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The intracellular interaction of biomolecules by means of emission and resonance of infrared photons. A hypothesis.

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Abstract

The diversity of biological processes in the cell, which often occur in parallel, requires very good temporal and spatial coordination. In addition to the very extensively studied intracellular chemical signalling, a comprehensive physical information system appears to be required. The hypothesis is presented that the thermally induced vibration and photon emission of the biomolecules is the basis of such an information system. The electromagnetic ultra-weak radiation exactly reflects the chemical structure of the emitting molecule. Under specific conditions, it is partially coherent and can then activate other molecules through resonance. Aspects of emission and resonance are discussed in detail. The hypothesis is demonstrated using the example of communication between the cell periphery with the Golgi apparatus, the signal transduction pathways and intranuclear transcription.

Keywords: intracellular Signaling, molecular Vibration, Signal Transduction, ultraweak Photon-Emission, Golgi Apparatus ,Transcription ,Transcription Error

Introduction

In every cell of a living organism, numerous chemical processes are constantly taking place that require intensive temporal and spatial coordination.The majority of biochemical reactions and important intracellular information processes on a biochemical basis have been excellently investigated (1,2,)In contrast, the innumerable necessary feedbacks, signal amplifications and cross-links in intracellular signal transduction are only incompletely investigated. It is not conceivable that these multifaceted intermolecular relationships only take place by means of chemical ligands or reactants through direct contact with the target molecules, whereby the reactants reach the contact through diffusion. However, it is quite conceivable that a physical intramolecular information system exists that complements the chemical information system studied in detail and enables the comprehensive networking ofthe various reactions. The basis of such an information system, which includes all moleculesof a living cell, could be molecular vibration and the photon emission associated with it. Endogenous electrical and electromagnetic phenomena in connection with biochemical processes have been investigated in many ways (3-13.), but molecular vibration as a possible basis of such an information system has not yet been fully discussed. In several articles we have developed a hypothesis of such an intramolecular signalling system on thebasis of photon emission and reception and discussed it using the example of communication between the Golgi apparatus and the cell periphery as well as intracellular signal transduction pathways.(14-18)

In the following, these publications will be reviewed, clarified in some aspects and processesof transcription, including error correction, will be discussed using this hypothesis. Above the absolute 0 point, all molecules oscillate. The characteristics of molecular vibrations have been extensively studied in the context of spectroscopy (19-22.) and some aspects of spectroscopic theory are presented below.

The molecular vibration

The oscillation is explained by the oscillation model of small mass particles which are elastically connected (19.). Even a two-atomic system oscillates in different axes and at different frequencies, which depend on the type of atoms and the bond and are sinusoidal. In polyatomic systems, there are numerous other possibilities according to the molecular structure. If the frequencies are different, they remain separate from each other; if they are

similar, they can couple and possibly form a new frequency. The number of different vibrational frequencies in non-linear macromolecules with n atoms is 3n-6. Atomic groups ina molecule that are not vibrationally coupled have in any molecule about the same frequencies. Atomic groups containing heteroatoms in specific bonds, so-called functional groups, have correspondingly specific frequency patterns (19-23). The overall frequency pattern of a molecule thus accurately reflects the structure of the molecule and is thus directly related to its function. The recognition of functional groups based on their vibration frequency is the basis of spectral analysis.

Electromagnetic radiation of biomolecules

The oscillation produces a specific electromagnetic radiation whose strength is temperature-dependent and whose frequency spectrum reflects the chemical structure of the molecule(19).

According to the dualism of radiation, it consists of photons whose energy differs by an exact number of quanta. The absorption of thermal energy results in an activation of the atoms by raising the electrons to a higher energy level. Photons are created by the decay ofthe exited state to a lower electronic state of the atoms. Each biomolecule thus constantly generates a photon stream with a constant frequency pattern. This frequency pattern is composed of the egg frequencies of the atoms. (24-26) The frequency of the individual photons is between 10^{13}-10^{15}Hz, their speed about $3x10^{8}$ m/s in vacuum (speed of light).Theoscillation plane and phase are random (incoherent), as long as there are no additional influences on the molecular groups that force or support the oscillation in the same phase (coherent emission).(24-26) The sum of the photons represents the thermal radiation.

Chemical reactions and crystal structures can lead to coherent emissions.

Photon absorption through resonance

If photons meet molecules that have atomic groups with the same oscillation frequency of sufficient energy and an identical oscillation plane in opposite phase, they are absorbed by resonance. The molecule reaches a higher energy state due to the energy absorption. This can cause a chemical change in the molecule, for example a conformational change, or thehigher energy state relaxes back by emitting photons. (27)

Conformational changes of the molecule can lead to functional changes, for example, to the

activation of enzymes or transport proteins or to a change in the polarity of the molecule. Cosic and co-workers (28) have investigated the interaction of protein-protein and protein-DNA. They were able to show that proteins resonate at frequencies in the range of 10^{13}-10^{15}Hz vibration patterns of macromolecules of different types can interact with certain proteins if parts of their vibration patterns match. Cosic et al. (28,29) experimentally demonstrated that proteins with the same or similar function share some common frequencies, needing for function of that specific target protein. There are dominant frequencies in the frequency pattern and a complete match is not required for activation. Theenormous number of molecules in a cell, all of which constantly emit a photon stream of different frequency in different phase and polarity, cause an electromagnetic background noise of the cell (29,30)

Coherence of photons

A cell consists of an enormous number of different molecules that constantly emit numerous photons of different frequency, phase and polarity at the temperature typical of the cell. A signal should emerge from this background in order to be utilised. In principle, the energy ofa photon is not sufficient to cause a conformational change in a molecule. The energy of a photon in the IR-range amounts to (1-4)x10^{-19}J.(31,32) A conformational change of a macromolecule of the cell involves the dissolution of dipole bonds, hydrogen bonds and different van der Wahls forces and the change of the stereoisomerism of a part of the molecule. The energy required for this is different for each molecule. The binding energy of the very soft dipole-dipole bond is about (0,1-10) x10^{-19}J, that of the hydrogen bond is tenfold higher, the energy differences of the stereoisomers of the structural very simple cyclohexaneare more than 5x10^{-19}J. (32). From this it can be deduced that a substantial number of coherent photons is required to produce a conformational change in a molecule and to put the molecule into an activated state8 (33,34). The coherence of the absorbed photons is thus an important condition. At the same time, this ensures that no random activations of enzymes or other unwanted activations of molecules occur.

Protein phosphorylation and signal transduction

Phosphorylation plays a central role in most signal transduction steps. Many signal transduction steps are associated with the activation of a specific kinase, which leads to the

phosphorylation of the protein. (35-39) The coherent photon current thus not only transfers the specific signal to the acceptor molecule, but also activates the specific kinase at the same time. The phosphorylation catalysed by this kinase provides part of the energy for the conformational change in the resonating part of the molecule. This activation enables the emission of the partially coherent photon stream with which the signal is transduced, and the corresponding kinase of the following transducer protein is activated. There are probably different variants of the processing of the recorded signal: A longer existing conformational change of a molecule is useful for the activation of an enzyme and will take place where it is required according to the signalling. However, most transduction steps are only intermediate steps and the protein involved must quickly return to its original state. This means that the energy absorption leads to the activation of a group of atoms in the resonating molecule, which return to their initial state after photon radiation and thus signaltransmission.

Coherence and quasicrystalline structure of water

Maintaining the coherence of the emitted photons to the next target protein is important. Chaotic water structures (bulk water) would cancel out the coherence. However, the water molecules are predominantly present in a quasicrystalline structure, caused by the charge of the membranes and the charge of the macromolecule (40-44.). The charge of a protein continues in the dipole order of up to approx. 10 water layers. Due to the relatively high concentration of such charged molecules, the proportion of bulk water in the cell is low.

Photons and membranes of the cell

The cell itself, the nucleus and the mitochondria are delimited by membranes whose micellar structure of polar lipids and proteins generates a permanent charge. It is likely that the coherence of the photons is cancelled out during passage. The membrane acts like a Faraday cage. (10) This means that neighbouring cells cannot be affected randomly and intracellularly the signalling effects are equally spatially confined to the organelle in question.Some organelles have membranes that are not closed, such as the Golgi apparatus or the microtubule system. Here, the passage of coherent photons is possible and functionally necessary.

The intracellular Signal Transduction Pathways

Numerous endogenous and exogenous substances that send signals into the cell dock to specific receptors on the cell membrane, are introduced into the cell with these receptors or remain bound to the receptor and emit specific signals into the cell. These signals are transmitted via a chain or network of specific proteins to the nucleus and special cell organelles in order to induce metabolic and genetic effects there. The primary step is the binding to the extracellular part of the respective membrane receptor, which leads to a conformational change of the intracellular part of the receptor. This change causes an affinity change of the molecule towards a specific messenger molecule and thus the prerequisite for chemical signal transduction. Many chemical signal transduction steps are well studied.(1,2,10). However, if they were the sole basis of signal transduction, temporal aspects, signal amplification, coordination and feedback mechanisms would be difficult to explain. Physical signal transduction is thus very likely for parts of the network.

The majority of protein-to-protein signal transductions involve a phosphorylation step (36-39).This provides the necessary energy for both a chemical reaction and coherent photon emission. Some of the proteins involved are interconnected and enable direct signal transmission. However, the number of proteins are separated by several water molecules. The versatile feedback and cross-linking required in the network, coupled with amplificationof the signal, makes it likely that photon-based signal transduction will predominate. The required energy is provided by accompanying phospholysis-reactions. Activation of the specific kinase occurs together with the reception of the coherent photon stream. Details ofthis hypothesis are presented in the articles. (16,17.)

Communication between Golgi apparatus and cell periphery

The macromolecules formed in the Endoplasmic Reticulum are stored in the Golgi apparatusand finalised as required, provided with signalling and transport proteins and transported as transport vehicles via the microtubule system to the site of need (15). Molecules that are intended for secretion are fused with the cell membrane and secreted into the extracellular space. However, many macromolecules of the membrane, cytoplasm and organelles need to be replaced because they have been altered by synthesis, oxidation or other chemical reactions. During this process, an altered infrared photon flux is emitted from the affected molecules, which is partially coherent due to the chemical reaction and the molecule activation caused by

it. The coherence is maintained by the quasicrystalline structure of thesurrounding water. This photon stream is conducted via the skeleton-microtubules system or the signal transduction pathway system to the Golgi apparatus. There it is absorbed by an enzyme responsible for the final processing of the molecule to be replaced, based on the frequency pattern. This activates the enzyme and initiates the chain of reactions leading to the replacement of the molecule, including navigation and directed transport to the site of demand. Details are described in articles (14,15).

Signalling in the nucleus

The question should be discussed whether the hypothesis is suitable for answering open questions of genetic transcription, including the mechanisms of error correction,

All cells of eukaryotes have a nucleus and signals, which often come from the cell periphery, control the transcription mechanisms in this nucleus. When a specific protein is required, these signals must reach the specific enzymes that initiate transcription and start the process at the specific gene.

The signal crosses the cytoplasm by means of the signal transduction pathway network. Link proteins are responsible for the passage through the nucleus envelope and the incoming signal leads to a conformational change of the link protein in the intranuclear part of the molecule. Photon emission and resonance activate the specific RNA polymerase and induce the formation of the preinitiation complex by means of the corresponding transcription factors. This enzyme complex docks with the promoter of the specific gene and initiates transcription. (47-49) The energy of each transduction step is provided by phosphorylation processes, as in the processes in the cytoplasm. The subsequent complicated process of transcription is well studied (47-49). Process control with the help of signalling by photon emission and resonance seems conceivable in principle.

It is more difficult to explain the signalling mechanisms in the correction of errors that occur during transcription with the help of the photon emission and resonance hypothesis. The triggering signal is the transcription error. However, that can be very different. Correspondingly, the emitted photon pattern generated by the error-hidden mRNA sequence is different (49), However, the same enzyme complex is often activated, which recognises this faulty RNA sequence and initiates their elimination. This means that very different photon patterns activate the same enzyme system. However, this is not in accordance with the

hypothesis. Possibly, the two DNA strands separated from each other during transcription, together with the transcription error in the developing RNA strand, generate the signal for enzyme activation or entanglement of the affected molecule parts plays a role. However, such mechanism needs separate intensive consideration.

The following steps of error correction probably take place with the help of specific programmes in which the individual steps and feedback mechanisms are induced and controlled by photon emission and resonance, which would be in good agreement with the hypothesis.

Discussion

In addition to the well-studied chemical signalling, a physical signal-transduction system seems to be required for many intramolecular processes.

At the temperature of life, macromolecules emit a photon flux in the IR frequency range that reflects the structure of the molecule. Under specific conditions, this photon flux is partially coherent. The hypothesis presented is based on the assumption that coherent photons of sufficient energy can lead to an activation of the receiver molecule through resonance. The resonating atoms in the molecule can also emit a coherent photon stream when returning tothe ground state. That enables the signal to be passed on to the following transduction molecules, or a conformational change in the receiver molecule occurs through additional energy supply with the help of protein phosphorylation and thus to enzyme activation or activation of transport processes.

The principal possibility that light, i.e. electromagnetic energy, can produce molecular conformational changes has been confirmed many times by studies of the visual process (50, 51). Photons hitting the rhodopsin anchored in the cell membrane with sufficient energy and suitable frequency lead to the conformational change of the rhodopsin-retinal complex of the eye. Intracellularly, the conformational change enables the binding of the G-protein to the complex and induces signal transduction, which immediately results in a strong amplification of the signal.

In the olfactory process, the primary conformational change of the receptor molecule throughthe chemical binding of the odorant to the extracellular part of the receptor is the primary process (52), although another theory is also being discussed. This theory assumes that the signal is

triggered by resonance of the photon pattern of the odorant in the receptor molecule (53, 54).

The principle of chemical binding of a ligand to a specific receptor on the cell membrane and the subsequent conformational change of the intramolecular part of the receptor is generallythe operating principle of the first step of signal transduction into the cell (55-58). For example, in the insulin signal transduction network, it is the primary step. In the very branched network, signal transduction is well studied. It can be assumed that it is partly physical. If the molecules are directly connected to each other, the signal is likely to be directly propagated. However, the many branches in the network and the amplification of theinsulin signal make it likely that a large part of the transmission takes place through the emission and reception of coherent photon patterns. Probably, as in many other intracellular information processes, chemical and physical transduction mechanisms coexist here. The majority of transduction steps involve protein phosphorylation (55,56), with some transduction molecules having kinase properties that are directly activated during signal transduction, or the transduction molecules are directly linked to specific phosphokinases. (56-58.) For example, the insulin receptor is a phosphokinase. Phosphorylation by kinases and dephosphorylation by phosphatases occur at high speed.

The question of how the hypothesis formulated here fits into previous knowledge of signal transduction in the cell is discussed as follows:

The chemically dominated signalling with all its components is supplemented by the physical signal transduction system. Some transduction steps are determined exclusively by chemical processes, such as the action of ion channels, the G protein coupled reactions, the second messenger dependent transduction steps. In other steps, the physical interaction shown is the sole mechanism, e.g. within the map cascade.

In chemical technology, electromagnetic energy is used to carry out reactions.

With the help of sufficient energy of specific wavelengths, many chemical reactions can be carried out e.g. by means of lasers (59, 60).

Infrared fingerprint patterns of different macromolecules have been used relatively rarely in biological research.

In pharmaceutical research, for example, molecular vibration patterns and their photon patterns have been successfully used to distinguish agonists and antagonists for adenosine receptors (61, 62).

Proteins with the same function have identical proportions in their molecular frequency patterns (29). The differentiation of stem cells into osteoblasts is triggered by light of specific wavelength according to Cosic et al. (24). It was shown in cell cultures that there is a direct correlation between chemical changes in the cell and specific photon emission (64) Ultraweak infrared frequency patterns have been used to differentiate dead and living cells in cell cultures (32) . With the help of the ultraweak photon pattern, malignant cancer cells can be detected,and this finding could become significant for clinical diagnostics (63, 64). While mitosis and apoptosis are based on fixed programmes, it is likely that the necessary feedback (66) is provided by physical information systems as described.

Conclusions

The presented hypothesis explains the interaction of biomolecules over intracellular distances. It could also be the basis for better understanding the communication between cells and the extracellular matrix and between cells themselves. The hypothesis has to be proven experimentally and could then be the basis for revealing pathogenetic mechanisms and their therapeutic influence. It is very likely that the application of quantum physics in biology and medicine will provide many new insights in the future.

References

[1] Cooper GM. The Cell: A Molecular Approach. 2nd edition. Sunderland (MA): Sinauer Associates; (2000). Pathways of Intracellular Signal Transduction. Available from: https://www.ncbi.nlm.nih.gov/books/NBK9870/

[2] Alberts B, Johnson A, Lewis J, Morgan D, Raff M, Roberts K, et al.Molecular Biology of the Cell, Wilson J, Hunt t , editors . Norton § Company;,2017 DOI 10.120179781315735368

[3] M. Levin: Molecular bioelectricity in developmental biology: new tools and recent discoveries: control of cell behavior and pattern formation by transmembrane potential gradients. Bioessays, 34(3), 205-17 (2012) DOI: 10.1002/bies.201100136

[4] N. Rouleau and B. T. Dotta: Electromagnetic fields as structure-function zeitgebers in biological systems: environmental orchestrations of morphogenesis and consciousness. Front Integr Neurosci, 8, 84 (2014) DOI: 10.3389/fnint.2014.00084

[5] M. Lemeshko, R. V. Krems, J. M. Doyle and S. Kais: Manipulation of molecules with electromagnetic fields. Molecular Physics, 111(12-13), 1648-1682 (2013)DOI: 10.1080/00268976.2013.813595

[6] B. T. Chernet and M. Levin: Transmembrane voltage potential is an essential cellular parameter for the detection and control of tumor development in a Xenopus model. Dis Model Mech, 6(3), 595-607 (2013)DOI: 10.1242/dmm.010835

[7] Kobayashi, M. Takeda, T. Sato, Y. Yamazaki, K. Kaneko, K. Ito, H. Kato and H. Inaba: In vivo imaging of spontaneous ultraweak photon emission from a rat's brain correlated with cerebral energy metabolism and oxidative stress. Neurosci Res, 34(2), 103-13 (1999) DOI: 10.1016/s0168-0102(99)00040-1

[8] R. Nuccitelli: Endogenous electric fields in embryos during development, regeneration and wound healing. Radiat Prot Dosimetry, 106(48), 375-83 (2003) DOI:10.1093/oxfordjournals.rpd.a0063

[9] R. H. Funk: Endogenous electric fields as guiding cue for cell migration. Front Physiol, 6, 143 (2015) DOI: 10.3389/fphys.2015.00143

[10] R. H.. Funk:Biophysical mechanisms complementing “classical” cell biology (2018)Frontiers in Bioscience 23(5),921-39 (2018) DOI: 10.2741/4625

[11] A. Foletti, S. Grimaldi, A. Lisi, M. Ledda and A. R. Liboff: Bioelectromagnetic medicine: the role of resonance signaling. Electromagn Biol Med, 32(4), 484-99 (2013) DOI: 10.3109/15368378.2012.743908

[12] A. Foletti, M. Ledda, S. Grimaldi, E. D'Emilia, L. Giuliani, A. Liboff and A. Lisi: The trail from quantum electro dynamics to informative medicine. Electromagn Biol Med, 34(2), 147-50 (2015) DOI: 10.3109/15368378.2015.1036073

[13] A. De Ninno and M. Pregnolato: Electromagnetic homeostasis and the role of low-amplitude electromagnetic fields on life organization. Electromagn Biol Med, 36(2), 115-122 (2017)DOI: 10...1080/15368378.2016.1194293

[14] Jaross W. Communication of the cell periphery with the Golgi Apparatus: A Hypothesis.

[15] Jaross W . Hypothesis on interactions of macromoleculesbased molecular vibraion patterns in cells and tissues. Frontiers in Bioscience. 2018;23(3):940-6 DOI: 10.2741/4626

[16] Jaross .W.The Possible Role of Molecular Vibration in Intracellular Signaling. J Cell Signal.2020 ;1(4) 180-6 DOI = {10.33696/signaling.1.027},

[17] Jaross W. Discussion on the Possible Role of Molecular Vibration in Intracellular Signalling. Current Advances in Chemistry and Biochemistry Vol 3 [Internet]. Book

Publisher International (a part of SCIENCEDOMAIN International); 2021 Mar 4;68– 76. : doi = {10.9734/bpi/cacb/v3/7722d},

[18] Jaross, W. (2016). Are Molecular Vibration Patterns of Cell Structural Elements Used for Intracellular Signalling? The Open Biochemistry Journal, 10(1), 12–16. DOI:10.2174/1874091x01610010012

[19] M. J. Pelletier and C. C. Pelletier: Spectroscopic Theory for Chemical Imaging. In: Raman, Infrared, and Near-Infrared Chemical Imaging. John Wiley & Sons, Inc., (2010)DOI: 10.1002/9780470768150.ch1

[20] R. W. Brown, Y. C. Cheng, E. M. Haacke, M. R. Thompson and R. Venkatesan: Electromagnetic Principles. In: Magnetic Resonance Imaging. John Wiley & Sons Ltd, (2014)DOI: 10.1002/9781118633953.app1

[21] G. Steiner and C. Zimmerer: IV. Infrared and Raman Spectra: Datasheet from Landolt-Börnstein - Group VIII Advanced Materials and Technologies · Volume 6A1: "Polymer Solids and Polymer Melts – Definitions and Physical Properties I" in SpringerMaterials (http://dx.doi.org/10.1007/978-3-642-32072-9_22). In: Ed K. F. Arndt&M. D. Lechner. Springer-Verlag Berlin Heidelberg, (2013)DOI: 10.1007/978-3-642-32072-9_22

[22] Z. Movasaghi, S. Rehman and D. I. ur Rehmann: Fourier Transform Infrared (FTIR) Spectroscopy of Biological Tissues. Applied Spectroscopy Rev, 43(2), 134-179 (2008)DOI: 10.1080/05704920701829043

[23] XX Atom-Photon-Wechselwirkungen: Absorption, Emission, Streuung. (2020). Fermionen, Bosonen, Photonen, Korrelationen Und Verschränkung, 2127–2161. DOI:10.1515/9783110649130-026

[24] M. Cifra and P. Pospisil: Ultra-weak photon emission from biological samples: definition, mechanisms, properties, detection and applications. J Photochem Photobiol B, 139, 2-10 (2014)DOI: 10.1016/j.jphotobiol.2014.02.009

[25] A. Rastogi and P. Pospisil: Spontaneous ultraweak photon emission imaging of oxidative metabolic processes in human skin: effect of molecular oxygen and antioxidant defense system. J Biomed Opt, 16(9), 096005 (2011) DOI: 10.1117/1.3616135

[26] I. Cosic, D. Cosic and K. Lazar: Environmental Light and Its Relationship with Electromagnetic Resonances of Biomolecular Interactions, as Predicted by the Resonant Recognition Model. Int J Environ Res Public Health, 13(7) (2016) DOI: 10.3390/ijerph13070647

[27] I. Cosic: Macromolecular bioactivity: is it resonant interaction between macromolecules?--Theory and applications(2013) Trans Biomed Eng, 41(12), 1101-14 (1994)DOI: 10.1109/10.335859

[28] I. Cosic, D. Cosic and K. Lazar: Is it possible to predict electromagnetic resonances in proteins, DNA and RNA? EPJ Nonlinear Biomedical Physics, 3(1), 5 (2015)DOI: 10.1140/epjnbp/s40366-015-0020-6

[29] I. Cosic, E. Pirogova, V. Vojisavljevic and Q. Fang: Electromagnetic properties of Biomolecules.(2006) FME Transactions, 34, 71-801

[30] O. Kucera and M. Cifra: Cell-to-cell signaling through light: just a ghost of chance? Cell Commun Signal, (2013) 11, 87 DOI: 10.1186/1478-811X-11-87

[31] D. Havelka, M. Cifra and O. Kucera: Multi-mode electro-mechanical vibrations of a microtubule: In silico demonstration of electricv pulse moving along a microtubule. (2014) Appl Phys Lett, 104(24), 243702 DOI: 10.1063/1.48841180

[32] Murugan NJ, Karbowski LM, Persinger MA. Cosic‘s Resonance Recognition Model for Protein Sequences and Photon Emission Differentiates Lethal and Non-Lethal Ebola Strains: Implications for Treatment. Open Journal of Biophysics. 2015;05(01):35- 43.DOI: 10.4236/ojbiphy.2015.51003

[33] IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxfordx .

[34] Electronic and Vibrational Molecular States. Charge and Energy Transfer Dynamics in Molecular Systems [Internet]. Wiley-VCH Verlag GmbH & Co. KGaA; 2011 Feb 25;9–66. Available from: http://dx.doi.org/10.1002/9783527633791.ch2

[35] Goffin, V., & Kelly, P. A. (2002). Protein Phosphorylation and Protein-Protein Interactions. Endocrine Updates, 3–19. DOI:10.1007/978-1-4757-3600-7_1

[36] Ghelis, T. (2011). Signal processing by protein tyrosine phosphorylation in plants. Plant Signaling & Behavior, 6(7), 942–951. DOI:10.4161/psb.6.7.15261

[37] Hunter, T. (1995). Protein kinases and phosphatases: The Yin and Yang of protein phosphorylation and signaling. Cell, 80(2), 225–236. DOI:10.1016/0092-8674(95)90405-0

[38] Fischer, E. H., Zander, N. F., Lorenzen, J., Dadabay, C., & Cool, D. E. (1993). Protein Tyrosine Phosphorylation-Dephosphorylation and Cell Signaling. Tyrosine Phosphorylation/Dephosphorylation and Downstream Signalling, 3–9. DDOI: 10.4236/ojbiphy.2015.51003 OI:10.1007/978-3-642-78247-3_1

[39] Ardito, F., Giuliani, M., Perrone, D., Troiano, G., & Muzio, L. L. (2017). The crucial role of protein phosphorylation in cell signaling and its use as targeted therapy (Review). International Journal of Molecular Medicine, 40(2), 271–280. DOI:10.3892/ijmm.2017.3036

[40] A. De Ninno and M. Pregnolato: Electromagnetic homeostasis and the role of low-amplitude electromagnetic fields on life organization. Electromagn Biol Med, 36(2), 115-122 (2017) DOI: 10.1080/15368378.2016.1194293

[41] De Ninno, A., & Castellano, A. C. (2011). Effect of Coordination of Molecules on the Properties of Water as Solvent. Key Engineering Materials, 495, 347–350. DOI:10.4028/www.scientific.net/kem.495.347

[42] De Ninno, A., & De Francesco, M. (2020). An equation for the isosbestic point wavelength in aqueous solutions of electrolytes. Journal of Molecular Structure, 1200, 127125. DOI:10.1016/j.molstruc.2019.127125

[43] De Ninno, A. (2017). Dynamics of formation of the Exclusion Zone near hydrophilic surfaces. Chemical Physics Letters, 667, 322–326. DOI:10.1016/j.cplett.2016.11.015

[44] Hwang, S. G., Hong, J. K., Sharma, A., Pollack, G. H., & Bahng, G. (2018). Exclusion zone and heterogeneous water structure at ambient temperature. PLOS ONE, 13(4), e0195057. DOI:10.1371/journal.pone.0195057

[45] Ardito, F., Giuliani, M., Perrone, D., Troiano, G., & Muzio, L. L. (2017). The crucial role of protein phosphorylation in cell signaling and its use as targeted therapy (Review). International Journal of Molecular Medicine, 40(2), 271–280. DOI:10.3892/ijmm.2017.3036

[46] Eukaryotic Transcription. (n.d.). Transcription, 71–84. DOI:10.4324/9780203166314_chapter_6

[47] Transcription initiation sequence (transcription initiator sequence;initiator, Inr; initiator element; initiator box, transcription initiation site, mRNA initiation site, transcription start site, cap site). (2015). The Dictionary of Genomics, Transcriptomics and Proteomics, 1–1. doi:10.1002/9783527678679.dg13524

[48] Zuo, Y., & Steitz, T. A. (2016). A structure-based kinetic model of transcription. Transcription, 8(1), 1–8. DOI:10.1080/21541264.2016.1234821

[49] Error in Transcription. (2008). Encyclopedia of Genetics, Genomics, Proteomics and Informatics, 630–631. DOI:10.1007/978-1-4020-6754-9_5523

[50] Standfuss, J., Edwards, P. C., D'Antona, A., Fransen, M., Xie, G., Oprian, D. D., & Schertler, G. F. X. (2011). The structural basis of agonist-induced activation in constitutively active rhodopsin. Nature, 471(7340), 656–660. DOI:10.1038/nature09795

[51] Palczewski K. (2012). Chemistry and biology of vision. The Journal of biological chemistry, 287(3), 1612–1619. https://doi.org/10.1074/jbc.R111.301150

[52] Branigan B, Tadi P. Physiology, Olfactory. [Updated 2021 May 9]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK542239/

[53] Hoehn RD, Nichols DE, Neven H and Kais S (2018) Status of the Vibrational Theory of Olfaction. Front. Phys. 6:25. DOI: 10.3389/fphy.2018.00025

[54] Lloyd S.(2011) Quantum coherence in biological systems. Journal of Physics: Conference Series,302: 012037. DOI.org/10.1088/1742-6596/3021/012037

[55] IJsbrand M. Kramer, Chapter 16 - Signaling through the Insulin Receptor: Phosphoinositide 3-Kinases and AKT, Editor(s): IJsbrand M. Kramer, Signal Transduction (Third Edition), Academic Press, 2016, Pages 849-886, ISBN 9780123948038, https://doi.org/10.1016/B978-0-12-394803-8.00016-4.

[56] Saltiel AR, Pessin JE. Insulin signaling pathways in time and space. Trends Cell Biol. 2002 Feb;12(2):65-71. DOI: 10.1016/s0962-8924(01)02207-3. PMID: 11849969.

[57] White MF, Insulin Signaling in Health and Disease Science • 2003 • Vol 302, Issue 5651 • pp. 1710-1711 • DOI: 10.1126/science.1092952

[58] Draznin, B. (2006). Molecular Mechanisms of Insulin Resistance: Serine Phosphorylation of Insulin Receptor Substrate-1 and Increased Expression of p85 : The Two Sides of a Coin. Diabetes, 55(8), 2392–2397. DOI:10.2337/db06-0391

[59] J T Knudtson, E M Eyring.(1974) Laser-Induced Chemical Reactions .Annual Review of Physical Chemistry 25:255-274 https://doi.org/10.1146/annurev.pc.25.100174.001351

[60] Córdova, M. O. N., Ramírez, C. I. F., Bejarano, B. V., Razo, G. A. A., Flores, F. J. P., Tellez, V. C., & Ruvalcaba, R. M. (2011). Comparative Study Using Different Infrared Zones of the Solventless Activation of Organic Reactions. International Journal of Molecular Sciences, 12(doi:10.1038/nature07050 . 12), 8575–8580. DOI:10.3390/ijms12128575

[61] Chee, H. K., & Oh, S. J. (2013). Molecular Vibration-Activity Relationship in the Agonism of Adenosine Receptors. Genomics & Informatics, 11(4), 282. DOI:10.5808/gi.2013.11.4.282

[62] Chee, H. K., Yang, J.-S., Joung, J.-G., Zhang, B.-T., & Oh, S. J. (2015). Characteristic molecular vibrations of adenosine receptor ligands. FEBS Letters, 589(4), 548–552. DOI:10.1016/j.febslet.2015.01.024

[63] Murugan, N. J., Persinger, M. A., Karbowski, L. M., & Dotta, B. T. (2020). Ultraweak Photon Emissions as a Non-Invasive, Early-Malignancy Detection Tool: An In Vitro and In Vivo Study. Cancers, 12(4), 1001.DOI:10.3390/cancers12041001

[64] Dotta BT. Ultra-weak Photon Emissions Differentiate Malignant Cells from Non-Malignant Cells In Vitro. Archives of Cancer Res,1.Cooper GM. The Cell: A Molecular Approach. 2nd edition. Sunderland (MA): Sinauer Associates; (2000). Pathways of Intracellular Signal Transduction. Available from: https://www.ncbi.nlm.nih.gov/books/NBK9870/ 4(2) (2016)DOI: 10.21767/2254-6081.100085 4(2) (2016)

[65] Santos, S.D.M.; Ferrell, J.E. (2008), "On the cell cycle and its switches", Nature, 454 (7202): 288–9,DOI:10.1038/454288a

[66] Holt L. J.; Krutchinsky A. N.; et al. (2008). "Positive feedback sharpens the anaphase switch". Nature. 454 (7202): 353–357. Bibcode:2008Natur.454..353H. DOI:10.1038/nature07050