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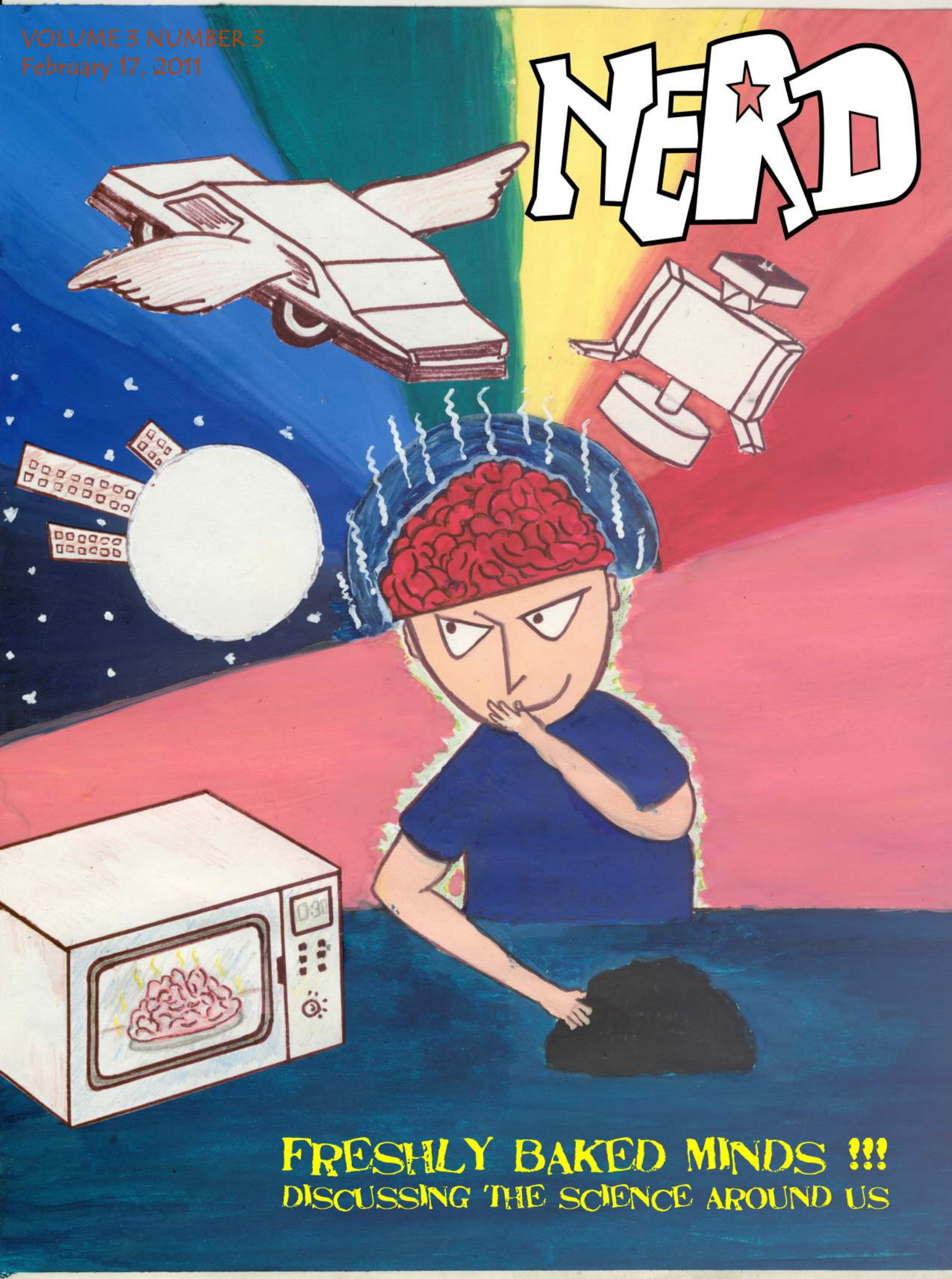
NERD



FRESHLY BAKED MINDS !!!
DISCUSSING THE SCIENCE AROUND US

CONTENT

Musings From Editor's Desk

"If you have an apple and I have an apple and we exchange these apples then you and I will still each have one apple. But if you have an idea and I have an idea and we exchange these ideas, then each of us will have two ideas."

— ***George Bernard Shaw***

We see Techkriti as a meeting ground of ideas and a primordial soup for the evolution of thought. It is befitting that this special issue of NERD be released over Techkriti 2011. All the articles from this issue come from a new initiative that is, in it's truest sense, a melting pot of ideas.

The journey started in July, 2010 when a a few friends came together to discuss ideas that interested them and make sense of the huge and ever exploding stockpile of learning resources accessible to us today. The group of 7 quickly expanded by word of mouth into one of 25 with members with interests ranging from Black holes and bicycles to peacocks and pigeon-holes! And here we stand, 7 months after we started our journey, waiting to meet every weekend to satisfy our appetite for new ideas.

In a time when we're trying to re-link the education system with life, for once, lets stop criticizing the ideas of making more IITs and the Board Exams optional. When we talk about the renaissance of the geeks, come,let's get our thinking hats back on, gather our like minded friends and start a meaningful discussion about ideas that excite and thoughts that give expression to creativity.

Let's talk about ideas that interest us!

Ish Dhand, Pranjal Nayak, Bhuvnesh Goyal and Utsav Kesharwani

Editors, NERD

Create, Communicate, Contribute!!!

The Nobel Engineer

Interview With Dr. Robert S. Langer

Mohit Kumar Jolly

Dr. Robert S. Langer

Dr. Robert S. Langer needs no introduction. He is the most cited engineer in history, with over 750 issued and pending patents worldwide. He has received over 170 major awards including the 2006 United States National Medal of Science; the Charles Stark Draper Prize, considered the equivalent of the Nobel Prize for engineers and the 2008 Millennium Prize, the world's largest technology prize. Time Magazine and CNN (2001) named him as one of the 100 most important people in America and one of the 18 top people in science or medicine in America (America's Best). Parade Magazine (2004) selected him as one of 6 'heroes whose research may save your life'. One of the NERD team members had the privilege to have a telephonic interview with Dr. Langer. Here are some of the excerpts:

INTERVIEW

NERD: You did your bachelors and doctoral studies in chemical engineering. How and why did you shift to the interface of biotechnology and material science?

Dr. Langer: When I was working as a post-doc with Dr. Judah Folkman in 1974 at Harvard Medical School, he told me that if I could stop blood vessels from growing (angiogenesis), I could stop cancer, and asked me if I could isolate the first substance which would prevent blood vessels from growing. But at that time, we had no assay (a procedure to test the activity of a drug/biochemical substance) for such substances.

We started using the rabbit eye to develop the assay. We knew that the cornea in the rabbit's eye had no blood vessels, but if we put a tumor in, blood vessels would grow. Hence we thought that if we could put in some possible inhibitor, we could have an assay. But if we tried putting in eye-drops with inhibitors, they would simply diffuse away and we would not have an assay. Then I tried to come up with a controlled drug delivery system for releasing large molecules (the inhibitors were large molecules) at a controlled rate to develop the assay for angiogenesis. Using this approach I isolated the first inhibitor of angiogenesis.

I have been always thinking ways in which I can help people, and save their lives.

NERD: Your research laboratory at MIT is the largest biomedical engineering laboratory in the world with over 100 researchers and $6million annual grants. What are the major research areas you/your lab are currently working on?

Dr. Langer: There are many, but broadly I would put them as drug delivery systems and creating new tissues and organs.

NERD: You are the youngest person in history to be elected to all 3 American science academies- National Academy of Science, National Academy of Engineering and Institute of Medicine. What has been your motivation for such an exemplary research career?

Dr. Langer: I have been always thinking ways in which I can help people, and save their lives. I had four job offers from Exon and once a scientist told me that if I could increase the percentage yield of oil by 0.01%, I could make a billion dollars, but that did not excite me. I wanted to do research to help people's health.

NERD: You were the first to design controlled drug delivery systems, which revolutionized the whole arena of drug delivery. Did you envision such a revolution?

Dr. Langer: I am delighted that it has happened, but I did not envision such a revolution. I did not anticipate that this whole area of genetic engineering and biotechnology would grow so fast that it became possible to produce large molecules, and that these molecules would face very serious delivery challenges. If you want to swallow them or take through a patch, they are just too big. If you want to inject them into the body, they have a short life time, so if you have to deliver them for chronic use, you need to deliver them in a way that maintains their unaltered form and yet protects them from harm. The conventional wisdom at that time said that it was not possible.

I am delighted that it has happened, but I did not envision such a revolution.

NERD: What have been major advances in controlled delivery mechanisms and biomaterials since?

Dr. Langer: There have been many, but one significant one I would say is that large molecules can now be delivered through polymers. Long-term delivery of molecules as insulin, anti-cancer drugs and vaccines is now becoming possible. Earlier, people used off the shelf materials in medical devices such as the lady's girdle for an artificial heart. Now many more

specific biomaterials designed for a particular purpose are being created.

NERD: You have also been interested in creating new approaches for delivering drugs such as proteins and genes across complex barriers in the body such as the blood-brain barrier, the intestine, the lung and the skin. What is the progress with that?

Dr. Langer: We have developed transdermal delivery systems which could deliver drugs through skin. The blood-brain barrier is a more complex one, we are still working on it.

NERD: In Spotlight at MIT 2007, you also talked about drug infused microchips, and designing of smart chips having sensors on them which control the rate of drug release. How are microchips being used today in context of drug delivery?

Dr. Langer: They are in animal trial stages. The idea is that you can use these microchips for delivery of drugs whenever and wherever in the body you want. If we have sensors on them, these sensors could track a signal and the chips can act as controlled delivery systems to vary the release rates as and when required. This can potentially also find applications in medical record keeping in times to come.

NERD: Please elaborate on the drug-eluting stent which you helped make available to patients with heart disease.

Dr. Langer: A Drug-eluting stent is a stent (a man-made 'tube'), which is placed into diseased coronary arteries. It slowly releases a drug that prevents cells from proliferating (growing rapidly) and hence prevents blocking of or clotting in the artery where the stent is put. They have been approved by FDA (Food and Drug Administration) and shown to be superior to bare metal stents (BMS) in treatment of narrowing of coronary arteries.

NERD: Tell us something about biodegradable polymeric systems for drug delivery which finally get absorbed by the body.

Dr. Langer: That is a very interesting area. Some polymeric systems are in animal trial stages while some are in clinical trials. The rate of degradation of such polymers can be controlled in many ways including using specific additives in a specific weight ratio.

NERD: What is Biorubber, the new flexible plastic you developed?

Dr. Langer: It is an elastic polymer which can be used for tissue engineering. It is strong, biocompatible and inexpensive. Its elasticity and degradation rate can be tuned as per requirements and different medical applications.

NERD: Also tell us about some new organs and tissues you have developed.

Dr. Langer: New skin for burn patients, cartilage, and spinal cord for patients with paralysis are some tissues which we have developed. Polymer fibers, cells and matrix are put in together to form a scaffold and with time, the polymer disappears and cells and matrix go on develop tissues and organs.

It was the academic industry collaboration which gave us new opportunities ... I have always held the view that this collaboration is terrific.

NERD: You have launched at least two dozen biotech firms and advise several more. More than 200 companies hold license to your 750 patents. How, do you think, this academia-industry collaboration has revolutionized your research?

Dr. Langer: It was the academic industry collaboration which gave us new opportunities for delivering drugs and for creating new tissues. I have always held the view that this collaboration is terrific. Each one of them can do different things- academicians can do basic research, and industries can develop products, but the collaboration makes this happen.

NERD: You have received over 170 major awards including the Charles Stark Draper Prize and the 2008 Millennium Prize. What is the one problem which you would like to see get answered in your field before you pass on the baton?

I would like to see these technologies be applied to as many diseases and help as many people as possible.

Dr. Langer: I would like to see these technologies be applied to as many diseases and help as many people as possible.

NERD: How would you describe Dr. Robert Langer in one line?

Dr. Langer: A nice person who wants to do good research and help save people's lives.

NERD: What final message would you like to give to students?

Dr. Langer: Research and teaching is wonderful and a great area to pursue.

NERD: Thank you very much for your time Dr. Langer.

Dr. Langer: Nice questions! Good luck with your effort! Just let me know if I can help you anyway.

About the Interviewer

Mohit Kumar Jolly (mkjolly@iitk.ac.in) is a first year M.Tech student in the Department of Biological Sciences and Bioengineering at IIT Kanpur. He is interested in Science Journalism and communication and is one of the founders of NERD.

Survival Of The Sickness!

Parasites, Disease And Host Manipulation

Sashank Pisupati

1.WHY DISEASE?

Germs: Love them or hate them, you can't ignore them. A major portion of the diseases that plague mankind are caused by these so-called 'pathogens'.But why do these creatures cause sickness? What motivates them?

Pathogens, like all other organisms, are driven by two motives: survival and propagation. This, along with their parasitic nature, leads them to live off hosts and 'manipulate' these hosts to get their genes ahead. This in turn harms the host in some way or the other. However, only some are fatally harmful, while others are just mildly annoying.Why is this?

The degree to which a parasite harms its host is given by its virulence. Let us see what virulence depends on.

2.VIRULENCE: THREE DEGREES

(i)Wouldn't hurt a flu:

The common cold is by far the most widespread disease we know of, but while it is indeed quite annoying, it is almost never debilitating, never harsh enough to get us bed-ridden. A person with a cold will still be able to move around and go about his activities.

Now this is exactly what the cold wants, since the cold virus would like its host to able to move about people, so it can spread through sneezing fits and airborne particles to other potential hosts! In effect, the cold cleverly makes us just sick enough to sneeze now and then, but keeps us healthy enough to sow it around!

In fact, this method of operation is so effective that the cold virus faces evolutionary pressure to remain relatively harmless, and thus has very low virulence.

(ii)Don't let the bad bugs bite:

The Malarial parasite, on the other hand, is a more dangerous bug. The parasite's mode of propagation is through vectors like mosquitoes, and so it is not dependent on humans to move around.

In fact, this bug wants us to be bed-ridden, and hence vulnerable to attack by mosquitoes, so that it can hitch a ride to its next host.Thus the disease is debilitating and weakens the host to a very damaging degree.

Now notice how it has nothing to do with its host once it has secured its winged transport, so it doesn't need to keep the host alive. Because of this, it just might kill you!

ARTICLE

(iii)Fang! You're dead!

Finally, we take a look at an example at a highly virulent parasite, the Rabies virus.

This virus gets around through a wide variety of carriers like dogs, bats, raccoons, monkeys, you name it.

But its mode of propagation is somewhat gruesome.The rabies virus is transmitted through saliva. Thus, quite literally, it spreads aggressively.

When the virus enters the bloodstream, one group migrates to the brain of the host, secreting certain chemicals that make the host aggressive. One group also populates the throat and makes water intake difficult. This in turn leads to salivation, and the victim, driven to madness, resorts to extreme behaviour like biting, which send the virus on its way to its next unwary host.

Due to this rather gory modus operandi, the disease is usually fatal, making this extremely virulent virus a deadly killer.

3. PARASITIC OVERLORDS:

Extreme Host Manipulation

As if all this wasn't scary enough, nature brims with examples of microbes that can only be described as tiny evil overlords:

•That's no fluke:

A certain type of liver fluke that inhabits the guts of sheep, doesn't want to die when the sheep excrete. Thus, once out of the sheep, it gets eaten by ants, then travels to the ant's brain, secreting a chemical that turns the ant suicidal. Every night, the ant leaves its colony, goes to a meadow and stands on the edge of a blade of grass, till it gets eaten by another sheep; thus returning the fluke to its home!

•Schrodinger worst nightmare:

A certain bacterium called Toxoplasma Gondii, lives in cats' digestive systems. When ejected out of its home, it somehow manages to get eaten by a mouse. Once eaten, it travels to the mouse's brain, secreting chemicals that turn the mouse into a manic zombie.

The mouse becomes slow to react, lazy, fat, and attracted to the smell of cats, thus becoming ideal prey. When it gets eaten but the cat, the bacterium gets a straight ticket home!

•True amazonian:

An amazonian wasp, called H. Argyraphaga, enslaves orb spiders. This wasp stings an unsuspecting spider, and lays its eggs inside the spider. The eggs hatch into larvae that start to migrate towards, and control the spider's brain.

An amazonian wasp, called H. Argyraphaga, enslaves orb spiders. This wasp stings an unsuspecting spider, and lays its eggs inside the spider. The eggs hatch into larvae that start to migrate towards, and control the spider's brain.

The spider starts to act crazy, building a shell like cocoon instead of orb webs. Finally, the larvae kill the spider, eat it and behold! They now have a large supply of food AND a ready-made cocoon!

4. MERCY! TRUCE!

What do all these scary examples of bug domination mean for us? Should we bring out the nuclear missiles and prepare for war?

Well, not really. By trying to kill or maim these creatures wit antibiotics, we are simply fighting an arms race with a side that has far stronger and deadlier weapon:evolution.

These creatures, with their simple genome , short lifespan and sheer number, seem to be able to out-evolve anything we throw at them. They can adapt to chemicals faster than you can say "Achoo!"

This does not mean there is no hope though. We can actually use this weapon of evolution AGAINST them.

During the great cholera outbreak of the 20th century, most of Europe suffered save one city. This city, somewhere near Italy, went completely unharmed. Curiously enough, they also had excellent sanitation.

Now people thought that this city escaped because the virus didn't get a chance to infect the people. Later on though, it was found that the people still carried the virus as much as any other city, but somehow they went unharmed!

This seems to be because, even though the virus inhabited them, due to the shutdown of the poor hygiene/drainage pathway(through which the virus usually propagates) it no longer made sense for the virus to cause debilitating diarrhoea!

In other words, there was evolutionary pressure on the virus to find an alternate means of transport, and thus leave the person unharmed!

This tells us something very important:If we play our evolutionary cards right, we can COEXIST with pathogens!

The bottom line is, If we somehow made it easier for a parasite to survive in a healthy body rather than a sick one, it would force the parasite to keep us healthy! Maybe if we follow this approach, we can one day live In peace with our worst enemies: germs!

Ponder Yonder

- *Science articles(July 2000 and July 2010)*
- *Survival of the Sickest, Sharon Moalem(2007)*
- *TED Talk given by Dan Dennet(2002)*
- *Other Resources: Wikipedia, RationalWiki, Scholarpedia*

About the Author

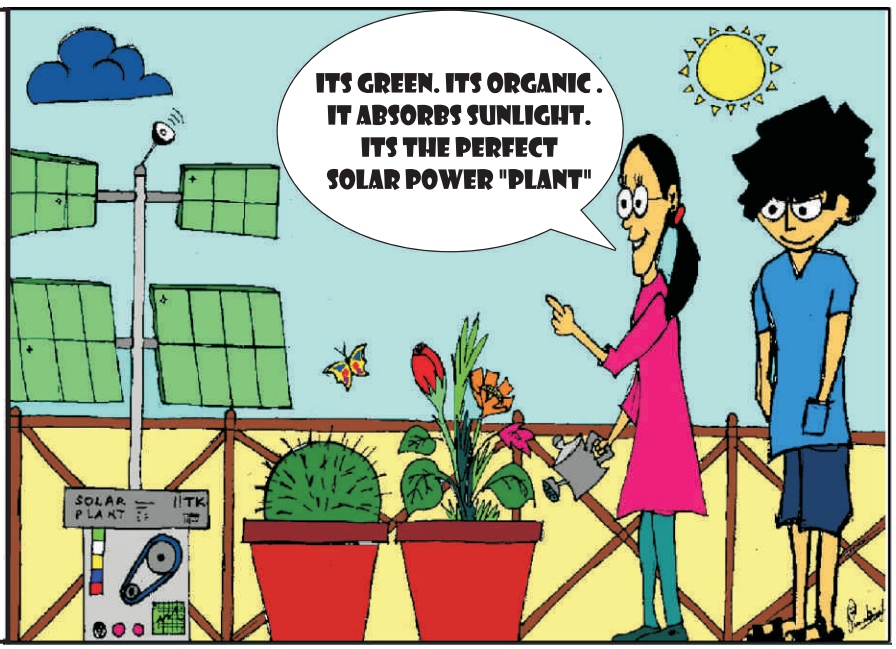
Sashank Pisupati is a first year undergraduate in the Department of Bio-Sciences and Bio-Engineering. He can be reached at (sashank.pisupati@gmail.com). His interests lie in neuroscience/psychology, Robotics/AI, Cryptology and Man-machine interface.

Errata

1. The picture of the cover page was wrongly refered to as Lawns in front of The H R Kadim Diwan builiding of Computer Science. The picture is of the fountains at Park 67 at IIT Kanpur.

2. The description beside the Scientoon on the last cover page was incomplete. The Scientoon by Puneet Singh with its complete description is as here:

Organic Solar cell performance depends on absorbing as much light as possible, converting the photon energy into free electrons, removing the electrons, and minimizing resistance.
They can be manufactured easily and cheaply, they have low environmental impact, and since they are compatible with flexible substrates, they could be used in many applications such as packaging, clothing, flexible screens, or for recharging cell phones and laptops.
Presently silicon solar cells are being used which have achieved efficiencies of more then 24% but have high cost and complicated technology.
IIT Kanpur is initiating new and augmenting the existing programs for long term research and development in solar power generation, storage, distribution, management and policy making.



A Male Less Society

Ruhi Dang

A Male Less Society: I would be tagged a lunatic for saying this, being a student of IIT Kanpur with the ratio of number of males to number of females being 10:1, but this is not a joke. Is this good news for the planet? Believers in Gaia might say this is earth's revenge. Scientists say it is simple Biochemistry.

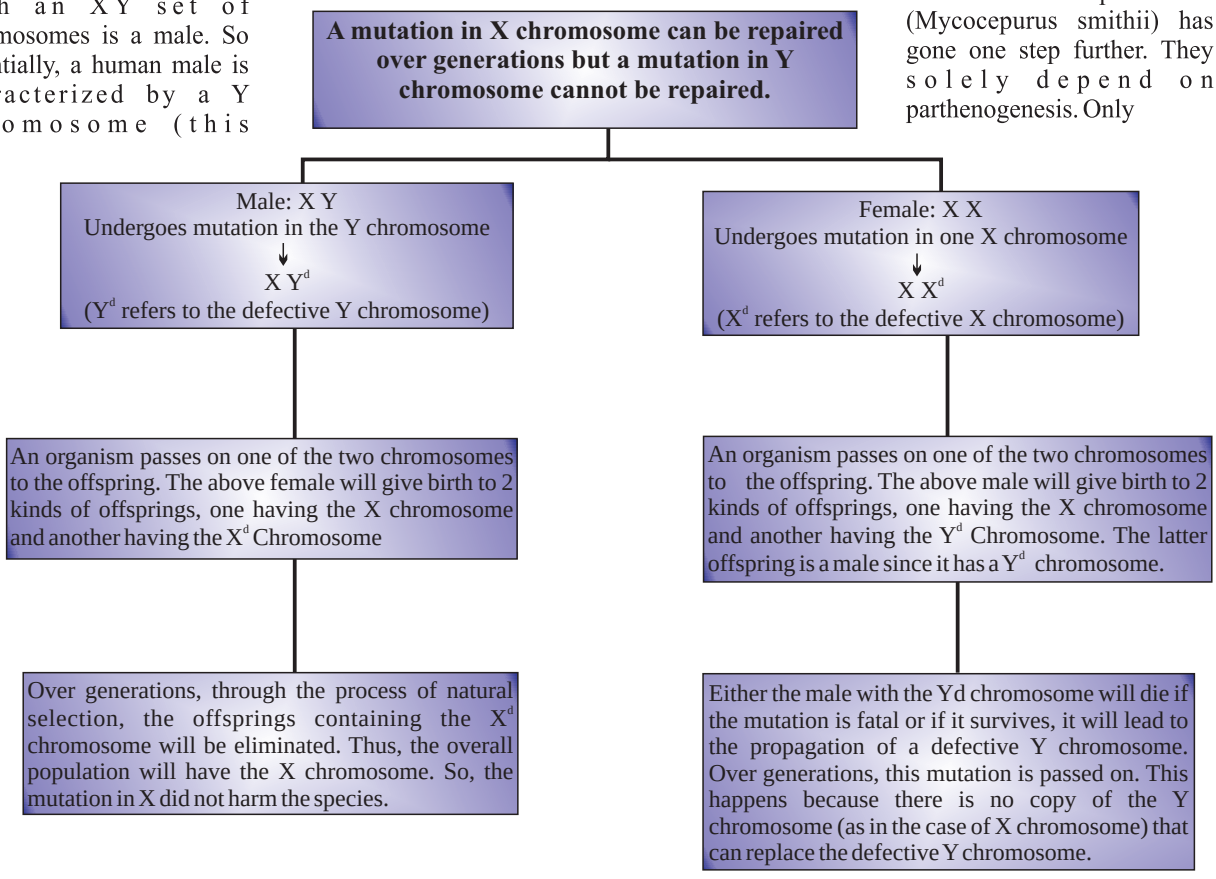
With the declining sperm count in men and the partial or complete wastage of the Y chromosome, within 5000 generations, males of the human species will become extinct.

300 million years ago, the Y chromosome had 1400 genes out of which only 45 are left today. Genes hold the information to build and maintain an organism's cells and pass genetic traits to offspring. Among humans, a person having an XX set of sex-chromosomes is termed as a female whereas a person with an XY set of chromosomes is a male. So essentially, a human male is characterized by a Y chromosome (this classification may vary in different species). Due to absence of a homolog of the Y chromosome, mutations in the Y chromosome cannot be repaired over generations unlike the X chromosome where a deletion or any other kind of mutation is suppressed by the evolution of the correct copy of the X chromosome rather than the mutated one. Thus, any deletion or change in the Y chromosome is carried further to the next generations, leading to loss of genes(refer to chart).

ARTICLE

Some previous evidence traces back to the species of Hymenoptera comprising ants, wasps and bees. In this species, males develop from unfertilized eggs and females develop from fertilized eggs. Typically females acquire sperm from one or more males in their early life and store them in a structure in their body called Spermatheca. Sperm can be released from here and flow to the oviduct to fertilize eggs. However, the mother can choose not to use the stored sperms and lay haploid eggs which develop into males or choose to fertilize them to develop females. She has precise control over the gender of the offspring. A few females of this species serve as sterile workers and attend to the chores of brood rearing, colony maintenance etc. and do not participate in reproduction. Males do not participate in the above activity thus they are disposable yet indispensible for producing future female progeny. In a few species, females evolved mechanisms to produce fertile diploid female progeny asexually called parthenogenesis.

Another species (Mycocepurus smithii) has gone one step further. They solely depend on parthenogenesis. Only



females have been found in these species over the past few decades. They failed to find males as well as sperms in the spermatheca. DNA fingerprinting shows all workers are genetically identical.

Then how will females reproduce? Even if men did not exist on the planet, women can still use 'single cell reproduction' to multiply. Scientists have already mastered technologies about 'artificial sperm'. The future might provide ways for females to reproduce asexually.

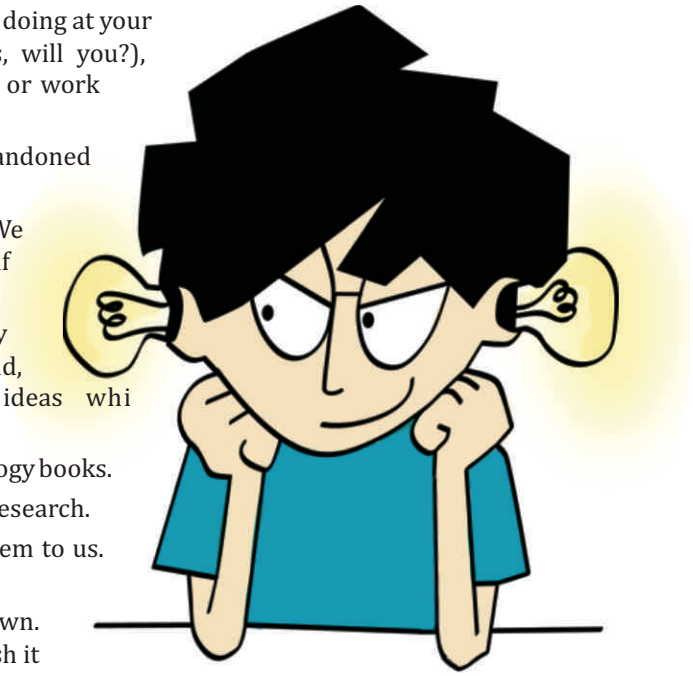
How will the ants overcome the problem of genetic invariability? Will a male less society survive? Will females adapt to ways of asexual reproduction? We are left with these unanswered questions and an entire world of genetics to explore!

About the Author:

Ruhi Dang (ruhidang@iitk.ac.in) is a second year undergraduate student of the Department of Biological Sciences and Bioengineering Indian Institute of Technology, Kanpur. Her areas of interests range from genetics and Bioinformatics to programming. In her spare time, she enjoys debating, reading fiction and listening to music.

Call For articles

NERD is the scientific and technical research and development magazine run by the students of IIT Kanpur. We publish news on scientific breakthroughs happening in various technical education institutes, research labs etc. across India and the world with an emphasis on work done by the students. So NERD is a magazine of the students, by the students, for everyone. The NERD magazine is first of its kind and we need everyone who is interested in science and technology to be on our team. Join the NERD Herd! Yes, you can be the one writing for the magazine. There are a variety of things that you can do:



- Write about the work that you have done or will be doing at your institute as hobby project (write about those robots, will you?), semester projects, internships, B.Tech. Projects, theses or work presented elsewhere as papers
- We even publish articles on failed projects, abandoned research so that people know what led to failure.
- "I've done work but it is incomplete." No worries! We publish work in any stage of completion – even ideas if they are well supported scientifically.
- "I am interested in this field but haven't done any work in it." So what! Since you are interested in the field, why not tell others about it? Who knows, you might get ideas whi le doing that!
- Write book reviews for popular science and technology books.
- Interview professors and eminent scientists doing research.
- Collect ideas for geeky cartoon strips and send them to us. You can also send illustrations and cartoons.
- Perform table-top experiments and pen them down. You could maintain a field diary of your work and publish it with us.
- Inspire more people to do these activities.
-

Note that although articles related to science and technology are published, these articles are NOT papers but accurate versions written by students that are more easily understandable to non-experts.

Interested people can drop a mail at nerd@iitk.ac.in Mail your queries, your articles and your ideas! You can also contact +91 93690 88560 for any related subject.

Scaling Down And Up

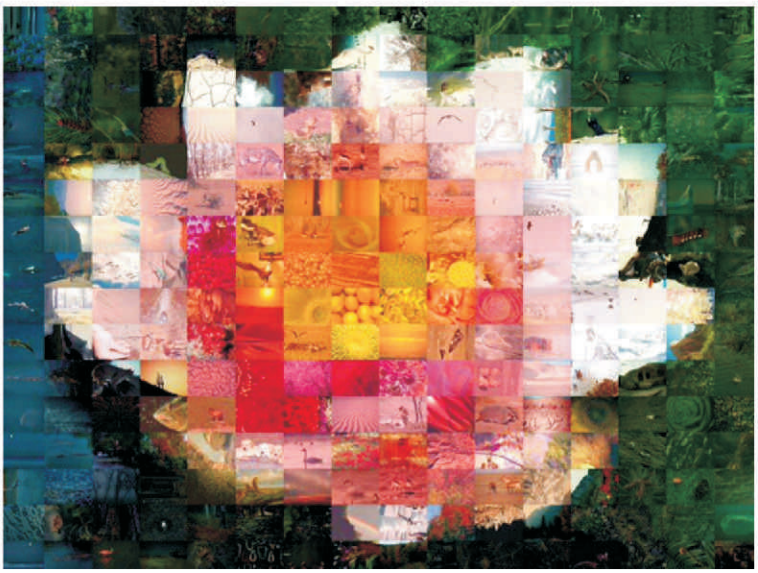
The Philosophy Of Science: Reductionism And Emergence.

Nitica Sakharwade

ARTICLE

Science is one of the subjects that we all study from our childhood. Even before we learn Calculus and Trigonometry that help us study science we are imbibed with notions of why Nature is the way she is and the philosophy of how the world is perhaps designed from just a couple of constituent particles.

Do you not remember being awed when you came to learn that everything that we see from fauna and flora to the sun to this piece of paper on which this article is printed is essentially composed of only three particles called electrons, protons and neutrons? Or the fact that all molecules are just a combination of the ninety odd naturally found elements on the periodic table?



Schematic Emergence of a Flower through 256 Mosaic Tiles.

However much the mathematics may get complex, underlying any phenomenon is some philosophy which is the crux that actually influences the way we think of the world. Even scientists hold viewpoints and have their interpretation of Nature which influences their research and beliefs. One must have heard about the great pursuit for The Theory of Everything in Physics. This is based on the belief that all interactions in Nature can be understood under a grand framework which is the Unification of all known forces. Respected scientists from Archimedes, Democritus, Newton, Laplace, Faraday and Einstein to Hawking are known to have worked towards unification.

Reductionism and Emergence are two such radically different fundamental philosophies or viewpoints that exist in the scientific community today.

Reductionism is essentially a philosophical position that a complex system is nothing but the sum of its parts, and that an account of it can be reduced to accounts of individual constituents.

The Theory of Everything too is reduction since it believes that understanding the fundamental forces and matter can explain the complex systems they create completely. The Higgs Boson is a hypothetical massive elementary particle predicted by the Standard model. The Standard Model of Particle Physics born out of reductionism today patiently waits for experimental evidence for existence of the Higgs Boson from the Large Hadron Collider in Geneva to prove its validity.

String Theory is another theory based on reducing all matter and particles to strings vibrating in 11 Dimensions to create the symphony known as the Universe. It is a developing theory in particle physics that attempts to reconcile quantum mechanics and general relativity and is a contender for the theory of everything.

Brian Greene, one of the best-known string theorists, talks about string theory and reductionism in his book An Elegant Universe and establishes a historical context for string theory as a necessary means of integrating the probabilistic world of the standard model of particle physics and the deterministic Newtonian physics of the macroscopic world.

What we observe is that the cause for viewpoints such as emergence or reductionism is the play of Length Scales. At the macro scale we have complex systems like life, societies which have organisation and at the micro level we have chaotic and probabilistic domination. It is this contrast and the causal relation between different length scales that fascinates humans.

Reductionism is a very elegant and intuitive approach and thus much of the modern period has been dominated by a `reductionist' theory of science. In recent years however reductionism has been dramatically challenged by a radically new paradigm called `emergence' which is holistic in nature, which surfaced in order to understand

the collective effect that comes into existence because of a principle of organization. Emergence is the way complex systems and patterns arise out of a multiplicity of relatively simple interactions, and here a complex system is more than the sum of its parts. According to it, natural history reveals the continuous emergence of novel phenomena: new structures and new organisms with new causal powers. Consciousness is yet one more emergent level in the natural hierarchy.

Symmetry breaking is an important example of an emergent phenomenon. Nobel laureate P. W. Anderson used this idea in his famous paper in Science in 1972, 'More is different' to expose some of the limitations of reductionism.

Emergence can also be observed in snowflakes which are complex symmetrical figures formed from simple ice crystals. Life is one of those elegant extreme cases of emergence. Here inanimate microscopic molecules following random and probabilistic laws organise themselves into a new structure that is 'alive' unlike the molecules it is made up of. The origin of life is one of those pleasantly disturbing phenomenon that always leaves one awed by Nature's ways.

Robert Laughlin, who was awarded the Nobel Prize for the Fractional Quantum Hall effect in 1998, argues for emergence as a replacement for reductionism in his book A Different Universe.

He points out an interesting flaw in the pursuit for a Quantum computer on the basis of emergence-

" ... Quantum computation has a terrible Achilles ……. the effects that distinguish quantum computers from conventional ones also cause quantum indeterminism. Quantum-mechanical wave functions do indeed evolve deterministically, but the process of turning them into signals people can read generates errors. Thus the frenzy over quantum computing misses the point that the physical basis of computational reliability is emergent Newtonianness. ……. Naturally, I hope that I am wrong, and I wish those who invest in quantum computing the best of luck."

Both Reductionism and Emergence are elegant approaches in our endeavors to understand the world we live in on all length scales and have taken humanity on an extraordinary intellectual journey, yet neither of them today fully explains the wonders of Nature. The quest is on.

I do not know how Elegant or Different our Universe is ……. but it definitely is Enigmatic!

Ponder Yonder

•An Elegant Universe Brian Greene

•A Different Universe Robert Laughlin

•en.wikipedia.org/wiki/Reductionism

•en.wikipedia.org/wiki/Emergence

About the Author

Nitica Sakharwade (nitica@iitk.ac.in) is a first year undergraduate in the Department of Physics at IIT Kanpur. She is interested in pursuing research after her post graduation and passionate about Physics and loves Nature. She is also interested in Combinatorics, Programming and Philosophy. Her hobbies include natural photography, writing poems and playing the guitar

Source of Image

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Be a part of NERD HERD!

First of all we welcome all the new members in the HERD and look forward to a great time working with them. We invite all those interested. Come forward and be a part of a NERD, a magazine which is the only one of its kind in the whole of India. Now, NERD has international outreach with students contributing from NUS, SUNY, Caltech, Princeton and many more universities. As we always say, there is something for everyone. We have a whole bunch of activities for all of you:

- Become a staff writer! Write regularly for NERD, and we will have a column solely dedicated to your articles in each issue.
- The designers get to take care of the layout and cover page design of the issue.
- Get a chance to interview eminent personalities!
- Are you a fanatic reader? We have a whole lot of popular science books and write book reviews for the same.
- Chance to become an editor! Learn a whole lot of science and technology in the process.

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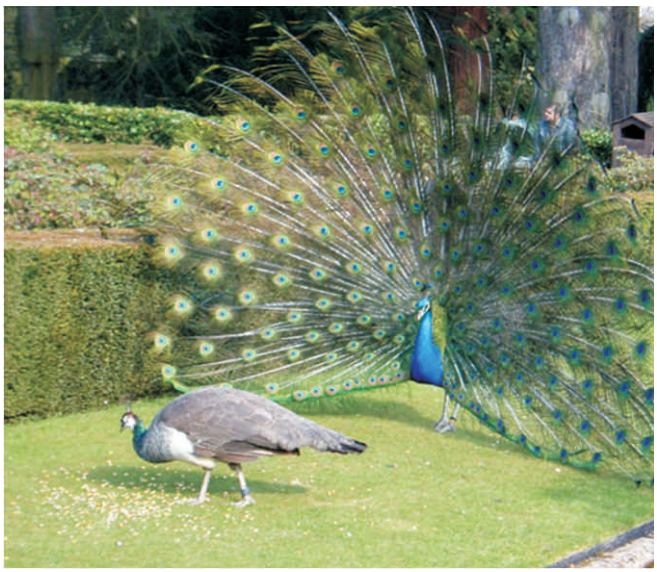
The Handicap Principle

An Exciting Way Of Looking At Longstanding Open Questions Regarding Evolution.

Ruhi Dang
Ish Dhand

ARTICLE

On a peaceful afternoon, a gazelle is quietly grazing in the golden grasslands of Africa. A cheetah approaches stealthily. As soon as the gazelle spots the approaching predator, what is the first response you'd expect from it? To run for its life, as fast as possible. However, initially, it runs slowly jumping up and down, lifting all four feet off the ground (also known as stotting), rather than focusing on running away at a faster pace. This behavior clearly endangers the life of the gazelle and is a handicap for it. Then why did the gazelle with such behavior not get eliminated by natural selected and win the struggle for existence? Why did nature promote this act? Baffling! Isn't it?



Peacock wooing Peahen

A peacock has a spectacular, but long and cumbersome tail, which makes it harder for the peacock to hide from predators. Again, why did the peacock evolve this way? An obvious argument could be that the longer and more beautiful tail is preferred by the peahen. However, evolution of such a 'handicap' cannot be explained on the basis of natural selection. Why, at all, should the peahen prefer beautiful features or longer tails rather than the more practical shorter tails?

The examples are endless! The lavish spending and conspicuous consumption by the rich is one. So is the excessive use of harmful steroids by modern body-builders to create the illusion of supreme physical and reproductive fitness. An elegant (game theoretic) framework can be used to explain all this, and much more.

A simple way of understanding the gazelle's paradoxical behavior is to look at it like a signal to the predator saying "I'm strong and have seen you. It makes no sense to waste your energy chasing me because I'll most probably outrun you".

Field observations have shown that very often, the predator, on receiving this 'signal' leaves and looks for other prey. This is how nature prefers the stotting gazelles to the equally strong (or weak) gazelles that don't stot. Amongst the stotting gazelles, nature selects the stronger ones by means of eliminating the weaker ones. Hence, after many generations, it's the strong gazelles that showed the stotting behavior who survived.

An analogy can be drawn from the above case to that of the long tail of the peacock. The longer tail of the peacock is a signal to the peahen saying "I could manage to survive even with this long and cumbersome

	Stronger Gazelles	Weaker Gazelles
Stotting Gazelles	The stotting gazelles are chased less often.	The stotting gazelles are chased less often.
Non-stotting Gazelles		

This is how nature prefers the stotting gazelles to the equally strong gazelles that don't stot.

+

	Stronger Gazelles	Weaker Gazelles
Stotting Gazelles	Nature selects only the stronger ones amongst the stotting gazelles as can be explained by Darwin's theory of evolution	
Non-stotting Gazelles	The non stotting one's are eliminated as explained above.	

→

	Stronger Gazelles	Weaker Gazelles
Stotting Gazelles	Survived	Eliminated
Non-stotting Gazelles	Eliminated	Eliminated

tail. Hence, I'm stronger." The peahen accepts this honest signal. Experiments show that peahens do, in fact, prefer peacocks with more number of eye-spots on their tails. Thus, the handicap principle helps us in understanding what even Darwin's evolutionary theory couldn't explain. In Darwin's own words, "There is wastefulness in sexual displays (that cannot be explained)."

Nature often behaves in mysterious ways. Science is the human endeavor towards understanding the enigmas of nature and appreciating its beauty.

About the Authors:

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Mathematics Of Risk Taking

Kavya Reddy

ARTICLE

What's Gambling?

It is a form of risking or staking something which has a material value, in an uncertain event, expecting a higher value or material goods. Dice gambling is the most common form of such "uncertain" events.

The famous quote "God doesn't play dice" in a way either ethical or moral, scrutinizes the fact of gambling in reality. Even maths, with its simple logic, probes and unravels the secret of gambling not being considered a healthy habit.

Mathematics, like the philosopher's god is indifferent with respect to the person taking the risk as well as the risk bearing. The following article describes the "amount" of risk one needs to take, especially the entrepreneurs, businessmen and investors.

Simple Gambling Scheme:

Suppose that Gambling is equivalent to tossing a coin. Heads, the gambler wins one rupee and Tails, he loses one rupee to the gambling house.

Let the gambler start off with an amount of Rs. 'a' and wishes to earn a profit until Rs. N (N>a) which means that earning the amount, he stops playing. Or in the case if he reaches Rs. 0 before earning the profit he ceases to gamble further.

Possibility	No. of tosses req.	Probability
Goal never accomplished	Infinite	0
Goal accomplished	Finite	a/N
Game over - Reaches Rs 0	Finite	1-a/N

Thus a rich investor has higher chances of achieving the goal than the poor investor.

The above gambling scheme can be generalized as the Simple Symmetric random walk where in the initial position is 'a' and it goes along the x-axis according to the tossed coin. Heads means moving one step ahead and tails would imply one step backward.

Let X_i be the capital at any point of time (a random variable). Assuming that the game stops at the nth toss and the capitals at the end of each toss are respectively a_1, a_2, a_3 etc., the sequence (a_1, a_2, a_3…an) is called the path of the gambler's fortune up to nth toss.

Markovian Process:

The present being conditional, the past and future are irrelevant, i.e. they are independent.

Thus, it is quite evident that the gambling process is Markovian. Hence the conditional probability of X_{n+1} depends only on the capital at time n and not on the path of earning. The present given, the value of X_n the past is irrelevant X_j (j<n-1) for the value of future X_{n+1}.

Now, let's take a more general case, the present day scenario where in the investors can probe about the capital being earned at every step.

Martingale's Walk-The case of a single investor:

This scheme allows the gambler to bet amounts as much as his wishes at any given time. Moreover, he can decide how much to bet based on the path of his capital until that time.

Supposing initially the investor invests an amount Rs. 'a' at time 0 expecting to win Rs. b (a<b<=N) but at time $t=t_1$ prepares to receive a smaller amount Rs. c (0<=c<a) anticipating the loss i.e. these quantities are decided before the gambling starts.

At time $t=t_1$,

Capital Invested (Rs.)	Expectation (Rs.)	(Rs.)
a	b	Gain (g) = b-a
	c	Loss (l)= a-c

Let x = p(b), y = p(c) i.e. the probabilities of receiving b and c at time $t=t_1$.

Hence, x+y = 1

bx+cy = a.

X= l/(l+g) y= g/(l+g)

The condition *bx+cy = a* is known as the *Martingale condition* in probability theory or a *fair game*, a consequence of no-arbitrage-opportunities-requirement which says the investors either gain or lose at every step of the game.

From the above equations, it can be inferred that the small gain has high probability while large gain has small probability.

Supposing that the investor invests an amount and receives an amount d at time $t=t_1$, which can be either b or c, or 0 and N which ends the game or if 0<d<N, then he invests amount d expecting a higher amount d (d<e<=N) at time $t=t_2$ but is prepared to receive a smaller amount f (0<=f<a) should he lose.

If the final value is 0 or N, it is again a Markovian process as mentioned in the first case, but if it has an intermittent value, then the process can turn out to be anti-Markovian which is explained below.

Applying the fair game conditions,

P(f) + P(e) =1

fP(f) + eP(e) = d and this process continues.

So, at time n if the investor has the capital (X_n) 0 or N, the game ends, else he invests it and chooses new quantities á and â accordingly. And the fair game equations apply as

P(á) + P(â) = 1

áP(á) + âP(â) = X_n

P(á) = (â- X_n)/ â- á

P(â) = (X_n- á)/ â- á

Hence, this process depends upon the capital of the previous step, thereby being anti-Markovian which is indeed unlike the Markovian process which is analogous to state functions.

Thus this model of the random walk confirms the advice honest investment advisers share with the middle class investors in India.

"If you do not have much money, or your livelihood depends on what you earn on your savings, or your margin of savings is small, be careful, but if your livelihood is taken care of, and if you are financially secure, then it is a good idea to take chances with mutual funds, and possibly earn a large return."

Law of large numbers:

If there is an experiment which results in success and failure with probabilities p and 1-p and when repeated n times independently, pn is the proportion of success, pn will get close to p with high probability and will tend to 1 as n tends to infinity.

Implications for the entire population:

As there are implications for a single investor, there are for the entire crowd too. The very old refrain "rich are getting richer and poor are getting poorer" is just a consequence of crude articulation of the proposition proved above and the law of large numbers. Indeed, it can be noted that the entire invested amount doesn't change much; it just gets re-distributed disproportionately owing to the market fluctuations.

As the present day involves free trading, market fluctuations owe themselves to the investors who are capable of momentarily changing the price as the market seeks to create a balance between supply and demand.

The model predicts the outcome with a fairly good probability anyway, market fluctuations notwithstanding. Despite the drawback, it is efficient enough to justify the refrain as well as predict the outcomes with acceptable error.

About the Author

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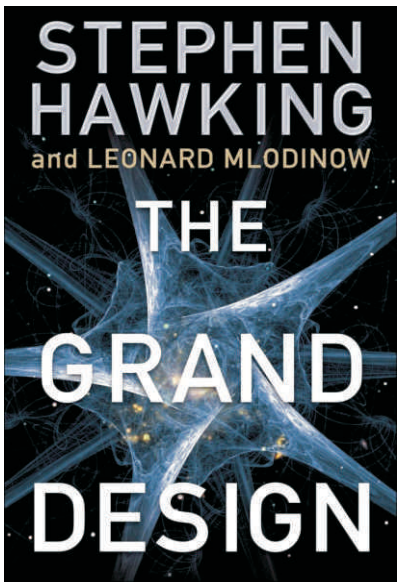
The Grand Design : Book Review

Pankaj Prateek



Author: Stephen Hawking and Leonard Mlodinow
Publisher: Bantam
Language: English
ISBN-10: 0553805371
ISBN-13: 978-0553805376
Pages: 208 pages

Stephen Hawking's recent book 'The Grand Design' came out in the first fortnight of November 2010. All major media of the world created what can be called as a marketing promotion for this book giving it a global media hype typically unheard for a science book.

The book nicely reveals the change in the thinking in the field of science from the philosophical point of view to the experimental point of view. It questions the ontology and the way of working of the universe. Hawking appears to try to bring out that the M-theory will become the ultimate theory of everything integrating the quantum mechanics with Einstein's general theory of relativity. According to the M-theory, ours is not the only universe existing; it's just one of the many universes, which form a multiverse system, each having its own history and governing laws but having no independent existence. Each such universe was created spontaneously out of nothing, arising naturally out of physical law, without any need of some outside intervention (e.g. a divine being). The theory also argues that our universe is just old enough for some stability so that stars and planets could be formed; also it has a biologically hospitable planet like the earth which allows the existence of biological organisms; this is the sole reason to why we happen to be here.

The M-theory is not a theory in itself in literal sense. It is not a normal theory but a collection of number independent string theories. Because the dimensionality of the M-theory exceeds the dimensionality of superstring theories in 10 dimensions, it is believed that the 11-dimensional M-theory unites all five string theories (and supersedes them). Though a full description of the theory is not known, the low-entropy dynamics are known to be supergravity interacting with 2- and 5-dimensional membranes.

The idea of the M-theory, first put forward by Edward Witten in 1995, revived the string theories which were fading in the theoretical physics community due to the lack of progress despite intense research. But even after 15 years, the M-theory remains vastly speculative to the point that many physicists would even dent it as a scientific theory since it lacks testability and predicting power.

There are some genuine controversies around the theory. So to many physicists working in this area, it seems the Hawking misguides the readers. Physicist Marcelo Gleiser, author of the recent book on a similar theme but a different angle 'A Tear at the Edge of Creation', criticized Hawking for misleading the public with his overly-confident presentation style and his tone of authority. He says, "It's extremely misleading to promulgate highly speculative theories as the accepted word of the scientific community."

The book argues that invoking God is not necessary to explain the origins of the universe, and that the Big Bang is a consequence of the laws of physics alone, thus questioning the very existence of God. The New York Daily News reported: "When it came to the creation of the universe, God just wasn't necessary. That's the conclusion renowned scientist Stephen Hawking has made in his latest tome, 'The Grand Design'. It was as if the Oracle of our time finally decided to tell us what the ultimate truth was.

It seems that the media misunderstood that Hawking has somehow proves the non-existence of God. Even the well known atheist Richard Dawkins was apparently mistaken, telling the Times of London: "Darwinism kicked God out of biology but physics remained more uncertain. Hawking is now administering the coup de grace."

Amid the increasing outcry from the religious, Hawking's co-author, Mlodinow, rushed to clarification; in his interview with USA Today, he said, "We're not saying there is no God. There is no need for God to explain the universe." The book does not directly deny the existence of God; the authors only write, "It is not necessary to invoke God to light the blue torch paper and set the Universe going... Spontaneous creation is the reason there is something rather than nothing, why the Universe exists, why we exist." Mlodinow's clarification, however logical, is not fully sincere. Still highlighting the 'No God' implication in the way the promoters did is simply not correct.

About the Author

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Heating By 700% Efficiency

☛ **Ish Dhand**

Most domestic room heaters in India use electrical resistance to generate heat. A few simple thoughts on heat flow and efficiency tell us that there exists a much more efficient way to heat our homes.

ARTICLE

As the temperature in North India plummet to near zero, I find myself staring at the resistance type room heater which claims to be 100% efficient. How true is this claim? Lets dive into a 185 years deep rabbit hole of thought to find out if we can do better than this '100%' as claimed by the 1 Kilowatt device and if yes, how much better.

The resistance heater does seem to be perfect at first sight. After all, it faithfully converts the whole of electrical energy that it receives through the wiring into heat. There is no scope for the energy to be lost; even the little light it emits is absorbed by the surroundings and is converted to heat.

Let's jump half a year into the past; into a time when air conditioners worked unceasingly to provide us relief from the scorching summer heat. How A/C's cool the inside of a building is simple to understand. They 'pump' out heat from the indoors to the hotter surroundings. To do so, they must work against the natural tendency of heat to flow from higher temperature to a lower temperature.

What overcomes this natural tendency is the electrical energy we provide is. The more the difference in the temperature, the more electrical energy is needed and vice versa. Ideally, to pump out a given an amount of heat, we have to provide that much energy times a factor of (Outside Temperature/Inside Temperature) - 1). This result was obtained by Sadi Carnot almost two centuries ago, in the year 1824.

Even on the hottest of days, with an outside temperature of 45 Degrees Celsius, the above mentioned factor is a mere 0.067 if we try to maintain an inside temperature of 25 Degrees. A 1 Kilowatt ideal A/C can pump almost 15 Kilowatt of heat flow out of the room. For an A/C with a realistic efficiency of 40 percent, that number is 6 Kilowatts. A total of 1+6 = 7 Kilowatts of heat are ejected into the atmosphere using just 1 Kilowatt of electrical energy.

Imagine a room with an A/C installed inside out. The region to which it pumps the heat into is now the inside of the room. This is our super-efficient heater. A 1 watt resistance heater would give the room 1 Watt of heat. Our super-efficient heater with the same input would provide 7 Kilowatt of heat! The idea is not new by any standards. I wish that the engineering hurdles in the path to making a cheap, safe and user-friendly heater based on this principle are overcome and such wonderfully efficient devices soon become 'house-hold'.

About the Author

Ish Dhand is a Junior Undergraduate Student at IIT Kanpur. He can be reached at (ishdhand@iitk.ac.in). He is deeply passionate about physics and wishes to take up research in pure physics in India in the future. He loves listening to music from many different genres ranging from Western Classical to Art-Rock.

Image Source

http://moreheaters.com/wp-content/uploads/2009/ 09/space-heaters1.jpg

TIME TO SHOOT

We are looking for some really mouth-watering photographs that might help us design the first cover pages of upcoming issues of NERD.

The photograph maybe a very beautiful image of a bird or a tree or anything picturesque in the campus. So come forwards and contribute by sending in the photographs latest by 30th January, 2011 to nerd@iitk.ac.in. If the photograph is selected for the cover page, you get certificate of appreciation. We require at least two photographs per issue. Please keep in mind that the photographs should be original and may be modified using any image editing software.

The Necessity Of The Space Program And The Cryogenic Technology

Vignesh R

The primary body for space research in India is the Indian Space Research Organisation (ISRO). It is one of the leading space research organizations in the world and among the most efficient. Space activities in the country started during early 1960s with the scientific investigation of upper atmosphere and ionosphere over the magnetic equator that passes over Thumba near Thiruvananthapuram using small sounding rockets. Realising the immense potential of space technology for national development, Dr. Vikram Sarabhai envisioned that this powerful technology could play a meaningful role in national development and solving the problems of common man.

ARTICLE

Why Is The Space Program Necessary?

A lot of questions have been asked on why a developing country like India should invest millions in space exploration while much of its population fights poverty on a daily basis.

Dr. Vikram Sarabhai- The Father of Indian space Program emphasized the importance of a space program in his quote:

"There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space-flight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society."

The fact remains that the space program has actually helped the country's prime concerns in many ways. Some of these technology advancements could even potentially help alleviate poverty and illiteracy.

Some of India's poorest districts owe their primary schools to ISRO due to the EDUSAT program (educational satellites) which has enabled beaming of the government's UGC (University Grants Commission) education channel to the children of these villages.

Weather monitoring satellites have helped the farmers plan their cropping patterns based on the estimated dates of the arrival of monsoons and storm warnings in the coastal areas.

ISRO has also applied its technology to "telemedicine", directly connecting patients in rural areas to medical professionals in urban locations via satellites.

Apart from these, the major objectives of mass communication, imaging and remote sensing for management of natural resource and defence, and further researches in science have been fulfilled to a large extent.

India also connects space exploration to national prestige, being in a highly select group of nations to boast of a full-fledged and successful space program which includes a mission to the moon, a recoverable space capsule and launching of 11 satellites on a single rocket, to name a few.

ISRO has also given a lot of importance to the development of new technologies- ion propulsion, cryogenics, reusable payloads etc., which will lead to an expansion of the space program. The article will give an outline on one of these developments- the cryogenic engine indigenously developed for rocket propulsion.

Cryogenic Engine

Cryogenic Engines are rocket motors designed for liquid fuels that have to be held at very low "cryogenic" temperatures to be liquid - they would otherwise be gas at normal temperatures. Hydrogen and Oxygen are used which need to be held below 20K and 90K respectively for them to remain in liquid state.

Why Cryogenic Technology

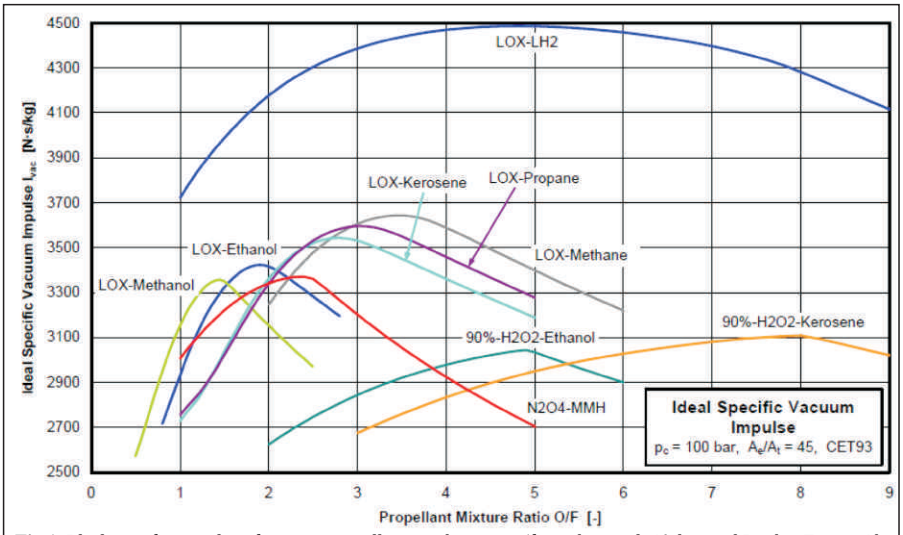

Fig.1 Ideal specific impulse of various propellant combinations (from the article 'Advanced Rocket Engines' by Oskar J. Haidn, Institute of Space Propulsion, German Aerospace Center)
(http://ftp.rta.nato.int/public//PubFullText/RTO/EN/RTO-EN-AVT-150///EN-AVT-150-06.pdf)

The main reason for the development of cryogenic fuels is the high Specific Impulse (the impulse per unit amount of propellant used) compared to other solid and liquid propellants. This technology gives the capability to launch even very heavy satellites. As of today, India has its heavy communication satellites launched by the ESA(European Space Agency), French Guyana.

India has developed the cryogenic engine after 18 years of research and hard work by scientists and engineers of ISRO on this complex technology, which has been a crucial asset for putting communication satellites heavier than two tonnes in the geostationary orbit (36000 km above the surface of the Earth).

Work on developing India's own cryogenic engine was started by ISRO shortly after the project to develop the GSLV (Geo Stationary Launch Vehicle) was initiated in 1986. However, failing in the initial attempt to develop the highly complex cryogenic engine on its own, ISRO procured seven Russian-built cryogenic engines, of which six have been used during the GSLV launches.

The indigenous cryogenic engine development programme was started again in 1996 due to some political reasons.

The first flight test of its indigenously developed Cryogenic Upper Stage (CUS) on GSLV-D3 on 15th April, 2010 ended as a failure. The possible reason was that a malfunctioning fuel booster turbo pump in the upper stage resulted in the lack of supply of liquid hydrogen to the main engine.

Fig.2 The indigenously developed cryogenic engine at the Liquid Propulsion Systems Centre of ISRO at Mahendragiri in Tamil Nadu. (http://defenceforumindia.com/showthread.php?t=9280&p=127876)

The scientists have taken up this failure in their stride and have announced that there would be a relaunch of a rocket with the indigenous CUS in 2011.

For the country's rocket scientists, the yet-to-be-achieved breakthrough is significant on two fronts - one, to achieve self reliance and confidence in space technology and two, India will then emerge as a serious player in the $4 billion global satellite launch market. If successful, India would be only the sixth country in the world to launch a rocket with indigenous cryogenic technology.

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Meeting Connectomes

.....to Know How Every Single Neural Connection Makes Us Uniquely Human

Harsha Mulchandani

ARTICLE

Brilliantly designed and sitting right there, at the top of our heads is our brain. It is, needless to say, an ultra complex and intricately crafted network. Well, if the brain is a network, studying this network would require studying the basic elements and the interconnections that together constitute this network. So, in our quest to understand our own brain, we aim to develop a description of how the neural interactions are organized within the brain.

Here steps in the very idea of what a connectome is. The word 'connectome' refers to a comprehensive map of neural connections in the brain picturing distinctly, all neurons and synapses. Connectomes were first conceptualized in 2005 by Dr. Olaf Sporns of indiana University and Dr. Patric Hagmann of Lausanne University independently.

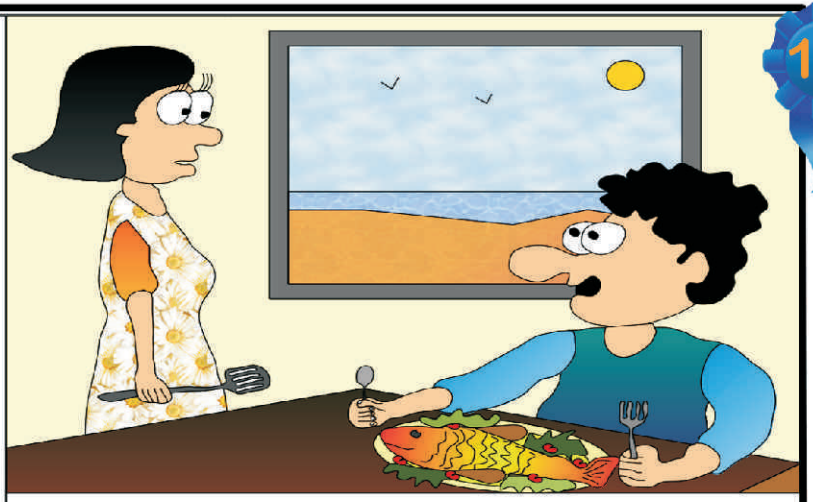
This map fosters our understanding of how various functional brain states emerge from underlying structural substrates. That is exactly what makes it a topic worth probing. It is intriguing to know that the set of all neural connections holds extra information; much more than what is provided by merely studying individual neurons.

Structure is intricately related to function, for almost every conceivable dynamic system. Thus, brain neuronal communication capacity and computational power rely

SCIENTOON

Poster

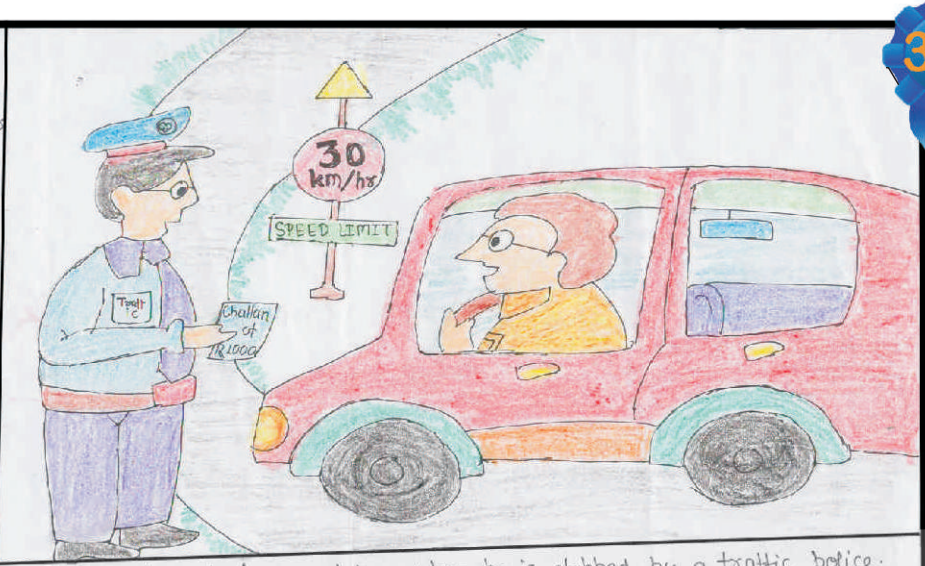
The coelacanths, which are related to lungfishes and tetrapods, were believed to have been extinct since the end of the Cretaceous period (145.5-65.5 million years ago). They were the "missing link" between the fish and the tetrapods until the first Latimeria specimen was found off the east coast of South Africa, off the Chalumna River (now Tyalomnqa) in 1938. This discovery 65 million years after they were believed to have gone extinct makes them arguable the most well-known example of a Lazarus taxon, a species that seems to have disappeared from the fossil record only to reappear much later. Since 1938, Latimeria chalumnae have been found in the Comoros, Kenya, Tanzania, Mozambique, Madagascar, and in iSimangaliso Wetland Park, Kwazulu-Natal in South Africa.



"Mom, I don't like the taste of this fish we caught today. It tastes stale like its a million years old."

1st

Heisenberg, a German physicist, one of the founders of quantum theory, is best known for his uncertainity principle which states that it is impossible to determine with high accuracy both the position and momentum of a substance or subatomic particle.



Heisenberg is out for a drive when he is stopped by a traffic police.
Traffic police: "Do you know how fast you were going?"
Heisenberg: "No, but I know where I am."

3rd

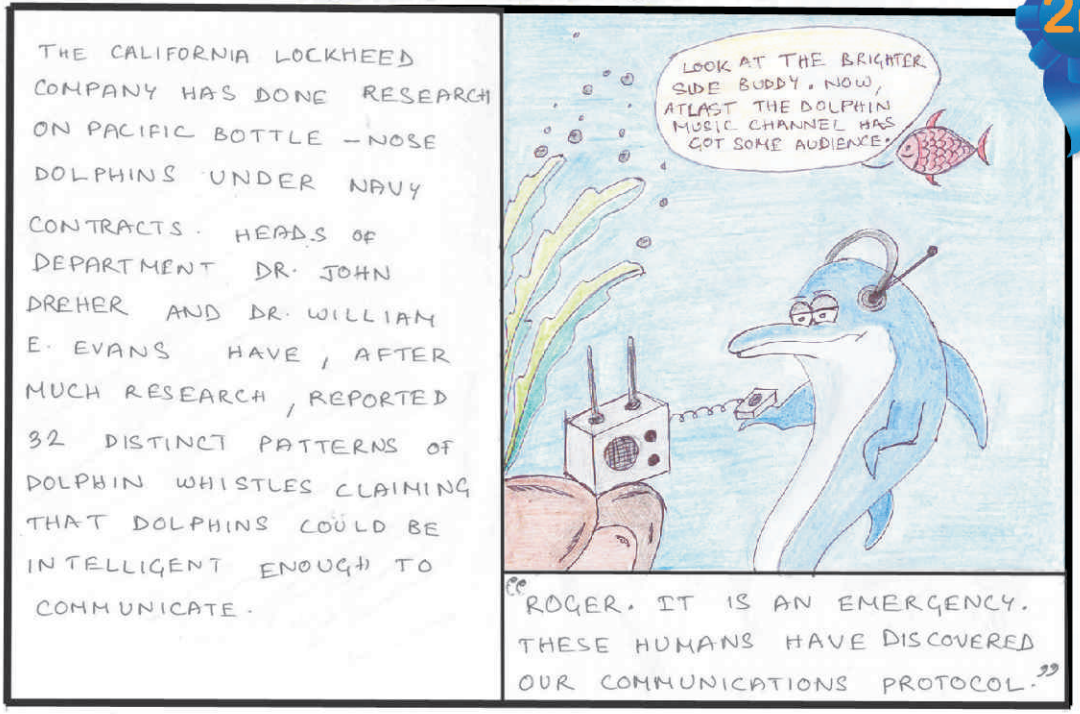
NOTES ON ENGINEERING RESEARCH & DEVELOPMENT

NERD

AN IIT KANPUR PUBLICATION

DOLPHIN DECODED:

2nd



THE ABOVE SCIENTOONS ARE THE PRIZE WINNING ENTRIES OF INTRA-IITK TECHNICAL FESTIVAL TAKNEEK 2010.

FIRST PRIZE - PUNEET SINGH (punsingh@iitk.ac.in)
SECOND PRIZE - ANKIT MAHATO (amahato@iitk.ac.in)
THIRD PRIZE - SHOUBHIK GUPTA (shoubhik@iitk.ac.in)

SCIENTOON

Poster

SCALE	REGIONS DEALT WITH	ADVANTAGE	DRAWBACK
1.Microscale (of micrometer resolution)	Deals with individual neurons to construct a neuron by neuron map.	Expected to be the most accurate map as its smallest basic unit would be a single neuron.	Creates large and unmanageable datasets due to immense number of neurons, imaging techniques fail.
2.Mesoscale (resolution upto hundreds of micrometers)	Deals with functionally distinct neuronal populations of around 80-100 neurons.	Throws light on intracolumnar functional interdependence of segregated neuronal populations, easier to comprehend.	Overlooks an individual neuron's distinctiveness, not as accurate and clear as microscale maps.
3.Macrosacle (of millimeter resolution)	Deals with various brain parcels/ modules with distinct connectivity patterns.	Most popular due to easy readability, would present a most general layout of the brain.	Again, not as accurate as single neurons are not captured.

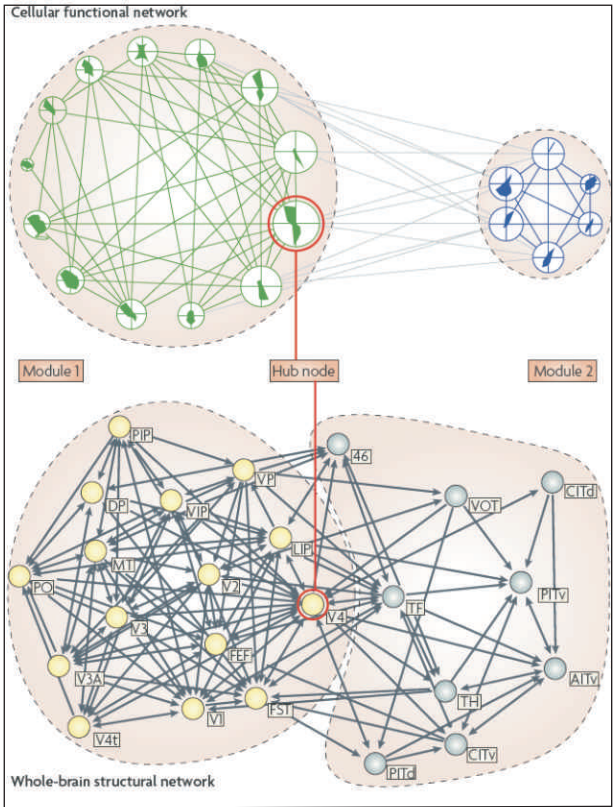


Fig. 1 Mapping connectomes
Source: http://humannaturegroup.files.wordpress.com/2009/12/gb.png

substantially on the structural architecture of the brain. This structure related functionality also puts strong natural constraints on the neural populations that can interact.

Add to this the fact that mapping a single individual brain is not sufficient to develop a general picture of human brain as there are large differences in connectomes of different individuals. This may be due to genetic differences, developmental history, gender differences, pathologies or responses to injury. Moreover, even a single individuals connections are plastic and changeable, thereby making this mapping an even more challenging task.

All the above considerations encourage us to dig a little deeper into the basic idea as to how exactly a rough map of the brain could be prepared. A prerequisite would be to visualize our brain. Three important levels of scale are Microscale, Mesoscale and Macroscale.

Tireless efforts to develop such a map at basic cellular level have been going on. Unfortunately though, imaging techniques to capture brains activity neuron by neuron have suffered certain serious drawbacks. One of these methods involved 'Cell Staining' using Golgi Stain, to trace cellular processes, but it faced difficulty in capturing long range neuronal projections. 'Electron Microscopy Reconstruction' is a method that employed usage of electron microscope to accurately observe and reconstruct brain images. Although it successfully captured C. elegans connectome (it being relatively primitive) its application to larger tissue blocks fails. Each of these experiments helped gain new insight in this field by contributing in their own

gain new insight in this field by contributing in their own way.

This was followed by a method called 'Combinatorial Color Labelling' which proved successful in effectively tracing and reconstructing cellular structure of neurons. It is based on labelling of each individual neuron with a distinguishable hue, thus allowing a complete and indepth structural mapping.

A noteworthy step towards solving the connectome mystery is the 'Human Connectome Project', initiated by National Institute of Health. The project aims at advancing our understanding of what makes us “uniquely human”. It involves studying abnormal brain circuits in neurological disorders (autism, schizophrenia). It promises to significantly deepen our knowledge of how genetic and environmental factors cause difference in brain circuitry. This would be done through a macroscale mapping, employing techniques of 'Diffusion Magnetic Resonance Imaging' (DMRI) and 'Functional Magnetic Resonance Imaging' (FMRI).

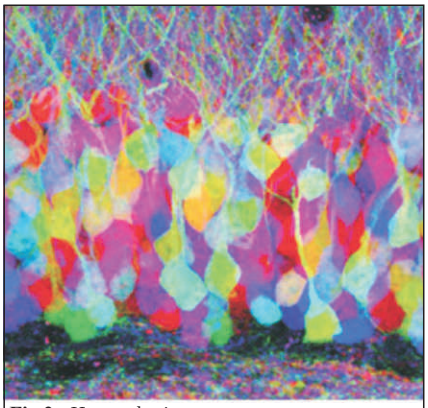


Fig.2 : Human brain connectome
Source:
http://dericbownds.net/uploaded_images/connectome.png

While DMRI would help reconstruct major fibre bundles in brain and demonstrate neural tracts connecting brain to body, FMRI would measure change in blood flow related to neural activity, enabling scientists to identify anatomically distinct but functionally related sections of brain. All this would help prepare a “basic connectome draft”.

Thus, solving the connectome mystery can be called a major breakthrough in every sense of the word; for, taking out your brain out of your head and painting it on a piece of paper is not just fascinating, but also an idea worth pondering over. Let's wait and see where connectome mapping takes the future of neurosciences. Research goes on, as human eyes await their encounter with connectomes.

About the Author

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Magic Fork

Kumar Ritikesh
Ish Dhand

What gives the bicycle its extraordinary stability? Come out with us into the open skies and cool breeze for a ride as we wonder how the simple bicycle had eluded our understanding for over 150 years.

ARTICLE

It takes hardly a few days for an eight year old child to learn how to stabilize a bicycle but, believe it or not, it was only in the last 40 years or so that we have begun to understand the stability of this delightful machine. In our high school, the explanation given to the stability of the bicycle was very similar to the ones used to explain the stability of a rolling coin. The arguments go something like this (long explanation, but hold on!): It is the large angular momentum of the bicycle that keeps it stable. Consider the angular momentum of the bicycle about its center of mass. The major component of angular momentum comes from the rotating wheels. Since the angular momentum is perpendicular to the direction of motion, and the torque which tends to topple the bicycle (on bending) is always along the line of motion, the angular momentum merely changes direction and hence the bicycle turns to left or right without toppling.

Fig.1: David Jones on his modified bicycle. Notice the additional dummy front wheel. Even on changing the total angular momentum of the bicycle, by changing the speed of rotation of this front wheel, the cycle could easily be ridden

So, to see if this claim was actually true, David Jones, a spectroscopist at Imperial Chemical Industries in England, did the best thing one can do. He asked nature if the above theory was true by setting up a bicycle with an additional dummy wheel attached to the front wheel. The dummy wheel was given a rotation such that the angular momentum of the system becomes zero. He observed that it 'could be easily ridden, both with the extra wheel spinning at high speed in

either direction. It did not tax my (average) riding skills even at low speeds.'

An attempt for a better explanation came from Timoshenko and Young, who tried to explain it from the rider's perspective. When a cycle leans onto one side, the only way to keep it stable is to make it go around in a circle and hence the rider turns the front wheel in the direction of lean. But, anyone who's ridden a bicycle would understand that it possesses some kind of a magical self-stabilization that works without conscious effort. It's this magical stabilization that allows us to ride a bicycle with our hands free.

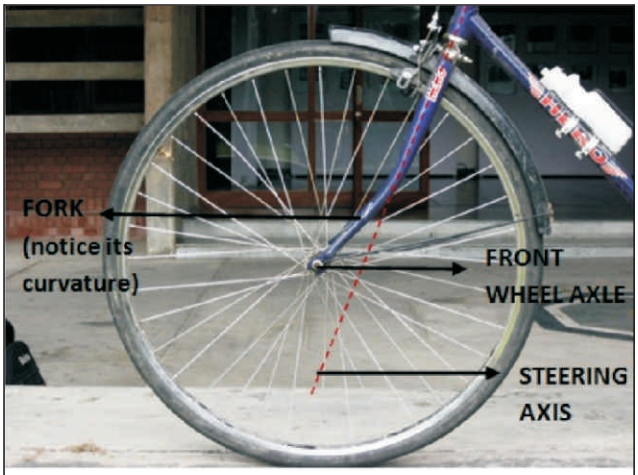

Fig.2 : Side view of the front wheel of the bicycle

Another way of looking at the stability of the bicycle is that in a leaning bicycle, the point of contact is moved towards the inner side and the radii of inner part of tire would be smaller than that of outer part. It is just like a rolling cone (or a tapered steel glass, or a chicken egg!) with greater outer radius and smaller inner radius, which, when rolled, moves in a circle. This is correct, no doubt, but hardly explains the self-stabilization.

Here's the explanation given by David Jones in 1970 that is now widely accepted. He said that there's something subtle about the design of the steering. When we try to bend a stationary or moving bicycle one way or the other and the front wheel turns on its own to negotiate the lean. Lean the bicycle to the left, the front wheel turns to the left on its own. Why does this happen? It is because of the curvature (concavity) of the fork (the 2 rods that hold the axle of the front wheel, Refer to adjacent figure). Notice that because the fork is bent inwards, the center of gravity of the cycle is located above the wheel axle. So, if the bicycle is leaning, and the front wheel rotates in the direction of the lean, center of gravity of the wheel will be lowered, which is something nature would favour! Think about it and imagine for yourself.

For example, when we're on the bicycle, leaning it to the left will make the front wheel turn to the left and the bicycle turns left thereby 'countering' the lean. This is precisely what a conscious rider would have done to maintain the stability of a bicycle.

Why then is it unstable at low speeds (as in a slow cycling race)? That is because the wheel that was turning left to counter the left-lean, will, at low speeds, turn a little too much! At high speeds, this problem does not occur and the bicycle is hence, stable.

It's this bent front fork where the magic of the stable bicycle lies. Let's ponder over stability of a bicycle which has a fork bent convex or one with a straight fork. The answer is hidden in the relative position of the centre of mass with respect to the wheel axle. Give it a thought because with intuition and experience we designed a bicycle. But, with just some thought and a little experimentation, we understood it!

About the authors

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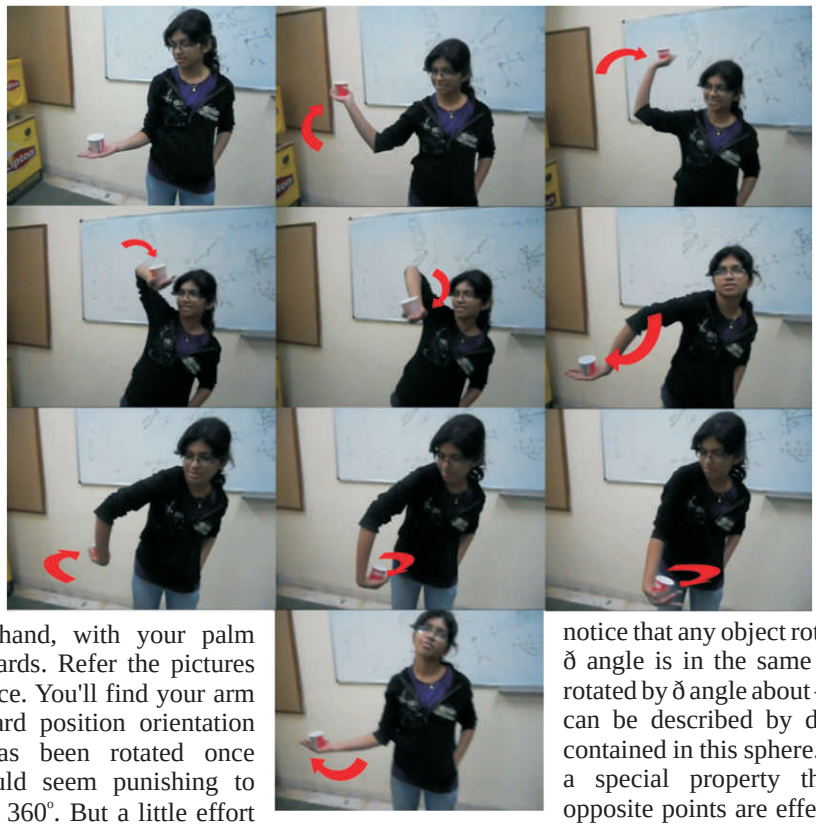
Fig.3 : Lowering Of CM of Front Wheel
(The dashed line shows the height of CM of front wheel in first image and the arrows show the descent of CM in other two images)

The Twisted Nature Of Nature

Pranjal Nayak
Ish Dhand

ARTICLE

Who would not doubt me if I say that an object rotated by two full rotations won't be in the same orientation as it would be when rotated by a single one. The orientation of anything seems to have a periodicity of 360° and a statement like the previous one seems completely out of this world. And yet nature manifests the difference between 360° and 720° often. One such example is the Dirac's Belt Trick. It can be performed by you even as you read this article. All you need to do is just hold anything like a cup of water on your palm with your hand outstretched (water is for one's satisfaction that the rotation of cup is about the vertical axis, because if it is not then you'll spill water on yourself!). Now try rotating your hand, with your palm always facing upwards. Refer the pictures attached for guidance. You'll find your arm in quite an awkward position orientation after the glass has been rotated once completely. It would seem punishing to rotate it by another 360°. But a little effort and you shall be back to the orientation you started with. And yes, the glass has rotated by 720°. Why does360° feels different from 720° of rotations? Another demonstration showing the same phenomenon is the Belt Trick. Take a belt and straighten it out, there should be no twists in the belt. Now give one end of the belt two full rotations. Now the puzzle is to straighten the belt without rotating the end, i.e., the rule is not to twist or rotate back the belt to original position. That is, the end from which you are holding the belt can only be moved up-down, left-right, forward or backwards. Explaining the solution to this puzzle in words is quite difficult but can be found at *http://www.youtube.com/watch?v=ay3gNFpB6wM.* Both these phenomenon can be explained using very simple concepts. To define a rotation, we need:



a. The axis about which rotation has occurred.

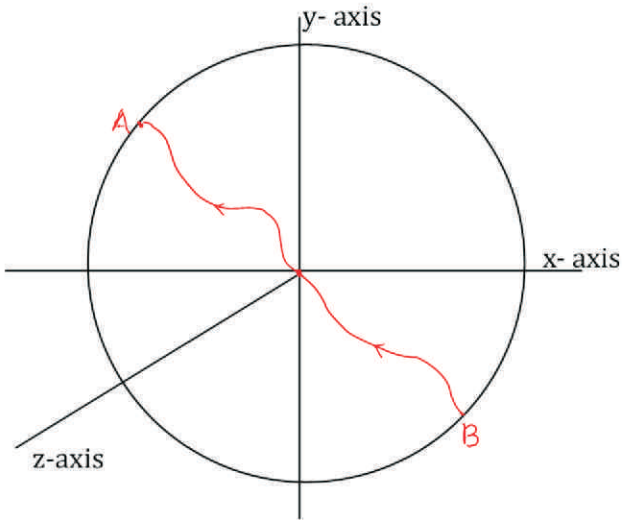
b. The angle by which the rotation has taken place.

Hence, a rotation can be described by a directed line segment èn along the direction of the axis (n) and with a length è, the angle of rotation

We don't call this directed segment a vector because it doesn't follow the rules of vector algebra. For example, vectors add commutatively.That is v1+ v2 = v2+ v1; but we know from our experience that order of two different finite rotations does affect the final orientation of the object.

With some thought, we can understand that any rotation can be described by a point in or on a sphere of radius ð, about the origin. Also notice that any object rotated about an axis n by ð angle is in the same orientation as a body rotated by ð angle about –n as axis. All rotations can be described by directed line segments contained in this sphere. In fact this sphere has a special property that the diametrically opposite points are effectively the same point because they describe the same orientation physically. So let us start from some point inside the sphere (say centre/ origin) and move radially outwards. As soon as we reach the boundary of the sphere we emerge at the diametrically opposite points. This being because any rotation (ð+è)n is the same as (ð-è)(-n). And so as we move still further we find ourselves moving radially inwards on the –n axis.

As we reach the origin, we have completed a closed loop inside the sphere. Yes it is a closed loop because the diametrically opposite points on the sphere are one and the same.



- Starts from the center
- Moves to the surface
- Emerges from the diametrically opposite point on the surface
- Finally goes to the origin

Fig. 1 Consider a sphere with radius pi. This represents the set of all rotations. Points A and B are diametrically opposite and so are the same point. As we traverse from origin to A (or B, they are the same points) and back to origin in a closed loop.

Loops are simply the curves that are closed as we understand in simple language. Now the loops that we consider are expandable or shrinkable, exactly like a rubber band. We find that expansion and shrinkage of the loops don't affect a few properties. For a familiar example, read Box-1.

Box -1: Loops in nature: An example.
As an example, consider any imaginary loop around a wire. If we calculate the quantity $\oint B.dl$ around the loop, it turns out that the quantity depends only on the number of times the wire loop. If the loop does not go around the wire, the above quantity is zero. If it goes around once, it's where $\mu_0 i_{enclosed}$ is the current enclosed in the loop. If twice, it's twice that number. Interestingly, this quantity does not depend on the shape or size of the loop or the distance from the wire. Magnetic fields around a wire form 'loops' (Figure 2). This can be easily detected by placing iron fillings on a paper around a current.

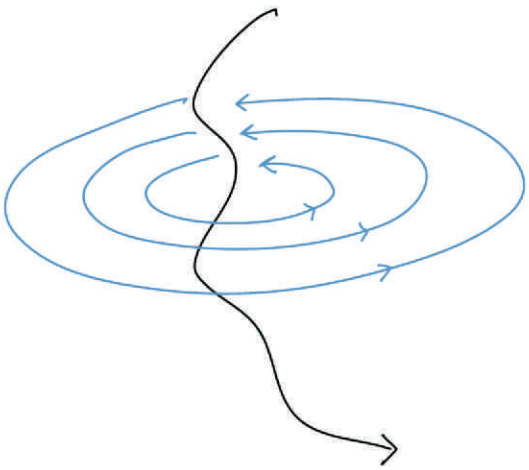


Fig. 2 Magnetic Field (represented in Blue) around a current carrying wire. Magnetic field forms closed 'loops' as is seen above.

Box -2
Here, we show what we mean by shrinking the loops with the figure 3 and 4.

- In figure 3 we consider a loop around a point O in 2D space and shrink it to the point O.
- In figure 4 we have tried to shrink a loop in a special type of 2-dimensional plane. We have subtracted a circle centred at origin from the normal 2D plane, i.e. this circular region is not included in the space of our interest. Then we have considered a loop around it. As we have tried to show from the figure, there is no way we can 'shrink' this loop to a point.
- One last example of a loop that can't be reduced/ shrunk to a point is a loop contained in a torus.

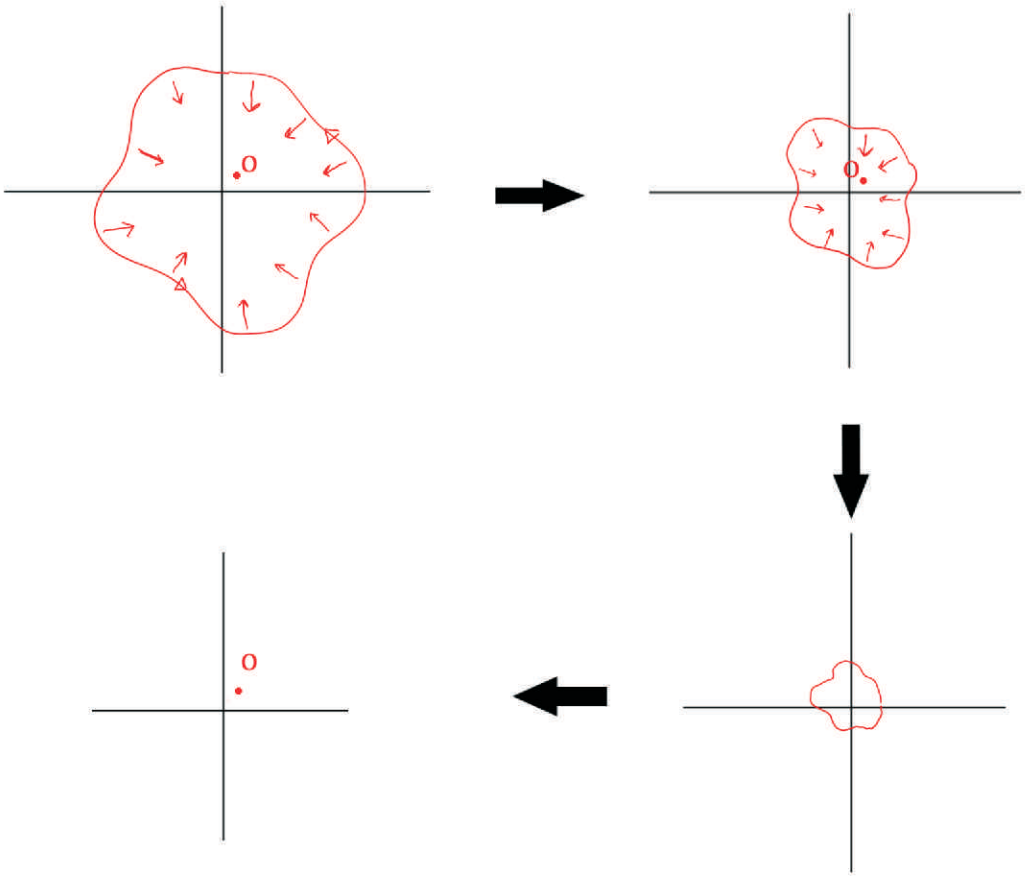


Fig. 3: *Shrinking of a loop to a point*- Consider any loop around a point O in the 2D plane. It can be shrunk to the point as shown in the series of figures above.

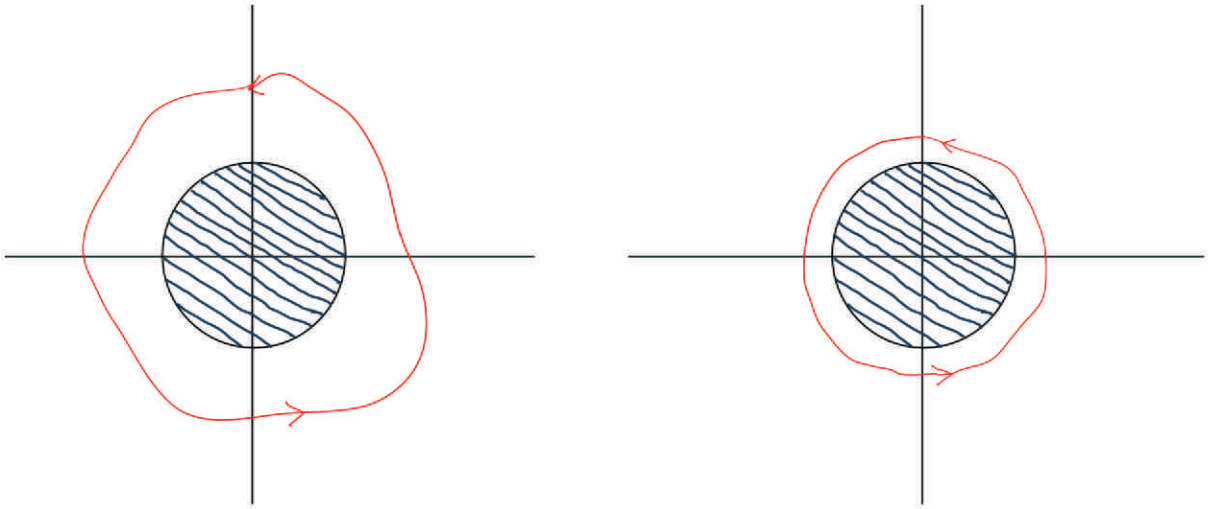
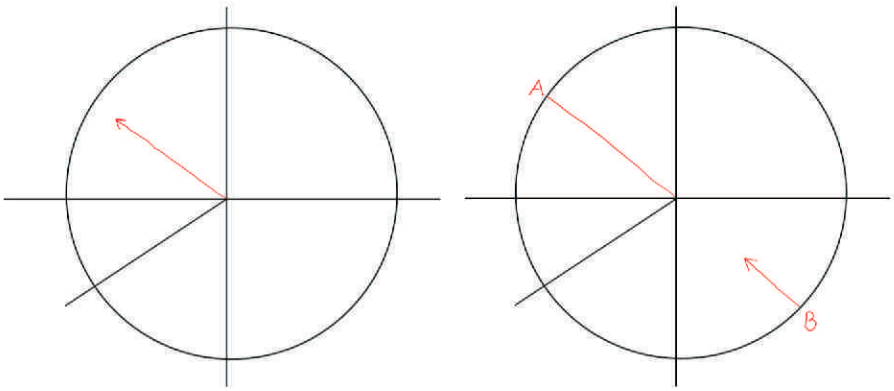
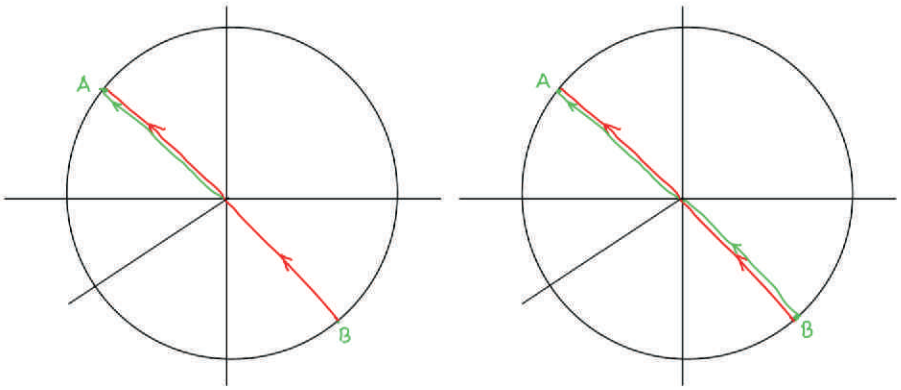


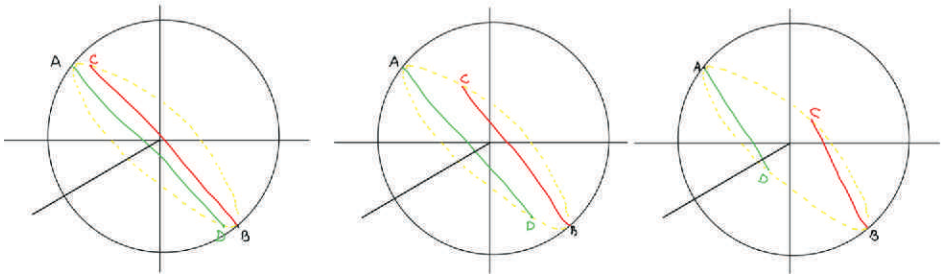
Fig. 4: A loop around a punctured space can't be closed. By punctured space we mean a normal 2D space with some part of it subtracted from it.



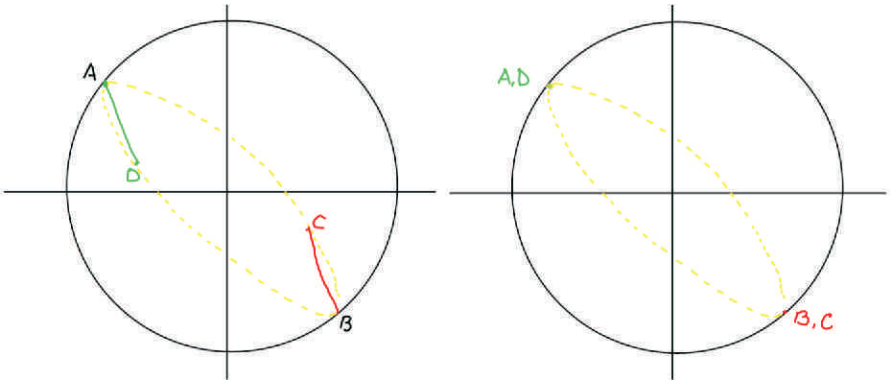
We start traversing a loop inside the sphere representing the set of rotations. We start from the origin, move to the periphery and re-emerge from the diametrically opposite point and move towards the origin on our journey ahead, hence forming a closed loop.



As we go further ahead, we start the second loop (shown in green colour). Thus when we reach back the origin again, we have completed two complete loops inside the sphere.



Two loops can be shrunk inside this sphere as explained here, we move the two arms AD and CB such that C and D are always diametrically opposite points (and hence the same). This is still a loop as points A and B are the same and so are the points C and D. Here we have moved the points C and D along a Great Circle such that they are always diametrically opposite.



The double loop has shrunk to a single point - A/B/C/D - they all are essentially the same points.

Now let us go back to our example of the Dirac belt Trick. We rotated our palm by 720° we actually form a loop inside the sphere representing all the rotations. One end of our arm, the end connected to the shoulder doesn't rotate (well does it?), and hence is always at the origin of our sphere. But while we rotate our palm, it moves towards the periphery of the sphere (representing ð rotations), out of the diametrically opposite point (the diametrically opposite points are essentially the same, as discussed above). This is represented by a series of diagrams below.

In the diagrams on the previous page, we traverse a double loop inside the sphere that describes all rotations and then show how that double loop is 'shrinkable' in the terms we have just discussed. One might try the same trick with a single loop and might find that is it is not shrinkable what so ever.The double loop represents a rotation by 720°, a single loop by 360°, while a point is no rotation at all. It thus shows that 720° are same as no rotations, while 360° are not. In the belt trick and the hand trick described above the same concept is used to bring the belt and the hand back to their initial orientations.

The fact that 360° is not the same as 720° had spun my head by 360° at the first thought! This is how twisted is the nature of nature.

Ponder Yonder

1. Mirrors and Merry-Go-Rounds, Resonance Vol.15 No. 8, Joseph Samuel

2. http://www.gregegan.net/APPLETS/21/21.html

About the Author

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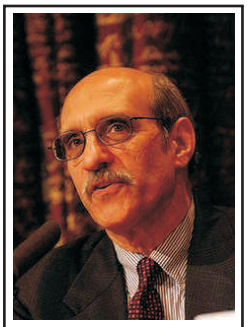
Microscope Of 21st Century

An Interview With Dr. Martin Chalfie (Nobel Laureate In Chemistry In 2008)

Mohit Kumar Jolly



Dr. Martin Chalfie

Dr. Martin Chalfie is the William R. Kenan, Jr. Professor and the Chair of Department of Biological Sciences at Columbia University, New York, USA. He shared the 2008 Nobel Prize in Chemistry for discovery and development of Green Fluorescence Protein (GFP). GFP has been termed as the microscope of 21st century, and currently used in laboratories all across the world to trace protein and gene expressions. Here are some excerpts from his interview taken by a NERD team member:

INTERVIEW

NERD: Prof. Chalfie, you were awarded the Nobel Prize in Chemistry in 2008 for discovery and development of Green Fluorescence Protein (GFP). To put in simple terms, can we describe GFP as a protein (a sequence of amino acids) which, when present in cells causes them to fluoresce green, when blue light is incident on them?

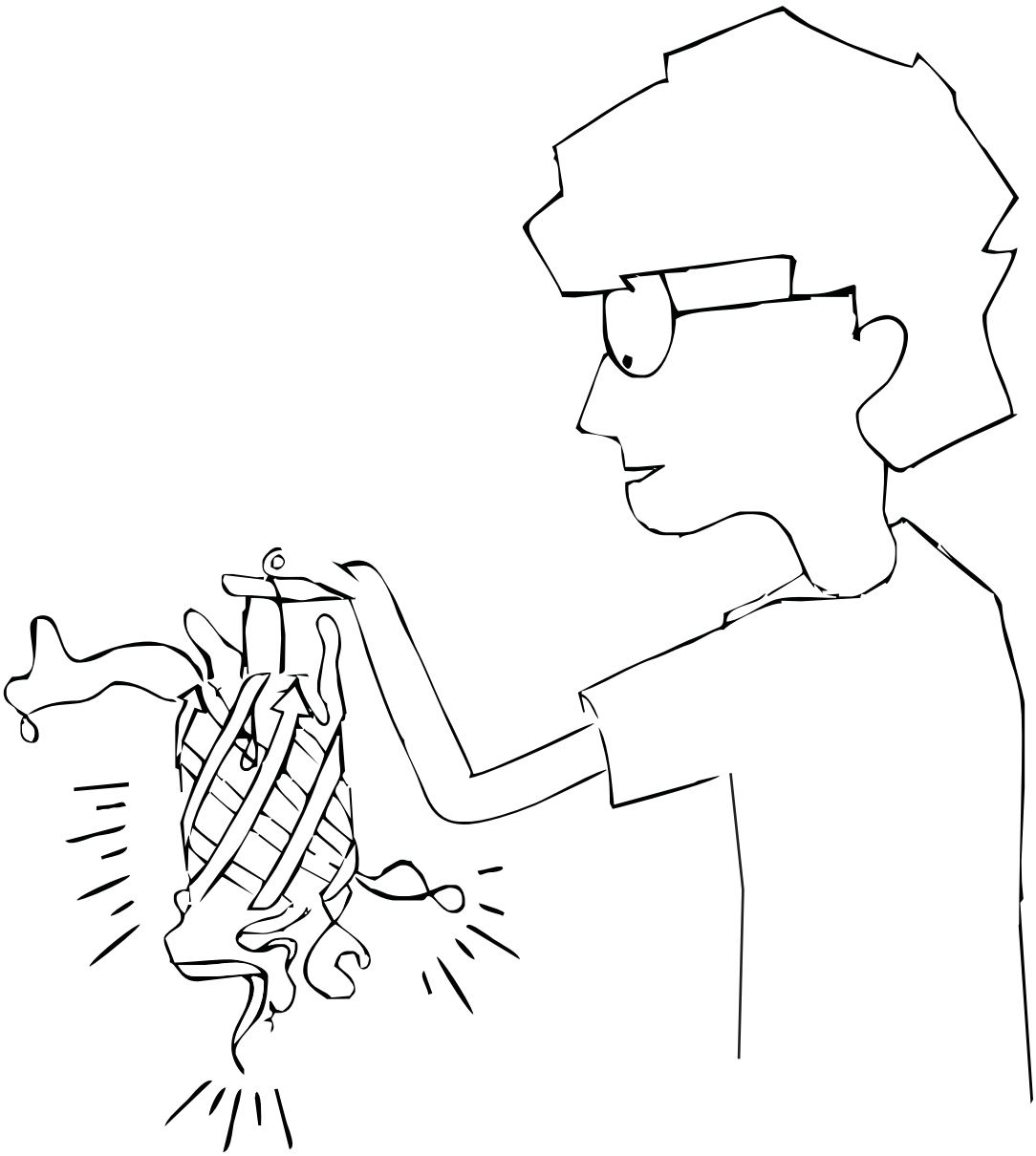
Dr. Chalfie: Yes.

NERD: GFP has been termed as the microscope of 21st century, and is currently used in laboratories all across the world to trace other proteins. (The protein of interest is biochemically attached to GFP). What makes GFP so different from other luminescence proteins that more than 10,000 research papers alone in 2007 relied on GFP's fluorescing properties?

Dr. Chalfie: Let me talk about the situation before GFP, when antibodies, in situ hybridization (using DNA probes) and beta-galactosidase (using E.coli lac Z) were used to trace proteins and look at gene expression profiles. All these methods required that you fix the tissue and make it permeable to allow the reagent or a cofactor enter the cell.

GFP does not require anything else. The only thing to be added is light. It is non-invasive method of tracing proteins/cells. It is heritable as well, so if you implanted GFP into the DNA of an organism to study gene expression, the GFP gene can be inherited by its progeny as well and you can see same results there. It can be used in living tissue, so you get a dynamic view and can actually see the proteins or cells moving or the genes getting expressed. These advantages make GFP so different and convenient to use.

NERD: Your primary research area is to investigate the aspects of nerve cell development and function using the



'O Proteins!
Enlighten My Way
Ahead'

nematode C.elegans. What got you interested in research on GFP?

Dr. Chalfie: I was very excited about one aspect of C. elegans and used to mention it constantly in each seminar that it is transparent. I was already studying gene expression profiles in C. elegans, so was aware of the labor expensive methods used to study it.

I was attending a seminar in which I heard that there was a protein which was inherently fluorescent, which was sufficient to have the cells fluoresce green when blue light was shone on them. I was so excited and thought that I would like to put it in C. elegans to see the gene expression and protein localization in living cells through its transparent body. It worked.

I was inspired to continue biology as my career.

NERD: GFP has now been into every organism-prokaryotes and eukaryotes. What have been major developments in GFP technology since your first paper in Science in 1994?

Dr. Chalfie: There have been a lot of developments since. Original GFP (which was discovered in jellyfish) got excited by blue light or UV light. It has been mutated to give variants which get excite at different wavelengths and emit different colors. Modified GFP which can remain stable at mammalian body temperature has been developed. Fluorescence has been coupled with many other events, for example pH indication. Protein-protein interaction has been studied by reconstituting GFP. Short-lived GFP which gets degraded soon has been developed. Many more colors have come into play with the discovery of coral proteins. FRET (Fluorescence Resonance Energy Transfer) based markers have been used for indicating concentration of calcium and kinases (enzymes which transfer phosphate groups from high energy donor molecules to specific substrates).

NERD: What are the state-of-art applications of GFP in cancer research and infection of viruses?

Dr. Chalfie: I am not an expert on applications of GFP. People have been used in extremely inventive with its uses. The basic logic is that GFP allows one to look at various biological processes and hence diseases as well. Anything which you can tag, you can watch. Mutate the gene sequence of a particular protein and then see using GFP how things get affected.

I prefer undergraduates working with me for a longer period of time, so I prefer that they come to lab in their first year, get some experience and stay in subsequent years if they get interested.

NERD: Marc Zimmer in his book 'Glowing Genes: A revolution in biotechnology' talks about use of fireflies to predict the existence of life on Mars. What is the most way out use of GFP you have heard of?

Dr. Chalfie: One particular idea which interests me a lot is that by Bob Burlage (a microbiologist at Oak Ridge National Laboratory, who was since moved to the University of Wisconsin at Milwaukee). He is trying to detect land mines using microbes. Land mines leak small amount of TNT (Trinitrotoluene) over time. This leaves a trace for bacteria on the soil surface. When the particular bacteria encounters TNT, it activates the genes required to digest TNT, and since GFP is attached to the genes which gets activated for digesting TNT, you can see a green fluorescence if ultra violet light is shone on it. You can detect land mines using bacteria, GFP and light. A wonderful idea in theory, but it hasn't yet been put into practice.

NERD: We read on your Noble Lecture slides the interesting conditions under which your wife, Prof. Hazelkrieg allowed you to include her unpublished results in your Science paper. Our readers would also like to know of the same.

Dr. Chalfie: (Smiles) Of course, she sent that letter to me, not to Science. She has a very good sense of humor. We both enjoy each other's company. You can take those conditions from the lecture.

NERD: What is your take on undergraduate research? Were you passionate about pursuing research in your undergraduate days?

Dr. Chalfie: I have had some terrific undergraduate students working in my lab. I prefer undergraduates working with me for a longer period of time, so I prefer that they come to lab in their first year, get some experience and stay in subsequent years if they get interested.

My undergraduate research experience was a disaster. I tried experiments all summer after my junior year, but they failed, and I decided not to be in science. I had a very terrible set of assumptions that if I have to be a real scientist, I have to do it all by myself. Science is collaborative, but I did not converse with anyone about my experiments and their results. It is possible that some things were working, but I was not able to pick them up.

It was three years later when I got a summer job in a laboratory at Yale University. I had done some experiments related to sodium transport through the skin of toad using an Ussing chamber. The head of the lab left for summer, and assigned me a project. This time I talked with lab members regarding different aspects of project and did some experiments I was interested in. Fortunately, the experiments worked, and I was inspired to continue biology as my career.

I realized that doing research can be very frustrating and time-consuming some time. What you need to do is troubleshooting and things get better.

NERD: How would you describe Dr. Chalfie in one line?

Dr. Chalfie: (Laughs) Lucky! One who likes to solve puzzles and things, and has been lucky.

NERD: How would you attract students to study other glowing molecules that exist in Nature?

Dr. Chalfie: I am intrigued by how much more we have to learn from Nature. It is really nice to look at nontraditional organisms like jelly fish, which are not studies for healthcare or biotechnology uses, but for producing light. We have lots more to learn from the sequence of the human genome, and also from organisms which we do not study. That is the freedom I enjoy as an academic scientist- following my own inclination.

This feeling of pursuing one's own interest should excite students in science. There are infinite ways of being a good scientist. As you see, the three scientists who shared Nobel Prize in Chemistry in 2008 work on three different areas in different ways.

NERD: What final message would you like to give to students?

Dr. Chalfie: There is no right or wrong way to do something. Just be enthused about the work.

Ponder Yonder:

If you are interested in GFP and some of its cool uses, you can browse through:

1. http://www.conncoll.edu/ccacad/zimmer/GFP-ww/cooluses0.html

2. http://www.ornl.gov/info/ornlreview/meas_tech/threat.html

Dr. Chalfie : Every successful man has a woman behind her

When Dr. Chalfie asked Prof. Hazelkrieg if he could publish her unpublished results in his Science paper in 1994, following is the response he got: Dear Marty, It is perfectly fine with me if you cite S.Wang's and my unpublished results in your Science paper on GFP, provided you meet the following conditions:

1. You make coffee each Saturday morning for the next two months, ready by 8:30 am.
2. You prepare a special French dinner at a time of your choosing.
3. You empty the garbage nightly for the next month. (Source: http://nobelprize.org/nobel_prizes/chemistry/laureates/2008/chalfie-lecture.html)

About the Interviewer

Mohit Kumar Jolly (mkjolly@iitk.ac.in) is a first year M.Tech student in the Department of Biological Sciences and Bioengineering at IIT Kanpur. He is interested in Science Journalism and communication and is one of the founders of NERD.

Why We Respect Our Teachers

A Note On Language Learnability And Active Learning

☛ **Purushottam Kar**

Language acquisition - especially in human infants - is a problem that intrigues the layman and baffles the expert. This article takes a computational viewpoint toward the problem and investigates the problem of learnability of languages. We look at some surprising results that show that learning is impossible even under very weak assumptions. We next look at a framework in which learning takes place with a helpful teacher and demonstrate the role such a teacher can play in easing the learning problem. The discussion would define language learning formally, survey classical results and point toward recent advances in the field.

I. INTRODUCTION

Many of us have witnessed a younger sibling (or a niece/nephew) learn to speak and wondered about it. The awesome feat achieved by these infants, namely learning a medium of communication used by adults far more experienced and neurologically developed, has captured the attention of researchers for quite some time now. Even the lay person finds himself devoting a minute or two to this problem at some point. If one ponders on the conditions in which language learning takes place then one easily notices a paradox - the infant is simply exposed to utterances in its mother tongue, utterances that are often ill-formed and spontaneous. Most of these utterances are not even directed at the child (in fact all that the child gets directed at itself are mollycoddles - nonsensical blabbers that caretakers make in order to show their affection toward the infant - which, in the author's view, can only obfuscate things further in the learning process).

Despite being immersed in such a hostile environment, the infant ends up learning the language of its caretakers and

eventually becomes a proficient speaker. In order to understand this problem better let us try to pose it in formal terms. This will involve making certain simplifications which we shall reason for as we go along. We shall strive to keep the exposition simple and shall supplement arguments with schematic diagrams to better convey the key ideas.

II. LANGUAGES AND LEARNING

The first simplification that we will make is that of interpreting a language as a set. To see why, let us take the set of all words present in our favourite English dictionary which would be sufficient to communicate most intentions (of course our favourite IITK lingo would be missing but let us choose to live with this handicap) and call this set Σ Let Σ^n denote the set of all sentences of length n where the words are taken from Σ (we shall use the terms "string", "utterance" and "sentence" interchangeably in this discussion). Let $\Sigma^* = \cup_{i>0} \Sigma^i$ be the set of all sentences of finite length that use words from Σ. Clearly Σ^* contains all English sentences. However, it also contains sentences like *"This celebrating Jubilee is institute our Golden its year."* and *"How it why now where is."* which are not well formed English sentences. Thus we see that the English "language" can be thought of as that subset $E \subset \Sigma^*$ which contains only well formed grammatical English sentences. Of course the debate on whether to consider sentences like *"Colourless green ideas sleep furiously"*, which although grammatically correct, do not make any sense (or do they ?) can be waged here and but the author chooses to invite readers to wage these debates among themselves instead of addressing it here. For the rest of the article, whenever we refer to a language, it will always be a set $L \subset \Sigma^*$.

A language L is said to be **finite** if $|L| < \infty$. For a set S, |S| denotes its cardinality: loosely speaking, the number of elements in S. Clearly English is not a finite language since for every sentence $s \in E$, one can always create another grammatically correct sentence like *"My friend thinks that s."* of length greater than that of s. Thus one can construct sentences of arbitrarily large lengths which make $|E| = \infty$.

Suppose the caretakers speak a language $L_t \subset \Sigma^*$ which the infant must identify or approximate in some sense. What the infant receives is a finite number of utterances $s_1, s_2, \ldots, s_n$ where each $s_i \in L_t$. We will call such a sequence a finite text. This is a reasonable assumption since the infant seldom receives ill-formed utterances which are tagged as ill-formed [7]. Note that we are assuming that the infant knows Σ . This is a simplifying assumption but is not too unreasonable as concept and word learning predate syntax acquisition [8] although these are not distinct stages. The job of the infant is to, given a finite text, identify the **target language** L_t. Suppose the infant has no prior information about the nature or properties of L_t. All it knows is that L_t is some subset of Σ^* which contains all the utterances that it has just heard. In this case the infant is faced with the following dilemma - there are an infinite number of such languages for any given text: which one should the infant identify as the target? We shall return to this question in a short while (in Section 2.B) after building some more notational apparatus to better discuss the problem.

A. Languages and their Grammars

A missing detail in the above discussion is that of representation. Since we have already agreed that English (or for that matter any language that supports recursive embeddings - in particular all human languages) is an infinite set, representation becomes a problem. In other words how does the infant represent the infinite set it has learnt - it certainly cannot store the entire set explicitly. However once we make the key observation that all of us have a representation of English in our minds, and a finite one since our minds are finite objects, we conclude that there must exist ways of finitely representing infinite sets: two commonly used ones in formal linguistics and computer science are automata and grammars. An automaton is like a computer algorithm which can accept input and give output. An automata representing a language is simply an algorithm that answers YES if and only if it is given a string in that language. A grammar, on the other hand, is a set of rules that can be used to generate some strings. A grammar corresponding to a language generates all and only strings in that language. Under the Church-Turing Hypothesis, only recursively enumerable sets admit such finite representations - but we do not have to worry about this technicality - all our languages will be far from raising recursive enumerability questions.

For example, take the following language over binary strings $L_1 = \{0^n1110^m \mid n,m \ 0\}$. This is a Regular Language that can be generated by the following grammar G_1 = 0*1110*. This grammar is called a Regular Expression. This grammar generates strings which consist of some (or possibly no) zeros followed by three ones followed by some (or possibly no) zeros. It is clear that G_1 generates L_1. It is a simple task to write an algorithm that answers YES if and only if given a string in L_1.

Take the following Context-free Language $L_2 = \{0^n1^n \mid n > 0\}$. This is generated by the following Context-free Grammar G_2

S 0S1

S 01

This grammar generates the string 01 and for every string s that can be generated, the grammar also generates 0s1. Thus 01 can be generated which in turn paves way for the generation of 0011, and so on. Again it is clear that G_2 generates L_2. It is easy to write an algorithm to say YES on strings in L_2 and NO to others.

Whether humans use grammars, algorithmic procedures or some other means to represent languages in their minds is a matter of intense study in a very exciting field called Cognitive Linguistics. However for us it is sufficient that the infant have ways to posit a hypothesis (its guess of what L_t is). Given a grammar g hypothesized by the infant, let L_g be the corresponding language. Let us assume that we have a notion of distance between languages that can allow us to judge how closely has the infant learnt L_t. Thus given two languages L_1 and L_2, we need a distance measure d: (L_1, L_2) . Many such distance measures can be considered, a natural

one being a measure that depends on the symmetric difference of the two languages when interpreted as sets i.e. $L_1L_2 = L_1\backslash L_2 \ \ L_2\backslash L_1$. This distance measure would penalize the infant if it learns a grammar that classifies a large portion of L_t as ungrammatical and a large chunk outside of L_t as well-formed (see Figure 1). One can be even stricter and define $d(L_1, L_2) = 0$ if and only if $L_1=L_2$ and 1 otherwise.

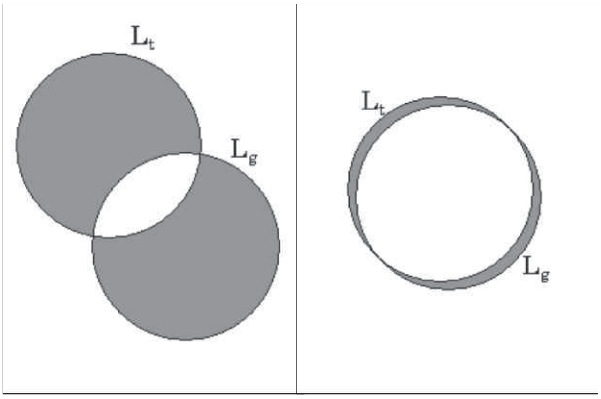


Figure 1: The results of two infants trying to learn English. The one on the left seems to have learnt Swahili instead. The shaded portion in the two figures denotes Lt ΔLg.

A language L_t will be said to have been learnt on a finite text τ (consisting of strings from L_t) as per a distance measure d if the infant (assuming it starts off with an "initial" hypothesis g_0 corresponding to a language L_0) outputs a grammar g_τ, corresponding to the language L_τ on being exposed to τ such that $d(L_\tau, L_t) = 0$. A language that can be learnt on any given finite text (so long as the text contains strings from L_t alone) is said to be learnable. A class of languages L (a class of languages is simply a set of languages) is said to be learnable if each $L \in L$ is learnable (see Figure 2).

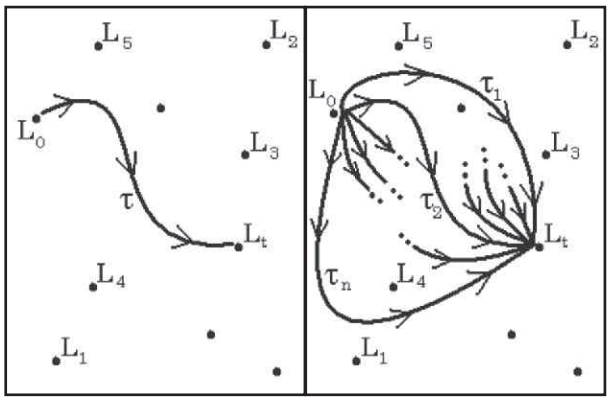


Figure 2: Learnability of Languages: the language L_t on the left is learnable on text τ whereas the one on the right is learnable on any valid text.

B. Language Learnability

Let us formalize the dilemma faced by the infant discussed earlier. The infant is provided with a finite text and has to posit a language as its hypothesis. The problem for the infant is that the target language could be any language that contains the strings it received – and these languages are usually infinite in number. In other words, if the infant were to be given an assurance before learning started that the language it has to learn will only come from a Target Language Class L , then the class in this case is L = POW(Σ*) which in effect gives the infant no prior information about L_t. For any set X, POW(X) denotes the power set containing all subsets of X, including the empty one. Thus the set POW(Σ*) contains all languages. One might wonder how such "assurances" can be given to an infant. It turns out that if one believes in the Universal Grammar Hypothesis [3], then such an assurance is inbuilt in all of us. The hypothesis, very broadly speaking, states that certain universal properties are shared by grammars of all human languages and hence infants only end up learning languages that have these properties.

Coming back to our problem, as observed earlier, the set of languages in POW(Σ*) which contain the finite text received by the infant (this holds for any finite text) is vast (uncountably infinite actually) and these languages are very different from each other according to the distance measures discussed earlier (in fact they would differ widely as per any reasonable distance measure). Hence the infant has no surety of arriving at a grammar that even closely approximates the target language even if it chooses a language that contains all the utterances it has heard. Thus we have the following result:

Theorem 1. The language class L = POW(Σ*) is not learnable with finite texts.

C. Learning with Infinite Resources

Were we expecting too much from the infant in the earlier section? Can we relax the learning conditions a bit and see if learning can take place? In particular can we give the infant more sentences to learn the language? Can we restrict the target language class so as to increase the chances of arriving at the target language? We shall see in the following discussion that even if we present the entire language to the infant (by giving it an infinite number of sentences) and restrict the target class to one step beyond the trivial, learnability continues to elude us.

First of all let us give the infant infinite texts. An infinite text for a language L is an infinite sequence of strings $s_1, s_2,...,s_n,...$ all of which are in L such that every element of L appears at least once in L. By τ_k we shall denote the finite text comprising the first k elements of the text τ.

Let g_k be the infant's hypothesis grammar and L_k, the corresponding language after receiving τ_k for $k > 0$. Then we say that a language L_t is learnt on an infinite text τ as per a distance measure d in the limit if $\lim_{k\to\infty} d(L_k, L_t) = 0$ i.e. if the infant converges to the target in the limit. Similarly we define what it means for a language and a class of languages to be identifiable in the limit (see Figure 3).

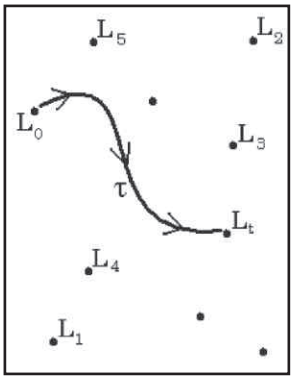


Figure 3: The infant will eventually converge to L_t.

Clearly these conditions are weaker than those in Theorem 1. However in a seminal paper, Gold [5] demonstrated that even under these weakened conditions and increased resources not only the does language class $L = POW(\Sigma^*)$ continue to be non-learnable but the non-learnability persists even the infant is given some prior knowledge about the target language by restricting the target class. We do not give Gold's original proof here but one that follows from results by Blum and Blum [2] in a manner presented in [7].

Theorem 2 (Locking Text Theorem). A language L_t is learnable in the limit only if for every $\varepsilon > 0$ there exists a finite "locking" text τ_ε composed of strings in L_t such that, for the language L learnt after viewing the text τ_ε, $d(L_\tau, L_t) < \varepsilon$ and moreover for all finite texts σ composed of strings in L_t, for the language $L_{\tau\circ\sigma}$ learnt after viewing and in succession $d(L_{\tau\circ\sigma}, L_t) < \varepsilon$. For two sequences σ and ,$\sigma\circ\tau$ denotes the concatenation of the two sequences.

Essentially, the theorem says that in order for a language to be learnable, there must exist finite texts that take the infant close to the target and "lock" it there so that more exposure to the language can only make the infant get closer to its target. Thus, after viewing the locking text, no matter what subsequent utterances it observes, the infant never makes a subsequent hypothesis that is farther off than i.e. no further exposure can mislead it. We shall prove the theorem by contradiction. We shall show that if locking texts do not exist then we can construct an infinite text on which the infant will never converge to the target. Since convergence is necessary on every infinite text for a language to be called learnable, we shall have proved the theorem.

Proof. (Sketch) Now for the actual proof. Notice that if there did not exist locking texts for every $\varepsilon > 0$, it means that there exists some $\delta > 0$ for which there is no corresponding locking text, that is to say no finite text τ taking the infant δ-close to the target is able to lock it there. This implies that for every such text τ that takes the infant close to the target, there must exist a "violator" text. More formally, although $d(L_\tau, L_t) < \delta$, there exists a violator text σ such that after encountering σ, $d(L_{\tau\circ\sigma}, L_t) > \delta$. See Figure 4 for a schematic. Note that if there is no locking text for δ then there are none for any $\delta' < \delta$either.

We can use these violator texts to create an infinite text ζ for which $\lim_{k\to\infty} d(L_{\zeta_k}, L_t) \neq 0$. We do the following: whenever we observe the infant gettingδ-close to the target on a finite text, we feed the infant the violator text corresponding to the text the infant has seen until now to force it to give a hypothesis that is at least ε far off from L_t. Such violator texts will always exist by our assumption of the absence of locking texts.

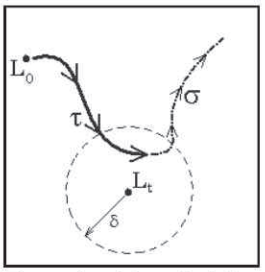


Figure 4: τ brings the infant close but the violator σ spoils the show - i.e. τ cannot be a locking text for δ .

For example if the infant gets δ-close on a finite text τ, feed it the corresponding violator text (say σ) so that $d(L_{\tau\circ\sigma}, L_t) > \delta$. Now it is possible that after listening to some more utterances (in the form of another finite text α), the infant again comes close. This means $d(L_{\tau\circ\sigma\circ\alpha}, L_t) < \delta$. But since we cannot lock ourselves ε-close to Lt, there would exist yet another violator text β such that after looking at β, the infant would yet again move far away from its target i.e. $d(L_{\tau\circ\sigma\circ\alpha\circ\beta}, L_t) > \delta$. See Figure 5 for a schematic.

Thus at each step, we are assured of the existence of violator texts since there are no locking texts. This way the infant would at best constantly oscillate in and out of the δ-neighbourhood of L_t but never converge to L_t.

Thus in order for a language to be learnable (given any text), there must exist finite texts that take the infant arbitrarily close to the target and lock it there. However notice that the existence of such locking texts does not guarantee learnability - it is just that their absence negates any possibility of learning.

This immediately gives us Gold's celebrated result.

Theorem 3. Any language class that contains all finite languages and at least one infinite language is not learnable in the limit with infinite texts.

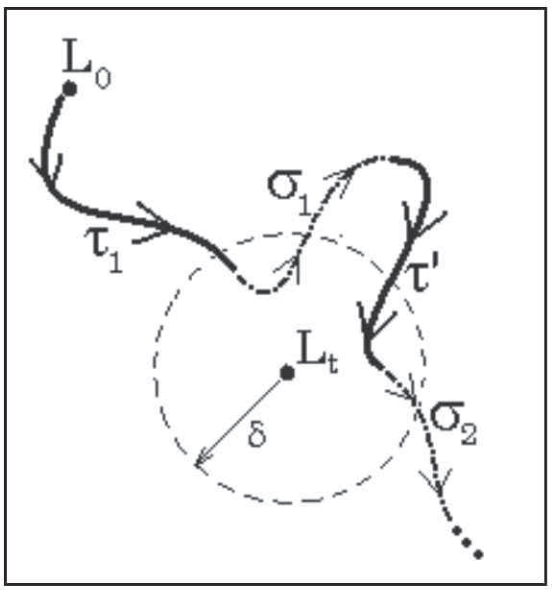


Figure 5: Each time the infant tries to perform well, we can make it perform badly since the infant is not able to lock its good performance

Proof. (Sketch) Consider such a family L and an infinite language $L_\infty \sim\in L$. Suppose (for sake of embarking on a proof by contradiction) that L is learnable. Thus L_∞ is learnable as well – by the previous theorem there must exist finite locking texts for L_∞ for every $\varepsilon > 0$. In particular consider the one corresponding to $\varepsilon = 0.5$ and call it τ. Note that the locking sets themselves are finite languages (a finite language is a just a finite set of strings) and hence are contained in L (since L contains all finite languages). Thus L contains $L(\tau)$, the set of strings in τ.

Now suppose the infant wants to learn $L(\tau)$ (that is to say that $L_t = L(\tau)$) and the infinite text it receives starts with τ itself. Then we have a problem: although the infant wanted to learn $L(\tau)$, it will get locked to L_∞ as is a locking text for L_∞. Thus either L_∞ or $L(\tau)$ is not learnable in the limit and hence *L* is not learnable in the limit as it contains a language that is not learnable in the limit.

A little analysis will tell us that in the above situation, it is actually the infinite language that is the trouble maker since finite languages are trivial to learn using just finite texts. However if infinite languages are a problem then we are in a fix since our English language is an infinite one and is believed to be a part of a language class called Context-Free Languages (or according to some experts Context-Sensitive Languages) which unfortunately contains all finite languages and also contains English, an infinite language.

The same holds true for the class of Regular Languages which is arguably the simplest possible non-trivial (read interesting) class of languages. Hence we have the following result that dashes all hopes of learnability for interesting language classes.

Theorem 4. The classes of Regular and Context-Free languages are not learnable in the limit.

D. Approximately Learning Languages

For those who consider this to be as bad as things can get, the author apologizes for providing yet another set of relaxations which fail to make these language classes learnable. Even if one only expects the infant to learn some nice approximation to the target language instead of learning it exactly, learnability continues to elude us. An approximation to a language is a language that is "close" to the language according to the distance measure d fixed earlier. Even if one relaxes things further and allows the infant to output a completely wrong hypothesis with some small probability (i.e. only expect it to output a nice approximation with high probability), learnability still remains unattainable. Some of these basic results can be found in [6]. However this is a much more difficult result to prove and we do not attempt to even state the result formally, let alone prove it.

Informally what these results show is that the Regular and Context-free language classes are too complex in the sense that their VC-dimension (see [6] for a definition) is infinite and this renders these classes non learnable in the Probably Approximately Correct model of learning which is a model that only expects the learner to output an approximately correct answer with high probability.

III. ENTER THE TEACHER

It turns out all that we need to get rid of the non-learnability results given in the previous section is the presence of a teacher! A teacher, who can provide answers to certain special types of queries made by the learner, can facilitate learning to the extent that it can take place not only in a finite number of steps but actually in a fairly small number of steps.

These results were presented in the seminal papers of [1][9] that proved that the classes of Regular and Context-free languages respectively are learnable with the help of teachers capable of answering two types of queries :

1. Membership Queries: The learner gives the teacher a string s and asks whether $s \in L_t$ or not. The teacher replies back with a YES/NO.

2. Equivalence Queries: The learner gives the teacher its current hypothesis grammar g and asks whether $L_g = L_t$ or not. The teacher either answers YES or gives a counterexample string $s \in L_t \Delta L_g$.

In order to learn context-free grammars some additional input is required but the presence of the teacher is indispensable in all these results. These results outline learning algorithms which when presented with the problem of learning a target language L_t that is guaranteed to be wither a regular or a context-free language (which is the prior information about the target language class) start asking questions to the teacher. The algorithms process the replies given by the teacher and formulate hypotheses and new questions to ask. If on an equivalence query, the teacher replies back with a YES, then the algorithms halt. It turns out that if the target language L_t can be encoded by the grammar g_t, then these algorithms do not take more than $|g_t|^3$ steps to learn the language. ($|g|$ denotes how much space it takes to write down the rules of the grammar).

These results, although stimulating, are fairly involved and well beyond the scope of this article. However we do realize the importance of teachers in learning situations such as these (and also in our real lives). Since these results came up, researchers have improved upon them and made them more amenable to practical application. For example we now have genetic algorithms [10], greedy algorithms [12][11] and kernel based algorithms [4] for grammatical inference for various classes of languages. The reader can refer to the article "An Introduction to Support Vector Machines and their Applications", NERD, 3(1):2-6, 2010 for an introduction to kernel based algorithms.

There has also been a lot of research on child language development and although very far from having the final word on child language acquisition, we now have a better idea of how human infants form word-concept correlations and acquire syntax. However this topic merits a dedicated article and we conclude this one with a vote of thanks to all our teachers for making the learning process fun and simple.

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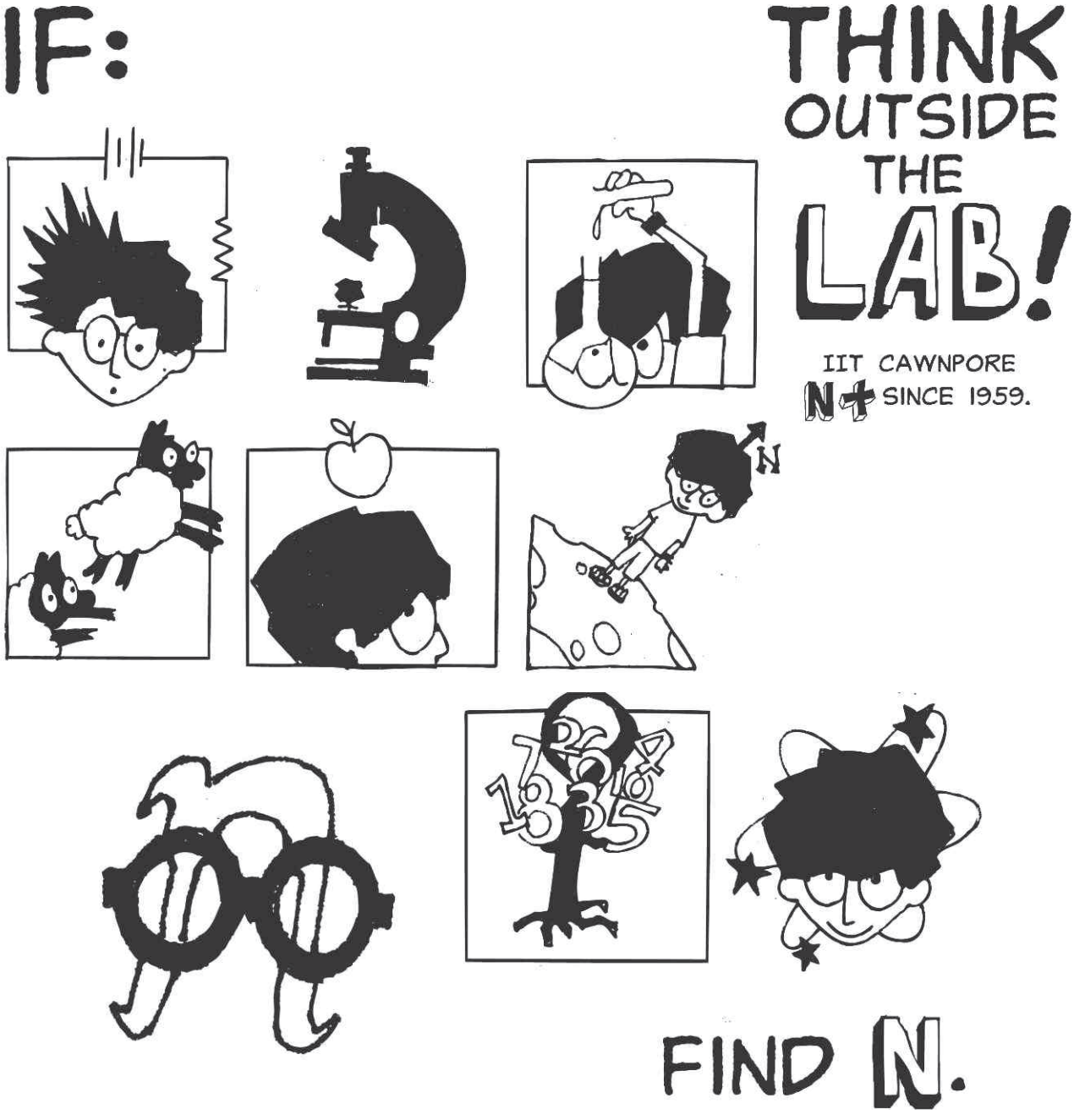

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