

Institution: University of Strathclyde		
Unit of Assessment: A3 Allied Health Professions, Dentistry, Nursing and Pharmacy		
Title of case study: Rapid mass screening and detection of bacteria and toxins in food using improved automated immunoassays		
Period when the underpinning research was undertaken: 2000 - 2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): William Stimson	Role(s) (e.g. job title): Professor	Period(s) employed by submitting HEI: 01/04/1983 – 30/09/2009
Period when the claimed impact occurred: August 2013 - 2020		
Is this case study continued from a case study submitted in 2014? No		
<p>1. Summary of the impact</p> <p>Advances in immunology by Professor Stimson adopted by Solus Scientific Solutions Ltd. have expanded their food testing products, grown sales, increased employment and extended the company's reach in microbiological testing. Rapid assays (<24 hours) for all strains of <i>Listeria</i>, <i>Salmonella</i> and <i>Escherichia coli</i> have been devised, augmenting Solus' automated pathogen detection systems for these bacteria. Dedicated culture media based on the Strathclyde research allows sensitive detection of targeted organisms and control of false positive results. New kits for testing meat authenticity and allergen screen have also been introduced. Sales are up 43% from 2014 to GBP5,400,000 in 2019, with sales in 30 countries; and the number of employees increased from 24 to 43. Customers achieve higher productivity and efficiency owing to the greater sensitivity, simpler methodology and lower costs afforded through inclusion of Stimson's discoveries in Solus products. In 2019, Perkin Elmer purchased Solus for USD34,000,000, increasing access to global food diagnostics markets.</p>		
<p>2. Underpinning research</p> <p>Relationship to case study submitted in 2014</p> <p>This case study builds on the version submitted to REF2014. Although the underpinning research includes references mentioned in the REF2014 version of this case, other research by Stimson is described from which additional and extended impact has been derived.</p> <p>Context</p> <p>The prevention of food poisoning is a major concern worldwide. Mycotoxins are present in around 25% of foods throughout the world and are associated with many diseases and physiological disorders, including liver damage and cancers. Food poisoning bacteria like <i>Salmonella</i> and <i>Listeria</i>, and increasingly <i>E. coli</i> 0157.H7, cause millions of people to be ill every year. Consequently, testing for food pathogens is of critical importance for food safety. In Europe and North America, food industry regulations indicate the need to detect as little as one single organism in 25g of food. In order to detect such low levels of contamination, which is beyond the current capabilities of assay technology, bacterial numbers must be grown to a detectable level. The more sensitive the assay, the less time is required for bacterial growth, and the sooner detection can be made.</p> <p>Stimson's initial research in developing assays for immunology ultimately led him to develop a platform for bacterial detection that was rapid, highly sensitive, stable, simple and inexpensive. A</p>		

key factor was the development of a novel broth that allowed bacterial growth at the fastest possible rate, and had the capacity to resurrect injured organisms to give the required detection level of 500 bacteria in a few hours, even in the presence of 10 million competing organisms [R1]. Before this research, bacterial assays required two broths and would take 40 or more hours to grow a bacterial sample to a detectable size. Discovery of the improved growth medium and research in other aspects of immunology led Stimson to form a spin-out company in 2007, which became Solus Scientific Solutions Ltd. in 2009. Further research by Stimson then allowed Solus to expand its product range and impact on the microbiological analysis of food.

Key research findings

Immunology research by Stimson and colleagues resulted in advances in methodology that Stimson recognised could benefit various aspects of immunoassay development. In particular, Stimson aimed to develop assays able to detect the complete range of *Salmonella* strains (comprising close to 3000 strains in total). This led to the development of highly selective murine polyclonal and monoclonal antibodies capable of identifying the vast majority of strains in a single assay, as opposed to the dozens of tests previously required [R1]. For *Salmonella* strains that could not be identified with murine antibodies, assays were developed from related research by Stimson, employing polyclonal sheep antibodies active against specific oligosaccharide or peptide sequences in the *Salmonella* cell wall. In order to mature the response to the immunogen, immunisation protocols were designed using a human interferon-alpha subtype additive to the adjuvant [R2]. In addition, pharmacological suppression was employed using mice/rats pre-immunised with whole bacteria and then treated with Cyclosporin A to eliminate any lymphocytes reacting strongly with dominant antigenic determinants. The animals were then re-immunised with the weaker antigenic determinants in order to obtain enhanced antibody recognition of the species/genus-specific carbohydrate sequences, or weakly antigenic sites of importance in bacterial definition [R3, R4]. Additionally, NZB/NZW F1 female hybrid mice with hyperactive immune responses were also employed to enhance the immune response and provide specific high affinity antibodies of suitable sub-classes (IgG1, 2a/b) for the assay procedures. Combination of these advances from Stimson's distinctive body of immunology research [R1-R4] provided the basis for development of more extensive and sophisticated immunoassays for food testing applications.

Additional research [R5] to refine the composition of the culture growth medium and improve other aspects of the methodology optimised the immunoassay procedures for different microbiological targets including *Salmonella*, *Shigella* and *Listeria* species. The discoveries included changes to the selection of a detergent that reduces the bacterial cell wall into the smallest units possible, thus providing the greatest numbers of detection entities. Methods for detection of bacterial lipopolysaccharides using an antibody to a core oligosaccharide epitope were described [R5]. Infrastructure for automation of the assay was also developed [R6]. For luminescence detection, Stimson recommended a chemiluminescent derivative which provided significantly enhanced light output compared to alternative molecules, producing useful light for up to 8 seconds, which allowed detectability in the attogram range. This has resulted in pathogen detection fifty times more sensitive than alternative colorimetric devices [R6]. Together, these advances led to a reduction in overall assay time without increasing costs, to the point where automated mass microbiological screening of food products could be achieved within the one day, if required.

3. References to the research (Strathclyde-affiliated authors in bold; FWCI at 02/02/2021)

R1 S. Rahman and **W.H. Stimson** (2001) Characterisation of monoclonal antibodies with specificity for the core oligosaccharide of *Shigella* lipopolysaccharide, *Hybridoma* 20(2):85-90.

Published online in 2004 <https://doi.org/10.1089/02724570152057571>

R2 W.H. Stimson (2014, 2019) Composition and methods relating to the treatment of diseases. International Patent WO 2014/037717 13 March 2014; EU Patent, EP 2892556 B1, 15 May 2019. <https://bit.ly/3vPhRxT>

R3 M. Khan, V. Ferro and W.H. Stimson, W. H. (2003) Use of a highly specific monoclonal antibody against the central variable amino acid sequence of mammalian gonadotropin releasing hormone to evaluate GnRH-I tissue distribution compared with GnRH-I binding sites in adult male rats, *American Journal of Reproductive Immunology*, 49(4):1-10
<https://doi.org/10.1034/j.1600-0897.2003.01202.x>

R4 V. Ferro, R. Costa, K. Carter, M. Harvey, M. Waterston, A. Mullen, C. Matschke, J. Mann, A. Colston and W.H. Stimson (2004) Immune responses to a GnRH-based anti-fertility immunogen, induced by different adjuvants and subsequent effect on vaccine efficacy, *Vaccine*, 22(8):1024-1031 <https://doi.org/10.1016/j.vaccine.2003.08.043> [FWCI: 1.36]

R5 W.H. Stimson (2010). Culture media and detection means for food microbiological analysis. UK Patent GB 2463369, granted 17 March 2010. <https://bit.ly/3cUQREg>

R6 D. Cowan and W.H. Stimson (2015). Automated assay. International Patent WO 2015/114316 A2, 6 August 2015. [Available from HEI on request]

Notes on the quality of research: All journal articles are published in peer-reviewed leading journals in the field.

4. Details of the impact

This impact study builds on a case submitted to REF2014, which described how initial research by Stimson and colleagues led to a new immunoassay concept and formation of a spin-out company Solus Biologicals Ltd., which became Solus Scientific Solutions Ltd in 2009. Advances in propriety anti-bodies and immunoassay methods derived from Stimson's research have had a major impact on Solus's success during the current REF period. In July 2013, the company make the decision to adopt the Strathclyde technology for its Enzyme-Linked Immunosorbent Assay (ELISA) products for *Salmonella* and *Listeria*. Further product development influenced by Stimson's research has followed, generating significant benefit for the company and its customers. The main impacts since August 2013 have been:

- Economic – expanded product range, increased sales, job creation, and growth in customer base;
- Food safety – through wide adoption of the Stimson-inspired Solus testing kits.

1. Growth in the commercial success of Solus Scientific Solutions Ltd.

Product range

According to the then Chief Executive Officer of Solus, 'Over the period since 2013, Solus has continued to refine its product portfolio taking advantage of discoveries from Stimson's original research' [S1]. As of 2020, Solus provides a broad and expanding range of products including:

- Automated pathogen detection systems for *Salmonella*, *Listeria* and *E. coli* 0157 [S2]. Each system comprises a specifically designed immunoassay kit, dedicated selective enrichment media and automated liquid handling. These assays have received independent accreditation from the Association Française de Normalisation (AFNOR) and Association of Official Agricultural Chemists (AOAC) [S3].
- 'Solus One' rapid assays for all strains of *Listeria*, *Salmonella* and *E. coli* that are completed in less than 24 hours rather than the previous industry standard of 48 hours [S4]. The tests

are also cheaper and easier to apply than alternative molecular methods and give better performance especially for spices and cocoa products owing to novel features incorporated from Stimson's research [S1]. 'Solus One' assays for *Salmonella* have achieved AOAC approval [S4].

- Dedicated culture media for the 'Solus One' and 'Solus ELISA' ranges, allowing for the sensitive detection of target organisms as well as the control of false positive results due to overgrowth of any background flora [S5].
- Meat species identification kits for determining the authenticity and adulteration of raw meat for food manufacturers and contract testing laboratories [S6]. The immuno-assays are available in ELISA and rapid flow-through formats.
- Allergen screening range for the detection of gluten, casein and soya contamination in raw materials, production equipment and food samples [S7].

Job Creation and Economic growth

In June 2018, Solus opened a regional office in Cincinnati, USA, which now employs three people. As of 2020, 43 jobs had been created by Solus – an increase of 19 since 2013.

Table 1 (below) shows sales from 2013 to 2019, by which time the annual turnover of the company had reached GBP5,400,000 and EBITDA had grown 75% from 2014 [S1]. The total sales in the period 2014-2019 were just over GBP26,500,00. In early 2016, Solus gained a USD1,000,000 contract with Toho Technology, Japan, to develop range of assays for pathogens on environmental swabs [S1].

In 2019, attracted by the strong financial performance of the company, Perkin Elmer - a major US-based diagnostics company - purchased Solus for USD34,000,000 [S1, S8]

Table 1 [S1]

	2013 actual	2014 actual	2015 actual	2016 actual	2017 actual	2018 actual	2019 actual
Sales (k GBP)	4,135	3,801	3,553	3,892	4,625	5,245	5,442
EBITDA* (k GBP)	(145)	434	125	391	424	617	759
EBITDA (%)	-3.51	11.43	3.52	10.05	9.17	11.77	13.94

* Earnings before interest, tax, depreciation and amortization

Customers and reach

Solus is now a leading supplier of pathogen food tests in the UK and is currently expanding into other regions. Productivity has increased in line with demand: in the first half of 2018, *Salmonella* kit production was up by 18% and *Listeria* by 49% compared to the same period in 2017 [S1]. As of 2020, Solus products are sold and used in 30 countries around the world, including countries in Europe, North America, Africa and the Asia-Pacific region [S1].

Customers include global food testing companies such as Eurofins, Bureau Veritas and Intertek, food manufacturers Kerry Foods and Bakkavor, and major retailers such as Tesco and Marks & Spencer in the UK, Walmart (USA) and Woolworth (South Africa) [S1].

In recent years sales and marketing have increased in the UK, USA and Asia-Pacific, benefitting from the wide distributor network that now exists [S9]. The 2019 purchase by Perkin Elmer allows Solus even greater access to the global food diagnostics market, especially in Latin America, India and China [S1].

2. Increases in efficiency and reliability of food testing

In Europe and the USA, food producers must conduct rigorous testing of their own food product ranges, or employ other companies to conduct testing on their behalf, to meet strict food hygiene standards. Large food testing laboratories have grown up to meet the demand for rigorous testing from food manufacturing companies and supermarkets. Intertek, Eurofins, and ALS Ltd are some of the leading players in this sector and all are supplied with testing kits by Solus [S1].

Food safety testing technologies produced by Solus are in demand by food manufacturers and food testing laboratories because of their advantages over molecular methods including: lower cost, simplicity, ease of automation and rapid detection rates. These benefits have been reported by ALS Ltd. which purchased automated DS2 Solus Pathogen Detection Systems for its Rotherham testing laboratory [S10]. Within 6 weeks of installation, the instruments had improved testing rates by 95%. According to the ALS laboratory manager, *'The Solus Pathogen Testing System has bedded down well in the laboratory equalling and soon surpassing the productivity achieved with alternative methods. The cost and time savings are significant'* [S10].

Solus's food testing kits have provided efficiency gains and time savings to companies who carry out rigorous food testing on behalf of producers, wholesalers and supermarkets supplying food in the UK and Europe, North and South America and the Far East. The time savings remove the need for expensive refrigerated holding facilities, which are required while waiting for assay results. Not only does this reduce refrigeration costs for food testing laboratories, but it allows for the early release of products and so extends their shelf life, reducing the waste arising from food spoilage. This benefits the producers, wholesalers and supermarkets by lowering the chances of food recalls and leading to longer shelf life of food products. This in turn allows customers to buy fresher foods.

5. Sources to corroborate the impact

- S1** Factual statement from Chief Executive Officer (2012-2019), Solus Scientific Solutions Ltd., dated 11 February 2021.
- S2** Solus Scientific website, 'Solus Pathogen Detection System', <https://www.solusscientific.com/pathogen-detection-system/>
- S3** Solus Scientific website, AFNOR and AOAC accreditation: 'Solus *Listeria* and *Salmonella* kits', <https://www.solusscientific.com/pathogen-testing-solutions/listeria-2/>
<https://www.solusscientific.com/pathogen-testing-solutions/salmonella/>
- S4** Solus Scientific website, 'Solus assays', <https://www.solusscientific.com/solus-assays/>
- S5** Solus Scientific website, 'Solus dedicated media', <https://www.solusscientific.com/dedicated-media/>
- S6** Solus Scientific product information sheet, 'Solus meat speciation solutions', <https://www.solusscientific.com/wp-content/uploads/2015/07/Solus-A4-Inners-Meat-Species.pdf>
- S7** Solus Scientific product information sheet, 'Solus AllergenScreen range' <https://www.solusscientific.com/wp-content/uploads/2015/07/Solus-A4-Inners-Allergens.pdf>
- S8** HMRC documents showing transfer of Solus to PerkinElmer in 2019.
- S9** Solus Scientific website, 'Distributor network' <https://www.solusscientific.com/distributors-2/>
- S10** Solus Scientific, 'Increasing pathogen testing throughput and efficiency at ALS Rotherham by employing Solus™ Pathogen Testing System', <https://www.solusscientific.com/wp-content/uploads/2018/02/Rotherham-article-final.pdf>