Institution: University of East Anglia

Unit of Assessment: 8 – Chemistry

Title of case study: Iceni Diagnostics Ltd. – Therapeutics and Point of Care Diagnostics for Infectious Diseases

Period when the underpinning research was undertaken: 2003 - 2016

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:
David Russell Robert Field	Professor of Chemistry Professor of Chemistry	1991 to 2016 2001 to 2007

Period when the claimed impact occurred: March 2014 to December 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

Iceni Diagnostics is a spin out company from research initiated in the School of Chemistry, University of East Anglia by Professor David Russell and Professor Rob Field. The company is developing carbohydrate-based therapeutics and point-of-care diagnostics for infectious diseases. These include: a ▮▮▮▮▮▮ vaccine that has undergone pre-clinical testing; separate lateral flow diagnostics for equine, avian and human influenza that have undergone beta testing and; a combined influenza / coronavirus lateral flow diagnostic for which a clinical batch has been manufactured and is currently being validated by Government agencies.

Iceni Diagnostics is an example of **economic impact**. Since foundation in March 2014, the company has attracted funds in excess of ▮▮▮▮▮▮. This sum has been achieved through: winning contracts from ▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮ UK and Swiss biotechnology industries; three equity-based investment rounds; research grants; and the award of a Longitude Discovery Prize. The company moved into independent laboratory and offices within the Norwich Research Park Innovation Centre in June 2016 ▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮

2. Underpinning research

Professor David Russell (UEA 1991 – 2016) and **Professor Rob Field** (UEA 2001-2007; John Innes Centre, Norwich 2007-2019; University of Manchester 2020 to date) have worked together for more than 17 years on the development of new methods in carbohydrate recognition in the context of detection, quantification and therapeutic impact. Over this period, they have developed a series of bioassays based on carbohydrate functionalised gold and silver nanoparticles for the detection of a variety of bacterial pathogens and viruses.

Initial research showed that by stabilising gold nanoparticles with a simple mannose derivative the cognate lectin could be readily quantified (1). This initial work led to glyconanoparticle bioassays being developed based on either gold or silver nanoparticles for the rapid detection of target analytes (2). Specific carbohydrate ligands, based on lactose, were synthesised to mimic the GM1 ganglioside to enable the specific detection of cholera toxin (3). An EPSRC project, co-funded by the Ministry of Defence (MoD) (via the Defence Science and Technology Laboratory, DSTL), enabled the development of a simple, yet rapid bioassay for the detection of RCA_{120}, a ricin surrogate (4). The latter work led to considerable media coverage.

Following the outbreak of the H5N1 avian influenza in 2008 a new project was initiated to develop a bioassay to detect, and discriminate between, human and avian influenza viruses. A glyconanoparticle bioassay system was devised that discriminated between human and avian influenza based on the binding characteristics of the conformation of the trivalent carbohydrate ligand. The carbohydrate ligand in the α2,6 configuration binds to the haemagglutinin of the human virus whereas the ligand in the α2,3 configuration only binds to the haemagglutinin on the avian virus (5).

Prior to publication, the work on the human and avian influenza was patented (6). In 2014 Dr María Marin (previously a PhD student and then post-doctoral research associate during the underpinning research period) presented this research at the *SET for Britain* at the Houses of Parliament. Not only did she win the gold medal for Chemistry, she also won the overall prize, the Westminster medal, across all five Science, Engineering and Technology disciplines.

A BBSRC Follow-on Fund grant was awarded to Field and Russell in 2014 to investigate the commercial viability of the development of bioassays, based on carbohydrate functionalised gold nanoparticles, for the detection and discrimination of human and avian influenza.

3. References to the research

Publications

(UEA authors in **bold**; citations obtained from Google Scholar December 2020)

1. Rapid, quantitative colorimetric detection of a lectin using mannose-stabilized gold nanoparticles
   D.C. Hone, **A. H. Haines** and **D.A. Russell**.
   Langmuir, **2003**, *19*, 7141-7144. (cited 211 times)
   DOI: 10.1021/la034358v

2. Silver and gold glyconanoparticles for colorimetric bioassays
   C.L. Schofield, **A.H. Haines**, **R.A. Field** and **D.A. Russell**.
   Langmuir, **2006**, *22*, 6707-6711. (cited 227 times)
   DOI: 10.1021/la060288r

3. Glyconanoparticles for the colorimetric detection of cholera toxin
   C.L. Schofield, **R.A. Field** and **D.A. Russell**.
   Analytical Chemistry, **2007**, *79*, 1356-1361. (cited 220 times)
   DOI: 10.1021/ac061462j

4. Colorimetric detection of Ricinus communis Agglutinin 120 using optimally presented carbohydrate stabilised gold nanoparticles
   C.L. Schofield, **B. Mukhopadhyay**, **S.M. Hardy**, M.B. McDonnell, **R.A. Field** and **D.A. Russell**.
   Analyst, **2008**, *133*, 626-634. (cited 100 times)
   DOI: 10.1039/b715250g

5. Glyconanoparticles for the plasmonic detection and discrimination between human and avian influenza virus
   M.J. Marín, A. Rashid, M. Rejzek, S.A. Fairhurst, S.A. Wharton, S.R. Martin, J.W. McCauley, **T. Wileman**, R.A. Field and **D.A. Russell**.
   Organic and Biomolecular Chemistry, **2013**, *11*, 7101-7107. (cited 76 times)
   DOI: 10.1039/c3ob41703d

6. **Patent** WO 2015/011441; PCT/GB2014/052026, Virus detection
   R.A. Field, A. Rashid, M. Rejzek, **D.A. Russell**, **M.J. Marín**.

Grants

1. EPSRC Technologies for Crime Prevention and Detection, *Nanostructured assemblies for the detection of biological agents* (grant co-funded by MoD)
   D.A. Russell and **R.A Field**, 2004-2007, GBP219,051 (UEA).

2. RCUK Basic Technologies, *Glycochips – Strategies for high throughput analysis of the glycome*
   S. Flitsch (Manchester); P. Crocker (Dundee); **R.A. Field** (UEA); **D.A. Russell** (UEA); A. Dell, T. Feizi (Imperial College); J. Turnbull (Liverpool); B. Davis (Oxford), 2004-2008, GBP2,925,689 (UEA - GBP386,933).

3. EPSRC Basic Technology, *Translation Exploitation of Glycoarrays – Translation to End-use*
   S. Flitsch (Manchester); A. Dell, S. Haslam, T. Feizi (Imperial College); P. Crocker (Dundee); J. Turnbull (Liverpool); **D.A. Russell** (UEA); R.A. Field (JIC); A. Powell (LJM), 2009-2011, Total award GBP846,367.

4. BBSRC Follow-on funding, *Glyconanoparticle diagnostics for the detection and discrimination of human and avian influenza*
   R.A. Field (JIC) and **D.A. Russell** (UEA), 2015-2016, GBP193,837 (UEA GBP83,338).

4. Details of the impact

Iceni Diagnostics Ltd. was founded in March 2014 [**corroborating source A**]. The company is a University of East Anglia (UEA) / John Innes Centre (JIC) spin out based on the research of **David Russell** and **Rob Field**. Iceni Diagnostics is focused on the synthesis of bespoke carbohydrates for the recognition of infectious diseases. The carbohydrates synthesised mimic natural interactions between the host and the pathogen. Importantly, while bacteria and viruses mutate rapidly, the recognition of host carbohydrates is essential for pathogens and so does not change year-on-year. By using the natural carbohydrate recognition, Iceni Diagnostics is developing innovative therapeutics and point-of-care diagnostics that will be immune to virus or bacterial mutation.

The company undertakes collaborative and contract R&D activities, through engagement with the UK and Swiss biotechnology sector and Government Agencies, whilst developing its own diagnostic and therapeutic products.

Iceni Diagnostics demonstrates **economic impact** as follows:

- ██
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  [**corroborating sources B and C**]

- Iceni Diagnostics has won three rounds of equity investment totalling ████████ Comprising:
  - Seed investment from the Iceni Seedcorn Fund LLP ████████ in October 2016
  - A second investment round from a group of Norfolk/Suffolk based investors, including New Anglia Capital (investment arm of the New Anglia LEP) in October 2018 ████████
  - A third investment round from angel and local enterprise investors including New Anglia Capital and members of Anglia Capital Group in December 2020 ████████
  [**corroborating source C**]

- In addition, Iceni Diagnostics has won six, non-dilutive, grants totalling GBP681,000. Grant funding obtained includes an Innovate UK Biomedical Catalyst grant to develop a diagnostic for norovirus (January 2017), an Eastern Agritech R&D grant to prototype a diagnostic for avian influenza (July 2017), two grants from the EU, both valued at GBP235,000 (April and July 2019 respectively), and an Innovate UK grant for the development of a coronavirus diagnostic (May 2020). [**corroborating source C**]

- Iceni Diagnostics was awarded an *International Longitude Discovery Prize* of GBP13,000 for the company's work on diagnostics to tackle anti-microbial resistance (November 2016). [**corroborating source D**]

- The combined investment, contracts, grant funding and prize, totals in excess of ████████.

- The combined funds have established Iceni Diagnostics as a commercially viable company, which has supported the sustained employment of ████████ ████████ since company foundation. In addition, Iceni Diagnostics has supported 5 PhD Industrial CASE students since 2015 – two at the John Innes Centre (Norwich), and

one each at Leeds, Manchester and Warwick Universities. [**corroborating source C**]

- A patent which describes the detection of, and discrimination between, human and avian influenza – originally filed by University of East Anglia and Plant Biosciences Ltd. in 2013 and assigned to Iceni Diagnostics in 2018 – has now been granted in GB, Europe, the US and China. [**corroborating source E**]

Product Development

The centrepiece of Iceni Diagnostics' product development portfolio is the rapid and facile detection of infectious viruses where the patented technology addresses a well-defined need in the USD4,000,000,000 equine, avian, porcine and human influenza market for a rapid point-of-care diagnostic. The developed technology is based around a lateral flow device – similar to a pregnancy test. Rather than using the traditional antibody or nucleic acid based technology, Iceni Diagnostics are using their bespoke carbohydrates for the molecular recognition of the virus, with the aggregation of gold nanoparticles used to provide a visible signal of the recognition event. The devices created are simple to use at the point of interest, whether that is at racecourse or stable yard for equine influenza, at the farmyard for avian influenza or the hospital ward / GP surgery for human influenza. Samples are collected using nasal or nasopharyngeal swabs, mixed in transport medium and then pipetted onto the lateral flow device. Results are obtained within 15 minutes. Such devices enable real time intervention rather than sending samples to be analysed at a laboratory and waiting, up to 48 h, for results. Whilst the company's focus has primarily been on influenza, the technology has applicability for any viral disease where carbohydrates are critical for the pathogen to replicate - the on-going coronavirus (SARS-CoV2) pandemic is the obvious example.

Equine, Human, and Avian Influenza Diagnosis
Beta products for equine influenza detection have been trialled at the British Horseracing Authority in Newmarket, and the Suffolk Punch Trust in Woodbridge, with positive feedback particularly with regard to the ease of use by non-scientific personnel, and the speed with which results are available. Sensitivity trials and comparison to qPCR were conducted in 2020 at the Animal Health Trust, Lenwade, Suffolk [**corroborating source C**]. Beta products for human and avian influenza detection have been validated by the UK Animal and Plant Health Agency. [**corroborating source C**]

Coronavirus
In March 2020 further development of the three single influenza diagnostics was paused as Iceni Diagnostics adapted its proprietary technology to develop a new point-of-care diagnostic for coronavirus. In May 2020 Iceni Diagnostics was one of the companies selected in the fast-track Innovate UK competition aimed at addressing the unique challenges arising from COVID-19, which attracted more than 8,600 applications. Iceni Diagnostics has now developed a combined SARS-CoV2 and influenza lateral flow diagnostic. BBI Solutions Ltd., an ISO13485 accredited manufacturer, was appointed to generate clinical batches of this combined diagnostic with the first 5000 devices already having been produced. The diagnostic is currently (December 2020) being validated by UK Government through Public Health England (PHE). [**corroborating sources C, F and G**]

Norovirus
In the human healthcare market, another disease target is norovirus (known as winter vomiting virus). Iceni Diagnostics, working with the Microbiology Laboratories at the Norfolk and Norwich University Hospital, were funded by Innovate UK to develop a simple lateral-flow based diagnostic for use on the hospital ward. [**corroborating source H**]

vaccine

[**corroborating source C**].

Recognition

Iceni Diagnostics has received external recognition for its work in the development of novel diagnostics and therapeutics. In November 2016, Iceni Diagnostics was awarded an *International Longitude Discovery Award* for the company's work on diagnostics to tackle anti-microbial resistance. This award was made to only 12 teams from the US, UK and India out of over 70 applications from 19 countries. This International Prize of GBP13,000 highlighted the innovative nature of the research at Iceni Diagnostics. [**corroborating source D**]

In addition to the *International Longitude Discovery Award* in 2016, Iceni Diagnostics has been the winner of three regional business awards. Firstly, the Eastern Daily Press '*Knowledge Catalyst*' Business Award (November 2017), secondly, the South Norfolk '*Excellence in Life Sciences*' Business Award (February 2019), and thirdly the joint winner of the Norfolk Business Awards '*Changing Lives Special Recognition Award*' (November 2020) for the company's response to the coronavirus pandemic. [**corroborating source I**]

5. Sources to corroborate the impact

[A]   Iceni Diagnostics Ltd. – Companies house registration 3rd March 2014

[B]

[C]   Letter from Iceni Diagnostics chairman (dated January 2021)

[D]   Longitude Prize Discovery Award, November 2016 (downloaded from Longitudeprize.org 17th October 2020)

[E]   Patent details - WO 2015/011441

[F]   Innovate UK press release (downloaded 27th September 2020)

[G]   Iceni Diagnostics appoints BBI Solutions Ltd. to manufacture combined coronavirus / influenza lateral flow diagnostic (downloaded from BBI Solutions Ltd. website 18th December 2020)

[H]   Innovate UK Norovirus grant award letter (November 2016)

[I]   Eastern Daily Press *Knowledge Catalyst* Business Award (downloaded from the EDP24 website 17th October 2020); South Norfolk *Excellence in Life Sciences* Business Award (downloaded from South-Norfolk.gov.uk 17th October 2020); Norfolk Business Awards *Changing Lives Special Recognition Award* (downloaded from EDP24 website – 18th December 2020)