Neuroendocrinology Letters ISSN 0172–780X

Cross-spectrally coherent ~10.5- and 21-year biological and physical cycles, magnetic storms and myocardial infarctions*

Franz Halberg,[1] Germaine Cornélissen,[1] Kuniaki Otsuka,[2] Yoshihiko Watanabe,[2] George S. Katinas,[1] Naoto Burioka,[1] Anatoly Delyukov,[3] Yuri Gorgo,[3] Ziyan Zhao,[4] Andi Weydahl,[5] Robert B. Sothern,[1] Jarmila Siegelova,[6] Bohumil Fiser,[6] Jiri Dusek,[6] Elena V. Syutkina,[7] Federico Perfetto,[8] Roberto Tarquini,[8] R.B. Singh,[9] Brad Rhees,[10] Dennis Lofstrom,[1] Paula Lofstrom,[1] Paul William Cort Johnson,[1] Othild Schwartzkopff[1] & the International BIOCOS Study Group[a]

1. Halberg Chronobiology Center, University of Minnesota, Minneapolis, MN, USA.
2. Tokyo Women's Medical University, Tokyo, Japan.
3. Institute of Physics, National Academy of Sciences of Ukraine, Kiev, Ukraine.
4. Institute of Materia Medica, Shandong Academy of Medical Sciences, Jinan, China.
5. Finnmark University, Alta, Norway.
6. Masaryk University, Brno, Czech Republic.
7. Institute of Pediatrics, Scientific Center for Children's Health, Academy of Medical Sciences, Moscow, Russia.
8. University of Florence, Florence, Italy.
9. Medical Hospital Research Centre, Moradabad, India.
10. Marine Expeditions, Toronto, Ontario, Canada.

a. the International BIOCOS Study Group - see p. 234

Correspondence to: Prof. Franz Halberg, M.D., Director, Halberg Chronobiology Center, University of Minnesota, Mayo Hospital, Room 715 (7th floor), Dept. of Laboratory Medicine, Minneapolis Campus, Del Code 8609 420 Delaware Street SE, Minneapolis, MN 55455, USA.
TEL:+1 612 624 6976 FAX: +1 612 624 9989
E-MAIL halbe001@tc.umn.edu
WEB SITE http://revilla.mac.cie.uva.es/chrono

Submitted: *April 24, 2000*
Accepted: *May 14, 2000*

Key words: **aa; biological cycles; B_z; chronomes; Dst; heart rate variability; infradian; K_p; magnetic storms; myocardial infarctions**

Neuroendocrinology Letters 2000; ***21**:233–258*

Abstract Magnetic storms trigger myocardial infarctions with mechanisms relating to heart rate variability. Solar cycle-to-solar cycle differences and solar cycle stage dependence shown herein may resolve prior controversy and serve to advocate coordinated worldwide systematically aligned biological and physical monitoring.

* This paper was originally invited by the historian-geophysicist Wilfried SCHRöDER of Bremen, Germany, for his biographical "Encounters," and is to serve as an update on the project on the BIOsphere and the Cosmos (BIOCOS) and its offspring ICEHRV (Dr. Kuniaki Otsuka's International Chronome Ecologic Study of Heart Rate Variability). It is intended for distribution at a NATO conference on space weather hazards, organized by Dr. Ioannis Daglis, June 18–29, 2000.

[a]For the BIOCOS Group:

Austria: Manfred Herold, University of Innsbruck.
Belgium: Christian Muller, Aerospace Institute.
Bulgaria: Nadejda Madjirova, Department of Psychiatry, Medical University, Plovdiv.
China: Ziyan Zhao, Shandong Academy of Medical Sciences, Jinan; Zhengrong Wang, West China University of Medical Sciences, Chengdu.
Czech Republic: Jarmila Siegelova, Bohumil Fiser and Jiri Dusek, Masaryk University, Brno.
France: Gerard Milano, Centre Antoine-Lacassagne, Nice.
Germany: Lübbo von Lindern, Sigrid Berger, Max-Planck-Institut für Zellbiologie, Ladenburg.
India: R.B. Singh, Medical Hospital and Research Centre, Moradabad; R.K. Singh, King George's Medical College, Lucknow.
Italy: Franca Carandente, Department of Chronobiology, and Cristina Maggioni, Department of Obstetrics, University of Milan; Federico Perfetto and Roberto Tarquini, Department of Medicine, University of Florence; Andrea Galvagno, Maurizio Montalbini, Pioneer Researches, Ancona.
Japan: Kuniaki Otsuka, Yoshihiko Watanabe, Department of Medicine, Tokyo Women's Medical College, Tokyo; Keiko Uezono, Institute of Health Sciences, Kyushu University, Fukuoka; Yuji Kumagai, Jichi Medical School, Tochigi; Naoto Burioka, Tottori University, Yonago.
Mexico: Salvador Sánchez de la Peña, Instituto Mexicano del Seguro Social, Mexico City.
Norway: Andi Weydahl, Finnmark College, Alta.
Romania: Ion Baciu, Professor and Head of Physiology, and Teodor Maghiar, Rector, Oradea University, Oradea.
Russia: Elena V. Syutkina, Institute of Pediatrics, Academy of Medical Sciences, Moscow; Anatoly Masalov, Lebedev Physical Institute, Moscow; Rina M. Zaslavskaya, Hospital #60, Moscow; Mikhail Blank, N.N. Petrov Oncology Research Institute, Ministry of Health, St. Petersburg; Tamara K. Breus, Space Research Institute, Moscow; Gennady and Denis Gubin, Tyumen.
Slovakia: Miroslav Mikulecky Sr. and Miroslav Mikulecky Jr., Comenius University, Bratislava; Alexander Kreze, Lubochna.
Spain: Miguel Revilla, Department of Mathematics and Computer Science, University of Valladolid; Leopoldo Garcia Alonso, Hospital Materno-Infantil 'Teresa Herrera,' La Coruña.
Switzerland: Waldemar Ulmer, VARIAN International, Zug.
Ukraine: Anatoly Delyukov, Institute of Physics, National Academy of Sciences, Kiev; Yuri Gorgo, Department of Human and Animal Physiology, Taras Shevchenko Kiev National University, Kiev.
United Kingdom: Hugh Simpson, Department of Surgery, University of Glasgow, Scotland; Douglas Wilson, ADAS, Cardiff, Wales.
USA: Earl Bakken, North Hawaii Community Hospital, Kamuela, Hawaii; Patrick Delmore, Medtronic Inc., Shoreview, Minnesota; Francine Halberg, Marin General Hospital, San Rafael, California; Katarina Borer, University of Michigan, Ann Arbor, Michigan; Daniel Kaplan, Macalester College, St. Paul, Minnesota; Jim Holte, Department of Electrical Engineering; David Benditt and Keith Lurie, Department of Cardiology; Julia Halberg, Department of Epidemiology; and the authors, University of Minnesota, Minneapolis.

Support: U.S. Public health service (GM-13981) (FH), National Heart, Lung, and Blood Institute, National Institutes of Health (HL-40650) (FH, GC); University of Minnesota Supercomputing Institute, Dr. h.c., Dr. h.c. Earl Bakken Fund, and Mr. Lynn Peterson, United Business Machines, Fridley, MN. dedicated by the first two authors to two co-authors, Tamara Breus, a solar physicist who gave us a precious gift of 6,300,000 diagnoses, and Elena V. Syutkina, a pediatrician who with Tamara demonstrated an association between local geomagnetic disturbance and vascular physiology in the human newborn and convened a special meeting of the Russian Academy of Sciences on June 30, 1997, unanimously endorsing a project on the Biosphere and the Cosmos, BIOCOS.

Chronoastrobiology

Wolf's relative sunspot numbers (WN), long known to undergo ~10.5- (circadecennian) and ~21-year (circavigintunennian) cycles, named after Schwabe and Hale, respectively, have near-matching numerical biological counterparts. About half-yearly, about-weekly and, in certain solar cycle stages, about half-weekly features of anthropogenically unpolluted geomagnetic indices, such as Kp or aa, also have biological near-matches. Rhythms with various frequencies coexist with chaotic changes and trends in temporal structures, the chronomes of variables in us and around us. Rhythmic elements of biological chronomes with a common genetic origin (in the sense of a classical homology) may also have a common environmental cycle, responsible for their genetic coding in the first place. We postulate a broad physico-biological homology, as compared to the classical homology implying only a common genetic origin; we extend it to our make-up in time, as done conventionally with respect to a spatial morphology which leads to several rules of procedure. A physical near-match in our environment may be sought to each built-in biological rhythm; a biological circa-match may eventually correspond to each physical environmental rhythm; a third possibility, a biological rhythm with a missing natural environmental near-match, impossible to definitively prove, may be a challenge posed by an internal evolution.

The biological week, free-running from the social one, seemed to be a case in point; eventually, we found a weak near-match of 6.75 days in over half a century's data on K_p, now confirmed by physicists and extended by them to data covering over a century of data on aa. The about-weekly biological component's origin may nonetheless be in part the result of an integrative evolution, of a consensus *partium in tempore:* in its genesis, perhaps away from the daily alternation of light and darkness, requirements internal to an organism prevailed, perhaps at the bottom of a sea if not on another planet, to look into a weak weekly geomagnetic component, nearest to these internal needs, e.g., for growth and repair by processes that took several days. It also seems possible that the prominent weekly component in newborns of several species may recapitulate, as a living fossil, the scenario of billions of years ago, when natural physical environmental factors exhibited a much more prominent environmental week than can be found today. The two possibilities are not mutually exclusive. Complementarity characterizes an internal integrative and an external adaptive evolution.

Eight-hour rhythms at this time have no external near-match. Dynamic features of the physical environment in organisms provide information of interest to physicists. In this context, the slow motion of the ontogeny of multicellular organisms may yield information not available from prokaryotes and may be telescoped into an excessively condensed lifespan, even in unicellular eukaryotes.

Introduction

Like circadian and circannual rhythms, other bioperiodicities may also be associated with positive adjustment value and timing according to them can make the difference between survival and death. This point is considered for a circadecennian rhythm in human myocardial infarctions. Evidence from spectra and from cross-spectral coherence, the latter less unspecific than product-moment correlations, is strengthened in some cases (such as myocardial infarctions or microbial sectoring) by superposed epoch analysis, and by other remove-and-replace approaches. Some results are further safeguarded by pseudoepochs, equivalent to blanks in chemistry. These methods reveal biomedical associations of non-photic solar activity, triggering magnetic storms in space that are known to displace the flux of galactic cosmic rays. Storms and/or cosmic rays, directly or via other natural physical environmental factors (NPEF), trigger fatal myocardial infarctions on earth, by mechanisms involving heart rate variability, among other physiological endpoints.

Anthropometric morphological variables influenced by helio- and geomagnetics, are neonatal body weight, body length and head circumference, insofar as they undergo cycles of similar length, as does non-photic solar activity, and, as a further hint, they also show cross-spectral coherence with geomagnetic indices. A spectrum of rhythms in natural physical variables is shown on the left of Figure 1, and the spectrum of biological rhythms is shown on the right of the same figure. Some biological components correspond as near-matches to physical environmental cycles with different frequencies, characterized as different physical kinds, here subdivided roughly into photic and non-photic.

The amplitude (A) of these components gauges the extent of predictable change with a given frequency. The As associated with a presumed biological near-match of a non-photic environmental cycle such as one of ~21 or ~10.5 years, can be part of a ratio (in the numerator), being referred to the amplitude of a photic cycle, such as a biological day or year (in the denominator). These A ratios may then represent gauges of the relative importance of photic and non-photic solar effects in biota. Along this line of thought, the amplitude of cycles regarded primarily as geophysical signatures, in the numerator of amplitude ratios, may then reflect the relative roles of geomagnetics and more broadly of NPEF. We assemble evidence to advocate global tests of any cyclic influences by NPEF on biota and the importance of a long-term coordinated physiological, archival and physical monitoring, not only for detecting further natural environmental effects on human and other life on earth, but also to examine the mechanisms of these effects and on this basis to develop countermeasures.

Archival monitoring with the analysis of time structures, chronomes, would become feasible at a relatively modest cost if all state health departments could provide for analysis by interested parties the records that most or many of them already collect. Improvements can be anticipated if data collection would be time-coded electronically in an internationally standardized way, while the recording itself, notably of natality, morbidity and mortality, whenever possible, is refined by including clock-hour and -minute. Physiological monitoring for scientific, broadly ecological purposes, currently opportunistic, could be systematized and coordinated with physical monitoring. The aligned physiological, morphological and pathological records, properly and accessibly archived, will serve epidemiologists and also physicists, once they are documented not only as sensitive but also as more or less specific radiation detectors that respond in a different way to various NPEF. The monitoring of vital functions will contribute to the individual's and thus to the community's health by detecting any risks, e.g., of vascular diseases such as strokes and myocardial infarctions, associated with NPEF. Eventually, countermeasures will have to be identified, notably for those who are about to venture to sites away from hospitals, such as certain polar regions and space. Once preventive measures are developed, a preferably automatic system of screening and acting upon detection of an enhanced risk is desirable.

Assessing ~10.5- and ~21-y rhythms: Focus on chronomes enlarges scope and reduces error

Problems at the interface of meteorology or geophysics with biology are often approached by ignoring rhythms, allowing these rhythms (if unassessed) to inflate a noise term. When assessed, the rhythms do more than deflate the noise term; by their characteristics, they reveal the critical, since predictable and important elements of broader time structures, the chronomes. Chronomes consist of rhythms, chaos and trends, and represent and quantify the physical and/or biological dynamics in and around us [1, 2].

The assumption that certain rhythms have anthropogenous components [3] is warranted, but there can be and are other natural physical rhythms as well. Unwarranted is, for instance, the view that about-weekly rhythms are purely social effects, to the point that natural near-weekly changes are not explored, e.g., in magnetic disturbance. Indeed, in a given setting, a precise weekly component may be present in both a physiological and social and further in a physical variable. But even this situation does not imply that geomagnetic disturbance or physiology each has *only* an anthropogenic precise 7-day component, a common assumption that must be tested, rather than a priori generalized. Prompted by biological concerns, a 6.75-day component

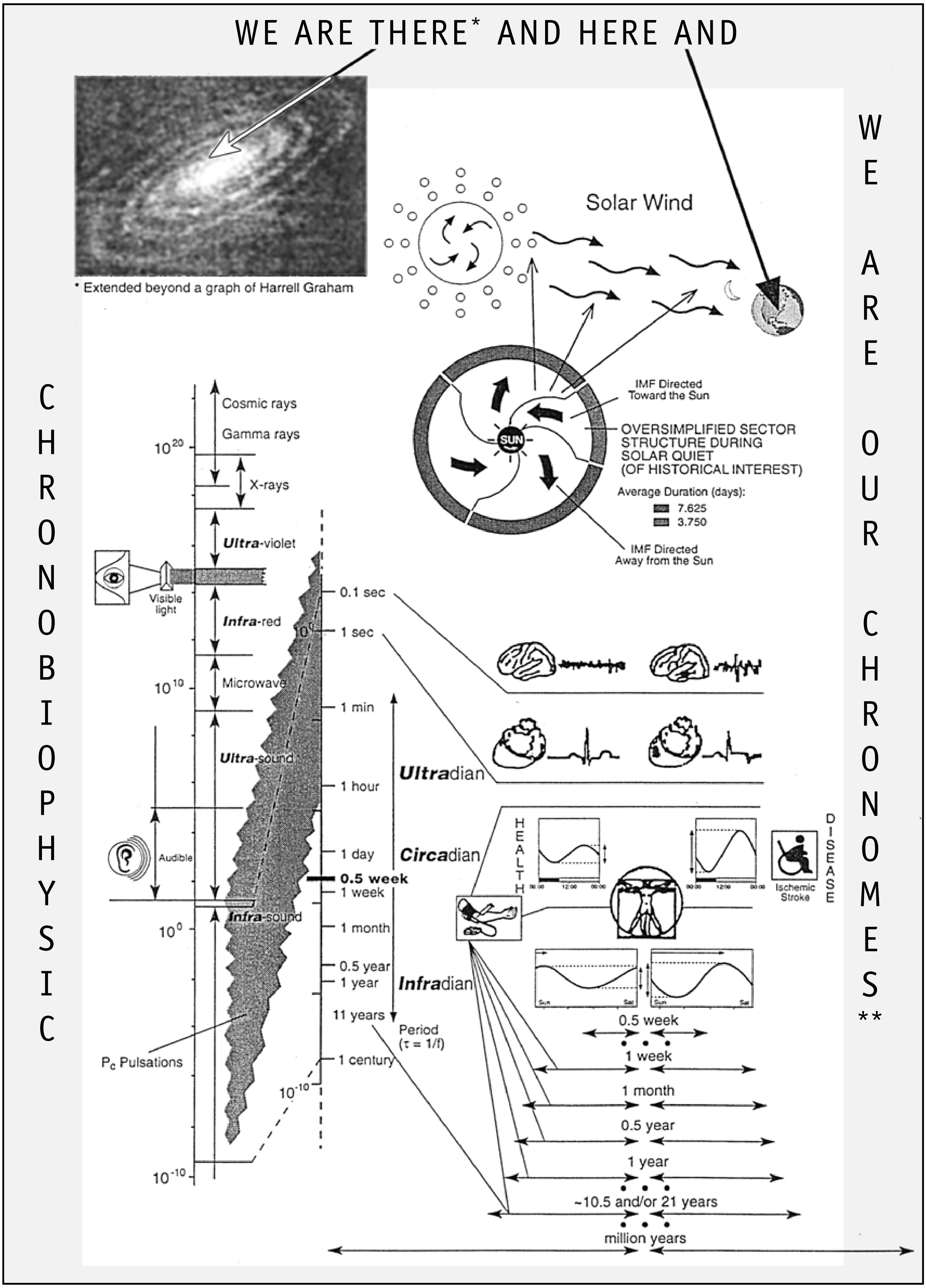


Fig. 1. ** Which further comprise age and other trends, including adaptive, integrative and cultural evolution toward a chrononoosphere, topics of chronobiology broadly.

was found to characterize the spectrum of over a half century's data on the geomagnetic disturbance index K_p [4]. This finding was confirmed and refined by the physicists Olson and Roederer for K_p [5] and extended, again by physicists, to data covering over a century on the related index aa [6]. Rather than focusing on one or a few anticipated rhythms, such as about 24-hour or about-yearly changes, when the data are dense and long enough in any one variable, it seems best to examine the whole chronome (chaos and trends as well as rhythms). For the rhythmic element of these structures, the spectrum that is assessable with the available density and length of a given observation span, may reveal previously not mapped candidate components. These in their turn can be examined in other series to see whether they can be confirmed. If so, they constitute validated evidence that justifies their anticipation in physics [4–6] or biology [1, 2, 4, 7].

Other instances are the most meritorious discoveries by reference to secularity, i.e., to variability along the scale of several years or even decades [8, 9]. In analyzing a time series of 20 years in the third millennium, it becomes possible for certain variables to anticipate about 10.5- and ~21-year rhythms, again not only in physics but also in biology [10–18], and to examine the validity of these rhythms by tests of the zero-amplitude assumption [2]. When the "no-rhythm" assumption is rejected (in keeping with a rhythm), one can next examine any differences, e.g., in period, between natural environmental variables and the biological series. Grave errors can thus be avoided, for instance in a middle-aged adult man whose 17-ketosteroid excretion can decline over several years. For the next several years, however, the excretion of these hormonal metabolites increases as part of a circadecennian rhythm, rather than as a function of an irreversible change with age [1]. Once the about 10-yearly change is mapped, it can be anticipated.

The cycle length itself in biological data series can be a signature of geomagnetics and may prompt focus on heretofore ignored effects. The extent of the effect can then be compared with the role of photic effects in the amplitude ratios discussed above. The risk of drawing incomplete, if not unjustified conclusions is particularly true when one deals with very wobbly sunspot activity, notorious for variability, but standing out nonetheless as recurrent in approximately 10.5- and 21-yearly cycles. By 1843, Samuel Heinrich Schwabe [19] recognized the importance of about 10.5-yearly (circadecennian) periodicities in solar activity, and George Ellery Hale [20] did likewise for about 21-yearly (circavigintunennian) rhythms in the early 20th century.

Cycles were deemed to be unimportant or were altogether missed by Galileo and others who started using telescopes, such as Scheinert, Fabricius and Harriot. Both in physics and biology, rhythms are still regarded as no more than confounders by many contemporary scientists. Very meritorious contributions with the best of methods [21, 22], however, eventually need to assess more than a full cycle, when, for instance, they consider the role of solar activity in relation to myocardial infarctions and to the field of heliobiology as a whole. Unjustified conclusions may be drawn, notably in studies of aging [1]. For solar effects on biota, maps need to be prepared of near-matches of heliogeomagnetic signatures, e.g., of about-weekly, about-half-yearly, about-10.5-yearly and about 21-yearly cycles, not only to deflate noise and clarify controversy, but in order to proceed eventually from temporal relations, on their basis, to the study of causal factors.

Premature extrapolation from data covering less than a solar cycle

We here consider the issue of deleterious (pathologic) and of other morphologic and physiological effects of magnetic storms by new and earlier analyses on data from Minnesota and elsewhere. We do so although, at least for the USA, the earlier claims by German [23, 24] and Russian [25–27] investigators had been refuted and heliobiology or cosmobiology had seemingly been laid to rest.

Mortality from all causes, from coronary heart disease, and from stroke in the US was studied in relation to solar activity as measured by the geomagnetic index, A_p, on a daily basis for the years 1964–66 and on a monthly basis for the years 1964–71. The data did not support previous assertions by Soviet researchers of an association between solar activity and cardiovascular mortality. [21]

One year later, Belinda Lipa et al. [22] complemented the foregoing summary, based on 8 years of data, with a study that also failed to support earlier findings or the proposal for a new branch of science, heliobiology. After summarizing 5 years of U.S. data, Lipa et al. added, very appropriately, that "it will be necessary to determine whether it [any association] is sensitive to geographical location, to phase of the solar cycle or to some other parameter which might distinguish the samples we have analyzed from those of the Soviet scientists" [22]. Indeed, we can here show for Minnesota that the solar cycle stage and solar cycle number are important parameters in a given geographic area, as revealed by the study of the time structure or chronome of time series covering several solar cycles [9–18].

Since the report by Lipa et al. [22], Russian scientists [28–30; cf. 31] have added further data, eventually doing so in cooperation with us [4, 32, 33]. Meanwhile, in the U.S., what has now become formal astrobiology [34–47] in the footsteps of G.A. Tikhov [48] had largely neglected any testable effects of geomagnetics, and ignored studies in the 1960s by the late Frank A. Brown Jr. [49, 50] and by Franklin H. Barnwell [51], as well as studies of the broader chronomes, encountered both in and around us [1, 2, 4].

Brown and Barnwell reported "subtle" effects of very weak geophysical forces and postulated that biological rhythms are externally timed by periodisms of natural geophysical frequencies, even in the organism kept in constant temperature and illumination. Brown concludes his contribution in 1965:

Whether or not, however, the extrinsic biological variations prove to be still sought timers of the circadian rhythms, they comprise a real element in the variations of terrestrial animals and plants. They are without question steadily contributing to the variations in the organisms, whether the latter are in the controlled constancy of the laboratory or are free in their natural habitats. [50]

Brown discussed biological time measurements first and foremost, but the foregoing statement brings his line of thought very close to a broader view of time structure. His proposal of autophasing is also very close to the free-running introduced with Earl E. Bakken [52] to be discussed below. Free-running helped to focus on a genetic component of rhythms, while Brown's "autophasing" argument [49, 50; see also 53, 54] may apply more appropriately to about-weekly or circaseptan rhythms among others related, perhaps, to the periodicities of the sun and moon, some of which are multiples or submultiples of several days, the multiseptans. Regrettably, Brown, an eminent physiologist, was attacked *ad hominem*[1] on general technical [55] and statistical [56] grounds by investigators who themselves mostly refrained from examining the actually criticized data by the results of inferential statistical meta-analyses, corrected for multiple testing. Instead, findings on "unicorns" served to remind the reader of Slutsky's important caveat, now a truism for the initiated, that spurious periodicities can occur [57].

Scenario by implication: magnetic storms are not mentioned as a health hazard

At this time, magazine headlines [58; cf. 59] report that stormy weather in extraterrestrial space blacks out within 8 minutes radio transmissions by ultraviolet and X rays travelling at the speed of light; threaten, within half an hour, by highly energetic particles, satellites and high-flying jets such as the Concorde; and within 2–4 days endanger power grids by masses of solar particles shaking the earth's magnetic field. NATO symposia rightly focus on such potential hazards mainly from the viewpoint of physics this year [60]. It is to Juan Roederer's credit [5], as a transdisciplinary physicist [61], that he aligned biological with biophysical spectra [62, 63], persuaded to look into this field by Tamara Breus [64]. Elena V. Syutkina [65], in turn, assembled a special session of an academy of medical sciences to endorse the biomedical relevance of coordinated mapping of biological and of NPEF chronomes. Beyond including a report on storms in space into routine weather reports, because they are health hazards, the chronome mapping is essential for basic biology and physics, and it is within the very scope of those who identify astrobiology solely as a concern with the origins of terrestrial and any extraterrestrial life [47]. Medically, the genetically encoded but environmentally influenced rhythms are the basis for self-help in health care on earth and more so in extraterrestrial space, since they allow detection of earliest abnormality that occurs within the otherwise neglected range of everyday physiology [1, 2]. A transdisciplinary meeting toward this goal, to be held next year, is being arranged by Tamara Breus with Ioannis Daglis [68] and its scope for the broader public which may indeed benefit from a space weather report, would be much broader in applied and basic science as well.

How about biohazards?

Some biological associations of indices used in space and earth physics are summarized in Table 1. One series available for analysis covers a span of ten Schwabe or five Hale cycles, Figure 2, as the first entry in Table 1. The time span covered by the data is less in other entries. It must be remembered that, e.g., in anthropometric population statistics, one does not deal with a single 21-year cycle in data covering 21 years of body lengths of millions of newborns. Behavior over a single cycle usually depends, rather than on a single extreme individual, on the physiology of a population as a whole. The "single" 21-year population cycle may thus signify that a majority of individuals have similarly timed physiology, contributing consistent data to the rhythm of the population. If so, the argument that one cannot speak of (repetitive) rhythms when a population series barely covers one or a few cycles has to be qualified along this line of thought, notably if the series does not have outliers.

Reinforced by this consideration, several lines of solid evidence based on data from large populations are in hand to advocate the existence of a critical mass of information in a budding chronoastrobiology. Population statistics on samples of millions of cases suggest some degree of generality for what is also seen in a scientist measuring a dozen physiological variables on himself longitudinally, about 5 times a day on the average, for over 3 decades, or in a physician who measured his blood pressure and heart rate automatically, with very few interruptions, every half-hour for 13 years, and

[1] By innuendo, e.g., by associating a "fabulous animal possibly based on faulty descriptions of the rhinoceros," the unicorn, with reference not only to intact mammals, "but to slices of living vegetables," a clear reference to potatoes studied by Brown [53, 54].

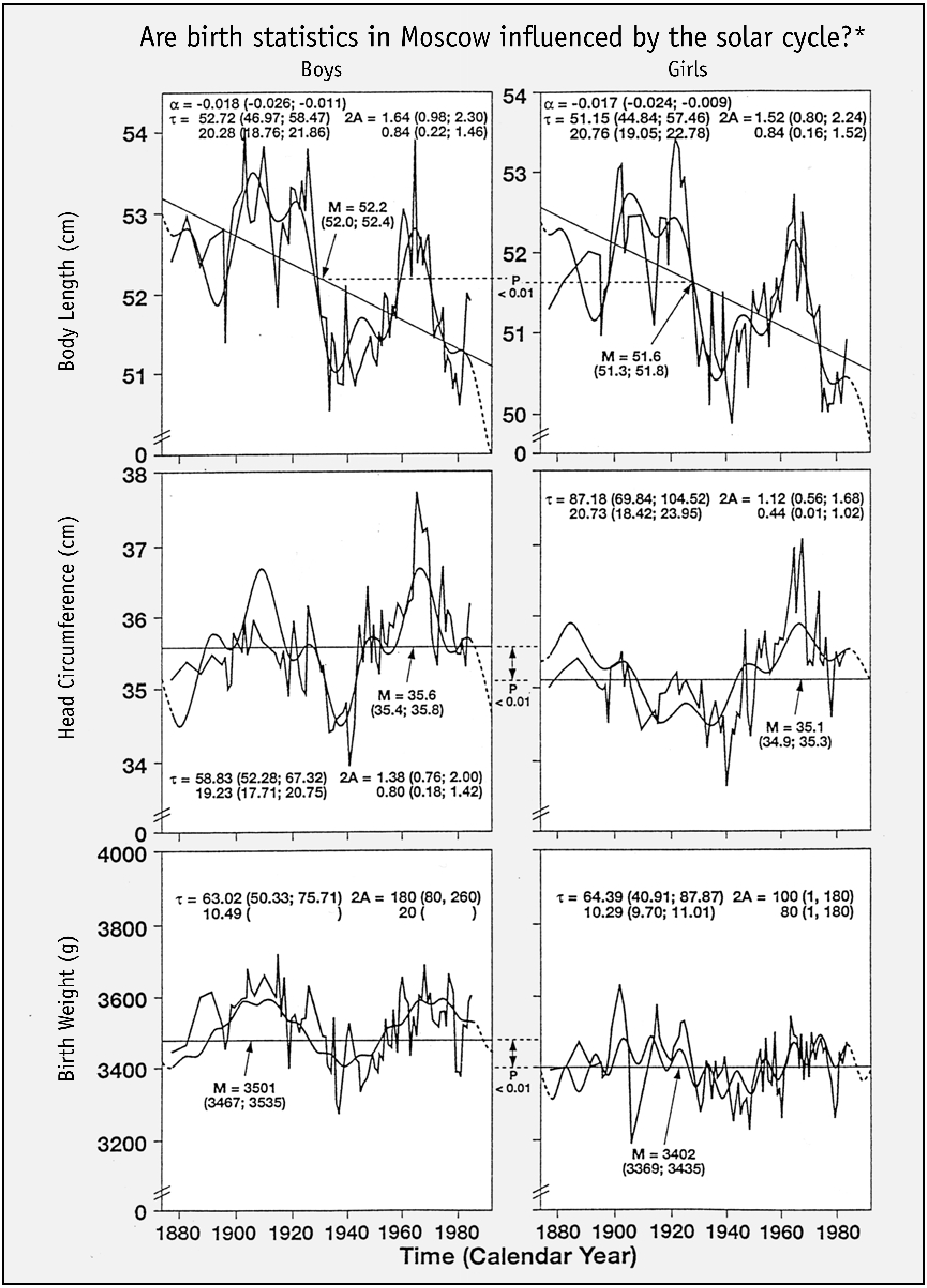


Fig. 2. * Recorded over 112 years (1874–1985). Nonlinear analyses yield estimate of period (τ, years), double amplitude (2A), MESOR (chronome-adjusted mean; M) and slope (α) with 95% confidence limits.

Table 1. Biomedicine, solar activity and terrestrial magnetism: inferential statistical analyses¶

Study (reference) *Design** *Variable(s)**	*Location (latitude [geographic/geomagnetic])*	*Population* *Sample Size* *Age (years)*	*Sampling* span	 interval	*Results** Spectral components	 Cross-spectral coherence (frequency) [period]
I. Data longitudinally covering up to 10 Schwabe (about 10.5-year) cycles on height and other morphology¶¶						
1. Weber et al. [1] T BH	Austria (49.02°N/48.57 [north-ernmost]-46.27°N/46.08 [southernmost])	Male recruits 507,125 18	10 years	monthly	After detrending (linearly): about 10-yearly component modulating circannual variation	With Kp: 0.813 (2.20 year^{-1}) [5.45 months] With sunshine: 0.545 (1.90 year^{-1}) [6.32 months] 0.963 (0.90 year^{-1}) [13.33 months] (using 22 degrees of freedom)
2. Weber et al. [2] T BH	Austria (49.02°N/48.57 [north-ernmost]-46.27°N/46.08 [southernmost])	Male recruits 713,162 18	14 years	yearly	After detrending (linearly): common about 9.25-year component consistent among recruits from 8 separate socio-economic strata	
3. Nikityuk (3, 4; u.p.†) T i. BH; BW; HC ii. CC; AC	Moscow, Russia (55.45°N/50.76)	Russian babies 25–150/year Birth	i. 112 years ii. 41 years	yearly	About 10.5- and/or 21-year cycles	BH with Kp: 0.819 (0.143 year^{-1}) [6.99 years] BW with Kp: 0.867 (0.143 year^{-1}) [6.99 years] (using 10 degrees of freedom)
4. Nikityuk (3, 4; u.p.†) T BH; BW; HC; CC; AC	Alma-Ata, Kazakhstan (43.19°N/33.67)	Russian and Kazakh babies 25–150/year Birth	40 years	yearly	About 10.5- and 21-year cycles with common characteristics for different endpoints	
5. Cornélissen [3, 4; u.p.†] T BW	Minnesota (45.00°N/55.00)	Newborns 2,150,122 Birth	33 years	yearly	About 21-year cycle	
6. Otto et al. [5] T BH; BW	Germany: Berlin (52.31°N/52.06) & Leipzig (51.20°N/51.19)	Newborns 574,600 Birth	1959; 1961; 1963; 1964	monthly	About-yearly and half-yearly changes	
7. Henneberg and Louw [6] T BH; BW (z-score)	South Africa (33.56°S/-32.70)	Impoverished rural schoolchildren 1,522 6–18	1 year	monthly	About-yearly change in BW and half-yearly variation in BH	
8. Garcia et al. [7, 8] H BH; BW	La Coruña, Spain (43.22°N/47.40)	Newborns 674 Birth	0–16 months	about-monthly	About-yearly and half-yearly components, more prominent by reference to the time of birth, i.e., as a partly endogenous function of age, than by reference to a fixed calendar date, i.e., as a function of exogenous factors such as sunlight, temperature and nutrition	

Study (reference) Design* Variable(s)*	Location (latitude [geographic/geomagnetic])	Population Sample Size Age (years)	Sampling span	Sampling interval	Results* Spectral components	Results* Cross-spectral coherence (frequency) [period]
II. Supportive evidence on human pathology						
9. Cornélissen et al. [9] T incidence	Worldwide	Morbidity 6,304,025 (largest only) Various ages	meta-analysis of 47 studies		About-weekly and half-weekly patterns of incidence of cardiovascular morbid events	
10. Halberg et al. [10] T incidence	Moscow, Russia (55.45°N/50.76)	Morbidity 6,304,025 Various ages	3 years	daily	About-yearly incidence of cardiovascular morbid events and half-yearly pattern of incidence of epileptic attacks	MI with Kp: 0.51 (0.315 day^{-1}) [3.17 days] MI with Bz: 0.58 (0.315 day^{-1}) [3.17 days] (using 25 degrees of freedom)
11. Düll and Düll [11] T morbid events	Copenhagen, Denmark (55.43°N/55.19)	Adults 36,000 Various ages	5 years	daily	Maximal cross-correlation between magnetic storms and mortality at 1-day lag on data summarized by superimposed epochs in relation to peaks in geomagnetic disturbance ("electron invasion")	
12. Faraone et al. [12] T sectoring in colonies of microorganisms	Milan & Rome, Italy (45.28°N/46.31 & 41.53°N/41.89)	Colonies of air bacteria and *Staphylococ-cus aureus* 200–250/day	12.5 (air) and 7 (staph) years	daily	Prominent components resembling time structure of Kp and WN, notably with periods of about 5 and 0.5 years	Air bacteria with Dst: 0.647 (0.054 day^{-1} [18.6 days]) Staph with Kp: 0.700 (2.262 $year^{-1}$ [0.442 year]) and 0.660 (0.303 day^{-1} [3.3 days], using 20 degrees of freedom)
III. Supportive evidence on human physiology						
13. Portela et al. [13] L BP	USA (45.00°N/55.00; 45.33°N/51.42; 42.19°N/53.20)	Adult males 3 20; 65; 71	14; 15; 26 years	5–6/day; 2/day; about-weekly	About 11-year cycles paralleling solar activity	
14. Cornélissen et al. [14] H HR	USA (45.00°N/55.00 [2]; 41.18°N/52.19; 34.00°N/41.01; 47.17°N; 47.53)	Adults 5 28–81	5 selected spans between Aug 1967 and Apr 1975	1–6/day (N: 382–2840)	About 11.6-year cycle; remove-and-replace approach showing resonance of about 7-day component with corresponding variation in solar activity. When the sun "removes" an about 7-day component from the spectrum of its velocity changes, the circaseptan HR amplitude is smaller.	
15. Baevsky et al. [15] H HR	Space (Soyuz spacecraft)	Russian cosmonauts 49 25–50	2–15 min	beat-to-beat	About 30% reduction in HR variability (gauged by standard deviation of R-R intervals) during magnetic storms vs. quiet days in extraterrestrial space	

Table 1

Study (reference) *Design** *Variable(s)**	*Location (latitude [geographic/geomagnetic])*	*Population* *Sample Size* *Age (years)*	*Sampling* span	*Sampling* interval	*Results** Spectral components	*Results** Cross-spectral coherence (frequency) [period]
I. Data longitudinally covering up to 10 Schwabe (about 10.5-year) cycles on height and other morphology¶¶						
16. Syutkina et al. [16] H BP; HR	Moscow, Russia (55.45°N/50.76)	Newborns 32 First month of life	up to 20 days	15 min	Correlation between nonlinearly-determined period of about 7-day component of BP and HR vs. local magnetic disturbance (K)	With K: >0.70 (around 0.3 day^{-1} and around 0.14 hour^{-1}) [3.33 days and 8.77 hours] (using 10 degrees of freedom)
17. Halberg et al. [10] L BP; HR; blood pH	Minneapolis, Minnesota, USA (44.59°N/54.60)	Premature baby 1 Birth	up to 26 months	up to 1–5/day; denser at outset	Near-match of some spectral peaks of BP and HR vs. Kp	DBP with Bz: 0.74 (2.0 week^{-1}) [3.5 days] (using 14 degrees of freedom)
18. Halberg et al. [17; u.p.†] L BP; HR	Ancona, Italy (43.37°N/ 43.48)	Adult woman 1 28	1 year (267 days in isolation from society)	15–30 min	Closeness of nonlinearly-determined period of about-half-weekly component of HR vs. Kp during isolation	HR: -with Kp: 0.558 (0.045 hour^{-1}) [22.22 hours] -with CR: 0.524 (0.138 hour^{-1}) [7.25 hours] -with 3hCR-SD: 0.546 (0.153 hour^{-1}) [6.54 hours] (using 22 degrees of freedom)
19. Watanabe et al. [18] L BP; HR	Tokyo, Japan (35.42°N/25.75)	Adult man 1 35 (at start)	3 years	15–30 min		With Kp: >0.5 (0.036 day^{-1}) [27.8 days] (using 26 degrees of freedom)
20. Watanabe [3, 19; u.p.†] L BP; HR	Tokyo, Japan (35.42°N/25.75)	Adult man 1 35 (at start)	11 years	15–30min monthly summary	About 10.5-year component in mean and SD of HR and in SD of SBP	HR with WN: 0.664 (1.636 year^{-1}) [7.33 months] (using 14 degrees of freedom)
21. Halberg et al. [10] L BP; HR	Minneapolis, Minnesota, USA (44.59°N/54.60)	Adult man 1 68 (at start)	4 years (with interruptions)	15–30 min	About 5% increase in HR during magnetic storm and in BP on day preceding a magnetic storm on earth	
22. Sothern (RBS) [3, 20, 21; u.p.†] L BW; SBP; DBP; HR; RR; PEF; TE; EH; mood; vigor	St. Paul, Minnesota, USA (45.00°N/55.00)	Minnesotan clinically healthy man 1 20.5 (at start)	30.8 years	1–6/day (N > 50,000/ variable; total N».5 million values)	About 10.5- and 21-year as well as yearly (P<0.001) cycles	With Kp: 0.740 (2.03 year^{-1}) [5.91 months] (using 22 degrees of freedom) [Cross-correlation with Kp of BP and HR maximal near lag 0]
23. Halberg et al. [22; unpublished] L Urine volume; urinary 17-ketosteroid excretion	Copenhagen, Denmark (55.43°N/55.19)	Clinically healthy man 1 44–59 years	15 years	daily	About 9.28 y (17-KS) or 4.18 y (UV), 1.0 y, 7 d and 3.5 d components, the latter two free-running from social schedule for 17-KS during last 3 y when subject self-administered testosterone	17-KS with Kp: 0.588 (11.98 year^{-1} [4.36 weeks] using 20 degrees of freedom)

Study (reference) Design* Variable(s)*	Location (latitude [geographic/geomagnetic])	Population Sample Size Age (years)	Sampling: span	Sampling: interval	Results*: Spectral components	Results*: Cross-spectral coherence (frequency) [period]
IV. Modulating role of melatonin?						
24. Tarquini et al. [23] H melatonin (MEL)	Florence, Italy (43.78°N/ 44.26)	Adults 172 20–90	3 years	4-hourly for 24 hours	About-yearly variation in MEL during daytime but half-yearly changes during nighttime at latitude of 43.47°N; half-yearly variation at 65.00°N around noon	
25. Maggioni et al. [24] H Melatonin	Milan, Italy (45.28°N/ 46.31)	Women in 3rd trimester of pregnancy (14 healthy and 11 IUGR)	1 year	4-hourly for 24 hours	About half-yearly variation found only in IUGR group, with 1.0 y A and 0.5 y (A,ϕ) difference between the two groups	
V. Theoretical Computations						
26. Ulmer et al. [25]	For a field of about 1 nT typical of a magnetic field associated with the human circulatory system and with the interplanetary magnetic field, the oscillating period of some ions found in cells (Na^+, K^+, Ca^{++}, Mg^{++}) is about one week and that of some proteins (albumin, hemoglobin) is about 1 month, both periods corresponding to prominent components in the time structure of human physiology (computations based on Earth's magnetic field of 0.5×10^{-4} T typically found at mid latitudes for ions or molecules in a vacuum)					

¶Some analyses or meta-analyses in the Chronobiology Laboratories of the University of Minnesota in Minneapolis, Minnesota; a review of the vast literature is beyond the scope of this table.

¶¶In dealing with biomedical equivalents of the about 21-year Hale cycle (and there are components with even lower frequencies and even larger amplitudes in our anthropometric data), one cannot collect too many cycles over a single lifetime and turns for replications to populations; in the case of each of the population rhythms, one deals with findings on many individuals' cycles, as in the case of findings covering 112 years of population anthropometry; in each of the two studies by Weber et al.[1,2], over half a million individuals must be sufficiently concordant to allow a demonstration of the 10-year population rhythm. The 30.8 years of self-measurements of over 10 variables around the clock for a total of over half a million values provide a longitudinal validation check, supporting other evidence collected transversely, by virtue of (bio)ergodicity properties (that is the consistency of findings made transversely on populations and longitudinally on individuals, notably in relation to temporal characteristics of a process, assumed to be [bio]stationary in the sense of reproducibility of some of its characteristics).

*Strengthening and broadening the scope as to mechanisms of the propositions of Weber et al.[1] by cross-spectral coherence, superimposed epochs, and remove-and-replace approach, among other analyses on even larger and more diverse data sets. Results thus obtained reveal not only about-yearly rhythms but also other components with periods ranging from half a week to about 21 years that are not shared with sunshine. Overall, the evidence points to mechanisms complementing sunshine effects, including geomagnetic disturbance effects that may be mediated via intermodulations involving melatonin produced by the pineal gland.

Cross-spectral coherence coefficients have in common with correlation coefficients that they describe the relation between two variables. Cross-spectral coherence coefficients are less unspecific in that they describe the relationship at a specific frequency. In order to avoid listing spurious associations, only cross-spectral coherence coefficients away from spectral peaks are listed herein.

L = longitudinal; T = transverse; H = hybrid (linked cross-sectional).

BH = body height; BW = body weight; HC = head circumference; CC = chest circumference; AC = abdomen circumference; BP = blood pressure (S=systolic; D=diastolic); HR = heart rate; RR = respiratory rate; PEF = peak expiratory flow; TE = 1-minute time estimation; EH = eye-hand coordination; MI = myocardial infarctions; MEL = circulating melatonin; Kp = geomagnetic disturbance index; WN = Wolf number of solar activity; Bz = vertical component of interplanetary magnetic field; CR = cosmic ray intensity; 3hCR-SD = 3-hour standard deviation of CR; SD=standard deviation.

†u.p. = unpublished

TABLE REFERENCES

1 Weber GW, Prossinger H, Seidler H. Height depends on month of birth. Nature 1998; **391**:754–755.
2 Weber GW, Seidler H, Wilfing H, Hauser G. Secular change in height in Austria: an effect of population stratification? Ann Hum Biol 1995; **22**:277–288.
3 Cornélissen G, Halberg F, Schwartzkopff O, Delmore P, Katinas G, Hunter D, Tarquini B, Tarquini R, Perfetto F, Watanabe Y, Otsuka K. Chronomes, time structures, for chronobioengineering for "a full life." Biomedical Instrumentation & Technology **33**:152–187, 1999.
4 Halberg F, Cornélissen G, Otsuka K, Syutkina EV, Masalov A, Breus T, Viduetsky A, Grafe A, Schwartzkopff O. Chronoastrobiology: neonatal numerical counterparts to Schwabe's 10.5 and Hale's 21-year sunspot cycles. In memoriam Boris A Nikityuk (Sept. 10, 1933–Sept. 30, 1998). Int J Prenat Perinat Psychol Med, in press.
5 Otto W, Reissig G. Zur Anthropologie der Neugeborenen. 4. Mitteilung. Länge und Gewicht der Neugeborenen in den verschiedenen Monaten. Monatsberichte der Deutschen Akademie der Wissenschaften zu Berlin 1963; **5**:549–559.
6 Henneberg M, Louw GJ. Further studies on the month-of-birth effect on body size: rural schoolchildren and an animal model. Am J Physical Anthropology 1993; **91**:235–244.
7 Garcia Alonso L, Hillman D, Cornélissen G, Garcia Penalta X, Wang ZR, Halberg F. Nature, not solely nurture: chronome as well as season governs growth patterns of infants. In: Chronocardiology and Chronomedicine: Humans in Time and Cosmos, Otsuka K, Cornélissen G, Halberg F eds, Life Science Publishing, Tokyo, 1993, p. 71–75.
8 Garcia Alonso L, Garcia Penalta X, Cornélissen G, Halberg F. About-yearly and about-monthly variation in neonatal height and weight. Scripta medica, in press.
9 Cornélissen G, Breus TK, Bingham C, Zaslavskaya R, Varshitsky M, Mirsky B, Teibloom M, Tarquini B, Bakken E, Halberg F, International Womb-to-Tomb Chronome Initiative Group: Beyond circadian chronorisk: worldwide circaseptan-circasemiseptan patterns of myocardial infarctions, other vascular events, and emergencies. Chronobiologia 1993; **20**:87–115.
10 Halberg F, Breus TK, Cornélissen G, Bingham C, Hillman DC, Rigatuso J, Delmore P, Bakken E, International Womb-to-Tomb Chronome Initiative Group: Chronobiology in space. Keynote, 37th Ann Mtg Japan Soc for Aerospace and Environmental Medicine, Nagoya, Japan, November 8–9, 1991. University of Minnesota/Medtronic Chronobiology Seminar Series, #1, December 1991, 21 pp. of text, 70 figures.
11 Düll T, Düll B. Zusammenhänge zwischen Störungen des Erdmagnetismus und Häufungen von Todesfällen. Deutsch med Wschr 1935; **61**:95–97.
12 Faraone P, Cornélissen G, Katinas GS, Halberg F, Siegelova J. Astrophysical influences on sectoring in colonies of microorganisms. Abstract, MEFA, Brno, Czech Rep, Nov. 3–6, 1999, in press.
13 Portela A, Northrup G, Halberg F, Cornélissen G, Wendt H, Melby JC, Haus E. Changes in human blood pressure with season, age and solar cycles: a 26-year record. Int J Biometeorol 1996; **39**:176–181.
14 Cornélissen G, Halberg F, Wendt HW, Bingham C, Sothern RB, Haus E, Kleitman E, Kleitman N, Revilla MA, Revilla M Jr, Breus TK, Pimenov K, Grigoriev AE, Mitish MD, Yatsyk GV, Syutkina EV. Resonance of about-weekly human heart rate rhythm with solar activity change. Biologia (Bratislava) 1996; **51**:749–756.
15 Baevsky RM, Petrov VM, Cornélissen G, Halberg F, Orth-Gomér K, Åkerstedt T, Otsuka K, Breus T, Siegelova J, Dusek J, Fiser B. Meta-analyzed heart rate variability, exposure to geomagnetic storms, and the risk of ischemic heart disease. Scripta medica 1997; **70**:199–204.
16 Syutkina EV, Cornélissen G, Grigoriev AE, Mitish MD, Turti T, Yatsyk GV, Pimenov K, Breus TK, Studenikin MY, Siegelova J, Fiser B, Dusek J, Johnson D, Halberg F. Neonatal intensive care may consider associations of cardiovascular rhythms with local magnetic disturbance. Scripta medica 1997; **70**:217–226.
17 Halberg F, Cornélissen G, Sonkowsky RP, Lanzoni C, Galvagno A, Montalbini M, Schwartzkopff O. Chrononursing (chronutrics), psychiatry and language. New Trends in Experimental and Clinical Psychiatry 1998; **14**:15–26.
18 Watanabe Y, Hillman DC, Otsuka K, Bingham C, Breus TK, Cornélissen G, Halberg F. Cross-spectral coherence between geomagnetic disturbance and human cardiovascular variables at non-societal frequencies. Chronobiologia 1994; **21**:265–272.
19 Watanabe Y, Cornélissen G, Sothern RB, Nikityuk B, Bingham C, Grafe A, Halberg F. Numerical counterparts to sunspot cycles in human blood pressure and heart rate variability. In: Proc 3rd International Symposium of Chronobiology and Chronomedicine, Kunming, China, October 7–12, 1998, p. 145.
20 Cornélissen G, Watanabe Y, Sothern RB, Grafe A, Bingham C, Halberg F. Dangers of correlation analyses assessing solar cycle stage-dependence of human blood pressure and heart rate. In: Proc 3rd International Symposium of Chronobiology and Chronomedicine, Kunming, China, October 7–12, 1998, p. 143.
21 Sothern RB, Cornélissen G, Bingham C, Watanabe Y, Grafe A, Halberg F. Solar cycle stage: an important influence on physiology that must not be ignored. In: Proc 3rd International Symposium of Chronobiology and Chronomedicine, Kunming, China, October 7–12, 1998, p. 144.
22 Halberg F, Engeli M, Hamburger C, Hillman D. Spectral resolution of low-frequency, small-amplitude rhythms in excreted 17-ketosteroid; probable androgen induced circaseptan desychronization. Acta endocrinol (Kbh) Suppl 103, 5–54, 1965.
23 Tarquini B, Cornélissen G, Perfetto F, Tarquini R, Halberg F. Chronome assessment of circulating melatonin in humans. In vivo 1997; 11:473–484.
24 Maggioni C, Cornélissen G, Antinozzi R, Ferrario M, Grafe A, Halberg F. A half-yearly aspect of circulating melatonin in pregnancies complicated by intrauterine growth retardation. Neuroendocrinology Letters 1999; **20**:55–68.
25 Ulmer W, Cornélissen G, Halberg F. Physical chemistry and the biologic week in the perspective of chrono-oncology. In vivo 1995; **9**:363–374.

others whose around-the-clock series for years also allow an exploration of infradians [4, 10, 11]. In this perspective, the Table 1 results suffice to warrant chronome mapping, at a rate that should be comparable to genome mapping. Transdisciplinary knowledge that may thus result should enhance the gain from genome mapping by identifying the molecularly coded bases for everyday physiology in its broadest sense, far beyond investigations on the genetic basis of biological time measurement, a step in the right direction. Otherwise nearly exclusive current focus by genomics upon pathology could gain first in clarifying the mechanism underlying everyday physiology, second by using the information thus gained for a much more complete attack on pathological consequences of physiological alterations in the normal range, and third both physiological and pathological biological chronomes may be of interest to physics as new endpoints for current effects of NPEF, and for a look via ontogeny and phylogeny at physical aspects of worlds before ours.

The scenario of the last half of the 20th century, when the validity, ubiquity, importance and usefulness of about 24-hour rhythms and then of about-yearly patterns and eventually of circaseptans, needed to be established, may repeat itself along the scale of decades. Space and other governmental agencies whose mandates are directly involved in the study of about 10.5- and about 21-year rhythms could provide the financial support that is their mandate, since few investigators can afford to make funding provisions for studies covering the required number of cycles prospectively.

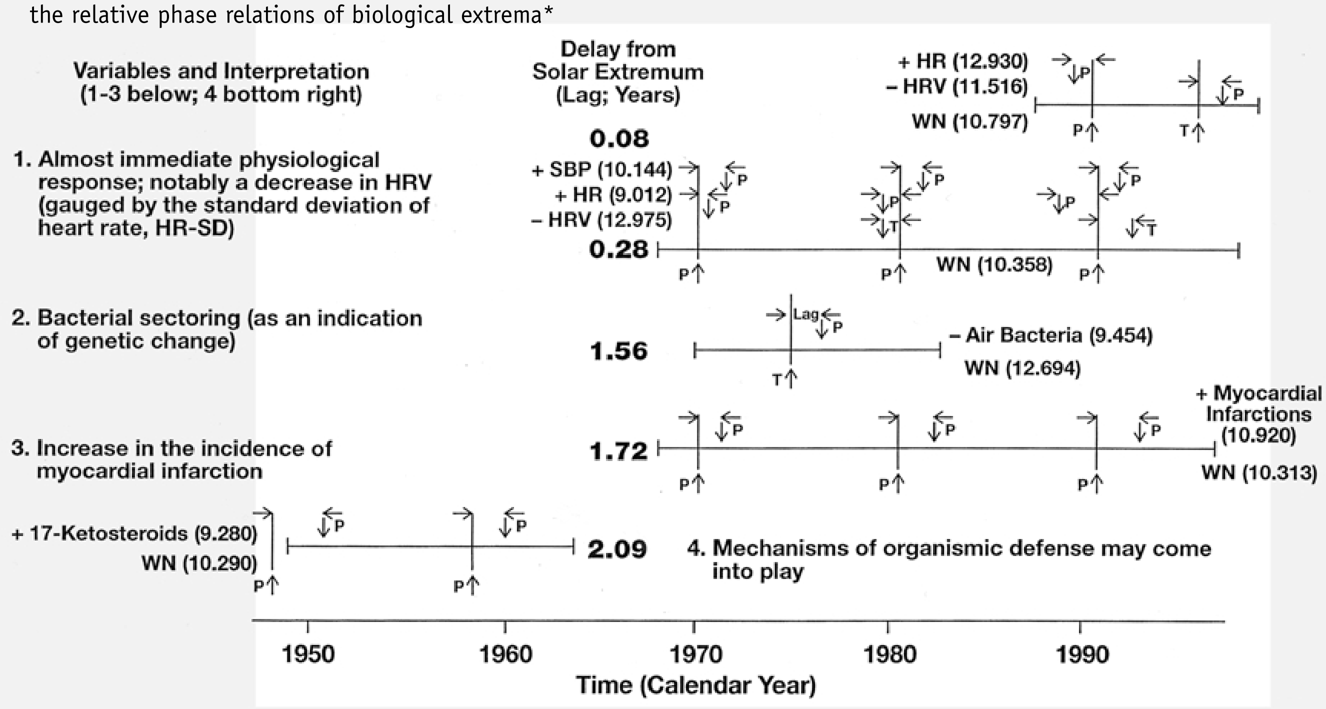
Industry should also realize opportunities for developing and mass-producing instruments that, albeit a sine qua non for ventures in extraterrestrial space, are also critical on a much broader scale for preventive health care, notably for catastrophic vascular disease prevention on earth [10, 11]. The necessary hardware and software is now state-of-the-science for laboratory animals. It should be implemented for use in preventive human health care of sensitive endpoints from the now-generally recognized circadian rhythms [52, 63, 69–72]. These were found to be partly endogenous, inferentially statistically validatable phenomena, nearly half a century ago [73, 74]. The developments leading to the recognition of ubiquitous and important circadians, started by 1950, were formulated as a science in its own right, as chronobiology, by 1969 [63]. In the 1950s, the mapping of circadians took some sleepless nights, while that of about-weekly and about-yearly changes was more prolonged. By comparison, however, the task of quantifying, with prospective designs, the biological counterparts of Schwabe's about 10.5-year (circadecennian) and Hale's about 21-year (circavigintunennian) cycles is more demanding, because it takes longer but also when the signal-to-noise ratio tends to be less favorable than that of about-daily and, in some cases, of about-yearly rhythms, Table 2.

The documentation of circadecennians and circavigintunennians in human heart rate and blood pressure is greatly facilitated by the availability of automatically and ambulatorily functioning hardware and software. The cycles in themselves have to be mapped, and while this is ongoing, rather than waiting for the completion of cycles covering, e.g., 50 years, Figure 2, their mechanisms must be explored in as-one-goes tests of factors from within and without. In this context, combined approaches by superposed epochs have revealed non-photic effects from the sun. The cycles in and around us and cross-spectral coherence among them, Table 1, can provide answers concerning responses to magnetic storms that superposed epochs and other remove-and-replace approaches may complement but may not replace [18; cf. 4]. The short-term effects within hours or at most within days, e.g., of magnetic storms, may depend upon the stages of cycles with a lower frequency, as suggested but not (yet?) validated to be the case for effects of Forbush decreases on mortality from myocardial infarction in Minnesota as a function of circadecennian solar cycle stage [75]. Certainly there is a need to look at more than the day of a storm or the day following it. In the case of myocardial infarctions in Minnesota, Table 3, after a (compensatory) decrease in incidence on the day after the storm, there is a statistically significant linear increase in incidence during the six subsequent days (not shown).

An about-10-year periodicity in deaths from myocardial infarctions and in related variables, Figures 3 and 4, is now documented by 3 circadecennian cycles [11, 18]. Magnetic storms, directly or indirectly, also acutely trigger not only myocardial infarctions, but also strokes (and traffic accidents) on earth, Figure 4 [4, 11, 76–81]. Furthermore, they affect a putative mechanism of this hazard, human heart rate variability [82, 83; cf. 11]. The numerical near-matches of Schwabe's and Hale's cycles in biota in Table 1 and Figures 3 and 4 are hints; coherences in this same table suggest an association with NPEF for several aspects of human morphology, physiology and pathology; differences in phase as well as in period, reveal a complex geography-, solar cycle stage- and solar cycle number-dependent association of broad time structures, chronomes, in us with environmental chronomes in variables of the weather in space and on earth, Tables 2–4.

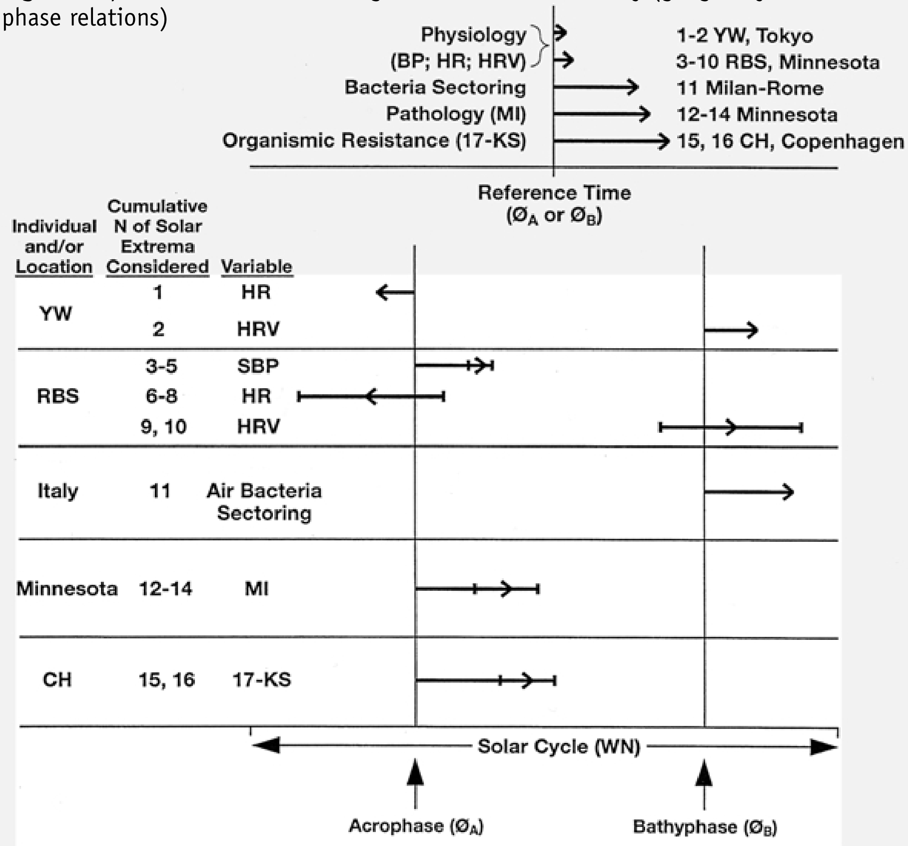
Among the physical proximate factors of the effect on heart rate variability, certain atmospheric pressure fluctuations deserve further testing [84]. Among organismic mediators, melatonin is implicated indirectly in view of geographic differences [85–89] and directly in view of studies on the nocturnal excretion of a melatonin metabolite in relation to geomagnetic disturbances [90], as is cortisol, since the adrenal glands constitute a critical mechanism for everyday physiology [52, 63, 69; cf. 91]. Other topics also await further study [92–96].

Fig. 3. About 10-yearly sequence of events following extrema of solar activity (gauged by Wolf number; WN) revealed by the relative phase relations of biological extrema*



* Depending on a postive (+) or negative (-) association of the given variable with WN.
(**S**)**BP**: (systolic) blood pressure; **HR**: heart rate; HR variability; Numbers in ( ) are nonlinearly estimated periods, in years; **P**: peak; **T**: trough; horizontal lines indicate spans of data availability.

Fig. 4. Sequence of events following extrema of solar activity (gauged by relative phase relations)



(**S**)**BP**: (systolic) blood pressure; **HR**: hear rate; **HRV**: HR variability, gauged by standard deviation; **MI**: myocardial infarction; **17-KS**: urinary 17-ketosteroid excretion; **WN**: Wolf number.

Table 2. Components resolved nonlinearly in longitudinal series of self-measurements recorded over 30 years and in Wolf number analyzed over corresponding span*

Variable (units)	*Trial periods only (years)*	Nonlinear estimates (95% CI) Period (years)			Amplitude (units)		
SBP	6.3	6.33	(6.00;	6.66)	1.67	(0.96;	2.38)
(mm Hg)	10.0	10.21	(9.05;	11.36)	1.24	(0.54;	1.93)
	1.0	1.01	(0.99;	1.02)	1.12	(0.44;	1.81)
	4.7	4.78	(4.42;	5.16)	0.81	(0.10;	1.52)
MAP	10.7	10.48	(9.50;	11.46)	1.55	(0.83;	2.27)
(mm Hg)	6.3	6.21	(5.83;	6.60)	1.41	(0.68;	2.14)
	1.0	1.01	(1.00;	1.02)	1.11	(0.41;	1.81)
	4.7	4.76	(4.33;	5.20)	0.73	(.001;	1.46)
	3.9	3.90	(3.65;	4.15)	0.83	(0.11;	1.55)
DBP	10.7	10.98	(10.09;	11.87)	1.84	(1.14;	2.54)
(mm Hg)	6.5	6.43	(5.97;	6.89)	1.24	(0.52;	1.95)
	1.0	1.01	(1.00;	1.02)	1.08	(0.39;	1.76)
	4.8	4.76	(4.30;	5.22)	0.68	(;	1.40)
	3.9	3.90	(3.67;	4.14)	0.89	(0.19;	1.60)
HR	15.0	16.53	(14.12;	18.94)	2.61	(1.59;	3.62)
(beats/min)	6.5	5.89	(5.48;	6.30)	1.67	(0.59;	2.75)
	1.0	1.00	(0.98;	1.01)	1.50	(0.45;	2.54)
	3.9	3.92	(3.71;	4.14)	1.35	(0.28;	2.42)
RR	4.5	4.48	(4.26;	4.72)	0.26	(0.10;	0.42)
(breaths/min)	3.5	3.57	(3.35;	3.78)	0.21	(0.06;	0.37)
	5.8	5.99	(5.35;	6.92)	0.15	(;	0.35)
	12.5	13.73	(10.13;	17.32)	0.19	(0.03;	0.35)
	7.9	7.24	(6.39;	8.29)	0.17	(;	0.36)
	1.0	0.99	(0.98;	1.01)	0.15	(.001;	0.30)
PEF	11.5	11.74	(10.36;	13.11)	3.84	(1.78;	5.90)
(L/min)	7.1	6.50	(5.97;	7.03)	3.29	(1.33;	5.26)
	2.4	2.42	(2.32;	2.51)	2.31	(0.36;	4.26)
	3.2	3.15	(2.96;	3.33)	1.97	(0.01;	3.93)
	4.2	4.21	(3.90;	4.53)	2.09	(0.12;	4.06)
	1.0	1.00	(0.98;	1.02)	1.86	(;	3.77)
Oral temperature	8.3	8.36	(7.66;	9.06)	0.07	(0.03;	0.11)
(°F)	25.0	26.58	(15.60;	37.56)	0.05	(0.02;	0.09)
	5.4						
	4.3	4.46	(4.15;	4.77)	0.04	(.001;	0.08)
	1.0	1.00	(0.98;	1.01)	0.04	(.001;	0.07)
TE	10.0	10.29	(9.38;	11.37)	1.08	(0.44;	1.72)
(sec)	2.9	2.94	(2.83;	3.05)	0.81	(0.18;	1.45)
EH	5.4	5.43	(5.03;	5.84)	0.68	(0.23;	1.12)
(sec)	7.1	6.90	(6.16;	7.65)	0.62	(0.21;	1.04)
	3.4;	3.50	(3.32;	3.68)	0.53	(0.11;	0.95)
	3.0	3.05	(2.92;	3.17)	0.57	(0.16;	0.97)
	11.5	17.20	(7.65;	26.75)	0.28	(;	0.67)
	2.3	2.34	(2.19;	2.48)	0.27	(;	0.66)
	1.0	1.01	(0.98;	1.03)	0.29	(;	0.67)
Mood	11.5	11.50	(10.11;	13.41)	0.19	(0.07;	0.32)
(AU)	6.2	6.26	(5.53;	6.99)	0.14	(.001;	0.27)
	25.0	21.00	(2.35;	39.65)	0.10	(;	0.23)
Vigor	4.3	4.33	(4.04;	4.62)	0.07	(0.01;	0.12)
(AU)	8.3	8.48	(7.33;	9.64)	0.07	(0.02;	0.12)
	1.0	1.02	(1.00;	1.04)	0.06	(.001;	0.11)
	6.0	6.21	(5.51;	6.91)	0.06	(.001;	0.11)
	3.5	3.42	(3.14;	3.69)	0.04	(.001;	0.09)
Sunspots	10.4	10.27	(10.06;	10.50)	65.97	(59.41;	72.53)
(Wolf number)	5.0	5.32	(5.07;	5.57;	13.87	(7.27;	20.47)

*RBS, a 20.5-year-old man in clinical health at the start of monitoring; 5–6 measurements were collected each day on most days and averaged monthly; components tested, selected from least-squares spectra, fitted concomitantly to residuals from trend assessed by stepwise linear regression, using a 6th-order polynomial at the outset; some trial periods from the complex model fitted whose statistical significance could not be ascertained are omitted. SBP: systolic blood pressure; MAP: mean arterial pressure; DBP: diastolic blood pressure; HR=heart rate; RR: respiratory rate; PEF: peak expiratory flow; TE: 1-minute time estimation; EH: eye-hand coordination. AU=arbitrary units (scale 1–10).

Table 3. Effect of Forbush Decrease (FD) in cosmic ray intensity on mortality from myocardial infarction (MI) in Minnesota*

% change in MI* relative to epoch mean + 100%		−1	Day FD	+1	Difference (day +1 vs. FD)
1968-1996		−0.275	+4.070	−3.795	7.865
(N=161)		± 2.128	± 2.240	± 1.916	± 3.585
	Student t	−0.129	1.817	−1.981	2.194
	P	NS	(0.071)	(0.049)	(0.030)
1979-1981†		−5.642	+2.801	+2.841	−0.041
(N=29)		± 5.614	± 6.548	± 4.551	± 9.781
	Student t	−1.005	0.428	0.624	−0.004
	P	NS	NS	NS	NS

*Epoch = 3 days, the day of the FD and the preceding (-1) and following (+1) days. NS=not statistically significant.
†Span for which a statistically significant effect of FD on the incidence of MI was found in Moscow, Russia.

Table 4. Myocardial infarctions in Minnesota from 1968 to 1996*

	MESOR (95% CI) (cases/day)	Period (95% CI) (years)	Amplitude (95% CI) (cases/day)
Original data (10.5 y cosine model)			
All 29 years (y)	12.19 (12.06; 12.33)	9.81 (9.61; 10.00)	1.15 (0.97; 1.34)
Original data (10.5 y cosine + linear trend model)			
All 29 y	12.16 (12.04; 12.28)	10.83 (9.93; 11.74)	0.40 (0.22; 0.57)
68-77 (10 y)	15.06 (14.83; 15.29)	8.03 (4.96; 14.76)	0.26 (−0.06; 0.59)
78-86 (9 y)	12.26 (12.05; 12.48)	12.10 (10.28; 15.17)	0.94 (−1.01; 2.89)
87-96 (10 y)	8.93 (8.75; 9.10)	—	—
Detrended data (10.5 y cosine model)			
All 29 y	−0.04 (−0.15; 0.07)	10.83 (10.00; 11.66)	0.40 (0.24; 0.56)
68-77 (10 y)	−0.22 (−0.43; −0.01)	11.48 (3.23; 19.72)	0.38 (0.09; 0.67)
78-86 (9 y)	0.20 (−0.61; 1.01)	10.64 (8.60; 13.28)	0.76 (0.45; 1.07)
87-96 (10 y)	−0.54 (−0.71; −0.38)	—	—

*Linear-nonlinear rhythmometry is used to resolve the best-fitting period which in this analysis is allowed to vary as a parameter rather than being fixed as in Table 5. Nonlinear analysis, just like the linear analysis in Table 5, failed to resolve the about 10-year periodicity for the span 1987-1996, another indication of the great variability encountered in the biological near-matches of the solar cycle just as in the solar cycle itself.
MESOR=**m**idline-**e**stimating **s**tatistic **o**f **r**hythm, a rhythm-adjusted mean; amplitude = measure of extent of change within one cycle; 95% CI=95% confidence interval.

Original link between myocardial infarctions and magnetic storms

An unusual opportunity to test the question of whether geomagnetics are health hazards arose when the senior author received from a solar physicist (see dedication) a data set of over 6,300,000 diagnoses, made in response to calls for an ambulance in Moscow during 3 years of an active sun (January 1, 1979, to December 31, 1981). These data had previously been analyzed in descriptive terms [30]. In our hands, a superposed epoch approach showed a modest yet statistically significant increase of about 7% in myocardial infarctions after an earthward turn of the north-to-south component, B_z, of the interplanetary magnetic field [4; cf. 32, 33]. As Figure 5 shows for Moscow (top left) (and Table 3 suggests for Minnesota), an increase in myocardial infarctions associated with the storm was followed by a decrease. (Another association suggested by superposed epochs related earthward turns of B_z to epilepsy [4; cf. 93].)

Our finding on 85,819 diagnoses of myocardial infarctions as a morbidity statistic [4] was reproduced on the same data set by Villoresi et al. after removal of periodic components [76] and was extended, again on the same data, to myocardial infarctions in association

Table 5. Differences among 3 consecutive solar cycles found by fit of 10.5-year cosine curve to daily mortality from myocardial infarction in Minnesota*

Cycle N	P (A=0)	MESOR ± SE		Amplitude (A) (95% CI)			Amplitude/ MESOR		Acrophase (95% CI)	
1	0.006	12.0 ±	0.1	0.36	(0.18;	0.53)	0.030	-135°	(-105;	-164)
2	<0.001	12.4 ±	0.1	0.76	(0.55;	0.96)	0.061	-145°	(-132,	-158)
3	0.830	12.1 ±	0.1	0.07	(	)	0.006	-144°	(,	)

Test of equality of parameters in the 3 cycles

Parameter(s)	df	F	P
MESOR	(2, 20)	11.296	0.0005
Amplitude	(2, 20)	12.820	0.0003
Acrophase	(2, 20)	0.231	0.7954
(A,ϕ)	(4, 20)	6.762	0.0013
(M,A,ϕ)	(6, 20)	9.586	<0.0001

*In data analyzed after removal of a linearly decreasing trend. MESOR=**m**idline-**e**stimating **s**tatistic **o**f **r**hythm, a rhythm-adjusted mean; amplitude and acrophase = measures of extent and timing of change within one cycle; 95% CI=95% confidence interval. Acrophase reference: 00:00 on 1 July 1967.

with another index of planetary geomagnetic activity, the aa index. Furthermore, there was also an association of myocardial infarctions with a (Forbush) decrease in the intensity of galactic cosmic rays, also used with B_z turns and aa increases as a third, albeit indirect index of magnetic storms [76]. These findings were extended even further, insofar as an increase in the incidence of strokes was first found in Moscow, Figure 5, again based on Forbush decreases [76], and was extended again to myocardial infarctions in St. Petersburg, Russia [77].

The importance of the findings had already been emphasized on the basis of our [4] and separate subsequent analyses of the Muscovite data [76] by Roederer [5], who called for further confirmations. These were forthcoming also from Mexico City [79], as from Minnesota [11] and thus strengthened the case of magnetic storm effects on myocardial infarction at various geomagnetic (and geographic) latitudes and on different continents. An association of pathology with Forbush decreases was further extended to strokes in Novosibirsk [78]. Studies in Slovakia suggested heliogeophysical effects on human sudden cardiovascular mortality [80] and traffic accidents [81].

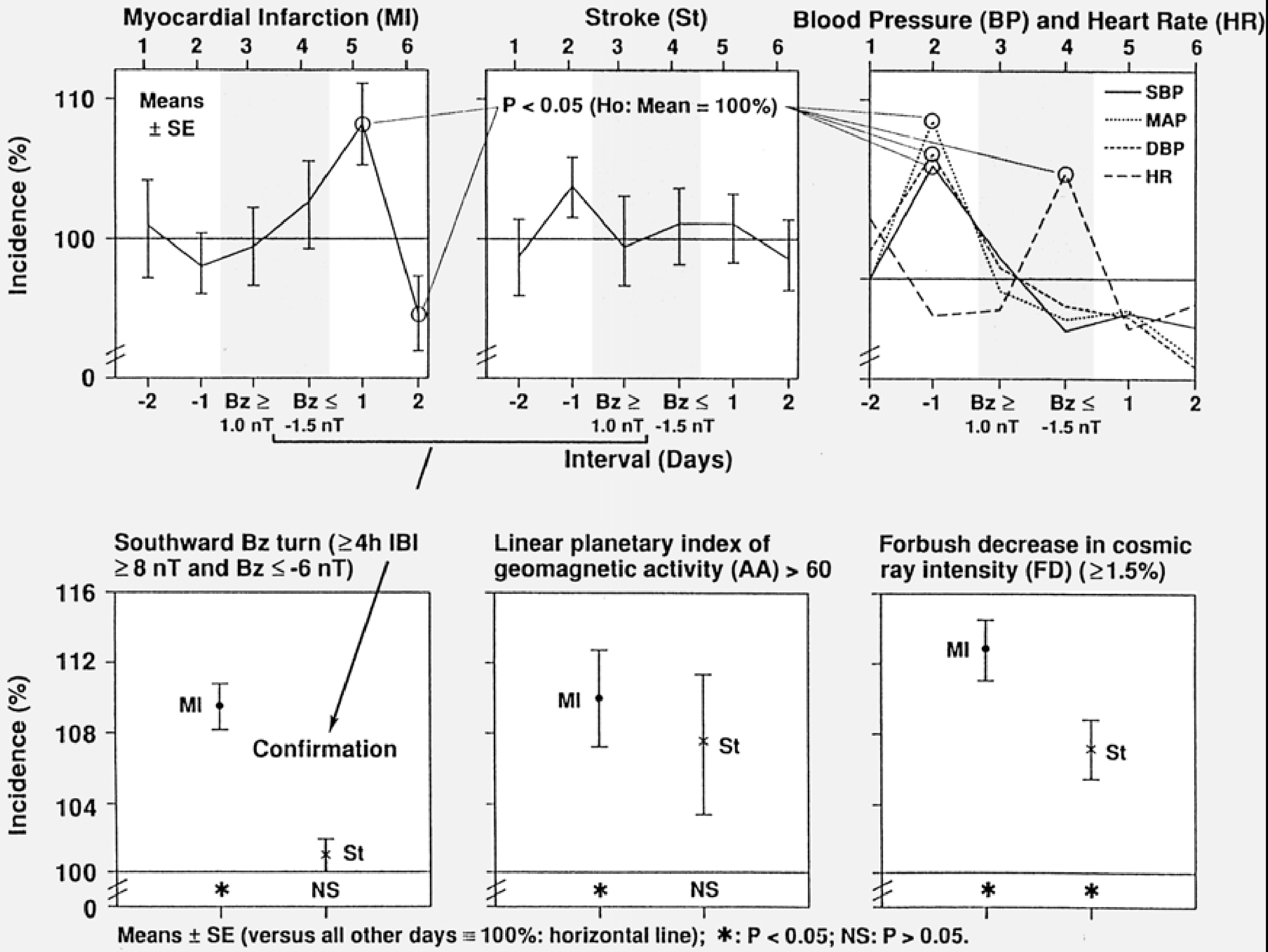
Population rhythm of deaths from myocardial infarctions

One of the two reports failing to detect a relation to geomagnetics of mortality from myocardial infarctions [22; cf. 21] rightly called for analyses by reference to solar cycle stage. We found intra- and inter-cycle differences both in mortality statistics from myocardial infarction and in longitudinal physiological data covering up to 3 solar cycles [82, 83; cf. 11]. In mortality from 129, 205 myocardial infarctions in Minnesota during the past several decades, a decreasing trend is obvious. It would be nice if it were solely a result of anthropogenous diagnostic and therapeutic endeavors and not also a feature of long-term cycles; it is currently beyond our scope focused on about 10.5-year rhythms. With or without removing this trend, a statistically highly significant cycle in the 1968–1996 data is apparent in Table 4. This cycle's medical significance is suggested by an excess of 220 deaths/year from myocardial infarctions during times of high vs. low solar activity [11]. There is also a statistically highly significant difference in the characteristics of about 10-year patterns of myocardial infarctions during the last 3 solar cycles when these characteristics are estimated separately. As summarized in part in Table 5, there are cycle-to-cycle differences in the MESOR (**m**idline-**e**stimating **s**tatistic **o**f **r**hythm), a rhythm-adjusted average, and also in the extent of change, the amplitude, and in the timing, the acrophase; Table 4 shows differences in the period, assessed by nonlinear least squares. These results all suggest the need for studies over more than 1 wobbly solar cycle, Figure 6, with also-wobbly biological counterparts.

As pointed out in a related context, geographic location may also be important: During the years 1979 to 1981, based on the analysis of 85,819 myocardial infarctions (from 6,304,025 ambulance calls in Moscow over that 3-year span), there is a statistically significant increase in the incidence of myocardial infarctions in Moscow on the day following magnetic storms. There was a similar increase in the incidence of mortality from myocardial infarctions after Forbush decreases in Minnesota when all data from Minnesota for three solar cycles are summarized, Table 3. As re-emphasized, in both geographic locations (in Moscow and in Minnesota), the increase related to the storm is compensated by a decrease on the following day; the difference is statistically significant at each site.

The foregoing finding suggests that while the presumably non-photic short-term solar effect is real, whether direct or indirect, at least part of it consists of having some of those who would have died on a given

Fig. 5. Distant drummers influence humans



day, die a day earlier: hence the decreased incidence on the day after the storm. A subsequent linearly increasing incidence of myocardial infarction during the ensuing six days and the excessive incidence during spans of solar maxima establish a long-term effect of non-photic solar activity as an actual if modest excess of myocardial infarctions, complementing the results of remove-and-replace approaches such as that by superposed epochs. By comparison to other features of weather, such as the winter (in temperate climates), described already by Victor Hugo as the killer of the poor, the non-photic solar activity effect is relatively small [11]. Nonetheless, the presumably solar effect (or is it an effect of a change in flux of galactic cosmic rays displaced by magnetic storms?) constitutes a statistically and biologically significant association, and thus a challenge to combined physical and physiological monitoring at each of several diverse geographic sites, in order to gain a reasonable picture of planetary behavior.

To recapitulate, there may be several kinds of associations of deaths from myocardial infarctions with enhanced solar activity: a short-term effect that is immediately compensated, at least in part, by fewer deaths on the day following the storm, an effect during the ensuing week that is statistically significant and may be dubbed subacute, and a long-term effect that provides a clear overall excess of deaths during years of solar maxima. Whether the short-term—acute and subacute—effects of storms may differ as a function of solar cycle stage is an impression not yet validated in inferential statistical terms. That, in the short term, the storm triggers at least some myocardial infarctions that would have otherwise occurred perhaps a day later, is established both for data from Moscow and from Minnesota [4, 11].

The already-noted failure to detect an increase in association with Forbush decreases in mortality from myocardial infarctions when, instead of all available data, Table 3, only those during 1979–1981 in Minnesota are considered, while an increase of 12% was found

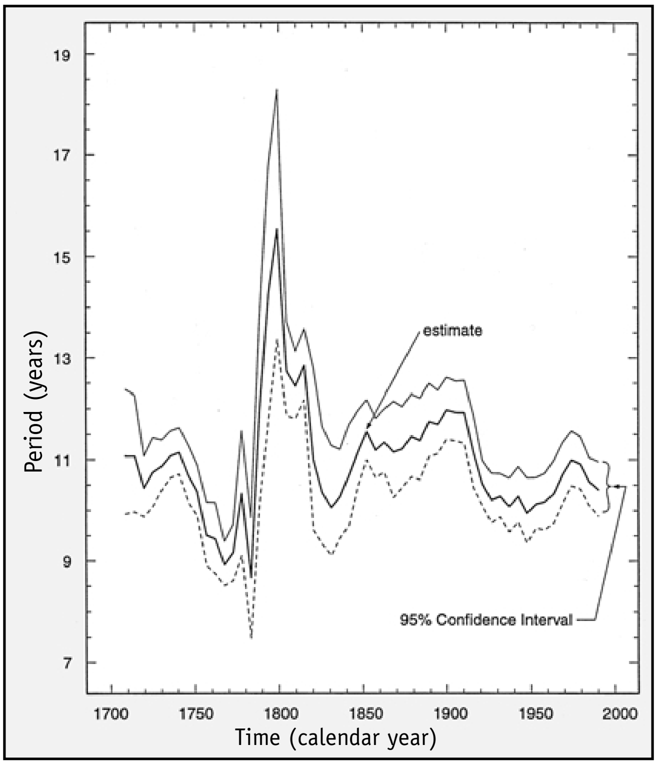


Fig. 6. Period length of solar cycle since 1700

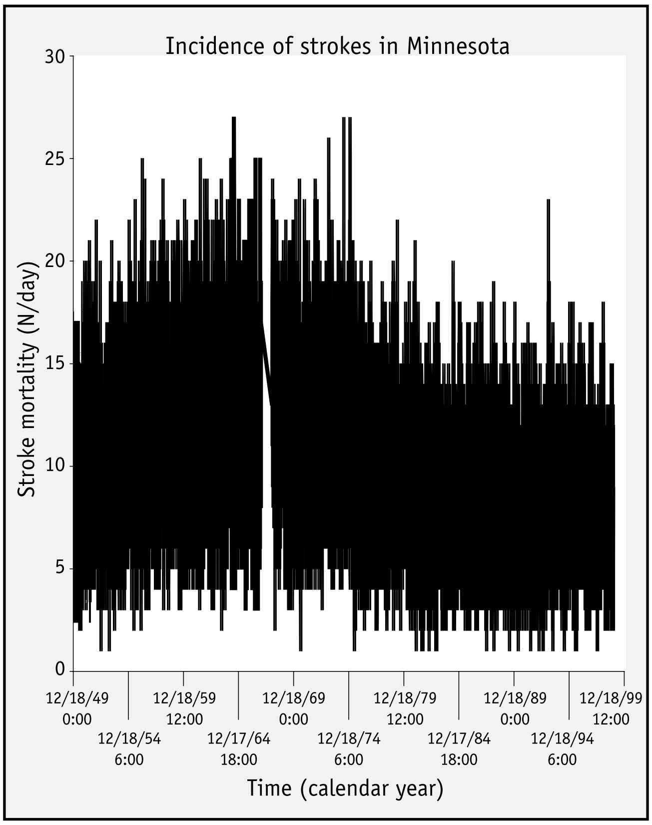


Fig. 7. Recently, as shown in figure 7, Germaine Cornélissen found a 51-year cycle in data for the last half of the century on the mortality from stroke in Minnesota. Conceivably, some of the decline in stroke during the past two decades is part of a natural cycle. This possibility is supported by an upward trend in most recent years in Minnesota, also found by Bjorn Johansson in Lund and with Paul W.C. Johnson in data from Arkansas.

by Villoresi et al. [76] in Muscovite morbidity of myocardial infarctions during the same span does not suffice to establish geographic differences. Whether morbidity in one location (Moscow) can be compared with mortality in another (Minnesota) is an open question. We also need to keep in mind that geomagnetic and geographic latitudes differ in opposite ways between Minnesota (45°00' N geographic, 55.00° N geomagnetic) vs. Moscow (55°45' N geographic, 50.76° N geomagnetic). Most important, the Muscovite morbidity data are based on a much larger data base than those on mortality from myocardial infarction in Minnesota during 1979–1981 only. The Minnesotan data over several decades are in keeping with the analyses of Muscovite data.

Since geographic location in the U.S. had not been explored earlier, the Minnesotan data render an analysis by state, as well as overall for the U.S. over several solar cycles, highly desirable. The difference in results on mortality from myocardial infarction in the U.S. as a whole vs. that in Minnesota [21, 22 vs. 11] may not stem only from a linear relation to latitude, since effects of magnetic storms on morbidity from myocardial infarction are also seen in Moscow and St. Petersburg, and furthermore much closer to the equator in Mexico City [79]. If latitude were involved, it would have to be a nonlinear relation where equatorial geomagnetic effects are reflected in the data from Mexico City [79]. The great differences among consecutive solar cycles are also relevant, in keeping with the Minnesota data, summarized in Tables 4 and 5. Myocardial infarctions and perhaps epilepsy [4, 92, 93], emotional depression [95] and suicide [91] may respond to storms in space, as do power stations that fail on earth [97] and perhaps communication in space [98, 99; cf. 100] that may also be influenced by magnetic storms and/or associated phenomena, perhaps only in certain stages of the Schwabe and Hale ~10.5- and ~21-year cycles of solar activity and/or in some cycles but not in others (Figure 7).

The BIOsphere and the COSmos, BIOCOS

Beyond aligning geophysical data with data about deaths from public health archives, associations of magnetic storms and/or galactic cosmic rays with physiological, pathological and morphological phenomena were found by superposed epochs and cross-spectral coherence, even in microbial sectoring, reflecting probable genetic changes [101; cf. 102, 103], and in human physiology [11, 104, 105]. A host of other results all support the proposition that we are influenced by storms in space (e.g., of the north-to-south turn of B_z) with effects trickling down to earth (as seen in K_p) [4, 33]. The observation that myocardial infarctions on the one hand are cross-spectrally coherent, on the other hand, with B_z or K_p at a frequency identical to nearly the second decimal place for K_p and B_z [4, 33], is pertinent.

Heart rate variability: the suspect

Nearly 3 years ago, the then-accumulated archival, morphological, physiological and pathological human data, most of them in Table 1, and comparative data on other species were sufficiently substantial to convene a special session of the Russian Academy of Medical Sciences in Moscow, to examine in particular results from monitoring worldwide under the informal project on the **BIO**sphere and the **COS**mos (BIOCOS) [66]. On this occasion, those in attendance unanimously signed a document endorsing the BIOCOS project. The BIOCOS concept was subsequently introduced by invitation at a symposium on the environment at the meeting of the International Union of Physiological Sciences in St. Petersburg, Russia, a few days later (in early July 1997; 106]. In the interim, BIOCOS was further strengthened by Dr. Kuniaki Otsuka's originally **A**sian, now **I**nternational **C**hronome **E**cologic Study of **H**eart **R**ate **V**ariability (ACEHRV/ICEHRV) collecting reference values for the chronomes of heart rate variability. BIOCOS now involves opportunistic monitoring of blood pressure and heart rate in Minnesota, Michigan, China, the Czech Republic, Italy, Japan and Mexico, and through ICEHRV 7-day or longer ECGs, in most of these countries, in India, in the arctic region of Norway and in Ukraine.

The ECG [11, 104, 105] and the circadian standard deviation of heart rate [11] served for the detection of effects of magnetic storms as lowered heart rate variability, a condition also constituting a feature of disease risk syndromes [11, 72]. The detection of a very high risk is critically important for those preparing to venture to sites away from hospitals, say in Antarctica or in extraterrestrial space. For an asymptomatic person who is already at an unrecognized high vascular disease risk, there will be double jeopardy during storms, e.g., in extraterrestrial space. The physiological monitoring of blood pressure and heart rate and also of the ECG, mostly for 7 days or longer has detected disease risk syndromes defined by too much variability in blood pressure [70, 72, 107, 108] and too little in heart rate [109, 110], and has also revealed the effect of magnetic storms on these endpoints.

Earlier, we had aligned a reduction of the standard deviation of heart rate [109, 110] (found earlier by others to be a risk factor; 111] in a meta-analysis of data from patients who died within 5 years after a myocardial infarction or had 24-hour ECGs before a sudden death [11]. A similar reduction in the standard deviation of heart rate was found in presumably healthy cosmonauts in earth orbit during magnetic storms by Baevsky (cf. 11]. A number of chronobiological alterations such as a reduction in variability below an evidently critical threshold or an increase in blood pressure variability above a threshold are now documented as risk syndromes in prospective and retrospective studies. The thresholds in question accumulate as information in a data bank to a workable extent for humans of both genders and various ages, and are to be refined further and to be specified for ethnicities beyond our current data bases that now pertain to Caucasians and Asians. Pertinent data were presented at recent geophysical meetings [112–114], and (by invitation) at special symposia [1, 115–118].

Melatonin

Apparent latitudinal effects involve melatonin as a possibly underlying and latitude-dependent mechanism. Thus, by day at the middle latitude of Florence at 43°N [85], a yearly pattern, probably reflecting sunlight, was seen during the hours of daylight. A half-yearly rhythmic signature of geomagnetics [119, 120] was seen only in data by night in Florence, whereas in the arctic the half-yearly pattern was seen at noon [85; cf. 87]. Latitudinal effects were also seen by others [86, 121, 122], although some samples were restricted to the night. Accordingly, day-to-night differences in the about-yearly modulation of circulating melatonin are not always assessable. Their investigation appears to be especially significant for follow-up work. There is a need for further investigation through the extension of systematic year-long sampling in both the Antarctic and Arctic, with simultaneous monitoring of pulsations that may be involved in resonances of human and other biological spectra.

Discussion

Most recently, in one of our ICEHRV studies, we found a marked disturbance of circadian rhythms and the appearance of a very large about 7-day (circaseptan) component in different endpoints of heart rate variability [11]. Inquiring about any unusual conditions during the 7 days of ECG monitoring, we were told that none were known. Somewhat later, however, we learned that a magnetic storm occurred on certain days of the 7-day monitoring. In separating data obtained during relative magnetic quiescence from those obtained during magnetic disturbance, we found a statistically significant difference in spectral regions centered around 10.5 seconds and 46.5 seconds, but not around 3.6 seconds [11, 104, 105], a spectral region associated with the parasympathetic autonomous nervous system. Hence, we postulated a role of the sympathetic activity, considered earlier by others in a different context in space [123]. This was at first a single anecdotal case on one subject [11, 104, 105]. Most recently, however, in 7-day ECGs recorded in Alta, Norway, at 70°N, results from 8 subjects reproduced the effect of magnetic storms observed earlier, again with a reduced heart rate variability in spectral regions associated probably with sympathetic and certainly not in regions corresponding to parasympathetic activity [11].

A physiological basis for the worldwide data accumulating on myocardial infarctions may be on the horizon. The transdisciplinary finding of solar and possibly broader bioeffects may be of interest to physics and biomedicine alike, each science using endpoints from the other. Biologically and geophysically interesting information may be found by exploring the relatively new area of geographic if not latitudinal effects on health and disease, with special focus on the auroral oval. This possibility has been explored at best with focus on only one or the other rhythm by others [124–134] without yet considering the spectrum of rhythms as a whole and the yet broader chronome that includes focus on chaotic changes and trends as well.

Also complementing any disturbance (dyschronism) following transmeridian crossing, or jet lag [63], is the opportunity to seek a "parallel lag" as a possibly geomagnetically influenced problem in the adjustment to new environments. A consequence of parallel crossing, just like jet lag, can have different effects upon rhythms with different frequencies and upon the even broader chronomes of different variables. As a precedent from transmeridian dyschronism, after the crossing of eight meridians, about 7-day (circaseptan) rhythms may not adjust for several weeks; their adjustment, is much slower than that of circadians [135]. The circannual rhythm in blood pressure, after crossing the equator from Minnesota to Brazil, may not adjust within a year as a study (limited to only a 2-year reference data base) suggests [136]. Studies with monitoring for several decades in each location before and after a transparallel shift seem desirable.

Systematic monitoring for purely scientific purposes could have substantial applied benefits not only in polar regions and in space, but anywhere on earth, irrespective of latitude. The auroral oval is one of the ideal sites to be included in geophysiological monitoring studies. But magnetic storms influence health worldwide: they affect mortality from vascular disease in Minnesota, Mexico City and Slovakia, and morbidity in Moscow and St. Petersburg, as they do in Novosibirsk, Russia; they influence human physiology in health in Tokyo and in Alta, Norway, as they do for cosmonauts in earth orbit [137].

The resolution of many remaining questions, no longer of a controversy, is a task worthy of a systemic program at different geomagnetic as well as geographic sites, particularly in the polar region and also call for the tearing down of disciplinary barriers, as Roederer also did by admonition [61] and implementation [138, 139]. A routine space weather report, and countermeasures, yet to be developed, the sooner the better, as suggested by others [67] and ourselves [10] are overdue, as is an investment into internationally coordinated physiological and physical monitoring so that biomedicine and ecology catch up with what physicists have been doing for centuries. In the tradition of Gilberd [140], the human body can provide a most sensitive radiation detector. Biologists, health care providers in particular, can serve science and physics in a transdisciplinary, Gilberdian way.

Outlook

Life can be viewed as a set of transiently self-sustaining organized structures in time and space. These structures, chronomes, consist of chaotic changes and rhythms undergoing trends, for a sufficient duration to possibly reproduce themselves and thereby to evolve. Chronomes of organisms continuously communicate with the time structures with similar elements in the environment, which provides photic and non-photic solar and further galactic modulations. The rhythmic elements of the chronomes, in and around us, intermodulate as feedsidewards, i.e., there are interactions among the rhythms in physiological and also among those in natural physical entities and in the intercommunicating open organism-environment systems. These interactions among two or more biological and/or physical entities are characterized by sequential patterns in time, involving recurrent quantitative or even qualitative changes. The latter can be the changing effect of one entity upon another, entailing a sequence of inhibition, no-effect and stimulation, recurring rhythmically and to that extent predictably. Certain ways of procedure, if not rules of chronomes (notably of rhythms in these time structures) are that:

1. for each inferentially statistically validated rhythm as an element of an organismic time structure, one can seek a corresponding element in the chronome of a natural physical environmental variable. This is how a 6.74-day component was detected in a record of geomagnetic disturbance (K_p) covering 59 years. The finding in biology of a near- (but not precisely) 7-day week prompted biologists to search for a geophysical near-match [4]. The near-weekly component was then further specified as to its variation with solar cycle stage [5] and for an even longer span of over 100 years [6];
2. for each periodic component in the environment, a near-matching organismic component may be sought, which is how a half-yearly period was found in severe attacks of epilepsy as a response to a hint from the biophysicist Armin Grafe [119];
3. biological rhythms without environmental near-matches may point to the disappearance, in the course of life's development on earth, of a natural physical environmental cycle. Accordingly, it would be most interesting if a biological rhythm would have no environmental near-match. A current challenge is the search for a possible environmental counterpart for about 8-hourly rhythms in vasoactive substances

such as in the case of endothelin-1, a powerful vasoconstrictor [11, 141], and also in the population density of the endotheliocyte [11];

4. in their growth and development, human beings and other multicellulars are living fossils that may replay in their rhythmic dynamics during ontogeny, the sequences that occurred during the development of life. In this context, humans are a source of information for scholars on the origins of life *par excellence,* in contrast to eukaryote single cells or prokaryotes whose growth, development and differentiation may not exhibit the time-lapse phenomena observed in more differentiated organisms. In this same context, certain multicellular organisms may be better "fossils" for certain things as compared to others. Thus, crayfish [142] may be a better subject of study than human beings [143–145], rats [146] or piglets [147], for the investigation of the biological week, since a circaseptan is present in locomotor activity of crayfishes at 6 months of age. In contrast, by the end of the first month of life the about 7-day component of physiological variables compares unfavorably in terms of its (circaseptan) amplitude with the amplitude of circadian rhythms in humans or rats. In old age, circaseptans and ultradians regain some relative prominence, but not necessarily exceed a circadian rhythm in amplitude.

The sites of an organism's origins may be distinguished on the basis of ontogeny. Organisms that have a prominent 7-day component early in life on earth may have developed away from the alternations of day/night and night/day recurring each day, on earth or on Mars, and may have locked into the near 7-day harmonic of the sun's rotation period that may be ubiquitous in the solar system. There may have been on earth some geomagnetic input from the moon as well, granted that the latter is reportedly small. Conceivably, the near 7-day period found early in the ontogeny of species such as rats, piglets, humans and crayfish is compatible with life originating anywhere in the solar system, deep at the bottom of the ocean on earth or inside Mars or in the ice of Europe. As the fourth harmonic of the sun's rotation around its axis, the physical week may have a wide influence, yet only in the absence of a near-daily alternation of light and darkness that may have been the principal driver for organisms evolving on the surface of the earth or of Mars.

Galactic and/or photic, thermic and other effects, associated with corpuscular radiation from the sun, are such drastic drivers as to affect microbial as well as human variables, morphological ones such as body length and weight, and physiological ones such as heart rate variability that may have some relation to the about 10-year cycle in myocardial infarctions and indeed vascular and probably other pathologies, notably those related to the brain and heart.

For the study of photic effects from the sun on earth, periodicities of about 1 year and about 1 day are useful. Conversely for the study of effects from corpuscular radiation from the sun and its effects on biota, about-half-weekly, about-weekly, about-half-yearly, about 10.5- and about 21-yearly cycles are of interest, and circasemicentennial cycles may lead us to thermic effects. The ratio of amplitudes of the latter periodicities (related, e.g., to geomagnetics) to the day or the year, may provide a hint about the relative prominence if not the roles played by photic and non-photic corpuscular effects of the sun, among the diversity of natural physical and environmental factors [148].

Galactic drivers concomitantly cannot be ruled out for life on earth. The effect of cosmic ray flux may actually be a more direct effect as compared to that of a magnetic storm that displaces cosmic ray flux to the earth, and may, for instance, thereby reduce the number of colonies with sectors in a testable model that may be used in a standardized fashion in long-overdue coordinated biological and physical, including physiological and archival human monitoring.

REFERENCES

1 Halberg F, Cornélissen G, Chen C-H, Katinas GS, Otsuka K, Watanabe Y, Herold M, Loeckinger A, Kreze A, Kreze E, Perfetto F, Tarquini R, Maggioni C, Schwartzkopff O. Chronobiology: time structures, chronomes, gauge aging, disease risk syndromes and the cosmos. J Anti-Aging Med, in press.

2 Cornélissen G, Halberg F. Introduction to Chronobiology. Medtronic Chronobiology Seminar #7, April 1994, 52 pp. (Library of Congress Catalog Card #94-060580; URL **http: //revilla.mac.cie.uva.es/chrono**)

3 Fraser-Smith AC. Effects of man on geomagnetic activity and pulsations. Adv Space Res 1981; **1**:455–466.

4 Halberg F, Breus TK, Cornélissen G, Bingham C, Hillman DC, Rigatuso J, Delmore P, Bakken E. International Womb-to-Tomb Chronome Initiative Group: Chronobiology in space. Keynote, 37th Ann Mtg Japan Soc for Aerospace and Environmental Medicine, Nagoya, Japan, November 8–9, 1991. University of Minnesota/Medtronic Chronobiology Seminar Series, #1, December 1991, 21 pp. of text, 70 figures.

5 Roederer JG. Are magnetic storms hazardous to your health? Eos, Transactions, American Geophysical Union 1995; **76**:441, 444–445.

6 Vladimirskii BM, Narmanskii VYa, Temuriantz NA. Global rhythmics of the solar system in the terrestrial habitat. Biophysics 1995; **40**:731–736.

7 Halberg F, Cornélissen G, Bakken E. Caregiving merged with chronobiologic outcome assessment, research and education in health maintenance organizations (HMOs). Progress in Clinical and Biological Research 1990; **341**B:491–549.

8 Wohlfahrt J, Melbye M, Christens P, Andersen A-MN, Hjalgrim H. Secular and seasonal variation of length and weight at birth. The Lancet 1998; **352**:1990.

9 Mikulecky M, Michalkova D, Petrovicova A. Coxsackie infection and births of future diabetic children: year seasonality and secularity. J Ped Endocr Metab, in press.
10 Halberg F, Cornélissen G. Chronoastrobiology. In: Proc 3rd International Symposium of Chronobiology and Chronomedicine, Kunming, China, October 7–12, 1998, p. 128–142.
11 Cornélissen G, Halberg F, Schwartzkopff O, Delmore P, Katinas G, Hunter D, Tarquini B, Tarquini R, Perfetto F, Watanabe Y, Otsuka K. Chronomes, time structures, for chronobioengineering for "a full life." Biomedical Instrumentation & Technology 1999; **33**:152–187.
12 Nikityuk B, Balakireva M, Cornélissen G, Halberg F. Similarities and differences in the 112-year time course of birth weight between boys and girls. Reports of Vinnitsa State Medical University 1998; **2**:332–333.
13 Nikityuk B, Balakireva M, Cornélissen G, Halberg F. Similarities and differences in the 112-year time course of neonatal body length between boys and girls. Reports of Vinnitsa State Medical University 1998; **2**:331.
14 Halberg F, Cornélissen G, Otsuka K, Syutkina EV, Masalov A, Breus T, Viduetsky A, Grafe A, Schwartzkopff O. Chronoastrobiology: neonatal numerical counterparts to Schwabe's 10.5 and Hale's 21-year sunspot cycles. In memoriam Boris A. Nikityuk (Sept. 10, 1933–Sept. 30, 1998). Int J Prenat Perinat Psychol Med, in press.
15 Mikulecky M, editor. The Moon and Living Matter. Kosice, Slovakia, September 23–25, 1993. Slovak Medical Society, Bratislava, 1993, 97 pp.
16 Mikulecky M, editor. Sun, Moon and Living Matter. Bratislava, Slovakia, June 28–July 1, 1994. Slovak Medical Society, Bratislava, 1994, 159 pp.
17 Mikulecky M, editor. Chronobiology & Its Roots in the Cosmos. High Tatras, Slovakia, September 2–6, 1997. Slovak Medical Society, Bratislava, 1997, 287 pp.
18 Cornélissen G, Halberg F, Gheonjian L, Paatashvili T, Faraone P, Watanabe Y, Otsuka K, Sothern RB, Breus T, Baevsky R, Engebretson M, Schröder W. Schwabe's ~10.5- and Hale's ~21-year cycles in human pathology and physiology. In: Schröder W, editor. Long- and Short-Term Variability in Sun's History and Global Change. Bremen: Science Edition, 2000, p. 79–88.
19 Farrell, Sister M, FCJ. [Schwabe, Samuel Heinrich.] In: Dictionary of Scientific Biography, Scribners, New York, 1975, vol. 12, p. 239–240.
20 [Hale, George Ellery.] In: The New Columbia Encyclopedia, Harris WH, Levey JS, editors. Columbia University Press, New York, 1975, p. 1176.
21 Feinleib M, Rogot E, Sturrock PA. Solar activity and mortality in the United States. Int J Epidemiol 1975; **4**:227–229.
22 Lipa BJ, Sturrock PA, Rogot E. Search for correlation between geomagnetic disturbances and mortality. Nature 1976; **259**:302–304.
23 Düll T, Düll B. Über die Abhängigkeit des Gesundheitszustandes von plötzlichen Eruptionen auf der Sonne und die Existenz einer 27tägigen Periode in den Sterbefällen. Virchows Archiv 1934; **293**:272–319.
24 Düll T, Düll B. Zusammenhänge zwischen Störungen des Erdmagnetismus und Häufungen von Todesfällen. Deutsch med Wschr 1935; **61**:95–97.
25 Chizhevsky AL. Cosmobiologie et Rythme du Milieu extérieur. Verhandlungen, Zweite Konferenz der Internationalen Gesellschaft für Biologische Rhythmusforschung, am 25. und 26. August 1939, Utrecht, Holland, Holmgren Hj, editor. Acta Med Scand 1940; **108**(Suppl):211–226.
26 Chizhevsky AL. The Earth in the Universe. VV Fedynsky, editor. NASA TT F-345 TT 66-51025, 1968, 280 pp.
27 Novikova KF, Gnevyshev MN, Tokareva NV, Ohl AI, Panov TN. The effect of solar activity on the development of myocardial infarction morbidity and mortality. Cardiology, Moscow 1968; **4**:109.
28 Gnevyshev MN, Novikova KF. The influence of solar activity on the Earth's biosphere (Part I). J Interdiscipl Cycle Res 1972; **3**:99.
29 Dubrov AP. The geomagnetic field and life: geomagnetobiology. (Translated by FL Sinclair; translation edited by FA Brown Jr) Plenum Press, New York, 1978, 318 pp.
30 Breus TK, Komarov FI, Musin MM, Naborov IV, Rapoport SI. Heliogeophysical factors and their influence on cyclical processes in biosphere. Itogi Nauki i Techniki: Medicinskaya Geografica 1989; **18**:138–142, 145, 147, 148, 172–174.
31 Gamburtsev AG, Alexandrov SI, Belyakov AS, Galkin IN, Gamburtseva NG, Kuzmin YuO, Nikolaeva RV, Oleinik OV, Privalovsky NK, Sidorov VA, Khavroshkin OB, Tsyplakov VV. Atlas of Natural Processes: Order and chaos in lithosphere and other spheres. Rossiiskaya akademia nauk, Moscow, 1994, 176 pp.
32 Breus T, Cornélissen G, Halberg F, Levitin AE. Temporal associations of life with solar and geophysical activity. Annales Geophysicæ 1995; **13**:1211–1222.
33 Halberg F, Cornélissen G, Hillman DC, Bingham C, Halberg E, Guillaume F, Barnwell F, Wu JY, Wang ZR, Halberg FE, Holte J, Schmitt OH, Kellogg PJ, Luyten W, Breus TK, Komarov FI, Mikulecky M, Garcia L, Lodeiro C, Iglesias T, Quadens O, Muller C, Kaada B, Miles L, Hayes DK. Chronobiology in a moon-based chemical analysis and physiologic monitoring laboratory. In: A Lunar-Based Chemical Laboratory (LBCAL), Ponnamperuma C, Gehrke CE, editors. A Deepak Publishing, Hampton, VA, 1992, p. 161–203.
34 Cowing K. The origin of the term "astrobiology." To the Stars, January–February 1999, p. 19.
35 Strughold H. The Green and Red Planet: A Physiological Study of the Possibility of Life on Mars. University of New Mexico Press, Albuquerque, NM, 1953, 107 pp.
36 Strughold H. Advances in astrobiology. Proceedings of Lunar and Planetary Exploration Colloquium 1959; **1**:1–7.
37 Strughold H. Lunar medicine. In: Proc 2nd Lunar International Laboratory (LIL) Symposium, Madrid, 1966, International Academy of Astronautics. New York: Pergamon Press; 1967, p. 112–121.
38 Strughold H. Your Body Clock. New York: Scribners; 1971.
39 Strughold H. Cycloecology in space on the moon and beyond. In: Scheving LE, Halberg F, Pauly JE, editors: Chronobiology. Proc Int Soc for the Study of Biological Rhythms, Little Rock, Ark Georg Thieme Publishers, Stuttgart/Igaku Shoin Ltd, Tokyo, 1974, p. 417–423.
40 Bunk S. Astrobiology makes debut under NASA. The Scientist 1998; **12**:1, 14.
41 Cady SL. Astrobiology: a new frontier for 21st-century paleontologists. Palaios 1998; **13**:95–97.
42 Lawler A. Space and life sciences: Astrobiology Institute picks partners. Science 1998; **280**:1338.
43 Soffen GA. Astrobiology from exobiology: Viking and the current Mars probes. Acta Astronautica 1997; **41**:609–611.
44 Zubrin R. The Case for Mars. New York: Touchstone/Simon & Schuster; 1996.
45 Lowell P. Mars as the Abode of Life. New York: Macmillan; 1908.
46 Lowell P. The Evolution of Worlds. New York: Macmillan; 1909.
47 First Astrobiology Conference, NASA Ames Research Center, Moffett Field, California, April 3–5, 2000.
48 Tikhov GA. Astrobotany. Alma-Ata: Acad Sci Kazakh SSR, 1949, 23 pp. Cf. also Tikhov GA Astrophysiology. Moscow: Molodaya Gvardiya, 1953, 63 pp.
49 Brown FA Jr. Response to pervasive geophysical factors and the biological clock problem. Cold Spr Harb Symp quant Biol 1960; **25**:57–71.
50 Brown FA Jr. A unified theory for biological rhythms: Rhythmic duplicity and the genesis of 'circa' periodisms. In: Circadian Clocks. Proceedings of the Feldafing Summer School, Sept. 1964, J Aschoff, editor. North-Holland Publishing Company, Amsterdam, 1965; p. 231–261.

51 Barnwell FH. A day-to-day relationship between oxidative metabolism and world-wide geomagnetic activity. Biol Bull 1960; **119**:303.

52 Halberg F. Temporal coordination of physiologic function. Cold Spr Harb Symp quant Biol 1960; **25**:289–310.

53 Brown FA Jr. Response of a living organism, under "constant conditions" including pressure, to a barometric-pressure-correlated, cyclic external variable. Biological Bulletin 1957; **112**:288–304.

54 Brown FA Jr. An exogenous reference-clock for persistent, temperature-independent, labile biological rhythms. Biological Bulletin 1958; **115**:81–100.

55 Heusner A. Sources of error in the study of diurnal rhythm in energy metabolism. In: Circadian Clocks. Proceedings of the Feldafing Summer School, Sept. 1964, J Aschoff, editor. North-Holland Publishing Company, Amsterdam, 1965; p. 3–12.

56 Cole LaMC. Biological clock in the unicorn. Science 1957; **125**:874–876.

57 Slutsky E. The summation of random causes as the source of cyclic processes. Econometrica 1937; **5**:105–146.

58 Jaroff L. Stormy Weather: Raining particles and radiation on an increasingly tech-dependent Earth, the sun's upcoming 'max' may zap everything from cell phones to power grids. Time 2000; **155**:64–66.

59 Smith N. Hot or what? It may be the biggest, most important thing in our solar system, but science has not yet succeeded in solving all its mysteries. Focus (London), August 1999. p.86–87.

60 Daglis IA, Baumjohann W, Gleiss J, Orsini S, Sarris ET, Scholer M, Tsurutani BT, Vassiliadis D. Recent advances, open questions and future directions in solar terrestrial research. Phys Chem Earth (C) 1999; **24**:5–28.

61 Roederer JG. Tearing down disciplinary barriers. Eos, Transactions, American Geophysical Union 1985; **66**:681, 684–685.

62 Roederer JG. Effects of natural magnetic field disturbances on biota. Space Medicine & Medical Engineering (Chn.) 1996; **9**:7–16.

63 Halberg F. Chronobiology. Ann Rev Physiol 1969; **31**:675–725.

64 Breus TK, Cornélissen G, Bingham C, Hillman DC, Halberg E, Guillaume F, Wang ZR, Han HW, Shao DL, Wu JY, Komarov FI, Rapoport SI, Levitin AE, Romanov YA, Musin MM, Naborov IV, Grigoriev AE, Safin SR, Syutkina EV, Grigoriev AI, Halberg F. Cardiovascular and other chronoepidemiology via ambulance calls versus geomagnetic and sunspot variability. In: Proc Workshop on Computer Methods on Chronobiology and Chronomedicine, Tokyo, Sept. 13, 1990, Halberg F, Watanabe H, editors. Medical Review, Tokyo, 1992, p. 203–231.

65 Syutkina EV, Cornélissen G, Grigoriev AE, Mitish MD, Turti T, Yatsyk GV, Pimenov K, Breus TK, Studenikin MY, Siegelova J, Fiser B, Dusek J, Johnson D, Halberg F. Neonatal intensive care may consider associations of cardiovascular rhythms with local magnetic disturbance. Scripta medica 1997; **70**:217–226.

66 Halberg F, Syutkina EV, Cornélissen G. Chronomes render predictable the otherwise-neglected human "physiological range": position paper of BIOCOS project. Human Physiology 1998; **24**:14–21.

67 Dorman LI, Villoresi G, Belov AV, Eroshenko EA, Iucci N, Yanke VG, Yudakhin KF, Bavassano B, Ptitsyna NG, Tyasto MI. Cosmic-ray forecasting features for big Forbush decreases. Nuclear Physics B (Proc Suppl) 1995; **39**A:136–144.

68 Daglis IA. Advanced Study Institute on Space Storms and Space Weather Hazards (Crete, Greece, 19–29 June 2000): Announcement and call for papers. (National Observatory of Athens, Institute of Space Applications and Remote Sensing, Metaxa and Vas. Pavlou Str, 152 36 Penteli, Greece;
URL **http://sat2.space.noa.gr/~daglis/asi2000.html**)

69 Halberg F. *Quo vadis* basic and clinical chronobiology: promise for health maintenance. Am J Anat 1983; **168**:543–594.

70 Otsuka K, editor. Chronome & Janus-medicine: Heart Rate Variability (HRV) and BP Variability (BPV) from a viewpoint of chronobiology and ecology. Medical Review, Tokyo, 1998, 213 pp.

71 Halberg F, Cornélissen G, International Womb-to-Tomb Chronome Initiative Group: Resolution from a meeting of the International Society for Research on Civilization Diseases and the Environment (New SIRMCE Confederation), Brussels, Belgium, March 17–18, 1995: Fairy tale or reality? Medtronic Chronobiology Seminar #8, April 1995, 12 pp. text, 18 figures.
URL http://revilla.mac.cie.uva.es/chrono

72 Halberg F, Cornélissen G, Halberg J, Fink H, Chen C-H, Otsuka K, Watanabe Y, Kumagai Y, Syutkina EV, Kawasaki T, Uezono K, Zhao ZY, Schwartzkopff O. Circadian Hyper-Amplitude-Tension, CHAT: a disease risk syndrome of anti-aging medicine. J Anti-Aging Med 1998; **1**:239–259. (Editor's Note by Fossel M, p. 239:

73 Halberg F, Visscher MB. Regular diurnal physiological variation in eosinophil levels in five stocks of mice. Proc Soc exp Biol (NY) 1950; **75**:846–847.

74 Halberg F. Physiologic 24-hour periodicity; general and procedural considerations with reference to the adrenal cycle. Z Vitamin, Hormon-u Fermentforsch 1959; **10**:225–296.

75 Cornélissen G, Halberg F, Baevsky R, Breus T, Holley D, Winget C. Solar activity, magnetic storms and myocardial infarctions. Abstract, Advanced Study Institute on Space Storms and Space Weather Hazards, Crete, Greece, 19–29 June 2000, submitted.

76 Villoresi G, Breus TK, Iucci N, Dorman LI, Rapoport SI. The influence of geophysical and social effects on the incidences of clinically important pathologies (Moscow 1979–1981). Physica Medica 1994; **10**:79–91.

77 Villoresi G, Kopytenko YA, Ptitsyna NG, Tyasto MI, Kopytenko EA, Iucci N, Voronov PM. The influence of geomagnetic storms and man-made magnetic field disturbances on the incidence of myocardial infarction in St Petersburg (Russia). Physica Medica 1994; **10**:107–117.

78 Feigin VL, Nikitin YuP, Vinogradova TE. Solar and geomagnetic activities: are there associations with stroke occurrence? Cerebrovasc Dis 1997; **7**:345–348.

79 Mendoza B, Diaz-Sandoval R. A preliminary study of the relationship between solar activity and myocardial infarctions in Mexico City. Geofisica Internacional 1999, in press.

80 Strestik J, Sitar J. The influence of heliogeophysical and meteorological factors on sudden cardiovascular mortality. In: Proceedings of the 14th International Congress of Biometeorology, September 1–8, 1996, Ljubljana, Slovenia, Part 2, vol. 3, p. 166–173.

81 Strestik J, Prigancova A. On the possible effect of environmental factors on the occurrence of traffic accidents. Acta Geodætica, Geophysica et Montanistica Hungarica 1986; **21**:155–166.

82 Watanabe Y, Cornélissen G, Sothern RB, Nikityuk B, Bingham C, Grafe A, Halberg F. Numerical counterparts to sunspot cycles in human blood pressure and heart rate variability. In: Proc 3rd International Symposium of Chronobiology and Chronomedicine, Kunming, China, October 7–12, 1998, p. 145.

83 Sothern RB, Cornélissen G, Bingham C, Watanabe Y, Grafe A, Halberg F. Solar cycle stage: an important influence on physiology that must not be ignored. In: Proc 3rd International Symposium of Chronobiology and Chronomedicine, Kunming, China, October 7–12, 1998, p. 144.

84 Delyukov A, Gorgo Yu, Cornélissen G, Halberg F. The biometeorological analysis of 50-day human ECG. In: Proceedings, 15th International Congress of Biometeorology and International Conference of Urban Climatology, Sydney, Australia, 8–12 Nov 1999, de Dear RJ, Potter JC, editors. ICB25.2: 6 pp. [CD-ROM].

85 Tarquini B, Cornélissen G, Perfetto F, Tarquini R, Halberg F. Chronome assessment of circulating melatonin in humans. In vivo 1997; **11**:473–484.
86 Wetterberg L, Bratlid T, Knorring Lv, Eberhard G, Yuwiler A. A multinational study of the relationships between nighttime urinary melatonin production, age, gender, body size, and latitude. Eur Arch Psychiatr Neurosci 1999; **249**:256–262.
87 Martikainen H, Tapanainen J, Vakkuri O, Leppaluoto J, Huhtaniemi I. Circannual concentrations of melatonin, gonadotrophins, prolactin and gonadal steroids in males in a geographical area with a large annual variation in daylight. Acta endocrinol (Copenhagen) 1985; **109**:446–450.
88 Randall W. The solar wind and human birth rate: a possible relationship due to magnetic disturbances. Int J Biometeorol 1990; **34**:42–48.
89 Randall W, Randall S. The solar wind and hallucinations—a possible relation due to magnetic disturbances. Bioelectromagnetics 1991; **12**:67–70.
90 Burch JB, Reif JB, Yost MG, Keefe TJ, Pitrat CA. Reduced excretion of a melatonin metabolite in workers exposed to 60 Hz magnetic fields. Am J Epidemiol 1999; **150**:27–36.
91 Stoupel E, Abramson E, Sulkes J, Martfel J, Nechama S, Handelman M, Shimshoni M Zadka P, Gabbay U. Relationship between suicide and myocardial infarction with regard to changing physical environmental conditions. Int J Biometeorol 1995; **38**:199–203.
92 Michon AL, Koren SA, Persinger MA. Attempts to simulate the association between geomagnetic activity and spontaneous seizures in rats using experimentally generated magnetic fields. Percept Mot Skills 1996; **82**:619–626.
93 Persinger MA, Psych C. Sudden unexpected death in epileptics following sudden, intense increases in geomagnetic activity: prevalence of effect and potential mechanisms. J Biometeorol 1995; **38**:180–187.
94 O'Connor RP, Persinger MA. Geophysical variables and behavior: LXXIII. A strong association between sudden infant death syndrome and increments of global geomagnetic activity: possible support for the melatonin hypothesis. Percept Mot Skills 1997; **84**:395–402.
95 Kay RW. Geomagnetic storms: association with incidence of depression as measured by hospital admission. Br J Psychiatry 1994; **164**:403–409.
96 Thalen BE, Kjellman B, Wetterberg L. Phototherapy and melatonin in relation to seasonal affective disorder and depression. In: Yu H, Reiter RJ, editors. Melatonin Biosynthesis, Physiological Effects, and Clinical Applications. CRC Press, Boca Raton, FL, 1993, p. 495.
97 Rostoker G. Nowcasting of space weather using the Canopus magnetometer array. Physics in Canada/La Physique au Canada, Sept./Oct. 1998, p. 277–284.
98 Lanzerotti LJ, Medford LV, Maclennan CG, Thomson D. Studies of large-scale earth potentials across oceanic distances. AT&T Tech J 1995; **74**:73–84.
99 Thomson DJ, Maclennan CG, Lanzerotti LJ. Propagation of solar oscillations through the interplanetary medium. Nature 1995; **376**:139–144.
100 Levi BG. Search and Discovery: Is the answer blowing in the solar wind? Physics Today, September 1995, 17–20.
101 Faraone P, Cornélissen G, Katinas GS, Halberg F, Siegelova J. Astrophysical influences on sectoring in colonies of microorganisms. Abstract 17, MEFA, Brno, Czech Rep, Nov. 3–6, 1999.
102 Faraone P. La frequenza delle colonie a settore differenziato (C.S.D.), fra i batteri in sospensione nell'aria esterna, in tre anni di osservazione (sua correlazione con vari parametri: numeri di Wolf, flusso solar, attivita' geomagnetica, fenomeni fluttuanti). Annali Sclavo 1973; **15**:207–224.
103 Faraone P. The CSD frequency variation with the solar activity and with the altitude, after twenty years researches. Proceedings, International Medical Congress of Mountain Climatology, Roccaraso (L'Aquila), Italy, June 7–9, 1991:1–18.
104 Otsuka K, Cornélissen G, Zhao ZY, Weydahl A, Delyukov A, Gorgo Y, Wang ZR, Perfetto F, Tarquini R, Kubo Y, Shinagawa M, Hotta N, Ishii T, Omori K, Watanabe Y, Nunoda S-i, Ohkawa S-i, Halberg F. Rhythm and trend elements in the time structure, chronome, of heart rate variability. Geronto-Geriatrics 1999; **2**:31–48.
105 Otsuka K, Yamanaka T, Cornélissen G, Breus T, Chibisov SM, Baevsky R, Halberg F. Altered chronome of heart rate variability during span of high magnetic activity. Scripta medica, in press.
106 Halberg F. Chronobiology and adaptations to environments near and far: the Cornélissen-series, Chizhevsky's legacy in 1997. Proc XXXIII Int Cong International Union of Physiological Sciences, St Petersburg, Russia, June 30–July 5, 1997, L041.02.
107 Otsuka K, Cornélissen G, Halberg F. Predictive value of blood pressure dipping and swinging with regard to vascular disease risk. Clinical Drug Investigation 1996; **11**:20–31.
108 Otsuka K, Cornélissen G, Halberg F, Oehlert G. Excessive circadian amplitude of blood pressure increases risk of ischemic stroke and nephropathy. J Medical Engineering & Technology 1997; **21**:23–30.
109 Otsuka K, Cornélissen G, Halberg F. Circadian rhythmic fractal scaling of heart rate variability in health and coronary artery disease. Clinical Cardiology 1997; **20**:631–638.
110 Cornélissen G, Bakken E, Delmore P, Orth-Gomér K, Åkerstedt T, Carandente O, Carandente F, Halberg F. From various kinds of heart rate variability to chronocardiology. Am J Cardiol 1990; **66**:863–868.
111 Kleiger RE, Miller JP, Bigger JT Jr, Moss AJ, Multicenter Post-Infarction Research Group. Decreased heart rate variability and its association with increased mortality after acute myocardial infarction. Am J Cardiol 1987; **59**:256–262.
112 Cornélissen G, Sothern RB, Gheonjian L, Paatashvili T, Watanabe Y, Breus T, Halberg F, Schroeder W. Within- and among-solar-cycle (s) variations and human morphology, physiology and pathology. Poster GA6.01/E/04-A5, 22nd General Assembly, International Union of Geodesy and Geophysics, Birmingham, England, July 19–30, 1999.
113 Halberg F, Cornélissen G, Schwartzkopff O, Schroeder W. Chronoastrobiology- and chronobioastronautics-agenda involving monitoring the BIOsphere and COSmos: the BIOCOS project. Poster GA6.01/E/05-A5, Friday, July 23, 1999, 22nd General Assembly, International Union of Geodesy and Geophysics, Birmingham, England, July 19–30, 1999.
114 Halberg F, Cornélissen G, Katinas G, Bruhn D, Sothern RB, Engebretson M, Watanabe Y, Otsuka K. Genetic memory-endowed microbial to human gauges of the cosmos. Abstract (Poster B32A-19, December 15), American Geophysical Union Fall Meeting, San Francisco, December 13–17, 1999. Eos, Transactions, AGU 1999; **80**(46) (Suppl): F70-F71.
115 Halberg F, Cornélissen F, Schwartzkopff O. What chronoastrobiology could do on earth and in space. Proc Symp Chronobiology and Non-Invasive Methods in Cardiology, 80th Anniversary Masaryk University Foundation, Brno, Czech Republic, May 26, 1999, p. 7–13.
116 Cornélissen G et al. Contribution at octogenarian symposium (visit website: **http://revilla .mac.cie.uva.es/chrono**).
117 Halberg F, Cornélissen G, Schwartzkopff O, Watanabe Y, Otsuka K. Feedsidewards: intermodulation (strictly) among time structures, chronomes, in and around us, and vasculo-neuroimmunity. Abstract A24, 4th Int Cong International Society for Neuroimmuno-modulation, Lugano, Switzerland, September 29–October 2, 1999. Neuroimmunomodulation 1999; **6**:400.

118 Herold M, Cornélissen G, Rawson MJ, Katinas GS, Alinder C, Bratteli C, Gubin D, Halberg F. About-daily (circadian) and about-weekly (circaseptan) patterns of human salivary melatonin. J Anti-Aging Med, in press.

119 Grafe A. Einige charakterische Besonderheiten des geomagnetischen Sonneneruptionseffektes. Geofisica Pura e Applicata 1958; **40**:172–179.

120 Russell CT, McPherron RL. Semiannual variation of geomagnetic activity. J Geophys Res 1973; **78**:92–108.

121 Resch J. Geographische Verteilung der Multiplen Sklerose und Vergleich mit geophysikalischen Grössen. Soz Präventivmed 1995; **40**:161–171.

122 Resch J. Die multiple Sklerose als Mortalitätsdiagnose in der Bundesrepublik Deutschland. Fortschr Neurol Psychiat 1982; **50**:52–63.

123 Robertson D, Convertino VA, Vernikos J. The sympathetic nervous system and the physiologic consequences of spaceflight: a hypothesis. Am J of the Medical Sciences 1994; **308**:126–132.

124 Yoneyama S, Hashimoto S, Honma K. Seasonal changes of human circadian rhythms in Antarctica. Am J Physiol 1999; **277**:R1091–R1097.

125 Cugini P, Camillieri G, Alessio L, Cristina G, Petrangeli CM, Capodaglio PF. Ambulatory blood pressure monitoring in clinically healthy subjects adapted to living in Antarctica. Aviat Space Environ Med 1997; **68**:795–801.

126 Miche F, Vivien-Roels B, Pevie P, Spehner C, Robin JP, Le Maho Y. Daily pattern of melatonin secretion in an antarctic bird, the emperor penguin, *Aptenodytes forsteri:* seasonal variations, effect of constant illumination and of administration of isoproterenol or propranolol. Gen Comp Endocrinol 1991; **84**:249–263.

127 Kennaway DJ, Van Dorp CF. Free-running rhythms of melatonin, cortisol, electrolytes, and sleep in humans in Antarctica. Am J Physiol 1991; **260**:R1137–R1144.

128 Midwinter MJ, Arendt J. Adaptation of the melatonin rhythm in human subjects following night-shift work in Antarctica. Neurosci Lett 1991; **122**:195–198.

129 Cockrem JF. Plasma melatonin in the Adelie penguin (Pygoscelis adeliae) under conditions of daylight in Antarctica. J Pineal Res 1991; **10**:2–8.

130 Barrell JK, Montgomery GW. Absence of circadian patterns of secretion of melatonin or cortisol in Weddell seals under continuous natural daylight. J Endocrinol 1989; **122**:445–449.

131 Broadway JW, Arendt J. Seasonal and bright light changes of the phase position of the human melatonin rhythm in Antarctica. Arctic Med Res 1988; **47**(Suppl 1):201–203.

132 Broadway JW, Arendt J, Folkard S. Bright light phase shifts the human melatonin rhythm during the Antarctic winter. Neurosci Lett 1987; **79**:185–189.

133 Griffiths PA, Folkard S, Bojkowski C, English J, Arendt J. Persistent 24-h variations of urinary 6-hydroxy melatonin sulphate and cortisol in Antarctica. Experientia 1986; **42**:430–432.

134 Griffiths D, Seamark RF, Bryden MM. Summer and winter cycles in plasma melatonin levels in the elephant seal *(Mirounga leonina)*. Aust J Biol Sci 1979; **32**:581–586.

135 Saito Yuzo, Cornélissen G, Saito YK, Saito YI, Saito J, Wu J, Hillman D, Wang Z, Hata Y, Tamura K, Halberg E, Halberg F. Gradual adjustment of circaseptan-circadian blood pressure and heart rate rhythms after a trans-9-meridian flight. Chronobiologia 1992; **19**:67–74.

136 Marques N, Marques MD, Marques RD, Marques LD, März W, Halberg F. Delayed adjustment after transequatorial flight of circannual blood pressure variation in 4 family members. Il Policlinico, Sez Medica 1995; **102**:209–214.

137 Roederer JG. The Physics and Psychophysics of Music: An Introduction. 3rd ed. Springer, New York, 1994, 219 pp.

138 Roederer JG. Physikalische und psychoakustische Grundlagen der Musik. Springer, Berlin, 2000, 263 pp.

139 Gilbert W. De magnete, magneticisque corporibus, et de magno magnete tellure; physiologia noua, plurimis et argumentis, et experimentis demonstrata [On magnetism, magnetic bodies, and the great magnet Earth]. London, Short, 1600, 204 pp.

140 Herold M, Cornélissen G, Loeckinger A, Koeberle D, Koenig P, Halberg F. About 8-hourly variation of circulating human endothelin-1 (ET-1) in clinical health. Peptides 1998; **19**:821–825.

141 Fanjul Moles ML, Cornélissen G, Miranda Anaya M, Prieto Sagredo J, Halberg F. Larger infradian vs. circadian prominence of locomotor activity in young vs. older crayfish. Abstract, 6° Convegno Nazionale de Cronobiologia, Chianciano, Italy, November 27–28, 1998, p. 65.

142 Halberg F, Cornélissen G, Kopher R, Choromanski L, Eggen D, Otsuka K, Bakken E, Tarquini B, Hillman DC, Delmore P, Kawabata Y, Shinoda M, Vernier R, Work B, Cagnoni M, Cugini P, Ferrazzani S, Sitka U, Weinert D, Schuh J, Kato J, Kato K, Tamura K. Chronobiologic blood pressure and ECG assessment by computer in obstetrics, neonatology, cardiology and family practice. In: Computers and Perinatal Medicine: Proc 2nd World Symp. Computers in the Care of the Mother, Fetus and Newborn, Kyoto, Japan, Oct. 23–26, 1989, Maeda K, Hogaki M, Nakano H, editors. Excerpta Medica, Amsterdam, 1990, p. 3–18.

143 Syutkina EV, Cornélissen G, Halberg F, Johnson D, Grigoriev AE, Mitish MD, Turti T, Abramian AS, Yatsyk GV, Syutkin V, Tarquini B, Mainardi G, Breus T, Pimenov K, Wendt HW. Could the blood pressure of newborns track the solar cycle? Abstract, 4° Convegno Nazionale, Società Italiana di Cronobiologia, Gubbio (Perugia), Italy, June 1–2, 1996, p. 62–63.

144 Siegelova J, Dusek J, Fiser B, Nekvasil R, Muchova M, Cornélissen G, Halberg F. Circaseptan rhythm in blood pressure and heart rate in newborns. Scripta medica 1996; **67**(Suppl 2):63–70.

145 Díez-Noguera A, Cambras T, Cornélissen G, Halberg F. A biological week in the activity chronome of the weanling rat: a chronometa-analysis. Keynote, 4° Convegno Nazionale, Società Italiana di Cronobiologia, Gubbio (Perugia), Italy, June 1–2, 1996, p. 81–82.

146 Thaela M-J, Jensen MS, Cornélissen G, Halberg F, Nöddegaard F, Jakobsen K, Pierzynowski SG. Circadian and ultradian variation in pancreatic secretion of meal-fed pigs after weaning. J Animal Science 1998; **76**:1131–1139.

147 Danet S, Richard F, Montaye M, Beauchant S, Lemaire B, Graux C, Cottel D, Marécaux N, Amouyel P. Unhealthy effects of atmospheric temperature and pressure on the occurrence of myocardial infarction and coronary deaths. A 10-year study: the Lille-World Health Organization MONICA Project (Monitoring Trends and Determinants in Cardiovascular Disease). Circulation 1999; **100**:e1–e7.