

On the biological role of Fraunhofer lines of the Sun

K. YA. KONDRATYEV, P. P. FEDCHENKO, A. I. IVANENKO, J. LACASA
and K. P. FEDCHENKO

*Research Centre for Ecological Safety, Russian Academy of Sciences and
Nansen International Environmental and Remote Sensing Fund
Korpusnaya St. 18, 197110 St. Petersburg, Russia*

(ricevuto il 12 Settembre 2004; approvato il 15 Settembre 2005; pubblicato online
il 18 Gennaio 2006)

Summary. — The important role of Fraunhofer lines formed in the solar atmosphere in the spectrum of the Sun for the biological evolution on Earth has been discussed. *In vitro*, laboratory experiments have been accomplished to substantiate the concept of the role of Fraunhofer lines as drivers of the evolution via impact on molecules of biological significance. As a practical application of the concept, successful results of clinical tests on humans have been obtained to demonstrate the possibility of non-medicinal means to be used for therapy in the cases of infectious diseases such as HIV/AIDS. The importance for human health of blurring Fraunhofer lines due to increasing atmospheric pollution has been emphasized.

PACS 92.60.Vb – Solar radiation.

PACS 87.50.-a – Effects of radiation and external fields on biomolecules, cells and higher organisms.

1. – Introduction

Radiation energy of the Sun is practically the only source of energy for the biosphere. Any biological process in plant or living organisms is in one way or another connected with the Sun. It is difficult to name any biochemical process which, like the light, could efficiently affect the biological mechanisms taking place in the living systems. In this connection, biology has a unique opportunity to use light as a sensitive and specific source of information to study the functions of the intracellular structures of living organisms. Any light-initiated biological process is a complicated sequence of functions of various molecular mechanisms in a cell of the living organism resulting in the formation of new and transformation of intermediate photoproducts.

The physical effect of the light absorbed by a molecule is that this molecule gets excited but does not differ from a usual molecule in its chemical properties except excess energy, which in turn causes various chemical reactions, including photodecomposition, at which chemical bonds get broken resulting in the decomposition of the molecule into

radicals, ions or neutral molecules, as well as photocomposition at which other molecules join the excited molecule, etc. [1]. Light easily hits a target molecule without any difficulties connected with membrane permeability and side reactions as is the case with the use of chemical methods.

The Sun-induced biological processes are highly specific. They involve strictly specialized organic molecules which have originated in the course of evolution to assimilate solar energy at certain wavelengths. The reason why this molecule can absorb light only at a certain wavelength is that the energy of the absorbed photon should equal the energy needed to excite the molecule.

One should remind here about an important natural process such as photosynthesis [2]. One quantum of light absorbed by chlorophyll transform the solar energy into chemical one available for biosynthesis of cellular components. Hence, the plant's cell can exist only under light conditions, having three systems to transform radiative energy: glycolytic, mitochondrial and that found in chloroplasts capable of transforming radiative energy. Besides, photosynthesis of plants is also a source of oxygen so necessary for life. Thus, life on our planet is entirely dependent on photosynthesis. Already K. A. Timiriazev had pointed out that it is chlorophyll that connects processes of energy release on the Sun with life on Earth.

Since light is so essential in biological processes, and the Earth from the very beginning of its existence has been directly influenced by the Sun, it may be assumed that radiative energy of the Sun has predetermined the structure of organic molecules. We have already mentioned that the Sun-induced biological processes are highly specific and realized with strictly specialized organic molecules built of chemical elements selected by nature.

In this connection one should remind the principles of selection of molecules responsible for adaptability of molecules to sunlight. It is common knowledge [3] that in building of practically all biological molecules, nature used only six chemical elements: carbon (C), hydrogen (H), nitrogen (N), oxygen (O), phosphorus (P), and sulphur (S). By their chemical properties this sextet is so diverse that it was enough to build almost all molecules needed for a cell. There are 12 chemical elements more of vital importance in living systems: calcium (Ca), chlorine (Cl), cobalt (Co), copper (Cu), iodine (I), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), potassium (K), sodium (Na), and zinc (Zn).

Whatever principle of a chemical selection may be, it is apparently dictated by two factors: availability and suitability [3]. While regarding availability everything is practically clear (*i.e.* the element chosen by nature should exist on Earth), as to suitability, we shall discuss it in more detail, especially because there is no consensus on this issue among scientists. As mentioned above, sunlight has played the crucial role in the construction of biological molecules. It means that all biological molecules have been "designed" to fit sunlight which has its specific spectral composition with all biological processes being "adjusted" to it. One could imagine another spectral composition of sunlight to which biomolecules would also be adapted, but it would be another living system with chemical elements as its basis quite different from those mentioned above.

Hence, the most important evolutionary factor that had played a key role in the beginnings of life on Earth was sunlight with its specific energy distribution throughout the spectrum. It should be noted here that simultaneously with life development there have been changes in the solar spectrum composition on the Earth's surface. These changes have been connected mainly with the appearance in the atmosphere of oxygen, carbon dioxide, ozone, and other optically active minor gas components.

The results of theoretical and experimental investigations of changes in the spectral

composition of radiant energy on the Earth's surface are described elsewhere [4, 5]. In this paper we shall consider a unique natural phenomenon relevant to special composition of solar radiation with emphasis on Fraunhofer lines of the Sun. The fact is that solar spectrum is not continuous. It is marked all over with thin lines named Fraunhofer (after their discoverer). The lines are located at fixed wavelengths and serve as natural marks in the solar spectrum. They are formed by chemical elements existing in the solar atmosphere. By location and intensity of these lines astronomers study the chemical composition of the solar atmosphere.

We are, however, interested in a quite different purpose of Fraunhofer lines. We want to find out whether these lines have any relation to the living systems, and if they do, what is their role in biological processes; whether nature had taken them into account when selecting chemical elements to construct biomolecules, and finally, would life have begun in the absence of these lines in the solar atmosphere. This will be the principal subject of further discussion.

The questions raised are radically new. In any case, as far as we know, there is no evidence in the scientific literature of the biological role of Fraunhofer lines, except for our earlier publications [6-13]. The relation between solar Fraunhofer lines and biological molecules on Earth may seem paradoxical, since at first glance these two phenomena bear no relation to each other. However, as will be shown below, this relation does take place and it is essential for normal functioning of all the living systems. We have already noted that structures of biological molecules created by nature from selected chemical elements are connected with the spectral composition of solar radiation, and the very principle of construction was such that biomolecules contained metals which could transport from place to place a group of atoms or molecules, fix them in a certain position, turn, polarize, etc., that is, take real part in the construction of biological molecules [14, 15]. Metals are known to act only in complex compounds. It means that they closely interact with their surrounding ligands, which can carry an electric charge, that is, be ions.

From the viewpoint of quantum mechanics, it is essential that electrons of metal ions and electrons of the adjacent ligands form common electron clouds of a regular geometric shape: triangle, tetrahedron, octahedron, etc. A disruption of such a shape can lead to various effects negative for life. Therefore the geometrical structure of molecules is of vital importance. It is precisely the formation and maintenance of a fixed geometric shape of a complex compound that is the main function of the ion of metal incorporated into various complex compounds. It should be pointed out here that the formation of a geometrical structure of a molecule is determined by combined properties of metal and its surrounding ligand, and this structure is maintained exclusively by metal ions. It should be particularly emphasized that this event will take place only when the electronic shell of the metal incorporated into the molecule is in a "quiet" (unexcited) state.

Then the question arises of practical application of such an event, namely: how to illuminate a molecule so that the electron shell of its metal remained unexcited. Consider a chlorophyll molecule as an example. Chlorophylls are cyclic tetrapyrrols provided with a number of physico-chemical properties needed for absorbing and transforming radiant energy of the Sun in photosynthesis. The light-absorbing role of chlorophyll in photosynthesis is the most striking example of specific biological functions of a natural object. It is not easy to find another pigment with which it could be possible to so perfectly use solar energy for chemical purposes. However, here our interest is mainly focused on the fact that a certain position in the tetrapyrrol structure of a chlorophyll molecule is occupied by magnesium ion which, as stated above, must ensure stability of the geometrical structure of this molecule.

It has been mentioned above that a molecule is stable only when the electron shell of the incorporated metal is in a “quiet” (unexcited) state. Not a simple situation results: on the one hand, being captured by Mg ion, light can break the geometrical structure of a chlorophyll molecule causing thereby the malfunctioning of the photosynthetic apparatus. Simple logic suggests that it is possible to get out of this situation only if during insolation of a chlorophyll porphyrine ring, Mg ion is protected from light.

The mechanism of protection from light of Mg ion in chlorophyll has originated as early as the very beginning of evolution, in natural selection of chemicals to construct biological molecules. The key feature of this mechanism is that nature included Mg ion into chlorophyll because in the solar spectrum it has a powerful Fraunhofer line in its green range corresponding to Mg electron transitions. Therefore, when sunlight strikes a chlorophyll molecule, Mg ion remains unexposed. So, the solar Fraunhofer line has maintained the “quiet” (unexcited) state of the magnesium electron shell.

In this context, one can now understand the two main principles of nature that form the basis for selection of chemical elements to construct the biological systems.

For instance, the chlorophyll tetrapyrrol structure could have incorporated other metals as well, such as zinc, copper, cobalt, etc., but preference has been given to magnesium. Chlorophyll complexes with Zn, Ni, Cu and other metals have been shown to remind to some extent those with Mg, but on the whole, none of the metal porphyrins behaves like Mg complexes [15]. The fact is that the coordinating properties of Mg in chlorophyll are such that none of other metals introduced into chlorophyll can copy the coordinating behaviour of magnesium. Thus the inclusion of magnesium into the chlorophyll composition is a unique property of biomolecules developed in the process of evolution to adapt its optical characteristics to the solar Fraunhofer lines for stabilization of functionally important chemical bonds responsible for the molecule’s conformation, and to ensure the normal functioning of the whole photosynthetic apparatus.

From the above theoretical consideration, the critically important role of the solar Fraunhofer lines in the photosynthetic (and not only photosynthetic) process becomes evident. Therefore as proof of our theoretical findings regarding this unique evolutionary phenomenon, a number of experiments have been carried out. Their results are presented below.

2. – Laboratory experiments

The aim of one of the initial experiments was to detect regeneration of protochlorophyllide in plants in case of addition to solar radiation of radiation at Mg Fraunhofer line. Etiolated plants (plants grown in the darkness) are a suitable model for these experiments, since in this case it is possible to trace the whole biological process of transformation of the chlorophyll precursor into chlorophyll. Here it is important to note that chlorophyll itself takes part in the formation of the structure of photosynthetic apparatus instead of being introduced into the final structure [1].

For this experiment, etiolated wheat seedlings were grown in special vessels. A total of 12 vessels were prepared, five to ten plants in each. Then all vessels were exposed to sunlight under different illumination conditions: six vessels were exposed only to sunlight, and six vessels were exposed to sunlight plus the light at the Fraunhofer line of magnesium. The final result of this experiment was evaluated following the procedure described by Kondratyev *et al.* [9].

It has been found out from the results of this fairly simple experiment that chlorophyll precursors are heavily oppressed, which indicated the influence of extra light at Fraun-

hofer lines on dark reaction of chlorophyll biosynthesis that precede protochlorophyllide formation. The result was somewhat unexpected. One would think quite the contrary, the formation of chlorophyll precursors had to be accelerated with the addition of the light at the Fraunhofer line. This did not, however, happen, which fits our concept of the effects of Fraunhofer lines on living systems.

It is well known that apart from chlorophyll, a number of other pigments take part in photosynthesis. In this respect, of great interest are pigments containing not magnesium but another metal, for instance, iron. With that end in view, let us consider a cytochrome known to be an essential component of all photosynthetic structures. It plays a key role in the photosynthetic electron transport chain. Cytochrome is a protein molecule that contains heme and is structurally close to chlorophyll, that is, it is a metaltetrapyrrol with the only difference that chlorophyll contains an ion of magnesium, and cytochrome an ion of iron. The ion contained in the cytochrome reacts with electrons, and the Fe ion with an added electron is reduced from Fe^{3+} to Fe^{2+} . We have replicated the experiment with etiolated wheat seedlings with the difference that in this replication the light at the Fraunhofer line of iron was added to sunlight. The results have demonstrated that chlorophyll illumination at the Fraunhofer line of iron, like in the first case, results in a significant inhibition of chlorophyll precursors. This is because we have disrupted the work of the electron transport chain in photosynthesis causing thereby malfunctioning of the whole biological process.

Thus our experimental findings have shown that extra lighting of etiolated wheat seedlings at the Fraunhofer lines of Mg and Fe during exposition of the plants to sunlight markedly inhibits biosynthesis of the major pigments. Therefore it can be deduced that the mechanism of light effect in the range of Fraunhofer lines is of a regulatory rather than energetic nature. This mechanism is based on the principle of disbalance in the spectral composition of physiologically active light simultaneously at several Fraunhofer lines.

Another experiment aimed at confirming the biological role of Fraunhofer lines in living systems was carried out to study whether $(\text{Na}^+ - \text{K}^+)$ ATPase is influenced by photo excitation of the magnesium electron shell. One of the most important Mg roles is to maintain functioning of the molecular electric pumps with the participation of proton ATPase and $(\text{Na}^+ - \text{K}^+)$ ATPase. Due to the activity of these enzymes, a potential difference of the order of 60–100 mV is maintained on the membrane surface of plant and animal cells necessary for transport of substances through a cell wall. During enzyme functioning, the Mg ion enters the enzyme active center ensuring a necessary conformation state of the enzyme in binding and releasing of H^+ , Na^+ , and K^+ [8]. Consequently, it may be assumed that photoexcitation of the Mg ion electron shell can exert a significant effect on $(\text{Na}^+ - \text{K}^+)$ ATPase functioning.

To verify this assumption, a special experiment has been carried out. Under laboratory conditions an enzymatic reaction has been modelled involving magnesium ions, namely: splitting out of inorganic phosphate from ATP by Mg-dependent adenosynt-riphosphatase, Mg-ATPase [8]. The sample was illuminated at the Fraunhofer line of magnesium. Microsome fractions of cattle brain were used as a specimen. In addition to the enzymatic specimen, a reaction medium was prepared consisting of Na-ATP 2 mM, MgCl_2 mM tris-HCl (pH 7.2) 60 mM.

The experimental results have revealed that after irradiation of the enzymatic specimen and complete reaction medium Mg-ATPase activity increased 1.5 times. This is indicative of a functional biological significance of Fraunhofer lines belonging to magnesium. Therefore, the absence of radiation at magnesium lines in the solar spectrum sta-

bilizes the mode of reactions involving Mg-ATPhases and makes them light-independent.

A similar experiment has been performed by Dreval *et al.* [16] to study the effects of photoexcitation of the electron shells of calcium and magnesium on the ATPPhase activity.

It has been shown that Mg-ATPhases and Ca-ATPhases in the events of Mg and Ca shells photoexcitation demonstrate selective photosensitivity. Thus when the reaction medium was irradiated at Mg Fraunhofer line (518 nm), the Mg-ATPhase activity increased 1.8 times and did not practically change after irradiation at Ca line, whereas illumination of the specimen at Ca Fraunhofer line (445.5 nm) resulted in a 1.9-fold increase in the Ca-ATPhase activity.

The experiments performed have provided a firm support to our hypothesis on the biological role of Fraunhofer lines which consists in the fact that the incorporation into the structure of biological molecules of a metal ion, whose absorption lines correspond to the Fraunhofer lines of the Sun, significantly reduces the probability of photoexcitation of chemical bonds arising between metal ions and neighbouring atoms of the molecule. This eventually culminates in enhancing the molecule structure stability against the solar spectrum effects. In other words, the interaction of the metal electron shell with the electron shells of the nearest atoms of the active center (ligands) provides an establishment of strong relations of metal ion with the protein part of the enzyme molecule. In this case the solar spectrum acts as an original "optical matrix" with narrow slits at Fraunhofer lines, and an additional lighting "closes" these slits in the spectrum, causing thereby micro-changes in the solar spectrum shape which appeared to be sufficient to induce alterations in the entire biological process.

It should be emphasized that the energy levels of an individual atom of metal that defines the Fraunhofer lines in the solar spectrum can be non-coincident with the levels of the same atom included into the biomolecule composition, because of the metal atom's electron shell affected by the surrounding electric fields of adjacent atoms of biomolecule. However, as evident from theoretical investigations in quantum mechanics carried out for ferroporphyrin complexes incorporated into various enzymes, the shift of Fe atom energy levels surrounded by ligands is varied for different levels. For instance, levels corresponding to the electron orbit of Fe atom lying in a perpendicular plane to that of a porphyrin ring and responsible for heme and protein bond in the fifth and sixth coordination position do not practically shift with respect to the relevant levels of an individual atom of iron. But it is exactly the electron orbit which plays a crucial role in dictating the active centre geometry of many enzymes containing iron (hemoglobin, myoglobin, cytochromes) during a catalytic reaction: oxygen transfer, electron transport.

Quantum mechanics calculations for other metal compounds with biological molecules are seldom the case because of an extremely complicated nature of biomolecules. However in general, when a metal atom is included into the molecule composition, one of the energy levels of the metal remains unchanged while others experience small or large shifts. Therefore the incorporation into the biomolecule structure of the metals, whose absorption levels at least partly coincide with the relevant Fraunhofer lines, reduces the probability of photoexcitation of the "metal-ligand" relations and serves thereby to increase the conformation stability of the whole molecule.

Thus even first findings have demonstrated that we deal with a radically new evolutionary phenomenon that may be of great practical importance. The question concerns the light control of various biological processes and interference in the life cycle of virus diseases. Therefore our further studies were directed at solving some specific practical problems, namely: development of fundamentally new methods using monochromatic radiation to treat diseases such as hepatitis B and C, herpes, leukemia, HIV, and AIDS.

3. – HIV/AIDS and other diseases

Certainly, within the framework of this paper it is impossible to discuss in detail the results from our investigations aimed at developing methods to treat infectious diseases. Some of these results have already been published. We shall dwell only upon methodological developments for treatment of virus infections, which have reached a stage when their practical application in medicine is feasible. First of all, it concerns methods of treating HIV and AIDS patients.

We have been studying specific features of the AIDS virus and its initiating agent for more than 15 years. Our studies have been focused on internal molecular mechanisms involved in HIV replication when illuminated by specific light. An essential feature of light effects on any biological object is that initially this process is of pure physical nature, but eventually it becomes of completely biological character. Synthesis of physical and biological sciences can provide data different from those currently available and obtained in a purely biological way. These data can serve the basis for the development of a brand new non-medicinal method to treat HIV and AIDS patients. This will provide an opportunity to complement available approaches to the treatment of these diseases which are not efficient enough having, besides, significant negative side effects.

Virus inactivation is possible in two ways: nucleic and protein. When nucleic acid is damaged, virus loses its reproduction ability. In case of destruction (or partial damage) of the virus protein shell, it does not penetrate into a cell. To inactivate virus, we have chosen the nucleic way. Every researcher studying the mechanisms of light effects on living organisms knows that to produce a photobiological effect in a biological process, precise knowledge is necessary of the spectrum of light absorption by molecules responsible for this process. Each individual biological molecule (chlorophyll, hemoglobin, DNA, RNA, cytochromes, etc.) has a spectrum of its own, which is a kind of an optical passport for this molecule. An exact wavelength can therefore be selected for photochemical and photobiological investigations.

Such a classical approach to light effect on biological systems follows the first rule of photochemistry (Grolus-Draper law), which reads that only absorbed-by-molecule light can induce a chemical reaction. If a molecule does not absorb light, a photochemical effect is impossible. Hence, the matter concerns a direct effect of light on a biological molecule. In this case photons are selectively absorbed by nucleic acids and proteins and, as a rule, cause an excitation of valence electrons in these molecules, and transfer electrons to higher energy levels. It is these chemical reactions caused by light at the molecular (physical) level that induce effects observed at the biological level. It follows from these results that to obtain a photochemical effect in DNA and RNA molecule, it must be exposed to the light that corresponds to the absorption band for these molecules, that is, in the spectral range with a peak at about 260 nm, otherwise no effect is possible (the basic rule of photochemistry).

On the other hand, it is common knowledge that ultraviolet light is ruinous for nucleic acids and as a result, tends to either block or modify all the known DNA and RNA functions [14]. In this case DNA loses its activity and capacity for replication and transcription, various mutations occur affecting cistrons which code the structure of all proteins. As for RNA, it also loses its translation activity, the matrix meaning gets distorted, etc. UV-light exerts an ill effect not only on nucleic acids but also on proteins that form the virus protein shell.

A challenging situation develops. On the one hand, a photobiological effect of nucleic acids is only feasible by their irradiation in the UV-range, and on the other hand,

UV-radiation can cause significant negative destructive-modifying reactions. Individual chemical groups (or a molecule itself) capable of absorbing light are known to act as chromophores in living systems. The main chromophores of nucleic acids are purine (adenine and cytosine) and pyrimidine (guanine and thymine in DNA and guanine and uracil in RNA) nitrogenous bases of nucleotides [1]. Therefore an exposure of nucleic acids to UV-radiation leads to electron excited states of different bases. Apart from the nitrogenous bases, chromophores of nucleic acids are also metals contained in these molecules which can interact with many electrodonor centres of nucleic acids (phosphate groups, bases, ribose hydroxyls). Konev *et al.* [1] have reported that an attachment to such centres in polynucleotides causes ligand reactions, destructing thereby the structure of macromolecules. One cannot but pay attention to the fact that a huge amount of various metals are involved in DNA and RNA functioning, each with its well-defined specific role.

Of interest here is that spectra of metal absorption and those of nucleic acid absorption (generated from nitrogenous bases with an absorption peak at 255–270 nm) do not coincide. And what is more important, the absorption spectra of most of the metals inherent in DNA and RNA are in the visible range, where photon energy is 1–3 eV. This photon energy can induce significant changes in the chemical structures of neither nucleic acids nor proteins. It has long been known [1, 14] that visible light plays a great role in biological processes connected with inactivation of a cell and in its mutation, although what processes are a coupling agent remains to be explained. It can be either photodynamic processes, when a dye artificially introduced into the cell sensibilizes the organism to visible light in the presence of oxygen, or reactions of molecular sensibilization. In this case, to generate a photoproduct, a molecule does not directly absorb radiation energy but receives it from another molecule whose energy has been raised due to absorption.

The situation gets significantly changed, since excitation of the electron shell of metals in the virus genome by visible light can influence practically all vital HIV stages: from its introduction into a cell to the formation of new viral particles. It is known, for instance, that RNA inactivation by UV-radiation (its sensitive targets are the remains of uracil and cytosine) is closely connected with the molecule's conformational alterations. Therefore it should be assumed that RNA irradiation by visible light at electron transitions of magnesium will induce conformational alterations of ribosome RNA, and a ribosome will lose its ability to correctly arrange the obtained transport RNA that carry relevant aminoacids. In this case no chemical changes will take place in ribosomes irradiated by visible light since spectra of ribosome inactivation are in the UV-range (ribosomes have two peaks, 260 and 280 nm). Hence, we have carried out a series of experiments focused on HIV inactivation.

First, our studies were carried out *in vitro* on cell cultures, MT-4 and CEM, differing in their biological characteristics and representing, respectively, two types of virus infection, acute (MT-4) and chronic (CEM). HIV-1 899A strain was also used from the virus collection of the Ivanovsky Institute of Virology. The methodology of the experiment has been described in detail elsewhere [11]. Here we only note that an exposure of HIV to light at certain wavelengths causes its inactivation, and the formation of virus-induced syncytia is reduced.

Since April 2004, the suggested method is being clinically tested on humans. The goal of these tests was, on the one hand, to verify the HIV and AIDS patients' safety in case of monochromatic radiation treatment and on the other hand, to assess the effectiveness of the method suggested for treatment of this disease.

More than 30 patients have been examined. Even first observations revealed a high

effectiveness of the method. All the patients examined showed an improvement of objective laboratory parameters of the HIV infection: reduced virus burden and increased number of T4 lymphocytes.

Based on the data obtained, a source of monochromatic radiation may be considered as an alternative therapeutic means for HIV and AIDS patients. It will help to save large financial resources needed to purchase expensive specific drugs for HIV-therapy. Besides, an introduction of the method into clinical practice will allow patients to avoid an exhausting therapy that prescribes a great deal of medicine to be taken for months or even years following a strict schedule and keeping to a diet.

Hence, we are talking about the introduction into clinical practice of an essentially new non-medicinal tool for HIV and AIDS therapy. It should also be noted that since the inactivation of virus by visible light does not disrupt the integrity of its protein shell, inactivated viruses will retain their antigenic properties. It means that they can be used as vaccine.

4. – Conclusion

The results considered demonstrate the most important evolutionary impact by which the Sun with its specific distribution of energy throughout the spectrum has played a key role in the construction of biological molecules and beginnings of life on Earth. Our discovery of a new phenomenon connected with an exclusive role of the Fraunhofer lines of the Sun in biological processes is new and extremely promising for further fundamental investigations. This discovery relevant to fundamental bonds between living and non-living natures, their functioning as a single whole, will give an insight into the inner deep secrets of biological processes dependent on light effects. It offers prospects for control of biological systems of biological systems of different complexity.

Using specific examples, we have demonstrated that during the planetary evolution the Fraunhofer lines have played a tremendous role in selection of chemical elements for construction of biological molecules. It has also been shown how “the very construction” of different biomolecules has originated and what role in the biomolecule-metal interaction has been played by metals incorporated into the molecule structure.

The issues considered above and connected with a phenomenon such as Fraunhofer lines are radically new in that our investigations have been aimed not only at studying the regularities and mechanisms of interaction between light and biosystems at the molecular level but also at deepening our knowledge of how various molecules have originated and why they are so strongly “tied” to the respective Fraunhofer line. It has made it possible to reveal cause-and-effect relations between the evolutionary constructions of biomolecules and maintenance of their major properties.

Thus the investigations we have performed can be practically applied in different areas of science, namely: biology, gene engineering, ecology, medicine, and others. We have used the phenomenon of Fraunhofer lines to develop radically new methods for therapy of virus diseases such as hepatitis B and C, HIV-infection, herpes, acute and chronic leucoses, and others.

At the same time, because of an exclusive biological role of Fraunhofer lines in life processes, a question arises of the stabilization of Fraunhofer lines. The matter is that due to atmospheric anthropogenic pollution the intensity of Fraunhofer lines can significantly change, that is, these lines can be “blurred”. And this can substantially influence different light-dependent processes. Thus, for instance, blurring of the Fraunhofer line of Mg,

which is known to be a component of the tetrapyrrol structure of a chlorophyll molecule, can significantly inhibit the whole photosynthetic process.

Grainger and Ring [17] were the first to pay attention to changes in the intensity of Fraunhofer lines. These authors carried out observations of the H line (396.8 nm) in the spectrum of the Moon-reflected sunlight to detect possible luminescent radiation. They found out that the filling of the H line increases, and this indicates that in addition to scattered sunlight, there is some extra skylight. Later on, Noxon and Goody [18] confirmed the hypothesis of Grainger and Ring and demonstrated that the scattered skylight contains a non-polarized component with an intensity of 1–3% of the full intensity of scattered light. They believe that the most likely reason for such a change is an “incoherent scattering” resulting from aerosol fluorescence. It is important to note that a decrease of the depth of Fraunhofer lines due to their extra illumination is strongly dependent on wavelength. For instance, at $\lambda = 398.6$ nm this effect can reach 25% [18] and at $\lambda = 438.3$ nm and 589.0 nm only 1–3%. Transformation of Fraunhofer lines has been discussed by Lukshin *et al.* [19]. Leaving aside the cause of this phenomenon, the authors believe that “blurring” of Fraunhofer lines occurs due to self-emission of the atmosphere.

The biological role of Fraunhofer lines is an object of fundamental investigations of different phenomena connected with possible selective damage to vital molecular structures. At present it is difficult to give a universal explanation of the role of Fraunhofer lines in biological systems. The only clear aspect is that the nature “has used” Fraunhofer lines for accomplishing different tasks, starting from the prebiological-chemical evolution that resulted in beginnings of life on Earth, and ending with stabilization of every-day biological reactions in different biological processes.

REFERENCES

- [1] KONEV S. V. and VOLOTOVSKY I. D., *Photobiology* (BGU Publ., Minsk) 1974 (in Russian).
- [2] RUBIN B. A. and GAVRILENKO V. F., *Biochemistry and Physiology of Photosynthesis* (MGU Publ., Moscow) 1977 (in Russian).
- [3] GREEN D. and GOLDBERGER R., *Molecular Aspects of Life* (Mir Publ., Moscow) 1968 (in Russian).
- [4] KONDRATYEV K. YA., *Radiant Energy of the Sun* (Gidrometeoizdat, Leningrad) 1954 (in Russian).
- [5] KONDRATYEV K. YA., *Actinometry* (Gidrometeoizdat, Leningrad) 1965 (in Russian).
- [6] KONDRATYEV K. YA., KANEVSKY V. A. and FEDCHENKO P. P., *Proc. USSR Acad. Sci.*, **287** (1986) 507 (in Russian).
- [7] KONDRATYEV K. YA., KANEVSKY V. A. and FEDCHENKO P. P., *Proc. USSR Acad. Sci.*, **289** (1986) 758 (in Russian).
- [8] KONDRATYEV K. YA., ROZHMANOVA O. M., KANEVSKY V. A. and FEDCHENKO P. P., *Proc. USSR Acad. Sci.*, **291** (1987) 1263 (in Russian).
- [9] KONDRATYEV K. YA., SUD'INA E. G., KANEVSKY V. A., FEDCHENKO P. P., SIVASH A. A., SHELYAD-SOSONKO YU. P., NEGRIYKO A. M. and TSELINKO A. M., *Proc. USSR Acad. Sci.*, **294** (1987) 1022 (in Russian).
- [10] KONDRATYEV K. YA., TELEGINA T. A. and FEDCHENKO P. P., *Proc. USSR Acad. Sci.*, **314** (1990) 988 (in Russian).
- [11] KONDRATYEV K. YA. and FEDCHENKO P. P., *Fine Structure of the Solar Spectrum and Its Role in the Biosphere Evolution* (PROPO Publ., St. Petersburg) 1992 (in Russian).
- [12] KONDRATYEV K. YA. and FEDCHENKO P. P., *Nuovo Cimento C*, **27** (2004) 255.
- [13] KONDRATYEV K. YA. and FEDCHENKO P. P., *Nuovo Cimento C*, **27** (2004) 273.

- [14] SMITH K. and HANWALT F., *Molecular Photobiology* (Mir Publ., Moscow) 1972 (in Russian).
- [15] AGORN G., *Inorganic Biochemistry* (Mir Publ., Moscow) **2**, 1978 (in Russian).
- [16] DREVAL V. I. and GIRNYK S. A., *Biofizika*, **45** (1990) 4 (in Russian).
- [17] GRAINGER J. R. and RING J., *Nature*, **193** (1962) 762.
- [18] NOXON G. and GOODY R., *Phys. Atm. Ocean*, **1** (1965) 275.
- [19] LUKSHIN V. V., ISAKOV A. A. and SVIRIDENKOV M. A., *Izv. USSR Acad. Sci., FAO*, **26** (1990) 135 (in Russian).