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REPORT

NOBEL PRIZES IN SCIENCE : 2020

CHEMISTRY

The Royal Swedish Academy of Sciences have announced on 7th October the award of Nobel Prize in Chemistry for 2020 to two women scientists – Emmanuelle Charpentier of Max Planck Unit for the Science of Pathogens, Berlin, Germany and Jennifer A. Doudna of the University of California, Berkeley, USA "*for the development of a method for gene editing*." The Prize money of 10 million Swedish krona, i.e. US $ 1,110,400 will be shared equally between the two Laureates.

Emmanuelle Charpentier

The scientists have discovered the CRISPR/Cas9 genetic scissors, a very useful tool of the gene technology. CRISPR is an acronym for *c*lustered *r*egularly *i*nterspaced *s*hort *p*alindromic *r*epeats and Cas is an abbreviation for *C*RISPR-*as*sociated. Using these scissors, one can change the DNA of plants, animals and microorganisms quickly and precisely at desired sites. The Chairman of the Nobel Committee for Chemistry said, "*there is enormous power in this genetic tool, which affects us all. It has not only revolutionised basic science, but also resulted in innovative crops and will lead to ground-breaking new medical treatments.*"

Emmanuelle Charpentier was born on 11th December, 1968 in Juvisy-sur-Orge, France. She did her Ph.D. in 1995 from Institut Pasteur, Paris, France and subsequently worked at several scientific institutes in France, USA, Austria, Sweden and Germany. She is at present the Director of the Max Planck Unit for the Science of Pathogens, Berlin, Germany. Jennifer Anne Doudna was born on 19th February, 1964 in Washington, D.C, USA, but she spent much of her childhood in Hilo, Hawaii. She obtained her Ph.D. degree in 1989 from Harvard Medical School, Boston, USA. She is now a Professor at the University of California, Berkeley, USA and also an Investigator at Howard Hughes Medical Institute, Chevy Chase, Maryland, USA.

The discovery of the genetic scissors has its origin in 2006 when Charpentier started investigating the repeated DNA sequences, called CRISPR, present in microorganisms as a part of their natural, antiviral immune system. In 2011, she found out that *Streptococcus pyogenes* bacteria, which cause enormous harm to human beings, are remarkably antiviral and possess a hitherto unknown type of small *tr*ans-*a*ctivating *CR*ISPR RNA (tracrRNA) molecules that disarm viruses by cleaving their DNA. These molecules constitute a part of the defence, i.e. immune system of these bacteria by transforming the long RNA stands, made from the CRISPR DNA sequence, into their active, virus-targeting form. She published her work in the same year. In the meantime, Doudna from the University of California, Berkeley, USA had identified Cas genes that encode for proteins able to unwind and cut DNA of a virus trying to enter the cell.

Jennifer A. Doudna

In 2011, Charpentier was introduced to Doudna by a colleague of the latter in a café at San Juan, Puerto Rico where both of them were attending a conference. On the following day, when they were strolling in the streets of the capital city, Charpentier proposed to Doudna a collaboration. They joined hands, and together they recreated the genetic scissors of the bacterium in the lab, simplified the molecular components of the scissors and rendered them easier to use. To be precise, Doudna and Charpentier showed that a combination of CRISPR-RNA, tracrRNA and the Cas9 protein can cut up viral DNA. They combined CRISPR-RNA and tracrRNA into a single molecule, called guide RNA. Combined with Cas9, they could now cut a target DNA sequence provided the Crispr part of the guide RNA matches with the code where a cut is desired.

They published their work in the following seminal paper: M. Jinek, K. Chylinski, I. Fonfara, M. Hauer, J.A. Doudna and E. Charpentier, 'A Programmable Dual-RNA-Guided DNA Endonuclease in Adaptive Bacterial Immunity,' *Science*, **337** (6096), 816-821 (2012); DOI: 10.1126/science.1225829.

The development of CRISPR/Cas9 has been successfully applied in basic research, in the development of crops that withstand mould, pests and drought. In medicine, clinical trials to treat cancer, sickle cell disease, beta-thalassemia and inherited blindness are underway. Also, CRISPR-based diagnostic tests for COVID-19 and its therapies are being developed. This tool has so far been used to edit genes in dogs, mice, butterflies, cows, pigs, snails and mosquitoes.

When interviewed, both Charpentier and Doudna opined that this recognition (Nobel Prize) of their work would send a message to women scientists that their research too can be recognized and have an impact on the society. They further hoped that, this award would inspire particularly young girls to pursue science as their career.

This year's Nobel Prize award in Chemistry is considered controversial for two reasons. Firstly, there are pioneers in the discovery, applications and modifications of CRISPR. They are Francisco Mojica of the University of Alicante, Spain (who first identified and named CRISPR in 1993 and hypothesised in 2005 that these sequences were part of microbial immune system), Virginijus Šikšnys, a biochemist at Vilnius University in Lithuania (who showed in 2012 how the Cas9 enzyme could cut DNA sequences at predetermined sites) and Feng Zhang at the Broad Institute of MIT and Harvard in Cambridge, Massachusetts (who modified the CRISPR–Cas9 system to make precise genome cuts in human and mouse cells; *Science*, 2013). The omission of Zhang's name from the list of awardees of Nobel Prize is allegedly the biggest surprise. Secondly, CRISPR technology was involved in a fierce patent battle. Doudna and Charpentier filed a patent application in 2012. Seven months later it was followed by a separate patent application by Feng Zhang. Both patents were awarded. A subsequent attempt by UC, Berkely to get Zhang's patent rescinded failed.

The use of CRISPR/Cas9 scissors requires ethical surveillance. A case in point is the example of the Chinese scientist, He Jiankui who was last year jailed for three years for his creating world's first gene-edited human babies by violating a government ban on carrying out experiments on human embryos. He, however, claimed to have undertaken the experiment only to give the babies protection against HIV.

Pertinently, both Charpentier and Doudna were named as Citation Laureates^{TM} in 2015 by Clarivate plc. ❐

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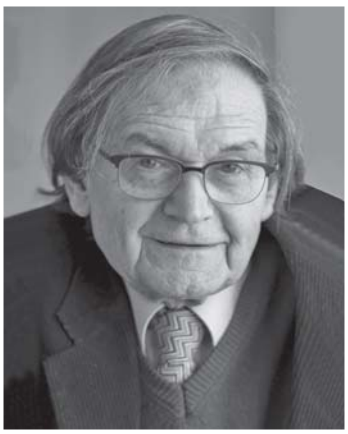
PHYSICS

The physics Nobel Prize in 2020 was awarded for an extraordinary achievement that resolved a fundamental problem. The Nobel citation noted Roger Penrose's contribution in showing blackhole formation to be " a robust prediction of the general theory of relativity". For Andrea Ghez and Reinhard Genzel, the citation commended their "discovery of a super-massive compact object at the centre of our galaxy."

These discoveries are related to the existence of objects with extremely high mass and densities, so much so that neither matter nor electromagnetic radiations can come out of them. This was conjectured by John Mitchell and Pierre-Simon Laplace in the late 18th and 19th century, on the basis of the idea that gravitational pull in dense, massive objects could be so high that the escape velocity would exceed the speed of light. These ideas were derived from Newtonian mechanics. But twentieth century physics showed that these Newtonian would breakdown at regions of high gravitational field and the corresponding physics should be decided in terms of the General Theory of Relativity (GTR), i.e. in terms of distortions of space-time curvature in presence of high gravitational fields.



Roger Penrose

According to the GTR, gravitational field at any point distorts the space time structure in such a way that length shrinks by a factor γ and time interval gets lengthened by a factor 1/γ. This factor γ becomes smaller if the gravitational field increases. Thus, if there be a point where gravitational potential is large enough to make γ = 0, and (1/γ) as infinite, then at such a point time intervals will be lengthened to infinity and lengths would be squeezed to zero! Thus sizes of all objects would shrink to a point; and any event that takes place in a certain time interval would not be seen to occur, as time becomes timeless! This is what gives a singularity.

Andrea M. Ghez

Reinhard Genzel

Soon after the publication of Einstein's pioneering paper, Karl Schwarzschild in 1916 showed that such a situation would arise, at a point located at a distance $r_0 = (2GM/c^2)$ from the centre of an object of mass M. This distance r_0 is called the "Schwarzschild radius". If we plug in the relevant numbers for the sun and the earth, their Schwarzschild radii, would be 3.0 kms and 9 mms respectively. Of course, the Sun and Earth are much larger than their respective Schwarzschild radii, but the question was: can such objects exist?

The answer was not very clear. Many believed (presumably Einstein too) that such catastrophic events cannot happen and nature intervenes to arrest them. It may be said that a section of the physics community also shied away from addressing this problem. But developments in other areas brought this question back, in the 1930's. As we know, stars are massive objects, e.g. the sun has a mass of 1.91×10^{30} kilograms. Since gravitation is always attractive, matter in all stars should be pulled inwards, by the star's own gravity. The question of stability of stars against their self gravity became an important topic in astrophysics in the 1930's, which saw notable contributions from S. Chandrasekhar, Walter Baade, Fritz Zwicky and Lev Landau. Their works put mass limits for stability of stars against gravitational collapse. For white dwarfs, the stability limit is 1.4 solar mass, so that pressure due to dense relativistic electron gas can stabilize against gravitational collapse due to the star's own gravitational pull. But if the end state of the star be heavier than the above Chandrasekhar limit, it is the internal pressure due to neutrons and protons that can arrest the collapse and stabilise the star to a neutron star. Their typical densities are as follows. A typical white dwarf has a density similar to what we would get if the sun be squeezed to the size of the earth and a neutron star's density would be like that of the sun when it is shrunk to a diameter of 15-20 kms.

But what if the star be heavier? In 1939, J. Robert Oppenheimer and Hartland Snyder, addressed the above problem for massive stars, incorporating GTR. This was the correct step since such stars would have strong gravitational fields due to their own mass. Oppenheimer and Snyder showed that for very massive objects, under GTR, gravitational collapse is inevitable.

That was a shocking news. Many believed that rotation and shear (i.e. matter having different flow velocities at different points) could arrest the collapse. The question was opened in 1955 in a pioneering paper by Amal Kumar Raychoudhuri that gave the conditions under which such collapsing events can be reached in a finite time. Thus, while others tried to push the question under the carpet, Raychoudhuri and later Arthur Komar faced it head-on, in the 1950s. This formed the basis of many a future work. The most decisive result was arrived at by Roger Penrose, in 1965, by invoking ideas of geometry in GTR. Penrose's approach was radical and showed that for massive objects collapse to a black-hole is inevitable and cannot be arrested by other physical processes and the conditions were stipulated. It was shown rigorously that such a result was not inconsistent with GTR but was a result of it. Later works by Roger Penrose and Stephen Hawking raised many issues related to space time and gravitation but that would take us away from the issue of reporting on this year's Nobel Prize.

Looking back, 1950's had seen a surge in radio astronomy. This happened because knowledge about radars was declassified after the World War II, and radio-telescopes were built at different sites by different groups. Observations demanded that some theoretical issues of GTR be revisited. Roger Penrose's work was extremely topical for the time, as they came close to the heels of the discovery of quasars. Quasars were discovered as extremely luminous radio sources, located at distances far outside our galaxy, the nearest one being 2.5 billion light years away from us. Subsequently, quasar were mapped in the entire electromagnetic spectrum and were found to lie in different parts of the sky. To the question, as to how quasars could generate such enormous energy, Donald Lynden-Bell proposed, in 1969, that they have super-massive black holes at their centre with several million solar masses of matter in them. Quasar emissions result from the in-fall of matter into the black hole, releasing the gravitational energy as radiation. Lynden-Bell had prophetically said, "We would be wrong to conclude that such objects in space-time should be unobservable."

Since quasars (and thus their own central black-holes) are found to be "hosted" at the centres of different galaxies (called active galactic nuclei or AGN) it was further suggested, "If that be so, one must also look for a super-massive black-hole at the centre of our own Milky Way Galaxy."

Such searches were continued by Reinhard Genzel and Andrea Ghez, for about last thirty years. The present author recalls having met Professor Ghez in a workshop in Carge'se, in 1988. She was then a young Ph.D. scholar and had come with a paper in which she presented the measurement of the size of the orbits of some binaries. The same ideas would be later used conclusively by her group and Reinhard Genzel's, to determine the sizes of the orbits of different stars in the Sagittarius A* region that go around our galactic centre. This evidence would be used as a signature whether they are orbiting around a super-massive black hole.

Certainly, dynamics of these stars in presence of the gravitational field of a super-massive black hole, must follow the equations of general theory of relativity. Due to their rapid revolution, the star's orbital period could be as low as a few years! Exciting thing was that its orbit could thus be tracked in one's own life time, while the sun takes 200 million years to go round the galactic centre! For stars in the region of Sagittarius A*, the period was estimated to be about 16 years. But the diameter of their orbit would be d = 17 light hours, at a point that is L = 26,000 light years away - that being the distance between the Earth and our galactic centre! The challenge, as explained by Reinhard Genzel was this: it is like trying to resolve from the earth, the details in a few cms on the surface of the moon! One had to use telescopes of high light gathering capacity, since the intensity of the starlight would be too feeble as it has to pass through 26,000 light-years distance though layers and layers of absorbing material like dust in the galaxy. Thus, Andrea Ghez and her team used the Keck Telescope in Hawaii, which has an aperture diameter of 10 metres and Reinhard Genzel's group used the 8 metre aperture telescopes at the European Southern Observatory (ESO), in Chile. Concerning the technological challenges, Reinhard Genzel said, over these thirty years they had to improve the resolvability and sensitivity of the instruments by several thousands to a few millions.

Technological challenges were many. For observations being made in the infra red, sensitive infra red detectors were the first requirement. Also, instead of using a single telescope, light from multiple telescopes (e.g. four such 8 metre class telescopes at the ESO) were combined in a multi-telescope interferometer. This way, the resolving power was improved. But one problem remained, that was the one of atmospheric “seeing” caused by atmospheric turbulence. For example, this turbulence causes the twinkling of stars. As starlight simmers, a long exposure would wash out all the details that one wants to get. This problem was tackled in two steps. Firstly, very short exposure (1-10 milliseconds) images were taken i.e. within the time in which the atmosphere does not change. In addition, a wave front correction method called “Adaptive Optics” was adopted.

Shorn of technical details, we briefly describe the principle of adaptive optics for the reader to appreciate its novelty and challenges. It consists of two steps, (1) wave front sensing and (2) wave front correction. In the first step, “atmospheric seeing” is monitored by creating an artificial star. This is done by shooting laser light of 548.2 nanometer wavelength into the atmosphere, from the telescope. This light is absorbed by the sodium atoms in the mesosphere, at a height of 90 kms. These sodium atoms would subsequently re-emit the light on de-excitation. This last process produces glowing point objects in the mesosphere that are like stars. Light from these artificial stars are now recorded at the telescope. The blurring effects in these image show the wave front distortions due to the “seeing” problem, which are thus monitored. This is wave front sensing. For wave front correction, this information is now fed to deform a flexible mirror that is placed just above the focal plane of the telescope. Several piezoelectric activators (essentially, tiny pistons) drive the multi-segmented mirror in such a way that the final image, from the object of interest, is made stable, being corrected for atmospheric disturbances.

The signal being thus “cleaned” of noise, observations could conclusively prove the existence of a superheavy black hole at the galactic centre with mass that is 4 million times the solar mass. The work of the Nobel Prize awardees has opened a new window for us for looking at the universe. Winning the Nobel Prize is certainly a landmark for the awardees but their work would perhaps bring science to a crossroad from where many a possibility would arise. Further, their achievements would act as motivation for many an aspiring scientist. Professor Andrea Ghez has thus stated, this prize would make her “more passionate about the teaching side of the job…” enhancing “people’s ability to question and their ability to think, which is crucial to the future of the world” : a noble message that would enthuse many. ❐

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PHYSIOLOGY OR MEDICINE

This year's Nobel Prize in Physiology or Medicine was awarded to Harvey J. Alter, Michael Houghton and Charles M. Rice for their discovery of the Hepatitis C virus. The Nobel Committee announcement said the Prize had been given to "three scientists who have made a decisive contribution to the fight against blood-borne Hepatitis, a major global health problem that causes cirrhosis and liver cancer in people around the world."

Harvey J. Alter

Hepatitis or liver inflammation, an amalgamation of Greek words for "liver" and "inflammation" is caused mainly by viral populations. It is no wonder that the first description of hepatitis dates back to approximately 400 BCE by the Greek physician Hippocrates. He noted the unique course of the disease called "*epidemic jaundice*" and wrote: "*The bile contained in the liver is full of phlegm and blood and erupts. After such an eruption, the patient soon raves, becomes angry, talks nonsense and barks like a dog"*

A leading investigator at the National Institutes of Health (NIH) USA, Baruch Blumberg determined that a blood-borne hepatitis was caused by a virus called Hepatitis B virus and 1976 Nobel Prize in Physiology or Medicine was awarded to him.

There are different types of hepatitis with different causes:

1. Hepatitis viruses A, B, C, D, and E cause viral hepatitis.
2. Toxic hepatitis occurs through certain poisons, chemicals, medicines, or supplements.
3. Alcoholic hepatitis through extensive alcohol consumption.
4. Autoimmune hepatitis is a chronic inflammatory disease.

Hepatitis C is a disease of the liver caused by the blood borne virus, HCV or Hepatitis C virus. The virus is capable of causing both acute hepatitis and chronic hepatitis, with a severity factor of mild symptoms lasting a few weeks to a lifetime illness including liver cirrhosis to cancer of the liver. Around 30% of infected persons sequester the virus within six months of infection with no treatment; however, the rest 70% develop chronic HCV infection. Around 71 million people have acquired chronic Hepatitis C virus infections globally. The WHO Eastern Mediterranean Region and the WHO European Region are the severely affected regions, with an estimated prevalence in 2015 of 2.3% and 1.5% respectively. As per WHO reports, India has approximately 40 million individuals chronically infected with hepatitis B virus and 6 - 12 million individuals chronically infected with hepatitis C virus. Hepatitis E virus (HEV) is the foremost cause of epidemic hepatitis, though Hepatitis A virus (HAV) is frequent among children.

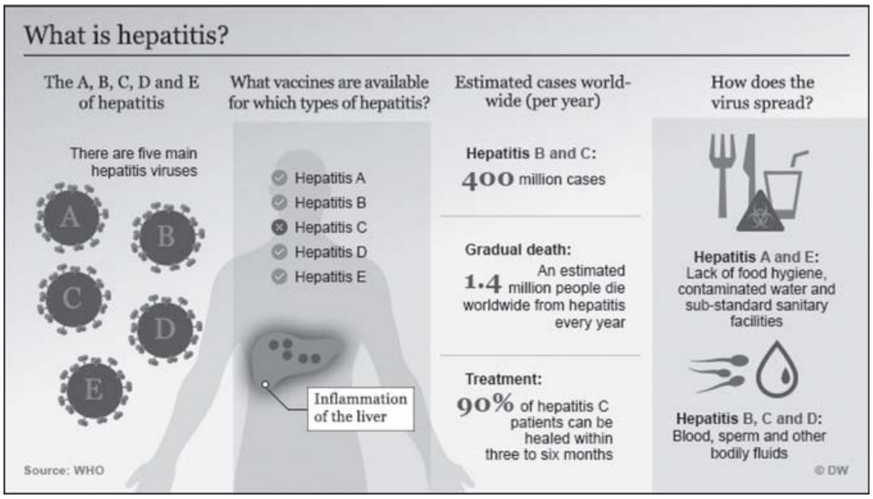
Michael Houghton

HCV transmission may happen through unsafe injection practices, injection drug use, unscreened transfusions of blood or its products, and sexual practices involving fluid transfer. The incubation period ranges from 2 to 24weeks. Acutely symptomatic ones may exhibit fatigue, fever, nausea, abdominal pain, reduced appetite, vomiting, joint pain, grey-colored feces, dark colored urine and jaundice.

Charles M. Rice

HCV diagnosis occurs in 2 steps:

1. Anti-HCV antibodies testing.
2. If the test for anti-HCV antibodies is positive, a nucleic acid test for HCV-RNA is essential to detect the presence of a chronic infection because about 30% of infected individuals sequester the



Hepatitis: A snapshot (Adapted from WHO reports)

virus with zero treatment. However, the individuals will still test positive for anti-HCV antibodies.

The WHO's 2018 guidelines recommended therapy using pan-genotypic DAAs or direct-acting anti-virals. DAAs treatment duration is short (12 to 24 weeks), depending on the presence or absence of cirrhosis. The suggested 3 classes are:

a) NS3/4A protease inhibitors.

b) NS5A polymerase inhibitors.

c) NS5B polymerase inhibitors.

NS3 protease inhibitors include glecaprevir, voxilaprevir and grazoprevir; the NS5B nucleotide inhibitor namely sofosbuvir; the NS5A inhibitors ledipasvir, elbasvir, pibrentasvir, and velpatasvir look promising to great lengths and NS5B polymerase inhibitor like sofosbuvir when used with other drugs found to improve the efficacy and tolerance.

To summarize the magnanimous efforts of the prime investigators associated with the HCV which lead to a comprehensive understanding of the disease as of today, I would like to re-iterate the contributions of the 3 scientists, now Nobel laureates briefly:

Dr. Harvey J. Alter at the NIH, was investigating the occurrence of hepatitis in patients who had received blood transfusions at various points of their lives. Tests for HAV infection were known and Hepatitis B virus (HBV) identification using blood tests were available too but it could not answer the huge portion of inexplicable cases. Hence, it was a matter of utmost anxiety that a notable number of people receiving blood transfusions developed the chronic hepatitis due to an infectious agent of unknown origin. Dr. Alter showed that hepatitis patients' blood could transmit the disease to chimpanzees which is the only susceptible host beside human beings. Further studies demonstrated that the unknown infectious agent hadfeatures of a virus, soon to be named as the "non-A, non-B" hepatitis (NANBH) illness.

Dr. Michael Houghton, was working for the pharmaceutical company Chiron Corporation and shouldered the perilous journey of excavating the genetic sequence of the elusive Hepatitis C Virus or HCV. With a presumption that antibodies against the unknown virus would be present in blood drawn from hepatitis patients, the researchers used patient sera to pinpoint cloned viral DNA fragments encoding viral proteins and a single positive clone was isolated. Subsequent rigorous work showed that this clone was derived from a novel RNA virus belonging to the *Flavivirus* family and it was finally named Hepatitis C virus.

Dr. Charles M. Rice, a scientist at the Washington University School of Medicine (St. Louis), together with other groups working on RNA viruses, noted an uncharacterized region in the end of the HCV genome that could be important for viral replication. In isolated viral samples, genetic variations were detected which might block the viral replication to a certain extent. Through recombinant DNA technology (RDT), he constructed an RNA variant of the HCV that included the newly defined region of the viral genome but was lacking the inactivating genetic variations. After transfecting the RNA construct into the liver of chimpanzees, viral load was detected in the blood and pathological changes similar to those in humans with the chronic form were observed, thereby, establishing the firm link of the virus to the disease.

Such was the amazing feat to the pinnacle of getting to know this virus and establishing a human link. The discovery of Hepatitis C virus revealed the obscurity associated with the outstanding cases of chronic hepatitis infections and made possible new sensitive blood tests and antiviral drugs that could save millions of souls and hence 28th July every year is observed as World Hepatitis Day where awareness in a global landscape is performed for the better of mankind. ❐

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ECONOMICS

In 2007, soon after Shri Andimuthu Raja became the telecom minister of India, the Department of Telecommunications (DoT) initiated the process of allotment of 2G spectrum and licences. In January 2008, DoT decided to issue licences on a first-come first-served basis with a retrospective cut-off date of 25 September 2007.This rather strange method of allocation, for obvious reason, raised suspicion of foul-play, and a report by the Comptroller and Auditor General of India (CAG) indicted the government for a presumptive loss of Rs1.76 trillion to the exchequer. A special CBI court was set up for hearing cases related to what came to be known as the 2G scam. The Supreme Court subsequently pronounced that the process of allocation was flawed, and cancelled 122 telecom licences allocated to nine companies during Raja's tenure. The Court ordered that the spectrum licences be auctioned.

Paul R. Milgrom

One wonders why DoT decided to allocate spectrum on a first-come first-served basis in the first place, when the whole world already knew that the best way to allocate such a thing as spectrum was by auction. By the time the Indian decision makers faced the spectrum allocation problem, auction theory had already reached its height of sophistication. As a matter of fact, by 1996, auction theory had become so influential that William Vickrey, a pioneer in auction theory, was awarded the Nobel Prize in economic science (i.e. 'Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel', to be precise) for his work. In 2020, the prize has gone once again to auction theorists. As per the citation of the Nobel committee, Paul R. Milgrom and Robert B. Wilson – both teaching at Stanford University – have been awarded "for improvements to auction theory and inventions of new auction formats." Their research addresses questions of fundamental theoretical and practical importance, such as, how bidders are likely to behave for a variety of auction formats and under different informational conditions, how regulators and governments should design auctions in order to maximize social value, and so on.

Although the economic theory of auctions had its beginnings in the1960s with Vickrey's seminal contribution, serious thinking about putting auction theories to work began in 1993–1994, with the design and operation of the spectrum auctions in US. Auction theorists have since designed spectrum sales for countries across the continents, electric power auctions in US and Europe, CO_2 abatement auctions, timber auctions, and auctions of financial assets such as government bonds. The early US spectrum auctions became almost a world standard, with their major features expressed in all the subsequent designs.

Robert B. Wilson

After Vickrey, Wilson and his student Milgrom emerged as the most prominent names in auction theory. Milgrom completed his Ph.D. thesis in 1978 under Wilson's guidance, who was then already advising governments about how to design auctions. Fifteen years later, Wilson and Milgrom together made proposals that became the basis for the design of the Federal Communications Commission (FCC) spectrum auctions – the most influential new auction design ofthe twentieth century. The FCC design was copied in other countries with variations here and there. In the intervening years, Wilson and Milgrom had taught auction theory in several universities – more as a set of abstract models than as a practical policy-oriented subject.

Auction theory began with investigations of the properties that underlie various auction formats –their efficiency property in particular. There are four well-known auction formats in practice that triggered initial theoretical work. The Dutch auction, where the price starts at a high level set by the seller and is gradually decreased until a bidder accepts and pays that price, was commonly followed in the flower auctions in the Netherlands. In the English auction, which is perhaps the most common format, bids increase from a starting price by open-cries until no bidder is willing to make a higher bid; the highest bidder wins and pays a price equal to her/his final bid. By contrast, sealed-bid tenders that we commonly see in procurement of materials and construction contracts are forms of auction in which each participant submits a single bid in sealed envelopes, not to be observed by others. Sealed-bid auctions can be ‘first-price’ or ‘second-price’. In the first-price sealed-bid auction, the highest bidder wins and pays the price she/he bid; and in the second-price sealed-bid auction – also known as ‘Vickrey auction’ –the highest bidder wins but pays the second-highest bid. Second-price auctions are presently used by internet-search engines for selling advertising space. One of the first design issues that the FCC considered was whetherto use an ascending bid mechanism or a single round sealed bid. The federal government generally used sealed-bid auctions for other objects. Wilson and Milgrom proposed simultaneous ascending bid auctions with discrete bidding rounds. This particular design could be shown to combine the operational simplicity of sealed-bid auctions with the economic efficiency of an ascending auction.

Apart from the *format* of the auction, which specifies the rules for how prices are announced, how participants place bids, etc, the other key concept is *information*: what do the participants know about the value of the auctioned object? In most cases, each bidder has some information that others do not know. In terms of different assumptions regarding information, auction models can be classified into three categories – private values models, common values models and affiliated values models. In a private values model, each potential buyer knows her/his own value for the object to be auctioned, which is not influenced by how other potential buyers value it. If individuals’ types are assumed to be independent from each other, then it is the case of the ‘independent private values’ model. If valuations are dependent on one another, then we have the ‘correlated private values’ model. A private values model might be appropriate for non-durable goods with no resale value. In the common values model, the object is worth the same to every potential bidder, but this value is unknown at the time of bidding. Typically, individuals have some information about the true value of the object, and that information may again be either independent or correlated across individuals. The common value model seems appropriate for analyzing the sale of mineral rights and offshore oil drilling leases. Milgrom and his colleague introduce the notion of ‘affiliated value’, which includes both private and common values as special cases. Roughly speaking, affiliated values capture the idea that individuals’ valuations for an object have a private component but are influenced by how other people value it. In most transactions, a bidder’s valuation for the object being sold does have a private component, but that valuation is also influenced by other individuals’ valuations.

The whole purpose of an auction is to create as much value as possible for the seller by assigning an object to the buyer who can make the best use of it. The complexity in auction design arises because the participants generally have different goals and different sets of information; and they act strategically. The behaviour of one bidder cannot be understood in isolation from that of the other bidders as each of them takes into account the strategies that others might adopt in response to their own. Thus it takes us to the realm of non-cooperative game theory. Game theory provides the tools of the trade in auction design. Thus, models of auctions have, in a sense, successfully demonstrated the empirical relevance of game theory in well-defined situations.

The contributions of Wilson and Milgrom are indeed far-reaching as the two economists have successfully combined their deep theoretical insight with the practical issue of auction design for resource allocation. Whatever be one’s value position regarding the ethical importance of valuation of resources through clever design of auctions, one has to admit that distributing spectrum licenses through an appropriate auction format is definitely far better than leaving it to the quackery of a DoT. ❐

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