DOI 10.1007/s10517-021-05234-z

EXPERIMENTAL BIOLOGY

Changes in Body Temperature of Small Mammals and Birds in a Few Minutes Range as Reflection of Environmental Influences

M. E. Diatroptov

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 171, No. 3, pp. 373-378, March 2021
Original article submitted October 13, 2020

The study examined the changes in intraperitoneal body temperature of laboratory mice, Jungar hamsters, European greenfinch *Chloris chloris*, and starlings. In a few minutes range, these changes significantly correlated not only between the animals of the same species, but also between the different classes such as birds and mammals, which were isolated from each other and maintained under different illumination regimen. This phenomenon indicates some external influence(s) on the central mechanisms of the thermal control system not related to illumination regiment. In 80% cases, the phases of most pronounced rhythms of body temperature oscillating with the periods of 8-9 and 12-13 min coincided with those of geomagnetic field within the accuracy of ±1 min. However, the amplitude of body temperature oscillations did not depend on the amplitude of geomagnetic field (GMF) oscillations. Synchronicity of the changes in body temperature and GMF was observed at the amplitude of GMF oscillation of 0.4 nT, which is extremely low value. In contrast, there was no reaction of body temperature to greater (6-10 nT) but irregular and abrupt perturbations of GMF.

Key Words: *ultradian rhythms; body temperature; geomagnetic field; environmental synchronizers*

Recently it was established that the changes in body temperature (BT) of isolated animals of the same species are synchronous [2]. This phenomenon was observed in animals maintained under persistent illumination, which excludes synchronization of examined rhythms by periodic daily light. In most cases (90%), the basic frequencies of BT spectra in animals of different species were identical and corresponded to the periods of 8-9, 12-13, and 19-20 min. These data attest to existence of environmental rhythmic factor affecting the fine structure of thermal regulation in living organisms. Probably, BT oscillations are mediated via the changes in the tone of autonomic nervous system [6,7].

It cannot be excluded that spectacular coincidence of the frequencies and phases of BT oscillations in isolated animals of the same species results from their common intrinsic physiological, ecological, and behavioral features. However, it is also possible that these processes are affected by external rhythmic influences. To test whether the rhythmic changes of BT with the period ranging 4-60 min are determined by some external quasi-rhythmic source, it is necessary to record BT in various species of mammals and birds in parallel. The proof of the effect of this hypothetical environmental factor on ultradian rhythms of BT can be synchronicity in the changes of BT in various isolated species maintained under different illumina-

A. N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow. ***Address for correspondence:*** diatrom@inbox.ru. M. E. Diatroptov

tion regimens. However, there are no studies focused of this problem.

This works was designed to examine synchronicity in the time course of BT variations in several species of small mammals and birds isolated from each other and maintained under different illumination regimens.

MATERIALS AND METHODS

The experiments were carried out on outbred male mature albino laboratory mice (n=10), Jungar hamsters (n=6), the males of common greenfinches *Chloris chloris* (n=6) caught in Staraya Kupavna (Moscow region), and the male common starlings (n=5) caught in Spassky district (Ryazan region).

These animals were selected because of their small size, which made it possible to detect the high-frequency BT oscillations due to a greater specific rate of heat irradiation. The mice and hamsters were maintained in individual plastic cages (40×14.5×24 cm) under persistent subdued illumination. The birds were kept in individual cages (40×35×30 cm) under natural illumination. Persistent light (700-800 lx) illumination was supplied by a source with the color temperature of 4200 K placed at the level of cages. Food and water were *ad libitum*.

BT dynamics was examined in March and April 2020. BT was measured every minute with DTN4-28 transducers (EMBI RESERCH) implanted intraperitoneally 2 weeks prior to experiments under intramuscular narcosis with Zoletil (Virbac Sante Animale, 5-7 mg/kg). The experimental protocols were approved by Bioethics Committee of A. N. Severtsov Institute of Ecology and Evolution (Protocol No. 14, January 15, 2018).

The data on geomagnetic field (GMF) were obtained with a magnetometer located in the Borok Geophysical Observatory (https://www.intermagnet.org/data-donnee/download-eng.php#view).

The results were statistically processed using Statistica 7.0 software (StatSoft, Inc.). To reveal synchronicity in dynamics of examined parameters, the Spearman correlation r was calculated. Significance was assessed at p<0.05. Spectrum analysis was performed with fast Fourier transform. To assess significance of the frequency of coincidence of BT and magnetic field extrema, we used z-test for two sampling fractions.

RESULTS

In various species, the study analyzed the changes in BT every minute. This approach eliminated the circadian and ultradian rhythms of BT, which depend on animal class and the character of their daily activity. Despite importance of analysis of BT rhythms in individual animals, we focused on the mean data in each group presented by the median of BT steps for each minute, which reflected the integral reaction of different individuals in the same group (species). The Spearman correlation r between such medians of BT steps in mice and common greenfinches depended on the date of experiment and ranged from 0.06 (p=0.03) to 0.24 (p=0.004). An example of such BT oscillations is given in Fig. 1, *a*. Similar data were obtained for mice and hamsters (r=0.22, p=0.001), mice and starlings (r=0.16, p=0.01), and hamsters and common greenfinches (r=0.18, p=0.008). Interestingly, the closest correlation was observed near midday and midnight. The correlation coefficients were positive and stable, but rather small, so we analyzed correspondence between the extrema of medians of one-minute BT steps in various groups (species). In mice and common greenfinches, the moments of maximal changes in BT coincided in 73% cases with the accuracy of ±1 min (n=1570, p<0.001), while in mice and starlings as well as in mice and hamsters, such coincidences were observed in 78% (n=1340, p<0.001) and 85% (n=642, p<0.001) cases, respectively. Thus, despite the fact that the classes of mammals and birds diverged evolutionary in about 310 million years ago [9], BT changes in them are still synchronous.

Thus, BT variations in various species of mammals and birds coincide in both frequency and phase. Evidently, there is some external environmental factor, which synchronizes these variations. The present study tested the hypothesis that this factor is GMF. Actually, GMF is characterized by the resonance frequencies corresponding to the periods of 6.4, 8.7, 12.8, and 19-21 min [3]. The frequencies of these oscillations do not depend on the geographic latitude and virtually do not change from one event to another or within the observational time.

Remembering that a living organism responds not to the absolute value of magnetic intensity but to the rate of its change, we compared the minute-long BT changes with those of GMF. In 82% cases (n=1467, p<0.001), the phases of BT oscillations with the period of about 8-12 min observed in examined species coincided with similar phases in GMF oscillations within the accuracy of ±1 min. Thus, BT of living organisms virtually immediately reacts to the changes in GMF. However, there were no close correlations between the amplitudes of BT and GMF changes. Figure 2 compares the changes of BT in mice and starlings within the range of few minutes with similar changes in horizontal component of GMF of various amplitudes. In most cases, the amplitude of BT changes did not depend on the amplitude of GMF undulations.

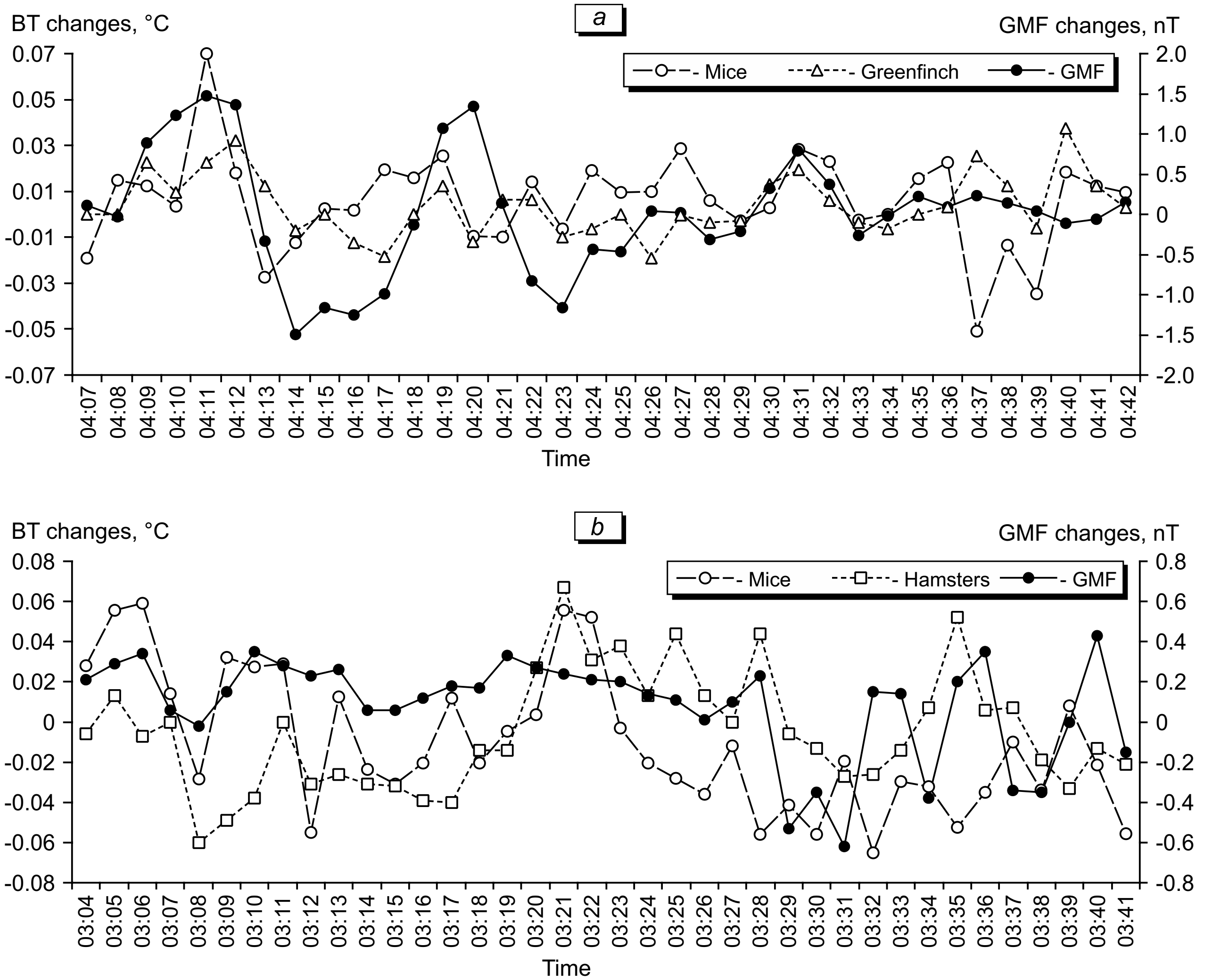

Fig. 1. Dynamics of every minute changes in BT median in groups of animals in comparison with similar changes of GMF horizontal component. *a*) Mice (*n*=7) and European greenfinch (*n*=5) on April 1, 2020; *b*) mice (*n*=7) and hamsters (*n*=6) on April 5, 2020.

It is important that synchronicity between oscillations of BT and GMF was observed at so small value of GMF intensity as 0.4 nT (Fig. 2, *a*). Probably, there should be no amplitude modulation of BT by GMF provided the sensitivity of a living organism to the changes in GMF is extremely high, while the amplitude of BT response is stable and does not depend on physiological state of the organism.

Particular attention should be focused on associations between BT and perturbations of GMF (Fig. 3). Interestingly, BT of animals did not respond to large, irregular, and abrupt perturbations of GMF. During such perturbations, the changes in GMF and BT did not coincide. It can be hypothesized that by some reason, the animals cannot sense the irregular changes in GMF. It is also possible that their response to pronounced changes in GMF differs from the reaction to weak but regular GMF undulations, and this response is not manifested by immediate changes in physiological parameters. In some cases, we observed elevations in BT increments, which was delayed by 5-10 min from GMF perturbation; in these cases, synchronicity between BT changes in various groups of animals was disturbed.

The hypothesis on biotropic effect of natural electromagnetic fields on living organisms is discussed and substantiated in some papers [8,11]. The quasi-rhythmic electromagnetic oscillations can synchronize the biological rhythms both within infra- and ultradian ranges [4,10]. In small animals, the revealed spectra of BT changes closely coincide with the spectrum of intrinsic oscillations of the Earth, which exert the modulating effects on numerous environmental processes manifest by microfluctuations of atmospheric pressure, electric and magnetic fields, thermal neutron flow, *etc.* [5]. It seems too early to conclude that the geomagnetic field is the only factor affecting thermal metabolism in biological organisms, especially because we established only the phase association between oscillations

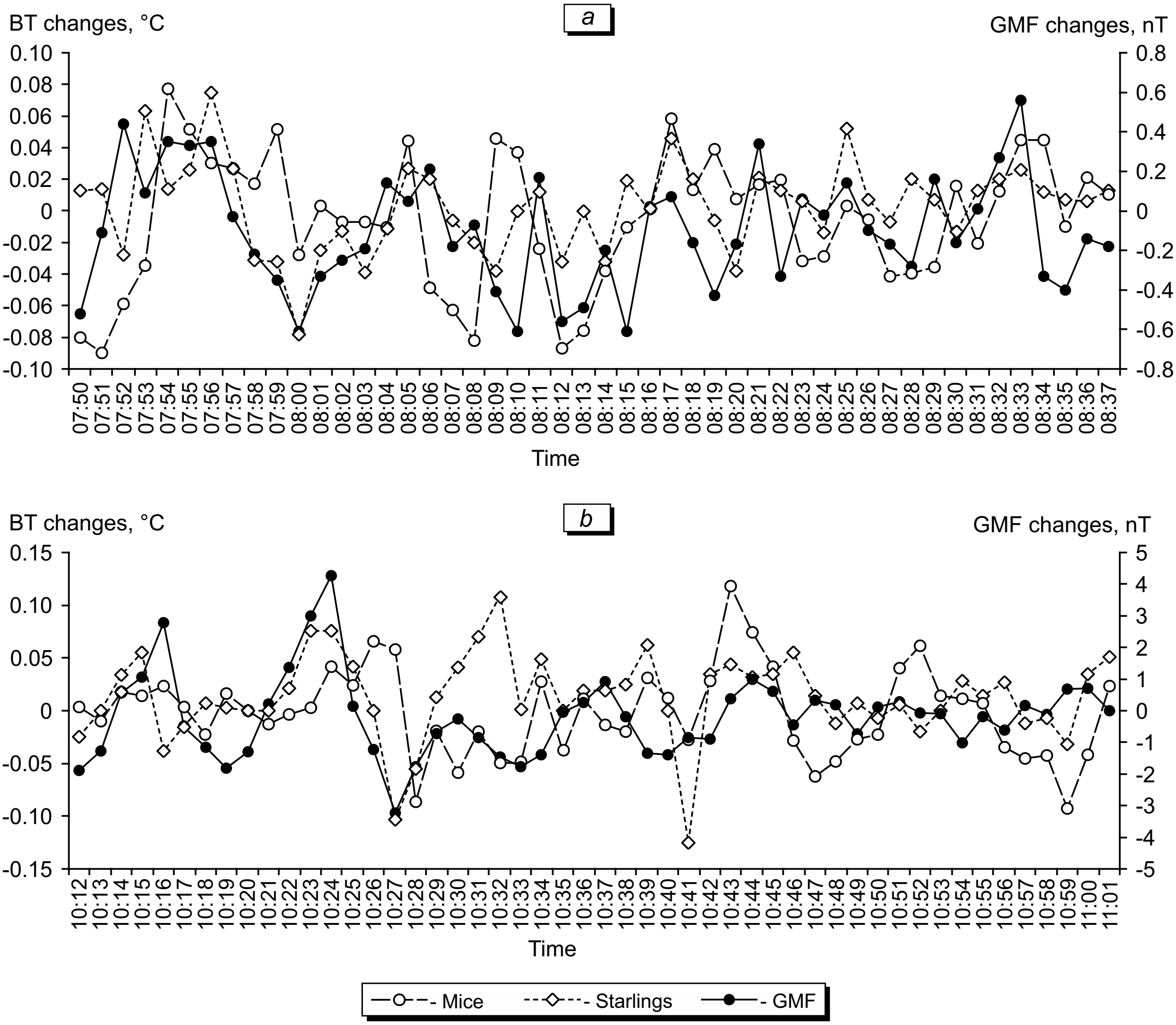

Fig. 2. Dynamics of every minute changes in BT median in mice (*n*=7) and starlings (*n*=6) in comparison with similar changes of GMF horizontal component recorded on April 5, 2020. *a*) Amplitude of GMF oscillations 0.3-0.5 nT; *b*) amplitude of GMF oscillations 2-4 nT.

of GMF and BT. Actually, there were no proportional responses of BT in examined animals to regular GMF changes and no reactions of BT to irregular and abrupt perturbations in GMF.

In this study, we demonstrated the phase coincidence in BT oscillations going on with the periods of 4-20 min in animals of different species and classes, which indicates existence of some external synchronizer of these biological rhythms. Comparison of BT rhythms characterized by approximately 8-9- and 12-13-min periods with similar quasi-periodic changes in GMF revealed the phase coincidence of these rhythms within the accuracy of 1 min. In contrast, the large, irregular, and abrupt magnetic perturbations desynchronized BT rhythms, which agrees with the common view about desynchronizing effect of magnetic storms on living organisms [1]. The present data attest to the absence of direct coincidence in dynamics of GMF and BT of various animals. However, they are not at odds with the hypothesis that namely the quasi-periodic undulations of GMF are external environmental synchronizers of BT.

The study was carried out within the framework of the theme of the State Assignment of A. N. Severtsov Institute of Ecology and Evolution “Ecological and Evolutional Features in Animal Behavior and Communication” (0089-2021-0004).

REFERENCES

1. Gurfinkel YuI. Coronary Heart Disease and Solar Activity. Moscow, 2004. Russian.
2. Diatroptov ME, Panchelyuga VA, Panchelyuga MS. Body Temperature Dynamics in Small Mammals and Birds in 10-120-

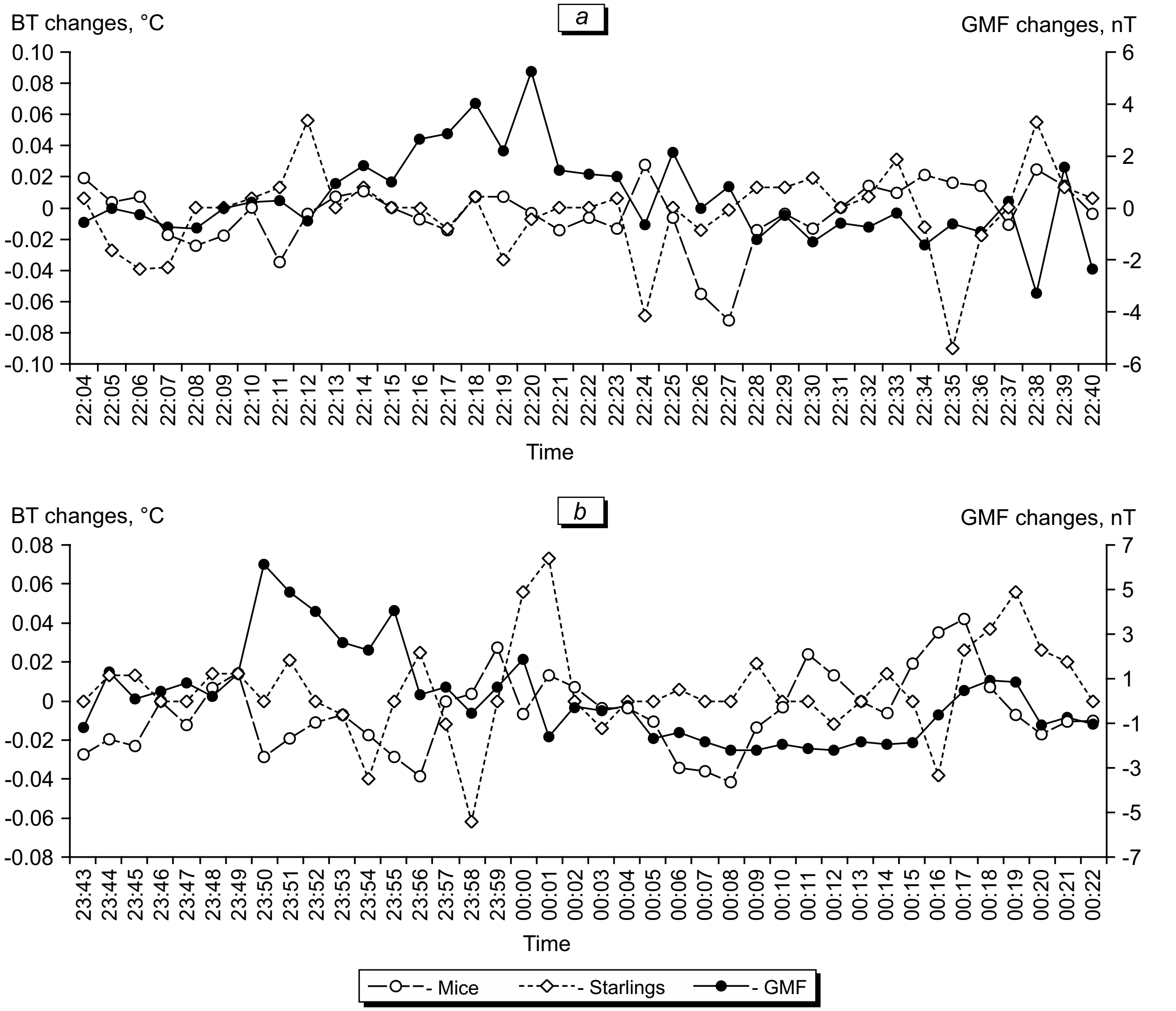

Fig. 3. Dynamics of every minute changes in BT median in mice (*n*=7) and starlings (*n*=6) during abrupt irregular changes in horizontal component of GMF. *a*) April 9, 2020; *b*) April 11-12, 2020.

min Period Range. Bull. Exp. Biol. Med. 2020;169(6):765-770. doi: 10.1007/s10517-020-04974-8.

3. Leonovich AS, Mazur VA. Why the super low frequency MHD-oscillations with discrete spectrum exist in magnetosphere? Soln.-Zemn. Fizika. 2005;(8):99-100. Russian.
4. Martynyuk VS, Vladimirskii BM, Temur'yants NA. Biological rhythms and electromagnetic fields of the environment. Geofiz. Protsessy Biosfera. 2006;5(1):5-23. Russian.
5. Panchelyuga VA, Panchelyuga MS. Local fractal analysis of noise-like time series by the all-permutations method for 1–115 min periods. Biophysics. 2015;60(2):317-330.
6. Blessing W, Ootsuka Y. Timing of activities of daily life is jaggy: How episodic ultradian changes in body and brain temperature are integrated into this process. Temperature (Austin). 2016;3(3):371-383. doi: 10.1080/23328940.2016.1177159
7. Braulke LJ, Heldmaier G. Torpor and ultradian rhythms require an intact signalling of the sympathetic nervous system. Cryobiology. 2010;60(2):198-203. doi: 10.1016/j.cryobiol.2009.11.001
8. Cherry N. Schumann Resonances, a plausible biophysical mechanism for the human health effects of solar/geomagnetic activity. Natural Hazards. 2002;26(3):279-331. doi: 10.1023/A:1015637127504
9. Kumar S, Hedges SB. A molecular timescale for vertebrate evolution. Nature. 1998;392:917-920. doi: 10.1038/31927
10. Martynyuk VS, Temur'yants NA. Extremely low magnetic fields as a factor of modulation and synchronization of infradian biorhythms in animals. Izvestiya. Atmospheric Oceanic Physics. 2010;46(7):820-829. doi: 10.1134/S0001433810070029
11. Weydahl A, Sothern RB, Cornélissen G, Wetterberg L. Geomagnetic activity influences the melatonin secretion at latitude 70 degrees N. Biomed. Pharmacother. 2001;55(Suppl. 1):57s-62s. doi: 10.1016/s0753-3322(01)90006-x