A Centenary Celebration!

Cambridge Materials 1920 – 2020

(From The Cambridge Review of 15 October 1920)

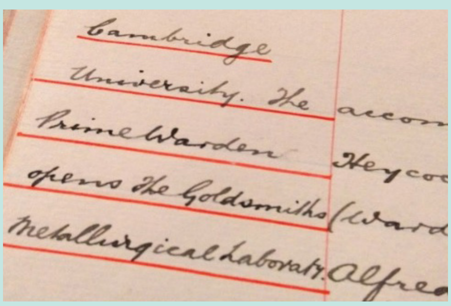
Opening of the Extension of the Goldsmiths' Metallurgical Laboratory

On Tuesday, October 5th, the Prime Warden of the Goldsmiths' Company, Mr R. Montagu Tabor, M.A. of King's, attended by the three Wardens and several members of the Court, came to Cambridge to open the extension of the Metallurgical Laboratory. After lunch at King's College, at which the Vice-Chancellor, Prof. Sir J. J. Thomson President of the Royal Society, the Master of Caius, the Master of Corpus, Prof. Sir Wm Pope, Prof. Sir E. Rutherford, the Vice-Provost of King's, Prof. Inglis, the Reader in Metallurgy, and others were present, the party proceeded to …

The Vice-Chancellor, before asking the Prime Warden to declare the building open, expressed the thanks of the University to the Goldsmiths' Company for their continued interest and generosity in promoting the study of Metallurgy … He then briefly sketched the rise in the scientific departments during the last twenty years.

The Prime Warden said he had great pleasure in representing the Goldsmiths' Company on this occasion. The Company was privileged to devote its funds not only for the relief of distress but also to the promotion of research...

Mr Heycock, Goldsmiths' Reader in Metallurgy, expressed his pleasure in seeing such a distinguished company present, and his thanks to the Goldsmiths' company for their munificent benefaction.

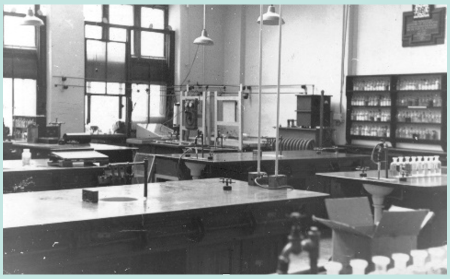

Cambridge
University. The
Prime Warden
opens the Goldsmiths'
Metallurgical Laboratory.

The Court Minutes of the Goldsmiths' Company record the opening of what was the first purpose-built accommodation for our subject in Cambridge.

The agility of the times is amazing. From Heycock's initial request for funds (19 March 1919) barely 18 months elapsed before the building was complete, equipped and opened!

One hundred years on...

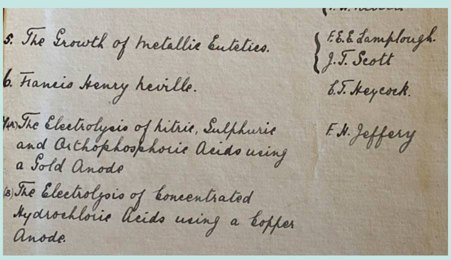
— the Laboratory has evolved (see centre-page spread) into our present Department of Materials Science & Metallurgy. This *Material Eyes* supplement celebrates the achievements flowing from the visionary support of the Goldsmiths' Company. We note the transformation of our facilities:



The 'new analytical room' of the Goldsmiths' Metallurgical Laboratory, October 1920.

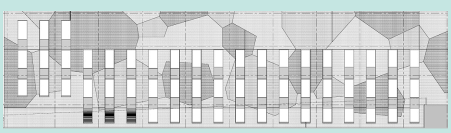
The very first practical class (Part IA Materials Science) in the new building, October 2013.

— and the transformation of the scale and diversity of our research:


5. The Growth of Metallic Eutectics. — F.E.E. Lamplough, J.T. Scott
6. Francis Henry Neville. — C.T. Heycock.
7(a) The Electrolysis of Nitric, Sulphuric and Orthophosphoric Acids using a Gold Anode
(b) The Electrolysis of Concentrated Hydrochloric Acids using a Copper Anode. — F.H. Jeffery

Excerpt from Heycock's Collected Papers from the Goldsmiths' Laboratory.

But, in our subject, some things endure, such as the importance of microstructure:

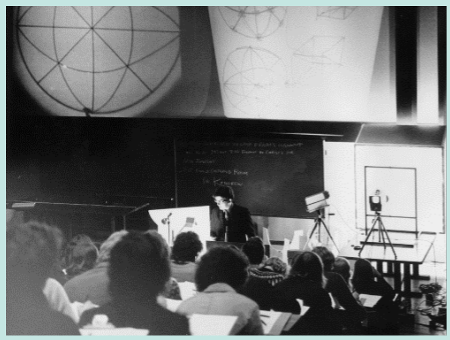


The grain structure represented in the brickwork of our present building would be very recognizable to Heycock.

Lindsay Greer

Chalk, Moodle and Zoom

When I joined the Department as a Lecturer in January 1968 the normal method of conveying information in lectures was blackboard and chalk, mostly white but occasionally coloured, *e.g.* red for crystallographic symmetry elements. To display more as a lecture developed, some lecture rooms had several boards, sometimes ones that slid up and down with a substantial heave‡. Use of (large clunky glass) slides was possible, and 2″×2″ slides were coming in, but the projectors were primitive. Reproduced by prehistoric means, handouts were basic, with diagrams usually hand-drawn, so students were expected to take full notes.



Brian Ralph lecturing Part IA Crystalline Materials, Babbage Lecture Theatre, 1981

Over the years, blackboards and chalk gave way to (passive) whiteboards with wonderfully aromatic markers and projectors controlled by the lecturer. With the development of the PC, detailed word-processed handouts became the norm. In parallel with this, came overhead projectors to display notes hand-written "live" by the lecturer onto a long scroll of clear plastic or on previously prepared viewfoils, initially written or drawn by hand, but later printed with word-processed text and diagrams, often identical to the handout. Next arrived applications such as PowerPoint, which provide for slick presentations – but do they get in the way of spontaneity? More recently (and after I retired) the University adopted Moodle to provide wide support for teaching; this proved its value when Covid-19 came along and teaching mostly went on line augmented by use of Zoom and such like. What will be the long-term impact of the past 18 months?

A wider view of the development of teaching, including practicals, projects, supervisions and DoITPoMS, over the past century is on the Departmental website.

John Leake

‡ After a tussle with one such board in the Pembroke St building, the author ended up in A&E and still bears the scar!

A Century, and more, of Cambridge

The starting point

From their research spanning 20 years in the laboratory at Sidney Sussex College, CT Heycock and FH Neville produce a series of seminal papers. Their first metallurgical work (**1889**) is *The lowering of the freezing point of tin caused by the addition of other metals*. Neville recognizes intermetallic compounds; his 1900 review lists the 37 then known (>20,000 today).

The Bakerian Lecture (1903)

The Royal Society's premier lecture in the physical sciences is given by Heycock and Neville, in distinguished company: the 1902 lecture was by Rayleigh, the 1904 by Rutherford. Heycock & Neville's paper *On the Constitution of the Copper-Tin Series of Alloys*, with 101 photomicrographs, is the foundation of modern studies of phase equilibria and microstructure in alloys. Later Bakerian lecturers from the Dept are AH Cottrell (1963) and A Kelly (1995).

Readership in Metallurgy

The Goldsmiths' Company endows a Readership for Heycock in the University Chemical Laboratory (**1908**), and in **1910** donates £700 to equip four rooms in the basement of the Chemistry building on Pembroke St. In Michaelmas Term 1909, Heycock offers a course on *Metallurgy of gold, silver, lead, platinum, copper, tin and other metals* (the fee is one guinea).

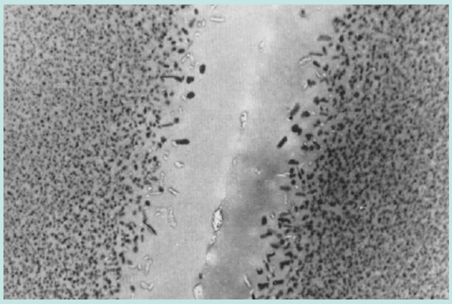
The date we celebrate: 5th October 1920
The Goldsmiths' Metallurgical Laboratory is opened by RM Tabor, Prime Warden of the Company. The Laboratory extends existing rooms and is the first purpose-built accommodation for metallurgy in Cambridge.

An undergraduate identity (1938)

Graduation of the first Part II Class in Metallurgy (cohort of 4 students).

Summer School (1953): *The use of electrons in the examination of metals*

The Dept acquires its first transmission electron microscope (Siemens 75 kV) in 1952, and plays a key role in this Cambridge Summer School. A world-leading series of papers on TEM of the interaction of dislocations and precipitates culminates in Kelly & Nicholson's 1963 review *Precipitation Hardening*. From then, the pathway of distinction (in technique development and materials understanding) is clear all the way to the Wolfson Electron Microscopy Suite, the world-class facility in our present building.



A grain-boundary precipitate-free zone [Unwin, Lorimer & Nicholson (1969)]

Crystalline State

This NST Pt IA course, shared with the Dept of Mineralogy & Petrology, begins in the Michaelmas Term **1965**, lectured in parallel by Tony Kelly and Christine Kelsey to a class too numerous to fit in one theatre. The course evolves through *Crystalline Materials* and *Materials & Mineral Sciences* to (in 2010) *Materials Science* (taught by us alone).

***Strong Solids* (1966)**

This influential book builds Tony Kelly's reputation. He goes on to be known as 'the father of composite materials', a research theme that further flourishes under D Hull, TW Clyne and WJ Clegg.

Birth of the Device Materials Group

Cottrell established the Dept's research on superconducting materials. In **1972** AM Campbell & JE Evetts publish their seminal (229 pp) *Flux Vortices and Transport Currents in Type II Superconductors*. Jan Evetts goes on to found the DMG, now the Dept's largest grouping of academic staff, working on a wide range of physical properties of materials.

At last!

1978: Jane Weston is the first female member of academic staff. Now women are 46% of our academic staff, and of our professors. From the start, of course, women made key contributions: in their Bakerian Lecture paper, Heycock & Neville acknowledge their indebtedness to Miss D Marshall, BSc, Lecturer at Girton, for 'help in the experiments'. Later, Dr Constance Tipper (one of Cambridge's most distinguished metallurgists and ultimately a Reader in Mechanical Engineering) lectures to our early cohorts of Metallurgy undergraduates.

Progressive crushing of fibre-reinforced composite tubes [D Hull (1991)]

University Technology Centre

Of the Dept's industrial partnerships, the Rolls-Royce UTC is the longest lasting and by far the most successful. Established in **1994**, the UTC has inspired many other companies to support research in the Dept.

***Material Eyes* (1996)**

Our newsletter starts to spread the word to our alumni, partners and friends.

Highs and Lows

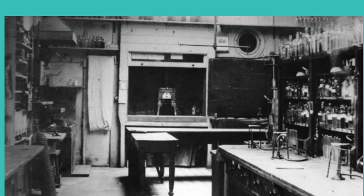
Our graduating classes reached a high of 62 in 1967 and 1968. A steady decline followed to just 11 graduates in 2002. Our student numbers have since risen sharply. From **1998**, our Part II Class may graduate with a BA or (as most choose) stay on for a further Part III year and gain an MSci degree.

Goldsmiths' Reader in Metallurgy & (from 1931)
Goldsmiths' Professors of Metallurgy

CT Heycock | RS Hutton | GPW Austin

Sidney College Laboratory | Goldsmiths' Metallurgical Laboratory | Sub-Dept of Metallurgy | Dep

1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950



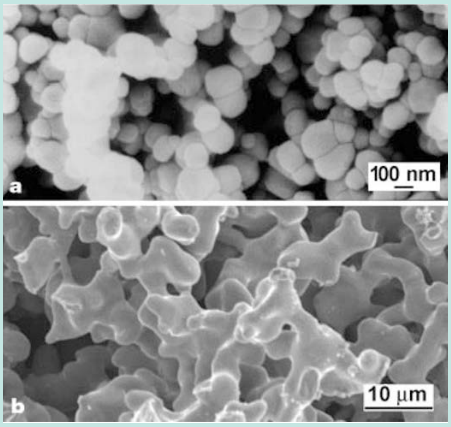
The elusive PhD

The first paper from the 'Metallurgy Laboratory, Cambridge' (**1914**) is *The System Silver–Silver Sulphide* by CC Bissett who, already a Sheffield graduate, is pursuing a BA by research. Cambridge awards its first PhD only in 1921. Cambridge's first Metallurgy PhD is TP Hoar's *The Mechanism of Metallic Corrosion* in **1932**, supervised by UR Evans.

***Corrosion of Metals* (1924)**

A student in Heycock's first course, UR Evans in this book promotes his 'new electrochemical theory'. He dominates this field for >50 years; in 1976, aged 87, he publishes his final, 421-page work. His 47 research students go on to distinction at Cambridge and far beyond.

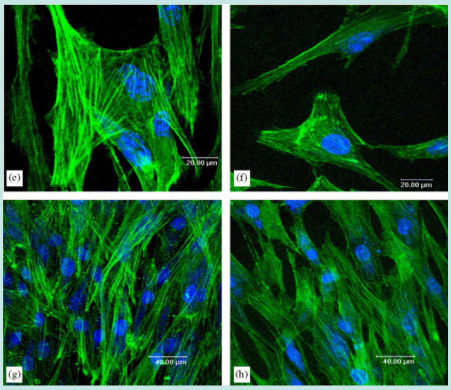
Materials Science & Metallurgy



Direct electrochemical reduction of TiO_2 to titanium in molten $CaCl_2$ [Chen, Fray & Farthing (2000)]. A worthy successor to the electrochemistry of UR Evans & the extractive metallurgy of JA Charles, Fray's work has also led to oxygen generation for wound healing and for survival in space missions.

Medical Materials (1999)

The appointment of Prof W Bonfield nucleates our thriving Cambridge Centre for Medical Materials, now directed by Ruth Cameron and Serena Best. Biomaterials is now an essential component of our undergraduate teaching.



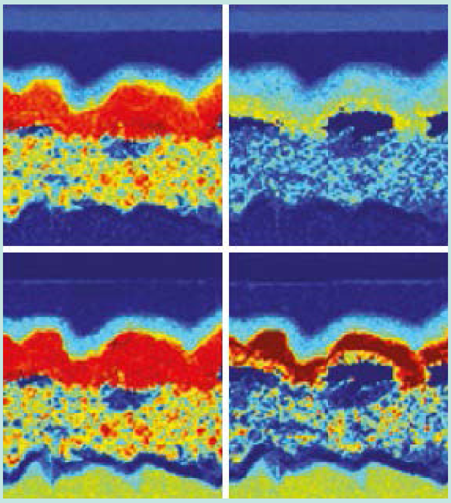
Response of osteoblasts to silicon-substituted hydroxyapatite thin films [Thian, Huang, Best, Barber, Brooks, Rushton & Bonfield (2006)]

***Modelling of Materials* (2000)**

Recognizing the rapidly growing importance of computer modelling, the Dept launches the UK's first masters' course in this subject.

DoITPoMS

Launched in **2000**, our on-line resource to assist undergraduate-level learning and teaching of Materials Science now has a library of nearly 900 micrographs in 12 categories, some 70 teaching and learning packages produced by and for students, and lecture demonstration packages. Over the last year, from across the world, there were 498,100 users and 2,134,434 page views.



In-situ observation of thermal degradation of perovskite solar cells [Divitini, Cacovich, Matteocci, Cinà, Di Carlo & Ducati (2016])

Armourers & Brasiers' Cambridge Forum

Inaugurated in **2004**, this incorporates the Kelly Lecture (1999). The Forum, supported by the A&B Company and other sponsors, highlights global developments in Materials Science. Each Kelly lecturer, whether Nobel laureate or captain of industry, provides insight on how Materials Science can transform, even save, our world. In **2007**, for example, our graduate **Mike Ashby** educated us on the environmental audit of materials choices.

Iron, cold iron, is master of them all

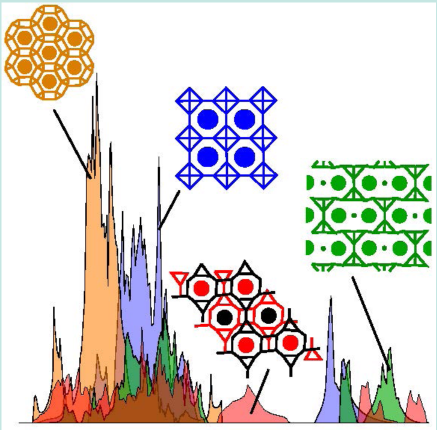
Kipling's words capture the importance of Harry Bhadeshia's work, recognized in his election (**2008**) as inaugural Tata Steel Professor (our second endowed chair), and in his knighthood (**2015**). Harry's work on nanoscale bainite is the culmination of the Dept's research on steels, first energized by his PhD supervisor Robert Honeycombe.

A greener light

Colin Humphreys' knighthood (**2010**) recognizes his services to science. We note in particular his work on gallium-nitride-based, energy-efficient, and now ubiquitous, light-emitting diodes. Spin-out companies have followed, and work on nitride semiconductors and quantum dots currently flourishes under the direction of Rachel Oliver.

Sir Alan Cottrell Professorship (2015)

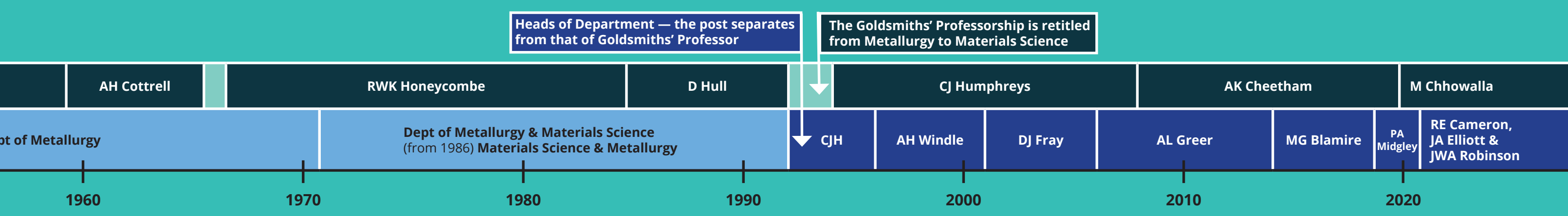
Christopher Pickard is the inaugural electee to our third named chair. His work realises Sir Alan's ambition, some six decades earlier, to predict materials properties from electron fundamentals.



High-throughput discovery: the highest-T_c conventional superconductors at 100 GPa. [Shipley, Hutcheon, Needs & Pickard (2021)]

Lindsay Greer

References to original sources for this centenary overview are available on the Departmental website.



New Museums cites

From 1972 to 2013 our postcode in the city centre was CB2 3QZ, from which we have more than 5800 papers. Two of these each have more than 7000 citations: *First Principles Methods using CASTEP* (2005) (co-author CJ Pickard, then at the Cavendish Laboratory); *Electron-Energy-Loss Spectra and...* (1998) (co-author CJ Humphreys).

Research Excellence

In **REF2014**, 69% of the Dept's activities are rated 'world-leading' and our grade point average is 3.65, the highest for any STEM unit of assessment across the UK's universities. This goes far beyond our lead in Materials Science in all previous RAE/REF assessments.

And looking forward

Our alumna Dame Julia King FREng FRS, Baroness Brown of Cambridge, brings us an authoritative view, spanning academia, industry and parliament. When Julia was at New Hall (now Murray Edwards College), our third-year course had separate streams for *Materials Science* and for *Metallurgy*. Julia chose the latter, obtaining (of course!) a first-class degree, followed by a PhD on *Fracture Mechanics in Embrittled Alloy Steels*. Research led to a faculty position at Nottingham, and (encouraged by Goldsmiths' Prof Colin Humphreys) to a lectureship back with us. In our pipeline of distinction, her place is special: Alan Cottrell was the PhD supervisor of John Knott, who supervised Julia; among her more-than-a-dozen research students was David Knowles, now CEO of the Henry Royce Institute, and himself the PhD supervisor of several students in our Dept.

Against stiff competition, Colin and Julia established our Rolls-Royce UTC. This so impressed the company that they hired her, ending her 16 years in university research. In Rolls-Royce, Julia rose fast: Head of Materials, Managing Director Fan Systems and Engineering Director Marine. She moved to be CEO of the Institute of Physics, then Principal of the Engineering Faculty at Imperial College London, then Vice-Chancellor of Aston University.

Julia has a CBE for services to materials engineering and a DBE for services to education and technology. In 2015 she was elevated to the peerage and sits as a crossbench member of the Lords. She chairs the Adaptation sub-committee of the *UK Committee on Climate Change*. She is Chair of *The Carbon Trust* and *STEM Learning Ltd*, a Non-Executive Director of *Ørsted* and a council member of *the Royal Society*. Who better could we have to introduce us to:

Critical, exciting, urgent!

There has been never a more critical or exciting time for materials – materials are at the centre of our global challenges.

As vice-chair of UK's *Climate Change Committee* from 2008 to February 2021, I was closely involved in the the advice that formed the basis for the *Climate Change Act 2008* with 80% emissions-reduction target for 2050, and the analysis that showed that the UK can reach Net Zero by 2050 which led to the amendment, in law, of the target to 100% reduction.
Meeting Net Zero in 2050 requires:

- energy and resource efficiency: using less, things that last longer, can be reused, and finally recycled
- take up of new technologies: electrification, hydrogen, batteries, small modular reactors, perhaps fusion ...
- a dramatic change in our fuel use: 80–90% reductions in oil and gas, more than doubling the size of our electricity system and growing a new low-carbon hydrogen industry

- carbon capture and storage: using nature-based solutions such as woodland and wetland creation and peat restoration, supported by direct-air capture and undersea storage.

The role of materials in this transition cannot be overestimated.

Lighter, stronger, more wear-resistant materials. Materials that reduce the energy consumption of electronic devices. New materials for insulating the 30 million buildings that account for about 20% of our CO_2 emissions from using gas for heating. Solid-state batteries, more-efficient fuel cells, new energy-storage materials, materials to resist the exceptional conditions in fusion reactors. Materials for a hydrogen-energy system. Hydrogen steelmaking, zero-carbon concrete and recyclable composites to build the 100 GW of offshore wind-turbines needed around our coasts in a zero-carbon electricity system in 2050.

New materials to capture CO_2 and other greenhouse gases from the air, molecular sieves to separate hydrogen from methane, replacements for rare metals and minerals in catalysts and electrodes. Artificial meats and milks to replace up to 35% of beef and dairy in our diets by 2050 to reduce emissions and free up space for tree planting.

Every step on the Net Zero transition needs better use of existing materials and throws up new materials challenges to decarbonise faster and more cheaply. It is not surprising that advanced materials feature as a key technology for the UK in the Government's new Innovation Strategy.

The Henry Royce Institute for Advanced Materials, of which Cambridge is a founding Partner, has been co-ordinating, with the wider materials community, a series of materials roadmaps for delivery of Net Zero. These show that many of the next-generation materials we need are already showing great promise; our challenge is to accelerate their translation through to production at scale.

Extreme weather events around the globe remind us that delivering Net Zero is urgent. Urgency is a challenging but also a motivating message. The staff and students in the Department at Cambridge, and what you do, will be critical to achieving our goals.

Julia, The Baroness Brown of Cambridge

And our Heads of Department respond that we are:

Ready for the challenge!

As our centenary closes, we look forward to the next 100 years of Materials Science in Cambridge, and beyond. As Niels Bohr put it, "prediction is very difficult, especially if it's about the future!" However, we can be sure that mitigating the effects of climate change and managing the energy transition from fossil fuels will be on the agenda for at least the next century. As Dame Julia makes clear, Materials Science is vital in delivering these objectives. Recognizing the scale of the challenges, Cambridge Zero and Energy Transitions@ Cambridge aim to bring together researchers with the right combination of skills. We are fortunate that the Department is well placed to lead the way, with an exciting portfolio of outstanding work by a diverse group of talented researchers at all levels.

Current work looks forward to materials for high-efficiency lighting, and for rechargeable batteries with higher energy density and lower cost than Li-ion. Solar spectral conversion, or plasmonic concentrators with highly efficient photovoltaic cells, will allow more capture of the energy we need directly from the sun. Compact, solid-state heat pumps will control the temperatures in our homes and workplaces. New materials will capture carbon that would otherwise be emitted by burning fossil fuels and enable removal of carbon emissions already in the atmosphere. Plastic packaging for foods will be made from plant-derived feedstocks. Large-scale manufacture of carbon nanomaterials will transform transport and electricity distribution. Further prospects are novel metallic alloys for modular nuclear reactors, and new generations of medical and pharmaceutical materials to protect and maintain the health of our demographically changing population.

Materials research will continue to rely on state-of-the-art characterization by: electron microscopy resolving single atoms both spatially and chemically; mechanical testing of soft and hard materials; X-ray analysis of structures; and methods not yet known. Computation, perhaps even running on quantum computers, will increasingly enable discovery of materials with unexpected properties; already the goal of materials that are superconducting at ambient temperatures and pressures is almost within our grasp.

We have no doubt that, 100 years on, our successors will have plenty of successes to extol as they survey our 2nd century!

James Elliott, Ruth Cameron and Jason Robinson