

Brain's Default Mode Network

With thousands of basic and clinical neuroscience studies carried out over the past 15 years, the Default Mode Network (DMN) – a network of highly co-correlated interacting regions whose activity is very active during wakeful rest and distinct from that of other neural networks – is one of the most highly-investigated networks of the brain. [22]

Columbia scientists have traced the origins of mysterious signals in the brain that have captivated the functional magnetic resonance imaging (fMRI) community for the last decade. Using a recently developed imaging technique in mice, the Columbia team revealed synchronized, network-like neural activity coursing around the brain, even when the mouse was 'at rest.' [21]

A major challenge in truly targeted cancer therapy is cancer's suppression of the immune system. Northwestern University synthetic biologists now have developed a general method for "rewiring" immune cells to flip this action around. [20]

Scientists at the University of Bonn have succeeded in observing an important cell protein at work using a method that measures structural changes within complex molecules. [19]

*Scientists have now explored a modified form that can produce light-generated electrons and store them for catalytic hydrogen production even after the light has been switched off. They present this biomimetic photosynthesis approach in the journal *Angewandte Chemie*. [18]*

Scientists at The Australian National University (ANU) have designed a nano crystal around 500 times smaller than a human hair that turns darkness into visible light and can be used to create light-weight night-vision glasses. [17]

Magnets instead of antibiotics could provide a possible new treatment method for blood infection. [16]

One of the biggest challenges in cognitive or rehabilitation neurosciences is the ability to design a functional hybrid system that can connect and exchange information between biological systems, like neurons in the brain, and human-made electronic devices. [15]

Wearable terahertz scanning device for inspection of medical equipment and the human body. [14]

Optical microscopy experts at Colorado State University are once again pushing the envelope of biological imaging. [13]

Researchers at the University of Melbourne have developed a way to radically miniaturise a Magnetic Resonance Imaging (MRI) machine using atomic-scale quantum computer technology. [12]

With one in two Australian children reported to have tooth decay in their permanent teeth by age 12, researchers from the University of Sydney believe they have identified some nanoscale elements that govern the behaviour of our teeth. [11]

When cryoEM images are obtained from protein nanocrystals the images themselves can appear to be devoid of any contrast. A group of scientists from the Netherlands have now demonstrated that lattice information can be revealed and enhanced by a specialized filter. [10]

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

From the standpoint of physics, there is one essential difference between living things and inanimate clumps of carbon atoms: The former tend to be much better at capturing energy from their environment and dissipating that energy as heat. [8]

This paper contains the review of quantum entanglement investigations in living systems, and in the quantum mechanically modeled photoactive prebiotic kernel systems. [7]

The human body is a constant flux of thousands of chemical/biological interactions and processes connecting molecules, cells, organs, and fluids, throughout the brain, body, and nervous system. Up until recently it was thought that all these interactions operated in a linear sequence, passing on information much like a runner passing the baton to the next runner. However, the latest findings in quantum biology and biophysics have discovered that there is in fact a tremendous degree of coherence within all living systems.

The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the Wave-Particle Duality and the electron's spin also, building the Bridge between the Classical and Quantum Theories.

The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate and the Weak and Strong Interactions by the diffraction patterns. The Weak Interaction changes the diffraction patterns by moving the electric charge from one side to the other side of the diffraction pattern, which violates the CP and Time reversal symmetry.

The diffraction patterns and the locality of the self-maintaining electromagnetic potential explains also the Quantum Entanglement, giving it as a natural part of the Relativistic Quantum Theory and making possible to understand the Quantum Biology.

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Preface

Jeremy England, a 31-year-old assistant professor at the Massachusetts Institute of Technology, has derived a mathematical formula that he believes explains this capacity. The formula, based on established physics, indicates that when a group of atoms is driven by an external source of energy (like the sun or chemical fuel) and surrounded by a heat bath (like the ocean or atmosphere), it will often gradually restructure itself in order to dissipate increasingly more energy. This could mean that

under certain conditions, matter inexorably acquires the key physical attribute associated with life. [8]

We define our modeled self-assembled supramolecular photoactive centers, composed of one or more sensitizer molecules, precursors of fatty acids and a number of water molecules, as a photoactive prebiotic kernel system. [7]

The human body is a constant flux of thousands of chemical/biological interactions and processes connecting molecules, cells, organs, and fluids, throughout the brain, body, and nervous system. Up until recently it was thought that all these interactions operated in a linear sequence, passing on information much like a runner passing the baton to the next runner. However, the latest findings in quantum biology and biophysics have discovered that there is in fact a tremendous degree of coherence within all living systems. [5]

Quantum entanglement is a physical phenomenon that occurs when pairs or groups of particles are generated or interact in ways such that the quantum state of each particle cannot be described independently – instead, a quantum state may be given for the system as a whole. [4]

I think that we have a simple bridge between the classical and quantum mechanics by understanding the Heisenberg Uncertainty Relations. It makes clear that the particles are not point like but have a dx and dp uncertainty.

Resolving contradictions: Better understanding the basic role of the brain's Default Mode Network

With thousands of basic and clinical neuroscience studies carried out over the past 15 years, the Default Mode Network (DMN) – a network of highly co-correlated interacting regions whose activity is very active during wakeful rest and distinct from that of other neural networks – is one of the most highly-investigated networks of the brain. Nevertheless, identifying the DMN's central role has remained elusive due to contradictory results: The dilemma is that while mind-wandering diverts attention from one's sensory environment and thereby creates unstable (i.e., variable) task performance, the DMN has been found to be active during what appear to be incompatible states. On the one hand, the DMN is active during intense mind-wandering (thinking about oneself or others, and recalling the past or planning the future), and on the other hand, the DMN is active during stable, rather than variable, behavior. Recently, however, scientists at Massachusetts General Hospital and Harvard Medical School as well as Boston University have demonstrated for the first time how these two explanations of DMN activity are more compatible than they might have seemed. In so doing – and while acknowledging that DMN fluctuations may reflect a higher-level function related to both stable behavior and mind-wandering (a potential example being memory reconsolidation) – the researchers conclude that their findings call for a need to reinterpret the significance of DMN activity fluctuations in daily life as well as DMN disruption in disease.

Dr. Aaron Kucyi, now at Stanford University, discussed the paper that he, Prof. Eve M. Valera and their colleagues published in Proceedings of the National Academy of Sciences. He notes that two aspects of their study – showing that DMN activity increases with stable, rather than variable, behavior, independent from increases with mind-wandering, and testing the hypothesis that single

measures of attentional states (based either on self-report or behavior) are alone insufficient to account for DMN activity fluctuations presented the researchers with the same challenge: the fact that previous studies – theirs and others' – showed seemingly contradictory results.

In some of those studies, Kucyi explains, people were instructed to perform tasks in which, every second or so, they had to respond quickly and consistently to changing images. Sometimes they perform more consistently and make fewer errors – often called being in the zone – and other times they are out of the zone, showing variable performance and making more errors. Also, he adds, in some studies people were asked from time to time whether they consciously thought that they were closely paying attention to the images in front of them or whether they thought their mind was wandering.

"Together," Kucyi tells Medical Xpress, "the studies showed three highly consistent results: mind-wandering occurs during inconsistent, out of the zone behavior; mind-wandering occurs during increased Default Mode Network activity; and consistent, in the zone behavior also occurs during increased DMN activity. We were therefore confused about how increased DMN activity could occur with both mind-wandering and with being behaviorally in the zone, even though mind-wandering tends to occur during out of the zone-like behavior." The problem turned out to be that previous brain imaging research studied either only mind-wandering (based on self-reports of when people thought they drifted off) or only behavior (based on fluctuations of reaction time).

Self-reported attention and RT variability additively account for DMN activity

"We had to develop a new way to study and analyze how DMN activity relates simultaneously to both mind-wandering and behavioral states. Doing so would let us determine whether the changes in DMN activity associated with behavior are independent from or are related to the changes associated with mind-wandering. "

The scientists developed two innovative approaches that allowed them to address these challenges. "We developed a cognitive task for people to perform during fMRI that allowed us to sensitively capture both when their behavior fluctuated and when they were spontaneously mind-wandering, which can be studied in the fMRI setting using thought probes where people are intermittently asked to report whether they were just thinking of the task that they are doing, of something in their sensory surroundings, or of something completely unrelated – for example, their dinner plans. My co-author Michael Esterman had previously developed a Gradual Continuous Performance Task, or gradCPT, which requires that people sustain their attention successfully for long periods. In that task, people view gradually changing images and have to press a button each time they see a new image showing a scene of a city, but they have to withhold their response whenever they see a rarely appearing image of a mountain." Over time, Kucyi points out, the speed at which people respond fluctuates considerably and somewhat spontaneously between states of being consistent and inconsistent. In the new study, however, the gradCPT was performed in combination with thought probes – that is, subjects are unexpectedly asked to relay what they were just thinking about – which captured both behavioral fluctuations and instances when people felt that they had drifted off and mind-wandered.

"We also developed a way to analyze data that allowed us to determine whether the changes in DMN activity associated with behavior are independent from or are related to the changes

associated with mind-wandering. In brief, the approach involved testing a statistical model which simultaneously took into account three things that fluctuated considerably over time within our volunteer subjects: DMN activity, self-reports of levels of mind-wandering, and levels of behavioral consistency."

The paper reported a number of interesting results, one being the implications of reinterpreting the significance of DMN activity fluctuations in daily life and in DMN disruption due to disease. "Mind-wandering is a huge part of our daily life," Kucyi points out, "accounting for 30-50% of our experience when awake." A currently predominant idea in neuroscience is that DMN activity fluctuates to high levels when people are disengaged with the external world and are instead focused on their inner thoughts. "Our study confirms that DMN activity is higher when people are mind-wandering, but our findings add a layer of complexity to that story: Yes, DMN activity increases with more intense mind-wandering, but DMN activity also increases with more consistent behavior that is completely unrelated to conscious mind-wandering. Therefore, if we could measure someone's DMN activity level at any given moment in their daily life, we could not conclude based on a high level of DMN activity that he/she is currently mind-wandering."

Subsystems of the DMN are associated with self-reported attention and RT variance

To the second point, Kucyi notes that DMN activity is disrupted in a very wide range of psychiatric and neurological disorders – for example, attention-deficit/hyperactivity disorder, depression, Parkinson's disease, epilepsy, and chronic pain – but that it is unclear how these disorders may change DMN activity or how DMN activity may predispose people to developing disease. "Sometimes a failure to shut down the DMN is interpreted as a lack of control over mind-wandering. However, our study suggests that the story is not so simple. An overactive DMN does not necessarily mean increased mind-wandering and could instead be indicative of a more fundamental dysregulation of brain activity with a range of possible consequences."

The paper also stated that further work is needed to uncover the behavioral relevance of dynamic communication within the DMN and with other networks. "In our study we analyzed the overall level of activity in the DMN, but we could also measure communication between regions of the DMN and other systems that work together as networks," Kucyi explains. "Thoughts that occur during mind-wandering likely involve a complex interplay of activity across different brain regions, and so network-level analysis could be a promising avenue for future studies of the DMN and how people are paying attention."

Moving forward, the researchers plan to study how DMN activity relates to peoples' experience and behavior using techniques other than fMRI, which Kucyi acknowledges is limited because it is based on blood flow which only indirectly reflects electrical brain activity. "We also hope to study other spontaneous behaviors that could reflect whether someone is in the zone or out of the zone, like eye movements and eye blinks, as well as more specific contents of mind-wandering such as thinking about the past versus future, or thinking about positive versus negative emotional events, rather than just the intensity of focus."

Regarding other areas of research that might benefit from their study, Kucyi concludes that "ultimately, a better understanding of the function of the DMN could help us in developing ways to appropriately target this network for therapeutic purposes while avoiding side effects." [22]

New study uncovers vivid patterns of neural activity in the resting mouse brain

Columbia scientists have traced the origins of mysterious signals in the brain that have captivated the functional magnetic resonance imaging (fMRI) community for the last decade. Using a recently developed imaging technique in mice, the Columbia team revealed synchronized, network-like neural activity coursing around the brain, even when the mouse was 'at rest.'

The researchers further demonstrated that this neural activity could predict slowly changing patterns of blood flow in the brain, connecting their findings to the enigmatic signals detected in so-called 'resting-state' fMRI. Taken together, this research provides a tantalizing new view of brain-wide neural activity that could lead to a better understanding of how distinct brain regions interact with each other, and how these connections—and the way they change with disease—can be studied in the human brain using fMRI.

The researchers published their findings today in the Proceedings of the National Academy of Sciences.

"Our results should reassure scientists in the resting-state fMRI community who have long believed that they were detecting patterns of neural activity," said Elizabeth Hillman, PhD, principal investigator at Columbia's Mortimer B. Zuckerman Mind Brain Behavior Institute, associate professor of biomedical engineering and radiology at Columbia's Fu Foundation School of Engineering and Applied Science and the paper's senior author. "At the same time, our results may come as a surprise for those who have remained skeptical that—first of all—this type of underlying neural activity even exists, but also that such activity can be accurately represented by fMRI signals."

Within a few years of the first demonstration of fMRI, scientists noticed that, even without an external stimulus, fluctuating signals could be detected in the brains of humans. Despite appearing to be random, analysis of these signals identified regions located on opposite sides of the brain that were synchronously singing the same random song. This synchrony was taken as evidence of interconnected functional networks throughout the brain. Moreover, properties of these networks were found to distinguish subtle signs of disease that are otherwise undetectable. However, these resting-state fMRI signals have proved challenging to interpret, in large part because fMRI works not by tracking the activity of neurons in the brain, but by tracking changes in blood flow as a proxy for that activity. As a result, it has been difficult to reconcile this high-level view of the brain with how scientists think of neurons interacting with each other individually.

To address this, Dr. Hillman and her team employed a wide-field, optical imaging method that allowed them to visualize both changes in blood flow and neural activity simultaneously across the surface of the mouse brain. Much to their surprise, they saw patterns of neural activity that flickered and swirled around the brain in elegant symmetric patterns.

"First, we only looked at small areas of the brain, seeing what seemed to be flashes and random activity," said Dr. Hillman. "But when we zoomed out to view both sides of the brain at once, we saw that this activity wasn't random—it was symmetrical, organized and composed of repeating patterns. We immediately thought of resting-state fMRI."

They then compared these patterns to changes in blood flow. And while these blood-flow changes at first appeared sluggish compared to the neural activity, further analysis revealed that the fluctuations did in fact represent a cumulative effect; each small neural signal was triggering a small, slow increase in blood flow.

"In essence, these findings tell us that resting-state fMRI is probably picking up a representation of these underlying neural signals," said Ying Ma, a doctoral candidate at Columbia and the paper's first author. "What is great about our data is that it lets us uncover how these signals get blurred and distorted in fMRI, and whether there are any additional changes in blood flow—or cellular activity—that are also occurring but that aren't accounted for by normal neural activity. We hope that this will help to improve how fMRI data is analyzed and interpreted."

The team has already begun working with fMRI researchers to help in the development of more robust methods of drawing information out of resting-state fMRI scans in the healthy human brain, and to explore how and why networks appear to change in disease states.

Moving forward, Dr. Hillman and her team are also expanding their studies of brain-wide neural activity to include more complex methods that, she hopes, will provide fundamental insights into how and why this resting-state neural activity is generated.

"Our high-speed imaging methods are giving us an entirely new view of what the brain is doing, one that we hadn't seen before," said Dr. Hillman. "We are eager to understand how this brain-wide activity fits with classic descriptions of the brain's underlying circuitry.

"Moreover," she added, "we can follow the lead of resting-state fMRI and understand why these activity patterns are affected by disease, this could be the first step to developing new treatments."
[21]

'Rewired' cells show promise for targeted cancer therapy

A major challenge in truly targeted cancer therapy is cancer's suppression of the immune system. Northwestern University synthetic biologists now have developed a general method for "rewiring" immune cells to flip this action around.

"Right now, one of the most promising frontiers in cancer treatment is immunotherapy—harnessing the immune system to combat a wide range of cancers," said Joshua N. Leonard, the senior author of the study. "The simple cell rewiring we've done ultimately could help overcome immunosuppression at the tumor site, one of the most intransigent barriers to making progress in this field."

When cancer is present, molecules secreted at tumor sites render many immune cells inactive. The Northwestern researchers genetically engineered human immune cells to sense the tumor-derived molecules in the immediate environment and to respond by becoming more active, not less.

This customized function, which is not observed in nature, is clinically attractive and relevant to cancer immunotherapy. The general approach for rewiring cellular input and output functions should be useful in fighting other diseases, not just cancer.

"This work is motivated by clinical observations, in which we may know why something goes wrong in the body, and how this may be corrected, but we lack the tools to translate those insights into a therapy," Leonard said. "With the technology we have developed, we can first imagine a cell function we wish existed, and then our approach enables us to build—by design—a cell that carries out that function."

Currently, scientists and engineers lack the ability to program cells to exhibit all the functions that, from a clinical standpoint, physicians might wish them to exhibit, such as becoming active only when next to a tumor. This study addresses that gap, Leonard said.

Leonard, who focuses on integrating synthetic biology into medicine, is an associate professor of chemical and biological engineering at the McCormick School of Engineering. He is a member of the Robert H. Lurie Comprehensive Cancer Center of Northwestern University.

The research comes out of a rich collaboration that Leonard's team has with clinical oncologists, immunologists and basic cancer researchers at Northwestern University Feinberg School of Medicine as well as other synthetic biologists.

The study, to be published Dec. 12 by the journal *Nature Chemical Biology*, provides details of the first synthetic biology technology enabling researchers to rewire how mammalian cells sense and respond to a broad class of physiologically relevant cues. Kelly A. Schwarz, a graduate student in Leonard's research group, is the study's first author.

"This work is exciting because it addresses a key technical gap in the field," Schwarz said. "There is great promise for using engineered cells as programmable therapies, and it is going to take technologies such as this to truly realize that goal."

Starting with human T cells in culture, the research team genetically engineered changes in the cells' input and output, including adding a sensing mode, and built a cell that is relevant to cancer immunotherapy.

Specifically, the engineered cells sense vascular endothelial growth factor (VEGF), a protein found in tumors that directly manipulates and in some ways suppresses the immune response. When the rewired cells sense VEGF in their environment, these cells, instead of being suppressed, respond by secreting interleukin 2 (IL-2), a protein that stimulates nearby immune cells to become activated specifically at that site. Normal unmodified T cells do not produce IL-2 when exposed to VEGF, so the engineered behavior is both useful and novel.

This work was carried out in cells in culture, and the technology next will be tested in animal studies.

While Leonard's team has initially focused on the application of this cell programming technology to enabling cancer immunotherapy, it can be readily extended to distinct cellular engineering goals and therapeutic applications. Leonard's "parts" are also intentionally modular, such that they can be combined with other synthetic biology innovations to write more sophisticated cellular programs.

"To truly accelerate the rate at which we can translate scientific insights into treatments, we need technologies that let us rapidly try out new ideas, in this case by building living cells that manifest a

desired biological function," said Leonard, who also is a founding member of the Center for Synthetic Biology and a member of the Chemistry of Life Processes Institute.

"Our technology also provides a powerful new tool for fundamental research, enabling biologists to test otherwise untestable theories about how cells coordinate their functions in complex, multicellular organisms," he said.

Related to this research, Leonard was an invited conferee at a special meeting held in October, "Systems and Synthetic Biology for Designing Rational Cancer Immunotherapies," as part of President Obama and Vice President Biden's Cancer Moonshot Initiative. [20]

Researchers watch biomolecules at work

Scientists at the University of Bonn have succeeded in observing an important cell protein at work using a method that measures structural changes within complex molecules. The procedure makes it possible to elucidate such processes in the natural environment. The researchers are also providing a tool kit, which allows a wide range of molecules to be measured. Their study has been published in *Angewandte Chemie International Edition*.

To open a Christmas season walnut, we usually use a nutcracker. The simplest of them consists of two arms that move against each other around a joint and can thus exert pressure on the shell.

Cellular molecules also alter their spatial structure as they work – similar to the nutcracker, which has arms that open or close. These conformational changes tell experts a great deal about the way in which the molecule fulfills its job. Unfortunately, it is very difficult to measure these kind of movements because they occur on a very small length scale. This complicates the observation of structural changes in the natural cellular environment, where countless simultaneous processes make it very hard to isolate any specific information from the general noise.

The working group from the Institute for Physical and Theoretical Chemistry at the University of Bonn has now succeeded in doing this. To this end, the scientists further developed a method that has been used for many years to measure distances within large molecules. "However, this normally only works in a test tube," explains the head of the study, Prof. Olav Schiemann. "In contrast, our technique can also be used in cells."

The researchers used what is known as electron paramagnetic resonance spectroscopy (EPR) for their measurements. The molecule to be measured is usually given a magnetic marker at two different sites. Through radiation with microwaves, the polarity of one of these mini magnets is reversed. The magnetic field emitted by it is thus changed, which in turn influences the second mini magnet. This influence is greater the closer both markers are to each other.

"We now measure how strongly the second magnet reacts to the reverse polarity of the first," explains Schiemann. "From this, we can ascertain the distance between both markers." If – metaphorically speaking – both arms of the nutcracker are marked in this way, their movement against each other can be understood.

Magnetic ruler measurements

In principle, the technique is not new. "However, we have succeeded in producing a new kind of label with which we can mark a wide range of biomolecules in a site-specific way", explains Schiemann's staff member Jean Jacques Jassoy. Usually, these labels consist of radicals – which are chemical compounds that carry a single free electron. The electron acts as a magnet during the measurement. The problem here: single electrons are highly reactive – they try to form pairs of electrons as quickly as possible. The chemists at the University of Bonn thus used a very stable radical in their work – a so called trityl group. They created various derivatives of this trityl radical. Each of these magnetic markers is designed to target specific sites within biomolecules and thus enables several approaches for the structural analysis of different biomolecules.

In their study, the researchers used this methodological advance to investigate a protein from the cytochrome P450 group. These proteins occur in almost all living beings and fulfill important tasks, for instance during oxidation processes in the cell. "With our method, we were able to precisely measure the distance between two areas of the cytochrome to a fraction of a millionth of a millimeter," emphasizes Schiemann's staff member Andreas Berndhäuser.

The procedure is suitable for making biomolecule conformational changes visible in the cell. At the same time, it also generally facilitates the clarification of molecular structures. Schiemann: "We are thus providing researchers with a new tool kit that could help answer many biochemical questions." [19]

Hydrogen from sunlight—but as a dark reaction

The storage of photogenerated electric energy and its release on demand are still among the main obstacles in artificial photosynthesis. One of the most promising, recently identified photocatalytic new materials is inexpensive graphitic carbon nitride. Scientists have now explored a modified form that can produce light-generated electrons and store them for catalytic hydrogen production even after the light has been switched off. They present this biomimetic photosynthesis approach in the journal *Angewandte Chemie*.

Nature has split photosynthesis into a light reaction generating electrons and holes from solar energy, and a dark reaction generating the actual "fuels" or chemicals that transport and store this energy. This second, time-lagged process is independent of the primary energy source, the sunlight, and thus ensures that fuel is continually produced over the entire diurnal cycle. This contrasts with current man-made systems, which suffer from an annoying disruption of energy production during the night.

In photovoltaic systems, solar cells generate electrons for either local use or to feed them into the public grid. Storage of electric energy is usually performed in batteries or by electrochemical conversion into fuels such as hydrogen or methane. Mimicking Nature's photosynthesis in a process known as "artificial photosynthesis" would imply using a material that is able to store the electrons right after their light-induced generation and release them on demand. Such a material was explored by Bettina V. Lotsch at the Max Planck Institute for Solid State Research, Germany, and collaborators in Zurich and Cambridge. It was obtained from "melon", an ordered carbon nitride polymer, which is currently heavily investigated for its photocatalytic and semiconducting properties.

The as-modified graphitic nitride is a yellow solid, which changes color upon exposure to light. "This polymer turns blue when photo-irradiated in the presence of certain electron donors in an oxygen-free environment," said the scientists. This "blue radical" state contains trapped electrons. The scientists found out that when the light was switched off and a hydrogen-evolution co-catalyst was added, the polymer turned yellow again while producing hydrogen by releasing the stored electrons. Thus it is possible to decouple the generation of photoinduced electrons from their use, for example, in fuel production, within one single, inexpensive material. This could be a significant advance for the production of storable solar fuels independent of the intermittency of solar irradiation. [18]

ANU invention to inspire new night-vision specs

Scientists at The Australian National University (ANU) have designed a nano crystal around 500 times smaller than a human hair that turns darkness into visible light and can be used to create light-weight night-vision glasses.

Professor Dragomir Neshev from ANU said the new night-vision glasses could replace the cumbersome and bulky night-vision binoculars currently in use.

"The nano crystals are so small they could be fitted as an ultra-thin film to normal eye glasses to enable night vision," said Professor Neshev from the Nonlinear Physics Centre within the ANU Research School of Physics and Engineering.

"This tiny device could have other exciting uses including in anti-counterfeit devices in bank notes, imaging cells for medical applications and holograms."

Co-researcher Dr Mohsen Rahmani said the ANU team's achievement was a big milestone in the field of nanophotonics, which involves the study of behaviour of light and interaction of objects with light at the nano-scale.

"These semi-conductor nano-crystals can transfer the highest intensity of light and engineer complex light beams that could be used with a laser to project a holographic image in modern displays," said Dr Rahmani, a recipient of the Australian Research Council (ARC) Discovery Early Career Researcher Award based at the ANU Research School of Physics and Engineering.

PhD student Maria del Rocio Camacho-Morales said the team built the device on glass so that light can pass through, which was critical for optical displays.

"This is the first time anyone has been able to achieve this feat, because growing a nano semi-conductor on a transparent material is very difficult," said Ms Camacho-Morales from the Nonlinear Physics Centre at ANU.

The research is published in Nano Letters and is being presented by Dr Rahmani at the Australian Institute of Physics Congress in Brisbane this week. [17]

Using magnets instead of antibiotics as a new treatment method for blood infection

Magnets instead of antibiotics could provide a possible new treatment method for blood infection. This involves the blood of patients being mixed with magnetic iron particles, which bind the bacteria to them after which they are removed from the blood using magnets. The initial laboratory tests at Empa in St. Gallen have been successful, and seem promising.

Blood poisoning is still fatal in more than 50% of cases, but can be cured if treated at an early stage. The highest priority is therefore to act quickly. For this reason, doctors usually administer antibiotics even in the event of a suspicion of blood poisoning, without first ascertaining whether it is actually a bacterial sepsis, which in turn greatly increases the risk of resistance to antibiotics developing. It is therefore important to identify and develop a fast and effective therapy, if possible without the need to use antibiotics.

An antibody for everything

Empa researcher Inge Herrmann and her team are developing a solution in collaboration with modelling expert Marco Lattuada from the Adolphe Merkle Institute and doctors from the Harvard Medical School. The idea for the treatment is the magnetic purification of blood. The principle is, at least in theory, quite straightforward. Iron particles are coated with an antibody that detects and binds the harmful bacteria in the blood. As soon as the iron particles are attached to the bacteria, they are removed from the blood magnetically.

However, there is (still) a small catch: So far, it has only been possible to coat the iron particles with antibodies that recognise one type of bacteria – but many different types of bacteria may be involved, depending on the species causing the blood poisoning. Using blood analysis, doctors must therefore first determine which bacteria is causing the poisoning before the appropriate antibodies can be used. "This blood analysis is time-consuming and time plays a vital role in the treatment of blood poisoning," explains Herrmann. This is also the reason for magnetic dialysis rarely having been used to date.

But a team at the Harvard Medical School led by Gerald Pier has now developed an antibody that can bind almost all the bacteria that can trigger blood poisoning - so if there is a suspicion of sepsis, the magnetic treatment could be started immediately, regardless of which pathogen is in the blood. This "allrounder" antibody to succeed in isolating pathogenic bacteria - similar to using dialysis.

How harmful are the iron particles?

The method is not yet sufficiently mature to be used on patients. In a next step, Herrmann wants to carry out tests with various other germs and find out whether the Harvard antibody can actually bind additional bacteria to itself. The nature of the iron particles is also not to be underestimated. It may be the case that some particles remain in the blood after the magnetic extraction has been carried out. The requirements for these carriers are thus clear: they must not harm the human body. But Herrmann's team already has a solution ready in this regard. The tiny iron particles are assembled into larger clusters and are thus more responsive to the magnet. In addition, the researchers have been able to demonstrate, in an in vitro simulation, that the iron particles are broken down completely after only five days.

Further experiments still to come

In the future, it should therefore no longer be strictly necessary to administer antibiotics as soon as there is a suspicion of sepsis. Blood will be taken from the patient for analysis, and the patient connected to a dialysis machine to cleanse the blood, no matter what bacteria are in it. As soon as the doctors have the detailed blood values, an antibiotic therapy tailored to the pathogen can be introduced, if necessary.

This idea is currently just a future ambition, as there are still numerous issues that need to be clarified. Firstly, it is imperative that this method is used in the initial stage of sepsis, when the damage has not yet spread from the blood to the organs or bodily functions, and there is also the issue of how well this treatment will work in unstable patients or patients with pre-existing conditions. But Herrmann and her team are optimistic - and also a step closer to achieving a new and more gentle treatment for sepsis. [16]

Interdisciplinary approach makes linking biological materials and electronic devices possible

One of the biggest challenges in cognitive or rehabilitation neurosciences is the ability to design a functional hybrid system that can connect and exchange information between biological systems, like neurons in the brain, and human-made electronic devices. A large multidisciplinary effort of researchers in Italy brought together physicists, chemists, biochemists, engineers, molecular biologists and physiologists to analyze the biocompatibility of the substrate used to connect these biological and human-made components, and investigate the functionality of the adhering cells, creating a living biohybrid system.

In an article appearing this week in AIP Advances, the research team used the interaction between light and matter to investigate the material properties at the molecular level using Raman spectroscopy, a technique that, until now, has been principally applied to material science. Thanks to the coupling of the Raman spectrometer with a microscope, spectroscopy becomes a useful tool for investigating micro-objects such as cells and tissues. Raman spectroscopy presents clear advantages for this type of investigation: The molecular composition and the modification of subcellular compartments can be obtained in label-free conditions with non-invasive methods and under physiological conditions, allowing the investigation of a large variety of biological processes both in vitro and in vivo.

Once the biocompatibility of the substrate was analyzed and the functionality of the adhering cells investigated, the next part of this puzzle is connecting with the electronic component. In this case a memristor was used.

"Its name reveals its peculiarity (MEMory ResISTOR), it has a sort of "memory": depending on the amount of voltage that has been applied to it in the past, it is able to vary its resistance, because of a change of its microscopic physical properties," said Silvia Caponi, a physicist at the Italian National Research Council in Rome. By combining memristors, it is possible to create pathways within the electrical circuits that work similar to the natural synapses, which develop variable weight in their connections to reproduce the adaptive/learning mechanism. Layers of organic polymers, like

polyaniline (PANI) a semiconductor polymer, also have memristive properties, allowing them to work directly with biological materials into a hybrid bio-electronic system.

"We applied the analysis on a hybrid bio-inspired device but in a prospective view, this work provides the proof of concept of an integrated study able to analyse the status of living cells in a large variety of applications that merges nanosciences, neurosciences and bioelectronics," said Caponi. A natural long-term objective of this work would be interfacing machines and nervous systems as seamlessly as possible.

The multidisciplinary team is ready to build on this proof of principle to realize the potential of memristor networks.

"Once assured the biocompatibility of the materials on which neurons grow," said Caponi, "we want to define the materials and their functionalization procedures to find the best configuration for the neuron-memristor interface to deliver a full working hybrid bio-memristive system." [15]

Wearable terahertz scanning device for inspection of medical equipment and the human body

Scientists at the Tokyo Institute of Technology have developed a portable and wearable terahertz scanning device using arrays of carbon nanotubes for non-invasive inspection of three-dimensional objects without requiring bulky peripheral optical components. The device is expected to have wide-ranging applications including noninvasive inspections of medical and drug delivery equipment such as syringes, as well as imaging cancer cells, blood clots, sweat glands and teeth. The findings are published in Nature Photonics, November 2016.

Imaging devices based on terahertz waves show promise for noninvasive inspection of solid objects and soft tissues of the human body. However, terahertz waves have difficulty in imaging and reproducing the curved contours of three-dimensional objects. Furthermore, terahertz devices currently used for whole-body scans at airports must rotate 360 degrees around the human body, and are thus large, bulky, and non-portable. In addition, the materials used to fabricate conventional terahertz systems are not flexible, and the terahertz detectors must be cooled in order to achieve high detection sensitivity.

Therefore, researchers seek terahertz imaging systems that are portable, flexible, and operate efficiently at room temperature. To address these challenges, Yukio Kawano and colleagues at the Laboratory for Future Interdisciplinary Research of Science and Technology, Tokyo Institute of Technology, have demonstrated a terahertz imaging device fabricated with arrays of carbon nanotubes (CNT). Notably, CNTs have previously been used for the fabrication of photodetectors that operate in the visible, infrared, and terahertz regions of the electromagnetic spectrum.

The Tokyo Tech team fabricated a flexible, wide-band terahertz scanner by integrating 23 CNT detector elements into a single array. The mechanical strength of the CNT film used in the detector could be readily bent over a wide range of angles, unlike conventional semiconductor materials that are fragile and break under stress. Importantly, the CNT films also absorb electromagnetic radiation over a broad terahertz range, which eliminates the need for planar antennas to scan objects. The terahertz scanner developed by Kawano and his team was successfully used for active imaging of flat

and curved samples; multiview scanning of cylindrical samples; and passive wearable imaging of a human hand.

In the future, the research team expects that the applications of their terahertz scanner will enhance the capability of noninvasive inspections in pharmaceuticals, food quality control, and medical monitoring. These applications are possible because the terahertz scanner is wearable, portable, and can scan 3-D objects without requiring complex optics or equipment. [14]

Fluorescent holography: Upending the world of biological imaging

Optical microscopy experts at Colorado State University are once again pushing the envelope of biological imaging.

Jeffrey Field, a research scientist in electrical engineering and director of CSU's Microscope Imaging Network, has designed and built a fluorescence-detection microscope that combines three-dimensional and high-resolution image processing that's also faster than comparable techniques.

The work, with co-authorship by Randy Bartels, professor of electrical and computer engineering, and former postdoctoral researcher David Winters, has been published in *Optica*, the journal of the Optical Society of America. They named their new microscope CHIRPT: Coherent Holographic Image Reconstruction by Phase Transfer.

Imaging tradeoffs

Field and other optics scientists work in a world of tradeoffs. For example: an advanced deep-tissue imaging technique called multiphoton fluorescence microscopy employs a short, bright laser pulse focused tight to one spot, and the fluorescence intensity from that one spot is recorded. Then, the laser moves to the next spot, then the next, to build up high-resolution 3D images. The technique offers subcellular detail, but it's relatively slow because it illuminates only one tiny spot at a time.

Other techniques, like spinning disk confocal microscopy, are faster because they shine light on multiple spots, not just one, and they scan simultaneously over a larger area. But unlike multiphoton, these techniques require collecting an image with a camera. As a result, fluorescent light emitted from the specimen is blurred on the camera, leading to loss in resolution, and with it, subcellular detail.

Call them greedy, but Field and colleagues want it all.

Breaking established boundaries

Their goal is working around each of these limitations - speed, resolution, size of field - to break through established boundaries in light microscopy.

Field and Bartels' new microscope builds upon a previously published technique, and permits digital re-focus of fluorescent light. It illuminates not one point, but multiple points by harnessing delocalized illumination spread over a large area. The physical principles they are using are similar to holography, in which scattered light is used to build a 3-D image.

Using a large illumination field, followed by back-end signal processing, the microscope can define distinct light modulation patterns of many points within the field of view. It builds up a 3-D image by combining the signals from all those distinct patterns.

"The idea is that you have a fluorophore at any point in the specimen, and the temporal structure of its fluorescence will be distinguishable from all others," Field said. "So you can have this huge array of fluorophores, and just with this single-pixel detector, you can tell where every one of them is in that 2D field."

3D, deep-tissue images

So what does this new technique allow? Deep-tissue images in three dimensions, with better depth of field than comparable techniques. Depth of field, like in photography, means background images are in sharp focus along with the main image. And the CSU researchers can work at 600 frames per second, which is many times faster than established techniques.

With their new microscope, images can also be post-processed to remove aberrations that obscure the object of interest. It's akin to being able to focus a picture after it's been taken.

The CHIRPT microscope could allow biomedical researchers to produce sharp, 3-D images of cells or tissue over a much larger volume than conventional fluorescence microscopy methods allow. It could lead to things like imaging multicellular processes in real time that, with a conventional light microscope, could only be seen one cell at a time. [13]

Atomic-scale MRI holds promise for new drug discovery

Researchers at the University of Melbourne have developed a way to radically miniaturise a Magnetic Resonance Imaging (MRI) machine using atomic-scale quantum computer technology.

Capable of imaging the structure of a single bio-molecule, the new system would overcome significant technological challenges and provide an important new tool for biotechnology and drug discovery.

The work was published today in Nature Communications, and was led by Prof Lloyd Hollenberg at the University of Melbourne, working closely with researchers at the ARC Centre of Excellence for Quantum Computation and Communication Technology (CQC2T) to design the quantum molecular microscope.

The team propose the use of atomic-sized quantum bits (qubits) normally associated with the development of quantum computers, but here would be employed as highly sensitive quantum sensors to image the individual atoms in a bio-molecule.

"Determining the structure of bio-molecules such as proteins can often be a barrier to the development of novel drugs," said Prof. Lloyd Hollenberg, Thomas Baker Chair in Physical Biosciences at the University of Melbourne.

"By using quantum sensing to image individual atoms in a bio-molecule, we hope to overcome several issues in conventional biomolecule imaging," Prof Hollenberg said.

State-of-the-art techniques create a crystal of the molecule to be studied and use X-ray diffraction to determine the molecules' average structure. However, the crystallisation and averaging processes may lead to important information being lost. Also, not all bio-molecules can be crystallised - particularly proteins associated with cell membranes, which are critical in the development of new drugs.

"Our system is specifically designed to use a quantum bit as a nano-MRI machine to image the structure of a single protein molecule in their native hydrated environments," added Prof Hollenberg.

"As part of our research in quantum computing we have also been working on the nearer-term applications of atomic-based quantum technology investigating the use of a single quantum bit as a highly sensitive magnetic field sensor," says Prof. Hollenberg.

Atomic qubits can be made to exist in two states at the same time, a disturbingly strange property that not only underpins the power of a quantum computer, but also the sensitivity of qubits as nano-sensors.

"In a conventional MRI machine large magnets set up a field gradient in all three directions to create 3D images; in our system we use the natural magnetic properties of a single atomic qubit," says University of Melbourne PhD researcher Mr. Viktor Perunicic, who was the lead author on the paper.

"The system would be fabricated on-chip, and by carefully controlling the quantum state of the qubit probe as it interacts with the atoms in the target molecule, we can extract information about the positions of atoms by periodically measuring the qubit probe and thus create an image of the molecule's structure." says Mr. Perunicic.

"The system could be constructed and tested relatively quickly using diamond-based qubits. However, to capture really high resolution molecular images in the longer term, CQC2T's silicon-based qubits might have the advantage because they have very long quantum coherence," said Prof. Hollenberg.

"The construction of such a quantum MRI machine for single molecule microscopy could revolutionise how we view biological processes at the molecular level, and could lead to the development of new biotechnology and a range of clinical applications." [12]

Researchers identified some nanoscale elements that govern the behavior of our teeth

With one in two Australian children reported to have tooth decay in their permanent teeth by age 12, researchers from the University of Sydney believe they have identified some nanoscale elements that govern the behaviour of our teeth.

Material and structures engineers worked with dentists and bioengineers to map the exact composition and structure of tooth enamel at the atomic scale.

Using a relatively new microscopy technique called atom probe tomography, their work produced the first-ever three-dimensional maps showing the positions of atoms critical in the decay process.

The new knowledge on atom composition at the nanolevel has the potential to aid oral health hygiene and caries prevention, and has been published today in the journal Science Advances.

Professor Julie Cairney, Material and Structures Engineer in the Faculty of Engineering and Information Technologies, said:

"The dental professionals have known that certain trace ions are important in the tough structure of tooth enamel but until now it had been impossible to map the ions in detail.

"The structure of human tooth enamel is extremely intricate and while we have known that magnesium, carbonate and fluoride ions influence enamel properties scientists have never been able to capture its structure at a high enough resolution or definition."

"What we have found are the magnesium-rich regions between the hydroxyapatite nanorods that make up the enamel.

"This means we have the first direct evidence of the existence of a proposed amorphous magnesium-rich calcium phosphate phase that plays an essential role in governing the behaviour of teeth. "

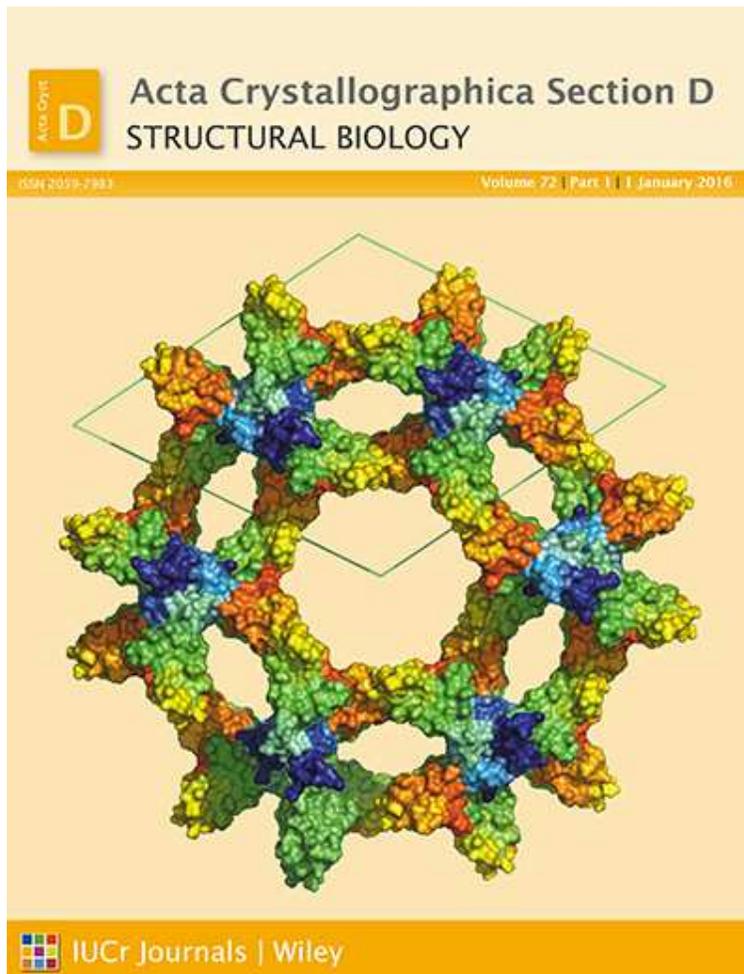
Co-lead researcher on the study, Dr Alexandre La Fontaine from the University's Australian Centre for Microscopy and Microanalysis, said:

We were also able to see nanoscale 'clumps' of organic material, which indicates that proteins and peptides are heterogeneously distributed within the enamel rather than present along all the nanorod interfaces, which was what was previously suggested.

The mapping has the potential for new treatments designed around protecting against the dissolution of this specific amorphous phase.

The new understanding of how enamel forms will also help in tooth remineralisation research." [11]

Digital enhancement of cryoEM photographs of protein Nanocrystals



The procedure described by van Genderen et al. [(2016). *Acta Cryst. D*71, 34-39] paves the way towards full three-dimensional structure determination at high resolution for protein crystals. The authors report on how lattice information can be enhanced by means of a wave finder in combination with Wiener-type maximum-likelihood filtering. The lattice filter is a very powerful tool for selecting and analysing extremely low contrast cryo-images of three dimensional protein/peptide nanocrystals. It confirms that the three-dimensional crystals are made up from multiple domains that are slightly differently oriented. Indeed, the algorithm can comfortably deal with multiple crystals with very different orientations, unit cells and/or space groups.

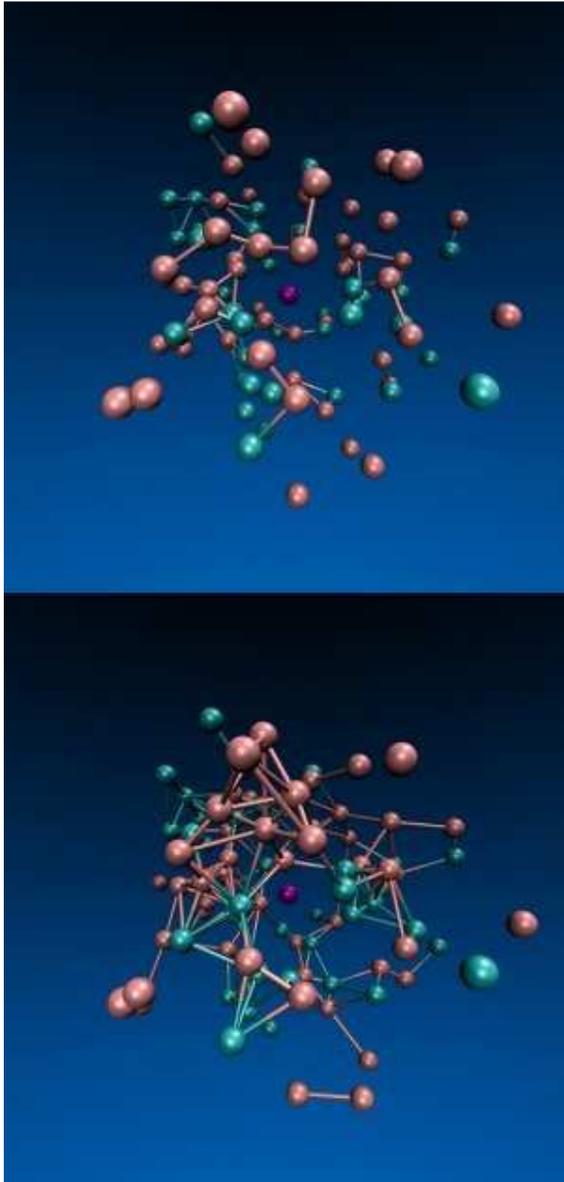
The authors of the paper propose the new lattice filter as a powerful tool for processing very noisy images with crystal factors (and thus the phase information) hidden within them. The filter is able to discriminate between noise images and the very noisy images with very low contrast which contain crystal-like structures. The lattice filter retains the shape of the spots in Fourier space and also retains any phase gradients within the Bragg spots (which determine the domain structure within the crystal). Thus, it retains all of the significant information from the Bragg spots. This will open the way to combining the phases acquired from stationary, two-dimensional images with intensities of rotation diffraction data taken from the same type of crystals. In this way, the authors expect to be able to phase the diffraction information of protein and peptide crystals. [10]

This Physicist Has a Groundbreaking Idea about Why Life Exists

“You start with a random clump of atoms, and if you shine light on it for long enough, it should not be so surprising that you get a plant,” England said.

England’s theory is meant to underlie, rather than replace, Darwin’s theory of evolution by natural selection, which provides a powerful description of life at the level of genes and populations. “I am certainly not saying that Darwinian ideas are wrong,” he explained. “On the contrary, I am just saying that from the perspective of the physics, you might call Darwinian evolution a special case of a more general phenomenon.”

At the heart of England’s idea is the second law of thermodynamics, also known as the law of increasing entropy or the “arrow of time.” Hot things cool down, gas diffuses through air, eggs scramble but never spontaneously unscramble; in short, energy tends to disperse or spread out as time progresses. Entropy is a measure of this tendency, quantifying how dispersed the energy is among the particles in a system, and how diffuse those particles are throughout space. It increases as a simple matter of probability: There are more ways for energy to be spread out than for it to be concentrated.



A computer simulation by Jeremy England and colleagues shows a system of particles confined inside a viscous fluid in which the turquoise particles are driven by an oscillating force. Over time (from top to bottom), the force triggers the formation of more bonds among the particles.

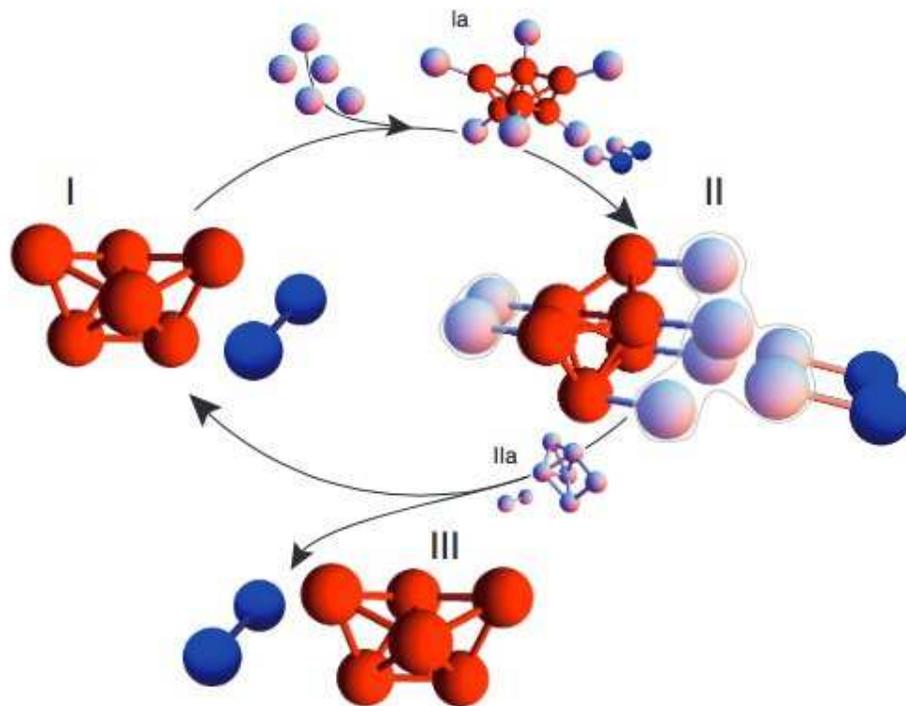
Thus, as particles in a system move around and interact, they will, through sheer chance, tend to adopt configurations in which the energy is spread out. Eventually, the system arrives at a state of maximum entropy called “thermodynamic equilibrium,” in which energy is uniformly distributed. A cup of coffee and the room it sits in become the same temperature, for example.

Although entropy must increase over time in an isolated or “closed” system, an “open” system can keep its entropy low — that is, divide energy unevenly among its atoms — by greatly increasing the entropy of its surroundings. In his influential 1944 monograph “What Is Life?” the eminent quantum physicist Erwin Schrödinger argued that this is what living things must do. A plant, for example, absorbs extremely energetic sunlight, uses it to build sugars, and ejects infrared light, a much less

concentrated form of energy. The overall entropy of the universe increases during photosynthesis as the sunlight dissipates, even as the plant prevents itself from decaying by maintaining an orderly internal structure.

Self-replication (or reproduction, in biological terms), the process that drives the evolution of life on Earth, is one such mechanism by which a system might dissipate an increasing amount of energy over time.

As England put it, "A great way of dissipating more is to make more copies of yourself."



Self-Replicating Sphere Clusters: According to new research at Harvard, coating the surfaces of microspheres can cause them to spontaneously assemble into a chosen structure, such as a polytetrahedron (red), which then triggers nearby spheres into forming an identical structure.

Scientists have already observed self-replication in nonliving systems. According to new research led by Philip Marcus of the University of California, Berkeley, and reported in *Physical Review Letters* in August, vortices in turbulent fluids spontaneously replicate themselves by drawing energy from shear in the surrounding fluid. And in a paper in *Proceedings of the National Academy of Sciences*, Michael Brenner, a professor of applied mathematics and physics at Harvard, and his collaborators present theoretical models and simulations of microstructures that self-replicate. These clusters of specially coated microspheres dissipate energy by roping nearby spheres into forming identical clusters. "This connects very much to what Jeremy is saying," Brenner said. [8]

Photoactive Prebiotic Systems

We propose that life first emerged in the form of such minimal photoactive prebiotic kernel systems and later in the process of evolution these photoactive prebiotic kernel systems would have produced fatty acids and covered themselves with fatty acid envelopes to become the minimal cells of the Fatty Acid World. Specifically, we model self-assembling of photoactive prebiotic systems with observed quantum entanglement phenomena. We address the idea that quantum entanglement was important in the first stages of origins of life and evolution of the biospheres because simultaneously excite two prebiotic kernels in the system by appearance of two additional quantum entangled excited states, leading to faster growth and self-replication of minimal living cells. The quantum mechanically modeled possibility of synthesizing artificial self-reproducing quantum entangled prebiotic kernel systems and minimal cells also impacts the possibility of the most probable path of emergence of photocells on the Earth or elsewhere. We also examine the quantum entangled logic gates discovered in the modeled systems composed of two prebiotic kernels. Such logic gates may have application in the destruction of cancer cells or becoming building blocks of new forms of artificial cells including magnetically active ones.

Significance Statement

Our investigated self-assembly of molecules towards supramolecular bioorganic and minimal cellular systems depends on the quantum mechanics laws which induce hydrogen and Van der Waals bindings (Tamulis A, Grigalavicius, M, *Orig Life Evol Biosph* 41:51-71, 2011).

In the work presented here, quantum entanglement takes the form of a quantum superposition of the active components in synthesized self-assembling and self-replicating living systems. When a quantum calculation of an entangled system is made that causes one photoactive biomolecule of such a pair to take on a definite value (e.g., electron density transfer or electron spin density transfer), the other member of this entangled pair will be found to have taken the appropriately correlated value (e.g., electron density transfer or electron spin density transfer). In our simulations, the separation distance of supramolecular bio systems changes took place during geometry optimization procedures, which mimic real-world intermolecular interaction processes.

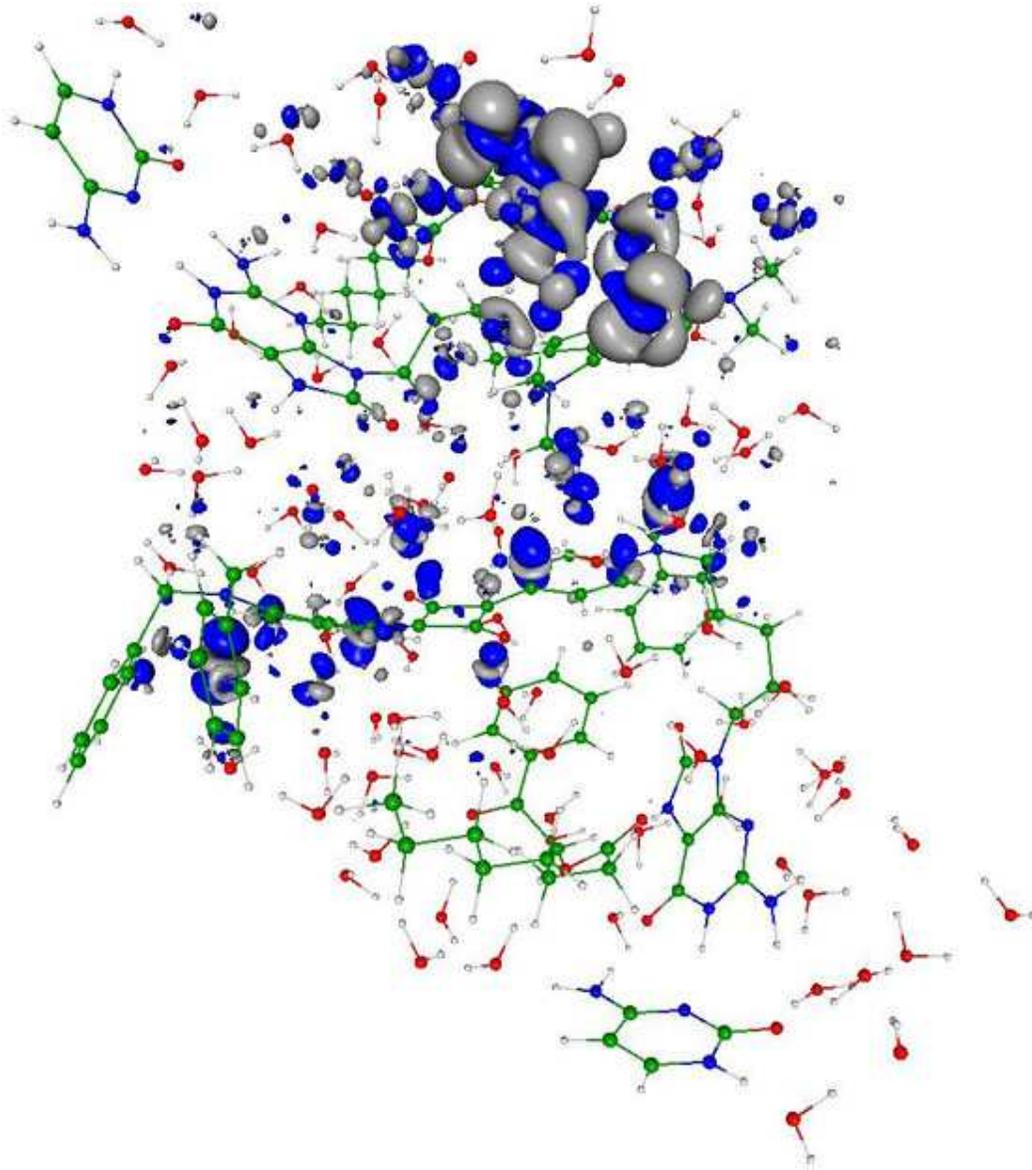
Our discovered phenomenon of the quantum entanglement in the prebiotic systems enhance the photosynthesis in the proposed systems because simultaneously excite two prebiotic kernels in the system by appearance of two additional quantum entangled excited states (Tamulis A, Grigalavicius M, Baltrusaitis J, *Orig Life Evol Biosph* 43:49-66, 2013; Tamulis A, Grigalavicius M, Krisciukaitis S (2014), *J Comput Theor Nanos*, 11, 1597-1608, 2014; Tamulis A, Grigalavicius M, 8:117-140, 2014.). We can propose that quantum entanglement enhanced the emergence of photosynthetic prebiotic kernels and accelerated the evolution of photosynthetic life because of additional absorbed light energy, leading to faster growth and self-replication of minimal living cells.

We can state that: Livings are self-assembled and self-replicating wet and warm stochastically moving supramolecular systems where quantum entanglement can be continuously generated and destroyed by non-equilibrium effects in an environment where no static entanglement exists; quantum entanglement involve the biomolecule inside one living or between other neighboring livings.

This warm quantum coherence is basic for the explanation of DNA stability and for the understanding of brain magnetic orientation during migration in more than 50 species of birds, fishes and insects. Exists experimental evidence for quantum-coherent is used for more efficient light-harvesting in plant photosynthesis. Quantum entanglement exists in supramolecules determining the sense of smell and in the brain neurons microtubules due to quantum vibrations.

In the work presented here, we started to design and quantum mechanical investigations of the molecular logical devices which are useful for construction of nano medicine biorobots against the molecular diseases such a cancer tumors, and against the new kinds of synthesized microorganisms and nano guns.

Figure legend



You can see in the enclosed figure the quantum entanglement phenomenon in the closely self-assembled two synthesized protocell system due to the photo excited electron charge transfer from one protocell to another that leads to closer self-assembly and exchange of energy and information.

Visualization of the electron charge tunneling associated with the 6th (467.3 nm) excited state. The transition is mainly from squaraine molecule of the first protocell situated in the bottom of this bi cellular system to precursor of fatty acid (pFA) molecule of the second subsystem (in the top) and little from the 1,4-bis(N,N-dimethylamino)naphthalene molecule (in the top-right) to the same pFA molecule of the second subsystem (in the top). The electron cloud hole is indicated by the dark blue color while the transferred electron cloud location is designated by the gray color.

As a result, these nonlinear quantum interactions compressed the overall molecular system resulting in a smaller gap between the HOMO and LUMO electron energy levels which allows enhanced tunneling of photo excited electrons from the sensitizer squaraine and (1,4-bis(N,N-dimethylamino)naphthalene) to the pFA molecule resulting in its cleavage. The new fatty acid joins the existing minimal cell thus increasing it in size. After reaching some critical size, the minimal cell should divide (i.e. self-replicate) into two separate smaller minimal cells. [7]

Quantum Biology

Researchers have long suspected that something unusual is afoot in photosynthesis. Particles of light called photons, streaming down from the Sun; arrive randomly at the chlorophyll molecules and other light-absorbing 'antenna' pigments that cluster inside the cells of every leaf, and within every photosynthetic bacterium. But once the photons' energy is deposited, it doesn't stay random. Somehow, it gets channeled into a steady flow towards the cell's photosynthetic reaction centre, which can then use it at maximum efficiency to convert carbon dioxide into sugars. Quantum coherence in photosynthesis seems to be beneficial to the organisms using it. But did their ability to exploit quantum effects evolve through natural selection? Or is quantum coherence just an accidental side effect of the way certain molecules are structured? [6]

Quantum Consciousness

Extensive scientific investigation has found that a form of quantum coherence operates within living biological systems through what is known as biological excitations and biophoton emission. What this means is that metabolic energy is stored as a form of electromechanical and electromagnetic excitations. These coherent excitations are considered responsible for generating and maintaining long-range order via the transformation of energy and very weak electromagnetic signals. After nearly twenty years of experimental research, Fritz-Albert Popp put forward the hypothesis that biophotons are emitted from a coherent electrodynamics field within the living system.

What this means is that each living cell is giving off, or resonating, a biophoton field of coherent energy. If each cell is emitting this field, then the whole living system is, in effect, a resonating field-a ubiquitous nonlocal field. And since biophotons are the entities through which the living system communicates, there is near-instantaneous intercommunication throughout. And this, claims Popp, is the basis for coherent biological organization -- referred to as quantum coherence. This discovery

led Popp to state that the capacity for evolution rests not on aggressive struggle and rivalry but on the capacity for communication and cooperation. In this sense the built-in capacity for species evolution is not based on the individual but rather living systems that are interlinked within a coherent whole: Living systems are thus neither the subjects alone, nor objects isolated, but both subjects and objects in a mutually communicating universe of meaning. . . . Just as the cells in an organism take on different tasks for the whole, different populations enfold information not only for themselves, but for all other organisms, expanding the consciousness of the whole, while at the same time becoming more and more aware of this collective consciousness.

Biophysicist Mae-Wan Ho describes how the living organism, including the human body, is coordinated throughout and is "coherent beyond our wildest dreams." It appears that every part of our body is "in communication with every other part through a dynamic, tunable, responsive, liquid crystalline medium that pervades the whole body, from organs and tissues to the interior of every cell."

What this tells us is that the medium of our bodies is a form of liquid crystal, an ideal transmitter of communication, resonance, and coherence. These relatively new developments in biophysics have discovered that all biological organisms are constituted of a liquid crystalline medium. Further, DNA is a liquid-crystal, lattice-type structure (which some refer to as a liquid crystal gel), whereby body cells are involved in a holographic instantaneous communication via the emitting of biophotons (a source based on light). This implies that all living biological organisms continuously emit radiations of light that form a field of coherence and communication. Moreover, biophysics has discovered that living organisms are permeated by quantum wave forms. [5]

Information – Entropy Theory of Physics

Viewing the confined gas where the statistical entropy not needs the information addition is not the only physical system. There are for example quantum mechanical systems where the information is a very important qualification. The perturbation theory needs higher order calculations in QED or QCD giving more information on the system as in the chess games happens, where the entropy is not enough to describe the state of the matter. The variation calculation of chess is the same as the perturbation calculation of physics to gain information, where the numbers of particles are small for statistical entropy to describe the system. The role of the Feynman graphs are the same as the chess variations of a given position that is the depth of the variations tree, the Information is the same as the order of the Feynman graphs giving the Information of the micro system. [9]

Information – Entropy Theory of Life

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that

is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction. The living biological systems have also entropy lowering and information growing direction by building more complicated or entangled molecules, governed by the quantum mechanics and the general weak interaction. On the other hand there is the arrow of time; the entropy growing is lowering the information by dissipating these entangled or otherwise connected biomolecules, aging the living systems.

Creating quantum technology

Another area of potential application is in quantum computing. The long-standing goal of the physicists and engineers working in this area is to manipulate data encoded in quantum bits (qubits) of information, such as the spin-up and spin-down states of an electron or of an atomic nucleus. Qubits can exist in both states at once, thus permitting the simultaneous exploration of all possible answers to the computation that they encode. In principle, this would give quantum computers the power to find the best solution far more quickly than today's computers can — but only if the qubits can maintain their coherence, without the noise of the surrounding environment, such as the jostling of neighboring atoms, destroying the synchrony of the waves. [6]

Quantum Entanglement

Measurements of physical properties such as position, momentum, spin, polarization, etc. performed on entangled particles are found to be appropriately correlated. For example, if a pair of particles is generated in such a way that their total spin is known to be zero, and one particle is found to have clockwise spin on a certain axis, then the spin of the other particle, measured on the same axis, will be found to be counterclockwise. Because of the nature of quantum measurement, however, this behavior gives rise to effects that can appear paradoxical: any measurement of a property of a particle can be seen as acting on that particle (e.g. by collapsing a number of superimposed states); and in the case of entangled particles, such action must be on the entangled system as a whole. It thus appears that one particle of an entangled pair "knows" what measurement has been performed on the other, and with what outcome, even though there is no known means for such information to be communicated between the particles, which at the time of measurement may be separated by arbitrarily large distances. [4]

The Bridge

The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories. [1]

Accelerating charges

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field. In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by

linearly increasing the way they take every next time period because this accelerated motion. The same thing happens on the atomic scale giving a Δp impulse difference and a Δx way difference between the different part of the not point like particles.

Relativistic effect

Another bridge between the classical and quantum mechanics in the realm of relativity is that the charge distribution is lowering in the reference frame of the accelerating charges linearly: $ds/dt = at$ (time coordinate), but in the reference frame of the current it is parabolic: $s = a/2 t^2$ (geometric coordinate).

Heisenberg Uncertainty Relation

In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on Δx position difference and with a Δp momentum difference such a way that they product is about the half Planck reduced constant. For the proton this Δx much less in the nucleon, than in the orbit of the electron in the atom, the Δp is much higher because of the greater proton mass.

This means that the electron and proton are not point like particles, but has a real charge distribution.

Wave – Particle Duality

The accelerating electrons explains the wave – particle duality of the electrons and photons, since the elementary charges are distributed on Δx position with Δp impulse and creating a wave packet of the electron. The photon gives the electromagnetic particle of the mediating force of the electrons electromagnetic field with the same distribution of wavelengths.

Atomic model

The constantly accelerating electron in the Hydrogen atom is moving on the equipotential line of the proton and it's kinetic and potential energy will be constant. Its energy will change only when it is changing its way to another equipotential line with another value of potential energy or getting free with enough kinetic energy. This means that the Rutherford-Bohr atomic model is right and only that changing acceleration of the electric charge causes radiation, not the steady acceleration. The steady acceleration of the charges only creates a centric parabolic steady electric field around the charge, the magnetic field. This gives the magnetic moment of the atoms, summing up the proton and electron magnetic moments caused by their circular motions and spins.

The Relativistic Bridge

Commonly accepted idea that the relativistic effect on the particle physics it is the fermions' spin - another unresolved problem in the classical concepts. If the electric charges can move only with accelerated motions in the self maintaining electromagnetic field, once upon a time they would

reach the velocity of the electromagnetic field. The resolution of this problem is the spinning particle, constantly accelerating and not reaching the velocity of light because the acceleration is radial. One origin of the Quantum Physics is the Planck Distribution Law of the electromagnetic oscillators, giving equal intensity for 2 different wavelengths on any temperature. Any of these two wavelengths will give equal intensity diffraction patterns, building different asymmetric constructions, for example proton - electron structures (atoms), molecules, etc. Since the particles are centers of diffraction patterns they also have particle – wave duality as the electromagnetic waves have. [2]

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry. The Electroweak Interaction shows that the Weak Interaction is basically electromagnetic in nature. The arrow of time shows the entropy grows by changing the temperature dependent diffraction patterns of the electromagnetic oscillators.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2 spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with $\frac{1}{2}$ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the

proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T- symmetry breaking!!! This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with $\frac{1}{2}$ spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater than subatomic matter structures as an electric dipole change. There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction.

Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing.

Van Der Waals force

Named after the Dutch scientist Johannes Diderik van der Waals – who first proposed it in 1873 to explain the behaviour of gases – it is a very weak force that only becomes relevant when atoms and molecules are very close together. Fluctuations in the electronic cloud of an atom mean that it will

have an instantaneous dipole moment. This can induce a dipole moment in a nearby atom, the result being an attractive dipole–dipole interaction.

Electromagnetic inertia and mass

Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

Relativistic change of mass

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

The frequency dependence of mass

Since $E = h\nu$ and $E = mc^2$, $m = h\nu / c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_0 inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [2]

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive

charges they need 2 photons to mediate this attractive force, one per charges. The Big Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass ratio $M_p=1840 M_e$. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass.

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy. There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

The Higgs boson

By March 2013, the particle had been proven to behave, interact and decay in many of the expected ways predicted by the Standard Model, and was also tentatively confirmed to have + parity and zero spin, two fundamental criteria of a Higgs boson, making it also the first known scalar particle to be discovered in nature, although a number of other properties were not fully proven and some partial results do not yet precisely match those expected; in some cases data is also still awaited or being analyzed.

Since the Higgs boson is necessary to the W and Z bosons, the dipole change of the Weak interaction and the change in the magnetic effect caused gravitation must be conducted. The Wien law is also important to explain the Weak interaction, since it describes the T_{max} change and the diffraction patterns change. [2]

Higgs mechanism and Quantum Gravity

The magnetic induction creates a negative electric field, causing an electromagnetic inertia. Probably it is the mysterious Higgs field giving mass to the charged particles? We can think about the photon as an electron-positron pair, they have mass. The neutral particles are built from negative and positive charges, for example the neutron, decaying to proton and electron. The wave – particle duality makes sure that the particles are oscillating and creating magnetic induction as an inertial mass, explaining also the relativistic mass change. Higher frequency creates stronger magnetic induction, smaller frequency results lesser magnetic induction. It seems to me that the magnetic induction is the secret of the Higgs field.

In particle physics, the Higgs mechanism is a kind of mass generation mechanism, a process that gives mass to elementary particles. According to this theory, particles gain mass by interacting with the Higgs field that permeates all space. More precisely, the Higgs mechanism endows gauge bosons in a gauge theory with mass through absorption of Nambu–Goldstone bosons arising in spontaneous symmetry breaking.

The simplest implementation of the mechanism adds an extra Higgs field to the gauge theory. The spontaneous symmetry breaking of the underlying local symmetry triggers conversion of components of this Higgs field to Goldstone bosons which interact with (at least some of) the other fields in the theory, so as to produce mass terms for (at least some of) the gauge bosons. This mechanism may also leave behind elementary scalar (spin-0) particles, known as Higgs bosons.

In the Standard Model, the phrase "Higgs mechanism" refers specifically to the generation of masses for the W^\pm , and Z weak gauge bosons through electroweak symmetry breaking. The Large Hadron Collider at CERN announced results consistent with the Higgs particle on July 4, 2012 but stressed that further testing is needed to confirm the Standard Model.

What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain indirect indicators.

The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

Conclusions

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

Prentiss, who runs an experimental biophysics lab at Harvard, says England's theory could be tested by comparing cells with different mutations and looking for a correlation between the amount of energy the cells dissipate and their replication rates. [8]

Exists experimental evidence for quantum-coherent is used for more efficient light-harvesting in plant photosynthesis. Quantum entanglement exists in supramolecules determining the sense of smell and in the brain neurons microtubules due to quantum vibrations.

In the work presented here, we started to design and quantum mechanical investigations of the molecular logical devices which are useful for construction of nano medicine biorobots against the molecular diseases such a cancer tumors, and against the new kinds of synthesized microorganisms and nano guns. [7]

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible they movement .

The accelerated charges self-maintaining potential shows the locality of the relativity, working on the quantum level also. [1]

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing.

The Secret of Quantum Entanglement that the particles are diffraction patterns of the electromagnetic waves and this way their quantum states every time is the result of the quantum state of the intermediate electromagnetic waves. [2]

These relatively new developments in biophysics have discovered that all biological organisms are constituted of a liquid crystalline medium. Further, DNA is a liquid-crystal, lattice-type structure (which some refer to as a liquid crystal gel), whereby body cells are involved in a holographic instantaneous communication via the emitting of biophotons (a source based on light). This implies that all living biological organisms continuously emit radiations of light that form a field of coherence and communication. Moreover, biophysics has discovered that living organisms are permeated by quantum wave forms. [5]

Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions also.

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