Interactions of Science, Technology and Medicine: Electromagnetic Radiation During the Twentieth Century

Yulia Petrovna Chukova

Abstract Maxwell's original prediction for existence of electromagnetic waves was quickly confirmed by experiment. And at once the basic sphere of use of electromagnetic radiation for communication was defined. Development of more and more powerful radar devices led to high morbidity of attendants and personnel. The term "radio wave illness" appeared, stimulating development of a new scientific direction in biology and medicine and demonstrating the need for standards of hygienic safety.

Detection of nonthermal effects of MM radiation radically increased the social importance of scientific medical researches, due to the proven existence of their positive medical effects. Presence of positive medical effect has changed orientation of technical workings out for radar devices. The orientation on creation of portable radar devices appeared. This allowed an expansion in the sphere of medical use, including about 80 diagnoses of illnesses.

Research into nonthermal effects had shown a poor reproducibility of results. Use of the thermodynamic theory of systems under electromagnetic radiation has allowed us to establish the reason for poor reproducibility of isothermal processes in the radio-frequency region. Moreover, thermodynamic theory has allowed us to establish a new approach to hygienic standardization of harmful actions of electromagnetic radiation, to explain a wide generality of applicability of the Weber-Fechner law, to establish a correlation between terminology of Western science and Chinese medicine and to estimate prospects of their integration.

Keywords Thermodynamics · Efficiency · Endergonic processes · The Weber-Fechner law

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1 A Short Historical Review

The English theoretical physicist James K. Maxwell predicted in 1865 the existence of electromagnetic waves. In 1888 this existence was demonstrated experimentally by the German physicist H. Hertz. In the same year the Russian physicist A.S. Popov repeated Hertz‘s experiment, and in 1889 he was the first to demonstrate the use of electromagnetic waves for signaling over a distance. Popov designed the generator and the receiver (detector) of signals and showed them to the Russian physical- and -chemical society for the first time on May, 7th 1895. He showed a signal transmission over a distance of 250 m to the same society on March, 24th, 1896. It was the first-ever radiogram and consisted of two words: “Henry Hertz”.

In 1897 Italian physicist G. Markoni received a patent for use of electromagnetic waves for wireless communication (in England). The scheme of Marconi’s receiver was the same as Popov’s receiver. Thanks to an abundance of material resources and energy, Marconi achieved wide practical application of this new method of communication. In 1901 Marconi sent a radio communication through the Atlantic ocean. His activity played a large role in the science of radio communication. In 1909 he was awarded the Nobel Prize in Physics.

As a result, in the twentieth century electromagnetic radiation became a highway of technical progress of our civilization. The second half of the twentieth century was marked by an unprecedented growth of quantity of the diversified man-made sources of electric and magnetic fields used in personal, industrial and commercial aims. All of these devices have made our life more comfortable. Communication possibilities between widely separate people has considerably extended. The work of ambulance drivers and police responders has been facilitated. Use of radar has improved safety of air flights and enhanced control over speed of movement on roads, etc.

But there is also a medal back.

2 Radars and Radio Wave Illness

The whole region of electromagnetic waves has 22 orders of frequency and consequently is usually given in logarithmic scale. Division of the whole region into ranges has been made by a number of experimenters, using a variety of means for generation and reception of radiation. Now there are seven divisions (Fig. 1):

- Extremely low frequencies
- Radio wave radiation
- Infra-red radiation
- Visible radiation
- Ultra-violet radiation
- X-ray radiation
- Gamma radiation.

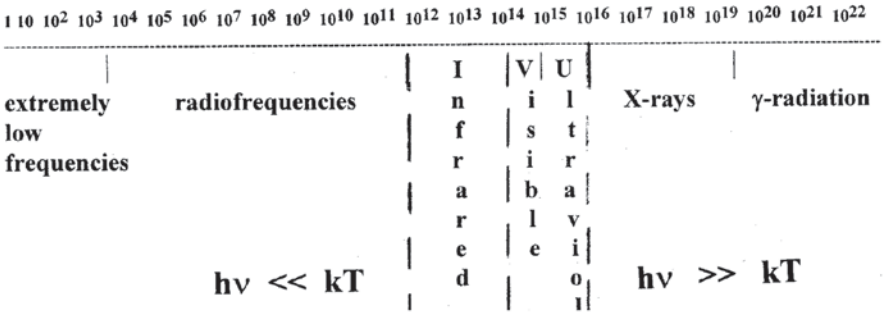

Fig. 1 Partition of the whole region of electromagnetic radiation by experimentalists

Experimenters have faced the fact of overlapping of some ranges:

- Radio wave and infra-red radiation
- Ultra-violet and x-ray radiation
- X-ray and gamma radiations.

A more exact division is a result of deliberations of the International organizations that are responsible for standardization, consequently it can be considered as a social decision.

The works of Hertz, Popov, Marconi and their followers encompass a wide area of radio frequencies among which use of microwave radiation ($3\ 10^8$–$3\ 10^{12}$ Hz) developed most quickly. They were widely used in military technology. This area will be the main object of our consideration, because scientists began to study biological and medical effects of other radiation (in particular visible light) much earlier.

Harmful action of radiofrequency radiation came to light already in the first half of the twentieth century and was studied by hygienists in connection with fast growth of radar power. In postwar years, power of radar devices increased 10–30 times over a decade. The staff of people working with radar devices became the first object of research on harmful actions of microwave radiation.

The response of an organism after exposure was so clearly expressed that a new term "radio wave illnesses" arose among researchers. However it later appeared that the majority of scientists did not have a definitive opinion on necessity in separate nosological[1] unit. Hygienists and physicians fixed (detected) and studied diverse known diseases that arose from the influence of radiofrequency radiation. There were neuro-physiological diseases (Baranski and Edelwejn 1974), diseases of the endocrine system (Micolajczyk 1974), the blood system (Pazderova et al. 1974), diseases of the eyes (mainly, cataracts, Ferri 1974; Tengroth and Aurell 1974), teratogenic diseases (Rugh et al. 1974) and others (Yagi et al. 1974; Miro et al. 1974; Baillie 1974).

An International Symposium on the biological effects and health hazards of microwave radiation ($3\ 10^8$–$3\ 10^{11}$ Hz) was held during the 4-day period October 15–18, 1973, at a conference center in Jadwisin, near Warsaw, under the joint spon-

[1] Nosology is a separate part of medicine.

sorship of the Government of Poland and the United States of America and of the World Health Organization.

Sixty participants from the following countries and from WHO attended: Canada, Czechoslovakia, Denmark, the Federal Republic of Germany, France, the German Democratic Republic, Japan, Poland, Sweden, the Union of Soviet Socialist Republics, the United Kingdom and the United States of America. English and Russian were the official languages of the Symposium.

The participants were scientists and program directors from various institutions, universities, agencies and laboratories concerned with the physical, biomedical and behavioral sciences.

Thirty-nine scientific papers were presented in six sessions:

- General effects of microwave radiation
- Influence of microwave radiation on the nervous system and behavior
- Effects of microwave radiation on the cellular and molecular level (Schwan 1974; Baranski and Edelwejn 1974)
- Measurements of microwave radiation
- Occupational exposure and public health aspects of microwave radiation
- Future research needs, conclusions and recommendations

Differences in approaches and findings, principally between countries in western Europe and North America and those in eastern Europe, have led to considerable variance in microwave exposure criteria and standards (Michaelson 1974; Gordon et al. 1974; Siekierzynski 1974).

3 Standards of Hygienic Safety

Standardization of harmful action is in many respects a social process. At the heart of a system of standards of safety always lies the scientific-and-practical work of experimenters. Figure 2 schematically explains the process of a birth (occurrence) of a standard of safety.

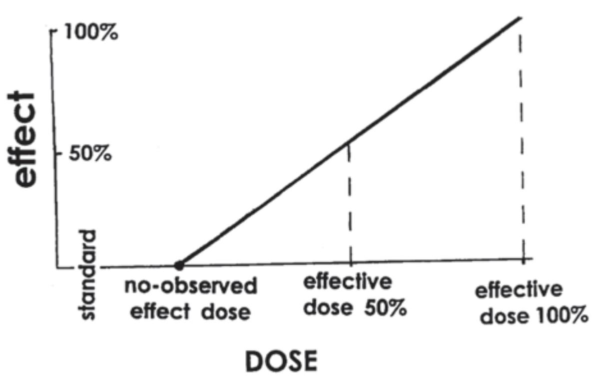

Fig. 2 Dependence effect—dose. (Chukova 2006)

Hygienists, being afraid of artifacts, do not love measurements under weak influences. Therefore they tend to begin measurements under strong influences (the big doses) when reaction of an organism (death, illness and other) is quite distinctly expressed; they then reduce the influence and discontinue it when, in a studied ensemble of individuals, any individual has not shown reaction under that influence. The point "no-observed effect dose" is the last stage of work of experimenters. The line on Fig. 2 is a natural-scientific basis (substantiation) for acceptance of the standard of safety.

The safety standard is the social decision of a commission of experts confirmed by the government or other supervising organization. The unique distinct requirement for a standard is to be smaller than the "no-observed effect" dose. This means that the safety standard should be more rigid than the "no-observed effect" dose. But the distance between a standard and a "no-observed effect" dose is defined independently in each State (or other organization). Therefore safety standards in the different States can differ in allowed percentage. American hygienists Johnson and Guy (1972) have written: "We hear strong arguments between the microwave oven industry, the military, and the Public Health Service, and also between reputable scientists, on where realistic safety level for microwave exposure should lie".

The USA and the USSR, leaders of the arms race in the middle of the twentieth century, were the first to have accepted standards of safety for microwaves. All works in this area were confidential. Frequencies of work of transmitters, their powers and configurations were confidential, but despite that, the first standards of safety appeared to be identical in the USA and the USSR. This standard of safety was equal to 10 mW/cm^2.

The reason for such coincidence is extremely simple. Powerful microwave radiation causes heating. Conservation of constant temperature of a live organism is the first and main requirement of preservation of a life. Therefore the first standards of safety answered the requirement of absence of appreciable heating.

The beginning of specifications of microwave irradiation for the standard of the USA was necessary still in 1942. Even in the time of its establishment (1960s) among scientists there was no unanimity. Some private companies (for example, Bell Labs and General Electric) adopted more rigid specifications, specifically, −1 and 0.1 мВт/$см^2$. The definitive statement of the standard of the USA occurred in 1966. However it was only the beginning of further discussions of a problem.

At once there was a question about the appropriate standard of microwave irradiation for nonprofessionals. Here scientists were more unanimous. They were assured that specifications for the population would be more rigid than specifications for professionals. At the same time the standard of the USA accepted for professionals was, for a long time, considered as admissible for the population at large.

At the first stage of standardization of microwave radiation, only the thermal effect in a living system under absorbed microwave radiation was taken into consideration. It is possible to tell that the first stage of standardization of electromagnetic radiation was a stage of maximum consent between hygienists, but it did not proceed along this path for long.

Soviet hygienists working under the guidance of Gordon (1974) quickly understood that microwaves of high intensity erase features of biological effect and initial shifts in characteristics of live objects, giving a total thermal effect. Weak intensity allowed the Soviet hygienists to see a weaker influence on nervous and cardiovascular systems an albuminous and carbohydrate exchange, activity of some enzymes, etc (Tolgskaya and Gordon 1973). They fixed morphological changes of living tissues under very low levels of influence (10 μW/cm^2). This value as a result was accepted for the Soviet standard of hygienic safety. So there appeared two standards of safety for long-term human exposure: 10 mW/cm^2 in the United States and 10 μW/cm^2 in the USSR.

These two standards of safety represented essentially different approaches to hygienic rationing. The American standard has a base of rise in temperature of a body of a person at 1°, which is observed under 10 mW/cm^2. If we take into consideration that the interval of existence of warm-blooded beings is very narrow (for a person about 10°), it becomes obvious that the influence which is taken into consideration by American hygienists is strong. Soviet hygienists have researched thermal and nonthermal effects of microwave radiation, but in a basis of the standard of safety have put a weak nonthermal influence.

4 Discovery of Nonthermal Effects of MM Radiation

The history of science attests to the extreme events connected with aceptance of the law of conservation of energy. The fact is that this law was formulated the first time not by physicists, but by physician Julius Robert Mayer (1841)—though James Joule (1843) and Herman Helmholtz (1847) had been considered as pioneers for a long time. And the second case of participation of physicians in the great discovery of physicists is connected with electromagnetic radiation The rigid Soviet standard of hygienic safety for microwave radiation (10 μW/cm^2) forced Soviet physicists to carry out researches under weak influences on various objects, therefore hastening the discovery of nonthermal resonant bioeffects of MM radiation.

On Jan. 17–18, 1973, there was a scientific session of the Division of General Physics and Astronomy of the USSR Academy of Science in Moscow. At this session, Academician Devyatkov (1974) reported for the first time frequency-dependent microwave bioeffects in the frequency range from 39 to 60 GHz. These effects were observed at the molecular, cellular, organic, and organismic levels of organization. Results were arrived by different experimentalists in laboratories of different institutes under the direction of Acad. Devyatkov. that the following facts were discovered for almost all of the biological objects studied:

- the existence of irradiation effects which depend on frequency, sometimes in a resonant manner,
- the existence of a threshold intensity necessary for induction of such effects, and that over an intensity range of several orders of magnitude above the threshold, the induced effects do not vary with intensity,
- the effects are observed to depend significantly on duration of irradiation.

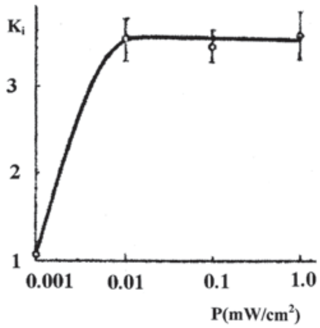

Fig. 3 Influence of the power density of radiation on induction of colicin synthesis. (Smolyanskaya and Vilenskaya 1974)

The results obtained are of great scientific and practical interest. For example, it was established that a vital activity of microorganisms is affected by millimeter wave radiation. The effect may be a both positive and negative one, depending on the particular conditions of irradiation and system characteristics. Different systems and many tests were studied, especially cell division under MM radiation. Some experiments, for example an experiment of Smolyanskaya and Vilenskaya (1974), now are considered as classical references (Fig. 3).

Smolyanskaya and Vilenskaya reported that under MM wave radiation, intracellular systems are responsible for lethal synthesis in bacteria, i.e., the synthesis of substances that results in the death of the cell. The so-called colicinogenic (col) factor of *E.coli* was chosen as the test paradigm. The col-factor is an extrachromosomic genetic element. The functional activity of this element is normally repressed, but a number of physical and chemical treatments can induce its activity. Under MM radiation the col-factor results in synthesis of a special protein substance known as colicin. The cell then perishes. The colicin that it produces has an antibacterial action with respect to other bacteria of the same and similar species.

The activity of the colicin synthesis was determined by the method of lacunas, in which the number of individual colicin-synthesizing bacteria are counted. The effect was evaluated by the so-called induction coefficient, which is determined by the ration of the lacuna formation frequencies in the experiment and the control.

It was found that the number of colicin-synthesizing cells increased sharply upon irradiation of the colicinogenic strain with millimeter waves of certain wavelengths. Thus, the number of cells that synthesized colicin increased by an average of 300 % upon irradiation at wavelengths of 5.8; 6.5 and 7.1 mm. At the same time neighbouring wavelengths (6.15 and 6.57 mm) showed no such effect. Thus the effect of *E.coli* to produce colicin was induced only at particular frequencies. The results obtained were reproduced with high regularity.

Smolyanskaya and Vilenskaya also studied the variation of the influence of power density of radiation on induction of colicin synthesis. They found that a variation by a factor of 100, from 0.01 to 1.00 mW/cm^2, had no influence on the induction coefficient, and only a further reduction of power density down to 0.001 mW/cm^2 (1 $\mu W/cm^2$) resulted in a sharp decrease in the biological effect.

That the effect does not depend on power was a strong argument in favor of the nonthermal effects of millimeter waves, since all thermal effects depend primarily on intensity of radiation.

As another example we cite the results by Sevast'yanova and Vilenskaya (1974). The investigations deal with damage to bone marrow cells of mice arising from exposure to X-rays and the protecting effect of microwave irradiation. When prior irradiation with microwaves has taken place, then at certain frequencies and intensities the damage is vastly reduced. Experimentalists investigated this protection effect of microwave fields at various power densities from 1 to 75 mW/cm^2. The X-ray dose was 700 rad.

A considerable number of experiments have been connected with irradiation of yeast cultures. A resonant effect of millimeter-wave irradiation on the division intensity of cells was observed. Thus, for example, irradiation of a culture of Rhodotorula rubra for 15 h at wavelengths of 7.16; 7.17, 7.18 and 7.19 mm showed a sharp frequency dependence. Irradiation of a Candida culture caused a marked change in the nature of cell division as compared with the control (Devyatkov 1974).

Academician Devjatkov concluded a report at a session of the Academy of Sciences with the words: "An explanation of the mechanism of the resonant effect of irradiation and some of its other properties would be of enormous interest from the scientific standpoint. As yet, we have no rigorous scientific explanations for the effects of millimeter-band electromagnetic waves. There have been only a few attempts to develop approximate hypotheses to account for the resonant effect, and they require further experimental and theoretical confirmation…."

"In addition to the scientific groundwork, a more active search should be made for fields of practical application of the effects of millimeter-wave irradiation"

The results of a scientific session of the USSR Academy of Science were more than simply pilot results. Around 1965, a number of organizations in the USSR began, under the direction of N. D. Devyatkov, systematic researches on the effects of low-power millimeter waves on biological objects. This scientific session of the USSR Academy of Science was a culmination of several years of research and scientific discussions at the highest level. At this scientific session, specialists working in the fields of biophysics, microbiology, biochemistry, and medicine, were invited. The brief contents of some papers were published in the Soviet journal "Uspekhi physicheskikh nauk". An English translation entitled "Soviet Physics—USPEKHI" was published in 1974. Therefore scientists of other countries learned of the Soviet results and tried to replicate some of them.

Further events developed in two directions. We will consider them below.

5 New Orientation of Development of Technical Devices

Before the Devyatkov report, a refinement of a radar device with constantly increasing power was the basic direction of development of radio engineering in the USSR. After the report, a new opposite direction appeared—designing of compact generators of MM with low power (less than 6–8 mW/cm^2). This problem was addressed by a big collective of scientists under the guidance of N.D. Devjatkov. Leading developers of these portable devices won the State award of the Russian Federation for science and technology in the year 2000.

As a result the new noninvasive method of MM-therapy was developed. It won all kinds of high level approbation and certification (Betskii and Lebedeva 2001).

The method was approved in more than 90 Russian clinics, including many large medical centers.

High efficiency of MM-therapy was confirmed in such areas as:

- Gastroenterology (a stomach ulcer and a duodenal gut, hepatitises, a cholecystitis, a pancreatitis)
- Neurology (a painful syndrome, neuritis, a radiculitis, an osteochondrosis)
- Cardiology (ischemic illness of heart, a stenocardia)
- Urology (a pyelonephritis, an impotence, prostatitis)
- Pulmonology (a tuberculosis, sarcoidosis of lungs)
- Skin diseases (psoriasis, neurodermite)
- Gynecology (erosion of a neck of a uterus, a fibroma)
- Surgery (acceleration of processes of regeneration)
- Oncology (protection of blood formation systems, elimination of by-effects in chemotherapy).
- Preventive maintenance of an aggravation of chronic diseases, cold and virus infections.

Experience of clinical use of this method allows us to speak about absence of remote consequences. Besides, the method combines well with other methods of treatment (medicinal, physiotherapeutic etc.). It has no absolute contra-indications.

MM radiation can be used as monotherapy.

Now in Russia there exist two authoritative journals devoted to these problems:

- “Millimeter waves in biology and medicine” (from 1992),
- “Biomedical technologies and radio electronics” (from 1998).

6 Difficulties of Experimental Measurements

After the publication of the Devyatkov report in English (1974), many foreign scientists tried to repeat the results of the Soviet scientists on different living systems.

Grundler et al. (1977, 1988), Grundler and Keilmann (1978) studied the growth behavior of yeast cultures under coherent microwave irradiation. To avoid thermal effects of irradiation he chose to use a yeast cell culture in stirred aqueous suspension, as this assures an efficient thermal exchange between the cells and the surrounding medium. The temperature of the suspension (32± 1°C) was continuously monitored.

Similar to a yeast experiment described by Devyatkov (1974), frequencies were chosen in a range near 42 GHz. When the cultures were irradiated by CW microwave fields of 1–2 mW/cm^2, the growth rate was considerably enhanced or reduced depending on the frequencies varying by no more than a few megahertz in the 42 GHz range. A spectral fine structure with a width of the order of 10 MHz was observed. Careful temperature monitoring excluded a trivial thermal original of this effect.

Webb (1979) published a paper in which the induction of lambda prophages by of *E. coli* under irradiation by millimeter microwaves was chosen as the test object. Lambda prophage is a particular virus that is parasitic within a bacterium: it is normally dormant, but when “woken up” by, for example, weak external microwave radiation of the correct frequency, it multiplies and kills the bacterium. The effect was distinctly frequency-dependent and has dependence on power density that looks like a step process.

At a symposium in Helsinki in 1978 and in Seattle in 1979, reports were presented by Dandanoni et al. (1978), who studied the action of MM waves on a culture Candida Ablicans. The first such research was described by Devyatkov (1974). Irradiation of a Candida culture caused a marked change in the nature of cell division as compared with the control. The difference between control and experiment at various stages during irradiation was illustrated. Dandanoni et al established that irradiation by MM waves on a frequency of 72 GHz for 90 min with power density level at a few mW/cm^2, and with pulse modulation on 1 kHz, considerably reduces cell growth at room temperature, whereas irradiation in the CW mode under the same conditions has no effect, or a slight growth.

It was quickly found that researchers in this discipline were having great difficulty in replicating results obtained by others. Moreover, the same scientist was sometimes able to observe the effect and sometimes not.

The strangest history was with colicin induction by *E. coli*. As noted above this effect was first reported by Smolyanskaya and Vilenskaya in 1973 (1974). It was confirmed by Swicord et al. (1978) at the 19th General assembly of URSI in Helsinki. It was reported that when *E.coli* W3110 (col E1) was exposed to MM waves on low power levels of less than 1.0 mW/cm^2 in the frequency range of 45.5–46.2 GHz, an effect was observed on induction of colicin synthesis. On the end points of this frequency band, the coefficient of induction was equal to unity. Maximum response was observed on a frequency of 45.9 GHz. The coefficient of induction was 8.

However, at the Bioelectromagnetics Symposium in Seattle, Athey (1979) reported: “We devoted about a year to the colicin induction experiment. In the pilot study using a temporary experimental system, we seemed to be getting some positive results; but after refining our experimental system we never again saw any increased colicin induction”.

In contrast to Athey, Motzkin and others (1979) described facilities for irradiating objects in the 26.5–75 GHz band. Colicin production was doubled on a frequency of 51.7 GHz at power density 0.5 mW/cm^2. This effect was observed with irradiation only on a few definite frequencies at temperatures of 25 and 37 °C. At the Seattle Symposium S.M. Motzkin reported results in support of the Smolyanskaya and Vilenskaya original observation.

At this symposium Partlow (1980) remembered in addition, that Hill et al. (1978) were unable to replicate the frequency-specific effects previously reported by Berteaud et al. (1975) on the rate of growth of *E. coli*.

So, it is no surprise that at the Bioelectromagnetics Symposium in Seattle, Partlow (1980) declared: “All that is needed is a confirmation that the reported effect is real”. These words relate to many bioeffects of MM radiation.

The Bioelectromagnetics Symposium in Seattle on June 22, 1979 was the most serious discussion of the problem after the scientific session of the USSR Academy of Science in Moscow in Jan. 1973.

In 1991 in Moscow there was an International symposium “Millimeter waves of nonthermal intensity in medicine”. Motzkin (1991) presented an abstract with the title “Low power continuous wave millimeter irradiation faills to produce biological effects in lipid vesicles, mammalian muscle cells and *E. coli*”.

It was clear that the real confusion can only be resolved by further millimeter wave bioeffects study. The following researches did not change the general situation. Brilliant works have been performed on studying of resonant bioeffects of MM of radiation, for example Belyaev et al. (1996); but simultaneously there still appeared works denying existence of effects.

It was clear that the science of electromagnetic radiation had faced the next great problem. In the history of electromagnetic radiation, there had been previous such problems. Such expressions as “ultra-violet catastrophe” and “thermal death of the Universe” remind us of them. All these problems were solved by a thermodynamic method. Therefore it was expedient to involve this method for the decision of a problem of bioresonant effects of MM radiation.

7 Thermodynamic Theory as a Key to Understanding of Laws of Energy Conversion

Consideration will be given to the basis of the thermodynamic method that was the leader in research into many problems of electromagnetic radiation. Stages of development of thermodynamics of electromagnetic radiation are distinctly connected with names of the scientists of different countries. Their names in chronological order of the published works are presented at first for equilibrium radiation, and then—for nonequilibrium radiation.

7.1 Equilibrium Radiation

W. Wien (1864–1928) generalized concepts of absolute temperature and entropy for thermal radiation and formulated two laws for the short-wave wing of equilibrium electromagnetic radiation (The Wien region of EMR). Nobel Prize 1911.

Lord Rayleigh (1842–1919) described the long-wave wing of thermal radiation (The Rayleigh-Jeans region).

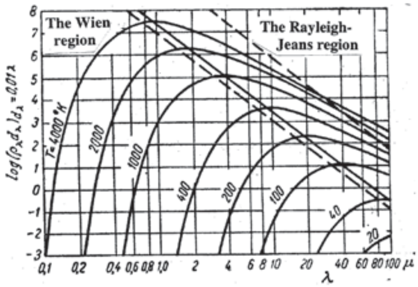

Fig. 4 Equilibrium thermal radiation for different temperatures. (Levich 1954)

Max Planck (1858–1947) (1914) introduced the concept of "action quantum", solved the problem of the theoretical description of full function of thermal radiation (the universal function of Kirchhoff $\varepsilon_{v,\ T}$) and deduced the formula for entropy of thermal radiation. Nobel prize 1918.

Albert Einstein (1879–1955) introduced representation about quantum structure of light and explained a photoeffect. Nobel prize 1921.

S. N. Bose (1894–1955) (1924) elaborated quantum statistics for particles with integer spin and deduced the Planck law for thermal radiation on this base.

The result of their works (Fig. 4) is well known. It has completely exhausted a problem of thermal electromagnetic radiation and has moved (transferred) Planck's law from independent autonomous position into a strictly designated place in the general structure of exact knowledge about Nature.

7.2 A Nonequilibrium Radiation

The first step from equilibrium radiation to nonequilibrium radiation was made by L.D. Landau.

Lev Landau (1908–1968) generalized the Planck formula for entropy of thermal radiation for nonequilibrium radiation (1946).

M.A. Weinstein (1960) deduced the formula for the efficiency limit of electroluminescence, taking into consideration its entropy.

Yu.P. Chukova (from 1969) formulated the general law of efficiency of electromagnetic radiation energy conversion into other kinds of energy in irreversible isothermal processes.

M.A. Leontovich (1903–1981) has calculated efficiency limit for direct conversion of sunlight into electric energy.

P.T. Landsberg (1923–2010) (1980) published the review of works on thermodynamics of nonequilibrium electromagnetic radiation.

8 The General Law of Efficiency of Electromagnetic Radiation Energy Conversion into Other Kinds of Energy

In Chukova's works (1969, 1985, 1999, 2001, 2004, 2009) a simple scheme of conversion of energy fluxes has been created. It is shown in Fig. 5, where the following designations are used:

$\dot{W}_a$ is the rate of electromagnetic energy absorption,
$\dot{S}_a$ is the flux of entropy of absorbed energy,
$\dot{W}_L$ is the flux of irradiated electromagnetic energy,
$\dot{S}_L$ is the flux of entropy of irradiated energy,
$\dot{U}_r$ is the flux of the internal energy of reactants,
$\dot{S}_r$ is the flux of entropy of internal energy of reactants,
$\dot{U}_P$ is the flux of the internal energy of products,
$\dot{S}_P$ is the flux of entropy of internal energy of products,
$\dot{S}_i$ is entropy generation rate due to irreversible processes inside the system,
$\dot{Q}$ is the flux of thermal energy,
T is the temperature of the system,
$\dot{Q}/T$ is the rate at which the entropy of thermal flux carries from the system.

The scheme in Fig. 5 indicates three ways of energy conversion:

- conversion of energy of electromagnetic radiation into other kinds of electromagnetic radiation. It is more often various kinds of luminescence. The efficiency is designated η_L.

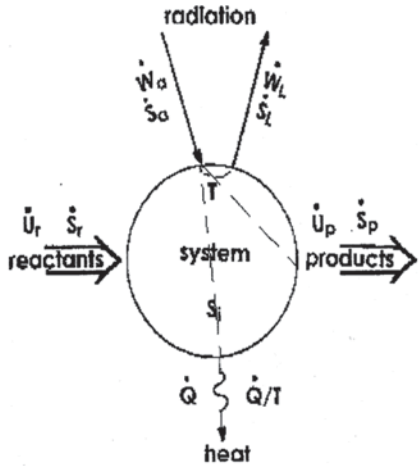

Fig. 5 Fluxes of energy and entropy in a thermodynamic open system. (Chukova 2001)

- conversion of energy of electromagnetic radiation into energy of chemical bonds and into electric energy. This efficiency is designated η and is introduced by the formula

$$\eta = \Delta F/\Delta W_a \tag{1}$$

where F is the Helmholtz free energy and is introduced by the formula F = U − ST,

$$\eta = [(\dot{U}_p - \dot{S}_p T) - (\dot{U}_r - \dot{S}_r T)] / \dot{W}_a \tag{1a}$$

- conversion of energy of electromagnetic radiation into thermal flux $\dot{Q}$. This conversion is considered as energy losses.

On the basis of the law of conservation of energy and the law of balance of entropy in equilibrium conditions, Yu. P. Chukova (2001) received the following generalized formula:

$$\eta_L + \eta = 1 + T(\dot{S}_L - \dot{S}_a - \dot{S}_i) / \dot{W}_a. \tag{2}$$

Within the limits of this article, the case of luminescence does not represent interest, therefore $\eta_L = 0$ and $\dot{S}_L = 0$, then the formula (2) becomes more simply

$$\eta = 1 - T(\dot{S}_a + \dot{S}_i) / \dot{W}_a. \tag{3}$$

According to rules of thermodynamics, calculations begin from a thermodynamic limit ($\dot{S}_i = 0$). The efficiency for a thermodynamic limit is designated η*

$$\eta^* = 1 - T\dot{S}_a / \dot{W}_a. \tag{4}$$

For calculation of the upper limit of efficiency, it is necessary to calculate the absorbed energy and its entropy according to formulas (5)–(7),

$$\dot{W}_a = \int E_\nu d\nu \tag{5}$$

where ν is the frequency of absorbed electromagnetic radiation and E_ν is the spectral intensity of absorbed power.

$$\dot{S}_a = 2\pi k c^{-2} \int \nu^2 [(1+\rho)\ln(1+\rho) - \rho \ln \rho] d\nu, \tag{6}$$

$$\rho = c^2 E_\nu / 2\pi h \nu^3 \tag{7}$$

where c is the light velocity, h is Planck's constant, k is Boltzmann's constant, ρ is distribution function.

The result of calculation η* is presented in Fig. 6 for a full region of frequencies of electromagnetic radiation.

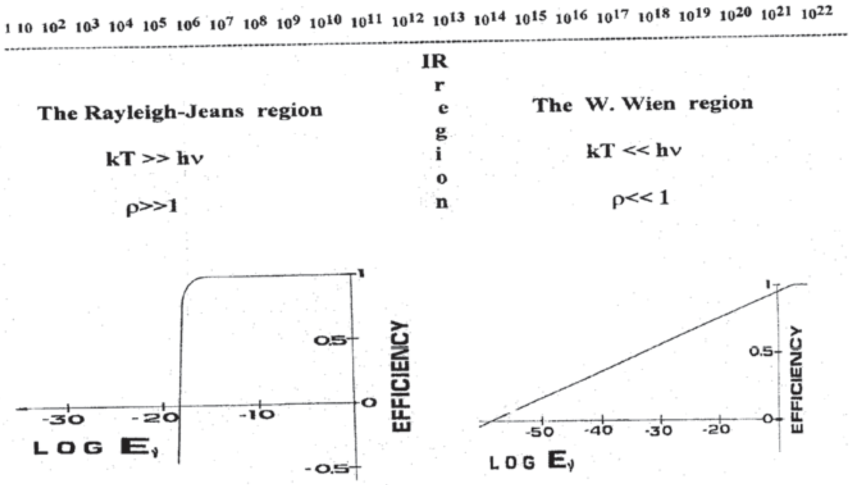

Fig. 6 Partition of the whole region of electromagnetic radiation by theoretical physicists (Chukova 2009)

Figure 4 shows that, according to fundamental laws of nature, a full region of electromagnetic waves breaks up on two areas: the Wilhelm Wien's region and the Rayleigh-Jeans region. Infra-red radiation is the boundary between them. Laws of energy conversion efficiency of electromagnetic radiation differ radically in these two areas. Functional dependence of conversion efficiency η^* (for which the linear scale is used) from spectral density of absorbed power Eν (for which the logarithmic scale is used) is presented at the bottom of Fig. 6.

Thus, we have a result in a semi-logarithmic scale. The straight line in the Wien region indicates (means), that this dependence is logarithmic. It is known to experimenters of different specializations (physiologists, biologists, light engineering, chemists and others) as the Weber-Fechner law which was formulated 150 years ago.

In the Rayleigh-Jeans region, dependence looks like a step process. Such results were obtained for in experiments for the first time by Russian scientists and were published in 1973 (the Devyatkov law).

Dependence on the absorbed power in the Rayleigh-Jeans region (the Devyatkov law), is rather unusual and is not joint with the main principle of an exact experimental (Chukova 1995). This principle demands averaging of results on a series of measurements. Such averaging is significant when the effect cannot change a sign. Figure 6 shows that, in the Rayleigh-Jeans region, endergonic processes (with increase of the Helmholtz free energy) which are located above an axis of absciss, and exergonic processes (with reduction of the Helmholtz free energy) which are located under an axis of abscisses are possible. At averaging of such results the probability of a total zero result is rather great, which we have seen in results of some authors mentioned above. When researchers experiment with an ensemble of microorganisms, the ensemble itself makes an averaging.

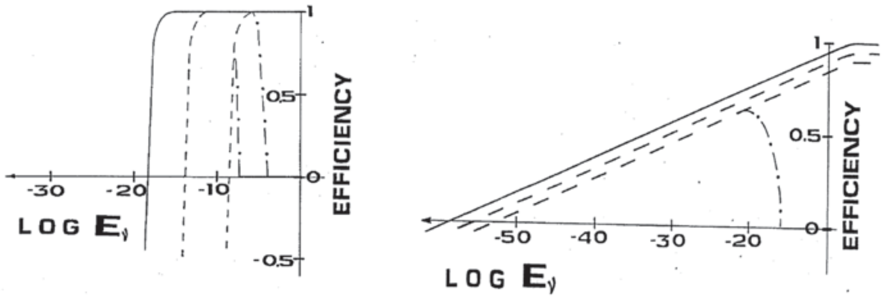

Fig. 7 Allowing for irreversibility processes in the Rayleigh-Jeans region (*left*) and in the Wien region (*right*). (Chukova 1999)

Exclusive skill of the experimenter in this case is required to avoid averaging and to fix an effect. The physician who works with an individual patient is always relieved of such averaging. Therefore medical researches with use of radio-frequency radiation have much higher repeatability than microbiological ones.

But that is not yet all we can say. In Fig. 6, dependences on spectral density of absorbed power E_ν is given for a thermodynamic limit of efficiency which are fair only for reversible processes. Reversible processes do not exist in nature. All natural processes are irreversible. To receive dependences, which is fair for them, it is necessary to consider speed of generation of entropy in the system under electromagnetic radiation. For this purpose it is necessary to calculate according to the formula (3).

The result of such calculation is presented in Fig. 7 for the Rayleigh-Jeans region and for the Wien region (Chukova 2001, 2002, 2009). A continuous line indicates a thermodynamic limit; a shaped line indicates efficiency of the account of linear irreversibility, and a dot-dash line indicates efficiency with the account's superlinear irreversibility. Results show that the account of linear irreversibility does not change the curve form: it remains the same, as in the case of a thermodynamic limit. But in the Rayleigh-Jeans region, it shifts (moves) along an axis of the absorbed energy, and this shift is very great. As calculations on the basis of experimental data have shown, the curve is displaced on 4–8 orders of absorbed power. As a result the experimenter in the Rayleigh-Jeans region has at once two inconveniences in comparison with the Wien region: very narrow interval of change η from 0 to 1 and the strongest change of position of this interval on an axis of the absorbed energy. The sum of these two factors can lead to "loss" of effect by the experimenter. This phenomenon is called the Cheshire cat effect (Chukova 2008). And if an experimentalist adheres more diligently to the standard rules in processing of results of experiments which are developed for visible light (the Wien region), the fixation of zero result ("loss" of effect) becomes more reliable (Chukova 2004).

It means that experimentalists who prepared for work with visible radiation or other radiation of the Wien region will have many extreme difficulties in successfully investigating effects under the Rayleigh-Jeans radiation. Knowledge of thermodynamics will allow one to avoid some errors in experiments and to give clarity to scientific discussion.

9 The Weber-Fechner Law

Now we will pass to consideration of the Wien region which includes (contains) visible light. It is most well investigated and is extremely important for all processes of life on the Earth, but first of all for processes of photosynthesis of plants and human vision. Human vision places first among other sense organs, providing a person with 80–90 % of the information available in today's world.

Research on activity of sense organs is of great importance not only for medicine and physiology, but also for philosophy. It is not an exaggeration to say that now a path of the most active struggle of idealism and materialism lies exactly here. Throughout the last two centuries scientists have moved steadfastly ahead in this area. There is a set of proofs of that, the Nobel Prize in 2004 being a bright demonstration. From this point of view the history of the Weber-Fechner law is interesting and certainly instructive.

9.1 Successes of the Nineteenth Century

In 1834 the German anatomist and psychologist E. H. Weber (1795–1878) presented outcomes of his research into the activity of sense organs. He studied a differential threshold of sensation by sense organs, i.e., he was interested in knowing what minimum change of a stimulus can be detected by a human observer. For example, he found that the addition of one candle to 60 burning candles allows a person to detect an increase of intensity of stimulus, and the addition of one candle to 120 burning candles appears poor for fixation of increasing of stimulus brightness. In the presence of 120 burning candles, for detection of an increase of intensity of stimulus, it was required to add, as minimum, 2 candles, and in the presence of 300 candles—5 candles. Weber concluded that two signals can be distinguished from each other, if the difference between them is proportional to their value. So, Weber's rule is

$$\Delta I/I = \text{const} \tag{8}$$

where I is stimulus intensity, ΔI is a value of the differential threshold, which being added to stimulus intensity I will call a hardly discernible difference in sensations and the numerical value of a constant (const) depends on the sensory system investigated. Weber investigated hearing, vision and touch.

The mathematical rule formulated by Weber did not break the norms of medical habitualness (i.e., did not upset the paradigm that had been adopted in medicine and in physiology) and has not become a source of stinging debate. Weber's experiment was simple and clear, and his outcome became a base for all following researches in sensory physiology.

The situation changed when the physicist, philosopher and physiologist Gustav Theodore Fechner (1801–1887), a contemporary of Weber, published a book under the title "Elemente der Psychophysik" (Fechner 1860). The essence of Fechner's ideas is extremely simple from the mathematical point of view: he integrated the ratio obtained by Weber and deduced the formula

$$\psi = \chi \log(I / I_0) \tag{9}$$

for a stimulus in conditions at the absolute threshold of sensation (Fechner 1860). Formula (9) is called the Weber-Fechner law. It became the fundamental law of psycho-physics and one of the fundamental laws of general sensory physiology. From a world point of view, formula (9) represents for physiologists and doctors something grandiose and continues to be an object of debate in the present day.

The intense discussion of this formula began at once after the publication of Fechner's book. It was started by some researchers who were certain that sensations are not subject to any measurements. Formula (9) represented a mathematical method for ordinary research of mental processes!!! It could not be accepted by those who stood on idealistic stands, contending that mental processes can not be a subject of measurement at all. But even for those who thought differently, the Fechner formula appeared unusual because of its use of a logarithmic function.

Perhaps it was not so important even then whether Fechner was or was not by nature a formidably argumentative person (controversialist, eristikos), or if he had been steeled in the heat of the passions that had boiled around his book; suffice it to say that in discussion, where he was always a victor, a phrase was born and recorded in the history of science: "The Tower of Babel was never finished because the workers could not reach an understanding on how they should build it; my psychophysical edifice will stand because the workers will never agree on how to tear it down".

Fechner had not taken into account that the scientific idea had appeared in a single head, that of his contemporary, Frenchman M.H. Plateau, to be exact. Plateau's objections had essentially been addressed to Weber, but not to Fechner. However Fechner accepted the impact upon himself.

As distinct from Weber, Plateau was sure that in sensory processes the ratio of sensations is a constant, if the ratio of the acting stimuli is constant. In this case, sensation is determined by a power function of stimulus (Plateau 1872).

The debate in the nineteenth century was finished by Fechner's victory, and the Weber-Fechner law became the basic law for five sense organs.

9.2 Events of the Middle of the Twentieth Century

Plateau's published article attracted attention only occasionally. In the middle of the 20^{th} century Stevens S.S. has attempted to give it an experimental verification.

In September 1960 in Chicago, Fechner was honored at a centennial symposium sponsored by the American Psychological Association and Psychometric Society. The main report was made by S.S. Stevens, director of the Psychological Laboratory of Harvard University. In 1961, his report in the adapted form was published in the journal "Science" (Stevens 1961) with a tendentious title "To honor Fechner and repeal his law" with the subheading "A power function, not a log function, describes the operating characteristics of a sensory system".

In the beginning of the paper, Stevens honored Fechner and the unique traits of his character, and then he presented a problem, which was bound up with the formula (2). He noted that no “opponents” of Fechner could adduce essential experimental arguments against his formula. Stevens himself adduced such arguments on the basis of his own experiences 100 years after appearance of the Fechner formula.

Stevens studied nine stimulus: electric shock (~60 Hz), warmth, lifted weights, pressure on the palm, cold, white noise, tone (~1000 Hz), and white light. He used the log-log scale for his experimental outcomes. The intensity of stimuli was given in arbitrary units on the abscissa. The sensation intensity, which was also investigated, was given on the ordinate axis. Intensity of sensation as a function of stimulus intensity was a straight line. The fan of straight lines in an accompanying figure showed that all these processes are quite satisfactorily described by a power function

$$\psi = m(I - I_0)^n, \tag{10}$$

where the above-mentioned symbols are used, m and n are constants.

For electric shock (~60 Hz), warmth, lifted weights, pressure on the palm and cold, the range of stimulus was equal to one order of magnitude, i.e., the stimulus had changed not more than ten times during the experiment. For vibration (60~), the range was equal to a 1.5 order of magnitude, for white noise and 1000~tone if it was two orders. And only for white light was this value equal to a 3.5 order. The dotted line was in the figure, which corresponds to $n=1$, i.e., it is a linear function.

As evident from the figure, among nine effects studied by Stevens, eight have power $n<1$, and only for electric shock $n>1$.

For a tenfold change of a parameter, the desire of an experimenter to present outcomes of experience in linear coordinates would be quite normal. It was made by Chukova for power functions with $n=0.33$; 0.5 and 1.2 (all three values correspond to Stevens experiment). The result was as follows: at tenfold change of stimulus, the power functions with the exponent $0.33<n<1.2$, can be quite satisfactorily described by a linear function with different coefficient of proportionality. The problem of legitimacy of linear approximating of outcomes can arise only for the smallest values of stimulus. But such measurements in physiology are specially difficult and are not often made. Usually a physiologist works at any average values of stimulus, when it is possible to expect the best repeatability of outcome and to claim large accuracy of outcome.

Thus, it is impossible to distinguish between linear dependence and a power function, if the exponent is less than 1.2. These functions are quite reliably distinct, if the power n is much higher than unity (2, 3 etc.) So for tenfold changes of parameter, mathematics does not allow us to consider Stevens’ power functions as a convincing advantage before a linear function for approximation of experimental data.

The range of change of stimulus in Stevens’s experiments is too small (an eye works in a range of change of stimulus on 10–16 orders, and an ear works on 6–9 orders) and it is insufficient for repeal of the Weber-Fechner law. Stevens did not manage to cancel the logarithmic law.

What was possible? Fechner had been separated from Weber. So the separate Fechner law had appeared and was called in publications a dubious, shady, notorious and so-called law. The word "law" appeared inside inverted commas. It was possible to put at the same level the Weber-Fechner law, the power function of Stevens and linear dependence. Formula (3) can be found in any modern textbook on psychophysics and sensory physiology alongside the Weber-Fechner formula. Thus this branch of science had become a field for voluntarism: each experimenter could approximate his or her outcomes by any function.

I will give two examples to show how the relation to the Weber-Fechner law changed after the Chicago anniversary.

The first example:

In the 1930's, teachers in Moscow schools speak to pupils about the Weber-Fechner law in lessons on biology.

The second example:

In the beginning of the twenty-first century a reviewer of the Russian journal "Successes of physiological sciences" declares that "the mental act "sensation" is not a subject for measurements and gradations".

9.3 Rigid Dictatorship of Thermodynamics

But the situation has changed considerably once again. In 2010 at the Lomonosov State University in Moscow, scientists with bunches of flowers celebrated the 150th anniversary of the Fechner book "Elemente der Psychophysik". Some organizations (including the German Embassy in Moscow) prepared this jubilee. Alexander Slobodin's video film "Anniversary" and the Chukova book "The Weber-Fechner law" in English (2010a) is devoted to this event.

After development of the thermodynamic theory of nonequilibrium electromagnetic radiation and the result presented in Fig. 6, there is no possibility to speak about cancellation of the Weber-Fechner law because logarithmic dependence follows from the law of conservation of energy, and it is not connected with any private restrictions or assumptions.

It is necessary to pay attention to the very big interval of change of illumination in the operating characteristics of human vision.

An eye sees badly at night, when the brightness of the night sky without stars is 10^{-6} cd/m^2 (cd is abbreviation of candelas). If in the night sky there are stars but there is no moon, the brightness of such a sky is 10^{-3} cd/ m^2, and at the full moon it is 10^{-1} cd/m^2. Metallic filament of an incandescent lamp has brightness more than 10^6 cd/m^2. At a cloudless summer solar noon, the sky brightness reaches 10^7 cd/m^2. Thus the change of illumination, where a human eye works normally and permanently, has more than 12 orders of magnitude, i.e., the human visual system during evolution has achieved such perfection that it was made possible to fix a change of stimulus in huge limits (more than 10 orders, i.e., more than ten billion times!!!). Brightness of the Sun is about 10^9 cd/m^2. But to look at the Sun on a bright summer day is bad for one's health. In this case, the working range of an eye is 15 orders, and the hygienists recommend wearing sunglasses in summer. The brightness of a pulse stroboscopic lamp is near 10^{11} cd/m^2, but it is already an adverse condition, which requires a special reliable protection for the eye. So, a human eye can work in a range of change of sunlight intensity on 17 orders of magnitude.

This raises a question: "Is there a mathematical function that is capable of making the eye work?"

Yes, it is the logarithmic function. The decimal logarithm is varied on 17 units, if the parameter is varied on 17 orders of magnitude, and if its parameter is varied on 15 orders of magnitude, the logarithm is varied on 15 units. So, the mathematical formula within a statute of the scientific law can describe mathematically the full operating characteristic of the human eye. The brightness of a pulse stroboscopic lamp is near 10^{11} cd/m^2, but it is already an adverse condition, which requires a special reliable protection for the eye.

Thus, from the point of view of mathematics everything is all right. What is it possible to say about physiology? Nature could not create a receptor that would be efficient in such a wide range. The human eye has two receptors of light: rods and cones. They have different spectral sensitivity and different efficiency of conversion of the absorbed radiation. The situation is described in detail by Chukova (2002a, b, 2010a). Now it is important for us to know the following: at transition from day sight (cones) to night sight (rods) on a straight line (in semi-logarithmic scale of Fig. 6), there is a change. And it is normal! Only in this range, Stevens's power function has some sense. Transition from cones to rods occupies about three orders of intensity. In this range it is possible to use the Stevens power function for approximation of experimental data. But we must never confuse mathematical operation of approximation and the physical law. These are essentially different things. The physical law gives logarithmic dependence!!! (Chukova 2010)

Change of spectral sensitivity of the human eye at transition from day illumination to evening illumination has been known from the beginning of the nineteenth century and is called the Purkyne effect. The Purkyne effect is well studied, but till now nobody could answer distinctly the question of why it exists. The exhaustive answer to this question was given by the thermodynamic theory of systems under electromagnetic radiation.

Thus, cancellation of the logarithmic law is impossible, because it is impossible to repeal the law of conservation of energy. It means, that there are no problems with human vision. The foregoing thermodynamic theory is quite right for it.

The thermodynamic theory stated above is capable of explaining not only the basic characteristics of human vision, but also many other photobiological phenomena with logarithmic dependence, such as photosynthesis and phototropism of green plants, all kinds of photomovement (Nultsch 1961a, b, 1962; Diehn and Tollin 1966) of the elementary organisms (phototaxis, phobotaxis and photokinesis), and also many other phenomena.

Apparently, the logarithmic base was understood by those who stood near the source of quantitative research of human hearing, whereas in this area the logarithmic scale has already been used for measurement of sound pressure level for a long time.

It is evident according to hygienic research, that a change of sound pressure from 0 to 80 decibels is a normal condition for operating of the human ear.

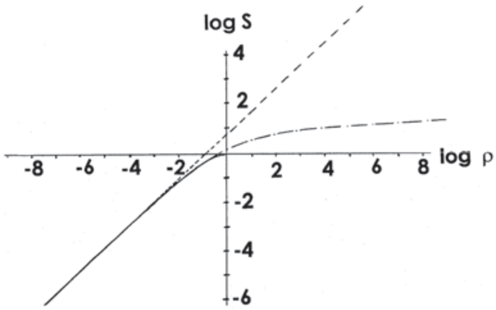

Fig. 8 Dependence of entropy from ρ for Fermi-Dirac distribution (*a continuous line*), Bose-Einstein distribution (a *continuous line* and a *dot-dash line*) and Maxwell-Boltzmann distribution (a *continuous line* and a *dotted line*). (Chukova 2010b)

Sound pressure from 80 to 110 decibels is considered as marginal conditions, and pressure of sound from 110 to 170 is a very bad condition for the work of the human ear, which can be a reason for damage and originating of disease. So it follows from hygienists studies that the human ear in normal conditions works in the range of 4 orders of stimulus magnitude. The general range of human audibility is 5.5–8.5 orders of magnitude.

But how is it be with other sense organs?

The system of Fig. 5 is right for electromagnetic radiation and for other influences. The same is possible to tell about formulas (1)–(4). Specificity of electromagnetic radiation is concluded in formulas (5)–(7), and the specificity of the Wien region is caused by value of distribution function ρ, which is less than unity. In the Rayleigh-Jeans region it is more than unity.

Dependence of entropy flux from ρ is presented in Fig. 8 for three distributions most often used by physicists: Fermi-Dirac distribution (a continuous line), Bose-Einstein distribution (a continuous line and a dot-dash line) and Maxwell-Boltzmann distribution (a continuous line and a dotted line). For the particles submitting to Fermi-Dirac statistics, values ρ can be only below unity. And for the particles submitting to two other statistics, they can be both lower and above unity. But now only the interval ρ below unity, which defines occurrence of logarithmic dependence, is of interest for us. Its presence in all three statistics says that logarithmic dependence is the general dependence for a huge circle of absolutely different phenomena which are now considered not only as independent, but absolutely alien to each other. Therefore, the presence of logarithmic dependence at quantitative studying of other sense organs of a person is absolutely natural.

So, the thermodynamic theory has answered all basic questions connected with the Weber–Fechner law.

10 Western and Chinese Medicine on an Integration Way

In the history of our civilization there is one big riddle connected with independent existence of Oriental (Chinese) and Western (European) medicines during two millenniums. This independence arose in a time when China was artificially divided from the world around.

Now in the period of globalization all artificial boundaries have fallen, and independence between European medicine and Chinese medicine becomes a subject of discussion. At the 13th International Congress of Logic, Methodology and Philosophy of Science (2007, Beijing, China) there appeared for the first time a Special Symposium "Chinese Traditional Medicine vs. Western Medicine". At this Symposium, scientists of China and France attempted to compare these independent sciences. But this comparison was like that of fire and ice because it contained only enumeration of characteristics of one and the other, which demonstrated clearly their deep difference.

Now we have a method that allows us to build a bridge from Western science to traditional Chinese medicine (TCM). This bridge was given by a new branch of thermodynamics, namely thermodynamics of irreversible processes in systems under electromagnetic radiation. This new branch of thermodynamics has been described above and can be used now with success.

Thermodynamics of irreversible processes in systems under electromagnetic radiation (the irreversible thermodynamics of physiological processes of electromagnetic radiation) can be a dictionary for translation of terminology of Chinese medicine into the language of Western science.

The key concept of Chinese medicine (energy Chi) corresponds to Helmholtz's free energy which is a basis of the foregoing theory. From this point of view, it is easy to understand why before it was not possible to find any conformity between Chinese medicine and western medicine. These are different sciences: western medicine has concentrated on morphology of patient, and Chinese medicine is a science about energy. More importantly, Chinese medicine is a science about weak influences while the western medicine studied until recently strong influences. Only in recent years has western medicine paid attention to weak influences of electromagnetic radiation. It has given us a chance to construct the bridge, connecting both sciences. As a result, there is now appearing a clear contour of new world medicine of the middle and the second part of the twenty-first century. But it is a theme for that calls for extensive research.

11 Conclusion

The face of our twentieth century civilization was defined by successes of space researches, cybernetics and semiconductors. Theoretically based works advanced experiments in these three areas. Theoretical science lit a lantern in areas where experimenters can work productively. In the middle of the twentieth century Sergey Ivanovich Vavilov, President of the Academy of Science of the USSR, repeatedly underlined the importance of continuing development of theory in science. All the above discourse shows his correctness: thermodynamic theory, for example, has allowed us to understand the most complicated contradictions of experiments with MM radiation, having explained the features of biological and medical effects which can be both beneficial and harmful for living organisms (Chukova 2001, 2011).

Even more to the point, this theory has shown the importance and generality of those problems which were solved in the twentieth century for radiation MM, for all regions of radio-frequency radiation and extremely low frequencies, including terahertz radiation, which only recently began to be used in biological and medical experiments.

The thermodynamic theory can be crucial in resolving a question on hygienic standards of safety on a strictly scientific basis. It is of the utmost importance that the WHO not ignore this opportunity (Chukova 2006, 2008, 2011). Chukova's Memorandum on this problem was addressed to Margaret Chen, the Director General of WHO. It was sent on July 30, 2012, arrived at WHO headquarters on August 17, 2012 and was fully expected to be taken up for consideration by qualified experts (Chukova 2013).

The thermodynamic theory has allowed us to thoroughly examine and assess the proposal made by Stevens to abandon the Weber-Fechner law and has proved that it cannot be discarded without also discarding the law of conservation of energy. Moreover, it has shown that the Weber-Fechner law has a much wider generality than physiological science only. It is one of the basic general laws of nature.

Such generality of the law of energy conversion of electromagnetic radiation allows us to use the general power basis not only for all phenomena studied by photobiology, but also for many other physical phenomena. All of this argument implies the need to write and publish new textbooks that will allow us to further our progress in knowledge about natural phenomena and to facilitate the process of acceptance of reasonable social decisions which do not contradict nature's laws.

A profound example is that thermodynamic theory has found a key (approach) for an explanation of distinctions between Western and Chinese medicine. Now it is possible to expect that this direction will open a way for treatment of many chronic diseases which now have no treatments within the limits of the regulations accepted by Western medicine

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