

*To my family,
for all these years of love and support.*

Dejan Raković

Prof. Dr. Dejan Raković
INTEGRATIVE BIOPHYSICS, QUANTUM MEDICINE & QUANTUM-HOLOGRAPHIC
INFORMATICS: PSYCHOSOMATIC-COGNITIVE IMPLICATIONS

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IMPLICATIONS**

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CONTENTS

Preface	7
1. Introduction	13
1.1 References	26
2. Quantum Neural Informatics: Hopfield Neural Networks and Quantum Holography	31
2.1 References	39
3. Physics of Enzyme-Substrate Interaction:	41
Biomolecular Recognition	
3.1 Semi-Classical Model of Electronic-Conformational Interactions and Biomolecular Recognition	41
3.2 Quantum Models of Electronic-Conformational Interactions and Biomolecular Recognition	44
3.3 References	52
4. Brain's Hierarchical Neural Networks	55
4.1 Hierarchical Models of Brain's Neural Networks	60
4.2 Implications for Modelling Cognitive Functions	71
4.3 References	74
5. Body's Hierarchical Neural Networks	75
5.1 Quantum and Classical Body's Hierarchical Neural Networks	81
5.2 Implications for Modelling Psychosomatic-Cognitive Functions	95
5.3 References	100
6. Appendices	107
6.1 Wave Functions of Systems of Identical Bosons and Fermions. Pauli's Exclusion Principle	107
6.2 Quantum Chemistry and Spectroscopy of Molecules. Adiabatic, Harmonic and Dipole Approximations	110
6.3 Second Quantization. Feynman's Propagator Form of Quantum Mechanics	115
6.4 Quantum Bases of RRM-Model of Resonant Recognition	117
6.5 Density Operator. Von Neumann's Entropy	121
6.6 Quantum Entanglement. Von Neumann's Quantum Theory of Measurement	125
6.7 Quantum Decoherence Theory. Stationary and Nonstationary Quantum States	129
6.8 Quantum Qubit Informatics. Quantum Teleportation, Cryptography and Computation	133
6.9 References	143
Excerpts from Reviews	145
About the Author	147

PREFACE

The subject of this monograph are integrative biophysics, quantum medicine and quantum-holographic informatics, which is of special importance because of wider application of integrative medicine in developed countries – as contemporary research of psychosomatic diseases indicates the necessity of application of holistic methods, oriented to the treatment of man as a whole and not diseases as symptoms of disorders of this wholeness, implying their macroscopic quantum origin.

The focus of these quantum-holistic methods are body's acupuncture system and consciousness, which in Feynman's propagator version of Schrödinger equation exhibit the quantum-informational structure of quantum-holographic Hopfield-like associative neural network, with memory attractors as a possible quantum-holographic informational basis of psychosomatic diseases.

The monograph is divided into several chapters. Introductory Chapter 1 reveals the history of the problems and phenomenology of integrative biophysics and quantum medicine. Chapter 2 provides a basis of quantum neural informatics, i.e. Hopfield's neural networks and quantum holography, which is a good quantum-informational framework for integrative biophysics and quantum medicine. Chapter 3 is dedicated to the physics of enzyme-substrate interaction, i.e. quantum models of biomolecular recognition, where the necessity of quantum-holistic approach is already obvious. Chapter 4 discusses brain's hierarchical neural networks, starting from the hierarchical models of brain's neural networks, and finishing with implications for the modelling of cognitive functions. Chapter 5 treats body's hierarchical neural networks, starting from quantum and classical body's hierarchical neural networks for modelling two modes of consciousness, and finishing with implications for the modelling of psychosomatic-cognitive functions. Because of self-reference of the book, Chapter 6 contains eight specialized appendices, dedicated to quantum chemistry and quantum informatics.

The main results of this highly multidisciplinary monograph are, on the one hand, demonstration that contemporary research of psychosomatic diseases indicates the necessity of application of holistic methods, and on the other hand, an overview of classical and quantum modelling of biomolecular recognition, cognitive and psychosomatic

functions, as a good extended quantum-holographic informational framework for integrative biophysics and quantum medicine.

Thus this monograph is naturally dedicated to specialists of biophysics and biomedical engineering, integrative medicine and holistic psychotherapy, and to all those who believe in quantum-holographic paradigm. I hope that some harder parts (especially the mathematical-physical appendices, written primarily for those with deeper physical education) will not discourage them from entering the studying of this intriguing book.

At this point, I would sincerely acknowledge the reviewers of the monograph, Prof. Djuro Koruga and Acad. Jovan Šetrajčić, for the long support, cooperation and useful suggestions. Also, I would honestly acknowledge Mitja Peruš PhD, whose papers in the field of biological neural networks and consciousness were very useful to me, to Prof. Miroljub Dugić, Prof. Milan Ćirković, Prof. Gordana Stanojević-Vitaliano, Prof. Emil Jovanov, Vlada Radivojević MD, Prof. Žarko Martinović, Nenad Rajšić PhD, Zvonko Šundrić PhD, Milka Ćosović MD, Zlata Jovanović Ignjatić MD, Zdenko Arsenijević MD, Mirko Ostojić MS, Milorad Tomašević MS, Predrag Šuković PhD, Dejan Radenović MS, Lazar Škarić BS, Djordje Baljuzović MS, Ana Vasić MS, Živorad Mihajlović Slavinski BA, Mirjana Sovilj PhD, Slavica Pantelić MS, Slavica Jovičić BA, Nikoleta Stevović BA, Jevrem Bojović MS, Milan Mladjenović MS, Ivana Džamić MD and Jelisaveta Kunosić PhD, for multidisciplinary theoretical or experimental cooperation in the field of states of consciousness, as well as to Acad. Lav A. Gribov, Acad. Bratislav Tošić, Prof. Miroljub Dugić, Prof. Milenko Plavšić, Goran Keković PhD, Prof. Dragomir Davidović, Prof. Irena Cosic, Jasmina Jeknić Dugić MS, Stevo Jaćimovski PhD and Prof. Vjekoslav Sajfert, for cooperation in the field of quantum theory of biomolecular recognition. For cooperation and support in the fields of integrative medicine and holistic biophysics I am deeply indebted to Acad. Antonije Škokljević, Acad. Ljubisav Rakić, Acad. Veselinka Šušić, Acad. Vladeta Jerotić, Acad. Dejan P. Kreculj, Acad. Nikola Milošević, Acad. Dragoljub Mirjanić, Acad. Evgeniya L. Macheret, Acad. Vlail P. Kaznacheev, Prof. Predrag Radenović, Prof. Paul Rosh, Prof. Joshiaki Omura, Hiroshi Motoyama PhD, Prof. Sergey P. Sitko, Prof. Nataliya N. Lebedeva, Prof. Oleg V. Betskii, Prof. Nikolay D. Kolbun, Prof. Konstantin G. Korotkov, Prof. Aleksander V. Trofimov, Sergey N.

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In Belgrade, winter 2009

– Dejan Raković

1. INTRODUCTION

The subject of this monograph is integrative biophysics, quantum medicine and quantum-holographic informatics, with special reference to some very significant psychosomatic-cognitive implications.

Most of contemporary books in the field of biophysics is of the reductionist type, mainly dedicated to the molecular biophysics and methods of biomolecular characterization, to a lesser number consider processes in the cellular level, and rarely are committed to a holistic integrative level of the organism and biosphere (which includes social and environmental aspects, biometeorology, geomedicine, chronobiology, psychosomatics, consciousness, homeopathy, acupuncture, yoga, meditation, transpersonal psychology) – although this trend is beginning to change with wider application of *integrative medicine* in the developed countries [1].

Historical Review of Integrative Biophysics. Let us mention some of the scientists whose research in various fields contributed to the development of integrative biophysics, with a brief description of the contribution [2].

Hippocrates was the first to point out that weather and climate play an important role in maintaining the health and development of human diseases, but only in the 20th century this idea was seriously tested, when the regular meteorological observations under standard conditions, reliable epidemiological records, adequate physiological understanding, and invention of the climate chamber for exposing people to artificial weather conditions – became available. Of modern scientists in the field of biomedicine, that dealt with the *influence of environment* on man, let us mention a few names: Arrhenius (in his paper on the topic of biometeorology claimed that body's clock forms an open system and that under constant conditions the time periodicity is set by outside influences), Chizhevsky (founder of heliobiology, examined the effects of positive and negative aeroions to life, human health and behavior), Bernard (introduced the concept of internal, earth and cosmic environments, as well as of rhythmical order), Hellpach (pointed out that natural environment has two modes of impact on the man, one which is observed directly through the senses, and the other which is mediated by the vegetative system), Henderson (examined regulation of acid-base

balance in the blood, introduced the idea that physical and chemical inorganic environmental characteristics, which originate from water, hydrocarbon compounds and carbon acid, are crucial for the development of organic life), Huntington (found that climate affects the physical strength and health, in one of three physiological and pathological processes he investigated), Halberg (introduced terms of biorhythms: circadian (about 24 h), ultradian (about 1.5-2 h) and infradian (weeks or months)), Fliess (created one of the most popular versions of biorhythmology, claiming that every man has a male and female cycle of 23 and 28 days, which control the physiology of each cell and flows of bodily and physiological vitality), Edmunds (stressed all the characteristics of circadian rhythm: ubiquity, periodicity of about 24 h, stability, possibility of moving phase, temperature compensation), Piccardi (examined the impact of lunar phases on the chemical test, and the influence of the earth, solar and cosmic phenomena on biological reactions such as the degree of blood sedimentation), de Rudder (developed the concept of the seasonality of disease, now a fundamental principle of biometeorological concepts), Petersen (found that response of the body on the external forces covers rhythmical changes of the autonomous nervous processes of the vegetative system, associated with the endocrine and biochemical changes), Cannon (introduced the concept of homeostasis as a mechanism to stabilize physiological changes in a particular range of variations), Bauer (proposed three fundamental biological postulates: all living systems are in a stable nonequilibrium state and therefore have the energy to do work for the conservation of this nonequilibrium state of homeostasis; living systems perform internal work, but also external work that grows with development; imbalance in living systems is created by a group of molecules whose conformation is storing metabolic energy that is used for their forming), Selye (performed a series of experiments to test nonspecific, the system responses of organism to stress, such as physical strains, exposure to radiation, cold and heat, traumatic injuries, blood loss, disease, infection, danger, fear; in his theory of 'General adaptive syndrome', identified three distinctive stages of stress: alarm phase, resistance phase, exhaustion phase).

Out of the physicists who dealt with *quantum bases* of integrative biophysics let us also mention several names: Gurwitsch (renowned for his discovery of bio-photon emission, proposed that groups of molecules

in living cells and tissues do exist in nonequilibrium state, which is the result of action of biological fields; appointed 'molecular groups' as a 'state of mutual adjustments and orientation' of molecules, which makes him the first to postulate what is now known as 'collective state' or 'cooperative phenomenon'), Bohr (gave philosophical contribution to the development of molecular biology (in terms of quantum biology) in his paper on the light and life, when he postulated that the new physics is necessary to explain the theory of life, and that life is not reducible to the atomic physics), Pascual (supported Bohr's idea, and in his 'amplification theory of life' claimed that living systems may have the ability to reinforce the weak signals, even of individual photon, in such a way that could trigger macroscopic events), Schrödinger (in his renowned book 'What is life?' discussed thermodynamics of living systems, the nature of genetics, and structure of genes as 'aperiodic crystals', pointed out that the organisms remain ordered by compensating 'negative entropy' from the environment), Prigogine (introduced nonequilibrium thermodynamics for an explanation of life processes, the notion of 'dissipative structures' as a new class of order far from thermal equilibrium, which originates from the sudden collective behavior of a large number of particles, triggered by small fluctuations which have no such an effect in the thermal equilibrium), Sinz (proposed 'oscillatory model of the organism' within the framework of the field model, claiming that a living organism with its endless rhythmical processes is a highly complex resonant system of the oscillating fields nonlinearly matched by their phase relationships), Fröhlich (pointed out that low-temperature phenomena in superfluids show macroscopic quantisation much subtler in nature, and based on these observations an existence of a 'new kind of order based on the concept of interphase relations' should be assumed in biological systems, with organized collective behavior), Einstein-Podolsky-Rosen (suggested theoretically now well-known EPR-correlations, which represent the mathematically precisely defined holistic (nonlocal) characteristics of quantum mechanics, afterwards experimentally verified), Primas (postulated, according to EPR-correlations and the principle of complementarity, that quantum mechanics provides the first consistent holistic theory, which is not possible to explain the whole by description of its parts and correlations among them; according to him, in addition to the world of objects and fields, there are some fundamental levels of reality such as the Schrödinger

wave function of quantum theory that describes the hidden domain of possibilities, non-observable, non-manifested, over-physical world of non-local correlations and the instantaneous connections (cf. App. 6.8), rather than visible phenomena – and only in the act of measurement the infinite possibilities, described by Schrödinger equation as a superposition of all possible quantum states, collapse in a single reality; associated with the concept of 'probability' is the concept of 'entanglement' (cf. App. 6.6) that describes characteristics of mutual connection of the quantum system and its quantum environment, so that in the absence of any interaction, such as measurements, these two quantum subsystems are in entangled state in which neither quantum system nor its quantum environment are in the 'pure state' (one quantum subsystem cannot be fully described without references to the other), so that these entangled domains can be regarded as fundamental dimensions of reality, the domains of dynamic inter-connections, which are not only the basis of physical world and matter, but are seemingly connected with consciousness, considered by some authors as a fundamental field which is the basis of reality).

Phenomenology of Quantum Medicine. Contemporary investigations of psychosomatic diseases imply the necessity of application of *holistic methods*, oriented to *healing the person as a whole* and not disease as a symptom of disorder of the whole, implying their *macroscopic quantum origin* [3,4]. In the focus of these quantum-holistic methods are body's *acupuncture system* and *consciousness* – which have *quantum-informational structure of quantum-holographic Hopfield associative neural network*, within the Feynman propagator version of Schrödinger equation [5] (cf. Ch. 2) – with surprisingly significant psychosomatic-cognitive implications (which will be a subject of the next subsection).

Acupuncture system is an ancient Chinese concept of the energy-informational channels/meridians and points, responsible for psychosomatic health and illness (cf. Ch. 5). The quantum electromagnetic (EM)/ionic basis of the acupuncture system (of 'non-threshold' electrical 'gap junction' (GJ) synapses [6]) is implied by *resonant windows* in frequency and intensity in tissue interactions with extremely weak 'non-threshold' EM fields (undetectable by nervous system of 'threshold' electrochemical synapses) [3,4], as well as *quantum-coherent characteristics* (highly resonant microwave sensory response of the disordered organism,

biologically efficient nonthermal microwave radiation of extremely low intensity and energy, and neglecting microwave energy losses across acupuncture meridians) and successes of the Russian-Ukrainian school of microwave (MW) resonance therapy [7,8] – which is now associated with the appearance of *Quantum medicine*.

Microwave resonance therapy (MRT) of the acupuncture system was internationally introduced by Sit'ko and collaborators in 1989, at the International Symposium in Kiev, when an expert commission headed by British theoretical physicists Fröhlich proclaimed MRT as a perspective approach in the regulation of living systems, and MRT clinical results as highly efficient. MRT also appears under other synonyms: SWT (short wave therapy), MWT (millimetre wave therapy), and IWT (information wave therapy). The method originates from the former USSR in mid-1960 with the advent of unique broadband backward-wave tube oscillators by two radioelectronics groups of the USSR Academy of Sciences, originally used in military industry and satellite communications. The interest in influence of EM MW radiation upon non-human biological objects appeared shortly afterwards (Zalubovskaya in Kharkow and Devyatkov et al in Moscow [7]), but necessity for application of microwave resonance therapy (MRT) upon *acupuncture points* was discovered only in the early 1980's (Sit'ko et al in Kiev [8]) as appearance of sharply-resonant characteristic eigenfrequencies of human organism – which successfully stimulated development of the second generation of coherent and the third generation of noise spectrum MW generators. The coherent spectrum MW generators with manually changeable frequency (from 52 to 70 GHz) are far less suitable in practice, because of much longer seeking of the resonant frequency, dependent on individual properties of the organism and the subjective state of the patient, which can result in therapeutic mistakes and overdosing. On the other hand, the noise spectrum MW generators enable simultaneous excitation of all possibly therapeutic resonance MW frequencies (52-78 GHz), and an organism continuously resonantly responds to currently appropriate (and changeable during therapy) frequency.

By affecting the appropriate acupuncture points by MRT generators of high frequency microwaves (52-78 GHz), remarkable clinical results of the treatment are being achieved in the *prevention and therapy of*

stress, as well as in many *psychosomatic disorders* (cardiovascular, respiratory, gastro-intestinal, nefro-urolologic, endocrine, gynecological, neurological, psychiatric, dermatological, orthopedic and traumatologic, ophthalmologic, ORL, stomatologic, pediatric, addictions ...) – with average efficiency of 82% in chronic and up to 100% in acute diseases, tested on population of several millions of patients of different pathologies in several thousands of MRT cabinets in Ukraine and Russia. On the other hand, the MRT is *rarely contra-indicated* (only in the cases of acute pain in abdomen demanding an operation, pregnancy, and menstruation cycle). The recommended MRT *treatment* at an acupuncture point is maximum 10 minutes, while the duration of the whole treatment is maximum 20 minutes, applied daily. Ten treatments in a course are applied (except in very difficult stadiums of diseases when they have to be prolonged), with minimum pause of 21 days and optimal of one month, in case a repeated course is necessary. The specific course of prophylaxis is advised at every 6 months.

MRT is practical realization of the Prigogine *theory of self-organization* of living systems [9]. On this line, Sit'ko and collaborators have proposed in early 1980's that the acupuncture system is a macroscopic quantum dynamic structure [8] which might be simply visualized [10] as differentiated at the locations of maxima of three-dimensional standing waves, formed as a result of the reflection of coherent MW Fröhlich excitations [11] of molecular sub-units in the cell membranes, proteins, microtubules etc – supported also by other investigations which have demonstrated that differentiation of gap junctions (through which an evolutionary older type of inter-cell communications is achieved, including acupuncture [6], whose conductivity can be modulated by intra-cell pH-factor, Ca^{2+} -ions, neurotransmitters and second messengers – and even by voltage) is slightly sensitive to voltage [12].

In that context an *explanation for efficiency* of the MRT, as noninvasive non-pharmacological medical treatment, should be sought [10]: Some disorders in the organism give rise to deformation in the standing wave structure of electrical field of the organism in the MW region, which influences corresponding changes in the spatial structure of the acupuncture system, and consequently its resonant frequencies, resulting in some disease; during the therapy, applying the MW sound at corresponding acupuncture point the excited acupuncture system of

the patient is relaxing to the previous healthy condition, while reaching normal resonant frequencies responses of its meridians upon the wide spectrum MW source – and following to physiological mechanisms of the acupuncture regulation the organism biochemically overcomes the disease.

On the other hand, bearing in mind the afore-mentioned *quantum-coherent characteristics* of MRT as well as that recent theoretical investigations show that any quantum system has formal *quantum-informational structure of quantum-holographic associative neural network* [5] (cf. Ch. 2) – then *memory attractors of acupuncture network* can be potentially treated as *psychosomatic disorders* which represent EM MW *quantum-holistic record* (which can be thus only holistically erased, as supported by extreme efficiency of MRT therapy, that removes the very information on psychosomatic disorders) – which might represent biophysical basis of (acupuncture *temporarily reprogrammable!*) *quantum-holistic local psychosomatics* [13,14] (cf. Ch. 5).

Namely, according to *Tibetan traditional medicine* [15] an acupuncture procedure must be *repeated* every several months – presumably as a consequence of *restituted* patient's mental loads from his *mental-transpersonal-environment* of closely related family members and enemies, that remained *non-reprogrammed* on the level of quantum-holographic collective consciousness, which might be supported by *Tibetan pulse diagnostics* based on 20 pulses, enabling precise diagnosis of psychosomatic disorders not only of the patient himself *but also* of his family members and enemies.

An additional support that acupuncture system is really related to consciousness is provided by novel *meridian (psychoenergetic) therapies* (with very fast removing of persistent phobias, allergies and other psychosomatic disorders [16-18]), whose simultaneous effects of *visualization* and *tapping/touching of some acupuncture points* might be interpreted as a '*smearing*' of *memory attractors* of the psychosomatic disorders, through successive imposing of new boundary conditions in the acupuncture energy-state space during visualizations of the psychosomatic problems [14,18] – so that *meridian (psycho-energetic) therapies* (alongside with psychosomatically healing positively-visualizing *meditation* [19]) might be also categorized into the field of *quantum medicine* (cf. Ch. 5).

The Meridian (Psycho)Therapies are also called Energy (Psycho) Therapies [16-18], because of the common observation of majority of practitioners that psychological problems might be understood as manifestations of energy disruptions of energy configurations in the human energetic field. In essence, systems of *Energy/Meridian (Psycho) Therapies* (EMPTs) represent an application of the energy paradigm to the removal of psychological and emotional aberrations, diseases, and other maladies. The proponents of these therapies believe that the causes of these aberrations are disturbances in the energy field (or aura) of a human being, fundamentally manifested as energy structures, which naturally manifest themselves neurologically, biochemically, cognitively and behaviourally. The introduction of the energy paradigm into the fields of psychotherapy and spiritual technology represents a quantum leap in the understanding of these important areas, since it makes us look at them from an entirely different viewpoint. Psychological problems are resolvable far faster if we approach them as if they were disturbances in energy fields, than if we start searching for their historical causes – as was characteristically done in earlier times, beginning from the Freud psychoanalysis. Changing the structure of the energy fields that are at the roots of problems is enough to create healing or a shift in the Spiritual Consciousness.

Let us mention just a few main systems of EMPTs. *Thought Field Therapy* (TFT) was invented by clinical psychologist Roger Callahan, who started this energetic revolution in psychology and psychotherapy. TFT entails diagnostic procedures to determine meridian disbalance, combined with percussing at specific acupuncture points in a prescribed sequence (algorithm) in order to treat an array of psychological problems. *Emotional Freedom Technique* (EFT) was developed by Gary Craig, one of the first disciples of Roger Callahan; he founded it on the same basis as TFT, but, judging by the statements of many practitioners, it is simpler and more efficient than TFT, because it uses just one algorithm for all disturbances. *Tapas Acupressure Technique* (TAT) was created by Tapasvini Fleming, who fruitfully connected her knowledge of acupressure with meridian systems; briefly, TAT is a 'do-it-yourself' therapeutic technique, based on *traditional Chinese Medicine*, which is extremely efficient with all kinds of allergies, sensitivities with different kinds of food and negative environmental influences. *Eye Movement*

Desensitization and Reprocessing (EMDR) works by diminishing sensitivity through eye movements and reprocessing traumatic incidents; it is simple and efficient method for healing traumas and disorders connected with anxiety.

Let us also mention recently developed processes of Živorad Mihajlović Slavinski [17]: *Basic PEAT*, *Deep PEAT*, *DP4 method* and *Fore-Finger Method*, having in common that they do not use associative chain of arising contents – but ‘frozen’ image or snap-shot of most dramatic and strongest moment of unwilling experience or problem.

Basic PEAT requests along with imagination of ‘frozen’ image an alternative using of the three acupuncture points around both eyes. Unpleasant experience disappears mostly in one treatment. The method has proved efficient not only in removing actual problems, but also in removing hard, chronic disorders.

Deep PEAT is improved method, with the following comparative advantages: In most EMPTs the subject taps certain points on his/her face, body, or fingers (hence, the popular name ‘Tapping Therapies’), while in *PEAT* one lightly puts two fingers on the points (without pressure or rubbing), take one deep breath, exhale, and remove them a few seconds later; In ultimate *Deep PEAT* the client focuses on the suppressed unconscious contents which come up to the surface of his/her consciousness, and in its application only 3 points are used; In contrast to other EMPTs, in the beginning of *Deep PEAT* the processor does not pay attention to the strength of unwanted states, because the goal is not to diminish the problem, but to resolve it completely at its deepest possible level, at its root. The *PEAT* processor does not end the session until the problem is resolved, and on average a session lasts from 20 to 45 minutes; The basis and greatest value of *Deep PEAT* is that the processor does not pay too much attention to the problem he/she is working with, but rather on the contents of the mind, which bubble up very quickly to the level of awareness; Most of these contents are unwanted psychological states, negative thoughts and limiting beliefs, uncomfortable physical sensations and wrong decisions we once made; *Deep PEAT* goes to the deepest possible level of the problem, its essence and root, so the processor is able to find and neutralize the client’s Primal Polarities or shortly Primes, thereby resolving many problems that previously appeared in the chain of

contents; PEAT is therapeutic method, and at the same time a system of Spiritual development, although such a division is artificial because Spiritual development has therapeutic effects and clearing (resolving) his/her problems makes the Being more free; As a method of healing PEAT is a transpersonal EMPT, which removes quickly, easily and elegantly whole chains of traumas and other negative contents without emotional abreactions, by releasing blocked energetic currents in the aura of a Being, and making conscious and neutralizing opposites from extremely remote times: problems, destructive fantasies, compulsions and obsessions, blockages, entities, implants etc.

DP4 Method is fourth level of Deep PEAT, which requires along with imagination of 'frozen' image an alternative using of only one 'insight' acupuncture point in the internal corner of both ocular orbits: By touching right-hand point, related to rational and logic left-hand hemisphere, it is requested from the client to feel himself/herself 'here and now', and to report the four elements he/she feels in this moment (psychic picture, thought, emotion, bodily sensation); Then by touching left-hand point, related to holistic and emotional right-hand hemisphere, it is requested from the client to feel problematic situation as if it is happening now, and to report their four elements; The client should move in his/her imagination alternatively between two situations (two polarities) and two points on the face, and very quickly these polarities will be empty. If the treated problem is related to some being or group, it is necessary to do circular process, i.e. from other viewpoints. If this method is used to create some new desired state, feeling or identity, the client puts his/her right-hand fingers on the right-hand point and feels himself/herself 'here and now', and then puts his/her left-hand fingers to the left-hand point and feels himself/herself within the snap-shot of the desirable situation.

Fore-Finger Method is the newest method, efficient for removing even very hard traumas. The method uses centripetal rotation 3-4 times counterclockwise around the client's bodily axis, with the client's previous closed-eyes visualization of the 'frozen' problematic situation. The client pays attention and reports four elements of that experience, alongside with putting the top of fore-finger in the center of this traumatic image and imagining that the image is stuck on the top of the fore-finger. The method is as simple as efficient. If the treated trauma

is related to some other person(s), and the trauma is not completely removed at the end of the process, it is necessary to do circular process, i.e. from all relevant viewpoints (just points of view which are emotionally charged).

Quantum-Holographic Informatics: Psychosomatic-Cognitive Implications.

In order to put psychosomatic-cognitive aspects of integrative biophysics and quantum medicine in the context of *quantum-holographic informatics* [5] (cf. Ch. 2), in this book it is firstly presented physics of the enzyme-substrate interaction, i.e. *quantum models of biomolecular recognition* [3,20-22] (cf. Ch. 3), wherefrom the necessity of quantum-holistic approach is already clear.

Then the biocybernetical *models of brain's hierarchical neural networks* [3,5] are presented (cf. Ch. 4). It is obvious that these models of brain's hierarchical neural networks (*self-organized mapping* neural networks, *associative* or *attractor* neural networks, and classical and neuro-quantum *synergetic* neural networks) demonstrate encouraging advances in modeling cognitive functions – which is not surprising bearing in mind that information processing on the level of central nervous system is going via hierarchically organized and interconnected neural networks; besides, during the learning process a significant role in global distribution (over whole cortex) of the hierarchically processed information is played by brainwaves. It seems that this hierarchy of biological neural networks is going down sub-cellular *cytoskeleton* mesoscopic level, being according to some scientists a kind of interface between *neural* and *quantum* levels [23].

However, for modeling most cognitive and especially psychosomatic functions the subtle biophysical *Hopfield-like quantum-holographic body's acupuncture neural networks* (modulated by UNF EM fields of brainwaves) are necessary as well, combined with *quantum decoherence theory* [3,14] (cf. Ch. 5). On the one hand, they demonstrate existence of two cognitive modes of consciousness (direct religious/creative one, characteristic of quantum-coherent transitional and altered states of consciousness, and indirect perceptively/rationally mediated one characteristic of classically-reduced normal states of consciousness) – together with conditions for their mutual transformations. On the other hand, they represent a natural framework for explanation of *psychosomatic diseases* related to somatization of generated memory attractor's states of the open macroscopic

quantum acupuncture system (created as a result of interaction with environment and quantum-holographically projected upon lower hierarchical cellular level, thus changing the expression of genes), but also for explanation of contemporary *meridian (psycho)therapies* for fast removing of numerous disorders (traumas, phobias, allergies, post-traumatic stress) – with significant psychosomatic and transpersonal implications.

It should be especially pointed out that *quantum decoherence* might play *fundamental role in biological quantum-holographic neural networks* [3,14,21], through adaptation of the energy-state hypersurface of acupuncture system/consciousness (in contrast to *low-temperature artificial qubit quantum processors* where it must be *avoided* until the very read-out act of quantum computation!) – which implies that Nature presumably has chosen elegant *room-temperature solution for biological quantum-holographic information processing*, permanently fluctuating between quantum-coherent states and classically-reduced states of acupuncture system/consciousness, through non-stationary interactions with out-of-body farther environment and through decoherence by bodily closer environment (cf. Ch. 5).

The same might be related to *lower hierarchical quantum-holographic macroscopic open quantum cellular enzyme-gene level* [3,21], which might be also functioning on the level of permanent quantum-conformational quantum-holographic like biomolecular recognition – so that *quantum neural holography* combined with *quantum decoherence* might be very significant element of the feedback *bioinformatics*, from the level of cell to the level of organism (cf. Ch. 3).

In the same context, fundamental bases of *quantum-holographic paradigm* are considered too, with implication that whole psychosomatics is *quantum hologram*, both on the level of *individual and collective consciousness*, and that quantum-holographic hierarchical parts carry information on wholeness, enabling quantum-holographic fractal coupling of various hierarchical levels [3,14] (cf. Ch. 5): acupuncture-based-quantum-informational (un)intentional control of ontogenesis and morphogenesis; quantum-holographic language-influence on the genes expression, with implications of great psychosomatic significance of thought-emotional contents; and global fractal-information coupling of various hierarchical levels in Nature with fundamental holistic implications on the origin of miraculous deep creativities and

determinism of the History through the coupling with the existing evolving state of collective consciousness. This forecasts a *great synthesis* of two cognitive modes, rationally-scientific (classically-reduced, in normal states of consciousness) and creative-religious (quantum-coherent, in altered and transitional states of consciousness) within the framework of the (sequentially) appearing *quantum-holographic holistic paradigm* – where personal role becomes indispensable due to the influence and care for collective mental environment, which is *fundamental question* of both mental health and civil decency, i.e. of both spiritual and civil morality.

In this context, it might be said that *three front lines of psycho-somatic medicine* do exist [3,14]: (a) the first one is *spirituality*, where prayer for others mentally/emotionally involved erases for good mutual memory attractors on the level of collective consciousness; (b) the second one is *traditional holistic Eastern medicine and deep psychotherapeutic techniques*, whose efforts temporary erase memory attractors on the level of acupuncture system/individual consciousness, and prevent or alleviate their somatization, as a consequence of the indolence on the first level; (c) the third one is *modern symptomatic Western medicine*, whose activities through immunology, pharmacology, biomedical diagnostics, and surgery, hinder or soothe somatic consequences of the carelessness on the first two levels. It should be stressed that *necessary* activities on the second and third levels, with *neglect* of the first level, have a consequence of *further transfer* of memory attractors on the level of *individual and collective consciousness* in this and further generations, thus *accumulating* quantum-holographic loads which *afterwards cause* not only illnesses, but also interpersonal fights, wars, and other troubles.

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2. QUANTUM NEURAL INFORMATICS: HOPFIELD'S NEURAL NETWORKS AND QUANTUM HOLOGRAPHY

Hopfield's *classical neural networks* [1] have been extensively studied, simulated and used in *cognitive neuroscience* too [2] (cf. Ch. 4). However, Peruš has also shown [3] that Hopfield's classical neural network model is mathematically analogous to Feynman's propagator version of the quantum theory, and that formal *informational parallelism* between classical and quantum Hopfield-like neural networks can be established, which will be elaborated in this chapter.

In the model of *Hopfield's classical neural network*, dynamics is a result of the minimization of 'cost function' proportional to free energy of the system:¹

$$E_K = -\frac{1}{2} \sum_{l=1}^N \sum_{j=1}^N J_{lj} q_l q_j - \frac{1}{2} \sum_{l=1}^N T_l q_l . \quad (2.1)$$

The process of gradient-descent of this energy function is a result of a web of interactions between the *system of neurons* described by vector \mathbf{q} (with elements q_l) and the system of *synaptic connections* described by the *memory matrix* \mathbf{J} (with elements J_{lj}), which is manifested with appearance of P minima (*memory attractors*) in the energy-state hyperspace of the neural network (cf. Fig. 4.8 in Ch. 4).

Thus, in the model of *Hopfield classical neural network*, Hebbian dynamic equation for *neuronal activities*

$$q_l(t_2 = t_1 + \delta t) = \sum_{j=1}^N J_{lj} q_j(t_1) \quad \text{or} \quad \mathbf{q}_{out}(t_2) = \mathbf{J} \mathbf{q}_{in}(t_1) \quad (2.2)$$

and dynamic equation for *synaptic connections* (weights)

$$J_{lj} = \sum_{i=1}^P q_l^{k_i} q_j^{k_i} \quad \text{or} \quad \mathbf{J} = \sum_{i=1}^{P_k} \mathbf{q}^{k_i} \mathbf{q}^{k_i T} \quad (2.3)$$

¹ On the structure of Hopfield's neural networks, their training and application for theoretical modelling of brain's functions, see Ch. 4.

exhibit a joint *classical parallel-distributed information processing system*. This is one of the simplest algorithms useful for theoretical brain modelling.

Equation (2.1) is *global* (variational) description, while the system of equations (2.2-3) is *local* (interactional) description of the learning of input-data vectors q^{k_i} , in Hopfield's classical neural network K . The corresponding neuronal activities can be inserted in the system of *neuronal states* \mathbf{q} iteratively, or can be put in the very beginning simultaneously into the *Hebbian memory matrix* \mathbf{J} which contains all synaptic weights J_{ij} .

Equations (2.2-3) can be rewritten in *continuous form* incorporating spatio-temporal description of neuronal and synaptic activities:

$$\mathbf{q}_{out}(\mathbf{r}_2, t_2) = \iint \mathbf{J}(\mathbf{r}_2, t_2, \mathbf{r}_1, t_1) \mathbf{q}_{in}(\mathbf{r}_1, t_1) d\mathbf{r}_1 dt_1 \quad (2.4)$$

$$\begin{aligned} \mathbf{J}(\mathbf{r}_2, t_2, \mathbf{r}_1, t_1) &= \sum_{i=1}^P q^{k_i}(\mathbf{r}_2, t_2) q^{k_i T}(\mathbf{r}_1, t_1) \quad \text{or} \\ \mathbf{J}(\mathbf{r}_2, \mathbf{r}_1) &= \sum_{i=1}^P q^{k_i}(\mathbf{r}_2) q^{k_i T}(\mathbf{r}_1) \end{aligned} \quad (2.5)$$

The *memory associative recognition* in Hopfield's classical neural network is done by input-output transformation $\mathbf{q}_{out} = \mathbf{J}\mathbf{q}_{in}$, or in developed form

$$\begin{aligned} \mathbf{q}_{out}(\mathbf{r}_2, t_2 = t_1 + \delta t) &= \int \mathbf{J}(\mathbf{r}_2, \mathbf{r}_1) \mathbf{q}_{in}(\mathbf{r}_1, t_1) d\mathbf{r}_1 = \\ &= \int \left[\sum_{i=1}^P q^{k_i}(\mathbf{r}_2) q^{k_i T}(\mathbf{r}_1) \right] \mathbf{q}_{in}(\mathbf{r}_1, t_1) d\mathbf{r}_1 \end{aligned} \quad (2.6)$$

From equation (2.6) it is obvious that if the input vector \mathbf{q}_{in} is most similar to some of the previously memorised vectors, say q^{k_1} (and simultaneously almost orthogonal to all other memory vectors q^{k_i} , $i \neq 1$), then the output vector \mathbf{q}_{out} converges to the memory pattern-quattractor q^{k_1} , i.e. Hopfield's classical neural network K *associatively recognises* the vector q^{k_1} .

Haken has shown [4] that introduction of biologically more plausible *neuronal oscillatory activities* gives a richer dynamics of the neural network, with Hopfield's classical neural net real-valued variables replaced by the *complex-valued* ones (similarly to quantum variables, although in contrast to thus conveniently modified classical formalism, the complex-valued quantum formalism is essential). A step further is done with *quantum generalization* of Hopfield's neural network: Sutherland's *holographic neural network* [5] and, equivalent to it, Peruš's model of *Hopfield-like quantum neural network* [3].

In this following we shall review *Peruš's model*, based on the direct mathematical correspondence between *classical neural* (left) and *quantum variables* (right) and corresponding Hopfield-like classical and quantum equations, respectively:

$$\begin{aligned} \mathbf{q} &\Leftrightarrow \Psi, \quad q^{k_i} \Leftrightarrow \Psi^{k_i}, \quad \mathbf{J} \Leftrightarrow G \\ (2.4) &\Leftrightarrow (2.7), \quad (2.5) \Leftrightarrow (2.8), \quad (2.6) \Leftrightarrow (2.9) \end{aligned}$$

The equations in pairs are *mathematically equivalent*, implying similar *collective dynamics of the neural and quantum systems*, in spite of different nature of the set of neurons (\mathbf{q}) and their memory synaptic connections (\mathbf{J}) in the neural network K , on the one hand, and wave functions (Ψ) and their propagator connections (G) in the quantum system S , on the other hand.

So, in Peruš's model of the *Hopfield-like quantum neural network*, dynamic equation for the *wave function of the quantum system S*

$$\begin{aligned} \Psi_{out}(\mathbf{r}_2, t_2) &= \iint G(\mathbf{r}_2, t_2, \mathbf{r}_1, t_1) \Psi_{in}(\mathbf{r}_1, t_1) d\mathbf{r}_1 dt_1 \quad \text{or} \\ \Psi_{out}(t_2) &= G \Psi_{in}(t_1) \end{aligned} \quad (2.7)$$

and dynamic equation for the *propagator of the quantum system S* (cf. App. 6.3)

$$\begin{aligned} G(\mathbf{r}_2, t_2, \mathbf{r}_1, t_1) &= \sum_{i=1}^P \Psi^{k_i}(\mathbf{r}_2, t_2) \Psi^{k_i*}(\mathbf{r}_1, t_1) \quad \text{or} \\ G(\mathbf{r}_2, \mathbf{r}_1) &= \sum_{i=1}^P \Psi^{k_i}(\mathbf{r}_2) \Psi^{k_i*}(\mathbf{r}_1) \end{aligned} \quad (2.8)$$

exhibit a joint *quantum parallel-distributed information processing system*, where Ψ^{k_i} are *eigenwave functions* of the quantum system S . So Ψ^{k_i} represents the *quantum memory state*, and the propagator G constitutes the *quantum memory* of thus informationally interpreted *quantum system S*! [Actually, so defined propagator G is related to the usually used Green function propagator \bar{G} , by equation $G = -i\bar{G}$]

The *memory associative recognition* in Hopfield-like quantum neural network S is done by input-output transformation $\Psi_{out} = G \Psi_{in}$, or in developed form

$$\begin{aligned}\Psi_{out}(\mathbf{r}_2, t_2 = t_1 + \delta t) &= \int G(\mathbf{r}_2, \mathbf{r}_1) \Psi_{in}(\mathbf{r}_1, t_1) d\mathbf{r}_1 \\ &= \int \left[\sum_{i=1}^P \Psi^{k_i}(\mathbf{r}_2) \Psi^{k_i}(\mathbf{r}_1)^* \right] \Psi_{in}(\mathbf{r}_1, t_1) d\mathbf{r}_1\end{aligned}\quad (2.9)$$

i.e. in the other form (where one can recognise the *quantum superposition principle*, i.e. the development of the wave function Ψ_{out} over the wave functions Ψ^{k_i})

$$\begin{aligned}\Psi_{out}(\mathbf{r}, t) &= \sum_{i=1}^P c_{k_i}(t) \Psi^{k_i}(\mathbf{r}) = \\ &= \sum_{i=1}^P \int \left[\Psi^{k_i}(\mathbf{r})^* \Psi_{in}(\mathbf{r}, t) d\mathbf{r} \right] \Psi^{k_i}(\mathbf{r})\end{aligned}\quad (2.9')$$

From equations (2.9) and (2.9') it is obvious that if the input wave function Ψ_{in} is most similar to some of the previously memorized (learned) eigenwave function, say Ψ^{k_1} (and simultaneously almost orthogonal to all other memory eigenwave functions Ψ^{k_i} , $i \neq 1$), then the output wave function Ψ_{out} converges to the memory pattern-qua-attractor of the eigenwave function Ψ^{k_1} , i.e. Hopfield-like quantum neural network S *associatively recognizes* the eigenwave function Ψ^{k_1} .²

² So, the propagator (quantum-holographic memory of the quantum system) enables at the input of the Hopfield quantum-holographic neural network a successive reconstruction of the wave functions of the memory states (complete,

Or translated into orthodox language of the quantum physics, in the above example the propagator G represents the *projector* onto the wave subspace/state Ψ^{k_1} , i.e. makes *reduction* (collapse) of the wave function Ψ_{in} of the quantum system into the eigenstate Ψ^{k_1} . Naturally, the collapse of the wave function (cf. App. 6.6) of the *quantum processor* S (not only of the hereby considered associative quantum memory) is also the final read-out phase of the *quantum qubit computers* (cf. App. 6.8) – as well as the *quantum decoherence* (cf. App. 6.7) *within consciousness*, presumably through the brain frontolimbic process of the *selection and amplification* of the one out of many (parallel processed subliminal ULF lower-frequency) unconscious pieces of information toward (ULF higher-frequency) conscious thought in *normal states of consciousness*.

Hopfield-like quantum neural networks are better then the classical ones because of the quantum phase differences which improve classical Hebbian amplitude coding. Namely, by insertion of the eigenwave functions Ψ^{k_i} in the form of modulated plane waves or wavelets,

$$\Psi^{k_i}(\mathbf{r}, t) = A_{k_i}(\mathbf{r}, t) e^{\frac{i}{\hbar} \alpha_{k_i}(\mathbf{r}, t)} \quad (2.10)$$

the propagator of the quantum system S (2.8) becomes

$$G(\mathbf{r}_2, t_2, \mathbf{r}_1, t_1) = \sum_{i=1}^P A_{k_i}(\mathbf{r}_2, t_2) A_{k_i}(\mathbf{r}_1, t_1) e^{\frac{i}{\hbar} (\alpha_{k_i}(\mathbf{r}_2, t_2) - \alpha_{k_i}(\mathbf{r}_1, t_1))} \quad (2.11)$$

which describes the *two-fold memory encoding of the quantum system* S : through the amplitude correlation, similarly to *Hebbian rule* in classical associative neural networks,

$$\sum_{i=1}^P A_{k_i}(\mathbf{r}_2, t_2) A_{k_i}(\mathbf{r}_1, t_1) \quad (2.11')$$

and through the phase differences, similarly to *holography*,

i.e. amplitudes and phases!) in recognizing wave functions of the states shown at their input (which is the basis of any holography!), whereas everything is simplified as compared to standard laser holography (which requires coherent reference and object laser beams)!

$$\delta\alpha_{k_i} = \alpha_{k_i}(\mathbf{r}_2, t_2) - \alpha_{k_i}(\mathbf{r}_1, t_1) \quad (2.11'')$$

The *correspondence of the informational-physical laws of neural and quantum physics*, presented in this chapter, seems to represent only one of illustrations of the *deep fractal inter-relations of the laws of Nature* on different levels. It has also been shown recently that physical laws which describe simple clocks, simple computers, black holes, space-time foam, and holographic principle – are inter-related [6]!

It should be noted that the model of quantum neural holography in combination with quantum decoherence might be *generally applied* to any quantum system and its stationary states and excitations, from *macromolecules and their conformations* (cf. Ch. 3), to *higher brain functions and processual bases of consciousness* (cf. Ch. 4) and *two modes of consciousness* (cf. Ch. 5), and that it might serve as bioinformational basis of *quantum medicine* across *acupuncture system and its psychosomatic states* (cf. Ch. 5).

Namely, as described in App. 6.7, an interaction of quantum system S with its closer environment, during the decoherence time τ_D gives rise to transition from quantum-coherent superposition $|\phi(t)\rangle_S =$

$\sum_i c_{k_i}(t) |\phi^{(k_i)}\rangle_S$ into classically-reduced stochastic state described by

density operator $\hat{\rho}_S(t) = \sum_i |c_{k_i}(t)|^2 |\phi^{(k_i)}\rangle_S \langle\phi^{(k_i)}|$ (with probabilities

$|c_{k_i}(t)|^2$ of the realization of one of the classically-reduced states

$|\phi^{(k_i)}\rangle_S$ – in quantum measurement-like process upon the initial

quantum-coherent state $|\phi(t)\rangle_S$). However, in the case of *nonstationary*

short-lasting external excitations from farther environment, the reverse transitions from the stochastic state $\hat{\rho}_S(t)$ into some new quantum-

coherent superposition $|\phi'(t)\rangle_S = \sum_i c'_{k_i}(t) |\phi^{(k_i)}\rangle_S$ are possible (as

the system is shortly no longer in any of the classically-reduced states $|\phi^{(k_i)}\rangle_S$, but in the *nonstationary* state which may be described by their

new superposition) – which can traverse into new classically-reduced

stochastic state $\hat{\rho}_S'(t) = \sum_i |c_{k_i}'(t)|^2 |\phi^{(k_i)}\rangle_{SS} \langle\phi^{(k_i)}|$ upon the decoherence

process induced by closer environment [7,8].

Under the *nonstationary* influence of the environment, these processes might be continuously dynamically interchanged giving rise to intermediate adaptation of quantum-coherent and classically-reduced states of the *open* quantum system S . On the one hand, temporal evolution (during short-time interval nonperturbed by closer environment) of the *quantum-coherent state* $|\phi(t)\rangle_S$ might be described within Feynman's representation by quantum-holographic Hopfield-like neural network, via dynamic equation (2.11) for *quantum-holographic memory/propagator of the quantum system* (which describes two-fold space-time memory encoding of the quantum system, through the amplitude correlation similarly to Hebbian rule in classical associative neural networks and through the phase differences similarly to holography. On the other hand, temporal evolution of the classically-reduced stochastic state $\hat{\rho}_S(t)$ (as a consequence of *non-stationary interaction of the open quantum system S with environment E* , which turns-over the system S from one stationary classically-reduced state into nonstationary quantum-coherent state and then into another classically-reduced state) might be described by classical Hopfield's neural network, presented by shape-changes of the energy-state potential hypersurface $E_S(\phi)$ of the open quantum system S , schematically presented in Fig. 3.3 of Ch. 3.

Although, from the viewpoint of von Neumann entropy ($S = -k\text{Tr}(\hat{\rho}_S \ln \hat{\rho}_S)$), transitions from 'mixture state' $\hat{\rho}_S(t)$ into 'pure state' $|\phi'(t)\rangle_S$ under the influence of environment look like as entropy decreasing (cf. App. 6.5), it should be noted that $\hat{\rho}_S(t)$ are 'reduced mixture states' of the open quantum (sub)system S over degrees of freedom of its quantum environment E , i.e. they are 'mixtures of second order' – so that strictly speaking a description of the state of (sub)system S by 'reduced statistical operator' $\hat{\rho}_S(t)$ is

more mathematical convenience than physical description (as in the framework of quantum decoherence theory it is strictly possible to define only a state of the total closed quantum system $S + E$, to which exact application of Schrödinger equation is only possible, cf. App. 6.7!) [8,9]. Besides, according to Prigogine theorem, an excitation of biological system far from equilibrium can give rise to an *entropy decrease* in the open non-equilibrium thermodynamic systems [10]!

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3. PHYSICS OF ENZYME-SUBSTRATE INTERACTION: BIOMOLECULAR RECOGNITION

The most important function of proteins is to act as enzymes: Enzymes serve as catalysts in all biochemical reactions [1,2]! A catalyst accelerates the rate of reaction but is not consumed in the overall process.

According to the Arrhenius formula, the *reaction rate constant* (k) greatly depends on *temperature* (T):

$$k = Ae^{-\frac{G^\ddagger}{RT}}, \quad (3.1)$$

G^\ddagger - is the *free energy of activation*, which characterizes the energy barrier, that must be overcome by the system for the reaction to occur. The dependence in Eq. (3.1) follows from the Boltzmann distribution among energy levels, where exponential indicates the fraction of molecules that possess sufficient free energy G^\ddagger for the reaction to take place.

The reaction is *possible* only if the *free energy is decreased*. However, this condition is *necessary* but is still *insufficient*: the free energy of activation must be sufficiently *low* that the rate constant is non-vanishing, i.e. that the reaction does proceed. *The catalyst serves to lower the activation barrier* (cf. Fig. 3.1b)!

3.1 Semi-Classical Model of Electronic-Conformational Interactions and Biomolecular Recognition

Conformational properties of enzymes are essentially important for understanding of enzymic catalytic activity! The *conformational lability of a protein* makes possible its *specific interaction* with *substrates*. As the substrate is (most frequently) low-molecular, and the enzyme is (high-molecular) protein, then the substrate directly interact with particular small part of the enzyme molecule – its *active site* (group and distribution of amino acid residues and cofactors (coenzymes, vitamins, metalo-organic complexes, hormones ...)).

In the *enzyme-substrate complex* (ESC) the *induced structural correspondence* of the enzyme and substrate is dynamically established, thus providing the optimal value of the free energy of interaction. The

conformational transformations involved lead to a structural fit between the enzyme and the substrate, i.e. *biomolecular recognition*! The enzyme-substrate interaction is a *weak chemical bond* (Van der Waals, hydrogen, hydrophobic, ...), which is, however, very *enhanced* due to *hydrophobic active site of the enzyme*: namely, relative dielectric permittivity ϵ_r of the cavity of active site of the enzyme is much less ($\epsilon_r \sim 3\div 4$) compared to water environment ($\epsilon_r \sim 81$), which significantly facilitates the occurrence of electric interactions ($F \sim q_1 q_2 / 4\pi\epsilon_0 \epsilon_r r^2$) between the substrate and the active site of the enzyme!

Practically, *electrostatic* interactions within *hydrophobic cavity* (active site) of the enzyme provide main contribution to bioenergetics of enzymic catalysis, i.e. *to reduction of the activation barrier* in the enzyme-substrate complex. The energy necessary for conformational changes of the enzyme structure is liberated upon binding of the substrate to the enzyme!

During enzyme-substrate interaction and formation of the enzyme-substrate complex, the states of the electronic shells of the substrate and of the atomic groups of the active site of the enzyme are excited. In the enzyme-substrate complex the energy of electronic excitation is converted to the work of *displacement of atomic nuclei*. Among the movements of atomic nuclei the *lowest energy* is demanded by *low-frequency deformational vibrations and rotations around single bonds*, i.e. *conformational changes*! Hence, for *enzymic catalysis* the most significant are interactions of electronic and conformational degrees of freedom – *electronic-conformational interactions* (ECI)!

In order to understand the *nature of ECI*, it is helpful to make use of a simplified model of the interaction between electrons and atomic nuclei – *electrons in a potential box* with infinitely high *mobile walls* (cf. Fig. 3.1a). Electrons are placed in the box: $2n$ electrons occupy n levels. The *possible values* of the energy of the electrons inside the box are easily calculated on the basis of the concepts of de Broglie electronic standing waves of the wavelength λ_e in the box of the width L : $n\lambda_e/2 = L$ ($n = 1, 2, \dots$); on the other hand the wavelength of the electron is given by the de Broglie relation $\lambda_e = h/p_e = h/m_e v_e$. By combining the last two equations the velocity of an electron in the box is found, $v_e = nh/2m_e L$, so that the energy of the electron inside the box is equal to its kinetic energy, $E = m_e v_e^2/2 = n^2 h^2 / 8m_e L^2$,

wherefrom the electron pressure force exerted on the wall is obtained: $f_e = |dE/dL| = n^2 h^2 / 4m_e L^3$. At equilibrium these pressure forces of the electrons are compensated for by the interactions with the surroundings of the box. A *change in equilibrium* results either from the excitation of electrons in the system (arises n) or from the addition of electrons (arises number of electrons, i.e. number of hits upon the walls of the box). Being no longer at equilibrium, the *walls of the box* move and pass to a *new equilibrium position*, at an increased distance from each other, $L + \Delta L$. In other words, the *work of displacement of the nuclei* ($f_e \Delta L$) is done at the *expense of the energy of electrons* – as the electronic energy decreases with increasing L (cf. Eq. (3.10)).

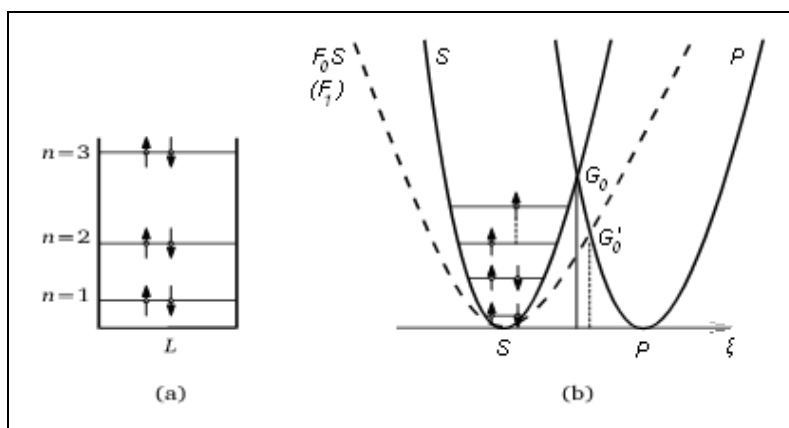


FIGURE 3.1 Schematic presentation of the two semi-quantum models of electronic-conformational interactions, with electrons in a (a) potential box with infinitely high mobile walls, and in a (b) parabolic potential well with mobile walls.

If one considers a *parabolic well* with mobile walls (Fig. 3.1b), it will be easy to show how *ECI lower the activation barrier* ($G_a \equiv G^\ddagger$). The *expansion of the parabola* of the initial reagents of the biochemical reaction, brought about by the added pressure forces of the electrons, results in the shift of the point of intersection with the second parabola of the products of the biochemical reaction, i.e. to *decrease of the free energy of activation* ($G_a' < G_a$)! Such *Volkenshtein's semi-classical consideration*

of ECI [2], demonstrates that the *energy of electronic excitations* is converted to the work of displacement of the nuclei, i.e. to the *conformational energy*! As a result, the *biochemical reaction* is accelerated (Arrhenius formula, Eq. (3.1)).

3.2 Quantum Models of Electronic-Conformational Interactions and Biomolecular Recognition

Two *unresolved issues* of the (semi)classically addressed problems in molecular biophysics are *unreasonably long time* necessary for *change* of biopolymer conformations (Levinthal paradox [3]) and *long-range directedness* of selective biomolecular recognition processes – implying their essential *quantum origin* [1].

The quantum nature of *biomolecular recognition* might be supported by: (1) *Theory of Non-Radiative Resonant Structural Transitions* [4], through intermediate quantum-coherent superpositions of the externally activated electronic-vibrational states of the participating biomolecules; (2) *Model of Quantum Decoherence* [5,6], through environment-induced conformational transitions in biomolecular recognition, with possibility to consider cellular biomolecular recognition as a Hopfield-like quantum-holographic associative neural network (by treating all biomolecules of the same type within a cell as *dynamically coupled identical quantum particles*, thus implying deeper *quantum holism of the cell*); and (3) *Resonant Recognition Model* (RRM) [7], based on findings that informational biomolecules and their targets have common RRM-frequency peak but almost opposite phases – which will be elaborated in detail further on.

Theory of Non-Radiative Resonant Structural Transitions (Gribov, 2001 [4]), within the framework of standard *quantum-chemical* Hamiltonian (including kinetic energies and Coulomb interactions of all biomolecular electrons and nuclei) and Born-Openheimer *adiabatic approximation* (of separated biomolecular electronic and vibrational degrees of freedom), replaces the (quasi)classical problem of many-electron hypersurface $E_e(\phi^{(k)})$, not adiabatically well-defined when traversing between two adjacent local minima, by better defined problem of two (virtually intersecting) isomeric many-electron hypersurfaces (hyper-paraboloids) serving as potential hypersurfaces for two vibrational (isomeric) problems, cf. Fig. 3.2.

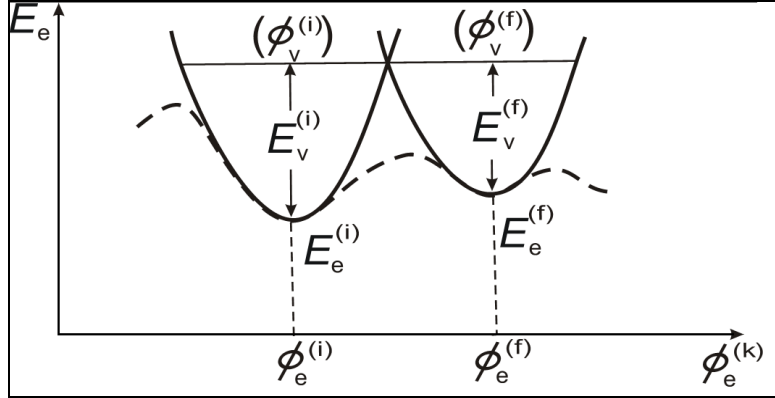


FIGURE 3.2 The (semi)classical problem of many-electron hypersurface $E_e(\phi_e^{(k)})$ as a potential energy for adiabatically decoupled Q1D vibrational and conformational system (with local minima as semi-classical 'positions', i.e. many-atomic isomer configurations on many-electron hypersurface (broken line in the figure)) – not adiabatically well-defined when traversing between two adjacent local minima – is replaced in the framework of the theory of non-radiative resonant transitions by better defined problem of two (virtually intersecting) isomeric many-electron hypersurfaces (hyperparaboloids) serving as potential hypersurfaces for two vibrational (isomeric) problems (full line in the figure). In this approach, by external perturbation of the isomers, at this very intersection the conditions for electronic-vibrational non-radiative resonant transitions between the two isomers (i, f) are achieved: in the first approximation, the matrix element of dipole transition from i-th to f-th isomer is given by $\mu^{(i,f)} \approx \mu_e^{(i,f)} S_v^{(i,f)} + \mu_v^{(i,f)} S_e^{(i,f)}$, and it is obvious that transition between two isomers will be allowed when components of corresponding electronic and vibrational dipole moments, $\mu_e^{(i,f)}$ and $\mu_v^{(i,f)}$, and electronic and vibrational overlap integrals, $S_v^{(i,f)}$ and $S_e^{(i,f)}$, do not vanish (cf. App. 6.2)! Also, during these resonant transitions the perturbed biomolecular system is shortly described by quantum-coherent superposition $(\phi_e^{(i)} \phi_v^{(i)} \pm \phi_e^{(f)} \phi_v^{(f)})/\sqrt{2}$, before its quantum decoherence into final electronic state $\phi_e^{(f)}$ or into initial electronic state $\phi_e^{(i)}$ (with subsequent de-excitations into lower vibrational states). For details cf. [1].

From consideration in Fig. 3.2, it can be concluded that *allowed transitions* between isomeric states (i, f) are possible only for close states with *non-vanishing* overlap integrals $S_v^{(i,f)}$ and $S_e^{(i,f)}$, or in *cascade* resonant transitions between *close intermediate* participating isomeric states, which might be related to nondissipative polaron/soliton-like transport [1,8].

Also, during these resonant transitions the perturbed biomolecular system is shortly described by *quantum-coherent superposition* $(\phi_e^{(i)} \phi_v^{(i)} \pm \phi_e^{(f)} \phi_v^{(f)})/\sqrt{2}$, before its *quantum decoherence* into final electronic state $\phi_e^{(f)}$ or into initial electronic state $\phi_e^{(i)}$ (with subsequent de-excitations into lower vibrational states).

Model of Quantum Decoherence (Raković, Dugić *et al*, 2004-6 [5,6]) is nicely agreed within the previously described picture of short-lasting description of *quantum-coherent superposition* of states of the two isomers before its quantum decoherence into one of the two final isomer states. It generally allows reproduction of both *existence and stability* of the (stationary) ligand-proteins/target-receptors key/lock nonmatching and matching conformations, and the *short time scales* for the quantum-mechanical processes resulting effectively in (nonstationary) nonmatching-to-matching conformational transitions in selective ligand-proteins/target-receptors key/lock *biomolecular recognition processes* under external (e.g. compositional/chemical, thermal, optical ...) influences on the cell's complementary cytoplasmatic environment (cf. App. 6.7).

Dynamic modification of (many-electron) energy-state hypersurface $E_e(\phi_e)$, of the *cell's quantum-ensemble* protein/substrate biomolecular macroscopic open quantum system (through changes in operator of density of states $\hat{\rho}_e(t)$), is a natural consequence of coupled electronic-conformational processes – which implies potential possibility to consider cell's biomolecular recognition as *Hopfield's quantum-holographic associative neural network* (cf. Ch. 2). This approach assumes *standard cell's local treatment of quantum ensemble of non-interacting dynamically non-coupled N distinguishable quantum biomolecular proteins of the same type (and their corresponding biomolecular classes of substrates)* [1,5].

However, there is an alternative possibility of *holistic cell's non-local treatment of quantum system of non-interacting dynamically coupled N in-distinguishable quantum biomolecular proteins of the same type (and their corresponding biomolecular classes of substrates)* [1,6]. Then dynamical modification of many-electron energy-state hypersurface of cell's biomolecular protein macroscopic open quantum system (and analogously their corresponding biomolecular classes of substrates), can be best represented in the formalism of *second quantization* (cf. App. 6.3), which treats *all biomolecules of the same atomic configuration as in-distinguishable quantum particles which occupy different isomeric-conformational states*, and considers such cell's *N -particle protein quantum state in quantum-mechanical occupational basis* which describes *number of proteins that occupy subsequently all states of complete basis set of single-particle isomeric-conformational protein states*.

In the formalism of second quantization – the mentioned cell's N -particle protein quantum state is considered in quantum-mechanical *occupational basis* (generally bosonic, because of protein-substrate integer spin due to even number of their covalent bonded electrons!), describing number of proteins which occupy complete set of *single-particle protein-substrate isomeric/conformational states*: $|n_0 n_1 n_2 \dots\rangle_e$, with conditions

$$N = n_0 + n_1 + n_2 + \dots \quad \text{and} \quad E_{S_e} = n_0 E_e^{(0)} + n_1 E_e^{(1)} + n_2 E_e^{(2)} + \dots$$

(where E_{S_e} is the many-electron energy of the total cell's N -particle-protein quantum state, while $E_e^{(0)}$, $E_e^{(1)}$, $E_e^{(2)}$... are the many-electron energies of the protein single-particle quantum isomeric/conformational states 0, 1, 2, ...). An many-electron energy-state hypersurface of such protein N -particle-isomeric/conformational state has a schematic representation of Fig. 3.3, where internal surface of every minimum is proportional to the partial energy ($n_i E_e^{(i)}$) of the i -th protein single-particle-isomeric/conformational state occupied by n_i isomers of the same form ($i = 0, 1, 2, \dots$), so that total energy ($E_{S_{ke}}$) of the cell's protein N -particle-isomeric/conformational state is proportional to the sum of internal surfaces of the all minima of the many-electron hypersurface. It should be noted that inclusion of *vibrational degrees of freedom (phonons) of all possible*

isomeric/conformational states, requires their consideration in quantum-mechanical *occupational basis* (also bosonic, because of phonon's integer spin!) – describing number of phonons occupying complete set of single-particle *phonon states* of the all protein-substrate isomers/conformations: $\left| n_1^{(0)} n_2^{(0)} \dots n_{3N-6}^{(0)} n_1^{(1)} n_2^{(1)} \dots n_{3N-6}^{(1)} n_1^{(2)} n_2^{(2)} \dots n_{3N-6}^{(2)} \dots \right\rangle_v$ where every isomeric protein-substrate complex composed of N_i atoms has generally $3N_i-6$ vibrational degrees of freedom (phonon types), out of which every phonon state can be occupied by an unlimited number of phonons (which is characteristic of all bosons, i.e. particles of integer spin). It should be pointed out that an energy hypersurface of multi-dimensional phonon quantum state has also a schematic representation of Fig. 3.3, with potentially unlimited number of phonons in every single-phonon state.

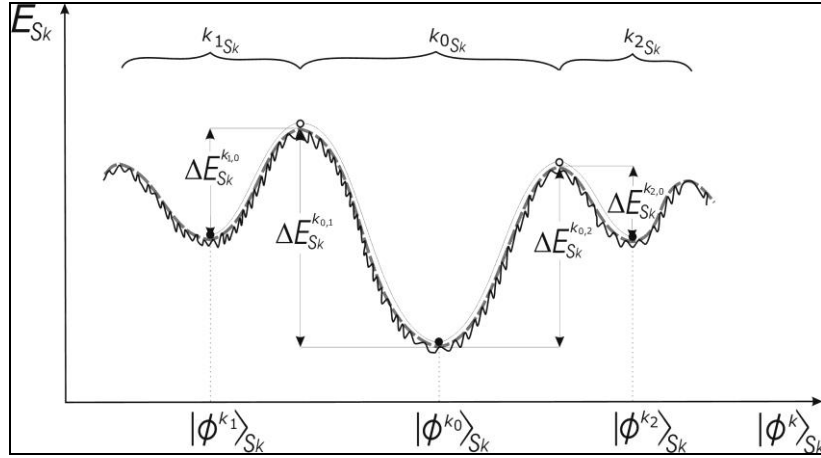


FIGURE 3.3 Schematic presentation of the memory attractors in the energy-state ($E_{S_k}(\phi^k)$) hypersurface of the quantum-holographic memory/propagator of the open macroscopic quantum system S_k (cell's protein/target biomolecular one, or acupuncture system/consciousness/collective consciousness [1,6]):

$$G(r_2, t_2; r_1, t_1) = \sum_{i=1}^P \phi^{k_i}(r_2, t_2) \phi^{k_i*}(r_1, t_1)$$

$$= \sum_{i=1}^P A_{k_i}(r_2, t_2) A_{k_i}^*(r_1, t_1) e^{\frac{i}{\hbar}(\alpha_{k_i}(r_2, t_2) - \alpha_{k_i}(r_1, t_1))}$$

It should be pointed out that quantum decoherence presumably plays fundamental role in biological quantum-holographic neural networks, through presented energy hypersurface shape adaptation (in contrast to low-temperature artificial qubit quantum processors where it must be avoided until the very read-out act of quantum computation, cf. App. 6.8) – which implies that Nature presumably has chosen elegant room-temperature solution for biological quantum-holographic information processing, permanently fluctuating

between quantum-coherent states $|\phi^k(t)\rangle_{S_k} = \sum_i c_{k_i}(t) |\phi^{k_i}\rangle_{S_k}$ and classically-

reduced states $\hat{\rho}_{S_k}^k(t) = \sum_i |c_{k_i}(t)|^2 |\phi^{k_i}\rangle_{S_k S_k} \langle \phi^{k_i}|$ of acupuncture system/

consciousness S_k (cf. Ch. 5), through nonstationary interactions with out-of-body farther environment and through decoherence by bodily closer environment of biological open macroscopic quantum system S_k (cf. Ch. 2 and App. 6.7). The same might be related to lower hierarchical quantum-holographic macroscopic open quantum cellular enzyme-gene level, which also functions on the level of permanent quantum-conformational quantum-holographic like molecular recognition. This represents a natural framework for explanation of psychosomatic diseases related to somatization of environmentally-generated memory attractor's states of the open macroscopic quantum acupuncture system/consciousness and quantum-holographically projected upon lower hierarchical cellular level, thus changing the expression of genes! The above approach might be generalized to highest hierarchical level of the quantum-holographic collective consciousness (cf. Ch. 5), with religious/social implications on necessity of transpersonal spiritual quantum-holographic removing of all unwilling side memory attractors (which non-reprogrammed by prayer will unless cause psychosomatic diseases and interpersonal fights in this and/or further generations they are trans-personally and unconsciously transferred to, on the level of collective consciousness).

The second approach provides a *plausible quantum-holistic* picture of biological cell, and especially *phenomenologically approved quantum-holographic (fractal) coupling of various hierarchical quantum levels* – from-biological cell-to-acupuncture system/consciousness-to-collective consciousness (cf. Ch. 5). This implies Hopfield-like quantum-holographic feedback influence of the EM field of acupuncture system on cells' conformational protein changes and genes' expression (so called macroscopic 'downward causation'), and not only reversed (microscopic 'upward causation'), with mutual quantum-informational control of ontogenesis/

embryogenesis and morphogenesis, starting from the first division of the fertilized cell when differentiation of the acupuncture system begins – with significant *psychosomatic and cognitive bio-informational implications* [1,6].

So, on the cellular level for *every set of identical molecules*, there would exist *two* (interacting) macroscopic quantum subsystems – first with *modifying many-electron hypersurface* $E_e(\phi_e)$ and second with *modifying EM multi-phonon hypersurface* $E_v(\phi_v)$ (where the second one might also include low-energy long-range coherent microwave Fröhlich excitations [9] – created as a result of interaction of electronic and phonon isomeric subsystems, of particular significance in *microwave resonance therapy* (MRT) of a dynamic modification of the EM multi-phonon (and related many-electron) *acupuncture* macroscopic quantum subsystem, cf. App. 6.7).

Resonant Recognition Model (Coscic, 1997; Veljković, 1980 [7]) is confirmed on more than 1000 proteins from more than 30 functional groups – with numerous potential practical advantages in the fields of molecular biology, biotechnology, medicine, agriculture and nanotechnology. It is based on findings that there is significant correlation between spectra of the numerical presentation of constitutive elements of primary sequences (amino acids, nucleotides) and their biological activity or interaction in corresponding biomolecules (proteins, DNAs). The RRM model interprets this linear information by assigning the electron-ion interaction potential (EIIP) value to each constitutive element of primary sequence thus describing their average energy states of valence electrons, with subsequent using signal analysis methods in FFT transforming this numerical series into single-electron wavenumber/RRM frequency domain and determining the common frequency components as peak frequencies in the multiple cross-spectral function for a group of primary sequences. The presence of peak with significant signal-to-noise ratio in a multiple cross-spectral function of a group of sequences with the same biological function means that all of the analysed sequences within the group have this single-electron RRM frequency component in common, with the following general conclusions: (1) such a peak exists only for the group of biomolecules with the same function; (2) no significant peak exists for biologically unrelated bio-

molecules; (3) peak frequencies are different for different biological function; (4) ligand-proteins and their biomolecular target-receptors have the same characteristic frequency in common but almost opposite phase – providing also novel theoretical possibilities for protein *de novo* design with desired functions!

In the context of the RRM-model, the same characteristic single-electron RRM frequency, and almost opposite phase, presumably characterises not only biomolecular protein and target general function, but also their *macroscopic quantum biomolecular recognition interaction* on the level of biological *cell* – possibly by externally *activated* (compositionally/chemically, by averaged intermolecular approaching of proteins and targets necessary for non-vanishing overlap integrals of the corresponding electronic and vibrational wave functions, or thermally/optically, by supplying vibrational energy necessary for making conditions for electronic-vibrational nonradiative resonant transitions between two isomers (*i*, *f*), cf. Fig. 3.2) ligand-proteins/target-receptors RRM quantum-resonantly electron-electron coupling *accompanied* by $\phi^{(i)}$ -annihilation and $\phi^{(f)}$ -creation of conformones' quanta in two-conformational transitions $\phi^{(i)} \rightarrow \phi^{(f)}$ (giving rise to (energy-favourable) many-electron energy-deepening of the final state $\phi^{(f)}$ and many-electron energy-shallowing of the initial state $\phi^{(i)}$ on the macroscopic quantum level of cell, i.e. to *dynamic modification of the many-electron hypersurface* $E_e(\phi^{(k)})$ of the cell's protein macroscopic quantum system (cf. Fig. 3.3 and App. 6.7 [1,6]). On quantum bases of the RRM-model cf. App. 6.4 [10].

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4. BRAIN'S HIERARCHICAL NEURAL NETWORKS

Brain and spinal cord are parts of the *central nervous system* (CNS). There are several constituent parts of the *brain* (cf. Fig. 4.1) [1].

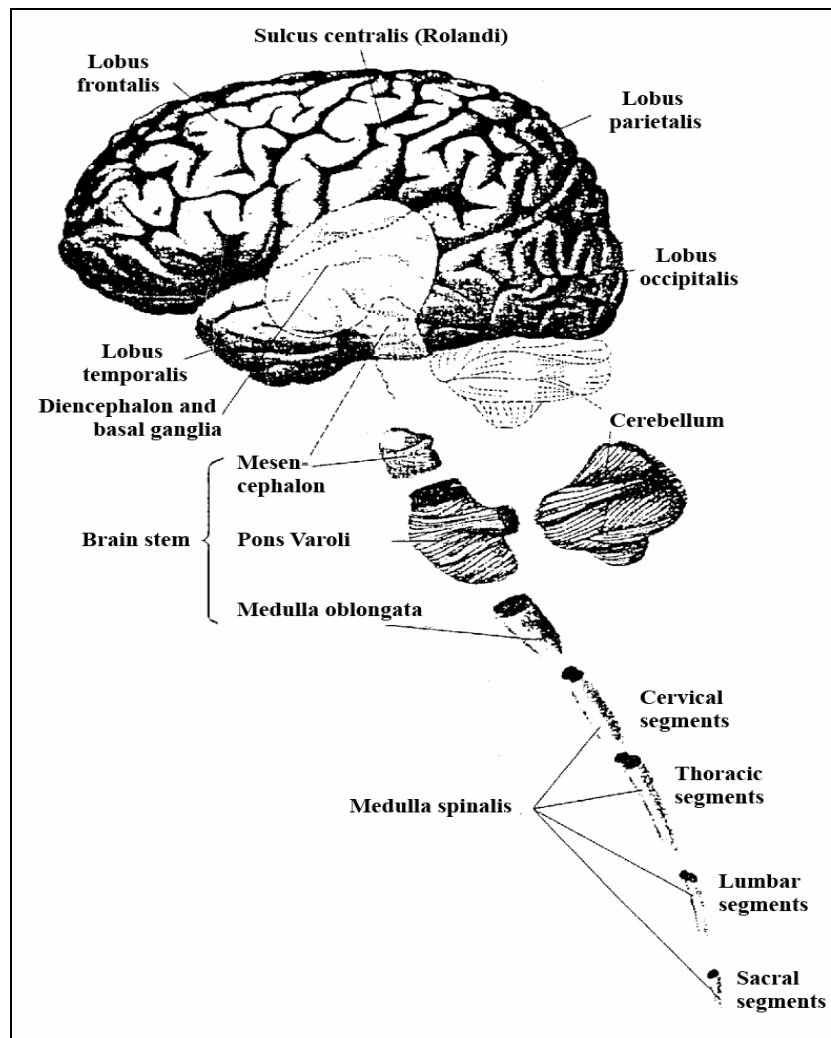


FIGURE 4.1 *Constituent parts of the central nervous system*

Brain stem continues to the spinal cord, and is constituted of *medulla oblongata* (mielencephalon), *pons Varoli* (derivative of metencephalon), and the *mid-brain* (mesencephalon). These are the older phylogenetic structures. In the brain stem *regulation centres of the vital functions* (breathing, heart work, blood pressure) are placed!

Cerebellum (derivative of metencephalon) is the younger phylogenetic structure in the brain of man. It plays a significant role in the *control of complex muscle movements*!

Diencephalon continues to the front end of the brain stem, and its constitutive parts are *hypothalamus* and *thalamus*. Together with the brain stem, it contains many small nuclei of gray mass of inter-related nervous fibers, called *reticular formation*. This formation (known also as *reticular-thalamic formation*), is the *main relay point* in the brain of man, which forms a large informational feedback (the so-called *extended reticular-thalamic activating system* (ERTAS), who *selects and amplifies only one piece of information* (out of the number of sensory and introspective pieces of information, currently processed within hierarchy of brain's neural networks), which thus becomes *conscious content* (while *other unamplified pieces of information* remain on the level of *contextual unconscious contents*, overlapped by the amplified conscious content) – in the *normal awake state*!

Cerebrum (telencephalon) consists of the *basal ganglia* (i.e. *sub-cortical nuclei*, responsible for *initiating and regulating volatile movements*) and *brain cortex*, responsible for all *complex forms of learning and memory*)! Its weight is 2-2.5% of body weight of man, and contains over 10^{10} *nerve cells*. By longitudinal fissure it is divided into *two hemispheres* (left and right), in the bottom *connected by commissural nerve fibers* (*corpus callosum*). Although the hemispheres are almost equal anatomically, they *differ in functions*: the *right hemisphere* processes stimuli *holistically* (as a whole), and *left hemisphere* processes stimuli *analytically* (as sequences)! *Dominate activities* of the left and right hemispheres *alternate with periodicity* of 1.5-2 h (of *ultradial rhythm*), but the degree of greater specialization of one hemisphere is determined by a greater *specialization* of the *opposite hand* (left-handed have more specialized functions of the right hemisphere, and right-handed of the left)! In Fig. 4.2 an overview of the specialized functions of the two hemispheres is given. *Perception* and *memorizing* are

related to *both hemispheres*, while *language* and *speech* are related to functions of the *dominant hemisphere*, which is in 90% the left one (there is a lot more right-handed than left-handed). Two *hemispheres interact functionally* by exchanging information over the commissural nervous fibers.

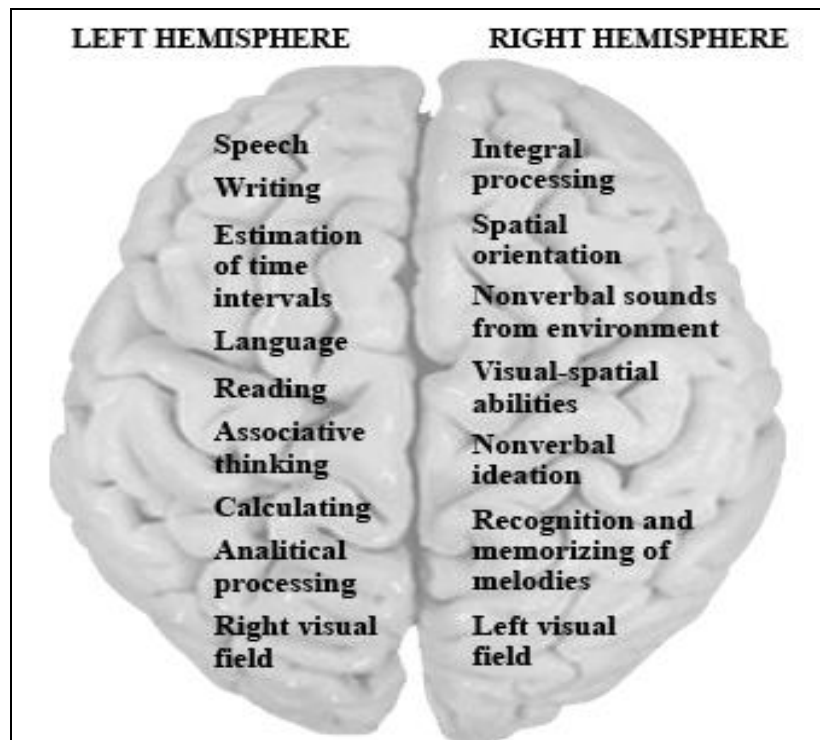


FIGURE 4.2 *Complementary functions of brain's hemispheres: analytical left and holistic right.*

Cortex thickness is 1.5-4.5 mm and constitutes a *large gray mass of brain*, while the *white mass* is in the *interior of brain*. Surface of the cortex is $\sim 1600 \text{ cm}^2$, and it is divided by cerebral sulci and gyri in *six lobes*: *frontal (lobus frontalis)*, *parietal (lobus parietalis)*, *occipital (lobus occipitalis)*, *temporal (lobus temporalis)*, *limbic (lobus limbicus)*, and *insular (lobus insularis)*. On the cortex there can be distinguished

primary sensory zones (visual, auditory, somatosensory, ...) and motor zone, *secondary* interpretational (visual, auditory, somatosensory, ...), and *tertiary* general interpretational zone and speech zone (Broca area), as well as *prefrontal* zone (cf. Fig. 4.3), out of them especially important for *higher cognitive functions* are *tertiary zone* and *prefrontal zone* (responsible for planning and control of behaviour)!

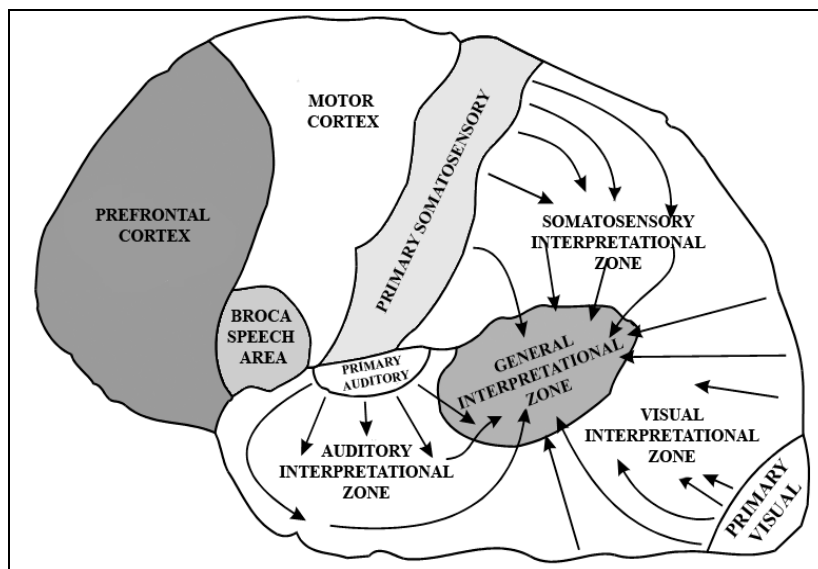


FIGURE 4.3 Functional organization of cortex on zones of various functions and levels

Cortical neurons (around 10^{10}) are very interconnected (*each neuron* has 10^3 – 10^5 *chemical synapses*). There are *excitatory* or *inhibitory synapses*, as if they generate exciting postsynaptic potentials on the membrane of output neuron (helping it to reach the *action potential*, approximately +40 mV; it should be added that the *resting potential* of the polarized membrane, about -80 mV, is achieved by active and passive membrane transport of the Na^+ ions outside nerve cell and K^+ ions inside nerve cell) or inhibiting post-synaptic potentials (preventing output neuron to reach the action potential), respectively. Pre-synaptic and post-synaptic neurons of chemical synapses in brain's neural networks *are not* structurally

interconnected: *synaptic cleft* at the chemical synapse is even slightly wider (20–40 nm, and more) compared to the normal intercellular distance (20 nm). Chemical synapses allow more plastic strengthening or weakening of synapses, necessary for memory and other brain functions. In addition, chemical synapses can significantly enhance small pre-synaptic electrical signal (action potential) releasing one or more *synaptic vesicles*, each containing thousands of molecular *neuro-transmitters* (usually *acetylcholine*) – which then cause conformational changes of post-synaptic receptors, opening (or closing) thousand of ionic channels in post-synaptic cell. However, the price that is paid is time delay of the post-synaptic signal, in respect to the pre-synaptic one, of a few milliseconds.

In Fig. 4.4 characteristic *lamellar* (layered) and *columnar* (vertical) *structure of cortex* is presented: There are *six layers* of neocortex (the older paleocortex has 3–4 layers of neurons) and 10^5 – 10^6 *columnar* sub-structures (of diameter $\sim 300\ \mu\text{m}$).

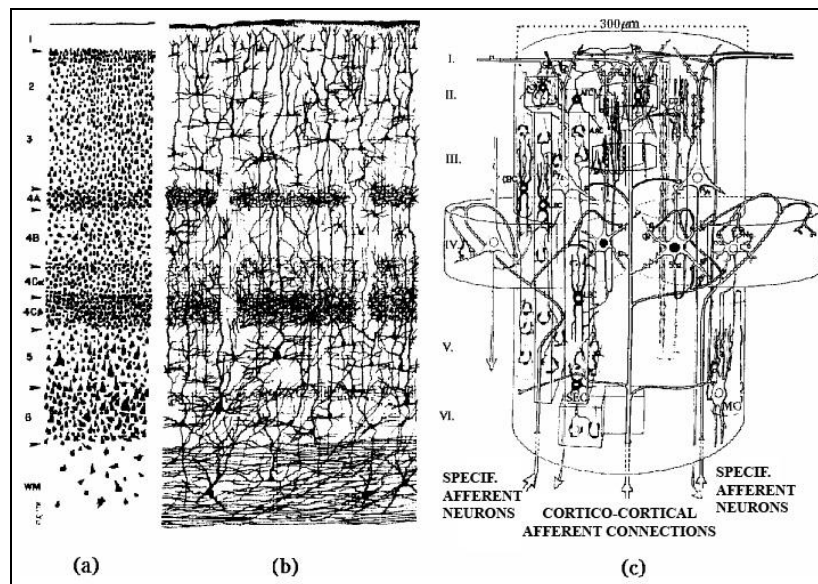


FIGURE 4.4 *Lamellar and columnar structures of neocortex: (a, b) lamellar structures obtained by different techniques of painting brain tissue; (c) columnar and mini-columnar organization of neocortex: right half shows excitatory connections, and left inhibitory.*

Around 70% of neurons of the cortex are *pyramidal nerve cells* (whose name comes from pyramidal shape of neurons). Their many short extensions, *dendrites*, which make *gray mass* of the cortex, reach radially 300 μm , enabling *connectivity* of neurons in the *lateral* columnar structure! Each pyramidal neuron of the cortex provides one *axon* which together with other axons make *white mass* of sub-cortex; each of these axons has a lot of *terminal branches*, *linking* an axon with dendrites of *remote cortical neurons* (in a radius of 3 mm, thus mutually connecting many columnar structures) or with dendrites of neurons of *deeper subcortical structures* (the last of them is only 5%, compared with 95% of the previously mentioned long-range cortical-cortical inter-columnar pyramidal neural connections)! *Pyramidal cells* form *excitatory synapses* with dendrites of remote neurons, while *nonpyramidal interneurons* of the cortex form *inhibitory synapses* with dendrites of nearby neurons.

4.1 Hierarchical Models of Brain's Neural Networks

The advantage of the architecture of hierarchical neural networks is that the *functionally specialized neurons* of each layer process only a *limited amount of information* from the previous layer! The total global situation is then pieced together as one ascends from one hierarchical layer to the next. Such approach requires a *spectacularly smaller number of neurons* in hierarchical neural networks, than it would be required by a network with massive parallelism of interconnections between neighbouring layers! It should be pointed out that hierarchical neural networks are only appropriate in those situations where the inputs to the network have low-level, intermediate-level, and high-level structures that can be consistently related to one another, as images or sounds from outdoor scenes. That is the reason why biological neural networks are organized as hierarchical networks!

Hierarchical models of brain's neural networks are *most promising models in cognitive neurosciences* [1-3], and can be divided into: *self-organizing feature mapping* unidirectionally oriented multilayer neural networks [4], *associative* or *attractor* massively and bidirectionally connected neural networks [5], and *synergetic classical* [6] and *neuro-quantum* [7] multilayer neural networks.

Kohonen's Self-Organizing Feature Mapping Networks [4] are *physiologically-plausible* model of feed-forward neural networks, which can perform self-organizing mappings for modelling *perception* (using sensor maps) and *motor action* (using motor maps), cf. Fig. 4.5.

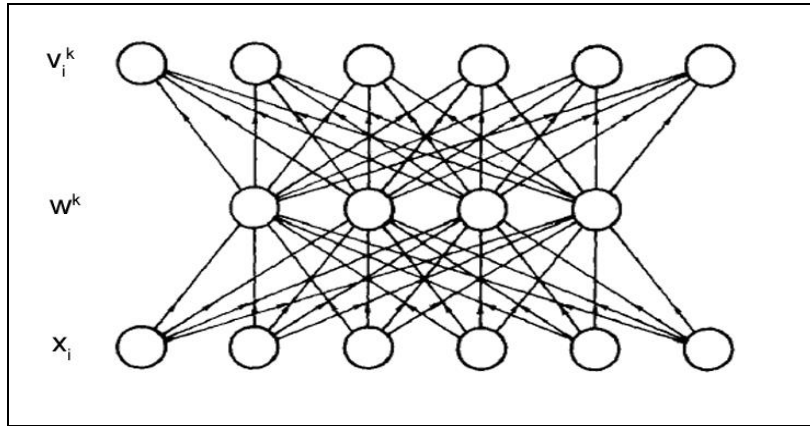


FIGURE 4.5 Kohonen's feed-forward network with input (sensory) layer, hidden (representation) layer, and output (motor) layer.

It should be noted that *topologically-correct mapping* is essential for *localized self-organizing encoding*, i.e. that topological relations are preserved while sensory input-pattern \vec{x} is transformed into internal representation (*prototype-pattern*) \vec{w} (cf. Fig. 4.6), by forming a state with minimal difference $\|\vec{w} - \vec{x}\|$.³

³ In neural networks dynamics is in general governed by minimizing a so-called 'cost function', which is in Kohonen's model proportional to the square of difference between the input-pattern \vec{x} and the target-pattern \vec{w} , and is analogous to the elasticity energy which is proportional to the dislocation from the equilibrium point (here \vec{w}). The network can 'spare energy' if similarity relationship between the input-patterns are transformed into spatial relationships among the corresponding cardinal neurons, which is 'energy'-optimization process. The self-organized map is a result of continuous and nonlinear approximate mapping which is defined implicitly by self-organized process of searching stability through maximal possible agreement of neurons. This process is called

$$\|\vec{w}_{\vec{r}'} - \vec{x}\| = \min_{\vec{r}} \|\vec{w}_{\vec{r}} - \vec{x}\|. \quad (4.1)$$

This mapping also means *dimensionality reduction of the representation space*, as high-dimensional space of input-patterns (of dimension n equal to the number of excited sensory cells of the input-layer) is reduced to 2D maps of internal patterns (defined by *cardinal neurons* determined by x and y coordinates belonging to cortical map).

These *2D maps* are mostly located in the *primary zones* of the neocortex, where they perform corresponding *feature extractions*. Examples are *somatotopic map* (in somato-sensory cortex) of the skin surface, *tonotopic map* (in auditory cortex) of the ear's cochlea spiral, *retinotopic map* (in visual cortex) of the eye's retina, *aromatopic map*

learning, and it is driven by learning examples from the network's evolutionary history. By using topology-preserving mapping a large set of P input-patterns \vec{x}^{k_i} , k_i ($i = 1, \dots, P$), gets encoded into a smaller set of P' prototypes $\vec{w}_{\vec{r}}$, where \vec{r} is used as an index, which refers to location of those neuron to which synapses are transmitting signals from sensory cells. The k_i^{th} input-pattern is described by a vector $\vec{x}_{k_i} = (x_1^{k_i}, x_2^{k_i}, \dots, x_n^{k_i})$, whose components represent individual pixels of the input-pattern which are projected into activities of n individual sensory cells on the retina (vision), cochlea (audition), etc. The prototype is represented by a vector $\vec{w}_{\vec{r}} = (w_{\vec{r}1}, w_{\vec{r}2}, \dots, w_{\vec{r}n})$, whose components $w_{\vec{r}l}$ represent synaptic connections between the potentially-cardinal neuron at location \vec{r}' and the sensory cells with index l (so, activities of neurons are not important in this model, but only their relations $w_{\vec{r}l}$ to configurations of sensory-cells are important). By this definition input-pattern \vec{x} and target-pattern $\vec{w}_{\vec{r}}$ have the same dimension (n) and can be subtracted: $\|\vec{w} - \vec{x}\|$. If some prototype $\vec{w}_{\vec{r}}$ matches the input-pattern \vec{x}^{k_i} more than other prototypes do, then the corresponding potentially-cardinal neuron at location \vec{r}' wins the competition (against other potentially-cardinal neurons \vec{r}') and becomes actually-cardinal neuron – the winner. In this case we say that the network has recognized input-pattern \vec{x}^{k_i} so that it classified this input as an example of the prototype $\vec{w}_{\vec{r}}$. By meeting every new input-pattern the prototype changes somewhat: the new updated prototype is a result of a compromise between the old prototype and new input. The prototype is encoded in the synaptic connections $w_{\vec{r}l}$ and/or in the cardinal neurons at location \vec{r} .

(in olfactory cortex) of the nose's mucous membrane etc. It should be noted that synaptic vectors and cardinal neurons are not genetically predetermined, but evolve gradually upon the selective influence of the environment.

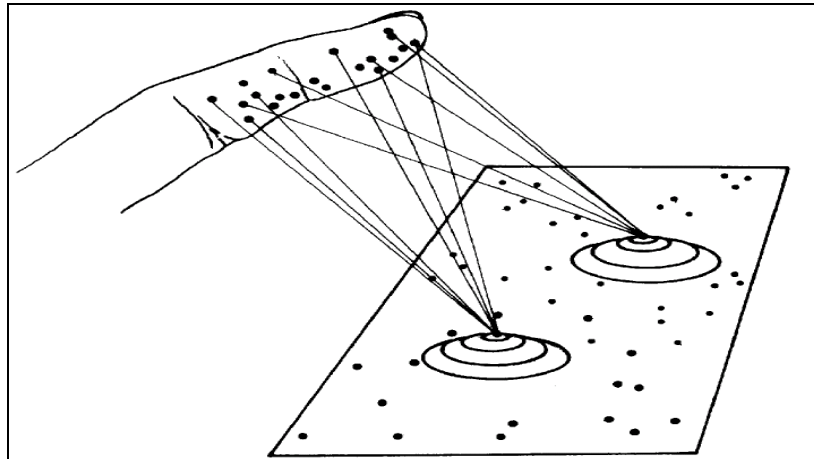


FIGURE 4.6 Kohonen's network reacts on input-pattern (represented in sensory cells of the finger's receptive field) by a local activation around a cardinal neuron which is the carrier of that input-pattern in the brain map.

In the neocortex there are *vertical columns*, as a product of self-organized topology-conserving mapping. They are specialized to *extract features of the input-patterns* (orientations, velocities and directions of movements, edges, periodicity, colour shades etc.), or to *regulate motor actions* (e.g. innervation of a common muscle). In association zones, columns are densely connected to execute collectively complex tasks like recognition of faces, speech comprehension, planning of arm trajectories etc. Columns provide informational basis for higher brain functions, modelled by attractor neural networks.

Hopfield's Associative Networks [5] are *neuropsychologically-plausible* model of neural networks for description and simulation of *associative cognitive processes* (*learning, memorizing, recognition, generalization, extraction of most relevant informational content...*) in secondary, tertiary and prefrontal associative zones of cortex.

These processes can be modelled successfully by using *massively and bidirectionally interconnected* Hopfield's neural networks (cf. Fig. 4.7), organized into functional and/or virtual hierarchies, with *Hebbian correlation matrices of the memory synaptic connections* \mathbf{J} , whose elements J_{lj} are sum of couplings of l^{th} neuron $q_l^{k_i}$ and j^{th} neuron $q_j^{k_i}$ participating in all k_i ($i = 1, \dots, P$) memory patterns of the neural network K :⁴

$$J_{lj} = \sum_{i=1}^P q_l^{k_i} q_j^{k_i} \quad (4.2)$$

⁴ Hebb's equation (4.2) describes how synaptic connections encode correlations between neuronal activities of a single memory pattern: if an individual product is positive (negative), then connection is strengthened (weakened) – which is in accordance with neurophysiological fact formulated in a renown Hebb's 'learning rule'. The connection strength J_{lj} is determined by the sum of such coupling of all memory patterns k_i ($i = 1, \dots, P$) which are stored simultaneously in the network. If the states of two connected neurons $q_l^{k_i}$ and $q_j^{k_i}$ collaborating in the formation of the k_i^{th} memory pattern are of the same sign, then they will contribute to the stability of the k_i^{th} memory pattern in the neural network; if their signs are different then they will weaken the memory pattern. Memory patterns stored in synaptic connections are loaded one atop another. Connections are determined locally according to mutual (dis)agreement of pairs of neurons. Globally, connections determine the (in)stability of all configurations. Neurons locally compete amongst themselves, each seeking to prevail and convert the rest to its state. A neuron succeeds in this if it is in best agreement with the other neurons and if it has the most support from the rest of the neural network; then the neuron has dominantly excitatory connections. In the opposite case a neuron has dominantly inhibitory connections. It should be noted that in the presented Hopfield's bidirectional model the Hebbian matrix J_{lj} is symmetrical, i.e. synapses are equally permeable in both directions: $J_{lj} = J_{jl}$.

On the other hand, the Hebbian equation for *neuronal activities* expresses the state of l^{th} neuron receiving information from the set of all $j = 1, \dots, N$ neurons in the network K :⁵

$$q_l = Sgn\left(\sum_{j=1}^N J_{lj} q_j\right), \quad (4.3)$$

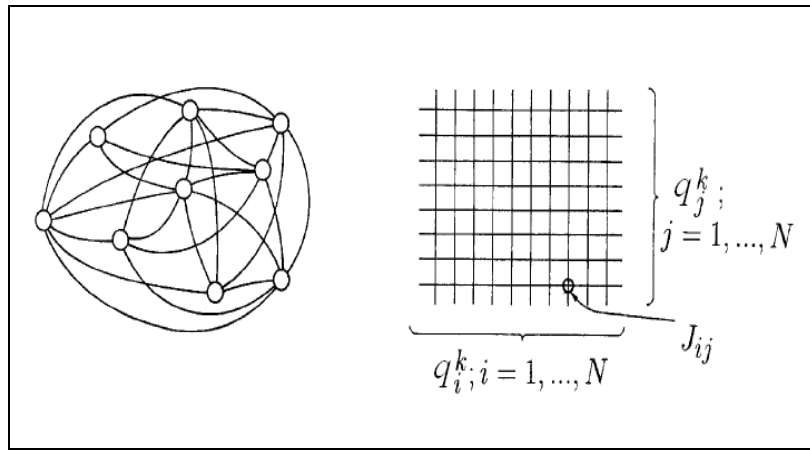


FIGURE 4.7 Diagram of Hopfield's neural network (left) and corresponding memory matrix J (right)

⁵ Function Sgn means that the result q_l is equal +1 (the neuron is active, or firing) if the above sum is greater than a certain threshold, or is equal to -1 (the neuron is quiescent, or inactive) if the above sum is smaller than the neuron's threshold. So, the function Sgn gives the motor (efferent) neuron the sign of the sum of all sensory (afferent) signals of other neurons. If P represents the number of memory patterns stored in the neural network, then each element of the connection matrix J varies over the set of integers $\{-P, -P+1, \dots, P-1, P\}$.

Neurons send each other electro-chemical signals according to the principle 'all for one, and one for all'. One neuron can either promote (through excitatory synaptic connection) or curtail (through inhibitory synaptic connection) the momentary state of another. Specifically, if the sum of signal contributions that a neuron receives from all other neurons exceeds a certain threshold of the neuron, then the neuron becomes activated or firing, and it will emit signals.

It should be noted that in biological neural networks it is *not necessary* that each neuron is interconnected *directly* with all others, as in the absence of direct connections *it is possible* to establish connections *via a mediator* [7]. Such biological neural networks within corresponding associative zones of the cortex, behave as if *all neurons* of this associative zone are *massively interconnected*. This situation can be *modelled* by Hopfield's associative networks, where various potential wells might appear in energy-configuration space $E(\vec{q})$, as *attractor patterns* (*attractors*) of the collective organization of neural states which attract all other neighbour neural configurations, cf. Fig. 4.8. ⁶ Once the network 'falls into' such a configuration, all further configuration-changing processes cease until the reception of a new stimulus.

As a response to various changing stimuli, the adaptation of the synaptic strengths of Hopfield's network i.e. *learning* is achieved, when energy of the whole network is decreased and the bottom of potential well is deepened, i.e. *energy-configuration hypersurface changes* in the process. Furthermore, several configurations may converge to the bottom of the same potential well if they are in the basin of attraction of the same attractor (cf. Fig. 4.8). In this manner a neural network realizes *classification*, which enables recognition of an

⁶ In the model of *Hopfield's neural network*, dynamics is a result of the minimization of 'cost function' proportional to free energy of the system:

$$E_K = -\frac{1}{2} \sum_{l=1}^N \sum_{j=1}^N J_{lj} q_l q_j - \frac{1}{2} \sum_{l=1}^N T_l q_l .$$

It is obvious that the free-energy-function E_K of the system is lower if neurons agree (their activities q_l and q_j have the same sign in that particular moment) while having positive connection J_{lj} (good history of agreement), or disagree while having negative (more disagreement in previous times); furthermore, E_K increases if neurons agree while having negative synapse or disagree while having positive synapse. In the same time, the energy is inversely-proportional to the agreement of neurons with the neuronal field T_l ('public opinion'), which represents the influence of the neuronal field on the l^{th} neuron, or in another interpretation, T_l may represent a neuron's threshold, its own threshold or its threshold as determined by others.

object in slightly different circumstances from those in which one is used to seeing the object in the past. However, perception of an external pattern under new circumstances is accompanied by changes in corresponding internal configurations, as a pattern is synthesized from the outside-world-information, from memory, and from contextual information from the other centres, and then such a *revised and corrected pattern* is stored again. So, *recognition* is also identical with *formation, reconstruction, and short-term memory of the pattern* in a system of bioelectrical processes in neurons.

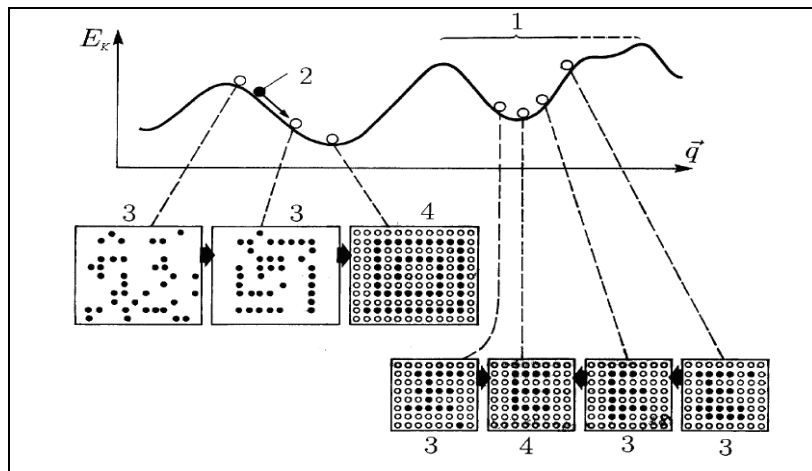


FIGURE 4.8 Configuration-energy hypersurface of Hopfield's neural network: 1 – basin of attraction; 2 – momentary state of the network; 3 – nonstable configuration; 4 – attractor pattern, i.e. stable configuration.

In the course of long-term memorizing, information is transferred through the process of learning from 'manifest awareness' (in the neurons – in \vec{q}) to 'latent awareness' (in the synaptic connections – in \mathbf{J}). Thus, memorizing is a single-valued mapping of some image of an external object into an internal virtual image firstly in the *system of neurons (short-term memory)*, whereupon this image is transferred to the *system of synaptic connections (long-term memory)*. So, there can be one pattern at a time in the system of neurons (*in manifest consciousness*), whereas in the system of synaptic connections (*in*

long-term memory/in latent consciousness/in the subconscious) there can be several patterns simultaneously, albeit it is necessary to recall them from memory: *through recall a memory is brought from the system of synaptic connections into the system of neurons!* The prompt for this is a similar external stimulus which draws neurons into a 'replication' of the externally-imposed pattern, although such a prompt can come from other cerebral sub-networks too.

So, in neural networks of the associative zones of cortex, the main factors determining direction of *mental associative processes* are *attractor patterns*, not single neurons and synapses, and thus even huge injuries of the cortex *do not destroy functionality* of the associative memory if only *attractor structures are preserved!* If associative neural network has *symmetric connections* (synapses equally permeable in both directions, $J_{ij} = J_{ji}$), as it is the case in bidirectional Hopfield's models of Eq. (4.2)), then the network can form *stable attractors* in energy-configuration space, which represent *implicate order* and determine formations of further *virtual mental structures*. On the other hand, if associative neural network would have *asymmetric connections* (synapses differently permeable in two directions: $J_{ij} \neq J_{ji}$), then attractor patterns would become unstable so that one pattern would disappear and other appear, and the system might describe periodic, quasi-periodic, or completely chaotic paths, whose sequences might represent origin of the *flow of thought*.

Haken's Classical Synergetic Networks [6] are *neurocognitively-plausible* model of neural networks for description of *collective virtual cognitive processes*. Synergetic networks unite multi-layer neural networks with associative neural networks, through intra- and inter-layer connections. Each layer is its own associative network which can have functional interpretation (*cardinal neurons* in the second layer) or virtual interpretation (*cardinal domains* as order parameters c_{k_i} in the second layer, or *attractor patterns* \vec{q}^{k_i} in the third layer). In Haken's network order parameters c_{k_i} measure the *overlap* of an attractor pattern

\vec{q}^{k_i} with the actual memory state \vec{q} of the network, i.e. c_{k_i} is projection of \vec{q} onto \vec{q}^{k_i} :

$$c_{k_i} = \sum_{l=1}^N q_l^{k_i} q_l = \langle \vec{q}^{k_i}, \vec{q} \rangle. \quad (4.4)$$

where l is the index of vector's components, and k_i is the attractor's pattern index. The order parameters c_{k_i} acts as coefficients in the series

$$\vec{q} = \sum_{i=1}^P c_{k_i} \vec{q}^{k_i}.$$

In modelling higher brain functions, synergetic neural networks with *generalized interpretation of neurons and connections* may be used: *generalized neurons* may be *cardinal neurons*, *cardinal domains*, *cortical columns* or *virtual attractor patterns* of various orders, while *generalized connections* may be large-scale physiological connections or virtual connections between cortical areas. *Higher order virtual attractor patterns contain lower-order patterns*, with large hierarchy which is sensitive, flexible and mobile!

The network with *asymmetrical generalized connections* ($J_{ij} \neq J_{ji}$) forms constant potential gradient, along which the network descends faster from one configuration to another, with larger associative context through its connections with other patterns which are within the range of attraction of the observed dynamic pattern, forming *associative train of thought*. If individual *nonlocal* attractor patterns are connected with their *localized* cardinal neurons or corresponding order parameters in *speech centres* (Wernicke area), then such a train of thought is encoded or *symbolized*, and it is possible to be *verbalized* (Broca area).

Peruš's Neuro-Quantum Synergetic Networks [3,7] are *quantum extrapolation* of Haken's classical synergetic networks, applied for modelling *higher brain's functions* and *processual bases of consciousness*, uniting brain's neural and virtual processes with subcellular and quantum processes. In this way it is possible to model *associative, intuitive and semantic* processes, although for modelling higher *symbolic, syntacting and logical* processes it is necessary to apply their *hybrid combining* with symbolic models of *artificial intelligence*.

Then it is pointed out that brain-mind is necessarily *multi-level phenomenon*, with overall scheme: *pure consciousness* is of *quantum nature*; *virtual representations* are associated with *neuronal patterns*; *external objects* are of *classical nature* – so that only *hierarchically united interaction of brain's neural and virtual processes with subcellular and quantum processes* might produce *effects of conscious experience*, like final interconnection of perceptual patterns into *united holistic qualitative experience* (manifestly conscious state).

Peruš has demonstrated *direct mathematical parallels* between *quantum processes in Feynman's version of quantum mechanics* and *neuro-informational processes in Hopfield's associative neural networks* (for details cf. Ch. 2). Although basic elements of quantum versus neural system (modelled by formal neurons and connections) are very different, their collective processes obey similar laws. So Hebb's correlation matrix of memory synaptic connections in Hopfield's associative neural networks, Eq. (4.2), corresponds to *Green's function (quantum propagator)* in Feynman's version of Schrödinger equation:

$$G(\mathbf{r}_2, \mathbf{r}_1) = \sum_{i=1}^P \Psi^{k_i}(\mathbf{r}_2) \Psi^{k_i*}(\mathbf{r}_1) \quad (4.5)$$

where Ψ^{k_i} is i^{th} *quantum memory attractor* (i.e. explicate *short-term memory* of i^{th} quantum state/attractor), and G is the *quantum memory* (i.e. implicate *long-term memory* of all P quantum states/attractors in the quantum memory) of such informationally interpreted (any) quantum system S ! Then, (re)construction of quantum attractor patterns, i.e. transformation of the representation of *long-term memory* (of quantum latent consciousness/the subconscious) into representation of the *recall/short-term memory* (of quantum manifest consciousness), is analogous to the *wave-function collapse*.

By using these analogies in *neuro-quantum synergetic networks*, it is possible to achieve information processes with *large hierarchy of patterns*, consisted of a set of *functional levels* and *virtual levels of abstraction*: neurons (first biological level); patterns (second biological level – first virtual level, generalized neurons); higher-order patterns (schemes, categories, meta-representations, symbols); dynamic pattern-sequences (associative chains, episodes, trains of thought); pattern

manifolds (combinations of higher patterns of various types and origins, with some common feature); semantic, symbolic or conceptual networks; global attractor conglomerates (personality, ego); and consciousness (in multi-level interaction with sub-cellular and quantum levels).

These neuro-quantum synergetic neural networks are *interactively self-organized and simultaneously consolidated on all hierarchical virtual levels*. A possible biophysical mechanism of interconnection of the lower-order patterns into higher-order ones or into informational unity of all patterns, might be *macroscopic neuro-quantum coherence of all virtual levels*.

4.2 Implications for Modelling Cognitive Functions

Biocybernetic models of the classical-electrochemical brain's neural networks presented in the previous section, demonstrate encouraging advances in the modelling of cognitive functions [1-3].

Consciousness, according to classical neuropsychological paradigm, is related to the role of *extended reticular-thalamic activating system* (ERTAS), which every ~ 0.1 s selects and amplifies one piece of information among a lot of sensory and introspective pieces of information, currently processed within the hierarchy of brain's neural networks. According to the model of *neuro-quantum synergetic networks*, only *large hierarchy of patterns over all levels* (neural, virtual, sub-cellular, quantum) might produce *effects of conscious experience*, like final interconnection of perceptual patterns into *united holistic qualitative experience*.

Perception (visual, auditory, olfactory, palatal, tactile), according to classical neuropsychological paradigm, is going on as perceptually-mediated and ERTAS-selected and filtered communication of hierarchical brain's neural networks with sensory environment. According to the model of *self-organizing feature mapping networks*, perception is self-organizing mapping from sensory input into internal representations, by developing two-dimensional sensory maps *within cortical primary zones*, with preserved topological relations of input sensory data.

Learning, according to the model of hierarchical brain's neural networks, is firstly related to self-organized mapping of the *localized cardinal neurons of cortical primary zones*, and then to interactively coupled generation and consolidation over all hierarchical virtual levels of *nonlocal attractor patterns in cortical associative secondary and*

tertiary zones, whose synapses dynamically strengthen and weaken according to Hebb's rule. Neurophysiological investigations imply that *brainwaves* presumably play essential role in (global) *distribution of information*⁷ from primary to secondary and tertiary cortical zones⁸ – where ERTAS *selects and amplifies one* piece of information every ~ 0.1 s on *conscious level* (of higher-frequency α , β , or γ brainwaves), while other pieces of information remain unamplified on *unconscious levels* (of lower-frequency δ or θ brainwaves).

Memorizing, according to the model of hierarchical brain's neural networks, is a single-valued mapping of some image of an external object into an internal virtual image, firstly in the *system of neurons* (**short-term memory**) whereupon this image is transferred to the *system of synaptic connections* (**long-term memory**); thus even huge injuries of the cortex *do not destroy functionality* of the associative memory if only *attractor structures are preserved*. So there can be one pattern at a time in the system of neurons (*in manifest consciousness*), whereas in the system of synaptic connections (*in long-term memory/in latent consciousness/in the subconscious*) there can be several patterns simultaneously, albeit it is necessary to **recall** them associatively from memory, *from the system of synaptic connections into the system of neurons*.

⁷ A significant contribution in modelling biological hierarchical neural networks was given by Freeman and his collaborators [9], whose neural network reflects the dynamics of olfaction. As a result of modelling, strange attractors with multiple 'wings' were obtained: the central part of attractor can be interpreted as a basal chaotic electric activity of the olfactory system (simulating the basal brainwave electroencephalographic (EEG) activity without olfactory stimulus), while the wings of attractor can be interpreted as 'near-limit cycles', corresponding to quasiperiodic states of the induced brainwave (evoked potential (EP)) activities upon the various olfactory stimuli, implying that EEG enables brain's quicker responses upon stimuli. Such neural networks with embedded EEG-activity do not depend on initial conditions of the network, and can classify uninterrupted chain of stimuli, which imply that EEG (without stimuli) is preparatory activity of the brain, which enables its faster response to stimuli!

⁸ However, John and his collaborators [10] have shown that after completed learning (habituation), the same visual stimulus might be found only in primary visual system i.e. it is not distributed farther into secondary and tertiary cortical zones (presumably as it would be a redundant piece of information)!

Thinking, according to the models of hierarchical synergetic networks with *asymmetric generalized connections*, could be related to quickly changing *associative train of thought*, where system descends faster from one configuration to another through its connections with other attractor patterns which are within the range of attraction of the observed dynamic pattern. Besides, according to classical neuro-psychological paradigm, thinking could be separated in at least two parts: first, the *ERTAS-selection and amplification of one piece of information* accompanied by its *emotional and verbal modulation* to the conscious level, and second, the *problem solving* related to this piece of information via cortical prefrontal region and associative secondary and tertiary zones.

Language, according to classical neuropsychological paradigm, is semantic/pragmatic/syntactic organized through cortical hierarchical primary, secondary and tertiary zones.⁹ Besides, if in hierarchical synergetic networks with *asymmetric generalized connections* some *nonlocal* attractor patterns are connected with their localized *cardinal neurons* or corresponding *order parameters* in **speech centres** (Wernicke area), then such *associative train of thought* is encoded or *symbolized*, and it is possible to be *verbalized* (Broca area).

Emotions, according to neuropsychological research, could be related to amplitude and frequency ERTAS-modulation, which might basically be the mechanism of '*emotional colouring*' of some selected and amplified information to conscious level (of higher-frequency α , β , or γ brainwaves).

⁹ According to Pribram [11], the basic brain mechanisms responsible for organization of natural language are known: (a) Semantic processing (which relates indicant and symbol to the sensory input from which they derive) is carried out by systems which involve the posterior 'association' areas that surround the primary sensory cortical areas; (b) Pragmatic processing (which relates sign and symbol to their user) is carried out by ERTAS-like systems which involve the frontolimbic cortical formations of the brain; (c) Syntactic processing (the arrangement of indicants and symbols) is carried out by the motor systems of the brain to which both posterior and frontal cortical formations project.

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5. BODY'S HIERARCHICAL NEURAL NETWORKS

As it was mentioned in the introductory Ch. 1, contemporary investigations of psychosomatic diseases imply the necessity of application *holistic methods*, oriented on *healing the person as a whole* and not disease as a symptom of the disorder of the whole, implying their *macroscopic quantum origin*, related to body's *acupuncture system* and *consciousness* – with surprisingly significant psychosomatic-cognitive implications (which will be elaborated in the next subsection).

Acupuncture, as one of the most significant fields of the *Chinese traditional medicine* [1-3], is an *ancient* method, dating from the Stone Age (Chinese tradition is talking about the emperor Shin-Nong (3200 B.C.) as the inventor of Chinese medicine), when needles of the polished stone had been used, until the invention of the copper, 2600 B.C.

The word *acupuncture* means insertion (*acus* - needle), and is related to the insertion of needles in strictly specific locations on the skin (*acupuncture points*), which regulates the flow of the vital energy (*qi*) within its energy paths (*acupuncture channels/meridians*), interconnecting appropriate acupuncture points. According to Chinese tradition, the channels are interconnected into *two symmetric and closed* (and mutually almost independent) energy-information somatic networks, one on each side of the body. Each network consists of 12 *meridians* – having correspondence to 12 visceral organs: 6 *fu (yang) hollow organs* (large intestine, triple warmer, small intestine, stomach, gall bladder, urinary bladder), which transform food into energy and blood, and 6 *tsang (yin) solid organs* (lung, pericardium, heart, spleen, liver, kidney), which receive energy and blood from the fu-organs, and refine and distribute energy within the body.

The *vital entity* is flowing equally and simultaneously throughout both sides of the body. The time of maximal *qi* activity of each channel is 2 hours, giving rise to a complete 24-hour circulation of *qi* through all 12 channels! Each organ has its hour of entrance (when maximal 2-hour activity of the organ begins) and its hour of exit of *qi* (when minimal successive 2-hour activity of the organ begins): corresponding acupuncture stimulation during its maximal activity is most efficient in decreasing the activity of the organ, while acupuncture stimulation during its minimal activity is most efficient in increasing the activity of the

organ. A stylized display of the daily dynamics of *qi* circulation is depicted in Fig. 5.1: the successive regularity of alternative sequence of the paired *yin-yin* and *yang-yang* organs can be noticed.

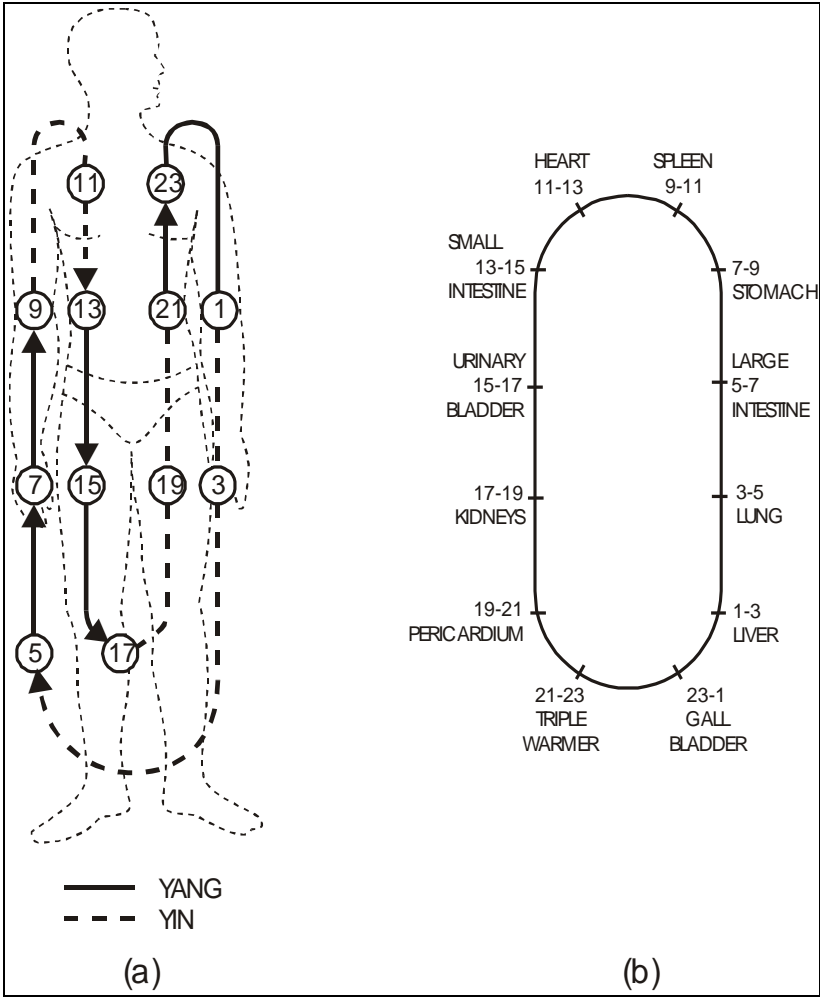


FIGURE 5.1 Stylized display of the traditional Chinese representation of circulation of the *qi* entity within the human body: (a) during 24 hours, and (b) hours of maximum activity of the organs; actually, each side of the body has its almost independent circulation of *qi*.

Beside 12 paired channels, which are great double circulation of *qi*, Chinese tradition has also depicted 2 middle channels, the back one and the front one, independent of the great double *qi* circulation. These central meridians do not correspond to organs but to their functions, being stimulated in the case the meridians of the organs do not react appropriately upon stimuli.

There is a total of 794 (397 + 397) main extra-bioactive points (acupuncture points) on the body. The points can be *stimulated* by sticking metallic needles, but also by heat, pressure, magnets, weak laser beam, ultra-low frequency currents, microwave resonance, aeroionic, and bio-therapeutic stimulation.

Indian traditional medicine, and especially one of its most prominent representatives, *swara yoga* [1,4], is also acquainted with an energy system analogous to the Chinese acupuncture system: in Indian terminology *qi* is known as *prana*, and *meridians* as *nadis* (14 of them being basic, like in acupuncture, although three of them being of special medical and spiritual significance: *ida*, *pingala*, and *shushumna* – being interconnected with brain's limbic system).

The *ida* activation influences hypothalamus and hypophysis, and thus the hormone growth synthesis and *anabolic processes*. This channel starts from the *spine base*, flows upward *left* to the backbone and terminates in the *left nostril*, branching into the fine capillars. This channel is active when the *left nostril* dominantly operates, i.e. when contralateral *right hemisphere* is more active.

The *pingala* activation influences hypothalamus and thalamus, but not hypophysis, thus activating *catabolic processes*. This channel also starts from the *spine base*, but flows upward *right* to the backbone and terminates in the *right nostril*, branching into the fine capillars too. This channel is active when the *right nostril* dominantly operates, i.e. when contralateral *left hemisphere* is more active.

The *shushumna* is interconnected with *corpus callosum* (connecting two brain's hemispheres) and cerebellum. This channel also starts from the spine base, being positioned *between* *ida* and *pingala*: its energy flows through the backbone, and terminates on the top of skull at the fontanella (the 'soft bone' on the child's skull, which hardens after 3-6 months after birth). *Shushumna* is active *very shortly*, in the time intervals of interchanged activities of *ida* and *pingala*. *Shushumna* is the only channel

which passes through all chakras,¹⁰ i.e. main acupuncture points alongside the backbone, being *functionally* interconnected with neighbouring endocrine glands.

Through its interrelation with *endocrine glands*, these three *nadis* influence biochemistry of the whole organism. Also, these channels are interconnected with the sympathetic and parasympathic *autonomous nervous system*, which implies that the *acupuncture mechanism*, initiated by acting upon the acupuncture points at the skin surface, is achieved via activation/deactivation of the autonomous nervous system, spine and brain.

Swara yoga is very familiar with the significance of *ultradial rhythms* (brain's and nasal),¹¹ and possibility of their *control* in the processes of

¹⁰ According to Hinduism, there are seven chakras, with ascribed mystical significance. By successive activation of these 'centres of consciousness' (in which prana/ions circulate clockwise in healthy state, whose circulation slows down in psychosomatic disorders with possibility of counterclockwise circulation in most serious diseases [1,5]), starting from the spine base and terminating on the top of skull, according to Indian esoteric tradition there proceeds gradual 'spreading of consciousness', acquiring of psychic powers ('siddhis'; there are eight of them), with final reaching of the state of 'nirvana' (mystical unity with Absolute), thus reaching the spiritual goal and terminating the cycle of reincarnations [5,6]. In this context the multimillennia controversy on post mortem evolution of soul should be mentioned, which is presumably related to interpretative epistemological level of the rationalization of transpersonal transfer of mentally-addressed loads within this and further generations via network of collective consciousness, with possibility that especially strong conflicts transferred as 'ego-states' give strong impression of previously spent lives [1,7]?

¹¹ According to *Swara yoga*, nasal rhythm has ultradian periodicity ~ 2 hours (i.e. ~ 1 hour of alternative dominance of the left and right phases: ida-pingala-...). Although this rhythm is apparently not in phase with ~ 24-hour acupuncture rhythm of the successive dominance of 12 paired meridians (i.e. ~ 2-hour successive dominance of every organ-related meridian with corresponding yin or yang functions in the mentioned order: yin-yin-yang-yang-..., cf. Fig. 5.1a), it seems that every ~ 2-hour organ-related acupuncture phase (either yin or yang) requires complete ~ 2-hour nasal phase (ida-pingala) in order to balance activities of corresponding organ-related pair of symmetrical left and right meridians, to enable both regenerative (anabolic, ida-like left-meridian) and

recovering or keeping energy and emotional balance of the organism [1,4]¹²

Besides their practical medical aspects, Chinese and Indian traditional medicines are deeply coloured with *mystical connotations*, which was one of the reasons why Western science has been hardly accepting experiences of the Eastern tradition. The second reason was a lack of clear *anatomical basis* of the Chinese and Indian energy system.

However, new investigations of the 'gap junctions' (GJ) non-threshold *electrical synapses* have shown their ~ 10 times increased concentration inside the acupuncture points [1,8], which is in accordance with significantly *less electrical resistance* (~ 50 kΩ) of the acupuncture points in respect to the surrounding tissue (~ 1 MΩ) [1-3]. Biophysical model of the acupuncture system and states of consciousness [1,9] also implies an *ionic nature of the acupuncture system*,¹³ with possibility of

degradative (catabolic, pingala-like right-meridian) organ functions [1,10], contributing finally to either yin or yang overall corresponding organ-effect from the viewpoint of the traditional Chinese medicine. This implies that both "-" and "+" ions are metabolically significant (which is confirmed by experiments with experimental animals which die after couple of weeks in the atmosphere without ions!), although small excess (ratio 5:4) of "-" ions is relaxing-well-being for the body!

¹² The brain ultradian rhythm controls the nasal rhythm contralaterally (more active left hemisphere gives rise to more active (more opened) right nostril, and reversely for opposite hemisphere). However, according to Swara yoga [1,4] there is also possibility for reverse influence of the nasal rhythm on the brain one, by activating less active nostril through special breathing procedure: the more active nostril is closed by finger pressure, this being followed by forceful and short inhaling 10-15 times through the less active nostril. In this way the previously less active channel (ida or pingala) is excited through ionic nostril receptors, then subsequently influencing the limbic brain centre to change the phase of ultradian rhythm. The effect is achieved after only several minutes, which might be monitored by exchanged activity of nostrils. The procedure is very simple, and can be efficiently used to prevent development of cold in early phase (through cutting the ultradian rhythm of developing disorder), for change of stressful mood, etc!

¹³ The above biophysical ionic interpretation of the acupuncture system can account for the origin of Chinese therapeutic yin-yang/tonification-sedation rules through the type/rotation of the needles [1,10]: yin syndrome (excess of "-" ions

its *partial displacements* out-of-body in *altered states of consciousness*, which is confirmed by several-millennia-old Eastern and Western *esoteric traditions*, as well as by contemporary investigations [1,5-7,11,12]. According to this model, *vital energy* (*qi*, *prana*, *pneuma*, *bioenergy*) would have its theoretical interpretation in *ions*, out of which "+" ions have degradative *catabolic* (*yang*) influence and flow dominantly through the *right* part of the circulatory acupuncture system, while "-" ions have inhibitory *anabolic* (*yin*) influence and flow dominantly through the *left* part of the circulatory acupuncture system (cf. Fig. 5.1a).¹⁴ The mechanisms of the acupuncture stimulation keep the activity of the "+" and "-" ions in balance, of normal healthy state.

in some left acupuncture channel) is tonified by taking in "+" ions from air or taking off "-" ions from the channel (through Ag needles working as anode) i.e. by rotating needles in counterclockwise direction on the left channel (thus closing its gap junctions for flow of "-" ions) or clockwise direction on the corresponding right channel (thus opening its gap junctions for flow of "+" ions); and yang syndrome (excess of "+" ions in some right acupuncture channel) is sedated by taking in "-" ions from air or taking off "+" ions from the channel (through Au needles working as cathode) i.e. by rotating needles in counterclockwise direction on the right channel (thus closing its gap junctions for flow of "+" ions) or clockwise direction on the corresponding left channel (thus opening its gap junctions for flow of "-" ions). On the other hand, some other Chinese therapeutic rules need taking into account functional physiological interactions between acupuncture system and nervous and humoral systems.

¹⁴ According to swara yoga the rhythmical breathing through the nose is especially important, in order to inhale as many as possible airoions (prana) within the two (out of three) most significant nadis (the left ida and the right pingala), with their entrances in corresponding nostrils: this is recommended in fresh and nonpolluted air, when even some excess of "-" ions exists, with the relaxing healthy influence on the body! It should be pointed out that breathing through the nose is crucial, with pauses for keeping breath between inhaling and exhaling (in order to inhale as many as possible airoions within ionic channels, and then redistributed through the whole acupuncture ionic system). For keeping good healthy state, a half-hour rhythmical breathing in the morning and evening relaxing walks, with rhythmicity 6:6:12 (during 6 steps deep inhale, next 6 steps keeping the breath, and following 12 steps the full exhale), 5:5:10 or 4:4:8, depending on individual lung capacity. In the same context, in closed environments a microclimate engineering can be recommended by applying airoionizers that produce an excess of "-" ions.

5.1 Quantum and Classical Body's Hierarchical Neural Networks

As it was mentioned in Ch. 4, the prevailing scientific paradigm considers information processing within the central nervous system as occurring through *hierarchically organized and interconnected neural networks*.

However, it seems that this hierarchy of biological neural networks is going down sub-cellular *cytoskeleton* level, being according to some scientists a kind of *interface* between *neural* and *quantum* levels [13-15]. At the same time it appeared, within the Feynman propagator version of the Schrödinger equation, that the *quantum level* is described by *analogous* mathematical formalism as *Hopfield-like quantum-holographic associative neural network* [16].

The mentioned analogy opens additional fundamental question as to how the *quantum* parallel processing level gives rise to *classical* parallel processing level, which is a general problem of the relationship between quantum and classical levels within the *quantum decoherence theory* as well (cf. App. 6.7). Naturally, the same question is closely related to the fundamental nature of *consciousness*, whose in-deterministic manifestations of *free will* [1,9,17,18] and other holistic manifestations of consciousness like *transitional states of consciousness* [1,8], *altered states of consciousness* [19], and *consciousness pervading body* [20] – necessarily imply that some manifestations of consciousness must have deeper *quantum origin* – with significant *psychosomatic and transpersonal implications*, which will be elaborated further on..

On the other hand, as demonstrated by *quantum-coherent characteristics* of the Russian-Ukrainian school of *microwave resonance therapy* (MRT) [21] (highly resonant microwave (MW) sensory response of the disordered organism, biologically efficient nonthermal MW radiation of the extremely low intensity, and neglecting MW energy losses alongside acupuncture meridians; about MRT see introductory Ch. 1) – the *acupuncture system* is the only *macroscopic quantum system* in our body (while brain still seems not to be [22]) which is the reason that *consciousness* is related to its MW ultralow-frequency (ULF) modulated *EM field* in the framework of the author's *biophysical quantum-holographic/quantum-relativistic model of consciousness* [1,9,23,24]).

And as recent Peruš's theoretical investigations show that any *quantum system* has formal mathematical structure of the *quantum-holographic Hopfield-like associative neural network* [16] (cf. Ch. 2) – then *memory attractors of the acupuncture network* can be treated as *psychosomatic disorders* representing EM/MW (*quantum*)*holistic records* (which might be therefore removed only holistically, supported by an extreme efficiency of the MRT therapy that consequently erases the very information of the psychosomatic disorders, cf. Fig. 3.3 in Ch. 3) – which represents biophysical basis of (*acupuncture temporarily reprogrammable!*) (*quantum*)*holistic local psychosomatics* [1,9,10,23-25].

Namely, according to the *Tibetan traditional medicine*, an acupuncture procedure must be repeated every several months [26] – presumably as a consequence of *restituted* patient's mental loads from his *mental-transpersonal-environment* of closely related relatives/enemies/deceased, that remained *non-reprogrammed* on the level of quantum-holographic collective consciousness, which might be supported by the Tibetan *pulse diagnostics* based on 20 pulses,¹⁵ enabling precise diagnosis of psychosomatic disorders not only of the patient himself *but also* of his family members and enemies.

An additional support that the acupuncture system is really related to consciousness is provided by novel *meridian (psychoenergetic) therapies* (with very fast removing of persistent phobias, allergies and other psychosomatic disorders [25,27]; about meridian therapies see introductory Ch. 1) – whose simultaneous effects of *visualization* and *tapping/touching of acupuncture points* might be theoretically interpreted as a '*smearing*' and *associative integration of memory attractors* of the psychosomatic disorders [26], through successive imposing new boundary conditions in the acupuncture energy-state space during visualizations of the psychosomatic problems [1,23-25], cf. Fig. 5.2.

In this context, the *association of individual consciousness to manifestly-macroscopic-quantum acupuncture system*, and *application* of theoretical methods of *associative neural networks* and *quantum*

¹⁵ Tibetan pulse diagnostics recognizes about 430 basic psychosomatic diseases and several thousands subdivided ones [26] (while Western symptomatic medicine recognizes about 80 basic psychosomatic diseases [3]).

neural holography and quantum decoherence theory, imply two cognitive modes of consciousness, according to the coupling strength consciousness-body-environment [1,7,9,23-25,28]: (1) weakly-coupled quantum-coherent direct one (in out-of-body¹⁶ religious/creative transitional and altered states of consciousness, like prayer, meditation, creative dozes, lucid dreams...), and (2) strongly-coupled classically-reduced indirect one (in bodily perceptively/rationally mediated normal states of consciousness, like sensory perception, logical and scientific thinking...) – with conditions for mutual transformations – and significant religious and epistemological implications related to re-gained strong coupling of quantum-holographic contents of consciousness with bodily-environment, classically-reducing directly obtained quantum-coherent informational content. This explains in principle non-adequate informational rationalization of any direct quantum-holographic spiritual/religious mystical experience (as a general problem of the quantum theory of measurement, of reduction of the implicate order of quantum-coherent (quantum-holographic) superpositions into the explicate order of measured projective quantum and mixed classical states [1,7,24]!).

So it seems that science is closing the circle, by *re-discovering two cognitive modes of consciousness* and at the same time by imposing its own *epistemological limitations* – as it was preserved for millennia in *shamanistic tribal traditions* [29], or as it was concisely described by Patanjali in *Yoga Sutras*, pointing out that mystical experience (samadhi) is 'filled with truth' and that 'it goes beyond inference and scriptures' [5,30], or as this difference between faith and knowledge was formulated at the beginning of the last century by Berdyaev in his *Philosophy of Freedom* as the difference of two modes of cognition, prayer-mediated 'comprehension of the affairs invisible' and rationally-mediated 'comprehension of the affairs visible' [31]!

¹⁶ Fundamentally-theoretical reasons for this out-of-body displacement of consciousness lays in necessity that consciousness must have, at least in (quantum-coherent) altered/transitional states, sufficiently isolated relevant macroscopic quantum degrees of freedom [1,9,23] – in order to have indeterministic characteristics of free will – which is otherwise not possible in strong body's environment which causes quick quantum decoherence of consciousness into (classically-reduced) normal state [22].

On this line, by defining open quantum system S_k to include k^{th} acupuncture system/individual consciousness and its complementary environment E_k , by applying *quantum decoherence theory* on quantum-coherent superposition $|\phi^{(k)}(t)\rangle_{S_{ke}} = \sum_i c_{k_i}(t) |\phi^{(k_i)}\rangle_{S_{ke}}$ (which may be described by superposition of all possible states $|\phi^{(k_i)}\rangle_S$) it is transformed into classically-reduced stochastic state described by density operator $\hat{\rho}_{S_{ke}}^{(k)}(t) = \sum_i |c_{k_i}(t)|^2 |\phi^{(k_i)}\rangle_{S_{ke}} \langle \phi^{(k_i)}|$ (with probabilities $|c_{k_i}|^2$ of the realization of one of the classically-reduced states $|\phi^{(k_i)}\rangle_{S_{ke}}$ – in quantum measurement-like process upon the initial quantum-coherent state $|\phi^{(k)}\rangle_{S_{ke}}$). Temporal evolution (during short-time interval nonperturbed by closer environment) of the *quantum-coherent state* $|\phi^{(k)}(t)\rangle_{S_{ke}}$ may be described within Feynman's representation by quantum-holographic Hopfield-like neural network, via dynamic equation for *quantum-holographic memory/propagator of the quantum system*

$$G(r_2, t_2; r_1, t_1) = \sum_{i=1}^P \phi^{k_i}(r_2, t_2) \phi^{k_i*}(r_1, t_1) \\ = \sum_{i=1}^P A_{k_i}(r_2, t_2) A_{k_i}^*(r_1, t_1) e^{\frac{i}{\hbar}(\alpha_{k_i}(r_2, t_2) - \alpha_{k_i}(r_1, t_1))},$$

while temporal evolution of the *classically-reduced stochastic state* $\hat{\rho}_{S_{ke}}^{(k)}(t)$ of the acupuncture system/individual consciousness S_k (as a consequence of its *non-stationary interaction with environment* E_k , which turns-over the system S_k from one stationary classically-reduced state into nonstationary quantum-coherent state and then into another classically-reduced state) may be described by classical Hopfield's neural network, *presented by shape-changes of the many-electron or multi-phonon energy-state hypersurface* $E_{s_k}(\phi^{(k)})$ of the open acupuncture system/individual consciousness S_k (cf. Fig. 3.3 in Ch. 3 and App. 6.7).

It should be pointed out, that in the context of *necessary conditions for decoherence* [32], the defining of open quantum system and environment is a *simultaneous process* – so that in the context of universal validity of quantum mechanics *consciousness is a relative concept*, non-locally also influenced by farther parts of existing observing universe (and *vice versa*!) [33], simultaneously creating conditions for the process of decoherence in the context of *existing relative borderline*:

$$|\Phi\rangle_S |\Psi\rangle_E \equiv |(partial) individual/collective consciousness\rangle_S \\ |(complementary) environment\rangle_E .$$

This is fully in accordance with the idea of *collective consciousness* as a possible *ontological property of the physical field itself* [1,7,9,23-25,28], with different micro-quantum and macro-quantum (both non-biological and biological, real and virtual) excitations. Then, as *cosmic collective consciousness* ($|\Phi\rangle_S \sim$

$\prod_k |\phi^k\rangle_{S_k} = \sum_i c_i |\Phi_i\rangle_S$), coincident with the 'field' of Universe, has its *complementary 'particle' cosmic environment* ($|\Psi\rangle_E = \sum_i c_i |\Psi_i\rangle_E$),

their strong-interaction-coupling affects *decoherence of the 'field' of cosmic collective consciousness* into stationary *classically-reduced (observing) stochastic state*, $\hat{\rho}_S = \sum_i |c_i|^2 |\Phi_i\rangle_{SS} \langle \Phi_i|$ (and reciprocally,

decoherence of the cosmic-consciousness-observable classically-reduced stochastic state of the complementary 'particle' cosmic environment $\hat{\rho}_E = \sum_i |c_i|^2 |\Psi_i\rangle_{EE} \langle \Psi_i|$), with probabilities ($|c_i|^2$) of realizations

of corresponding classically-decoherent states of cosmic collective consciousness. However, *cosmic composite quantum state* ($|\Phi\rangle_S |\Psi\rangle_E$) *evolves without collapse (due to absence of the complementary outside-cosmic environment!)*, which implies that *Universe as a whole might be considered as a quantum hologram* subject to deterministic Schrödinger evolution [1,7,24,25,28]!

At the same time, the *analogy between mathematical formalisms of Hopfield's associative neural network and Feynman's propagator version*

of the Schrödinger equation [16] additionally implies that *collective consciousness* is a possible *ontological property of the physical field itself* with various micro-quantum and macro-quantum (both non-biological and biological) excitations [1,7,9,23], which is a widely spread thesis of *Eastern esoteric/religious traditions* [6] – and then *memory attractors of the quantum-holographic space-time network of collective consciousness* can be treated as *psychosomatic collective disorders* representing *generalized (quantum)holistic field records* (including *interpersonal hesychastic-prayer finally-reprogrammable loads* [11]) – which might represent *biophysical basis of (quantum)holistic global psychosomatics* [1,7,9,23], with *religious/social implications* on the necessity of *trans-personal spiritual quantum-holographic removing* all unwilling collective memory attractors (which unless non-reprogrammed by prayer will cause psychosomatic diseases and interpersonal fights in this and/or further generations they are transpersonally and unconsciously transferred to, on the level of collective consciousness).

The same might be related to *lower hierarchical quantum-holographic macroscopic open quantum cellular enzyme-gene level*, which might be also functioning on the level of permanent *quantum-conformational quantum-holographic like* molecular recognition (through changes in operator of macromolecular electronic-conformational density of states $\hat{\rho}_e(t)$) – so that *quantum neural holography* combined with *quantum decoherence* might be very significant element of the feedback *bioinformatics*, from the level of cell to the level of organism and further to the level of collective consciousness, cf. Fig. 3.3 in Ch. 3 [1,24,25].

All this additionally implies that the *whole psychosomatics is a quantum hologram* [1,23-25,28], both on the level of *individual and collective consciousness*, which resembles Hinduistic relationship *Brahman/Atman* ('*Atman is Brahman*' [5,30]), as the whole and its part which bears information about the whole. The mentioned quantum-holographic picture also implies that quantum-holographic hierarchical parts carry information on the whole, enabling *quantum-holographic fractal coupling* of various hierarchical levels in Nature:

(1) *Quantum-holographic coupling with evolving state of collective consciousness*: (i) *locally*, via (non)intentionally mentally-addressed states of acupuncture system/consciousness, with significant psychosomatic

implications (due to subsequent acupuncture-based¹⁷ quantum-informational control of ontogenesis and morphogenesis, starting from the first fertilized cell division which initializes differentiation of the acupuncture system of (electrical synaptic) ‘gap-junctions’ [1,8,24,25], also supported by experimentally demonstrated *quantum-holographic-language-influence on the genes expression* [35]), as well as with transpersonally-addressed classically-reduced quantum-holographic cognitive-creative implications (Tesla and Mozart as extraordinary examples of miraculous creativity [28,36])), and (ii) *globally*, via advancing individual and collective events¹⁸ (whose memory attractors might be *reprogrammed by hesychastic prayer for others* thus removing interpersonal loads of the quantum-holographic Hopfield-like neural network of collective consciousness – via prayer-induced hypothetical macroscopic vacuum non-loaded spiritual excitations, as indeterministic intervention in otherwise deterministic evolution of the quantum-holographic evolution of collective consciousness (and complementary ‘particle’ environment of the advancing individual and collective events!) which thus provides essentially new non-Schrödinger boundary conditions [1,24,25]!). This leaves room for *free will and influence on future preferences*, and implies indispensable personal role and care for collective mental environment;

(2) *Meridian (psycho)therapies*, with very fast removing of traumas, persistent phobias, allergies, post-traumatic stress and other psychosomatic disorders [25,27], via simultaneous effects of *visualization of the psychosomatic*

¹⁷ On local quantum-holographic coupling on the level of bodily acupuncture system and its numerous projection zones see reports contemporary Su Jok therapy [34]. On transpersonally-addressed classically-reduced quantum-holographic coupling of closely related relatives/enemies/deceased reports acupuncture-based Tibetan traditional medicine [26].

¹⁸ On most fascinating manifestation of global quantum-holographic coupling on the level of preferences of collective and individual history, reports so called ‘Bible Code’ revealing series of characteristic keywords for all historical persons coded by equidistant letter sequences within The Old Testament [37] revealed to Moses on the Mount Sinai 3000 years ago – which might be interpreted as a consequence of the quantum-holographic nature of the cosmic collective consciousness (God!?) and its every original manifestation (including The Old Testament, as well as every individual consciousness). On fractal-informational coupling of various hierarchical levels in Nature report several contemporary investigations [38].

problems and tapping/touching of some acupuncture points, which might be interpreted as '*smearing*' and *associative integration of memory attractors of the psychosomatic disorders*¹⁹ through successive imposing of new boundary conditions in the energy-state space of acupuncture system/consciousness (cf. Fig. 5.2), which can be additionally accompanied by discharge of memory attractors of psychosomatic disorders – thus demonstrating a close relationship between consciousness and acupuncture system! Bearing in mind very high efficiency of transpersonal circular meridian (psycho)therapeutic processes, i.e. from all relevant mentally-addressed viewpoints of other persons involved in the treated trauma, this implies that these interactions of the trauma-related persons have quantum-gravitational origin via a miniature '*wormhole*' space-time tunnels in transitional states of consciousness²⁰ of the trauma-related persons

¹⁹ It should be pointed out that discovery and neutralization/integration of client's (Yin-Yang) 'Primordial Polarities' during Deep PEAT (cf. introductory Ch. 1), presumably points to most fundamental roots of client's compulsive and unconscious life game, i.e. on deep roots of thought processes on the very borderline (quantum-coherent) implicate order – (classically-reduced) explicate order of the quantum-holographic individual/collective consciousness [25]. In the moment of neutralization/integration and getting conscious of 'Primordial Polarities', on the one hand they become quantum-entangled in quantum-coherent state of the implicate order, and on the other hand they become psychologically integrated in classically-reduced state of the explicate order of client's consciousness – and Being regains its spiritual and psychological freedom out of previously unconscious and compulsive life game. In this context it is worth mentioning to point out discovery of the Tibetan Buddhism, that there exist more than 84,000 possible psychic 'entities' or 'thoughts' (created by separation from Oneness on the very borderline of (classically-reduced) explication of quantum-holographic individual/collective consciousness) and that their cloned associative constructs (i.e. memory attractors) overflow our consciousness, as carriers of some sort of 'meta-language' of altered states of consciousness [25].

²⁰ This could be deeply related to so called 'wave packet collapse (objective reduction)' which might have quantum-gravitational origin in space-time miniature 'wormhole' tunnels of highly-noninertial microparticle interactions [1,9] in quantum measurement-like situations (fully equivalent, according to Einstein's Principle of equivalence, to strong gravitational fields – in which opening of 'wormholes' is predicted [39]). The question as to how it is possible that these highly noninertial microparticle processes with inevitable relativistic

[24,25] (or ‘silver cord’ of vital energy of the astral/mental body, extrasensory observable in altered states between the heart, stomach or throat chakras of the interconnected persons; in African-Haitian voodoo magic the ‘silver cord’ between the operator and the victim is intentionally created by visualization, while in Hawaiian hooponopono tradition the ‘silver cord’ is cut by visualization thus removing traumatic emotional relationship – which otherwise naturally exists between mother and child, and spontaneously arises by intense exchange of the vital energy between relatives, close collaborators, actual or ex-lovers, friends and enemies, and can even persist *post mortem* between the alive and dead persons [25]).

So, our theoretical investigations imply *real origin of religious and other transpersonal experiences* of various traditions of East and West [6,11] – and according to our elaborated theoretical relationship *consciousness/acupuncture* EM-ionic quantum-holographic Hopfield-like associative neural network [1,9,23-25,28], *esoteric notions* like *astral body* (*manomaya*, *lingasarira*, *manovijnana*, *ka*, *psyche*, *subtle body*, *psychic body*, *soul*...) and *mental body* (*vijnanamaya*, *suksmasarira*, *manas*, *ba*, *thymos*, *noetic body*, *spiritual body*, *spirit*...) [6,11] might be biophysically related to *out-of-body displaced part* (connected with the body by miniature ‘wormhole’ space-time tunnel) of the *ionic acupuncture system*, and with embedded *EM component* of ionic MW/ULF-modulated currents, respectively.

generation of miniature ‘wormholes’ were not taken into account within quantum mechanics which is yet an extremely accurate theory (?) – might be answered that they were (!), but implicitly within the ad hoc von Neumann’s projection postulate [17] (cf. App. 6.6) to account for quantum mechanical ‘wave packet collapse’ in quantum measurement situations (implying also that von Neumann’s ad hoc ‘projection postulate’ is based on quantum gravitational phenomena, being on deeper physical level than nonrelativistic quantum mechanical ones). In this context, it is expected that only on the level of quantum gravitation the nature of ‘black holes’, ‘wormhole’ tunnels, and ‘cosmological singularities’ will be revealed, when on the Planck-Wiler’s scales of length $\sim 1,62 \cdot 10^{-35}$ m and time $\sim 0,54 \cdot 10^{-43}$ s the concept of space-time ceases to exist and remains only Wiler’s ‘quantum foam’, out of which not only space-time singularities but also tiny surrounding parts of space-time are made.

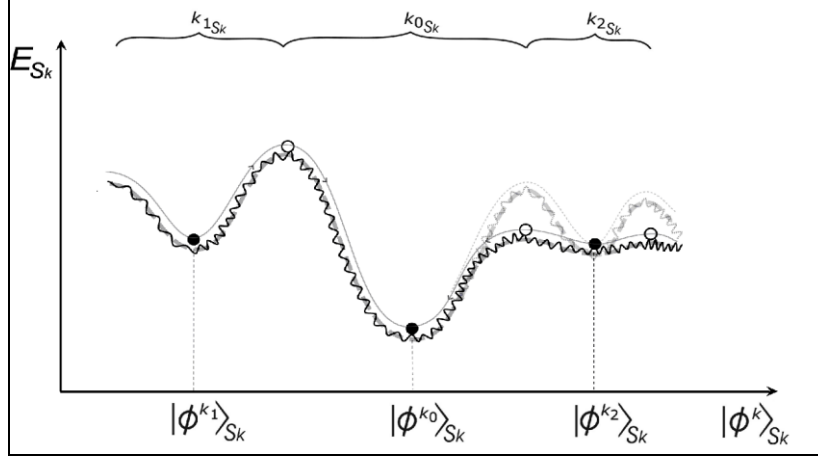


FIGURE 5.2 Schematic presentation of 'smearing' and associative integration of the memory attractor of psychosomatic disorder ϕ^{k_2} into normal ego-state ϕ^{k_0} , via simultaneous effects of visualization of the psychosomatic problems and tapping/touching of some acupuncture points, in meridian (psycho)therapies – which might be interpreted as successive imposing of new boundary conditions in the energy-state space of acupuncture system/consciousness $E_{S_k}(\phi^{k_i})$ – when memory attractor of the initial psychosomatic disorder ϕ^{k_2} (dashed line) becomes shallower and wider (full line), with greater overlap and followed associative integration into memory attractor of normal ego-state ϕ^{k_0} .

Then, *transpersonal interactions* [12,40-49] might be interpreted [1,7,9,23-25,28] by *collapse-like consciousness-channelled quantum-gravitational tunnelling of operator's individual consciousness* – mentally addressed on the target's content of collective consciousness in operator's (short-lasting) transitional states of consciousness – thus *intentionally channelling composite state of the 'field' of target-under-influence-of-operator part of collective consciousness* ($|\Phi\rangle_S \rightarrow |\Phi_j\rangle_S$) and *automatically influencing complementary 'particle' output* ($|\Psi\rangle_E \rightarrow |\Psi_j\rangle_E$) in *quantum-gravitationally-induced and consciousness-channelled collapse*

$$|\Phi\rangle_S |\Psi\rangle_E \rightarrow \sum_i c_i |\Phi_i\rangle_S |\Psi_i\rangle_E \rightarrow |\Phi_j\rangle_S |\Psi_j\rangle_E.$$

This could be also the model for unusual *anticipative properties of psyche* both in *quantum-holographic* short-lasting quantum-coherent *transitional states of consciousness* and quantum-gravitational-tunnelling of *mentally-channelled transpersonal-communications* of the out-of-body displaced EM/ionic part of acupuncture system/individual consciousness with subsequent *classically-reduced extrasensory-perception* of the mentally-addressed out-of-body complementary environment (that might be also Jung's '*archetype*' of the *problem-with-solution* on the level of *quantum-holographic collective consciousness*, which arises association on the Plato's '*world of ideas*' too!). After returning of the displaced consciousness upon the body, in order that transpersonally acquired information ascends to the level of *normally conscious state*, it is necessary to *overcome two filters* [1,24,28] (*acupuncture system/nervous system threshold filter*, which requires 'emotional colouring' of the solving problem, and *frontolimbic-amplification ERTAS filter*, which requires 'emotional-thinking priority' of the solving problem).²¹

²¹ It should be pointed out that (practically) non-threshold potential of the acupuncture electrical GJ-synapses [8] makes body's acupuncture system extremely sensitive quantum sensor [1], which can resonantly 'detect' even ultraweak EM fields [50] – with radiesthetic-diagnostic, noncontrolable-patogenic, or quantum-therapeutic psychosomatic effects [51]. Possible biophysical mechanisms of 'radiesthesia detection' of geopathogenic and technical EM fields might be categorized in local (through EM induction within EM/ionic circulatory acupuncture system, thus modulating non-threshold acupuncture currents by even extremely weak external EM fields) and non-local (through intentional mentally-controlled quantum-gravitational-tunnelling of the operator's individual consciousness on the 'target-of-radiesthesia-detection' part-of collective-consciousness in operator's transitional states of consciousness; in this context it is worth to mention the non-local 'radiesthesia detections' of so called 'abstract radiations' of natural geometric 'forms' and human 'artefacts' [51], that might be related to corresponding object-mediated operator's interactions with corresponding Jung's 'archetypes' at the level of collective consciousness – which also arises associations on Plato's '*world of ideas*' as all-pervading quantum-based creative source). Possible mechanisms of 'radiesthetic protection' of so-called 'radiation neutralizers' are also interesting, working seemingly – not by Faraday's screening of harmful EM fields – but by preventive quantum-

All mentioned conditions might be realized in *waking* quantum-coherent state of *meditation* (by entering in this prolonged altered state of consciousness, with mental addressing on the solved problem, which Tesla was doing by persistent mental focusing on the solving problem [28]), while during the *sleep state* they can be realized in quantum-coherent transitional states of *falling asleep* and quantum-coherent stationary states of *REM-sleep phases* (with previous intense concentration on the solving problem before sleep, and subsequent amplification of the obtained classically-reduced answer mostly in the form of symbolic dream, which should be then correctly interpreted in the context of personal internal symbolism [53]). Of course, for solving conceptually complex *scientific problems* it is necessary to be an *expert* in the corresponding field, in order to scientifically *rationalise* a solution that represents corresponding scientific shift. The same might be applied to *artistic creative experiences* and their subsequent *expressions* [36], while very *art-works* then behave like *mental addresses of 'archetypes'* being in contact with artists in transpersonal communications during the acts of creation (therefore *deep artistic experiences* of the public might have strong *spiritual note* too, through *spontaneous mental addressing* of the artistic audience on the *masterpiece* and *emotionally-induced excitation* into transitional state of consciousness; similarly this might be extended to *deep spiritual experiences* of the believers with their *mental addressing* on *holy icon/relic*).

From the above elaborated quantum-holographic idea [44,54] there appears that classically-reduced level of quantum system/consciousness $\hat{\rho}_S(t)$ or environment $\hat{\rho}_E(t)$, is permanently 'emerging' from and 'dissolving' into quantum-holographic level ($|\Phi(t)\rangle_S |\Psi(t)\rangle_E$), and this permanent 'pulsating' is going on extremely fast – with observing Bohm's *explicate order* of either average state of so called 'classical mixtures' (of quantum system/consciousness $\hat{\rho}_S(t)$ or environment

holistic harmonizing influence upon human acupuncture system exposed to harmful EM field [28] (like necklaces with 'homeopathic' pendants or 'mentally coded' crystal/non-crystal neutralizers, as suggested by pilot-study with Kirlian camera of the control and experimental groups exposed to EM fields of mobile phones with and without 'radiation neutralizers' [52]).

$\hat{\rho}_E(t)$) of quantum-holographic reality via classical measuring devices/senses, or classically-reduced so called ‘stationary quantum states’ (quantum system/consciousness $|\Phi_i\rangle_S$ and environment $|\Psi_i\rangle_E$) via macroscopic semi-quantum measuring devices – while non-stationary quantum/holographic reality of Bohm’s *implicate order*

$$|\Phi(t)\rangle_S |\Psi(t)\rangle_E \sim \prod_k |\phi^k(t)\rangle_{S_k} |\Psi(t)\rangle_E = \sum_i c_i |\Phi_i(t)\rangle_S |\Psi_i(t)\rangle_E$$

might be observed *exclusively* in ‘non-stationary quantum-coherent superpositions of states’, characteristic of quantum-holographic creative-religious altered and transitional states of consciousness (individual

$$|\phi^k(t)\rangle_{S_k} = \sum_i c_{k_i} |\phi^{k_i}(t)\rangle_{S_k} \quad \text{or collective} \quad |\Phi(t)\rangle_S = \sum_i c_i |\Phi_i(t)\rangle_S.$$

This viewpoint is close to experiences of many *shamanistic tribal traditions*, which consider that *genuine* (quantum-holographic!) reality is represented by *dreams* [45], while (classically-reduced!) awake state is lie/illusion (*maya*, as it is argued in *Eastern traditions* [5,6,30])!

In the same context, necessity of direct quantum-holographic coupling of individual and cosmic collective consciousness in observing *implicate order* needs weak out-of-body quantum-communication coupling consciousness-environment, i.e. previous *reprogramming of all psychosomatic loads* (cleansing of possessive or hedonistic *emotional-mental sin/karmic connections* with the world – which as loading ‘mental addresses’ would give rise to *quantum projections* of mentally/channelled tunnelled consciousness on the *out-of-body environment*, and thus to classically-reduced out-of-body *extrasensory observing* of the mentally-addressed environment!) – and so the efforts of *mystics of all traditions* to *clean consciousness/soul* through spiritual practice (*prayer, meditation, ...*) and thus to reach their final eschatological goal (*Kingdom of God, nirvana, ...*), i.e. *post-mortem salvation* (of the sin-free/karmic-free non-bounded soul) [6,11] appear reasonable!²²

²² It still leaves room for personal love, whose highest manifestation is ability and readiness for permanent and unconditioned forgiving to loving person (and because of him/her to everybody else, including enemies!), in spiritual prayer

It should be also pointed out that our investigations mentioned above are on the line of the again arisen scientific interest for investigation of the phenomenon of consciousness in the past decades [1,4-7,9-20,22-31,33-65] – with forecasting *great synthesis* of two cognitive modes, *rationaly-scientific* (classically-reduced, in normal states of consciousness) and *creative-religious* (quantum-coherent, in altered and transitional states of consciousness) in the framework of new *quantum-holographic holistic paradigm* – where *personal role* becomes indispensable due to the influence and care for collective mental environment, which is *fundamental question* of both mental health and civil decency, i.e. of both spiritual and civil morality [1,7,9,23-25,28]!

In this context, it might be said that *three front lines* of psychosomatic medicine do exist [1,24]: (a) the first one is *spirituality*, where prayer for others mentally/emotionally involved erases for good mutual memory attractors on the level of collective consciousness; (b) the second one is *traditional holistic Eastern medicine and deep psychotherapeutic techniques*, whose efforts temporary erase memory attractors on the level of acupuncture system/individual consciousness, and prevent or alleviate their somatization, as a consequence of the indolence on the first level;²³ (c) the third one is *modern symptomatic Western medicine*, whose activities through immunology, pharmacology,

and (subtly related quantum-holographic) living practice! The same refers to love for relatives and friends.

²³ It should be pointed out that healing/psychotherapeutic effects upon patient's acupuncture system/consciousness are frequently blocked by spiritual quantum-holographic coded personal acceptance of the illness as a kind of (self)punishment (as suggested by experiences of volunteers in 'post-hypnotic regressions' [44]). In this case prayers for health of others are necessary in order to realize necessity of stopping (self)punishment (or themselves to support it by their repenting prayer of the type '...My Lord, I accept myself, my personality, my body, my illness, my environment, my relatives, my friends, my enemies, my therapists and my therapies, and I thank You for the past support, and I pray You to spare us of further vast temptations...') – thus performing spiritual integration of personality, i.e. removing corresponding attractor's energy blockades within patient's acupuncture system/consciousness (cf. Fig. 5.2), which initiate the process of permanent healing [53].

biomedical diagnostics, and surgery, hinder or soothe somatic consequences of the carelessness on the first two levels. It should be stressed, that *necessary* activities on the second and third levels, with *neglect* of the first level, have a consequence of *further transfer* of memory attractors on the level of *individual and collective consciousness* in this and further generations, thus *accumulating* quantum-holographic loads which *afterwards* cause not only illnesses, but also interpersonal fights, wars, and other troubles.

5.2 Implications for Modelling Psychosomatic-Cognitive Functions

The biophysical quantum-holographic/quantum-relativistic model of consciousness, described in the previous section, might have significant influence on understanding many *psychosomatic-cognitive functions* [1,9,23-25], if further experimental tests confirm theoretical predictions of the model, i.e. its only hypothesis – on the nature of consciousness!

Individual consciousness, according to the model, is a subtle *acupuncture macroscopic quantum-holographic neural network* in the form of an *EM component* of MW/ULF-modulated ionic currents (embedded within *nonhomogeneous ionic structure*), in which over-threshold ULF information is continuously coded from brain's neural networks, while non-threshold extrasensory broad-band information is coded from quantum environment!

Collective consciousness, according to the model, is a subtle *cosmic macroscopic quantum-holographic neural network* related to the unified field of the Universe.

Free will, according to the model, is perceptually/rationally mediated strong intentional classical/quantum/classical backward hierarchical interaction nervous/acupuncture/nervous systems, which adequately modifies the *shape of many-electron energy-state hypersurface of the open acupuncture system/individual consciousness* – with *most space* for adaptation/free will through **prayer for others** with permanent transpersonal cleansing of conflict memory attractors' states of individual and collective consciousness.²⁴

²⁴ During EM/ionic interactions with environment the continuous but weak adaptation of the existing energy-state hypersurface of the acupuncture system/

Altered states of consciousness (REM sleep phase, hypnosis, meditation, hallucinogenic states, some psychopathological states, clinical death, ...), according to the model, are consequence of an *out-of-body displacement of the part of EM/ionic acupuncture system* (when $\varepsilon_r \approx 1$) – when *quantum-parallel information processing is biophysically extremely accelerated*, accompanied with *relativistic mixing of normally conscious and unconscious contents* as well as with *relativistic extremely dilated subjective 'time base'*.

Normal states of consciousness (normal waking state, non-REM sleep phase, ...), according to the model, are realised *without this out-of-body displacement* (when acupuncture ionic currents propagates exclusively through strongly body tissues, when $\varepsilon_r \gg 1$).

Transitional states of consciousness, according to the model, are accompanied by '*consciousness projections*', i.e. by *tunnelling of out-of-body displaced part of the acupunctural EM/ionic macroscopic quantum neural network* through Einstein-Rosen bridges (*space-time 'wormhole' tunnels*), which might interconnect extremely distant space-time events. Then consciousness (as in the previous passage) has a role of an *active quantum display*, with extrasensory information which is not a consequence of the activity of brain's neural network: the roles of these networks are interchanged.

Displaced ionic/EM acupuncture structure, according to the model, has a form of *weakly ionised gaseous EM MW/ULF-modulated*

consciousness is going on (cf. Fig. 3.3 in Ch. 3), so that quantum effects of decoherence leave little 'free will' for change of the shape hypersurface, which is dominantly determined by its 'prehistory'. However, during prayers for others (non-Schrödinger non-unitary quantum-gravitationally mediated via prayer-induced hypothetical macroscopic vacuum powerful and non-loaded spiritual excitations [24], variously rationalized in personalized pantheons of religious traditions of East and West [5,6,11,29,46,47]) the most 'free will' is achieved as the whole mutual conflict (corresponding memory attractor state) of two persons is thus permanently removed as a net-effect – while other non-reprogrammed interpersonal conflicts in other related persons cause their (unconscious mentally-addressed) transpersonal re-inducement within the two prayer-included persons. Whether circular processing in meridian (psycho-energetic) therapies can have permanent effects in removing mutual conflict [25], depends on whether this removes the whole associative chain of the conflict or only particular aspects of them.

macroscopic quantum neural network, which plays a role of *quantum sensor in altered states of consciousness*, with perception of the environment in *broad frequency band*. It is clear that this quantum **perception** is *extrasensory*.

Dreams and similar hallucinogenic states, according to the model, are characteristics of out-of-body *altered states of consciousness*, with the role of *integration of normally conscious and unconscious levels of personality* around one associative 'ego-state', which gives rise to *personality growth* and to *alleviation of emotional conflicts*. **Meditation**, as a *prolonged* altered state of consciousness, enables *more efficient personality growth*.

Creativity, according to the model, is a consequence of intense concentration on some problem before *transitional states of consciousness*, when '*individual consciousness projections*' on (associatively related) *answer to the problem within quantum-holographic memory/propagator of collective consciousness* is going on, with amplification of the answer after return into normal awake state. One way of control of creative processes is *visualization of the problem* in the awake *meditative* altered state of consciousness, while simpler way is in using *transitional period waking-sleep*, with subsequent decoding of the symbolic dream.

Memorising, according to the model, within the brain is both *ultralow-frequency* (lower-frequency δ, θ -unconscious i higher-frequency α, β, γ -conscious), and not only through Hebb's spatial distribution of electrical potentials in the brain. Besides, there exists *psychosomatic spatial memorising* in the form of *quantum-holographic attractors of acupuncture network* (as a basis of holistic psychosomatic disorders), in addition to EM ULF interactions with hierarchical neural brain's ERTAS networks.

Learning, according to the model, is going also in *nonlinear quantum-holographic acupuncture networks* (through generalization), with *distribution* of generalized information via *EM interactions* of acupuncture network with hierarchical neural brain's ERTAS networks. Besides, *nonlocal distribution* (locally learned) information in hierarchical neural brain's ERTAS networks is going on via *ULF brainwaves* (before habituation).

Thinking, according to the model, is also related to altered states of consciousness (with *intense associative mixing* of normally *conscious and unconscious memorising contents* related to the problem, which can contribute to its faster resolving) and transitional states of consciousness

(with anticipative *creative insights* into the levels of collective consciousness), with especially important *making conscious* processed or received thoughts through their 'frequency ascending' (under the influence of ERTAS-amplification) of lower-frequency δ, θ -unconscious form of subliminal thought toward higher-frequency α, β, γ -conscious form of thought – which might provide fundamental information about *relation of consciousness and thinking*.

Language, according to the model, is memorised on lower-frequency δ, θ -unconscious level in case of *mother tongue learning and second language contextual learning*, i.e. on higher-frequency α, β, γ -conscious level in case of *second language school-grammatical learning*. Besides, quantum-holographic fractal coupling of various hierarchical levels within the organism, implies the *unique quantum-holographic code* of the gene, acupuncture system, consciousness, and language.

Emotions, according to the model, are *related to deeper quantum-holographic attractors of acupuncture system*, together with EM interactions with hierarchical neural brain's ERTAS networks. This has *numerous quantum-holistic implications: acupuncture* (related to MW and ULF resonant stimulations) and *psychotherapeutic* (related to dreaming and meditation, autogenic training, deep psychotherapeutic techniques, meridian (psychoenergetic) therapies, and transpersonal Christian-religious prayer techniques).

Transpersonal interactions of the organism and its environment (long-range and short-range) are *significant implications of the model*. One of the most unusual is the *state of 'empty' individual consciousness*, when direct *quantum-holographic coupling* with *cosmic collective consciousness* is achieved. On the other hand, 'consciousness projections' in transitional states are presumably basis of various mentally-channelled *mystical experiences*.²⁵

²⁵ It should be pointed out that apart from the EM field (embedded into displacing part of ionic acupuncture system), subjected to strong inertial accelerations in transitional states of consciousness, through locally created 'wormhole' must also tunnel displaced ionic structure [1,9] (in the form of EM/ionic quantum-holographic neural network, having the sensory function in long-range interactions of this type, transcending space-time barriers). In esoteric literature these interactions are known as 'astral projections' of consciousness, which might be the basis of spiritual healings [44,48] (upon mental addressing



It is evident that *biocybernetic models of brain's hierarchical neural networks* presented in Ch. 4, demonstrate encouraging advances in modelling *cognitive functions*, through information processing via hierarchically organized and interconnected brain's neural networks. However, for modelling most *psychosomatic and cognitive functions* the subtle biophysical *quantum-holographic Hopfield-like body's acupuncture neural networks* are necessary as well, combined with quantum decoherence theory, as presented in Ch. 5. This implies a necessity of *combined using* of hierarchical brain's neural networks and body's acupuncture neural networks, in modelling cognitive and psychosomatic processes!

on ionically powerful spiritual structures, when ionic-informational transfer on displaced ionic structure of the patient in its transitional states of consciousness is realized), as well as of some 'paranormal phenomena' [40,44] (clairvoyance, precognition, retrognition...). This provides also explanation for transitional nature and difficult reproducibility of these phenomena in laboratory: the conditions for them are spontaneously realized shortly every 1,5-2 hours, with periodicity of ultradian rhythms which govern interchange of normal and altered states of consciousness. It should be noted that the same mechanism, which can achieve space-time tunnelling of displaced acupuncture ionic neural structure in transitional states of consciousness by virtue of relatively weak EM fields $\sim 10^2$ V/cm, reveals also theoretical possibility for tunnelling more massive objects by using stronger EM fields, although many practical problems ought to be resolved in this direction. It should be additionally noted that some theoreticians of gravitation have pointed out potential possibility of practically instantaneous space-time trips by using 'wormholes', provided they are stabilized by so called 'exotic matter', which pushes the wormhole's walls apart (anti)gravitationally [39] (which otherwise have tendency to close very quickly, so that for a 'black hole' of the Sun's mass it takes less than 10^{-4} s, which does not permit even light beam to pass across the tunnel) – which might reveal the basis for explanation of 'psychokinetic psychic powers' in transitional and altered states of consciousness [40,44]. This 'exotic matter' must have negative average energy density, as seen by a light beam travelling through it. Almost all kinds of matter have positive average energy density, measured in any reference frame, but it is discovered that vacuum fluctuations near a black-hole's horizon are exotic. Similarly, strongly curved space-time of the 'wormhole' tunnels makes vacuum fluctuations exotic, thus stabilizing the tunnel.

5.3 References

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6. APPENDICES

6.1 Wave Functions of Systems of Identical Bosons and Fermions. Pauli's Exclusion Principle

Wave function of the system of N identical particles can be either symmetrical or antisymmetrical function in respect to the mutual exchange (permutation) of two particles. Symmetric wave functions describe the bosons (particles with integer spin), while antisymmetric wave functions describe fermions (particles with half-integer spin). Pauli's exclusion principle is a consequence of antisymmetric wave functions of the fermion system of identical particles [1].

To show this, consider a system of N identical particles, described by wave function

$$\Psi(\xi_1, \xi_2, \dots, \xi_i, \dots, \xi_k, \dots, \xi_N, t), \quad (6.1)$$

where the ξ_i represents the totality of coordinates and spin variables, which characterize the i^{th} particle.

After permutation of two indistinguishable particles ($\xi_i \leftrightarrow \xi_k$), particle state of the system is not changed, i.e. the result of measurement described by square module of the wave functions, $|\Psi|^2 = \Psi^* \Psi$. Since the square module does not change, wave function in Eq. (6.1) after permutation of two particles can be changed only by the phase factor $\exp(i\alpha)$ (whose module is equal to 1):

$$\Psi(\xi_1, \xi_2, \dots, \xi_i, \dots, \xi_k, \dots, \xi_N, t) = e^{i\alpha} \Psi(\xi_1, \xi_2, \dots, \xi_k, \dots, \xi_i, \dots, \xi_N, t) \quad (6.2)$$

After repeated permutation of the same two particles, then according to Eq. (6.2) there finally appears the phase factor $\exp(i2\alpha)$, which must be equal to 1 – as after double mutual permutations of the wave function Ψ returns to the initial state of Eq. (6.1). This means that $\exp(i2\alpha) = 1$, i.e.

$$e^{i\alpha} = \pm 1. \quad (6.3)$$

In this way, from Eqs. (6.2) and (6.3) it follows that after the permutation of two identical particles, the wave function of the system

of identical particles either does not change the sign (even function) or changes sign (odd function)!

In the case of N *non-interacting* identical particles, stationary wave function is the product of stationary single-particle wave functions, which in the general case is neither symmetrical nor antisymmetrical upon permutation of two particles. This is best seen on the example of two-particle system, when out of the two non-symmetrized stationary two-particle functions

$$\psi_{k_1}(\xi_1)\psi_{k_2}(\xi_2), \psi_{k_1}(\xi_2)\psi_{k_2}(\xi_1),$$

that correspond to the same total energy of the system ($E = E_{k_1} + E_{k_2}$), it is possible to form two symmetrized combinations of the same energy:

$$\psi_s = \frac{1}{\sqrt{2}} [\psi_{k_1}(\xi_1)\psi_{k_2}(\xi_2) + \psi_{k_1}(\xi_2)\psi_{k_2}(\xi_1)],$$

(6.4)

$$\psi_a = \frac{1}{\sqrt{2}} [\psi_{k_1}(\xi_1)\psi_{k_2}(\xi_2) - \psi_{k_1}(\xi_2)\psi_{k_2}(\xi_1)], \quad (6.5)$$

the first of which is symmetrical, and the second is antisymmetrical upon permutation of the particles (multiplier $1/\sqrt{2}$ provides normalization of the symmetrized wave functions on the 1, if one considers orthonormalized single-particle wave functions ψ_{k_1} and ψ_{k_2}). Eqs. (6.4-5) can be generalized for a system of N identical non-interacting particles, in the form

$$\psi_s = \sqrt{\frac{n_1!n_2!\cdots n_N!}{N!}} \sum_p \psi_{k_1}(\xi_1)\psi_{k_2}(\xi_2)\cdots\psi_{k_N}(\xi_N), \quad (6.6)$$

$$\psi_a = \frac{1}{\sqrt{N!}} \begin{vmatrix} \psi_{k_1}(\xi_1) & \psi_{k_1}(\xi_2) & \cdots & \psi_{k_1}(\xi_N) \\ \psi_{k_2}(\xi_1) & \psi_{k_2}(\xi_2) & \cdots & \psi_{k_2}(\xi_N) \\ \vdots & \vdots & \ddots & \vdots \\ \psi_{k_N}(\xi_1) & \psi_{k_N}(\xi_2) & \cdots & \psi_{k_N}(\xi_N) \end{vmatrix}, \quad (6.7)$$

In the case of *symmetrical wave function*, Eq. (6.6), summation is going over all permutations with repetition of indices k_1, k_2, \dots, k_N , where n_i indicates the number of these indices that have the same value (the same single-particle quantum state), i.e. how many particles occupy the state ψ_{k_i} , with fulfilled $\sum_i n_i = N$. The number of additives in Eq. (6.6), $N!/n_1!n_2!\cdots n_N!$, represents the number of permutations with repetition, determining the orthonormalizing multiplier, bearing in mind orthonormalized single-particle wave functions ψ_{k_i} . It is obvious that symmetrical wave function, Eq. (6.6), allows the existence of *more particles* in the same i^{th} single-particle quantum state, which corresponds to *bosons* that are subject to *Bose-Einstein statistics* due to such possible form of occupation of the single-particle states.

In the case of *antisymmetrical wave function*, Eq. (6.7), the one single-particle state can be occupied by only one particle (if $k_1 = k_2$, then the two rows of the determinant are equal, and the determinant vanishes). Then $n_1 = n_2 = \cdots = n_N = 1$, and the more general normalizing factor in Eq. (6.6) reduces to $1/\sqrt{N!}$ in Eq. (6.7). The fact that antisymmetric wave function, Eq. (6.7), allows *only one particle* in one single-particle state – represents the *Pauli (1925) exclusion principle*, which corresponds to *fermions* that are subject to *Fermi-Dirac statistics* due to such possible form of occupation of the single-particle states.

So, a system on N identical non-interacting bosons is described by symmetrical wave function, Eq. (6.6), while a system of N identical non-interacting fermions is described by antisymmetrical wave function, Eq. (6.7). Pauli (1940) demonstrated within the framework of Quantum Field Theory (requesting invariance of the relativistic field equations) that there is a connection between spin and statistics. Particles with *integer spin* (0, 1, 2, ...) are subject to *Bose-Einstein statistics*, while particles with *half-integer spin* (1/2, 3/2, 5/2, ...) are subject to *Fermi-*

Dirac statistics! Hence, *electrons* (of spin 1/2) are fermions and are subject to Pauli's exclusion principle, which is very important for explaining the electronic structure of atoms (i.e. of the Mendeleev (1869) Periodic system of elements), molecules and solid states! On the other hand, *photons* (quanta of electromagnetic field), *phonons* (quanta of crystal lattice vibrations) and *Cooper's two-electron superconducting pairs* – are examples of bosons!

6.2 Quantum Chemistry and Spectroscopy of Molecules. Adiabatic, Harmonic and Dipole Approximations

In the system of coordinates in which the molecule as a whole moves neither translatory nor rotationally, the electronic-vibrational Schrödinger equation has the form:

$$(\hat{T}_e(r) + \hat{T}_i(q) + V_{ei}(r, q) + V_{ee}(r) + V_{ii}(q))\psi_{ev}(r, q) = E_{ev}\psi_{ev}(r, q) \quad (6.8)$$

with includes operators of kinetic energy of the subsystems of electrons and ions/nuclei (\hat{T}_e i \hat{T}_i) and all Coulomb interactions of electrons and ions (electrons-ions (V_{ei}), electrons-electrons (V_{ee}), and ions-ions (V_{ii})). This is the Schrödinger equation in Coulomb approximation (while complex types of interactions like spin-orbit ones are neglected as the effects of higher order), which is a standard approach in Quantum Chemistry and Molecular Spectroscopy [1,2].

The Schrödinger equation, Eq. (6.8), *cannot be solved exactly*, and it is necessary to apply a series of approximations. The most widely used is the Born-Openheimer *adiabatic approximation*, based on the assumption that atomic nuclei in a molecule are fixed ($\hat{T}_i \ll \hat{T}_e$) as $m_i^{-1} \ll m_e^{-1}$. In this case, the problem is reduced to *the movement of electrons* in the field of many *non-moving ions* (term $V_{ii}(q)$ may be accounted as *additive term* to the energy of purely electronic movements), and the wave function ψ_{ev} may be represented in the factorized form (due to decoupling of electronic and ionic degrees of freedom)

$$\psi_{ev}(r, q) = \psi_e(r, q)\psi_v(q) \quad (6.9)$$

and Eq. (6.8) reduces to the form of the *electronic Schrödinger equation*

$$(\widehat{T}_e(r) + V_{ei}(r, q) + V_{ee}(r) + V_{ii}(q))\psi_e(r, q) = E_e\psi_e(r, q). \quad (6.10)$$

The electronic Schrödinger equation, Eq. (6.10), is also solved only by *approximative methods*, usually of the variational type: the extreme values of total electronic energy of molecules $\langle \psi_e | H_e | \psi_e \rangle$ are determined with *various simplifications* of the electronic Hamiltonian H_e (usually in matrix, Heisenberg representation), with presentation of electronic wave function ψ_e in the form of Slater's determinants (or their linear combinations) with molecular orbits, which are sought in the form of linear combinations of atomic orbits (LCAO). Beside these *quantum-chemical* approximations (CNDO, MINDAO, PPP, HFR, CI ...), the approximative methods from the *Solid State Physics* are also used [3].

By solving Eq. (6.10) in one way or another, the values of electronic energy levels $E_{en}(q)$ are obtained, which depend on the mutual fixed distribution of the nuclei (Q). By deforming molecule in a wide interval of changes of relative positions of nuclei, the values $E_{en}(q)$ ($n = 1, 2, 3, \dots$) will describe smooth hypersurface (actually q (or ξ) denotes the set of varied relative positions of all N atoms in the appropriate interatomic configurations $\{l_{12}, l_{13}, \dots, l_{N-1}, l_N\}$, called *coordinate of chemical reaction*). Cross-section $E_e(q)$ along some l_{ij} direction gives the *potential curve* (dashed line in Fig. 3.4 of Ch. 3, presented also in the kinetics of enzyme reactions as a potential curve of free energy versus coordinate of chemical reaction, cf. Fig. 3.1). If potential hypersurface has more minima, they correspond to different stable *isomers of* (macro)molecules!

Let's determine further the equation that must meet vibrational part $\psi_v(q)$ of the wave function, Eq. (6.9), starting from the mean value of the initial electronic-vibrational Hamiltonian in the electronic-vibrational state:

$$\bar{H}_{ev} = \langle \psi_e \psi_v | \widehat{T}_v + H_e | \psi_e \psi_v \rangle = E_{ev}, \quad (6.11)$$

where a replacement for the symbol of kinetic energy of nuclei is introduced, $\widehat{T}_i \equiv \widehat{T}_v$. An integration in Eq. (6.11) over electronic coordinates, with taking into account an orthonormalization of the wave functions and the *weak* dependence of the wave function $\psi_e(r, q)$ on q (which

is true in the absence of degeneration of electronic level E_e) so that an action of \widehat{T}_v upon $\psi_e(r, q)$ can be neglected, gives

$$\int \psi_v^*(q) [\widehat{T}_v(q) + E_e(q)] \psi_v(q) dq = E_e(0) + E_v. \quad (6.12)$$

By adopting $E_e(q) = E_e(0) + \Delta E_e(q)$ (where the origin of q -axis is put at the position of the minimum of potential hypersurface) one obtains

$$\int \psi_v^*(q) [\widehat{T}_v(q) + \Delta E_e(q)] \psi_v(q) dq = E_v,$$

wherefrom we conclude that the *vibrational Schrödinger equation*, in *adiabatic approximation*, has the form

$$\{\widehat{T}_v(q) + \Delta E(q)\} \psi_v(q) = E_v \psi_v(q), \quad (6.13)$$

in which *the role of potential energy* is played by $\Delta E_e(q)$, as the energy difference of the 'bottom of well' and its value for a given deformation q in respect to equilibrium ($q = 0$) position. If potential hypersurface of the molecule has the deep minimum, the movement of nuclei will have 'finite' character, which in accordance with the general laws of quantum mechanics imposes a discrete set of solutions E_v . Since $m_i^{-1} \ll m_e^{-1}$, then $E_v \ll E_e$, which leads to the usual distribution of the electronic and vibrational energy levels in a many-electron molecule ($\Delta E_v \sim 10^{-3} \cdot \Delta E_e$). Obviously, the vibrational problem must be solved separately for each electronic state $\Delta E_{en}(q)$, as their potential hypersurfaces ($n = 1, 2, 3 \dots$) can differ significantly.

If the potential hypersurface $\Delta E_e(q) \equiv V(q)$ is developed around its minimum ($V(0) = 0$) and only the second order term is retained (as the first-order term is $[\partial V(q)/\partial q]_{q=0} = -F = 0$ in the vicinity of the minimum), this is known as the *harmonic approximation*, in which vibrational Hamiltonian in matrix form

$$\widehat{H}_v = \frac{1}{2} \sum_{\alpha, \beta} (\tau_{\alpha\beta} p_\alpha p_\beta + u_{\alpha\beta} q_\alpha q_\beta) = \frac{1}{2} \{ \|\tilde{p}\| T_p \|p\| + \|\tilde{q}\| U_q \|q\| \} \quad (6.14)$$

has the form of the sum of two square forms, which can be simultaneously diagonalized due to positive definiteness of the real symmetric matrices T_p i U_q (by transition from the generalized

coordinates $\|q\|$ to so called *normal coordinates* $\|Q\|: \|q\| = L_q \|Q\|$), so that \hat{H}_v takes the form of the sum of one-dimensional Hamiltonians ($3N-6$, in total, as the number of internal degrees of freedom)

$$\hat{H}_v = \frac{1}{2} \sum_{\alpha} (\hat{P}_{\alpha}^2 + \lambda_{\alpha} Q_{\alpha}^2) = \sum_{\alpha} \left(-\frac{\hbar^2}{2} \frac{\partial^2}{\partial Q_{\alpha}^2} + \frac{1}{2} \lambda_{\alpha} Q_{\alpha}^2 \right) = \sum_{\alpha} \hat{h}_{\alpha} \quad (6.15)$$

which correspond to the Hamiltonian of *harmonic oscillator* of the unit mass, with solutions in the form

$$E_{v_{\alpha}} = \hbar \sqrt{\lambda_{\alpha}} \left(v_{\alpha} + \frac{1}{2} \right) = \hbar \omega_{\alpha} \left(v_{\alpha} + \frac{1}{2} \right) \quad (6.16)$$

$$\psi_{v_{\alpha}} = N_{v_{\alpha}} e^{-a^2 \omega_{\alpha} Q_{\alpha}^2} H_{v_{\alpha}} \left(a \omega_{\alpha}^{1/2} Q_{\alpha} \right)$$

(where H_v are Hermite polynomials, v_{α} is the vibrational quantum number, ω_{α} is the frequency of the harmonic oscillator in the α^{th} normal mode, $N_{v_{\alpha}}$ is the normalizing multiplier), so that overall solution of the vibrational problem of the molecule has the form

$$E_v = \sum_{\alpha} E_{v_{\alpha}} = \sum_{\alpha} \hbar \omega_{\alpha} \left(v_{\alpha} + \frac{1}{2} \right) \quad (6.17)$$

$$\psi_v = \prod_{\alpha} N_{v_{\alpha}} e^{-a^2 \omega_{\alpha} Q_{\alpha}^2} H_{v_{\alpha}} \left(a \omega_{\alpha}^{1/2} Q_{\alpha} \right)$$

Upon infrared irradiation of the molecule, an absorption of the radiation quanta may be achieved, accompanied by different transitions between the vibrational levels of the molecule. Transitions accompanied by change in one quantum number ($\Delta v_{\alpha} = 1$) are called *fundamental* transitions, when one quantum of light of the energy $\hbar \omega_{\alpha}$ is absorbed or emitted. There are possible (but much less probable) transitions in two quantum numbers ($\Delta v_{\alpha} = 2$ – so called *overtone*s) and transitions of

two quantum numbers in single quant each ($\Delta \nu_\alpha = 1$ and $\Delta \nu_\beta = 1$ – so called *combination* transitions).

In diagonalization of the vibrational Hamiltonian, Eq. (6.14), the transitional matrix L_q from the generalized to the normal vibrational coordinates is obtained, whose *column vectors* $\|\ell_q\|$ satisfy equation:

$$(T_p U_q - \lambda_\alpha I) \|\ell_q\|^{(\alpha)} = 0 \quad (6.18)$$

i.e. they represent *eigen vectors* (and $\lambda_\alpha = \omega_\alpha^2$ *eigenvalues*) of the *dynamic matrix* $D = T_p U_q$; the eigenvectors define so called *forms of normal vibrations*.

In *dipole approximation*, the *probability of absorption*, and hence the *intensity of absorption bands* (J), is determined by the *number of incoming photons* (i.e. by intensity of incoming light beam), by the *number of molecules in the ground state* (m), and by *Einstein's coefficient* (B_{mm}), which in the case of optical transitions (when photon energy is small) is proportional to the *square of matrix element of dipole moment* for the transition from initial (m) to final state (n) of the molecule:

$$J_{ev}^{i,f} \sim (\bar{\mu}_{ev}^{i,f})^2 = \left(\iint \Psi_{ev}^{f*} \bar{\mu}_{ev} \Psi_{ev}^i dr dq \right)^2 \quad (6.19)$$

where $\Psi_{ev}^{(i)} = \Psi_e^{(i)}(r, Q) \Psi_v^{(i)}(Q)$ and $\Psi_{ev}^{(f)} = \Psi_e^{(f)}(r, Q) \Psi_v^{(f)}(Q)$ are electronic-vibrational wave functions of the molecule in initial and final states, and *operator of dipole moment*

$$\bar{\mu}_{ev} = \sum_{\ell=1}^N Z_\ell \bar{R}_\ell - \sum_{j=1}^N \bar{r}_j = \bar{\mu}_v + \bar{\mu}_e \quad (6.20)$$

contains contributions of all nuclei and all electrons in the molecule.

Matrix element of dipole transition can be rewritten in the form

$$\bar{\mu}_{ev}^{i,f} = \iint \psi_e^{f*} \psi_v^{f*} (\bar{\mu}_e + \bar{\mu}_v) \psi_e^i \psi_v^i dr dq = \bar{\mu}_e^{i,f} S_v^{i,f} + \bar{\mu}_v^{i,f} S_e^{i,f} \quad (6.21)$$

where corresponding *overlap integrals* of electronic and vibrational components are:

$$S_e^{i,f} = \int \psi_e^{f*} \psi_e^i dr,$$

(6.22)

$$S_v^{i,f} = \int \psi_v^{f*} \psi_v^i dq.$$

Dipole approximation may be applied to the *theory of isomer transitions (from one isomer form to another i.e. from one to another minimum on the energy hypersurface of the ground electronic state):* $\Psi_e^i(q_1)\Psi_{v_1}^i \rightarrow \Psi_e^f(q_2)\Psi_{v_2}^f$, so from Eqs. (6.21) and (6.22) it is obvious that such isomer transitions are possible if *overlap integrals and dipole moments of electronic and vibrational transitions* for these two isomer forms do not vanish, and take place *resonantly between vibrational levels of the excited states* with fulfilled condition (cf. Fig. 3.4 of Ch. 3):

$$E_{e_0}^i(q_i) + E_{v_1}^i = E_{e_0}^f(q_f) + E_{v_2}^f$$

6.3 Second Quantization. Feynman's Propagator Form of Quantum Mechanics

Green function (propagator) is introduced in non-relativistic approximation by considering the process of scattering via the Hygens principle, according to which the amplitude of incoming wave in the point r' and at the moment t' ($\psi(r', t')$) is proportional to the initial amplitude ($\psi(r, t)$) considering that at the moment $t < t'$ each point r was a source of spherical wave:

$$\psi(r', t') = i \int_V \bar{G}(r', t'; r, t) \psi(r, t) dr; \quad (t' > t) \quad (6.23)$$

where the finding of Green function/propagator $\bar{G}(r', t'; r, t) = -ih(t'-t) \sum_i \psi_i(r', t') \psi_i^*(r, t)$ is equivalent to the complete solution of the Schrödinger equation (with set of basis functions $\{\psi_i(r, t)\}$) in Feynman's representation in the Quantum Theory of Many-Particles Systems [1,4].

Physical world consists of many interacting many-particles systems. In principle, N -particle wave function in the configuration space contains all the necessary information, but the direct solution of N -particle

Schrödinger equation is practically impossible, so various approximations are necessary (of which the quantum-chemical ones are mentioned in App. 6.2). One of the approaches of the *Solid State Physics* is the *Quantum Theory of Many-particles Systems*, based on the techniques of *Second quantization*, *Quantum Field Theory* and the use of *Green functions* (i.e. *propagators*). In *relativistic theory*, the concept of second quantization is critically important for the description of the *creation and annihilation of particles*, but even in *non-relativistic theory* method of the second quantization *significantly simplifies* consideration of many *interacting identical particles*! This approach *only reformulates* the starting *Schrödinger equation*, but it also brings *significant advantages*: (a) *The operators of the second quantization incorporate statistics* (of *bosons* or *fermions*) via appropriate (*commutation* or *anticommutation*) relations between the *creation and annihilation operators*; (b) *Methods of the quantum theory of many-particles systems allow concentration on a few matrix elements* of direct interest for chosen *physical approximation*; (c) *Green functions/propagators contain main physical information* (energy and other *thermodynamic functions* of the ground and excited states, *life time* of the excited states, and *linear response on external perturbations*).

In the *second quantization* wave functions $\Psi(\xi_1, \xi_2, \dots, \xi_N, t)$ of the system of N identical particles (cf. Eqs. (6.1) and (6.6-7) for bosons and fermions), where ξ_i denotes the totality of coordinates and spins variables that characterize the i^{th} particle, are replaced by the abstract time-dependent *state vectors* $|\Psi(t)\rangle$ in the *occupational basis* $|n_1 n_2 \dots n_k \dots n_\infty\rangle$, independent of the coordinates of particles, whose notation indicates that n_i particles occupy single-particle state k_i ($i = 1, 2, \dots, k, \dots \infty$),
$$|\Psi(t)\rangle = \sum_{\{n_i\}} f(n_1 n_2 \dots n_k \dots n_\infty, t) |n_1 n_2 \dots n_k \dots n_\infty\rangle,$$
 and time-independent creation and annihilation operators (\hat{a}_k, \hat{a}_k^+) are also defined, that satisfy the (*boson*) *commutation relations*

$([\hat{a}_k, \hat{a}_k^+] = \delta_{kk}, [\hat{a}_k, \hat{a}_k] = [\hat{a}_k^+, \hat{a}_k^+] = 0)$ and (fermion) anticommutation relations $(\{\hat{a}_k, \hat{a}_k^+\} = \delta_{kk}, \{\hat{a}_k, \hat{a}_k\} = \{\hat{a}_k^+, \hat{a}_k^+\} = 0)$, with characteristics:

$$\begin{aligned}\hat{a}_k |...n_k... \rangle &= (-1)^{s_k} \sqrt{n_k} |...n_k - 1... \rangle \\ \hat{a}_k^+ |...n_k... \rangle &= (-1)^{s_k} \sqrt{n_k + 1} |...n_k + 1... \rangle \\ \hat{a}_k^+ \hat{a}_k |...n_k... \rangle &= n_k |...n_k... \rangle\end{aligned}\quad (6.24)$$

[and conditions $n_k = 0, 1, 2, \dots \infty$; $S_k = 0$ (bosons) and $n_k = 0, 1$; $S_k = n_1 + n_2 + \dots n_{k-1}$ (fermions)], and satisfy the Schrödinger equation:

$$i\hbar \frac{\partial}{\partial t} |\Psi(t)\rangle = \hat{H} |\Psi(t)\rangle, \quad (6.25)$$

with Hamiltonian

$$\hat{H} = \sum_{i,j} \hat{a}_i^+ \langle i|\hat{T}|j\rangle \hat{a}_j + \frac{1}{2} \sum_{i,j,k,l} \hat{a}_i^+ \hat{a}_j^+ \langle ij|V|kl\rangle \hat{a}_l \hat{a}_k, \quad (6.26)$$

where $\langle i|\hat{T}|j\rangle$ and $\langle ij|V|kl\rangle$ are matrix elements of the kinetic and potential energies between single-particle states (of the standard) *first quantization* (in *Dirac's notation* of so called 'bra' $\langle i|$ and 'ket' $|j\rangle$ state vectors, which correspond to the standard complex-conjugate wave functions ψ_i^* and wave functions ψ_j , where in matrix elements an integration over corresponding coordinates of the wave functions and operators is assumed!).

6.4 Quantum Bases of RRM-Model of Resonant Recognition

The Resonant Recognition Model (RRM) is based on representation of the protein primary structure as a discrete signal, by assigning to each amino acid the electron excitation energy E_m [5], which is calculated as an electron-ion interaction pseudopotential (EEIP values). After that, these numerical series are converted into Fourier spectrum by using discrete Fourier transform (DFT). The coefficients in the discrete Fourier transform are defined as:

$$E(n) = \sum_m E_m e^{-i \frac{2\pi mn}{N}}, \quad (6.27)$$

where N is the number of amino acids in a given sequence and n is the n^{th} member of the original numerical series. In practice, the energy density spectrum is defined as:

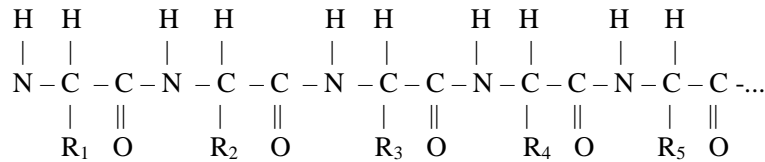
$$S(n) = E(n)E^*(n); \quad n = 1, 2, \dots, \frac{N}{2} \quad (6.28)$$

which is very convenient for analysis of information contained in macromolecules and which is called information spectrum. The above result can be generalized in case when there exists a number of proteins with same or similar biological function:

$$M(n) = \prod_{i=1}^m S_i(n); \quad n = 1, 2, \dots, \frac{N}{2} \quad (6.29)$$

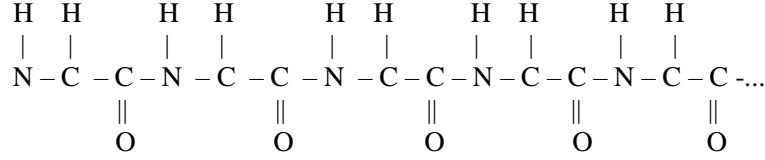
where in the energy density spectrum appears peak which describes the same or similar biological function of these macromolecules. In that sense, group of HIV viruses [6] envelope proteins which have the same peak at the frequency $f = 0.1855 \pm 0.001$ and which interact with CD4 cell surface antigen, represents an interesting example. By using the RRM model several types of macromolecules have been designed to block this type of interaction and inhibit infection, with the same characteristic peaks, and phase differences between antigen and target $\approx \pi$ rad.

Protein amino acids sequences determine their structure and biological function. Thus investigation of this sequence is very important for understanding biomolecular recognition. In that sense, a Hückel-like theory [7] of molecular orbits could be relevant and simplified theoretical framework. The primary structure of proteins has the following shape:



where the terms $\text{R}_1, \text{R}_2, \dots, \text{R}_N$ identify residues of amino acids which carry relevant information about the biological function of a protein,

and C, N, H, O signify atoms of carbon, nitrogen, hydrogen and oxygen, respectively. Within further procedure, we shall consider backbone of a protein without external (residual) attachments:



The problem can be simplified if we consider the structure motif $-NH-CH-CO=$ as an elementary cell, described by wave function φ_m (as a molecular orbit (MO) in the form of a linear combination of atomic orbits (LCAO) centred on m^{th} elementary cell). In this case wave the function of molecular chain is:

$$\psi = \sum_m c_m \varphi_m; \quad (m = 1, 2, \dots, N). \quad (6.30)$$

By insertion into the Schrödinger equation $H\psi = E\psi$, we obtain:

$$\begin{aligned}
 \sum_m c_m \int \varphi_n^* H \varphi_m dV &= E \sum_m c_m \int \varphi_n^* \varphi_m dV; \quad (n = 1, 2, \dots, N) \\
 \int \varphi_n^* \varphi_m dV &= \delta_{nm}.
 \end{aligned} \quad (6.31)$$

The above expression can be presented in matrix form:

$$\begin{bmatrix}
 H_{11} - ES_{11} & H_{12} - ES_{12} & \dots & H_{1N} - ES_{1N} \\
 H_{21} - ES_{21} & H_{22} - ES_{22} & \dots & H_{2N} - ES_{2N} \\
 \vdots & \vdots & \ddots & \vdots \\
 H_{N1} - ES_{N1} & H_{N2} - ES_{N2} & \dots & H_{NN} - ES_{NN}
 \end{bmatrix}
 \begin{bmatrix}
 c_1 \\
 c_2 \\
 \vdots \\
 c_N
 \end{bmatrix} = 0 \quad (6.32)$$

Further on, by employing approximation of the nearest neighbours $H_{mn} = \int \varphi_n^* H \varphi_m dV \neq 0$, ($m = n \pm 1$), cyclic boundary conditions, and condition of weak overlap of wave functions of the nearest neighbours:

$$S_{nm} = \int \varphi_n^* \varphi_m dV = \begin{cases} 1; & n = m; \\ 0; & n \neq m \end{cases} \quad (6.33)$$

similarly to Hückel's theory we arrive to the following expression:

$$\begin{bmatrix} H_0 - E & H_1 & 0 & \dots & 0 \\ H_1 & H_0 - E & H_1 & 0 & 0 \\ 0 & H_1 & H_0 - E & H_1 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ H_1 & 0 & 0 & 0 & H_1 \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix} = 0 \quad (6.34)$$

$$H_0 = \int \varphi_n^* H \varphi_n dV; \quad H_1 = \int \varphi_n^* H \varphi_m dV.$$

By inspection of above expression we observe the relationship:

$$c_{m-1}H_1 + c_m(H_0 - E) + c_{m+1}H_1 = 0; \quad (6.35)$$

which can be solved if we choose the coefficients

$c_m^{(k)} = e^{i \frac{2\pi mk}{N}}$ (periodicity), where the index $m = 1, 2, \dots, N$ denotes number of cells and $k = 0, \pm 1, \pm 2, \dots, \pm \frac{N}{2}$ signify *molecular orbits*

(bonding and anti-bonding). After simple algebraic manipulations in Eq. (6.35) there appears expression for (single electron) energy of molecular orbits:

$$\begin{aligned} E(k) &= H_0 + 2H_1 \cos \frac{k\pi}{l}; \\ k &= 0, \pm 1, \pm 2, \dots, \pm \frac{N}{2}; \quad l = \frac{N}{2}; \end{aligned} \quad (6.36)$$

and corresponding wave functions:

$$\psi^{(k)} = \sum_m c_m^{(k)} \varphi_m. \quad (6.37)$$

The wave functions specified above allow us to calculate the correction of energy induced by interactions of amino-residues R_1, R_2, \dots, R_N with

backbone in the framework of the perturbation theory (the first order correction) [8]:

$$\Delta E^{(k)} = \langle \psi^{(k)} | H_{\text{int}}(k) | \psi^{(k)} \rangle. \quad (6.38)$$

By specifying the potential of interaction of amino-residues with backbone $H_{\text{int}}(k) = \frac{1}{N} \sum_m W_m$, $W_m \varphi_m = E_m \varphi_m \delta_{m'm}$ (where for the interaction energy of m^{th} amino-residues R_m and m^{th} elementary cells we can take the electron excitation energy E_m of the m^{th} amino acid, which is specifically determined by local electronic structure of the amino-residues R_m [5], with corresponding eigen functions φ_m as MO LCAO centered on m^{th} elementary cell, while $1/N$ is normalizing factor for (single electron) first order energy corrections), it follows:

$$\Delta E^{(k)} = \frac{1}{N} \sum_{mm'} c_m^{(k)} c_n^{(k)*} E_m \langle \varphi_n | \varphi_m \rangle \delta_{m'm} = \frac{1}{N} \sum_m E_m. \quad (6.39)$$

So, it can be seen that DFT (6.27) in bioinformational RRM model is basically related to *sequential contributions to the first order correction of energy* (6.39) (i.e. *primary sequence of amino-residues*, but not to (single electron) energy of the periodic part of protein's chain), which is then connected with energy density spectrum (6.28).

Finally, results of the RRM model imply that on the biomolecular level an information processing is going on in the *inverse space* of Fourier spectra of the primary sequences of biomolecules, bearing resemblance to quantum-holographic ideas that cognitive information processing is going in the *inverse space* of the Fourier spectra of the perceptive stimuli [9], tentatively suggesting possible *quantum-holographic fractal coupling* of various hierarchical levels in biological species, with significant potential psychosomatic implications as well (cf. Ch. 5).

6.5 Density Operator. Von Neumann's Entropy

In Quantum mechanics states that cannot be described by state vectors $|\psi\rangle$ i.e. pure states, are called the mixed states (or statistical

mixtures) and are described by density operator of the mixed state (or statistical operator)

$$\hat{\rho} = \sum_i |c_i|^2 |\psi_i\rangle\langle\psi_i| \equiv \sum_i |\psi_i\rangle p_i \langle\psi_i| \quad (6.40)$$

(where Dirac's notation introduced in the previous section is used, while $p_i \equiv |c_i|^2$ is probability for quantum system to be found in the i^{th} state of the ensemble $|\psi_i\rangle$, while summing goes all over the ensemble (in the sense of quantum and statistical physics!) and it is assumed that the ensemble states are normalized $\langle\psi_i|\psi_i\rangle = 1$ (but not necessarily orthogonal!)). Also, the probabilities typically satisfy: $0 \leq p_i \leq 1$, $\sum_i p_i = 1$, $\sum_i p_i^2 \leq 1$). In the case that all p_i vanish except the j^{th} ($p_i = \delta_{ij}$) one obtains density operator of the pure state $|\psi_j\rangle$,

$$\hat{\rho} = |\psi_j\rangle\langle\psi_j|, \quad (6.41)$$

(which is a 'projection operator' on the state $|\psi_j\rangle$, and in the general case of Eq. (6.40) density operator is the sum of projection operators over the ensemble, with the probability as a weighted factor for each member of the ensemble!) [1,5-7].

By introducing a complete, orthonormalized basis $\{|\varphi_n\rangle\}$ $\left(\sum_n |\varphi_n\rangle\langle\varphi_n| = 1\right)$ of the eigen states of some observable (for example, energy), the i^{th} member of the ensemble can be rewritten as

$$|\psi_i\rangle = \sum_n |\varphi_n\rangle\langle\varphi_n|\psi_i\rangle = \sum_n c_n^{(i)} |\varphi_n\rangle \quad (6.42)$$

where $c_n^{(i)} = \langle\varphi_n|\psi_i\rangle$. Matrix elements of the operator $\hat{\rho}$ between eigen states n i n' is

$$\langle\varphi_n|\hat{\rho}|\varphi_{n'}\rangle = \sum_i \langle\varphi_n|\psi_i\rangle p_i \langle\psi_i|\varphi_{n'}\rangle = \sum_i p_i c_n^{(i)} c_{n'}^{(i)*} \quad (6.43)$$

The elements $\langle \varphi_n | \hat{\rho} | \varphi_n \rangle$ form *density matrix*, whose trace ($Tr \hat{\rho}$) is

$$\begin{aligned} Tr \hat{\rho} &= \sum_n \langle \varphi_n | \hat{\rho} | \varphi_n \rangle = \sum_i \sum_n \langle \varphi_n | \psi_i \rangle p_i \langle \psi_i | \varphi_n \rangle \\ &= \sum_i \sum_n p_i \langle \psi_i | \varphi_n \rangle \langle \varphi_n | \psi_i \rangle = \sum_i p_i = 1 \end{aligned} \quad (6.44)$$

As $\hat{\rho}$ is Hermitian operator (which is obvious from the construction in Eq. (6.40)), diagonal elements $\langle \varphi_n | \hat{\rho} | \varphi_n \rangle$ must be real, so that from Eq. (6.44) it follows: $0 \leq \langle \varphi_n | \hat{\rho} | \varphi_n \rangle \leq 1$.

Consider further the *square of the density operator*, $\hat{\rho}^2 = \hat{\rho} \cdot \hat{\rho}$. For *pure state*, for which is $\hat{\rho} = |\psi\rangle\langle\psi|$, it follows

$$Tr \hat{\rho}^2 = Tr \hat{\rho} \quad (6.45)$$

i.e.

$$\hat{\rho}^2 = |\psi\rangle\langle\psi| |\psi\rangle\langle\psi| = |\psi\rangle\langle\psi| = \hat{\rho}. \quad (6.46)$$

For the *mixed state* is

$$\hat{\rho}^2 = \sum_i \sum_j p_i p_j |\psi_i\rangle\langle\psi_i| |\psi_j\rangle\langle\psi_j|, \quad (6.47)$$

whose tracing out gives

$$\begin{aligned} Tr \hat{\rho}^2 &= \sum_n \langle \varphi_n | \hat{\rho}^2 | \varphi_n \rangle \\ &= \sum_n \sum_i \sum_j p_i p_j \langle \varphi_n | \psi_i \rangle \langle \psi_i | \psi_j \rangle \langle \psi_j | \varphi_n \rangle \\ &= \sum_i \sum_j p_i p_j \left| \langle \psi_i | \psi_j \rangle \right|^2 \leq \left[\sum_i p_i \right]^2 = 1 \end{aligned} \quad (6.48)$$

where equality applies only if $\left| \langle \psi_i | \psi_j \rangle \right|^2 = 1$ for every pair of states $|\psi_j\rangle$ and $\langle\psi_i|$, which is only possible if all $|\psi_i\rangle$ are colinear in Hilbert

space, i.e. if they are equivalent up to the phase factor. So we get the criteria for pure and mixed states:

$$Tr\hat{\rho}^2 = 1 \quad (\text{pure state}) \quad (6.49)$$

$$Tr\hat{\rho}^2 < 1 \quad (\text{mixed state})$$

Consider now a *simple example*: a superposition of the vacuum and single-photon beam state, as a *pure state*

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|0\rangle + e^{i\theta}|1\rangle),$$

where θ is some phase factor. The density operator of this *pure state* is

$$\hat{\rho}_\Psi = |\psi\rangle\langle\psi| = \frac{1}{2} [|0\rangle\langle 0| + |1\rangle\langle 1| + e^{i\theta}|1\rangle\langle 0| + e^{-i\theta}|0\rangle\langle 1|], \quad (6.50)$$

while on the other hand the density operator of the equally occupied *statistical mixture* of the vacuum and single-photon beam state is

$$\hat{\rho}_M = \frac{1}{2} [|0\rangle\langle 0| + |1\rangle\langle 1|] \quad (6.51)$$

It is obvious that these two density operators, $\hat{\rho}_\Psi$ i $\hat{\rho}_M$, differ by the presence of 'nondiagonal'/'coherent' terms in $\hat{\rho}_\Psi$, which are absent in the case of mixture $\hat{\rho}_M$!

For one of the ensemble states $|\psi_i\rangle$, itself *pure state*, the mean value of the operator \hat{O} is given by $\langle\hat{O}\rangle_i = \langle\psi_i|\hat{O}|\psi_i\rangle$, so that for the *mixed state* the mean value of the operator \hat{O} over ensemble is

$$\langle\hat{O}\rangle = \sum_i p_i \langle\psi_i|\hat{O}|\psi_i\rangle = Tr(\hat{\rho}\hat{O}) \quad (6.52)$$

as

$$\begin{aligned}
Tr(\hat{\rho}\hat{O}) &= \sum_n \langle \phi_n | \hat{\rho}\hat{O} | \phi_n \rangle = \sum_n \sum_i p_i \langle \phi_n | \Psi_i \rangle \langle \Psi_i | \hat{O} | \phi_n \rangle = \\
&= \sum_i \sum_{ni} p_i \langle \Psi_i | \hat{O} | \phi_n \rangle \langle \phi_n | \Psi_i \rangle = \sum_i p_i \langle \Psi_i | \hat{O} | \Psi_i \rangle.
\end{aligned} \tag{6.53}$$

According to the *Principle of correspondence*, von Neumann has introduced *quantum-mechanical entropy* as a mean value of the operator $-k \ln \hat{\rho}$, i.e. according to Eq. (6.52)

$$S = -k Tr(\hat{\rho} \ln \hat{\rho}) \tag{6.54}$$

which after the tracing out reduces to the Shannon *classical entropy*

$$S = -k \sum_i p_i \ln p_i \tag{6.55}$$

For *pure state* $\hat{\rho} = |\psi_j\rangle\langle\psi_j|$ from Eq. (6.57) one obtains (for $p_i = \delta_{ij}$)

$$S_{\psi_j} = 0, \tag{6.56}$$

i.e. *entropy of pure state vanishes* (which is reasonable, because the *pure state provides the maximum possible information* about the quantum system!), i.e. there is no lack of information about the system!

On the basis of Eq. (6.56) *entropy of the mixed state does not vanish* (which is reasonable, because the *mixed state gives only probable information* about the state of quantum system!), while in the so-called Schmidt basis, in which the density operator is diagonal, entropy comes from diagonal terms of Eq. (6.54):

$$S_M = -k \sum_k \rho_{kk} \ln \rho_{kk} > 0 \tag{6.57}$$

6.6 Quantum Entanglement. Von Neumann's Quantum Theory of Measurement

Quantum entanglement (quantum non-separability; quantum correlation) is [with the quantum principle of superposition] one of the most intriguing concepts of quantum mechanics, because [with quantum uncertainty] brings additional uncertainty – the lack of state of subsystems [1,10-13]!

Consider two-particle (two-mode; bipolar) system, and assume that both particles can be in any of the two single-particle states $|\psi_1\rangle$ or $|\psi_2\rangle$. By using notation

$$\begin{aligned} |\psi_1^{(1)}\rangle &, \text{ particle 1 in state 1,} \\ |\psi_2^{(1)}\rangle &, \text{ particle 1 in state 2,} \\ |\psi_1^{(2)}\rangle &, \text{ particle 2 in state 1,} \\ |\psi_2^{(2)}\rangle &, \text{ particle 2 in state 2,} \end{aligned}$$

consider *pure two-particle state of superposition* (generally *entangled state*!)

$$|\psi\rangle_{12} = C_1 |\psi_1^{(1)}\rangle \otimes |\psi_2^{(2)}\rangle + C_2 |\psi_2^{(1)}\rangle \otimes |\psi_1^{(2)}\rangle \quad (6.58)$$

(whose one example is singlet spin state). *Entangled states* of the type of Eq. (6.58) *cannot be factorized*, in any basis, *in the product of states of two subsystems*, i.e.

$$|\psi\rangle_{12} \neq |\phi^{(1)}\rangle |\chi^{(2)}\rangle \quad (6.59)$$

[In Eq. (6.58) tensor product was used in order to emphasise that this is the case of 2 single-particle Hilbert subspaces, but further on it will be tacitly assumed. This can be also generalized on multi-partit systems.]

Density operator of the pure two-particle pure state of Eq. (6.58) is

$$\begin{aligned} \hat{\rho}_{12} &= |\psi\rangle_{1212} \langle\psi| = \\ &|C_1|^2 |\psi_1^{(1)}\rangle \langle\psi_1^{(1)}| \otimes |\psi_2^{(2)}\rangle \langle\psi_2^{(2)}| + C_1 C_2^* |\psi_1^{(1)}\rangle \langle\psi_2^{(1)}| \otimes |\psi_2^{(2)}\rangle \langle\psi_1^{(2)}| \\ &+ C_2 C_1^* |\psi_2^{(1)}\rangle \langle\psi_1^{(1)}| \otimes |\psi_1^{(2)}\rangle \langle\psi_2^{(2)}| + |C_2|^2 |\psi_2^{(1)}\rangle \langle\psi_2^{(1)}| \otimes |\psi_1^{(2)}\rangle \langle\psi_1^{(2)}| \end{aligned} \quad (6.60)$$

while so called *reduced density operator* for particle 1 (obtained by tracing out the $\hat{\rho}_{12}$ i.e. by integration over degrees of freedom of the second system (particle 2) which is not of our interest)

$$\begin{aligned}\hat{\rho}_{12}^{(1)} &= Tr_2 \hat{\rho}_{12} = \langle \psi_1^{(2)} | \hat{\rho}_{12} | \psi_1^{(2)} \rangle + \langle \psi_2^{(2)} | \hat{\rho}_{12} | \psi_2^{(2)} \rangle \\ &= |C_1|^2 |\psi_1^{(1)}\rangle \langle \psi_1^{(1)}| + |C_2|^2 |\psi_2^{(1)}\rangle \langle \psi_2^{(1)}| \end{aligned} \quad (6.60')$$

which has the form of density operator of the mixed state for particle 1 as long as $C_i \neq 0$, $i=1,2$, and similarly for particle 2:

$$\hat{\rho}_{12}^{(2)} = Tr_1 \hat{\rho}_{12} = |C_1|^2 |\psi_1^{(2)}\rangle \langle \psi_1^{(2)}| + |C_2|^2 |\psi_2^{(2)}\rangle \langle \psi_2^{(2)}|. \quad (6.60'')$$

Obviously, when one considers one particle without considering the other one, it is generally in the mixed state! So the level of entanglement can be considered according to the purity of any of the two subsystems: if $Tr[\hat{\rho}_{12}^{(2)}]^2 = 1$ then state $|\psi\rangle$ is not entangled (but is factorized, of the type $\psi = |0^{(1)}\rangle |\chi^{(2)}\rangle$), but if $Tr[\hat{\rho}_{12}^{(2)}]^2 < 1$ then state $|\psi\rangle$ is entangled (of the type like Eq. (6.58))!

Moreover, the subsystem's single-particle density operators $\hat{\rho}_{12}^{(1)}$ and $\hat{\rho}_{12}^{(2)}$ (reduced density operators) are not states of the subsystems 1 and 2, but are so called 'mixtures of the 2nd kind', as for them hold inequalities:

$$|\psi\rangle_{12} \neq \hat{\rho}^{(12)} \neq \hat{\rho}_{12}^{(1)} \otimes \hat{\rho}_{12}^{(2)}$$

where $\hat{\rho}^{(12)}$ is density operator of the mixed two-particle state:

$$\begin{aligned}\hat{\rho}^{(12)} &= |C_1|^2 |\psi_1^{(1)}\rangle \langle \psi_1^{(1)}| \otimes |\psi_2^{(2)}\rangle \langle \psi_2^{(2)}| + |C_2|^2 |\psi_2^{(1)}\rangle \langle \psi_2^{(1)}| \otimes |\psi_1^{(2)}\rangle \langle \psi_1^{(2)}| \\ &\neq \hat{\rho}_{12} = |\psi\rangle_{1212} \langle \psi| \end{aligned} \quad (6.61)$$

So, quantum non-separability is not only familiar with the 'quantum uncertainty' on the level of wholeness 1+2 (in the sense of uncertainty relations), but brings additional uncertainty – lack of the state of subsystems (although the overall system 1+2 is in a pure state, of the entropy $S_{\Psi_{12}} = 0$)!

Basically, for complex quantum systems, quantum entanglement (nonseparability) is more the rule than the exception! So, 'lack of the state of subsystems' (which is the meaning of 'the existence of quantum correlations') leads to a quantum nonseparability of the object and device(!) i.e. to a quantum nonseparability of the system and environment!

It should be noticed that the *quantum nonseparability* (non-objectivity of 'non-real mixtures' i.e. 'mixtures of the 2nd kind' as (quantum) states) – is the price that must be paid within the *von Neumann Theory of Measurement* – and is the consequence of the assumption of *universal validity of the Schrödinger equation* (only for the *object and device* ($O + A$) as a whole(!), or only for the *quantum system and environment* ($S + E$) as a whole(!) within the *Zurek Theory of Decoherence*, cf. App. 6.7).

In this context, let us mention the *similarities and differences* of the *von Neumann Theory of Measurement* (vNTM) and the *Zurek Theory of Decoherence* (ZTD). Namely, although they are formally-mathematically the same, the ZTD is elaboration of the vNTM:

- (1) In ZTD an open system S is *macroscopic physical system* (nonisolated from the environment E , with the requirement of existence of the 'robust' states), as well in fNTM, but in ZTD request of Eq. (6.62) for the existing stability of 'robust' states (so-called 'counter basis' in ZTD) refers to *indefinitely long time interval*(!), while in fNTM it is considered *arbitrarily short*(!);
- (2) If the condition (1) is not fulfilled, in fNTM it is considered that the *measurement is not done*(!), while in ZTD *neither macroscopic quantum system nor its corresponding observables are defined*(!);
- (3) In fNTM the *initial state of the device is not arbitrary*(!), while in ZTD the *initial state of the environment E cannot be prepared*(!):

$$\hat{U}(t)|\varphi_i\rangle_S \otimes |\chi\rangle_E = |\varphi_i\rangle_S \otimes |\chi_i(t)\rangle_E. \quad (6.62)$$

However, it is necessary to point out that *neither the von Neumann Theory of Measurement nor the Zurek Theory of Decoherence do provide a solution for the problem of classical limit* (i.e. *objective separability* of the object/system and the device/environment, which exists in *classical physics*!), because the 'subsystem density matrix' is the '*mixture of the 2nd kind*'(!), while it should be '*made*' *objective state* i.e. the '*mixture of the 1st kind*' (which is the subject of theories of measurement like, for instance, the *Penrose objective reduction* (OR) of the wave package [14])!²⁶

²⁶ As an opposite extreme in interpretation of the act of quantum measurement, Everett's many-worlds interpretation of Quantum mechanics [13] proposes that no collapse of initial wave function is happening in the process of measurement,

but that there exists splitting of the composed initial state, consisted of initial state Ψ and the apparatus state Φ , into the superposition of all possible composed states, consisted of eigenstates Ψ_j and corresponding observers states Φ_j , $\Psi\Phi \rightarrow \sum_i c_i \Psi_i \Phi_i$ – each element of the resulting superposition describing an observer who perceived a definite and generally different result, and to whom it appears that the initial state Ψ has been transformed into the corresponding eigenstate (Ψ_j , if particular observer's state is Φ_j). In this sense the 'popular' assertion of the wave function reduction appear to hold on a subjective level to each observer described by an element of the superposition. The price to be paid for physical consistency – is the splitting of the initial system into many copies with different eigenstates, existing simultaneously further on! Actually, all that consistently applies to the whole Universe, which is constantly splitting into a stupendous number of branches, all resulting from the measurement-like interactions between its myriads of microparticles.

6.7 Quantum Decoherence Theory. Stationary and Nonstationary Quantum States

Simply speaking, a process (effect) of decoherence is a physical process 'induced' by environment E of quantum system S , leading by unavoidable interaction between environment and quantum system to an effective, approximately classical-physical behaviour of the quantum system. The composite system $S + E$, as the closed quantum system, is subject to the Schrödinger law (although this does not holds true separately for neither S nor E , which are referred to as the open quantum systems), with Hamiltonian $\hat{H} = \hat{H}_S + \hat{H}_E + \hat{H}_{\text{int}}$ which exists in the unitary operator of temporal evolution of the composite system: $\hat{U}(t) = \exp(-2\pi i \hat{H} t / h) \cong \exp(-2\pi i \hat{H}_{\text{int}} t / h)$ (as the interaction Hamiltonian (\hat{H}_{int}) is usually much greater than the 'self-Hamiltonian' of the mutually noninteracting system (\hat{H}_S) and the environment (\hat{H}_E)) [1,10,11].

The first task is to calculate the state of the open system S , the so-called 'reduced statistical operator' $\hat{\rho}_S$:

$$\hat{\rho}_{S_k}(t) = \text{tr}_E \left(\hat{U}(t) \hat{\rho}_{S_k+E_k}(t=0) \hat{U}^*(t) \right) \quad (6.63)$$

where $\hat{\rho}_{S+E}(t=0)$ is the initial state of the composite system $S + E$, while " tr_E " refers to the integrating over the environmental E degrees of freedom. Further, under the set of the special conditions, one can observe the *occurrence of the decoherence effect* defined loosely as:

(1) in the representation of a special orthonormalized basis $\{ |\phi^{k_i}\rangle_S \}$

of the Hilbert state space of the system S – the so-called 'pointer basis' – one obtains *disappearance of the off-diagonal elements* of $\hat{\rho}_S$:

$$\lim_{t \rightarrow \infty} \rho_{Smm'}(t) = 0, \quad m \neq m' \quad (6.64)$$

(2) with the requirement of *stability* ('robustness') of the elements of the pointer basis:

$$\hat{H}_{\text{int}} \left| \phi^{k_i} \right\rangle_S \left| \varphi \right\rangle_E = \left| \phi^{k_i} \right\rangle_S \left| \varphi_{k_i} \right\rangle_E \quad (6.65)$$

or equivalently

$$\hat{U}(t) \left| \phi^{k_i} \right\rangle_S \left| \varphi \right\rangle_E = \left| \phi^{k_i} \right\rangle_S \left| \varphi_{k_i}(t) \right\rangle_E \quad (6.66)$$

Then, effectively, there appear the environment-induced superselection rules (decoherence), which forbid the coherent superpositions of certain states of the system S . In other words, decoherence establishes existence and robustness of a preferred set of states - e.g. of the 'pointer basis' - of an open system S . If the initial state of S is a coherent superposition,

$\left| \phi \right\rangle_S = \sum_i c_{k_i} \left| \phi^{k_i} \right\rangle_S$, then the decoherence process can be presented as:

$$\left| \phi \right\rangle_S = \sum_i c_{k_i} \left| \phi^{k_i} \right\rangle_S \xrightarrow{\tau_D} \hat{\rho}_S = \sum_i |c_{k_i}|^2 \left| \phi^{(k_i)} \right\rangle_S \left\langle \phi^{(k_i)} \right| \quad (6.67)$$

where τ_D , the *decoherence time*, is the order of magnitude of the unfolding of the decoherence process. Eq. (6.67) exhibits the loss of the initial coherence - which justifies the term *decoherence*.

The further task is the proper modelling of the interaction Hamiltonian, \hat{H}_{int} , in order to deduce (1) and (2), i.e. Eq. (6.66) for the composite system $S + E$. Without employing any details, we emphasise that that virtually independently on the model of the environment E , the following simplest separable *interaction Hamiltonian* fulfils our requirements:

$$H_{\text{int}} = C \hat{S} \otimes \hat{D}_E \quad (6.68)$$

where C stands for the coupling constant (determining the strength of interaction), $S = \sum_i k_i \left| \phi^{(k_i)} \right\rangle_S \left\langle \phi^{(k_i)} \right|$ is the corresponding observable of the quantum system S , and \hat{D}_E is arbitrary observable of the environment E .

Everything presented above referred to *stationary states established by decoherence process*, whose previous condition (2) tends to *freeze dynamics of an open system*, once the system is in a 'preferred' stationary state.

However, in the case of *nonstationary states* resulted as a consequence of an external action on the composite system $S + E$, the previous stationary state might be firstly broken and afterwards accompanied by re-establishment of the effect of decoherence due to the interaction in Eq. (6.68). In this context, the following *physically and phenomenologically plausible* assumptions can be introduced, generally applicable to any quantum system [15]: (i) the external influence is *much stronger* than the interaction in Eq. (6.68), and (ii) *after* the external action, the composite system relaxes to equilibrium ('stationary state') due to the interaction in Eq. (6.68).

Hence, we have the following physical situation: *initially*, the composite system $S + E$ is in a 'stationary state':

$$\hat{\rho}_S = \sum_i |c_{k_i}|^2 |\phi^{(k_i)}\rangle_S \langle\phi^{(k_i)}| \quad (6.69)$$

Then, the *strong external action* generally noncommuting with \hat{H}_{int} in Eq. (6.68), redefines the environment E' during the time T_{ext} , giving rise to the following nonstationary state transformation for the system S :

$$\hat{\rho}_S \rightarrow \hat{\rho}_S' \quad (6.70)$$

such that, *in general*:

$$[\hat{\rho}_S, \hat{\rho}_S'] \neq 0 \quad (6.71)$$

Next, *after the external action*, the composite system $S + E'$ is subject to the nonstationary *relaxation process* of the duration T_{rel} , which in general gives rise to another state change of S :

$$\hat{\rho}_S' \rightarrow \hat{\rho}_S'' \quad (6.72)$$

Finally, the relaxation process *re-establishes* the stationary state and interaction of Eq. (6.68), which *guarantees existence and stability of the stationary states of the system S* , giving rise to its final state:

$$\hat{\rho}_S'' = \sum_i |c_{k_i}''|^2 |\phi^{(k_i)}\rangle_S \langle\phi^{(k_i)}| \quad (6.73)$$

during the decoherence time τ_D , of the transition $\hat{\rho}_S'' \rightarrow \hat{\rho}_S'''$.

The difference between initial $\hat{\rho}_S$ and final $\hat{\rho}_S'''$ should be pointed out. Both states refer to the stationary states $|\phi^{k_i}\rangle_{S_k}$, guaranteeing their existence and stability. However, the relative contribution of different states – i.e. their 'statistical weights' – is different, $|c_{k_i}'''|^2 \neq |c_{k_i}|^2$. *In effect*, there has occurred the *state change of the quantum system S under the nonstationary influence of the environment E*, i.e. the shape change of the potential hypersurface in the energy-state space of the system S (cf. Fig. 3.3 in Ch. 3).

The total *duration of the nonstationary effect* of the state change of quantum system S reads:

$$T = T_{ext} + T_{rel} + \tau_D. \quad (6.74)$$

As the *process of quantum decoherence is enormously fast* (for many-particle systems $\tau_D \ll 10^{-23}$ s),

$$T_{ext} + T_{rel} \gg \tau_D \quad (6.75)$$

then the *duration of the state change of the quantum system S in our model is of the order $T_{ext} + T_{rel}$* , i.e. determined by the duration of classical macroscopic processes of the external action and relaxation of the system.

It should be pointed out that the proposed quantum-decoherence model might be *generally applied* on any quantum system and its stationary states and excitations, from *macromolecules and its conformations* (cf. Ch. 3) to *two modes of consciousness* (cf. Ch. 5), and might serve as bio-informational basis of *quantum medicine* related to *acupuncture system/ consciousness and its psychosomatic states* (cf. Ch. 5).

So, for instance, during *application of MRT therapy* for transferring disordered acupuncture system S from the psychosomatically excited state $|\phi^{k_2}\rangle_S$ (cf. Fig. 3.3 in Ch. 3) into the attracting healthy ground state $|\phi^{k_0}\rangle_S$, it is necessary during the strong external action (T_{ext}) to provide external microwave energy for skipping over potential barrier of the disordered state ($\Delta E_S^{k_2,0}$), which after relaxation process (T_{rel}) of

taking-off the excess external energy ($\Delta E_S^{k_0,2}$), gives rise to condition of the completed quantum state change of the acupuncture system $\hat{\rho}_S \rightarrow \hat{\rho}_S''$, with additional decoherence time (τ_D) and decrease of one quantum of microwave energy in the state $|\phi^{k_2}\rangle_S$ and increase of one quantum of microwave energy in the state $|\phi^{k_0}\rangle_S$! By multiple repeating of this process, the depth of the memory attractor k_2 is getting shallower in favor of deepening of the attracting acupuncture healthy state k_0 , finally giving rise to complete erasing of the psychosomatic disorder $|\phi^{k_2}\rangle_S$ and deepening of the healthy state $|\phi^{k_0}\rangle_S$, i.e. *dynamic modification of the potential hypersurface of the acupuncture system*, in full analogy with the situation of learning classical Hopfield associative neural networks (cf. Fig. 3.3).

Finally, it should be added in the context of necessary conditions for decoherence process, that defining of open quantum system and its environment – is a simultaneous process – implying that, within the context of universality of quantum mechanics, *consciousness is only a relative concept* [16], nonlocally defined with all distant parts of the existing observed Universe (and vice versa!) – which is in accordance with the idea of *collective consciousness* as a possible ontological property of the physical field itself, with various microquantum and macroquantum (both non-biological and biological) excitations (cf. Ch. 5).

6.8 Quantum Qubit Informatics. Quantum Teleportation, Cryptography and Computation

One important application of quantum entanglement is quantum teleportation (and sometimes associated with it (by Ekert-protocol) quantum cryptography), and the other is quantum computing, which will be elaborated in this appendix [1,11,12].

QUANTUM TELEPORTATION allows the transfer of (*unknown*) *quantum state* from one to another (*distant*) point. In the procedure (protocol) of teleportation two persons are involved: A (Alice) and B (Bob), and suppose that *Alice is given the quantum state*

$$|\psi\rangle = c_0|0\rangle + c_1|1\rangle, \quad (6.76)$$

which *she wants to teleport to Bob*, so that he may come to its possession in his quantum mode! The *superposition* in Eq. (6.76) of the two states $|0\rangle$ and $|1\rangle$ represents so called *qubit* (quantum bit of information), while basis states $|0\rangle$ and $|1\rangle$ are states of any 'two-level' system (vertically and horizontally polarized photonic states, two spin states, or states of two-level atoms).

The state in Eq. (6.76) is generally *unknown* to Alice, i.e. she *does not know* the coefficients c_0 i c_1 (if she knew, she could simply convey the information to Bob over a classical channel (e.g. via telephone)). Suppose further that *some source* of light can produce an *entangled state which is shared between Alice and Bob*, as indicated by subscripts:

$$|\Psi_{AB}\rangle = \frac{1}{\sqrt{2}}(|0\rangle_A|0\rangle_B + |1\rangle_A|1\rangle_B) \quad (6.77)$$

So Alice has in her possession the state to be teleported, $|\psi\rangle$, and part of the shared state $|\Psi_{AB}\rangle$, whereas Bob has only his part of the shared state, so far.

So one can rewrite the *total state* for Alice and Bob as

$$|\Phi_{AB}\rangle = |\psi\rangle|\Psi_{AB}\rangle = \frac{1}{\sqrt{2}}(c_0|0\rangle + c_1|1\rangle)(|0\rangle_A|0\rangle_B + |1\rangle_A|1\rangle_B) \quad (6.78)$$

which can be expanded as

$$\begin{aligned} |\Phi_{AB}\rangle = & |\Phi^+\rangle(c_0|0\rangle_B + c_1|1\rangle_B) + |\Phi^-\rangle(c_0|0\rangle_B - c_1|1\rangle_B) \\ & + |\Psi^+\rangle(c_0|1\rangle_B + c_1|0\rangle_B) + |\Psi^-\rangle(c_0|1\rangle_B - c_1|0\rangle_B) \end{aligned} \quad (6.79)$$

where so called *Bell states* were introduced (which, as mutually orthogonal, constitute a *basis* in a four-dimensional Hilbert space)

$$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|0\rangle|0\rangle_A + |1\rangle|1\rangle_A) \quad (6.80)$$

$$|\Phi^-\rangle = \frac{1}{\sqrt{2}}(|0\rangle|0\rangle_A - |1\rangle|1\rangle_A) \quad (6.81)$$

$$|\Psi^+\rangle = \frac{1}{\sqrt{2}}(|0\rangle|1\rangle_A + |1\rangle|0\rangle_A) \quad (6.82)$$

$$|\Psi^-\rangle = \frac{1}{\sqrt{2}}(|0\rangle|1\rangle_A - |1\rangle|0\rangle_A) \quad (6.83)$$

The Bell states in Eqs. (6.80-83) are constructed from the basis states of the unknown state to be teleported and of the Alice's share of the entangled state. Each Bell state in Eq. (6.79) is correlated with a different superposition of the states in Bob's share of the entangled state. Perhaps it is important to *point out* that nothing physical has happened here yet: the state in Eq. (6.78) was only re-written in the form of Eq. (6.79)!

The next step in the protocol is for *Alice* to perform '*projective quantum measurements onto the Bell basis*', where each of the four Bell states will occur randomly with an equal probability of 1/4:

(1) Suppose Alice obtains the state $|\Phi^+\rangle$ and that she *knows* that she has obtained that state; thus Bob's photonic system is projected onto the state $c_0|0\rangle_B + c_1|1\rangle_B$. Over a *classical channel* Alice then tells Bob that she has detected the state $|\Phi^+\rangle$ and thus *both know* that Bob *already has in possession* the teleported state and thus he needs to do nothing. Note that *neither Alice nor Bob know what the teleported state is!*

(2) If, on the other hand, Alice reports that she has detected the state $|\Phi^-\rangle$, then Bob's photonic system has been projected onto the state $c_0|0\rangle_B - c_1|1\rangle_B$, and he knows that his state differs from the original (teleported) state by the sign of the second term so that he must perform the transformation $|0\rangle_B \rightarrow |0\rangle_B$, $|1\rangle_B \rightarrow -|1\rangle_B$ to obtain the original state.

(3) If, however, Alice detects $|\Psi^+\rangle$, Bob's photonic system is in the state $c_0|1\rangle_B + c_1|0\rangle_B$ and he needs to perform operation $|1\rangle_B \rightarrow |0\rangle_B$, $|0\rangle_B \rightarrow -|1\rangle_B$ to obtain the original (teleported) state.

(4) Finally, if Alice detects $|\Psi^-\rangle$, then Bob's photonic system has been projected onto the state $c_0|1\rangle_B - c_1|0\rangle_B$ and he must perform the

transformation $|1\rangle_B \rightarrow |0\rangle_B$, $|0\rangle_B \rightarrow -|1\rangle_B$ to obtain the original (teleported) state. This completes the *description of the teleportation protocol!*

Note once again that *neither Alice nor Bob knows what the original teleported state is*, as well as that in the process of projective quantum measurements onto the Bell basis the *original state is itself destroyed!*

Quantum teleportation may seem to have an element of magic, and if so this is because the state $|\Phi_{AB}\rangle$ shared by Alice and Bob is *entangled*, i.e. because of its (*nonlocal*) *quantum correlations!* Quantum teleportation is not merely a theoretical curiosity but is an *experimental reality*, and it is now a basis of *quantum cryptography* (in so called *Ekert protocol*), and may become a basis of *future quantum communications* (to transfer the quantum state from Alice to Bob, if they have a *common entangled state!*).

QUANTUM CRYPTOGRAPHY allows an encrypted piece of information to be *quantum-transferred* from Alice to Bob with an *absolute protection!* By using so called *quantum key distribution (QKD)*, a mechanism for Alice and Bob to create a shared key over so called *public channels* is enabled. [In so called *public crypto-systems*, Bob sends the public key of the two very large prime numbers ($e, p \cdot q(N)$), where p and q are chosen randomly from the set of large prime numbers ($> 10^{1000}$), $N = p \cdot q > 10^{2000}$, $p \cdot q(N) \equiv (p-1)(q-1)$, and $e < N$ are chosen so that e and $p \cdot q(N)$ have no common factors other than 1. Alice then encrypts the text message by using Bob's public key and then sends encrypted message to Bob, which Bob then decodes. What makes this channel secure is the *size of number N, which should be factorized* ($N = p \cdot q$) and for a classical *supercomputer* it would take many years – but *not to quantum computer(!)* – which might be thus used (in near future) by 'eavesdropper' Eve to attack this crypto-system easily. But hereby *quantum cryptography* enters the race!].

QKD offers the possibility for Alice and Bob to exchange a secret key without physically meeting (directly or indirectly). The *security of QKD* is conditioned on the *principles of quantum mechanics*. The central idea behind QKD-idea is that it is *impossible for an 'eavesdropper' to obtain all the information from the transmitted quantum state in a single general measurement(!)*: Namely, transmitted (and eavesdropped) quantum state

$|\psi\rangle = c_0|0\rangle + c_1|1\rangle$ has c_0 and c_1 unknown, impossible to determine in a single measurement (they can be determined only via a number of measurements upon identically prepared copies of the state $|\psi\rangle$). However, in *QKD-protocols the same qubit is neither reused*, nor it is taken in the form of orthogonal states ($|0\rangle, |1\rangle$), but there are always used several non-orthogonal states ($|\psi\rangle = c_0|0\rangle + c_1|1\rangle$).

There are a number of QKD protocols (BB84/Bennet & Brassard (1992); B92/Bennet (1992); Ekert protocol (1991)... out of which the Ekert protocol exploits a set of n entangled qubit pairs, where each pair is in the form

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|0\rangle|0\rangle + |1\rangle|1\rangle), \text{ and uses two bases: } \{|0\rangle, |1\rangle\} \text{ and } \{|+\rangle, |-\rangle\}.$$

By successive measurements of Alice and Bob in one or another basis (depending on the values of randomly created numbers $a, a' = 0$ or 1), according to Ekert-protocol, with publicly communicating results of measurements (b, b') a part of the cryptographic key bit (a, a') is established [only in the case $b = b'$] – and whole *key bit* is completed by performing this procedure on the all n entangled qubit pairs! All of these schemes are *experimentally* (and some also *commercially*) realized.

QUANTUM QUBIT COMPUTATION is an algorithmic procedure performed via taking example by classical computation, i.e. all good experience of classical computing is adopted in quantum computing – but it uses *quantum parallelism* to drastically accelerate parallel processing and *quantum decoherence* to read-out information!

Thus, for example, the classical notion of *bit* is transferred in the quantum physics through notion of *qubit* (i.e. quantum bit), which represents any 2-D Hilbert space state (analogue of the spin state space of spin 1/2, or any two-level quantum system), with *computational basis states* $\{|0\rangle, |1\rangle\}$ (instead of the classical pair states $\{0, 1\}$ that may take a classical bit), which in *quantum mechanics* allows *coherent superpositions of states* (with no classical analogues!):

$$|\psi\rangle_n = c_0|0\rangle_n + c_1|1\rangle_n, \quad (6.84)$$

where n enumerates qubits (i.e. two-level quantum states: vertically and horizontally polarized photonic states $\{|V\rangle, |H\rangle\}$, two spin states $\{|\uparrow\rangle, |\downarrow\rangle\}$ etc.), $n = 1, 2, \dots, N$.

Note the following: all the while one has the states that *are not* coherent superposition like Eq. (6.84), *there is no difference* between the quantum and classical computing (so, for example, to *string of bits* from the classical computer

$$000101001, \quad (6.85)$$

corresponds a number of states from *computational basis*,

$$|\psi_i\rangle = |0\rangle_1 |0\rangle_2 |0\rangle_3 |1\rangle_4 |0\rangle_5 |1\rangle_6 |0\rangle_7 |0\rangle_8 |1\rangle_9 \equiv |000101001\rangle, \quad (6.86)$$

where in Eq. (6.86) *tensor product* of states of N particles ($N = 9$) is tacitly assumed, $|0\rangle_1 \otimes |0\rangle_2 \otimes \dots \otimes |1\rangle_9$, and indices (1, 2, ..., 9) that enumerate particles (qubits) are usually omitted. However, as the *qubit states* are *generally coherent superposition* like Eq. (6.84), hence *quantum strings* are tensor product of such qubits:

$$|\psi_i\rangle = |\psi\rangle_1 \otimes |\psi\rangle_2 \otimes \dots \otimes |\psi\rangle_N \quad i = 1, 2, \dots, 2^N \quad (6.87)$$

and there are 2^N such *linearly independent strings* of N -qubits in 2^N -dimensional Hilbert space formed out of the N qubits (each of these N qubits create its 2-D Hilbert space)! In this 2^N -D Hilbert space the normalized N -qubit state has the form of *superposition of states* given in Eq. (6.87):

$$|\psi\rangle = \sum_{i=0}^{2^N} c_i |\psi_i\rangle, \quad \left(\sum_{i=1}^{2^N} |c_i|^2 \right) = 1 \quad (6.88)$$

If *quantum computation* is a (reversible unitary) linear operation \hat{U} , then the computation upon the state in Eq. (6.88) is given by

$$\hat{U}|\psi\rangle = \sum_{i=0}^{2^N} c_i \hat{U}|\psi_i\rangle \quad (6.89)$$

that is the point of *quantum computing*, which is a *parallel processing in all strings* $|\psi_i\rangle$, $i = 1, 2, \dots, 2^N$ – that *has no classical analogues* (as in *classical computing* one has a series of time separated (non-simultaneous) computations: $\{\hat{U}|\psi_i\rangle, i = 1, 2, \dots\}$)! This possibility of parallel processing in quantum computing is called *quantum parallelism*!

Now, however, a new problem appears: how to *read out* useful information from the coherent superposition in Eq. (6.89) – as the results of ‘individual’ (classical) ‘trajectories’ $\hat{U}|\psi_i\rangle$ are quantum-uncertain (with ‘probabilistics’ $\sim |c_i|^2$, $i = 0, 1, \dots, 2^N$). Naturally, it is clear that *quantum measurement* is necessary, but the whole process requires *some creativity* – how to prepare the state of the system, so that the appropriate *quantum measurement* can extract useful information (i.e. *the result of computation*).

So, *quantum computing is the algorithmic procedure*, which is generally consisted of *two main types of procedures*:

- (a) *Application of unitary transformations* on the system of N qubits;
- (b) *Performing of appropriate quantum measurements* on this system or specific subsystem, which gives a result of quantum computation!

In the context of the procedure (a) *there exists a universal quantum computation* (i.e. an *arbitrary unitary transformation* of the state of N -qubit system can be made *with arbitrarily small error*)! Namely, it is shown that *there is a set of one- and two-qubit transformations*, which constitute a *universal set of quantum logic gates* (i.e. unitary transformations on one qubit or on pair of qubits, which can perform arbitrary unitary transformation on the set of N qubits). Naturally, to achieve such transformations over all N qubits, it is necessary to apply in the algorithmic order (beside one-qubit) also two-qubit transformations – for instance on the pair 1-2, then 2-3, and 3-4 etc.

One set of ‘*universal logical gates*’ includes two *1-qubit transformations*, *Hadamard transformation*

$$\hat{U}_H|0\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle), \quad \hat{U}_H|1\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle) \quad (6.90)$$

(which obviously *introduces quantum uncertainty* for observables in the characteristic 'computational basis') and operation $\pi/8$

$$T = \begin{pmatrix} 1 & 0 \\ 0 & \exp(i\pi/4) \end{pmatrix} \quad (6.91)$$

as well as one 2-qubit transformation, 'Exclusive OR' (XOR, CNOT)

$$\hat{U}_{CNOT}|0\rangle_1|i\rangle_2 = |0\rangle_1|i\rangle_2, \quad \hat{U}_{CNOT}|1\rangle_1|i\rangle_2 = |1\rangle_1|\perp i\rangle_2 \quad (6.92)$$

(where the symbol \perp_i means 'negation': $\perp 0 = 1$, $\perp 1 = 0$; generally CNOT *introduces quantum entanglement* in the states of the complex system 1+2).

A special kind of transformations in quantum computing are so-called *quantum 'black boxes'* (i.e. *quantum 'oracles'*) defined by

$$\hat{U}_f \sum_{i=1}^{2^N} C_i |\psi_i\rangle_1 |0\rangle_2 = \sum_{i=1}^{2^N} C_i |\psi_i\rangle_1 |f(i)\rangle_2 \quad (6.93)$$

where f denotes the desired *mapping* such that its result is *always either 0 or 1* (indices 0 and 1 in Eq. (6.92) refer generally to the case of *two strings of N bits each*, i.e. *two 'qubit registers'* in-between which quantum oracles act). Eq. (6.93) is *typical for the quantum theory of measurement*, which determines the way of oracle functioning.

Quantum computers can solve some *tasks practically unsolvable* by classical computers (however, what *in principle cannot be done by classical computers, it is not possible by quantum as well*). There are currently developed *quantum algorithms* that in comparison with classical give a *significant acceleration*, which can be divided into two groups:

- (a) *Non-exponential acceleration* (Grover (1997): *search data base*);
- (b) *Exponential acceleration* (Shor (1994): *factorization of large numbers*).

Exponential accelerations originate from 2^N -times faster quantum computers as compared to the classical ones, due to the quantum parallelism of Eq. (6.89) (so the time required to resolve the serious problems in the classical computer – which grows exponentially with the number of inputs – reduces on polynomial growth in the quantum (Schor) computer!).

Typical *quantum algorithms* are combination of the procedures:

- (1) *Preparation of states of both registers* (usually in states of 'computational basis');
- (2) *Hadamard transformation* (usually on qubits in both registers simultaneously);
- (3) *Quantum Fourier transformation* (usually in the first register, which converts coefficient in the development c_i into a constant $c_i e^{i\lambda_i}$, where new phase factors λ_i redefine interference of states);
- (4) *Application of quantum oracles* (there are quantum oracles (Grover) which do not require entangled states);
- (5) *Suitable quantum measurement* (only in one register, or its subsystem – but it is always the case of *collective measurements* of observables of the (sub)system as a whole, and not simultaneous measurements of observables of the individual qubits).

[The first *quantum methodical algorithm* of Deutch (1985) was 2 times faster than classical (1 instead of 2 oracles) – as a principal demonstration!]

In connection with quantum algorithms, there remain *open questions*:

- (a) New algorithms for classically difficult (first of all NP-complete) computation problems;
- (b) Universal vs. partial advantage of quantum computers (only some tasks?);
- (c) Does application of entangled states means the communication faster than light?
- (d) Physical realization of entangled systems for multi-partit systems (not only two-partit) like a system of identical fermions or bosons;
- (e) Is the entanglement of states necessary a factor in quantum algorithms (or it is only suitable for destructive interference and preparation of states of the system for suitable quantum measurement)?

One of the important practical issues in quantum computing is development of the *quantum error correction*: (a) due to *non-ideal unitary transformations* (logic gates) and *quantum measurements* (can be practically neglected(!)); and (b) due to *decoherence on qubits* i.e. qubit registers (*cannot be neglected(!)*), as decoherence leads to *destruction of quantum coherence*, which is the *essential basis of the quantum parallelism*, that *reduces quantum computing to the classic*:

$$|\psi\rangle = \sum_{i=1}^{2^N} C_i |\psi_i\rangle \rightarrow \hat{\rho} = \sum_{i=1}^{2^N} |C_i|^2 |\psi_i\rangle\langle\psi_i| \quad (6.94)$$

Hence *decoherence must be avoided 'at any price'(!)*, before the quantum measurement at the end of computation. In the fight against decoherence there are several approaches: (a) ECC (Error Correcting Codes – for the correction of errors caused by decoherence) (b) EAC (Error Avoiding Codes – for defining the subspace state of register invariant on interaction of register and environment) (c) DISD (Decoherence-induced Suppress of Decoherence – for suppression of decoherence on registers, inducing decoherence on the ‘bathroom’ by his environment).

The main task of *the practical realization of quantum computers* is the *implementation of qubits and logical gates* for universal quantum computation on a large number of qubits, which is only part of research programs in its infancy, on potentially different hardware:

- (a) *Optical hardware* (polarization of photons/qubit and optical logic gates – *most research claimed in the hope of this hardware!*);
- (b) *Rydberg states* (atoms in the quantum electromagnetic cavity, with ground and excited states/qubit);
- (c) *Quantum dots* (electrons in each of a series of quantum dots in condensed state feel the effect of potential well with two local minima of the same depth/qubit – *very perspective direction!*);
- (d) *Spintronics* (spins of ions/qubit in the condensed state, controlled by electric and magnetic field);
- (e) *Nuclear magnetic resonance* (NMR with nuclear spin/qubit – *small perspective!*).

Practical demands for quantum qubit computers are large, with little tolerance ($\sim 0.1\%$), which will require work at low temperatures ($\sim \mu\text{K}$, to eliminate thermal noise), as well as the high degree of isolation from the environment (to reduce the decoherence).

On the other hand, quantum-holographic neural networks in their work can use quantum decoherence not only for reading but also for computing (cf. Ch. 2), and are much robust and resistant on the above requirements – with possible work at room temperatures (as biological feedback cells/acupuncture system-consciousness/collective consciousness probably functions [1,15,17])!

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Excerpts from Reviews

... Author is dealing with the research and educational work in the fields of integrative biophysics, quantum medicine and quantum-holographic informatics for many years, and as a connoisseur of classical and quantum physics explains biophysical phenomena and provide arguments for the application of integrative biophysical diagnostic and therapeutic methods and techniques in medicine. Bearing in mind that contemporary research indicates the increasing presence of psychosomatic factors in the origin of many diseases, then the inclusion of psychological phenomena (consciousness, stress, etc.) oriented to the treatment of man as a whole and not of diseases as symptoms, represents a shift in the diagnosis and treatment of human health, in respect to the classical medicine. The book also makes a shift in the field of traditional medicine, as it provides a satisfactory explanation for the application of some traditional methods and techniques.

Outside common approaches to the existing scientific and scholarly literature, the focus of this new approach are quantum-holistic methods, in the first place the bodily acupuncture system and consciousness, which can be in Feynman propagator version of the Schrödinger equation interpreted as quantum-informational structures with the characteristics of quantum-holographic Hopfield associative neural networks. Biological structures that have properties of memory attractors of deterministic chaos, the author considers as possible quantum-holographic informational basis of psychosomatic states.

The monograph is of the multidisciplinary character and is primarily dedicated to open-minded physicians who practice classical and traditional medicine, to specialists and students of the postgraduate studies in biophysics and biomedical engineering, as well as to all those interested in the application of new scientific methods and techniques in medicine. The book is warmly recommended for printing, and to students of biophysics and biomedical engineering it is recommended as a mandatory literature ...

– Djuro Koruga

... This book is a very contemporary overview of new information, knowledge and explanation of the phenomena of the human mind, consciousness, and the whole psychosomatics. According to the structure and contents, it can be equally classified into a higher educational textbook, but also into a very advanced and specific (by issue and research approach) multidisciplinary (physics, biology, medicine, philosophy) scientific monograph.

The book offers a broader and deeper information about hot development of the biophysics of consciousness at the end of the 20th century and the beginning of the 21st century, which is not only of fundamental importance, but allows a wide implementation, from the genetic to biomedical engineering. In order to understand physics of living nature the whole tool of modern theoretical physics is used, in all levels: from molecular, via cellular and over-cellular, to bodily level, including the biosphere as a whole. Therefore, to help readers the appendices on quantum mechanics, quantum chemistry, and quantum informatics are added.

Generally speaking, before the readers is a unique book-monograph. The presented material can be used by students on master and doctoral studies, and it may serve very well to all professionals who are dealing with a human body. Naturally, this material is fairly good for all researchers of the phenomena related to the origin, state, and functioning of biological systems...

On the basis of examination and analysis carried out... bearing in mind that the author helped me to actively get into the field of studying phenomena related to the problems of biophysical functioning of organism as a whole ... I hereby sincerely recommend the book for printing, stressing that the publishers will thus get another strong and recognizable reference as leaders of holistic understanding of man...

– Jovan Šetrajčić

About the Author

Dejan Rakovic was born in 1951 in Belgrade. He graduated Engineering Physics at the Faculty of Electrical Engineering in Belgrade, got a M.S. degree and Ph.D. in theoretical physics at the Faculty of Science, University of Belgrade. He is Professor at the Faculty of Electrical Engineering in Belgrade, where he held numerous primary and post-graduate courses in physics and materials science, biophysics and biomaterials, quantum solid state theory and quantum informatics, and as (co)author published over ten textbooks in Serbian from University to High-school level (among them, *Materials Science & Engineering*; *Advanced Materials & Engineering*; *Fundamentals of Biophysics*; *Biomaterials*). He was heading Department of Materials Science & Engineering in several electoral mandates, and now is heading graduate Biomedical and Environmental Engineering Curriculum. His research interests cover the fields of nanomaterials and biomaterials, nanotechnology and spectroscopy, as well as biophysics and bioinformatics of cognitive, psychosomatic and electrophysiological functions. He co-edited the seven books in the journal *Materials Science Forum* published by Trans Tech Publications (Vols. 282-283, 352, 413, 453-454, 494, 518, 555); co-edited the five books published by the *European Centre for Peace and Development (ECPD) of the United Nations University for Peace* in Belgrade (among them, *Consciousness: Scientific Challenge of the 21st Century*; *Brain and Consciousness, Workshop & Symposium*); he is Co-founder and President-elect of the Governing Board of *International Anti-Stress Center (IASC)* in Belgrade with a broad educational holistic anti-stress activities (and co-author of the book in Serbian, *Anti-stress Holistic Handbook: With Fundamentals of Acupuncture, Microwave Resonant Therapy, Relaxational Massage, Airoionotherapy, Autogenic Training, and Consciousness*); he also co-edited a few more books in Serbian (*Science - Religion - Society*; *Speech & Language*; *Religion & Epistemology*; *Recollections, Dreams, Thoughts: About Past and Future 1984-2007*, *On Crossway of Quantum-Holographic and Classically-Reduced Reality*; *Integrative Biophysics*, *Quantum Medicine*, and *Quantum-Holographic Informatics: Psychosomatic-Cognitive Implications*). He published about two hundred scientific papers and communications, cited over two hundred times in the scientific periodicals and held numerous invited lectures in the country and abroad.

