperature [19].

Conclusions

1. The rhythms with periods close to geophysical rhythms (circadian rhythm, lunar rhythm, a year rhythm, and a rhythm of Earth's biosphere productivity-the Galaxy rhythm) have fundamental nature and take place not only in bio-objects, but also in physical and chemical processes at temperatures significantly higher than temperature of bio-objects.
2. The mechanism of time sensor of biological clock has exogenous nature.
3. The time sensor of biological clock is the changing of total energy $E_{\text{total}} = KE + U$ of atoms/molecules on the surface of the Earth, caused by moving of the Earth in Space.
4. For global prove of the results and theoretical interpretation, experiments may be held to study the process of water evaporation from a thermostated vessel simultaneously in different places of the same latitude and/or longitude.

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