**Institution:** Imperial College London

**Unit of Assessment:** 8 – Chemistry

**Title of case study:** B8-4 Interdisciplinary Chemistry-led research leading to new ventures in Drug Discovery, Diagnostics and Personal Care

**Period when the underpinning research was undertaken:** 2010 – 2018

**Details of staff conducting the underpinning research from the submitting unit:**

| Name(s): | Role(s) (e.g. job title): | Period(s) employed by submitting HEI: |
|---|---|---|
| Professor Edward Tate | Professor of Chemical Biology | ET: April 2004-present |
| Professor David Klug | Professor of Chemical Biophysics | DK: Oct 1987- present |
| Professor Robert Law | Professor of Biological Materials | RL: Jan 1997 -present |

**Period when the claimed impact occurred:** 1 August 2013 – 31 December 2020

**Is this case study continued from a case study submitted in 2014?** N

## 1. Summary of the impact

Cultivating synergies between the physical and life sciences is at the heart of Imperial College's (IC's) interdisciplinary Institute of Chemical Biology (ICB). Chemistry research originating at the ICB in collaboration with other scientists and clinicians at IC and elsewhere has led to a pipeline of innovative corporate ventures in drug discovery, diagnostics and personal care. Recent highlights include the IC spinout Myricx Pharma, which is driving new therapeutic approaches for refractory cancers and has attracted over £4.5 million in seed funding; Vidya Health, which is developing at-home diagnostic devices, with a prototype currently in patient trials and around [redacted] in seed funding; and BioMin, a now trading company disrupting the global consumer dental health market – currently valued at [redacted] with an annual turnover of [redacted] and sales/ licensing across Europe, China, USA, India and Australia.

## 2. Underpinning research (indicative maximum 500 words)

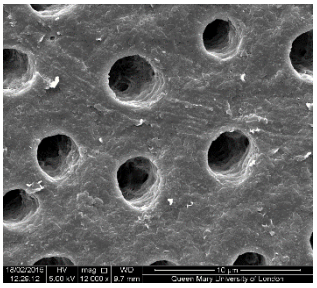
For 15 years, the Institute of Chemical Biology (ICB) at IC has pioneered and led research, innovation and education at the interface of the physical, life and medical sciences. Its mission is to develop novel tools and techniques to solve pressing challenges in biomedical science. Research themes cover the spectrum of healthcare, and include **drug discovery, diagnostics and personal care**. A major priority for the ICB is training of the next generation of scientists and innovators who are well versed in both physical and life sciences – which is delivered through Centres for Doctoral Training (CDTs). Highlighted below are three multidisciplinary research projects – all involving academic staff and postgraduates in Chemistry, Physics, and Life Sciences at IC and medical departments including the National Heart and Lung Institute, the Centre for Experimental Medicine (Belfast), the Institute of Cancer Research, the Royal Marsden Hospital and Dental Physical Sciences at Barts – that have ultimately underpinned promising and successful biotech ventures (detailed further in Section 4).

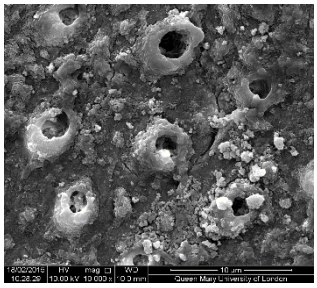
A major research theme of the ICB is **drug discovery**, and **Professor Edward Tate** leads a group focused on the design and application of chemical approaches to understand and modulate living systems, with an emphasis on controlling processes important to the progression of diseases. Over several years, the team has investigated the action of human *N*-myristoyltransferase (NMT) 1 and 2, which catalyse *N*-terminal protein myristoylation. This derivatisation plays vital roles in modulating protein-protein interactions, targeting proteins to cytoplasmic and plasma membranes, and regulating cellular signalling pathways in several biological processes. In 2018, the group

discovered a potent and selective inhibitor of human NMT- 1 and 2, which was found to block capsid assembly and replication of the common cold virus **[1]**. NMT has also been proposed as a target in cancer. Most recently the group undertook a large-scale screening of cancer cell lines against a panel of NMT inhibitors, combined with a systems-level analysis of cellular response. This revealed that deregulation of MYC or MYCN renders cancer cells acutely sensitive to NMT inhibition **[2]**. This has formed the basis of IC spinout and funding of the company **Myricx Pharma**.

Another key pillar of research at the ICB is **healthcare diagnostics.** Working in this area is **Professor David Klug**, a co-founder of the ICB who chaired the Single Cell Proteomics Project, a £5 million multidisciplinary collaboration developing novel platform technologies for high throughput analysis. His group's recent work was focused on single molecule-sensitive affinity assays for the analysis of single and rare human primary cells in a variety of contexts. These methods were based on microfluidics, with optical trap cell handling and incorporating single molecule detection **[3]**. For example, the group has used a microfluidic antibody capture (MAC) chip to measure the expression of the tumour suppressor protein p53 and of its post-translationally modified form phosphorylated at serine-15 **[4]**. This work ultimately demonstrated a practicable workflow for single cell proteomics in clinically relevant samples and thus a potential translational route for single cell proteomics into medical diagnostics. The knowledge and experience developed during this research has led to the formation and funding of Vidya Health.

The **personal care sector** is of significant economic importance, with links to healthcare, and is a research focus for the ICB. **Professor Robert Law**, Professor of Biological Materials in the ICB, leads projects in this area. He specialises in materials chemistry, particularly the use of solid-state nuclear magnetic resonance (NMR) spectroscopy. Professor Law and team have used these techniques in the field of dental science, specifically in designing and characterising the behaviour of a novel toothpaste additive: fluoro-calcium-sodium phosphosilicate. This material rapidly dissolves during teeth brushing and directly crystallises to fluorapatite (FAP), $Ca_5(PO_4)_3F$, covering the tooth surface and thereby enhancing its resistance towards acid erosion **[5,6]**. Using Magic Angle Spinning (MAS) NMR, Professor Law and team were able to model and elucidate the mechanisms of the dissolution processes involved in the formation of FAP. This was critical in designing a formulation which released the correct ratios of ions to allow the direct precipitation of the FAP onto the tooth surface **[6]**. This research was key to the formation and funding of the now trading and profitable **BioMin Technologies Ltd.**





Occlusion of dentinal tubules by toothpaste, BioMin F®, shown right.

**3. References to the research** (indicative maximum of six references)

**[1]** Mousnier, A.; Bell, A.S.; Swieboda, D.P.; Morales-Sanfrutos, J.; Pérez-Dorado, I.; Brannigan, J.A.; Newman, J.; Ritzefeld, M.; Hutton, J.A.; Guedán, A.; Asfor, A.S.; Robinson, S.W.; Hopkins-Navratilova, I.; Wilkinson, A.J.; Johnson, S.L; Leatherbarrow, R.J.; Tuthill, T.J.; Solari, R. and Tate, E.W., Fragment-derived inhibitors of human N-myristoyltransferase block capsid assembly and replication of the common cold virus. *Nature Chem* 10, 599–606 (2018). https://doi.org/10.1038/s41557-018-0039-2

**[2]** Tate, E.W.; Faronato, M.; Calado, D. and Lueg, G., Patent: WO2020128475 A1 [Cancer Treatments] https://patents.google.com/patent/WO2020128475A1/en

**[3]** Salehi-Reyhani, A.; Kaplinsky, J.; Burgin, E.; Novakova, M.; de Mello, A.J.; Templer. R.H.; Parker, P.; Neil, M.A.A.; Ces, O.; French, P.; Willison, K.R, and Klug, D., A first step towards

practical single cell proteomics: a microfluidic antibody capture chip with TIRF detection. *Lab Chip*. 11, 1256-61 (2011). https://doi.org/10.1039/C0LC00613K

**[4]** Magness, A.J.; Squires, J.; Griffiths, B,; Khan, K.; Swain, A.; Willison, K.R.; Cunningham, D.; and Klug, D., Multiplexed single cell protein expression analysis in solid tumours using a miniaturised microfluidic assay, *Convergent Science Physical Oncology*, 3, 2057-1739 (2017). https://doi.org/10.1088/2057-1739/aa6aae

**[5]** Brauer D.S., Karpukhina N., Law R.V., Hill R.G., Structure of fluoride-containing bioactive glasses. *Journal of Materials Chemistry* 19 (31), 5629-5636 (2009). https://doi.org/10.1039/B900956F

**[6]** Brauer, D.S.; Karpukhina, N.; O'Donnell, M.D.; Law, R.V.; Hill, R.G., Fluoride-containing bioactive glasses: Effect of glass design and structure on degradation, pH and apatite formation in simulated body fluid. *Acta Biomaterialia* 6, 3275-3282 (2010) https://doi.org/10.1016/j.actbio.2010.01.043

**4. Details of the impact** (indicative maximum 750 words)

Since its formation in 2005, the Institute of Chemical Biology in the Department of Chemistry has had considerable influence on the chemistry-facing multidisciplinary landscape at IC and beyond. Its success in forging links between physical and life scientists, as well as with engineers and clinicians, underpinned the approach and design of the £167 million Chemistry-led Molecular Sciences Research Hub (MSRH) at IC's White City Campus, which opened in October 2019 **[A]**. Representing the largest investment in a university building in 21st century London, the MSRH is designed to break down traditional barriers between chemistry, other physical sciences, biological sciences and medical disciplines: it brings together the collective expertise of more than 800 scientists, clinicians, engineers and corporate business partners.

Allied to this major multidisciplinary initiative, the ICB has long placed considerable emphasis on translation, drawing in commercial and clinical partners – an approach which also underpinned the wider innovation initiatives at the IC White City campus. This ecosystem now includes space and specialist facilities for ideation and business development at every stage – from prototyping facilities at the Chemistry-led IC Advanced Hackspace, to laboratories and offices for early-stage start-ups at the IC White City Incubator, as well as greater scope for fast growing companies at the Scale Space facility **[A]**. This ecosystem has also proved attractive for multinationals, for example with the pharmaceutical giant Norvartis locating its European HQ to White City in 2020 **[A]** along with L'Oréal, the world's largest cosmetics company **[A]**.

Highlighted below are three recent ventures, that have respectively resulted from research in drug discovery, healthcare diagnostics and on personal care products at the ICB (detailed in Section 2).

**New therapeutic approaches to cancer: Myricx**

The MYC family oncogene is deregulated in over half of all human cancers and is frequently associated with poor prognosis and patient survival. Indeed, MYC has a central role in almost every aspect of the oncogenic process, orchestrating proliferation, apoptosis, differentiation, and metabolism. However, direct targeting of MYC has been a challenge for decades owing to its supposed 'undruggable' protein structure. Yet, recent work from the laboratory of Professor Ed Tate in Chemistry has shown *N*-myristoyltransferase (NMT) inhibition, with a potent and selective small molecule, is lethal to MYC-deregulated cancer cells. This mechanistic framework supports NMT inhibition as a novel targeted therapeutic approach and led to the formation of small molecule drug discovery company Myricx Pharma, with Professor Tate as Chief Scientific Officer (CSO) and Dr Roberto Solari, from the National Heart & Lung Institute at IC as Chief Executive Officer (CEO). The Company raised an initial £4.5million in seed investment from Sofinnova Partners and Brandon Capital Partners in 2020 **[B]** [redacted]

The initial focus is the development of novel NMT inhibitors for oncology [redacted]

[redacted]. The Myricx collaborative team has also been actively studying the role that NMT plays in viral pathogens, with a view to developing anti-viral therapies.

[redacted]

**Next generation diagnostics: Vidya Health**

The consumer health monitoring market has gained traction recently, with companies offering at-home postal blood testing services. A closed-loop saliva test would be far more attractive prospect, allowing longitudinal testing at different times of day. Professor David Klug is the Chief Scientific Officer of Vidya Health – a company developing technology for saliva testing at home, at the point of care and in retail outlets, underpinned by Chemistry research in the ICB at IC. Vidya has raised a cumulative total of around [redacted] in investment to date from a syndicate of investors **[C]**. [redacted]. Vidya recently took part in a trial of its technology supported by Innovate UK and in collaboration with UCL, St. Bartholomew's Hospital, Royal Free Hospital and UCLH aimed at detecting coronavirus antibodies in around 300 healthcare workers **[D]**. This is helping to address specific questions around immune function. Future trials in other clinical areas are planned, with the ultimate aim being early detection of a range of conditions including but not limited to cancers, liver and kidney conditions, diabetes, pregnancy related conditions, cardiovascular and inflammatory and infectious conditions **[E]**.

[redacted]

**Consumer dental health: BioMin Technology**

Virtually all toothpastes currently on the market rely on very old technology from the 1930s. Essentially the presence of fluoride, $F^-$, inhibits the reaction between food and drink-derived acid (e.g. citric, maleic, tartaric, lactic, phosphoric acid) and the alkaline ($OH^-$) tooth surface. Over a number of years, ICB Professor Robert Law developed a novel toothpaste additive that rapidly dissolves during teeth brushing and directly crystallises to cover the tooth surface to resist acid erosion and enable remineralisation of enamel. In addition, this precipitation allows suppression of hypersensitivity at the gum-tooth join through the occlusion of dentinal tubules. This technology platform led to the creation and funding of BioMin Technologies Ltd. in 2013 (biomin.co.uk). Several independent dental clinical studies have confirmed the efficacy of the additive against dental tooth decay and hypersensitivity (e.g. **[F]**). The company began production and online sales of its proprietary toothpaste in 2018, through Amazon **[G]**. Currently the company is valued at [redacted] and has a turnover of [redacted], which includes direct sales and licensing **[H]**. Indeed, the active ingredient of the toothpaste has been sold under license to other toothpaste manufacturers around the world including those in China (Guangdong Kanwan Cosmetics Corp.), India (Group Pharmaceuticals Ltd. (Elsenz)), USA (Dr.Collins, Inc.), Australia (BioMin Technologies Ltd.) and Europe (BioMin Technologies Ltd.). Uniquely in the USA, BioMin Technologies Ltd possesses a considerable market advantage in producing only remineralising toothpaste product available that contains a single active component and therefore compliant with FDA regulations for medical devices **[I]**. Through this global expansion, the company aims to reduce the economic and healthcare burden associated with dental diseases.

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

**[A]** Collated evidence for the impact of the MSRH at the White City Campus (Archived here)

- Imperial College's £200m 'rent-a-lab' complex opens in west London. Evening Standard. https://www.standard.co.uk/news/london/imperial-colleges-200m-rentalab-complex-opens-in-west-london-a3379116.html
- How universities can drive an inclusive recovery. Imperial Stories. https://www.imperial.ac.uk/stories/inclusive-recovery/
- Novartis headquarters opens in White City, London. European Pharmaceutical Review. https://www.europeanpharmaceuticalreview.com/news/112652/novartis-headquarters-opens-in-white-city-london/
- L'Oreal opens new London HQ... because it's worth it. Evening Standard. https://www.standard.co.uk/news/london/l-oreal-opens-new-london-hq-because-it-s-worth-it-a4327271.html

**[B]** Collated evidence for investment in Myricx Pharma

- Myricx Pharma Launches with £4.5M Financing to Progress its Novel NMT inhibitors in Cancer. Bloomberg. https://www.bloomberg.com/press-releases/2020-11-16/myricx-pharma-launches-with-4-5m-financing-to-progress-its-novel-nmt-inhibitors-in-cancer (Archived here)
- Confirmation letter from Sofinnova Partners and Brandon Capital Partners

**[C]** Confirmation letter from a Partner at Hoxton Ventures.

**[D]** COVID-19: Healthcare Worker Bioresource: Immune Protection and Pathogenesis in SARS-CoV-2 (COVID19-HCW) https://clinicaltrials.gov/ct2/show/NCT04318314 / Innovate UK funded projects since 2004 https://www.gov.uk/government/publications/innovate-uk-funded-projects [Competition Code: 2003_CRD_CO_COVID19_P1] – see related grant here (Archived here)

**[E]** Funding to Vidya Health for Saliva Diagnostics. NHS Health Research Authority. https://www.hra.nhs.uk/planning-and-improving-research/application-summaries/research-summaries/saliva-diagnostics/ (Archived here)

**[F]** Shaikh K, Pereira R, Gillam DG, Phad S (2018) Comparative Evaluation of Desensitizing Dentifrices containing BioMin®, Novamin® and Fluoride on Dentinal Tubule Occlusion before and after a Citric Acid Challenge– A scanning Electron Microscope in-vitro Study. J Odontol 2: 105. https://www.longdom.org/open-access/comparative-evaluation-of-desensitizing-dentifrices-containing-biominnovamin-and-fluoride-on-dentinal-tubule-occlusion-before-and.pdf (Archived here)

**[G]** BioMin Toothpaste 75ml: to Support Natural remineralization with Fluoride, Fight Tooth Decay and Prevent staining to Assist Teeth whitening. Amazon's Choice. https://www.amazon.co.uk/toothpaste-EasyPick-support-remineralisation-cleaning/dp/B01N901QRD/ (Archived here)

**[H]** Letter from Richard Whatley, Chief Executive Officer, BioMin Technologies Ltd.

**[I]** Dr.Collins BioMin Toothpaste Receives FDA Approval. https://markets.businessinsider.com/news/stocks/dr-collins-biomin-toothpaste-receives-fda-approval-1028470492 (Archived here)