DNA may store information with base pair and communicate by UV

DU Lin

(Zhongkai University of Agriculture and Engineering, Guangzhou 510225, China)
Email: dulin2000@163.com

Abstract: In this paper,UV is suggested to be a medium of the information transmission in DNA. DNA bases can certainly absorb UV. They also have a typical structure to emit UV. And the stacking way of base pairs in DNA can accelerate the luminescence efficiency. Electrical signaling information from UV could be stored in base pair, in ways such as change of π conjugated electrons. The evaluation and calculation of information in DNA may base on quantum effect of π conjugated electrons and photon entangling. A hypothesis about origin of this UV communication and origin of life is also proposed here, which involve in the irradiation of the circular polarization light and self-organization of aromatic N-heterocycles.The hypotheses can explain some biological phenomena.

Key words: DNA base; UV absorption and emission; information storage; quantum computation; life origin

0 Introduction

Presently, biochemical process in cell is assumed to be based on direct interactions of molecules. While the molecules or ions are closed enough, charges or parts of molecular are transferred and biochemical process react.

In order to cooperate properly, instant communication or signal transition is very important, especially in a highly sophisticated system. So, in cell, information calculation and information transition may be essential.

Ultra-weak photon emission (UPE) and non-chemical distant interactions (NCDI) in organism was initially studied tens of years ago [1] [2] [3].To human individual, visible light is the main way to get information instantly from surrounding environment. But visible light cannot work well to transmit signal in cells because of obstacles such as noisy background [4].

The UV light of 230 -280 nm (UV- C) is almost completely absorbed by the ozone layer, and the ability of UV to trans-pass cell is weak. So inside the cell there is almost no outside interference in the wavelength spectrum less than 300nm. Although it is well known that light in the near-UV region(around 250-300nm) can be absorbed by purine and pyrimidine bases in nucleic acids and then result structure damage of DNA, a much lower level of UV should not be harmful. But, do the nucleic acids absorb and emit UV, and store information? Can the information be recorded, received and send out with purine and pyrimidine base pairs? How does the cell communicate in the intracellular space with UV and evaluate the information in UV?

1 DNA bases may absorb UV, emit UV, and store signaling information from UV

For information transfer, there should be three physical elements: the emitters, the medium and the receivers. Some specialties of DNA structure can be explained by the necessity of UV absorption and emission.

1.1 DNA has an obvious absorption of UV light

Usually, only chemicals which can absorb visible light or UV possibly emit fluorescent light. Most small molecular chemical groups absorb waves in the far UV region. Light in the near-UV region (around 250-300nm) is mainly absorbed by aromatic group, or by the purine (A, G) and pyrimidine (U, C, T) bases of nucleic acids. DNA and RNA have strong absorbency to 260-270nm UV, because of the π-π* transition in the purine and pyrimidine rings [5]. From the view of fluorescence chemistry, the chemicals absorb UV light probably be chromophores and emit photons with a longer wavelength.

1.2 The DNA base pair has a typical structure to emit photon in spectrum of UV light

Can DNA bases emit UV?

It is said that the influence factors of electron transition and fluorescence are: rigid plane, large conjugated π-bonds systems structure, and electron donating group. Fluorophores typically contain several combined aromatic groups, or plane, cyclic molecules with several π-bonds [6]. Aromatic heterocyclic compounds containing nitrogen atoms have more photochemical stability and stronger electron transfer capacity than benzene [7]. In fact, the structure of bases or base pairs is just such typically fluorescent group. Purine and pyrimidine are both π-conjugated organic molecules, which has a highly conjugated π-bonding aromatic system. Besides, G·C or A·T base pair, which is connected by hydrogen bonds, is flat and rigid.This flat and rigid conjugated new structure, the base pair, can intensify the emission of light. And the wavelength of emission should be decided by the subtle state of electrons on this conjugated structure [6] .

Lengthening or extending a conjugated system with more unsaturated bonds in a molecule will tend to shift absorption to longer wavelengths. From the molecular structure of bases, and the wavelength of the absorbed UV light by DNA, the light emitted from DNA should also be UV light, with a wavelength less than 300nm.

Maybe a base pair can be seen as exciton or excimer (excited dimer), or biexciton which can result reverse polarization of light. Solo photon or several photons may be produced by each pair. Because of the different constituent on different bases, emission wavelengths are obviously different too. Base pairing extends the conjugated structure and lead to ICT (intramolecular charge transfer). ICT is a common phenomenon in organic optoelectronic materials. The electron acceptor (acceptor, A) and electron donor (donor, D) are usually introduced into a conjugated system to form the D-π-A conjugated molecule [8] [9]. When the molecule is excited, the excited electrons transfer through the conjugated bridge or conjugated plane to realize ICT. This ICT brings a larger Stokes shift, and makes the peak of absorption or emission deviate greatly. And ICT can decrease the energy level coincidence, and then decrease the self-absorption and fluorescence quenching caused

by the solid state or the accumulation state. So ICT may also exist after base pairing and accelerate the photon emission of base.

And the double helix structure of DNA seems also contributes to the UV emission, wave polarization, and maybe photons entanglement.

1.3 Stacking way of base pairs in DNA can accelerate the luminescence efficiency

The stacking way of base pairs may also come from the need of improving luminescence efficiency.

Knowledge in the Luminescent Conjugated Organic Molecules may help to understand the luminescent structure of DNA. In the π-Conjugated Organic Molecules in aggregated state, luminescence efficiency and carrier mobility dependent on the stacking mode as well as the molecular structure. The J-aggregate mode and X-aggregate stacking mode have higher luminescence efficiency than the face to face H--aggregate stacking mode [10].

In DNA, the helix stacking mode of bases can be seen as a combine of J-aggregate and X-aggregate stacking mode. The distance of neighbor pairs is important to the luminescence [10]. The deoxyribose sugar in backbone may help to define the base pairs on a suitable distance.

2 Information could be stored in single base pair

If the signals can be transmitted by UV, can the signals be recorded in the DNA too?

In typical DNA complexes, hydrogen bonds connect the G·C or A·T base pairs together. The flat of base pair is perpendicular to the axis of double-helix. The edges of these flat bases are studded with hydrogen bond donor and receptors. And as a rigid flat, base pair has obviously rotary flexibility [11]. Information could be stored in ways such as: the rotation of bases pair flat, change of hydrogen bonding and π-π interaction, re-distribution of electronics potential in the base, photochemical isomerization, or even DNA methylation. All these changes can represent certain information and result in different wave-length of UV emitting.

Of course, there may be other ways of information storage: changes in certain quantum state, such as spin of electron or the direction of electric current in the hexatomic ring of purine or pyrimidine. Information may more probably be stored in the base pair in the form of π conjugated electrons spin, angular momentum, or orbital fine energy level of electron and so on. In general, information is transited from photonic systems to electronic systems. And quantum level changes have unique merits. Quantum theory shows the magical possibilities of spin, such as that the logic gates can vary 1 billion times per second.

At present, two kinds of spin polarized electron injection methods are used in the semiconductor: electric injection and optical injection [12] [13]. The optical injection method uses circularly polarized light to excite the valence band electrons, when the spin polarized electrons are injected into the guiding band. The left and right circularly polarized light has units of angular momentum, but their signs are opposite. When the polarized photons interact with electrons, the angular momentum of photons and electrons must be conserved, and then the electron is polarized. So circular polarized photons can be injected into multiple π-conjugated electrons to form spin polarization.The spin polarized electron clusters can be obtained by using the polarized laser irradiation on the common semiconductor materials. The electron cluster is not only circularly polarized, but also shows the precession, which in line with the direction of the right-hand rule.

So one possible mechanism of information recording is spin polarization of π conjugated

electrons.

UV absorption changes the bases and base pairs. The existence of fine structure of molecule is the reason of wide spectrum absorption. Each base or bases pair may emit one photon, and the wavelength of photon is decided or influenced by the electronics potential distribution (or quantum state) in base or bases pair.

3 Energy source of the UV emitted from base

The emission of UV need energy source. Energy may come from the absorbed UV, just like other light excited fluorescence. But the energy also could come from the main energy source of biochemical reactions: the ATP. Compared to DNA, the structure of ATP is so special that it can even be seen as part of DNA backbone. The phosphate bonds in the backbone may be hydrolyzed and release energy for the fluorescent emission, while the ATP is the upstream energy resource.

Electrons can flow in the molecular layers along the direction of π stacking in DNA [14][15]. And the energy of electronic flow in the π stacking may result electroluminescence. Rigid conjugated main chain is an important feature of electroluminescent conjugated polymers. It can form large conjugated π electron system, so that the charge can transfer within the molecule [16] [17]. The phosphoribose backbone is overall negative and provides an opposing force to the base pairing, and perhaps it is helpful to provide an isolated electronic space.

The place the energy will be provided may be controlled by the base pair or pairs. And the intensity of emitted light is also connected with the energy supply.

The functions of duplicate helix of DNA should be: ① Similar to helical antenna to produce the polarization of light wave. DNA molecules can work as spin-polarizer [18]. ② J-stacking of bases enhances luminescence. ③ The need of information transmission, to ensure the difference of wave phase and frequency etc. ④ For the strong correlation and quantum entanglement. Besides, the functions of duplicate helix are also connected with coupling of two bases, or coupling of two strains in the double helix. Maybe because of excitation and coupling, double helix accelerates the luminescence. So there is an obviously increase of fluorescence after some fluorescent dyes binding on the double helix, such as EB binding.

Some higher level structures in nucleus may also have special functions, such as signal amplification or wavelength transformation, for the intro-cellular or inter-cellular communication.

4 The calculation in DNA may base on quantum effect and photon entangling

Without evaluation or calculation, the received information is meaningless. But how does the cell calculate the information? Using knowledge of computer, and looking DNA base pair as a basic unit of computer such as transistor, calculation in DNA is more understandable. In the view of computer science, DNA should be the combination of memory and CPU. Certain state of base or base pair can represent certain logical meaning. After absorption of photon, base or base pair may change its logic meaning in ways such as photochemical isomerization, different electronics potential distribution on its structure, reverse polarization, change of current direction in the six-member nitrous heterocylic, or change of electron spin.

Quantum calculation or Quantum computation has been studied for years. It uses quantum bits (qubits or qbit), which can get into superposed states. Because of the small size of DNA and its bases, it has the prerequisites of producing entangled photons or entangled electrons: base can be seen as quantum dot which emit solo photon; two bases of a pair or bases of some pairs are close enough and have similar structures, and make the photons entangled; furthermore, double helix and cave-like structure of DNA could strengthen this entanglement. Circular polarization light (photons) may form a photon - electron logical gates. The time of decoherence of the polarized light is very long, so the coherence time of the photon should persist long enough.

QED (quantum electro-dynamics) cavity leads to strong coupling between atoms and photons, and coupling between photons generated by quantum dots [19]. How to combine multiple independent QED systems to form a more effective large system to achieve the "distributed quantum computing" has become a hot issue in recent years [20]. The stacking of base pairs may form such a QED cavity in the center of DNA helix, where there are more than one photon in this cavity.So this cavity provide an independent space for the entanglement of photons. And these photons could be produced or transferred as an entangled and integrated whole unit.

Entanglement makes the communication to be more specific in noisy background. Base pairs and the emitted photons are in a special quantum state, so quantum calculation is possible. Such a quantum computing should be powerful: the storage and computation are integrated; logic gates such as electronic spin can change very fast; it is a parallel calculation. Signal in the circular polarization light is absorbed by base pair and then some quantum state of electron such as self-spin of conjugated π electron system is changed, to fulfill the Boole-like calculation.

So it should be possible in cell to use knowledge of computer and wireless communication to find programmed calculation, which is based on quantum entanglement and computation.

5 Other molecules and electronic waves may also take effect in this intercellular or intracellular communication

In addition to information about protein structure, other information is also importance to cell. The genome of human is large, but the number of genes is relatively small. The exon is just 1% of total DNA sequences. Genome of other eukaryotic cell shows much redundancy too. Synchronization is very important in a highly complicated system [21]. The repetitive DNA in eukaryotic genome may relate to the larger size of these cells. Some of the repeated sequences may have special effects such as synchronize or longer-distance communication. Long -range correlation exists obviously in intron -containing sequence, but does not exist in cDNA and coding regions [22]. Then the knowledge of wireless communication is helpful to understand these sequences. The reason for the left hand helix of DNA in mitochondria and chloroplasts should be preventing the interference of the corresponding signal in DNA.The potential for base-paired helical structures in many RNAs is also quite common, which may also have relation to photon communication.

There are also right hand helical structures in the proteins or polypeptides. In DNA, there is about 10.5 base per circle, which is very similar to 3.6 amino acid residues (corresponding with 10.8 bases) per circle in α-helical of protein. This should be explained by principle which resemble to the reciprocity principle of antenna. And it is known that the UV absorbed by protein is about

280nm, which seems to be a suitable emission wavelength of DNA. Such light and energy transfer mechanism probably even connect to the enzyme catalytic activity.

Because of the inter-cellular distance and wave absorption, UV is not a suitable choice for longer distance signal transmission. Longer wavelength waves, such as infrared ray could be better. Based on some larger structure such as nucleosome, which could be seen as resonant cavity, UV may be transited to electronic waves with a longer wavelength. In the time such as multiplication, entangled infrared ray may be used to deliver information.

Structures similar to base exist in many bio-molecules. So molecules, for example ATP, cAMP, cGMP, G-protein, NADPH, some enzymatic cofactors, may also involve in this UV transition mechanism. And in human body, molecules such as caffeine, which have a similar structure to purine and can effect on spiritual state, may emit similar electronic signals to influence the bases or signals from the bases. And alcohol may have a different mechanism that it changes the DNA helix as a solvent.

6 About the origin of this mechanism and origin of life

Origin of life is a large problem [23] [24]. Before cell-life and ozone layer emerged [25], UV light range in 230-280 nm (UV-C) was not completely absorbed by the atmosphere. UV and other high-energy radiations might result the formation of some organic small molecules.

Electron conjugated system such as six-member ring molecules are more stable than other organic small molecules. So the benzene compounds and six-member nitrous heterocylic are more stable, and have much chance to accumulate in natural environment. Resonance molecules such as benzene compounds are also more electronic active, easier to absorb and release electronic energy, and to form a larger scale of electron conjugation or aggregation.

It is known that small molecules and conjugated polymer fluorescent chemosensors based on aromatic N-heterocycle are electron rich group system, which have more photochemical and thermodynamic stability, and stronger electron transfer capacity. After coupling, the hydrogen bond between purine and pyrimidine extends π-conjugated structure. And bases stacking makes these π-conjugated molecules more stable too.

Hydrogen bond induced self-assembly occurs in two molecular systems that can form multiple hydrogen bonds [26]. The main driving forces of molecular self-assembly are intermolecular hydrogen bonds and π-π interactions [27] [28]. From the view of self-organization, formation of nucleic acid chain may be a result of one-dimensional self-assembly of planar π-conjugated molecules.So self-assembly of purine and pyrimidine can result structure similar to DNA. They can also be regarded as self-organized quantum dots.

When free rotation of the groups is restricted in the solid state or aggregated state, photoemission efficiency will be higher. This phenomenon of low luminous efficiency in solution and high luminous efficiency in solid is called aggregation induced luminescence (AIE) [29].The J-aggregate and X-aggregate stacking mode have higher luminescence efficiency than other modes. So the aggregated and luminescent molecules forming structure similar to double helix.They are more stable and more luminous, and may have evolutionary advantage.

But why UV absorption and photon emission molecules have evolutionary advantage? Reason may be: UV has more energy than visible light and can be absorbed by hexatomic ring compounds. Photon absorption, emission and molecule communication may accelerate larger scale of electron

conjugation, and larger scale of self-organization. After AIE, nucleic acid absorb more energy from UV, deliver energy to molecules with similar structure in the way of entangled photons, so these energy and information from entangled photons help to sustain the base order and improve the stability of molecular.This kind of communication may also promote self-correction.

How do such self-organized molecules begin to reproduce? Quantum entanglement leads to the overall transfer of photons. Because the information about the self-organized molecule is entangled, and can be transmit only in an entangled way, so the new individual must be highly similar.Then the molecular reproductions produce more similar molecules.

The reason of the right-handed helices of DNA may relate to the property of electromagnetic waves, or the spin of celestial bodies. At early stage, it could be right-handed circular polarization electronic wave to get to the earth, and produce spinning entangled photons. Origin of some chiral molecules may also relate to spin of galaxy. Galaxy produces circularly polarized light [30] [31], which result right helix of DNA. Then the helical in protein must be right handed too. Right hand helical formed with D-amino acids is less stable, then these amino acids must be L-amino acids.

So it may be true that light (electromagnetic wave) play an essential role in the origin of life.

7 Verification and application

Several ways are suggested here to testify these hypotheses:

(1) A simple way to test this mechanism is to prove that UV can be emitted from DNA or RNA, and this UV has much effect on the enzymatic activity (effect on corresponding protein structure). Certain DNA or RNA can be used to adjust the enzymatic activity, for example, speed of chromogenic hydrolysis reaction catalyzed by enzyme.

(2) Try to testify that DNA or RNA can be used to adjust the activity of ATP. Then biochemical reaction which consumes energy of ATP is detected to find the change of the reaction speed.

(3) The direction of some α-helix in protein may relate to the biochemical activity because it response to UV. The α-helix in GFP may be an example.

(4) Mechanism of molecules which change spiritual state：electron donating groups on molecules similar to base effect on fluorescence of nucleic acid. So some molecules such as Morphine, which changing spiritual state, may have fluorescence similar to UV spectrum.

(5) Circularly polarized UV accelerates the supramolecular self-assembly of some π-conjugated systems. So circularly polarized UV may be used to promote the reproduction of DNA in tube.

8 Conclusion

Many biochemical processes must be acted synchronously, and corresponding information should be transmitted in a very fast and accurate way. But presently, it is said that information is customarily transited through contact of molecules or ions in cell.

To single cell, nucleus is just like the brain of the body. People assumed that the nucleus just keeps information mainly about the sequences of proteins, and transcript these sequences in a controlled way, then the cell can run well. But it still seems very difficult that so limited information can make such a sophisticate system run smoothly and stably.

Then the information may not only be encoded in the sequence of DNA, but also exist in the

bases connections of the two chains in the double helix. And the function of bases pair is an integration of storage and computation. Just like Tai Chi diagram, the meaning exist in the conjunction and integration of two opposite parts.

UV has a tremendous wide bandwidth and is a not line of sight（NLOS）way of communication, with clear background. Entanglement of photons in the double helix also makes communication and calculation in quantum level becoming possible. It is a new way of observation to regard base pairs as information storage, signal receivers, emitter and calculators.

Then there are some similarities between cell and computer. Hardware and software compose a functional computer. Now the “hardware” of cell is extensively studied, and here it is suggested that the basic unit of “software” of cell is in some molecules, especially in the base pair of DNA. Stacking bases form a QED cavity, which is an independent space for the entanglement of photons.This cavity is also a space for entangled information. It seems not ridiculous to say that “essence of life exist in the vacuum”.

References

[1]Volodyaev I, Beloussov L V. Revisiting the mitogenetic effect of ultra-weak photon emission.[J]. Frontiers in Physiology, 2015, 6:241

[2]Laager F. Light Based Cellular Interactions: hypotheses and perspectives[J]. Frontiers in Physics, 2015, 3:55.

[3]Cifra M, Fields J Z, Farhadi A. Electromagnetic cellular interactions[J]. Progress in Biophysics & Molecular Biology, 2011, 105(3):223.

[4]Kučera O, Cifra M. Cell-to-cell signaling through light: just a ghost of chance?[J]. Cell Communication and Signaling, 2013, 11(1): 1

[5]Khandelwal G, Bhyravabhotla J. A Phenomenological Model for Predicting Melting Temperatures of DNA Sequences[J]. Plos One, 2010, 5(8):e12433

[6]Tang B, Hong Y, Chen S, et al. Photostable AIE luminogens for specific mitochondrial imaging and its method of manufacturing thereof: US, US 20140212359 A1[P]. 2014

[7] Kong S S, Li S J. Progress in nitrogenous heterocyclic organic luminescent materials [J]. Chinese Journal of Colloid & Polymer, 2010.

[8]Grabowski Z R, Rotkiewicz K, Rettig W. Structural changes accompanying intramolecular electron transfer: focus on twisted intramolecular charge-transfer states and structures[J]. Chemical Reviews, 2003, 103(10):3899.

[9]Chaozhi Zhang, Changgui Lu, Zhu J, et al. The Second-Order Nonlinear Optical Materials with Combined Nonconjugated D−π−A Units[J]. Chemistry of Materials, 2006, 18(26):6091-6093.

[10]Wang H, Xie Z Q, Ma Y G, et al. Progress on the optoelectronic functional organic crystals[J]. Science China

Chemistry, 2007, 50(4):433-452

[11]Neidle, Stephen. Principles of nucleic acid structure = 核酸结构原理[M]. 科学出版社, 2008. **P24**

[12]Wolf S A, Awschalom D D, Buhrman R A, et al. Spintronics: a spin-based electronics vision for the future[J]. Science, 2001, 294(5546):1488-1495

[13]Liu B L, Renucci P, Carrère H, et al. Spin injection probed by combined optical and electrical techniques in spin‐LED[J]. Physica Status Solidi, 2004, 1(3):475-478

[14]Murphy C J, Arkin M R, Jenkins Y, et al. Long-range photoinduced electron transfer through a DNA helix[J]. Science, 1993, 262(5136):1025-9.

[15]Genereux J C, Barton J K. Mechanisms for DNA Charge Transport[J]. Chemical Reviews, 2010, 110(3):1642-62.

[16]Friend R H, Gymer R W, Holmes A B, et al. Electroluminescence in conjugated polymers[J]. Nature, 1999, 397(6715):121-128.

[17]Chan W K. Metal containing polymers with heterocyclic rigid main chains[J]. Coordination Chemistry Reviews, 2007, 251(17-20):2104-2118.

[18]Grynko O, Lozovski V, Ozerov O, et al. Electron spin-polarizer on the base of DNA array[C]// IEEE, International Conference on Electronics and Nanotechnology. IEEE, 2014:250-253.

[19]Sleator T, Weinfurter H. Realizable Universal Quantum Logic Gates.[J]. Physical Review Letters, 1995, 74(20):4087-4090

[20]Cirac J. I,,Ekert A. K., Huelga S. F.,et al. Distributed quantum computation over noisy channels [J].Phys. Rev. A, 1998,59(6): 4249-4254.

[21]Boccaletti S, Kurths J, Osipov G, et al. The synchronization of chaotic systems[J]. Physics Reports, 2002, 366(1‐2):1-101

[22]Peng C K, Buldyrev S V, Goldberger A L, et al. Long-range correlations in nucleotide sequences[J]. Nature, 1992, 356(6365):168-70

[23]Di M E, Saladino R, Trifonov E N. The path to life's origins. Remaining hurdles.[J]. Journal of Biomolecular Structure & Dynamics, 2014, 32(4):512.

[24]Spitzer J, Pielak G J, Poolman B. Emergence of life: Physical chemistry changes the paradigm[J]. Biology Direct, 2015, 10(1):33.

[25]Trainer M G. Atmospheric Prebiotic Chemistry and Organic Hazes[J]. Current Organic Chemistry, 2013,

17(16):1710-1723.

[26]Zimmerman S C, Corbin P S. Heteroaromatic Modules for Self-Assembly Using Multiple Hydrogen Bonds[M]// Molecular Self-Assembly Organic Versus Inorganic Approaches. Springer Berlin Heidelberg, 2000.

[27]Shi W J, Hou L, Li D, et al. Supramolecular assembly driven by hydrogen-bonding and π－π stacking interactions based on copper(II)-terpyridyl complexes[J]. Inorganica Chimica Acta, 2007, 360(2):588-598.

[28]Rybtchinski B. Adaptive supramolecular nanomaterials based on strong noncovalent interactions[J]. Acs Nano, 2011, 5(9):6791-818.

[29]Hong Y, Lam J W, Tang B Z. Aggregation-induced emission.[J]. Chemical Society Reviews, 2009, 2009(12):1345-1345.

[30]Bailey J. Astronomical Sources of Circularly Polarized Light and the Origin of Homochirality[J]. Origins of Life and Evolution of Biospheres, 2001, 31(1):167-183.

[31]Lucas P W, Hough J H, Bailey J, et al. UV Circular Polarisation in Star Formation Regions: The Origin of Homochirality?[J]. Origins of Life and Evolution of Biospheres, 2005, 35(1):29-60.

DNA 以碱基对存储信息并以紫外线通信的可能性探讨

杜林

(仲恺农业工程学院，广州， 510225，中国)
email: dulin2000@163.com

摘要：本文探讨了细胞 DNA 中以紫外线作为信息传递媒介的可能性。DNA 碱基可以吸收紫外线，也有典型的发射紫外区辐射的化学结构，DNA 碱基对的堆积方式可以提高发光效率。紫外线中的信息可以储存在碱基对中，如以改变π共轭电子的方式储存。在 DNA 中相关信息的分析计算可基于碱基对中π共轭电子与纠缠光子的量子效应。文中还推测紫外信息传递以及生命起源，可能和圆偏振光的照射及含氮芳杂环分子的自组织等有关。这些猜想可能有助于解释一些生物学现象。

关键词： 核酸；DNA 碱基；紫外吸收和发射；信息存储；量子计算；生命起源