ANNUAL
REPORT
2018

i-sense
EPSRC IRC in Early Warning Sensing
Systems for Infectious Diseases

EPSRC
Engineering and Physical Sciences
Research Council

Foreword

Contents

Professor Rachel McKendry

Director of i-sense EPSRC IRC
Professor of Biomedical Nanotechnology at the London Centre for Nanotechnology and Division of Medicine at UCL

This special annual report celebrates the highlights of five years of i-sense. It feels like only yesterday, that the small acorn of an idea for a new centre of excellence began. As Director, I am immensely proud to see how i-sense has grown into a tremendous interdisciplinary network, with research excellence evidenced by 78 publications, including the journal Nature, 58 awards, six fellowships, three lectureships, two Associate Professorships, and 14 international partnerships. We have seen our research transition into IP, patents, products and practices to benefit patients and populations. Our 'i-sense flu' AI algorithms have been adopted by Public Health England for national influenza surveillance, our smartphone applications and diagnostic test prototypes are being piloted with end-users, and our data dashboard is part of the Africa Health Research Institute's population implementation platform.

Education, engagement and advocacy are also central to our values and ethos. Our Education Alliance programme has nurtured the careers of more than 55 PhD students and postdocs, and our outreach activities have communicated our research at 11 external events. i-sense members have also held advocacy roles and placements with the World Health Organization and the UK government as well as in industry and across academia. However, these are testing times and there is no time for complacency with new diseases emerging every year and the rise in antimicrobial resistance. Looking ahead, with Next Steps funding, we will grow our capabilities to track, test and treat infectious diseases, harnessing agile molecular and sequencing platform technologies and the ability to predict outbreaks in different settings using unsupervised learning. We have secured funding for two new i-sense Plus Awards and are delighted to welcome the University of Strathclyde and Columbia University as partners.

I hope you enjoy reading about our wonderful team and their extraordinary research outcomes over the last five years of i-sense. If you are interested to find out more, please do get in touch. We are always open to new collaborations.

Professor David Heymann

i-sense Advisory Board Chair
Professor of Infectious Disease Epidemiology at the London School of Hygiene & Tropical Medicine, and former Head of Centre of Global Health Security at Chatham House

As i-sense Advisory Board Chair, and along with the members of the Board, I have watched the project grow from strength to strength, developing collaborations across in the UK and internationally. We all agree that i-sense, under the leadership of Professor Rachel McKendry, has made outstanding achievements in the areas of rapid diagnostic testing, machine learning, big data, and app and dashboard development.

The quality of research and dedication of its researchers has seen many high impact papers published and awards received from competitive programs. On behalf of the Advisory Board, I would like to congratulate all those who have worked on the project since its inception, and look forward to seeing the next steps.

i-sense EPSRC IRC

Engineering new digital early warning sensing systems to track, test and treat infectious disease

The i-sense mission is to engineer a new generation of early warning sensing systems to identify outbreaks of infectious disease much earlier than ever before, helping people gain faster access to care and protecting populations.

Outbreaks of infectious disease can spread rapidly and unpredictably, causing enormous losses to health and livelihood. Without adequate diagnostic tools, there is the threat of ongoing transmission of serious infections and delay in the identification of emerging outbreaks. Our mobile phone-connected diagnostic devices aim to widen access to testing in the home, including self-tests and devices to support front-line health workers in care homes and remote African villages. The aim is to build tools that are simple to use, low-cost to manufacture, and provide rapid and accurate results.

The capability to detect infections and then wirelessly connect test results to healthcare systems has become increasingly important, to help patients gain faster access to treatment and support public health efforts to map indicators of emerging infections and the success of interventions in real-time.
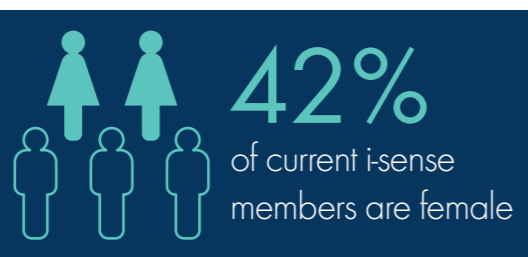
We are also using the vast amount of web-based information on Google and Twitter to identify early indicators of disease outbreaks before people attend clinics, or from geographical regions that are not covered by traditional public health systems.

The work of i-sense is made possible through funding from the EPSRC. i-sense is one of three EPSRC Interdisciplinary Research Collaborations funded to build critical mass in disruptive sensing systems for healthcare.

We have worked across many locations around the world

United Kingdom | America | Japan | Uganda | South Africa
Canada | Australia | Netherlands | France | Switzerland
Denmark | South Korea | Spain | Germany | Malaysia

195+ talks and poster presentations

at conferences and events across the UK and internationally, including the World Wide Web Conference in Perth, Australia (Cox group, 2017), International Conference on Re-emerging Infectious Diseases in Addis, Ethiopia (Dr Noah Fongwen, 2017), the Chief Scientific Officer's Annual Conference in London, UK (Professor Rosanna Peeling, 2018, and Professor Rachel McKendry, 2019) and the International Conference on Molecular Diagnostics & Biomarker Discovery in Penang, Malaysia (Newcastle group, 2017).

17 affiliated students have completed their PhD

78 published papers

in journals, such as *Nature, Nature Nanotechnology*, and *ACS Nano*

41 events and engagement activities

including public engagement activities, school days, and our internal Education Alliance events.

SUSTAINABLE DEVELOPMENT GOALS

In September 2015, the United Nations introduced the Sustainable Development Goals. The 17 Goals are a blueprint to achieve better and more sustainable future for all.

The i-sense project strongly aligns with a number of the United Nations' Goals, including Good Health and Well-being, Industry, Innovation and Infrastructure, and Reduced Inequalities. i-sense aims to reduce inequalities in healthcare by making tools and technologies to reduce the burden of disease on patients, healthcare systems, populations, governments and policy makes, and public health systems.
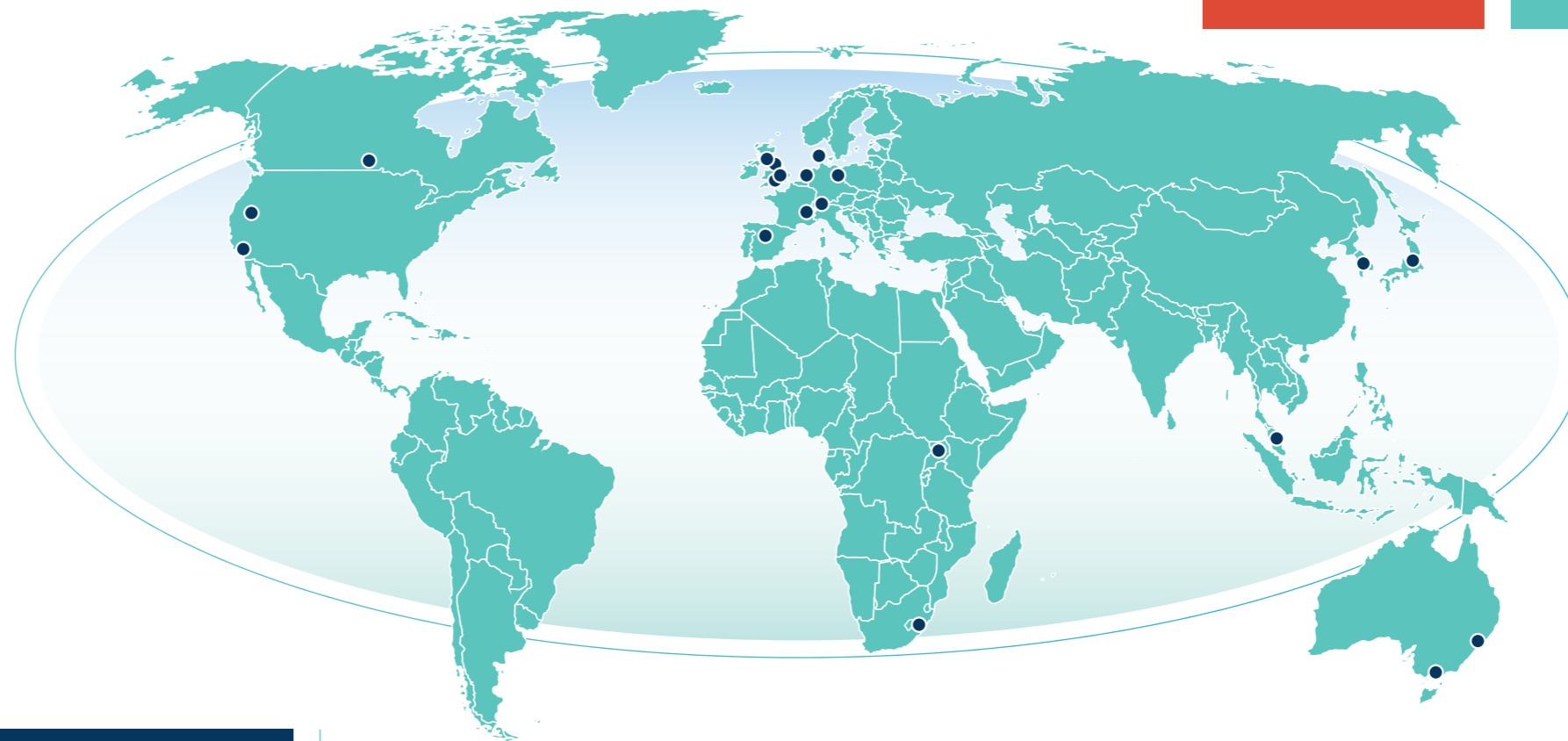
i-sense members have won more than 58 prizes and awards

including the Royal Society Rosalind Franklin Award (Professor Rachel McKendry, 2014), IEEE Signal Processing Society Sustained Impact Award (Professor Ingemar Cox, 2015), the Harrison Award from the Royal Pharmaceutical Society (Professor Molly Stevens, 2017), as well as a number of speaker and poster prizes for our PhD students and Postdocs, including at the MRC DTP Colloquium (Dr Harriet Gliddon, 2014), Biosensors Australia Conference (Dr Valérian Turbé, 2014), UCL EEE Cisco Poster Prize (Evdokia Pilavaki, 2016), and UCL Population and Lifelong Health Domain Symposium (Dr Polina Brangel, 2017).

42% of current i-sense members are female

38 funded projects

through our Partnership Resource Fund and Exploratory Projects

5 years of i-sense

The i-sense project started in 2013 as a five-year, £11M project funded by the EPSRC. In October 2018, we received £3.8M from the EPSRC in follow on funding for i-sense Next Steps, which will run until September 2022.

Academic staff | Research associates | Affiliated students | Administrators and support

Year	Total
2013	44 TOTAL
2014	73 TOTAL
2015	87 TOTAL
2016	110 TOTAL
2017	143 TOTAL
2018	151 TOTAL
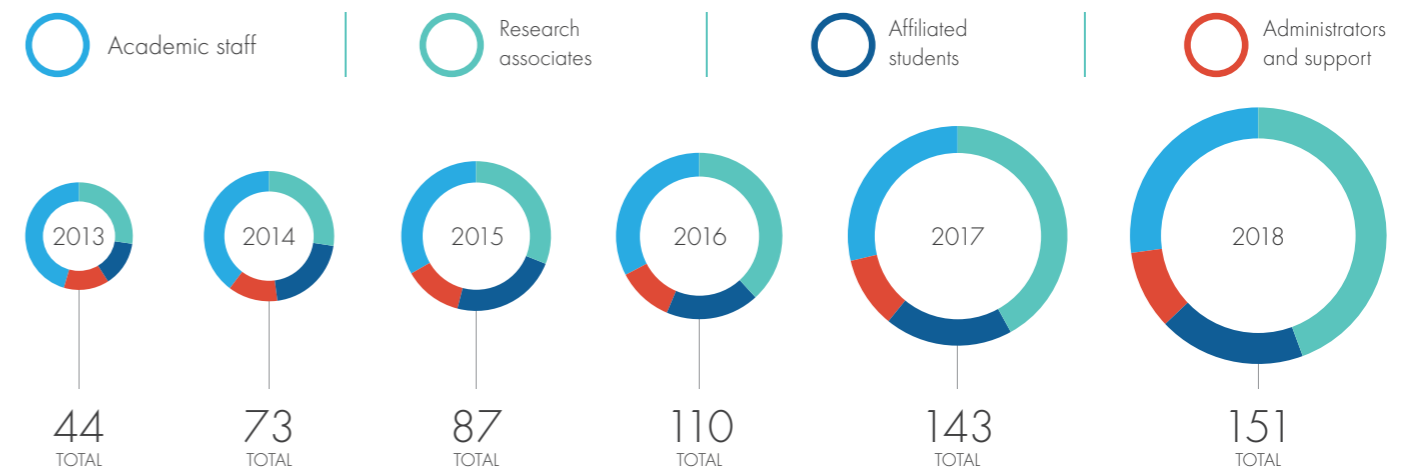
Celebrating women in STEMM

i-sense is proud to have a strong network of women in science, including our Director, Prof Rachel McKendry, who was the first women to become a Director of an EPSRC Interdisciplinary Research Collaboration. During International Women's Day 2018, i-sense celebrated the brilliant female researchers that contribute to the ideas, development, highlights, and successes of the project. Here is a snapshot of some of our female PhD students and postdocs sharing what motivates, inspires, and excites them about their career in STEMM.
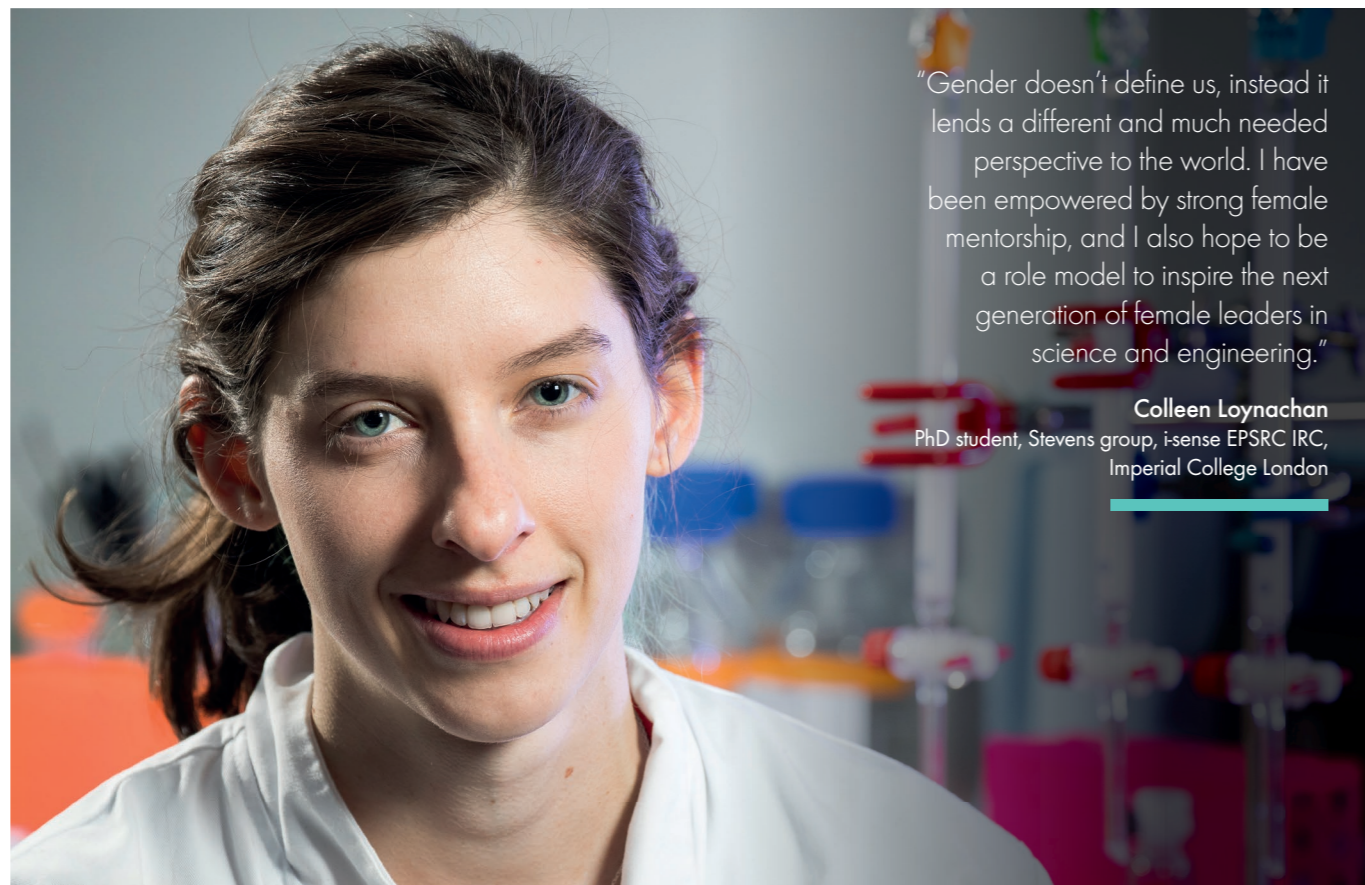
"Gender doesn't define us, instead it lends a different and much needed perspective to the world. I have been empowered by strong female mentorship, and I also hope to be a role model to inspire the next generation of female leaders in science and engineering."

Colleen Loynachan
PhD student, Stevens group, i-sense EPSRC IRC, Imperial College London

"As an early career researcher, it is a pleasure to work in the i-sense project alongside inspiring female role models. By working together we can better understand and improve the world."

Dr Marta Broto Aviles
Postdoctoral Research Associate, Stevens group, i-sense EPSRC IRC, Imperial College London

"Bench science involves logical thinking, through planning, and careful analysis, but also experimental creativity, flashes of insight, and fun! Along the way you get to understand how the world works and contribute to solving some critical problems facing mankind. I can't think of anything I'd rather do."

Dr Eleanor Gray
Postdoctoral Research Associate, McKendry group, i-sense EPSRC IRC, London Centre for Nanotechnology, UCL
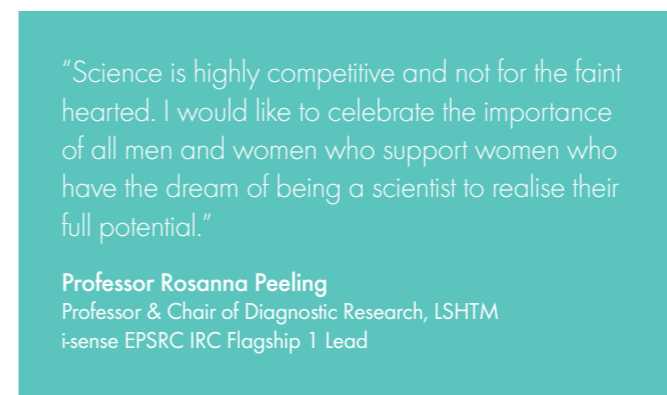
"Science is highly competitive and not for the faint hearted. I would like to celebrate the importance of all men and women who support women who have the dream of being a scientist to realise their full potential."

Professor Rosanna Peeling
Professor & Chair of Diagnostic Research, LSHTM i-sense EPSRC IRC Flagship 1 Lead

"As researchers, I believe it is our responsibility to share our knowledge to educate others. I enjoy being able to learn from people with different experience, and am passionate about empowering new leaders in science by sharing my expertise in point-of-care diagnostics."

Dr Polina Brangel
Postdoctoral Research Associate, McKendry group, i-sense EPSRC IRC, London Centre for Nanotechnology, UCL

Awards and recognition

More than 58 prizes and awards have been received by i-sense members since 2013. Here are some of the highlights from the past year.

Professor Molly Stevens
Imperial College London
Elected and inducted as a Fellow of the Institute of Physics at Imperial College London • Rosalind Franklin Medal and Prize • Celebrated 10 years as a full Professor at Imperial College London

Dr Christopher Wood
Stevens group, Imperial College London
Marie Sklodowska-Curie Fellowship from H2020 programme and is now working at the Department of Medical Biochemistry and Biophysics in the Karolinska Institute, Stockholm

Nayoung Kim
Stevens group, Imperial College London
First Poster Prize at the 2017 Postgraduate Research Day at Imperial College London

Dr Matt Lougher
McKendry group, UCL
UCL BEAMS Professional Service Departmental Award

Dr Eleanor Gray
McKendry group, UCL
Masters in Clinical Microbiology and the Principal's Prize

Isabel Bennett
McKendry group, UCL
Government policy placement at Government Office for Science

Dr Harriet Gliddon
McKendry group, UCL
UCL Patient and Public Involvement grant for workshop at Positive East

Dr Polina Brangel
McKendry group, UCL
First prize for speakers at Early Career Researcher Presentation Competition at the UCL Population and Lifelong Health Domain Symposium

Matthew Setterfield
Newcastle University group
First prize PhD student poster competition at Newcastle University's Institute of Cellular Medicine Director's Day

Completed PhDs in 2018

Candice Keane
McKendry group, UCL

Hannah Swinburne
Newcastle University group

Bin Zou
Cox group, UCL

Evdokia Pilavaki
Demosthenous group, UCL

Colleen Loynachan
Stevens group, Imperial College London

The future of i-sense

i-sense IRC Next Steps

In December 2017, the then Science Minister, Jo Johnson, announced £3.8M in follow-on funding from the EPSRC awarded to i-sense IRC Next Steps.

The funding is to pioneer the development of agile early warning sensing systems for infectious disease and antimicrobial resistance. Next Steps funding will begin in October 2018 and continue until September 2022.

The funding is part of a larger £11M boost to the EPSRC's three IRCs to support the development of leading healthcare research into National Centres of Excellence. The i-sense IRC Next Steps award was the largest funding awarded to any IRC.

This funding will maximise the impact of i-sense, retaining key staff and delivering a step change in new capabilities to respond to emerging infections.

i-sense Next Steps aims to continue developing digital tools and technologies to track, test, and treat infectious diseases.

In addition, i-sense has leveraged £10M in-kind and direct funding, including new laboratory infrastructure, academic positions and funding from Public Health England, the Africa Health Research institute, UCLH Biomedical Research Centre NIHR, academic partners and industry.

Our future vision will be to build population test-beds in the UK and South Africa to pilot new technologies that will be ready for clinical trials, translation and product development.

Key academic partners include UCL, Imperial College London, Newcastle University, Africa Health Research Institute, University of Surrey, and Glasgow Caledonian University. Other project partners include Google, Mologic Ltd, Public Health England, University College Hospitals London, Microsoft, University of California Los Angeles, Oxford Nanopore Technologies, Royal College of General Practitioners, The Francis Crick Institute, Cambridge Life Sciences Ltd, Ixscient Ltd, O2, and Diagnostic Evidence Cooperative London.

We have also secured a total of £2.3M in funding for two new i-sense Plus Awards. The first is led by Prof Molly Stevens at Imperial College London and titled 'A smartphone powered mRNA sequence detector', and the second is led by Dr Neil Keegan at Newcastle University and titled 'Ultra-sensitive enhanced nanosensing of antimicrobial resistance (u-Sense)'. These two Plus Awards build on existing collaborations and we are delighted to welcome the University of Strathclyde and Columbia University as new partners.

i-sense — Agile Early Warning Sensing Systems for Infectious Diseases and Antimicrobial Resistance

Flu | STIs | AMR | Ebola

Track   Test   Treat
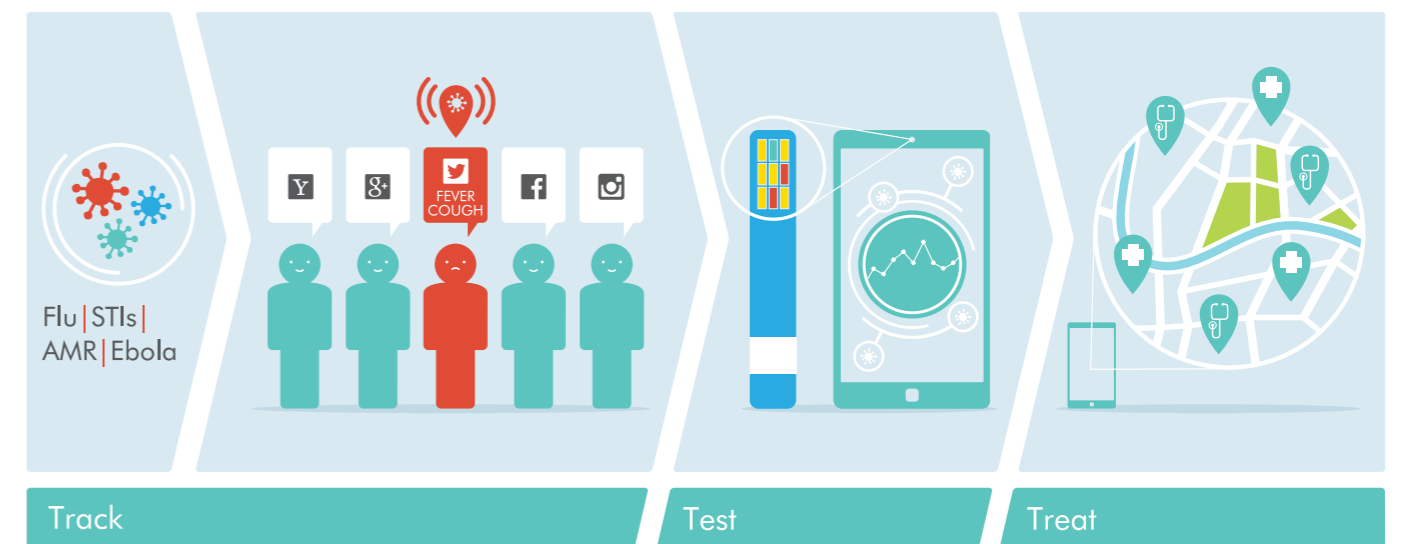
Flagship 1: Systems level perspective of end-user needs

Led by Professor Rosanna Peeling, Professor and Chair of Diagnostics Research, LSHTM

1. Environment scan of current early warning systems

2. Guide test development by defining product specification

3. Collaborate with i-sense Flagships on emergency preparedness

4. Promote mechanisms for accelerating the tool development to impact pathway

5. Facilitate connectivity solutions for early warning systems

4 internal i-sense workshops

15 talks, presentations, and posters

7 policy engagements

Infectious diseases continue to pose serious threats to human health and global health security. Enhancing the capacity of early warning systems to rapidly detect and respond to these infectious disease threats is crucial for the prevention and management of outbreaks.

One of the main risks facing any new technology is its acceptance by the end-user. Throughout the last five years of i-sense, Flagship 1 members have been working on the five key areas above to better understand how we can engage with end users, develop suitable tools and technologies, and implement these outputs. This work is central to i-sense and outcomes feed into our Core Flagship Programmes.

The key highlight of i-sense Flagship 1 has been the work on the environmental scan of current early warning systems. This project was called 'Dare to Dream' and was conducted in consultation with key stakeholders at national and global levels to assess how the current systems work and, in the wake of recent outbreaks, what changes have been made and what can be envisioned in the future.

To ensure these key learnings are shared, Flagship 1 has conducted four workshops over the last five years to collaborate with other i-sense Flagships on emergency preparedness and test development. These workshops have been highly beneficial

in identify how and where i-sense tools and technologies can bring maximum benefit and have helped researchers consider their test design to best suit end-user needs.

Flagship 1 researchers have also been engaging with a wide range of potential users of our technologies, including clinical leads, hospital managers, patient representatives and healthcare commissioners in the UK and in select countries in Asia and Africa. Highlights of key engagement activities over the years have included Dr Noah Fongwen being invited for a policy talk on diagnostic priorities for the implementation of antimicrobial resistance surveillance in Africa during the 1st International Conference on Re-emerging Infections Disease in Addis, and Professor Peeling being invited to speak on the critical role of diagnostics to combat antimicrobial resistance (AMR) at the 2016 World Health Assembly in New York, the AMR event at the 2017 World Economic Forum in Davos, in 2018, she was invited
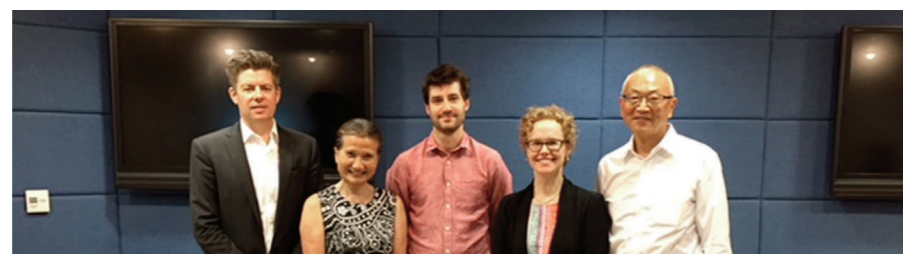
to present at the UK Chief Scientific Officer's Annual Conference in London, the Latin America IVD Alliance meeting in Sao Paulo, the WHO meeting on Zika and other Flaviviruses in Geneva, and the World Health Summit in Berlin.

With rapid advances in diagnostic technologies, policy makers need to be aware of these advances and policy issues around technology assessment and adoption. Professor Rosanna Peeling initiated an Advanced Course in Diagnostics in Annecy, France for this purpose and have taught over 300 policy makers from over 75 countries since 2010. Fellows from i-sense have participated in these courses and Dr Noah Fongwen has been conducting interviews with policy makers and industry regarding their views on the development to impact pathway.

Key collaborations on mHealth have been developed with the Africa Centre for Disease Control and Prevention (Africa CDC), the World Health Organization to set up health centres by phone and leapfrog public health practice in Africa. Professor Rosanna Peeling and Dr Valérian Turbé also presented at the University of Hong Kong conference on Phones, Drones & Disease: Epidemic Intelligence and the Future of Communications in East Asia (photo below). This work strongly links to the fifth and final aim for the Flagship; to facilitate connectivity solutions for early warning systems.

Dare to Dream: Scenarios for early warning systems

By Professor Rosanna Peeling, LSHTM

Over the i-sense project, Flagship 1 members conducted consultations with key stakeholders at national and global levels to assess how the current systems work, what changes have been made over the years, and what can be envisioned for the future.

The outcome of the landscape review was that the UK surveillance systems is considered 'fit-for-purpose' and consists of a combination of clinic or syndrome-based surveillance and laboratory-based reporting systems from 180 laboratories across the UK. The information is shared nationally and fed into various global reporting systems. With recent outbreaks, UK surveillance systems have had to evolve and will continue to evolve.

The 'Dare to Dream' scenario for a future early warning system in the UK will take advantage of improving technologies and social media use. It will consist of earlier warning through diversification of data sources, including automated reporting and alerts from laboratories as well as point-of-care testing sites across the country. i-sense is uniquely placed to help develop and implement such technologies for early warning systems.

i-sense has the potential to bring major human and economic benefits to millions of people worldwide.

Patients benefit from fast diagnosis of infection and ongoing treatment and care through mobile connectivity.

Healthcare systems benefit from improved service delivery and sustainable models of community care.

Populations benefit from early detection, leading to reduced spread of infection and resistance to antibiotics.

Public health benefits from real-time information and system surveillance to control disease outbreaks.

Governments and policy makers benefit from balanced information about barriers to adoption of new products.

Guiding future test development

Dr Noah Fongwen and Professor Rosanna Peeling, LSHTM

A key aim of Flagship 1 is to guide test development by defining product specifications. We are evaluating current early warning systems and assessing the characteristics of our sensors such as sensitivity, specificity, stability and cost in order to deliver high-performance systems, adapted for our specific disease targets.

A key part of this has been developing partnerships with professional bodies and key influencers such as the World Health Organization, Chatham House, and the Africa CDC.

Our partnership with the Africa CDC, in collaboration with the World Health Organization's Special Programme for Research and Training in Tropical Diseases, aims to use social innovation to leapfrog public health practice in Africa using the 'Health Centre by Phone' project as an example. This collaboration is well in line with these strategic goals of i-sense.

There is also an urgent need to introduce novel rapid diagnostic tests to reduce inappropriate use of antibiotics as part of the global response to antimicrobial resistance. This is a compelling reason why a new model to accelerate the assessment of acceptable risks versus incremental clinical benefits is needed. To address this a workshop is being organised in collaboration with Chatham House to bringing together experts, regulatory

authorities and policy makers in a round table discussion and provide the way forward for a new radical model for an efficient and transparent means of making diagnostics accessible to those who need them.

Future work of Flagship 1 also includes conducting systematic reviews and diagnostics landscapes for Lassa and Nipah viruses. These two pathogens are in the World Health Organization's list of pathogens of epidemic potential.

Flagship 1 workshops: collaborating on emergency preparedness

Flagship 1 has supported i-sense members over the years by running four informative workshops that included invited speakers and provided opportunities to discuss projects and collaborations. The aim of the workshops was to share outcomes and findings of Flagship 1 work with the three other i-sense flagships, getting members to explore the potential for i-sense tools and technologies to address the diagnostics needs, particularly in global health emergencies, while also considering medical countermeasures and policy decisions.

In 2016, there were two workshops; one on Zika diagnostics and the other on preparing a global health response. The 2017 workshop covered system needs for diagnostics in global health emergencies, and finally a workshop dedicated to the i-sense mapping was held in 2018.

These workshops have been organised by PhD students and postdocs, and supported by Professor Rosanna Peeling. i-sense members have heard from invited speakers such as Dr Mike Short from the Department for International Trade, Dr Sarah Wise from UCL Centre for Advanced Spatial Analysis, Dr Penny Wilson from Innovate UK, Bill Rodriquez from Foundation for Innovative New Diagnostics, Professor Laura Rodrigues and Dr Adam Kucharski from London School of Hygiene & Tropical Medicine, and Andrew Eland from Google DeepMind.

These workshops are a great opportunity to ensure we can maximise the potential of i-sense technologies to address the landscape of diagnostic needs, as well as identify potential for collaboration.

Mapping mobile health potential

Jobie Budd and Professor Rachel McKendry, UCL and Professor Rosanna Peeling and Dr Noah Fongwen, LSHTM

i-sense Flagship 1 have recently begun work on a collaborative project between UCL and LSHTM that looks at ways to inform roll out of mHealth technologies across Africa. This has been done to facilitate digital connectivity solutions by mapping network coverage and collating other publicly available data, such as population density and location of health facilities, to identify regions where mobile health interventions could most improve access to healthcare.

This work initially began as part of our review for *Nature*, *'Taking Mobile Health Connected Infectious Disease Diagnostics to the Field'* (see page 22), where the digital divide in Uganda is highlighted, and how this divide could affect the adoption of connected diagnostics. The map on the right was first published as part of the *Nature* review.

Flagship 1 are now looking to expand both the geographic range and the types of data included in the analysis, taking advantage of the public datasets made available by the growing incentive to map African health infrastructure since the 2014 Ebola outbreak. By looking at indicators such as vaccination coverage and migration flows, we can map populations most at risk to infectious disease outbreaks.

The aim is to continue this work to develop a high-granularity platform for the whole of Africa, which is able to process and visualise different datasets so that policy makers can effectively target mobile health interventions down to village level.
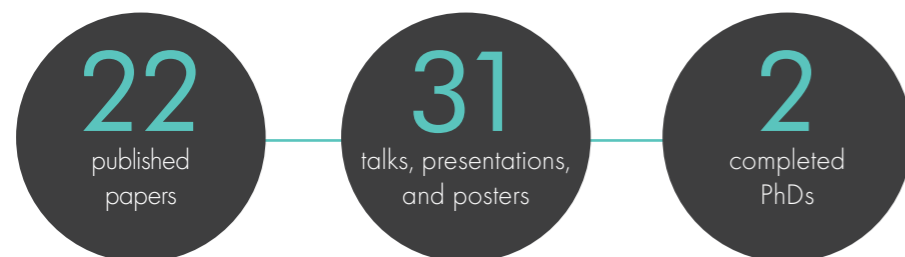
i-sense Researchers, Jobie Budd, Dr Noah Fongwen, Professor Rosanna Peeling, and Professor Rachel McKendry, met with Dr John Nkengasong, Director of the Africa CDC, and Dr John Reeder, Director of the World Health Organization Special Programme for Research and Training in Tropical Diseases, to discuss how this mapping work could help countries use mHealth tools to improve access to healthcare and provide alerts of disease outbreaks.

Wood, C., S., Thomas, M. R., Budd, J., Mashamba-Thompson, T., P., Herbst, K., Pillay, D., Peeling, R. W., Johnson, A., M., McKendry, R. A., and Stevens, M. M. 'Taking connected mobile-health diagnostics of infectious diseases to the field' *Nature* (2019); DOI: 10.1038/s41586-019-0956-2
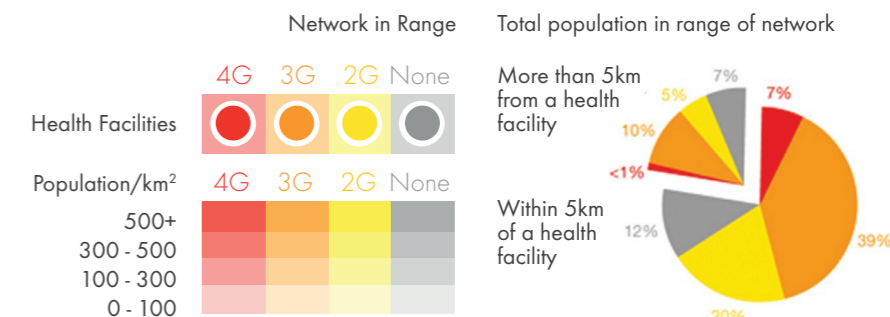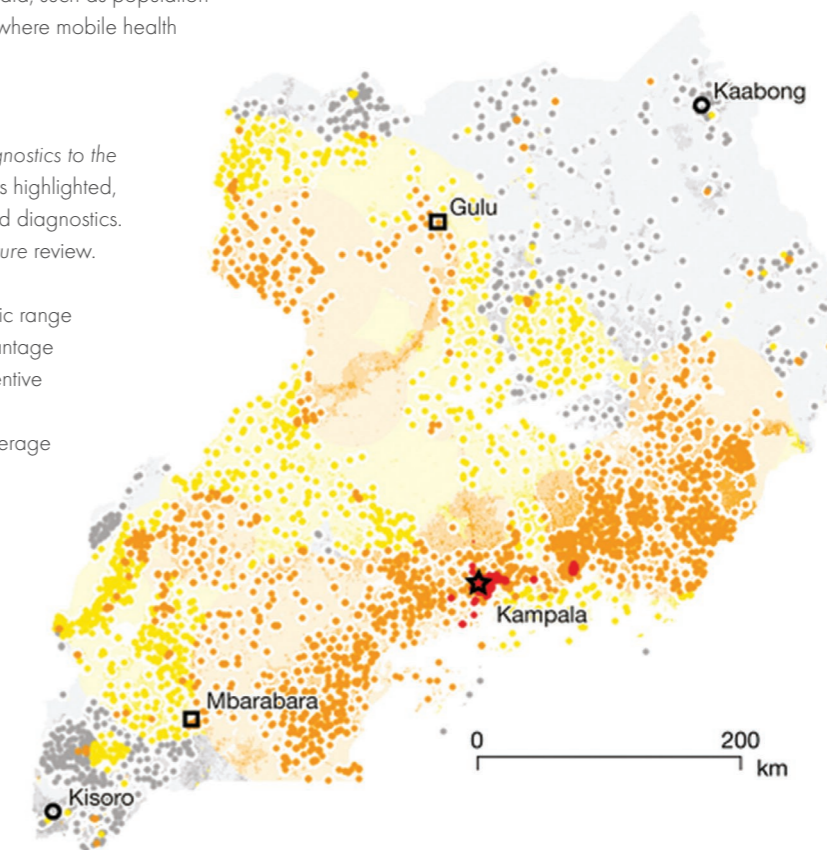
Flagship 2:

Early-warning sensing system for influenza

Led by Professor Ingemar Cox, Professor of Computer Science at UCL and i-sense Deputy Director

1. Use machine learning to understand how people are talking about their symptoms online (Twitter, Google)

2. Explore new diagnostic tests

3. Conduct pilot studies to understand use and impact of tools and technologies

22 published papers

31 talks, presentations, and posters

2 completed PhDs
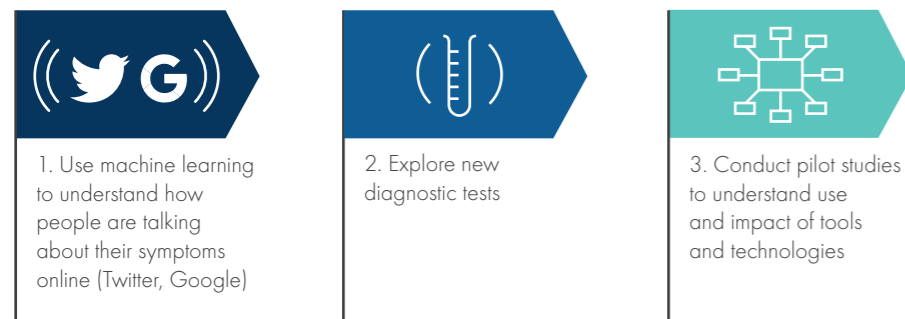
Throughout the i-sense project, Flagship 2 has been responsible for early warning sensing systems for influenza. Influenza is an infectious disease responsible for 250,000 to 500,000 deaths worldwide each year. Influenza and influenza-like-illness causes a considerable burden on health in the UK, and pandemic influenza ranks at the top of the Cabinet Office risk register of civil threats.

In the UK, Public Health England has a range of surveillance systems to monitor influenza activity and the impact on the population. The major component of Flagship 2 has been the work on analysis of data derived for nonhealth purposes (e.g. twitter or web searches) to infer health information and support current surveillance systems. A smaller stream within the flagship has explored new diagnostic test development, including the design of new sensor technologies incorporating novel paper-based microfluidics coupled with a mobile phone. i-sense Exploratory Projects have further supported small pilot studies for Flagship 2, including using Flusurvey to assess the feasibility of self-swabbing, to understand the use and impact of our tools and technologies.

This work on influenza within i-sense started as a relatively new strand of work, yet has made significant progress. Over the years, we have worked closely with Google, Microsoft Research, the Royal College of General Practitioners, and Public Health England to study how web searches and tweets can be used to understand the health of a population or an individual, using machine learning for big data analysis. Our methods have been applied
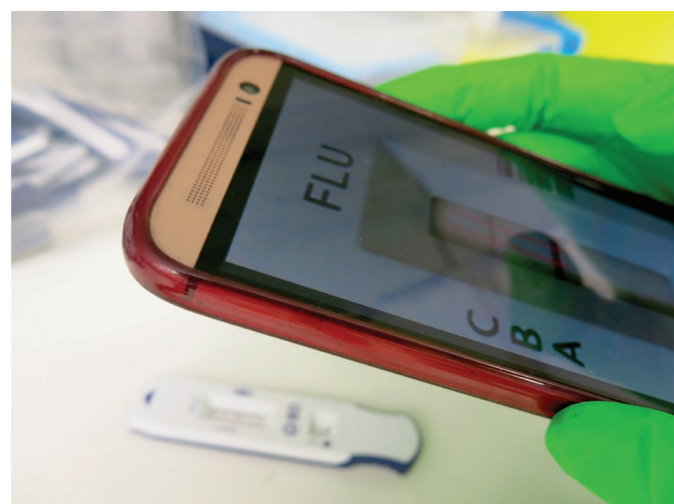
to a variety of problems including detecting infectious disease outbreaks at mass gatherings, estimating the effectiveness of an influenza vaccine for children, estimating the virulence of influenza, and estimating the prevalence of influenza in England.
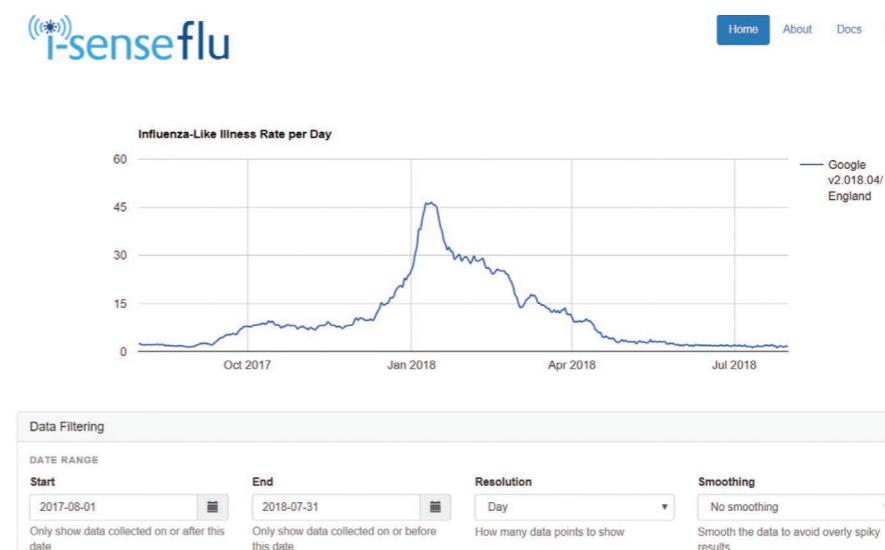
Most recently, we have also begun to investigate how transfer learning can be used to build models for influenza surveillance in low-and middle-income regions where training data (i.e. a sentinel doctors' network) are not available. Many of these studies have also involved close, ongoing collaboration with Public Health England. This has been a very fruitful collaboration that has culminated in our 'i-sense flu' software being adopted by Public Health England as part of their suite of influenza surveillance tools.

Linking to the 'i-sense flu' work, i-sense researchers at Public Health England collaborated with members at UCL to understand how Google search data can help to assess the impact of heatwaves on the health of the population in England. In 2018, a timely study was published on this work in Environmental Research.

The progress that has been made around diagnostic tools and technologies within Flagship 2 has included the development of an in-house lateral flow test that can more rapidly and accurately detect influenza using gold nanoparticles, and the development and evaluation of a mobile app to be used for readout of influenza A and B test strips in collaboration with Becton Dickinson.

Estimating flu rates from online search queries

Dr Vasileios Lampos, Bin Zou, Dr David Guzman, Dr Simon Moura and Professor Ingemar Cox, Department of Computer Science at UCL

> The i-sense collaboration has continued to be fruitful. Evaluation of the i-sense flu tool has shown that it provides an accurate estimate of flu-like-illness rates in the general population, with ready availability of daily data. Work is on-going, and we consider this will provide a valuable contribution to UK flu surveillance and have application in other settings."
>
> **Dr Richard Pebody**
> Head of Respiratory Disease Surveillance and Influenza Surveillance, Public Health England

Public Health England has one of the most advanced public health systems for influenza surveillance in the world, which brings together multiple data sources including GP reports, hospital cases and symptoms reported to NHS111.

Since the beginning of i-sense, Flagship 2 has been focusing on approaches that could complement these traditional syndromic surveillance approaches. We have experimented with content from social media (Twitter) and online search engines (Google, Bing), and have seen that, when appropriately modelled, the latter can be an accurate predictor of influenza-like illness rates in primary care in the US or England. Apart from the timeliness of predictions including daily availability of outputs and the uninterrupted coverage (unaffected by weekend or holiday closures), online data can represent broader segments of the population who have not consulted the health care system.

In collaboration with Public Health England and with data contributions from Google, Microsoft and the Royal College of General Practitioners, we have been working on additional assessments of our models, aiming

to obtain a more concrete understanding of their benefit to the current national syndromic surveillance systems. The initial outcome of this evaluation process was the decision by Public Health England to include our estimates in their Flu annual report: winter 2017 to 2018. Prior to that, we had already established that online data can be useful in assessing the impact of a health intervention in the general population, by measuring the health impact of an influenza vaccination of school-aged children on the general population over two influenza seasons as our case studies.

In parallel, we have been working on a software system that can collect online search data and use the proposed machine learning models to compute and visualise disease rate estimates. This tool, named i-sense flu (https://i-senseflu.org), currently provides daily influenza-like illness rate estimates for England based on Google search data. As a result of the ongoing evaluation process and given the various indicators of added value, Public Health England have adopted the current version of i-sense flu so that they can further evaluate how this approach can support their current surveillance systems.

This collaboration is an example of how i-sense research outcomes are being transformed to support active components of England's public health surveillance system.

Wagner, M., Lampos, V., Cox, I. J., and Pebody, R. 'The added value of online user-generated content in traditional methods for influenza surveillance.' *Scientific Reports* (2018); DOI: 10.1038/s41598-018-32029-6

Wagner, M., Lampos, V., Yom-Tov, E., Pebody, R., Cox, I. J. 'Estimating the Population Impact of a New Pediatric Influenza Vaccination Program in England Using Social Media Content' *J Med Internet Res* 19(12):e416 (2017); DOI: 10.2196/jmir.8184

Flusurvey to assess feasibility of at-home self-swabbing for influenza

Traditional influenza surveillance is only able to detect cases that reach hospitals or GPs. Set up during the 2009 pandemic, Flusurvey (flusurvey. org.uk), the UK's biggest crowd-sourced study of influenza, uses self-reporting from the community to rapidly monitor influenza-like-illness. Through a collaboration between i-sense and Flusurvey, a former i-sense Postdoc at LSHTM, Dr Clare Wenham, has carried out a pilot study asking volunteers to use self-swabbing kits at home to determine whether their symptoms were caused by influenza virus or not.

The study was funded through an i-sense Exploratory Project and brought together researchers from LSHTM, Public Health England, ISI and UCL. Published in the *Journal of Medical Internet Research*, the paper showed that self-swabbing for influenza at home could help surveillance of emerging stages of pandemics and understand ongoing transmission.

The self-swabbing pilot was carried out to understand whether it was feasible to ask individuals to perform a self-swab at home to confirm their diagnosis and whether it was possible to detect influenza virus on these self-collected samples. Swabbing kits were sent to 700 participants, of which 66 were asked to complete the test because they met the required symptoms, and 51 samples were returned. From these samples, the influenza virus was isolated via PCR testing, and therefore validates that this method is suitable for influenza surveillance.

This research demonstrates the feasibility and acceptability of self-swabbing at home and lays the foundations for larger studies and future work on self-testing for influenza using a diagnostic test. People with a confirmed diagnosis from a self-swabbing test could be encouraged to visit a doctor, take appropriate medication to reduce the misuse of antibiotics, and ensure quick recovery, or prevent spread of infection.

Can Google help to assess the impact of heatwaves on the health of the population?

Building on the success of the 'i-sense flu' work, i-sense researchers have been exploring other applications of data. Researchers at Public Health England collaborated with i-sense members at UCL to understand how Google search data can help to assess the impact of heatwaves on the health of the population in England.

The most recent study, Led by Dr Helen K Green at Public Health England and published in *Environmental Research*, looked at the frequency of Google search terms indicative of heat-related morbidity and compared these to indicators from established surveillance systems on a daily basis.
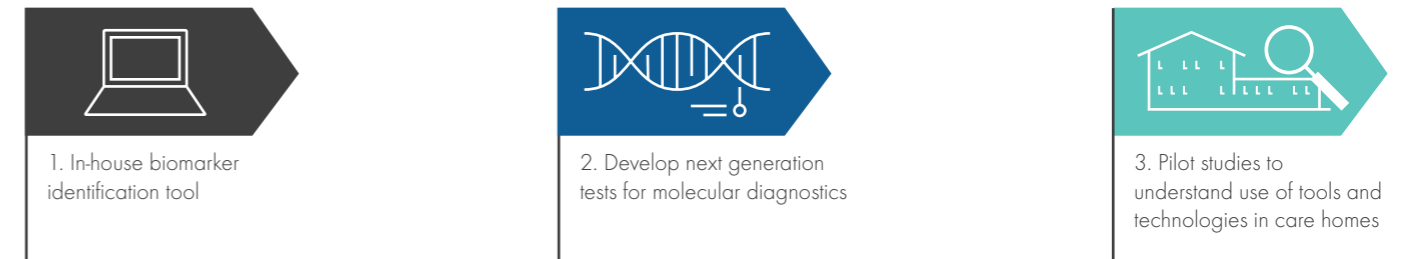
In 2003, the European heatwave resulted in more than 70,000 deaths across Europe. Heatwaves were also in the headlines across the UK during the summer of 2018, with reported temperatures being some of the highest on record.

The Heatwave Plan for England was launched in 2004 and, as part of this Plan, Public Health England monitors heat-related morbidity across a number of syndromic surveillance systems on a daily basis.

Monitoring online user-generated content could support traditional surveillance methods with the potential to identify illness in individuals with symptoms, including those who do not present to their doctor.

During this particular study, patterns in frequency of Google search terms such as heat exhaustion, heatwave, 'sunburn' and 'sunstroke' were monitored in England. Each search term showed an increase in frequency during periods of hot weather in summer months. During 2017, the increases coincided with heatwave alerts and demonstrated a similar timeliness with syndromic data. The results showed the potential benefits of using internet search data to assess the wider population health impact of exposure to heat.

Public Health England and UCL have been working closely on a number of projects within i-sense and this recent work builds on our continued collaborative success.

Flagship 3:   Early detection and diagnostics for bacterial infections

Led by Dr Neil Keegan, Senior Lecturer, Institute of Cellular Medicine at Newcastle University

1. In-house biomarker identification tool

2. Develop next generation tests for molecular diagnostics

3. Pilot studies to understand use of tools and technologies in care homes

13 published papers

17 talks, presentations, and posters

7 awards and prizes

4 completed PhDs

Being part of a dynamic project has been a hugely rewarding experience for Flagship 3 researchers whose focus has been the diagnosis of bacterial infections.

A key challenge for current diagnostic tests is that they can take several days to perform. This often leads to patients being administered a broad-spectrum antibiotic, which can fuel antibiotic resistance. Flagship 3 have been developing mobile phone-connected diagnostic tests to improve the early detection and identification of bacterial infections, including MRSA, *C. difficile*, *E. coli* and tuberculosis.

The main research highlight of the Flagship since the beginning of i-sense has been the application of an in-house biomarker identification tool, termed IDRIS. IDRIS has been used to guide the production of monoclonal antibodies, specific and sensitive for the hospital 'superbug' *C. difficile*.

Significant progress has also been made in next generation molecular diagnostics using simple and rapid isothermal amplification methods for the detection of bacteria and antimicrobial resistance, including carbapenem resistant enterobacteriaceae. The fundamental aspects of this research have been published in *Scientific Reports* and we envisage this will be a hugely fruitful area of research going forward. The team have recently engaged in a strategic research collaboration with Professor Duncan Graham and Professor Karen Faulds at the University of Strathclyde, who will introduce surface-enhanced Raman spectroscopy (SERS) as an ultrasensitive readout to the isothermal assays. This work has received further funding from the EPSRC as an i-sense Next Steps Plus Award (u-sense).

To understand how these tools and technologies could be beneficial to end-users, the team at Newcastle University collaborated with Professor Jackie Cassell's team at the Brighton and Sussex Medical School on a care home-based study. This study explored the challenges for using mobile phone-connected point-of-care tests in the care home setting when testing for bacterial infections.

Exciting work has also started taking shape exploring the role of sequencing in the diagnosis of multidrug-resistant tuberculosis in South Africa and how connected tests can be used in the pathway. This research is being led by Dr Harriet Gliddon in the McKendry group at UCL, and Dr Daniel Frampton a postdoc with Professor Deenan Pillay at UCL.

Members of Flagship 3 have seen the importance of disseminating our work both nationally and internationally to raise awareness of our research, share ideas and build collaborations. Engagement highlights from over the years have included talks at the 2016 Rapid Methods Europe conference in the Netherlands and the 2017 Sensors in Medicine event in the UK, both by Dr Chris Johnson. In addition Dr Hannah Swinburne and Dr Chris Johnson both gave talks at the 2017 Molecular Diagnostics and Biomarker Discovery conference in Malaysia, and the 2018 Biosensors conference in the USA.

Not only has being part of an Interdisciplinary Research Collaboration promoted scientific excellence, it has fostered the progression of numerous students. Hannah Swinburne successfully completed her PhD as an i-sense affiliated student and subsequently enjoyed a role as an i-sense Postdoc Research Associate at Newcastle University. After successfully defending her i-sense affiliated PhD, Beth Lawry secured a teaching fellowship at Newcastle University. Additionally two i-sense technicians have been inspired to undertake PhDs, one of which is associated with another EPSRC IRC, Proteus, and two i-sense affiliated PhD students, Katie Griffith and Sinziana Popescu, were winners of the Prestigious SenseWell Action Prize (2014), developing a business plan to help people with dementia.
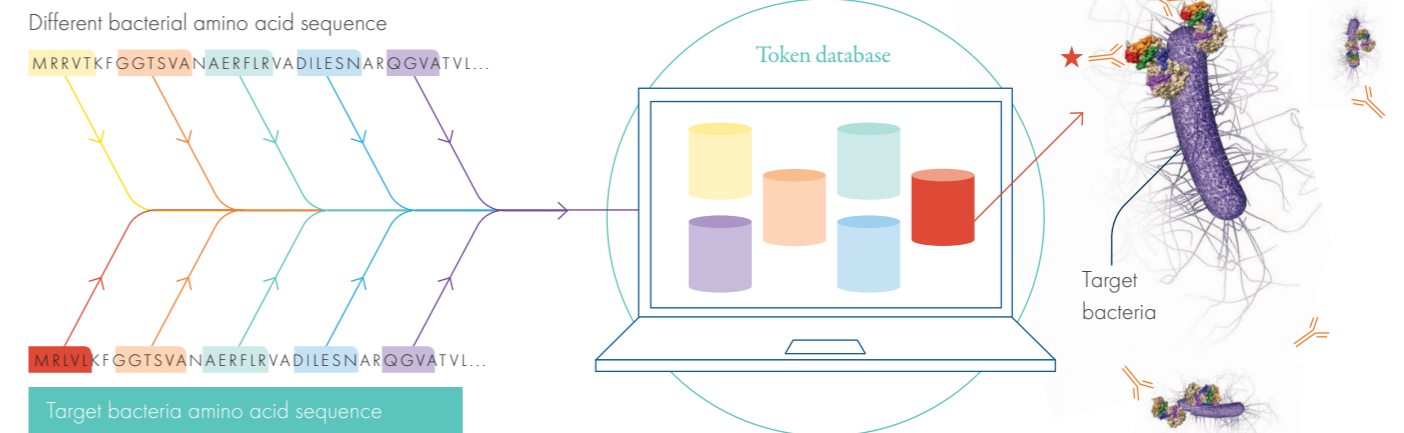
All of this work has culminated in the team securing additional EPSRC funding, namely an i-sense Next Steps Plus project (u-sense), which received £1.3M and will run from October 2018 to August 2022.
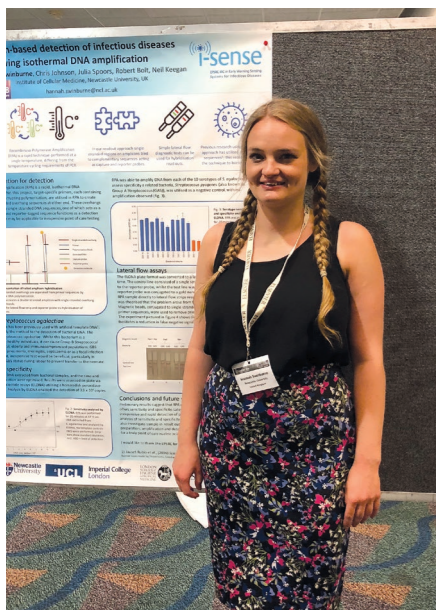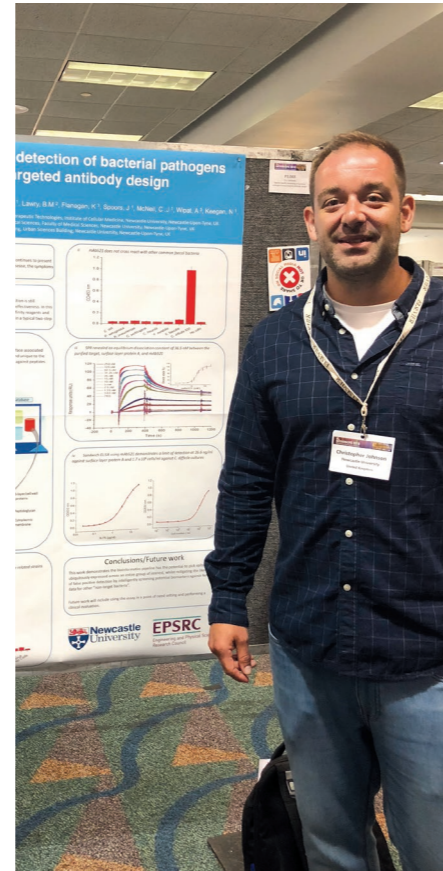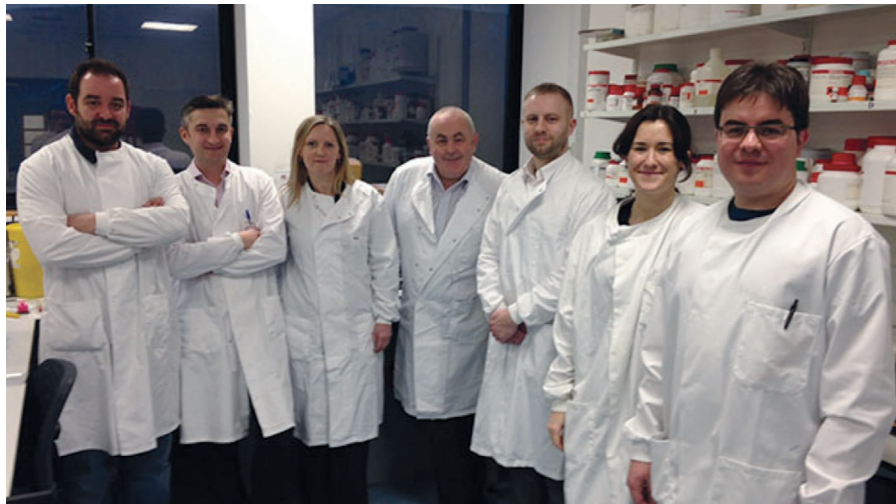
Cloud computing software for diagnostics - IDRIS

Professor Anil Wipat and Dr Keith Flanagan, Newcastle University

Cloud Computing Software IDRIS System

Different bacterial amino acid sequence

MRRVTKFGGTSVANAERFLRVADILESNARQGVATVL...

Token database

MRLVLKFGGTSVANAERFLRVADILESNARQGVATVL...

Target bacteria amino acid sequence

Target protein

Target bacteria

To help identify capture molecules for diagnostic tests, the i-sense team at Newcastle University, under the direction of Professor Anil Wipat, have developed novel software that harnesses the huge amount of genetic data available for bacteria. The cloud computing-based system, called IDRIS, processes genome sequence data to identify highly conserved amino acid 'tokens' present in proteins located at the surface of the target bacteria. These token amino acids then guide the development of a variety of capture molecules for incorporation into diagnostics sensors. Identifying target tokens reduces the need for complex sample handling and extensive screening, improving the speed and development of diagnostic tests.

The utility of this novel computational approach to antibody design for diagnostic tests is the ability to produce universal species identifiers, whilst mitigating the likelihood of false positive detection by intelligently screening the potential biomarkers against genomic data for non-target bacteria. In relation to this work a patent application has been filed (1807367.6, *C. difficile* biomarkers and antibodies, May 2018).

The patent protects the diagnostic antibodies produced from this research, which has now been followed up with a high-quality publication, in *Analytical Chemistry*. The latest developments in the IDRIS system are now aimed at releasing the system for direct use by scientists outside of i-sense, free for use by academics and under license from industrial users. The system has also been updated to cope with massive increase in the size of publicly available genome datasets.

Testing in care homes

Professor Jackie Cassell, Jo Middleton, and Stefania Lanza, Brighton and Sussex Medical School

In 2015, the Flagship 3 team began to explore the testing of bacterial infections in care homes. In 2017, a pilot study was carried out in collaboration with Professor Jackie Cassell's team at the Brighton and Sussex Medical School. The study was designed to explore and address usability challenges in care home settings for a largely hidden and vulnerable population.

The study looked at how point-of-care tests were currently being used in care homes, and aimed to understand how these tests could potentially be used to help decision making for *C. difficile* and MRSA infections.

It also looked at the benefit to healthcare professionals in using such tests and at what points in the care pathways these tests should be used.

The findings demonstrated multiple and often contradictory perspectives on the use of these tests. A key consideration is the action the test result would trigger, and timing in relation to visits or other episodes of care. While mobile communications were welcome, existing communication technologies were very variable and often surprisingly dated. Engagement with this complex range of potential users in residential and nursing care homes will be critical to successful introduction of future tests.

Pushing the limits with next generation molecular diagnostics

i-sense researchers at Newcastle University have had an ongoing collaborations with researchers at Rovira i Virgili University to create a simple sample-in-result-out system using low-cost paper-based approaches that require limited infrastructure, are user-friendly, quick to manufacture and provide accurate results. Such tests are crucial for the emerging field of personalised medicine, for which companion diagnostics are essential.

Significant progress has been made in next generation molecular diagnostics using simple and rapid isothermal amplification methods for the detection of bacteria and antimicrobial resistance, including carbapenem resistant enterobacteriaceae. The fundamental aspects of this research have been published in *Scientific Reports*.
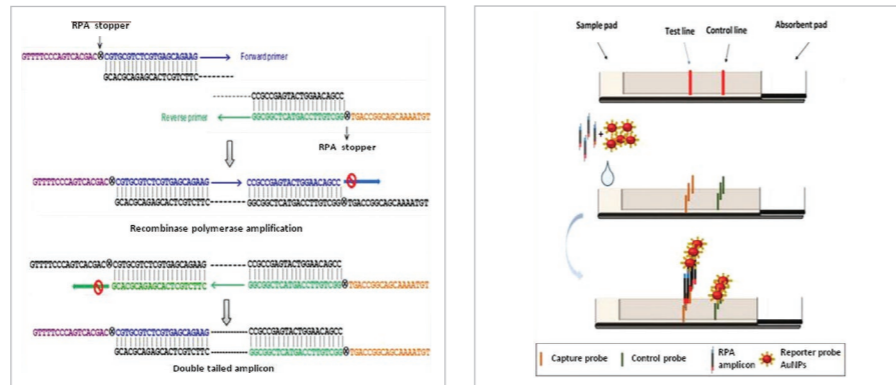
Jauset-Rubio, M., Svobodová, M., Mairal, T., McNeil, C., Keegan, N., Saeed, A., Abbas, M. N., El-Shahawi, M. S., Bashammakh, A. S., Alyoubi, A. O., O'Sullivan, C. K. 'Ultrasensitive, rapid and inexpensive detection of DNA using paper based lateral flow assay.' *Scientific Reports*, 6, 37732, (2016); DOI: 10.1038/srep3773

Collaborating with South Africa on diagnostics for Tuberculosis

In 2017, Dr Harriet Gliddon, a Postdoc in the McKendry group at UCL, travelled to South Africa with the support of a UCL Global Engagement Grant to plan for a study looking at new sequencing technology to diagnose drug-resistant tuberculosis.
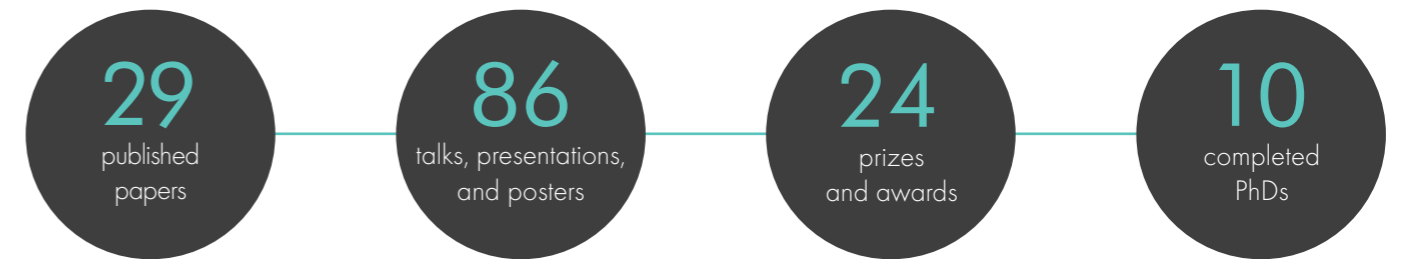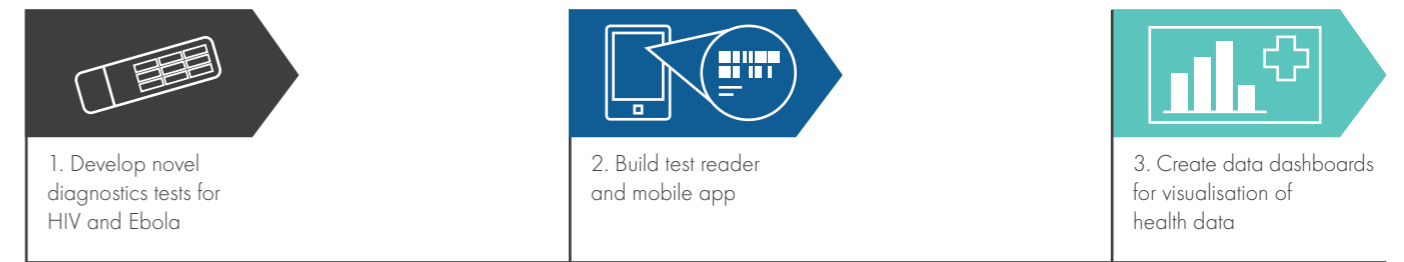
During her visit, Dr Gliddon aimed to understand the pathway of diagnosis for multidrug-resistant tuberculosis in South Africa, and to consider how genome sequencing could hasten it. Dr Gliddon met and formed collaborations with researchers at the Africa Health Research Institute, built new partnerships in tuberculosis research, commenced planning a preliminary study to develop a rapid workflow for tuberculosis drug-resistance genotyping, and explored future funding opportunities.

During her time in South Africa, Dr Gliddon visited the two sites of the Africa Health Research Institute, a number of hospitals in the area, and communities affected by tuberculosis. During this time she was able to meet a number of clinicians and researchers who were extremely useful in refining our aims for this work. The visit has already informed i-sense research and will aid the planning of future studies.

Low-cost diagnostics for HIV and Ebola in developing countries

Led by Professor Molly Stevens, Professor of Biomedical Materials and Regenerative Medicine at Imperial Collage London

1. Develop novel diagnostics tests for HIV and Ebola

2. Build test reader and mobile app

3. Create data dashboards for visualisation of health data

29 published papers

86 talks, presentations, and posters

24 prizes and awards

10 completed PhDs

Early diagnosis of HIV and Ebola is crucial for effective treatment and care of these diseases. The global HIV pandemic is estimated to currently infect 35 million people and one in five people with HIV in the UK are unaware of their status.

During the 2014 Ebola outbreak in West Africa, nearly 29,000 people were infected and there were more than 11,000 fatalities, yet limitations in available diagnostic and prognostic tests meant that fewer than 60 per cent of cases were diagnosed. These epidemics are driving the development of new mobile phone-connected technologies to test and track HIV in resource-limited settings and feed into health surveillance systems. Flagship 4 are dedicated to developing new, urgently needed point-of-care tests to control outbreaks.

A key highlight from the Flagship 4, in collaboration with Flagship 1, has been a recent review published in Nature on how combining mobile health (mHealth) technologies with connected diagnostics can increase access to testing and care for patients, and improve the ability of public health authorities to monitor outbreaks and intervene to stop them.

Led by the Stevens Group, in collaboration with the McKendry group, the Flagship 4 team also published landmark papers in ACS Nano, reporting point-of-care tests for HIV and Ebola. The HIV lateral flow immunoassay is capable of early-stage detection at the point-of-care and outperforms current standard commercial lateral flow point-of-care test for HIV. The team's Ebola lateral flow based assay, which has been developed by Dr Polina Brangel, was successfully deployed in the field in Uganda with 91 Ebola survivors and was able to distinguish between different strains of the virus. This research was also featured as a highlight in the Chemical & Engineering News magazine.

The key to our success has been good, interdisciplinary collaborations across partner universities, as well as external institutions and industry partners. The Stevens and McKendry groups have developed a number of collaborations and partnerships over the years, including with USAMRIID, the Africa Health Research Institute, Foundation of Innovative New Diagnostics, Uganda Virus Research Institute, and UCLA.

The collaboration with the Africa Health Research Institute has supported a number of our members to travel to South Africa to test i-sense tools and technologies in pilot studies and in the field. The i-sense developed data dashboards were originally designed to support the Treatment as Prevention trial at the Africa Health Research Institute and they are now being used to influence strategy. The collaboration has also helped the development of a mobile phone app to read test results and link people to prevention messages or care. This is being developed with the help of AHRI field workers who are taking images of HIV tests in the field to help train a model to more accurately read test results.

Stemming from a collaboration with Professor Stevens and Professor Sangheeta Bhatia, a Howard Hughes Medical Institute Investigator and the John J. and Dorothy Wilson Professor at the Massachusetts Institute of Technology, joint IP has been filed on an innovative biosensing technology for proteases corresponding to a range of diseases.

To support further research, this year Professor Stevens and Professor McKendry were awarded a £1M EPSRC IRC Next Steps Plus Award to develop an mRNA detection device for biomarkers of TB, in partnership with UCL, the Africa Health Research Institute, and Columbia University.

Nature review: Building the future of mobile healthcare

Led by Professor Molly Stevens' group at Imperial College London, i-sense researchers authored a review, published in Nature, that discusses how mobile health (mHealth) solutions combined with connected diagnostics could increase access to testing and care for patients, and improve the ability of public health authorities to monitor and intervene in outbreaks.

Today more than half the world's population own a smartphone, and these highly accessible technologies have the potential to change the future of healthcare, particularly for infectious diseases. We are now seeing how simple diagnostic devices can be complemented by the processing power and connectivity of modern mobile phones to produce portable devices with the potential to match the performance of traditional expensive and cumbersome laboratory diagnostic equipment.
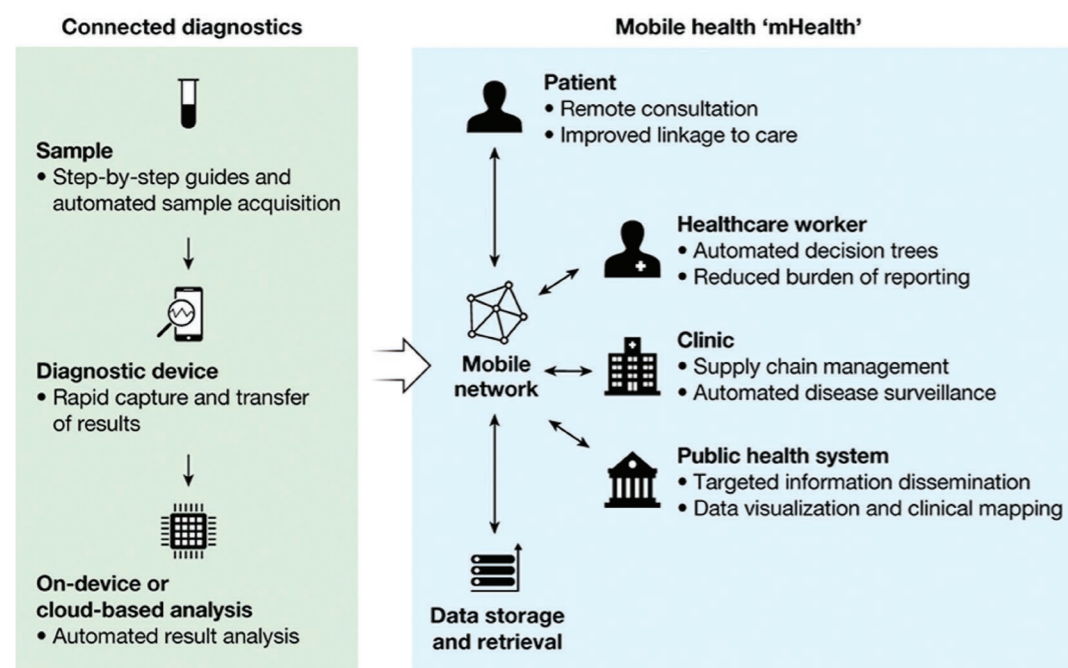
The review outlines the benefits and challenges that mHealth solutions could have for various groups, including patients, healthcare workers, clinics, and public health systems. Smartphones are increasingly used in sub-Saharan Africa. By 2020, GSMA forecast that one in two mobile phone connections in the region will be via smartphone – a similar figure to worldwide smartphone adoption. Concerns also arise in age and gender gaps in relation to the use of digital technologies as well as privacy and confidentiality of test results.

This piece was the first time the i-sense mapping (page 13) work, developed by Jobie Budd, a PhD student in the McKendry group at UCL, was published and is used to demonstrate the relationship between population density, access to cellular networks, and distance from health facilities. The review shows that one in five of the population in Sub-Saharan Africa have no access to cellular networks. However, of the 22 per cent that live more than 5km from the nearest health centre, approximately two in three people are in range of a cell tower, meaning that they could benefit from accessible mobile health interventions.

In addition to the digital divide, connectivity standards and regulatory science have not kept pace with technological advances, making it challenging for the adoption and implementation of mHealth solutions. Regulatory frameworks need to be developed to consider the emerging field of medical apps and regulators need to work together with mHealth experts to ensure that regulations do not become barriers for innovation.

This review shows an exciting opportunity for researchers and policy makers to develop new tools and systems that could drastically improve human health and wellbeing in the future.

Wood, C., S., Thomas, M. R., Budd, J., Mashamba-Thompson, T., P., Herbst, K., Pillay, D., Peeling, R. W., Johnson, A., M., McKendry, R. A., and Stevens, M. M. 'Taking connected mobile-health diagnostics of infectious diseases to the field' *Nature* (2019); DOI: 10.1038/s41586-019-0956-2

Connected diagnostics

Sample
- Step-by-step guides and automated sample acquisition

Diagnostic device
- Rapid capture and transfer of results

On-device or cloud-based analysis
- Automated result analysis

Mobile health 'mHealth'

Patient
- Remote consultation
- Improved linkage to care

Healthcare worker
- Automated decision trees
- Reduced burden of reporting

Clinic
- Supply chain management
- Automated disease surveillance

Public health system
- Targeted information dissemination
- Data visualization and clinical mapping

Mobile network

Data storage and retrieval

The history and developments of i-sense work on p24

HIV p24 has been a strong focus of i-sense since the start, and our research has led to a series of diverse and interesting publications. This p24 capsid protein of HIV is a key target for early diagnosis, and a review published in AIDS looked back over more than 25 years of research and development of assays to detect p24 at high sensitivity and specificity.

The landscape of diagnostics and needs have changed over the years as treatments and technologies become available, such as the availability of pre-exposure prophylaxis, self-testing in home settings, and the small but growing number of people involved in HIV-vaccine trials.

Although there is a clear need for a simple and rapid test to detect p24, and hence HIV infection in the priority populations identified, key challenges to developing a test that is fit for purpose remain and were presented alongside health-economic analyses of antigen-based assays in these groups.

Having set the scene, i-sense researchers have also made strides into designing their own test to detect p24. This makes use of enzymatic amplification via platinum nanocatalyst particles and is the simplest and most sensitive colorimetric paper-based lateral flow diagnostic test for HIV to date. The test uses nanobodies developed by researchers in the McKendry group at UCL and at QVQ, modified by novel linker chemistry developed at UCL, and the nanocatalyst particles were developed and refined by the i-sense team at Imperial College London, alongside collaborators.

Excitingly, this work also received an i-sense Mobility Fellowship to test the HIV p24 lateral flow assay in the field in collaboration with the

Africa Health Research Institute. The first visit from this funding took place in November 2017, when Professor Rachel McKendry and Professor Molly Stevens met with the Research Nursing Manager, Siphephelo Dlamini, and Clinic Research Assistant, Xolisile Mkhwanazi, at the Africa Health Research Institute's Somkhele health clinic in KwaZulu-Natal. In the same visit, Dr Michael Thomas and Dr Eleanor Gray initiated discussions to coordinate testing with researchers and staff at the Africa Health Research Institute.

HIV p24

HIV capsid
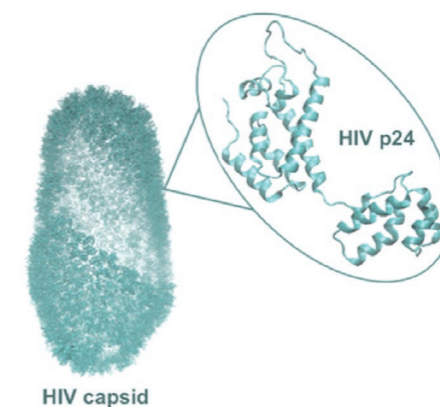
A separate, second novel rapid test that requires just a single finger prick of blood to produce a positive test result within 10 seconds, makes use of ubiquitous surface acoustic wave (SAW) biochips, which are based on components already found in every consumer smartphone. The test has been trialled in a pilot study with over 130 diagnostic remnant patient samples for antibody detection, with 100% sensitivity and 100% specificity versus gold-standard laboratory tests.

Alongside translational research to develop tools to detect infection, team members have also been

contributing to basic research underpinning some of the findings above. Researchers in the areas of theoretical physics, crystallography and molecular biology came together to unravel the mechanism of high affinity binding of the llama antibody, used in the nanocatalyst and the SAW biosensors, to its target HIV p24.

Key to the successful deployment of this nanobody has been the interaction across multiple groups and disciplines across i-sense, with expertise coming to bear on a topic from many different angles.

Gray, E. R., Bain, R., Varsaneux, O., Peeling, R., Stevens, M. M., and McKendry, R. A. 'p24 revisited: a landscape review of antigen detection for early HIV diagnosis.' *AIDS* (2018); DOI: 10.1097/QAD.0000000000001982

Loynachan, C.N., Thomas, M.R., Gray, E.R., Richards, D.A., Kim, J., Miller, B.S., Brookes, J.C., Agarwal, S., Chudasama, V., McKendry, R.A., Stevens, M.M. 'Platinum Nanocatalyst Amplification: Redefining the Gold Standard for Lateral Flow Immunoassays with Ultrabroad Dynamic Range' *ACS Nano* (2017); DOI: 10.1021/acsnano.7b06229

Turbé, V., Gray, E. R., Lawson, V. E., Nastouli, E., Brookes, J. C., Weiss, R. A., Pillay, D., Emery, V. C., Verrips, C. T., Yatsuda, H., Athey, D., McKendry, R. A. 'Towards an ultra-rapid smartphone- connected test for infectious diseases' *Scientific Reports 7*, Article number: 11971 (2017); DOI:10.1038/s41598-017-11887-6

Gray, E.R., Brookes, J.C., Caillat, C., Turbe, V., Webb, B.L., Granger, L.A., Miller, B.S., McCoy, L.E., El Khattabi, M., Verrips, C.T., Weiss, R.A., Duffy, D.M., Weissenhorn, W., McKendry, R.A. 'Unravelling the molecular basis of high affinity nanobodies against HIV p24: in vitro functional, structural and in silico insights.' *ACS Infectious Diseases* (2017); DOI: 10.1021/acsinfecdis.6b00189

Promising new technology for diagnosing immunity to Ebola

Since the major West Africa Ebola outbreak in 2014, a wide range of tools have been developed to allow rapid diagnosis of patients. i-sense Flagship 4 expanded its reach to incorporate work on Ebola diagnostics, which was led by Dr Polina Brangel when she started her PhD at Imperial College London, under the supervision of Professor Molly Stevens.

The most recent outbreak in 2017, which occurred in a very remote, forested region of the Democratic Republic of Congo, highlighted the need for simple and portable tests not only for diagnosis, but also to detect immunity to the virus for effective disease surveillance. In 2018, *ACS Nano* published research conducted by Dr Brangel and her collaborators on a promising new approach to detecting immunity to Ebola virus infection.

This research focused on developing mobile-connected paper-based tests that detects IgG antibodies against key viral proteins that play an important role as the basis of most currently developed vaccines. Unlike similar tests, it also classifies this protein against two additional viral proteins that could be used as a tool for the identification of exposed populations to the deadly virus, as well as predication of acute patient survival rate. While lab based tests can take up to five hours, this point-of-care test takes just 15 minutes to result.

The identification of IgG antibodies might help understand exposure to the different strains of the Ebola virus, enable detection of immunity in the early stages of recovery, and potentially benefit the detection of asymptomatic infections and pre-vaccination assessment.

Further to this, the identification of antibodies is particularly advantageous for developing vaccines as it provides a more enhanced evaluation of vaccine efficiency under outbreak conditions.

Future work will look into developing the test to use whole blood samples (from a finger prick) to simplify the operational process even more and enable 'on the spot' results without any need for further equipment and facilities.

Brangel, P., Sobarzo, A., Parolo, C., Miller, B.S., Howes, P.D., Gelkop, S., Lutwama, J.J., Dye, J.M., McKendry, R.A., Lobel, L., Stevens, M.M. 'A Serological Point-of-Care Test for the Detection of IgG Antibodies against Ebola Virus in Human Survivors' *ACS Nano* (2018); DOI: 10.1021/acsnano.7b07021

Building a mobile phone application for HIV testing and care

Dr Valérian Turbé, McKendry group, London Centre for Nanotechnology at UCL

Our mobile phone-connected diagnostic tools aim to widen access to testing in GP surgeries, in the community throughout developing countries, and in the home. The capability to detect infections and then wirelessly connect test results through a mobile phone app to healthcare systems will help patients gain faster access to treatment and support public health efforts to map indicators of emerging infections in real-time.

To help develop a mobile phone app for HIV, i-sense researchers have been collaborating on the m-Africa project, which started in May 2017. The project is a two-year Medical Research Council GCRF Global Infections Foundation Award, which brings together researchers from UCL, Imperial College London, and the Africa Health Research Institute.

The m-Africa project has an initial focus on building a library of images of HIV point-of-care tests to train a machine learning model, being developed by i-sense, to automatically read the test results from a photo taken on a mobile device.

Today, more than 60 fieldworkers from the Africa Health Research Institute have been trained to help capture images of two, government issued, HIV point-of-care tests they use in the field. i-sense researchers have developed a plastic tray to aid in image collection, which was designed to hold the two HIV tests in place and features alignment markers to facilitate data processing.

The image library now has approximately 20,000 images that are being used to train various models through machine learning, with the most accurate model currently showing high sensitivity and specificity.

In parallel, the smartphone app has been developed and a prototype is currently being piloted in clinic to investigate participant feelings about self-testing using an app, as well as participant reactions to being told their test results by a device (rather than by a healthcare professional), and the phone counselling and support that follows.

Dashboards for treatment interventions

Dr Ed Manley and Dave Concannon, Centre for Advanced Spatial Analysis at UCL, and Dr Kobus Herbst, Africa Health Research Institute

The increase in the use of digital devices to record and generate health data has changed the landscape of how data can be used to combat the spread of infectious disease, especially in low-income countries where the use of mobile phones is increasing rapidly.

The i-sense dashboards are an exploration of how a data dashboard for early warning systems can function, exploring how data from different sources can be integrated to provide insight. Working in collaboration with the staff at the Africa Health Research Institute, the dashboards were designed to allow quick interpretation of large data sets.

The dashboard presents the results from the Treatment as Prevention trial, which included 24,000 participants and took place in KwaZulu-Natal, South Africa. The platform was able to demonstrate near real-time progress of the study by updating daily from the information collected by fieldworkers. The dashboards have been designed to be adapted to different studies and allows the user to identify areas of interest from datasets for further analysis and action.

Following the development of the dashboards, a task-based evaluation was undertaken to assess ease of use and user attitudes. The evaluation recruited a diverse range of users and although there were significant differences in the usability between user groups, the dashboards were well received by all with interest of using these tools in future. The results of the study demonstrated the need for the consideration of visualisation and data literacy in future designs.

Our core research and flexible funding; Exploratory projects and Partnership Resource Fund

Led by Professor Rachel McKendry, UCL, and Professor Vince Emery, Surrey University

£1.7M has been awarded to 12 Exploratory Projects since the beginning of i-sense. This programme, which is led by Professor Rachel McKendry, supports short collaborative projects between two or more academic partner institutions, to ensure that i-sense benefits from the latest scientific developments. Importantly, Postdocs have the opportunity to lead projects.

Over the last five years, there have been three rounds of applications, which included projects covering building and maintaining public trust in early warning systems, a survey on digital health detection of influenza in the community, mapping out the self-testing pathway for HIV, developing target product profiles for influenza, and more.

These projects have fostered interdisciplinary collaborations across our core partners, as well as UCL School of Pharmacy, Farr Institute and Glasgow Caledonian University to expand on Core research.

The Partnership Resource Fund, which is led by Professor Vince Emery, was created to grow i-sense into a self-sustained hub of innovation, by building networks of excellence with external academic, clinical and industry partners. By offering flexible funding opportunities to our members through Knowledge Transfer Grants and Mobility Fellowships, we are able to build national and international partnerships.

£640K has gone to funding for Knowledge Transfer Grants to date. These projects aim to support the translation of i-sense technologies into products and practices. Over the last five years, there have been 13 Knowledge Transfer Grants supported through i-sense.

£90K has gone to funding for Mobility Fellowships to date. These projects offer our members the chance to expand their knowledge and experience in different dynamic scientific environments, while also supporting external researchers to visit the i-sense team. Over the last five years, i-sense has supported 13 Mobility Fellowships.

Exploratory projects

Team	Title	Collaborators
Round one		
Dr Stephen Hilton, Dr Matthew Penny, Dr Michael Thomas, Professor Molly Stevens and Professor Rachel McKendry	A novel sensor system for influenza: The synergistic combination of responsive chemical sensors and mobile phone based spectral analysis for rapid diagnosis	UCL and Imperial College London
Professor Milo Shaffer, Dr Claudio Parolo, Benjamin Miller, Professor Neal Skipper and Professor Rachel McKendry	Carbon Nanotubes for the fabrication of a high performance paper based electrode: Use for a sensitive, quantitative and fast diagnosis of influenza A nucleoprotein	Imperial College London and UCL
Professor John Edmunds, Professor Rachel McKendry, Dr Ellen Fragaszy, Professor Andrew Hayward, Dr Richard Pebody, Dr Daniela Paolotti, Professor Ingemar Cox, Dr Patty Kostkova, Henry Potts, Professor Ann Blandford, Dr Matthew Donati and Dr Clare Wenham	Flusurvey: Digital health detection of influenza in the community	London School of Hygiene & Tropical Medicine, Public Health England and UCL
Dr James Wilson, Benedict Rumbold, Professor Rosanna Peeling, Professor Rachel McKendry, Dr Richard Pebody and Professor Ingemar Cox	Building and maintaining public trust in early warning sensing systems for influenza	UCL, Public Health England, London School of Hygiene & Tropical Medicine
Round two		
Professor Ingemar Cox, Professor Emiliano De Cristofaro, Dr Lukasz Olejnik, Professor Emil Lupu and Dr Vasileios Lampos	A technical framework for enabling and supporting data donors for medical research	UCL
Dr Vijay Chudasama, Dr Daniel Richards, Dr Chris Wood, Dr Mike Thomas, Dr Adam Creamer, Ye Wang, Dr Philip Howes, Joao Nogueira, Professor Martin Heeney and Professor Molly Stevens	Highly controlled nanoparticle-antibody conjugates for next generation point of care diagnostics	UCL and Imperial College London
Professor Kenny Dalgarno	Exploiting microfluidics and printing technologies to rapidly detect MRSA in nasal swabs	Newcastle University and UCL
Dr Matthew Penny, Dr Michael Thomas, Professor Molly Stevens, Professor Rachel McKendry and Dr Stephen Hilton	Smart detection of influenza: The chemical interface between the virus and mobile-phones	UCL School of Pharmacy, London Centre for Nanotechnology, and Imperial College
Dr Nathan Green, Professor Andrew Hayward, Dr Peter J White, Dr Ellen Fragaszy, Dr Perrine Pelosse, Professor Christl Donnelly and Dr Richard Pebody	Developing target profiles of point-of-care tests for influenza: How could they increase the cost-effectiveness of national pandemic flu service (NPFS) and of the management of seasonal influenza	UCL and Public Health England
Dr Jo Gibbs, Professor Ann Blandford, Professor Pam Sonnenberg, Dr Aneesha Singh and Professor Claudia Estcourt	Advancing HIV self-testing: developing an NHS-based online clinical care pathway and system to link self-testers into appropriate services and surveillance	UCL and Glasgow Caledonian University
Round three		
Professor Ingemar Cox	Consolidating Core research excellence: Flagship 2	UCL and Public Health England
Professor Molly Stevens and Professor Rachel McKendry	Consolidating Core research excellence: Flagship 4	UCL and Imperial College London

Total: £1,704,609

Knowledge Transfer grants

Team	Title	Collaborators
Professor Jackie Cassell, Jo Middleton, and Stefania Lanza	Assessing the needs for mobile phone connected tests for infections in residential and nursing homes for the elderly (RNCs)	Brighton and Sussex Medical School
Professor Anil Wipat and Dr Keith Flanagan	IDRIS system: proof of concept and exploration of commercialization routes	Newcastle University and UCL
Colleen Loynachan, Dr Michael Thomas, Dr Eleanor Gray, Dr Dan Richards, Jeongyun Kim, Ben Miller, Dr Jenny Brookes, Shweta Agarwal, Dr Vijay Chudasama, Professor Rachel McKendry and Professor Molly Stevens	Nanozyme lateral flow diagnostics: development towards translation	Imperial College London and UCL
Professor Rosanna Peeling and Dr Adriana Goncalves	Factors influencing the design and development of sensors for early warning systems of infectious diseases	London School of Hygiene and Tropical Medicine
Dr Jo Gibbs, Professor Professor Ann Blandford, Professor Pam Sonnenberg, Dr Aneesha Singh and Professor Claudia Estcourt	Development of an integrated eSexual Health Clinic (i-eSHC): from diagnostics to online management of sexually transmitted infections and HIV.	UCL and Glasgow Caledonian University
Dr Maryam Shahmanesh, Professor Frank Tanser, Philippa Matthews, Professor Nuala McGrath, Professor Janet Seeley, Professor Sally Wyke, Professor Till Barnighausen, Professor Deenan Pillay and Professor Ann Blandford	To develop EPIC-HIV to increase HIV-testing and linkage to care in a hyper endemic, rural setting in Umkhanyakude, KwaZulu-Natal, South Africa	UCL and Africa Health Research Institute
Dr Melody Ni, Simone Borsci and Professor Rachel McKendry	Model of the potential health-economic benefits of mobile phone connected tests for HIV based on p24 and antibody detection	Imperial College London and UCL
Professor Claudia Estcourt, Professor Pam Sonnenberg, Dr Jo Gibbs, Professor Ann Blandford, Professor Anne Johnson and Soazig Clifton	From innovation to implementation: identifying and addressing policy and structural barriers to achieving the full potential of i-sense	UCL and Glasgow Caledonian University
Professor Ingemar Cox, Dr Vasileios Lampos and Dr Richard Pebody	Knowledge transfer to Public Health England and international bodies	UCL and Public Health England
Dr Polina Brangel, Chris Isaacs, Dr Valérian Turbé, Nestor Arsenov, Jobie Budd and Professor Rachel McKendry	Evaluation of optimal conditions for smartphone RDT readers	UCL and Foundation for Innovative New Diagnostics
Dr Dan Horton and Prof Roberto La Ragione	Proposal to undertake a systematic review: Exploiting the full potential of rapid diagnostic test technology and mobile connectivity for improved animal disease detection and control	School of Vet Medicine, Surrey University
Chris Isaacs, Dr Valérian Turbé and Professor Rachel McKendry	Commercialisation of HIV app	UCL and Connected Diagnostics Ltd
Total:		£641,489

Mobility Fellowships

Researchers	Aim	Universities/ Departments
Christine Wang	In situ Visualisation of the dynamic interactions at the bio-nano interface using liquid-cell transmission electron microscopy (LC-TEM)	To visit the Molecular Foundry in Berkley from Imperial College London
Dr Lucia Massi	Acquisition of polymer chemistry skills for the development of an enzyme-responsive polymer-based platform for enabling earlier HIV detection	To visit University of New South Wales from Imperial College London
Lucie Felkova	i-sense inward Mobility Fellowship to work with UCL Department of Computer Science	To visit UCL from Technische Universität Darmstadt
Dr Ed Manley and David Concannon	Developing new data dashboards to support HIV trials and exploring the relationship between transport accessibility and the treatment of infectious disease in South Africa	To visit the Africa Health Research Institute from UCL
Professor Molly Stevens, Professor Rachel McKendry, Dr Michael Thomas, and Dr Eleanor Gray	Building a digital health 'test bed' in the heart of the HIV epidemic	To visit the Africa Health Research Institute from UCL and Imperial College London
Ben Miller	Collaboration with nanophotonic pioneer with Professor Aydogan Ozcan and his group	To visit UCLA from UCL
Isabel Bennett	Developing a mobile phone- connected tool to measure antibiotic susceptibility of bacteria, specifically for uropathogenic *E. coli*, with Professor Aydogan Ozcan and his group	To visit UCLA from UCL
Dr Polina Brangel	Empowering new leaders in Uganda	For Uganda Virus Research Institute from UCL
Petar Stupar	Nanomotion sensing for antibiotic susceptibility	To visit UCL London Centre for Nanotechnology from Swiss Federal Institute of Technology in Lausanne
Professor Irene Yarovsky	Undertaking simulations of the properties of the novel nanomaterials for biomedical applications	To visit Imperial College London from Royal Melbourne Institute of Technology
Dr Virgilio Valente	Visit research group on nanoscale Integrated and circuits at Tufts University, Medford, MA	To visit Tufts University from UCL
Siddharth Nair	i-sense inward mobility fellowship	To visit UCL from University of Melbourne
Colleen Loynachan	Catalytic nanoclusters for in vivo disease monitoring	To visit Massachusetts Institute of Technology from Imperial College London
Total:		£90,464

Photo credit: EPSRC Proteus

Partnership Resource Fund workshops

Led by Professor Vince Emery, Senior Vice-President (Global Strategy and Engagement) and Professor of Translational Virology, University of Surrey

In addition to supporting projects, the Partnership Resource Fund has also supported three workshops over the last five years, including the 'new frontiers in digital influenza surveillance,' held in 2014, the EPSRC All IRC conference in 2017, and most recently, the i-sense and 5G Innovation Centre workshop in 2018. Across the three workshops there were more than 145 attendees, including members of the EPSRC's three IRCs, mobile companies including Samsung and Huawei, other diagnostics companies, the Surrey 5G Innovation Centre, and members of government, academia, and policy makers.

Our recent workshop at the 5G Innovation Centre in the University of Surrey aimed to discuss and share outputs that have been created as part of i-sense, the role that 5G technologies play in the ecosystem, and how they intersect with a range of industry needs.

During the one-day workshop, we heard from i-sense members about the developments of their projects, from leads at the 5G Innovation Centre about the exciting future of 5G, and from a range of industrial partners

including those from areas such as diagnostics, telecommunications, data analytics and technology. Through short talks, video sharing, breakout sessions and round table discussion attendees were able to talk about their projects, ideas for the future, and potential collaborations.

The workshop was an excellent example of how engagement across a range of disciplines from diagnostics through to big data and cutting-edge communication technologies, such as 5G, allows new avenues of activity to be explored between university and industry partners, which will ultimately make an impact locally, nationally and globally.

5G promises to solve many of the challenges associated with connecting remote diagnostics as well as enabling a plethora of new solutions and services destined to impact the health of citizens across the world. Collaboration between academia, industry, governments and policy makers is critical to define and execute the vision of a world free of disease.

Education Alliance

Led by Dr Neil Keegan, Senior Lecturer, Institute of Cellular Medicine, Newcastle University

The i-sense Education Alliance was created to introduce new teaching and training events in order to grow the interdisciplinary skills of our students and early-career researchers. Led by Dr Neil Keegan and supported by a team of representatives across i-sense partner institutions, the unique programme is designed to inspire and prepare our members for their future careers.

Over the last five years, there have been seven events held across the UK, including in London, Newcastle, Bath, and York. Education Alliance activities have attracted more than 300 total attendees across all events and received consistently great feedback.

A challenge the committee faced was to provide opportunities to our members that were not already available across the partner universities. In 2017, the Committee reached out to its members to understand what future activities could be planned to best benefit the cohort. Those who responded to the survey suggested that workshops focused on statistics and data visualisation could complement their skills and help support their work and presentations.

Over the past 12 months, three events were organised. The first event was the Presentation and Communication Skills workshop that was facilitated by Mortal Fools at the University of Newcastle's Northern Stage in November 2017. The day was attended by a combination of 30 students, postdocs, academics and support staff from the i-sense group. The workshop was about learning by doing, practising and observing others. Participants discussed their concerns when presenting and key themes from the discussion were addressed through activities during the day. These included bringing the subconscious into awareness, dealing with fear, having an authentic communication style, controlling nerves through breathing techniques, and eye contact. Each participant had the chance to practice their skills in front of their colleagues, receive constructive feedback, and help others by providing guidance.

The next two workshops were held as a two-day series and were designed in response to the survey feedback. The first was titled 'Designing trials of diagnostic test accuracy, which was facilitated by Dr Sue Mallett from the

University of Birmingham, and the second was titled 'Data Visualisation Masterclass,' which was facilitated by the Guardian.

The statistics workshop was attended by 24 i-sense members and was an interactive day that included examples and active participation for attendees to complete exercises in small groups. The focus of the workshop was to study the design and role of diagnostic tests and how they can be evaluated, study sample size, assess potential sources of bias and applicability, and understand how to interpret and communicate results of diagnostic test accuracy.

In the feedback survey, i-sense members mentioned that this was the best activity organised by the Education Alliance to date, saying that the workshop and that the content was very useful to the context of their work and that it was a great introductory course on the methods of evaluating diagnostic tools, outlining current best practice in theory and then applying it to real world examples.

The data visualisation workshop was attended by 32 i-sense members with various skills and experience in design. This course is usually run as part of the Guardian Masterclasses and was adapted to fit the i-sense team. It provided the opportunity for all i-sense members to think about ways to present their data in an interesting, aesthetically appealing way, that is easy for their audience to understand.

The workshop was facilitated by two graphic designers who provided examples of good and bad data visualisation and facilitated small group activities for participants to apply the skills learnt. The focus of the workshop was to learn the art of good infographic storytelling, understand each specific audience and their needs, see and learn about data visualisation best practice, and design infographics to make your graphs and charts impactful.

For i-sense Next Steps, the Education Alliance will focus on helping all researchers develop and manage their own career plans. The Education Alliance will continue to facilitate researchers to be all they can be, nurturing the next generation of leaders in their field.

Communication and engagement

Led by Erin Manning, i-sense Communications Officer

Communication and engagement has played an important role in reaching i-sense objectives. Speaking with a wider audience has helped our members generate public awareness, engage conversation and dialogue about our research outcomes and important topics, and gain input and insights from potential end users.

Our main source of communication is our dedicated i-sense website (www.i-sense.org.uk) and social media accounts (Twitter, Facebook and LinkedIn). The website was launched in October 2014 and has had more than 100,000 unique page views to date. Our Twitter page (@isenseIRC) has grown by almost 100 followers in the last year with now more than 550 followers. In 2018, i-sense also started a LinkedIn page in response to feedback from the public and our Advisory Board members.

Over the years, we have taken part in nine public engagement activities including simulating 'outbreaks' at Greenman Festival in Wales, Courtyard Festival, New Scientist Live, and Bloomsbury Festival in London. We have also developed the Rosalind Franklin Appathon for Women in STEMM, and ran two activities at the Science Museum. Our members have also organised six school days to encourage young people, particularly girls, to consider studying and building a career in science. Recognition for outstanding contribution to public engagement was given to then

i-sense Communications Officer, Kailey Nolan, who won the UCL Provost's Public Engagement Award in 2016.

Our members have also given approximately 75 talks and poster presentations at conferences and events around the world. This year, our students, researchers and academics gave talks in the UK, Portugal, Hong Kong, South Africa, France, Ethiopia, USA, Germany, and more. Highlights include Professor Rosanna Peeling and Dr Valérian Turbé giving talks at the International Workshop on Phones, Drones and Disease at the University of Hong Kong, Professor Rachel McKendry's talk at the Sixth International Molecular Diagnostics conference in Lisbon, a presentation from Dr Noah Fongwen at the 1st International Conference on Re-emerging Infectious Diseases in Addis, and Professor Molly Stevens' Lecture to celebrate 10 years as a full Professor at Imperial College London.

The high standard and importance of our research has also been noticed by the media with i-sense research featuring in The Evening Standard, a BBC One documentary called 'The Truth About HIV', The Guardian, Financial Times, Business Report, on Deutsche Welle (Germany's international broadcaster), in The Lancet, and The BMJ Opinion. We have also featured several times on UCL, LSHTM, and Imperial College London's news pages, and in MRC and EPSRC news and blogs.

More than 100,000 unique page views on our website to date

9 public engagement events
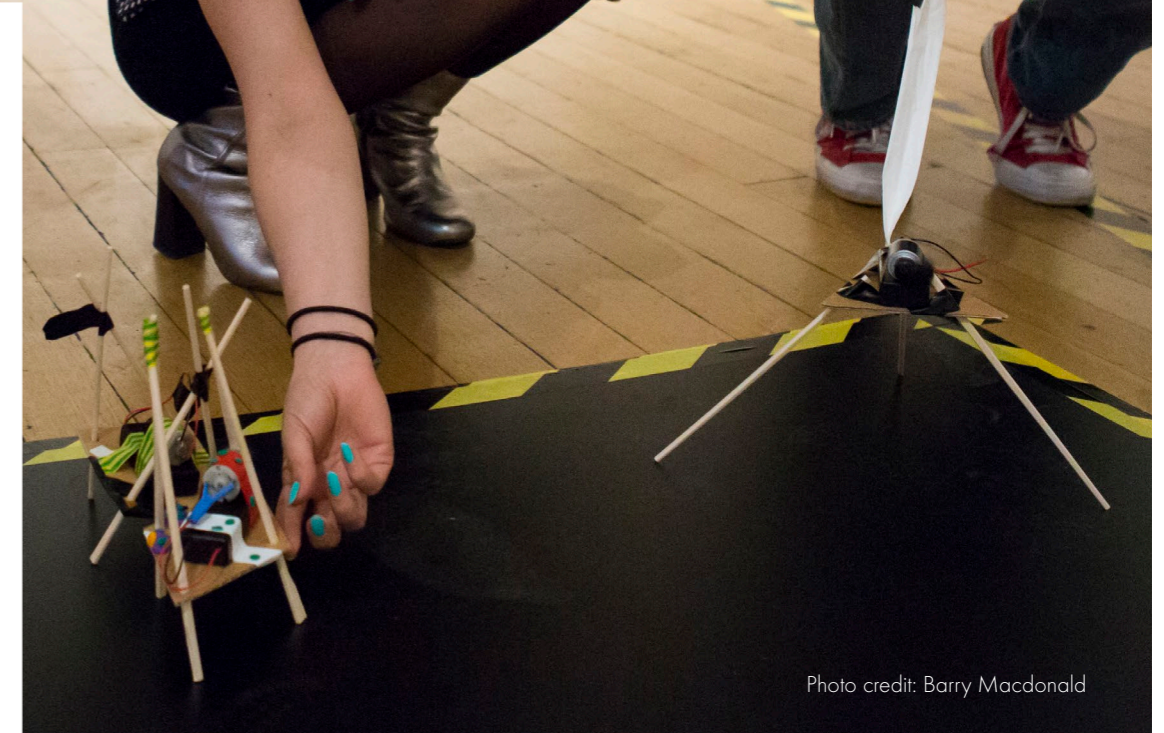
6 school visits

Photo credit: Barry Macdonald

Publications

There have been 72 publications from i-sense since 2013. Below are the recent highlights.

2019

Gray, E. R., Heaney, J., Ferns, R. R., Sequeira, P. C., Nastouli, E., and Garson, J. A. 'Minor groove binder modification of widely used TaqMan hydrolysis probe for detection of dengue virus reduces risk of false-negative real-time PCR results for serotype 4' *Journal of Virological Methods* (2019); DOI: 10.1016/j.jviromet.2019.03.006

Wood, C., S., Thomas, M. R., Budd, J., Mashamba-Thompson, T., P., Herbst, K., Pillay, D., Peeling, R. W., Johnson, A., M., McKendry, R. A., and Stevens, M. M. 'Taking connected mobile-health diagnostics of infectious diseases to the field' *Nature* (2019); DOI: 10.1038/s41586-019-0956-2

Benjamin S. Miller, B., S., Gliddon, H., D., and McKendry, R. A. 'Towards a Future of Rapid, Low-Cost, Multiplexed Detection of Antimicrobial Resistance Markers for Tuberculosis and Other Pathogens' *Clinical Chemistry* (2019); DOI: 10.1373/clinchem.2018.296715

Lin, Y., Mazo, M. M., Skaalure, S. C., Thomas, M. R., Schultz, S. R., and Stevens, M. M. 'Activatable cell–biomaterial interfacing with photo-caged peptides' *Chem. Sci.* (2019); DOI: 10.1039/C8SC04725A

2018

Pilavaki, E., Valente, V., and Demosthenous, A. 'CMOS Image Sensor for Lateral Flow Immunoassay Readers' *IEEE Transactions on Circuits and Systems II: Express Briefs* (2018); DOI: 10.1109/TCSII.2018.2855054

Gelkop, S., Sobarzo, A., Brangel, P., Vincke, C., Romão, E., Fedida-Metula, S., Strom, N., Ataliba, I., Mwiine, F. N., Ochwo, S., Velazquez-Salinas, L., McKendry, R. A., Muyldermans, S., Lutwama, J. J., Rieder, E., Yavelsky, V., and Lobel L. 'The Development and Validation of a Novel Nanobody-Based Competitive ELISA for the Detection of Foot and Mouth Disease 3ABC Antibodies in Cattle' *Frontiery in Vetinary Science* (2018); DOI: 10.3389/fvets.2018.00250

Neshatvar, N., Langlois, P., and Demosthenous, A. 'A Non-Linear Feedback Current Driver With Automatic Phase Compensation for Bioimpedance Applications' *IEEE Transactions on Circuits and Systems II: Express Briefs*(2018); DOI: 10.1109/TCSII.2018.2856377

Samadhan B. Patil, S. B., Al-Jehani, R. M., Etayash, H., Turbe, V., Jiang, K., Bailey, J., Al-Akkad, W., Soudy, R., Kaur, K., McKendry, R. A., Thundat, T., and Ndieyira, J. W. 'Modified cantilever arrays improve sensitivity and reproducibility of nanomechanical sensing in living cells' *Nature Communications Biology* (2018); DOI: 10.1038/s42003-018-0179-3

Schormans, M., Valente, V., and Demosthenous, A. 'A Low-Power, Wireless, Capacitive Sensing Frontend Based on a Self-Oscillating Inductive Link' *IEEE Transactions on Circuits and Systems I: Regular Papers* (2018); DOI: 10.1109/TCSI.2018.2835148

Lawry, B. M., Johnson, C. L., Flanagan, K., Spoors, J. A., McNeil, C. J., Wipat, A., and Keegan. N. 'Species-Specific Detection of C. difficile Using Targeted Antibody Design' *Analytical Chemistry* (2018); DOI: 10.1021/acs.analchem.8b03349

Gray, E. R., Bain, R., Varsaneux, O., Peeling, R., Stevens, M. M., and McKendry, R. A. 'p24 revisited: a landscape review of antigen detection for early HIV diagnosis.' *AIDS* (2018); DOI: 10.1097/QAD.0000000000001982

Wagner, M., Lampos, V., Cox, I. J., and Pebody, R. 'The added value of online user-generated content in traditional methods for influenza surveillance.' *Scientific Reports* (2018); DOI: 10.1038/s41598-018-32029-6

Gibbs, J., Clifton, S., Sonnenberg, P., Blandford, A., Johnson, A. M., and Estcourt, C. S. 'Legislation and regulation in the era of online sexual health: how do we ensure provision of safe, high-quality care?' *BMJ* (2018); DOI: 10.1136/sextrans-2018-053679

Gray, E. R., Turbe, V., Lawson, V. E., Page, R. H., Cook, Z. C., Ferns, R. B., Nasouli, E., Pillay, D., Yatsuda, H., Athey, D., and McKendry, R. A. 'Ultra-rapid, sensitive and specific digital diagnosis of HIV with a dual-channel SAW biosensor in a pilot clinical study' *Digital Medicine* (2018); DOI: 10.1038/s41746-018-0041-5

Creamer, A., Wood, C. S., Howes, P. D., Casey, A., Cong, S., Marsh, A. V., Godin, R., Panidi, J., Anthopoulos, T. A., Burgess, C. H., Wu, T., Fei, Z., Hamilton, I., McLachlan, M. A., Stevens, M. M., and Heeney, M. 'Post-polymerisation functionalisation of conjugated polymer backbones and its application in multi-functional emissive nanoparticles' *Nature Chemistry* (2018); DOI: doi.org/10.1038/s41467-018-05381-4

Green, H. K., Edeghere, O., Elliot, A. J., Cox, I. J., Morbey, Pebody, P., Bones, A., McKendry, R. A., Smith, G. E. 'Google search patterns monitoring the daily health impact of heatwaves in England: how do the findings compare to established syndromic surveillance systems from 2013 to 2017?' *Environmental Research* (2018); DOI: 10.1016/j.envres.2018.04.002

Blandford, A., Gibbs, J., Newhouse, N., Perski, O., Singh, A., and Murray, E. 'Seven lessons for interdisciplinary research on interactive digital health interventions' *Digital Health* (2018); DOI: doi.org/10.1177/2055207618770325

Miller, B. S., Parolo, C., Tube, V., Keane, C. E., Gray, E. R., McKendry, R. A. 'Quantifying Biomolecular Binding Constants Using Video Paper Analytical Devices' *Chem. Eur. J.* (2018); DOI: 10.1002/chem.201802394

Wenham, C., Gray, E. R., Keane, C. E., Donati, M., Paolotti, D., Pebody, R., Fragaszy, E., McKendry, R. A., Edmunds, W. J. 'Self-Swabbing for Virological Confirmation of Influenza-Like Illness Among an Internet-Based Cohort in the UK During the 2014-2015 Flu Season: Pilot Study' *J Med Internet Res; 20(3):e71* (2018); DOI: 10.2196/jmir.9084

Brangel, P., Sobarzo, A., Parolo, C., Miller, B.S., Howes, P.D., Gelkop, S., Lutwama, J.J., Dye, J.M., McKendry, R.A., Lobel, L., Stevens, M.M. 'A Serological Point-of-Care Test for the Detection of IgG Antibodies against Ebola Virus in Human Survivors' *ACS Nano* (2018); DOI: 10.1021/acsnano.7b07021

Fragaszy, E. B., Warren-Gash, C., White, P. J., Zambon, M., Edmunds, W. J., Nguyen-Van-Tam, J. S., Hayward AC, 'Effects of seasonal and pandemic influenza on health-related quality of life, work and school absence in England: Results from the Flu Watch cohort study.' *Influenza Other Respir Viruses, Vol: 12, Pages: 171-182* (2018); DOI: 10.1111/irv.12506

Management Committee

Professor Rachel McKendry, Professor of Biomedical Nanotechnology at UCL with a joint position at the London Centre for Nanotechnology and Division of Medicine, and i-sense Director.

Professor Ingemar Cox, Professor of Computer Science, UCL and i-sense Deputy Director and Flagship 2 lead (Influenza).

Professor Vincent Emery, Senior Vice-President (Global Strategy and Engagement) and Professor of Translational Virology, University of Surrey; and i-sense Partnership Resource Fund lead.

Professor Dame Anne Johnson DBE, Professor of Infectious Disease Epidemiology and Chair, UCL Population and Lifelong Health Domain and i-sense Deputy Director.

Dr Neil Keegan, Senior Lecturer, Institute of Cellular Medicine, Newcastle University and i-sense Flagship 3 (Bacterial infections) and Education Alliance lead.

Professor Calum McNeil (Retired), Professor of Biological Sensor Systems, Newcastle University and i-sense Deputy Director.

Dr Richard Pebody, Head of Respiratory Disease Surveillance and Influenza Surveillance, Public Health England.

Professor Rosanna Peeling, Professor and Chair of Diagnostics Research, London School of Hygiene & Tropical Medicine and i-sense Flagship 1 lead (System needs).

Professor Molly Stevens, Professor of Biomedical Materials and Regenerative Medicine, Imperial College London and i-sense Flagship 4 lead (HIV and Ebola).

Professor Deenan Pillay, Director of the Africa Health Research Institute and i-sense Deputy Director.

Advisory Board

Professor David Heymann (Chair), Professor of Infectious Disease Epidemiology, London School of Hygiene and Head of the Centre on Global Health Security at Chatham House.

Professor John Brownstein, Associate Professor of Pediatrics, Harvard Medical School, co-founder of HealthMap.

Professor Peter Dobson OBE, Former Director of Begbroke Science Park, University of Oxford.

Andrew Eland, Engineering Director, Google.

Professor Christoph Gerber, Professor, Swiss Nanoscience Institute, University of Basel.

Professor Patrick Maxwell, Regius Professor of Physic and Head of the School of Clinical Medicine, University of Cambridge.

Professor Ciara O'Sullivan, Research Professor Nanobiotechnology and Bioanalysis Universitat Rovira i Virgili.
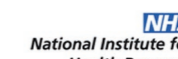
Dr Mike Short CBE, Chief Scientific Advisor, Department for International Trade.

Dr Annette Bramley, Director, N8 Research Partnership.

Industry and clinical partners