NOBEL 2012

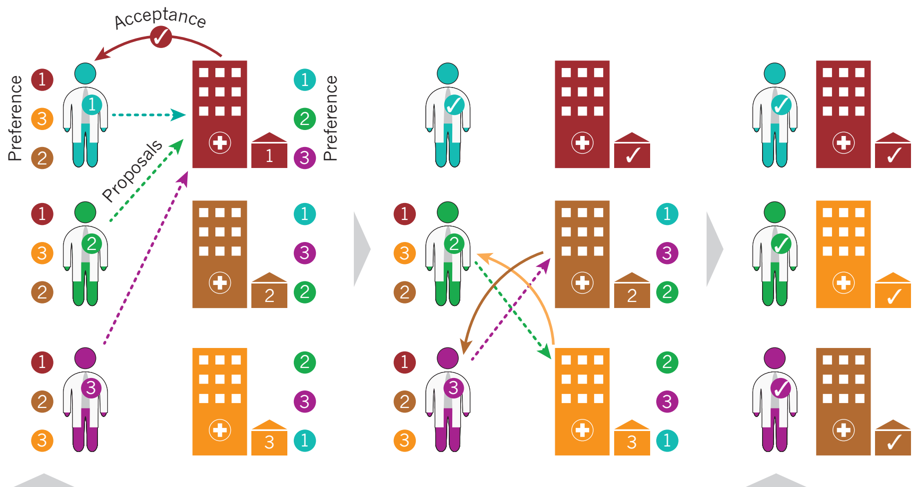
As the recipients of the 2012 science Nobel prizes gather in Stockholm to celebrate and be celebrated, News & Views shares some expert opinions on the achievements honoured.

ECONOMICS

Stable allocations and market design

What is the best way to match up entities that have different preferences for one another, if price cannot be used to determine the allocation? The 2012 Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel went to Lloyd S. Shapley and Alvin E. Roth for the theory and practical demonstration that such processes are optimized by achieving stable matches (see figure).

THE PROBLEM: Three doctors each have a preference list of where they would like to work, but the three hospitals have different ideas of whom they most want to employ.



THE PROCESS: A matching system based on the Gale–Shapley algorithm uses a series of proposals and acceptances to pair up the doctors and hospitals.

THE OUTCOME: Not everyone ends up with their first choice, but the matches are stable, because no pair can be found in which both parties would prefer each other over their current match.

EXPERIMENTAL ECONOMICS
by Yan Chen

In a seminal paper, Gale and Shapley[1] outline an algorithm that always produces stable matching in situations in which legal or ethical obligations preclude the use of price to determine the allocations. Extensions of this algorithm have been applied to several important fields, including the labour market for doctors[2], school admissions[3] and kidney exchange[4], to improve the stability and reduce gaming of the matching systems in use.

In such system redesigns, controlled laboratory experiments are frequently used to compare the performance of the systems at a level of detail that cannot be obtained from field data. For example, Kagel and Roth's experiments[5] on regional medical markets in Britain allowed a comparison of the performance of two algorithms for assigning doctors to hospitals, and this demonstrated that the stability of the algorithm contributes to the functioning of such markets. Laboratory experiments can also generate the first data on the performance of a theoretically superior mechanism for which there are no field data. For example, the first school-choice experiment[6] helped to persuade the public-school authorities in Boston, Massachusetts, to switch in 2005 from the Boston mechanism then in use to the Gale–Shapley mechanism.

These examples demonstrate how laboratory experiments can serve as a wind tunnel for evaluating new institutions. Matching and auction theories thus provide new areas for experimental research and are canonical examples of scenarios in which theory, laboratory experiments and real-world implementations form a healthy feedback loop. For these reasons, more economists are now conducting laboratory experiments to evaluate policies and institutions.

AN ENGINEERING APPROACH
by Jacob Goeree

Roth's early work illuminated how the Gale–Shapley algorithm[1] led to the successful matching of newly qualified doctors to hospitals, where decentralized systems had failed. New challenges arose, however, when a growing number of couples graduated from medical school and started to contact hospitals directly, causing instabilities. So Roth and Peranson designed an algorithm that could accommodate joint applications by doctors. Many entry-level labour markets now use this algorithm, which produces stable outcomes even when the applicants are couples.

In the process, Roth came to realize that many practical problems could not be solved by theory alone, and that computer simulations and laboratory experiments were invaluable tools for comparing alternative matching mechanisms. This 'engineering' approach inspired an entirely new field, referred to as market design, which draws on insights from game theory, experimental economics and computer science to improve the functioning of economic and social institutions.

The tools of market design are now being applied to a host of settings, including auctions to privatize public assets[7] and cap-and-trade programmes to reduce greenhouse-gas emissions[8]. In an interview about the Nobel award, a reporter asked Roth's opinion on the European debt crisis, and he modestly replied that he is not "that kind of economist". And yet his engineering approach to market design could help to create stable financial markets that avoid excessive risk-taking and taxpayer bailouts of banks or countries, such as those that are currently plaguing economies around the world. ■

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PHYSICS

Manipulating individual quantum systems

Serge Haroche and David J. Wineland have been awarded the Nobel Prize in Physics for developing techniques to measure and manipulate single particles without destroying their quantum properties. Haroche traps photons and measures and controls their quantum states with atoms. Conversely, Wineland traps ions and controls them with light (see figure).

SINGLE-PHOTON CONTROL
by Ed Hinds

Serge Haroche and his colleagues have developed an experiment to study the quantum mechanics of microwave light trapped between two mirrors (a cavity)[1]. They show that the quantum of light — the photon — can be controlled at an astonishing l evel of precision, and have used this to bring the abstract ideas of quantum entanglement to life in the laboratory.

Light is usually detected by destroying it: for example, a light sensor called a photodiode generates an electrical pulse when it absorbs, and so destroys, a photon. But Haroche's group measures the intensity of trapped light using a non-destructive method that probes the light using atoms flying through the trap. Each atom acts as a clock whose ticking rate depends on its energy level. As an atom flies through the cavity, its energies are shifted by the trapped light, and the total number of ticks of the clock changes accordingly, without any light being absorbed.

When a kind of excited atom called a Rydberg atom is used, the technique is sensitive enough to detect a single photon, and repeated measurements allow the same photon to be observed as it lives and eventually dies in the cavity[2]. Similarly, starting with several photons, the researchers can watch the photons disappearing one by one as they are absorbed by the cavity mirrors. The group has even prepared photons in a 'Schrödinger's cat' state — a fragile quantum state in which many photons are collectively doing two things at once (being dead and alive in the case of the cat) — to study how the state is destroyed by photon loss in the cavity[3]. These studies allow deep insight into the way quantum systems work, and provide a practical basis for developing powerful devices based on the strange laws of quantum mechanics.

MASTERING SINGLE IONS
by Rainer Blatt

A consummate experimentalist, David Wineland pioneered the use of electromagnetic devices known as Paul traps to hold single trapped ions for quantum metrology. Along the way, he has developed a plethora of groundbreaking experimental methods that have since become standard means of manipulating single atoms.

Armed with efficient single-atom detection through a technique called electron shelving, together with laser cooling to bring an ion to its lowest-energy vibrational state, Wineland masterfully conducted ultra-high-precision spectroscopy of single ions. Using precisely timed and tuned laser pulses, he tailored the coupling between the ions' internal states and their quantized vibration[4].

Notably, it is with this technology that he laid the groundwork for unprecedented control of a single trapped particle's electronic and motional degrees of freedom, which he in turn applied to generate many kinds of non-classical states that could otherwise be observed only through light–matter interactions in a cavity[5].

These methods culminated in Wineland's quantum-logic clock, in which the ions' motion is used to transfer otherwise inaccessible spectroscopic information to a read-out ion[6]. This technology has produced the most precise measurement of an atomic frequency ever obtained, with a fractional uncertainty of less than 10^{-17}. Moreover, Wineland's spectacular quantum mastery will continue to have a major impact. His techniques are already a crucial element of the exciting field of quantum information processing, and will prove invaluable for both fundamental tests of quantum physics and future quantum technologies. ■

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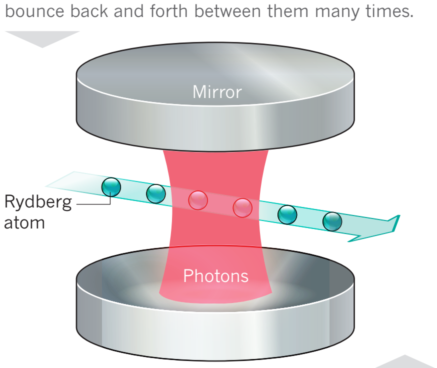
HAROCHE METHOD

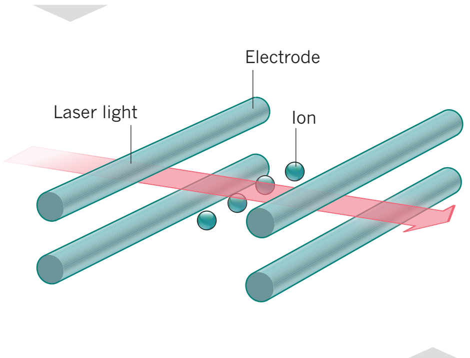
Microwave photons are placed between two highly reflective mirrors that enable an individual photon to bounce back and forth between them many times.



Rydberg atoms, which have one electron in a high-energy level, are sent through the system to measure and manipulate the photon's quantum state.

WINELAND METHOD

An electric field produced by an arrangement of electrodes holds one or several ions inside a trap.



Laser light is shone on the ion, suppressing its thermal vibration and allowing its quantum state to be measured and controlled.