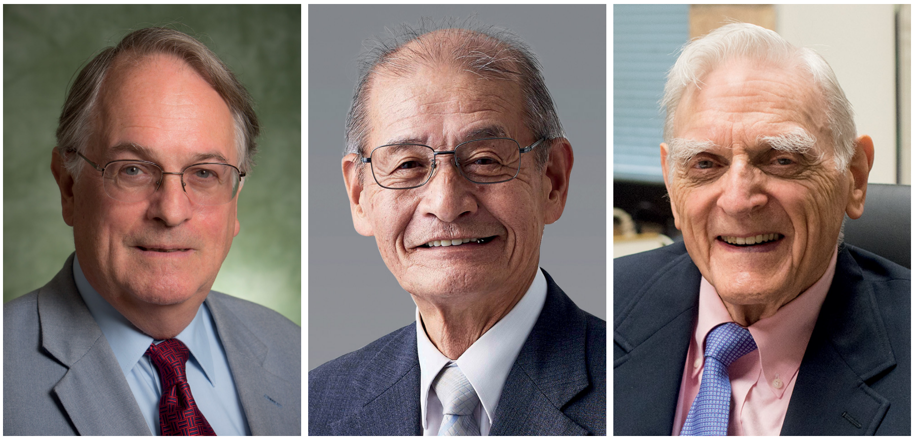

Stanley Whittingham (left), Akira Yoshino and John Goodenough (right) share the Nobel chemistry prize.

L TO R: BINGHAMTON UNIV./THE JAPAN PRIZE/UNIV. TEXAS AT AUSTIN

CHEMISTRY PRIZE

World-changing batteries win Nobel

Prize honours three researchers who developed rechargeable lithium-ion batteries.

BY DAVIDE CASTELVECCHI & EMMA STOYE

Three scientists whose work led to the development of lithium-ion batteries — a technology that ushered in a revolution in energy storage — won the 2019 Nobel Prize in Chemistry on 9 October.

John Goodenough, Stanley Whittingham and Akira Yoshino all contributed to the evolution of the kind of lightweight, rechargeable batteries that power today's mobile phones and other portable electronic devices. The technology also makes "possible a fossil fuel-free society", the Nobel Committee for Chemistry said.

Goodenough, a solid-state physicist at the University of Texas at Austin who is 97, became the oldest ever Nobel laureate. "I am very grateful that I had that honour, it's splendid," Goodenough told *Nature*. "But I am the same person I was before."

"Amazing! Surprising!" Yoshino, a chemist at Meijo University in Nagoya, Japan, told journalists after the announcement. The three researchers will get equal shares in the prize, which is worth 9 million Swedish kronor (US$910,000).

RECHARGEABLE WORLD

"In my view, this award is long overdue," says Saiful Islam, a materials chemist at the University of Bath, UK. "It's great to see that this important area of materials chemistry has been recognized. As we know, these batteries have helped power the portable revolution."

In a lithium-ion battery, lithium ions move from the negative electrode (anode) to the positive electrode (cathode) through an electrolyte as the battery discharges, then travel back the other way when it is recharged.

While working for the oil company Exxon in the 1970s, Whittingham, who is now at the State University of New York at Binghamton, proposed the idea of rechargeable lithium batteries and developed a prototype that used a lithium-metal anode and a titanium disulfide cathode. The battery had a high energy density and the diffusion of lithium ions into the cathode was reversible, making the battery rechargeable. But high manufacturing costs and safety concerns meant the technology could not be commercialized.

In the late 1970s and early 1980s, Goodenough developed rechargeable batteries with cathodes made from layered oxides capable of storing lithium ions. This greatly improved the batteries' energy density, and lithium cobalt oxide remains the cathode material of choice for lithium-ion batteries.

And in the 1980s, Yoshino made changes to the materials that drastically improved safety and enabled commercial production of the batteries. His design pioneered the use of carbon-rich anode materials into which lithium ions could be inserted. "I started in 1981, and I invented the lithium-ion battery in 1985," Yoshino said.

Laboratories around the world are busy experimenting with technologies that could replace lithium-ion batteries, as well as with further developments to make existing batteries safer, more sustainable or longer lasting. But the fundamental design of the current battery will dominate for the foreseeable future, and — through electric vehicles and grid-scale energy storage — could play a crucial part in the decarbonization of the economy, says Clare Grey, a materials chemist at the University of Cambridge, UK. "It's poised to be around for a long time."

SUSTAINABLE FUTURE

The Nobel committee also highlighted the role that the battery might have in creating a more sustainable future as nations try to move away from fossil fuels. Batteries are increasingly being used to store energy from renewable sources, such as solar and wind power, it noted.

"I salute the Nobel committee for recognizing something that is of practical importance," says Donald Sadoway, a chemist at the Massachusetts Institute of Technology in Cambridge. Islam adds that rechargeable batteries being developed for electric vehicles will have a crucial role in improving air quality, as well as lowering greenhouse-gas emissions.

Olof Ramström, a chemist at the University of Massachusetts Lowell who was a member of the Nobel chemistry committee, emphasized that this year's award recognizes a truly interdisciplinary effort. "It involved many branches of chemistry [and] it's also connected to physics and engineering," he said while announcing the prize. "It's a very good example of when all these disciplines can come together."

Grey, who has collaborated with Whittingham, says that a number of people have made major contributions to developing the technology, but that the committee made a good choice. Goodenough, in particular, is an "intellectual giant" in the field of materials research, and made many fundamental contributions beyond batteries. "He changed the way we think about magnetism, and he has helped to explain electronic conductivity," Grey says.

Asked whether lithium batteries were his favourite work, Goodenough told *Nature*: "No, I think my favourite work was to investigate what's called the Mott transition," a process in which the electrons in a material go from being able to move freely to being linked to individual atoms. ■

CORRECTION

The News Feature 'Humans versus Earth' (*Nature* **572**, 168–170; 2019) incorrectly located the groups doing some work on samples from Crawford Lake. The testate amoebae work was done by a group at Carleton University, and the microplastics work was done at Brock University.

The News Feature 'The crystal kings' (*Nature* **572**, 429–432; 2019) erred in saying that Pablo Jarillo-Herrero was a graduate student of Philip Kim. He was a postdoctoral fellow.