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NOBEL PRIZES IN SCIENCE : 2019

CHEMISTRY

The Nobel Prize in Chemistry for 2019 has been awarded jointly to John B. Goodenough (born in 1922 in Jena, Germany) of the University of Texas at Austin, USA, M. Stanley Whittingham (b. 1941 in Nottingham, U.K.) of the Binghamton University, State University of New York, USA and Akira Yoshino (b. 1948 in Suita, Japan) of Meijo University, Nagoya, Japan 'for the development of lithium-ion batteries'. The prize money of 9 million Swedish krona was shared equally between the three Laureates. The powerful. lightweight and rechargeable (hundreds of times) lithium-ion battery (LIB) is at the heart of portable electronics like smart phones, laptops, i-Pads, electric vehicles and storage of renewable energy like solar energy and wind power energy. The LIBs entered the market in 1991 and have changed our lives ever since. The Nobel Press release aptly commented that the discoverers of the LIBs "*have laid the foundation of a wireless, fossil fuel-free society, and are of the greatest benefit to humankind.*"

M. S. Whittingham

In the mid-20th century, the alarming increase in atmospheric pollution by the ever increasing number of petrol-driven vehicles and the fast depletion of liquid fossil fuel (i.e. petrol) highlighted the need to develop electric vehicles and find out alternative sources of energy. Powerful batteries were needed to fulfill both these objectives. But the then extant heavy lead battery and nickel-cadmium battery were not suitable for the purpose.

At this stage, the oil giant Exxon recruited Whittingham from the Stanford University to develop light but more energy-rich batteries. Whittingham found out that 'intercalation' (i.e. the attachment of charged ions within the atom-sized spaces of solid materials) of potassium ions within tantalum disulphide solid resulted in a surprisingly energy-rich (2 Volts) material, considerably more powerful than the then existing batteries. He subsequently replaced heavy tantalum by titanium, a much lighter element. Since the objective of Exxon was to develop a galvanic (i.e. voltaic) cell where electrons freely flow from the negative electrode (anode) to the positive electrode (cathode), titanium was finally replaced by lithium, the lightest solid element on earth, which is known for its remarkable potential to release its lone outer electron. Whittingham was thus able to develop a light and energy-efficient lithium battery that worked at room temperature.

J. B. Goodenough

Unfortunately, when the lithium battery was repeatedly charged at room temperature, thin whiskers of lithium grew from the lithium electrode, which ultimately led to explosion of the bettery. Aluminium was then added to the lithium bettery in 1976. Exxon started small scale production of these batteries, but in the wake of falling of oil price across the globe, Exxon backed out from its production in 1980.

Akira Yoshino

Goodenough, then a Professor of Inorganic Chemistry at Oxford University, U. K., took up the challenge and found out that replacing pure lithium by lithium-cobalt oxide in the cathode led to a two-fold improvement. The resulting battery was almost twice as powerful, viz. 4 Volts and the battery did not have to be manufactured in the charged state (in contrast to the case of Whittingham's battery) and could be charged afterwards.

Yoshino, then at Asahi Kasei Corporation, Japan took up the final challenge. He used (Whittingham's) lithium-cobalt oxide as the cathode but cheap and commercially available petroleum coke as the anode. When the coke was charged with electrons, lithium ions (LI^+) were drawn into the coke, and when the battery was turned on, electrons and Li^+ ions flew towards cobalt oxide in the cathode. It resulted in a lightweight battery of high voltage (4 Volts). In 1986, Yoshino put the newly developed battery to safety test, and it was found to be absolutely safe. Thus the commercially viable LIBs were born. The first series of electronic equipment using LIBs were released in the market in 1991 by a Japanese company.

Pertinently, two post-Nobel advances have been made for the LIBs. Firstly, researchers from the Johns Hopkins Advanced Physics Laboratory, USA have developed a new class of gel polymer electrolytes, which has rendered the LIBs incombustible – a breakthrough in safety. Secondly, researchers from Penn State University, USA have modified commercial LIBs in such a way that if such a LIB is heated to 60ºC, it can be charged up to 80% in just 10 minutes to enable electric cars to undertake long road without recharging. A 5-minute charge-up is in the offing. ❐

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PHYSICS

Our understanding of the origin and evolution of the universe has undergone many changes in the past 100 years since the Belgian astronomer Georges Lemaître proposed what became known as the Big Bang theory. Cosmic background radiation was discovered in 1965 and turned out to be a gold mine for our understanding of how the universe developed from its early childhood to its present day. On another scale, a major discovery of an Earth-like planet orbiting a sun-type star outside our solar system was made in 1995. Together these discoveries led to a new understanding of our place in the universe.

James Peebles

The 2019 Nobel Prize in Physics has been awarded to three scientists "for contribution to our understanding of the evolution of the universe and Earth's place in the cosmos". James Peebles of Princeton University, USA, receives the prize "for theoretical discoveries in physical cosmology" while Michel Mayor of the University of Geneva, Switzerland and Didier Queloz, of the University of Geneva and Cambridge University, UK, have been awarded "for the discovery of an exoplanet orbiting a solartype star".

The Big Bang model describes the universe from its very first moments, almost 14 billion years ago, when it was extremely hot and dense. Since then, the universe has been expanding, becoming larger and colder. Barely 400,000 years after the Big Bang, the universe became transparent and light rays were able to travel through space. Using his theoretical tools and calculations, James Peebles was able to interpret these traces from the infancy of the universe and discover new physical processes.

Didier Queloz

Michel Mayor

The results showed us a universe in which just five per cent of its content is known, the matter which constitutes stars, planets, trees – and us. The rest, 95 per cent, is unknown dark matter and dark energy – that still remain a mystery and a challenge to modern physics. Peebles' insights into physical cosmology have enriched the entire field of research and laid a foundation for the transformation of cosmology over the last fifty years, from speculation to science. His theoretical framework, developed since the mid-1960s, is the basis of our contemporary ideas about the universe.

In October 1995, Michel Mayor and Didier Queloz announced the first discovery of a planet outside our solar system, an exoplanet, orbiting a sun-type star in our home galaxy, the Milky Way. Before this finding, the only confirmed exoplanet known orbited a pulsar – a dense remnant from a supernova explosion. Using custommade instruments at the Haute-Provence Observatory in southern France, they were able to see planet 51 Pegasi b, a gaseous ball comparable with the solar system's biggest gas giant, Jupiter. Mayor and Queloz carefully measured a star's velocity using Doppler shift and found that it wobbles back and forth in a tell-tale pattern produced by the gravitational pull of an orbiting planet. This discovery started a revolution in astronomy and over 4,000 exoplanets have since been found in the Milky Way.

This year's laureates have transformed our ideas about the cosmos. While James Peebles' theoretical discoveries contributed to our understanding of how the universe evolved after the Big Bang, Michel Mayor and Didier Queloz explored our cosmic neighbourhoods on the hunt for unknown planets. Their discoveries have forever changed our conceptions of the world and strange new worlds are still being discovered, with an incredible wealth of sizes, forms and orbits.. ❐

Biman Basu

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PHYSIOLOGY OR MEDICINE

When we talk of life on Earth, we know how important oxygen is to our survival. Animals and humans need oxygen to convert food into useful energy. The fundamental question of how cells sense oxygen has implications for several biological processes including development of embryo, cancer, stroke, diabetes, and other ischemic diseases. No wonder, this is an important scientific mystery that researchers have been trying to crack for many years. Yet, despite the publication of hundreds of papers on this subject, till recently there was no clear consensus regarding what the cellular oxygen sensor is, or even the number of sensing mechanisms there might be. Now scientists seem to have solved the mystery.

William Kaelin

The Nobel Prize in Physiology or Medicine for 2019 has been awarded to three scientists – cancer researcher William Kaelin of the Dana-Farber Cancer Institute and Harvard Medical School, Boston, Massachusetts, USA; physician-scientist Peter Ratcliffe of the University of Oxford and the Francis Crick Institute, London, England; and geneticist Gregg Semenza of the Johns Hopkins University School of Medicine, Baltimore, Maryland, USA, “for their discoveries of how cells sense and adapt to oxygen availability”.

The body’s tissues can be deprived of oxygen during exercise or when blood flow is interrupted, such as during a stroke. Cells’ ability to sense oxygen is also crucial for the proper growth of a developing foetus and placenta, and also in tumour growth, because the mass of rapidly growing cells can deplete oxygen in the interior of a tumour.

During researches carried out in the 1990s, the three scientists, working independently, revealed the chain of molecular events that allow cells to detect and respond to different levels of oxygen. They had discovered the molecular processes that cells go through to respond to oxygen levels in the body. They found that central to this is a mechanism involving a protein complex called hypoxia-inducible factor (HIF) and a gene called VHL.

The work of the three scientists has helped researchers to understand how the body detects and adapts to low oxygen levels by, for example, making more red blood cells and growing new blood vessels. Their work has established the basis for our understanding of how oxygen levels affect cellular metabolism and physiological function. Their discoveries have also paved the way for promising new strategies to fight anaemia, cancer and many other diseases.

Gregg Semenza

The work of Semenza and Ratcliffe concerned study of the regulation of a hormone called erythropoietin, which is crucial for stimulating the production of red blood cells in response to low levels of oxygen. Semenza and his team identified a pair of genes that encode the two proteins that form HIF and work together to turn on certain genes and boost erythropoietin production when oxygen is low.

Meanwhile, Kaelin’s work showed that the VHL gene may also be involved in how cells respond to oxygen, after studying a genetic syndrome called von Hippel-Lindau’s disease. This genetic disease leads to dramatically increased risk of certain cancers in families with inherited VHL mutations.

Peter Ratcliffe

Thanks to the ground-breaking work of the three Nobel Laureates, we know much more about how different oxygen levels regulate fundamental physiological processes. Oxygen sensing allows cells to adapt their metabolism to low oxygen levels: for example, in our muscles during intense exercise. Other examples of adaptive processes controlled by oxygen sensing include the generation of new blood vessels and the production of additional red blood cells. Our immune system and many other physiological functions are also fine-tuned by the oxygen-sensing machinery. Oxygen sensing has also been shown to be essential during foetal development for controlling normal blood vessel formation and placenta development.

The work has led researchers to develop drugs that target oxygen-sensing processes, including drugs for cancer. Drugs that prevent VHL from binding to HIF and causing its degradation are also being investigated as treatments for anaemia and renal failure. Chinese regulators approved the first of these drugs in 2018. ❐

Biman Basu

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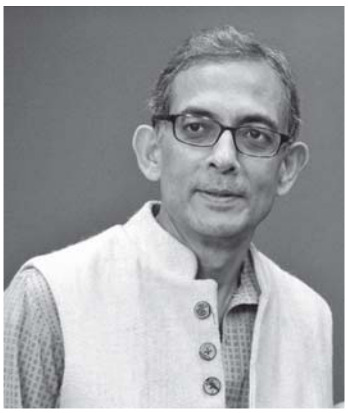
ECONOMICS

This year's (2019) Nobel Prize in Economics was awarded to Abhijit Banerjee (MIT), Esther Duflo (MIT) and Michael Kremer (Harvard University)"for their experimental approach to alleviating global poverty." The choice of the winners' works led to huge amount of discussions in the global economics community. Some years' Nobel prizes were less contentious. This year was not one of them. The main contribution of Banerjee et al. was no less than a revolution in how economists thought about the whole field of development economics. The standard toolkit in applied microeconomics and development economics was much more theory-dependent and was deductive in its core. If a theory does not work in terms of matching data which was notorious in social science for lack of reliability, then economists would simply move on to a new theory. It has now changed due to two major factors. One, credible data started being gathered at an unprecedented rate, leading to data-intensive analysis. Two, economists started experimenting directly in real-life economic scenarios, testing predictions of theoretical models and often going beyond that, testing whether common-sensical policy interventions actually work or not (hint: often they don't; economics is more complex than navel-gazing[1]).



Abhijit Banerjee

None of the winners were initially doing experimental work at the beginning of their careers. In the beginning of 90s, Kremer produced his now famous O-ring theory of economic development (the theory was named after the infamous Challenger shuttle disaster in 1986) along with other influential works on economic growth and technological change. Like many other economists, Abhijit Banerjee's one of the most important works was in theoretical economics, in which he explained why seemingly rational people might simply follow a crowd ignoring their own information, resulting the society collectively getting into an inefficient equilibrium. While these theoretical ideas were popping up, econometricians (econometrics can be roughly summarized as statistical analysis for observational non-experimental and typically small-sized data) just began to go beyond correlation/association and start looking into *causality*. Causality in social science is more complex than it sounds. For example, suppose a school runs an interest survey among its final year students to elicit responses on whether they would like to take up special training for the final exam. Suppose a group of students express their interests and get admitted to a camp for special training and let's assume that eventually they indeed did better on average than the students who did not go for the training. Can we directly attribute the difference in grades between these two groups of students (those who went for the camp and those who did not) to the effect of the training? The answer is a resounding no. The reason is that it is quite possible that only those students expressed interests who were more interested in doing good to begin with and therefore would exert more effort either way. Even in absence of the training camp, probably they would have done better. Technically, such a sample suffers from *selection bias* and the *treatment* is not *randomly assigned*.

Esther Duflo

The randomistsas (as now the whole group of people who engage in deliberate intervention to tease out causal effects) took this point very seriously, and Banerjee, Duflo and Kremer became the face of the so-called RCTs or *Randomized Controlled Trials* which aims to randomly assign treatments (in the form of interventions like giving lentils and metal plates for vaccination vs. no treatment in the *control group*)[2] to estimate causal effects of interventions in a credible and statistically robust way. As a toolkit it is not very new and had been in use for quite some time in medicine. Banerjee et al. brought it at the core of economics and essentially

Michael Kremer

made it the mainstream approach almost simultaneously dethroning other approaches. The tool was very appealing and while the execution is very costly (since one needs to intervene at a region-level with multi-period observations; often these are multi-country studies[3]), the main message can be very easily conveyed to policy-makers. So it gained a lot of tractions worldwide due to its intuitive simplicity and appeal. Thus the Nobel committee noted *'…it involves dividing this issue into smaller, more manageable, questions – for example, the most effective interventions for improving educational outcomes or child health. They have shown that these smaller, more precise, questions are often best answered via carefully designed experiments among the people who are most affected.'*[4]

In the end, we note that like all other methods, RCTs have their own pitfalls and shortcomings which we do not discuss here as we can do justice to the nuances due to lack of space. However, it definitely changed the way development economics is done, the way causality is discussed in economics and social sciences in general and also, how seemingly obvious policies can be dead-wrong. It is noteworthy that Esther Duflo became the youngest Nobel-prize winner in economics and the second female laureate, creating a role model for female economists as was long wanted. Finally, on a personal note, the author of this article was taught by Abhijit Banerjee's father Prof. Dipak Banerjee in Presidency College, Kolkata (now university). DB sir (as we used to call him) is no more, but I am sure he would have been proud as another feather was added to the proverbial hat of Presidency College. An open-ended question one might wonder about is how come such a small economics department produce so many top-rated economists with multiple Nobel-laureates (Abhijit and Amartya Sen). The answer might shed a lot of light on innovations in developing countries, knowledge transmission via social networks and migration of skilled workers, all burning questions of the present day. ❐

[1]https://www.jstor.org/stable/23644707?seq=1#metadata_info_tab_contents

[2]https://www.bmj.com/content/340/bmj.c2220

[3]https://science.sciencemag.org/content/348/6236/1260799

[4]https://www.nobelprize.org/prizes/economic-sciences/2019/press-release/

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