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THE EFFECT OF CERTAIN SPACE AND GEOPHYSICAL FACTORS ON THE BIOSPHERE OF THE EARTH

Edited by

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16. Abstract

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ANNOTATION

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FOREWORD

This collection is based on reports read at the Space Science Division /5* of the Moscow branch of the All-union Astronomical and Geodetic Society (VAGO), revised for this publication. The main thought in the reports is that geophysical factors of an electromagnetic nature as well as space factors play a much greater role in the evolution and existence of life on Earth in its present-day forms than was assumed previously on the basis of generally-accepted biological and physical concepts. The problems set forth are not absolutely new in natural science. They were touched upon even in the works of A. L. Chizhevskiy, N. A. Shultz, N. S. Shcherbinskiy and others. However, these factors were interpreted only in relation to solar activity without specific definition of the actuating source. There can, in fact, be several sources: either the direct effect of radiation penetrating in various doses or the mediated effect of disturbed electric and magnetic fields on the Earth or barometric pressure and humidity altered in connection with general disturbances. What is more, changes in the periodicity and power of light flux, also electromagnetic in nature, which are by themselves a very effective factor, under natural conditions are usually closely related to other kinds of electromagnetic radiation. We must also remember that not only solar activity is able to disturb the Earth's atmosphere, magnetosphere, etc., but also the position of the Moon in relation to the Earth, possibly the position of other planets, and that of the Earth in relation to the ecliptic plane and center of the galaxy.

Unfortunately, the word "position" does not clarify very well the essence of the matter and only indicates a relation between given phenomena. Such relations are revealed, clarified, and specified with any validity as yet only with respect to the Moon, based only on gravitational disturbances. But

* Numbers in the margin indicate pagination of original foreign text.

this by no means indicates that galactic cycles are of this nature.

At the same time, the mechanisms of the reaction of living objects to such a disturbance are still not completely understood. Theories advanced by various authors, as a rule, sidestep the energy capacity of the disturbing factor or the time characteristics of this disturbance. However, appealing to such concepts as the "information effect of the EM field," although it helps at first glance to distinguish a certain group of biologically effective, energetically weak influences, often creates a false idea of its nature, and is often far from being informational.

Attempts have been made in this collection to investigate the nature of these interactions at various levels (see the articles of N. I. Muzalevskaya, Yu. I. Novitskiy, A. P. Dubrov, etc.).

The sequence of articles in the collection basically proceeds from general to particular. Thus, if the article of Yu. M. Malinovskiy indicates biogeochemical and geological questions of a global and epochal character, namely how the position of the solar system in the galaxy affects rates of biogeochemical processes, that of N. K. Serov attempts to show how (from a general philosophical point of view) various space factors will affect human mental and social activity.

V. N. Yagodinskiy analyzes the general results of change in heliophysical /6 factors on development of the epidemic process, closely related to the social medium.

A. P. Dubrov concretizes the effect of heliophysical factors on plants, concluding that the disturbing effect of the geomagnetic field on the membrane apparatus of the cell can be a decisive factor of heliophysical action.

S. A. Stanko, analyzing the effect of pulsed concentrated sunlight, in theory not only a geomagnetic but also a light factor under certain conditions (although not yet found in this form on Earth, it exists in space), must be considered by space biologists as a violent element causing extremely varied consequences. Specific physical approaches to the evaluation of the energetic and informational effect of the stationary geomagnetic field, disturbed and acting as a stimulus, are given by N. I. Muzalevskaya.

The articles of Yu. A. Kholodov and Yu. I. Novitskiy attempt to evaluate the effectiveness of the stationary magnetic field, as a physical and geophysical factor, on man, animals and plants at various levels.

The brief reports of V. S. Levashov et al., and B. M. Vladimirskiy et al., give specific results of the effect of solar activity and the electromagnetic field on microorganisms. The collection concludes with a brief review, of obvious interest to the reader, by V. Yu. Strekova on the state and course of such an important process in the living organism as mitosis in a magnetic field.

It must be noted that during the editorial preparation of this publication books appeared directly relating to its subject matter. These include the collections, "Vliyaniye solnechnoy aktivnosti na atmosferu i biosferu Zemli" (The effect of solar activity on the atmosphere and biosphere of the earth) (Moscow, "Nauka," 1971); "Vliyaniye magnitnykh poley na biologicheskiye ob'yekty" (The effect of magnetic fields on biological objects)(Moscow, "Nauka," 1971); "Issledovaniya po geomagnetizmu, aeronomii i fizike Solntsa" (Studies in geomagnetism, aeronomy and solar physics)(Voprosy geliobiologii i biologicheskogo deystviya magnitnykh poley — Questions of heliobiology and the biological effect of magnetic fields — Vol. 17. Moscow, "Nauka,", 1971); the book of M. P. Travkin, "Zhizn' i magnitnoye polye" (Life and the magnetic field)(Belgorod, 1971); the book of Yu. A. Kholodov, "Chelovek v magnitnoy nautinye" (Man in a magnetic web)(Moscow, "Znaniye", 1972), as well as material from the symposia "Reaction of biological systems to weak magnetic fields" (Moscow, 1971) and "The effect of artificial magnetic fields on living organisms" (Baku, 1972), which naturally could not be properly reflected in this publication.

The publication of these data again indicates the timeliness of the questions included in this collection.

Yu. A. Kholodov, Yu. I. Novitskiy

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THE DEPENDENCE OF THE PRODUCTIVITY OF THE BIOSPHERE ON THE POSITION OF THE SOLAR SYSTEM IN THE GALAXY

Yu. M. Malinovskiy

World reserves of oil, gas, coal, bituminous shale and phosphorites are very unevenly distributed. A study of their distribution in a cross section of the Earth's crust shows that maximum accumulations of these minerals are found at the same or neighboring stratigraphic levels, corresponding to the same phases of anomalistic periods of rotation of the solar system in the galaxy. /7

The question of the periodicity of geological processes is not new. It was touched upon in the works of S. N. Bubnov, L. V. Pustovalov, B. L. Lichkov, N. M. Strakhov, V. V. Belousov, V. D. Nalivkin, etc.

Now a new direction has been noted in analyzing the periodicity of precipitation formation which also includes periodicity of productivity of the biosphere. It consists of a detailed correlation of various age stages in the development of the Earth which is called cophasal stratigraphy by the author (1963).

The first attempt to compare separate phases of geological history was undertaken by S. N. Bubnov who formulated a curve (spiral) of the cyclic development of the Earth, distinguishing five cycles.

S. V. Tikhomirov (1960) compiled a "scheme for a general stratigraphic scale for post-proterozoic time." His scheme is closest to that suggested by the author.

N. F. Balukhovskiy (1963, 1965) distinguished a total of three cycles and considered each succeeding cycle to be 20 million years longer than the preceding.

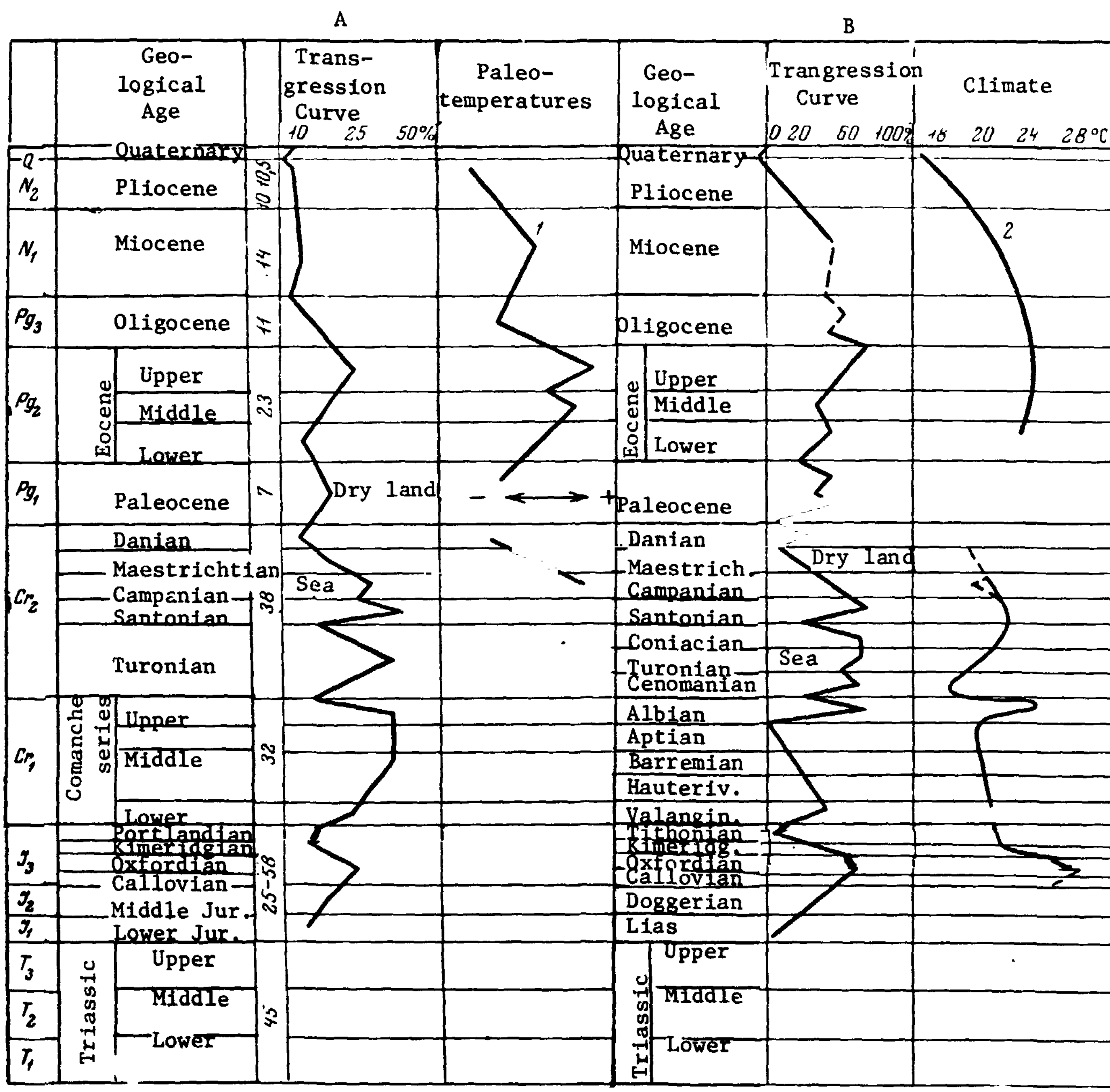


Fig. 1. Transgressions and climate of middle latitudes of the northern hemisphere (Alpine Epoch)

A — North America; B — Western Europe; C — Eastern Europe (south of the Russian platform); D — middle latitudes of the northern hemisphere; E — Central Asia (southwest of Turgai plateau); 1 — after Dorf (1957); 2 — after Eric (1961)

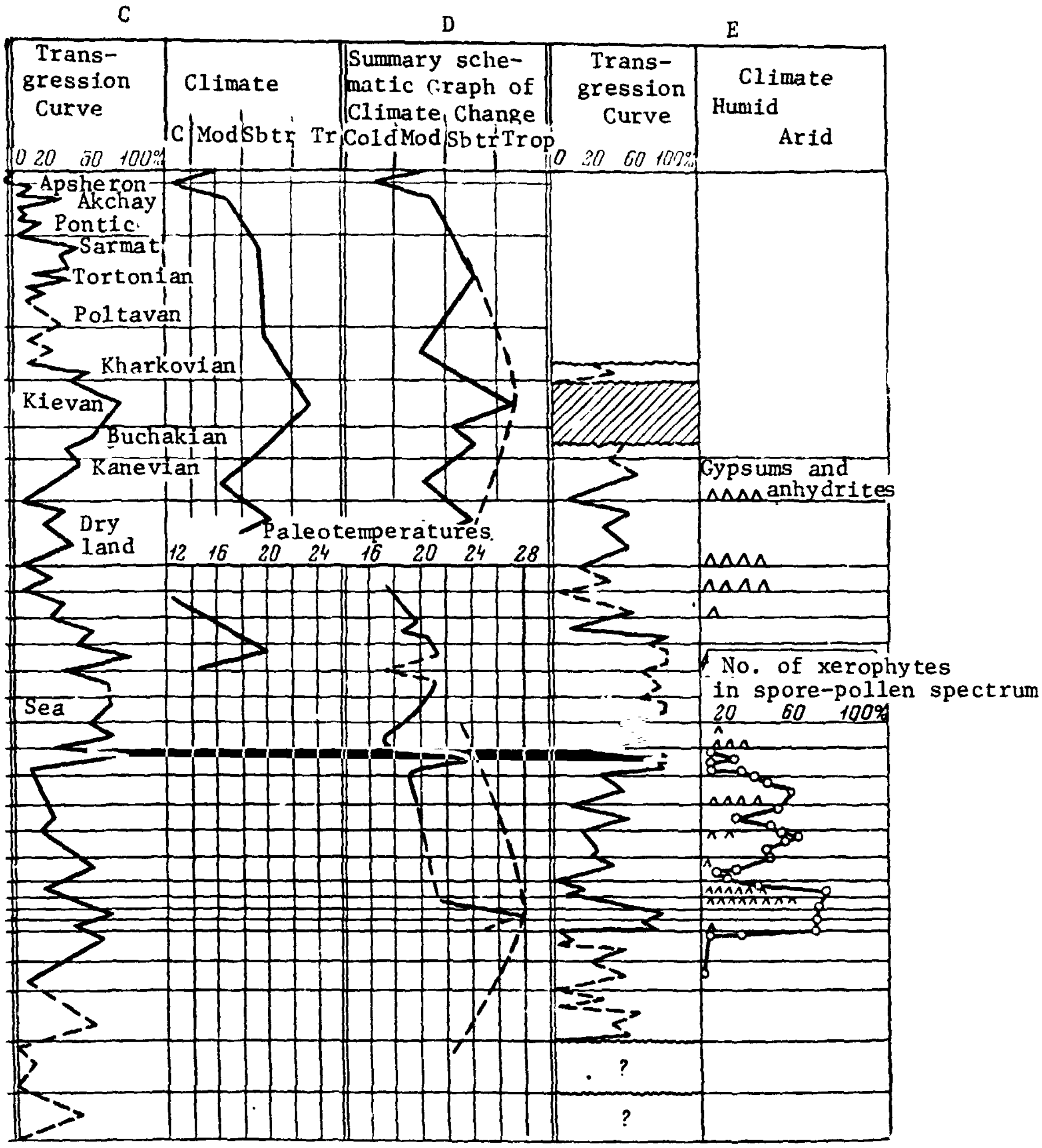
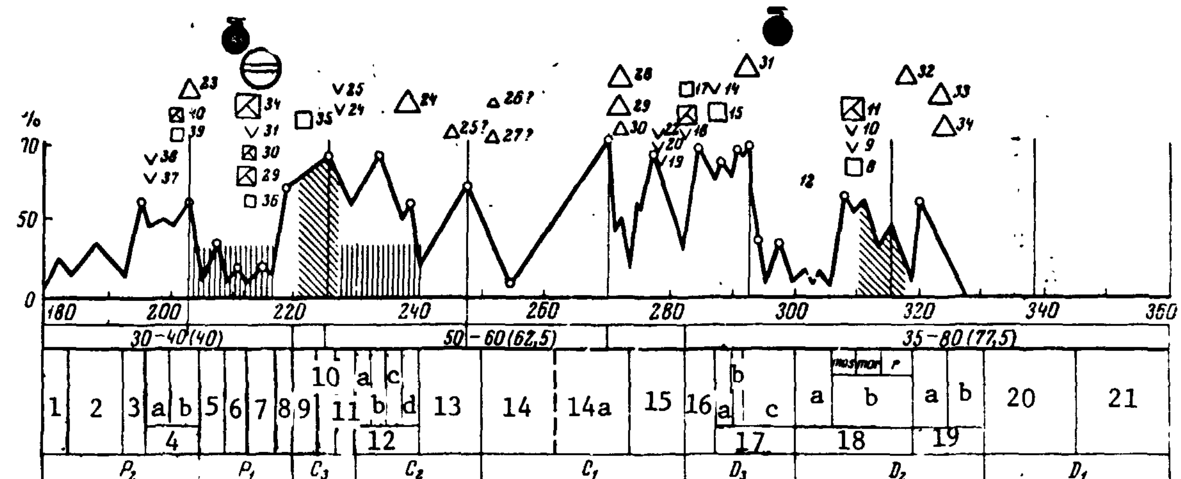


Fig. 1. Continuation



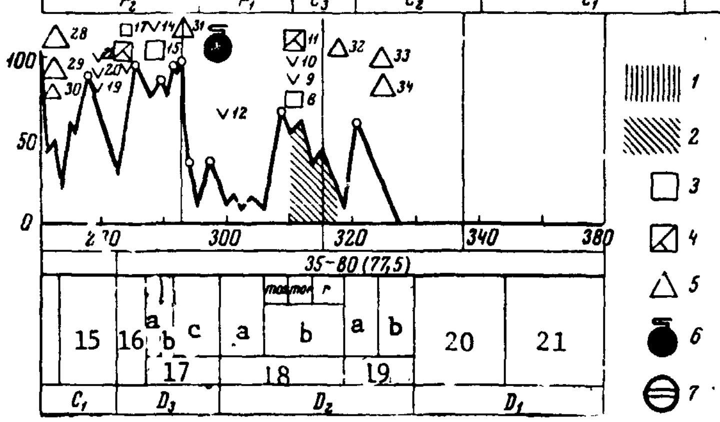


Fig. 2. Correlation scheme of transgression curves for Alpine, Variscan and Caledonian stages in the development of the Russian platform

1 — carboniferous epochs; 2 — epochs of bituminous shale formation; 3 — beds of rock salt; 4 — beds of potash salt; 5 — bauxite beds; 6 — largest deposits of oil and gas; 7 — largest phosphorite deposits

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1 — Filay horizon
2 — North Dvina series
3 — Tatarian
4 — Kazanian
  a — Upper
  b — Lower
5 — Ufimian
6 — Kungurian
7 — Artinian
8 — Sakmaran
9 — Pseudo-fusulina
10 — Gzhelian
11 — Kasimovian
12 — Moscovian
  a — Myachkovian
  b — Podolian
  c — Kashiran
  d — Vereyan

13 — Bashkiran
14 — Namurian
14a — Viseskian
15 — Tournaisian
16 — Famennian
17 — Frasnian
  a — Upper
  b — Middle
  c — Lower
18 — Givetian
  a — Upper
  b — Lower
19 — Eifelian
  a — Upper
  b — Lower
20 — Coblenzian
21 — Gedinnian

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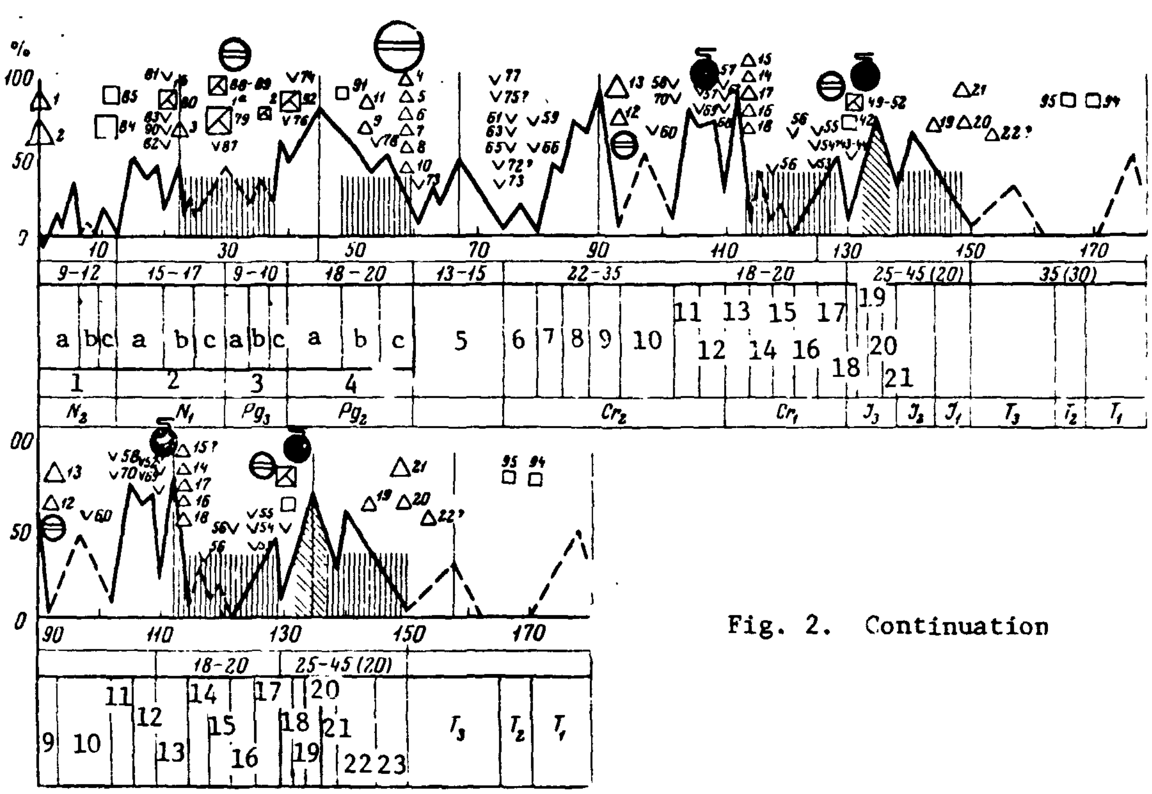

Fig. 2. Continuation

1 — Pliocene
  a — Upper
  b — Middle
  c — Lower
2 — Miocene
  a — Upper
  b — Middle
  c — Lower
3 — Oligocene
  a — Upper
  b — Middle
  c — Lower
4 — Eocene
  a — Upper
  b — Middle
  c — Lower
5 — Paleoce

6 — Danian
7 — Maestrichtian
8 — Campanian
9 — Santonian
10 — Coniacian
11 — Turonian
12 — Cenomanian
13 — Albian
14 — Aptian
15 — Barremian
16 — Hauterivian
17 — Valanginian
18 — Tithonian
19 — Kimeridgian
20 — Oxfordian
21 — Callovian
22 — Doggerian
23 — Lias

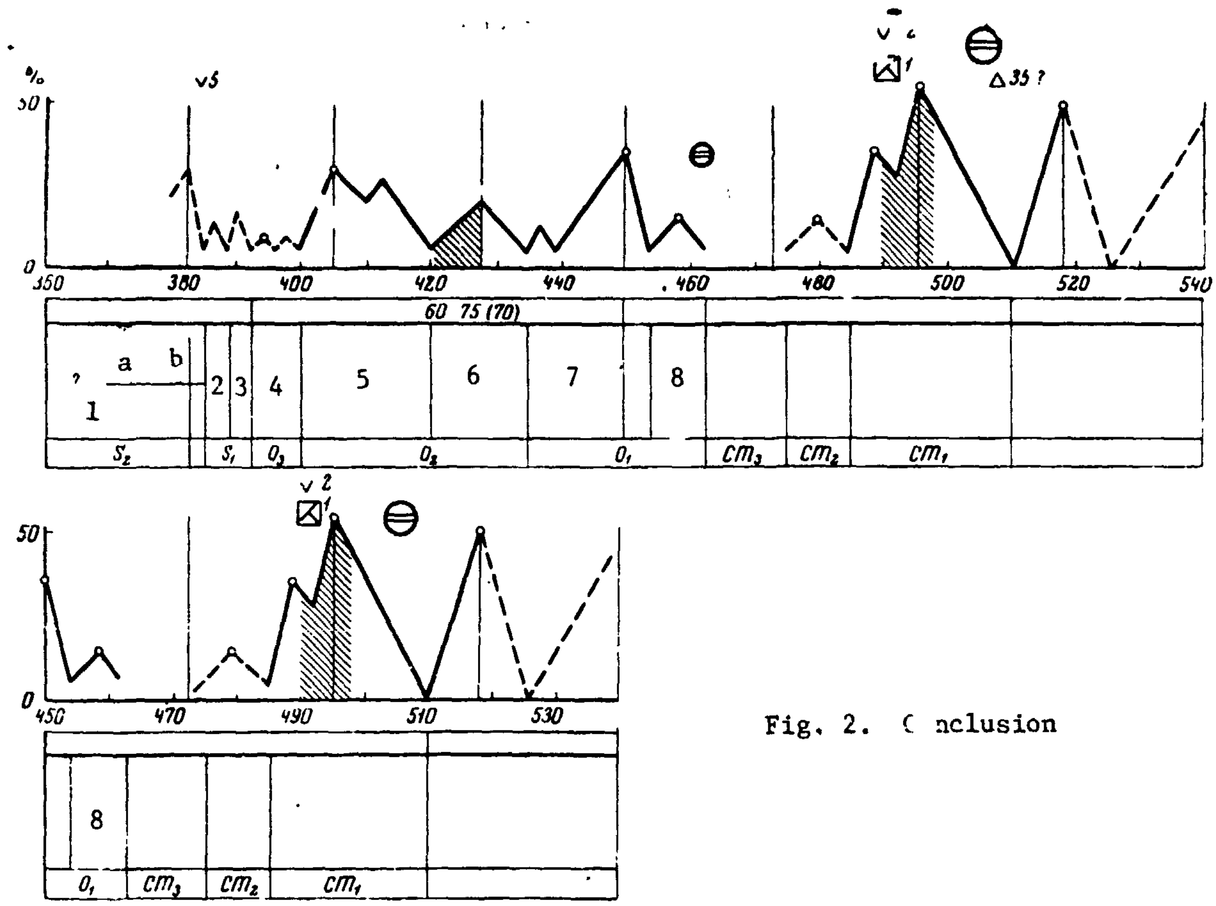

Fig. 2. Conclusion

1 — Ludlovian
  a — Upper
  b — Lower
2 — Wenlockian
3 — Llandoverian
4 — Ashgillian
5 — Caradocian
6 — Llandeilian
7 — Arenigian
8 — Tremadocian
  (Pakerordi)

1. CORRELATION SCHEME

In order to correlate geological events of Caledonian, Variscan and Alpine stages in the Earth's development, we plotted transgression curves for post-proterozoic basins of the Russian platform (Fig. 1, pp. 4-6)

In plotting these curves the approximate percent ratio of dry land and sea was noted along the vertical axis and absolute time along the horizontal axis, according to the 1964 Soviet scale. Basically we used the Atlas of lithologo-paleographic maps of the Russian platform and its geosynclinal framing (Vinogradov et al., 1960, and others). /11

As the result of studying transgression curves, we found that the periodicity of maximum transgressions was 20-25 million years in Kainozoic and 20-35 million years in Mesozoic and Paleozoic eras. It was thus possible to distinguish natural rhythms during which a complete period (in the physical sense) of fluctuations in the level of the world oceans from maximum to maximum occurs.

We assumed a connection between transgressions and fluctuations in the level of the world oceans (1963) on the basis of data on the synchronism of basic Mesozoic and Kainozoic transgressions in the northern hemisphere and their regular connection with general warming of climates (Fig. 1).

Moments of maximum transgressions are determined more certainly than moments of maximum regression or any other kind of adequate moments; therefore, rhythms distinguished by maximum transgressions are more reliable.

This periodicity of 20-35 million years made it possible to compare the rhythms of Alpine, Variscan and Caledonian stages in the development of the Earth and to note a periodicity of rhythms of approximately 180 (age) and 90 (halfage) million years. As a result a correlation scheme of transgression curves was produced (Fig. 2), based on the periodicity of changes in the rhythms.

Because we distinguish layers formed in the same phases of geological stages of the Earth's development, i.e. we intend to determine cophases in the formation of particular deposits, the correlation of stages can be called "cophasal stratigraphy."

Correlation of transgression curves which reflect variations in the level of the world oceans during stages in the development of the Earth consists of a detailed comparison of one basic index connected with the formation of mineral beds and other geological phenomena. Therefore, if correlation between geological processes is correct, mineral beds of one type will be located in the scheme along one, two or a few lines — along the cophasal axis (Fig. 2).

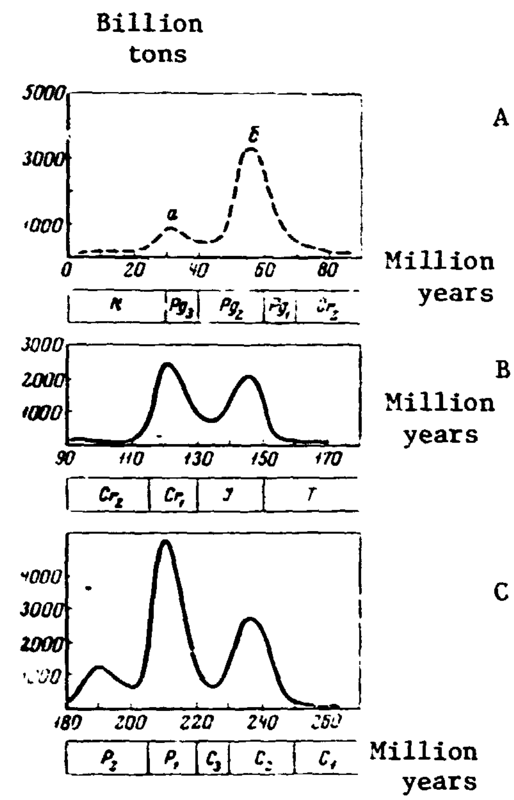

Fig. 3. Diagram of world coal reserves by stages (A, B, C).

a — lienites of the Turgayskiy depression. Coal deposits of the Far East; b — Lignite deposits of the Ukraine

II. VERIFICATION AND MORE PRECISE DEFINITION OF THE CORRELATION SCHEME ACCORDING TO DATA ON THE STRATIGRAPHIC DISTRIBUTION OF MINERAL BEDS, PALEONTOLOGY AND ABSOLUTE GEOCHRONOLOGY

In order to verify and precisely define cophasal individual sections of geological time,it is necessary to use data on the best known minerals, for example, salts and coals. Beds of non-ferrous and rare metals of sedimentary origin cannot always be used to the proper extent for cophasal stratigraphy. Study of these deposits, except bauxite, can determine cophases of only individual beds and roughly ascertain cophases of ore-formation epochs. In cases when a cophasal deposit is unknown, discovery can be predicted in deposits of the same age or halfage.

Salts. Deposits of potassium salts in the USSR (Ivanov, Levitskiy, 1960) are found only in tops of Middle Miocene (Kalush) and Lower Miocene (Stebnik) in the Precarpathian depression, Tithonian in the Guardak-Kugitang region, the Kungur stage in the Preural depression, the Famennian stage in the Pripyat depression and in tops of Lower Cambrian in Eastern Siberia.

In plotting these deposits on the correlation scheme of stages in the earth's development (see Fig. 2), potassium salt beds of Tithonian and the tops of Lower Cambrian occur on one vertical line in the halfage system, the largest deposits of potassium salts of Lower Miocene and the Kungur stage on another and Famennian deposits of the Pripyat depression and Tortonian deposits of potassium salts in the Kalush-Golyn region on a third. The presence of other potassium deposits on these same lines can be assumed in Middle Devonian which is an analog to Jurassic and Lower Cambrian (age) as well as in Kazanian and Tatarian stages of Upper Permian and in Upper Silurian which are cophasal (halfage) to Upper Devonian; this can be proved by information on foreign deposits.

Data on the stratigraphic distribution of potassium salts in other /13 countries (Bykhover, 1963) show that all large deposits are located in the system on lines marked for deposits in the Soviet Union. Thus, Middle Devonian beds in the Canadian province of Saskatchewan, with potassium oxide reserves of 17.7 billion tons, are cophasal (age) with Gaurdak and Lower Cambrian deposits. They are cophasal (halfage) with Lower and Middle Oligocene potassium salt deposits in Spain (Ebro basin) and France (Alsace) with total reserves of about 1 billion tons.

The vast Upper Zechstein deposits of potassium salts in East and West Germany, with total reserves of about 20 billion tons, were cophasal (halfage) with Upper Devonian salts of the Pripyat depression and Tortonian salts of the Precarpathian depression. Large Upper Permian potassium salt beds are also found in the US Permian basin.

Thus, all commercial potassium salt beds in the world are located along three lines in the scheme, which verifies the correct correlation of the stratigraphic classifications containing these deposits. Deposits of Lower Miocene and Lower Permian potassium salts were cophasal, coordinated with forward depressions. It is interesting that they are not cophasal by halfage. Extremely varied salts (halites), formed in epicontinental seas, are also cophasal by age. These are salts of the Guardak series of Central Asia, sea salts (D_2^2) of the Russian platform, salts of the Saskatchewan province in Canada and salts of tops of Lower Cambrian in Eastern Siberia. Because the latter are cophasal with the large potassium salt deposits in Guardak and Saskatchewan, there is every basis for assuming the presence of vast potassium salt beds in halogen strata of Lower Cambrian in Eastern Siberia.

Besides world potassium deposits, Fig. 2 also shows stratigraphic distribution of the majority of deposits of halites, gypsums and anhydrites in the USSR, Triassic salts in the Federal Republic of Germany and Ludlovian salts in the Michigan basin (Ivanov, Levitskiy, 1960). Almost all belong to III-IV and VII-VIII rhythms of each stage, which also include potassium salt beds.

Coals. Another example of cophases in the occurence of minerals is the distribution of world coal reserves through three halfages (Fig. 3). A preliminary scheme of the stratigraphic distribution of world coal reserves was compiled from the data of N. M. Strakhov (1960). Later data on coal reserves introduce no essential changes in this scheme.

During each of the last three halfages there were two epochs of coal formation occurring in the second and third quarters (see Fig. 4). Coal formation epochs of the second quarter (C_2, J_{1+2}, Pg_2) are characterized by almost universal absence of salt deposits. On the other hand, simultaneous large deposits of coal and vast salt deposits (P_1, Cr_1, N_1–Pg_3) are typical of coal formation epochs of the third quarter. Thus, in each halfage there is one epoch of simultaneous coal and salt formation (strong zonal climate), occurring in the III and VII rhythms, and one epoch with coal but no salt formation in the II and VI rhythms of geologic stages (weak zonal climate). /14

Along with the marked periodicity of coal accumulation, its irreversible evolution is also observed, expressed in gradual attenuation (from 5.2×10^{12} to 0.1×10^{12} tons) of coal formation, connected with sharply expressed zonal epochs, and in intensification (from 2.3×10^{12} to 4.2×10^{12} tons) of coal formation, connected with weak zonal epochs.

Therefore, cophasal epochs of coal formation are characterized not only by maximum coal reserves, but also by extremely varied paleographic conditions. Moreover, their similar spatial distribution of coal basins is typical. Almost all coal basins of Middle-Upper Carboniferous, Lower-Middle Jurassic and Upper Cretaceous are located in the zone between 30 and 60° north lati-

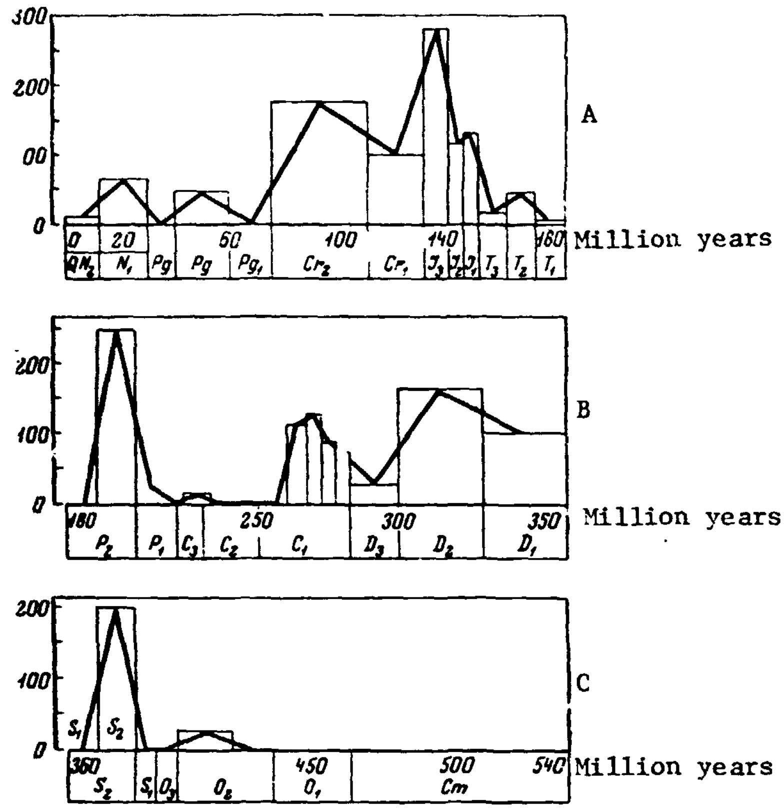

Fig. 4. Correlation of three stages A, B and C in the development of the Earth according to the number of Eurasian species of Eurasian and cosmopolitan types of crinoids of Paleozoic and Meso-Kainozoic in North America

tude, except extreme east Asia, and all coal basins of the Lower Permian and Lower Cretaceous are north or south of this band and in extreme eastern Asia. /15

Taking the above into account, it can be noted that the character of coal formation epochs and the spatial distribution of coal basins is repeated periodically and depends on the phase of geological stages.

Fauna. One verification of the comparison scheme of transgression curves is correlation of the three geological stages by the number of species of sea lilies in Paleozoic and Meso-Kainozoic basins of North America (see Fig. 4). Moore's data on the number of Eurasian species of Eurasian genera and Eurasian species of cosmopolitan genera of crinoids (Bubnov, 1960) are plotted along the vertical axis and the absolute time according to the transgression correlation scheme is plotted along the horizontal axis. The extent of Mississippian and Pennsylvanian stage systems was assumed from the data given in the "Geological Dictionary" (1955). The maximum number of Eurasian species of Eurasian and cosmopolitan genera of crinoids, in some measure reflecting the connection between the continents of America and Eurasia, occurs in epochs of transgression; an exception is the Middle Triassic maximum. However, no direct relation is observed between the intensity of transgressions and the number of sea lily species. This was determined by a complex combination of conditions causing the development of new species.

Typical maximums of Eurasian species of Eurasian and cosmopolitan genera of crinoids occur at the same phases of various stages in the development of the Earth (see Fig. 4). This verifies the correctness of determining age cophases with the help of transgression curves: Miocene to the Kazanian stage and early Ludlovian; Eocene to the time from the start of the Moscovian age to the end of Late Carboniferous and the Carodocian stage of Middle Ordovician; Senonian to early Carboniferous; Jurassic to Middle Devonian. There are no data on the number of crinoid genera for Cambrian and early Ordovician.

Conditions causing an increase in the number of species of living organisms can rival in complexity the conditions for the formation of minerals. It must be noted that conditions for the development of crinoids are so complex /16 that they are not cophasal by halfage.

Bituminous shales. As seen from Fig. 2, all commercial reserves of shale in the Soviet Union are related to one halfage phase, i.e. they are coordinated to Caledonian and Variscan analogs of Jurassic, which verifies the analogy between Upper Jurassic and Upper Carboniferous, as well as between Jurassic, Middle Devonian, Middle Ordovician and Early Cambrian.

Giant oil and gas deposits. At the present time in the entire world over 15 thousand oil and gas deposits are known; however, the main reserves and the extraction of oil and gas are concentrated in a small number of the largest fields (Varentsov, Ryabukhin, Yudin, 1966).

To completely understand the distribution of the main oil and gas reserves, it would be necessary to study the stratigraphic distribution of all oil and gas deposits in over 15 thousand beds. Because gas and oil deposits are usually multilayered, the total number exceeds 100 thousand. At the same time, studying distribution in a geological cross section of giant deposits will reveal the basic maximums of oil and gas accumulation without taking into account the vast number of deposits because, first of all, large, medium and small deposits are primarily located in the same horizons as the giants and, secondly, maximums caused by giants will not be leveled out, even with equal distribution of all other oil and gas reserves (Brod, Vysotskiy, 1965).

Clearly distinguished in the Alpine stage are (1) Oligocene-Lower Miocene and (2) Upper Jurassic-Senomanian maximums of oil and gas accumulation and also several secondary maximums; (3) in Middle Pliocene; (4) Paleocene; (5) Lower-Middle Jurassic and (6) Triassic.

In the Variscan stage are distinguished: (7) Upper Carboniferous-Lower Permian; (8) Lower Visean-Upper Tournaisian; and (9) Upper Givetian-Lower Frasnian maximums of oil and gas accumulation and one secondary; (10) in the bases of Bashkirian and Moscovian stages.

In the Caledonian stage one small maximum of oil accumulation (11) is distinguished in the base of Ordovician and one more significant maximum (12) in Cambrian.

All giant oil and gas accumulations, along with their main reserves, are concentrated in deposits of these 12 comparatively brief formation epochs. Regarding the migration of hydrocarbons these are not epochs of oil or gas bed formation; these were formed much later than the enclosing deposits.

At the same time prehistory and later geological history of the development of vast regions of the earth indicate that huge deposits of oil and gas were formed in these 12 particular epochs and have remained until the present /17 time.

All these sections of geological time, related to deposits of the main oil and gas reserves, are grouped in four cophasal oil and gas bearing epochs (see Fig. 2).

The first oil and gas bearing epoch of the halfages is connected with the Paleocene carbonate collectors of the giant Sultan oil field, the Middle Jurassic sandstones of South Mangishlak oil giants and the Bashkir carbonate collectors of the Kuleshov oil field and the Orenburg gas field.

Giant deposits of gas or oil have not as yet been found in bases of the Eifelian stage, bases of Middle Ordovician or Lower Cambrian which were formed during this oil and gas bearing epoch. However, their cophases with Paleocene, Middle Jurassic and Upper Bashkirian deposits give rise to prospects for discovering giant accumulations of oil and gas there also.

Huge accumulations of oil and gas occurred in the second oil and gas bearing epoch of the last three halfages. This epoch in the Kainozoic halfage is connected with Oligocene carbonate rock of the Asmara series which contains giant oil and gas fields in Iran and Iraq, Oligocene sandstones of the North Stavropol gas field and Oligocene and Lower Miocene sandstones of the Bolivar Coastal region of Venezuela.

Cophasal with these oil and gas bearing strata in the Mesozoic halfage are carbonate rock in the tops of Upper Jurassic, containing the giant oil deposits at Ghawar as well as the giant gas deposit in the Lac field in France.

In the Carboniferous-Permian halfage, Oligocene and Upper Jurassic collectors containing these giants are cophasal to terrigenous-carbonate collectors enclosing the giant Panhandle and Hugoton deposits in North America (P_1) and the Shebelinsk gas field (P_1) in the USSR as well as the red sandstones (P_1) containing the colossal gas deposit in the Slochteren field in Holland.

No giant deposits have yet been found in Eifelian top-Givetian base stages, upper Ordovician and Lower Silurian or Lower Cambrian top-Middle Cambrian base deposits, but cophasal deposits containing colossal oil and gas fields suggest they may also be found there.

The third oil bearing epoch of the halfages is coordinated to a world maximum accumulation of hydrocarbons of Albian-Senomian (Burgan, Urengoyskoye gas fields, bitumens of Atabaska, East Texas, etc.) and giant deposits of oil in sandstones of the Lower Frasnian halfage in the Romashkin /18
and Novo Elkhov fields of Tatary. Deposits containing these gigantic fields are only cophasal by age. No halfage cophasal giants are known. Here the basic role was probably played by factors destructive to the hydrocarbon deposit, as giant fields in Upper Jurassic and Oligocene were covered with thick salt-bearing strata in the previous epoch. Oil or gas giant fields in Albian-Senomian and Lower Frasnian substages do not have salt-bearing rock in their covering. Their younger analogs, located at the end of the Variscan (bases of Kazanian stage) and Alpine (Middle Miocene) stages of development of the earth, have been subjected to a much greater degree of erosion.

This third oil and gas bearing epoch is probably connected with Cambrain sandstones of North Africa which enclose the giant deposits of oil in the Hessi-Messaud field.

Despite the fact that no giant deposits of oil or gas have yet been found in bases of Upper or tops of Middle Cambrian, because this moment is cophasal to Albian-Senomian and Upper Givetian-Lower Frasnian time, it can be expected that such fields will be found there. This conclusion is extremely important to those searching for oil and gas in the Eastern Siberian platform.

The main world hydrocarbon reserves belong to the third and second epochs of oil and gas formation. In addition, rich deposits of oil and gas are located between these epochs, including such giants as the Ust-Balyk and Samatlor oil fields, which united them in the great gas and oil bearing stages.

As was noted in preceding sections, all main deposits of bituminous shales belong to the Upper Jurassic and its Paleozoic analogs: Upper Carboniferous, the Eifelian stage of Middle Devonian, the end of Middle Ordovician and tops of Lower Cambrian. But world maximums of coal accumulation are coordinated to Lower-Middle Jurassic and Lower Cretaceous and their Kainozoic (Paleogene-Lower Miocene) and Paleozoic (Middle Carboniferous-Lower Permian) analogs, i.e. approximately the same sections of geological time as maximum accumulations of hydrocarbons. Therefore, main oil and gas reserves are connected with stages of the greatest productiveness of the biosphere, which are indicated by coal and shale, whose organic origin is undoubted.

Maximums of hydrocarbon accumulation are shifted slightly upward in cross section with reference to maximums of coal formation and "conclude" each of two maximums of biosphere activity. The Upper Jurassic oil and gas bearing maximum and its analogs accordingly close the Jurassic maximum of biosphere productivity and its cophases, and Senomanian-Albian and its cophases close Lower Cretaceous and its cophasal maximums.

Cophases of oil and gas bearing strata containing giant accumulations of /19 oil and gas indicate the correct correlation of Alpine and Variscan stages in the development of the Earth.

III. PERIODIC SCALE OF ABSOLUTE AGE

Based on the assumption that rates of geological processes during the entire Neocene are approximately equivalent, a "Periodic scale of absolute time" was composed which in general does not contradict the existing scale, but is more detailed and geological phenomena have a periodicity in the physical sense of the word. The practical meaning of such a scale is obvious. The lengths of Paleozoic and Mesozoic systems and their sections are determined by stratigraphic classifications of cophasal Kainozoic.

In comparing geological events on this scale with phases of the galactic year of approximately 176 million years (Pa :nago, 1952), it appears that similar geological events correspond to the same times of the galactic year. Therefore, it was assumed that geologic events depend on time of the galactic year. It was shown that perigalactics correspond to moments of strongest geological revolutions and apogalactics - to times of maximum regressions (Danian, Namurian and Llanvirnian).

To find the dependence of magmatic processes on time of the galactic year in order to prove the new scale of absolute age, a curve of distribution of granitoid intrusion ages was plotted (Fig. 5). The large number of measurements (406) made it possible to select intervals of five and ten million years in plotting the curve and histogram. In this case each point on the distribution curve shows what number of the 406 intrusives was formed during the indicated five or ten million years. The histogram and distribution curve of ages of granitoid massifs notes a periodicity of intense formation of granitoid bodies of 80-92 and 170-180 million years. Thus, this periodicity can be considered sufficiently validated. Average periodicity of 86 and 175 million years almost exactly corresponds to the length of the galactic year (176 million years) and half year (88 million years).

All moments when the solar system passes through three apogalactics and two perigalactics were marked by characteristic outbreaks of intrusive activity, followed by a period of minimal intrusive activity and rock formation. This and the high correlation between the curves of intrusive activity intensity of three galactic years (Fig. 6) leads to the conclusion that the inten- /20
sity depends on time of the galactic year, and the latter, as is known, is

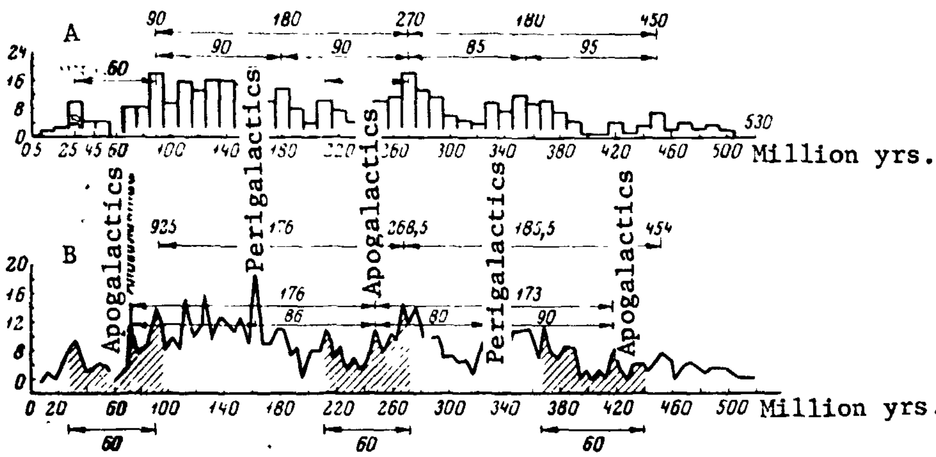

Fig. 5. Histogram and distribution curve of ages of granitoid massifs
A — every 10 million years; B — every 5 million years

closely connected with rock formation and folding.

In comparing transgression curves and the curve of intrusive activity, it was found that in the first 120-140 million years, on both scales of absolute age, each maximum on the curve of intrusive activity intensity corresponds to regression in the platform and, on the other hand, each minimum corresponds to transgression. This regularity will be maintained in Variscan and Caledonian stages if the scale of absolute age used is based on the correlation method suggested here.

Phosphorites. Everyone knows the huge role of phosphorus in the life of animals and plants. Therefore, it is interesting to trace how maximums of phosphate accumulation correlate with flourishings and abatings of vital activity in the biosphere throughout the history of the Earth.

At the present time the majority of geologists accept with some additions the homogeneous theory of phosphorite formation. According to this theory, deep waters of sea basins (beginning at 200 m) are the chief reserve of dissolved phosphates, but the main agent converting the phosphates of deceased organisms to solution is carbon dioxide. When these deep waters, saturated with CO_2 and P_2O_5 (to 300-600 mg/m^3), are fed with deep-water currents near a shelf the partial pressure of CO_2 is reduced. Therefore, the balance is disturbed and the water becomes supersaturated with phosphate minerals, which

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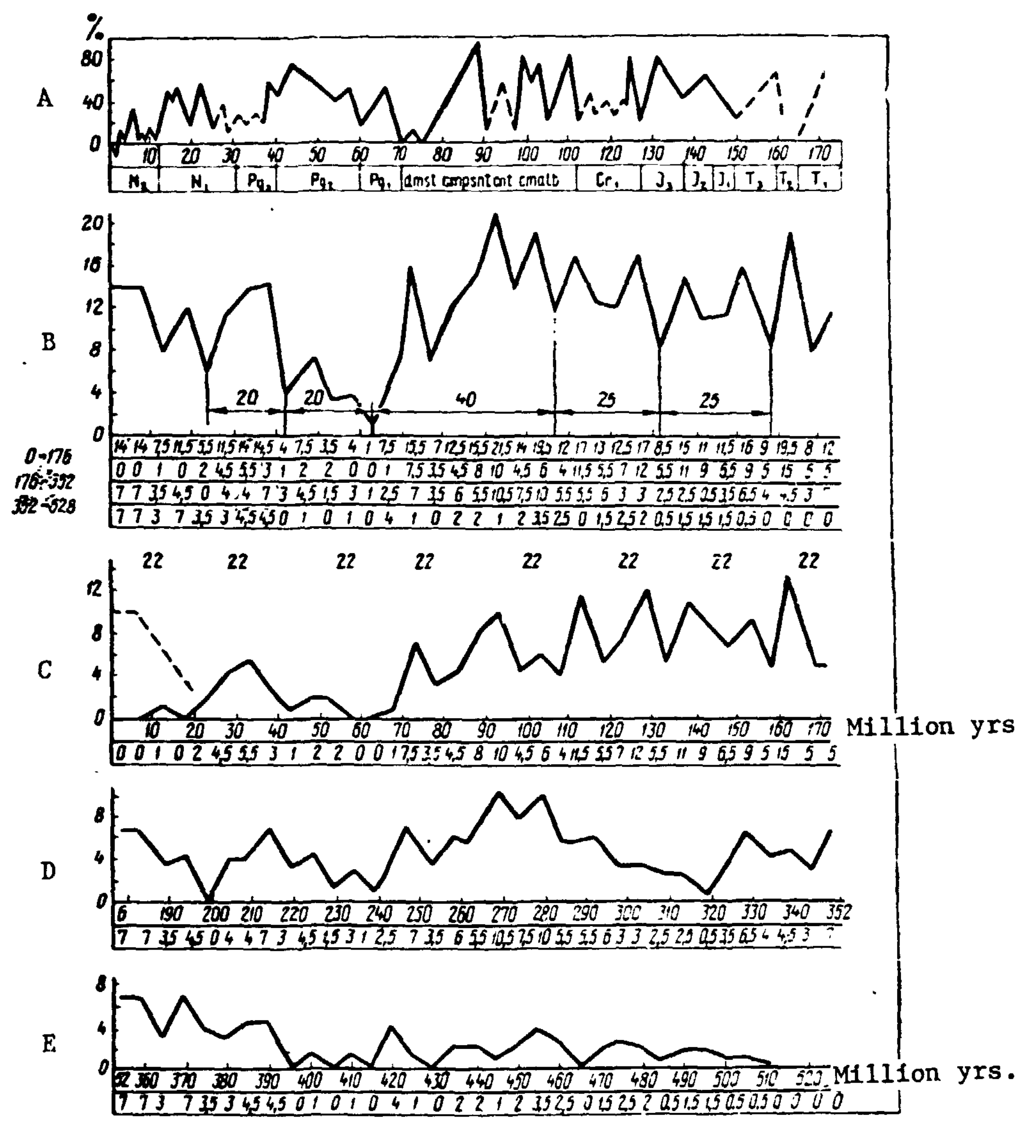

Fig. 6. Correlation of distribution curves of ages of granitoid massifs of the last 3 galactic years; summary distribution curve and comparison with transgression curve

A — transgression curve; B — summary characteristics of the intensity of intrusive activity (number of massifs); C — Alpine period; D — Hercynian period; E — Caledonian period also begin to precipitate, usually in the vicinity of calcium carbonate.

The chief and generally-accepted regularity of phosphorite formation is / 22 the genetic connection between the majority of known phosphorite beds and transgressions of the sea and periods of extension of sea basins.

Data on the distribution of basic phosphorite mineral reserves in cross section of the Earth's crust are given in Fig. 2. Basic world phosphorite reserves consist of deposits of Lower Miocene in the Florida peninsula of the USA (about 5000 million tons), Lower Eocene of Central Africa (25,000 million tons), Santonian of the Aktyubinsk basin (over 500 million tons), tops of Upper Jurassic-bases of Valanginian of the Russian platform (2320 million tons), Lower Permian "Phosphoria" formation in the US Rocky Mountains (8000 million tons), the Tremadocian stage of Prebaltica (1000 million tons), bases of Middle Cambrian of Kara-Tau and Ulu-Tau in Kazakhstan (over 1500 million tons) and in Lower Cambrian deposits in the Yunan basin of China (about 1500 million tons).

All the largest deposits are arranged (Fig. 2) one under the other, verifying the correct correlation between Alpine, Variscan and Caledonian stages in the development of the Earth, with the exception of the phosphorite beds of North Africa which have no analogs in Middle Carboniferous or Middle Devonian. Now, if we turn to activity maximums of the biosphere, we see this is where all the largest deposits of phosphorites occur, containing over 90% of the world's resources. An exception is noted in Middle-Upper Ordovician maximums of organic carbon accumulation.

To the author the relation between these maximums does not seem purely accidental. The main mass of phosphorus, equal to 30 times the world's phosphorite reserve, is contained in the ocean. A complete cycle of all phosphorus does not occur in the ocean and it accumulates in large amounts in deep layers of water.

In modern oceans (Strakhov, 1960) four horizons are distinguished with various amounts of phosphorus: 1) the surface layer to a depth of 50 m with low concentration, from "biologically zero" (under 1 mg/m^3) to 10-20 mg/m^3; 2) a transitional horizon at several hundred meters where the phosphorus content increases sharply with depth; 3) a horizon of maximum phosphorus concentrations, reaching 150-200 mg/m^3 (depths of 500-1500 m); 4) a strong zone of deep water where the phosphorus content is lower than in the third horizon and depends little on depth.

With large transgressions connected with a rise in the level of the world oceans, the water surface increases almost 40% (surface of the Earth — 510 x 10^6 km, surface of modern day seas and oceans — 361 x 10^6 km). Therefore, the depth of the layer of water depleted of phosphorous is [illegible]nded and contracted, but deep waters which contain huge reserves of phosph[illegible] and CO_2 begin to /23 rise above the shelf and penetrate farther into contin[illegible], fertilizing vast living area spaces in its path. The greater the volume of water again produced by the sea, the higher will the phosphorus-rich layer rise. The volume depends on the amplitude of rise in ocean level and the flatness of the continent flooded by the ocean.

A rough estimate of the possible amount of phosphorus returned in this way to the biosphere when the ocean level fluctuates by 200-400 m is approximately 5 billion tons, which corresponds to the approximately 11.2 billion tons of P_2O_5 (converted to phosphorite) in about 50 billion tons of ore — an amount equal to world reserves.

What effect will such an additional amount of P_2O_5 have on the biosphere? It is interesting that the increased yield of sugar beets and potatoes per ton of additional P_2O_5 is 40-55 tons. The increase of plankton is probably still higher, as phosphorus in the photosynthesis zone is almost entirely consumed and the development of plankton increases at the present time in estuaries and in places with intensive rising water movements which carry biogenic elements from the bottom to the top. Taking into consideration the gradual supply of phosphorus in the course of transgression and the mixing of ocean waters in the upper 200 m, it can be assumed that the phosphorus arriving at the upper level will almost entirely be consumed by organisms. In this case, the increase in organic carbons will approximately correspond to the ratio of C_{org} and P in living organisms. This ratio is 46:1 in plankton, 80:1 in mollusks and 16:1 in fish (Strakhov, 1960). If even a minimum increase of 20-30 tons of C_{org} per ton of P is assumed, we obtain not less than 100-150 x x 10^9 C_{org} additionally. This figure is almost 100 times greater than the current amount of C_{org} included in living matter in the ocean, which consists of about 1.46 x 10^9 tons and is characterized by the highest productivity.

Thus, even each small transgression (+200 m) should be accompanied by activation of the biosphere not only because of the warming of the climate and equalization of its latitude differences, but also because of the additional introduction of phosphorus and other biogenic elements in the sphere of intensified vital activity.

Therefore, we can understand the close connection in formation time between bituminous planktogenic shales and the largest phosphorite deposits. Phosphorus arriving from the ocean at the moment of transgression promoted increased productivity of plankton in some regions and in others led to homogeneous thickening of phosphate minerals and in some cases (Prebaltica) to almost simultaneous accumulation of phosphorites and bituminous shales.

The structural characteristics of platform and geosynclinal phosphorite beds, noted by B. M. Himmelfarb in 1965 are also easily explained from this point of view. According to his data,in platform beds phosphorites already start to form from the first moments of transgression. In beds of geosynclinal /24
and boundary depressions phosphorites are nowhere formed from the first moment of transgression,but always after a long or short interval during which phosphorite-formation might either not occur or might be very sporadic. This is due, in my opinion, to the gradual development of transgressions which first, when they are still not enriched with deep water, cover geosynclines and boundary depressions and then higher sections of platforms. With the further development of the transgression, waters rich with phosphorus extend beyond the shelf, penetrate the platforms and give rise to the formation of phosphorites at almost the same time in geosynclines and in platforms; but,in geosynclines, above the discontinuity, by this time a layer of phosphorites has already begun to form, but not yet in the platform.

Probably the largest phosphorite beds are connected with the greatest amplitudes of rise in ocean level, preceded by the largest regressions (Preordovician, early Permian, Prevalanginian, Presantonian and early Miocene). At these moments the highest rise of deep horizons is possible, since the lower the water table before the transgression, the more the surface layer (poor in biogenic elements) is extended.

At the same time as phosphorus from deep layers of the ocean penetrated the vital level, from these same waters the atmosphere received an additional amount of CO_2 which was also increased by the general warming of the climate accompanying the transgression (Malinovskiy, 1963). In turn, CO_2 in the atmosphere also increased this effect. Possibly such mobilization of biogenic elements from the ocean together with warming and equalization of the climate of [illegible]e planet also led to simultaneous activation of biosis in the ocean and on dry land, particularly as plant productivity largely depends on the amount of CO_2 in the atmosphere.

* * *

The above data indicate that maximum productivity of the biosphere on dry land and in the ocean is largely determined by cosmogenic factors beginning approximately 10-15 million years after the solar system passes through the apocenter or pericenter and lasting (with two flares) for 40-45 million years. It is basically due to the periodic mobilization of phosphorus, CO_2 and other biogenic elements from the depths of the world ocean — a storehouse of biogenic elements.

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SOME PROBLEMS OF IN-DEPTH DIACHRONIC STUDY OF HUMAN MENTAL AND SOCIAL PROCESSES

N. K. Serov

INTRODUCTORY REMARKS

At the center of attention of diachronic research are various processes /26 reflecting certain aspects of the activity and existence of objects in question. Every example of a process recorded for an individual object of study can be characterized by its duration. A characteristic of a large number of examples is the so-called time module, which is the average duration of this large number of examples expressed in time units.

The problem of studying processes with a specific time module can be variously formulated: in some cases the characteristics of examples of the processes are studied as such; in other cases there is primary emphasis on the structure of the process in which processes with a lesser module are considered as its elements. Finally, problems can also be set up to find the variations between examples of the process, depending on their distribution in time against a background of more extensive processes with a greater module. It is the last type of problem that we mean when we speak of in-depth diachronic research, as this actually includes study of all three levels of the process: 1) a level of processes with a smaller module, of which the process being investigated is composed; 2) a level of processes with the given module, as such; 3) a level of processes with a greater module which compose the background of the process being investigated.

The main purpose of this type of study is to reveal the relations between the course of human mental and social processes, on the one hand, and the characteristics of cosmic, geophysical and meteorological environmental changes, which serve as the background for the development of human life activity, on the other.

The establishment of such relationships creates a reliable base for pre- /27 dicting the condition and behavior of a person or a group of people during certain changes in the natural environment, in order to develop measures to prevent the harmful effects of the medium on man's ability to live and work.

The distinct applied direction of this type of research is first of all due to the necessity of solving urgent safety control problems for human space flights. At the same time, preliminary results have already shown that such organized studies can also be important in solving a wide range of problems which now concern engineering psychology, psychology and the psychophysiology of work, and are touched upon by the theory of scientific organization of work, the theory of planning and control of human productive activity, etc.

The establishment of applied in-depth diachronic studies dictates a series of requirements for research programs. These include: 1) obtaining data which would provide recommendations for specific objects in specific conditions of place and time; 2) obtaining data which would not only reflect the condition of objects at a fixed moment of time but would also make it possible to foresee the course of events; 3) studying the action not so much of individual isolated agents under laboratory conditions as the integral natural complexes of environmental factors under ordinary production conditions. At the same time, in order to work out specific recommendations, the most accurate and reliable determination possible of these relationships is necessary. This is impossible to obtain without the use of quantitative methods of evaluation and comparison of initial data.

One means of satisfying these requirements is using so-called phase spaces to record the course of empirically-observed processes. Here the characteristics of the course of processes are reflected by the plotting of trajectories with a particular pattern and a particular composition (Andronov et al., 1959; Eshbi, 1959, 1964; Derusso et al., 1970). If the time axis is used as one of the coordinates of the phase space, with calendar-dated intervals marked off in specific time modules (Serov, 1970), it then becomes possible to characterize quantitatively a particular trajectory even when the supporting characteristics of the process do not yield to direct instrumental measurement. This is attained by analysis of so-called chronomorphological characteristics of the process, including its total duration, the duration of individual phases or pauses, frequency of events, rate or speed of their course, characteristics of the distribution of extremes along the entire /28 trajectory, lag and other characteristics determined numerically using coordinates of notable points of the trajectory along the time axis.

Primary use of chronomorphological characteristics of processes is also theoretically important in solving basic problems of in-depth diachronic research to reveal the relationships between the course of such diverse procedures as mental and social processes,on one hand,and processes of change in the natural environment,on the other. This results from the necessity of recording the first and second types of processes by plotting qualitatively different phase spaces; the time axis is the only element common to them and, correspondingly, these chronomorphological characteristics of the various processes are the only comparable element.

Thus, after determining the purposes and specific subject of in-depth diachronic research (the chronomorphological characteristics of processes of various modules), it remains only to determine accurately the material objects of study. Such objects in the study of human mental and social processes include: 1) a specific individual; 2) a specific small group (crew, team or a generally compact collective with less than 30 individuals); 3) variously sized human communities inhabiting territory with similar natural living conditions.

Variable cosmic, geophysical and meteorological environmental factors, whose effects can be significant for human life activity, are broken down according to degree of investigation: a) adequately studied, such as temperature, humidity, barometric pressure, etc.; b) little studied (cosmic radiation, electrostatic and magnetic fields, gravitational fields, etc.); c) still unknown. For example, there is the assumption, requiring experimental proof, that not only absolute statistical values of particular environmental characteristics can be effective, but the characteristics of their variability in time, etc., as well.

External factors can also vary in their degree of "pliability" by the regulatory action of man. Some of them — temperature, pressure, humidity, etc. — can be altered within given limits; some — for example, penetrating radiation or electromagnetic fields — can be estimated in advance and partially "neutralized." Finally, some are evidently theoretically not subject to human control because of their excessive power, unpredictable irregularity of occurrence or objective nonremovability.

It is also perfectly clear that the effect of external factors on modularly-different human social or mental processes can also vary. The effect of the /29 very same factor can be significant for processes with a module under 24 hours and indifferent for those with a large ten-year or more module, and vice versa. The same can evidently also be said about the significance of different factors for different objects, be it a specific individual with a certain type of nervous system and certain level of training or groups of people varying in number and density, etc.

THE HISTORY OF THE QUESTION

Do external cosmic, geophysical and meteorological factors affect the mental state and social behavior of man? To what degree do they determine the life of individuals or entire groups and communities?

A large number of attempts have been made to give some kind of answers to these important questions, as on them depends not only the solution of many urgent problems of everyday activity but also the development of scientific bases for predicting and foreseeing the future.

One of two extreme points of view on this problem is the categorical denial of any connections between natural environmental factors and human behavior. Its proponents through the ages have included those with extremely varied ideological views such as Pope Sixtus V (Gurev, 1970) and Hegel (1956).

The modern American sociologist P. Sorokin (1962), studying rhythms in social life, defended the theory of their particular social genesis: "If we postulate a very close dependence of socio-cultural systems on any external cosmic or biological forces, then we must deny any essential autonomy of these systems."

Detailed analysis and criticism of such expressions are not the purpose of this work. However, it can be noted that their authors remain on a purely speculative level of reasoning, operating with indistinctly determined concepts. In particular, neither Hegel nor Sorokin differentiates various cosmic factors by nature or by scales and degree of their possible effect on man nor by the effective module. In extremely generalized form they also discuss human social and mental processes. Several of these processes, evidently, do not really depend on particular changes in the environment. Others, for example, daily rhythms of human activity and condition, are so closely connected with them that it is usually unnoticed by people. The knowledge that people have about their own mechanism is also still far from perfect. Only recently /30 has it become known that each living person, considered as a physical object, is characterized not only by a material body, but also by several complex fields in the space immediately around the body. From what components this field is comprised, how far it extends, how it interacts with the fields of other people and with external geophysical fields, how the physical and mental state of man correlates with the variable states of the inherent element of human life — there are yet no valid answers to these and similar questions.

In addition to the above extreme point of view, researchers of cosmic effects on man have been known to run to another extreme — the complete determination of human life by cosmic factors. In the most categorical form this is typical of characteristic representatives of the unfortunately well-known popular astrology; however, it sometimes also finds adherents among rather serious naturalists as undoubtedly were Kepler, Bruno, Cardan and some others.

Various astrological ideas were especially widespread in the ancient civilizations of India, China, Japan, Mesopotamia, Egypt, Greece and Rome, in Celtic, North American Mayan and South American Incan cultures, etc. They were also prevalent in Europe until the 16-17th centuries. A detailed familiarity with them leads to the conclusion that in the thick layer of religio-mystical prejudices and superstitions surrounding them we sometimes find perfectly rational ideas about the structure of the world, based on experimental practice. It is very noteworthy that the so-called geomagnetic compass was used in Ancient China to select the site and orientation of new settlements as well as to solve other everyday problems (Needham, 1956). For researchers enanthiomorphism can be very interesting: the persistent prejudice of the ancients for distinguishing between right and left, fixing fertility in the form of a special symbol, which indicate the connection between natural and social phenomena (Lemann, 1900). The physical aspect of these phenomena could be a kind of "black box" for observers, as they are primarily interested in stable connections between the appearance of certain indicators and events in human life. The latter is also favored because predictions derived from external signs usually have a probable, but not categorically determined character.

Returning to the question of the two extreme points of view, it can be noted that empirical material already accumulated by modern science verifies neither one of these two extremes. An example of the modern position on the question of cosmic effects is the program undertaken by the organizational conference of the International Bioclimatological Society in 1956 which established that studies "be conducted under natural or laboratory conditions in order to characterize by measurement and reproduction the physical, chemical and biological factors for which a rather high statistical correlation is observed with measured physiological and pathological processes, making it possible to assume the existence of a reliable causal relation between the organism and the environment" (Biometeorologiya, 1965). /31

In the development of this program, by 1963, S. Tromp in cooperation with 26 scientists of various specialities, prepared a basic introduction to medical biometeorology, containing a bibliography of 4000 titles.

One of the pioneers in the study of the effect of space on human life in this country was A. L. Chizhevskiy (1924) whose first work contained a number of theoretical miscalculations. Later, various aspects of this problem, on basically a physiological level, were studied by L. L. Vasil'yev, S. V. Kaufman, P. G. Mezernitskiy, G. M. Danishevskiy, K. M. Bykov et al., and many others (see Yankelevich, 1961). The huge volume of experimental work and the various aspects of the main problem have now led to the formation of a cluster of scientific disciplines such as heliobiology, medical geography, biorhythmology, space biology and medicine, bioclimatology, magnetobiology, etc. An active role in the development of these disciplines is being played by A. T. Platonova, V. V. Parin, O. G. Gazenko, Yu. A. Kholodov, V. N. Chernigovskiy, V. A. Kozlov and others. In recent years a number of scientific conferences have been held in this country and numerous monographs and collections published (see Chubinskiy, 1965; Presman, 1968; Assman, 1966; Druzhinin et al., 1969; see references).

Unfortunately, in the total stream of publications, psychological, sociopsychological and sociological works today occupy an unjustifiedly small place.

In addition to traditional subjective-ideological barriers (unwillingness to admit the existence of extra-natural effects. etc.), serious difficulties for psychologists and sociologists are presented by the objective complexity of the problem and largely inadequate development of general methodology and concrete methods for empirical study. Therefore, an attempt will be made below to discuss two areas of methodological problems: 1) those arising in studying the effect of particular natural factors on man's mental and social life; and 2) /32 those connected with the necessity of taking into account the external variable background in psychological and sociological experiments. The discussion is built on the initial positions stated above in the introductory remarks to this work.

METHODOLOGICAL PROBLEMS IN REVEALING EXTRA-NATURAL EFFECTS ON HUMAN MENTAL AND SOCIAL PROCESSES

To more precisely define the object of discussion, first of all let us divide the majority of conceivable processes into combined classes according to the value of μ — the time module of the process.

All processes with a time module less than several minutes we place in the micromodular class. Mesomodular processes will include those with μ longer than several minutes but less than a day. All processes with μ longer than 24 hours we shall call macromodular, distinguishing within this class, when necessary, processes with month, year, decade, etc. modules.

We note that today very little reliable experimental data is yet available about processes with a module longer than several years because the length of the experiment in this case, taking into account reproducibility control, must be at least ten years.

Methods for the experimental study of micromodular processes are already well developed in the fields of physiology, psychophysiology, electroencephalography, engineering psychology, etc. Therefore, primary attention in the future will be given to revealing extra-natural effects on meso- and macromodular mental and social processes in man.

It is advisable from the very start to differentiate extra-natural effects:

energetic types, represented by various levels of physiological, mental and social activity, and informational (signal) types, dealt with in one of the works of P. K. Anokin (1962). However, the question of such a differentiation has as yet been little developed, but the theoretical scheme of in-depth diachronic research in both cases remains the same.

Nodal points of this scheme are as follows:

— precise definition of the time module of the processes being studied and selection of indicators, i.e. those suitable for recording phenomena with the smallest module unequivocally connected with the course of the process;

— plotting phase spaces, accumulation of empirical data and construction of trajectories in phase spaces which reflect the course of the process under /33 study;

— comparison of trajectories plotted for various examples of the same type of process, as well as for simultaneous examples of mental or social processes, on one hand, and examples of processes of change in extra-natural factors forming the background for the phenomena, on the other;

— finding quantitatively pronounced regularities in the pattern and composition of comparable trajectories;

— experimental control proof of these regularities.

It is obvious that each point in this scheme encompasses a series of more detailed operations, whose completion requires prolonged efforts. Many of the points and individual operations are interconnected as their final coordination is usually reached by successive approximations.

Let us consider several problems which arise in attempting to realize individual points.

Determination of the time module and selection of indicators. Two theoretically different approaches to the precise definition of μ are possible, characterizing the process being investigated. In the first, μ is determined as the average duration of some large number of examples of a particular process; the process is considered as something complete and final, with a more or less clearly pronounced beginning and end. Thus, the time module of an object can be determined as a whole, beginning with its appearance and ending with its disappearance. In this case we arrive at a concept analogous to that which Yu. A. Urmantsev and Yu. P. Trusov (1961) called the individual time of the object. We use this means to determine μ in considering processes characterized by a certain relaxation time (G. Gudvin, 1966). A variant of this method when direct measurements of the duration of the process are impossible is selection of a suitable interval on the scale of different time modules by excluding intervals with obviously insufficient and obviously excessive lengths.

In the second approach the value of μ is designated without regard for the actual duration of the process, but on the basis of practical requirements, characteristics of technical organization of the experiment or other considerations. Fragments of the process are considered as examples; their duration is equal to previously established values of μ. This method is advisable in studying rhythmically-fluctuating processes, especially macromodular examples. Therefore, in establishing the standard duration of individual acts of registering characteristics of the process, we thereby distinguish fragments with a specific /34 module. It is obvious that a more or less complete representation of the course of the integral process in this case depends on a rational distribution in time of individual acts of registration. An example of such an approach to the study of macromodular processes of human occupational activity is distinguishing daily cycles which encompass the performance of a daily program of occupational activities and periods of rest between.

Precise definition of the value of μ_k of the process also predetermines the value of μ_{k-1}, which characterizes particular phenomena to be used as indicators of the course of the process, as it is evident that there are certain ratios between μ_k and μ_{k-1}, depending on the specific nature of the process: μ_{k-1} must be significantly less than μ_k in order to obtain several measurements of the duration of the process. At the same time, μ_{k-1} cannot be so fractional that it is difficult to analyze results of observation, if only because of the increased time consumption.

Indicator-phenomena can be either readings of some measuring instrument or events recorded by an observer, etc. The assortment of various indicators and their nature are determined in each specific study depending on its purpose and technical means.

Plotting phase spaces and recording trajectories. Having selected a certain system of indicators for the process, we thereby fix selection of its variable characteristics. If a large number of conceivable values of some variable are ordered by their numerical value or some qualitative sign, then a coordinate axis can be constructed with reference to which the values of this variable will be orderly recorded.

Repeating this operation for each of n variables and correspondingly obtaining n cordinates, it is possible to construct n-dimensional phase space (state space) whose various points will reflect the specific measurements of variable characteristics of the process. Introducing the time axis among the coordinates, measured off in calendar-ordered intervals with a specific time module, we finally obtain a modular phase space in which individual measurements are represented by a system of discrete successive points. If, finally, these points are connected with a line, a trajectory will be obtained, an image of the process in the previously constructed phase space.

Phase spaces plotted in this way are a unique research tool, a kind of lens or filter helping to convert direct empirical observation of some real process /35 in all the diversity of its specific signs to an evidently depleted, but in return clearly fixed,image of the process.

In the most simplified cases the number of coordinates of a phase space can be n = 2. Here the image of the process is recorded on the common, ordinary two-dimensional graph. In more complex cases, with $n>3$, graphic representation of phase space is difficult. However, there are means of simplifying graphic registration of trajectories. For example, a multi-dimensional graph can be plotted according to the same principle used in topographical maps of a locality when numerous characteristics of the same point are mapped on a plane by using various notations.

One of the main problems in recording trajectories for large-module human mental and social processes is that in many cases the variable characteristics of these processes do not yield to any instrumental measurement. Therefore, here it is necessary to develop special designs for phase spaces. In particular, spaces can be used in which only the modulated time axis is numerically determined,while coordinates of supportive characteristics of the process are marked off in several segments with more or less clear boundaries, corresponding to individual qualitatively-different states of these characteristics. It is also possible to mark off the entire phase space beforehand in certain areas corresponding to more or less clearly pronounced qualitative states of the object. Points determining the trajectory will, in this case, fall at the intersection of areas corresponding to the observed state of the object, on one hand, and the calendar moment of the act of registration, on the other.

As calendar moments of acts of registration can be fixed on the time axis with any required accuracy, quantitative comparison of trajectories for various examples of the process here consists of determining the topological characteristics of the trajectory pattern. This basically depends upon which of the qualitatively-different regions a particular point falls. Therefore, the necessity of accurate determination of the position of the trajectory within a certain area becomes secondary. It is important here to point out that the theoretical validity of comparing various examples of the process wholly and completely depends on whether uniformly plotted phase spaces are used in recording their trajectories.

Above we discussed plotting phase spaces primarily for that stage of research when directly observed phenomena are being recorded. It must be noted that in analyzing primary data, phase spaces and correspondingly primary trajectories can be repeatedly transformed (generalized, consolidated and formalized) if this is necessary for accurate mathematical analysis of data and construction of models of the process. /36

It is possible to transform both modulated time intervals (by consolidation and conversion from module μ_k to module μ_{k+1} or further to module μ_{k+2}, etc.) and supportive characteristics of the trajectories (by conversion to typologically generalized groupings or analysis of the formal characteristics of the trajectory pattern, etc.).

Problems of comparing trajectories. As has already been mentioned, the primary condition for high-quality comparison is using uniformly plotted phase spaces to study various examples of the process. As applied to characteristics of the organization of time study, it means that three standard numerical values must be noted beforehand: T, ϑ and i, where T is the total duration of a single study, ϑ is the analysis increment or the time quantization increment and i is the so-called moment of analysis which determines the duration of an individual measurement of characteristics at each analysis increment. In studying macromodular processes modules T, ϑ and i are usually in the following ratio: $\mu T >> \mu \dot{v} >> \mu_i$, i.e. measurement events are distributed discretely over the period of T with significant gaps between. If characteristics of the process are registered with automatic recorders, modul.s $\dot{v}$ and i are determined by the inertial characteristics of these instruments.

Methods of comparing trajectories for various examples of the same process have already been adequately developed in experimental practice (Vinogradov, 1958; Rokotova, 1967). General methods of statistical-probability analysis of trajectories have also been developed (Romanenko, Sergeyev, 1968). If we speak of comparing the course of specific meso- and macromodular processes of human activity with the course of specific processes of change in natural factors, there is today a series of difficulties. In accordance with already determined division of scientific work, the course of natural processes is being recorded in individual scientific disciplines, be it astronomy, meteorology or geophysics. Each uses various methods and technical means to rec and analyze initial data, developed on the b. the internal requirements of the individual disciplines (Tverskoy, 1962; Yanovskiy, 1964).

Preliminary meteorological, magnetometrical and other data are recorded at specific calendar moments and at specific geographical points which, as a rule, do not coincide with the moments or points of psychological and sociological observations. Therefore, we must note that a comprehensive, thorough comparison will evidently be possible only in the distant future when more complete data on the environment are available. /37

It remains to give basic consideration to collecting psychological and sociological data which will be most suitable for comparison with the characteristics of natural processes using already existing methods of recording the latter.

Problems of accumulating empirical data. As is known, in modern science there are two basic methods of obtaining initial data: organized observation, encompassing various means of recording natural conditions and the course of phenomena under natural conditions and a strictly experimental method where the effects of individual isolated agents on a test object (one variant is the laboratory method) are recorded.

Before considering the methodological problems of obtaining data from these two possible sources, let us attempt to give a rather brief resumé of available information on the effect and natural variableness of extra-natural factors.

1. Their numerical characteristics fluctuate during the course of a day, a month, a year, a multi-year interval., etc., so that a multi-stag system of more or less regular varied-frequency rhythms is formed.

2. The "normal" rhythmic pattern of natural fluctuations for many factors is upset by the appearance from time to time of disturbances with various time modules.

3. It is possible to differentiate long-acting factors which are stable for a given geographic point from brief changes of either a "normal" daily, etc. scale or related to sudden, transient disturbances.

4. Finally, even if some extra-natural factors also affect the state or behavior of man, their effect always occurs against that complex background which is created by their entire aggregate. In addition, human states observed under natural conditions are formed under the influence of a series of factors of another kind: general biological, individual-physiological and psychological, /38 social (perceived and unperceived), regularly stable and random, etc.

Analysis of these circumstances shows that the aims of organized observation can be variously formulated. In some cases it will be study of processes of adaptation and acclimatization (this type in particular includes the majority of biometeorological studies). In other cases a correlation can be found between the "normal" rhythm of extra-natural factors and the "normal" (with the exception of random deviations) rhythm of human activity, in others — the effect on the human condition of sudden brief disturbances of the natural background, etc.

It is evident that in each of these problems the character of preliminary data and the method of analyzing them are varied. However, several general methodological requirements for all these cases can also be noted. In organized observation, accurate calendar dating of recorded phenomena is especially important; frequency of acts of registration and their distribution throughout the day, month, year, etc., must be coordinated as well as possible with similar characteristics of recorded indices of extra-natural media, assumed in the work of already existing specialized observation services. Also the accumulation of a rather prolonged series of observations is very important, providing multiple repetition of these effects and the possibility of excluding random deviations.

A necessary requirement in studies of this type is the registration not only of the "normal" course of phenomena, but also all kinds of anomalies. This relates not only to absolute values of measured indices but also to the position of individual notable points on the fixed trajectory in time.

Directly observed mesomodular phenomena, of which macromodular human mental and social processes are composed, are not only a complex product of the current effect of diverse factors — biological, social, meteorological, etc. — but also the product of factors variously distributed in time. What is more, methodological requirements for organized observation must include those making it possible to detect typological differences in reactivity. In particular, in statistical generalization of initial data it is advisable to make preliminary groupings of individual trajectories similar in pattern and dating. Data for statistical analysis must be collected within the boundaries of a locality with uniform bioactive characteristics, etc. Let us now consider the second source of empirical data — experimentation.

We first note that laboratory experiment, because of the specificity of /39
this form of research, cannot be considered as a main source of data. This is due, first of all, to the fact that using it in studying macromodular processes will lead to serious technical complications and for processes of year or longer modules it becomes simply impractical. Secondly, by itself the principle of controlling external test conditions while investigating the effect of cosmic and geophysical factors on human life activity cannot always be realized, as the inventory of conditions to be controlled is unknown beforehand. Finally, thirdly, orientation toward only laboratory experiment contradicts the basic application of the research: its ultimate purpose is the development of practical recommendations for everyday human, particularly production activity, which is completely absent under laboratory conditions.

Therefore, the problem arises of developing specific experimental methods suitable for use outside the laboratory in ordinary, everyday conditions of human activity. To illustrate this methodological problem, let us list once again several initial circumstances: 1) the complexity and indivisibility of the entire aggregate of extra-natural factors; 2) the impossibility of controlling their values and the character of spontaneous variability; 3) superpositioning of the effect of extra-natural factors on the effect of biological, social, etc., factors; 4) the existence of more or less determined regularities in fluctuations of the external background; 5) possible incompleteness of the list of bioactive factors known today; 6) the necessity of using environmental data already obtained by existing specialized services — meteorological, magnetometrical, astronomical, etc.; 7) the spontaneous variability during a macromodular experiment of the object of study itself — a person, groups or communities of people; 8) will the presence of specific applied purposes of the experiment in each particular case prove the theory of external effects or be the basis of recommendations for the organization of activity of the object.

As seen from even this incomplete list, initial conditions and requirements for experiment in our case differ significantly from those ordinarily needed for classic laboratory experiment when test objects and the most significant external conditions are standardized and it is possible to isolate and measure out the effect of particular agents on the objects.

One possible means of developing experimental methods which satisfy these conditions is based on refusal to search for global universal relations which will be valid at any moment for any object in favor of looking for /40 more modest, but in return more specific solutions. It must be noted here that such an approach in no way excludes the possibility of formulating generalized unified methods, suitable for solving various types of specific problems.

The principle of experiments of this sort is a distinct inversion of the basic principles of classic laboratory experiment: instead of standard objects, specific objects are selected, clearly differing from each other; instead of controlled external conditions, a naturally varying extra-natural background is intended. It is assumed that the condition of the object is determined not by the effect of isolated agents but all at one time by their entire complexes which can also include previously undetermined components. It is not the extra-natural factors themselves, which affect the object, which are standardly reproduced and experimentally metered, but specially-selected so-called test loads for each specific purpose.

Such an experiment records doses of test loads, the calendar moments of their application and the characteristics of reactions of the object to a standard test load.

Various types of test loads can be selected, depending on the problem, from arbitrarily designated physical exercises, as in some functional tests in medicine, to standard programs of actions included in the object's usual activity.

The postulative assumption underlying the appearance of extra-natural influences on human activity in the use of test load methods is as follows: if these effects actually occur and affect the perception of the test load by the object, then in a sufficiently long series of load applications a correlation should be detected between the trajectory of reactions to the load and a particular trajectory describing natural changes in extra-natural factors.

Of course, the cognitive value of these kinds of empirical data is limited as they characterize this one object and the effect of natural factors on the application of a given test load. However, for many practical problems exactly such an approach is necessary. Even if after a long series of test loads no correlations are found with any external factors, the pattern of the recorded trajectory itself can serve as the basis for recognizing character- /41 istic regularities in the reaction of a specific object to test loads distributed in time; and if these loads correspond to the occupational activity of the object, the regularities can be used for individualized prediction of this activity and for its systematic organization.

<u>Problems in finding quantitative regularities in trajectory patterns</u>.

Taking into account the above characteristics of extra-natural factors and objects of study, it can certainly be assumed that strictly-determined effects of external actions on human social and mental processes can hardly be observed. Rather, we must evidently expect irregular effects with intensity varying from case to case Correspondingly, the assumed regularities are also most likely probable.

This means that methods of generalization and analysis of empirical data must be oriented toward searching in this direction. For generalization a sufficiently large number of measurements must be used, either a great many simultaneously studied objects or a great many nonsimultaneous conditions of the same object; obtaining negative or positive results in single comparisons must not serve as the basis for categorical conclusions of one type or another.

Some of today's most developed means of trajectory analysis are based on the theory of random processes (Romanenko, Sergeyev, 1968). However, they are not always used, both because of their complexity and time consumption and because the sought regularities appear in far from all cases of correlation of compared trajectory patterns. Therefore, the question of developing sufficiently simple and at the same time reliable methods of analysis remains open on the agenda.

Among the possible approaches to solving this problem we can note that which was used in the work of I. P. Druzhinin and N. V. Kham'yanova who, searching for regularities in the effect of solar activity on terrestrial processes, suggested that a sharp change (discontinuity) in the existing course of natural processes on earth can be considered the result of sharp changes in solar activity.

In addition to sharp discontinuities, other systematically occurring deviations in the trajectory pattern can evidently also be a diagnostic sign of regular external actions: changes in the typical delay reaction of a given object, changes in the length of particular cycles in periodic processes, interruptions or pauses in their course, deviations in chronomorphological /42 characteristics of test load reactions, etc.

One of the basic criteria for establishing regularities in the effect of external factors on the course of human life processes is a time shift between their action and the reflection in the course of these processes.

THE PROBLEM OF REPRODUCIBILITY OF RESULTS OF PSYCHOLOGICAL AND SOCIOLOGICAL EXPERIMENT

Reliable and accurate knowledge of regularities of the effect of extra-natural factors on meso- and macromodular human life processes is as yet only beginning to be accumulated. This requires that a whole series of fundamental problems be solved: finding types of bioactive effects, learning the degree of their effect, establishing typological groupings of people according to the degree of their reactivity to change in extra-natural conditions, etc.

However, even now, recognizing as yet only the theoretical possibility of regular connections between changes in the natural background and in human conditions, several general methodological conclusions can be drawn concerning planning and conducting many kinds of psychological and sociological experiments.

The main part of these conclusions concerns conditions for the reproducibility of the experiment. The reproducibility requirement is now one of the main criteria of the scientific significance of experimental data. It is based on the postulate of the uniformity of time characteristics.

With an unlimited number of identical objects, remaining unchanged in time, and with the fulfillment of other conditions of the classic laboratory experiment this postulate is completely acceptable.

In psychology and sociology the objects of study have individual differences and, moreover, are characterized by spontaneous multistage rhythmical variability. Therefore, the question of the validity of using the above postulate requires special analysis in each specific case. Solution of this problem depends on whether the object of study is a single specific object (a person, a compact group, a community of people) or many uniform objects (individuals, groups, communities) and on the time module of the phenomena, states or processes comprising the subject of the study.

Let us consider separately these conditions of reproducibility of results in the following types of experimental problems.

1. Finding stable average characteristics of a large aggregate of uniform /43 objects.

2. Finding a brief specific reaction of a particular kind of object to a particular effect using a large number of uniform objects, assumed to be identical, in the experiment.

3. Finding a specific reaction to a standard action in experiments with a particular specific object.

Reproducibility of results in problems of type 1. Such problems arise, for example, in engineering psychology in selecting principles for designing man-machine type systems (Woodson, Conover, 1968) and in general psychology in studying age changes of the human mind (Anan'yev, 1969; Birren, 1959). In sociology they are encountered when it is necessary to find characteristics of a statistical aggregate of people according to a particular sign (object interests, dominant form of interactions, value orientations, etc.)(Grushin, 1967; Yadov, 1968; Galtung, 1967).

Experiments of this type are conducted at any arbitrarily selected calendar moment. Stable reproducibility of results is ensured by inclusion of a representative sample which, as a rule, contains a large number of individual objects.

In problems of this type, therefore, the postulate of equivalency of calendar moments can be considered valid for long intervals if numerical ratios are observed between the whole mass of objects and the size of the sample which includes a large number of objects.

Problems of reproducibility of results in problems of type 2. Reproducibility of results here depends on whether the experiment is conducted in compact calendar periods simultaneously on an entire set of sample objects or individual tests are distributed, for example, over a number of months, years, etc. In the latter case, with a large enough sample and equal distribution of tests throughout the experiment, its results are methodologically similar to those of a type 1 experiment.

In the first case, with compact periods of experiment, the brief reactions of objects can be dependent on comparatively rapidly changing conditions in the extra-natural background. For example, according to data of the Biometeorological station of the Krakow Medical Academy, daily changes in the biometeorological situation can on some days cause elevated nervous excitability and disturbances in attention stability; on other days, on the other hand, they can cause delayed reactions, states of depression, memory disturbances, etc. It is natural to expect that the results of a psychological test or sociological in- /44
terrogation, obtained on a day with certain biometeorological characteristics, will be dissimilar to results of analogous tests on days with other situations. This assumption is also verified, for example, by statistical data on variations in the number of traffic accidents on different days, as well as by well-known cases in universities when the results of the same examination are different for similar groups taking it on different days.

Taking into consideration the possibility of similar effects of the extra-natural background on the outcome of type 2 experiments, the following methodological conclusions can be formulated: 1) basic and control experiments must be conducted in psychologically or sociologically equivalent calendar moments;

2) if these moments are unknown beforehand, in any case it must be kept in mind that they are not continuous, but intermittent in time. Correspondingly, it must also be taken into consideration that complete reproducibility of the results of a specific experiment is possible only at certain "spotty" intervals.

These conclusions are evidently essential for methodological prevention of hasty conclusions about the quality of the experiments, as well as for selecting specific requirements for the development and control of the experiment. In particular, in publishing experimental data is is mandatory to indicate the time organization of the experiment as well as the calendar date. Indication of the date not only increases the significance of published data for quality comparison, but also has independent scientific value: it makes it possible to use previously obtained data to reveal variability characteristics of the specific reactions of an object with the passage of time in in-depth diachronic research.

Problems of reproducibility of results in problems of type 3. The conditions for applying the postulate of uniform time in planning experiments of this type are especially limited. This is connected, first of all, to the universal objective property of real objects which in physics has been named hysteresis. Methodological errors caused by disregarding this property were prevented by P. Fress and G. Piaget (1966) and others. Analysis of this property as applied to a social object was made in the works of V. A. Yadova (1968) and others.

Secondly, in experimentation with the same object, both its comparatively slow changes (age, experience, training, social environment, aims, etc.) and various-frequency fluctuations in conditions with modules of less than a day, several days, etc., must be taken into account. Finally, thirdly, it is necessary to keep in mind that varying fluctuations in the object are caused by /45
certain rhythmic changes in the natural background which predetermine the heterogeneity of various calendar moments. This is necessary to obtain identical results of the experiment even when the effect of hysteresis and comparatively slow natural changes in the object can be excluded.

In experiments with the same object,the alternation between equivalent and nonequivalent (according to a particular sign) time intervals appears most clearly. In these cases special attention must, therefore, be given to finding conditions for discontinuous (in time) reproducibility of results of experiments.

On the methodological level, interpretation of experimental data also acquires theoretical importance. The basis for generalized conclusions about the properties of an object in individual experimentation must not be the results of a single experiment, represented by a single point in a corresponding phase space, but the typical characteristics of the pattern of a more or less long trajectory, plotted after successive experiments.

CONCLUSION

Only several of the problems of in-depth diachronic study of human mental and social processes were touched upon above. Many of them need more detailed and well-grounded development. Thus, the use of phase spaces to register factual data, which opens up extensive possibilities for selecting quantitative methods of analyzing meso- and macromodular processes and solving a number of applied problems, introduces a whole series of particular and theoretical problems which we, unfortunately, are not able to dwell on here.

In itself, formulation of the problem of in-depth diachronic research of human life processes is related to a sharp increase in the time necessary to perform its individual stages in comparison with synchronic or elementary-diachronic studies; it includes the latter as individual points of the total program of gathering empirical data and plotting sufficiently long trajectories. The time consumed by analysis in searching for regular connections between trajectories reflecting the course of the object's life activity and those of the course of various extra-natural factors is also significantly increased. Therefore, a number of important methodological problems are introduced concerning standardization of research methods to ensure coordination of the collective forces not only of psychologists and sociologists, but also of specialists in physics of the atmosphere and of the earth's magnetic field, solar physics, space biology and medicine and other branches of science, as these provide data /46
on the extra-natural background and on the biological-physiological basis of mental and social processes.

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HELIOGEOPHYSICAL FACTORS IN THE DEVELOPMENT OF THE EPIDEMIC PROCESS

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In the elimination of infectious diseases, it is necessary to take into consideration the entire complex of social and natural forces which determines their development. But along with the well known role of social elements, the importance of one of the most common natural conditions, solar activity, which controls climatic and other terrestrial rhythms (Agadzhaniyan, 1968; Assman, 1966; Vitel's, 1951; Druzhinin and Kham'yanova, 1969; Konovalenko, 1966; Maksimov, 1955; Mustel', 1968; Eigenson, 1963, and others) is still being overlooked in analyzing the dynamics of epidemics. There is already proof of a connection between many different biological processes and fluctuations in solar activity. /47

SOLAR ACTIVITY — NATURAL CONDITIONS — THE EPIDEMIC PROCESS

In focal diseases among wildlife, the reproductive cycles of the animals which carry the infection are to a large extent determined by hydrometeorological conditions and the forage reserve they control. The growth of plants and their productivity, as seen from Fig. 1, shows definite signs of a connection not only with climatic factors, but also with the dynamics of solar activity (Shvedov, 1892; Douglass, 1919; Bitvinskas, 1966; Dolgov and Shmidt, 1968; Dolotov, 1967; Komin, 1969; Dostin, 1968, and others). This does not rule out the effect of solar radiation through the earth's magnetosphere on biological objects (Dubrov, 1969; Krylov, 1964). The mediation of this effect on the yield of some agricultural crops through meteorological and other factors (Knyaginichev, 1969) can create tendencies toward cyclic changes in food production, which will also cause changes in the general reactivity of the body.

This is seen most clearly in "wild nature." For example, food hoarding by the white hare in Yakutia very significantly depends on solar activity (Fig. 2).

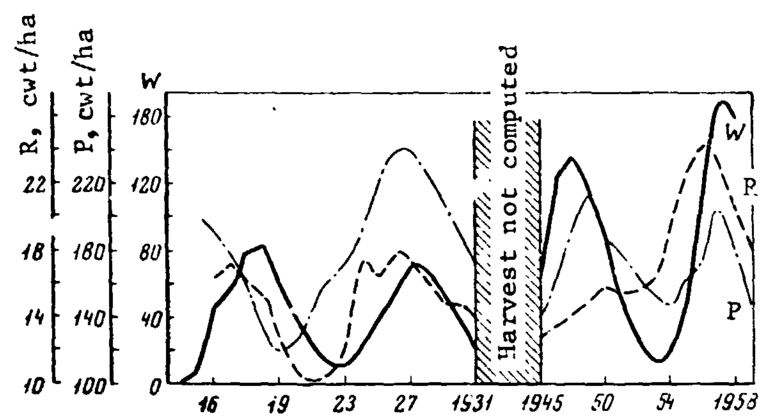


Fig. 1. Solar activity and the average yield of rye and potatoes, according to field test station data (Dolgov, Shmidt, 1968) /48
W — Wolf number; R — rye harvest (cwt/ha); P — potato harvest (cwt/ha)

This dependence is also reflected to a certain degree in the dynamics of predators, for which hares are a source of food. An obvious case of this is presented by the cycles of fur-bearing animals in Canada where the reproduction of hares and muskrats regularly is followed by an increase in the number of predators (Fig. 3).

Evidently, the gradual lag in the cycles of different species is related to biotic ratios and coincides with changes in the number of sun spots from many to few. Increases in the number of different species occur in various phases of the 11-year solar cycle; therefore, let us say tularemia will have a different phase ratio in areas with a predominance of muskrats than epizootics related to hares. The shift of phases will be even greater during epizootics of rabies among wolves, foxes and other predators. It follows that it is not always justified to look for a certain coincidence between maximums of biological phenomena and solar maximums.

Moreover, because of a certain autonomy of terrestrial processes, helioepidemic connections will never be perfect. They may be absent when there are effective means of combatting infections or their sign is reversed during a change in the nature of the connection between terrestrial processes and solar activity, as is often observed in 22-year cycles.

The most common regularity in solar-biological ratios is a tendency toward formation of a double wave in the course of biological processes during one 11-year cycle. This is related to the formation of a recurrent burst of magnetic disturbance in preminimums of solar activity whose physical nature differs from the disturbances caused by solar flares when the primary role in the geoeffect is played by their corpuscular streams. Shortly before the maximum, another

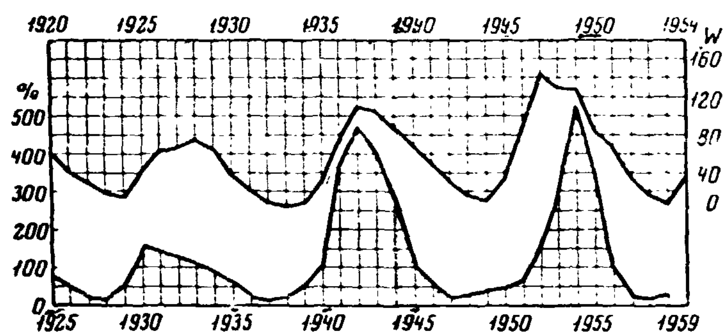


Fig. 2. Dynamics of food hoarding by white hares in Yakutia (in percentages of average — according to Kolosov et al., 1961) and the course of solar activity (top line) with a shift of phases in five years

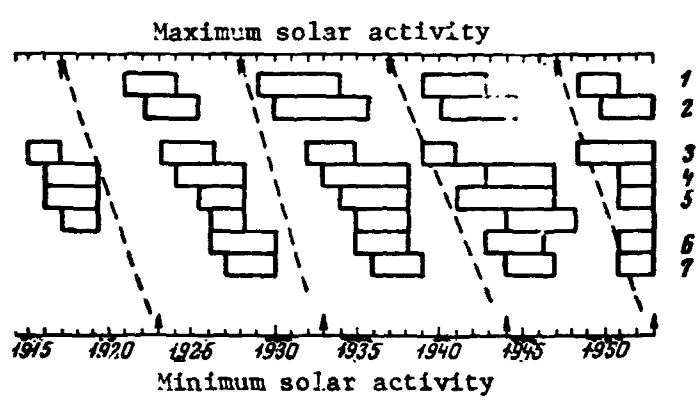


Fig. 3. Cyclicity of mass reproduction of fur-bearing animals in Canada 1 — muskrats; 2 — minks; 3 — white hares; 4 — lynxes; 5 — foxes; 6 — coyotes; 7 — wolves (according to Batler from Makfed'yen, 1965)

kind of corpuscular radiation, ejected from so-called M-regions of the sun (Ol', 1971), becomes most important. It must be added that during preminimums of the solar cycle the spots are close to the solar equator, where it is easier for radiation to reach the earth.

This does not rule out the possibility that these effects are also responsible for quite frequent correlation between increases in biological processes and not only maximums but also minimums of solar activity.

The connection between animal reproduction and solar activity, therefore, becomes perfectly clear; this was indicated by C. Elton (1924) and has been adequately verified in many works by a number of authors (Vinogradov, 1934; /50

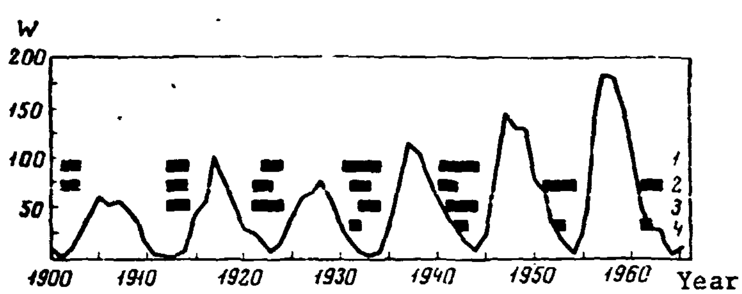


Fig. 4. Curve of solar activity and periods of mass reproduction of mouse-like rodents in the European part of the USSR.

1 — according to Formozov; 2 — Bashenina and Vinogradov; 3 — Ioff and Pilipenko; 4 — Taurin'sh

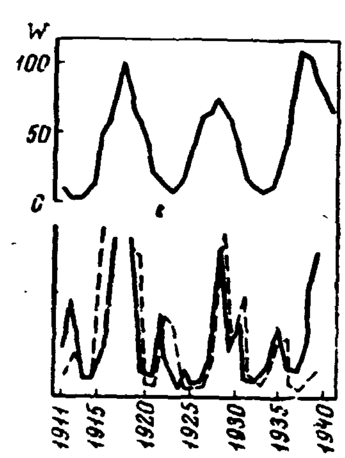


Fig. 5. Population curves of pine martens in two geographic regions and the course of solar activity (lower curves — according to Shverdtfegery, Yakhontov, 1964)

Dorofeyev, 1964; Kashkarov, 1945; Lavrovskiy, 1969; Lek, 1957; Maksimov, 1966; Panteleyev, 1968; Taurin'sh, 1964; Formozov, 1947; Chizhevskiy, 1930, and others). Generalizing their information and taking into consideration the data of other authors on "large waves" of reproduction of mouse-like rodents in the European part of this country, we see their definite correlation with periods of of low solar activity (Fig. 4).

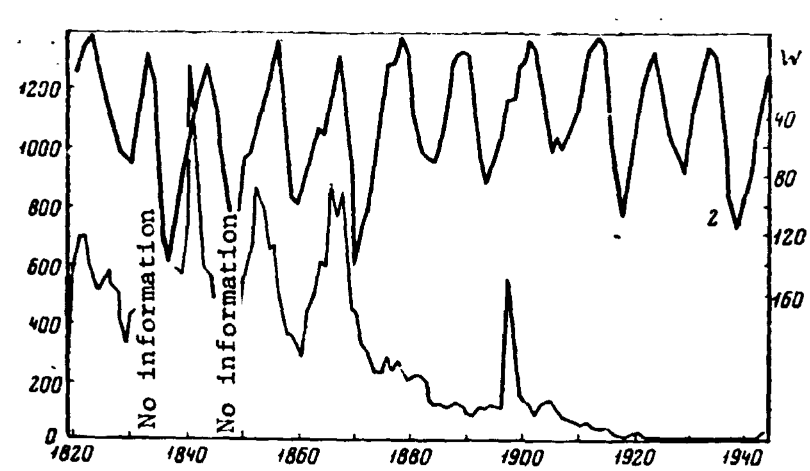
It is natural that in periods of rodent multiplication the number of their parasites will also increase — fleas, ticks and other carriers of pathogenic infections. Therefore, the probability of people being infected by such diseases as tick-borne encephalitis, tularemia, plague, listeriosis, erysipeloid, pseudotuberculosis, tetter, etc., can also increase or decrease with fluctuations in solar activity. This is all the more probable as synanthropic rodents, for instance house mice, in the Stavropol area also were most frequent in the periods of 1922-1923, 1932-1933, 1940-1944, 1952-1953 (Prokof'yeva, 1962). We must point out the possibility not only of the effect of solar activity, mediated by natural (food) conditions, on the life activity of arthropoda, which has been indicated by N. S. Shcherbinovskiy (1964) and other authors, but also of the direct effect of cosmic agents on insects. In particular, V. B. Chernyshev (1966) has shown that the activity of the latter depends on the earth's magnetic field (disturbed by solar streams) no less than on changes in air temperature. Perhaps population curves of insects from various climate-geographic zones are, therefore, synchronous among themselves and related to solar activity (Fig. 5). All this taken together can cause the cyclic recurrence of epizootics connected with cycles of animal development and arthropoda reproduction. Pronounced cyclicity is noted in infections of domestic animals which are connected with solar activity, for example, infectious rhinitis in swine (Nitsmanye, 1970). It is natural that with fluctuations in the epizootic process the probability of human infection also changes. /51

In fact, even against a background of intensive and very effective vaccination against tularemia some cyclicity continues to be observed. As we showed earlier (Yagodinskiy, 1969), 80% of all tularemia infections are observed during four years of high solar activity. Knowing such regularities, prophylaxis of infection can be intensified in these dangerous periods. In areas where rodents multiply in antiphase with solar activity, epizootics increase in frequency during its minimums. In the majority of water vole and muskrat regions they are timed to maximums of solar activity.

The mechanism of these relationships is due to changes in feeding conditions, depending on the water and thermal regime of reservoirs where these animals live. A definite relation is noted even in fish catches (Birman, 1955).

Therefore, following an increase in solar-dependent food resource the mass reproduction of rodents increases, but flooding and starvation and crowding contribute to devastating epizootics.

But such a general scheme requires more accurate definition in specific foci of diseases. A. A. Maksimov (1966) found that in the forest-steppe zone the number of water rats is synchronized with solar cycles. Bursts of reproduction and epizootics are encouraged by years of increased humidity when swamp areas — the places where the animals live — increase sharply. On the other hand, in lake-steppe regions outbreaks are more frequent in years with a low water level after periods of abundant water, which most often occurs in times of minimum solar activity. Of course, totaling the number of tularemia cases in various centers distorts and levels out the connection between epi-



/52

Fig. 6. Drop in malaria cases in the US army
(1 — according to Svarup, 1967) and the course of Wolf numbers (2)

demics and solar activity. It follows that helioepidemic connections vary depending on the landscape and zoological-parasitological structure of pathogenic centers because the "terrestrial atmosphere in its own way effectively mediates solar activity" (Eigenson, 1963).

Similar explanations of helioepidemic connections can also be give . r other wild focal diseases. Waves of epizootics of plague in the Precaspian area, according to A. A. Lavrovskiy (1969), as a rule, coincide with poor harvests, when the rodents separate in search of food and carry the infection to other areas and they correspond to a transition from low solar activity to high.

Sometimes an analogous mechanism can be seen not only in zoonoses, for example tick-borne encephalitis (Yagodinskiy, Aleksandrov, 1965), but also in several anthroponoses — diseases which affect man. In particular, with malaria, the undulating form of its dynamics, shown in Fig. 6, is evidently due to variations in foci, expanding the area of mosquito hatching, warm seasons, accelerating the maturation of parasites in their organisms, etc. The fall in the disease rate is related to active battles against infections and, particularly in America,to the ploughing up and general development of natural landscapes. Therefore, cyclicity as a probable phenomenon, requiring the mass character of the process in order to be identified, cannot now be seen.

In relation to anthroponoses, the connection with solar activity is in general much more complex and diverse and is strongly colored by the effect of /53 powerful social factors. Therefore, before proceeding to a discussion of the mechanisms of this connection, we must investigate their statistical characteristics.

THE STRUCTURE OF THE CYCLIC RECURRENCE OF THE EPIDEMIC PROCESS AND STATISTICAL PROOF OF THE REALITY OF SOLAR-EPIDEMIC CONNECTIONS

Cyclicity is an aggregate of changes interrelated by the same cause in the epidemic process, repeated with a stable average period of fluctuations. From a strictly formal point of view, cyclicity is best described by a sinusoid, modulated in frequency and amplitude of fluctuations. The cycles of epidemics are only a part of the total changes in the process, along with systematic trends and irregular random changes, caused in the majority of cases by social factors. In order to distinguish cyclic components from the total combination of epidemiological changes, an appropriate mathematical apparatus is required. The generally accepted methods of revealing latent periodicity masked by random fluctuations and trends are periodograms and autocorrelation-spectral analysis, proved in the study of many fluctuating systems in technology, geophysics and biology (Bruks, Karuzers, 1963; Konovalenko, 1966; Maksimov, 1955; Merser, 1964; Serebrennikov, Pervozvanskiy, 1965; Panovskiy, Brayer, 1967, and others). These methods have been used to analyze world statistics of infectious diseases and were cited in publications of the World Health Organization and

TABLE 1. AVERAGE INDICES OF THE CYCLICITY OF THE EPIDEMIC PROCESS AND NATURAL PHENOMENA

Process studied	Number of years	Number of series	Harmonics revealed (lengths of cycles)				
			Epidemic process				
Dysentery	*2777	50	3.3	5.6	8.4	11.5	**14
Scarlatina	2053	47	3.2	5.5	8.0	11.3	14
Measles	1449	32	3.1	5.4	8.0	11.0	14-15
Whooping cough	1065	22	3.2	5.7	8.6	11.2	14-15
Smallpox	623	14	3.5	5.5	7.5	11.3	14
Cerebrospinal menengitis	484	12	3	5.5	8	10.6	14
Influenza	284	4	2-3	5-6	8	10	13
Typhoid fever and paratyphoid	1528	29	2.9	5.4	8	10.6	14
Poliomyelitis	1032	22	2.8	5.5	8.0	11.5	14
Cholera	362	4	3	6		10	15
Infectious hepatitis	67	2	4	6		10	
Typhus and relapsing fever	355	8	3	6	8	11	13
Malaria	199	4	3	6		11	
Siberian ulcer	219	6	3	6	8		
Plague	65	1	4	6		10	
			Natural phenomena				
Atmospheric pressure and air temperature***	3975	78	3.4	5.8	8.4	11.1	14.7
Air circulation	3150	42	3.6	5.8	8.4	10.5	14.8
Air circulation****	1539	36	3.7	5.5	7.[illegible]	10.6	14.8
Humidity characteristics of the area ****	2985	34		5.0	18.2	11.9	14.9
Water temperature in the North Atlantic*****	916	15	4.1	6.9		11.2	
Flow of rivers in the Volga basin******	599	7	2.8	6.5		10.1	14.3

*Total of all series of observations. **Approximately. ***According to the data of N. A. Khaminov (1963). ****According to the data of V. F. Loginov (1967). *****According to the data of N. P. Smirnov (1965). ******According to the data of E. Sarukhanyan and N. P. Smirnov (1971).

other sources (Baroyan, 1967a, b; Burgasov, 1968, and others). Data were analyzed with the use of computer technology (BESM-2, BESM-4, "Nairi") by Z. P. Konovalenko, I. P. Druzhinin, N. V. Kham'yanova, N. P. Smirnov, S. B. Elyukim and Yu. G. Klevantsov.

Without dwelling on a description of research methods, which have been thoroughly covered in the literature, we shall only present the generalized results of their use to analyze the cyclicity of the epidemic process.

As can be seen from Table 1, the most diverse infectious diseases are on the average characterized by the same cycles of 3, 5, 8, 11 and 14 years. With a limited observation time, large scale fluctuations in epidemics can be distinguished less accurately with periods of about 18-19, 30, 65 and 80-90 years. Therefore, the multi-rhythmicity of the epidemic process must be considered with the 11-year component representing only one of the elements in the dynamics /54
of changes. When it is isolated by using the difference of moving averages, as shown in Fig. 7., the distinguishing features of the relation between the epidemic process and 11-year changes in solar activity are revealed, but with a shift in fluctuation phases.

Perhaps, for practical purposes it is best to determine phase shifts, since the connection between processes often exists only at certain frequencies and appears only generally, as seen from the same illustration, in 10-11 year fluctuations with randomly varying parameters in all other observation periods, when changes in the process are determined by other factors. The difference /55
in phases between processes depends on the inertia of one of them during the influence of the other. For example, unlike diphtheria, during scarlatina the direct nature of the connection is observed (Fig. 8). However, in different geographic regions, probably because of the zonality of the course of natural processes, the nature of the connection can vary, as is illustrated by the data in Fig. 9. Direct helioepidemical connections are, therefore, found in Crimean hemorrhagic fever in the Rostov district and tetter in the Kaliningrad district, while tick-borne spotted fever in Northern Asia and in the Irkutsk district have the opposite kind of connection.

To all appearances the 11-year fluctuation in the course of the epidemic process coincides with the 11-year solar cycle. What are the reasons for the other cycles?

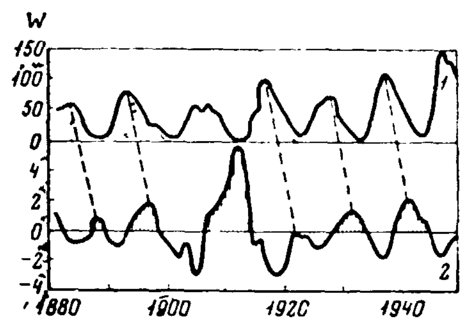


Fig. 7. Phase ratios between the dynamics of solar activity (1) and cases of diphtheria (2) in the USSR (differences between 11-year and 7-year average indices)

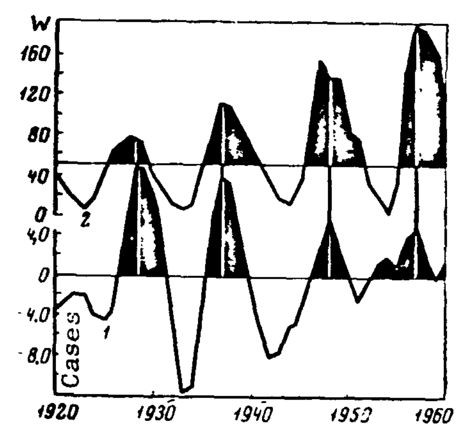


Fig. 8. Comparison of indices of cases of scarlatina in the RSFSR, with fluctuations of less than 5 and over 11 years removed by the method of differences in moving averages (1) with the dynamics of solar activity (2)

According to B. M. Rubashev (1964) as well as the data of other authors (Eigenson, 1963; Druzhinin and Kham'yanov, 1969), solar activity can affect terrestrial processes in periods of sharp changes in the 11-year cycle. It is natural that the sharpest transitions from low to high Wolf numbers and vice /56 versa are observed in the middle of ascending or descending legs of the 11-year cycle, where 5-6 year cyclcity can also occur. In addition, the geoeffect of solar activity is, as a rule, increased in periods of maximums and in periods of minimums; this is usually seen in greater disturbance of the earth's magnetic field. A 5-6 year cyclicity of natural and biological phenomena can also occur here. 3, 6, 8 and 14-year variations in the latter can also be connected with solar activity due to varying lengths of the ascending or descending branches in 11-year cycles in each pair of 22-year cycles characterized by a special magnetic situation (Rubashev, 1964).

Thus, practically all cycles of a similar scale can be attributed to the effect and characteristics of solar activity. Cycles on the order of 18-19

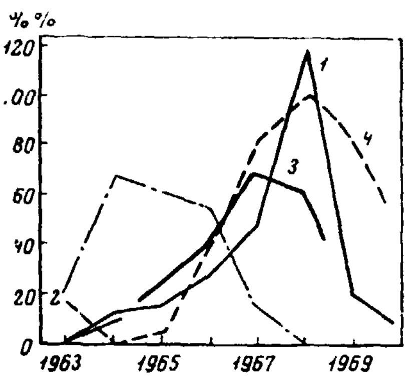


Fig. 9. Cases of Crimean hemorrhagic fever in the Rostov District (1), tick-borne spotted fever in the Irkutsk District (2) and tetter in the Kaliningrad District (3) in connection with solar activity (4) in percentages for the same year

years, according to I. V. Maksimov (1955), must be considered as the effect of gravitational influence of the moon.

In order to prove the statistical validity of solar-epidemical connections analysis was made of the frequencies of multi-year interruptions in the epidemic process in comparison with sharp changes in solar activity during the 11-year cycle, which, according to the data of I. P. Druzhinin and N. V. Kham'yanova (1969), were observed in 1901, 1903, 1905, 1906-1908, 1910, 1915, 1917, 1918, 1920, 1925, 1928, 1930, 1936, 1940, 1942, 1946, 1948, 1950, 1952, 1956, 1961 and 1964. These dates were also compared with breaks in the epidemic process. By breaks we mean a change of signs in increments of quantitative indices in successive years, i.e. if the number of cases increases several years in a row then the increment will be positive and the break appears the year the number of cases is less than in the preceding year. The next break occurs when negative increments change to positive, etc. In other words, we have re- /57
solved the question of a connection between changes in some terrestrial processes and changes in other cosmic phenomena powerful enough to be their cause.

The first step in solving the problem, in order to fix supposedly sun-dependent breaks in the course of the process, is to calculate corresponding frequencies of breaks and evaluate the non-randomness of their differences in years with solar "benchmarks" and in other years. For example, we took the data on influenza mortality, presented by V. M. Zhdanov et al. (1958), and found the frequency of breaks in years with solar marks and in years without any sharp changes in solar activity. As seen in Table 2, epidemic changes in years with sharp increments in solar activity were 1.3 times more frequent than in other years. Evaluation of the significance of these connections by the χ^2 method showed that in relation to influenza, $\chi^2 = 39.9$ i.e. the confidence

TABLE 2. FREQUENCY OF BREAKS IN THE MULTI-YEAR COURSE OF INFLUENZA DEATHS (ZHDANOV et al., 1958)

Country	Period of observation, years	Number of years subjected to study	Frequencies of breaks,%	
			in years with solar marks	in other years
UAR	1921-1950	29	90	79
Canada	1921-1951	30	80	60
USA	1920-1950	30	90	55
Chile	1920-1950	30	90	50
Japan	1920-1943, 1947-1950	26	75	56
Australia	1920-1950	30	90	55
New Zealand	1920-1950	30	90	65
Belgium	1921-1951	31	90	71
Czechoslovakia	1920-1942	22	100	79
Denmark	1920-1951	31	80	76
Netherlands	1920-1951	31	90	76
Norway	1920-1951	31	90	76
Spain	1920-1950	30	80	70
Switzerland	1920-1951	31	100	67
Greece	1921-1938	17	100	69
Hungary	1920-1938	18	100	62
Iceland	1920-1937, 1939-1944, 1946-1950	26	100	87
Ireland	1920-1951	31	90	76
Italy	1920-1951	31	100	62
Total		535	90	67

level significantly exceeds 0.01% (Van-der-Varden, 1960), which corresponds to 99.99% probability of connections between sharp changes in solar activity and breaks in the course of the epidemic process. This is more clearly illustrated by the 44 periods of influenza epidemic known since 1749 of which 42 correspond to periods of severe changes in solar activity. /58

To verify these appraisals we analyzed multi-year changes in the epidemic process of other common infections. The natural series lasted from 30 to 100 years, basically covering the period from 1900 to 1960, and totalling 4750 years.

As the result of analysis of the total aggregate of data it was established that the probability of random differences in frequency is extremely low

(0.01-6%) and for these processes is below 0.01%. A rough estimate shows that the proportion of solar-dependent changes is about half (44%) of all breaks in the epidemic process. This leads us to conclude the reality, from a statistical point of view (99.99% probability), of the assumption that sharp changes in solar activity affect the epidemic process and, therefore, its 2-4 year fluctuations can be the result of the same frequency of alternation of solar marks. The entire hierarchy of cycles can thus be taken as brief recurrence of a single "period" of that order, against a background of the 11-year cycle of solar activity.

THE SIGNIFICANCE OF VARIABILITY IN THE CYCLIC RECURRENCE OF THE EPIDEMIC PROCESS

All changes in the epidemic process are the result of the effect of social and natural factors on the susceptibility of the population to infection (reactivity of the macroorganism), on biological properties of the microorganism and on mechanisms (pathways and factors) of transmission of the stimulus. Social factors do not have the characteristic of periodic recurrence while natural conditions are under cosmic influences, varying with a certain regularity (the alternation of day and night, seasons of the year, solar and lunar rhythms, etc.). Therefore, it is natural that the cyclicity of the epidemic process is a reflection of biological rhythms, arising under the influence of the above causes.

Among the biological components of the epidemic process changes in macro- and microorganisms can play an important role in the formation of its cyclicity. In particular, the significance of the factor of immunity in the periodicity of epidemics has been known since the end of the last century. This question has been well investigated and needs no verification. However, immunological changes themselves, in turn, depend on the sum of social and natural factors — /59 population migrations, vaccinations, insolation, etc. Social factors, for example, antibiotic therapy, produce a progressing decrease in lethality and mortality in many infectious diseases but cannot cause their cyclic fluctuations. Therefore, cycles of lethality in, let us say, whooping cough, as seen in Fig. 10, cannot be connected with social or with immunological changes as

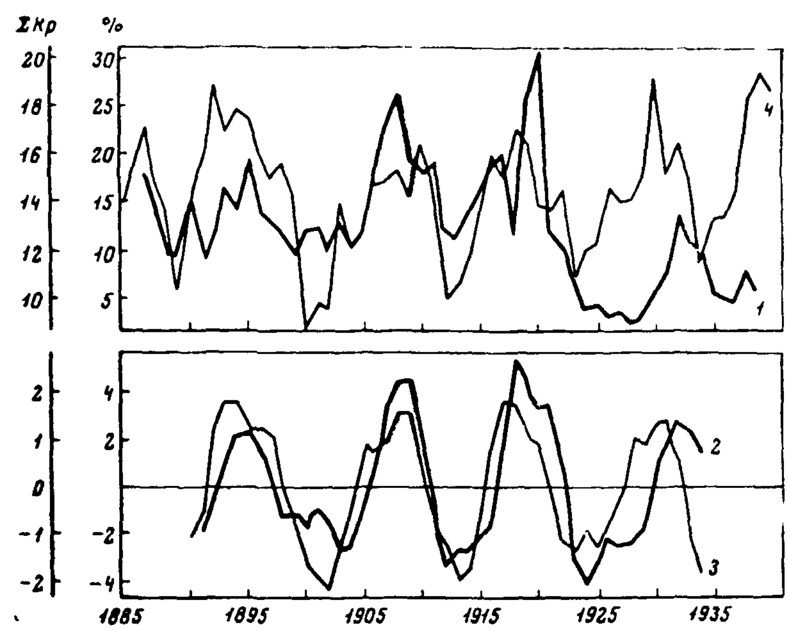


Fig. 10. Lethality of whooping cough in Moscow (1) and the course of the K-index of magnetic disturbance (4), in lower part of the graph — the same for lethality (2) and K-index (3) with the elimination of periods under 5 and over 11 years by the method of differences of moving averages

such. Perhaps the effect of cosmic factors is also to some degree determined by immunological shifts, but in this case they cannot be ascertained. Most likely the variability of the biological properties of microorganisms is important here.

Let us consider this question in connection with fluctuations in solar activity and in its magnetic displays on earth.

Variability as a general biological rule appears in its clearest form in the microworld because of the simplicity of its organization, and the rapidity and multiplicity of population development. For a long time the opinion predominated about the absolute indeterminism of mutation processes. But in nature there are always sufficient mutagenic factors and the agents of solar activity /60 are of paramount importance among them.

As an example we can use such a common disease as dysentery whose level in the USSR has changed in recent years according to changes in solar activity

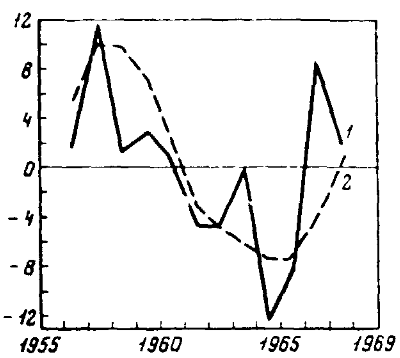


Fig. 11. Cases of dysentery in the USSR (1) 1:10C thousand population and the dynamics of solar activity (2) in Wolf numbers for 1956-1967 in deviations from averages

(Fig. 11). As seen from the graph, in 1966 cases of dysentery returned to the 1956-1957 level. To what is this related?

With steadily improving public welfare and the high organization of the anti-epidemic service, which has significantly improved the sanitary-hygienic living conditions of the people, this rise cannot be connected with social factors, although the concentration of the child population and the centralization of meals create the preconditions for increased circulation of the stimulus. The majority of researchers have come to the conclusion that change in circulating strains of the stimulus is of essential importance. The leading varieties of the 50 existing dysentery microbes are those with the greatest chance for distribution and, therefore, for continuing the species (and the epidemic process). According to the material of S. N. Kaganovskaya (1964), during the solar cycle maximum in 1957 in Moscow there was a sharp shift in the composition of Shigella — stimuli of dysentery. In 1950 Shigella flexneri comprised 82% and Shigella sonnei 15%, but in 1957 their ratio w reversed: 18 and 74%. This was reflected in the epidemic situation as Shigella sonnei produce a more effaced form of the disease making it difficult to liquidate sources of infection; they are more stable in the environment and can not only survive but can also reproduce in food products, especially milk. The rise in dysentery in 1966 coincided with an even greater predominance of Shigella sonnei (95%) in a larger area of the country; this does not rule out the development among these stimuli of strains with even greater ability to propagate. It is possible that episomes play an important role. These are extra-chromosome genetic elements whose material base consists of DNA.

Just as with whooping cough, according to the data of a number of authors, change in the typical landscape of the stimulus is significant. This change is even more important in an infection such as influenza. For example, certain magnetic conditions are related to changes in the influenza virus which are naturally of varying intensity and touch upon various aspects of the antigenic and general biological activity of the stimulus. Therefore, we need not expect that these changes will always lead to severe epidemiological consequences. /61

Be that as it may, the connection between the variability of microorganisms and cosmic factors is undoubted and has been verified by many authors. In 1930 A. L. Chizhevskiy noted that "bacteria must be resonators of electromagnetic fluctuations of a certain frequency" (p. 153). Therefore, the theory of A. S. Presman (1968) that the biological effect of magnetic fields is connected with their information-resonance properties, bound up in the evolutionary processes of nature, acquires basic importance.

However, we must not leave out of consideration such atmospheric factors as the widely-known effect of solar radiation components whose biological role has been clearly determined in numerous works on radiation genetics and space biology (Gazenko, Gyurdzhian, 1967; Glembotskiy, 1970; Zhukov-Varenzhnikov, Pekhov, 1963, and others). The dependence of life processes in microorganisms on weather conditions has also been noted (Bortels, 1956). Distinct acceleration of bacteria reproduction during increased atmospheric pressure was noted by Wildfuhr (1959).

Nevertheless, A. Sirp (1970) has shown that the basic factor in changes in Azotobacter is solar activity.

The use of electromagnetic fields (EMF) in regions characteristic of solar radiation, in tests with Chorynebacteria, Salmonella, Escherichia and Staphylococci, led Yu. N. Achkasova and B. M. Vladimirskiy (1969) to conclude that EMF cause changes in morphological, cultural and enzymatic properties and stimulate growth of microorganisms. In general, according to the data of S. A. Pavlovich (1969), under the influence of magnetic fields Staphylococci are able to alter their color, configuration and resistant properties. With respect to dysentery bacteria, a sharp increase in resistance to bacteriophagia is noted after exposure to EMF (100-1000 times). This could be of exceptional practical importance.

I is possible that even at the present stage of krowledge of cosmic agents we are still leaving out some unknown components or characteristics of the biological effect of already known radiations (Vel'khover, 1935; Moriyama H., 1963).

On the whole, a rather large amount of information has been accumulated in favor of the undoubted effect of cosmic agents on the biological properties of microorganisms. At the present time there is also every basis for assuming as real the action of solar agents on the reactivity of macroorganisms. The blood system, serving as the carrier for many of the body's protective forces, as has been shown conclusively by N. A. Shul'ts, V. A. Kozlov, A. T. Platonova and others, is subject to the effects of the sun and magnetic fields. In particular, the magnetic field probably affects antibody formation (Vasil'yev, 1968) and the nuclein exchange of immunocompetent tissue, which occurs in many serological reactions (Boginich, 1970). /62

SOME PROSPECTS FOR USING SOLAR DATA TO PREDICT THE DYNAMICS OF THE EPIDEMIC PROCESS

For test purposes we have given predictions of influenza, tick-borne encephalitis, tularemia and infectious hepatitis (Yagodinskiy, Aleksandrov, 1965, 1966; Dorofeyev, Yagodinskiy, Aleksandrov, 1965; Yagodinskiy, Umanskiy, 1969).

Until now in epidemiological prognosis only a brief prediction of the course of epidemics already underway and their spread to a neighboring territory have been made, taking into account such determinants as transportation communications and the immunity of the population (Barovan, Rvachev, 1967; Zhalko-Titarenko et al., 1967; Bartlett, 1958, and others). Long-term prognosis will require a different methodological approach and different evaluations of communication of the process as in this case there is no specific information about time or place of origin of a future epidemic. Basically we must rely on data on the dynamics of the process in the past and probably assumptions of trends in its development in the future, taking certain factors into account.

In predictions it is extremely important to separate types of fluctuations in the disease rate into three categories: trend or systematic; irregular ("random") and cyclic-quasiperiodical components.

The probable tendency in the development of a process can be calculated by the method of least squares or by parabolas of various order. With the existence of information about the degree of an effect, let us say, vaccination, altering this tendency, a corresponding correction is introduced into the calculations. In the absence of definite numerical determinants, expert estimates of leading specialists must be used.

Random (irregular) deviations from the trend in simplest form are determined by certain gradations in the variation of fluctuations; however, in actual calculations this variation will, as a rule, also include cyclic changes. Therefore, calculation of "purely random" variations is of no great value, although /63 it is a necessary step of research.

The value of predictions of cyclic components is that they contain prognostic information about specific times of future outbreaks of epidemics.

Analysis has shown that mass dissemination of all groups of infectious diseases have the same cycles of 3, 5, 8, 11 and 14 years. Several prognostic conclusions can already be made from that. For example, considering the origin of an outbreak of cholera in 1965 (Baroyan, 1967b), favorable conditions for its penetration into this country could be expected in 5 years — 1970, which would make it much easer to fight the disease. If in 1957, when the level of dysentery in this country was 25% higher than in 1956-1958 (Yagodinskiy, 1969), the possibility of a connection between this rise and maximum solar activity could have been evaluated. Then we could better have been able to prepare for a new outbreak of dysentery during the next maximum. The organization of antiepidemic measures requires time which prognosis can primarily provide.

However, the use of statistical examples of prediction is especially complicated by multi-rhythmicity, geographic variability and varying periodicity, which in the latter case is connected primarily with the effect of human activity. Therefore, the use of solar activity data, which can be precomputed for a long period (Vitinskiy, 1963), is extremely important. But it is also necessary to know how many lines of development there are in the studied object and on what causes and circumstances it is based. From among these we must select a general line and the basic mechanisms providing certain causal relationships. It is well known that the development of influenza epidemics is largely determined by shift in circulating strains of the stimulus timed to extremes of solar activity. Therefore, if we take our previously published data (Yagodinskiy, Aleksandrov, 1966) on the times of influenza epidemics and solar dates, then the probability of epidemic outbreaks can be calculated as follows:

Years from extreme of solar activity	-3	-2	-1	0	1	2	3
Frequency of occurrence of new cycles of influenza (abs)	1	8	12	27	6	0	0
Probability of the start of large epidemics of influenza in percentages	2	15	22	50	11	0	0

Thus, there is a 50% probability that a new cycle of influenza epidemics /64 will begin in the extreme periods of solar activity and a 98% probability of cycles occurring in the two years before the extreme, its critical phase, and a year after. Of course, the characteristics of influenza spreading will depend on specific socio-historical conditions.

On the basis of this spreading, we expected a similar change in the biological activity of the virus in 1968, a year of maximum solar activity, with the control date of development of the epidemic in 1969. The times we predicted (Yagodinskiy, Aleksandrov, 1966) were completely verified. It is more difficult to plot quantitative forecasts, although in most general form the equations suggested by N. I. Knyaginichev (1969) can be used.

Similar predictions can be useful both in organizing antiepidemic measures and in designing and producing medicinal, prophylactic and diagnostic preparations. The economic effect of forecasting the dynamics of the epidemic process or epizootics can be extremely important.

The reduction of infectious diseases in this country is connected with the elimination of social roots of epidemics and with the general progress of science and public health. But the rates of future battles against pidemics are limited by poor knowledge of their cyclicity, which appears in the most heterogeneous and mass infections. It has been established that cycles of infectious disease are related to heliogeophysical factors, among which the most important are changes in solar activity. The mechanism of their effect on the dynamics of epidemics, especially zoonoses, is seen after climatic and hydrological changes. The direct effect of solar agents on the biological properties of microorganisms and specific and general reactivity of macroorganisms is also not ruled out.

Helioepidemiology is probably important in establishing a plan for long-term predictions and must be taken into account in solving other important scientific and practical questions. Now, when detailed study of cosmic factors has begun, it is necessary to organize comprehensive research of solar-biological connections. Stimulation of this research has also been the intention of this work.

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HELIOGEOPHYSICAL FACTORS AND THE DYNAMICS OF THE EXCRETION OF ORGANIC SUBSTANCES BY PLANT ROOTS

A. P. Dubrov /67

1. BASIC PROBLEMS OF HELIOBIOLOGY

One of the fundamental problems in modern science is that of the cyclic recurrence of natural processes (Sollberger, 1965). This cyclicity can be traced in the rhythm of biological processes and the periodicity of biospheric processes. Many years of research by heliobiologists have revealed interesting regularities — a connection with solar activity, the global character of cyclic recurrences, the coincidence of biological and physico-chemical processes (Chizhevskiy, 1931, 1963; Shostakovich, 1928; Eigenson, 1957; Berg, 1957; Druzhinin, Kham'yanova, 1969; Dubrov, 1970b).

On the basis of theoretical analysis and direct experimental testing, researchers have come to the opinion that the global and synchronic characteristics of biological and natural biospheric processes are based on unknown heliogeophysical factors (Tchijevsky, 1938; Moriyama, 1963; Takata, 1951). Heliobiological research confirms that these factors differ in their properties from known physical parameters of the environment (light, temperature, humidity) and at the same time are similar in their effect to magnetic and gravitational fields. Let us note that these heliobiological studies were made using colossal volumes of statistical and experimental material (Brown, 1968; Schulz, 1967; Düll, Düll, 1935; Reiter, 1955). The use of a large volume of experimental data and the use of correlation-spectral analysis and periodograms and the superpositioning of periods has helped raise the level of significance of these heliobiological connections and eliminate the effect of random causes and trend changes, thereby exposing latent periodicity. Many years of continuous research by physiochemists and chemists have also provided conclusive data on the effect of solar activity on the rate and character of reactions occurring in nonliving systems (Piccardi, 1967; Melikadze et al., 1969).

Let us briefly discuss the effect of solar activity in medicine, agriculture and public activities. /68

Medicine. The effect of heliofactors on public health has attracted the attention of researchers primarily because of the periodic recurrence of diseases (especially pandemics, taking hundreds of thousands of lives), as well as the high correlation between the periodicity of epidemics (diphtheria, cholera, influenza) and cyclic activity of the sun (Chizhevskiy, 1930, 1931). The subsequent development of these works led to unexpected results indicating a close connection between a great many pathological processes and solar activity. A far from complete list of these diseases and processes includes pulmonary hemorrhages, cerebrospinal meningitis, pulmonary embolisms, fatal tuberculosis (Düll, Düll, 1935) eclampsia and preeclampsia (Tremel, 1951), psychoses (Friedman et al., 1963), myocardial infarcts (Poumailloux, Viart, 1959), insults, etc. Even this brief list of diseases indicates the broad scope of these connections.

We note that researchers emphasize the role of chromospheric flares in severe aggravation of a disease or process (Düll, Düll, 1935; Reiter, 1955; Schulz, 1961).

Heliobiologists have given special attention to the effect of solar activity on the blood as one of the most important parts of the internal environment of the body which performs a great functional role. This research received a solid factual base after continuous 40-year studies of the effect of heliofactors on electrocolloidal properties of the blood (Takata, 1951) and its formative elements (Schulz, 1967). In the latest of these works a direct connection with solar activity was concluded on the basis of the generalization of over 400 thousand analyses of healthy individuals.

The vast amount of material accumulated up to now shows that the entire blood system as a whole, its component elements (Schulz, 1962; Kozlov et al., 1963), important functional test-indices (Caroli, 1950; Danti, Piccardi, 1955) and fine regulatory mechanisms (Platonova, 1969) in healthy individuals are directly related to solar activity. In the ailing organism, where these systems are completely or partially disturbed, sharp changes in solar activity can lead to a fatal outcome.

It must be pointed out that because of the complex causal relationship the effect of solar activity does not always and everywhere appear openly and identically. This is connected with the geographical conditions of place (Eigenson, 1957) as well as with change in the etiology of the disease, the general and specific reactivity of the body and the prophylactic measures undertaken (Yagodinskiy, 1969).

It is especially necessary to note that prognostic evaluations of the origin of epidemics are of great practical value in studies in the area of medical heliobiology. Detailed study of the etiological structure of the disease, /69
comprehensive calculation of various factors powerful enough to have an effect, the reactivity of the organism, the level of bacteria, characteristics of the circulation of types and varieties of viral infections, the timing of certain weather factors, etc., as well as knowledge of the periodicity of diseases appearing during various solar activities make it possible for epidemiologist-heliobiologists to make predictions with a high degree of confidence. As an example we cite that the forecast of aggravation of the influenza epidemic situation, given in one work (Yagodinskiy, Aleksandrov, 1966) several years beforehand was completely verified in 1968-1969 when an epidemic of influenza swept through all continents and took on a catastrophic character because of the high mortality and mass inclusion of all groups of the population.

<u>Agriculture</u>. Researchers have long been turning their attention to the close connection between economic indices in agricultu[illegible] lar activity (Shostakovich, 1928). In the area of agriculture, hel[illegible]gical research has been faced with two important problems: fluctuations in crop yields and the frequency of epiphytoses and epizootics in connection with solar activity.

As the result of these works it has become clear that heliobiological evaluation must be taken into consideration in the development and planning of productivity in agriculture (Knyaginichev, 1969). It has been shown, for instance, that a chronological graph of average grain harvests for five years has a clear coincidence with annual Wolf numbers. The author has noted that for the most effective use of heliobiological connections, reference graphs of yield must be plotted by region and even for individual crops and fields. Prognostic evaluations of future yield, important in the economics of agriculture, are plotted on the basis of heliobiological analysis. For example, it has been indicated that the unfavorable climate conditions for harvests of 1951-1955 and 1961-1965 will be repeated in the Omsk district of the USSR in 1971-1975 (Boynov and Knyaginichev, 1969).

Heliobiological research shows that important agricultural problems concerned with protecting crops from pests and disease must be resolved by taking into account heliobiological principles. We must note that complex study and the comprehensive scope of this problem have uncovered not only direct heliobiological connections, but also a complicated chain of intermediate transformations and ecological characteristics in the development of diseases and the effect of attendant meteorological factors. This relates equally to outbreaks of mass reproduction of insect pests (Shcherbinovskiy, 1964) and phytopathological diseases (Minkevich et al., 1969). A striking example of such in-depth analysis of heliobiological and ecologo-functional connections /70 is found in the works of Professor N. S. Shcherbinovskiy. Because of his scientific recommendations and the measures he developed, based on heliobiological connections, a large area of the USSR and adjoining countries (Iran, Turkey, etc.) were saved from colossal harvest losses and the destruction of crops and vegetation from Schistocerca-locusts.

It is noted that mass plant diseases are greatly affected by weather conditions which act on all stages of development of the disease. However, analysis of the dependence of the cyclicity of mass diseases of agricultural crops on the state and course of changes in solar activity makes it possible to forecast the long-term tendency of damage from these diseases (Minkevich et al., 1969). Thus, in the next 6-7 years we can expect increased damage from yellow and brown rust, powdery wheat smut, potato Phylophthora and drying up of fruit crops in the Non-chernozem zone. At the same time a reduction is expected in rust damage and mildew of grapes, citrus damage in the Black Sea coastal area of the Caucasus and drying up of apricots in the southern Ukraine will be slight.

Public activity. Of all the questions previously considered in this area (Chizhevskiy, 1924, 1930), we shall mention only those which are connected with accidents in traffic and industry. The rapid development of industry and technology has turned serious attention to the sharp increase in the number of traffic wrecks, accidents and industrial traumatisms. Study of a great deal of statistical material (130 thousand cases) also indicated the definite effect of solar activity in these areas of public activity (Reiter, 1955; Martini, 1952; Desyatov, 1962). The validity of these conclusions is confirmed by the appearance of common heliobiological principles: factual data indicate the special effect of solar flares on the frequency of accidents in industry and traffic. This connection is moderated through changes in the geomagnetic field where sharp disturbances will lead to changes in conditioned reflexes, disturbed orientation and physiological functions. Therefore, a high correlation is noted between traffic accidents and geomagnetic disturbance (Bhaskara Rao Srivastava, 1970).

Basic unsolved problems in heliobiology. On the basis of the above it is evident that basic progress has been made in the last ten years in the area of practical heliobiology: the establishment of clear undoubted connections between certain processes and solar activity and prediction of the future tendency of these connections. Significantly less has been done in the area of theoretical heliobiology and knowledge of basic heliofactors, discovering the / 1
mechanism of their effect and the basic regularities in the geographic occurrence of heliofactors.

However, recently shifts have also been marked in the solution of these problems. The main effective factors of solar activity constitute one of the basic problems, since without knowing them it is difficult to understand the mechanism of the effect of heliofactors. This problem is closely affiliated with that of the geoactive indices of solar activity. Until recently the basic index of solar activity, with which natural processes were compared, was the Wolf index (W), i.e. the number of sun spots, combined with the decuple number of their groups on the visible hemisphere of the sun. However, this index is not always satisfactory for complete exposure of solar-terrestrial connections (Schulz, 1965; Rubashev, 1969) since, possibly, various factors of solar activity are geoactive in various phases of the 11-year solar cycle (Bezrukova, 1954). Therefore, suggestions have been made to use a new index of solar activity changes in the F layer of the ionosphere and the neutron flux (Wing, 1962), the area of spots, the photospheric index of solar flocculi and the coronal index of line strength with λ = 6374A (Schulz, 196 , the flow of radio waves in the 200 Mc range (Tsimakhovich, 1967), the index of magnetic activity combined with the flow of certain radio frequencies (Rubashev, 1969), etc. These suggestions were connected with the desire of researchers to reflect most completely the physical basis of solar-terrestrial connections.

In fact, solar active formations — spots, flares, faculae, protuberances, coronal condensations — are powerful sources of corpuscular radiation, radio waves and electromagnetic fluctuations in a wide range of frequencies, magnetic fields "frozen" in plasma (Vitinskiy, 1966). However, it must be kept in mind that almost all forms of solar and cosmic radiation are distinctively tr[illegible]med in the magnetosphere, ionosphere and atmospheric layers interacting with electric and magnetic fields of the earth and the atmosphere (Troitskaya, 1964; Imyanitov, Shifrin, 1962). The radiation belt and powerful current systems above the earth play an important role in all transformation of solar bioactive radiation.

The above illustrates all the complications of introducing a common heliobiological index but, nevertheless, there are several approaches to proper solution of th problem. The universality of the connections between periodic changes in vital processes and solar activity (global, synchronic and cophasal characteristics) indicate the existence of a distinctive single "unit of interaction" — this could be the magnetic-electric properties of molecules in the living organisms, transformed to the surface potential of cells, plasma and /72
membrane potentials, surface energy and electric activity of the system as a whole. In such a case the effect of other important geophysical factors — the gravitational field of the moon and sun, — can also be explained along with the direct gravitational effect (displacement and redistribution of intracellular masses and energy) by the formation and change of electric potentials as the result of polarization of membranes (Brauner,1969).

Thus, in analyzing heliobiological connections it is necessary to consider [illegible] least three important geophysical factors (besides gravity and cosmic fields): geomagnetic activity including periodic magnetic variations, short-period oscillations (KPK) and the permanent magnetic field. Changes in the permanent magnetic field are important for long-period biospheric changes. Two other importan factors are change in gradients of the electric field of the earth and the atmosphere. Experiment[illegible] works on the effect of weak and superweak magnetic and electric fields verify these assumptions (Brown, 1968, 1969; Wever, 1967; Vladimirskiy, Volynskiy, 1969; Presman, 1968; Kholodov et al. 1970).

As is clear from the above, the earth's magnetic field is one of the important characteristics of the heliobiological effect: an important role is played by a change in all its vectors. The electric fields of the Earth and the atmosphere, the corpuscular streams of high energy particles have their own effect, as cells of living organisms and their biocolloids are charged particles, but ionization plays a significant (perhaps the most important) role in biological processes.

Our opinion that the geomagnetic field and its change play a decisive role in solar-terrestrial connections is verified by the data of biologists, doctors and geophysicists. The works of heliobiologists, especially on the dynamics of cardio-vascular diseases, have shown that the frequency of diseases largely depends on the level of intensity of the geomagnetic field and its changes, connected with solar activity (Sosunov, Manik, 1966; Sedov, Koroleva, 1966). Recently it has been found that the possible cause of this unusual and close connection between disturbance of the geomagnetic field and increase in the number of cardio-vascular diseases is a change in the permeability of biological membranes and walls under the influence of the geomagnetic field (Dubrov, 1969a, 1970c).

The geomagnetic field, controlling permeability and several important properties of biological molecules and water, has literally a decisive effect on all processes in individual cells, organisms and, finally, on the entire biosphere (Dubrov, 1969b, 1970a). Our research shows that physiological and genetic homeostasis, i.e. the ability to maintain dynamic constancy of compo- /73
sition and phenotype and genotype properties, depends on the geomagnetic field and is under its control. These data reveal the possibility for in-depth and complete explanation of several heliobiological problems. The basis for recognizing the leading role of the geomagnetic field in the vital activity of living organisms is the clear global and synchronic characteristics of heliobiological reactions, as the geomagnetic field is highly pervasive and has unitary variations. The sudden appearance of new types and the succession of variants of virus stimuli is explained, as we have shown that the mutation process is connected with change in the geomagnetic field and, therefore, sharp

local changes in geomagnetic fields lead to the development of new forms. Of course, fixation of these mutations depends on many things. Later, the various appearances of solar activity at different geographic points will become clear, as this is connected with the specifics of geomagnetic conditions in a given geographic place which superimposes its characteristics on heliobiological connections. From our point of view the numerous data on the connection between cardio-vascular diseases and disturbance of the magnetic field are explained. Because the organism is constantly under the control of and is interconnected with the geomagnetic field, sharp disturbances here will disturb the functional state and mechanism of permeability, especially in people with elevated decompensation and disturbed regulatory systems.

In addition, these characteristics in the mechanism of heliobiological connections pose important new questions. One of these concerns norms of the reactions in living organisms to the effect of heliofactors and the geomagnetic field. Study of the reaction of animals and humans to the effect of heliofactors has shown their great variety. But at the same time it has been shown that approximately three basic groups of organisms can be distinguished by their reaction to these factors (Koval'skiy, 1965), particularly geomagnetic disturbances (Podshibyakin, 1967). These reaction norms are related to the effect of the neuro-humoral system on the action of environmental factors and are basically connected with the fundamental properties of the symmetry of biological objects (Sulima, 1970; Urmantsev, 1965; Dubrov, 1970e, 1971). Determination of individual reactions to heliogeophysical actions, isolation of these groups and their description are very important as such reaction norms are found in relation to medicines, load tolerance, physical procedures and functional indices of the body. Calculation of these reactions will be important in many areas of human activity, especially in specific living conditions /74
(submarine and space conditions, etc.).

As already shown above, the studies cover extremely varied geographic points, which provide a detailed map of heliobiological reactions (Danishevskiy, 1962; Piccardi, 1967). Therefore, the urgent question arises of creating global heliobiological base stations for continuous observation and study of heliobiological reactions in healthy organisms. The organization of a permanent biological observation service (with continuous automatic registration of the most important functional indices and heliotests) at various geographic points will make it possible to calculate the characteristics of local heliobiological effect, to find the nature of its mechanisms, to work out a common geoactive index which will most completely reflect solar-terrestrial connections and create helioecology as an independent scientific discipline. A basic role in the creation of such a permanent heliobiological service could be played by global biological base stations, created by order of UNESCO within an international biological program to observe changes in the most important parameters of the biosphere. From all the above, it follows that solar activity continuously affects the biosphere and is a decisive factor in the periodicity of biological processes. One of the main factors in the solar effect is the geomagnetic field and its variations. A change in natural processes on earth reflects the contemporaneous effect of solar, planetary and cosmic forces.

II. THE EFFECT OF HELIOGEOPHYSICAL FACTORS ON THE DYNAMICS OF ROOT EXCRETIONS OF PLANTS

As evident from the above brief review, heliogeophysical factors have an effect on the rhythm of biological processes at very diverse levels — from cellular to effects on population Of course, determination of the causes of this rhythmicity is very important for the solution of many questions in practical medicine, space biology, agriculture and biology. Special importance is given to the study of rhythmics now when actual human space flights have become a reality. With launch into space, a serious change occurs in important parameters of living organisms Many are important factors in the evolutionary process on earth — gravitation, the geomagnetic field, radiation, pressure, electromagnetic fields.

Therefore, it is very important to find the causes of biological rhythms and the role of heliogeophysical factors in this process. In our work on sorp- /75
tion, the plasmolytic properties of cells, and the functional state of plants radiated with ultraviolet rays, we showed that there is a definite rhythm of change in the permeability of cells, determined by unknown factors of the environment (Dubrov, 1963, 196?, 1970a, b). Experimental tests have shown that among these factors an important role is played by geomagnetic variations of various periods and change in gravity, connected with the effect of cosmic

forces and planets. This work shows how we studied the role of heliogeophysical factors as possible synchronizers of the rhythm of functional processes (Dubrov, Dubrovina, 1966, 1968).

Method. The majority of our studies were conducted in thermostatically controlled chambers (with constant humidity and illumination) in the Artificial Climate Laboratory and the MGU (Moscow State University) Institute of Plant Physiology, USSR Academy of Sciences. To study the rhythmicity of the excretory activity of plants, we devised a spectrophotometric method, based on a known physical phenomenon — the absorption of ultraviolet rays by solutions of organic substances (Dubrov, Bulygina, 1967). As shown by the study, this method was a highly sensitive test of the permeability of cell walls and membranes (Dubrov, 1970 a-c). At the same time, in studying root excretions in plants it served as a summary test of the excretion of endogenic organic substances through cell membranes of roots. It was shown that in test plants (barley, wheat, oats, etc.) these substances contain amino acids, amino sugar, acids of the tricarbon cycle, vitamins and other organic derivatives (Vančura, 1964; Izmaylov, 1968). The appearance of these substances in a purely nutrient solution changes the optical density of the solution. Measuring the optical density of the solution in the ultraviolet region of the spectrum at necessary periods, the researcher obtains data on the summary level of root excretions at any point in time and can thereby characterize the dynamics of permeability, the basis of the test. In recording rhythmical changes in permeability, we selected two typical wavelengths of ultraviolet light — 240 and 270 nm. All measurements of optical density were subsequently conducted in these wavelengths if test conditions did not require registration of the entire ultraviolet spectrum of absorption. Studies were made in 1965, 1966, 1968 and 1969. Specific dates and time of the tests are given in the figure captions or specified in the text.

We must note that studying the rhythmicity of vital processes in plants (and the permeability test, in particular) has several advantages over animals. This is primarily because plants can remain in extremely limited and strictly controlled conditions for a long time in a standard nutrient medium. This is /76 largely due to the autotrophic character of their nutrition. The latter is especially important in studying external synchronizers of rhythmical activity when conditions of the experiment superimpose strict limitations on the state

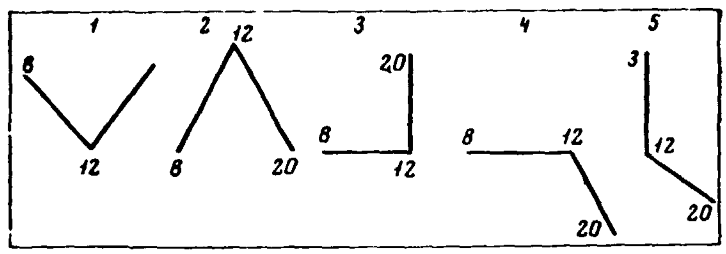

Fig. 1. Schematic representation of arbitrary "types" of root excretions in plants. The drawing shows the relative location of levels of optical density obtained in studying the rhythmics of plants at 8, 12 and 20 hours local time

of the object. It is often very difficult to maintain homeostasis of animals under such conditions and this hinders finding the causes of rhythmicity. In addition, in animals rhythmical processes are closely connected with and often completely controlled by the powerful neuro-humoral apparatus which strongly masks the direct role of cosmic and geophysical factors in the dynamics of rhythmical processes occurring in the organism.

Results. Research conducted according to the above method has shown that complete ultraviolet spectra of aqueous solutions of root excretions, reflecting change in the permeability of cell walls, vary during the course of a day, both in the absolute value of optic density and in the form of the UV spectrum itself (Dubrov, Bulygina, 1967).

In order to present a complete picture of rhythmic changes and the character of the test objects, let us consider data from triple determination of optic density at 8, 12 (14) and 20 hours, Moscow time (Fig. 1).

Study of the dynamics of excretion of organic substances by roots during a day has shown that the location of relative values of root excretions at 8, 12 (or 14) and 20 hours is specific for each day. On the basis of long research the following typical groups (or arbitrarily "types of root excretions for a given day") of physiological reactivity to the effect of heliogeophysical factors were distinguished (see Fig. 1). In addition to those illustrated, there is another series of groups with a different location of levels at the same time, but they are rarely encountered and are not considered here. As an example, Table 1 gives the percentage distribution of "types" of root excretions

Table 1 /77

TABLE 1. PERCENTAGE DISTRIBUTION OF THE DYNAMICS OF ROOT EXCRETIONS BY ARBITRARY "TYPES" IN 1965

Crop and period of measurement	Total number of measurements	Arbitrary "type" of excretion				
		1	2	3	4	5
Oats, June	84	42.8	27.3	11.9	9.5	8.3
Oats, March-July	182	34.0	28.5	12.6	8.7	15.9
Barley, June	84	40.4	19.0	10.0	19.0	10.7
Barley, March-July	115	42.6	21.7	11.3	8.6	15.6
Oats, barley, wheat and corn as a whole for the year	494	36.0	24.8	12.5	9.8	16.6
Wheat, barley (individual plants)	40	35.0	30.0	10.0	0	25.0

in oats, barley, wheat and corn for various periods of time and for individual plants, not combined into groups.

The studies showed high coincidence of arbitrary types of root excretions during the same days in different containers with wheat, barley, oats and corn. This coincidence (and the shift in types itself) is quite typical: neither radiation with ultraviolet rays nor lowered temperatures change the coincidence of the appearance or shift of types. For example, these data show (Fig. 2) that barley plants reacted to heliogeophysical factors according to type No. 1 (reduced level of excretions at 14 hours in comparison with the level at 8 and 20 hours) from June 1 to 3, 1965, but on June 4 the type of reaction pertained to No. 3; June 5, to No. 2, etc.; sharp changes in types were noted in the period from June 9 to 15, 1965. During this period, according to the data of a number of geophysical stations in this country (IZMIRAN, Pleshchenitsy), magnetic storms and changes in terrestrial currents were observed (Babushnikov, 1966).

It must be noted that such a shift in the reactions of plants resembles the "scaling" phenomenon known in automation and radioelectronics when a self-adjusting system, after certain external effects fluctuates, and after proper analysis of information about the state of the system again returns to the original level.

The data clearly indicate that the endogenic rhythm of plants is the result of a multi-factor effect, causing a disturbance of the normal dynamics of excretion which can be easily traced in the shift of arbitrary types of root excretions.

Thus, the shift in types of root excretions is an integral index of changes in external heliogeophysical conditions and at the same time an index of the

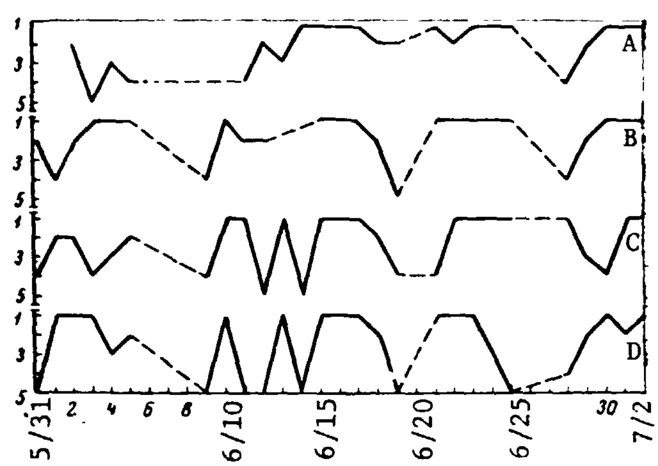

Fig. 2. Graphic representation of the shift in arbitrary "types" of root excretions in oats (A, B) and barley (C, D) from May 31 to July 2, 1965

operation of the internal regulatory system in the plants. It must be pointed out that the rhythmicity we studied underwent unexpected changes under the influence of unknown heliogeophysical factors, as the ordinary environmental factors (temperature, humidity, illumination, nutrient media, etc.) remained constant.

Prolonged observations of the dynamics of root excretions showed that along with even changes in this test, days are noted when the level of excretions sharply increases (June 21, July 12, August 24-27, 1965) and is sharply reduced (June 3-4; August 9, 12, etc.);this is clearly evident in the graph (Fig. 3). We arbitrarily called periods with a sharp increase in root excretions "bursts" and those with a sharp reduction of excretions — "zero points."

As the research showed, for all these cultures (barley, oats, corn, tobacco, etc.) there is a similar change in the level of root excretions and, in particular, the appearance of zero points and bursts. Therefore, it can be assumed that these facts — change in rhythm by days (shift in arbitrary types), the periodicity of bursts and zero points covering all cultures at the same time — indicate the effect of some external and, moreover, common factors changing synchronously the permeability of these root membranes in different plants.

The validity of this assumption has been confirmed by additional tests. For example, we made daily measurements of the form (type) and degree of

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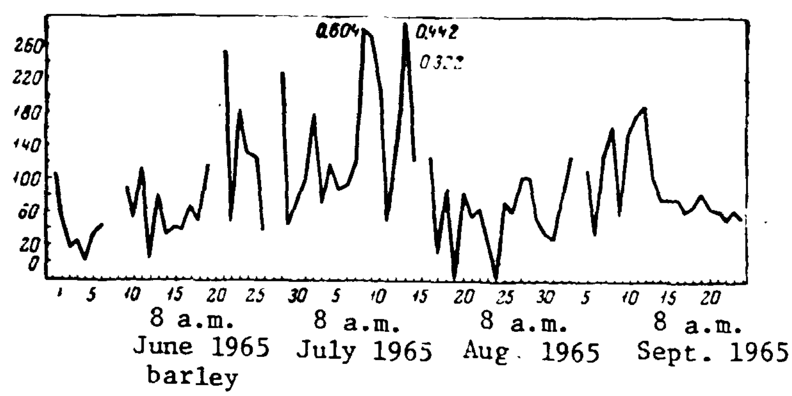

Fig. 3. Dynamics of root excretions in barley measured at 8 a.m. every day from May 31 to September 11, 1965. Moscow, MGU Phytotron. Vertically — optical density (D x 10^{-3}), horizontally — days

change in the plasmolytic properties of epidermal cells of onion scales, previously studied in detail (Dubrov, 1963). Plasmolytic data, as is known, indicate a change in the permeability of cellular protoplasmic layers — plasmalemma and tonoplast — and change in their adhesion and cohesion properties. It has been shown that the form and degree of cell plasmolysis changes hourly (Fig. 4). These changes occur simultaneously in different slices of the epidermis, just as noted above for the dynamics of root excretions. Additional tests with the dynamics of root excretions verify the above conclusions about the coincidence of changes. Thus, along with control plants grown at a temperature of 25°C, studies were made of plants placed in a thermostatically controlled chamber with a low temperature (+5°C) as well as plants grown at a temperature of 25°C and kept in a small lead chamber (40 x 20 x 20 cm, walls 2 cm thick). At the same time we studied a group of plants irradiated with ultraviolet rays (BUV-ZOR lamp, distance from lamp 30 cm, time of radiation 30 min., once) and grown at a temperature of 25°C.

As in the preceding studies, the dynamics of root excretions in all versions of the test are the same despite differences of species and test regimes (Fig. 5). As an example we cite selected data for oats and barley for the period from August 4 to 17, 1965.

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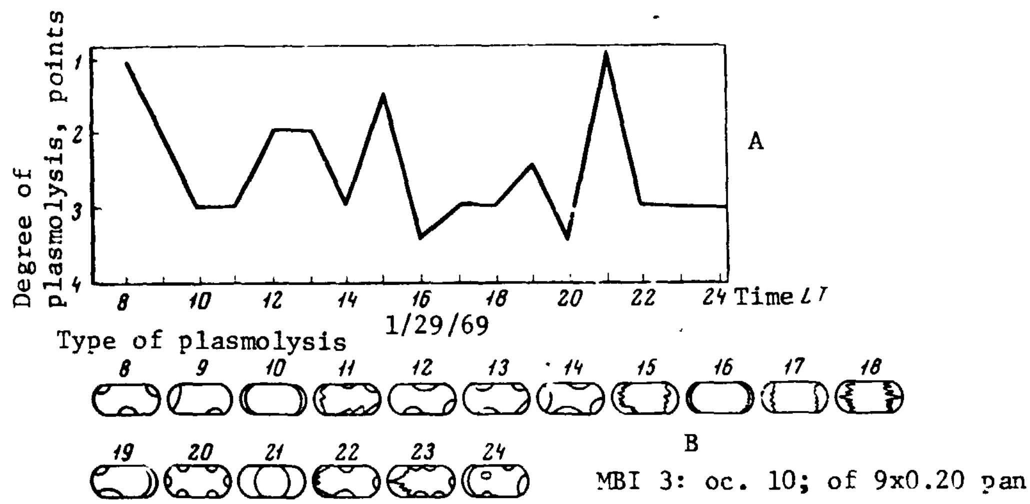

Fig. 4. Change in degree (A) and type (B) of plasmolysis in epidermal cells of onion scales January 29, 1969. Plasmolytic 0.5 M KNO_3. MBI-3 microscope: oc. 10, ob. 9 x 0.20 panochromat. Moscow time

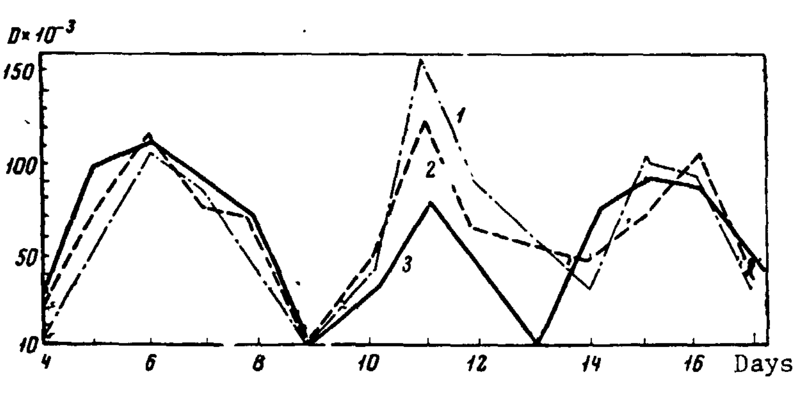

Fig. 5. Rhythm of root excretions in oats grown at a temperature of 25 (1) and 5°C (2) and in barley, temperature 25°C (3) measured at 8 p.m. each day from August 4 to 17, 1965. MGU Phytotron. Vertically — optical density, horizontally — days

Identical rhythmicity of root excretions in different plants, moreover, placed under different experimental conditions, could indicate in this case the existence of an endogenic rhythm maintained by evolution in all plants, regardless of external factors. But a number of facts indicate than an important role in the dynamics of root excretions belongs to an external synchronizing factor (or factors) with an absolute effect on plants. In particular, ultraviolet radiation, usually causing a shift in the endogenic rhythm of proto- /81
zoa (Ehret, 1961) in this case had no effect. Moreover, the same rhythmicity noted in such varied plant species as onion, tobacco, oats, barley and others is not even and steady in phases and amplitude but instead aperiodical, with sharp rises and falls, operating in all plants simultaneously. For more detailed study of the nature of this rhythm we conducted 24-hour and semidiurnal measurements.

a) Semidiurnal measurements of plant rhythms. For more experimental testing of our assumptions and to find the various aspects of the connection between the test and effective external factors, we made semidiurnal measurements, in most cases covering the period from 8 a.m. to 8 p.m. each day.

First of all, in studying the dynamics of root excretions in plants of various ages, as well as the differences in the absolute level of root excretions (seemingly with identical test plant containers: calibrated seeds, the same number of plants in the container, orientation of seeds during soaking, etc.) attention was given to the following fact. It has been shown that the absolute level and rhythm of root excretions in an unknown way depend on the time the seed is soaked with regard to the phases of the moon. Plants grown from seeds soaked before a change in the lunar phase differed in the rhythm and level of root excretions in comparison with those plants which were grown from seeds soaked at exactly the time lunar phases changed or a short time after (Fig. 6, 7).

As was shown, distinctions are noted even when the difference in soaking the seeds with regard to shift in lunar phases is only one hour. As possible explanation of this fact we can assume the effect of high-low tidal phenomena, connected with change in forces of gravity (mainly the effect of the sun and moon). In this case extremely insignificant (in absolute value) periodic changes in the forces of gravity, on the order of hundred millionths (i.e.

10-30 miligals) are very important.

Therefore, experiments were set up in which a plant container on a horizontal stand was raised each hour to a certain height (3.25 cm) above the orig-

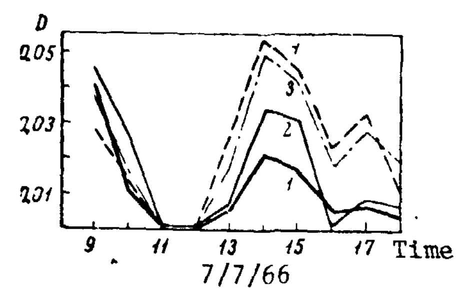

Fig. 6. Change in the level of root excretions when seeds are soaked in different phases of the moon. July 7, 1966.

1, 2 — seeds soaked 8 hours before shift in phase; 3 — after shift in phase; 4 — soaked exactly at the time of shift. Vertically — optical density, horizontally — time of day /82

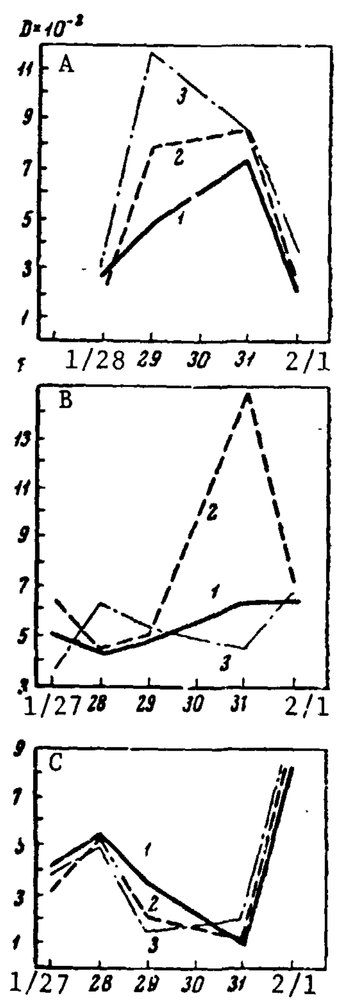

Fig. 7. Dynamics of root excretions in barley plants grown from seeds soaked at various times in relation to shift in lunar phases

A — rhythm with root excretions determined at 9 a.m.; B — determined at 2 p.m.; C — at 4 p.m. Vertically optical density, horizontally — 1966 dates. Seeds soaked: 1 — January 21, 1966 (before shift in phase); 2 — January 22, 1966 (after change of phase); 3 — January 21, 1966 (phase) inal level and then lowered. Raising or lowering the plant stand to the indicated height should have hourly compensated changes in the force of gravity due to tidal forces at that moment of time at the place where the test was conducted (MGU, Leningrad hills). Results of tests with this elevator show that the dynamics of excretion of periodically-raised and stationary (control) plants are practically the same (Fig. 8, A) although the effect of the time of seed soaking, with regard to the shift in lunar phases, was maintained.

For additional proof of the above stated possible role of small changes in the force of gravity in the rhythm of plants, a test was conducted in which the plants were subjected for half a day to continuous rotation at a speed of 33 rpm on a disk 25 cm in diameter. This rotation created acceleration and the additional force of gravity exceeded the daily hourly changes in gravitation due to tidal phenomena. Control plants were placed alongside on the table. Rotation did not alter the rhythm of root excretions in the test plants. It must, therefore, be concluded that the basic difference in the rhythm of root excretions when seeds are soaked at various times in relation . changes in

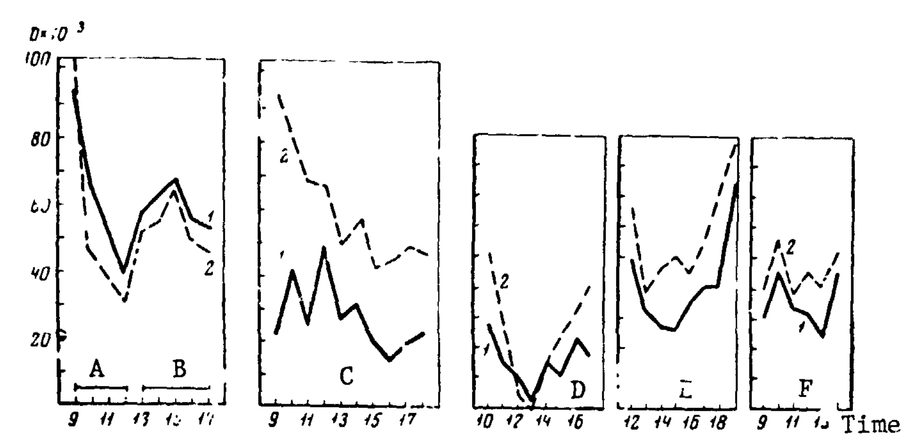

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Fig. 8. Rhythmics of root excretions during various experimental tests

A — hourly raising, B — lowering of plants: test February 5, 1966; C_1 — rhythmics of plants during complete compensation of the geomagnetic field July 28, 1966; C_2 rhythmics of plants under ordinary laboratory conditions. Test July 28, 1966; D — F — rhythmics of root excretions with plants on a horizontal platform or a pendulum — February 10-12, 1966: 2 — test; 1 — control. In all vertically — optical density, horizontally — time. Moscow time lunar phases is a complex of unknown conditions. Possibly this is a natural gravitational-magnetoelectric complex which at the shift in lunar phases has particular characteristics and at the time the seeds are soaked changes the physico-chemical properties of the solution and the water in the cellular membrane which is later expressed in altered rhythmics of the plants.

How complex the interrelations are between plants and this set of unknown conditions is shown by a special test which we arbitrarily called the "pendulum test." The plants were suspended on a horizontal support on a thin (0.5 mm in diameter) steel wire 6 m long. The control sample was alongside the "pendulum" on a stationary stand, the same height from the floor as the horizontal support on the "pendulum." In all tests it was found that placing the plants in a suspended state increases the absolute level of root excretions and slightly alters the rhythm — clearer manifestation of the basic maximum (for example, February 12, 1966, see Fig. 8, F) or the appearance of an additional maximum (for example February 11, 1966, see Fig. 8, E).

The opinion has been expressed that these differences are related to additional crossing of the earth's magnetic lines of force by the "pendulum," a polyelectrolyte plants-solution system. This assumption has necessitated study of the effect of the magnetic field on the dynamics of root excretions.

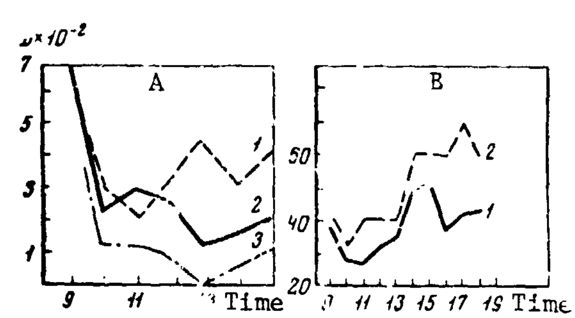

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Fig. 9. Rhythm of root excretions under the influence of a permanent ring magnet, 40 oe

A — oats: 1 — control, 2 — magnet placed on roots, 3 — on the leaves, test April 23, 1966; B — barley: 1 — control, 2 — magnet placed on roots, test July 21, 1966

b) The effect of artificial permanent magnetic fields. As the geomagnetic field has a force of 0.4 oe, a study was made of the effect of permanent ring magnets with a strength of 40 oe, which were clearly stronger than the geomagnetic field.

For the tests, plant containers were placed in the field of a permanent ring magnet. At the same time, in parallel rhythmicity tests we studied the effect of the magnetic field acting separately on leaves and roots. Placing parts of the plant in a permanent magnetic field changed the dynamics of root excretions at a certain time of the day (primarily from 10 a.m. to 5 p.m. especially in the initial periods of the effect; the rest of the time the effect was weaker). The variability of the effect of the permanent magnetic field throughout the day was traced in all plants to the same degree. The effect could be seen better when the magnet was placed on the roots than when it was on the leaves (Fig. 9).

This series of tests indicates that in the natural complex of heliogeophysical factors which affect the rhythm of plants there are various periods when a certain factor is weakened or intensified and the action of another increases or decreases. This is reflected in the varying sensitivity of plants to the effect of an artificial permanent magnetic field.

To prove these assumptions, tests were set up with compensation of the geomagnetic field.

c) The rhythmics of excretion during compensation of the geomagnetic field. Compensation of the geomagnetic field was attained by gating a direct current in Brownbeck rings. Plants placed inside the ring were in a "zero" /85 geomagnetic field. Under these conditions a change was observed in the rhythm of excretion in comparison with the control (see Fig. 8, C). At the same time, individual components of the geomagnetic field were compensated, the vertical and the horizontal. Compensation (especially of the horizontal component) also disturbed the rhythm of the process.

For a more detailed study of rhythmics, 24-hour measurements were made.

d) 24-hour measurements of the dynamics of root excretions. As in preceding tests, 24-hour measurements revealed significant differences in the daily rhythm of root excretions on different dates (Fig. 10). Again we emphasize that despite the fact that daily rhythms of root excretions vary on different days, nevertheless, on the same day in different kinds of plants the rhythmics of excretion are the same (see Fig. 10). This again indicates the unity of the synchronizing factor for all plants. Cases of relatively dissimilar rhythmics are very rarely noted (for example, May 14-15, 1965; see Fig. 10).

A corresponding test was set up to discover the rhythmics of excretion in plants placed in complete darkness. For three days before the start of 24-hour tests the plants were in darkness and measurements were made on the fourth day, also in the dark. The rhythmics of plants placed in the dark were similar to the control lighted version (Fig. 11). It is interesting to note that the rhythm of root excretions in the surviving plants (shoots were completely decapitated, only root parts of the shoots were placed in the containers) was similar to that in normal plants (see Fig. 11). This led to the conclusion that the external synchronizing factor affects the permeability of membranes and controls this property of living cells completely. In the opposite case, with such a serious operation as complete dismemberment of the plant (removal of the upper leaf part), the dynamics of the process of excretion through the roots would be completely disburbed because of a sharp change in homeostasis. Analogous data were obtained in tests with whole plants grown in various photoperiodic regimes.

We conducted comprehensive experiments to determine more accurately the reactions of plants to external physical factors, the ionic composition of the solution in which the plants were placed, the number of plants in test containers and the character of the rhythm, the reactions of individual plants, etc. We shall not dwell on these questions as we are limiting this article to heliogeophysical factors. Therefore, in conclusion we shall discuss global experimen s simultaneously studying the rhythmics of plants. /88

e) <u>Simultaneous study of rhythmics at various geographical points</u>. To find the essence of an external synchronizer and understand the principles of rhythm, simultaneous studies were conducted of the above test at various geographical points. A distinctive feature of these experiments was study of the rhythmics of plants under the same type of conditions at various geographic points. To this end all participants in the tests used the same seed (barley, "Moskovskiy-121" variety), salts for the nutrient solution (according to Knop), the

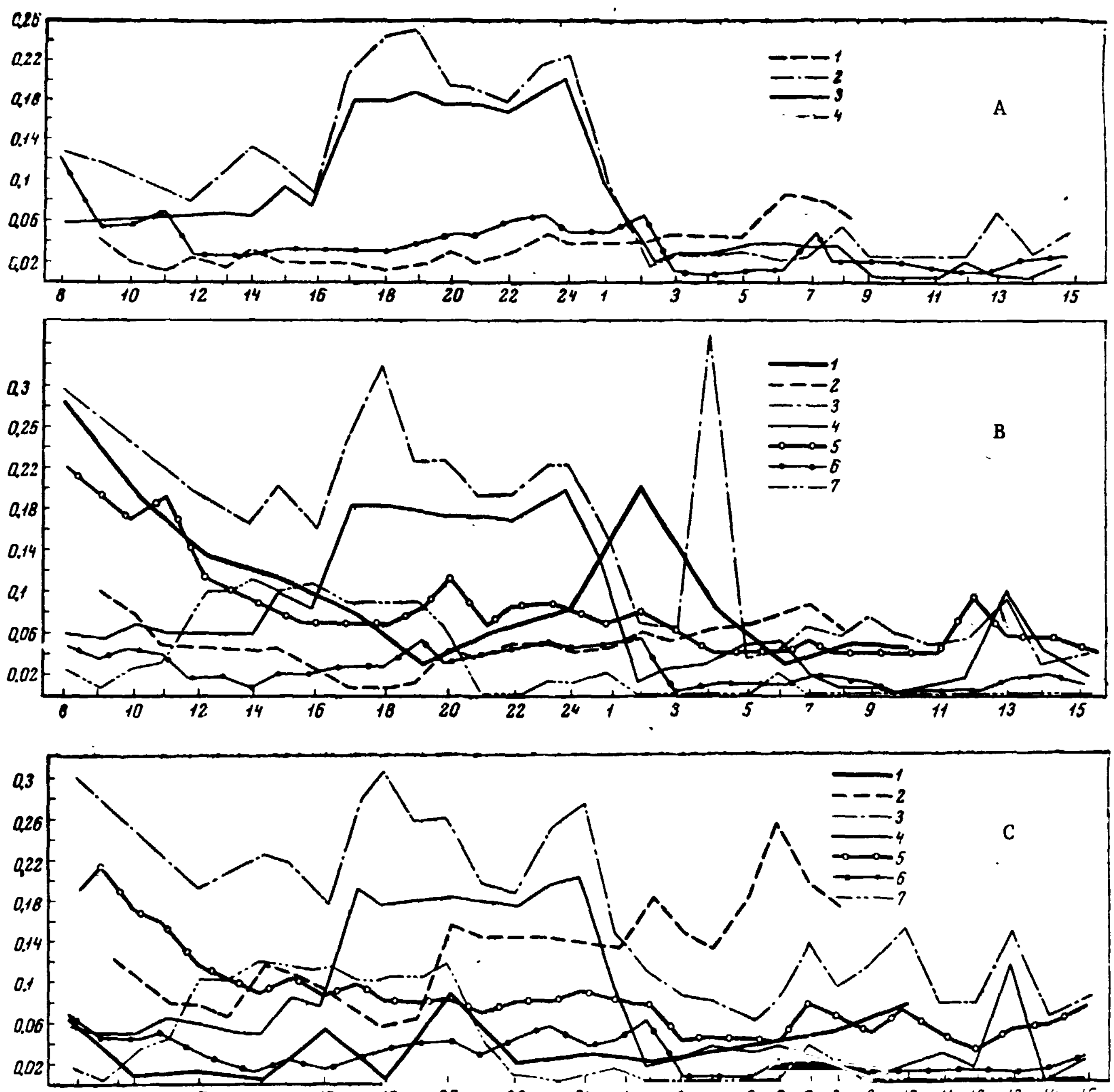

Fig. 10. Rhythmics of root excretions in 24-hour studies

A — corn: 1 — June 13-14, 1965 (two-day shoots), 2 — June 21-22, 1965 (10-day), 3 — June 21-22, 1965 (2-day), 4 — June 28-29, 1965 (9-day); B — barley: 1 — May 14-15, 1965 (4-day), 2 — June 13-14, 1965 (16-day), 3 — June 21-22, 1965 (23-day), 4 — June 21-22, 1965 (2-day), 5 — June 28-29, 1965 (30-day), 6 — June 28-29, 1965 (9-day), 7 — August 11-12, 1965 (10-day); C — oats: 1 — May 14-15, 1965 (6-day), 2 — June 13-14, 1965 (16-day), 3 — June 21-22, 1965 (23-day), 4 — June 21-22, 1965 (2-day), 5 — June 28-29, 1965, 6 — June 28-29, 1965 (9-day), 7 — August 11-12, 1965 (10-day) same glass dish, etc. At two points, Moscow (USSR) and Florence (Italy) the studies were made in phytotrons with constant temperature, lighting and humidity conditions. At the other points (Sverdlovsk, Minsk, Tallin, Yerevan) tests were conducted in ordinary laboratory rooms with observance of the same temperature and lighting conditions (Dubrov et al., 1969a, b).

Simultaneous study of the rhythmics of excretion under the same laboratory conditions at several geographic points showed that rhythmics can be extremely varied and are distinguished by the following characteristics. On one hand, /89
in these experiments there are cases when the daily rhythms are similar at points thousands of kilometers apart (Moscow-Irkutsk) and on the other — different for comparatively close points (Moscow-Minsk)(Fig. 12). This is clearly seen in the daily rhythmics of root excretions studied simultaneously at Irkutsk and Sverdlovsk, October 19, 1968.

It must be noted that the absolute level of optical density, reflecting the total excretion of organic substances, was also different for these geographical points (Table 2).

TABLE 2. CHANGE IN THE OPTICAL DENSITY OF A SOLUTION WITH ROOT EXCRETIONS IN SIMULTANEOUS TESTS AT VARIOUS POINTS
(BARLEY, 4-DAY SHOOTS; λ = 240 nm; $D = n \cdot 10^{-3}$; OCT. 24, 1968)

City	Greenwich time										
	5	6	7	8	9	10	11	12	13	14	15
Irkutsk	1	7	5	15	15	20	50	30	15	35	18
Minsk	32	32	31	39	41	42	43	47	56	50	61
Moscow	1170	1160	1250	1250	1470	1320	1150	1200	1080	1070	1370
Tallin	11	13	14	19	18	36	26	17	8	16	6
Florence	61	43	42	35	55	51	37	45	28	42	37

Our studies, therefore, noted that the excretory rhythm of each geographic point, along with the general global character, has its individual traits. The rhythmic activity of plants has a general daily course and in addition, there is another excretion maximum or minimum or phase shifts of maximums and minimums at 1-2 a.m. These differences are seen especially clearly in continuous two-day registration of the dynamics of root excretions (Fig. 12).

These facts again emphasize the above stated opinion that this test and the permeability of cellular membranes on which it is based are under the influence of a number of external factors and that the rhythmics of functional activity appear in a complex interaction between homeostatic systems of the organism and heliogeophysical factors.

Discussion. The above shows quite clearly that the plant organism is under the influence of several heliogeophysical factors having an effect on functional rhythmicity. Therefore, after prolonged continuous observation we also com- /91 pared various heliogeophysical factors with the dynamics of root excretions; these could have their own effect. This analysis verified the decisive role of natural magnetic and electric fields. At the same time, several characteristics of this effect were revealed: evidently (thorough investigation with special tests is necessary), in addition to the geomagnetic field, terrestrial currents in a north-south direction are biologically significant (Fig. 13); for short-period fluctuations of the geomagnetic field (KPK) this direction is east-west (Fig. 14).

Our studies have not resolved the question of the role of gravitational forces for the rhythmics of this test. However, our studies of the dependence of rhythm on lunar phases, analytical comparisons (Fig. 15) and literature data (Hoshizaki, 1967) also indicate the obvious role of gravitation in rhythmical changes. Undoubtedly, new experimental approaches are needed to clarify this question, particularly direct experiments in the weightless conditions of space. The coincidence of long periods (calculated in days from 3-8) in the dynamics of root excretions with periods of gravitational changes (measured, for example, by shift in lunar phases or shift in the curves of correction tables for tidal phenomena; see Shokin, 1965) indicates the role of gravity in the dynamics of this process and rhythm in general. In addition, the above noted "zero days" can be related to the effect of tidal forces but the non-coincidence of these days and gravitational action can be explained by the effect of other heliogeophysical factors causing "bursts" and sharply disturbed permeability. In this sense, our studies verify the opinion that rhythmic changes reflect the effect of several external factors (Piccardi, 1967; Brown, 1965, 1968). The possibility is not ruled out that plants exist in critical states according to a series of heliogeophysical factors or their specific para-

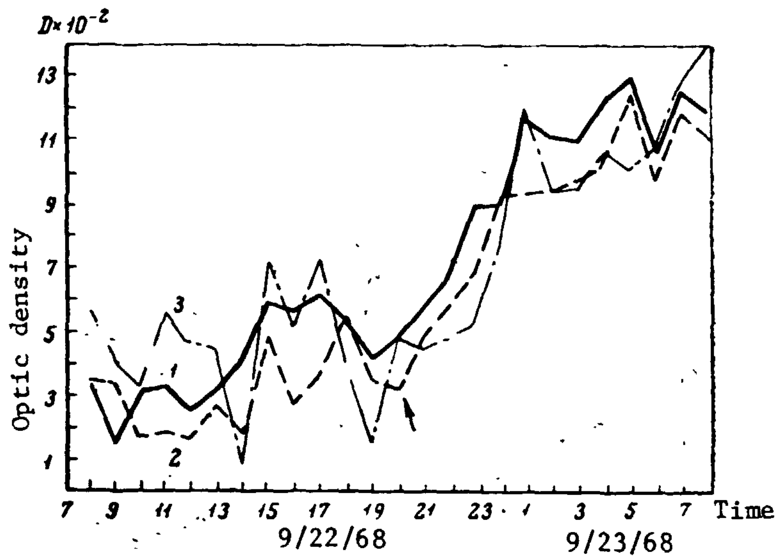

Fig. 11. Rhythm of root excretions in 4-day growths of barley during abrupt disturbance of homeostasis

1— darkness; 2 — decapitation, in which the primary leaves are completely removed and only the roots remain; 3 — control, plants placed in the light. The arrows indicate the decapitation time. The experiment was performed on 22-23 September 1968 during a solar eclipse (from 13 to 15 hours). Phytotron of the Institute of Plant Physiology im. K.A. Ti ryazev (IFR) of the USSR Academy of Sciences.

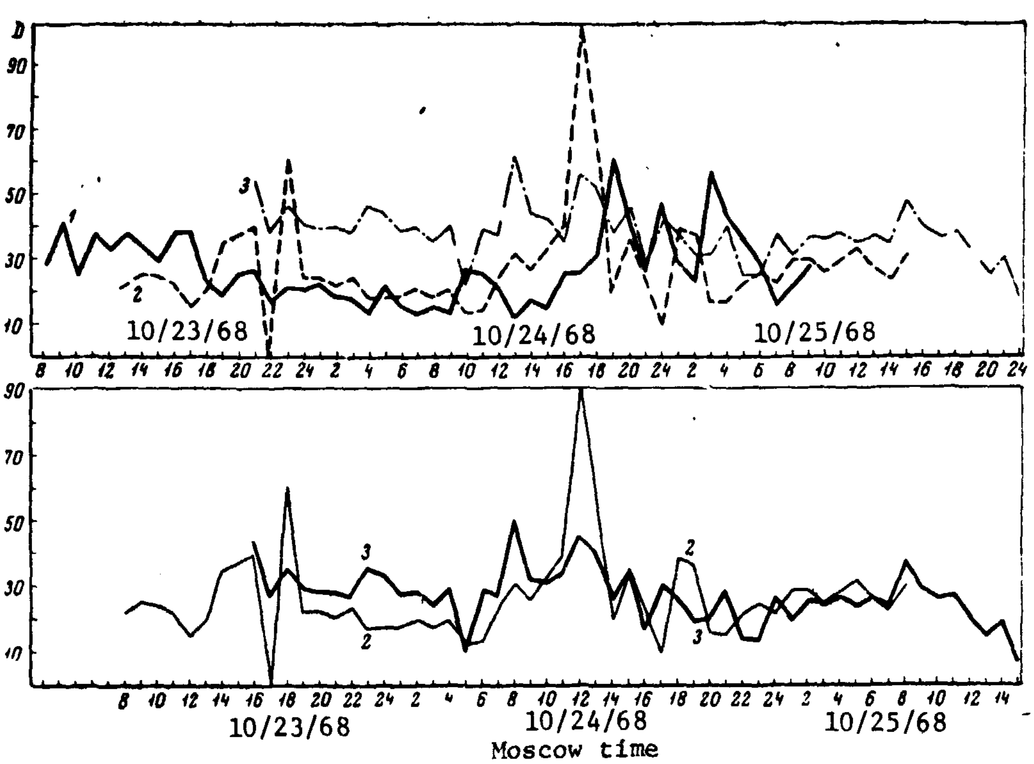

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Fig. 12. Rhythmics of root excre ons in barley in simultaneous studies in Irkutsk (1), Moscow (2), Florence (3), October 23-25, 1968

The graph shows Moscow time (for conversion to world time subtract 3 hours)

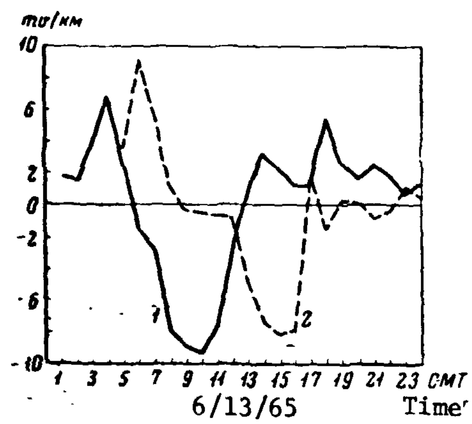

Fig. 13. Rhythmics of root excretions (2) in barley and the change in north-south components (1) of terrestrial currents, June 13, 1965 (Pleshchenitsa observatory). Greenwich time indicated. Plant tests at the MGU phytotron

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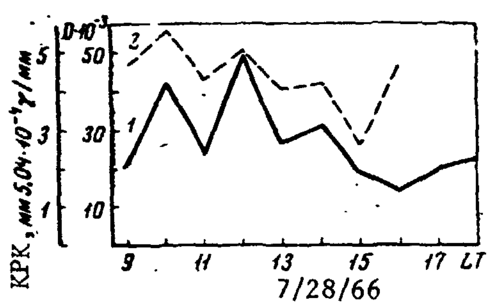

Fig. 14. Rhythmics of root excretions in compensated geomagnetic field (1) and the change in amplitude of east-west components of brief-period fluctuations of the geomagnetic field (Borok observatory (2) July 28, 1966. Moscow time

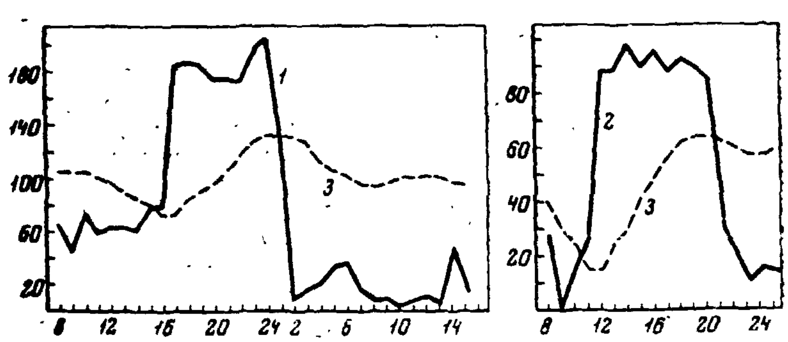

Fig. 15. Rhythmics of root excretions in barley June 21-22 (1) and August 11, 1965 (2) and change in gravity for the corresponding dates (3). Moscow time

meters; for several of them there are threshold boundaries of action.

The universality of these rhythmic changes indicates the existence of a single mechanism of connection between living organisms and heliogeophysical factors. Based on our experimental work and analysis of the data of other researchers, we have come to the conclusion that underlying this connection is a change in the permeability of biological membranes and walls. As permeability is a fundamental property of cells of all organisms, the universal dependence of various biological processes on solar activity (which has a decisive effect on the electromagnetosphere of the earth) becomes apparent. As analysis shows (Dubrov, 1970), the mechanism of this dependence is connected /93
with the effect of heliogeophysical factors (including the geomagnetic field and gravitation) on water molecules in cellular membranes and the nutrient solution. The effect of these magnetic fields on the physico-chemical properties of water is clearly shown (Klassen, 1967). Heliogeophysical factors have their own effect on the magneto-electric properties of molecules in cellular membranes; they thereby change the surface potential of the cells and the membrane potential and have an affect on the surface energy of the system as a whole. As is known, an important role in the stabilization of biological membranes is played by electric and polarization forces; change in them leads to changes in the permeability of membranes (Piruzyan, Aristarkhov, 1969). Therefore, it can be concluded that the geomagnetic field and gravitation have their own effect on permeability through polarization of membranes and walls of living cells. A verification of our basic conclusion is given by data which indicate the role of the gravitational field in changing the electric potentials and polarization of membranes (Brauner, 1969).

Because living organisms are multi-frequency systems (Presman, 1968), they react to various natural electromagnetic fields. The effect of these fields can also be explained, taking into consideration their ability to change the polarization of walls and membranes. To explain all effective factors, automatic continuous registration of functional-dynamic characteristics of living organisms is necessary, of which we spoke in the first part of our work. How fruitful this work can be is shown by the experiments simultaneously studying the rhythmics of plants at various geographic points. These studies are a new step in the development of heliobiology and will help solve important problems in space biology and medicine and open new perspectives in understanding the role of heliogeophysical factors in the vital activity of living organisms on earth.

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THE EFFECT OF CONCENTRATED SUNLIGHT IN A PULSED REGIME ON GROWING PLANTS

S. A. Stanko

Sunlight is one of the basic sources of energy sustaining the vigorous /96
course of processes in living and nonliving nature on earth.

The mastery of solar energy, in the opinion of F. Zholio-Kyuri (1950), will mean not only a new path to large and small discoveries, but also a means to improve the public welfare.

If the energy of all fuel now on earth is estimated to be about $55 \cdot 10^{15}$ kW·hr, the Sun annually sends to the earth a constant stream of energy equalling $580 \cdot 10^{15}$ kW·hr, i.e. in one year 10 times more than all the energy included in all the fuel on earth. This amount of energy is more than 20 thousand times that consumed for the needs of all mankind. Therefore, the possibility of practical utilization of even a small portion of the vast energy of the flux of radiation will be immensely important. This flux, more or less evenly decreasing with distance from the Sun, on reaching the surface of the earth undergoes significant changes in spectral composition and varies with time in power and quality. These fluctuations are due not only to astrophysical causes connected with the seasons and the daily rotation of the earth, but also to climatological and meteorological factors.

The periodicity of radiation (photoperiodicity) causes in biological objects the formation of corresponding adaptations in metabolism, physiology and ontogeny (photoperiodism). The consequences of this periodicity are occasionally deeper than we usually imagine because they are distributed throughout the entire sphere of vital activity including conscious human activity. Many years of evolution have so complicated the interaction between primary energy sources of life and life's "natural rhythmical phenomena" that even in the world of green plants, whose life entirely depends on light, it is difficult to distinguish the direct primary energy effect of light from the informational effect connected with maintaining the normal "daily" course of these energy processes, their "intensity" in time. /97

Therefore, every change in the "nature" of the light flux, its spectral, power or time characteristics, invariably entails deviations (or disturbances) in the normal course of photoenergetic and other closely related metabolic processes in plants.

The consequences of change in long photocycles in plants (on the order of several hours or days) have already been quite well investigated. The ·eneral biological aspect of short period pulsed variations, except specific cases of studying the mechanism of photosynthesis, have been only slightly touched upon until recently.

At the same time, in the world of space, in the world of variable stars, the cosmonaut will more than once encounter a phenomenon such as pulsed and concentrated light (svet--IKSS) and a study of its effect on earth would be very timely.

In many branches of chemistry, medicine, biology and agriculture, the prospects for using such light are now already extremely good.

IKSS energy, depending on the design of the concentrator, can be tens and hundreds of times greater than that of solar radiation and using light filters or special selective concentrators, a certain region of the spectrum with the desired radiation energy can be produced.

Phytophysiological research of IKSS as a powerful photoenergetic factor was first used by A. A. Shakhov and S. A. Stanko in polar regions in 1959-1962 in preplanting radiation of seeds and then in barley and wheat plants in various phases of their development. As a result of the studies, it was established that preplanting radiation of seeds with IKSS lasting 20, 30 and 60 minutes, with a 15-25-fold

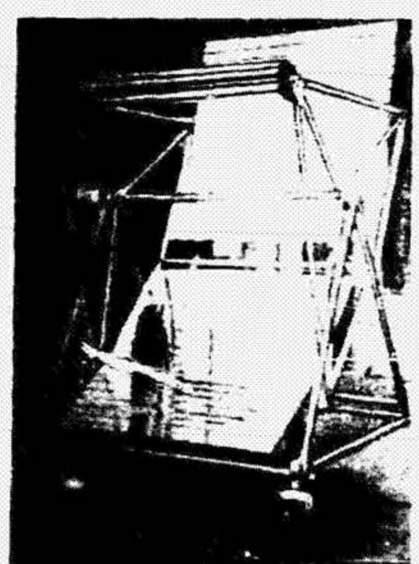

Fig. 1. Gene . view of a solar faceted glass reflector for the radiation of seeds and plants

concentration of direct sunlight, favorably affected field germination, productive bushiness, growth, development and yield of the plants.

It has been shown that the optimum energy doses of IKSS from various kinds /98 of solar concentrators stimulating germination and sprouting and then growth, development and yield, are doses with a total photoimpulse energy of (1.5-3.0)$\cdot$ $\cdot 10^9$erg/cm^2 in a radiation procedure lasting 25-30 minutes.

The effect of IKSS on plants is polyhedral. Depending on intensity and spectral composition, IKSS can cause a photostimulating or a photoinhibiting effect in plants.

Stimulation is based on photophysical and photochemical reactions with the appearance of relatively long-lived free radicals whose number depends on the duration of photoinduction, the intensity and spectral composition of IKSS. High energy density during the impulse and a broad spectrum of IKSS action affect a broad scope of excitable photoreceptors, including photosynthesis, and the productivity of the plants.

IKSS energy , absorbed "above normal" by the plants and not characteristic of ordinary solar radiation absorbed by the plants during the course of evolution, is utilized by them, depending on a number of factors in the external and internal environment and ultimately has certain biological effects.

The entire complex of photoenergetic processes in plants, from the absorption of IKSS quanta to their complete utilization in metabolism and growth, analogously to the absorption of energy from other physical sources, can arbitrarily be divided into three stages: physical, chemical and biological.

The physical stage begins at the moment IKSS quanta are absorbed by photoreceptors, resulting in the excitation of atoms and molecules, the transmission and transformation of absorbed energy, thermal activation of electrons, ionization of atoms and molecules, breaking of chemical bonds, formation of short and long-lived unpaired electrons (free radicals), luminescence of energy, etc.

The chemical stage includes photochemical oxidation, intensification of oxidation-reduction reactions, synthesis of ATP and other high energy compounds, change in the rate of enzyme reactions and transmembrane transmission of substances, activation of biosynthetic reactions, changes in macromolecules of nucleic acids, nucleoproteins, proteins, complex polysaccharides and specific, more extensive non-photosynthetic utilization of light energy, etc.

The biological stage covers changes in biological structures of the cell, especially the membrane systems and metabolism, growth, development, productivity and mutation.

Thus, the plant exposed to IKSS radiation differs from a non-radiated /99 object in its higher level of potential energy. This absorbed "above normal" solar energy causes distinctive changes in structural-metabolic processes and produces a broad front of still inadequately investigated phenomena of photobiological stimulation and inhibition.

Two periods in the development of plants have been found when the effect of IKSS causes the greatest shaping and mutagenic effect: the first is radiation of plants from the appearance of shoots to the start of tillering (the majority of monocots) or until the appearance of second-third leaves (dicots); the second is radiation from the beginning development of reproductive organs until the formation, ripening and maturing of seeds.

In the first period of radiation meristematic tissue in the growth point is exposed to the active effect of IKSS, as a result of which metabolic changes in the cells can cause chromosome aberrations at the growth point and the appearance of point (gene) mutations; in the second period IKSS acts directly on the generative processes, meiosis, the specifics of formation and maturation of seeds, and indirectly through changes in structural-metabolic processes.

In this work we shall consider and discuss experimental data concerning the stimulating effect of IKSS on growing plants in various phases of ontogeny, on the composition and content of various metabolites of the cell and the structure of its organelles.

Procedure and objects of study. Tests were conducted on corn (Sterling variety), soy bean (Biruintsa-12), wheat (Bel'tskaya-32 and Moldavanka) and tomato (Gruntovyy Gribovskiy-1188) plants, raised in growing dishes against various backgrounds of mineral nutrition. Subsequent generations were raised in soil conditions with the usual agricultural technology for each culture.

Plants were radiated with a solar faceted mirror reflector which increased direct solar radiation 50 times. The length of radiation for the procedure was 30 minutes and each light impulse lasted 0.025 seconds; pauses between impulses were 0.45 seconds. In a 30-minute period of radiation the plants received a total of 3.5 kilopulses, which was about $2 \cdot 10^9$ erg or about $13 \cdot 10^{20}$ eV per each cm^2 of radiated leaf surface.

Analyses were made according to the following methods: pigment content — chromatographically and spectrophotometrically according to D. I. Sapozhnikov et al. (1955, 1959), strength of the chlorophyll-lipoid-protein complex bond — according to T. G. Maslov (1958), sugar and free amino acids — chromatographically, with subsequent determination of the concentration of eluates spectrophotometrically (Pavlinova, 1962; Zavadskaya et al., 1962; Andreyeva and Osi-

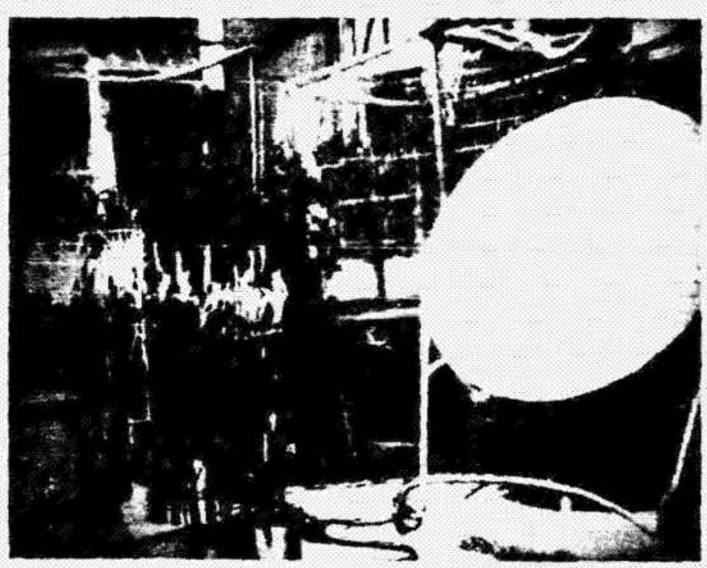

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Fig. 2. Radiation of growing plants with an all-metal aluminum solar reflector

pova, 1962; Uspenskaya, Kretovich, 1962), nucleic acid content — spectrophotometrically (Kulayeva, Popova, 1965; Nechayeva, 1966; Konarev, 1967). Chloroplasts were extracted according to the directions of O. P. Osipova (1968) and the protein content in chloroplasts, according to Lowry. Chromosome aberrations in somatic rootlet cells were studied according to the method of S. G. Kaptar' (1967).

Productivity data were statistically analyzed.

RESULTS OF THE STUDIES AND THEIR DISCUSSION

The effect of the radiation of plants with IKSS on the photosynthetic apparatus

The biosynthesis of pigments in the leaves of plants is closely connected with the characteristics of metabolism due to the effect and aftereffect of a number of factors. And as the content and ratio of chlorophyll in the plastid directly depend on the physiological condition of the cell and the entire plant (Shlyk, 1965), we feel that energetically powerful IKSS primarily affects the accumulation, content and ratio of plastid pigments, the strength of their bond with the lipoid-protein complex, the structural-functional characteristics of chloroplasts and the free-radical state of individual leaf biopolymers.

The effect on the course of photosynthesis can be revealed through the biosynthesis and metabolism of chlorophyll. /101

In our opinion, the essence of the stimulating IKSS radiation of plants consists, on one hand, of a change in the activity of the photosynthetic apparatus through activation of pigment biosynthesis and photosynthesis and, on the other, activation of general metabolism and the increased storage of light energy through non-photosynthetic processes, differing from its accumulation in macroergic compounds during photosynthesis and respiration in ordinary solar radiation. These are, for example, the formation of unpaired electrons photoinduced through IKSS, photoactivation of a number of enzymes, the biosynthesis of protein and nucleic acids, the photoconformation of biopolymers and membranes, etc. Therefore, in order to obtain a positive effect of IKSS on the plant, it is necessary that it not inhibit the process of pigment biosynthesis and not cause photodegradation of the already existing pigment reserve.

Our first tests have already shown that the longer plants were radiated with IKSS (of course, in doses not causing a pathological state), the more pigments were accumulated (Shakhov, Stanko, 1962; Stanko, Gvozdikovskaya, 1967, 1969; Stanko, 1971). It was noted that during radiation (with one session lasting 30 min.) of plants with IKSS there is a significant increase in the relative ratio of chlorophyll a and xanthophyll , but the relative content of chlorophyll b and carotene is slightly reduced. As a result of this, the ratio of chlorophyll a/b was increased. At the same time, the chlorophyll-lipoid-protein complex bond was stronger in radiated plants (Table 1). Table 1 shows that,as the number of sessions of IKSS radiation of plants increases, the total amount of chlorophyll in leaves rises.

The increase in the total amount of chlorophyll is primarily due to chlorophyll a. There was 45-55% more in test plants and 25-30% more chlorophyll b than in the control.

It is known that in the living cell there are forms of chlorophyll which vary in photoresistance and in maximums of absorption, which is also basically responsible for the strength of its bond with the lipoid-protein complex. Chloroplasts, isolated from leaves of plants grown with a more intense illumination and characterized by more intense photosynthesis, also have more photoresistant chlorophyll (Osipova, Ashur, 1963, 1964). An important role in the increased photoresistance of chlorophyll and its protection during photooxidation is played by carotenoids (Anderson, Robertson, 1960; Osipova, Ashur, 1963). Usually more photoresistant chlorophyll in chloroplasts corresponds to less photoresistant carotenoids.

The function of carotenoids consists either in transferring energy to /102 chloroplasts or in the role of collectors of excess energy of chlorophyll excitation.

Excited carotenoid collectors are deactivated by molecular oxygen or undergo disintegration. This is responsible for the well-known screening role of yellow pigments in protecting chlorophyll and the photosynthetic apparatus as a whole from lethal photooxidation.

In connection with the above, it was of interest to study the strength of the bond between individual carotenoids and the lipoid-protein complex in the plastid of test and control leaves (Table 2). /103

Table 2 shows that after only the first 30-minute IKSS radiation of plants their total amount of carotenoids is reduced primarily because of the decreased relative content of carotene and violaxanthin. The amount of lutein either is not reduced at all or only very slightly. In this instance, along with possible considerable photooxidation of carotenoids from the effect of IKSS, there is probably also interconversion of some carotenoids to others (Godnev, Rotfarb, 1963; Sayakov, 1968).

It has been shown that the strength of the bond of all carotenoids in the plastid lipoid-protein complex in leaves of plants radiated with IKSS is less than in the controls. With prolonged systematic IKSS radiation of plants, the absolute content increases significantly, although the bond strength in the lipoid-protein complex of the plastid remains lower than in the control.

It is extremely important that energetically powerful IKSS does not have a thermal or "denaturing" effect on leaves during prolonged radiation of plants

TABLE 1. PIGMENT CONTENT (mg/in^2) AND THE STRENGTH OF THE CHLOROPHYLL-LIPOID-PROTEIN COMPLEX BOND DEPENDING ON IKSS RADIATION OF PLANTS

(numerator — absolute chlorophyll content in mg/in^2, denominator — % of total amount)

Number of radiations	Date of analysis	Total chlorophyll content			Stably bound form			Unstably bound form		
		a	b	(a+b)	a	b	(a+b)	a	b	(a+b)
					Corn (Sterling)					
Control	22 July	1.40/100	0.54/100	1.94/100	1.[illegible]8/84	0.52/96	1.70/89	0.22/16	0.02/4	0.24/11
1	22 July	1.45/100	0.56/100	2.01/100	1.30/90	0.49/91	1.79/90	0.15/10	0.07/9	0.22/10
4	27 July	2.05/100	0.72/100	2.77/100	1.90/92	0.67/93	2.57/93	0.15/8	0.05/7	0.20/7
10	27 July	1.92/100	0.67/100	2.59/100	1.77/92	0.65/98	2.42/94	0.15/8	0.02/2	0.17/6
13	28 July	2.06/100	0.84/100	2.90/100	1.95/94	0.79/95	2.74/94	0.12/6	0.05/5	0.17/6
Control	28 July	1.33/100	0.47/100	1.80/100	1.04/79	0.44/93	1.48/82	0.29/21	0.03/7	0.32/18
					Soy beans (Biruintsa-12)					
Control	19 July	2.10/100	0.49/100	2.59/100	1.65/78	0.27/55	1.92/74	0.45/22	0.22/45	0.67/26
8	19 July	2.47/100	0.48/100	2.95/100	2.00/81	0.21/44	2.21/75	0.47/19	0.27/56	0.74/25
22	22 Aug	3.68/100	0.78/100	4.44/100	3.12/85	0.49/63	3.61/81	0.56/15	0.29/27	0.85/19
Control	22 Aug	2.39/100	0.60/100	2.99/100	1.81/75	0.34/57	2.15/72	0.58/25	0.26/43	0.84/28

and does not disturb the integrity of the chlorophyll-lipoid-protein complex in the plastid. Otherwise an increase would be noted in unstably bound chlorophyll, as was noted by T. G. Maslova (1958, 1959) and D. I. Sapozhnikov et al. (1962) in thermal analysis of leaves and S. A. Chernomoriy (1961) in radiating leaves with ultraviolet rays.

A number of researchers, using powerful light sources to radiate etiolated and green shoots, also noted the stimulating effect of intense pulsed light on the accumulation of chlorophyll (Stanko, Gvozdikovskaya, 1967; Godnev, Domash, Akulovich, Khodasevich, 1971; Stanko, 1971) and on the rate of conversion of protochlorophyll to chlorophyll (Madsen, 1960; Godnev et al., 1964, 1966). Powerful light pulses also did not destroy the pigment system and did not disturb subsequent normal functioning of the photosynthetic apparatus (Koski, 1950; Sironval, Kandler, 1958).

We noted that photoinduced stimulation of greater accumulation of pigments in plants radiated with IKSS in various phases of growth also occurs in the aftereffect, up to 30-40 days, which is characterized by relatively greater accumulation of chlorophyll b and carotenoids. The relative amount of chlorophyll a is not increased so intensely in the aftereffect as during radiation. The strength of the chlorophyll-lipoid-protein complex bond in radiated plants is also higher than in the controls.

This motivated study of the structure and protein complex of chloroplasts in plants exposed to radiation.

Electron microscope studies have established that daily radiation of /105
growing plants with IKSS does not cause a pathological state in chloroplasts. However, the matrix of chloroplasts in test plants is slightly less electron-dense than control plants and the lamella of stroma and grana are more clearly oriented along the chloroplast, lipoid globules are smaller in size and their number per chloroplast slightly more than in the control. Starch grains in chloroplasts of test plants are also finer than in the control and unlike the latter, where 2-3 large starch grains are found in each, in test plants each chloroplast contains 8-9 or more starch grains.

Very often two-three or more mitochondria are arranged "end to end" along chloroplasts of test plants. These mitochondria have a well developed system of crystals. Probably because of better spatial distribution of the chloroplast-mitochondria complex in the cells of test plants, as will be shown below, phosphorylation processes are also more active, as a result of which they contain a higher content of organic, lipoid, protein and nucleoprotein forms of phosphorus.

TABLE 2. CAROTENOID CONTENT AND THEIR BOND STRENGTH WITH THE LIPOID-PROTEIN COMPLEX DEPENDING ON IKSS RADIATION OF PLANTS
(numerator — absolute carotenoid content in mg/in^2; denominator — % of total amount)

Number of radiations	Total content				Stably bound form				Unstably bound form			
	carotene	lutein	violaxanthin	total	carotene	lutein	violaxanthin	total	carotene	lutein	violaxanthin	total
Corn (Sterling)												
Control	0.143/100	0.183/100	0.140/100	0.466/100	0.131/91	0.080/46	0.085/60	0.296/63	0.012/9	0.103/54	0.055/40	0.170/37
1	0.126/100	0.189/100	0.118/100	0.433/100	0.104/83	0.061/32	0.033/28	0.198/46	0.022/17	0.128/68	0.085/72	0.235/54
10	0.118/100	0.232/100	0.155/100	0.505/100	0.103/87	0.140/61	0.054/35	0.297/59	0.015/13	0.092/39	0.101/65	0.203/41
Soy beans (Biruintsa-12)												
Control	0.171/100	0.210/100	0.177/100	0.558/100	0.154/90	0.155/76	0.072/41	0.391/70	0.017/10	0.055/24	0.105/59	0.177/30
1	0.164/100	0.200/100	0.125/100	0.469/100	0.124/76	0.124/62	0.046/36	0.294/64	0.040/24	0.076/38	0.079/64	0.195/36
9	0.186/100	0.216/100	0.225/100	0.627/100	0.135/72	0.121/56	0.090/41	0.346/56	0.051/28	0.095/44	0.135/59	0.279/44

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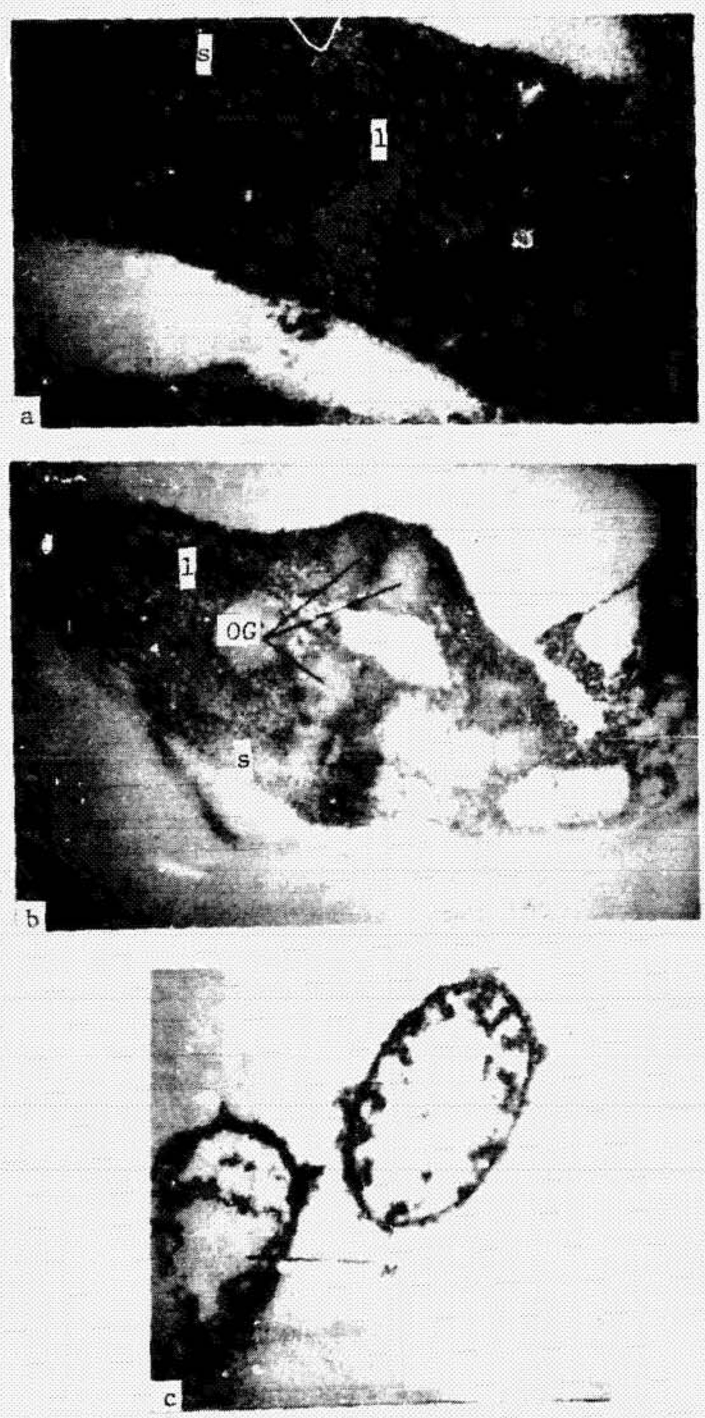

Fig. 3. Chloroplasts and mitochondria from leaves of control and IKSS-radiated Biruintsa-12 soy bean plants

a, b — chloroplasts; c — mitochondria of leaves of control plants

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Fig. 3. Continued

d, e — chloroplasts, OG — osmiophilic globules; M — mitochondria
f — mitochondria of leaves of radiated plants; l — lamellae; s — stroma; g — grana

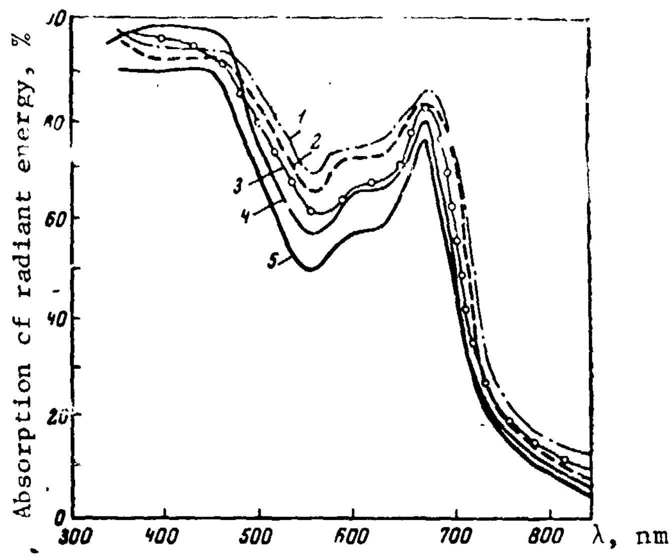

Fig. 4. Spectral curves of the absorption of radiant energy by leaves of Biruintsa-12 soy beans, depending on IKSS radiation of plants

1 — daily radiation from the 2-3rd leaf phase to the end of vegetation; 2 — daily radiation from the flowering phase to the end of vegetation; 3 — sixfold radiation in the 2-3rd leaf phase; 4 — sixfold radiation in the flowering phase; 5 — control

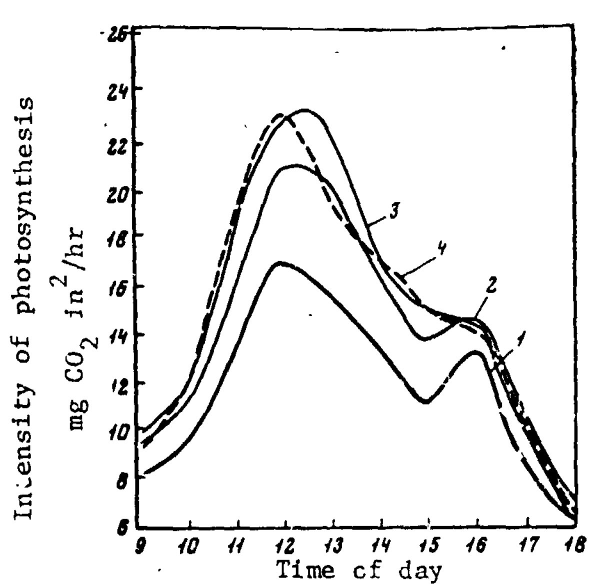

Fig. 5. Daily course of intensity of photosynthesis in leaves of Biruintsa-12 soy beans depending in IKSS radiation of plants

1 — control; 2 — daily radiation from the 2-3rd leaf phase to the end of vegetation; 3 — daily radiation from the flowering phase to the end of vegetation; 4 — sixfold radiation in the flowering phase

At the present time the existence of a dynamic chloroplast-mitochondria bond has been reliably established (Sisakyan, 1959; Goffman, 1971). The mutual effect of processes occurring in the chloroplast (autotrophic system of the cell) and mitochondria (heterotrophic system) facilitates rather high selective permeability of external membranes. In the light, when chloroplasts produce and transport compounds necessary for mitochondria, contacts between chloroplasts and mitochondria are stable, but in the dark mitochondria are detached from chloroplasts. Therefore, the dynamics of the photosynthetic apparatus are largely the initial cause of many functional metamorphoses in energy and plastic exchange in the cell.

We found very significant differences in the protein content of chloroplasts of tomato plants radiated with IKSS and those grown against various backgrounds of mineral nutrition.

It has been shown that daily IKSS radiation of tomato plants grown with normal and elevated backgrounds of mineral nutrition (compared with corresponding control variants) led to a reliable increase in the total amount of (readily soluble + structural) proteins in chloroplasts: against a background of NPK — 24%, against a background of (3N)PK — 56%, against a background of NP(3K) — 26%, against a background of N(3P)K — 7%. Regardless of the background of mineral nutrition, radiation of the plants reduced readily soluble proteins 10-25% in chloroplasts and increased the amount of structural proteins 22-57%, as compared with the control.

Thus, IKSS radiation of plants even at the chloroplast level, i.e. /109
directly during photosynthesis, has a significant effect on the specifics of protein biosynthesis and its metabolism in the cell. Reduction in the relative content of the readily-soluble protein fraction in chloroplasts of test plants indicates the possibility, evidently, of high permeability of the membrane of chloroplasts [illegible] their rapid removal from the sphere of activity of the photosynthetic apparatus in cyt[illegible] and creates the necessary conditions for long maintenance of chlor[illegible] an active state. But increase in the amount of the structural [illegible]n indicates the probability of better structural-functional org[illegible] chloroplasts in test plants.

These data on the stimulating effect of IKSS were favorably reflected in the absorption of radiant energy and the intensity of photosynthesis.

The leaves of test plants increased their absorption of radiant energy in comparison with controls in the blue-violet range of the spectrum 4-6%, in the green 10-25%, in the red 3-12% and in the far red 5-15%.

The increased ability of leaves to absorb radiant energy stimulated photosynthesis. It was found that daily radiation of soy bean, corn, tomato and wheat plants partially or completely eliminated the midday depression of photosynthesis occurring in control plants. Evidently, radiation of plants causes them to reorganize their photosynthetic apparatus toward greater light requirement and to very effectively use the energy of the Sun at noon (Stanko, 1971). This can largely favor timely removal of assimilators from the sphere of activity of the photosynthetic apparatus, which promotes prolonged maintenance of chloroplasts in an active state (Kursanov, 1972).

The effect of IKSS on several metabolic processes in plants

According to current opinions, light can alter the metabolism of plants, acting not only as a "substrate" in photosynthesis, but also as a catalyst. Nevertheless, light regulation of various plant functions is accomplished mainly through metabolic processes (Kosover, 1964; Bernfel'd, 1965; Devis et al. 1966; Leopol'd, 1968; Kretovich, 1971, 1972; Stanko, 1971; Kursanov, 1972, and others).

According to N. P. Voskresenskaya (1965, 1972), the intensity and spectral composition of light can significantly determine the general direction of metabolism in the plant and ultimately affect the amount of biological yield. L. N. Bell (1968, 1972) suggests that change in the intensity and spectral com- /110
position of light, as well as the length of its effect, can lead, on one hand, to a change in metabolic channels of conversion of the early "primary" product of photosynthesis and, on the other, to storage of light energy through other non-photosynthetic reactions.

According to our data of many years, radiation of plants with IKSS of the cited parameters at any phase of growth stimulates in them a series of physiological-biochemical processes. Thus, the accumulation of nucleic acids, proteins, free amino acids, sugars and other substances is significantly stimulated. Changes in the content of these compounds to some degree begins immediately after the first 20-30 minute radiation and disappears in 5-10 days. With prolonged radiation of plants, changes in metabolism after IKSS is terminated can be maintained from one to one-and-a-half months.

Stimulating growth with IKSS, we assumed that there is a definite correlation between the radiation regime and processes of photosynthesis and general metabolism. It has been established (Stanko, 1968, 1971: Stanko, Zenchenko, 1968a, b; Stanko, Gvozdikovskaya, 1966a, b, 1969, 1970; Stanko, Gordiyenko, Kroytor, 1969; Stanko, Byrgeu, 1969; Stanko, Semin, Filipp, Yakimov, Gornovskiy, 1971; Stanko, Shishchenko, 1972) that increased photosynthetic activity of the leaves of a number of plants under the effect of IKSS radiation leads to increased uptake from the nutrient solution through the roots and inclusion in the leaves and seeds or fruit (primarily in organic and protein compounds) of nitrogen, phosphorus and potassium.

As seen from Table 3, the radiation of corn, soy bean and wheat plants in various phases of ontogeny led to an increased total content of sugars, free amino acids and nucleic acids in comparison with the control of 10-80%. It was noted that radiation of plants at various phases of development led to increased accumulation of nearly all sugars, which indicates a normal course of photosynthesis and biosynthesis in the leaves under such a strong effect as IKSS. Thus, IKSS supports the "carbohydrate base" at a rather high level and promotes interchanges in nitrogen-carbohydrate metabolism.

The radiation of plants in any phase of development, causing significant changes in the amount of free amino acids in leaves, barely affects their qualitative composition. A high free amino acid content correlates with an increase in the amount of nonprotein forms of nitrogen and indicates more rapid uptake and inclusion of nitrogen in organic compounds than in the control. These changes in the amino acid metabolism of leaves under the effect of IKSS also affect the protein content in seeds of the new yield.

It can be assumed that the effect of powerful IKSS radiation also significantly intensifies the interchange of amino acids in leaves of plants /111 through processes of reducing, hydrolytic and oxidizing deamination, as well as decarboxylation of a number of amino acids and induces synthesis and activity of many enzymes (Kretovich, 1972).

TABLE 3. THE EFFECT OF RADIATION OF PLANTS WITH IKSS IN VARIOUS PHASES OF GROWTH ON THE SUGAR, FREE AMINO ACID AND NUCLEIC ACID CONTENT

No. of radiations	Phase of development	Sugars		Free amino acids		Nucleic acids	
		μg per 1g dry substance	% of control	μg per 1g dry substance	% of control	μg/100 mg abs. dry substance	% of control
Corn (Sterling)							
Control	3-5th leaves	7 129	100	1193	100	1154	100
1		11 189	157	1477	124	1620	140
4		12 251	172	1924	161	1800	156
10		13 267	186	1936	162	1885	163
Control	6-7th leaves	11 042	100	1245	100	1379	100
13		18 389	166	2048	164	1926	139
Control	Earing	8 473	100	902	100	1532	100
		10 042	118	1598	177	2267	148
Soy beans (Biruintsa-12)							
Control	2-3rd leaves	5 397	100	1512	100	1264	100
1		6 120	113	1945	128	1937	154
7		6 720	125	2262	149	1994	158
Control	6-7th leaves	5 959	100	1664	100	1504	100
8		7 545	126	2533	152	2378	158
Control	Flowering	6 382	100	1752	100	1795	100
10		7 915	124	2803	160	2359	131
Winter wheat (Bel'tskaya-32)							
Control	Bushing out	5 520	100	5285	100	1683	100
30		6 528	118	6636	125	2254	134
Winter wheat (Moldavanka)							
Control	Bushing out	5 310	100	5432	100	1604	100
30		5 933	110	7428	137	2094	130

It is known that metabolism as well as processes of plant growth . . le- velopment depend on nucleic exchange. Light affects nucleic exchange both through photosynthesis (K. arev, 1959; Semenko, 1964) and through nonphotosynthetic processes and the direct effect of light on these biopolymers (Bogorad, 1967; Weidner, Mohr, 1967; Chroboczek, Cherry, 1965). RNA is especially sensitive to light and its accumulation is linked (Iwamura, 1955) with the accumulation of protein nitrogen. Intensive uptake and inclusion of nitrogen in organic compounds in the light favorably affect the synthesis of amino acids, protein and RNA. /112

According to our studies (see Table 3), it is evident that under the influence of IKSS, even after the first radiation, the nucleic acid content in leaves increases 40-50% as compared with the control.

It is very possible that the synthesis of nucleic acids in the leaves of test plants increases because of the activation of meristematic tissues and the intensification of cellular metabolism and the destabilization of the bonds between RNA and proteins and other components of cellular structures. The result is increased protein synthesis and content in chloroplasts and leaves of test plants and a predominance of organic and protein fractions of nitrogen, phosphorus and potassium over nonprotein elements.

As seen from Table 4, with increase in the number of radiation sessions, the amount of total nitrogen in the leaves of test plants, depending on the phase of development, increased 24-30% in comparison with the control, protein nitrogen increased 10-15%, nonprotein 65-270%, total phosphorus 10-60% and organic 10-15%; inorganic phosphorus either remained unchanged or increased 15-40%; the total potassium content increased 3-20%, soluble 15-18% and adsorption-bound potassium either remained unchanged or was slightly higher than in the control.

Thus, the longer plants were radiated with IKSS, the more significantly did the relative proportion of nonprotein forms of nitrogen and organic forms of phosphorus increase in leaves with a high level of protein forms. This indicates increased synthesis of free amino acids and phosphororganic compounds in plants under the influence of IKSS, the intensification of energy processes and greater storage of energy in the form of macroergic compounds.

TABLE 4. THE EFFECT OF IKSS ON THE UPTAKE AND INCLUSION OF NITROGEN, PHOSPHORUS AND POTASSIUM IN ORGAINIC COMPOUNDS IN PLANT LEAVES

(in μg per 1 g absolutely dry substance)

Number of radiations	Phase of development	Nitrogen			Phosphorous					Potassium		
		Total	Protein	Non-protein	Total	Acid soluble			Protein	Total	Soluble	Adsorption-bound
						Inorganic	Organic	Sum				
					Corn (Sterling)							
Control	2-3rd leaves	20 700	16 500	4 200	3375	220	1155	1375	2000	16 500	16 500	0
1		25 800	18 800	7 000	3687	179	1196	1375	2312	16 900	16 500	400
10		26 700	18 400	8 300	3662	175	1137	1312	2350	19 800	19 400	400
Control	6-7th leaves	24 000	19 800	4 200	3462	129	1183	1312	2150	16 500	16 000	500
13		29 000	18 800	11 200	5412	116	2884	3000	2412	18 800	18 000	800
Control	Flowering	25 000	18 500	6 500	3750	100	1400	1500	2250	16 400	16 200	200
19		31 000	19 200	11 800	4912	142	2483	2625	2287	18 500	18 000	500
					Soy beans (Biruintsa-12)							
Control	2-3rd leaves	20 750	16 750	4 000	3000	175	1450	1625	1375	14 200	14 000	200
1		29 000	20 500	8 500	3350	212	1500	1712	1638	27 600	27 500	100
Control	6-7th leaves	27 750	22 750	5 000	3246	104	1146	1250	1996	14 600	14 600	0
7		32 040	28 540	4 500	3962	278	2097	2375	1587	27 800	27 100	600
Control	Flowering	29 880	24 265	5 615	3831	247	2003	2250	1581	16 000	15 900	100
10	"	43 500	31 000	12 500	4724	244	2568	2812	1912	29 200	29 000	200

/113

To find the effect of IKSS on the rate and specifics of uptake and inclusion of individual elements of mineral nutrition, particularly phosphorus, directly during radiation and in the aftereffect, a radioactive isotope was used. It was shown that the effect of IKSS on soy bean plants after only 30 minutes significantly increases the uptake and inclusion of phosphorus. The highest content of total phosphorus and its individual fractions (with the exception of lipoprotein) in the control variant with ordinary solar radiation for a 30-minute period of exposure was in leaves of the first (lower) stage; for those radiated with IKSS it was in leaves of the third (highest) stage. The accumulation of lipoid and protein phosphorus is more intense in the light than in darkness.

The radiation of plants with IKSS stimulates the uptake and inclusion of phosphorus (and other elements of mineral nutrition as well) in organic and protein compounds in leaves and seeds both directly during radiation and in the aftereffect. This phenomenon plays an extremely important role in the intensification of metabolism in plants as a whole and also in increasing the nutrient value of seeds. /114

More intense uptake and inclusion of phosphorus, nitrogen and potassium in seeds under the influence of IKSS radiation of the plants led to an increased protein content in the seeds: 2-3% in barley and wheat (Stanko, 1963, 1965), 3-4% in corn (Stanko, 1966; Stanko, Gvozdikovskaya, 1966a, b, 1970) and 8-10% in soy beans (Stanko, 1965, 1968a, 1972; Stanko, Gvozdikovskaya, 1966a; Stanko, Gord.yenko, Kroytor, 1969) as compared to the control.

Selection-genetic aspects of the radiation of plants with stimulating doses of IKSS

The basic idea of radiating plants with IKSS in various phases of ontogeny was to find the change in metabolism and the metabolic foundation which would affect the yield, its quality and progeny.

The stimulation of carbohydrate, amino acid and nucleic as well as protein exchange and the presence of significant reserves of nitrogen, phosphorus and potassium in the leaves of radiated plants in the form of organic and protein compounds provided the basis for expecting a positive effect in selection.

It has been established (Stanko, Gvozdikovskaya, 1966a, b, 1969, 1970; Stanko, Gordiyenko, Kroytor, 1969; Stanko, 1971, 1972), that changes developing under the influence of IKSS radiation in various phases of plant development in yield, fast ripening and protein content are maintained in the next generation. However, the effectiveness of obtaining forms with useful agricultural characteristics by radiating plants with IKSS in various phases of development is different in progeny.

Thus, weak radiation of corn plants with IKSS in the 2-3rd leaf and flowering phase led to 15-37% increase in leaf surface the year of the radiation, 17-50% increase in absolutely dry weight of stalks and 4-11% increase in absolute weight of grain in comparison with the control. In test variants with daily radiation from the 2-3rd leaf phase or from the flowering phase to the end of vegetation, unlike other variants, the yield of grain the year of the radiation of IKSS did not increase. Therefore, it can be assumed that excessive radiant energy caused an inhibition of the grain yield.

However, the effectiveness of daily radiation increases significantly in comparison with other variants of radiation in the first and subsequent generations. In the first generation, shoots from seeds of radiated plants were noted 1-2 days earlier than the control, earing 3-6 days earlier and complete ripeness of the grain 7-12 days earlier. Variants with daily radiation from the 2-3rd leaf phase and from the flowering phase to the end of vegetation shortened their growing period more intensely than variants with weekly radiation in the 2-3rd leaf phase or in the flowering phase. In the second generation this dependence was seen even more clearly. Shoots in variants with daily radiation appeared 2 days earlier, earing 8-9 days earlier and complete ripening 10-12 days earlier than the control. Shoots in variants with weekly radiation appeared 1 day earlier and earing and complete ripening only 2 days earlier than the control.

Yield and the absolute weight of the grain of variants with daily radiation in all years of the test also essentially differed from those with weekly radiation and the control. The greatest increase of yield in the first and in the second generation was in the variant with daily radiation from the 2-3rd leaf phase to the end of vegetation; it was slightly lower in the variant with daily radiation from the flowering phase until the end of vegetation, while in the variant with weekly radiation in the flowering phase this effect was very slight and was completely absent in that with weekly radiation in the 2-3rd leaf phase.

An analogous relationship was also noted in the absolute weight of seeds of these variants.

A study of the aftereffect of radiation of growing plants of Biruintsa-12 soy beans in various phases of development upon yield, absolute weight and nature of the grain in first, second and third generations led us to the following conclusions. Daily radiation of plants with IKSS slightly depressed the grain yield in the year of the radiation and its absolute weight; but, six-fold radiation in the 2-3rd leaf and flowering phase increased the absolute weight of the grain in comparison with the control.

In field tests in the first generation the growing period of soy bean plants was shortened 8-12 days as compared with the control. The yield, nature and absolute weight of the grain in variants with daily radiation from the 2-3rd leaf phase and from the flowering phase to the end of vegetation increased 9-11, 6-7 and 4-6%, respectively, and in variants with weekly radiation in the 2-3rd leaf and flowering phase yield was 2-4% higher than the control, nature-1,and absolute weight of the grain-2-3%.

Test plants in the second generation, as in the first, shortened their growing period 8-12 days (daily radiation variants) and 5-6 days (six-fold radiation variants) in comparison with the control; the increased yield in variants with daily radiation was even clearer than in the first generation. Thus, the average yield from 100 plants in the variant with daily radiation /116
from the 2-3rd leaf phase until the end of vegetation was 26% higher than the control, and in the variant with daily radiation from the flowering phase until the end of vegetation it was 22% higher. In variants with weekly radiation in the 2-3rd leaf phase and in the flowering phase it exceeded the control 5-8%. The nature of the grain and the absolute weight in test variants were 1-3% higher than the control.

Test plants from daily radiation in the third generation, as in the two preceding ones, shortened the growing period 10-12 days in comparison with the control and in the variant from six-day radiation, 2-3 days.

The grain yield of soy beans in the third generation in the variant from daily radiation gave a reliable increase of 15-21%,while there was no increased yield in variants from six-day radiation. The nature of the grain in variants from daily radiation was 4% higher,and absolute weight 7% higher than the control. In variants from six-day radiation,the nature of the grain was only 1.5% and absolute weight only 2% higher than the control.

Thus, the greatest effectiveness of radiation of plants in various phases of development for yield occurs in those with daily radiation during the entire active growing period, as well as in those with daily radiation from the flowering phase to the end of vegetation. In both these variants,radiation affects flowering, fertilization and formation of the new yield. It can be assumed that the effect of IKSS during this period after a change in nucleic-protein exchange superimposes deep impressions on the formation of new properties of embryonic tissue of the future seed which, possibly, also affects fast ripening, harvest and quality of yield with serious aftereffects in subsequent generations. At the same time, in other variants of the test (six-day radiation in the 2-3rd leaf phase and in the flowering phase), when radiation does not affect the formation of yield, changes in agriculturally useful characteristics, occurring in the fir. and partially in the second generations, are almost completely lost in the third.

Repeated tests with daily radiation of growing soy bean plants with IKSS in 1968, conducted together with F. M. Byrgeu, led to the appearance of mutants with the growing period shortened 25-28 days, increased grain harvest and higher protein content in the grain.

Separate sowing of lower, middle and upper beans from soy plants radiated daily with IKSS showed a very high incidence of mutants in the second generation with agriculturally useful characteristics: 26% among lower beans, 48% in middle and 33% in upper. In the four generations studied until the present, fast ripening, high yield and protein content of the seeds have been maintained. Therefore, new permanent forms, differing from the original Biru- /117
intsa-12 variety, have been developed.

It is extremely desirable and important that the increased yield of the plants and the shortened growing period of new forms do not reduce the protein content.

Table 5 shows that the highest protein content in soy beans of the first and succeeding generations was found only in variants with daily radiation from the 2-3rd leaf phase to the end of vegetation and from the flowering phase until the end of vegetation. Variants from six-day radiation in the 2-3rd leaf phase and in the flowering phase, differing in the high protein content of seeds in the year the plants were radiated, in succeeding generations significantly decreased their protein content. Similar results were obtained in the Sterling variety of corn.

In studying the fractional composition of protein of third generation grain from the photomutant forms of winter wheat, it was shown that the absolute increase of protein was due to increased gluten and gliadin content. The relative amount of protein in albumin, globulin and underived protein fractions in the grain of mutant forms was less than in the original varieties.

In grain from the fast-ripening photomutant forms of soy beans, the absolute increase in protein was due to an increase in the globulin fraction and partially to that of glutelins. But the relative amount of proteins in albumin, gliadin and insoluble fractions, as in wheat mutants, was slightly lower than in the original variety (Table 6).

Therefore, IKSS radiation of plants significantly affects the reorganization of the protein-synthesizing system in succeeding generations as well. Brief daily IKSS radiation of plants will, therefore, probably to a certain extent, affect the specifics of synthesis and the accumulation of individual proteins.

It has been noted that in the seeds of all test variants of corn and soy beans, both in the year of the IKSS radiation and in succeeding generations, the total amount of phosphorus and potassium was also higher than in the control. In all test variants the predominance of the phosphorus content in seeds, in comparison with the control, was due to a larger proportion of its organic and protein fractions. However, the increased content of phosphorus forms, as also the higher nitrogen form content in seeds of the first and succeeding generations of test variants, occurred only in the aftereffect of daily radiation of plants from the 2-3rd leaf phase and from the flowering phase until the end of vegetation.

TABLE 5. THE AFTEREFFECT OF RADIATION OF BIRUINTSA-12 SOY BEAN PLANTS IN VARIOUS PHASES OF DEVELOPMENT ON THE NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT IN THE GRAIN /118

(μg per 1 g absolutely dry substance)

Element compounds of mineral nutrition	Control	Daily from 2-3rd leaf phase	Six-day in 2-3rd leaf phase	Daily from flowering phase	Six-day in flowering phase
			Nitrogen		
Total	72 500*	82 655	79 680	82 400	77 453
	69 585**	82 368	72 980	83 111	78 895
	70 852***	83 526	69 925	81 653	71 325
	70 852****	80 455	70 280	78 625	72 425
Protein	61 350	77 020	75 250	74 600	72 640
	64 840	75 405	65 110	75 284	71 048
	64 220	75 685	63 810	75 510	64 625
	60 735	74 068	63 118	71 852	62 175
Nonprotein	11 150	5 635	4 430	7 800	4 813
	4 745	6 983	7 870	7 827	7 847
	6 632	7 841	6 115	6 143	7 700
	10 117	6 387	7 162	6 873	10 250
Proteins, %	38.2	48.0	46.8	46.6	45.5
	40.5	47.2	40.2	47.0	44.3
	40.0	47.3	39.8	47.2	40.4
	37.8	46.2	39.4	44.4	38.8
			Phosphorus		
Total	2 525	2 775	3 287	3 062	3 245
	3 012	3 772	1 325	3 929	3 325
	2 800	3 613	3 337	3 363	3 263
Inorganic	63	71	71	59	105
	59	86	71	70	67
	87	75	66	86	75
Organic	937	1 116	1 191	1 129	1 146
	1 216	1 851	1 179	1 680	1 500
	1 350	1 500	1 370	1 352	1 240
Protein	1 525	1 588	2 025	1 874	2 004
	1 737	1 835	1 875	2 179	1 758
	1 363	1 988	1 901	1 925	1 948

Table 5, continued

Element compounds of mineral nutrition	Control	Daily from 2-3rd leaf phase	Six-day in 2-3rd leaf phase	Daily from flowering phase	Six-day in flowering phase
			Potassium		
Total	1 490 1 538 1 360	1 805 1 822 1 886	1 585 1 570 1 645	1 831 1 820 1 760	1 445 1 510 1 685

* All top lines — the year of the IKSS radiation
** All second lines — first generation
*** All third lines — second generation
**** All fourth lines — third generation

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TABLE 6. FRACTIONAL COMPOSITION OF PROTEIN IN SEEDS OF ORIGINAL VARIETIES AND IN MUTANT FORMS DERIVED FROM THEM UNDER THE EFFECT OF IKSS

Variant of test	Total protein, %	Fraction content, % of total					
		albumins	globulins	glutelins	gliadin	insoluble	total
		Winter wheat (Bel'tskaya-32)					
Control (original variety)	14.8	12	4	35	37	12	100
Form No. 3, M_3	16.2	10	4	39	39	8	100
		Winter wheat (Moldavanka)					
Control (original variety)	15.1	12	5	38	35	10	100
Form No. 3, M_3	16.5	9	4	41	38	8	100
Form No. 6, M_3	17.1	10	4	44	38	6	100
Form No. 7, M_3	16.8	8	3	43	39	7	100
		Soy beans (Biruintsa-12)					
Control (original variety)	38.8	24	55	2	10	9	100
Form No. 1, M_3	48.2	21	59	4	11	5	100

On the basis of data analysis of phosphorus compounds in seeds of test variants and the control, it can be assumed that daily radiation of plants with IKSS during the formation of reproductive organs, flowering, pollination, formation, development and ripening of seeds, significantly affects the synthesis of organic phosphorus compounds and protein phosphorus compounds, including nucleoproteins, in later generations.

The content of all potassium forms in seeds also significantly changes, both in the year of the IKSS radiation and in succeeding generations.

Later in a series of tests lasting many years with the radiation of growing plants of winter varieties of wheat and barley (Stanko, Byrgeu, 1972), in autumn and spring the appearance of the ear and the yellow ripe stage were accelerated (along with daily radiation) 6-8 days, yield and its quality were high. Permanent forms of winter wheat produced with autumn radiation were 5-10% more frost resistant than the original variety.

Cytogenic study of these new forms hat this effect is attained by fixing favorable point mutations which develop in meristematic tissue during radiation. Analysis of mitosis showed that in rootlets of control plants mitosis basically proceeds normally. Only isolated (1.2 ± 0.5%) chromosome aberrations are noted in the form of bridges and bridges with fragments. In studying samples of rootlets of mutant plants, a sharp increase (8.0 ± 0 1%) /120 was noted in the number of anaphases with bridges. Chromosome fragmentation appeared in 3.0 ± 0.2% of the cells. Chromosomes were readily visible on the metaphase plate and they could easily be counted (Stanko, 1968; Stanko, Semin, Filipp, Yakimov, Gornovskiy, 1971).

Significant chromosome aberrations in photoinduced forms occurred in the first and partially in the second generations with a considerable decrease in the third.

Using IKSS as a powerful light and energy factor, we note that analogously to many other mutagenic factors, it causes typical chromosome and chromatid reorganizations on rather large scales. Breaks, exchanges and adhesions (primary contact) of chromosomes, promoting increased chromosome and chromatid reorganizations, are, therefore, very frequently noted.

Probably, IKSS photons with high energy density transmitted through the plant and thus affecting the entire thickness of tissues, combined with heat radiation which causes vibration processes, very strongly affect protoplasm, the nucleus and its membrane and nuclear substance in various phases of cell division.

As is known, the nuclear membrane is a very active organoid. It takes part not only in protein synthesis, but also plays a regulatory role in the transport of nuclear products to cytoplasm and vice versa. The nucleus has programming significance. It contains within itself keys to the past and the future, near and far. Cytoplasm, on the other hand, is connected with the present; it provides the needs of the moment and its reactions to external conditions are immediate. Therefore, the effect on the cell of the high energy of IKSS photons, in our opinion, increases the interference between nucleus and cytoplasm and as a result structural-metabolic processes between them become more dynamic. Against this background extensive biological effects of stimulation, inhibition and mutation are possible.

Summarizing the above, concerning the effect of IKSS, we come to the conclusion that concentrated pulsed light is an extremely powerful factor affecting all aspects of vital activity of plants. This factor must be taken into consideration in studying outer space, evidently, not only as a stimulating agent. Investigation of this aspect of its action was determined by the specific aims of this work. The general biological importance of the entire question will, evidently, be revealed with more complete knowledge of both the stimulating and inhibiting characteristics of this action.

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CHARACTERISTICS OF THE DISTURBED GEOMAGNETIC FIELD
AS A STIMULUS

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1. The earth's magnetic field as an ecological factor has repeatedly /123
attracted the attention of many researchers studying problems of solar-terrestrial connections, particularly the effect of solar activity on the biosphere. There is special interest in this question because at the present time experimental observations and theoretical research indicate that the geomagnetic field (GMF) along with the electromagnetic can be considered the chief mediating factors responsible for characteristic biological effects correlated with variations in solar activity.

It is known that during periods of greater solar activity the intensity of corpuscular and electromagnetic streams from the sun increases. Large doses, however, do not reach the biosphere because of the screening effect of the earth's atmosphere, particularly its upper ionized layers. On the other hand, simultaneous changes in the earth's magnetic and electric fields occasionally lead to a significant change in the electromagnetic background of the environment of all terrestrial life.

Biological objects, including the human organism, do not remain indifferent to these changes. Many researchers have been able to find statistical regularities which undoubtedly demonstrate the close connection between the dynamics of geomagnetic disturbances and dysfunction of living organisms at various structural levels of their organization.

The patterns of pathological changes observed in man are extremely varied, from subtle disturbances in the occupational stereotype of reactions in perfectly healthy people (accident statistics) and changes in the composition of the blood and the appearance of depressive states to fatalities among individuals suffering diseases of the nervous or cardio-vascular systems [see "Zemlya vo vselennoy" (The earth in the universe), 1964; Presman, 1968; "Biological effects of magnetic field," 1964; Piccardi, 1965; Obzor inostrannoy literatury (Review of foreign literature), 1963, 1964]. If statistical methods of study helped show the great probability that GMF affects the organism, they could explain neither the mechanism of this effect nor the increasing complexity and variety of the clinical pattern. Understanding the physical and biophysical essence of this phenomenon could give us the possibility of developing both effective means of protection against this unfavorable and in certain situations dangerous effect and fundamentally new methods for delicate directed effects on both the organism as a whole and on its individual systems using magnetic fields, varying in a certain way in time. /124

On the other hand, in magnetobiology the effect of artificially created magnetic fields on biological objects has been studied [Biological effects of magnetic field, 1964; Kholodov, 1966;"Soveshchaniye po izucheniyu vliyaniya magnetnykh poley na biologicheskiye ob'yekty" (Conference on study of the effect of magnetic fields on biological objects), 1966]. In sufficiently strong fields (both permanent and industrial frequencies) as varied a picture of disturbances is observed as in GMF.

We shall show that from the point of view of theoretical biology we can assume the theoretical possibility of biological activity of the disturbed GMF and approach essentially an understanding of the mechanism of its effect on the human organism.

2. Environmental factors are infinitely varied, both in qualitative characteristics and quantitative phenomena. In the process of evolution this led to a diversity of reactions of the organism to external influences. The qualitative diversity of factors developed differentiated reception of these signals in living systems. We find a reflection of quantitative changes in the environment in the structural functional organization of the organism, in processes of excitation and inhibition.

In recent years works on the theory of reception have revealed general regularities underlying the reception by analysors of signals in the environment with different energy characteristics. In the monograph of P. V. Simonov (1962) generalization of a large amount of experimental data showed that the reaction of the organism to the increasing influence of an ecological factor does not depend on the qualitative nature of this influence and with a given means of reception is determined by the value of the stimulus. In the absence of external stimulation, the organism finds itself in a stable nonequilibrium state. This property of living systems is reflected in Bauer's "theory of stable nonequilibrium" (1935a, b). In proportion to the increased intensity of various influences, three phases of change in unconditioned reflexes are observed (Simonov, 1962): initial depression (preventive inhibition), excitation /125 and extreme inhibition (Fig. 1).

The living reacting system is "shielded" by inhibition on two sides. Preventive inhibition provides initial analysis, differentiation of environmental influences, adapting the organism to signals at the "noise" level and protecting the system from weak, unimportant stimuli, from useless expenditure of energy. At the same time, initial inhibition performs a protective-compensatory function, as then there is a "rest" and prophylactic "running maintenance" of excited structures along with continuous preparation for adequate activity. The functional mobility (switching from excitation to depression and back) of structures in a state of preventive inhibition remains high. Inhibition is quickly eliminated as soon as the stimulus attains sufficient strength.

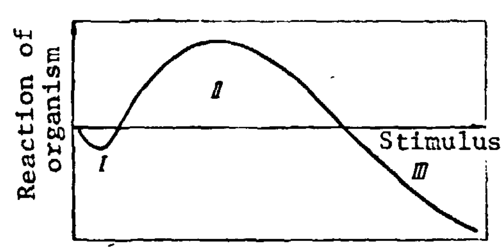

Fig. 1. Three phases in the reaction of the organism to a growing stimulus

Ultrastrong influences disturb the normal autoregulation of the organism and it must be shielded from their effect by extreme inhibition, protecting the living system from overstimulation, exhaustion and death.

The second phase of the reaction — excitation — covers the range of external influences encompassing normal vital activity and orientation of the organism in the environment.

It is significant that a gradual reaction occurs in certain sections of the range of intensities of a stimulus: the effect is greater, the stronger the stimulus. For the first half of phase I this is an increase of inhibition which decreases with further intensification of the stimulus,as this increases the significance of the signal and it predominates over the noise, its excess over noise grows.

The second phase has as its lower boundary the maximum threshold sensitivity of a given receptor. If a signal which is adequate for a given analysor exceeds this threshold, the receptor structures are excited; the more intense the signal, the more they are excited. However, beginning with certain values, further excitation becomes useless for the organism, excitation decreases, changing to /126 extreme inhibition, which becomes stronger with increase of the stimulus. The upper limit of extreme inhibition is dysfunction and irreversible changes in structures taking part in the complex of reactions; the lower boundary is the pain threshold.

How can we explain such an astonishing similarity of reactions of different receptors to the most varied kinds of energy of actuating stimuli: radiant energy of photons, chemical energy of molecules of odorous and flavoring substances, sound energy, etc.?

The fact is that any cell in an organism can be a nonspecific receptor (Plekhanov, 1965), since the property of stimulability — local reaction of protoplasm as the result of an external stimulus — is preserved by any cell in a multicellular organism (Nasonov, 1962). "We are dealing here with a very common and, perhaps, very ancient reaction," writes D. N. Nasonov (1962).

Originally the cell responded to external influences universally. As the result of evolutionary processes, reorganized structurally, chemically and functionally, it "learned" to differentiate in perceiving certain kinds of environmental energy. However, becoming specialized cells responsible for reception, structures (kinocilia) at the same time preserved the original elementary structure, chemism and functional characteristics, identical for different sense organs. In addition, these basic characteristics are the same for receptor cells of man, animals and even some protozoa, i.e. kinocilia are "the most ancient instruments, structurally, chemically and functionally developed during the process of evolution for the active interaction of unicellular and multicellular organisms with the environment" (Vinnikov, 1965). Specialization does not lead (Plekhanov, 1965) to a loss of sensitivity by noninformational cells, but results in information coming from specific receptors being perceived by man; information perceived by other cells does not usually reach consciousness.

It must be noted that this unity occurs not only on a cellular but also on a molecular level. It has been shown (Vinnikov, 1965) that "the act of reception of a certain kind of environmental energy always begins with or is accompanied by molecular reorganizations of specific or nonspecific chemical, biologically active substances localized in certain structures (organelles) of receptor cells. Evidently, this reorganization is the basis of the so-called excited state of receptors, transmitted in the form of impulses through synapses to the central nervous system."

From the point of view of the unity of structural functional and physico- /127
chemical bases of reception of various kinds of energy, the quantitative energy scale introduced by Plekhanov (1967), which is common for all stimuli, becomes more valid. He correlates this scale to the quantitative pattern suggested by Simonov. Table 1 (Plekhanov, 1967) gives the character of responses, depending

TABLE 1. CHARACTER OF RESPONSES OF THE ORGANISM DEPENDING ON THE STRENGTH OF THE EFFECTIVE STIMULUS

Phase	Reaction of organism	Property of the organism	Character of interaction	Intensity of effective stimulus			Dimension
				min.	opt.	max.	
I	Preventive inhibition	Indifference	Passive	10^{-10} 10^{-13}	510^{-10} 510^{-13}	10^{-7} 10^{-10}	erg/sec·cm^2 erg/cm^3
II	Excitation	Sensitivity	Informational	10^{-9} 10^{-12}	10^{-4} 10^{-7}	1 10^{-3}	erg/sec·cm^2 erg/cm^3
III	Extreme inhibition	Stimulability	Energy	1 10^{-3}	10^2 10^{-1}	10^5 10	erg/sec·cm^2 erg/cm^3

on the strength of the effective stimulus, expressed in corresponding energy units. It classifies the properties of the organism for reacting variously to different levels of an actuating stimulus, corresponding to the three phases of reaction considered above. Here it is appropriate to define the concepts "stimulability" and "sensitivity," which are often understood as synonyms.

As shown in the work of Leont'yev (1965), these are two different and essential characteristics of the living organism.

Stimulability is the ability of a biological structure to react to external influences. This ability is the natural result of metabolism and the exchange of energy; energy and material environmental factors participate directly in life processes with their energy or substance.

Sensitivity can be characterized as the ability of an organism to perceive signals about the presence or absence of external stimuli. A signal carrying information causes only a redistribution of energy in the system itself; the energy or material nature of the signal and stimulus can differ. /128
Therefore, sensitivity, or the mediated perception of stimuli, is a more perfect means of orienting the living organism in the environment.

G. F. Plekhanov (1967) correlates the informational and energy interactions of the organism with the medium to sensitivity and stimulability. He writes: "If the energy of the actuating stimulus is much less than the energy released by the organism because of its effect, then this process can be called sensitivity (from the point of view of the organism), signal effect (from the point of view of analyzing the actuating stimulus) or informational interaction between the organism and a given environmental factor. If the energy of the effective stimulus is assimilated by the organism and compared with energy processes in the organism itself, then we have the phenomenon of stimulability, power effect or energy (material) interaction between the organism and the environment."

As seen from Fig. 1, the character of the reaction of the organism — the phase of the reaction — changes at two typical points. The first point is characterized by transfer of structures from the zone of preventive inhibition to the phase of excitation, which occurs when the actuating stimulus exceeds some threshold value. Maximum values of energy density and power flux density of the signal, corresponding to phase boundaries, determined by the influence of various kinds of energy, have very slight variance, which is not surprising given the common bases of reception which we noted above. This has made it possible to introduce the concept of energy input parameters, characterizing maximum sensitivity of the human organism and corresponding to the lower boundary of the excitation zone.

As the maximum threshold of sensitivity (in Bayer, 1962, the "absolute energy threshold") of the human organism are taken (Plekhanov, 1967) energy density W* and power flux density S* calculated per cell, equal respectively to

$$W^* = 10^{-12}\ \text{erg/cm}^3, \quad S^* = 10^{-9}\ \text{erg/sec}\cdot\text{cm}^2.$$

These values were experimentally obtained for specific receptors (vision, hearing). However, experimentally studying the effect on the organism of various kinds of nonspecific signals by their energy characteristics belonging to the informational zone of interaction, Plekhanov concludes that signals for which there is no specific receptor can be objectively perceived by man, enter conditioned and unconditioned connections with threshold signals and inhibit or stimulate the work of particular centers. Along with other signals, electric, magnetic or electromagnetic fields (Plekhanov, 1965, 1967) can also be objectively perceived if their intensity is within the range (10^{-9}-1 erg/sec$\cdot$cm^2). /129
Decrease or increase of intensity of the signals in relation to these values should lead to inhibition or appearance of nonspecific reactions.

We note that the majority of works generalizing a large amount of both Soviet and foreign research only concern the region of the energy range of magnetic field interaction with biological structures. This has led researchers to a generally uneven conclusion about the nonspecific character of its effect and indicates that the magnetic field is a factor causing inhibition

Extending Plekhanov's conclusions to the case of GMF, after having determined its energy and flux for various stages and classes of magnetic storms, we can determine the range of its parameters on the above noted energy scale of actuating stimuli. This makes it possible to judge (from the energy point of view) the theoretical possibility of interaction between the human organism and the earth's magnetic field and on the basis of Table 1 to predict the nature of this interaction.

It must be noted that in our opinion Simonov's curve (see Fig. 1) is a cross section of at least a four-dimensional functional of the dependence of the reaction of the organism — value and phase — not only on the strength of the stimulus, but also on the length of its action or parameters characterizing this action in the time zone for complex signals, as well as on the initial functional state of the system. Therefore, conclusions with regard to the characteristics of the biological activity of the geomagnetic field, based on these works (Simonov, 1962; Plekhanov, 1967) must be corrected, taking into consideration the effect of at least the time factor and the functional state of the organism.

3. Let us turn to determination of the local energy characteristics of the geomagnetic field: energy density W(t) and power flux density S(t).

In the literature (Chapman, 1964; Bryunelli, 1966) only the energy of the disturbed geomagnetic field as a whole is considered. Of course such an integral picture must have theoretical differences from that of the field in volume unit. The main characteristics of the total terrestrial field is the equivalence of zero to the so-called "combined energy" (Chapman, 1964). The illegitimate extension of this rule to the case of the volume unit (element) led (Plekhanov, 1967) to theoretical errors in resolving the question of the biological activity of geomagnetic disturbances. Therefore, let us consider in detail the energy characteristics of the field per volume unit.

We will indicate by $H_T(t)$ the complete vector of GMF intensity at moment t at some fixed point close to the earth's surface. According to Maxwell's /130
second equation

$$\operatorname{rot} \vec{E}(t) = -\frac{\partial \vec{H}(t)}{\partial t}, \tag{1}$$

a change in $\vec{H}_T$ (t) in time causes the appearance of electric component $\vec{E}(t)$, i.e. it would be more correct to consider the geoelectromagnetic field. However, because ionospheric currents are a quasi-stationary system, the electric component of the field for a given frequency range will be several orders less than the magnetic (Skilling, 1947) and will not be considered in subsequent calculations.

The energy density W(t) of the magnetic field in air is determined by the equation (in the Gaussian system)

$$W(t) = \frac{1}{8\pi} H_T^2(t). \tag{2}$$

The rate of change in stored energy is

$$\frac{\partial}{\partial t} W(t) = \frac{1}{8\pi} \cdot \frac{\partial}{\partial t} H_T^2(t). \tag{3}$$

For free space a change in the energy reserve can occur only under condit. with equal outgoing (or incoming) power flux. Therefore, formula (3) determines the specific power flux S(t):

$$S(t) = \frac{k}{4\pi}\left[\vec{H}_T(t)\frac{\partial \vec{H}_T(t)}{\partial t}\right]. \qquad (4)$$

The complete vector $\vec{H}_T$ is the vector sum of vectors $\vec{H}_0$, determining the average value of the field and the running value of time variable vector $\vec{h}(t)$:

$$\vec{H}_T(t) = \vec{H}_{0'} + \vec{h}(t). \qquad (5)$$

Vector $\vec{H}_0{}'$ depends on geographic latitude and, therefore, each geomagnetic observatory has its own value, determined by three components: horizontal H_0, vertical Z_0 and declination D_0, in a cylindrical system of coordinates (Yanovskiy, 1964; Eigenson et al., 1964). The vector $\vec{h}(t)$ is described by recording three components: H(t), Z(t) and D(t), being variations of the horizontal and vertical components and declination of the GMF, respectively. The variations H(t), Z(t) and D(t) are recorded on magnetograms at geomagnetic observatories. In Cartesian coordinates the complete vector $\vec{H}_T(t)$, expressed by its components, /131
takes the form $H_T(t) = [H_0 + H(t)]\cos[D_0 + D(t)]\vec{i} +$

$$+ [H_0 + H(t)]\sin[D_0 + D(t)]\vec{j} + [Z_0 + Z(t)]\vec{k}. \qquad (6)$$

Formula (6) makes it possible to calculate energy density W(t) according to (2) and power flux density S(t) according to (3)

$$W(t) = \frac{1}{8\pi}\{[H_0 + H(t)]^2 + [Z_0 + Z(t)]^2\}\ \mathrm{erg/cm^3}, \qquad (7)$$

$$S(t) = \frac{1}{4\pi}\left\{[H_0 + H(t)]\frac{dH(t)}{dt} + [Z_0 + Z(t)]\frac{dZ(t)}{dt}\right\}\ \mathrm{erg/sec\cdot cm^2}. \qquad (8)$$

The dimensions in (7) and (8) are indicated on condition that $H_T(t)$ is given in oersteds.

We note that properly the energy of the disturbance, equal to

$$\Delta W = W(t) - W_0 = \frac{1}{8\pi}\{2[H_0 H(t) + Z_0 Z(t)] + H^2(t) + Z^2(t)\}, \tag{9}$$

contains as its first term "combined" energy

$$W_j = \frac{1}{4\pi}[\vec{H}_0 \cdot \vec{h}(t)], \tag{10}$$

which in case of the volume element differs from zero, as vector $\vec{h}(t)$ on the surface limiting the volume element is usually not equal to zero. Only integration on global scales according to the volume encompassing all ranges where $\vec{h}(t) \neq 0$ and limited by two conductive surfaces, the ionospheric and the terrestrial, for which $\vec{h}(t) = 0$, will lead to

$$\int_V W_j dV = 0. \tag{11}$$

4. Let us find the conditions when energy density W and power flux density S of the disturbed GMF will exceed threshold values W* and S*.

The geomagnetic field will be objectively perceived by the organism if

$$W > W^*, \tag{12}$$

$$S > S^*. \tag{13}$$

Here the receptor structures switch over to the excitation phase, replacing the phase of preventive inhibition which occurs when this inequality is not fulfilled. Let us evaluate the reality of fulfilling conditions (12) and (13).

It is not difficult to show that condition (12) is easy to fulfill. If /132
we assume

$$H_0 = 1.505 \cdot 10^{-1}\ \text{э}, \quad D_0 = 6^\circ 50',9,$$

$$Z_0 = 4.861 \cdot 10^{-1}\ \text{э} \text{ and } W_0 = 10^{-2}\ \text{erg/cm}^3$$

(data from the magnetic-ionospheric observatory im. Voyeykov), then taking into account inequalities

$$H_t(t) \ll H_0; \quad D(t) \ll D_0; \quad Z_t \ll Z_0 \qquad (14)$$

we obtain $W \approx W_0$. As $W_0 >> W^*$, condition (12) is formally guaranteed.

Medical literature gives data (Schulz, 1964) indicating that a change in leukocytic reactions during solar activity has a typical geophysical characteristic: reduction of the total number of leukocytes during these periods is more pronounced in polar regions and is practically unknown in equatorial zones.

This indirectly indicates that taking into account the combined field in considering the interaction of the organism with the local geomagnetic field is not only theoretically necessary but also physically expedient.

If we assume that the organism adapts to the continuously acting component of field energy W_0, then we must prove the possibility of exceeding the variable component of the field

$$\Delta W(t) = W(t) - W_0$$

above threshold W^*. Table 2 gives values of the variable component of field energy ΔW for four classes of storms, according to the classifications of magnetic field disturbances accepted in geophysics (Kosmicheskiye dannye, 1968). It is easy to see that ΔW certainly exceeds the threshold value of the energy by several orders.

TABLE 2. VALUES OF THE VARIABLE COMPONENT OF FIELD ENERGY FOR CLASSES OF MAGNETIC STORMS

Class of storm	ΔH, γ	ΔD, γ	ΔZ, γ	ΔW (for middle of range), erg/cm³	Δt (S=S*) hrs	Δt (S=100 S*), min
Small	80-125	100-140	40-90	$1.1 \cdot 10^{-7}$	10.8	6.48
Moderate	125-200	240-200	90-200	$3.0 \cdot 10^{-7}$	21.5	12.9
Large	200-270	200-290	140-250	$6.0 \cdot 10^{-7}$	28.6	17.1
Very large	270	290	250	$6.0 \cdot 10^{-7}$	28.6	17.1
	500	500	500	$30 \cdot 10^{-7}$	72.0	43.0

Now let us evaluate the actual feasibility of inequality (13). As initial data for estimated approximate calculations of the conditions for exceeding the threshold flux, we take the suggested (Kosmicheskiye dannye, 1968) component differentials of variable vector $\vec{h}(t)$: $\Delta H_1 \Delta D_1 \Delta Z$, maximum for in general unknown periods of time. /133

We transform the problem. We shall show in what time intervals Δt given changes in components will guarantee GMF power flux S, exceeding the threshold sensitivity S*.

To simplify the problem we make the following assumptions:

a) variations of components $\vec{h}(t)$ occur simultaneously, i.e.

$$\Delta t_{\Delta H} = \Delta t_{\Delta D} = \Delta t_{\Delta Z},$$

which does not contradict reality;

b) variations ΔH, ΔZ and ΔD are reckoned from levels H_0, Z_0, D_0, i.e. the moment of the start of variation $\Delta\vec{h}$:

$$H(t) = Z(t) = D(t) = 0.$$

Taking into account these assumptions, flux formula (8) takes the form

$$S \frac{1}{4\pi\Delta t}(H_0\Delta H + Z_0\Delta Z). \tag{15}$$

Later we determine Δt^*, where condition $S = S^*$ is fulfilled:

$$\Delta t_{S=S^*} = \frac{1}{4\pi S^*}(H_0\Delta H + Z_0\Delta Z). \tag{16}$$

The condition $S > S^*$ corresponds to inequality

$$\Delta t < \Delta t^*. \tag{17}$$

In the sixth and seventh columns of Table 2 are given the numerical values of time intervals Δt^*, when the given values of $\Delta\vec{h}$ for various types of geomagnetic storms will create power flux densities equal to and 100 times exceeding threshold value S*, respectively.

In fact, for any type of storm, condition (17) is actually fulfilled. However, if for small and moderate storms this occurs only in isolated moments, for large and very large storms the threshold can be exceeded for a prolonged period of time.

Thus, the real possibility of fulfilling necessary conditions (12) and (13), in which the GMF is biologically active, is in general proved.

5. According to specific magnetograms, obtained at the magnetic-iono- /134
spheric observatory im. Voyeykov, running energy parameters of the local GMF were calculated corresponding to all phases of development of geomagnetic storms: undisturbed GMF, disturbance, storm maximum, abatement and again an undisturbed field. Values of the components were taken from the magnetograms after 3 minutes and energy density W(t) and power flux density S(t) were calculated[1] according to formulas (7) and (8).

Ten geomagnetic storms, typical of all known types of disturbances, with a total duration of about 500 hours, were analyzed.

The data obtained lead to a number of conclusions about both the dependence of GMF energy parameters on the degree of disturbance and the relative biological activity of this disturbance.

As was to be expected, values of running W(t) are several orders above threshold energy value W^*. During a storm ΔW also exceeds this threshold and is greater the stronger the disturbance. Fig. 2 gives GMF parameters for W(t) and S(t), calculated for the maximum of a very strong storm with sudden commencement, observed from May 24 to 26, 1967. In reduced scale, realizations of initial components $\vec{h}(t)$ are given in "Solnechnye dannye" (1967). The curve (see Fig. 2, a) illustrates fulfillment of condition (12), as W = 0.01 erg/cm^3. We must note that the energy of the disturbance unequivocally and in a physical sense clearly characterizes the degree of GMF disturbance and can be the basis for the energy theory of storm classification; however, this question is beyond the scope of this work.

The power flux density S(t) curve essentially differs from the energy curve. The flux is a strongly fluctuating alternating function. As S(t)

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[1]Calculations performed on "Minsk-22" electronic digital computer at the Pulkhov computer center.

characterizes only the orientation of the flux vector with regard to the volume unit (energy can either increase or decrease), its consideration in our case is not essential; therefore, analysis can limit only the module of energy flux density S(t). Fig. 2, b gives an example of curve S(t) for the storms listed above, drawn according to function maximums.

In an undisturbed field the flux curve has a specific characteristic: maximum flux values have very slight variance and fluctuate around the level 10^{-9} erg/sec·cm^3 , which is astonishingly coincident with threshold value S*; flux jumps to the zero level reflect only the moments of change in direction of the flux (Fig. 3). Can the coincidence of the flux level, characterizing /135

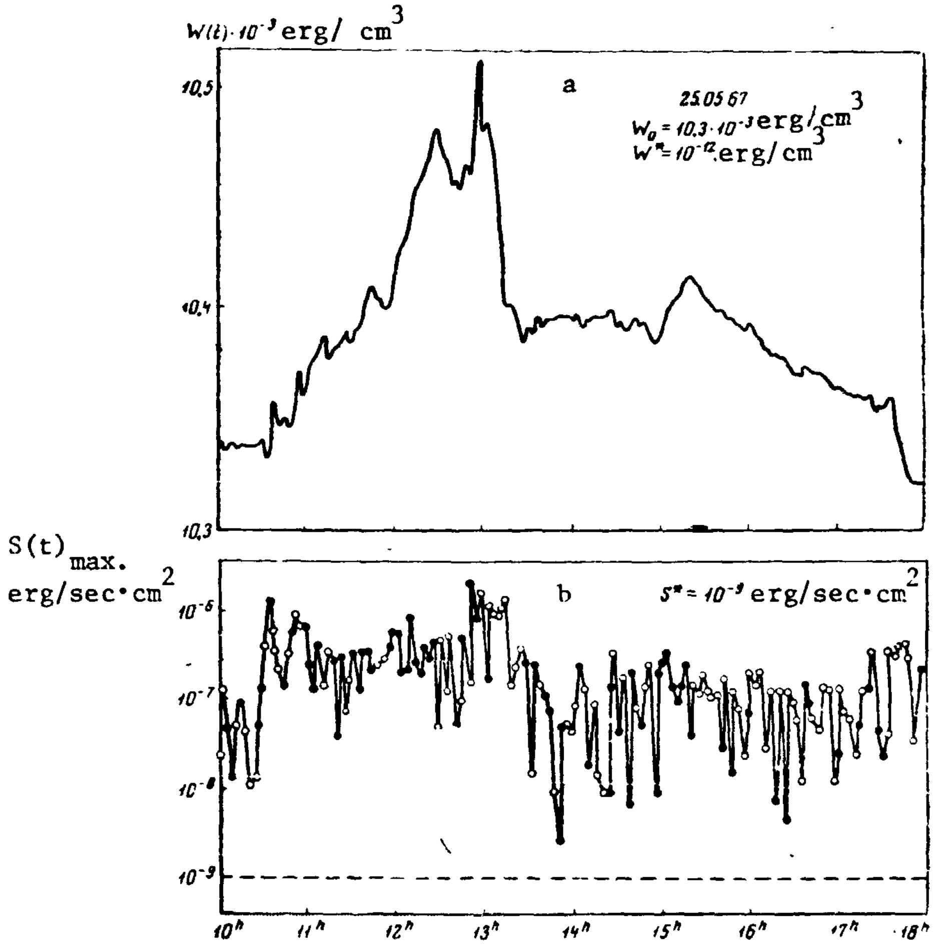

Fig. 2. Running energy parameters of the geomagnetic storm of May 25, 1967
a — power flux; b — positive values of power flux density indicated by black circles and negative by white

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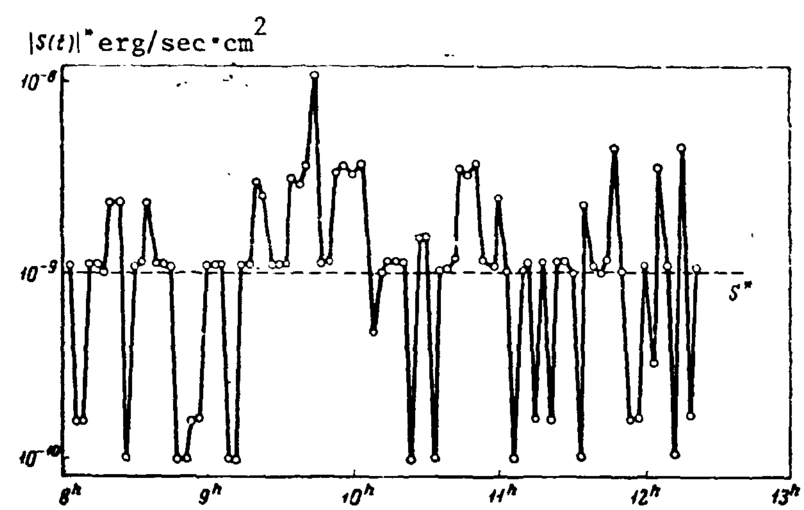

Fig. 3. Curve, drawn according to maximums of the function of the power flux density module of the undisturbed geomagnetic field

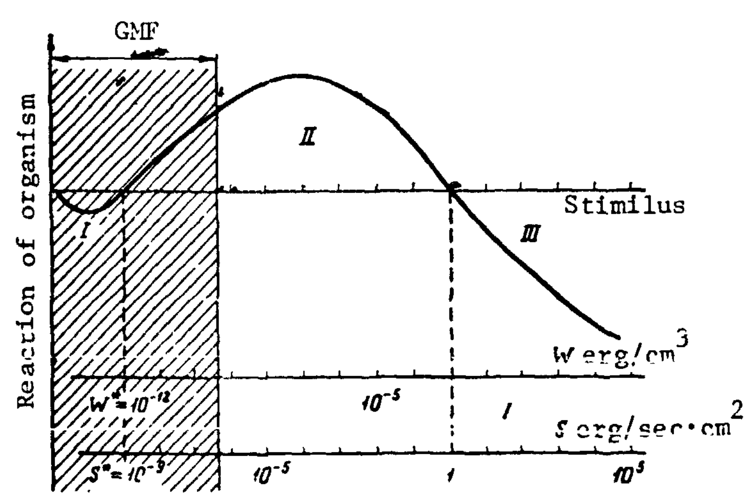

Fig. 4. Dependence of the organism's reaction on local energy parameters of the actuating stimulus

(Explanation in text)

the GMF background, with the threshold sensitivity of the human organism be considered simple chance? Does this not mean that the GMF background is the environmental factor which, during the process of evolution determined, the formation of the threshold of sensitivity at the boundary of fluctuation maximums of its power flux? According to Table 1, preventive inhibition, which corresponds to the pre-threshold range of the effective stimulus, adapts the organism with respect to these fluctuations. The reaction of the organism is indifference. This reaction protects the organism from environmental background noise. /137

It is another matter if this signal exceeds the threshold value. Power fluxes in the region (10^{-7}—10^{-4} erg/sec·cm^2) which correspond to the disturbed GMF are two-five orders (depending on the class and characteristics of the storm) higher than the threshold. Fig. 4 gives a comparison of the curve of the organism's reaction and the energy scale of the actuating stimulus, according to energy density and power flux density. The shaded area corresponds to the range of simultaneous change in both local energy parameters of the GMF with various degrees of disturbance. This range covers almost the entire ascending branch of the disturbance zone. This zone (according to Table 1) corresponds to the sensitivity of receptor structures of the organism. The reaction is informational.

These conclusions regarding the character of the biological activity of the geomagnetic field were based on consideration of the one-dimensional functional dependence of reactions of the organism on the increasing stimulus. However, as was indicated above, the value and phase of the reaction are really multi-dimensional functionals, formed by the dependence of the reaction on a number of factors. Certain combinations of these factors can aggravate the effect of the geomagnetic field.

Let us consider the effect of these factors.

a) A number of researchers (Makarov, 1947; Akhmerov, 1963) have studied the role of the time factor in nerve signaling — the dependence of this effect on the intensity and duration of the stimulus, which in these works was an electric current. It has been shown that two methods can act on living creatures to produce the same threshold effect: a strong stimulus acting for a brief period or a weak stimulus acting for a long time. The result of the methods depends on the intensity and time of the effective stimulus. This principle is widely known in information theory and, evidently, can in general be extended to the effect of different kinds of stimuli.

As study material shows, during weak storms only brief excesses of the threshold by the GMF flux are possible; however, during strong storms steady fluxes develop which greatly exceed the threshold and can last for hours. This can increase the effect of strong storms.

b) It is necessary to take into consideration the initial functional state of the organism. The healthy organism, in proportion to increase of the geomagnetic disturbance, can actuate protective-compensational mechanisms so that comparatively strong phases of the storm interact with a relatively active state of structures which weakens the effect of the energy and time factors. /138
However, for the organism weakened by disease, with dysfunction of the protective mechanisms, the aggressiveness of the flux greatly exceeding the threshold will be increased by the length of the effect, as adaptational properties of the organism are disturbed.

In the literature (Makarov, 1947, 1958; Kholodov, 1966) there are indications of the existence of differentiated excitability and zones of greatest reactivity of the stimulus to a given functional state of the central nervous system and the organism as a whole. This also explains the broad "spectrum" of possible reactions of the organism: from subtle mental shifts to serious dysfunctions of vital complexes (brain, heart, blood stream) in sick people [Zemlya vo Vselennoy (The earth in the universe), 1964; Solnechanya aktivnost' i zhizn' (Solar activity and life), 1967].

c) The factor of suddenness in any case increases the equivalent force of the stimulus, increasing the effect of the action (Menitskiy, 1960). In this respect, storms with sudden commencement, characterized by a sharp jump in components $\Delta\vec{h}$ for a brief interval of time Δt are dangerous. A sudden jump in the flux of five orders occurs against a subthreshold background. The organism is not able to actuate the protective systems and without preliminary "preparation" by gradual increase of stimulation falls into a strong long-lasting flux. From the point of view of the quantitative characteristics of the signal, it is a question of the slope of its initial front. The greater this slope, the greater the flux itself and the stronger its undesirable effect, intensified by the factor of suddenness.

d) The structural characteristics of the storm (stimulus) — the degree of turbulence of the flux, computation of its variable properties, the frequency spectrum of fluctuations, computation of the sign of the flux and the characteristics of its alternation of signs — require special study. However, preliminary work in this direction today already indicates several important characteristics of the GMF.

First of all, analysis of the variable properties of the GMF make it possible to estimate the high (in comparison with other known environmental factors) degree of its variableness; the parameter characterizing it (Romanenko et al., 1968) is comparable to analogous characteristics of the variability of biocurrents of the brain (Sergeyev et al., 1968).

Preliminary study of frequency properties of storms has shown that frequency characteristics of the field largely coincide with biorhythms of the human organism, especially with fluctuations in metabolic functions.

As from the signal point of view the GMF can be considered as informational intereference (Presman, 1968), coincidence of the structural characteristics of the storm and processes occurring in the human organism cannot fail to affect the latter and distort the normal work of both individual structural formations and the entire organism as a whole. /139

Remember that it is always a matter of the objective perception by the organism of disturbances in the geomagnetic field. The reception of this information is not reflected in the consciousness, as conditions are not fulfilled whereby the environmental signal can be subjectively perceived by man. First, the magnetic and particularly the geomagnetic field, evidently, have no specialized receptor and secondly, fluxes even during rather strong storms are an order below (see Table 1) those optimum values when the signal is subjectively perceived, even with adequate reception. For these reasons, the consciousness does not participate in suppressing this informational interference because it does this by differentiating degrees of informational value of the perceived signals. This makes its filtration additionally difficult.

Thus, today it is possible to imagine the biological activity of the disturbed GMF from the point of view of reception theory.

6. Let us dwell separately on the question of how properly, in our opinion, to understand the sensitivity of the organism to the geomagnetic field, assuming lack of a specialized receptor.

When light acts on the eyes or sound on the ears, etc., we have reception of a specific adequate signal. Specific if the energy nature of the signal corresponds to the range of sensitivity of a given receptor and adequate if the signal acts on the corresponding receptor.

Modern theoretical biology does not have information available on the properties and role of electric and magnetic fields, formed in the biological substrates themselves at various levels of reception: submolecular, molecular, structural and even the organ as a whole. However, it is known that all processes of vital activity, including reception, are accompanied by the development and complex transformation of these fields (Bauer, 1935a; Zabotin, 1967). There is no basis for doubting that these fields can interact with external fields. When we speak of lack of adequate reception of the GMF, we only meant to point out the absence of a special receptor, the action itself is adequate.

The specificity of the geomagnetic field as a signal is demonstrated by comparison of the power flux of the field with the range of intensity of the effective stimulus to which specific signals correspond and by conformity to the nature of internal processes (Table 3).

Thus, we suggest considering the influence of the disturbed geomagnetic /140 field on the human organism as specific adequate informational intereference, distorting the reception and analysis of vitally important signals from the internal informational and energy "service" of the organism, as the energy range of this action exceeds the threshold sensitivity of the organism.

7. We shall now attempt to imagine the mechanism of the effect of the GMF at the molecular level.

It is known (Setlou, Pollard, 1964; Aleksandrov, 1968) that processes occurring in the cell do not depend only on chemical conversions, i.e. combinations, splittings or displacements of atoms in the primary structure of molecules of biopolymers. An important role in the course of a particular reaction is played by the configuration of bonds, the spatial distribution

TABLE 3. ENERGY CHARACTERISTICS OF ELECTRIC AND MAGNETIC FIELDS OF THE ORGANISM AND THE GMF

Energy indices	1 cm from the nerve during impulse	2 cm above the head of a person during contraction of heart muscle	GMF
Energy density of the electric component of the field $W_E \left(\frac{erg}{cm^3}\right)$	10^{-11} Nerve	10^{-13} Heart	--
Energy density of the magnetic component of the field $W_H \left(\frac{erg}{cm^3}\right)$	10^{-21} Nerve	10^{-23} Heart	10^{-2} GMF
Power flux density of the electric energy in the impulse $S_E \left(\frac{erg}{sec \cdot cm^2}\right)$	10^{-7} Nerve	10^{-11} Heart	$0-10^{-4}$

of their parts and resultant secondary, tertiary and quaternary structures[1]. Bonds within these structures are weak and can easily be broken by external influence (Aleksandrov, 1968), leading, for example, to increased or weakened catalytic activity of enzymes. According to Bauer (1935a, b), the value of structural energy is $\approx 10^{-13}$ according to W_E. Nevertheless, in normalcy, these bonds probably have a definite dynamic resistance to external influences which is disturbed during pathological processes in the organism. In these cases the energy of the disturbed GMF can be sufficient to cause additional reorganizations and thereby intensify the dysfunction of certain biological /141

[1]Actually these bonds are even more complex, as protein molecules must be considered not in isolation, but together with the medium (Sent=D'yerdi, 1960), the base of which consists of water with complex physico-chemical properties.

formations. In a number of cases this intensification can be decisive for the organism, in others it causes only a subtle functional shift in the most vulnerable system of the organism. The variety of possible dysfunctions of various biological systems also explains the variety of effects produced by the disturbed GMF.

On this level the concept of biological plasma (Sent-D'yerdi, 1960, 1964; Inyushin et al., 1968) seems promising, making it possible to imagine conformation changes resulting from the direct interaction of the GMF and systems of its own protein molecule fields.

Final resolution of the question of the biological activity of the GMF will be aided, in our opinion, by experiments which take into account the specifics of the GMF outlined in this work and the characteristics of responses at various levels of biological organization.

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THE REACTIONS OF ANIMALS AND MAN TO MAGNETIC FIELDS

Yu. A. Kholodov

Only in the middle of the 19th century and the beginning of the 20th century /143 was it noted that the cyclicity of many biospheric processes coincides with that of solar activity, reflected in a change in the number of solar flares and sun spots (Chizhevskiy, 1930, 1963; Chizhevskiy, Shishina, 1969: Piccardi, 1967; Presman, 1968, and others). This information leads us to assume that a connection exists between some kind of cosmic factor and life processes on earth.

The question of exactly which extraterrestrial factors, following the dynamics of solar activity, affect the human and animal organism still remains open. Here we can also note weather conditions (atmospheric pressure, temperature, wind speed, humidity, etc.), increased solar radiation in x-ray, ultraviolet and radiowave regions of the spectrum, fluctuations in the geomagnetic field (GMF), a kind of radiation unknown to physics (Chizhevskiy, 1963), etc. Most likely the biosphere is affected by a complex of factors whose fluctuations in intensity correlate with solar activity, but it is assumed that electromagnetic fields play the main role (Achkasova, Vladimirskiy, 1969). We shall only be concerned here with GMF; in this article we shall limit ourselves to a review of information about the effect of magnetic fields (MF) on animals and man. The effect of MF on plants is discussed in another article in this collection (see Yu. I. Novitskiy).

We would like to begin the historical description of the problem with the quotation: "Lamont of Munich in the 1860s was one of the first to indicate a possible connection between epidemics and perturbations in the earth's electric and magnetic field, which depends, in turn, on the effect of a cosmic factor" (Chizhevskiy, 1930).

Such an assumption was natural in the 19th century as the effect of MF on man, detected in magnetotherapeutic research, was not doubted (Grigor'yev, 1881).

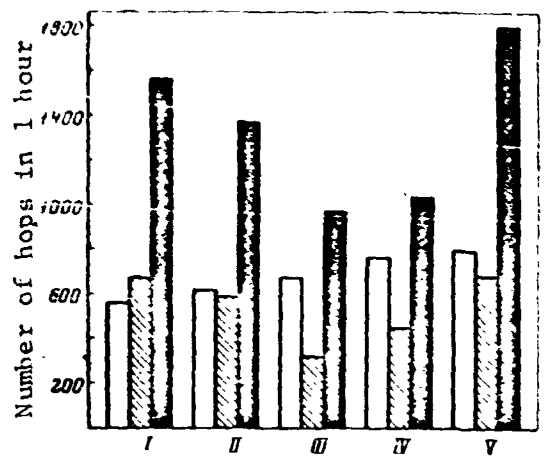

Fig. 1. Motor activity of various birds in the village of Rybachiv in clear (white columns) and cloudy weather (shaded columns) as well as in the town of Gubkin in cloudy weather (black columns) /144

1 — finch; II — linnet; III — garden bunting; IV — blackcap; V — lark (according to data of Shumakov, 1967)

Theoretical biologists of the 20th century were sceptical of the possibility of a biological effect of MF (Akkerman, 1964). The appearance of isolated magnetobiological publications was not able to overcome this attitude. A concept of vital processes was completely devised without taking into account the existence of MF of any intensity whatsoever in the environment. In addition, many theoretical physicists found no basis for the existence of magnetobiological effects even under the influence of quite strong (10^3 oe) artificial MF. However, the accumulation of factual material forces reconsideration of the possible effect of MF on the biosphere.

We must point out that an important role in quickening interest in magnetobiology has been played by space biology which must reevaluate all terrestrial conditions for the existence of life. In addition, occupants of a space ship will be the first to spend long periods in very strong MF (with the ship magnetically protected against cosmic radiation) and in very weak MF, encountered in outer space and in the nearest space flight stations (the moon, Venus, Mars).

These circumstances can explain the sharp increase in the number of publications on magnetobiology since 1961 when the space era began.

In recent years all the more frequently (Chizhevskiy, 1963; Presman, 1968, and others) it is being assumed that the most probable candidate for the role of mediator between solar activity and the biosphere is GMF fluctuations caused by solar particles. Many years of observations conducted at Leningrad (Ryvkin, 1966), Sverdlovsk (Novikova et al., 1968), Irkutsk (Platonova et al.,

1968) and other places have shown that increased magnetic activity according /145 to the K-index (an arbitrary 10-point scale of GMF fluctuations from 0.00004 to 0.005 e) correlates with increase in the number of cases of various diseases (primarily diseases of the cardio-vascular system) and the number of fatalities. These results of heliobiological research indicate the practical necessity of organizing a medico-biological solar survey.

It is appropriate to recall that the GMF varies in intensity not only in time but also in space. In the latter case the question is magnetic anomalies, particularly the Kursk magnetic anomaly, where the vertical component of the GMF is 2-3 times greater than in neighboring regions. Comparing the incidence of disease among the population of the Kursk and Belgorod districts with corresponding indices from the Perm district and the Primorskiy region, I. V. Dardymov (1966) suggests that increased incidence among the population of hypertensive disease, nephritis, malignant neoplasms and rheumatism is connected with an elevated GMF. The conclusions of this work deserve much criticism with regard to the method of comparison, but it correctly states the problem of the possible effect of GMF anomalies on the biosphere. A comparison of the incidence of disease among the population of the Belgorod district, living in conditions of a magnetic anomaly, with that of neighboring regions showed that in anomalous regions the incidence of neuropsychic and hypertonic diseases is up 160% and rheumatism of the heart, vascular disturbances of the central nervous system and eczema 130% in comparison with neighboring regions having a normal GMF (Travkin and Kolesnikov, 1969). The task of future researchers will be to conduct more detailed comparisons of various biological processes in adjacent districts which differ in GMF intensity.

The possibility of an elevated GMF affecting a biological object was shown in the experiments of M. Ye. Shumakov (1967) who observed increased motor activity in caged birds after transporting them from the Kaliningrad district (village of Rybachiy) to the area of the Kursk magnetic anomaly (town of Gubkin)(Fig. 1).

Thus, we already have several facts indicating that natural changes in the GMF can affect a biological object.

A great deal of medical data, such as the number of cases of disease, is often evaluated according to subjective indices, depending on the qualification of the researcher, the perfection of diagnostic methods, etc. Therefore, the use of "pure" quantitative indices of the functional state of a healthy individual — the number of leukocytes in peripheral blood (Schulz, 1964) or sensitivity to various stimuli (Friedman et al., 1967) — will give more detailed and objective information on the connection between biological

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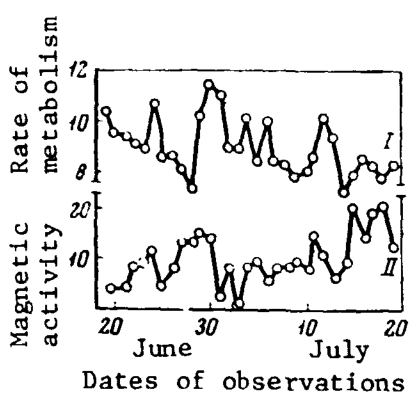

Fig. 2. Dynamics of oxidizing metabolism in the snail (I) and fluctuations of geomagnetic field (II)

Vertically — intensity of recorded indices. Horizontally — time in days (according to Barnwell, 1960)

processes and fluctuations in GMF intensity. Objectivity increases even more in shifting to experiments on animals. Motor activity of insects (Chernyshev, 1968), the consumption of oxygen by mollusks (Barnwell, 1960) clearly correlates with GMF fluctuations (Fig. 2).

However, any advances in improving methods to register biological processes cannot answer the question of basic interest to us — are these biological reactions caused by fluctuations in the GMF alone or by some other geophysical factor alone which changes simultaneously with the GMF or, what is most probable, by a complex of geophysical factors? A help in solving this complex problem would be the existence of specific reactions of the organism caused only by MF and nothing else. Such a specific effect of MF might be its orientation effect. The concept of a possible orientation effect on the behavior of several migrating animals probably arose earlier than the idea of other forms of GMF influence on the biosphere. A. T. Middendorf (1885) was the first to suggest that spring flights of Siberian birds are oriented in the direction of the magnetic meridian. Not considering in detail more than the long history of the geomagnetic theory of the orientation of birds, we note that even today it has both its few proponents and its more numerous opponents (Matthews, 1968).

In this general statement of the question of the ecological importance of the GMF for the biosphere, the geomagnetic orientation of birds is too particular. Actually, in recent years the theory of geomagnetic orientation of animals is being tested on a wide range of objects.

It has been reported that freshwater fish in an unfamiliar reservoir most often move in the direction of the magnetic meridian if no other stronger orienting stimuli are acting on them (Poddubnyy, 1965). Many insects in landing and at rest prefer to arrange the axis of their body in a north-south /147
or east-west direction (Becker, 1966). Orientation to the GMF was observed in worms and mollusks (Brown, 1966) when under laboratory conditions they crawled out of an artificial enclosure to a broad area. The application of artificially weak MF changed natural orientation and shielding from the GMF caused orientation to disappear.

These facts indicate that orientation to the GMF is easier to see in many animals than in birds and this can be considered a general biological problem.

Although many questions regarding the mechanism of orientation of different animals in the GMF and the method of determining it remain unclear (Chernyshev, 1970), the very fact of the existence of such orientation is finding ever wider acceptance. Unfortunately, a positive solution to the question of geomagnetic orientation does not affect solution of the question of the possibility of a biological effect of GMF fluctuations connected with solar activity.

Experimental proof of the importance of a certain environmental factor for biological processes usually includes tests under conditions of controlled decrease or increase of the factor in question. This method is being used to study the effect on the organism of hypo- and hyperoxia, hypo- and hypervitaminosis, hypo- and hyperthermal conditions, etc. Analogously to these research tactics, we shall consider the existing information on the effect of hypo- and hypermagnetic conditions on animals and man, assuming as normal a GMF intensity of about 0.5 oe.

As yet there are very few studies of the effect of weakened magnetic field (WMF) in which two existing methods of WMF are used: the shielding (screening) method using sheets of metal and the creation of an antifield using Helmholtz rings.

In a recent review dealing with the biological effect of a WMF, Conley (1969) lists about 30 works which studied the effect of a WMF on various representatives of the animal world. We shall indicate a few of them.

After the GMF is reduced approximately 10 times by means of screening, reproduction of a culture of Staphylococcus aureus was decreased approximately 15 times (Becker, 1963). The same report indicated that A. L. Chizhevskiy in 1940 noted increased mortality of rats after they were placed in a shielded area. It was found that under experimental conditions, when the GMF was compensated 95% with Helmholtz rings, flies changed the character of their orientation in landing and resting (Becker, 1966).

Under similar conditions of screening against the GMF, changes were observed in the dances of bees by means of which these animals signal their partners in the beehive about the location of their find (Lindaner, Martin, 1968).

In greater detail, the life of mice was studied in a shielded area where /148 the MF intensity was 0.001 oe. The animals lived in families each of which included one male and three females. The mice lived in this WMF for a long time (about a year). Control animals lived in a similar closed space but in the GMF (Halpern, Van Dyke, 1966). These studies supported Chizhevskiy's conclusion about increased mortality of animals in a WMF. However, the greatest interest is in the particularization of disturbances developing in a WMF. Miscarriages and eating of newborn mice were more often observed in the test group. Surviving baby mice were usually listless and inactive. Many of them would often lie on their back for a long time, which is usually not natural for these animals. Coarse hair, typical of adult mice, appeared earlier. Approximately 14% of the adult mice grew bald on the back of the head and evenly down the middle of the back. Microscope studies showed that the skin in the bald area was thicker, swollen and had forced out the hair follicles.

Often small tumors were observed in various sections of the body. The activity of such important organs as the liver, kidneys and sex organs was disturbed. Sometimes death was diagnosed as the result of poisoning by urine which could not be excreted normally because of tumors in the kidneys or ureters

(Busby, 1968). C. C. Conley et al., (1966) reported that resistance to introduced microorganisms is reduced in mice placed in a WMF with an intensity of 0.0008 oe. Thus, animals reacted sharply to being in a WMF for a prolonged period.

The brief effect of a WMF was also studied on man. Creating a WMF with Helmholtz rings (with an intensity of about 0.0001 oe), two future astronauts were placed under these conditions for 10 days (Beischer, 1965). Body temperature was measured, EKG and EEG were recorded, the activity of the vestibular apparatus was studied and several psychological tests were given. No serious deviations were detected. However, under these conditions a subjective sensation of continuous light appeared with lower frequency of flashing than under GMF conditions in the same person (Fig. 3).

We must add that later the same results with regard to changes in the organ of vision were obtained again on four persons under similar test conditions and then on two subjects in a WMF created by means of screening. These changes were reversible, i.e. vision became normal soon after return to the GMF.

These few data indicate that WMF produced by means of shielding or by creating an antifield have the same biological effect. But it is possible that the selective reaction is nonspecific and arises both with reduction of the GMF and with increase of MF.

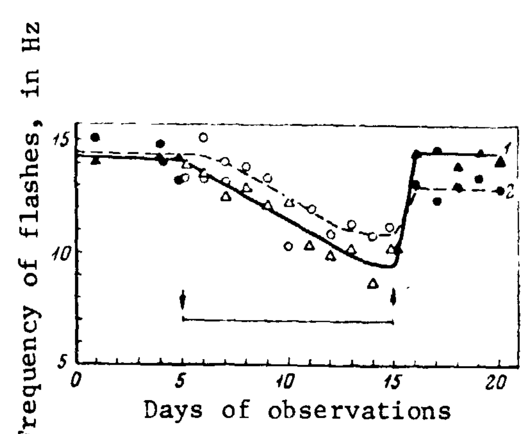

Fig. 3. Change in the lowest frequency of a flashing light needed to produce a subjective sensation of continuous light in a person shielded from the geomagnetic field (0.0005 oe) /149

1, 2 — different subjects. Arrows indicate moments of creation and removal of a magnetic screen (according to Busby, 1968)

Without solving the question of the similarity or diversity of the biological effect of WMF created by different means, we can already conclude that reduction of the GMF causes a biological reaction. Therefore, the GMF is an essential ecological factor and, possibly, its fluctuations affect processes occurring in the biosphere.

In tests modeling "magnetic storms," when an artificial MF of about 1 oe with a frequency from 0 to 10 Hz acted on the head of a person, a reduction was noted in pulse rate (Bil'dyukevich et al., 1969). Another group of researchers (Mikaylovskiy et al., 1969) showed that some subjects can perceive changes in the intensity of artificial MF that are 0.5-3.0% of the GMF with a frequency of 0.01-2.00 Hz. This was found in recording human EEG and in producing a conditioned reflex to MF. Finally, changes in motor apparatus of the upper extremities, holding a wooden roller, were noted in a moving person during a MF gradient of only from 0.1 to 3 me/m (Rocard, 1964). These still isolated reports indicate high sensitivity of some (not all) people to MF.

In animal tests weak MF primarily affected orientation (see above) and development. If pregnant rats are placed in a MF with an intensity of several oersteds and a frequency of 0.5 Hz, their offspring at 21-25 days of age will display behavioral disturbances distinguishing them from control baby rats. Test animals moved less and defecated more often in open field testing; disturbances were more pronounced in males than in females (Persinger, 1969).

A two-day effect of a strengthened magnetic field (SMF) of several oersteds on the developing embryo of a hen egg led to a reduction in the diameter of blastoderm, change in orientation of the embryo to the light, disturbance of development (most often the nervous system) and reduction in the total amount of iron in the embryo (Veneziano, 1965). A similar SMF acting on
a developing pigeon egg under natural conditions caused a predominance of /150
males among offspring (Kiryushkin, Kim, 1969).

The largest number of magnetobiological studies dealt with the effect of increased (in comparison with the GMF) artificial fields on different biological objects. In the majority, separate experiments were unsystematically conducted. They differed in the means of creating the MF and in its intensity (from several to 140,000 oe) and in the length of the action (from seconds to months), not to mention the variety of biological objects. Most often a qualitative purpose was pursued — to prove the existence of a biological effect of MF. But, nevertheless, despite the diversity of existing experimental data, we shall attempt to systematize it in order to answer the most general questions regarding which animals react to MF, which organs and systems are most sensitive to MF and what is the possible physiological mechanism of the effect of MF on a biological object.

We must point out the methodological similarity in approaches to evaluating the biological effect of MF and ionizing radiation. Both physical factors have a penetrating effect, neither causes a specific sensation in man. It is not surprising, therefore, that magnetobiology borrows many concepts from more developed radiobiology. Here we must first of all note the concept of magnetosensitivity, which means a specific reaction of a certain biological object to minimum MF intensity. Unfortunately, in magnetobiology we must not mechanically transfer the concept of dose,as many magnetobiological effects have a long latent period and increasing the intensity of the MF will not lead to its proportional reduction. However, we can already differentiate magnetosensitivity and magnetosusceptibility, having in mind in the second case prolonged and sometimes also irreversible reactions.

Although no systematic studies have as yet been made of the comparative magnetosensitivity of animals at various levels of organization, existing separate publications show that representatives of a majority of species of the animal kingdom react to artificial MF (See Table 1). In this table we do not present the sources of the analyzed information in order not to overload the references. Qualitative characteristics of MF (uniformity, direction of lines of force, etc.), the length of the action and a detailed description of the biological object are beyond the scope of the table.

The data in Table 1 show that even the simplest unicellular animals are able to react to external artificial MF, altering their behavior and their metabolism. This leads us to assume that initial magnetobiological effects in multicellular organisms can develop at the cellular level. /152

We know of no publications in which data are analyzed on the effect of MF on sponges or coelenterata. At the same time, information on reactions to MF by coelenterata, in which a nervous system first appears, would more vividly set off the characteristics of reactions of multicellular organisms in comparison with unicellular.

TABLE 1. THE EFFECT OF ARTIFICIAL MAGNETIC FIELDS ON VARIOUS INDICES OF VITAL ACTIVITY OF INDIVIDUAL REPRESENTATIVES OF THE ANIMAL WORLD

Species	Class	Representative	MF intensity in e	Recorded biological index
Protozoa	Infusoria	Paramecia	100-8.000	Orientation, behavior, motor activity, reproduction, growth, metabolism
Flatworms	Turbellaria	Planaria	100-1,000	Orientation, behavior
Round worms	Oligochaeta	Earthworms	0-0.5	Behavior
Arthropoda	Crustacea	Crayfish, artemia	500-2,000	Bioelectric activity, development
	Insects	Drosophila, house flies, cockroaches, May bugs, termites, etc.	10-140,000	Orientation, behavior, motor activity, bioelectric activity, reproduction, genetic effect
Mollusca	Gastropoda	Helix nassarius, chiton, garden snail	4-8,000	Orientation, motor activity, bioelectric activity
Echinodermata	Echinoidea	Sea urchin	1000-140,000	Development
Chordata	Fish	Mormyr, carp, crucian carp, stickleback, trout, etc.	[illegible]	Behavior, motor activity, development
	Amphibians	Frogs	100-10,000	Sensitivity, development, heart activity
	Reptiles	Tortoise	10,000	Heart activity
	Birds	Pigeon, hen, bullfinch, etc.	200-1,000	Behavior, motor activity, EEG, development, etc.
	Mammals	Mouse, rat, guinea pig, rabbit, cat, dog, monkey, man	100-140,000	Behavior, development, growth, EEG, etc.

The representative of flatworms — planaria - displays clear behavioral reactions to MF which has been reported by several independent groups of researchers.

Round worms (earthworms) in the GMF crawled more quickly in daylight than at night; in a WMF close to zero this circadian difference was not found.

The next species — arthropoda - crustacea and especially insects have been intensively studied in various MF. Changes in electric activity of neurons (most often inhibition) were noted in crayfish and cockroaches. Noted in other insects were orientation in the GMF, changes in motor activity in the GMF and artificial MF, changes in development, genetic effects and other aftereffects of MF.

Mollusks were included in the orbit of magnetobiological studies because in several cases ferromagnetic substances were found in the shell and radula. However, this fact could hardly explain their orientation in the GMF or even more, change in the activity of an isolated heart in an artificial MF.

Only fertilized sea urchin eggs were placed in MF as representatives of Echinodermata. Their development after such action was often retarded.

Of the species chordata, only representatives of subspecies vertebrates have been intensively studied. Primary consideration has been given to mammals and then by the degree of their use in magnetobiological experiments are: birds, fish, amphibians and reptiles. The high interest in mammals is due to their evolutionary closeness to man. Birds and fish have been studied primarily in connection with the geomagnetic theory of orientation of these animals. Amphibians and reptiles have been used as experimental objects.

Thus, different representatives of the animal world display varied reactions to MF. Disregarding several problems distinguishing our table from the regular zoological table, we can say that all animals react to MF. This conclusion is important as it has been our purpose to determine if MF can affect the biosphere. If only migrating birds reacted to MF, as suggested by some researchers, this could hardly have a serious effect on the biosphere. We must remember that plants and microorganisms also react to MF and, therefore, /153
the whole biosphere can, in theory, react to MF.

We now pass on to physiological particularization of this general conclusion; we shall consider how different systems of the most complex vertebrates react to artificial MF.

Blood has been intensively studied, both under the influence of MF in a test tube and under the influence of MF on the complete organism. Reactions were observed in all its component parts. Protein fractions of serum (Sel'kov, 1963; Chernaya, 1966; Vyalov, 1967, and others) and the enzymes found in it (Belokon' et al., 1966) reacted to MF. Under the effect of MF the number of erythrocytes was increased and the sedimentation rate was slowed down (Mogendovich et al., 1948). The number of leukocytes and their phagocytic activity changes (Sherstneva, 1951, and others). The coagulability of blood was altered, possibly connected with changes in thrombocytic activity (Danilin, 1957). It is important to note that changes in the blood system could also occur with the indirect effect of MF on the blood mediated through the central nervous system.

The circulatory system was quite sensitive to MF. Pathomorphological study noted dilation of blood vessels in animals which had been placed in MF (Karmilov, 1948; Toroptsev, 1968, and others). In people coming in contact with MF in industrial conditions, bradycardia was often noted (Vyalov, 1967); in squirrel monkeys a strong MF caused a reduction of palpitations and increase of the T wave on EKG (Knepton and Beischer, 1966). The isolated heart of a tortoise, frog and garden snail also reacted to MF. As in the case with the blood system, MF could act on the heart both directly and through the central nervous system.

The respiratory system altered its activity under the eff[illegible] of MF at various levels. It has already been indicated that erythrocyte[illegible] reacted to MF. In pulmonary tissues, distal ectasia and emphysema were noted. There was an increase in substances of a mucopolysaccharide nature and almost complete loss of tinctorial properties of argyrophilic substances (Gorshenina, 1965). Total consumption of oxygen by mice in MF [illegible] reduced (Tishan'kin, 1950; Shishlo, 1966).

The digestive system under [illegible] influence of MF has received comparatively little study. A reduction in the weight of the liver was noted in mice after they had been in MF (Barnothy, 1960). Certain morphological changes occurred in not only the digestive, but also the excretory system. Weak destructive changes were usually found in epithelium of nephritic tubules. However, increasing the function of these organs by the introduction of choleretics and diuretics intensified magnetobiological effects. In the liver changes were /154 found In Kupffer's cells in the form of hypertrophy and vacuolization of nuclei. In the kidneys the epithelial part of the nephron was more sensitive (Rassadin, 1966). Reactive changes were noted in nerve elements of the gastro-intestinal tract in the form of increased argyrophilia (Ryzhov, 1964).

In nerve elements of the integumentary system in the skin of guinea pigs, reactive changes were observed under the influence of MF (Ryzhov and Anufriyeva, 1968). People who often placed their hands in strong MF in their work noted disturbances in the skin as well as changes in the sweat-excretion function (Shiyanevskiy, 1966; Vyalov, 1967). The question arises of peripheral vegetative-trophic disturbances in the skin of upper extremities of people in MF.

The isolated muscle system of vertebrate animals has been relatively little studied in magnitobiological experiments. However, a neuro-muscular frog specimen has often been placed in various MF. Usually the effect produced has been due to the influence of MF on the nerve. However, the local action of MF on an individual nerve fiber had no effect on the neuro-muscular specimen (Liberman et al., 1959). Possibly the reaction of the neuro-muscular specimen in a SMF, recorded by several researchers (Aminev, 1966; Pustovoyt et al., 1967, and others) is produced with the participation of muscle tissue.

The effect of magnetic fields on the nervous system has received the most intense study (Kholodov, 1959, 1966; Aminev, 1966; Druz', 1967, and others). Reactions of the entire organism have been noted in the form of changes in motor activity (most often increase), inhibition of conditioned reflexes, lowering of sensitivity to various stimuli and the possible development of reflexes to MF, which were distinguished by low strength in comparison with conditioned reflexes to ordinary stimuli (light, sound).

At the system level the reaction of the nervous system to MF was studied using electrophysiological methods. EEG changes, most often in the form of increase in the number of slow waves and spindle-shaped fluctuations, were observed in reptiles (Becker, 1963), pigeons (Gualtierotti, 1963), rabbits (Luk'yanova, 1967, Chizhenkova, 1966, and others) monkeys (Knepton and Beischer, 1966) and man (Vyalov, 1967). Fig. 4 shows an example of the EEG

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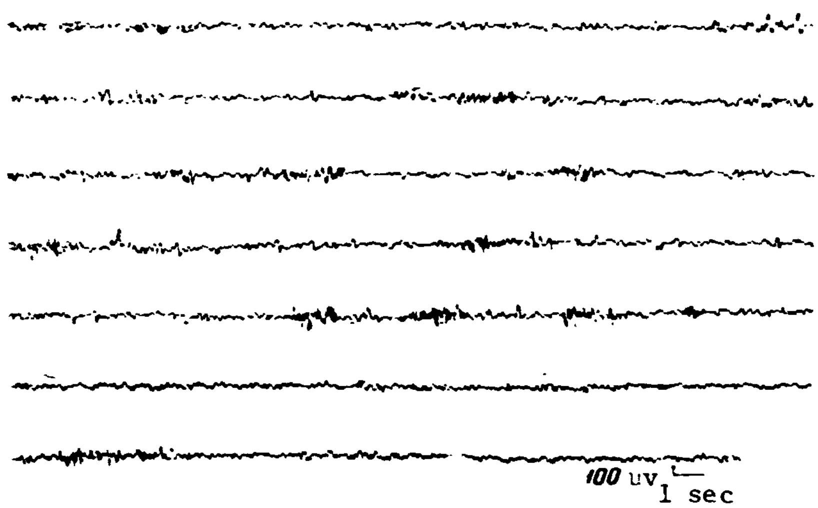

Fig. 4. Changes in rabbit EEG under the influence of a permanent magnetic field of 1000 oe on the head of the animal

Continuous EEG recording of the sensory-motor area of the left hemisphere. At the middle of the second recording — the field was turned on, at the middle of the fifth recording — it was turned off

reaction of a rabbit while its head was under the influence of a magnetic field with an intensity of 1000 oe, leading to an increase in the number of spindles on the EEG.

At the cellular level, reactions of the central nervous system to MF were studied by electrophysiological and histological methods. MF most often retarded the rate of impulse activity of neurons in various sections of the rabbit brain (Luk'yanova, 1967), abdominal neuroplexus (Luk'yanova, 1966) and the tension receptor of the crayfish (Kogan et al., 1968) and the submaxillary ganglion of the cockroach (Sittler, 1966). Affinity for silver after the effect of MF was especially increased in glial cells of the mammal brain (Aleksandrovskaya and Kholodov, 1966).

Experiments with the neural isolation of individual nerve structures showed that MF acts on the section of the brain deprived of nerve connections to all receptors even more strongly than on the intact section. Therefore, a magnetic field, which has a penetrating effect, can affect the brain directly, by-passing the sense organs.

Sections of the rabbit brain have been arranged in the following order according to diminishing intensity of the EEG reaction to MF: hypothalamus, sensory-motor cortex, visual cortex, specific nuclei of the thalamus, nonspecific nuclei of the thalamus, hippocampus and reticular formation of the mesencephalon. The proximity of the hypothalamus to the center of humoral regulation, the pituitary gland, already indicates that the endocrine system does not remain indifferent to the effect of magnetic fields.

The hypothesis has been expressed that MF, acting through the nervous system on the anterior lobe, increases the production of adrenocorticotropic hormone and thus leads to atrophy or complete disappearance of the bundle zone of the adrenals in mice (Sumegi et al., 1966). Hypersecretion of the thyroid gland was noted under the influence of MF (Ukolova et al., 1969), and morphologically a definite disturbance in the activity of sex glands, especially the testes (Toroptsev, 1968). The endocrine system, therefore, takes an active part in the reaction of the organism to magnetic fields.

Although MF can also affect the central nervous system in the absence of /156 receptors, this does not mean that sense organs do not react to MF. Man does not usually sense the presence of MF, but a change can be perceived in the form of flares (magnetophosphene). When a magnet is presented to the surface of the skin, some people feel a twinge, burning or itching. Thus, MF, which does not cause specific "magnetic" feelings, can penetrate the sensual sphere by means of nonspecific stimulation of several receptors.

The reaction of the organ of sight to MF has also been studied by morphological methods. Vascular hyperemia, edema of the cornea and lowering of its sensitivity, as well as vacuolization of its epithelium, have been noted. In addition, disturbances were noted in lymph-formation in the ciliary body, hydrosc changes in epithelium of the anterior capsule of the crystalline lens, vacuolization of its cortical layers and necrobiosis of individual ganglion cells of the retina (Teplyakova, 1967) have been noted. Even the bone system did not remain indifferent to SMF. It has been shown that in rabbits the repeated (45 days) hourly influence of a strong magnetic field (intensity of 3000 oe) at the site of a fracture of the radius negatively affects immature osteogenic elements (Krut'ko, Dolzhikov, 1968).

Summarizing this brief review of information on reactions to artificial magnetic fields of vertebrate animals, we can say that physiological and morphological data both indicate the participation of all systems of the organism in these reactions. We note that pathological changes under the influence of MF were not catastrophic in the majority of cases, which would characterize it as a relatively weak stimulus.

It is difficult to say on the basis of this review which system of the organism is most sensitive to MF, as most often the reactions were evaluated only qualitatively by different methods and according to the total effect of MF on the organism. However, the impression is produced that the nervous and circulatory systems can be distinguished as most reactive. We recall that these systems are most often studied in heliobiological works.

This conclusion about the greatest magnetosensitivity of the nervous system is supported by the results of a special study which compared the magnitosensitivity of various organs by one index. On the basis of studying maximum hydration ability of tissue after the one-minute effect of MF in vitro, the following decending order of sensitivity in rat organs was obtained: brain, kidneys, spleen, small intestine, heart muscle, testicles (Madiyevskiy, 1968).

On the other hand, morphological studies of various organs of guinea pigs, kept in a magnetic field for several hours, showed that the testes were /157 the "shocked", i.e. the most damaged organs. Ovaries were affected to a lesser degree, indicating a sex difference in reactions to MF and greater "magnetosusceptibility" of males. Disturbances were found in the lungs, liver, kidneys, in structures of the eye and in the central nervous system (Toroptsev, 1968).

Thus, the sequence of organs arranged according to their reactions to MF differs according to data of different researchers. These seeming contradictions can be reconciled in this case if we take into consideration that magnetosensitivity and magnetosusceptibility are determined by different methods and characterize the organ in question from different points of view. The brain is then a very sensitive, but at the same time, also a quite resistant organ. Radiobiologists have come to a similar conclusion comparing physiological and morphological data by the effect of ionizing radiation on the central nervous system (Livanov, 1962; Gorizontov et al., 1966).

It is important to note that the accumulation of morphological changes developing under the influence of MF on the entire organism leads us to assume specificity of the pathologo-anatomical pattern (Toroptsev, 1968). At the same time, the magnetosensitivity of various organs is nonspecific, i.e. under the effect of altering factors, tissues reacted the same way and in the same sequence as under the effect of MF (Madiyevskiy, 1968). The nonspecific character of reactions to MF were noted in studying reactions of the central nervous system (Kholodov, 1966) and in studying immunological reactions (Vasil'yev, 1968). Therefore, it it difficult and perhaps completely impossible to tell the effective factor by the early reactions of individual organs or systems. This must also be taken into consideration in heliobiological studies.

Magnetobiological experiments revealed the dependence of the effect on the characteristics of the biological object. Here we must first note the level of its evolutionary organization. Some fragmentary information indicates the possibility of reduction of magnetosensitivity in evolutionary order. For example, in planaria a motor reaction was observed to MF (Cherkashin et al., 1965), in fish a conditioned motor reflex to MF could be developed (Kholodov, 1959; Lissman, 1958) and in birds and mammals MF of a similar intensity could only alter conditioned reflexes developed in reaction to other stimuli (Kholodov, 1966). Possibly, in the process of evolution, the increased number and complication of specialized receptor systems began to change the nonspecific reaction to MF. However, this assumption requires careful verification on more experimental material.

The dependence of magnetosensitivity on age has been ascertained more /158
accurately. MF acted more strongly on embryos and the developing organism than on adults (Barnothy, 1960; Aminev, 1966, and others).

In strong magnetic fields the development of frog eggs was delayed, causing death of the embryos (Neirath, 1969). Similar experiments led to the conclusion (Levengood, 1969) that MF is a teratogenic agent. The majority of deformities were caused by the effect of MF at the gastrulation stage.

Under the influence of a strong magnetic field (intensity of 400 oe) on rats from the first to the thirteenth day of pregnancy, a reduction was found in the number of fetuses, an increase in the number of miscarriages and the appearance of deformities, often expressed in the formation of spinal hernia (Tarakhovskiy et al., 1969).

The dependence of magnetobiological effects on seasons was noted. For example, electric activity in the abdominal neuroplexis of crayfish under the influence of magnetic fields of the same intensity changed more distinctly in autumn and winter than in summer and spring (Luk'yanova, 1966, 1970).

We have already noted a sex difference in magnetosensitivity. It will be interesting to find out if males are, therefore, more sensitive to changes in solar activity.

Individual differences are found in all magnetobiological studies. In addition, it has been found that a MF which did not affect processes of labyrinthine training in fish individually began to have its effect upon training of the same fish in a school. In connection with this, the theory of "collective reception" of MF has been expressed (Aminev, 1966). This shows that the results of studying sensitivity of individual organs and organisms can only with great reservations be transferred to reactions of the entire biosphere.

Finally, we must indicate the dependence of the effect of MF on initial functional state. Using the same FM, reaction in the same object was not observed every time (Kholodov, 1966, 1967, and others). The strength of the reaction (ratio of the number of reactions to the number of influences) could be raised by injecting adrenalin into the blood of a rabbit. Functional load on the brain or kidneys increased the intensity of reactions of corresponding organs to MF (Rassadin, 1966). This is important for heliobiology, as a sick organism will often respond to fluctuations in solar activity with increased reactivity. In experimental conditions it is possible to raise the sensitivity of a biological object to fluctuations in the intensity of environmental factors.

Tests to artificially raise the sensitivity revealed the reactivity of a biological object to MF on the order of GMF fluctuations. Studying changes in the frequency of contractions of an isolated /159
frog heart, A. K. Podshibyakin (1968) noted that specimens in a state of hypoxia reacted to increasing the MF 0.006 oe. In planaria it was shown that orientation changed more quickly in an artificial MF of 0 05 oe than in one

of 4 oe (Brown, 1966). Motor activity of birds was increased even with a MF of 0.7 oe (El'darov and Kholodov, 1963). Other examples of the biological effect of MF close to the GMF were given earlier.

We note that a threshold effect of MF was often observed with a MF intensity of 50-100 oe. Such indices as absorption of oxygen by isolated tissue (Pereira et al., 1967), EEG (Kholodov, 1966) or hematological changes (Dernov et al., 1968) were used. In these cases we are, possibly, encountering examples of magnetosusceptibility, as some experimental data show that artificial MF close to the GMF in intensity can have a biological effect. Therefore, the theory of the effect of GMF fluctuations on biological objects receives direct experimental verification.

However, the problem cannot be considered finally resolved. Complications arise in explaining primary physico-chemical processes of the biological effect of strong magnetic fields (Kholodov, 1970). In citing the data we have already indicated various difficulties in attempting to transfer the results of experiments to natural conditions in the interaction between the GMF and the biosphere. Now we would like to turn our attention back to one thing. As MF can affect the activity of any system of the organism and at any stage of its development, this effect can become apparent over a long period of time and in various forms. Therefore, changes in integrated indices of the activity of an organism (a disease as an example) can appear at various intervals after the action.

In conclusion we must state that, in theory, MF can serve as the mediator between several cosmic phenomena and biological processes on earth, but further intensive studies are necessary for specific conclusions about the biological role of the geomagnetic field.

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THE MAGNETIC FIELD IN THE LIFE OF PLANTS

Yu. I. Novitskiy

The earth's magnetic field as a geophysical factor for planets of this type is a very unique phenomenon. At the same time there are no stars which do not have it and for those like the Sun it averages ~ 5 oe, i.e. 10 times greater than on earth. In sun spot regions the field fluctuates from 100 to $3 \cdot 10^3$-10^4 oe. The magnetic field of the galaxy is hundredths of an oersted and in interstellar fields of intergalactic space it is ~ 10^{-5} oe. With the colossal distances inherent in the galaxy, these fields are quite enough to produce radio-frequency radiation in fast electrons and deflect the trajectories of any fast-moving charged parcicles. Nevertheless, as yet there is absolutely no proof that these fields are necessary for life or affect it in any way, directly or indirectly. /164

However, the question of the ecological and physiological importance of the earth's magnetic field has been stated more than once, primarily by the founders of the theory of electricity and the cell, great evolutionists and geochemists such as V. I. Vernadskiy, L. Pasteur, etc.

Undoubtedly the assumption that this factor is necessary to support life is primarily based on sensitivity to it of living natures as well as corresponding structural or exchange mechanisms underlying this sensitivity. It follows that before studying the mechanism of the "sensation of the field," we must prove the very fact of existence of this sensitivity (effectiveness of the field) and establish those "lower limits" beyond which the field (as a normalizing natural factor) does not exist for a given biological object.

Thus, the biological role of the earth's magnetic field is divided into two closely related questions: 1) the effect of a constant magnetic field on plants in general; 2) the lower limit of sensitivity to a magnetic field.

We shall have to consider these two questions as separately as possible, /165 returning as necessary and repeating what has already been touched upon to some degree or another.

I. In this part of the work we shall be concerned with the effect of a constant magnetic field on plants and the possible ecologo-physiological importance of this factor which, evidently, must also be considered in planning prolonged medico-biological space experiments.

Despite the fact that such works were begun in the Soviet Union by P. V. Savostin in the 1920s (Savostin, 1928, 1937; Ssawostin, 1930a, b), interest in them was not awakened until the end of the 1950s when A. V. Krylov and G. A. Tarakanova (1960) "rediscovered" this field of knowledge for plant physiologists. Nevertheless, the works of Savostin can now definitely be considered as classics. In the breadth and depth of the problems he raised he still has no equals in plant magnetobiology. As our purpose does not include a detailed review of these works, we shall limit ourselves to only the basic propositions which follow from them.

Plants are sensitive to the effect of a constant magnetic field. The magnetic field affects the growth of plants and its modification (growth movements), gas exchange, absorption of minerals, movement of protoplasm in the cell, etc.

The effectiveness of the field depends on its intensity and configuration. However, there is no direct correlation between the intensity of the field and the character of responses to it, it acts along many channels at the same time; therefore, the final reaction often does not correspond to the expected.

In addition to the above stated causes, determined by the parameters of the field, its effectiveness is also determined by the age and physiological state of the plant organism, i.e. the stage of ontogeny, daily rhythmicity of exchange, general condition and functional intensity of metabolism. Of course, the informative and energy effect of the environment here plays far from the decisive role, leveling or, the opposite, intensifying the action of the basic factor. In the end, P. V. Savostin comes to the conclusion that the earth's magnetic field is a necessary environmental factor for higher plants, without which their development must as a result be disturbed. Therefore, it is impossible for plant forms to exist for a long period without the magnetic field.

About 25 years passed before interest was again awakened in the biological effect of the magnetic field on plants. A new stage of research was begun by the works of A. V. Krylov and G. A. Tarakanova in the USSR and Audus in Great Britain (both in 1960), who related the biological effect of the field to the phenomenon of magnetotropism. The former understood this term to mean the /166 accelerated germination of seeds, oriented before germination toward the south magnetic pole, in comparison with those oriented toward the north, as well as intensified growth of roots and stems of the "southern" seedlings in comparison with the "northern" variant and bending of the root system in the latter toward the south (tropism proper). They observed this reaction both in the earth's magnetic field and in an artificial field whose intensity reached 400 oe (Fig. 1).

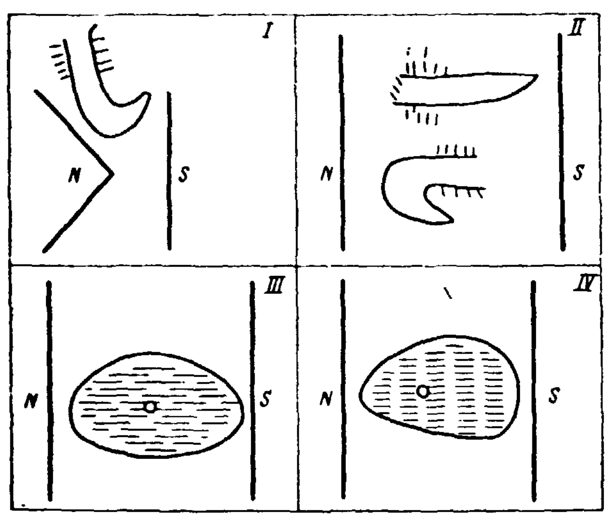


Fig. 1. Various views of magnetotropisms

I — Audus; II — Krylov and Tarakanova; III — Pittman (general view of the distribution of the root system in a magnetic field); IV — the same according to Molotkovskiy and Derevyanko; central point — stem axis

Unlike A. V. Krylov, Audus used magnetotropism to indicate the phenomenon of the bending of the seedling rootlet of watercress in an inhomogeneous magnetic field with a steep gradient toward the side of the field with the least gradient.

A. V. Krylov (1961) himself attached great importance to this phenomenon. He suggested that discovering the mechanism of magnetotropism will throw light on the nature of polarity in plants, the mechanism of photosynthesis, the mechanisms of growth, etc. Not denying the importance of this fact, we, nevertheless, note that, first of all, no one except the authors were able to observe

bendings of the root system, growing in a direction from one pole to the other, in a fairly homogeneous field and, secondly, unequal rate of seed germination during rotation with its embryo toward different magnetic poles was first noted by M. Puma (1952). However, in view of the low "demonstrability" of his tests /167
(they were conducted on only a few plants), the phenomenon was not taken into consideration by biologists. But even from these tests there followed the very interesting fact that in a homogeneous field, germination can be accelerated not only toward the "south" but also toward "north." The problem, evidently, is that not only different plants were used in the tests of these investigators (Krylov as a rule used corn and wheat and Puma used beans), but a different field intensity (Krylov 0.5-400 oe, Puma 400 oe) which is far from indifferent for the formation of a response to the longitudinal direction of the field with reference to the axis of the root. By now there is a sufficient amount of factual material to support the tests of A. V. Krylov and G. A. Tarakanova concerning the existence of differences in germination rate and the rates of subsequent growth of a root system with various orientations of the seed in relation to the vector of field intensity — with or against the lines of force (Novitskiy et al., 1965; Chuvayev, 1966; Abros'kin, 1968; Abros'kin, Zadonskiy, 1968; Travkin, 1969). Pittman (1962-1965, 1967, 1971), in tests showing the existence of magnetotropism of the root system in agricultural crops under natural conditions, discovered essentially a third form of magnetotropism — tropism of the roots in relation to transverse and longitudinal directions of lines of force of the earth's magnetic field. These tests, therefore, did not confirm the "polar" tropism of A. V. Krylov. Nevertheless, we must not exclude the possibility that in the future, conditions will be found for the reproduction of polar tropism which will have to be taken into consideration as a real phenomenon. First of all, evidently, it must be sought in an inhomogeneous field caused by various configurations of polar points, symmetrical to each other, i.e. look for it first of all as mixed tropism. As the phenomenon of polar tropism itself is ambiguous, i.e. as was noted above, it depends on the nature of the plant and the intensity of the magnetic field. With change in the parameters of the field we must expect growth inversions, i.e. reversals of tropism, which was indicated by P. P. Chuvayev (1966). Of course, the limits of the inversion will also be affected by the physiological state of the plant,

determined by a number of external and internal factors. Therefore, when maximum yield of a vegetative mass is required of a culture of higher plants, the distribution of the root system in space, as a factor in the optimum use of mineral elements in the circulation system of a spacecraft, can to a significant degree be determined by the structure of the local magnetic field and, thus, indirectly affect the level of maximum of this mass. However, at the present moment we have no specific recommendations with regard to permissible deviations in the level and gradient of the field in comparison with the earth's, as the /168
question as a whole has received little study.

Stem tropism. With regard to the incidence of this phenomenon, we find only a short description with interpretation in Chuvayev (1967a). Depending on the location of the seedling with regard to the point of the compass and latitude of the place, the angle of deflection of the coleoptile of cereals changes in relation to coordinate axes. However, the author of this work feels that along with the earth's magnetism, coriolis forces are also responsible for this phenomenon. On the whole, in addition to disturbances of nutation movements, observed by P. V. Savostin in peas in a strong magnetic field, until now no other proofs of the effect of the magnetic field on tropic movements of the stem have been produced.

Growth in a constant magnetic field. The growth of plants entirely within a magnetic field (especially a homogeneous field) has hardly been investigated at all. Essentially all tests studying the growth process pertain either to the first stages of seed germination and the growth of seedlings in a magnetic field or to cases when only part of the plant is continuously in the field and the other parts extend outside its limits. In the latter case it is, as a rule, the roots and less often the tips of the stems. The factors determining the degree of effect in these cases are field intensity, its gradient and the physiological importance of the organ exposed to the effect in the life of the plant. With average low field intensities growth will, evidently, be determined by the gradient of the field. On the other hand, with small gradients, field intensity is the factor which determines growth. Let us consider these cases.

The effect of a very weak constant magnetic field on growth was studied by P. P. Chuvayev et al. (1967a, b). Rye, corn and bean seeds were grown in the dark for 7-10 days in a superweak homogeneous magnetic field, produced with the use of Helmholtz rings or a special solenoid with square cross section. The field inside the rings varied between $5 \cdot 10^{-4}$-10^{-3} oe, in the solenoid to 10 oe and in Permalloy chambers to 10^{-4}-10^{-5} oe. The authors were able to show that in a superweak field rye and buckwheat seeds germinate and their growth proceeds in general at the same rate as in the geomagnetic field (to 7 days old). However, the embryonic rootlets in this field are larger in diameter. As the observations of these authors on the growth of isolated wheat roots showed, the larger diameter of the rootlet in a superweak field is due to a delay in differentiation of tissues. In addition, a thicker layer of the primary root is retained, whose surface is covered with tumor-like formations.

With regard to lower plants, under these conditions, cultivations of chlorella (Chlorella vulgaris L.) and euglena (Euglena viridis L.), placed for /169 five weeks in a field of Helmholtz rings, did not reveal essential differences between test cultures and controls (according to optic microscope observations). Only in Azotobacter chroococcum and yeasts (Sach. cerevisiae) after 3½-4 weeks is a delay observed in rates of cell multiplication and an increase in cell size.

These authors also note that in a weak field (10^{-4} oe) differences in germination rates of seeds oriented with and against the vector of intensity of the magnetic field disappear. It is very important that, according to the observations of the authors, placing germinating seeds in a magnetic field daily for 1½-2 hours produced differences in the rate of germination.

The germination of rye (Vyatka), oats (Golozernyy), beans (Kuz'minskiye) and other cultures was studied in a weak homogeneous magnetic field of Helmholtz rings. The effect of two intensities (10 and 20 oe) was studied, directed with and against the vector of the earth's magnetic field (Tarakanova et al., 1965).

It was shown that in both cases orientation of seeds with the embryos along the vector of intensity, more accurately along the horizontal component of this vector, increases growth rates of seeds in comparison with the other direction of the field. This difference on the average does not exceed 15-20%. Such is the picture generally and with horizontal superposition of a constant magnetic field on the horizontal component of the vector of intensity of the earth's field.

In one case of prolonged growth of beans in the light under conditions when their system continuously remained in a homogeneous field 10 times greater than the earth's (20 oe), but the aboveground part extended beyond the limits of this field (Tarakanova, 1968a, b), after 30 days a progressive increase in the length of the root system was ascertained in comparison with the control, despite the fact that available indices generally indicate an unfavorable course of the process in a magnetic field — blackening and increased dying off of root tips. Nevertheless, it was concluded that as a whole, fairly large excess of the field above normal is an unfavorable factor for growth.

In an inhomogeneous field of 60 oe (vertical) and 400 and 12,000 oe (horizontal), a bean root system growing in the field for almost a week in the first case experienced a stimulating effect of the field and in the other two cases, an inhibiting effect. In the latter instances this was primarily expressed in reduction in the length of the roots and their bending. The stimulating effect of the field on growth could reach 20% (inhibiting — 25%). In the light these indices were slightly higher.

As was revealed in cytological studies of sections of a root system exposed to the effect of a magnetic field, the real state of affairs in the ex- /170 ternal manifestation of altered growth pattern is the effect of the field on the process of cell division and elongation of cells in the growth zone. In both visible "stimulation" of growth by a magnetic field and in its inhibition a delay is observed in cell division. Therefore, the visible growth effect is often determined by the state and reactions to the magnetic field of the elongation zone. A detailed analysis of the growth process at the cytological level in a magnetic field is given in her works by V. Yu. Strekova (1966, 1967). The mechanism of the effect of the magnetic field on the elongation zone has not been investigated. But that this is precisely what constitutes the effect of the field on growth is verified by the relatively fast rate of reaction to the actuation of a weak magnetic field of 18 oe by root tips of a 3-4 day old rye seedling placed in Helmholtz rings in a thermostatically controlled glass chamber. Thirty-minute exposure in a magnetic field, alternating with the same length invervals "free of the field," gives a sufficiently clear representation of its effect, expressed by reliable inhibition (Vyatka rye) or acceleration (Gibridnaya-2 rye) of root growth, observed in a horizontal microscope, in com-

parison with intermediary intervals where the vector of field intensity coincides in direction with the vector of intensity of the natural magnetic field. With actuation of a field of opposite direction, on the average it does not alter growth during exposure in comparison with the control; it reliably increases the coefficient of growth variability on the average for shorter intervals in comparison with the control (Novitskiy et al., 1966). The percent of increase of growth in a magnetic field of natural direction varies from 1 to 15. According to the observations of F. F.Leysle and A. V. Nikulin (1967) and A. V. Nikulin (1969), the character of the reaction to the direction of the field can be determined (in addition to the parameters of the field) by biosymmetrization of the seed. Thus, seedlings from left-hand seeds of corn accelerate growth with orientation to magnetic north, and those from the right side to magnetic south. The role of asymmetry in plants in determining the character of their reaction to the earth's magnetic field is discussed in detail in the monograph of Yu G. Sulima (1970) and we shall not dwell on it here. Yu. I. Novitskiy and O. Ye. Fedorova (1969a, b) attempted to apply concepts of biosymmetry to the reaction of seedlings to a magnetic field in the above noted tests with Helmholtz rings. However, under the given specific conditions of the test, the character of the reaction of left, right and symmetrical seedlings to the magnetic field was the same: growth was inhibited by a field of 18.3 oe, directed along the vector of the earth's field (true, least reliably for right and most reliably, $P < 0.001$, for symmetrical) and did not change, on the average, for right and left seeds (and very often not for symmetrical seeds either) when the field was reversed. This does not rule out, /171
however, the possibility that under other field intensities these differences could be observed. In conclusion we point out that one of the causes of recorded differences in the reaction of left and right seeds to the direction of the field could be the slight difference in the weight composition of left and right seeds (when it does occur; Fig. 2). In this case improper sampling could be the cause of the small difference in the energy of germination of like-oriented seeds, which appears in different weight fractions of grain (Fig. 3) and, as a result, rather large differences in the length of the root system.

All this supports the opinion that viewing the magnetic field as a weak stimulus is extremely inaccurate. Sharing the opinion of Yu. A. Kholodov

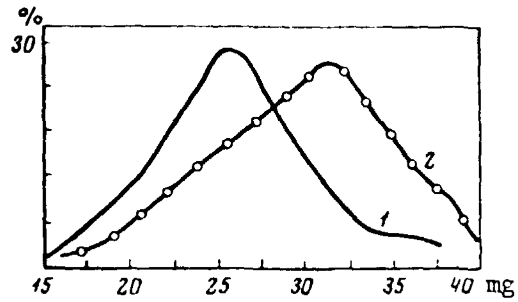


Fig. 2. Curve of weight distribution of right and left seeds in rye (Vyatka) of the 1966 yield

Vertically — incidence in percent; horizontally — weight of one grain in mg; 1 — left seeds; 2 — right

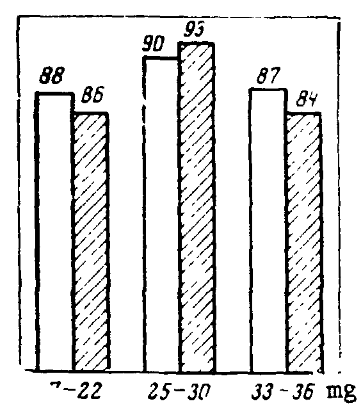


Fig. 3. Energy of germination of left and right seeds of rye (Vyatka) oriented to the south magnetic pole of the earth, of the same weight fractions

Shaded columns with right seeds. Figures above — energy of germination, below — weight fraction

(1965), we can qualify it rather as an "odd" stimulus of the natural order in a range close to that of intensities of the earth's magnetic field, and of an unnatural order in all other ranges. In this connection we must not fail to note that a number of Russian works (Krylov, 1961; Larin, 1965; Novitskiy, 1967a, b; 1969) and those of Pittman (1962-1965, 1967, 1971) verify the opinion that the earth's magnetic field is a natural factor in the distribution of the /172
root system in the soil. A proof of the regulating value of this factor is found not only in tests with an artificial field, causing changes in the direction of increased seed germination with preservation of the original position in relation to the sun and magnetic coordinates of the earth's field (Novitskiy et al., 1966), but also in corresponding studies of the orientation of root systems under natural conditions of an anomalous field in the Kursk magnetic anomaly where the typical preferred distribution of root furrows in two main directions (N-S and E-W) of sugar beets is shifted following a change in mag-

netic declination (Novitskiy, Travkin, 1970). We understand that, in theory, it is incorrect to reduce all orientation of the root system in the soil for many plants to tropic bending under the influence of the earth's magnetic field, all the more as the internal nature and physiological conditionality of this phenomenon remain completely unknown. As we are convinced that other forms of tropisms (thermo-, hydro-, photo-, salitropisms) contribute their own portion to this distribution and here, as in all physiological processes and phenomena, Blackman's principle of limiting factors plays an important role.

Returning now to the intimate aspect of the effect of the magnetic field on plants at cellular, ultracellular and subcellular levels, we point out that, first of all, disturbance of the cell division cycle is one of the most serious aftereffects of the field. In the opinion of B. Yu. Strekova (1967), interphase is the most probable link in the cellular cycle where the effect of field forces is first noted. She feels that the magnetic field by itself, i.e. independently, can cause the appearance of such attributes of this disturbance as bridges, fragments, micronuclei, change in RNA content in the cell, etc. -- in literal agreement with the previously obtained data of M. R. Celestre (1957), true for different objects and with different magnetic field intensities. A. A. Pozolotin et al. (Gattiyattulina, Pozolotin, 1970; Pozolotin, Tarchevskaya, 1970), studying the effect of magnetic fields of various intensities against various radiation backgrounds, suggest that basically, by itself, the field can not cause such disturbances and only contributes to the realization of those due to radiation effects or other causes, i.e., in other words, disturbances depend on the level of radiation effect. This significant moment, concerning the mechanism of the effect of a constant magnetic field, cannot be by-passed in the discussion, as it is generally accepted in other areas of magnetobiology that the effect of the magnetic field reduces the radiation syndrome and lowers sensitivity to radiation, while radiation increases sensitivity to the magnetic /173 field.

However, in the tests of A. A. Pozolotin et al., as a rule, short exposures of test objects in a magnetic field are used (1-5 min.) and radiation largely preceeds magnetic treatment, and the point of its application is the swelling seed during the stretching period. The most important conclusion which follows from these tests is that depending on the radiation dose, the field can either stimulate or depress growth in the post-radiation period, change the course of mitosis, etc. The authors feel that the constant field itself, regardless of its intensity, although it has a biological effect, does not interfere with the course of mitosis and does not cause chromosome aberrations, although it is able to increase mitotic activity in the meristem of peas at the start of the first mitosis after the effect. A constant magnetic field proper can be an active modifier of radiation injury. The same field by itself (8.3 koe) does not affect the mitotic activity of the root meristem of radiated and nonradiated pine seeds. The essential characteristic of the tests discussed above, as has already been pointed out, unlike those of V. Yu. Strekova (Strekova et al., 1965) and those of M. R. Celestre (1957) is relatively brief exposure in the magnetic field, measured in minutes and hours, while in the tests of Strekova it approached several days.

The ambiguity of the reaction to an applied magnetic field depends both on the parameters of the field and on the parameters of the preceeding exposure.

At the same time it is quite well shown today that the individuality of reaction is also determined by physiologo-genetic characteristics of the plant. V. G. Shakhbazov et al. (1965, 1968, 1969) feel that heterotic forms of hybrids, as a rule, are less sensitive to the field. This point of view borders on that earlier expressed by P. V. Savostin (1930) that pure-bred varieties in general are more suitable for studying the effect of the field than random-bred. As follows from the work of A. I. Mochalkin, Rik and Batygin (1962), who studied the reaction of germinating rye, wheat and barley seeds to various lengths of time in fields of several intensities, growth rates of seedlings after magnetic treatment varied in each group of plants very individually, nonuniformly, thereby confirming their dependence (along with other factors) on the genetic nature of the test material.

As the growth process is based on material and energy resources of the cell, illumination of the question of the effect of the magnetic field on cellular energy exchange in plants also seems necessary to us. As magnetic flux /174
density in those areas of the magnetic field with which biology is concerned is relatively small and magnetic permeability of biological objects and their individual parts also differs little from the environment, it is difficult to expect a direct energy effect of the field on the majority of processes occur-

ring in the cell.

However, because energy processes of a living object are an interrelated chain of exo- and endothermic reactions, disturbance of the course of one or several of them, linked in a magnetic sense, entails change in the energy balance of the organism, primarily a worsening. This occurs because the magnetic field is not strictly a determining factor and equilibrium of a living system seems to us to be a dynamic equilibrium, and the magnetic field to a certain degree stabilizes the movement of charged structures, which ion fluxes in the cell, native protein micella and membranes strictly are. Thus, the paradox is that, on one hand, the magnetic fields should in certain cases foster preservation of native properties of the living structure, especially during reduced exchange, and on the other hand, should limit the intensity of exchange in the actively growing organism, as its stabilizing effect is vectoral in nature, i.e. compulsory. A disproportiace effect on exchange would thus be expected from the magnetic field, even with outwardly expressed stimulation of its effect on individual aspects, which are, as a result, temporary. Study of the energy state of plants in a magnetic field has been dealt with essentially only in the works of G.A. Tarakanova et al. (Tarakanova, 1968a, b; Tarakanova, 1969; Tarakanova et al., 1965; 1969), completed exclusively within the last ten years.

The author conducted studies of a culture of beans (Kuz'minskiye variety) raised in the dark in river sand or agar-agar. The seedlings were 4-7 days old. The seeds germinated in an inhomogeneous field on the order of 60 oe; 4.5 and 12 thous. oe. As the index of several aspects of the energy state of the plants in the field, the author selected the degree of conjunction of respiration and phosphorylation processes. It is generally accepted that increased conjunction of these processes means simultaneous increase in the effectiveness of respiration and reduced conjunction means weakening of effectiveness. The index of this conjunction is the P/O ratio. In Tarakanova's preliminary studies it was shown that germination in a magnetic field leads, as a rule, to a reduction in the consumption of oxygen by the objects, regardless of their biological membership in either a homogeneous or an inhomogeneous field of various intensities from 10 to 12,000 oe; in strong fields there is an aftereffect, expressed in a temporary increase of oxygen consumption after /175 the object is removed from the field. In general, the release of carbon dioxide is reduced proportionally so that the respiratory coefficient as a whole does not change. Study against this background, characterizing the state of respiratory gas exchange, of energy ratios showed the following. The proximate aftereffect of the field on isolated bean shoot roots was either stimulation of the consumption of oxygen in the presence of optimum concentrations of dinitrophenol (with a field on the order of 60 oe). i.e. increased conjunction, or reduction in the oxygen consumption (a field of 4.5 and 12 thous. oe), i.e. dissociation of oxidation and phosphorylation. It can be assumed that to a certain degree the proximate aftereffect gives us an indication of the course of processes directly in the field itself while later it indicates the reducing forces of the organism, directed toward removing the developing imbalance in metabolism. In the same way as this, Jitariu et al. (1962) observed that in an electromagnetic impulse field the effect of a weak field has practically no aftereffect while a strong field is characterized by the development of a reverse process in the after effect (in this case increased conjunction), gradually returning to normal. This also means that, in the case of a longer time in a high-intensity magnetic field, compensatory mechanisms of the cell are hardly able to restore energy exchange mechanisms to their original state, as a result of which there is either partial loss of cell viability or death. In this sense, study of the aftereffect of the field indicates the reanimation ability of the organ in response to the effect of the field and the degree of damage produced.

As energy in living cells, along with ATP and ADP, is stored in the form of compounds containing thiol groups through the formation of a macroergic thioether bond, G. A. Tarakanova et al., (1969) discussed the question of the possible effect of a constant magnetic field on change in the content of thiol groups. It was shown that in those cases when no effect of the field on growth appears (swelling rye seeds in a field of 20 oe), the content of SH-groups also does not change in comparison with the control. At the same time in a field of 4 koe with a very pronounced overwhelming effect on the growth of bean roots, a significant reliable reduction of SH-group content is observed. It thus becomes obvious that the field does not act directly on thio-ether groups, but through the growth process. Still another series of works dealing with the

energy state of plants in a magnetic field concerns the interconnection between the effect of fields with a different intensity and spontaneous chemiluminescence of bean shoot roots grown in this field. The authors (Doskoch et al., 1969) were able to show that the level of spontaneous chemiluminescence "correlates" /176
with the intensity of the growth process in a magnetic field: if growth in the field is suppressed, then the level of chemiluminescence also falls, if growth is stimulated then this level increases. From the data obtained they conclude there is a direct effect of the field on the intensity of superweak luminescence, which seems to us very doubtful for many reasons. First of all, the mechanism of this effect in fields of such relatively low intensities is completely unclear; secondly, a similar interrelation between growth and the level of superweak luminescence is also observed in all other effects; and finally, thirdly, change in the character of the effect of a field of the same intensity on growth, depending on a number of attendant factors, causes a corresponding change in the level of spontaneous superweak luminescence (Travkin et al., 1970). Therefore, study of spontaneous chemiluminescence as an indication of the level of equilibrium oxidizing processes in the cell has some value for the general characteristics of the state of energetics of the cell but is only indirectly connected with the mechanism of the effect of the field.

Above we considered the energetics of darkened seedlings in a magnetic field. However, there is no less interest in light energetics, primarily photosynthesis. Works in this area are comparatively few and they have been conducted primarily on two-week-old wheat seedlings grown outside the field. I. A. Tarchevskiy and A. I. Zabotin et al. (Tarchevskiy, 1964; Zabotin, 1965, 1969) in a number of works using a constant magnetic field of 8-10 thous. koe were able to show that photosynthesis in a magnetic field after exposure is reduced 20%. This reduction is accompanied by a disturbance of photosynthetic phosphorylation and a change in the distribution of labeled products in carbohydrates and animo acids. This change is reliable, but not specific; it is typical of many experimental factors and consists of a reduction of the label in free sugars and increased inclusion of ^{14}C in free amino acids. As A. I. Zabotin feels, acceptors of the magnetic field in the cell are macromolecules of cytoplasm whose fine structure is possibly deformed under the effect of the magnetic field.

Summing up what is known today about the effect of a constant magnetic field on plants, we can state the following.

1. As a rule, the temporary effect of a magnetic field on germinating seeds and seedlings has been tested.

2. In the majority of cases plants were not entirely in the field, only parts, primarily the root system.

3. Fields of high and low intensities were effective. High intensity fields (over 1000 oe) as a rule suppress root growth, low intensity fields (10, 20, 60 oe) stimulate it. Inhibition and stimulation of growth are accom- /177 panied by disturbances of mitotic activity in root cells. Evidently, the decisive role in determining the final result is not played by the zone of elongation.

4. The gradient of the field and its direction determine the distribution of the root system in space and, therefore, can affect the mineral nutrition of plants.

5. High intensity fields affect photosynthesis, reducing its intensity and causing changes in the formation of its basic products.

6. The gas and energy regimes of the plant cell are altered: the consumption of oxygen is reduced, the conjunction of oxidation and phosphorylation is changed.

7. Placing a plant in a superweak field (10^{-3}-10^{-4}) causes gradual deformation of the removed object when the plant is put briefly in a normal field.

8. In the majority of cases the effect of strong and superweak fields is reversible when the plants are returned to normal conditions after the object has been in an altered field more than a week. Evidently, 10-15 brief changes in the intensity of a field in both directions are safe; however, final judgment on this question requires special experiments.

9. At the present time it is impossible to construct a good generalized representation of either the mechanism of the effect of the field or the seriousness of aftereffects of such a field on the genetic plane in view of lack of special and reliable experimental proof.

However, it is evidently incorrect to imagine that a magnetic field affects ly objects with a rather high level of metabolism. For example, dry barley, rye, etc., seeds, stored in a magnetic field of 450 oe (Fig. 4) experience an aftereffect in the form of change in the structure and value of yield; there are optimum and maximum lengths of time in a field which variously affect futur development of plants. For barley, for example, two days in such a field has a positive effect in the form of a small reliable increase of yield, but one- and three-day exposure has a depressing effect (Novitskiy et al., 1965). According to the data of M. A. Khvedelidze et al., (1968a, b), wheat of the Ubkho-11 variety is even more sensitive to treatment by a magnetic field. In addition, it has been shown that the field is an active protective factor against the effect of high temperature on the seed (Novitskiy et al., 1965; Novitskiy, 1968) if located along the lines of force of a horizontal magnetic field. As shown in the work of V. G. Shakhbazov, L. M. Chepel' and /178

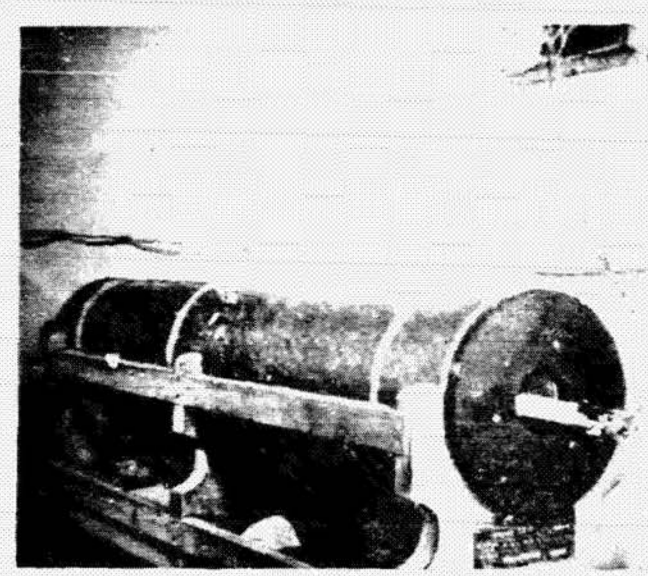


Fig. 4. General view of solenoid for conducting tests with dry seeds Visible is the substrate for the seeds and wires leading to units for recording and maintaining temperature within given limits

P. V. Kotenko (1971), a constant magnetic field can (although not always) be a factor increasing heat resistance of some plants and animals. This conclusion, made by the authors on the basis of many years of research on seeds, plants and insects, is very similar to that developed by the author of this work and chalazonitis, Arvanitaki (1964), and in comparison with a number of other works suggests paths for finding magnetoresistant structures among certain proteins.

This, evidently, far from exhausts the range of aftereffects of a plant being placed in a constant magnetic field.

II. Turning to a discussion of the lower limit of sensitivity to a constant magnetic field, we should immediately point out that such a statement implies acknowledgement of the fact that a constant magnetic field is not indifferent for the existence of a plant, and that not only change in the value or direction of a field is reflected in the vital activity of the plant, but the level itself of this field is of some importance.

When Reinke (1876, 1882) posed the question of the sensitivity of plants to a magnetic field, he had in mind the first half of the problem as he was trying to find the relation between daily variations in the earth's magnetic /179 field and daily variations in growth. We know he did not ascertain this relation. On the other hand, exploring the question of the effectiveness of a constant magnetic field of high intensity on freely suspended algae particles, he also noted no significant effect, understanding by this the orienting ability of the suspended particles in the magnetic field. At the same time, such an effect, evidently, does exist in these and slightly higher intensities (Savostin, 1928; Ambroze, 1965, and others) related to that obtained in torsion balance and similar devices (Khvedilidze et al., 1966; Novitskiy, 1966, and others). It is clear that this phenomenon is based on a magneto-mechanical effect which is also inherent in non-living objects and is determined by the molecular composition of the cell, organ, etc. It is sometimes completely veiled, however, because the object as a whole can emerge as diamagnetic and paramagnetic due to change in the intensity and direction of metabolism and primarily in processes connected with the movement of protoplasm (see Savostin, 1928).

However, this is a question of how the cell behaves in a field rather than how the field affects the cell, understanding the latter in a physiological sense, i.e. what effect the field has on vital functions of the cell.

We still cannot consider the passive turning itself of suspended cells in a magnetic field as proof of the physiological effect of the field. If the possibilities for such turning are limited, then the effect of the field should be expressed in a change in the rate of movement of protoplasm (Savostin, 1928), which is a necessary attribute of active vital activity and, therefore, a field of 10,000 and 5000 oe will affect the vital activity of the cell. If we take the rate of protoplasm movement as the index of effectiveness of the field, then we can reduce the level of the field which markedly affects that rate in comparison with ordinary earth conditions from 10 thous. to 20 oe (Novitskiy et al., 1966).

Several other physiological indices which are also changed at the new level (excretion of oxygen, consumption of carbon dioxide, rate of growth of the root system and the above-ground part), verify the actual effectiveness of this level of field intensity. It is interesting to note that even in these extremely wide limits of effectiveness of the field on the plant of three orders of magnitude ($10-2 \cdot 10^3$) differences in this effectiveness are not very large, and within the limits of the tested exposures the field causes practically no fatal outcome or changes in any physiological index more than 50%. True, changes at the cytological level are greater (Celestre, 1957; Dunlop, Schmidt, 1964, 1965), but only rather lengthy tests can here lead to serious after-effects. Noteworthy is the fact, indicated by P. V. Savostin (1930), of non- /180 proportional (in relation to field intensity) response of seedlings when a field of 1600 oe had absolutely no visible effect on growth of the coleoptile and 60 oe caused a stimulating effect. This is presented well in the theory of stimulation and stimuli in plants (Bos, 1964; Gunar, 1953) and illustrated by the curves obtained by A. N. Mochalkin, G. R. Rik and N. F. Batygin (1962). However, a magnetic field is also a very "odd" stimulus for plants (Kholodov, 1965). First of all, it is a very unstable stimulus, within certain limits depending little on field intensity and extremely dependent on attendant factors (physiological activity of the object, astronomical factors, radiation level, etc.).

But, nevertheless, recent data indicate that a constant magnetic field is effective even two orders below the earth's (Dycus, Shultz, 1964). (Unfortunately, comparative prolonged tests have not been conducted where plants would be grown in weaker fields from seed to seed nor has genetic analysis been made of generations from these fields).

Therefore, we cannot fail to indicate that the question of the lower limit of sensitivity to a magnetic field is closely connected with the importance of a weak magnetic field for plants, or more accurately, the earth's magnetic field as an ecological factor (Chuvayev, 1967a, b).

We recall that Savostin (1937) attached great importance to this factor as a "coordinate" which together with other natural "coordinates" — force of gravity and rotation of the earth — "controls" the location of the plant in space and creates conditions for proper realization of hereditary properties. On the other hand, G. Braun (1962), J. Palmer (1963) and others look differently on the problem of the effectiveness of a weak magnetic field, seeing in it a time coordinate, controlling the periodicity and course of physiological and biochemical processes in plants and other organisms, along with "internal clocks." Thus, the majority of authors of this persuasion conclude that with the help of the magnetic field as one of the geophysical factors, space-time relations of the organism are controlled in the environment. Since, however, not one of the geophysical factors can be a perfectly constant coordinate, it can be assumed that the plant analyzes them together so that a slight temporary change in one factor still does not cause a significant reaction in the living object or else it leads to slight changes. In turn this suggests that within certain limits of intensity, not the value of field intensity, but rather the very fact of its existence and its direction can play /181
the role of "coordinate" and thus a physiological reaction (theoretically "all" or "nothing") of maximum or minimum occurs here. But this also means that under conditions of a "minimal field" or when the sensitivity of the plant to the field is reduced, all physiologically-acting factors will essentially affect the ability of the organism to determine the presence or absence of the field, as well as its position along or across the lines of force.

If the physiological reaction to the magnetic field is considered more or less unstable through almost the entire range of considered intensities, then it can only mean that the mechanism of realizing the reaction according to the above principle ("all" or "nothing"), the material carrier of this mechanism, is sensitive to the "foreign factors" to no less degree (and possibly even to a greater degree) than to the magnetic field itself.

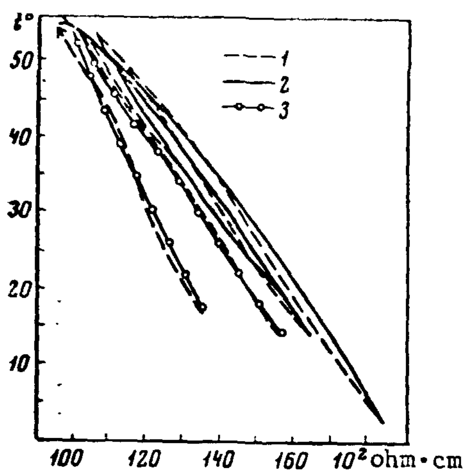
It seems to us that the only system satisfying these conditions would be a high-polymer gelatinous structure in an unstable state, capable of containing within itself properties of a true and colloid solution, sol and gel. This structure is protoplasm as a whole, but individual traits in the behavior of such a structure can be clearly traced in the behavior of a model in the form of agar or starch gelatin in a low-intensity magnetic field. Earlier (Novitskiy, 1966) we reported change in the electrical conductivity of agar and starch gelatin in a constant magnetic field of Helmholtz rings.

However, we repeatedly encountered cases when a "constant" magnetic field did not affect the electrical conductivity of the gel. Analyzing these, we came to the conclusion that the cause could be either the appearance of a variable component of the magnetic field resulting from disturbance in the power supply of direct current rings or the effect of specific electromagnetic radiation accompanying solar flares, as well as the space-statistical character of the reaction in the control.

It is rather well known (Shur, 1966) that a constant electric field has an orienting effect on solutions of high-polymer, high-molecular compounds; electric field energy is used here for priming, to begin the orientation process. Later the process occurs spontaneously with release of energy.

However, if a variable electromagnetic field is applied to a given polymer solution (on which a constant electric field has been superimposed) or if it is radiated with a high dose of radioactivity, then the ability of the high-molecular solution to form an orienting structure is sharply reduced or completely disappears. It is clear that the "disrupting" action of an electro- /182
magnetic field of the same value will be much stronger on the orienting effect of a magnetic field, as the orienting effect is very slight (Dorfman, 1966). Fortunately, the spontaneous mechanism of the reaction makes it possible in a high-molecular system, but change in the viscosity of the system, achieved in artificial systems by changing the temperature and in natural systems by altering permeability or concentration of ions, is fixed (although temporarily) in the form of an oriented structure whose properties vary according to directions along and across lines of force of the magnetic field.

It seems to us that only from the viewpoint of such a mechanism can we explain the change in the electric resistance of gels, measured at a frequency



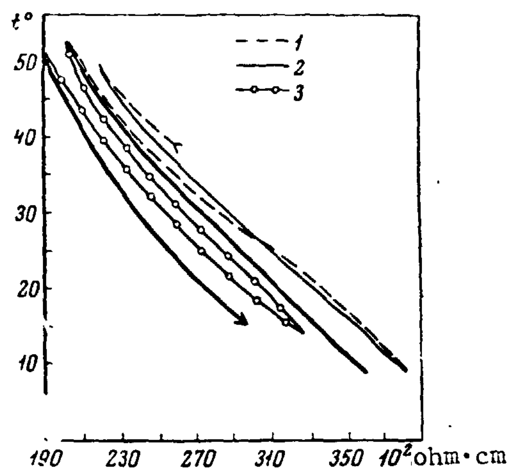


Fig. 5. Change in the resistance of a 0.5% starch gel in a magnetic field (3) of 8 oe with periodic raising (1) and lowering of temperature (2)

Horizontally — electric resistance of 10^2 ohm·cm; vertically — temperature in Celsius degrees.

Fig. 6. Change in resistance of a 0.5% agar gel in a magnetic field of 8 oe with periodic raising and lowering of temperature

Horizontally — electric resistance of 10^2 ohm·cm; vertically — temperature in Celcius degrees.

Notation same as in Fig. 5.

of 50 Hz with an almost vertical (74°) constant magnetic field of 8 oe (Figs. 5 and 6). As evident from the illustrations, the electric resistance of gels (and agar-agar and starch as well) changes with gradual successive increase and decrease of temperature. Electric resistance is reduced every time the temperature is increased (general slant of all curves to the left) and it in- /183
creases when the temperature is lowered (deviation of lower part of the curves to the right). In a hermetically sealed vessel, excluding evaporation, the general course of curves of electric resistance, depending on temperature, is shifted in the majority of cases with respect to its original position. As statistical analysis of the tests shows, this shift appears in 70-80% of the cases

almost equally toward reduction as toward increase of electrical resistance. After a certain number of sessions of repeating the series of raising and lowering temperature, the course of the curve is stabilized and shifting ceases. When the position of the container with the electrodes remains constant, it stays that way indefinitely.

In applying an artificial field (in our cases directed almost vertically) to the vessel, in the overwhelming majority of cases, regardless of the initial course of the curve shift, when the temperature cycles resume, the curves begin slowly shifting to the left, i.e. toward a drop in resistance, until this shift again attains a definite stationary state (blending of successive cycles, which in the figures is reproduced in the form of a solid heavy line). As experience shows, further shifting of resistance is not observed, even when the intensity of the magnetic field is increased 2.5 times (from 8 to 20 oe).

Analyzing these curves, it can be understood why a given phenomenon is not always observed if it is connected with orientation of super-molecular or molecular formations. This is because, in the absence of a clear decisive factor, as the result of spontaneous polymer orientation this direction can be largely arbitrary, determined by random causes. We can also understand why the ability to "orient" appears with repeated alternating increase-decrease of temperature. Because the effective "orienting" magnetic start is rather weak and appears as a "magnetizing" factor only when the order of orientation forces coincides with the external field, Brownian movement and polymerization orienting forces. As forces acting on the part of the magnetic field are rather weak, all new material units are gradually involved in the orienting process by repetition of the temperature cycles. However, it is also possible to find another interpretation of these tests if it appears that a given phenomenon is not accompanied by anisotropy of resistance. In particular, one of these interpretations could be recognition of changes in the character of the water-material (agar, starch) bond under the influence of the magnetic field.

It seems to me that such a point of view, in theory, does not contradict /184 the already known fact that glial cells of the brain, structurally the least specialized and differentiated, are the first to react to a magnetic field (Aleksandrovskaya, Kholodov, 1966). These data make it possible to construct the first, although not perfect, model colloid systems containing no traces of iron and sensitive to a magnetic field on the order of 5 oe. We feel that thorough physico-mathematical and physico-chemical validation of such a model will make it possible to calculate optimum and maximum limits of sensitivity of given systems to a constant magnetic field.

From the literature it is known that the structuring ability of starch and especially agar gelatins is very high and depends on such factors as the level of radiation, light, contact with metallic surfaces, etc. At the same time, the sensitivity of individual colloid structures in the transition from gel to sol to such astronomical factors as solar flares, the position of a given point on earth with reference to the ecliptic plane, has already been studied in part (Picardi, 1962; Chizhevskiy, 1964).

In relation to plants this was shown by A. P. Dubrov and Ye. P. Bulygina (1966).

Protoplasm, a "simultaneous synthesis of all these states," as a vastly more complex structure should also be vastly more sensitive to any of these factors. The above allows us with certain confidence to refer to facts presented in the work of Dycus and Schultz (1964), where the difference in effectiveness of 0.5 and 0.001 oe fields was quite clear. Nevertheless, their work does not allow us to establish the location of this limit of sensitivity to the field in a given specific population of plants. It is evidently to be found where the difference in behavior between plants placed in succeedingly reduced fields disappears i.e. below a given level for a given group of plants a constant magnetic field does not exist.

In this connection it seems that even taking into consideration the effect of all the above attendant factors, raising and lowering the sensitivity of the cell to the field, the physiological and genetic adjustment itself of the plants (Shakhbazov, 1966) will be of great importance.

Let us give this example. Earlier we (Novitskiy, et al., 1966) as well as Pittman (1962) showed that orientation of root systems in nature and experiment is determined not only by the sun but also by the earth's magnetic field. However, perhaps only purebred varieties have similarly expressed orientation of root systems. Analysis of the orientation of root furrows and lateral root systems in sugar beets and radishes (Dunganskiy) (Table 1) led us to conclude

TABLE 1. ORIENTATION OF ROOT FURROWS OF BEET AND RADISH ROOTS IN NATURAL AND ARTIFICIAL MAGNETIC FIELDS

Kind, variety	Place and time of determination	Declination	Number of samples examined	Orientation of furrows %				No strict orientation
				N-S	E-W	NW-SE	NE-SW	
Sugar beet Verkhnyaskaya	Moscow, 1964	0°	360	38	50	2.0	0.8	9.2
Sugar beet Velotserkovskaya	Kaluga dist. 1967	5°	10,220	54.3	36.4	3.2	1.9	4.2
Sugar beet Yaltushkovskaya	KMA, 1969	48°	1,086	39.3	26.9	8.3	7.6	17.8
Sugar beet Ramonskaya	KMA, 1969	13°	1,797	50.6	29.6	7.2	9.3	3.3
Radish Dunganskiy	Skhodnya 1966	0°	377	61.3	34.7	1.5		2.5
Radish Rozovyy s konch.	Moscow, Slavyansk	45° H-5 oe	360	38.9	25.7	7.2	8.9	20.3

KMA — Kursk magnetic anomaly

that in these populations two main directions in relation to the magnetic meridian are determined (90%) — along and across — with a reliable predominance in test varieties of the longitudinal direction. Considering these two types of plants from the point of view of either hypothesis — the resonance effect (when the frequency of forced mechanical oscillations of the system coincides with its own frequency) is secondary (Dorfman, 1966) or from the point of view of the above assumptions — we must come to the conclusion that these two groups of plants differ in the sensitivity of their systems to a constant magnetic field, both as a reference point and as a stimulus. Therefore, they are arranged most advantageously with regard to this stimulus in order that the level of the signal is not too high or low. It is difficult to tell which of them is more sensitive to the field. It would follow that certain groups, by their sensitivity to the stimulant, can belong to different physiological types of plants. But this gives us the opportunity to organize sensitivity to the field depending on the physiological type of the plant.

The tests of Dycus and Schultz and our tests in the earth's field, as well as those of Pittman, plus the above, make it possible for us to determine the lower limit of sensitivity to the field at a el not over 0.01 oe.

In constructing a model of a system sensitive t gnetic field according to the above indicated principle, therefore, we not forget that it should also ultimately reflect the idea of "physiological types" in the perception of a stimulus.

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THE LEVEL OF SPONTANEOUS PHAGE PRODUCTION IN THE LYSOGENIC SYSTEM E. COLI K_{12} AS A TEST OF SOLAR ACTIVITY

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It has now been established that many processes in the biosphere are /189
closely connected with solar activity. The work of A. L. Chizhevskiy (1938) first generalized and analyzed extensive material concerning the correlation between solar activity and the course of pandemics and epidemics of cholera, influenza, relapsing fever, plague, diphtheria, meningitis, poliomyelitis, etc. Chizhevskiy showed that the rhythm of these epidemics and pandemics coincides with the rhythm of solar activity. At about the same time, S. T. Ver'khover (1935, 1936), in elaborating the ideas of Chizhevskiy, spent years in close observations of the metachromasia of Corynebacteria. As a result, such a close connection was established between metachromasia of Corynebacteria and solar activity that the degree of metachromasia could be used as a test of solar activity (Chizhevskiy-Vel'khover effect).

These works indicate that the development and behavior of microorganisms to one degree or another are controlled by solar activity. This is seen in the biosphere in the form of changes in various helio- and geophysical factors. Therefore, it can be assumed that all microbiological processes, depending on external physical conditions, can to some degree depend on solar activity. One of these processes is the production of phage by lysogenic bacteria.

Many investigators studying this phenomenon note that the proportion of bacteria in a population of lysogenic cells producing phage varies. This suggested to several authors (Lwoff, Gritmann, 1950) that the formation of phage can be induced by external factors. Later such inducing factors were ascertained. They include, in particular, gamma, roentgen and ultraviolet rays. On the other hand, the cause for variation in spontaneous production of phage by lysogenic bacteria has remained unexplained. According to the suggestion of Kh. Markovich (1956), spontaneous lysis is fostered by natural ionizing factors. However, there are no experimental proofs of this and no other suggestions in the literature. /190

The above led us to analyze the phenomenon of spontaneous phage production by lysogenic bacteria in connection with solar activity. We proceeded from the assumption that variations in the spontaneous production of phage are caused by changes in geo- and heliophysical conditions.

MATERIALS AND METHODS

Bacterial strains. E. coli k_{12} (λ) is a lysogenic strain for phage λ in which the level of spontaneous production of phage was studied. E. coli STZ^R-500 — the indicator strain for phage, λ is resistant to 500 units of streptomycin per 1 ml medium.

Medium. Liquid medium for growing a population of lysogenic bacteria — beef heart bouillon with yeast hydrolysate (medium No. 11). The lysogenic culture grown in this medium is distinguished by a high level of spontaneous phage production. The liquid medium for growing the indicator strain — MPB (meat-peptone bouillon). The medium for titration of phage — 1.3% MPA (meat-peptone agar) with the addition of $MgSO_4$ to a concentration of 0.01 M. The upper layer — 0.7% MPA The medium for dilution — 0.85% solution of NaCl.

The cultures were kept refrigerated at a temperature of 4° in beveled MPA and resown weekly.

The typical test consisted of the following. An eighteen-hour culture of E. coli K_{12} (λ) in medium No. 11 was diluted in fresh medium 1:100 and placed on a rocker at 37°C. Samples were taken from the growing culture to determine the number of viable bacteria by sowing on agar, and the number of liberated phages was determined by Bertani's streptomycin method (1954). Increase in the population was traced by photocolorimetry. The test was made daily at the same time.

RESULTS AND THEIR DISCUSSION

We first studied the change in the amount of phage liberated during lysis under natural conditions in four samples at hourly intervals (in a culture of lysogenic bacteria). The first sample is from the initial phase, the other three from the exponential phase of development of the bacterial population. Fig. 1 gives data on an experiment conducted from March 22 to May 16, 1969 (numbers of the curves coincide with those of the samples).

From these results it is evident that all four curves have the same shape; this means that the factor promoting cell lysis is not random. It is also evident that the proportion of cells of the bacterial population subject to lysis under normal conditions is really extremely variable. Finally it must /191

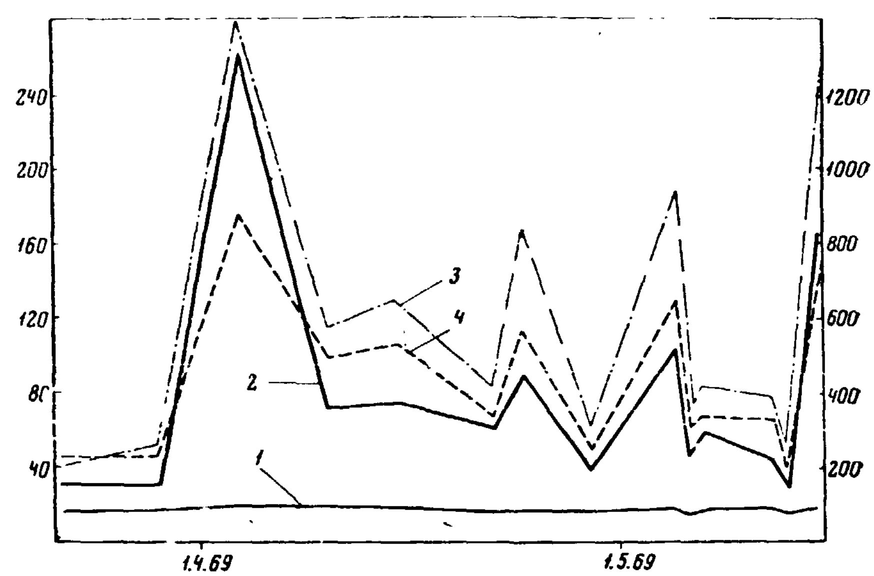

Fig. 1. Change in the amount of liberated phage under normal conditions in a culture of lysogenic bacteria

1-4 — first-fourth samples, respectively, vertically — scales of the curves; 1, 2 indicated on the left, 3, 4 on the right; horizontally — time scale of the test

be noted that cells are most sensitive in the exponential phase of growth. This agrees with the classic assumptions of biochemistry and physiology about microorganisms, according to which metabolic processes are most intense in the exponential phase and cells are most sensitive to changes in external conditions and inductive actions during this period.

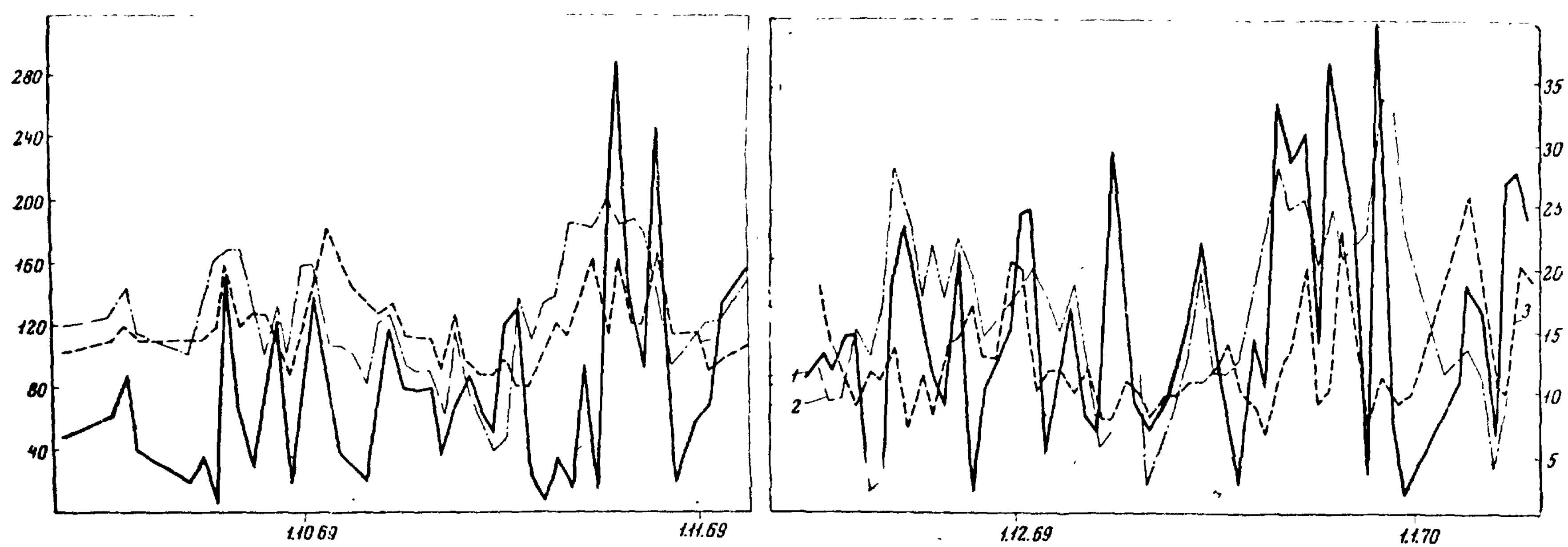

Fig. 2. Time dependence of the amount of liberated phage (1) and Wolf numbers (2), the intensity of solar radio-frequency radiation flux at 200 Mc (3) for December 9, 1969-October 1, 1970

Horizontally — time scale; vertically — scale of curves (1, 2) on the left and (3) on the right

The described preliminary two-month experiments made it possible for us to proceed to the next studies whose purpose was quantitative determination of the degree of correlation between spontaneous lysis and solar activity. Here we were limited to the two most significant samples (the second and third). As the result of continuous daily (with the exception of several days due to circumstances beyond our control) observations, we obtained the data given in Figs. 2 and 3. Fig. 2 gives the time the test was conducted (calendar dates) along the horizontal axis. Curve 1 represents the time dependence of the amount of liberated phage per unit of optic density of the bacterial population in the sample. Curve 2 — the daily Wolf number (data from the Kislovodsk astronomical observatory). Curve 3 — the coefficient of solar radiation at a frequency of 200 Mc (Moscow data). Fig. 2 shows that all three curves have a very similar /192
shape. Correlation analysis produced a coefficient of correlation between the amount of liberated phage and Wolf numbers of 0.79, with a probability of 0.99 ($P < 0.01$); corresponding values for radio-frequency radiation flux were 0.69 with a probability of 0.99 ($P < 0.01$).

In Fig. 3, curve 1 is the same as in Fig. 2; curve 2 is the horizontal component of the geomagnetic field intensity at the hour of the experiment. The coefficient of correlation between the first and third curves is 0.71 with a probability of 0.99 ($P < 0.01$).

We compared the data of our experiments with the course of one of the most common indices of geomagnetic activity — the so-called K-index. The comparison showed that correlation between the K-index and the amount of liberated phage is considerably less. This is evidently because the K-index is interpolated by means of rather rough averagings.

In the course of all the above curves, 27 and 13.5-day rhythms are clearly evident. The first is due to the synodic period of the sun (approximately 27 days) and the second indicates that the centers of activity causing the change /194
in terrestrial processes (in this case — in geomagnetism and the development of a culture of E. coli) are distributed in antipodal heliographic longitudes. We note that, according to the observations of a number of authors, the latter rhythm is often more pronounced in earth processes and not in manifestations of activity visible on the surface of the Sun.

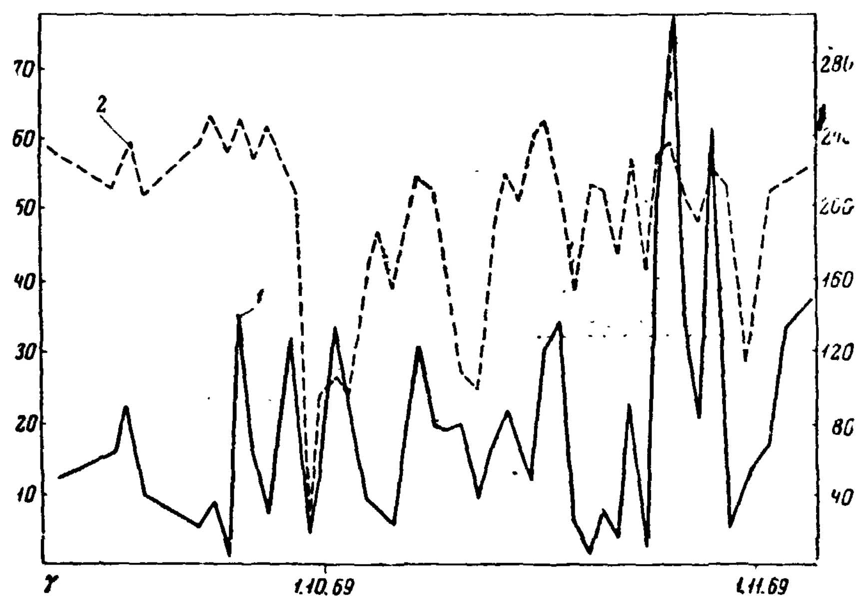

Fig. 3. Time dependence of amount of liberated phage (1) and the horizontal component of the geomagnetic field at the time of the experiment (2)

Vertically — scale of curves: 1 — on the ri ıt, 2 — on the left; horizontally — tıme scale

The results of our studies can be summarized as follows.

1. There is a close connection between solar activity and the state of lysogenesis of bacteria E. coli.

2. The lysogenic system E. coli is a sensitive microbiological test of solar activity.

3. Variations in the spontaneous foundation in lysogenic bacterial systems are caused by variations in geo- and heliophysical conditions. Therefore, actually the background is not spontaneous, but predictable.

4. In all microbiological tests, experimentors must take into consideration the high sensitivity of bacterial systems to changes in geo- and heliophysical conditions. In particular, this must be taken into account in selecting the time of the experiment.

5. Of the standard indices of solar and geomagnetic activity, the best correlation with the microbiological test of solar activity is seen in daily Wolf numbers.

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DISTURBANCES OF THE EARTH'S ELECTROMAGNETIC FIELD AND THE PROBLEM OF HELIOBIOLOGICAL CONNECTIONS

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A. L. Chizhevskiy not only established the fact of the very existence of a /195 connection between solar activity (SA) and processes in the biosphere, but studied in detail these connections in a vast amount of material. He expressed the important idea that the essential role in the mechanism of this connection must be attributed to electromagnetic phenomena.

At the present time the degree of study of electromagnetic phenomena reaching the surface of the earth is such that Chizhevskiy's concept can be used as the basis for formulating a working hypothesis provable by experiment. In condensed form this hypothesis is as follows: solar activity can affect processes in the biosphere through increased intensity of the variable electromagnetic field (EMF) in the frequency range corresponding to low-frequency "transparent windows" in the ionosphere. It has been shown (Vladimirskiy, 1970) that such an assumption in fact follows directly from analysis of empirical data relating to the effect of individual sporadic effects of SA (large chromospheric (solar) flares, magnetic storms) on several parameters of physico-chemical and biological systems. In these "transparent windows" — they are located in the frequency range of 1-10 kc and 5kc-1 Mc — the field intensity reaches impressive figures and varies widely. These variations of intensity are closely connected with SA; the character of this connection itself is complex because it is mediated by processes occurring in the earth's magnetosphere (particularly in radiation belts). For example, the intensity of the electric vector on one frequency band near 5 kc with undisturbed conditions is about 1 mV/Mc. During disturbances the intensity can increase an order of magnitude (during strong disturbances — two orders); disturbances can last many hours. These increases in field intensity are often observed several days after the sudden commencement of a magnetic storm. However, they can also appear in periods when the magnetic /196 field is relatively quiet. According to international classification, this type of phenomenon is designated as Pc1. The main phase of a magnetic storm is usually accompanied by a wide-band emission with slightly lower frequencies (type P1). At the same time cosmically originating field intensity also increases in another range — audio frequency (2-10 kc); usually significantly in the aurora zone. This phenomenon has been called magnetospheric hisses (Troitskaya et al., 1969). In the lowest frequency range are located the natural frequencies of the magnetosphere, brief-period fluctuations of the magnetic field of the Pc2-Pc5 types. More detailed information on these and other phenomena not noted here can be found in reviews (Troitskaya, 1966; Heutquist, 1966; Kimura, 1967). It is important to note that as the mechanisms of the disturbance of various types of fluctuations are different, the amplitude and frequency of their appearances change variously during the course of the 11-year solar cycle.

The biological effect of EMF in the low and ultra-low frequency range in the low-intensity region has had absolutely no investigation. At the same time it is evident that the assumption that SA affects the biosphere through changes in EMF intensity can be considered valid only when the effect of the corresponding EMF on the organism is perfectly analogous to the effect of SA. Special experiments are, therefore, necessary. Such experiments have been carried out at the Crimea medical institute, USSR Ministry of public health (Simferopol). Several results of these tests on mammals have already been reported (Volynskiy, Vladimirskiy et al., 1969a, Vladimirskiy, 1970). Briefly noted below are the results of experiments with microorganisms.

Various kinds of bacteria were selected for the study: standard strains of Salmonella, Shigella, Escherichia, Staphylococci, Anthracoid and Corynebacteria diphtheriae. In these experiments cultures were placed in a 0.4 x 0.5 x 0.5 m condenser attached to a thermostat. Condenser plates were supplied with sinusoidal voltage from a generator whose operation was systematically controlled. In the ultra-low-frequency range, tests were conducted at frequencies of 1, 0.5 and 0.1 Mc with field intensity of 0.3-0.4 mV/m. For frequencies in the audio range, the "action spectrum" in the interval 0.3-10 kc was taken. Field intensity was $5 \cdot 10^{-3}$ mV/m. These field intensities were approximately 10 times higher than the background. Exposure was continuous and usually lasted 18-20 hours.

We studied the effect of the EMF on the vital activity of bacteria, the intensity of reproduction, sensitivity to antibacterial drugs, genetic apparatus, as well as morphological, cultural, enzyme and antigen properties.

The intensity of reproduction was calculated by change in the degree of transparency in a photoelectronic nephelometer, the number of viable individuals was determined by the number of colonies formed in a meat-peptone agar after filtering various dilutions of "radiated" and control cultures. Sensitivity to penicillin and streptomycin was tested in solid and liquid nutrient media. The mutagenic effect of EMF was evaluated by detection of auxotrophs. Enzyme activity of bacteria was studied in liquid media with carbohydrates; calibrated floats were used for gas trapping. Antigenic properties were studied in the reaction of agglutination with monoreceptor and visible serums. /197

TABLE 1. RESULTS OF THE ACTION OF EMF OF ULTRA-LOW FREQUENCIES ON SEVERAL MICROORGANISMS

Strain	Field frequency Mc	Number o[illegible]: Total	Number o[illegible]: Stimulation observed	Average increase in no. of colonies, %	Morphological properties
S. typhimurium	0.1	23	20	320	Gram negative, slightly shortened bacilli
	0 [illegible]	10	8	286	" "
	1 [illegible]	10	8	190	Filamentary forms observed
Staph. aureus	0.1	26	19	180	Typical, no changes
	0.5	10	6	140	" "
	1.0	12	7	230	" "
Bac. anthracoides	0.1	22	18	150	Typical, no changes
	0.5	10	7	250	" "
	1.0	10	5	120	" "

These experiments have established that EMF of both ultralow and audio frequencies affect the vital activity of the tested microorganisms. Cultivation in EMF with frequencies of 0.1, 0.5 and 1 Mc revealed an increase in the rate of reproduction of bacteria, the number of colonies formed when test samples were filtered regularly exceeded that in the control (Table 1). The enteral group of bacteria was most sensitive to the effect of EMF. With filtering, Salmonella and Escherichia formed 2.8-3.9 times more colonies.

Studies in the frequency range from 0.3 to 15 kc showed that EMF with frequencies of 2.6 and 10 kc (Fig. 1) have the most pronounced biological activity. Cultivation of microbes in these frequencies was also accompanied by more intensive reproduction and the formation of a larger number of colonies in fil- /198 terings of "radiated" cultures. Sensitivity to antibiotics changed in the test

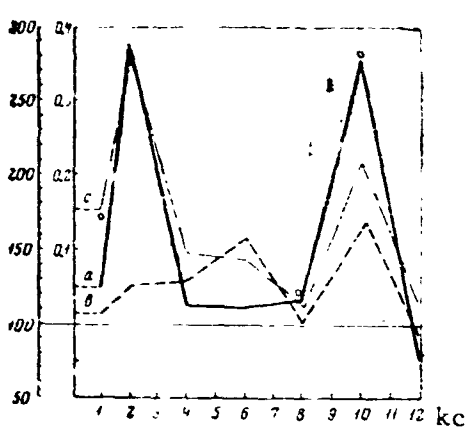

Fig. 1. Dependence of the intensity of bacteria reproduction on EMF frequency

Horizontally — EMF frequency in kc; Vertically — intensity of bacteria reproduction in percent of control; a — S. typhimurium; b — Staph. aureus; c — Bac. anthracoides; o — the effect of the electromagnetic treatment of water on electrophoretic mobility of silicium

strains. They acquired the ability to grow in the presence of penicillin and streptomycin in concentrations double that in the control. This property was not stable and was not retained in succeeding cultures.

To develop bacteria with disturbed metabolism 5000 subcultures were studied after growth in EMF of ultra-low frequencies; 3 variants were found which lost the ability to grow in a minimal medium. Twenty thousand colonies cultivated in EMF with frequencies of 1-15 kc were studied; 22 subcultures were distinguished with a disturbed type of nutrition. After 3-4 seedings, all these cultures reestablished the prototrophic type of nutrition. In control cultures no bacteria with a nutrition deficit were detected. It is typical that the cultivation of Salmonella, Shigella and Escherichia in EMF in media containing antibiotics was accompanied by a high incidence of bacteria with disturbed metabolism, which was also restored with succeeding inoculations. Growth in media with antibiotics without EMF treatment was accompanied by the formation of auxotrophic mutants which stably preserved the acquired requirement in amino acids.

The morphological and cultural properties of bacteria after "radiation" changed only very slightly. Microscopy of Corynebacteria diphtheriae revealed some polymorphism. Growth in Martin's bouillon was accompanied by the formation of a coarser waxy film. These cultures fermented the same carbohydrates as the initial cultures, but with more pronounced gas formation. The antigenic structure of Salmonella, Shigella and Escherichia remained unchanged.

These results agree with some already-existing data. In particular, the above described changes in Corynebacteria somewhat resemble changes correlated with SA detected by S. T. Vel'khover and A. L. Chizhevskiy (1936, 1963). /199

It is interesting that F. Vering (1958) and P. Becher (1963) observed the inhibition of bacteria growth in their cultivation under a metallic screen. With screening, the intensity of the natural EMF is reduced (toward the higher frequencies). Therefore, with a higher intensity it is logical to expect a stimulating effect.

The "action spectrum" has the same character as for frequencies in the microwave region (Webb, 1968, 1969). As Fig. 1 shows, it coincides with the action spectrum obtained for a simple colloid solution (Ficher et al., 1968). This can, evidently, be considered as an indication of the validity of the concepts developed by L. D. Kislovskiy (1970), i.e. that the basic mechanism of the effect of EMF at the molecular level is found in the structural reorganization of water.

Obviously, the results of these tests can be considered a certain experimental verification that the effect of SA on biological processes is connected with electromagnetic disturbances. The idea of A. L. Chizhevskiy, expressed more than 30 years ago, is, therefore, evidently confirmed.

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MITOSIS AND THE MAGNETIC FIELD

(Brief review of literature)

V. Yu. Strekova

All living organisms on earth for thousands of years have been continually experiencing the effect of various environmental factors (temperature, the gravitational field, barometric pressure, ionizing radiation, etc.) and, evidently, each of these factors has played its role in evolution.

Some investigators feel that cosmic rays which reach the surface of the earth are one of the factors of evolution responsible for the mass of spontaneous mutations (Kol'tsov, 1935; Nadson, 1935; Tobias, 1959, and others), although no strong proof is presented.

It is also suggested that the earth's gravitational field has a definite effect on the physiology of cellular and subcellular structures and in the first stages of cleavage of the fertilized egg the axes of the body could be specificially oriented in the gravitational field (Sisakyan et al., 1962).

However, until recently the ecological role of the earth's magnetic field has been underestimated. The biological importance of the terrestrial magnetic field was limited to protecting the surface of the earth from cosmic rays.

Now numerous data have been accumulated showing that change in the intensity of a magnetic field in comparison with that of the earth has a significant effect on various aspects of vital activity (Savostin, 1937; Murphy, 1942, Puma, 1952; Krylov, 1961; Tarakanova et al., 1965; Strekova et al., 1965; Novitskiy, 1967, and others). Therefore, it can be assumed that the natural magnetic background of the earth, along with other environmental factors, is a necessary, evolution-determined condition for the normal vital activity of organisms. Possibly P. V. Savostin (1937) is right: he feels that the magnetic field and the gravitational field of the earth aid in the realization of hereditary properties in ontogeny.

With flight into outer space, the entire complex of environmental factors is altered and the intensity of the magnetic field is also changed. It is known that the intensity of the magnetic field in interplanetary space is tens of thousands /201 of times less than the earth's magnetic field (Dolginov, Pushkov, 1963). In addition, space research includes plans to use strong constant magnetic fields to protect the spacecraft crew from cosmic rays.

Thus, during space flights it is possible the crew will be exposed to very weak (in comparison with the earth) and very strong magnetic fields.

The rapidly developing new branch of science — space biology — is successfully studying the effect of the entire complex of extreme factors connected with space flights on living organisms. A number of works (Glembotskiy et al., 1961; Arsen'yeva, Antipov et al., 1961; Delone et al., 1963, 1966) note the effect of space flight factors on the process of mitosis (increase in percent of chromosome aberrations, change in the frequency of mitotic divisions). To evaluate the importance of changes in the intensity of the magnetic field in connection with space flights, an important role is played by experimental research conducted on earth in magnetic fields differing from that of the earth.

In this article we shall briefly dwell on the basic works concerned with the effect of artificial constant magnetic fields on cell division. Study of the effect of a magnetic field on mitosis began long ago, immediately after the discovery of this process (Ererra, 1890). The first tests in magnetic fields were connected with attempts to explain the internal mechanism of mitosis. In the last ten years the development of these studies has also been stimulated by space flights (Beischer, Muller, 1965) and the use of magnetic fields in scientific research and industry.

A number of studies have been conducted on various living tissue cultures. I. Lenguell (1933) studied the effect of magnetizing needles on a heart tissue culture in which, under the effect of a magnetic field, he observed the formation of gigantic mononuclear cells. P. Payne-Scott, Love (1936) kept a culture of the hearing organ of a chick in a magnetic field with an intensity of 5000 gauss for 3-6 hours. The studies showed that the culture had no obvious anomalies of division; only a tendency toward protoplasmic disintegration was observed. In the tests of E. Delorenzi (1935, 1961) exposure of a chick tissue culture for 8 hours in a magnetic field with intensity varying from 200 to

1000 oe led to a change in the frequency of mitotic divisions. Significant anomalies of mitosis were also noted: agglutination, breaking, chromosome lag, changes in the density of cell division. The effect of a homogeneous magnetic field with an intensity of 33,000 gauss and inhomogeneous fields of 8800 and 43,000 gauss on cleavage of sea urchin eggs was studied by N. Perakis (1939). It was established that a homogeneous magnetic field has no effect on the development of the eggs; an inhomogeneous field slightly delays it. /202

There are a number of works studying the effect of a magnetic field on division in lower and higher plants. According to the data of L. G. Buksa (1950), a magnetic field with an intensity of 750 oe has a depressive effect on the reproduction of yeast. M. P. Travkin et al. (1968) found an increase in the rate of cell division in chlorella in a relatively weak (400-500 oe) field and a decrease in a strong (1200-2500 oe) field. However, M. Halpern and D. Konikoff (1964) discovered the "dramatic effect of accelerated growth" of chlorella on the seventh day of exposure in a strong magnetic field; a magnetic field of 20,000 oe accelerated growth 138% in comparison with the control. No effect on growth in magnetic fields of 750 and 1000 oe was found. In the work of P. F. Milovidov (1949) it is noted that exposure of bean and onion roots in a magnetic field of 28 and 35,000 gauss for several hours causes no mitotic anomalies. The Italian scientist M. R. Celestre (1957) kept root tips of hyacinth and tulip in a magnetic field with an intensity of 15,000 gauss for 3-5 hours. He established that exposure in the field caused a sharp inhibition of spindle activity, the formation of chromatin bridges with fragments and a sharp reduction of mitotic activity. Interesting are the works conducted in magnetic fields with an intensity of 500-1000 and 5000 gauss with exposure of onion (roots), narcissus and amaryllis from 15 to 60 days (Dunlop et al., 1964, 1965). The authors noted a reduction in the number of mitotic forms, change in the external shape of the nucleus, and the affinity of chromatin for stains. Our studies (Strekova, 1966) conducted in low intensity magnetic fields, inhomogeneous — (60) and homogeneous — (20 oe), established increased mitotic coefficient, nucleus size, number of nucleoli, and RNA content in the root cells of a number of plants, due to a slight delay in cell division. With growth of bean roots for four days in a high intensity inhomogeneous field of 12,000 oe, a significant reduction of the mitotic coefficient was observed (from 10.6% in the control to

5.1% in the test) as well as chromosome aberrations (8.1%) consisting of the formation of bridges, fragments and micronuclei (Strekova, 1967).

A number of works (Lenzi, 1940; Magrou, Manigault, 1946, 1948; Ukolova and Khimich, 1960; Barnothy, Dean, 1964; Butler, Dean, 1964; Gross, 1964) report success in attempting to affect tumor tissue with a magnetic field. Tests with tissues in vitro showed high field sensitivity of tumors in comparison with normal tissue, usually due to the increased mitotic activity of tumor cells. There are studies in which no effect of a magnetic field on a culture of cancer cells was established (Halpern, 1964; Hall and Bedford, 1964).

Thus, it can be concluded that study of the effect of a magnetic field on /203
mitosis has been conducted on a variety of plant and animal objects with pathologically altered (tumor) and normal tissue in fields with various intensities and gradients. The results obtained in this area are far from unambiguous. Along with studies which note the effect of a field, there are also works in which no effect of the field is found. This is evidently due to various sensitivities of objects to the field, the dependence of the reaction on the physiological state of the organism and its orientation in relation to the poles of the magnetic field (Puma, 1952; Krylov, 1961, and others) as well as the parameters of the magnetic field: its intensity and gradient (Perakis, 1939; Magrou, Manigault, 1948, and others). Evidently a magnetic field, as any extreme factor, acts as an ordinary physiological stimulus and has a lower threshold of sensitivity, a zone of stimulation and inhibition.

The specific manifestation of a reaction to the field depends on environmental factors (temperature, ionization and radiation). In this connection there is great interest in the data obtained by many authors (Fosbery, 1940; Barnoth, Dean, 1964; Mericle, 1964, and others) in studying the simultaneous effect of a magnetic field and radiation where it has been established that, depending on various combinations of these factors, either a protective effect of the field against radiation can appear or synergism is found in their action. In the latter case the radiosensitivity of objects is heightened.

In conclusion we must point out that in space flights it is necessary to take into consideration the great effect which change in the magnetic field has on cell division. And studies must also be made of the effect of artificial magnetic fields in combination with those extreme factors which accompany space flight.

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