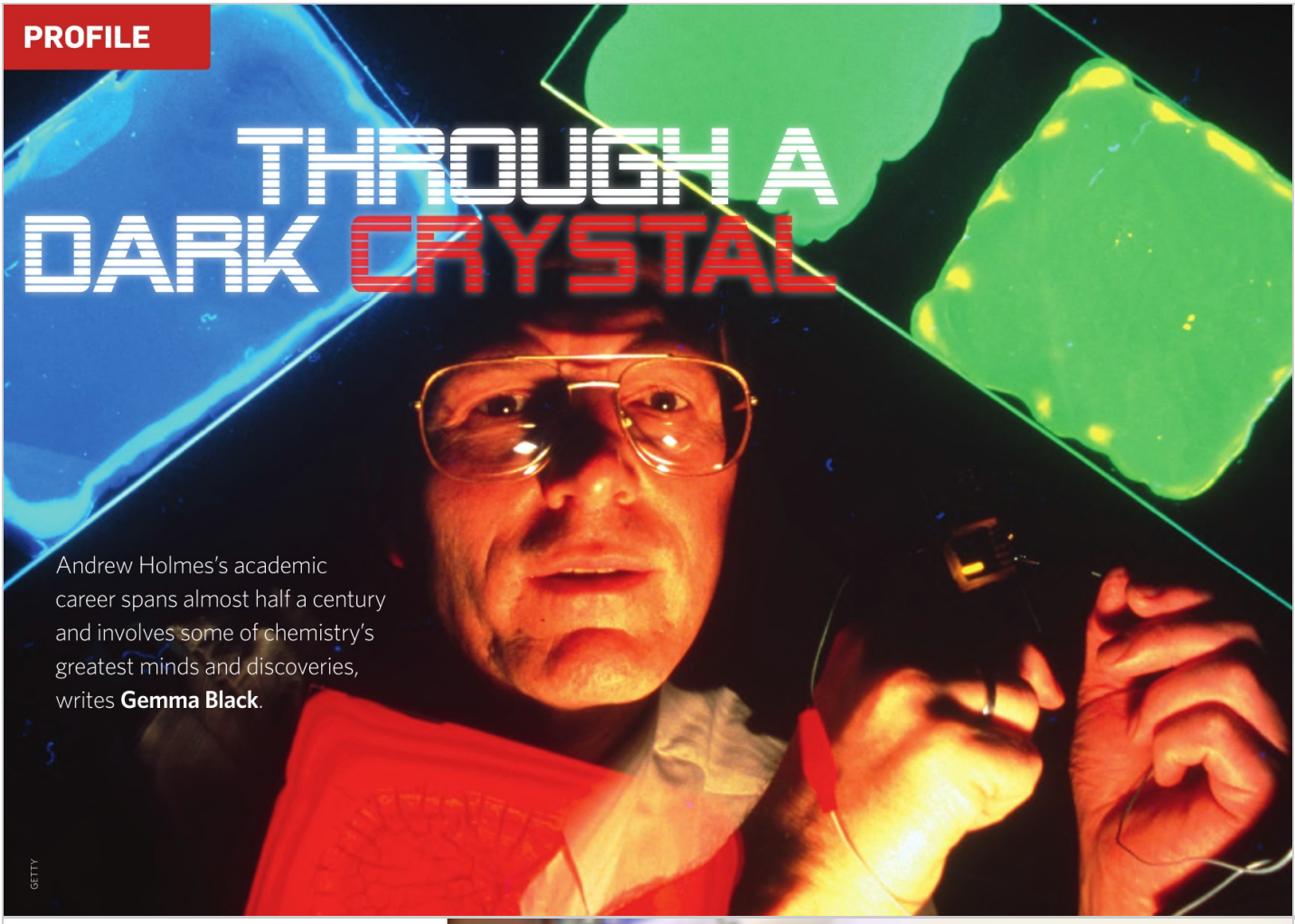
PROFILE

THROUGH A DARK CRYSTAL



GETTY

Andrew Holmes's academic career spans almost half a century and involves some of chemistry's greatest minds and discoveries, writes **Gemma Black**.

IN THE LATE 1970s, Australian organic chemist Andrew Holmes was working in his laboratory at the University of Cambridge in Britain when one of his PhD students reported an odd finding. Chloe Jennings-White was trying to synthesise a molecule isolated from a Hawaiian seaweed. Surprisingly, the crystals she had prepared spontaneously formed into a long molecular chain. Even stranger, this novel substance then turned a metallic blue-black colour while sitting on the bench in the lab.

Intrigued, Holmes took the find to a senior Cambridge solid-state chemist, John Meurig Thomas. "I vividly recall the day Andrew came into my room with the glistening polymer in his hand," says Thomas. "He was bemused by the fact the crystals exhibited two different colours depending on the angle at which they were viewed."

"You should follow this up," Thomas announced. Holmes took Thomas's advice and decided to investigate these odd plastic molecules that behaved like metals. His research would lead to the development of materials used throughout digital technology and would kick-start the field of organic electronics. He sought out physicist Richard Friend in the Cavendish Laboratory, who was interested in using semiconducting plastics in transistor applications. "We quickly developed a joint research program that turned out to be of huge consequence," Friend recalls.

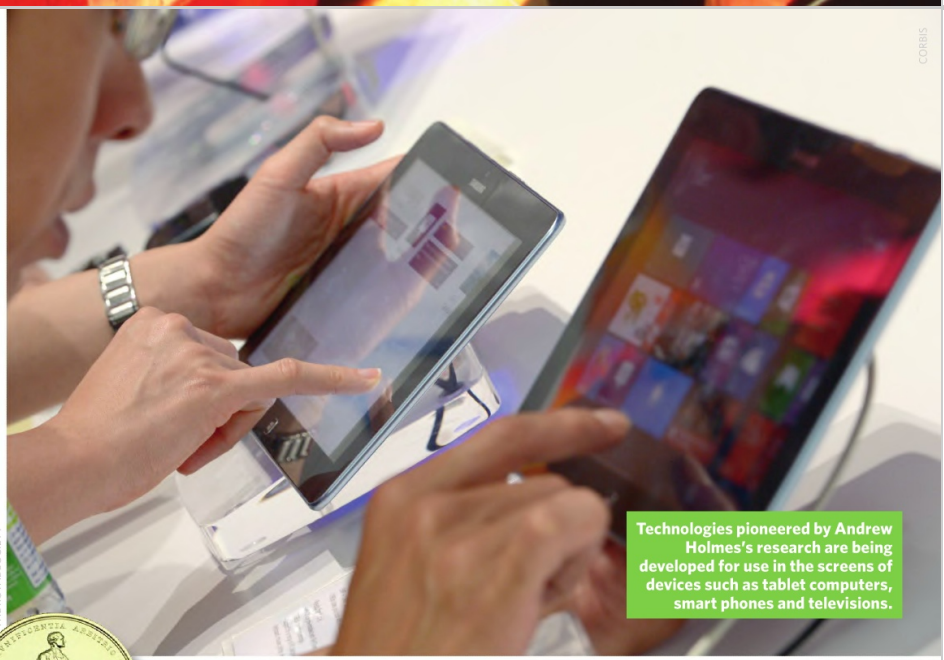
The collaboration, which included another Australian chemist, Paul Burn, led to the development of polymer organic LEDs (light-emitting diodes) and was later hailed as "one of the most influential UK chemistry–physics interactions in recent times" in a 2009 editorial in a special commemorative issue of *Chemical Communications*. Holmes and his colleagues had created a semiconducting polymer that could emit light when sandwiched between electrodes and hooked up to a power source – heralding a new version of electroluminescence, the same phenomenon by which LEDs function. The team's 1990 *Nature* paper, describing how they stumbled on the strange new world of semiconducting polymers, has been referenced more than 8,000 times.

HOLMES MOVED TO Cambridge's newly founded Melville Laboratory for Polymer Synthesis, where he served as director from 1994 to 2004, joining the "tight-knit" community of polymer chemistry, as he terms it. The team also founded a company, Cambridge Display Technology.

"All sorts of things came out of that collaboration," says Holmes. "It was a whole new life."

In 2012, more than 20 years after that serendipitous day in a Cambridge lab, Holmes joined the prestigious ranks of Charles Darwin and Francis Crick as a recipient of a Royal Medal for his involvement in "pioneering the field of organic electronic materials" or, as Holmes sometimes puts it in his lectures, "for organic reactions that went wrong".

The Royal Society awards three Royal Medals every year for the most important contributions to physical, biological and applied sciences. Holmes, who won in the applied science category, was the first Australian to win a Royal Medal since biologist Suzanne Cory in 2002.



CORBIS

Technologies pioneered by Andrew Holmes's research are being developed for use in the screens of devices such as tablet computers, smart phones and televisions.

THE ROYAL SOCIETY

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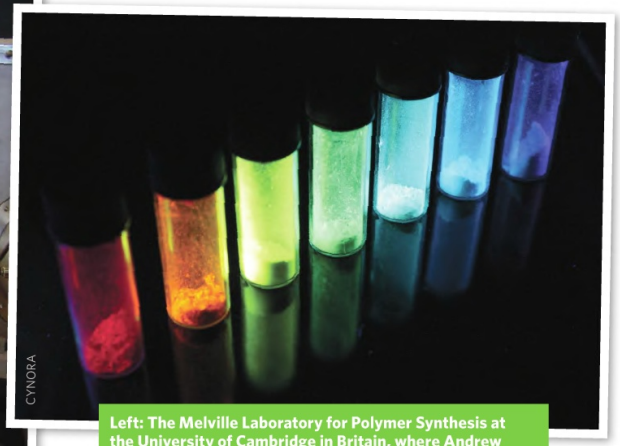


Left: The Melville Laboratory for Polymer Synthesis at the University of Cambridge in Britain, where Andrew Holmes researched polymer organic light-emitting diode (OLED) technologies.
Right: OLEDs are formed by sandwiching organic materials that fluoresce when irradiated by ultraviolet light between electrodes, and applying a charge to these.

>> **WITH THE REFINED** accent of a British academic, it's not immediately obvious that Holmes is Australian. He was born in Melbourne in 1943, son of Bruce and Frances Holmes. He quickly revealed an aptitude for science and was allowed to fool around in the school chemistry lab, conducting experiments that "probably wouldn't be allowed nowadays", he says.

Science was in his blood. His father Bruce was a chemist who worked in building materials research with Australia's national research organisation CSIRO in Victoria. His paternal grandmother, Marjory Holmes (née McLaren), was one of the few female graduates of science from the University of Melbourne in the early 20th century. And Marjory's brother – Holmes's great uncle – Samuel Bruce McLaren, was a talented mathematician who graduated from the University of Melbourne in 1897 and, during his career as a professor at Reading, worked on cutting-edge mathematical physics and corresponded with Danish physicist and quantum mechanics pioneer Niels Bohr. McLaren was killed in battle in World War I, while Holmes's father died in the 1954 polio epidemic.

Holmes dabbled with the idea of studying medicine before discounting it because it would take too long to qualify, and graduated from the University of Melbourne with a Bachelor and Master of Science in 1967. While at Melbourne, he met his future wife, Jennifer, who was studying to become a high school teacher. "Andrew is probably the reason I was able to get my degree," she says. "He used to work late so I decided I'd better keep working too. He was always such a hard worker – much more than I was!"

In 1967, Holmes boarded the *SS Galileo Galilei* at Port Melbourne to travel to Britain to take a PhD in organic chemistry at University College London (UCL). He turned 24 during the four-week voyage and, apart from a few short visits, did not return to his home country for 37 years.

At UCL, Holmes's PhD supervisor Franz Sondheimer became an important early mentor. As a child, he had fled Nazi Germany for London. Sondheimer had once worked for U.S. pharmaceutical company Syntex in Mexico City, where he joined the team that developed the world's first oral contraceptive pill (which was derived from the root of the Mexican yam). The pill's success made Sondheimer a millionaire.

"Franz spent his money generously," says Holmes. On one occasion, he paid to have expensive lab equipment replaced because he didn't think it was up to scratch. "He didn't thrust it around but he invested in science. He was a great scientist and a wonderful, stimulating person to work for." >>

Andrew Holmes (left) during his postdoctoral research days in Albert Eschenmoser's laboratory in Switzerland, with colleague Naruyoshi Obata.

>> Sondheimer suffered from depression and took his own life in 1981, aged 55 – though had already made an indelible mark on Holmes. "I still find myself doing things – and teaching my students things – that Sondheimer taught me," he says.

Holmes then moved to Zurich, where he spent a year as a postdoctoral research fellow at the Swiss Federal Institute of Technology. There, he worked for distinguished Swiss chemist Albert Eschenmoser on the synthesis of vitamin B12, which Holmes calls the "molecule of molecules of the 1970s... the pinnacle of complexity in organic synthesis".

Two research teams were working on the project. One, at Harvard University, was led by Nobel laureate Robert Woodward. The other was Eschenmoser's team. "It was meant to be a collaboration but as it got towards the end it was serious competition to get there first," says Holmes. "We both got there about the same time, so it was good fun."

Eschenmoser recalls the young Holmes as a "sheer pleasure, personally as well as scientifically" to work with on difficult projects. "To hear of his ever-increasing reputation has been a great pleasure."

IN THE WAKE OF his work in Switzerland, Holmes was given a post at Cambridge by a former colleague of Sondheimer's. He remained at Cambridge for the next 32 years, during which time he and Jennifer had three sons – Ian, Tim and William.

His passion for science dominated Holmes household life: washing the dishes could become a discussion about the viscosity of dishwater or the properties of the non-stick Teflon coating on the pans. His long hours in the laboratory were an accepted part of family existence. Jennifer recalls the groans around the dinner table when, with their father expected home 'any minute', the phone would ring. "Guess what Dad's doing?" she would later ask the boys. "Backing up!" they would chorus in response – referring to the regular, hefty task of saving laboratory data in those days.

"I remember thinking, if I ever have a computer lab, I'm going to automate this," says Holmes's oldest son, Ian, who has an undergraduate degree in physics from Cambridge and is now a professor of bioinformatics at the University of California Berkeley.

"Dad's got one of the strongest work ethics I've seen," he adds. "He was almost always working in one way or another. I know some scientists who focus on big, showy 'look at me' projects, whereas Dad's work is not so much about the big result, or being ground-breaking – even though it was in most cases. It always had this focus on wanting to do something concrete or practical."

Of his father's award-winning role in pioneering polymer organic LEDs, Ian mainly recalls the association he made at the time with the science fiction books of his childhood. "In the books, there were video screens everywhere, and they'd be made of fabric and things like that, and it always seemed so futuristic and impossible – so it's pretty impressive when your dad brings your sci-fi books to life," he says. "But I was also kind of disappointed that he wasn't more like the characters in the books, like some grizzled 25-year-old cyberpunk."

HOLMES'S LIFE TOOK another significant turn when a former Cambridge colleague, Craig Francis, back at the CSIRO, wrote to ask if he would be interested in returning to Australia. Holmes accepted but decided, in the process, to reverse the direction of his research.

"In the UK we'd put electricity into polymers and get light out. Here we thought we could put light in and get electricity out," he says. The result is a form of renewable electricity generation with huge potential – plastic solar cells that would be printed using similar technology to the way Australia prints its plastic bank notes. The result is – potentially – cheap, malleable solar cells with myriad possible uses, from being sewn into clothing to charge portable electronic devices to power-generating rooftops.

Soon after Holmes's return to Australia, the Victorian Organic Solar Cells Consortium was formed between Australian universities, national research bodies and industry partners.

The result is a form of renewable electricity generation with huge potential – plastic solar cells that would be printed using similar technology to the way Australia prints its plastic bank notes.

"By this time, I'd realised this was more than just a scientific curiosity to me – this was our national duty to work on renewable energy in Australia," Holmes says. At just 2% efficiency in terms of transferring light to electricity, the technology has a way to go before competing with domestic silicon solar panels, which can reach efficiencies of 10% to 15%. Nevertheless, the technology works. Holmes says he was even able to turn the blades on his display fan using his plastic solar cells and with nothing but the dim winter sunlight inside an Oxford lecture hall on a recent trip back to Britain. >>

>> "We'll get there," says Holmes. "With the 40 years that silicon has had, I think we'll be very competitive. In 10 years I think it'll be a market product." The research was given a boost in July 2012 when Australia's Federal Minister for Resources and Energy, Martin Ferguson, announced a $2.3 million contribution into the development of 'building-integrated solar cells'. Troy Coyle, the manager of coated products development at BlueScope Steel, one of the Consortium's industry partners, says the technology "has the potential to revolutionise the roofing market".

"The ability to coat steel roofing with photovoltaic [solar] cells in a continuous manufacturing process offers the potential for low-cost, durable photovoltaic roofing," Coyle says.

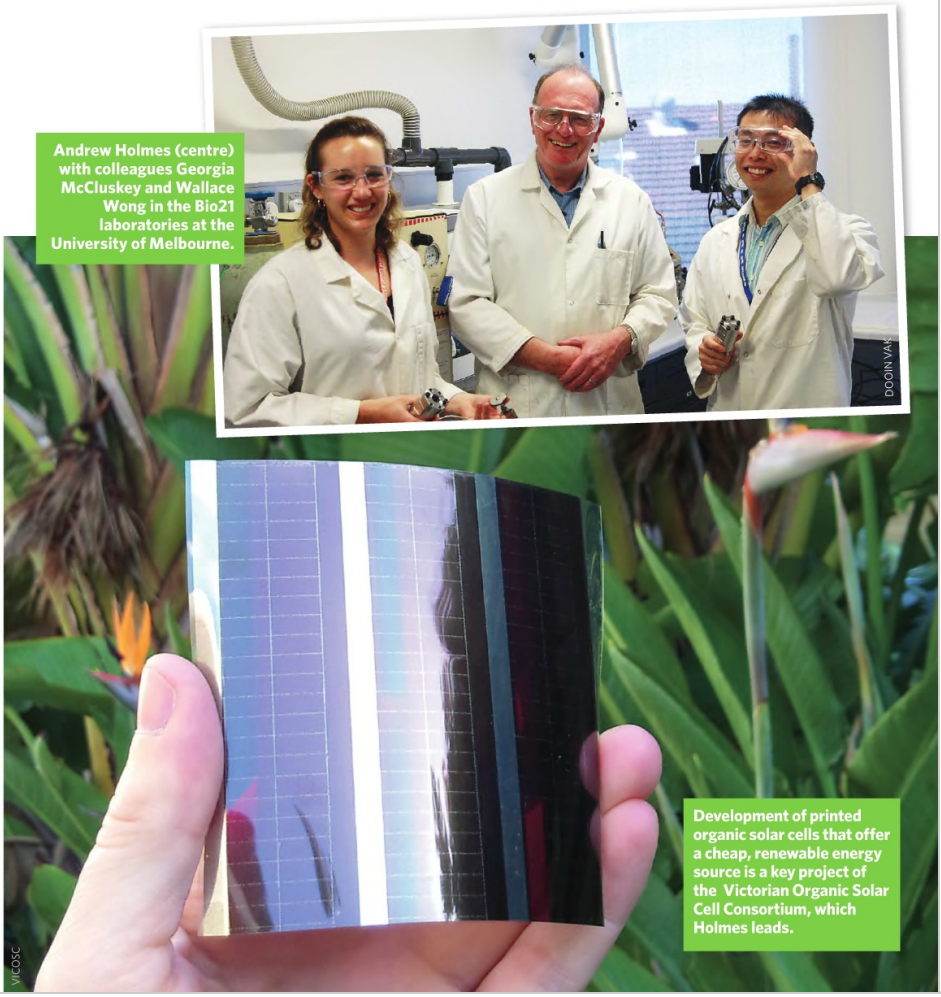
While Holmes says the most likely short-term application for the solar cells will be as plastic laminates stuck directly onto steel roofs, he has big hopes for the future. Solar cells work by having metal electrodes to extract the current, meaning steel itself is potentially a conductor – which could drastically reduce the cost of putting solar cells onto roofs as they are built. "It's technically challenging and it would be a long way downstream, but one could imagine that," Holmes says.

SCIENCE AND administration go hand in hand in academia, and Holmes, as foreign secretary of the Australian Academy of Science, does plenty, using his long career working with some of the world's most distinguished scientists to broaden the horizons of the nation's science.

"I think the thing I can do best in coming back to Australia is bring connections from abroad," he says. "The greatest ideas are often exchanged in these interactions and new ideas are brought back and shared through these collaborations. It's important that young Australian scientists continue to experience these opportunities."

Edging towards 70 years old, Holmes shows no signs of retiring, but does lament that he's "not as good at doing recreational things" as he'd like – such as taking long hikes, like the ones he used to do in the Scottish highlands, and visiting the opera and theatre. "I've let my work become an obsession," he says. "But my family helps keep me sane."

Gemma Black is *COSMOS Magazine's* staff writer.



Andrew Holmes (centre) with colleagues Georgia McCluskey and Wallace Wong in the Bio21 laboratories at the University of Melbourne.

Development of printed organic solar cells that offer a cheap, renewable energy source is a key project of the Victorian Organic Solar Cell Consortium, which Holmes leads.