Stowe Science Review

Stowe's Mathematics, Technology & Science Newsletter

Nuclear Power

Could this field explode into life soon?

Love in the Brain

An examination into the processes that take place under the spell of love

Systems Chemistry

The next step in solving the problem of life?

Volume 3, Issue 2 Summer Term 2016

Welcome to Stowe Science Review!

The magazine that gives you a fascinating insight into the miraculous world of Mathematics, Technology and Science.

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Contents

3 Sebastian Wood explores the uses of the ideas of Nuclear Fusion and Nuclear Fission.

4 Georgie Skinner investigates the processes in the body and the brain behind love.

6 The effects of music on our brains is explored by Skye Longworth.

8 Rachel Sherry looks at the science in our voices, and sheds light on our vocal chords.

10 Elliot Mitchell explores the science linking Biology and Chemistry

11 Brace yourselves for the first compilation of scientific humour on the new jokes page.

12 Our seventh crossword will challenge your knowledge of inventions and inventors. The solution to the previous crossword can also be found here.

Have your say...

Science Review wants to know what you think about scientific affairs - please email sciencere-view@stowe.co.uk with your views on the topics discussed in this issue.

We look forward to hearing your views!

The Reality of Nuclear Fusion

You could say that not so long ago, around 50 years ago, the idea of fusion was not feasible; how could you successfully make a large amount of power from just a few atoms? In the 1950s, specifically 1957, researchers in Britain tested the ZETA fusion reactor, which used magnetic fields to confine atoms into a small space in the hope that they would fuse. From this research there was a significant jump in demand for fusion to be a reality. So in 1964 the Soviet Union tested the doughnut-shaped tokamak, which was a predecessor to dozens of fusion devices that would be tested over the following decades. Furthermore, in the 1970s three large-scale tokamaks began to be developed in the USA, Japan and Britain. Yet the advancement of small projects like ZETA, which had hopes of fusion; and attempts to harness more of the energy from the consistent fusion of matter, the devices failed to produce more energy than they consumed. This in itself was the elephant in the room, as it was the sole purpose for us humans to harness more energy, and therefore produce fuel and develop the world, without burning and depleting fossil fuels that will affect the earth itself. Here fusion creates an almost unfeasible amount of energy from a small source and we have a surplus of the main ingredient – H_2 or Hydrogen, which is plentiful from water.

Now closer to the present, a team at the US defense-funded National Ignition Facility (NIF), in California, are working on the laser-based method. By firing 192 lasers at a fuel pellet the size of a pinhead, and compressing it 35 times to produce the pressure and heat needed to start a fusion reaction, the scientists succeeded in producing slightly more energy than that used by the lasers – a breakthrough after years of setbacks and slipped timescales. However, the 17KJ of energy released during the reaction is equivalent to around 1.5% of the energy contained in a Mars bar and the reactor itself still needs much more energy to operate than it produces. Nevertheless, many hailed this finding as a significant step.

So over the last 50 years we have moved from hopes to aspirations to reality of harnessing fusion, even if it is on a small scale. Now you may be asking about the problems or dangers of fusion, as it sounds too good to be true. Firstly, the debate of FUSION vs. FISSION. Well, fission is the splitting of nuclei of an atom into smaller parts. It releases enormous amounts of energy and radiation. Fusion is the merging of nuclei and is the same process that occurs in stars - which explains the problems of getting the experiment toasty enough on earth. Now you may think that fission sounds great, it's producing lots of energy from small nuclei which we have plenty of. Yet fission also produces nuclear waste which is expensive to dispose of and must be stored deep underground to allow time for it to be destroyed. Fission also requires certain elements that are radioactive, like uranium and plutonium, which are not common and of the three isotopes for uranium, only one (uranium-235) is fissionable. Unfortunately a fission reactor can melt down, for example Chernobyl. On the other hand fusion is safer by comparison to fission as the levels of radiation involved are lower, and although it requires extremely high temperatures, if any of the plasma escaped from containment, its heat would dissipate rapidly and harmlessly into the atmosphere.

There was a study in 2000 in *Fusion Engineering and Design* that showed the paybacks of energy sources: The total energy produced divided by the energy required to build and maintain:
Gas Power - 5
Coal Power - 11
Nuclear Power - 16
Fusion - 27

So fusion is safe and could produce almost twice as much power than Nuclear Fission, yet it is very hard to achieve over long periods of time, as scientists have learnt. Scientists are optimistic that fusion could be available as soon as 2040 on the national grid. It may sound like a long way away, but in terms of mitigating climate change, fusion will play a very critical role. Just think, no more power plants pumping sulfur dioxide and carbon dioxide into the atmosphere, and the availability of cheap and near unlimited energy on the grid from a supply. It's use could be very wide with efficiency in areas ranging from electric cars to space travel. Fusion truly is not a thing of the past, rather an excitable prospect in the near future, which may just aid our world in a way we cannot fathom.

By Sebastian Wood

The Neural Basis of Love

We call it love. It feels like love. But the most exhilarating of all human emotions is probably nature's beautiful way of keeping the human species alive and reproducing. Therefore Mother Teresa was spot-on when she said, "The greatest science in the world, in heaven and on earth, is love." So when asked to define love, one might easily say it is a strong feeling of affection. But what is more difficult to determine is whether love is a feeling that is synthesised by the presence of numerous emotions, or whether it is the other way around, and actually it's the feelings that create the emotions. Who knows? I do not wish to digress into the complicated labyrinth of literary definitions, and instead will focus on how the secretion of chemicals in the brain causes love and how this type of romantic love differs from unconditional love.

Love comes in many forms, but was first categorised by the ancient Greeks into seven main groups that describe love in all its shades and complexities. These are: Agape (the love of humanity), Storge (platonic and family love), Pragma (love which endures and which has been developed over a long period of time), Philautia (self respect and the love for oneself), Philia (a shared experience), Ludus (flirting, playful affection), and finally Eros (romantic love).

Take Eros for example, the intense over-powering feelings of being truly, madly, deeply in love are the result of complex and rapid brain activity. Thus being in love encompasses chemical, cognitive, and goal-directed behavioural components, suggesting that love can only derive from the one place complex enough to manage this process – *the brain*; making love a science.

The brain is, in my opinion, the most outstanding artefact that nature has ever created. The brain has 150,000 miles of blood vessels and approximately 100 billion neurons, giving man the intelligence to invent the light bulb, master languages simultaneously and travel to the moon; the power to start and end wars, persuade and inspire millions and to fall in love.

Researchers have recently discovered that twelve areas of the brain work together to produce and sustain the one process of falling (and staying) in love. Chemicals and hormones play a large role in love and the process occurs in three stages: lust, attraction and attachment. Interestingly, the chemicals involved in orchestrating these feelings of love in certain areas of the brain are those that are also active when people are under the influence of euphoria-inducing drugs, suggesting that falling in love may have a similar effect on the brain as using cocaine.

Lust simply involves the release of testosterone and oestrogen. However, the romantic fairy tales that have couples falling in love at first sight may not have been as far-fetched as you once thought. In fact it has been revealed that the first brain activity specific to love starts within one fifth of a second of being besotted by a certain individual.

Stage II of love maps out the development of love and relates those familiar feelings with scientific explanations. Ones first response to attraction is of stress, which leads to an increase in blood levels of adrenalin and cortisol. This has the charming affect of making you nervous in front of that special someone. Next is Dopamine. This chemical stimulates 'desire and reward' and, as said above, is the specific chemical that is also released when drugs, such as cocaine, are consumed. In the final stage of attraction ones serotonin levels would be expected to rise; serotonin is one of loves most important chemicals in the brain and is the explanation to why ones crush is constantly on ones mind. Remarkably, it has also been shown that these early stages of love change the way you think. Evidence for this was found by Dr Donatella Marazziti in her landmark experiment, which showed that serotonin levels of new lovers were the equivalent to the serotonin levels of Obsessive-Compulsive Disorder patients, implying that the brain mechanisms that cause you to constantly think about your lover are very similar to the brain mechanisms that cause an individual with OCD to have a compulsion.

To enter the next stage of love, which is attachment, psychologists actually believe we need 'rose tinted spectacles' or at least the ability to magnify our lover's virtues and explain away their flaws. Attachment is the bond that keeps couples together long enough for them to have and raise children. Scientists think there might be two major hormones involved in this feeling of attachment: oxytocin and vasopressin.

Oxytocin, also known as the cuddle hormone, promotes bonding when adults are intimate. Oxytocin is released by the hypothalamus gland during childbirth and also helps the breast to produce milk and aids the strong bond between mother and child. Dick Frans Swaab, a Dutch physician and neurobiologist, goes into great detail about this maternal bond of love in his book, '*We Are Our Brains*'.

The second of the two chemicals, vasopressin, is another important hormone in the long-term commitment stage. This anti-diuretic hormone works with the kidneys to control thirst – so what does it have to do with love? Well, its potential role in long-term relationships was discovered when scientists looked at the prairie vole. Prairie voles, like humans, form fairly stable pair bonds. When male prairie voles were given a drug that suppresses the effect of vasopressin, the bond with their partner deteriorated immediately as they lost their devotion and failed to protect their partner from new suitors. Therefore, scientists concluded that vasopressin plays a significant role in ones ability to love another. When it comes to choosing a partner, are we at the mercy of our subconscious mind? Once these partners are chosen, the brain can begin the complicated process of falling in love, which as you may know, can also be unbearable when the significant other doesn't love you back.

Agape, or unconditional love, forms the second part of my article and can be defined as affection without any limitations - true altruism. New research into unconditional love has revealed that caring for someone, without needing to receive any kind of reward, involves seven areas of the brain. It has also been discovered that these impulses differ from the romantic love as described above, suggesting unconditional love is actually a separate emotion. In a way, science works against the idea of unconditional love because according to evolutionary theory we should only feel such emotions for people who pass our genes to future generations, such as our partners and children. Yet in reality, unconditional love can often be experienced towards people with whom there is no connection. Therefore this exceptional presence of what we call unconditional love can be explained by three areas of science: quantum science, neuroscience, biological science.

Firstly, quantum science has shown that everything and everyone in the universe is connected on a quantum level. Experiments have shown how human DNA can change the arrangement of photons (light particles, the building blocks of our world) – which is strange but true - and how our feelings can change the shape of our DNA. Therefore, considering just these two points, it is clear how, on a quantum level, the way in which we feel affects the world around us; being in a state of unconditional love means affecting that world in a positive, empowering way.

Secondly, neuroscience and further study of the brain has indicated that the thoughts we have create connections between nerve cells in the neocortex of the brain. These connections then cause the chemical brain to produce matching chemicals, which give us the sensations of matching emotions. When the same connection is made regularly and consistently, it becomes "wired" - making it a more permanent connection allowing the information to be transferred faster. This is how we learn intellectually. As a result of this, the chemical reaction becomes a habit and the human brain becomes programmed, at which point the response and behavior become automatic. In order to change our negative and destructive habits one must choose a state of compassion and unconditional love over the habitual anger, resentment, frustration and other emotional responses. Therefore, with practice and consistency, one can cause the old connections (of anger etc.) to break away, leaving compassion and unconditional love as someone's automatic response to a certain situation where kindheartedness should be shown. In other words, we can train ourselves to love one another unconditionally, suggesting that just about anyone is capable of unconditional love and that it is similar to the way we learn academically.

Thirdly, human biology explains that when we feel compassion, unconditional love and kindness, the brain produces a cocktail of "feel good" chemicals, which are very similar to those referred to in the first part of the article. It has also been shown that the release of certain hormones lowers blood pressure and helps to reduce hardening of the arteries and even heart disease; love cures illness.

I conclude with yet more words of Mother Teresa, a true saint of love, who said, "I have found the paradox, that if you love until it hurts, there can be no more hurt, only more love."

By Georgina Skinner

Music on the Mind

For thousands and thousands of years humanity has listened to music. It is one of the most common pastimes and an almost universal activity. Why do we do it? Philosophers, psychologists and neuroscientists throughout the ages have all tried to answer this question. Why can we never get that tune out of our head?

Obviously, music has an evolutionary origin. There are a few conflicting theories on why we evolved to listen and create music. It had been proposed that it is like a courtship display - if you have the time and ability to make music you must be strong and healthy - a social signal for being a compatible mate. Another theory is that music is a way of binding groups of people together. Humans have evolved to be highly sociable and dependent on each other: our societies are built on co-operation. Singing can be a group activity so things like work songs, war songs, and national anthems have helped give group identities and can reduce social stress, cementing relationships. A different theory is that it arose with mothers who needed to free their hands to do other jobs, they put the baby down and sang to them to keep them quiet in the absence of physical contact - therefore lullabies (humming/singing) has the evolutionary origin of consoling and closeness. Other ideas include that it was a way to learn a language, especially amongst the young. This could explain why we have a tendency to remember poetry and lyrics so much more easily than things we are meant to remember; or that it was a method of passing down historical and cultural traditions from one generation to the next.

Music also has mental and physical effects. Certain rhythms can activate specific centres in the brain; an example of this is the rhythm of 60 beats per minute. It initiates activity simultaneously in the left and right brain, maximising learning and retention of information. Mozart and Baroque music therefore could be the best music to revise to. One study reported that this rhythm increases learning potential by five times. The psychologist Dr George Lozano used this knowledge to design a method to teach foreign languages. He managed to teach half a term's worth of language/vocabulary in a day with an average retention rate of 92%. Learning an instrument uses both sides of the brain, which makes it capable of processing more information - this is why musicians have more symmetrical brains than others. This is due to the corpus callosum, the strip of tissue connecting the left and right hemispheres of the brain, being larger in musicians which consequently means the firing of neurons is more in sync. Music is incredibly complex, triggering brain activity in regions involved in movement, planning, action and memory. It is both mathematical and creative - there is both the expression and timing and accuracy involved in playing an instrument.

So music can be beneficial, it has evolved to become a pivotal part of society, proving its key role. But why are some tunes catchier than others?

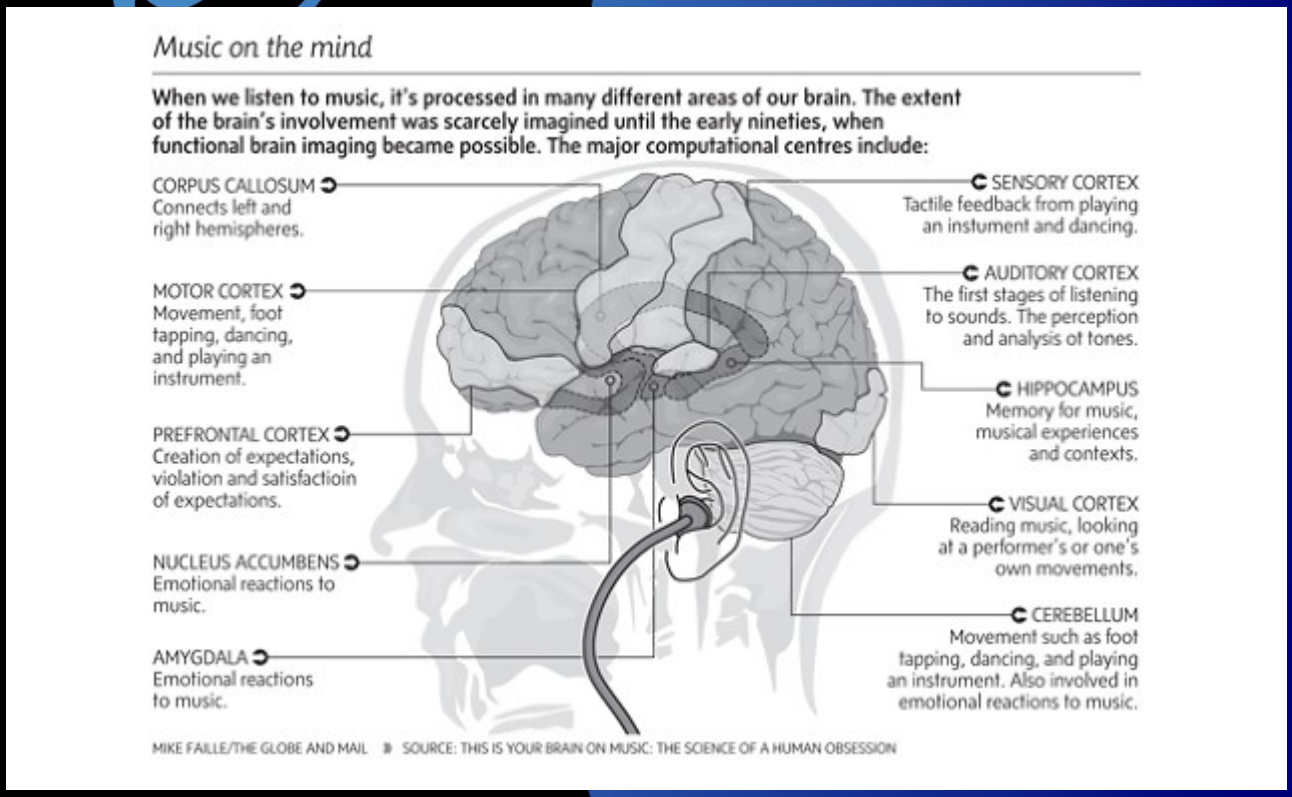
Research has shown that when we have a tune stuck in our head, we sing along without the music, and finish the song. We don't need research to tell us that, we've all had the feeling. Some ideas as to why this

happens is that our brain loves repetition and making predictions of what will follow (this explains why we tap out the beat of tunes). Others think it may be a way to keep our idle brain occupied - this could mean that those who get earworms (the phrase used to describe catchy tunes) are the daydreamers amongst us. Psychologist Dr Lauren Steward suggested that earworms stem from stressful situations, enhanced emotions and word memory links in addition to what is suggested above.

Studies have shown that those who get earworms frequently have thicker cerebral cortices; those who enjoy these earworms have a larger hippocampus (the memory centre of the brain) and those who disliked them had more gray matter in the temporal probe - an area involved in emotion.

In conclusion, although we all have different music tastes, preferences, and reactions, it is a universal experience and is both physically and mentally advantageous. As Albert Einstein said: “If I were not a physicist, I would probably be a musician. I often think in music. I live my daydreams in music. I see my life in terms of music.”

By Skye Longworth



Science and the Singing Voice

Visitors to my room may have noticed a poster about the anatomy of the larynx, together with a pull-apart laryngeal model. I am fascinated by the complex mechanics of the voice, its moving parts capable of countless variations, producing different qualities of sound and expressing a huge range of emotions. It is an exciting time to teach singing because advances in imaging and fibre optic technology mean that it is currently possible to view the vocal mechanism working normally in real time, and to slow the resulting images down so events in the larynx can be analysed. This means there is precise information on what happens and when, as well as enabling diagnosis of problems in laryngeal function. This is coupled with increasing international interdisciplinary collaboration between those with a professional interest in the voice in medicine, speech therapy, vocal practitioners/teachers, teachers of physical approaches such as Alexander Technique and performance psychologists.

Treatises on the singing voice first appeared in the 17th Century, with advice on posture, facial expression and descriptions of 'desirable' tone for the serious singer. The 'historical' tradition of singing teaching was based on audible and observable external features and outcomes. The ears and eyes of a singing teacher are still some of the most important tools used in the teaching studio today. If a singer looks uncomfortable either in the face or body, the resulting physical tension is likely to have a detrimental effect on the sound, even if the tension is away from the larynx. Qualities such as hoarseness (perhaps from yelling at a sports match) or unexplained loss of range are obvious indicators of vocal problems. Health issues can also have an impact on the voice. Sore throats and colds are common, but conditions such as acid reflux can affect the voice too. If stomach acid comes into contact with the delicate surface of the vocal folds. I use the term 'folds', rather than 'cords' as it is a more accurate description of the structure. A teacher's ear has to be acute, noticing minute variations in tone, usually connected to issues of fine motor co-ordination. This co-ordination can be affected by both physical and emotional issues as the sound of our voice tends to express our general state. My job is to give the pupil strategies to help them use their voice optimally. Some pupils like precise physical instructions, some prefer images. For me there is no single 'right' way to teach, it has to suit the pupil and allow them to make progress.

Applying scientific knowledge in the teaching of singing began in the mid 19th century, with the invention of the laryngeal mirror, a device which is still in use today. 'Say 'ah'' is a familiar instruction in the GPs surgery for patients complaining of a sore throat. The use of a laryngeal mirror allows the observer to see the top of the larynx and vocal folds. However, it is difficult to vocalise normally with the likelihood of the laryngeal mirror stimulating the 'gag' reflex. At best it shows the activity at the top of the vocal folds, together with any surface inflammation or pathology in the area. Despite its limitations, the laryngeal mirror provides some information about the workings of the larynx. Prior to this, most knowledge of vocal function was limited to assumptions made from the

dissection of cadavers. Currently, there are a number of imaging techniques which are applicable to the singing voice. Fibre optic cable with a micro camera on the end (inserted through anaesthetised nasal passages) allows viewing of the vocal folds both at rest and while vocalising. This enables diagnosis of any vocal pathology, such as nodules, polyps or vocal fold haemorrhage. Images can be slowed down, enabling precise information on event sequence as well as analysis of any problem in vocal function. Both Ultrasound and Magnetic Resonance Imaging (MRI) are used to view the voice in action and can show the co-ordination of function between the various moving parts used in vocalising and articulation. There is a wealth of online material showing the function of the vocal folds, for example.

My approach to teaching singing tends to include some explanation regarding the workings of the voice. It can be argued that just as knowing how a car works will not in itself make you a better driver, knowing how the voice works will not necessarily make you a better singer. But it will give you information on how to make healthy choices in voice use. To give an example, telling a student not to clear their throat so much can sound as if the teacher is picking fault. Explaining that 'every time you clear your throat you irritate the surface of the vocal folds, stimulating the seventy-odd mucous glands in the vicinity to produce more mucous to soothe the irritation, thus creating a vicious circle' takes a little longer, but I'd like to think that the reasoned explanation allows the student to make an informed choice and to become more independent from their teacher.

I use my iPad in teaching, not only because it allows me to carry a large vocal library at my fingertips, but the wide range of available apps means I can have tools available that were once limited to Physics departments. As a child, I used to love going in to my father's labs and use the oscilloscopes to see the sound wave pattern of different voice qualities. I now have an iPad app (Sound View) that allows a pupil to see how pure (in the sense of a single frequency) their sound is. This is a sound we traditionally associate with a young chorister's voice. For many styles of singing, a single frequency may not be desirable, whether in pop, jazz, musical theatre or classical genres. An operatic aria will not sound appropriate with only a single frequency in the sound, for example. Neither will it carry above an orchestra. The 'singer's formant', is a combination of frequencies which allows a trained classical singer to be heard over an orchestra without amplification. I have an app (Formant Plotter) for that too! Vocal training in classical and musical theatre styles relies on learning to manipulate the vocal tract to obtain the best combination of frequencies appropriate for the style, character and composer. Acoustic awareness is vital for the singing teacher, whether or not it is described in terminology a physicist would use. Seeing frequency readouts or anatomical images may not stimulate every pupil, but to those with a passion for science, it might enhance their interest in the voice. I've certainly always been fascinated by cross-disciplinary connections!

By Rachel Sherry

Systems Chemistry - The Future of Life

Since humanity's genesis, we have always wondered where we have come from. The seeds of all the world's sciences, and religions, are based around trying to answer this question in one form or another. Whilst our theories have been becoming ever more accurate and descriptive, and our understanding of much of the world has grown, we have never been able to successfully bridge the gap between the physical and teleological sciences. We know that the universe consists of atoms, waves, and physical laws, and those all combine to form compounds and a beautiful variety of chemicals. We also know that life is built from these atoms and compounds interacting, and that life has evolved to have a purpose and this purpose drives organisms to survive and reproduce, and us as humans – we live our lives with a purpose. Just to clear up some vocabulary, the physical sciences are Physics and Chemistry, the sciences that study the physical laws and interactions of matter and the universe. The teleological sciences, Biology, Psychology, etc. all study the way that life itself functions and acts, but assuming there is a motivation, a purpose. A fox will hunt for its food and reproduce, its instincts tell it that it must do this to further the survival of the species. But why does it know it must do this? Why does life insist it must survive? Hence why is it there in the first place? This is the question that bridges the gap between the physical and the teleological - or more specifically - the gap between Chemistry and Biology.

Biochemistry is the closest discipline in biology to chemistry, but biochemistry still consists of extremely complex chemical systems, operating on a huge scale to perform a function within an even more complex, self-sustaining chemical system. Chemistry is yet to completely understand every part of these systems, both on the microscopic and holistic scale. Systems Chemistry is therefore the field that attempts to study and describe these systems.

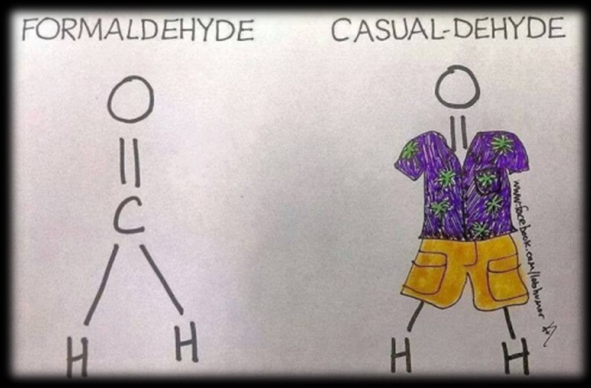
A distinctive feature of biochemical systems is replication. In the same way organisms reproduce, biochemical systems take in base ingredients and produce copies of themselves. A perfect example of this is RNA. A strand of RNA, when placed in a solution of its nucleotides ('links in its chain'), will bind the nucleotides into a chain resembling itself, with no assistance from any enzymes or proteins. This self-replicating system is the embodiment the object of Systems Chemistry's study.

In order to understand what life is, we need to decide its definition. This is not an easy task, but understanding life's emergence, its 'creation', will give us the key to defining life from physics, and the aforementioned RNA systems give us a way of forming laws of replication. Observation of these systems reveals that they 'evolve'. RNA systems evolve as life does, with the more effective replicating RNA molecules becoming more popular, and competing against the less effective ones, a trait well known to be observed in the biological world. This observation of evolution in chemicals will let us understand evolution on a physical level, a level where we can much more easily define laws and see its goals. Once we manage to comprehend the manner of these systems, the understanding of life itself is within our grasp.

Systems Chemistry will be the next step in understanding the world and the universe, and it will grow very soon. Addy Pross's book, '*What is life?*', covers the subject of Systems Chemistry in great detail, and I would truly recommend it to any Chemist or Biologist. Systems Chemistry is a stepping-stone toward the knowledge of what we are, all we need to do now is to take that step.

By Elliot Mitchell

There are two kittens on a sloped roof. Which slides off first? The one with the lowest mew!

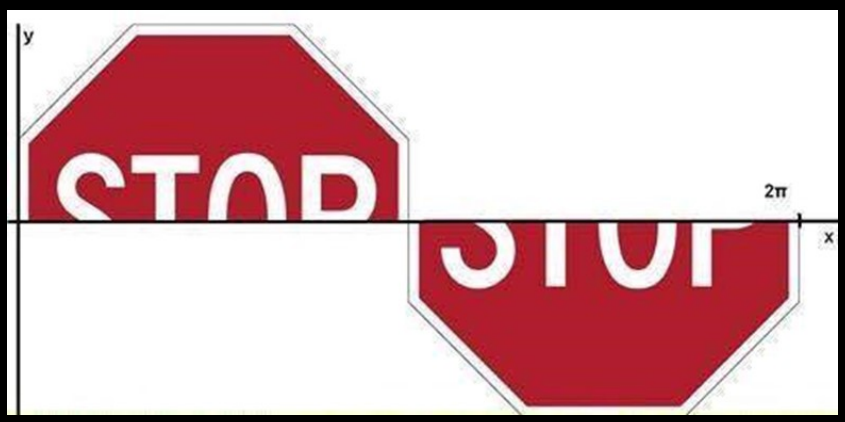


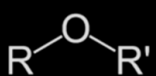
The different types of Aldehydes:

What did the biologist wear on his first date?
Designer genes!

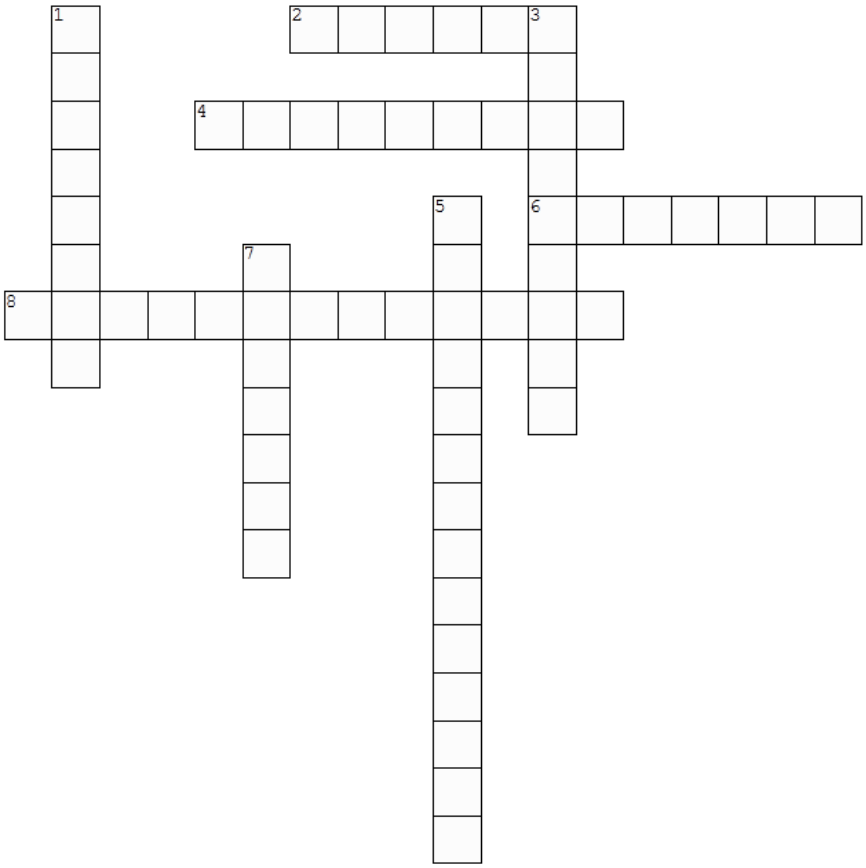
Did you hear about the man who was cooled to absolute zero?
He was OK

Stop Sine:



You  get organic chemistry or you don't!

Inventions Crossword



1. Which American Chemist claimed to have developed vulcanized rubber by accident in 1839?
2. What concept of travel was invented by Orville and Wilbur Wright?
3. What did Alexander Graham Bell famously invent?
4. Which bright idea was pioneered by Thomas Edison?
5. What very famous British invention became a global phenomenon in 1995?
6. Which company (along with CCETT and IfR) proposed the best technique for implementing the .mp3 information storage format in 1991?
7. Which Italian pioneered Long-Distance radio transmission?
8. Mary Anderson invented which crucial device for the automotive industry in 1903?

SSR Volume 3, Issue 1

Solutions

1. Orbit
2. Andromeda
3. Rosetta
4. Gegenschein
5. BinaryStar
6. Neutron Star
7. Perturbation
8. Comet

Note from the Publisher

This seventh issue is the second Science Review issue to be edited and developed by Matthew Hill (Upper Sixth Grafton) and Elliot Mitchell (Upper Sixth Bruce). This is our longest issue yet, and we have worked hard to get this one out. We would like to extend our thanks to the Lower Sixth writers for their contributed articles towards the issue. Finally, we would like to thank Mr Tearle and Mrs Roddy for their help and support with the editing process.