Digital Health in Oxford and the Thames Valley

A project carried out on behalf of the Oxford AHSN, Oxford University and Isis Innovation to examine factors influencing the growth of the digital health sector in the region that covers Oxfordshire and much of the Thames valley.

Mark Edwards

March 2016

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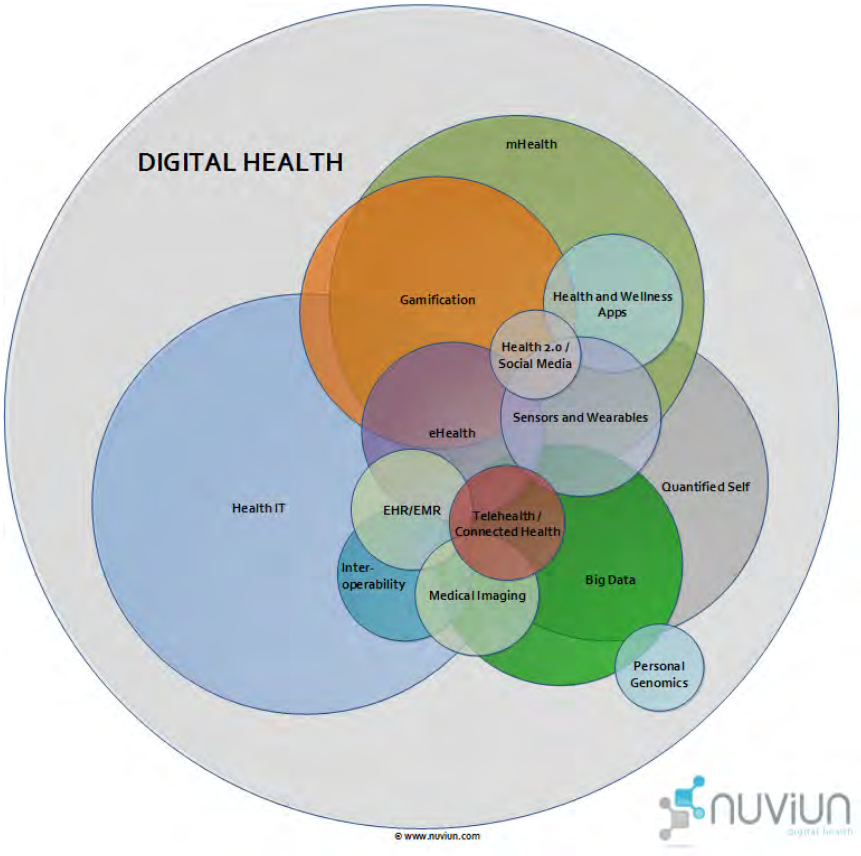


Figure 1 A broad definition of digital health from Nuviun Digital Health

Summary

This report was commissioned by the Oxford Academic Health Science Network (AHSN), Oxford University and Isis Innovation. The overarching objective was to examine the state of digital health research and related commercial activity in the Oxford AHSN region, and to assess its ability to contribute to the transformation of healthcare envisioned in the NHS Five Year Forward View.

The brief in more detail was to:

- Carry out a review of the digital health stakeholders in the region or closely allied to it
- Review the commercial and population health opportunities presented by digital health for the region and assess areas of strength and weaknesses
- Identify barriers to the Oxford AHSN gaining a reputation as a global leader in digital health
- Suggest actions that would strengthen the region's position

In a systematic review of the region I identified 408 stakeholders of which 140 were academic institutions, 113 established companies and 45 startup or emerging companies.

This analysis confirmed that the region did indeed represent a digital health cluster, with particular concentrations of activity around Oxford and Reading.

The digital health sector in the region is underpinned by a large number of strategically important assets:

- Oxford is a world leading centre for medical research, mathematics, computer technology, biomedical engineering, epidemiology and applied health services research
- Oxford is home to a major genome centre and the Li Ka Shing Centre for Health Information and Discovery, a new initiative seeking to use 'big data' to transform medicine
- Oxford is a medical and academic publishing centre and has pioneered a number of widely used health outcome measures
- The wider region is home to several large IT companies, and there is a ready supply of qualified IT professionals
- The University has a global outreach, and the local networks such as Oxford AHSN and digital health Oxford are creating a centre for health entrepreneurism
- Oxford already has a number of leading academics working in digital health; this in turn has led to the formation of startups and attracted additional investment from existing companies

These strengths, coupled with the demographically diverse population of 3.3 m and a thriving Smart Town initiatives means that the region is an ideal testbed for innovative approaches to transform healthcare and population health.

I examined eight dimensions to the opportunity presented by digital health:

- **Improved treatment** - better use of technology to monitor patients coupled with freeing up nurses and doctors to talk to their patients.
- **Efficiencies and savings** - within the NHS by eliminating waste will allow reassignment of resources to where they will deliver the best value in terms of public health.
- **Personalised medicine** - tailoring treatments based on molecular diagnosis and an individual's genomic information coupled with life-style parameters and the patient's values.

- **Population health** - learning what makes a difference using very large studies with the resolution and sensitivity to reliably inform policy.
- **Healthcare research** - bigger data sets and better defined ‘deeper’ phenotypes mean better insights and ultimately better, more personalised treatments.
- **Society engagement** - use the launch of personal health records and centralised dynamic consent to change perception of the NHS from a resource allocated by a bureaucracy towards a shared social enterprise.
- **Improved well-being** - through better engagement with patients, better appreciation of their values and improved communication with medical staff, carers and family, brokered by a better connected health system.
- **Improved outcomes** - using mobile technology to improve recording of outcomes and tightening the feedback of this data to inform into improved care.

In all cases the Oxford AHSN region is well-positioned to drive improvements in healthcare through development of new technologies, finding better ways of applying existing technologies and contributing to policy. This strong base has led to significant commercial activity in the form of licensing agreements and new company formation, though the pace of this does not yet match the scale of the academic enterprise.

I identified eight main obstacles to realising the vision for digital health as laid out in the NHS Five year forward view.

- **Resistance to change** - due to innate conservatism, conflicting short term priorities and prior bad experiences of large IT projects.

- **Data silos** - real and imagined barriers to the seamless sharing of data linked via a unique NHS identifier.

- **Intellectual silos** - driven by traditional academic concerns and a resistance to open-source working models and shared enterprise.

- **Budgetary silos** - NHS budgets allocated horizontally across the three levels of health and social care, meaning that investment and outcome benefits have become dissociated.

- **Large proprietary health management systems** - an understandable short term imperative that will act as a major barrier to the crowd sourcing of innovation.

- **Evidence and validation** - the iterative, local and agile cycles of innovation - that will be needed within our health care systems do not fit well with a classical clinical trial model of validating modified care pathways.

- **Monetisation of health applications** - as a large monopolistic provider of healthcare, NHS policy on app accreditation and reimbursement - as yet undecided - will have major impact on investment in the commercial digital health sector.

- **Oxford specific issues** - the complexity of the Oxford environment means that more investment is needed in the networking hub that connects the multiple strands of activity needed for successful digital health innovation. If this is not done correctly, there is a risk that the region will lose young entrepreneurs to other more collaborative centres. This risk is heightened by the logistic issues of living and working in Oxford.

In light of these considerations, I suggest nine initiatives as a catalyst for further discussion.

- **Develop Digital Health Oxford (DHOx) as an entrepreneurial hub** securing its excellent networking function and extending its role as an innovation catalyst to provide a permanent base for idea generation and selection of candidates of proof of principle studies.
- **Build the case for an interdisciplinary/multiagency Digital Health Institute in Oxford.** The complexity of achieving healthcare transformation is spawning new theory, and arguably requires a sound basis of academic research to provide policy guidance and provide a better framework for introducing innovations into the NHS. This is best achieved through establishing a new institute to transcend existing intellectual silos while capitalising on existing strengths in the Oxford area.
- **Assemble a partnership of the willing to build an open-source EHR** as the core of a new flexible health management system for the NHS that can adapt and contribute to the rapid evolution of care pathways
- **Describe the vision for big data more clearly.** This is a politically charged area, and as the Big Data Centre nears completion it seems like a prudent step to explain its role more fully.
- **Go on to the front foot in terms of public engagement.** We will realise few of the benefits of digital health without seamless data sharing on a much larger scale. We need to learn from previous mistakes and make a long term commitment to educating people about the benefits of sharing data - and the real risks of not sharing data.
- **Develop new sources of funding for early stage innovation.** We need new sources of seed funding that are specifically directed at health and social care innovation. These will fuel an entrepreneurial chain reaction that will retain and attract the type of entrepreneur life-scientists we need in the region.
- **Credit young medics or academics for involvement in entrepreneurial activity.** Engagement in innovation, translational research and entrepreneurial activity needs to receive equal credit to academic achievement to help retain key people.
- **Use the bed blocking problem as the focus for a collaborative "Apollo programme".** If you want to change the way the people work - demanding interdisciplinary working and radical new ideas - then it makes sense to start with a big problem.
- **Review how healthcare innovation is introduced in medical and nursing training.** Digital technologies are catalysing a cultural transformation in healthcare, and the way we train the workforce needs to reflect this new environment.

Failure to seize this opportunity will result in the Oxford AHSN region being just a contributor to rather than a leader in the push to build a next-generation health service.

Mark Edwards

March 2016

Introduction

I carried out this work on behalf of the Oxford AHSN to examine factors influencing the growth of the digital health sector in the region that covers Oxfordshire and the wider academic heath science network (see figure 5 - Oxford AHSN region shaded in blue).

Digital health can be defined simply as “the use of digital technologies to improve human health”. However, this simple definition conceals the web of multiple agencies embedded in Human health care, and the disruptive potential of the technologies.

Furthermore, the set of technologies themselves are rather broad - see figure 1 taken from the Nuviun Digital health website[1]. I have simplified this in figure 2, which depicts the three aspects of the technology - big data, algorithms and artificial intelligence (AI), and new generation wireless sensors, overlaid with the research they enable and the IT solutions - now usually branded as ‘apps’ - that provide integration and the essential human interface. This is broadly similar to the classification adopted in the 2015 Monitor Deloitte report on digital health in the UK[2]. Other definitions also include robotics and virtual reality technologies because of the ability of these technologies to enable surgery at a distance[3].

The term health has now come to mean “a state of physical, mental and social well-being” rather than a simple lack of disease. Thus digital health impinges not just on the three layers of health-care within the NHS, but also on wider considerations of social care, cradle to grave population health and social deprivation.

Digital health does not distinguish between mental and physical health which are now viewed as equally important objectives[4]. It is also concerned with issues of the built and natural environment as important players in all three health dimensions. It is therefore inextricably linked with initiatives such as ‘smart cities’, and has considerable overlap with other disruptive technologies such as the internet of things (IOT). Social media and the data cloud that surrounds us all is transforming our ability to tackle public health issues. This new approach was the subject of the ECOHOST symposium on New Frontiers in Public Health[5].

The potential for digital health to revolutionise the delivery of healthcare is recognised by Government, in part because of the potential efficiency savings it can deliver. This is largely based on the positive impact that the

“Everyone has greater control of their health and their wellbeing, supported to live longer, healthier lives by high quality health and care services that are compassionate, inclusive and constantly-improving. “

NHS Vision

Figure 2 Digital health as a floral diagram

I want (the NHS) to become paperless by 2018. The most modern digital health service in the world.

… between the NHS and social care, there must be total commitment to ensuring that interaction is paperless, and that, with a patient’s consent, their full medical history can follow them around the system seamlessly.

Jeremy Hunt

Government Digital Service[6] has had in other areas of government. This lead to the challenges issued to the NHS by Jeremy Hunt in 2013[7].

Realistically, a complete reinvention of the way that we deliver healthcare is going to be the only way that we can reconcile a move towards more effective personalised medicine with the demands of an ageing population, spiralling healthcare costs and epidemics of diseases such as obesity and type 2 diabetes.

These considerations led to the NHS Five Year Forward View published in October 2014[8], and the subsequent 'Time to deliver'[9]. It identified three main gaps that were opening up in the ability of the NHS to deliver 21st century healthcare, and fulfil the mission laid out in the NHS constitution[10]. These were gaps in funding and efficiency, care and quality, and health and well-being.

The importance Government is attributing to digital health in underpinning the future of the NHS has been underlined by the recent Nuffield Trust report[11], and the recent commissioning by the Government of a further review of digital health and the NHS by Robert Wachter (The Digital Doctor)[12].

The three-pronged strategy for bridging these gaps involves reducing demand for NHS services by tackling the root causes of ill-health; giving patients more control and responsibility over their treatments; and re-engineering healthcare to give fully integrated care pathways (figure 3).

> *"The NHS belongs to the people. It is there to improve our health and wellbeing, supporting us to keep mentally and physically well, to get better when we are ill, and when we cannot fully recover, to stay as well as we can to the end of our lives."*
>
> ***NHS Constitution 2015***

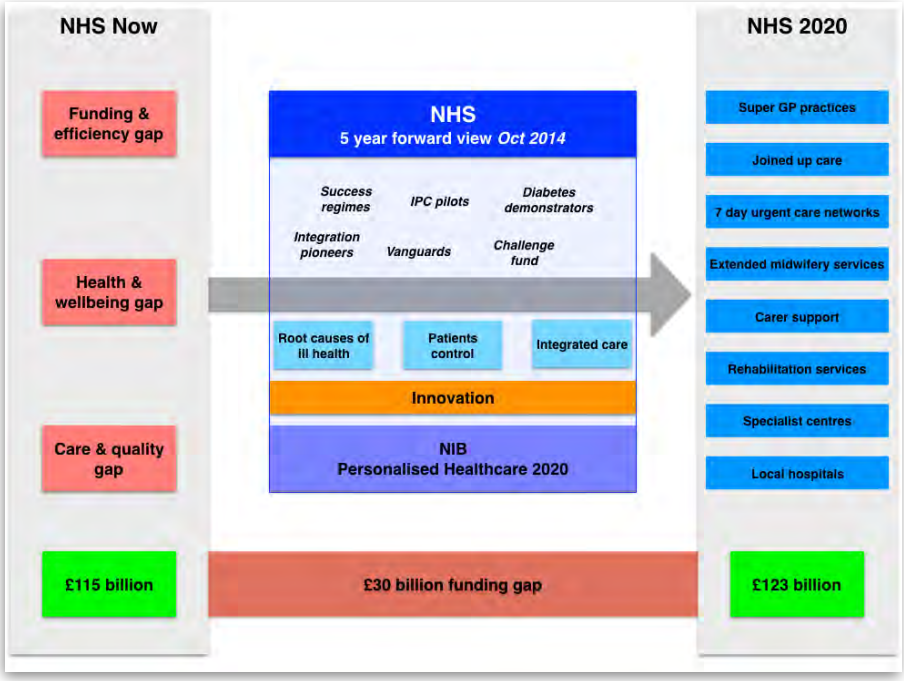


Figure 3 Summary of the Five Year Forward View for the NHS

The figure shows the three gaps opening up in the ability of the NHS to deliver value, and the size of the impending budgetary deficit over the next five years.

Innovation in general and digital health technologies in particular play a central role in the drive to transform the NHS.

The NHS in 2020 will be characterised by a shift in investment to public health, a greater diversity of healthcare provision and better integrated care, all connected and informed by digital health technologies.

The strategy also stressed the central role of innovation in general and digital technologies in particular in enabling this transformation. As a result, the National Information Board (NIB) published its own strategy shortly after the forward view in November 2014[13].

This mapped out an IT strategy for the NHS (figure 4) with two major objectives reflecting Jeremy Hunt's challenge:

- Primary care, acute care services and all transitions will be paperless by 2018
- All care records will be digital, real-time and interoperable by 2020

"One of the greatest opportunities of the 21st century is the potential to safely harness the power of the technology revolution, which has transformed our society, to meet the challenges of improving health and providing better, safer, sustainable care for all."

Personalised Health and Care 2020 NIB

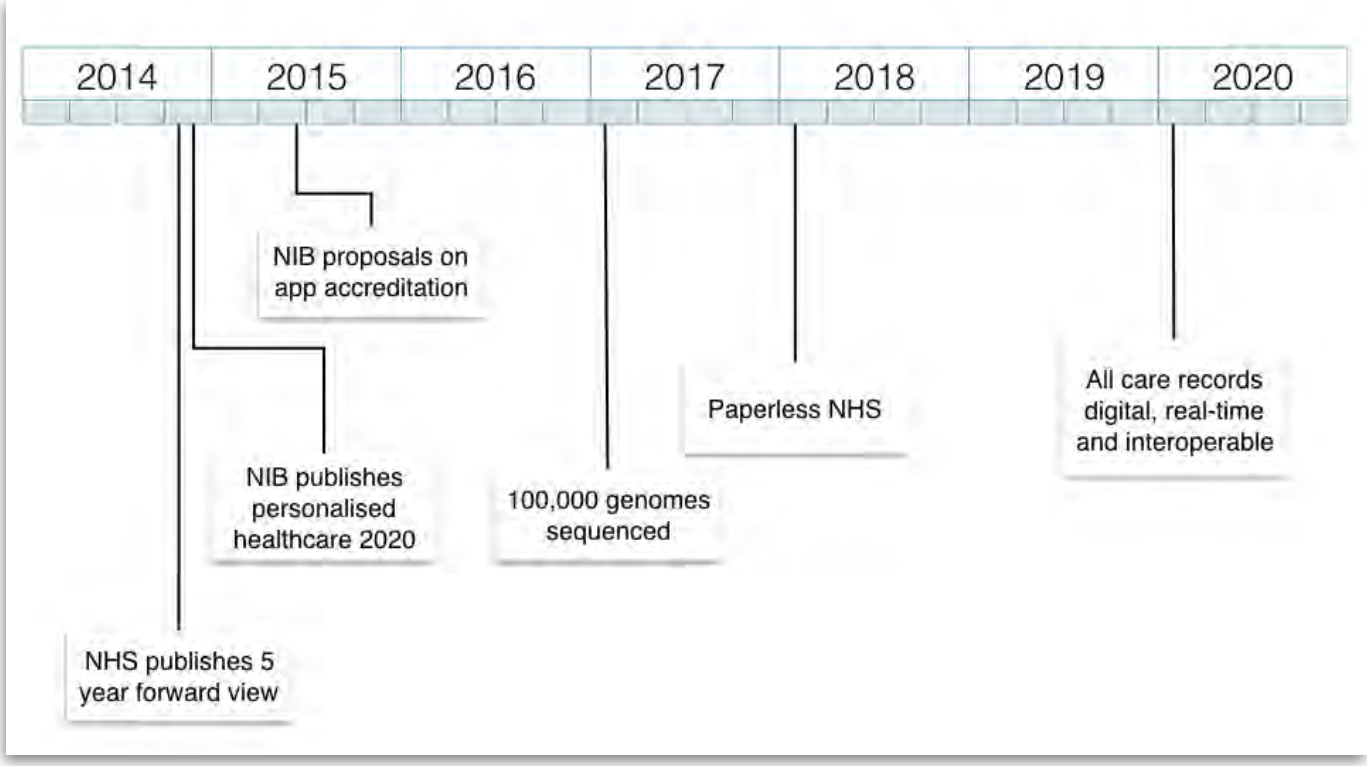


Figure 4 NIB timeline for NHS digital innovation

The Government remains committed to the goal of a paperless NHS, and recently announced an extra £4 billion to help fund the transition[14]. Some, however, view this objective as a political talisman that misses the transformational opportunity offered by rethinking systems[15]. This view was also evident from the conclusions in the industry "Intellect" response to the paperless objective[16].

The NIB pathway also included a target date for the completion of collecting sequence data in the 100,000 genome project, underlining the increasing importance being given to big data projects.

"You really solve nothing by replacing hand-written or typed sheets with a computer screen that can provide the same kind of information, in the same place, in the same format, that's where a lot of the initiatives that have been taken have really missed the game."

Philippe Houssiau CSC

Digital health encompasses a range of inter-related innovations and areas of application, which can be broadly defined as:

- Interactive health apps for mobile devices (mHealth)
- Electronic health records
- Mining large data sets for information (big data)
- Telecare and telehealth
- Healthcare logistics (e.g. e-prescribing)

Against this background, therefore, digital health innovations in the UK are perhaps best viewed as a catalyst for completely reimagining how we manage health. I explore these ideas more fully in section 5.

However, there are dissenting views, coloured by recent IT implementation disasters, arguing that resources today are better invested in providing more nurses and doctors. To put this in perspective, the overall investment in the Government's IT scheme for the NHS, abandoned in 2011, was widely reported as close to £10 bn[17]. While some elements of the project were retrievable, this figure represented about 10% of the NHS total budget at the time.

In this camp, any move to rethink how the NHS works is all too often misrepresented as an attack on the fundamental principles of the NHS. Overcoming these ideas is one of the challenges for digital health implementation I examine in sections 7 and 8.

In the first phase of the project, I identified as many of the stakeholders as possible divided to provide a snapshot of current activity in the field. The results of this stage of the project are discussed in section 3.

In the follow-up phase, I held face to face interviews with key individuals selected from a representative cross section of these institutions - see Appendix 1. I present the results of these discussions and follow up research as a list of the regional assets in section 4, a description of the key opportunities presented by the technology in section 5 and a summary of the potential obstacles to realising this potential in section 6.

These interviews also provided much of the information for the case studies that I present in section 7.

Finally in section 8, I present my own conclusions as to a way forward for the region, much of which is already being actively promoted by the Oxford AHSN .

> *"Patients are waiting too long in A&E and being treated in under-staffed hospitals - they will not thank him (Jeremy Hunt) for making this a priority"*
>
> ***John Reid***

Digital Health Stakeholders

The list of stakeholder categories I have used is given in table 1. It is inevitably rather subjective, and in many cases there is some ambiguity in the assignment institutions. I have opted for an inclusive approach, and have tried to include all institutions with a potential stake in digital health, whether or not I can find evidence of their active involvement in the field.

In the case of companies, rather than try to assign them to sub-sectors, I have used a set of descriptors that further define the role they are playing in digital health (table 2). This is necessarily a dynamic process, and it is still evolving. Nonetheless I have included them as they at least represent a set if useful key words. The distinction between start up and established companies is fairly arbitrary.

In the case of academic institutions, I have included a comprehensive list of departments to illustrate the depth and breadth of research relevant to digital health. At least 50% of them are already directly involved with active projects in the field, and the remainder are at least stakeholders in the enterprise.

A full list of the stakeholders by category is given in Appendix 2. It includes a snapshot of the organisations role and - for companies only - a list of the descriptors I have assigned. The number of stakeholders in the different classes is given in table 1. In total, I have identified a total of 408 stakeholders either physically within the Oxford AHSN region, or with close connections to the region.

Figure 5 is a map of the Oxford AHSN region showing the strong cluster of innovation over Oxford and the surrounding area. A map centred on Oxford (figure 6) gives a better impression of the level of activity in and around the Universities. (Note - I have randomised the precise location of some of the flags to avoid overlaps in some cases.)

This information is also available online as an interactive and searchable map through the Oxford AHSN website, or directly at the following url:

http://tinyurl.com/jqxvnwa

Table 1 Stakeholder categories

Academic institutions	138
Established companies	112
Start up and emerging companies	40
Networking organisations and consortia	36
Health organisations, CCGs etc	20
Projects, proposals and apps	13
Incubators and business parks	13
Investment organisations and sources of finance	11
Others - charities and consultancies	4

Table 2 Sector descriptors

App development	Interactive healthcare
Big data	Logistics
Biomechanics	Mobile technology
Care pathways	Process improvement
Clinical trials	Sensors
Connectivity	Social context
Devices	Telecare
Diagnostics	Therapeutics
Education	Tissue engineering
EHR	Visualisation
Genomic medicine	Vital signs monitoring
Image analysis	

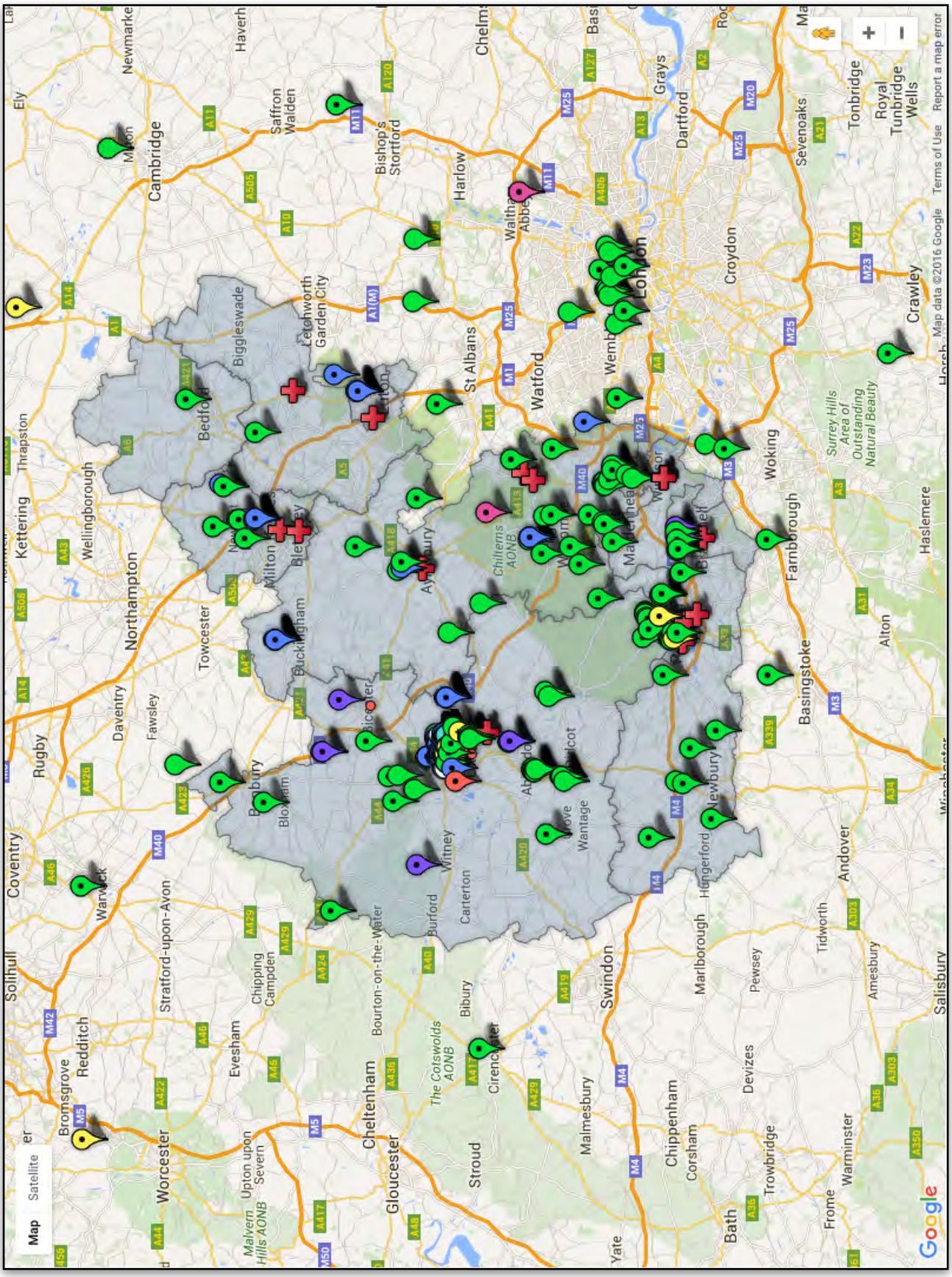


Figure 5 **Digital health stakeholders in the wider Oxford AHSN region**

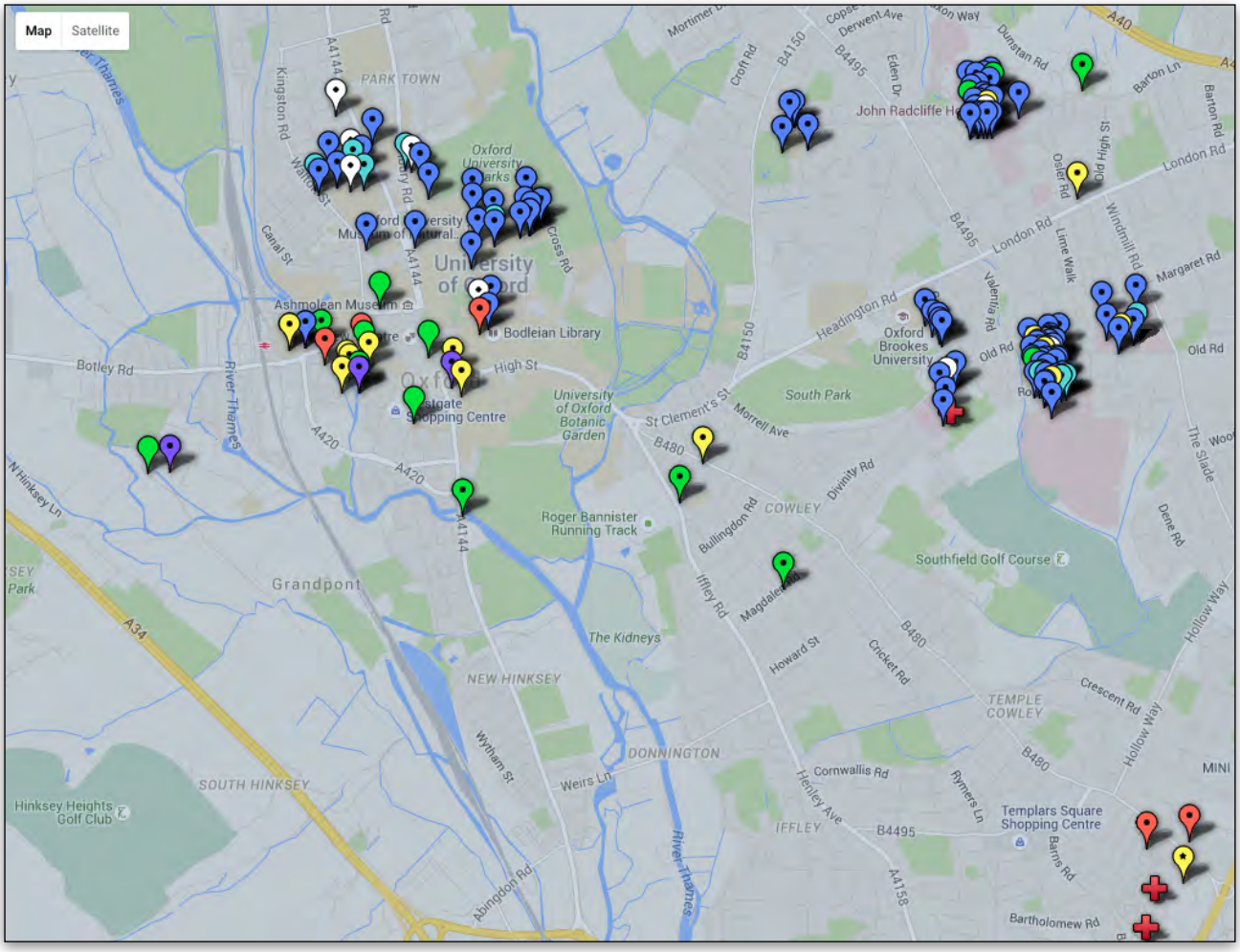


Figure 6 Map showing digital health stakeholders in and around Oxford

The very high levels of activity in and around the John Radcliffe Hospital and the University Old Road Campus are still incompletely resolved at this resolution.

Regional strengths, assets and caveats

Discussions with the interviewees highlighted 12 areas in which the Oxford AHSN area possessed clear strengths with obvious relevance to its role as a pioneer in digital health. Although much of this is centred on Oxford and the University, a vital contribution is made by the wider region, particularly in the Reading area and from the other Academic Institutions.

"The Li Ka Shing Centre for Health Information and Discovery will pioneer new advances in the analysis of medical data which can help scientists to better understand human disease and its treatment.

This will help to further develop a strong and competitive science and research base in this country which is vital for the UK to compete and thrive in the global race."

David Cameron 2013

Genomics, big data and epidemiology

Oxford is home to the Wellcome trust Centre for Human Genetics, a world leading centre for studying the genetics of Human disease. The centre is home to the Oxford Genomics Centre, one of the largest genome centres in the UK with matching strengths in bioinformatics and statistical genetics.

Oxford is also the site of the new Big Data Institute at the Li Ka Shing Centre for Health Information and Discovery[18]. Close to the Genomics Centre on the Old Road Campus in Headington, this initiative will capitalise on Oxford's existing strengths in statistics, epidemiology and handling large data sets.

The Nuffield Department of Population Health is home to 500 researchers with a pedigree that stretches back some 40 years to the pioneering work of Richard Doll and co-workers. Oxford is also a specialist centre for cancer epidemiology. This provides a background of rigorous analysis on which to build the knowledge extraction tools required for big data initiatives.

A concentration of large IT companies

The Thames Valley is home to a large cluster of IT companies, including the local presences of very large enterprises such as Microsoft, Hewlett Packard and Oracle. Major players in the Health IT market such as GE Healthcare, Cerner and CSC also have a presence. The region is also well supplied with smaller companies that provide connectivity, data handling and consultancy.

Though some would argue that large monolithic companies are not going to provide the open, next generation solutions required to transform the NHS, they do at least provide the reservoir of expertise and skilled labour that will be required to build the next generation of healthcare. They are also potential partners - and investors - in the process, as potentially are large local pharmaceutical companies.

World-leading centre for medical research

The University of Oxford is ranked first in the world for medicine, and its Medical Sciences Division is among the largest in Europe.

It is also partner to the NIHR Biomedical Research Centre at the University Hospitals NHS Foundation Trust, a major government initiative to promote translational research. The objective of this initiative is to accelerate the conversion of research results into clinical benefit for patients.

Oxford is a leading centre for applied health services research, as evidenced by the Oxford CLAHRC, and key groups in public health, psychiatry and primary care departments. These groups already have digital health projects to develop and evaluate digital tools and more broadly investigate how health services can harness digital technology.

Outside Oxford University, the Institute of Public Care at Oxford Brookes University has a growing reputation in public health care research, and Bucks New University is a centre of excellence for Telehealth and Telecare, and is a leading centre for training nurses and allied health professionals.

This state of the art knowledge of medical practice, coupled with cutting edge translational research provides a fertile breeding ground for healthcare innovation.

World-leading centre for mathematics and computer technology

The Oxford Department of Computing is internationally competitive, and is among the top three UK computer science departments. It is one of a consortium of nine universities involved in a £23m Internet of Things research hub. Together with the Mathematical Institute and the E-research Institute within the Mathematical, Physical and Life Sciences Division of the University, Oxford is extremely well-placed to develop next-generation analytical tools. These will be needed to extract useful information from the enormous amounts of operational and legacy data within a combined health and social care platform.

The Oxford Internet Institute is a world leading institution for study of the societal impact of the internet and related technologies. Insights into the way that people interact with and respond to digital technology will be key to realising the societal benefits of DH initiatives.

"Oxford has witnessed incredible digital success in recent years with Natural Motion Games, Dark Blue Labs and Vision Factory acquired by Zynga and Google respectively. World-leading academic institutions in the area provide tech startups with exceptional talent and there are now nearly 22,000 people in digital employment in the area and 79% report good access to social networks."

Tech City UK

Both Oxford University and Oxford Brookes University also have a strong background in artificial intelligence (AI). AI will become increasingly important in the development of tools to support and augment clinical decision taking. The Oxford AI startup DeepMind was purchased by Google in 2012, and has recently announced a major investment in digital health, through collaborations with Imperial College and a £25m

Oxford Brookes is also a centre for robotics and communication research.

Medical publishing centre

Oxford has a strong tradition in both medical publishing and continuing education. As both these fields move rapidly to on line delivery, there will be a large number of competing players with products of variable quality.

The opportunity for Oxford is to stand out from this noise as an authoritative source for medical knowledge, and to incorporate this best practice into a digital framework for healthcare delivery. For example, Map of Medicine[19] is an existing product, used by the NHS, that provides clinicians to locally customised care pathways, underwritten by guidance from the world's leading medical institutions.

Map of Medicine is based in London; but Oxford has already played a pioneering role in developing decision support technologies through Deontics, a start up company emerging from the Department of Engineering. These pioneering efforts suffered from a lack of support, and did not really gain traction in Oxford. In this regard, it is rather telling that Oxford performed really badly (6/100) in this particular aspect of the Digital Maturity Assessment carried out by the University Hospitals Trust.

However, if it can couple its world class medical and computer sciences and strong publishing infrastructure, Oxford would be well-placed to develop the next-generation systems decision management systems that will incorporate aspects of AI.

International reputation in biomedical engineering

The core objective of the Institute of Biomedical Engineering at Oxford is to develop novel medical devices, technology and systems capable of delivering substantial healthcare benefit, and to translate new engineering technologies into clinical practice.

Situated on the Old Road Campus along with a large number of other Medical Science Departments, the IBME is ideally placed to serve as an interdisciplinary

environment for developing innovative solutions to healthcare problems, and they are already working with groups in primary care and psychiatry departments.

A testbed for big city problems

With a population of 3.3 million people, the Oxford AHSN region is large enough to deliver datasets with the resolution required to give unambiguous readouts of important population health questions.

Despite the fact that Oxford is a relatively small city, it is viewed by many as a test bed for big city problems. There is a wide range of demographics represented in Oxford, from affluent areas through to regions of social deprivation[20].

As a result, there is a vibrant network of organisations focused on testing new solutions to city problems including population health, pollution, housing, transport and well being. This includes the Oxford AHSN, the Oxford Local Enterprise Partnership (OxLEP)[21], the Oxford Strategic Partnership[22] and the Oxford Smart Cities initiative[23]. The strength of the partnership was recognised recently with the announcement that developments in Bicester and Oxford (Barton) had been selected as NHS Healthy Towns - testbeds for the use of smart technologies and the built environment to engender healthy life-styles[24].

The Oxford Flood Network[25] is an example of how a low cost solution to a local problem was developed within the Smart City framework using mobile technology. It is now being rolled out nationally.

Global outreach

As a result of its international standing among universities, Oxford has a truly global outreach, attracting thousands of students, researchers and clinicians from around the world. This provides a strong source of inspiration and ideas, and has resulted in a large number of strong international links.

Among these it is worth mentioning the George Institute for Global Health, the Jenner Institute and the Centre for Tropical Medicine and Global Health within the Nuffield Department of Medicine.

Researchers from Oxford are playing an important role in shaping health systems in emerging economies, and are drawing lessons that may in time be applicable within the NHS.

"The City of Oxford itself is compact at 46km^2 but has a surprisingly diverse demographic. The region that the City serves has both challenging environmental, transportation and housing problems, but also an enviable intellectual capacity and capability able to develop, test and deploy smart city technologies at scale."

University of Oxford 2015

"We are working with ten housing developments to shape the health of communities, and to rethink how health and care services can be delivered. This programme offers a golden opportunity to radically rethink how we live – and takes an ambitious look at improving health through the built environment."

NHS England March 2015

However, and important caveat is that Oxford has perhaps been less successful in **attracting** the type of businesses and entrepreneurial technologists required to build a thriving digital health sector.

This is due in part to structural issues such as cost of housing and transport links, but the main issue seems to be a failure to engender the networking required for a highly collaborative enterprise. Young tech savvy and socially motivated individuals are increasingly drawn to the more innovation friendly environment in London.

An emerging centre for clinical entrepreneurship

The Oxford region has long been associated with turning technological developments into new company formation. Notable examples include Oxford Instruments and Immunocore. However, it has rather lagged behind other regions such as Cambridge, and along with the rest of the UK has failed to recreate the hot-bed for start-ups that is a feature of US centres in the Bay area and Boston.

There are signs, however, that Oxford is seeing an increased interest in entrepreneurship, especially among young researchers. This is particularly apparent in the biotech and digital health sectors, both of which have thriving entrepreneurship societies.

These efforts are supported by the dynamic efforts of the Said Business School, which runs courses in entrepreneurship, and by annual competitions run by the University, the Oxford University NHS Trust. Other sources of early stage funding include the Nominet Trust, and the Oxfordshire Social Entrepreneurship Partnership, a joint venture between the University, Brookes University and Student Hubs.

It is important to realise that these are highly motivated and mobile individuals, who are likely to move to other centres if they feel a lack of entrepreneurial ‘buzz’ or are frustrated in their efforts to develop new technologies and progress their careers - see my comments in the previous section.

“The student community is also a core driving force behind the innovation which is taking place and Oxford Entrepreneurs, a student society based in Saïd Business School, claims to be the largest student entrepreneur society in the world.”

Tech City UK

Thriving academic health science network

The Oxford AHSN is among the most active of the fifteen academic health science networks across England.

The Oxford region is home to a wealth of world-leading organisations involved in clinical care, life sciences and medical research, education and training, innovation and informatics.

The Oxford AHSN works to break down traditional organisational boundaries in these areas and build stronger relationships between industry, scientific and academic communities – coupled with better knowledge exchange – to bring lasting benefits as best practice is spread quickly and widely across the NHS.

Areas of opportunity for digital health

In this section, I review the potential benefits of implementing digital health technologies to human health in its widest sense. These benefits are inevitably overlapping and inter-related, but I have divided them into eight main areas of opportunity shown in table 3.

This analysis reveals the complexity of the field, and hints at some of the problems of demonstrating incremental benefits as digital innovations are implemented.

In figure 7, I tentatively map these onto the existing health and social care ecosystem.

So for example, I see big data playing an important role in providing the associations and other research that will underpin personalised medicine and ultimately better outcomes. But equally it is the critical for informing population health initiatives and reducing the load on the NHS. None of this will be possible, however, if this is not seen as a social enterprise of the willing.

Table 3 Areas of opportunity for digital health

Personalised medicine
Better treatment
Financial sustainability
Healthcare research
Population health
Better outcomes
Improved well-being
Society engagement

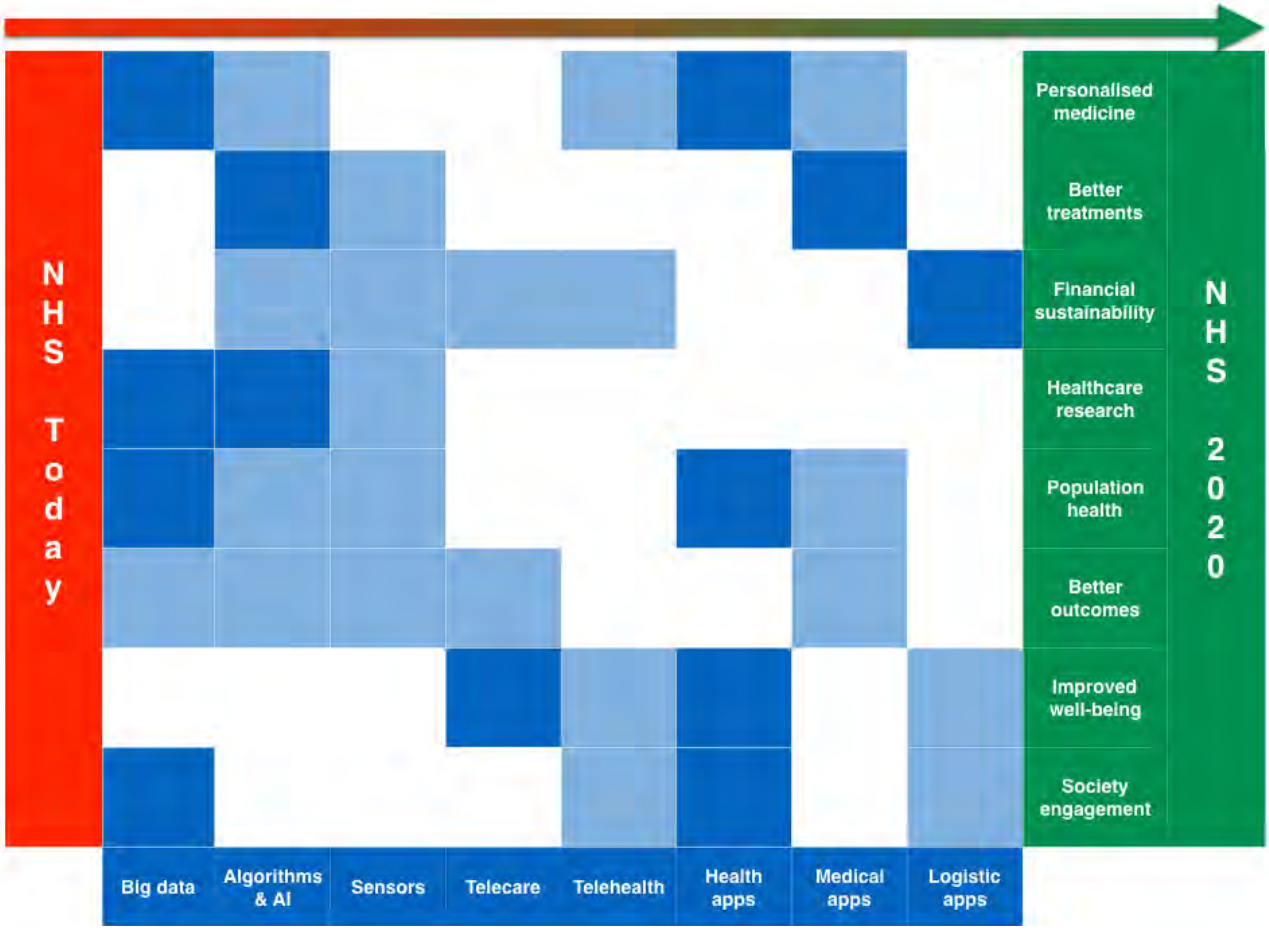


Figure 7 Mapping areas of digital health opportunity onto the enabling technology areas

Personalised medicine

Personalised medicine is defined by the FDA as an "innovative approach to disease prevention and treatment that takes into account differences in people's genes, environments and lifestyles"[26].

The theoretical benefit of personalised medicine is that while most medicines and medical treatments are developed on the basis of showing statistical benefit to the average individual, in reality no one is average. Drugs that benefit some people may harm others. By better understanding the differences between people, and the implications these have for therapy, the better we can tailor treatments.

The relevance of this for digital health is that very large data sets will be needed to provide the fine grained resolution of conditions into smaller and smaller subgroups. This requires collection of the data in the first place, and subsequent detailed statistical analysis. Increasingly, this data is genomic, demanding new analytical tools. But we are also going to see an explosion in phenotypic data due to mobile sensors, which will allow continuous monitoring of even complex phenotypes such as ECGs. This 'deep phenotyping' will be coupled with an exponentially growing data cloud from the internet of things and lifestyle parameters integrated through mobile health apps. This all has to be underpinned with the clinical expertise to define the datasets and avoid the rubbish in rubbish out principle.

Finally, the implication of this is that care pathways are going to become more complicated. They will be increasingly based on genomic data and a wider range of diagnostic descriptors. Delivery of all this within the NHS will only be possible with the help of expert systems using AI to help clinicians by filtering the data.

The big opportunity is the identification of warning signs that allow early intervention and the avoidance of hospitalisation wherever possible.

"If we all opened up Facebook, we wouldn't be looking at the same thing. That personalisation doesn't exist in health."

Source | David Ebersman, Lyra Health

"The shift to personalised medicine is already underway – our role as a system leader and commissioning organisation is to consider how this transformation can be accelerated."

Sir Bruce Keogh Sep 2015

"It costs less to get your genome sequenced than a month of cable."

Source | J. Craig Venter, Human Longevity Institute

Improved treatment

There are a wide range of ways in which digital health could in theory be used to improve the treatment of patients, whether this is in their local health centre, during a visit to A&E or during a stay in hospital or subsequent referral. These can be divided into six main overlapping areas:

Timeliness - Delivering care faster by removing avoidable delays. This could be achieved by engineering logistic improvements through extending digital asset management. Much of this is already being done - for example through digital systems for the scheduling of appointments. Supply of prescriptions through an EPS (electronic prescription service) has been implemented at the John Radcliffe Hospital. Management of hospital assets such as operating theatres and radiology are also amenable to such approaches leading to fewer cancelled operations.

All of this will be dependent on extending broadband access, but has the potential to deliver high reach, low cost and highly scaleable health public health tools.

Better bed availability is a longer term objective that relies on more integrated management of patients as they pass through primary, secondary and social care.

Accuracy - Improving treatment by optimum selection of care pathways with dynamic reference to international best practice. Examples of this might include ensuring that the most appropriate drugs are selected by early detection of antibiotic resistance; or use of state of the art imaging and artificial intelligence to ensure that the treatment options selected are optimum.

Relevance - making sure that the care delivered is always appropriate to the patients needs and circumstances by providing effortless access to care plans and full information on the patient's expressed wishes. From the patient's perspective, simplifying the route to obtaining consent and making sure that it is delivered in a way that is appropriate will enhance their ability to make decisions that are right for them. And analysis of large data sets will help to help prioritise those interventions with the most value for both patients and the NHS.

Safety - Digital protocols, positive ID, bar codes are all fundamental to the science of avoiding mistakes in a complex environment. In the near future, AI systems will

"Technology must be seen as part of the team of carers that contribute to patient care. The advantage of this team member is it obeys a rigid set of instructions and behaves consistently. Electronic prescribing has been shown to make prescription errors 50% less likely compared to handwritten ones.

However, a recent survey of acute hospitals in England showed that although 69% had some form of e-prescribing, the vast majority of these were for discharge medication or chemotherapy, and only 13% are using it for general ward-based prescribing."

Dr Mark Ryan May 2014

cross check prescriptions to look for anomalies, unappreciated drug interactions or allergies.

Developments in sensor technology make it much more feasible to provide continuous monitoring. In combination with AI systems, these can lead to the detection of sudden deteriorations that might be missed on a 12 hourly observation cycle.

In many cases, the clinical scoring algorithms result from the subjective judgement of groups of clinicians, without a clear evidential base. Ultimately large scale data mining will allow resource to be focused on those parameters that evidence shows are really useful early warning signs.

Improved safety will result in reduced spending on medical defence and litigation insurance.

Follow up - A fully connected EHR will improve communication between primary and secondary care, making sure that a patient's doctor is immediately aware of follow up care priorities after discharge.

Once a patient is discharged from hospital, everyday life takes over and it can be difficult to remember a doctors advice in relation to life-style. Motivation drops away, and it is too time consuming for either patient or clinician to set up follow on appointments.

Digital technologies are already changing this picture dramatically, with the prescription of mobile apps that provide life-style prompts, monitor activity and simplify communication between the clinician and patients. Peer networks are well established tools for maintaining motivation, and are relatively simple to set up using medical support apps.

Patient experience - The above considerations suggest that digital health technology will significantly improve medical treatment. However, they also have the potential to transform the patient's experience of the NHS in the same way that the Government Digital Service is revolutionising the way we access other public services[27].

Booking systems will be simple and user-friendly. There will be less duplication of effort - repeatedly being asked for personal details for example. All staff that interact with a patient will already know some basic information about them. There will be less time waiting; and less time spent on repetitive tasks means that staff will have more time to relate to the patient as an individual.

"A service that's easier to use is also cheaper to run: it means less paperwork, fewer people being put on hold in a call centre queue, fewer forms filed in error, less risk of fraud.

At the core is the transformative potential of technology. And I make no apology for putting technology at the heart of reform. For the infinitely replicable nature of information is central to understanding the sheer force behind the technological revolution we are living through."

Matt Hancock Oct 2015

"In my hospital there are 19 software systems across departments—few of which communicate with each other."

Source | Cosima Gretton

"Since the introduction of the NHS Friends and Family Test (FFT) in April 2013, over three million individual pieces of feedback have been collected on patients' experiences of inpatient, A&E and maternity services. Such achievement demonstrates and supports that the FFT has enabled a large number of patients to submit feedback on their personal experiences that might not have otherwise been heard."

NHS Employers 2015

Patient experiences will be collected and amalgamated on-line and incorporated into a positive feedback loop to rectify problems fast and inform more strategic priorities[28].

Improving the patients experience will bring intangible benefits. It will make our hospitals a nicer place to be in, and it will reduce frustration and complaints. It may also improve outcomes, as better experience will lead to more engagement. This in turn increases the probability that people will take responsibility for their own health rather than delegate it to the system.

Joined up care - The seamless sharing of records between primary, secondary and social care will reduce the frustration of patients having to repeatedly give their details to multiple agencies. More importantly, it will reduce delays caused by waiting for records to be sent, and in many cases avoid unnecessary appointments, and improve safety by making sure that healthcare professionals have all the data they need - for example in relation to allergies.

The case for integrated care records was accepted by the NHS and laid out in "Safer Hospitals, Safer Wards"; a 2013 report by NHS England[29]. This was followed by the establishment in 2014 of the integrated digital care fund to provide as source of transitional support[30].

The case for interagency information sharing and a framework for achieving it was again clearly laid out by the HSICC in 2015[31]. The review identified six main purposes with impact across a spectrum from improved care to better commissioning - see the sidebar.

The Centre of Excellence for Information Sharing carried out case studies on four centres that had pioneered this approach, and found evidence for benefits in three main areas[32]:

- *More efficient use of resources* - through prevention of readmission, time saving and a reduction in home visits.
- *Reducing risks and improving care* - by reducing delays in treatment, more accurate prescriptions and better coordinated care.
- *Smoother transitions* - particularly in hospital discharge and supporting multidisciplinary teams dealing with complex cases.

Six purposes of integrated care records

- ***Care Coordination, Planning and Delivery:*** *Supporting coordination of care across providers*
- ***Sharing Information Electronically:*** *Integrated Digital Care Records*
- ***Risk Stratification for Case Finding:*** *Identifying those at risk of an adverse event*
- ***Tracking Outcomes across a Pathway of Care:*** *Tracking particular cohort groups irrespective of care setting*
- ***Understanding Current and Future Population Needs****: Strategic and commissioning needs analysis*
- ***Developing Alternative Payment Models:*** *Including capitated budgets*

From "Enabling Information Sharing: A user's map for health and social care"

HSICC 2015

Improved outcomes

Health outcomes are quantifiable measurements that provide an essential indicator of whether an intervention is delivering value to an individual or to society as a whole. These might include obvious clinical parameters such as blood glucose levels. However, equally important are measures of quality of life and mental state that are harder to quantify, but are central to any true measure of the value of a treatment.

For example, the Government and NHS England has developed an overarching set of outcome measures to assess progress in improving public health and reducing prematures mortality - figure 8.

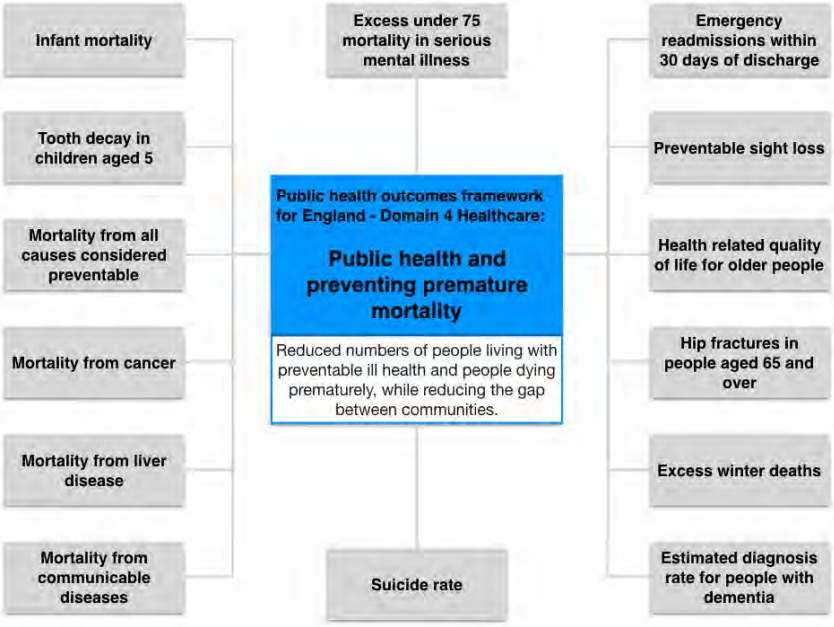


Figure 8 Healthcare outcome measures from public health framework for England

Digital health tools and the use of seamless EHRs will make it much easier to amalgamate and analyse this type of information. For example, structured questionnaires to assess lifestyles and mental state are already delivered on mobile devices. Oxford has a good record of developing widely adopted outcome measures such as the Oxford hip, knee and shoulder scores for orthopaedic outcomes; though the digital implementation and integration of these was carried out in the US.

This type of data collection could and should be applied to all chronic conditions, and in principle could be extended as a follow up to all hospital admissions. This could include general feedback along the lines of the NHS "Friends and Family test"[28].

As an authoritative centre for medical research, Oxford could play a leading role in developing and/or adapting validated outcome measures for mobile applications.

The effect of digital health technology on outcomes will extend far beyond mere measurement of outcomes. Personalised medicine, improved care pathways and improved safety will all have a beneficial effect.

Perhaps the most fundamental shift that will be catalysed by digital tools, however, will be true integration of primary, secondary and social care. This will be enabled by seamless record sharing and a shift in philosophy from funding health care on the basis of outcomes rather than activity.

Research

The aspects of digital health technology that are going to improve healthcare research fall into four categories.

- The widespread use of EHRs with a single unique identifier (the NHS number) will greatly facilitate record linkage and the amassing of very large data sets. Large data sets lead to higher resolution studies and resolve uncertainty in association studies. For example, a recent meta-analysis of trials examining the relationship between blood pressure and mortality from coronary heart disease was carried out in Oxford. This showed for the first time that higher blood pressure was associated with higher risk of CHD mortality in the elderly, and that any decrease in blood pressure would be expected to deliver therapeutic benefit (figure 9)[33].
- Improved sensors, the internet of things and widespread use of smart phone technology will result in an explosion of data, much of which will be continuous. This will in turn lead to denser data collection which will provide denser phenotypes revealing hitherto unappreciated associations.
- One of the major new opportunities for digital health are large "social" datasets which give direct or derived information on our lifestyle habits. For example, mobility and pollution exposure could be derived from mobile phone and social media records, and nutrient intake data from supermarket loyalty card records - see the section on population health below.
- Better communication between stakeholders in the healthcare system will lead to better questions being asked in the first place. Better informed and more informed populations will be more willing volunteers for research studies. This will lead to faster recruitment and shorter research and development cycles.

Oxford has a fantastic track record in epidemiology, and is well placed to maintain a leadership position through its commitment to big data and genomics.

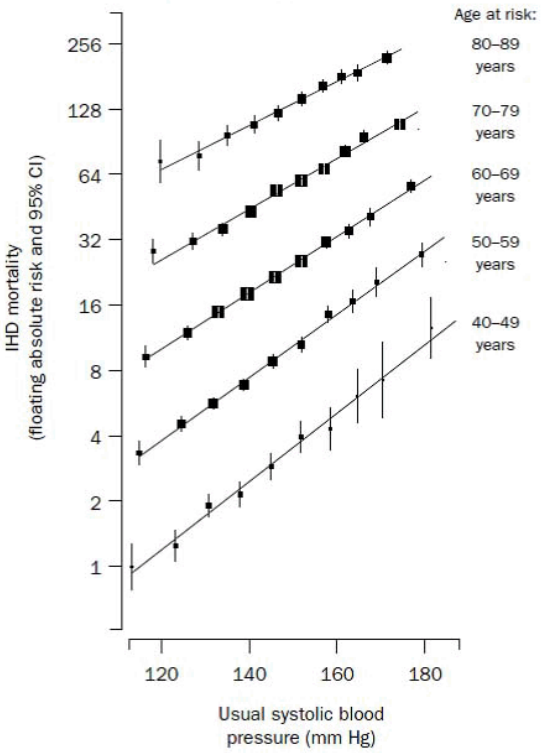


Figure 9 A large meta-analysis of trials examining the relationship between blood pressure and CHD mortality[19]

Financial savings

The budget for the NHS in England for 2015/16 is £116.4 billion. Despite a government commitment to increase NHS spending, much of this will be swallowed up by inflation. The King's Fund[34] estimates that over the next few years, the projected annual real terms increase will be 0.9%.

Despite the severe funding constraints, the NHS is also under enormous pressure to improve outcomes - for example by removing health inequalities by region, demographic or time of admission.

The third dimension of this 'perfect storm' is the ageing population and an epidemic of chronic debilitating conditions such as dementia, type 2 diabetes and obesity.

Against this background, it is not surprising that the government is an enthusiastic proponent of digital health technologies. They are seen as a catalyst for re-engineering the healthcare system to achieve improved outcomes. Whilst there may not be any overall financial savings, it would be a major achievement merely to avoid the inexorable and unsustainable increase in funding.

Many of the efficiencies that digital technologies deliver can be categorised as logistic. These include electronic appointment systems with texted reminders and automatic rescheduling. These are already in widespread use in primary care, and their wider implementation in the NHS is inevitable as part of the drive to make the NHS paperless by 2018. Another good example is electronic prescribing, widely adopted in general practice, but yet to make a major impact in hospitals (though the John Radcliffe is a notable exception). Principles from the asset management tools that are widely used in commerce for just in time delivery could be used to develop new systems for controlling bed occupancy and valuable resources such as theatres, scanners and beam therapies.

"The research group (Accenture) estimates that FDA-cleared digital health devices -- defined as 'an internet-connected device or software created for detection or treatment of a medical indication' -- saved the US healthcare system $6 billion last year in the form of improved medication adherence, behaviour modifications and fewer emergency room visits. They predict that savings will grow to $10 billion in 2015, $18 billion in 2016, $30 billion in 2017 and $50 billion in 2018."

Mobile Health News 2015

"We **waste** more money in healthcare than we **spend** on education."

Source | Unknown, Health Matters 2015

Population health

While the direct efficiency savings achieved through improvements in healthcare logistics are important, of greater significance will be improvements in public health. In other words controlling the rate of use of the NHS.

Reducing demand, managing expectations and inculcating a sense of shared responsibility for the NHS are going to be key to ensuring a sustainably equitable healthcare system.

Here digital technologies have a vital role as part of the smart city initiatives to support better life-style choices through using 'nudge' techniques[35] and health apps. The behavioural insight team has shown in repeated trials that targeted text messaging and social media are very effective at influencing behaviour. All of this will be underpinned by insights from big data initiatives.

Mobile apps allow simple text messaging to be augmented with social networks, and allow text or E-mail prompts to be targeted, personalised and timely. All of these are key attributes to the 'nudge' approach.

Dietary apps are becoming increasingly sophisticated, and can already calculate nutritional data from product barcodes. This may even be extended to detailed portion analysis through exploiting image analysis using a smart phone[36]. Integrated with wireless scales and activity monitors, the next generation social health apps will be a powerful tool for helping to stem the tide of obesity and type 2 diabetes.

In terms of dementia, brain training apps can ensure that the elderly maintain mental stimulation. The best of these can also detect early stages of mental deterioration. Apps in development can identify early markers of Parkinson's disease by analysing voice patterns[37].

Another area of huge potential is digital disease detection, where the digital cloud is monitored for early signs of changes in disease patterns[38]. These techniques are already in use by the WHO and ECDC to monitor spread of disease, but the mining of big data could enable more active monitoring of public health and early intervention to reduce health impacts.

Thus a combination of life-style choices, environmental improvements and early diagnosis of chronic conditions has the potential to move the relationship between the population and the NHS to a more sustainable footing.

"This study, developed in concert with our advisory board, will monitor individual's health and symptoms of PD progression like dexterity, balance and gait using questionnaires and sensors via the Parkinson mPower mobile phone application and wearable devices if available. By participating in this study you will help us learn the range of PD symptoms and find out whether mobile devices can help measure PD progression and manage these symptoms better. In this unique study you will be a partner in the research process."

mPower: Mobile Parkinson Disease Study

Improved well-being

A positive sense of well-being is an important goal in itself, but is also a major contributor to physical health.

There are five key components to a sense of mental well-being, all of which can be influenced directly or indirectly through digital health innovations[39].

Connection - Ensuring that people stay in contact with friends and family; and helping them to make new friends.

There is an obvious role for social media as a catalyst to make it easier to stay connected. But there is also a role for social care to be more proactive in helping people to take steps to guard against loneliness.

Activity - Promoting exercise in the community and increasing experience of nature. There are plenty of mobile apps available that help with this. Many of these have a social dimension.

Continuous learning - Education is a great way to keep mentally active, and has a high level of social interaction.

Charitable giving - Giving - either financially or freely of one's time has the ability to transform the lives of both the giver and the receiver. It helps put one's own problems in perspective, and provides a purpose to life.

Social networks are an incredibly powerful way of engaging people in charitable activity, by removing the succession of small obstacle that might otherwise deflect good intentions.

Mindfulness - Is defined as "knowing directly what is going on inside and outside ourselves, moment by moment". Professor Williams of Oxford University Department of Psychology says that "mindfulness can be an antidote to the 'tunnel vision' that can develop in our daily lives, especially when we are busy, stressed or tired".

Mindfulness apps are now fairly commonplace, as are apps that apply cognitive behavioural therapy principles to the treatment of mental health problems, and potentially to other chronic physical conditions such as inflammatory bowel disease.

These apps are now widely available, and the best validated can be prescribed by doctors to complement and extend treatments.

"Why is mental wellbeing important? First, we all want to feel good about ourselves and the world around us, and be able to get the most from our lives.

There is also evidence that good mental wellbeing is important for our physical health, and that it can help us achieve the goals we set for ourselves."

NHS Choices website

Mental illnesses are very common

Among people under 65, nearly half of all ill health is mental illness

Mental illness is generally more debilitating than most chronic physical conditions.

Mental health problems impose a total economic and social cost of over £105bn a year

Yet, only a quarter of all those with mental illness such as depression are in treatment

We tend to view physical and mental health treatment in separate silos in health services

People with poor physical health are at higher risk of experiencing mental health problems…

…and people with poor mental health are more likely to have poor physical health

NHS England

Society engagement

If the future of the NHS as originally envisioned[10] is to be sustainable, we need to change our perception of it from a resource allocated by a bureaucracy towards a shared social enterprise.

This was recognised in the Health and Social Care Act 2012[40], and lead to the development of the 'Transforming Participation in Health and Care' guidance for commissioning groups, published by NHS England in 2013[41].

There are several factors that can influence such a shift in perception.

Personal health records - giving people access to their health records will encourage them to take greater responsibility for their healthcare.

Centralised dynamic consent - bringing all health related consent activity into a single dynamic portal. This will ensure consistency across medical consent procedures, and will allow individuals to modify their preferences where appropriate. This could apply to data sharing between agencies and use of data for research. The portal could be extended to include other related consents, such as organ donation, blood donation and end-of-life preferences. This dynamic approach to consent is under active investigation by the Oxford Centre for Health, Law and Emerging Technologies (HeLEX)[42, 43].

Feedback - the Friends and Family test could be extended to all branches of the NHS, to provide a fast and responsive feedback loop for continuing improvement of the patient experience.

Local accountability - an essential component of the feedback loop described above. This should operate at a level no higher than the local CCG.

These factors will be drivers of a virtuous circle, where improving NHS experiences drive an improved sense of shared responsibility for the NHS.

Governance - there is an overarching requirement for good governance. Without this, positive social engagement will be a lost cause. Fortunately Oxford has a good governance record. This is backed up by active investigation of the ethical issues surrounding consent at HeLEX. Oxford is also home to important opinion leaders such as Dame Fiona Caldicott, who chaired a commission reviewing the use of patient information and published

"The NHS belongs to the people. It is there to improve our health and wellbeing, supporting us to keep mentally and physically well, to get better when we are ill, and when we cannot fully recover, to stay as well as we can to the end of our lives."

NHS Constitution

'We must put citizen and patient voice absolutely at the heart of every decision we take in purchasing, commissioning and providing services.'

Tim Kelsey

National Director of Patients and Information, NHS England

"Patients and their caregivers are the biggest untapped resources in healthcare"

Source | Larry Chu, Stanford

hugely influential reports in 1997 and 2013[44], and who is currently Chairman of the Oxford University Hospitals NHS Trust. Finally, Professor Muir Gray continues to influence thinking in the field through the organisation Better Value Healthcare[45].

Case studies

In this section, I will review a number of case studies that highlight how institutions, companies and individual entrepreneurs are applying digital technologies to improve healthcare.

I have also tried to show how they fit into the picture of the healthcare ecosystem, to give an impression of how well the Oxford AHSN region covers the landscape of digital health opportunity (figure 10).

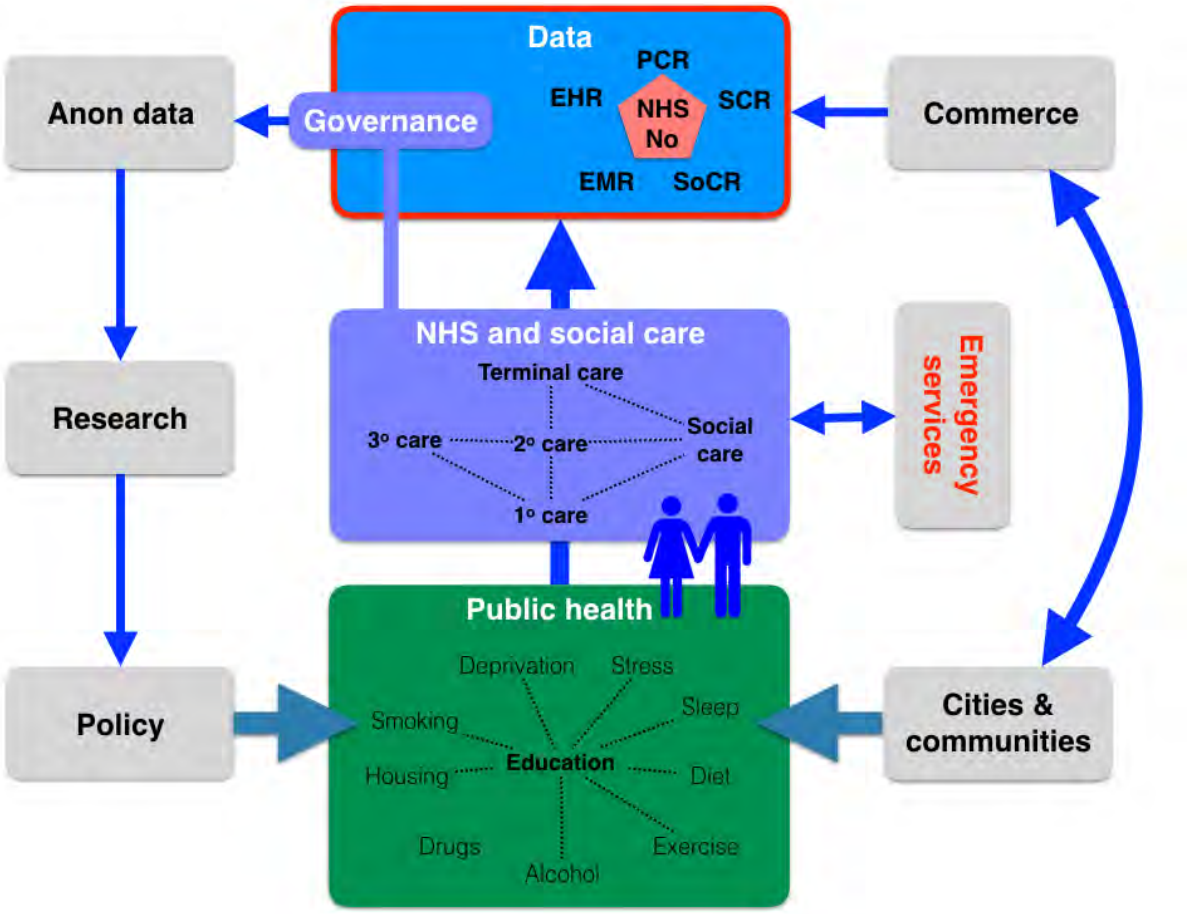


Figure 10 The digital health ecosytem

Data flows are shown in blue. Patient data is linked via the NHS number as the shared unique ID. EHR, PCR and EMR are all acronyms that apply to digital health records and are used interchangeably. SoCR refers to a digital social care record. SCR refers to the summary care record - an abstract from the individual's detailed health record.

Case study 1 Incuna

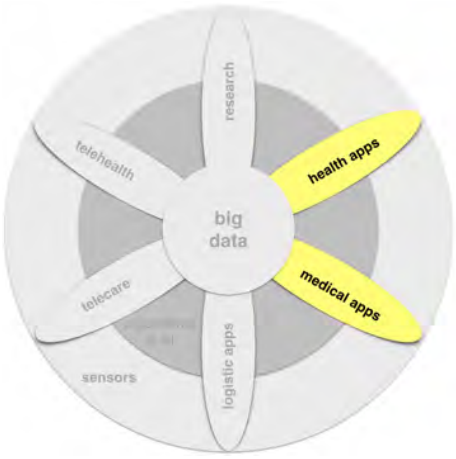
Incuna is an international digital healthcare agency, working for clients in both the global health and pharmaceutical sectors. Founded in 2005, it now also has an office in Singapore.

Incuna comprises a combination of experienced medical and healthcare professionals, cutting-edge multimedia designers, leading IT and software developers and highly experienced project managers.

The team have experience that extends all the way from augmented reality to interactive 3D and gamification, which they use to create innovative and bespoke apps for pharmaceutical and healthcare organisations.

A good example of Incuna's work is their patient adherence platform, Incuna ePatient™. It supports patients by combining useful digital tools and tailored clinical information that is based on their condition, their location and the product they have been prescribed.

By bringing all this together into an easy-to-use app, accessed via a PC, smartphone or tablet device, Incuna's ePatient not only improves a patient's understanding of their condition, but increases compliance with prescription instructions and life-style advice.



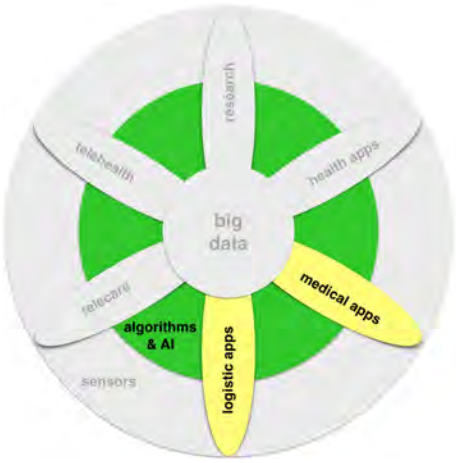
Incuna is a digital agency that maps onto the health app and medical app spaces within the digital health sector.

Case study 2 Brainomix

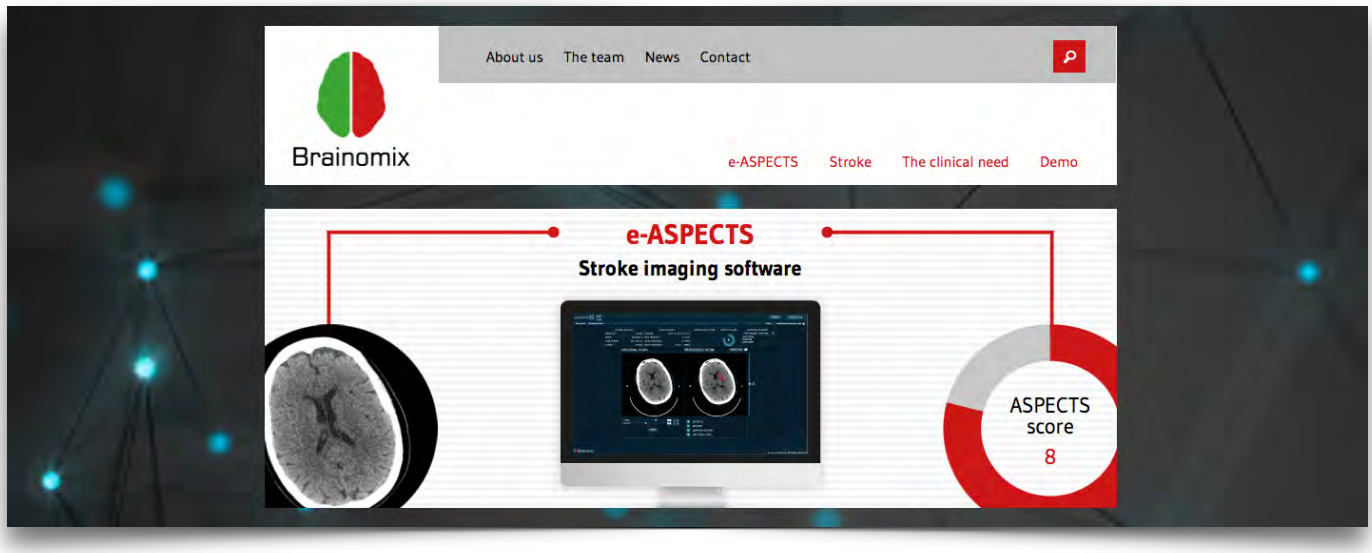
Brainomix is a start up company that entered the Isis Software Incubator in 2012. It is now based in Summertown, Oxford. The company is addressing a common problem in medicine which is the reliable and reproducible interpretation of diagnostic imagery. In the case of Brainomix, the problem was the interpretation of brain scans in stroke patients and the decision on whether to carry out mechanical re-vascularisation.

The standard clinical basis for making the decision is the e-ASPECTS score, which combines measurements on the damage to several key regions of the brain. The problem is that these judgements can be quite subjective, and require specialist neurologist input which might not be immediately available. The solution was to develop a sophisticated image processing algorithm which eliminates the subjectivity and leads to more reliable scoring.

The Brainomix image analysis platform has now been validated in seven clinical trials, and is being installed in IC units world-wide. This example is a model for how AI systems and advanced image processing can improve care pathways and reduce variability in outcomes across health systems.



Brainomix is a medical image analysis company that maps onto the medical app and logistic app spaces within the digital health sector.



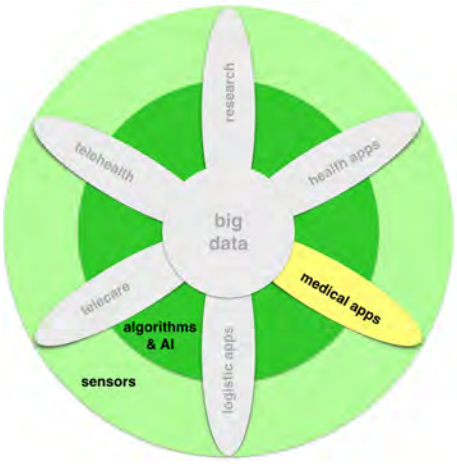
Case study 3 Isansys

Isansys Healthcare is a company based on Milton Park near Oxford that specialise in the production of wireless body-worn monitoring systems for the remote and continuous recording of vital sign data. The fundamental approach is based on work carried out at Toumaz, which exploited a new generation of chips that had extremely low power requirements.

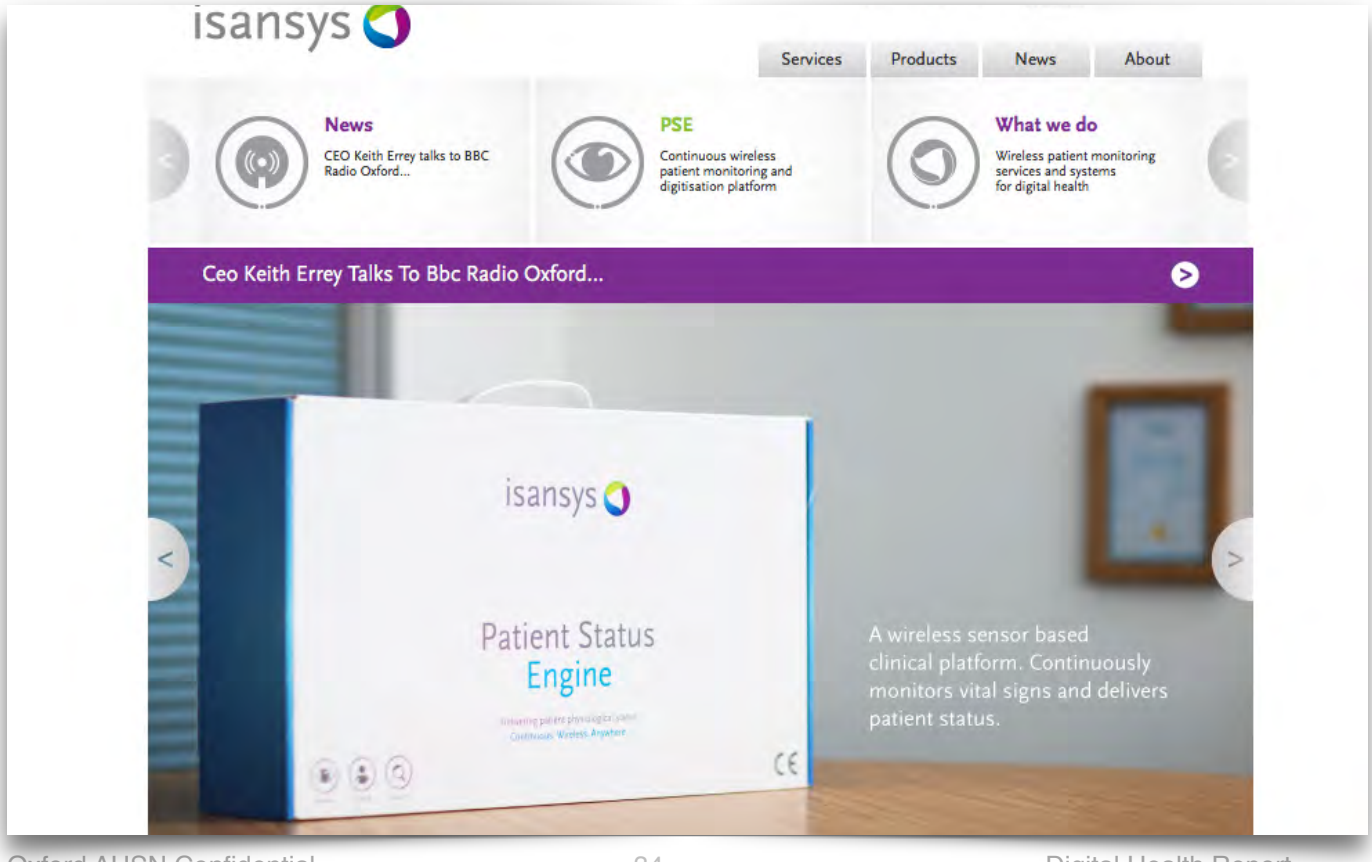
The founder of Isansys, Keith Errey, adopted a more pragmatic approach using current off-the-shelf chips that allowed for more rapid prototyping and development. This led to the development of wireless sensors for pulse, heart rate and oxygen saturation data. These are used in conjunction with a tablet device for each patient to allow continuous vital sign monitoring with the inconvenience of leads. The tablets all communicate with a central monitoring station, which could be local or even remote for telecare applications.

One unanticipated benefit of this approach has been the improvement in the experience of hospital for the families of neonates in intensive care, who can now have much better access to their child.

An as yet unexplored opportunity will be the large data sets created by continuous monitoring, with the potential to define new patient phenotypes and better tailored care pathways.



Isansys is a medical sensor company that maps onto the medical app, algorithm and sensor spaces within the digital health sector.



Case study 4 Bounts

Bounts is a mobile and web based platform that allows anyone to gain credits through everyday activities, which they can then redeem for goods and services at participating retailers. Developing motivational tools is going to be a vital component of growing an interactive health service where individuals take more ownership of their own well-being.

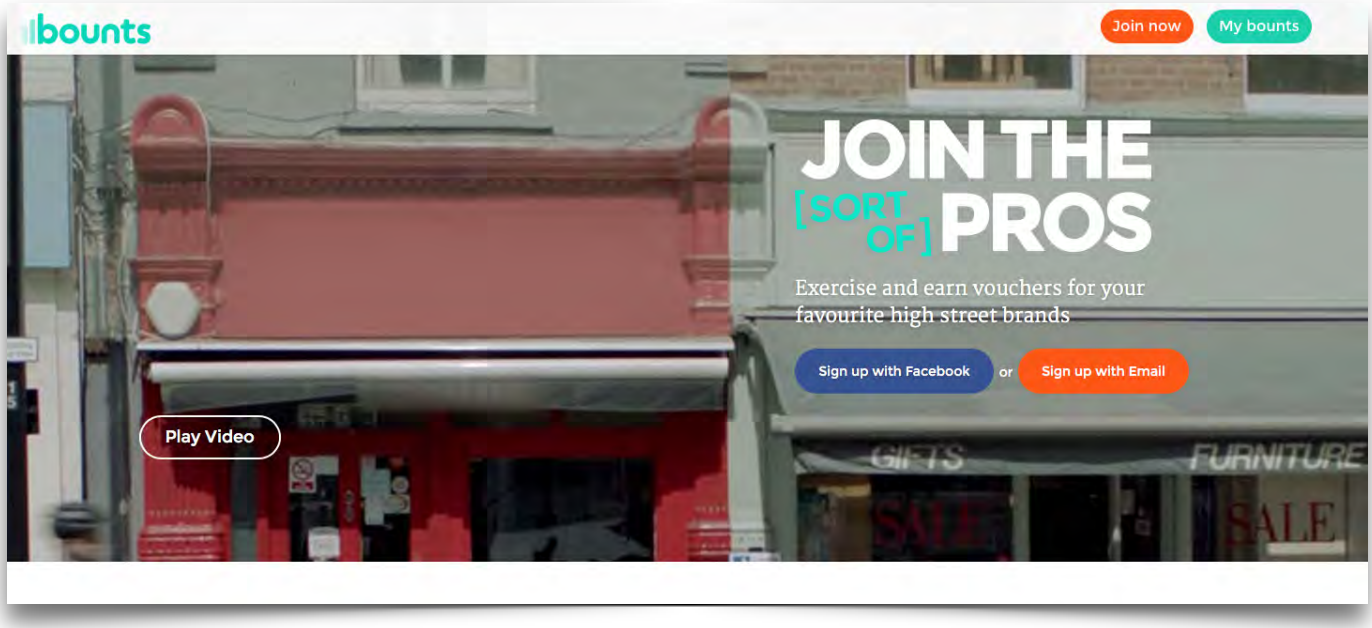
More recently, Bounts entered into partnership with Cancer Research UK, to inspire people who raised money for the charity to extend their activity throughout the year.

In a graphic example of how nudge psychology can be a powerful way of influencing life-style choices, a recent survey revealed that over 70% of people believe fitness apps would motivate them to do more exercise.

Bounts was founded by John Stuart in 2011 and entered the Isis software incubator in 2012. It already has 3 million members collecting their exercise data, and has expanded internationally to USA, India and Canada.

Bounts is a graphic demonstration of the power of mobile technology when it is done well.

Bounts is a health engagement company that maps onto the consumer health app space within the digital health sector.

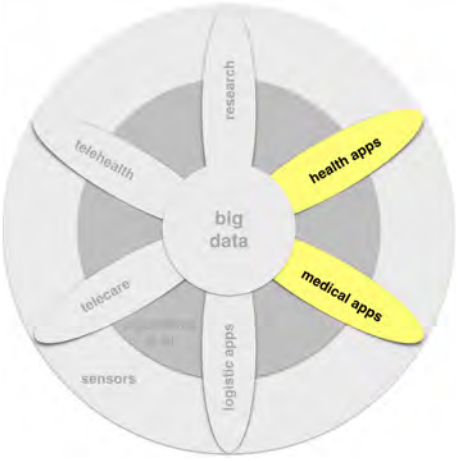


Case study 5 Care4today Heart Health

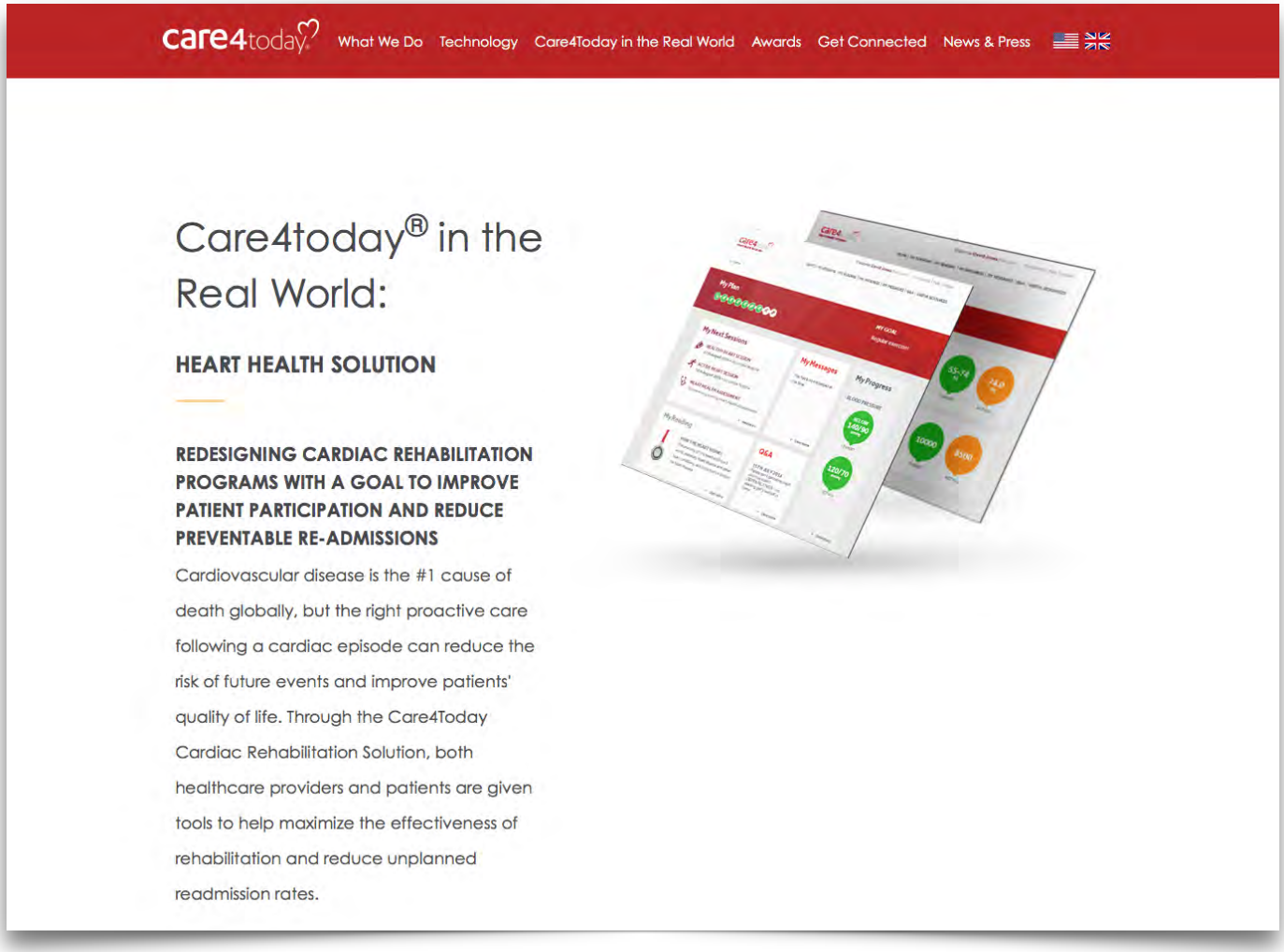
Care4Today Heart Health is a cardiac prevention and rehabilitation programme that aims to help improve the health and wellbeing of people who have heart problems. It was developed by Dr Piers Clifford in the Buckinghamshire Hospitals, working closely with Janssen using their Care4today digital health platform.

The platform is an evidence-based programme, which aims to support coronary care patients to continue to live as full a life as possible, helping them to change their lifestyle and providing them with web-based tools to support them in managing their condition and help prevent a further admission to hospital.

Dr Clifford has been recognised for his contribution as one of the top 50 innovators by the Health Service Journal. He is continuing to augment the programme with further mobile applications and services to improve compliance with diet and exercise regimens.



Care4today is a healthcare initiative that maps onto the medical app and health app spaces within the digital health sector.

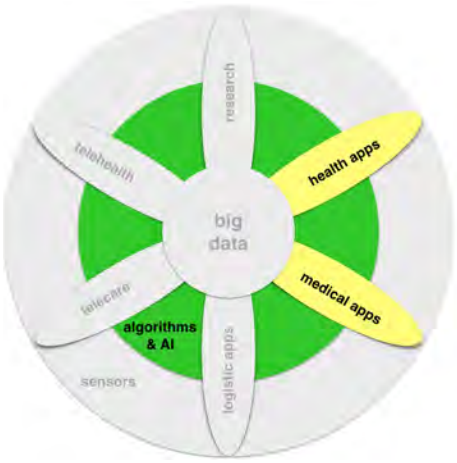


Case study 6 True Colours

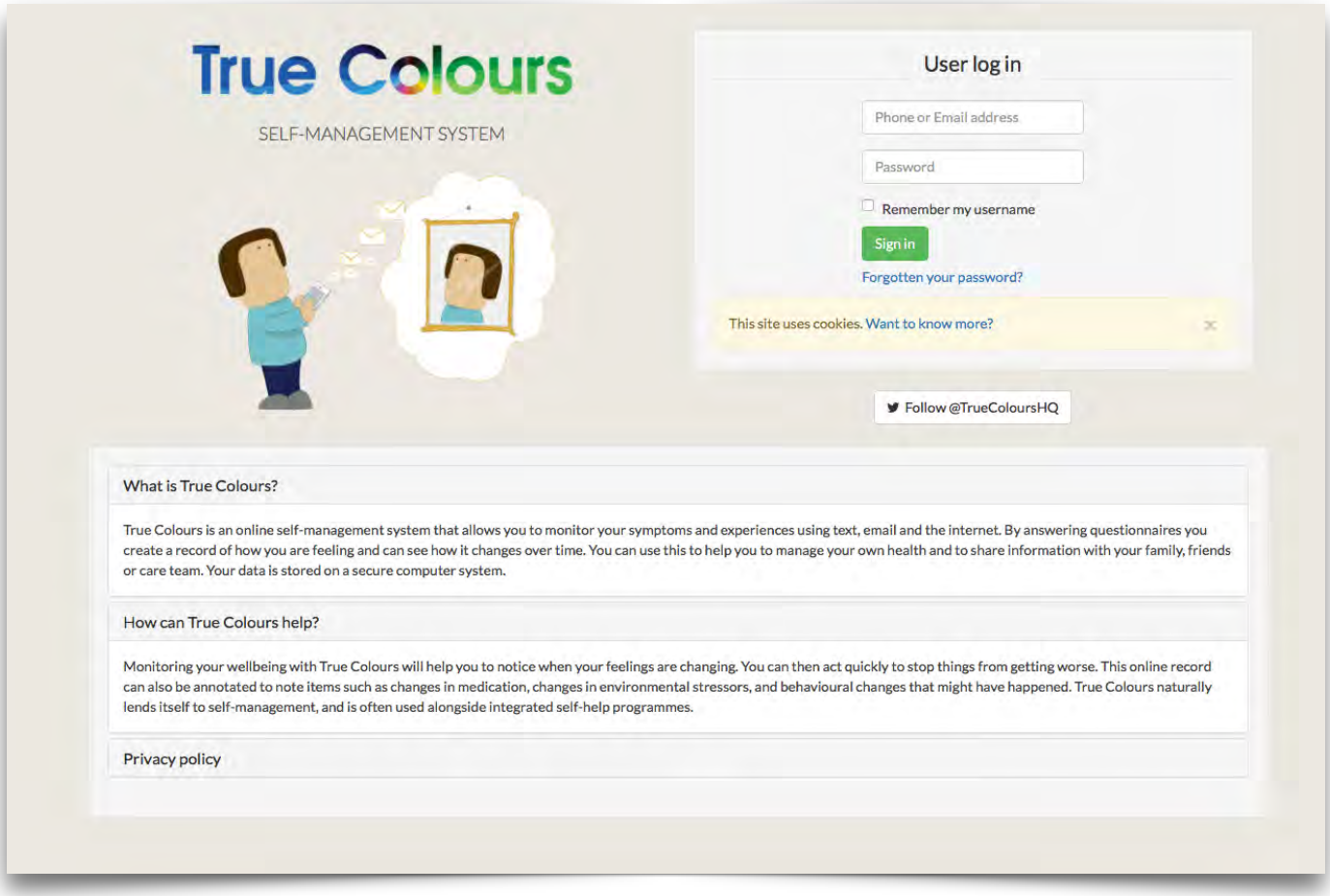
True Colours is a web and mobile app based system developed at the Department of Psychiatry in Oxford by Dr Chris Hinds and coworkers to help patients manage mental health conditions. Mobile digital technologies allowed relatively unstructured responses on mood to be transformed into useful quantitative data that could be used to improve monitoring and treatment of the conditions, improving outcomes.

Key to the success of True Colours is the highly developed user interface, and the sense of empowerment that the tool brings to patients. To date, the system has acquired over 300,000 patient responses, illustrating the potential of this type of approach in collecting data for research and the further improvement of treatment pathways.

The tool is now widely available through the NHS, and the model is being further developed to improve the management of other chronic health care issues such as inflammatory bowel disease.



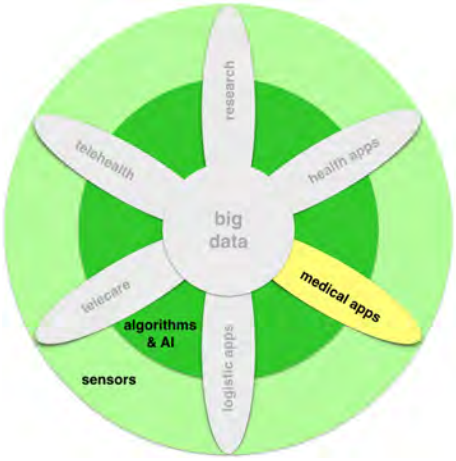
True Colours is a healthcare initiative that maps onto the health app, medical app and algorithm spaces within the digital health sector.



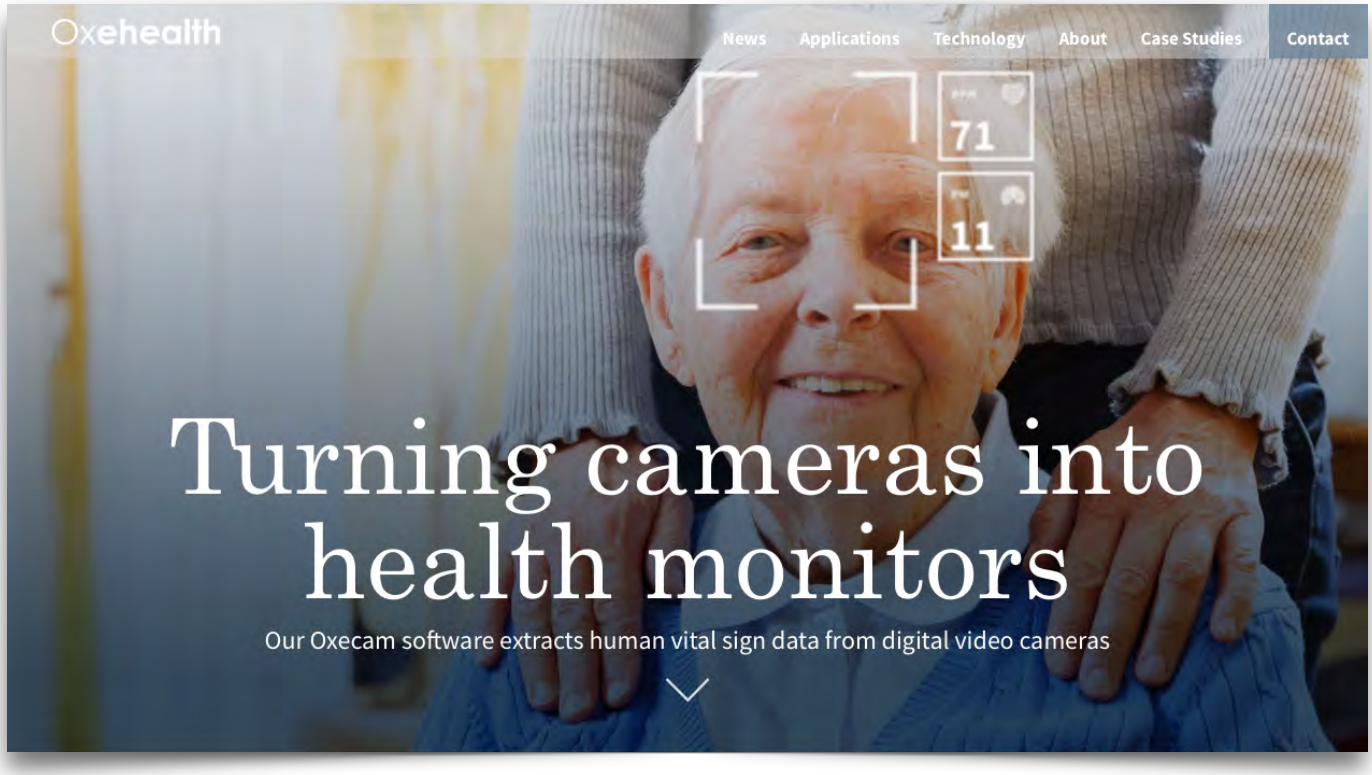
Case study 7 Oxehealth

Founded in 2012, Oxehealth was the first joint spin-out from the University of Oxford and Oxford University Hospitals NHS Trust. It capitalised on patented technology invented by Professor Lionel Tarassenko, Founder of the Institute of Biomedical Engineering (IBME) in Oxford and Founding Director of Oxehealth.

Oxehealth has developed a radical new non-invasive approach to the monitoring of vital signs based on sophisticated image processing of conventional video feeds. In addition to obvious applications in intensive care and paediatric monitoring, the approach also has huge potential in Telecare applications, and the monitoring of vulnerable individuals in detention.



Oxehealth is a healthcare startup that maps onto the sensor, medical app and algorithm spaces within the digital health sector.

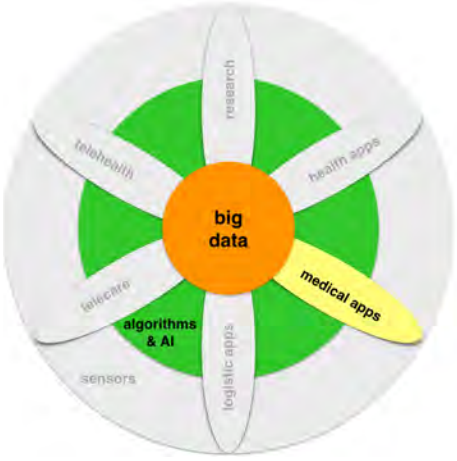


Case study 8 Mykrobe

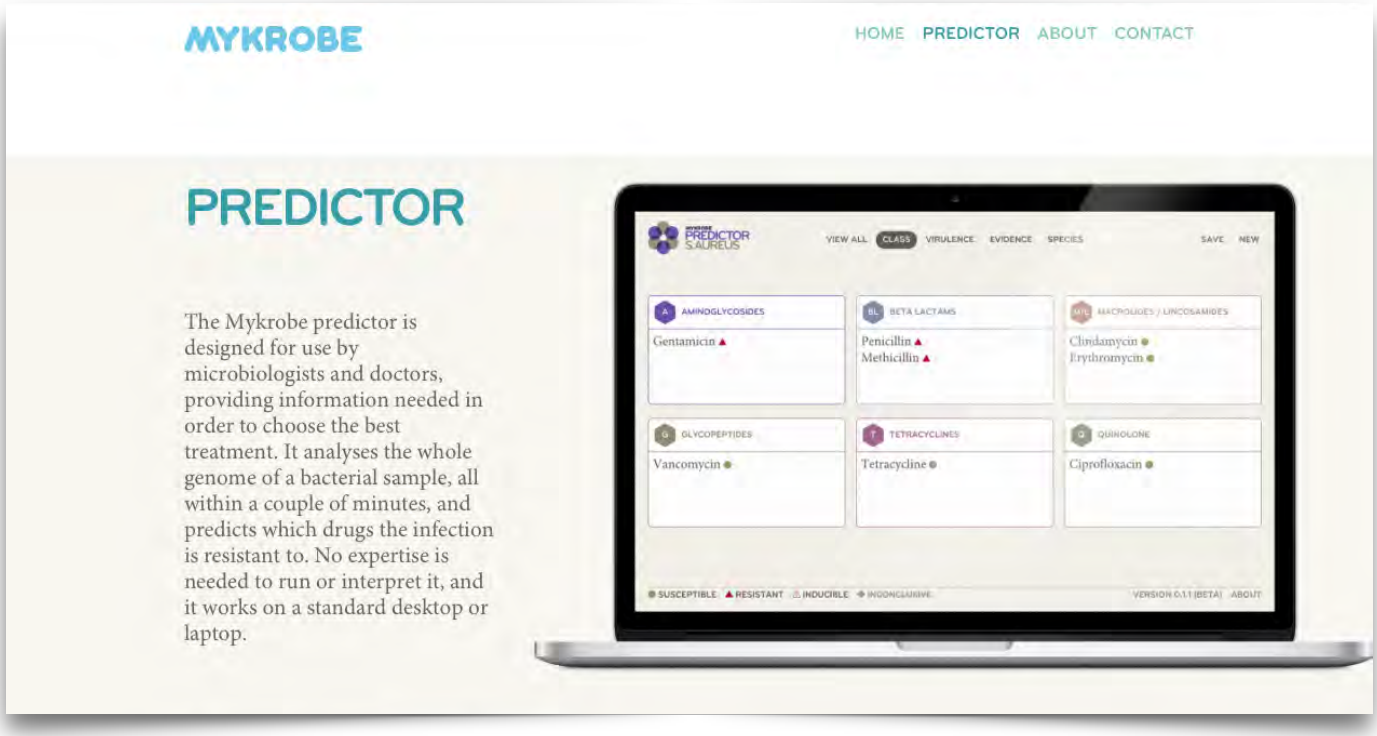
Mykrobe is a sequence analysis tool coming out of the Wellcome Trust Centre for Human Genetics in Oxford. Developed by Dr Zamin Iqbal and co-workers, Mykrobe Predictor is a suite of software applications that process raw microbial genomic sequence data and produce a clinical report on species identification that includes crucial data on antibiotic resistance. These data are increasingly vital in making decisions on treatment pathways, with profound implications on managing antibiotic use and the cost of patient isolation.

Mykrobe predictor has an extremely simple web interface, and the goal is to make the application the most widely used worldwide, accumulating valuable databases on microbial variation in the process. The team are currently working to validate the technology and gain regulatory approval for identification of TB and Staphylococcus aureus.

MYKROBE PREDICTOR TB



Mykrobe is a healthcare startup that maps onto the big data, algorithm and medical app spaces within the digital health sector.

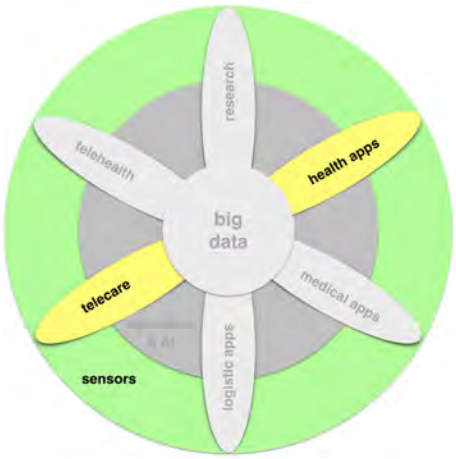


Case study 9 Sentimoto

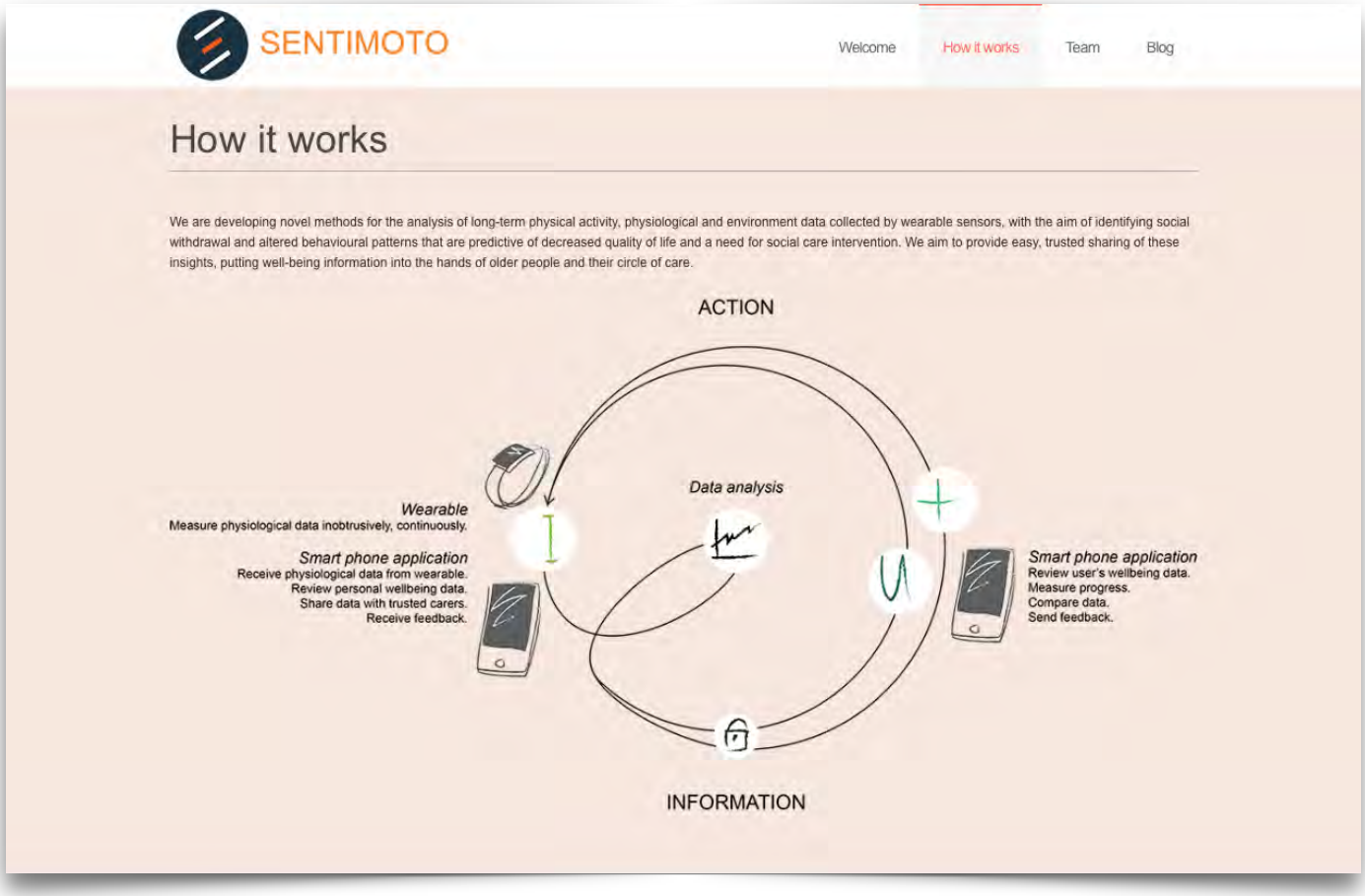
Sentimoto is an Oxford-based start up focused on the use of wearable technology to improve the lives of the elderly through unobtrusive home-monitoring and the identification of altered patterns of behaviour.

They believe that through early intervention, deterioration and hospitalisation can be avoided and lives can be improved for both the individual and their carers.

Sentimoto was started in 2013 by three entrepreneurial Oxford DPhil students. It is now based in Thame, Oxfordshire, and won the best startup award in the 2016 Wearables Conference in London.



Sentimoto is a healthcare startup that maps onto the sensor, health app and telecare spaces within the digital health sector.

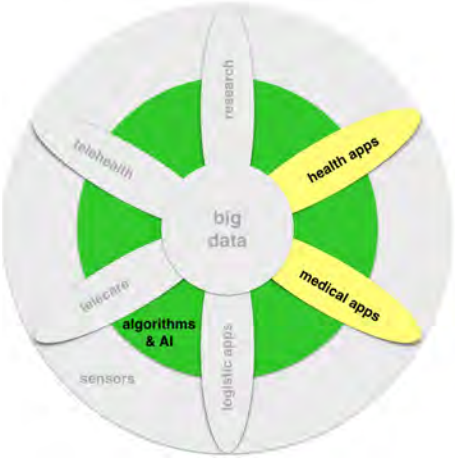


Case study 10 Big Health

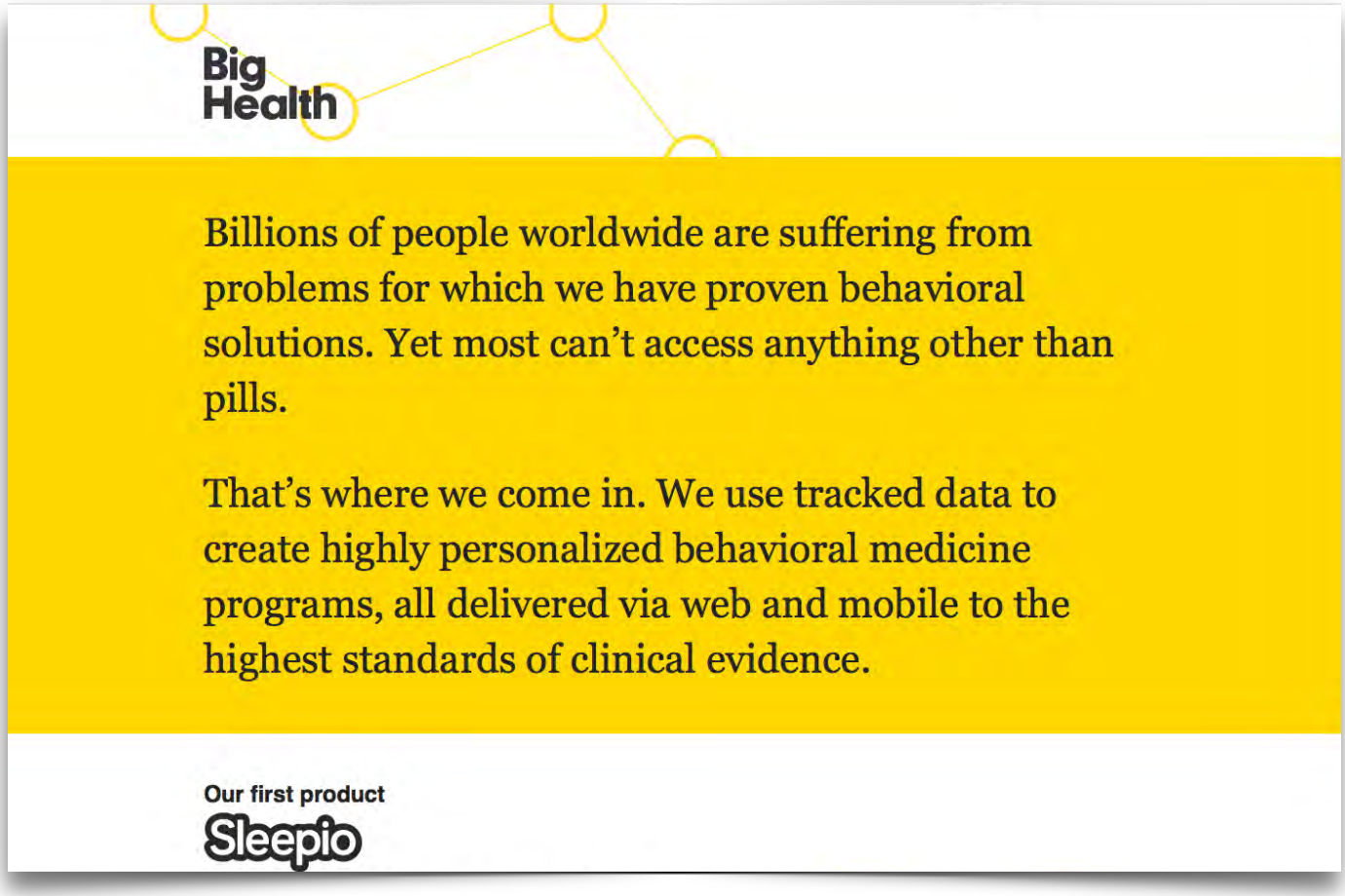
Big Health is a digital health company focused on the use of apps to deliver behavioural therapy. Big Health was originally called Sleepio, a company formed in 2010 to commercialise an application developed by Professor Coli Espie, from the Department of Clinical Neurosciences at Oxford.

The app uses the principles of cognitive behavioural therapy (CBT) in the treatment of sleep problems.

Professor Espie realised that this approach had much wider application, with potential utility in the management of anxiety disorders and depression, leading to the rebranding of the company as Big Health.



Big Health is a healthcare startup that maps onto the health app, medical app and algorithm spaces within the digital health sector.



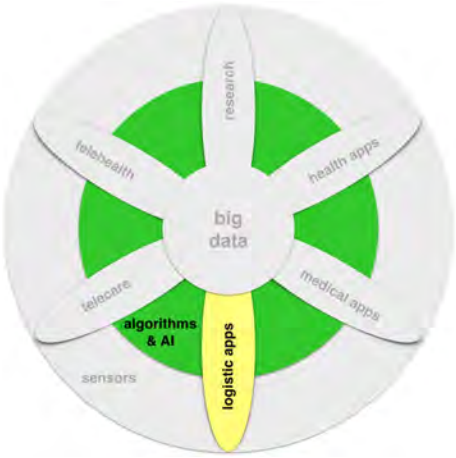
Case study 11 **Inquire**

Improving NHS Quality Using Internet Ratings and Experiences. This project, funded by NIHR, is using both quantitative and qualitative methods to examine how the NHS should harness online patient feedback. It builds on previous work funded by the Oxford CLAHRC, and is working with the Oxford Health NHS Foundation Trust as one case study site.

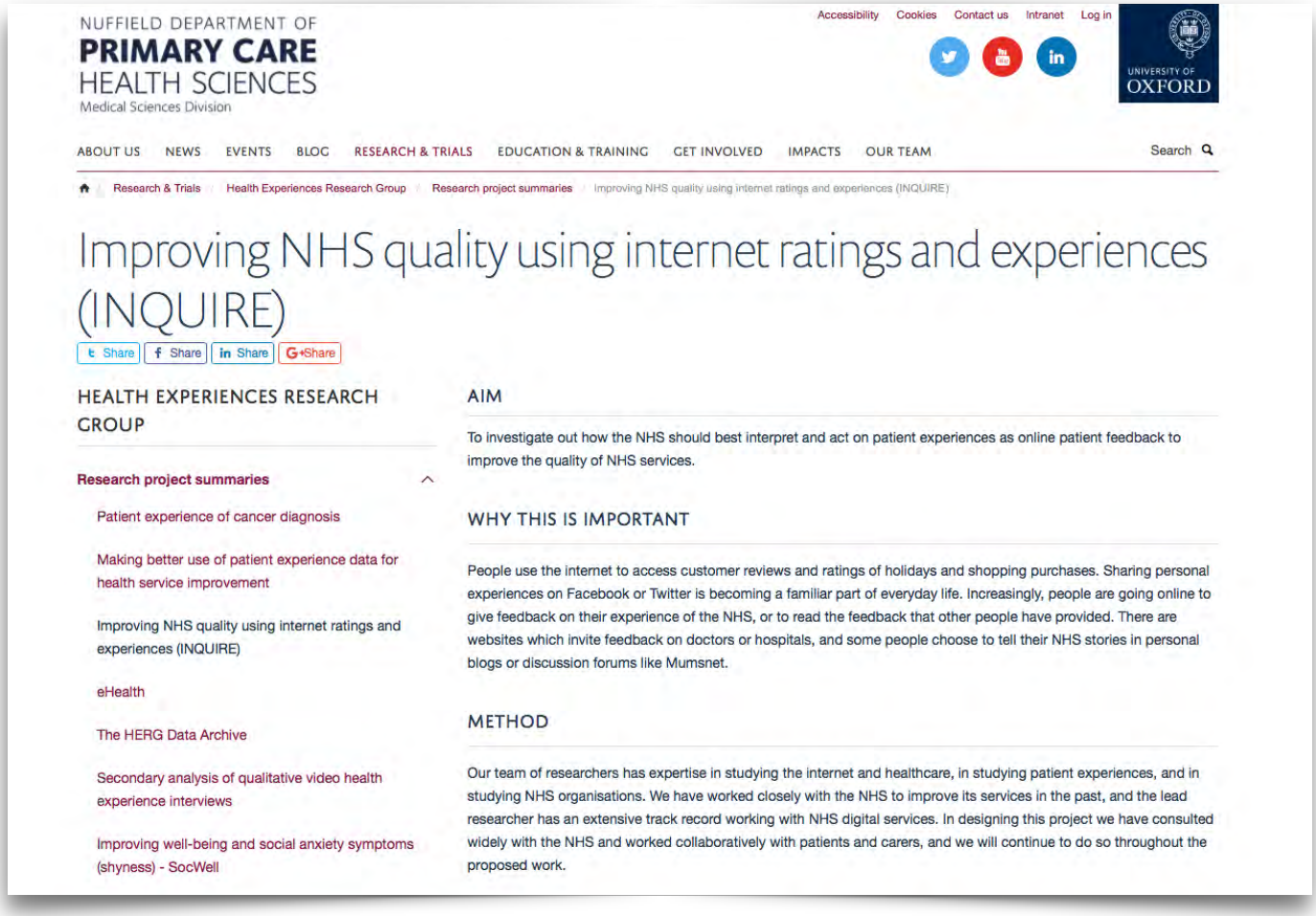
Sharing personal experiences on Facebook or Twitter is becoming a familiar part of everyday life. Increasingly, people are going online to give feedback on their experience of the NHS, or to read the feedback that other people have provided. There are also dedicated websites which invite feedback on doctors or hospitals, and some people chose to tell their NHS stories in personal blogs or discussion forums like Mumsnet.

This research examines how the NHS should interpret and act on patient experiences from online patient feedback to improve the quality of NHS services.

NUFFIELD DEPARTMENT OF PRIMARY CARE HEALTH SCIENCES
Medical Sciences Division



Inquire is an academic project that maps onto the logistical app and algorithm spaces within the digital health sector.



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Medical Sciences Division

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Research & Trials / Health Experiences Research Group / Research project summaries / Improving NHS quality using internet ratings and experiences (INQUIRE)

Improving NHS quality using internet ratings and experiences (INQUIRE)

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HEALTH EXPERIENCES RESEARCH GROUP

Research project summaries

- Patient experience of cancer diagnosis
- Making better use of patient experience data for health service improvement
- Improving NHS quality using internet ratings and experiences (INQUIRE)
- eHealth
- The HERG Data Archive
- Secondary analysis of qualitative video health experience interviews
- Improving well-being and social anxiety symptoms (shyness) - SocWell

AIM

To investigate out how the NHS should best interpret and act on patient experiences as online patient feedback to improve the quality of NHS services.

WHY THIS IS IMPORTANT

People use the internet to access customer reviews and ratings of holidays and shopping purchases. Sharing personal experiences on Facebook or Twitter is becoming a familiar part of everyday life. Increasingly, people are going online to give feedback on their experience of the NHS, or to read the feedback that other people have provided. There are websites which invite feedback on doctors or hospitals, and some people choose to tell their NHS stories in personal blogs or discussion forums like Mumsnet.

METHOD

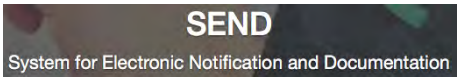
Our team of researchers has expertise in studying the internet and healthcare, in studying patient experiences, and in studying NHS organisations. We have worked closely with the NHS to improve its services in the past, and the lead researcher has an extensive track record working with NHS digital services. In designing this project we have consulted widely with the NHS and worked collaboratively with patients and carers, and we will continue to do so throughout the proposed work.

Case study 12 SEND

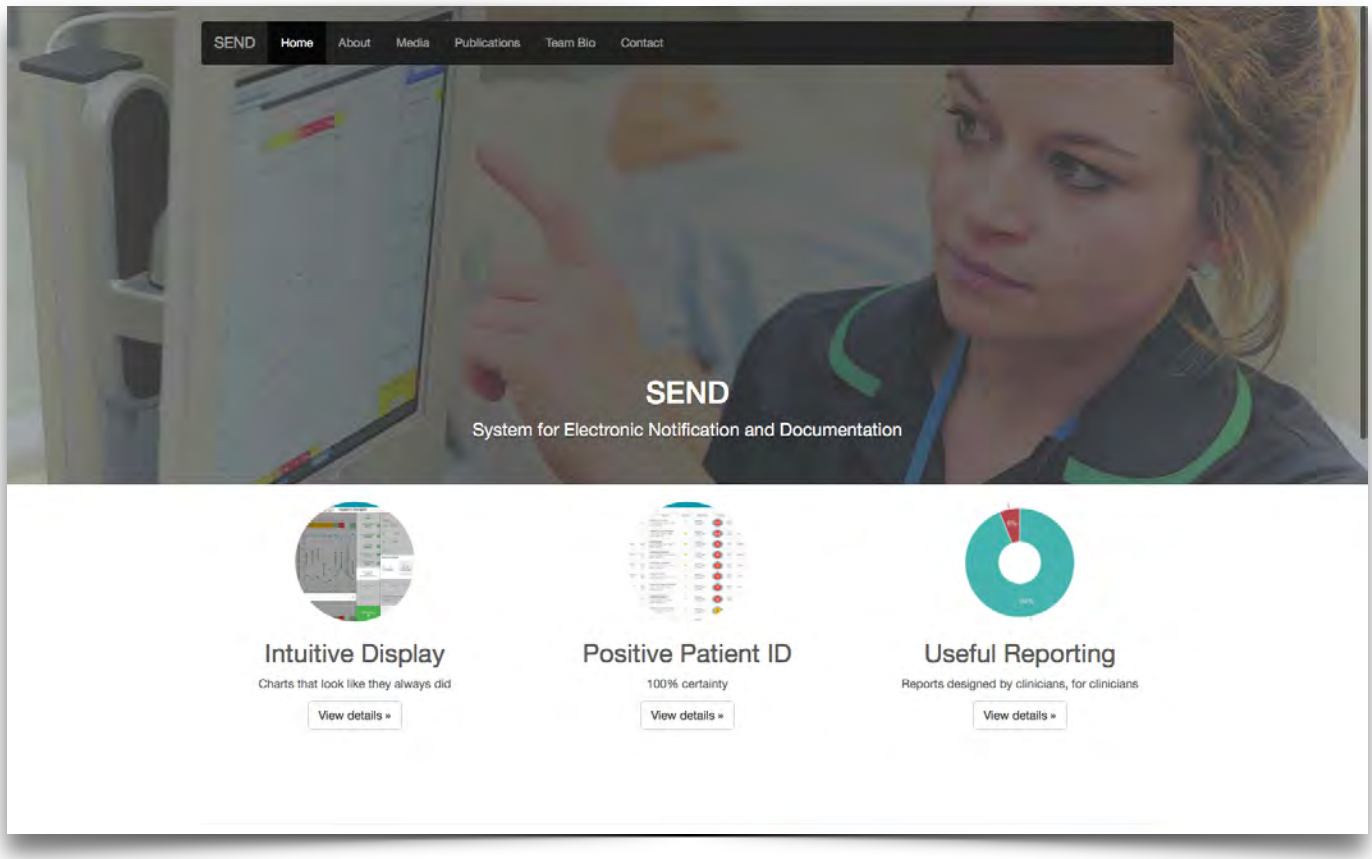
In 2011, Oxford University Hospitals (OUH) NHS trust implemented an evidence-based paper "Early Warning" chart, which standardised recognition of deteriorating patients throughout the organisation. Recognising the limitations of a paper-based approach, OUH determined that an electronic solution could further improve patient safety.

Using in-house IT resource alongside human factors and engineering expertise from the University of Oxford, the team developed tailored software that allowed compatibility with tablets and bedside devices whilst integrating with the OUH Electronic Patient Record.

The SEND system - **S**ystem for **E**lectronic **N**otification and **D**ocumentation - is currently being used in everyday clinical practice within the Churchill Hospital, the Nuffield Orthopaedic Centre and the Horton General Hospital. SEND is being rolled-out at the John Radcliffe Hospital and full deployment is due for May 2016.



Send is a hospital-based project that maps onto the medical app and algorithm spaces within the digital health sector.



Obstacles

In this section I will examine the barriers to full realisation of the digital health opportunities discussed in section 5 that emerged in my stakeholder interviews. I will conclude this section with a brief examination of Oxford specific issues.

Figure 11 is a spider diagram giving an overview of the issues that arose in my discussions.

> *"To most of us it feels like there has been more change in the way we book taxis, shop, bank or store photos than the way we access healthcare. Yet for every single one of us healthcare is more important than all of those things."*
>
> ***Jeremy Hunt Sep 2105***

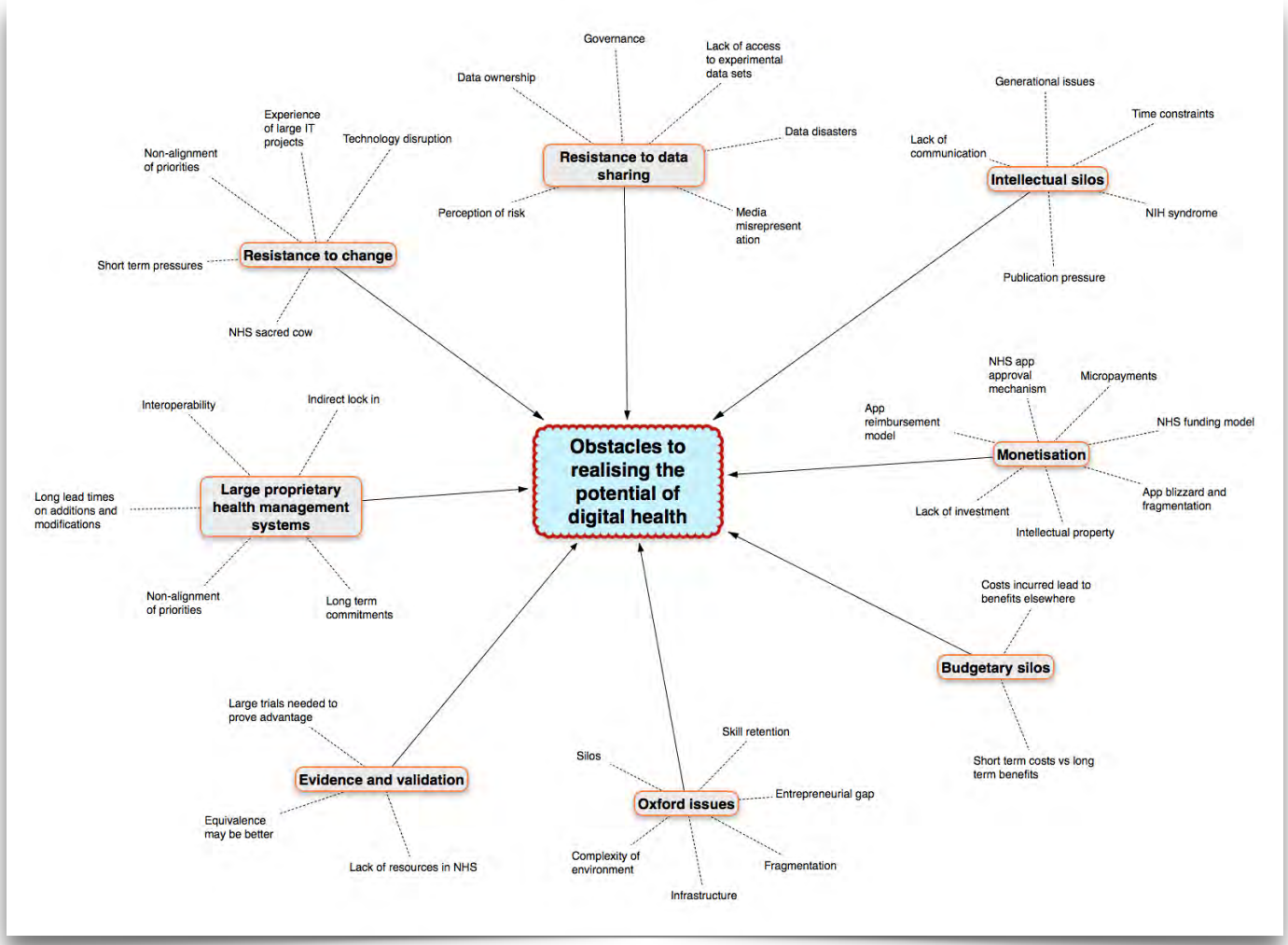


Figure 11 Spider diagram showing obstacles to realising the benefits of digital health

Resistance to change

All institutions exhibit a certain amount of inertia when it comes to adopting new ways of thinking. In many cases this serves a useful function of avoiding deflection by shifting fashions. Taken too far, however, this institutional inertia will cause an organisation to be left behind and rendered irrelevant.

This is a particular problem with the NHS, where its central mission is too important to risk by adopting every innovation. Thus short term pressures might always seem more important than long term investment in improving processes. This non-alignment of priorities within the system can only make it harder for innovators.

It is not helped by health systems being touted as the next monolithic structure that is ripe for digital disruption (after entertainment, retail, travel and the banking system). The last thing the NHS needs now is more disruption.

Unfortunately, those who resist change have plenty of ammunition in previous experience of large scale IT initiatives within the NHS[46]. Furthermore, the NHS has become something of a sacred cow. It is politically impossible to talk of replacing the NHS, or of sacrificing the principle of an NHS "available to all and free at the point of care". This makes it too easy for opponents of beneficial change labelling innovation as an attack on these founding principles.

Another issue is that clinicians and academic scientists have well established career pathways that reward and therefore reinforce current practice. Individuals who devote time to exploration of radically new ways of doing things risk falling behind in the metrics - such as publications - that underpin career progression.

"The figures speak for themselves. This week's public accounts committee (PAC) report on the NHS national computer system uses moderate language, but ought to cause outrage. It underlines the calamity of a project that was supposed to transform patient care in England but which has instead achieved little except enrich IT consultants and waste billions."

Guardian August 2011

Data silos

Transformation of the healthcare system through digital health innovation is going to be built on knowledge extracted from data. This will only happen if we can connect the huge number of data sets to allow health information to be correlated with fine-grained outcome, geographic, demographic and life-style information. This correlation has to be at the level of the individual, and therefore needs to be keyed on unique identifiers. In the absence of a national ID card, the only candidate for this identifier is the NHS number.

The obstacles to opening up data sharing are only too apparent. There is obvious concern about data privacy. People do not want sensitive details of their health leaking into the public domain. Identity theft is a big problem, and the personal identifiers embedded in health records would be of value to anyone involved in computer fraud. These perceptions are fuelled by well-publicised incidents of data loss in the NHS, and compounded by media reporting that lacks balance.

The other side of the argument - seldom reported in the press - is that not sharing data also conveys risk. The risk to individuals in emergency situations where paramedics do not have immediate access to key information. The risk to patients who do not get improved treatments because of delays in the research process. The risk to populations because policy judgements are bogged down in controversy because of underpowered public health studies.

Indeed I would argue that many more people have died as a result of not sharing data than have been affected by theft of data. In addition, it is clear that the governance structures are now in place to make sure that data sharing arrangements are relatively secure, and that they operate in the public interest. Though these measures are viewed as bureaucratic and an obstacle to data sharing, they are a political necessity. Moreover it is clear that they have a clearly stated principle of being in favour of data sharing as the default position. The NHS has an important role here as a trusted guardian of this public interest principle.

One other obstacle to data sharing is that some researchers feel proprietorial over ‘their patients’, and are reluctant to share access in order to gain advantage in publication. Thankfully this attitude is dying out, with open access to the anonymised data now almost the norm.

“There are people in my profession who think they can ignore this problem (the care.data controversy). Some are murmuring that this mess is like MMR, a public misunderstanding to be corrected with better PR. They are wrong: it's like nuclear power. Medical data, rarefied and condensed, presents huge power to do good, but it also presents huge risks. When leaked, it cannot be unleaked; when lost, public trust will take decades to regain.”

Ben Goldacre Feb 2014

“However, it was assumed that accredited apps – those that had been badged as trustworthy by organisational programmes such as the UK’s NHS health apps library – would be free of such (privacy) issues.”

“Our study suggests that the privacy of users of accredited apps may have been unnecessarily put at risk, and challenges claims of trustworthiness offered by the current national accreditation scheme being run through the NHS.”

Guardian September 2015

Finally initiatives such as the Oxford dynamic consent model should make overcoming the data governance issues much more straightforward, by building them algorithmically into the architecture of the IT systems. When coupled with biometric access to records or consent portals - for example using fingerprint id enabled mobile devices - it should be possible to build systems that allow data sharing and improve security.

“With Apple's Touch ID, for the first time on a mass scale doctors and patients are logging into medical records with biometrics," drchrono COO and cofounder Daniel Kivatinos told MobiHealthNews in an email. "We have released Apple's Touch ID login to over 70,000 physicians using our iPad electronic health record (EHR) and to over 3 million patients using our iPhone personal health record, onpatient PHR. With this launch, I believe this is the largest mobile biometric medical records login push ever.”

Mobihealthnews Dec 2014

Intellectual silos

In the case of data silos there is an understandable concern over data security. Unfortunately, the factors at play in the construction of intellectual silos within institutions such as a University are less defensible.

A lack of communication between departments and disciplines is largely down to insular thinking. And insular thinking is a real handicap in this highly connected world.

This insularity can be partially explained by geographical barriers, partially by generational trends. There are also considerations of publication preference and IP leakage, but these are usually rather weak excuses in this era of research as an open access and pre-competitive endeavour. A less understandable but perfectly human factor is ‘not invented here syndrome’ - a tendency to want to solve problems in their entirety, even if it means reinventing the wheel.

In the context of a complex and multidisciplinary field such as digital health, such approaches are anachronistic and ultimately doomed to failure. Even worse, they can be quite alienating for the new generation of researchers and entrepreneurs who are going to supply much of the drive and legwork in the digital health transformation of our healthcare system.

“Senge's view of the academic enterprise places the blame on faculty who remain "bunkered" in these silos. These faculty have “blinders on”. They cannot meet the needs of the institution because their goals are not aligned with the university. Most faculty members will not sacrifice or even empathize with the goals of the institution if it conflicts in any way with their professional goals or the discipline they operate within. Their priority will be always being their research and publishing because prosperity comes from achieving tenure or publishing recognition (Senge)”

Don Capener on Peter Senge Aug 2015

Budgetary silos

The third silo and perhaps the most significant are the budgetary silos within the health system. At present, there are distinct budgets for primary care, secondary care and social care.

As a result, there is no incentive for an investment in secondary care that will only realise a benefit to the social care budget. Even if the management were open to the shared objective of improving health for all, such an initiative would always be of lower priority given the lack of capacity and tight budgets in hospitals.

Even within secondary care there will be examples where particular departments will see the benefit of 'their' investment be realised in other cost centres.

Finally there is the temporal mismatch between investment and benefit. It is politically difficult to make investments in health infrastructure if the benefits are only going to be seen when you are no longer in office. An example of this is NHS investment in public health, where any benefit on long term demand might take decades to become apparent.

The solution to this problem is strategic, and involves shifting the basis of healthcare reimbursement to outcomes rather than medical treatments. In this model, all layers of health and social care are equal partners in ensuring that there are better outcomes. This is essentially the model recommended for the NHS by Monitor, the health sector regulator, in a follow-up report[4] to the Five Year Forward View.

For example, it does not make sense for elderly patients to be kept in (very expensive) hospital beds because there are not enough (relatively cheap) community beds for them to be discharged to.

A transition to more outcome-based reimbursement with integrated care will be challenging, fraught with the problem of unintended consequences. But it will result in a more aligned health service.

Digital health technologies have an important role here. First because they are the systems that will lubricate seamless transitions of patients between the layers of the NHS. Secondly, they will enable much higher resolution outcome data, ensuring that the system obtains the best possible value for its healthcare spend.

"…..when people do need health services, patients will gain far greater control of their own care – including the option of shared budgets combining health and social care. The 1.4 million full time unpaid carers in England will get new support, and the NHS will become a better partner with voluntary organisations and local communities….

…. the NHS will take decisive steps to break down the barriers in how care is provided between family doctors and hospitals, between physical and mental health, between health and social care."

NHS five year forward view Oct 2014

Large proprietary health management systems

At the core of the digital health revolution are electronic health records (EHR). Other terms that are used interchangeably or with subtle differences in meaning are electronic patient records (EPR) or personal care records (PCR). Related to these are the social care records (SoCR) and summary care records that provide an abstract of health-critical information (SCR).

Most hospitals and GP surgeries meet their patient data requirements through contracts with providers of large health management systems[47].

These are complex and expensive systems that have required many years of development and involve hundreds of thousands of lines of code.

As a consequence, they are expensive, require extensive customisation to embed them in each hospital, and are very slow to adapt to a rapidly changing healthcare environment.

Because there are multiple vendors of these systems competing for business, there has been a tendency for companies to exploit the long lead times, creating an effective 'lock in' once a hospital has committed to a system.

This is compounded by a lack of interoperability and limited or no access to the source code that would allow other parties to contribute.

If a hospital wants a new module added to the system, then this would either be a very expensive piece of bespoke consultancy, or would rely on waiting for the system supplier to recognise it as having general utility and incorporate it in its next release.

Furthermore, this effective monopoly acts as a barrier to innovation, as it is very difficult for new companies to explore novel solutions to healthcare problems in a meaningful way, or test prototype systems in an authentic IT environment[48].

These commercial systems have an obvious advantage of being robustly designed and validated for resilience to failure. However, they are usually based on versions designed for the private standalone healthcare model in the US. So they end up being a compromise that is retrofitted into the NHS.

The alternative model - one which relies on open source software and common data standards - would provide a

"Our recovery plan will invest in electronic health records and new technology that will reduce errors, bring down costs, ensure privacy, and save lives."

President Obama Feb 2009

"Too often I pull up a record, either in peer review or another setting, and it's almost impossible to really get an understanding of the story line. On a daily basis I can't find the information, particularly nurses' notes and things like that that are really valuable to me. In a sense it's turned us into data entry clerks. Communication with patients is not only suffering, but communication with nursing and others, as well. It breaks down, we all communicate now just by what goes into that electronic record."

US MD Oct 2015

"From the report, it is clear from the outset that there is one vital element that underpins not only successful integration of digital healthcare technologies, but also its key premise: implementation and standardisation of electronic health records."

Royal College of Physicians on the Nuffield Trust report[7] Feb 2016

much better environment for these sorts of innovation. However, with little track record of resilience for such systems, coupled with a lack of relevant experience in their IT departments, it is not surprising that open source is viewed as a leap into the dark.

Viewed from the narrow perspective of a hospital trust, it is therefore possible to see how the option of investing in a large data management system looks like the prudent option. Oxford University Hospitals NHS Trust has pursued this approach with the Cerner Millenium EPR, and has won a number of awards for EPR implementation in a complex legacy environment, culminating in the Digital Hospital of the Year Award in 2015[49]. An independent 2015 review by the HSICC concluded that:

"All but one of the capabilities planned in the LSP and trust business cases have been delivered; and a critical mass of adoption achieved which is beginning to yield evidenced benefits."[50].

But from a wider perspective - outside the secondary care silo - it looks like a parochial and short term fix. This is particularly true in Oxford, where the combination of strengths in computing and medical science would seem to offer a tremendous opportunity to build the next generation systems along the lines of an open collaborative model.

"We know how organisations within the NHS function. We understand Interoperability, Information Governance, Clinical Safety and how to make sure that our services work perfectly with the rest of your infrastructure, and how to comply with all of your security policies.

All of our work is Open Source, Open Governance. Vendor neutrality is baked in to the licenses we provide at a fundamental level. Our customers are always free to customise and re-use the work with other partners."

Open Health Care UK Website Jan 2016

Evidence and validation of digital health innovations

Everybody now agrees that trying to implement a top down digital health solution is an incredibly bad idea.

The model that is being followed is rather one of small-scale innovations that offer quick gains, usually within a particular specialty or level of organisation. Even an innovation with widespread potential application - such as replacing paper observation charts with electronic records on tablet devices - will be introduced in piecemeal fashion.

The idea is that this minimises risk, and that the benefits once demonstrated will propagate through the organisation by demand rather than edict.

This model is also more in keeping with the agile development methodology that is now routine in the IT software industry.

The problem with this approach is that small scale trials lack statistical power. If the purpose of the evaluation is to prove improvements in treatment, reduction in morbidity or simply cost savings, then there is a likelihood that the results will be inconclusive. Large trials would be very resource intensive, and the series of preliminary trials necessary to justify the resource would greatly extend the innovation cycle.

Local introduction of new working patterns or care pathways will inevitably lead to parallel systems within the hospital. This may well have the paradoxical effect of an innovation increasing costs with no demonstrable clinical benefit. This may be an acceptable 'means to an end' with the short or medium increase in costs being accepted as an inevitable 'activation energy' necessary to reach the nearby valley of improve efficiency.

It may also be necessary, for some innovations, to accept that an evaluation will need to be more anecdotal in nature[34]. The trials would still be systematic, but ultimately an estimate of the value of the innovation would be delegated to the staff involved in patient care.

In summary, the process of seeding digital innovation into healthcare systems, and catalysing its wider adoption, is itself an area that is ripe for innovation in trial design and interpretation[51].

A crisis in evidence based medicine?

The evidence based "quality mark" has been misappropriated by vested interests

The volume of evidence, especially clinical guidelines, has become unmanageable

Statistically significant benefits may be marginal in clinical practice

Inflexible rules and technology driven prompts may produce care that is management driven rather than patient centred

Evidence based guidelines often map poorly to complex multi-morbidity

Professor Trish Greenhalgh

Jun 2014

"*There need to be more informal mechanisms for assessing the costs, benefits and risks of new technologies, which could then be subject to post-implementation evaluation to confirm or revise the initial assessment.*"

The Kings Fund

Monetisation of digital health innovations -

One often cited problem with digital health innovations is that there is no established pathway for generating revenue. In reality, this problem applies mainly to developers of consumer health or medical apps. Companies that operate in the Telecare space usually have a broader business model, and developers of large-scale medical logistic apps - such as electronic prescription services or EHRs - operate with a licensing model. According to Accenture, the UK is the biggest EHR market in Europe worth some $2.1 billion by the end of 2015, with an annual growth rate of 5.5%[52].

A recent report by McKinsey and company[53] identified five modes of revenue generation for mobile players in the digital health game - see side bar. They noted that educating consumers was likely to be key in unlocking the potential markets - an important point to note for potential entrants into the space.

With respect to other apps, the lack of a clear monetisation pathway will be an obstacle to companies who want to operate in this space, since it can typically cost more that £100k in developer fees just to code a fairly simple app.

This does not appear to be an obstacle to many developers, as the blizzard of consumer health apps that have appeared testifies to. However, many of these are derivative or me-too type apps, distinguished only by their interfaces rather than their content or algorithmic basis, and probably have rather low development costs.

If the target of the app is the NHS, then in addition to developer fees, there are the much greater costs associated with testing and validation.

There are three models for revenue generation from apps that are in widespread use. Premium apps charge a significant upfront fee and/or a monthly subscription. The app would have to be very distinctive to justify this approach.

An alternative approach is to make a very low upfront fee - perhaps free - for a basis version of the app, then make extra features available for a fee once the purchaser has decided they like the app.

Finally, there are a large number of apps that are free to download, but that generate a revenue from advertising.

Five routes to revenue generation in mobile digital health

- *Connected devices*
  $3-5 billion
- *Secure connectivity*
  $2-3 billion
- *Hospital of the future analytics*
  $10-20 billion
- *Health data aggregation*
  $5-10 billion
- *Enabling direct-to-consumer services*
  $2-5 billion

McKinsey Apr 2015

"Healthcare apps will go through a four-stage recommendation process as part of NHS England's plans to create an endorsement model for these tools.

Speaking at the National Information Board meeting at the King's Fund Digital Health and Care Congress, Diarmaid Crean, deputy director, digital at Public Health England, said the model was being developed to help the developers of good apps differentiate themselves from the "dross of apps that are of low quality."

digitalhealth.net Jun 2015

There are many examples of digital health apps that fall into the first two categories. For example, Diabetes Pal is an example of a premium app (£22.99) that helps diabetics track and manage their blood glucose levels

Babylon Health is a company that offers health advice and access to a medical practitioner via an app that is free to download. The app provides free medical advice on line - including responses to questions sent by text. Users have pay for premium services such as telephone or video consultations with a doctor, or access to diagnostic services. Unlimited consultations are available for a fee of £4.99 month, or on a pay as you go basis. longer private consultations cost £49 per hour.

Optimism is a mood chart app that helps users manage mental health issues such as depression and bipolar disease. It is free to users, but is designed to be linked to a paid for dashboard application so that clinicians can monitor the status of multiple patients.

In most cases, key to the ability to charge significant fees for a medical app will be NHS endorsement. Although this will require significant upfront development and validation costs, accreditation will provide the distinctiveness required for premium payment.

Linked to this idea of NHS endorsement is the possibility of the NHS prescribing apps, with the app available to the patient for a low - or zero fee - and the NHS paying the developer. Digital apps are already delivering 'therapies' such as CBT, and there is clearly the potential for other medical apps that could reduce or displace drug prescribing. It is therefore inevitable that health app prescriptions will increase dramatically, and that the NHS needs a framework to manage the process.

This is going to be challenging, because NHS accreditation will be a valuable asset - akin to approving a new drug in many respects. As the number of medical apps increases, however, the potential for dysfunctional code to cause harm will become a real risk. Starkly, it is inevitable that a malfunctioning health app will lead to an avoidable death.

The NHS has not yet got this right, as the mess over the governance issues surrounding the care.data fiasco and the more recent sanctioning of apps with security flaws illustrate.

So the issue is not so much of monetisation of apps per se, but rather the lack of a clear regulatory framework for

"There's just no plausible medical way that some of these apps could work," said Nathan Cortez, an expert in medical technology law and regulation at Southern Methodist University's law school in Dallas…..

….Besides wasting your money, these apps may actually do harm," Mr. Cortez said in an interview. "If you're diabetic and your app is misreading your blood glucose levels, you may give yourself more insulin than you need and go into diabetic shock."

New York Times Mar 2015

"If we were talking about health apps generally in the wider world, then what we found would not be surprising," said Kit Huckvale, a PhD student at Imperial College London, who co-wrote the study.

But given that the apps the study looked at were supposed to have been vetted and approved, finding that most of them did a poor job of protecting data was a surprise, he added."

BBC Website Sep 2015

app approval, and a decision on how apps are going to be prescribed and reimbursed with in the NHS.

The risk for the NHS is that if it fails to do this is that the disruptive power of digital technology and the free market will start to degrade its pre-eminent role in delivering healthcare, as experience in other monolithic and or monopolistic enterprises has shown.

Intellectual property is also an issue with medical or health apps, as patent protection is unlikely to be available unless the app is linked to novel sensor technology, or uses new algorithmic approaches.

Weaker but useful protection is available to cover design elements, such as novel user interfaces, and the software that drives it. These are unlikely to be substantial barriers to me-too products, however.

The key protections are most likely to come from being the first in class, building a large-user base, and continuous improvements. This, coupled with NHS accreditation, should be a sufficient platform to generate the revenues required to justify significant upfront investment.

On this final note, sources of funding for digital innovation and app development exist within the NHS, the bodies that fund research and from private investors. The NHS runs innovation competitions, with seed funding available to generate proof-of-principle data. A good example of this is the 2023 competition run within the Oxford University Hospital Trust.

Many of the disease charities fund similar early stage exploratory programmes. There are plenty of examples of patient facing apps providing disease specific support that started out this way.

Bethnal Green Ventures stands out as a fund that specialises in supporting early stage social innovations. It has invested in a number of digital health innovations, including Konnectis, a startup company focused on aiding communication between the main providers of domiciliary care: paid carers, volunteers and family members. BGV has funded one project emerging from a Digital Health Oxford initiative - Project Tide - a diagnostic test strip reader app that uses a smartphone to help improve the diagnosis of TB.

From an investment perspective, digital health apps provide very attractive opportunities. It is a rapidly growing field, and the potentially transformative effect has a strong

When a company identifies how to integrate the processes needed to give the consumer a sense of job completion, it can blow away the competition. A product is easy to copy, but experiences are very hard to replicate.

Source | Clayton M. Christensen

“Amsterdam-based dermatology app company SkinVision has raised $3.4 million from pharmaceutical company Leo Pharma with contributions from SkinVision's existing investor and majority stakeholder Dutch investment firm Personal Health Solutions Capital. The company plans to use the funding to move its app's capabilities beyond melanoma recognition and into other skin conditions, according to a report in TechCrunch.”

Mobihealthnews Aug 2015

“Starting a digital health company comes with an obligation to positively impact the healthcare industry.”

Source | Alejandro Foung, Lantern

social element. The sums of money required are much less than drug development, and the development life-cycle is much faster - typically less than two years.

Oxford issues -

In this section, I have examined seven general issues that provide challenges to the successful development of next-generation healthcare catalysed by digital innovations .

These challenges are more to do with attitudes, organisations, processes and communications than they are to do with the technology itself.

But how prepared is Oxford and the wider Oxford AHSN region to tackle these issues and play a leading role in developing healthcare v2? I will briefly examine each of the seven issues and how they relate to Oxford in particular.

In terms of resistance to change, Oxford is an uneasy amalgam of revolutionary thinking and conservatism. A state of affairs that has probably persisted for 900 years. I'm not sure that this is going to change

Like any other region, the health and population data lives in silos. But Oxford has pioneered many of the approaches to data amalgamation through record linkage. The challenge will be to pioneer the next phase of data integration, which is going to require major initiatives in public engagement and innovative approaches like centralised dynamic consent.

In terms of intellectual silos, the stereotypic view of Oxford is that it goes in for bunkers rather than silos. These outmoded ideas are being blown away in Oxford, where there are plenty of examples of open collaborative models - such as the very successful structural genomics consortium (SGC). The SGC was set up to shake up the stale, wasteful and unproductive drug development model of the last twenty years, and I suspect that we will need similar thinking to tackle the complexities of digital health.

With respect to the budgetary silos within the NHS, the situation in Oxford is no different to elsewhere. However, Oxford has a tradition in pioneering medical practice and a strong record in public health and developing outcome measures. It also has a forward-looking set of commissioning groups. It is therefore extremely well-placed to realign health spending to fund outcomes rather than activity.

As with most of the UK, the Oxford AHSN region hospitals and GP practices run a mixture of large proprietary medical records systems. It is likely that this situation will be effectively locked in for a number of years for the

Oxford lecture c 1736 (William Hogarth)

"Since I arrived in Oxford I have tried to get collaborative cross department activity going but have been dismayed at the lack of desire to work in this way."

Unattributed

perfectly justifiable reasons I have discussed. However, this presents a significant barrier to innovation.

The significant problems associated with evaluating and validating digital health innovations are clearly also present in the Oxford AHSN region. However, Oxford is a world-leader in epidemiology, clinical trial design and analysis. So it seems to me that we are better placed than most to come up with solutions to these problems that will accelerate the introduction of fit for purpose technology.

Finally, with regard to monetisation of medical or consumer health apps, there is probably scope for further innovation - perhaps through micro-payments and other models. The region has shown that it can innovate in the medical app space and there are several highly successful apps with a wide user base. However, it is not clear yet that these are a commercial success. In the end Oxford and the rest of the UK are waiting for the NHS to shape the environment through its reimbursement and certification policy.

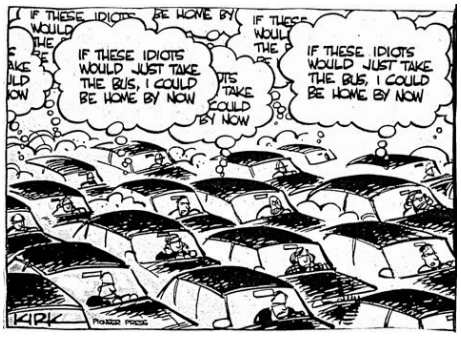
Above and beyond the seven digital health specific issues, there are a number of general Oxford-centred problems that must also be considered as they affect the environment for innovation.

Retaining staff with the requisite skills is always going to be an issue, because of the famously low-affordability of property in the area. The young, digitally literate entrepreneurial innovators that will be needed are always going to be highly sought after and highly mobile.

Any shortage of risk-capital for investment in the area will only fuel this potential brain drain.

Then there are the logistic issues. Although Oxford should be one of the most desirable places in Europe to live, the transport links are not what they should be. The effective size of the city is greatly increased by the transit times, and the amount of traffic reduces the quality of life.

All of this militates against providing the right environment for entrepreneurial fusion.



Oxford traffic c 2016

"The average property in the university city, at £340,864, now sells for more than 11 times local salaries, or twice the national average. Rents have risen less dramatically, but are also squeezing lower income families who are unable to buy a home. 'We are seeing one-bed flats fetching around £900 a month, which on our affordability measures means that people have to be earning £36,000 a year to be able to rent it', says James Scott-Lee, managing director of estate agency Chancellors."

Guardian Mar 2014

A way forward

In this final section, I try and weave some of this thinking into ten suggestions that build on the region's strengths and would allow it to establish a leadership position in the digital health arena.

Establish a permanent entrepreneurial hub for digital health

Digital Health Oxford has emerged as the most effective networking organisation supporting digital health innovation in the area. The complex and often fragmented nature of the Oxford research environment requires networking groups like this to attract the focus of disparate groups of researchers. This is especially true of digital health, which is extremely multidisciplinary.

There is already a candidate hub proposal known as 'The Hill'[54] which aims to provide an environment close to the John Radcliffe Hospital for medics, nurses, media developers and entrepreneurs to dream up new solutions to problems identified on the front line of delivering healthcare.

The hub will operate as a rolling triage of ideas, providing a supportive environment for ideas through from early brainstorming to proof of principle and investment ready proposals. In effect, it will replace and enhance existing semi-annual innovation competitions operated by the NHS and the Oxford AHSN.

This proposal should be supported to foster a permanent culture of reinventing healthcare. The environment will be particularly attractive to young entrepreneurs, and will serve as a magnet both to retain talent and draw talent from elsewhere.

"A healthcare ideas lab, situated at the heart of Oxford's medical, academic, digital and entrepreneurial communities. Catalysing a generation of globally impactful healthcare innovation."

The Hub website

Create a digital health institute

Throughout this report, I have used the term digital health as shorthand for the process of redesigning healthcare based on the use of digital technologies as the enabling principle.

Looked at in this way, the challenge of digital health is much larger than a technological challenge, as it is embedded in wider societal issues of value in healthcare and public health. How can we best validate and measure effectiveness of medical applications? Which outcomes should we measure and how? What can we learn from other industries on how to re-engineer processes within a hospital? Perhaps above all else there are the ethical

issues that are often the elephant in the room. The need for informed public debate on data sharing and models of consent.

All of these issues are areas of active research and new theories are being developed. I think that such a complex set of interconnected problems deserves a large-scale academic enterprise to provide a sound theoretical framework to support healthcare change.

A second argument in favour of forming a new institute is that despite the wealth of strengths and opportunities in the region, it is undoubtedly the case that there are very significant obstacles to efficient and productive collaboration within the University. The region in general and Oxford in particular is falling behind other centres, and is in danger of being a contributor to rather than leader in transformational health care research.

A number of other centres in the UK have already formed interdisciplinary institutes - see figure 12. In some cases, such as London, Scotland and the Northeast, they are forging ahead of Oxford as digital health pioneers.

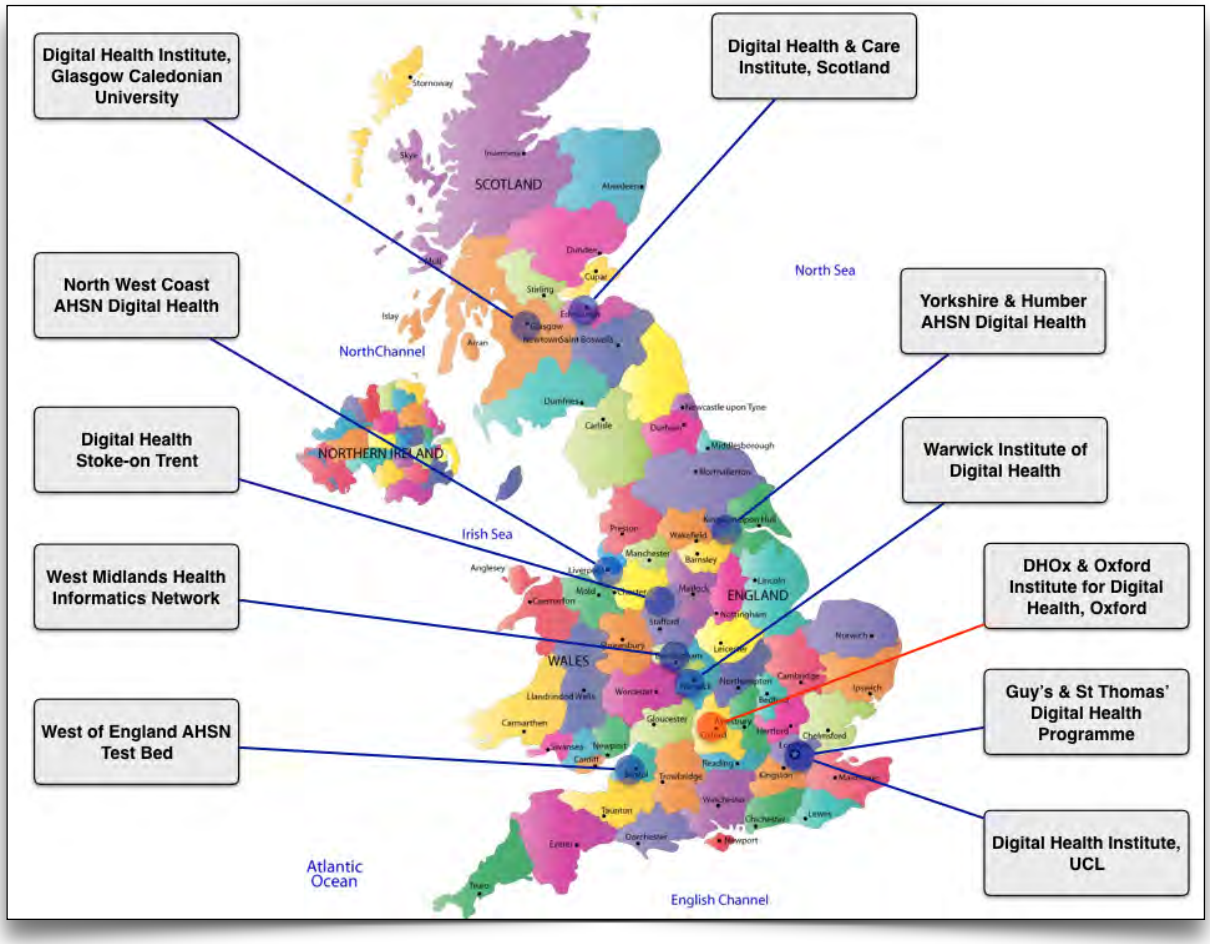


Figure 12 Spider diagram showing obstacles to realising the benefits of digital health

New institutes that span organisational and cultural boundaries are a well established way of breaking down silos and fostering productive interdisciplinary working - especially across research and practice boundaries.

An Oxford Institute for Digital Health should bring together academics working in the fields of health care research, ethics, clinical trial design, process engineering, management and business planning, as well as software developers, AI specialists and computer scientists. It should encompass all levels of healthcare from primary care through to social care and population health.

Matching funding should be sought from corporations that are large enough to have significant social responsibilities. These could include large IT firms, supermarkets and healthcare providers as well as pharmaceutical companies looking to diversify.

Assemble a partnership to build an open source EHR for the region

For the reasons that I outlined in section 7, the use of large commercial EHR solutions is a barrier to innovation. The complexity of the healthcare environment is such that it is unlikely that a single developer is going to come up with a solution for the NHS that is fit for purpose and future proof. However, the local decisions by trusts to buy in solutions is understandable.

I think that there is a strategic need to develop an open source EHR that can eventually be implemented across the region. The complexity and scale of the task means that a successful product could be a prototype for nationwide implementation. At the very least it would be an attractive option for other trusts or regions.

Open source effectively crowdsources the innovation and keeps development costs low. It also means that modules can be developed in line with a users priorities rather than waiting for it to fit into the developer's schedule.

There are already a number of proven open source EHR projects, and the region could choose to join forces with one of these or start from scratch to ensure that it matches NHS requirements more closely from the start.

"I often compare open source to science. To where science took this whole notion of developing ideas in the open and improving on other peoples' ideas and making it into what science is today and the incredible advances that we have had. And I compare that to witchcraft and alchemy, where openness was something you didn't do.

Linus Torvald - Linux founder

Map out the vision for big data more clearly

Big data - and the analysis that will turn it into useful information and knowledge - should be at the heart of the digital health revolution.

Big Data was identified by the ABPI as an area of real opportunity for the UK, leading to the publication of their 2013 roadmap for Big Data[55]. This report identified four main challenges - see side bar - to realising this potential in the UK, all of which apply to our region, but which Oxford is perhaps better placed than most to overcome.

That Oxford is well-placed to play a pivotal role in this is clear. It has a fantastic track record in medical science in general and epidemiology in particular thanks to the legacy of Richard Doll and co-workers. This leadership position was recently consolidated by the announcement of the £30m Li Ka Shing Centre for Health Information and Discovery - also known as the big data centre.

Although the building is now well under construction with completion expected in December 2016. Although the purpose of the institute is "directed at obtaining and characterising large datasets to improve our understanding of human disease", there is currently very little information on what new initiatives are going to be enabled. In particular, it would be helpful to know what the large datasets were and where they were coming from.

Given that issues over the use of personal data have a habit of coming back to haunt those that use the information - even in the public good - it seems to me that this is an area where we need to be very careful (see below). The big data concept is already in the public eye[56], and Oxford needs to be at the forefront of presenting a responsible and balanced view of its potential.

More positively, it would also be good to have some idea of how the data is going to be structured. Is it going to include a 'data lake' of unstructured information from the wider community? Or is it going to focus on structured data sets from health records.

Finally, we need to get the environment right. Oxford needs to be seen as an amazing place to work in terms of the infrastructure, the data set and the entrepreneurial atmosphere. Here a litmus test will be the extent to which we can attract innovators back from institutions like Google and Facebook.

Fragmented service providers across healthcare and academia with embryonic industry-facing services, risking duplication of investment, assets and services

Immature methodologies, algorithms, platforms and models and associated governance

Ad-hoc mechanisms to build innovative partnerships and shared products

A serious shortage of data scientists, bioinformaticians and chemoinformaticians with the appropriate skills and understanding to handle the complexities of big data and all its applications

Challenges identified in the ABPI Roadmap for big data 2013

A campaign of public engagement on data sharing

Enhanced data sharing, enabled using the NHS number as a unique identifier, is going to be key to the maximising the value of health records.

Given that fact, and the unfortunate track record of the NHS in managing information campaigns around access to medical records, it seems to me imperative that we start a campaign of public information and education around the use of health records. This should be honest and transparent about the risks and benefits associated with data sharing. But this should include an emphasis on the risks of **not** sharing data. This risk is seldom given air time, yet has arguably killed thousands of people through lack of availability of data or failures to properly audit clinical outcomes.

The goal of the campaign should be to build on the idea of "our NHS - our data". Data sharing should be the default option for most people, with the NHS as guardians of the public interest. It should refer to the strengths of the region in terms of governance discussed in the previous sections. This should be backed up with lobbying for more specific data protection laws applied to health records, with draconian penalties for those who steal or otherwise misuse medical information.

The tangible core of the campaign could be the introduction of personal health records that an individual could access and add to, and potentially a dynamic consent module. This would allow an individual to control how their data was used, and could also be extended to include preferences regarding organ donation, blood donation, clinical trial volunteering and end of life care to be managed.

Develop new sources of funding for early stage innovation

There are plenty of sources of finance available for investment-ready propositions that have proof-of-principle and a convincing route of return. Most if not all early stage digital health projects fail on both of these counts. Seed funding is required to do the necessary prototyping before proof of principle studies can be carried out; validation pathways are difficult to devise and implement; and routes to monetisation are currently problematic.

There is thus a critical need for more funding to support early stage exploratory and proof of principle studies.

Sources of funding that could provide £5k-£25k do exist, but they tend to be in the form of special awards or competitions such as the Innovation Challenge 2023[57]. What is needed is a specialist fund, geared to provide this early stage funding, open to all-comers. The fund should also be a source of mentoring and business support, and have a strong social enterprise mission to offset the problems associated with monetisation.

The fund would not have to be large, perhaps in the range £5m - £10m in the first instance that could come, at least in part, from the OSI fund. It could be modelled on other funds such as Bethnal Green Ventures[58] and the Nominet Trust[59] in the UK, or Rock Health[60] in the US.

The presence of such a fund, focused on local solutions with the potential for wider propagation, could initiate an entrepreneurial chain-reaction. It would attract and retain talented young scientists and medics, ensure a steady stream of startups, and go a long way to embedding a transformational mind-set in the local hospitals.

Credit young medics or academics for involvement in entrepreneurial activity

At the moment the career prospects of young researchers depend to a very large extent on publication output. This can therefore be a powerful disincentive to involvement in entrepreneurial activity with its very uncertain outcome.

Arguably this goes with the territory - entrepreneurs are risk-takers after all. However, innovation and translational research are now key to an academic institutions survival, and it seems perverse not to realign incentives as part of the required cultural change.

I would also argue that the balance of risk and reward is likely to be different in digital health, where return on investment is just as likely to be in social capital as it is in shareholder value.

Use the bed blocking problem as the focus for a collaborative “Apollo programme”

The Oxford AHSN is sponsoring a number of networks focused on re-engineering clinical pathways. I propose that this model is taken a step further and that the region identifies a particularly difficult inter-agency issue to provide a focus for new ways of working.

The counter-intuitive idea is that if you want to change the way the people work - demanding interdisciplinary working and radical new ideas - then it makes sense to start with a big problem. Bed blocking is one obvious

example of such a problem, and digital technology will provide the framework required to enable the two levels of health care, social care and the voluntary sector to work together seamlessly.

Review how healthcare innovation is introduced in medical and nursing training

A central theme to emerge from this review is that digital technologies are a catalyst for transformation of healthcare. A large part of this is will involve cultural change; from old systems of top down bureaucratic dictat, monolithic structures and inherited wisdom to a new model of innovation, continuous improvement and agile development. This new way of working gives everyone working in the NHS a role in the process, and training for doctors, nurses and allied healthcare professionals needs to reflect this.

Health Education England recognised the importance of this in their 2013 strategic review[61]. A key objective was to generate a “Flexible workforce responsive to research and innovation”. However, the scope was rather limited, referring merely to the use of technology to access information and to “realise the potential of research and innovation and to invest in education and training in genomics”.

I think that we need to go further than this. The Oxford AHSN could play a role in encouraging Junior doctors and nurses to participate in the transformational process through workshops and conferences. But there is also a more fundamental need to embed the practice of continuous process improvement and digital literacy in their training. As a major centre for the education of doctors and nurses, it is important that the region leads the way in updating courses to fit the new more dynamic model of healthcare.

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I would particularly like to thank Dr Richie Harrington and Dr Alex Finlayson from DHOX for their support and several lengthy and wide ranging discussions. Dr Jackie Birks from the Centre for Statistics in Medicine shared background information on an ongoing trial on electronic observation charts, and is a continuous source of insight.

Finally, Professors John Powell, Muir Gray and Sheila Greenhalgh, who in addition to being extremely generous with their time shared a lot of additional information.

“When facing a difficult task, act as though it is impossible to fail. If you are going after Moby Dick, take along the tartar sauce.”

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Appendices

Appendix 1 List of interviewees

Name	Institution	Role
Alexander Finlayson	The Hill	Co-founder & medical director
Bill Imlah	Oxford Internet Institute	Researcher
Chris Goard	Oxford University Hospitals NHS Foundation Trust	Non-executive director
Chris Hinds	Digital Health Oxford	Team leader
Chris Paton	Centre for tropical medicine and global health	Group head for global health informatics
Claire Hill	Reading University	Clinical psychologist
Dave Fletcher	White October	Founder
Fred Kemp	ISIS Innovation	Deputy Head of Technology Transfer
Hugh Penfold	Oxford Academic Health Science Network	Commercial development manager
Jackie Birks	Oxford Biomedical Research Centre	Senior statistician
James Semple	Mathematical Physical and Life Sciences Division	Industrial partnerships
Jane Kaye	Centre for Health, Law and Emerging Technologies (HeLEX)	Director
Joanna Cox	Cranfield University	Head of business partnerships
John Bell	University of Oxford Medical Sciences Division	Regius professor of medicine
John Fox	Deontics	Consultant
John Geddes	Department of Psychiatry	Director
John Powell	Nuffield Department of Primary Care Health Sciences	Associate professor
Kazem Rahimi	George Institute for Global Health (GIGH)	Deputy director
Keith Errey	Isansys Lifecare	Co-founder and EO
Kevin Maynard	Brookes University	Business manager
Louize Clarke	Connect Thames Valley Tech	Director
Martin Landray	Nuffield Department of Population Health	Professor of medicine and epidemiology
Michalis Papadakis	Brainomix	CEO
Mike Denis	Oxford Academic Health Science Network	Director of information strategy

Name	Institution	Role
Muir Gray	The Hill	Chairman
Nicholas Edwards	Oxford Academic Health Science Network	Director
Nick de Pennington	Medical Sciences Division	Consultant
Nick Scott-Ram	Oxford Academic Health Science Network	Director
Nicki Bromwich	Oxford Academic Health Science Network	Commercial development manager
Oksana Artyomenko	Illiria Ltd	Managing Director
Oliver Voss	Medical Sciences Division	Business development manager
Patricia Greenhlagh	Nuffield Department of Primary Care Health Sciences	Professor
Phil Clare	Smart Oxford	Board member
Piers Clifford	Buckinghamshire Healthcare NHS Trust	Clinical lead for cardiology
Richard Jones	Buckinghamshire New University	Principal lecturer, faculty of design, media & management
Richard Maher	Buckinghamshire New University	Research Reader, faculty of design, media & management
Richie Harrington	Digital Health Oxford	Founder and organiser
Sarah White	Cranfield University	Business development executive, research and innovation
Sian Rees	Health Experiences Institute	Director
Simon Lovestone	Department of Psychiatry	Professor of translational neuroscience
Tony Hart	Oxfordshire Local Enterprise Partnership	Network navigator
Zamin Iqbal	Mykrobe	Founder

Appendix 2 Tables of digital health stakeholders

- Established companies
- Start up and emerging companies
- Networking organisations and consortia
- Projects, proposals and apps
- Academic institutions
- Investment organisations

Established companies

Name	Location	Descriptors	Summary	Website
Alcatel-Lucent	Newbury	Big data Connectivity	Provide cloud-based IT solutions for organisations to control costs, increase access to services, and improve quality of care	https://www.alcatel-lucent.com/healthcare
Alfresco		EHR Interactive healthcare	Brings order to the vast amounts of structured and unstructured data stored in multiple locations throughout every NHS trust	https://www.alfresco.com
AliveCor	Slough	Mobile technology Interactive healthcare Vital signs monitoring	Provides mobile ECG devices and apps that tracks symptoms and gives early warning of exacerbations and serious events	http://www.alivecor.com/home
AppSense	Reading	Devices Connectivity Mobile technology Process improvement	User Environment Management platform that helps deliver a personalised, secure and highly responsive clinical desktop experience	http://www.appsense.com/solutions/healthcare-pc-productivity-software/
AsterLiving	Newbury	Telecare	Provide sheltered housing and Telecare solutions for vulnerable people across the southern counties	http://www.asterliving.co.uk/
Atos	Reading	Logistics Connectivity Process improvement	Extensive experience in the implementation of IT systems for the NHS including the Choose and Book system for GP\'s and the ePharmacy tool	http://uk.atos.net/en-uk/home/your-business/healthcare.html
Axicon		Logistics Devices	Provider of high-quality barcode images, labels, and barcode verification equipment for the printing industry	http://www.axicon.com
Barco Healthcare	Bracknell	Devices Logistics Visualisation	Enterprise visualisation specialist that boosts clinical performance in every department via a connected network of display systems	http://www.barco.com/en/markets/Healthcare
Biff Bang Pow	Abingdon	App development	Design and develop bespoke, responsive, user-friendly websites that provide our clients with full content management	http://www.biffbangpow.com/
Blackberry Europe	Slough	Mobile technology Devices Connectivity	A strong focus on the Internet of Things market space and specialized industries that rely on embedded systems such as medical devices	http://uk.blackberry.com/enterprise/industries/healthcare.html

Name	Location	Descriptors	Summary	Website
Bridge-it Options	Newbury	Vital signs monitoring Telecare	Supply, fit, maintain and manage a range of none intrusive Telecare technology that is then linked to a monitoring centre	http://www.bridge-it-options.org/portfolio/tele-care/
Cambio Healthcare Systems	Reading	Interactive healthcare EHR Care pathways	A comprehensive and fully integrated e-Health system for clinical care support and patient administration with over 100,000 users	http://www.cambiohealthcare.co.uk
Canary Care	Abingdon	Telecare Social context Vital signs monitoring	Canary provides non-intrusive monitoring of people in their own homes via movement and temperature levels for telecare applications	https://www.canarycare.co.uk/
Caradigm	London	Big data EHR Care pathways Social context	A population health company dedicated to improving patient care, advancing the health of populations and reducing healthcare costs	https://www.caradigm.co.uk/en-gb/#
Care Harmony Solutions	Aylesbury	Telecare Mobile technology Social context	Provide telecare devices and services triggered in response to an alert activated by a vulnerable user after a fall or medical episode	https://www.careharmony.co.uk/
Carers Little Helper	High Wycombe	Telecare Social context	Provide a telecare service to schedule a message or reminder to be sent to those who need it when the carer is unavailable	http://www.carerslittlehelper.co.uk/
Ccube solutions	Milton Keynes	EHR Connectivity	Enterprise CMS, comprising electronic document and records management, workflow, electronic forms, portal software, and systems integration	http://www.ccubesolutions.com
CenturyLink	Reading	Mobile technology Connectivity Devices	Secure networking and communication specialist providing IT solutions tailored to the healthcare sector	http://www.centurylink.com/business/solutions-healthcare.html
Cerner UK	London	EHR Care pathways Logistics	A global provider of health and care solutions that has supplied to the NHS since 2001	https://www.cerner.com
CGI	Reading	EHR Process improvement Logistics	Supports digital healthcare with electronic medical records, health information exchange, portals and administrative systems	http://www.cgi-group.co.uk/health

Name	Location	Descriptors	Summary	Website
Cisco Systems	Reading	Connectivity Devices Mobile technology Big data	Provide services and products for secure and accurate handling of the vast amounts of data that is generated in the digital health sector	http://www.cisco.com/web/strategy/healthcare/index.html
Citrix	Gerrards Cross	Big data Process improvement Logistics	Reinventing how people connect with ideas and how processes and facilities are designed to enable new ways for businesses and people to work	https://www.citrix.com
Cmed	Horsham	Therapeutics Clinical trials	A full service CRO and developer of advanced eClinical & smart data capture technologies	http://www.cmedresearch.com
CSC	Banbury	Logistics Connectivity EHR	CSC is one of the world's largest providers of healthcare IT solutions. It has several UK locations, including one in Banbury	http://www.isofthealth.com
Dan Medical Ltd	Kingham	Vital signs monitoring Mobile technology	Realtime patient monitoring based on D-MAS, clinical diagnostic and monitoring devices integrated into medical grade laptop computers	http://www.danmedical.com
Dell	Bracknell	Big data Connectivity Devices Mobile technology	Provide IT solutions and strategies to speed up healthcare delivery, improve patient satisfaction and outcomes and meet compliance standards	http://www.dell.com/learn/uk/en/ukbsdt1/healthcare
Digital Health Intelligence	London	Education	The company behind digitalhealth.net and the publisher of Digital Health News, Digital Health Intelligence, and Digital Health Networks	http://www.digitalhealth.net/
Draeger Medical UK	Hemel Hempstead	Vital signs monitoring Devices	Provides a wide range of equipment for the intensive care, neonatal and operating theatre arenas - UK arm based in Hemel Hempstead	http://www.draeger.com
Drayson Technologies	London	Sensors Devices	A development stage electronic hardware & software company with an interest in crowd-sourced environmental monitoring	http://www.draysontechnologies.com/home.html
ECA Services	Reading	Visualisation Devices Connectivity	Supply computing technology to NHS Trusts and Healthcare operations from Point-of-Care terminals to information and surgical displays	http://ecahealth.com

Name	Location	Descriptors	Summary	Website
EIZO	Bracknell	Visualisation Image analysis	Supplier of advanced medical monitors for reviewing clinical images	http://www.eizo.co.uk
Elsevier Clinical Solutions	Oxford	EHR Education	Products and services to increase the efficiency of healthcare, including electronic health records and evidence-based patient education	https://www.elsevier.com/clinical-solutions
Equinix	Slough	Big data Connectivity	Provide secure and reliable interconnected data centres for healthcare information storage and exchange	http://www.equinix.co.uk/
ESRI UK	Newbury	Big data	Provides a suite of geographic information system applications in the healthcare analytics space to address health inequalities	http://www.esriuk.com/industries/health/health-analytics
Extreme Networks	Reading	Connectivity Devices	High-performance switching and routing products for data networks, wired/wireless LAN access, and unified network management	http://www.extremenetworks.com
Fujifilm UK	Bedford	Image analysis Visualisation Mobile technology	Provides complete medical imaging systems ranging from system administration, clinical diagnosis support to mobile access	http://www.fujifilm.eu/uk/
Fujitsu	Reading	Big data Connectivity Devices Mobile technology	Improve health care delivery with solutions for mHealth, infrastructure storage and archiving, data security and operational support	http://www.fujitsu.com/uk/solutions/industry/healthcare/
GE Healthcare	Chalfont St Giles	Image analysis EHR Connectivity	GE Healthcare provides transformational medical technologies and services that are shaping a new age of patient care	http://www3.gehealthcare.co.uk
Glide Technologies	Milton Park	Devices Diagnostics	Patient-friendly, non-invasive diagnostics - such as PROSPECT - a spectroscopic measure of citrate in the diagnosis of prostate cancer	http://glide-technologies.com

Name	Location	Descriptors	Summary	Website
GMV	Harwell	Interactive healthcare Telecare Connectivity Visualisation Diagnostics Vital signs monitoring	A global ICT Company that has developed a complete portfolio of healthcare products including Antari, a suite of eHealth products	http://www.gmv.com/en/
Graphnet	Newport Pagnell	EHR Logistics	The UK's leading supplier of shared care record software to the NHS and care services	http://www.graphnethealth.com
Harris Corporation	Reading	Clinical trials EHR Care pathways	Provide enterprise intelligence solutions and services for commercial and government healthcare customers	http://itservices.harris.com/
Healthlogistics	Tring	Logistics Process improvement	Specialises in the design and provision of integrated, standards-based eProcurement services to the UK healthcare community	http:// www.healthlogistics.co.uk
Hewlett Packard Enterprise	Bracknell	EHR Interactive healthcare Connectivity	Offers a portfolio of customized solutions to help health and life science businesses transform their IT	https://www.hpe.com/us/en/home.html
Hitachi	Maidenhead	Big data	The European Big Data Laboratory is collaborating with the NHS in Manchester to study applications of big data analytics	http://www.hitachi.eu/erd/research/bigdata/
Hospedia	Slough	Interactive healthcare Logistics Care pathways Education	Provide point of care systems driving clinical and management efficiency through a range of value added services for healthcare providers	http://www.hospedia.co.uk
HP	Bracknell	Devices Visualisation	Provide tablets and workstations for access to electronic medical records and thin client and print solutions to improve workflow	http://www8.hp.com/uk/en/home.html
HTC	Slough	Big data Connectivity Devices Mobile technology	Provide telecommunication and data network solutions to provide secure handling of healthcare related data	http://www.htcinc.net/business-solutions/healthcare-solutions/

Name	Location	Descriptors	Summary	Website
IGEL Technology		Visualisation Devices	IGEL is one of the world's leading thin client vendors, Europe's No. 1 in linux based thin clients and UKs fastest growing thin client brand	https://www.igel.com/uk/
IMI mHealth Solutions	Reading	Mobile technology Connectivity	Aims to bring technical innovation and medical know-how together and to promote and develop solutions for Mobile Health using open systems	www.imi-health-technology.com
IMS Maxims	Milton Keynes	EHR Connectivity	A leading provider of high-quality patient administration systems and electronic patient record systems	http://www.imsmaxims.com
Incuna	Oxford	Mobile technology Interactive healthcare	Incuna is an international digital healthcare agency that has developed Incuna ePatient, a unique patient adherence platform,	http://www.incuna.com
InHealth	High Wycombe	Telecare Mobile technology Interactive healthcare	Provide a teledermatology service that helps GPs manage the high number of patients that present with concerns over changes in their skin	https://www.inhealthgroup.com/services/teledermatology
Intel	Reading	Big data Connectivity Genomic medicine	Intel has developing interests in the fields of personalised medicine and in technology for home-based healthcare	http://www.intel.co.uk/content/www/uk/en/healthcare-it/healthcare-overview.html
Intersystems	Windsor	EHR Connectivity	Provide products for data management, interoperability, analytics, and health information systems to gain the benefits of connected health	http://www.intersystems.com/uk
Intouch with Health	Cirencester	Logistics EHR Process improvement	Provides electronic systems for steamlining patient flow and clinic management including eOutcomes and Mobile Check-in	http://www.intouchwithhealth.co.uk/
IO	Slough	Big data Connectivity	Provide secure data centre facilities for a variety of clients including some in the health sector	https://www.io.com/
Isansys Lifecare	Milton Park	Connectivity Sensors Vital signs monitoring	Developing wireless body-worn monitoring for continuous, remote and unobtrusive capture and analysis of patient vital sign data	http://www.isansys.com/

Name	Location	Descriptors	Summary	Website
Janssen	High Wycombe	App development Interactive healthcare Mobile technology Care pathways Vital signs monitoring	Outcomes-focused solutions designed to deliver quality and customized healthcare when and where our patients need it	http://www.janssen.co.uk/home
KLOC Digital Solutions	Hungerford	App development	Web and software development business providing websites, mobile apps, web integration, CRM customisation, SEO and hosting	http://kloc.co.uk/
Lexmark Enterprise Software	Maidenhead	EHR Connectivity	Healthcare solutions offering a modular approach to archive, document management, enterprise viewing, image connectivity and print services	http://www.lexmark.com/en_gb.html
Logi Analytics	Reading	EHR Devices	Provide healthcare analytic solutions to address the challenge of maintaining long-term performance and patient care while cutting costs	http://www.logianalytics.com/solutions/healthcare/
Logicalis	Slough	Big data Connectivity Devices	ICT solutions with full lifecycle management - from planning, design, implementation and integration to support, management and optimisation	http://www.uk.logicalis.com
McAfee	Slough	Big data	Now part of Intel Security, McAfee helps with implementation and cost of healthcare security and risk management	http://www.mcafee.com/uk/business-home.aspx
McKesson	Warwick	EHR Connectivity	Integrated IT solutions for healthcare improving patient outcomes through better care coordination, collaboration and management	http://www.mckesson.com/
McLaren Applied Technology	Woking	Interactive healthcare Mobile technology Sensors	Developing wearable technology that collects real-time data and uses analytics to predict outcomes and suggest lifestyle improvements	http://www.mclaren.com/technologygroup/
Medelinked	Henley-on-Thames	EHR Interactive healthcare Mobile technology	Online platform that empowers users to take control of their health via a secure personal database and connections with providers	http://www.medelinked.com/

Name	Location	Descriptors	Summary	Website
MedVivo Careline	Bracknell	Telecare Social context	Operate 24/7 to help people live independently in their homes and businesses to be reassured their staff and customers are taken care of	http:// www.magnacareline.org.uk
Meru	Bracknell	Connectivity Devices	Provide in hospital WiFi systems to optimise patient care and clinical efficiency using a dedicated core system (Uninterrupted Care Network)	http://www.merunetworks.com/Industries/Healthcare.html
Microsoft	Reading	Connectivity Mobile technology Devices	Helping health organisations worldwide to deliver proactive, personalised care	https://www.microsoft.com/en-gb/about/
Mindme	Ampthill	Telecare Social context	Telecare provider with a 24/7 minding service via a fob with built in receiver and microphone, GPS location and a multi-network SIM	http://www.mindme.care/
Minervation	Oxford Centre	Social context App development Interactive healthcare	Consultancy providing evidence-based healthcare advice and presenting it on usable and reliable web-sites	http://www.minervation.com
Mirada medical	Oxford	Image analysis Visualisation	Software solutions for radiology, molecular imaging, radiation oncology used in multidisciplinary meetings in hospitals and cancer centres	http://www.mirada-medical.com/about-mirada-medical/
Nervecentre Software	Wokingham	Mobile technology EHR Connectivity	Provides a whole hospital mobile platform that delivers electronic observations, handover, task management and clinical assessments	http://nervecentresoftware.com
Network-I	Slough	Big data Connectivity	Provides secure data centre services to the NHS, the MOD and the Ministry of Justice and also to the private healthcare sector	http://www.network-i.net/markets/government-health-and-education
Nuance	Marlow	Interactive healthcare Devices Connectivity	Through its voice and language technology, Nuance offers a more natural, clinically focused approach to capturing the complete patient story	http://www.nuance.com/index.htm
O2	Slough	Mobile technology Devices	Provides a number of services to the healthcare sector through a dedicated Healthcare Practice unit within its Public Services Team	http://www.o2.co.uk/enterprise/sectors/public-sector/health

Name	Location	Descriptors	Summary	Website
OBS Medical	Milton Park	Vital signs monitoring Sensors Devices	A medical device company which supplies patient monitoring software solutions, formed by merger of t+ Medical and Oxford Biosignals	http://www.obsmedical.com/
Omron Healthcare UK Ltd	Milton Keynes	Devices Vital signs monitoring	A global company focusing with particular expertise in blood pressure monitors, respiratory devices, and fever and activity monitors	http://www.omron-healthcare.co.uk/
Open Text	Reading	EHR Connectivity	Enterprise systems for a one patient, one record environment to encourage better patient care and more informed medical treatment	http://www.ot.co.uk
Optum Health Solutions	Maidenhead	Big data	Combine data and analytics with technology and expertise to power modern health care	http://www.optum.co.uk
Oracle	Reading	Big data EHR Connectivity	Provides a broad range of healthcare systems and applications designed to increase efficiency of healthcare delivery and management	http://www.oracle.com/uk/industries/healthcare/overview/index.html
Orange Healthcare		Mobile technology Interactive healthcare	Capitalising on its expertise in the healthcare sector, its capacity for innovation and its brand to respond to public health issues	http://healthcare.orange.com/eng/discover-e-health/all-folders/mHealth
Orion Health	London	Care pathways EHR	ECR solution for all of N Ireland's 1.8 m population, enabling the sharing of data across acute, community, primary health and social care	https://orionhealth.com
Overpass Apps	Grove Technology Park	App development	Oxford-based app and mobile content developer that uses out-sourced programming resources	http://www.overpass.co.uk
Oxford App Studios	Oxford	App development Interactive healthcare Mobile technology	Create engaging and compelling native mobile apps for iOS, Android and Windows devices, including the digital health space	http://www.oxfordappstudios.com/
Oxford Computer Consultants	Oxford	App development Interactive healthcare Logistics Process improvement	A software development company and IT consultancy with experience of developing applications for healthcare integration	http://www.oxfordcc.co.uk

Name	Location	Descriptors	Summary	Website
Oxford Nanopore Technologies	Oxford Science Park	Diagnostics Genomic medicine Big data	Developing a new generation of electronic molecular analysis systems for use in scientific research, personalised medicine and more	https://www.nanoporetech.com
Oxford Outcomes	Oxford City	Patient experience Outcome measures	Oxford start-up focused on developing and deploying patient reported outcome measures; now merged with ICON	http://isis-innovation.com/about-isis/people/oxford-outcomes/
Oxford Web Applications	Oxford centre	Interactive healthcare App development	A team of designers, developers and systems professionals who develop and host interactive web applications and mobile apps	https://www.oxfordwebapps.co.uk
P1vital	Wallingford	Care pathways Mobile technology Diagnostics	Consultancy with a range of services in CNS experimental medicine, including the Oxford Emotional Test Battery - a biomarker for depression	http://www.p1vital.co.uk
Physiomics plc	Magdalen Centre	Therapeutics Big data	Using bioinformatics to inform novel dosing schedules and drug combinations for their pre-clinical oncology candidates	http://www.physiomics-plc.com
Qmatic UK	Cranfield	Logistics Care pathways	Proprietary patient flow methodologies to improve check in, appointment management and resource optimization	http://www.qmatic.com/uk/
Rackspace	Hayes	Big data Connectivity	Provide cloud-based solutions for data storage and usage requirements of the Health Insurance Portability and Accountability Act	http://www.rackspace.com/
Rareform New Media	Oxford centre	Interactive healthcare Mobile technology App development	Contract development of new media applications	http://rareformnewmedia.com
Raytheon/ Websense	Reading	EHR Big data	Provide the TRITON APX solution which provides secure access to patient data held locally or in the cloud	https://www.websense.com/content/healthcare.aspx?intcmp=nav-mm-solutions-industry-healthcare
Redcentric	Reading	EHR Connectivity Big data	A leading UK IT managed services provider that offers a range of IT and Cloud services	http://www.redcentricplc.com

Name	Location	Descriptors	Summary	Website
Redhat	Aldershot	Big data Connectivity	Provides secure, open source, IT infrastructures that by-pass the limitations on healthcare imposed by proprietary software-based systems	https://www.redhat.com/en/technologies/industries/health-life-sciences
Rivendale		Interactive healthcare EHR Connectivity	Rivendale is an independent software vendor promoting patient safety, efficiency and the Digital NHS	http://rivendalesoftware.com
SAS Software	Marlow	Big data Clinical trials	A global company focused on statistical tools now finding application in the analysis of big data for improving the standard of healthcare	http://www.sas.com/en_gb/industry/health-care-providers.html
Sectra	Stansted	Image analysis Devices Connectivity	More than 20 years experience in delivering and servicing complete radiology and medical imaging solutions	http://www.sectra.com/medical/
Sensium Healthcare	Milton Park	Devices Sensors Vital signs monitoring	Developed SensiumVitals, awireless system designed to monitor the vital signs of patients on general wards.	http://www.sensium-healthcare.com
Sharp Laboratories of Europe Ltd	Oxford Science Park	Devices Sensors Image analysis Visualisation Diagnostics	Repurposing Sharp's core technologies to deliver new tools for diagnostics, medical imaging and life science research	http://www.sle.sharp.co.uk
SiteKit	Banbury	EHR Telecare Social context	A healthcare technology company committed to developing software solutions that improve health and care delivery	http://www.sitekit.net/
Solutions 4 Health	Reading	Social context Big data	Provide a wide range of telehealth services, targeted at the hard to reach members of society across the UK through courses and on-line	www.solutions4health.co.uk
Symantec	Reading	Big data Connectivity	Provides solutions for efficient patient care by maximizing the accessibility of IT infrastructures while protecting sensitive data	http://www.symantec.com/en/uk/products-solutions/industries/?ind=healthcare

Name	Location	Descriptors	Summary	Website
The Guiness Partnership	High Wycombe	Social context Telecare	Telecare service provider with a range of detectors, including fall detectors, door exit sensors, smoke alarms and medication reminders	http://www.guinnesspartnership.com/care-and-support/telecare-services
Toumaz Technology	London	Connectivity Devices	Develops low cost, ultra-low power wireless technologies for connected healthcare devices - has UK offices in Oxford and Cambridge	http://www.toumaz.com/
Verizon	Reading	Big data Connectivity	Provide solutions for secure data handling and management which enhances patient physician communication and the standard of patient care	http://www.verizonenterprise.com/industry/healthcare/
Vodafone M2M	Newbury	Mobile technology Interactive healthcare Telecare Social context	Improving patient care and quality of life through a focus on condition management, hospital to home, and assisted living	http://www.vodafone.com/business/m2m/health
Welch Allyn	Aston Abotts	Devices Interactive healthcare Connectivity	Medical devices coupled with digital and connectivity solutions to make accessing patient information faster, more accurate and efficient	http://intl.welchallyn.com/default.htm
White October	Oxford Centre	App development Interactive healthcare Mobile technology	Web-app and mobile-app developer with an interest in digital health	http://www.whiteoctober.co.uk
Wolfram	Long Hanborough	Big data	Respected computer, web, and cloud software company with powerful analytic tools for unstructured data	http://www.wolfram.com/

Startup and emerging companies

Name	Location	Descriptors	Summary	Website
Accentus Medical Ltd	Harwell	Devices	Developing advanced surface coatings for implantable medical devices to improve durability, biocompatibility and reduce infection	http://www.accentus-medical.com
Babylon	London	Telecare Interactive healthcare	Developing a platform offering immediate healthcare advice via a smart phone	http://www.babylonhealth.com
Big Health	London	Mobile technology Interactive healthcare	Use tracked data to create highly personalized behavioral medicine programs, all delivered via web and mobile and clinically validated	https://www.bighealth.com
Bounts	Wallingford	Interactive healthcare	A digital health app that provides incentives to individuals for adhering to programmes via prizes, rewards and targeted discounts	https://www.bounts.it
Brainomix	Oxford	Image analysis Vital signs monitoring	Developing a software platform that automatically implements the ASPECTS clinical scoring methodology for stroke	https://www.brainomix.com
cnBio innovations	Welwyn	Tissue engineering	Using human organ-on-a-chip models to test and develop therapeutics for liver diseases and infections	http://www.cn-bio.com
Cybersensors	Windsor	Sensors Diagnostics	Developed a range of wireless sensors called Cybersensors, which include a patented implantable glucose sensor for diabetics	http://www.cybersensors.com
Cytox	Oxford Science Park	Genomic medicine Diagnostics	Developing tests to identify individuals at risk of cognitive decline, Alzheimer's disease and other dementias	http://www.cytoxgroup.com
DarkBlueLabs		Artificial intelligence	AI company involved in deep structured and unstructured representations of data to make natural language understanding a reality	http://darkbluelabs.com
Databiology	London	Big data Genomic medicine	Providing technology to manage the increasingly large and complex R&D data assets assoicated with genomics	http://www.databiology.com

Name	Location	Descriptors	Summary	Website
DeepMind		Artificial intelligence	British AI company acquired by Google in 2014 and collaborating with the department of Computer Sciences at Oxford	http://deepmind.com/index.html
Digital Life Sciences	London	Interactive healthcare Care pathways Social context	Designs tools to enable heath and social care integration, support self-management of long-term conditions and expand access to services	http://www.digitallifesciences.co.uk
Fluid motion	Oxford	Biomechanics Interactive healthcare	Runs a water-based rehabilitation programme designed to be fun and beneficial for people with a range of health issues	http://www.fluid-motion.org.uk/home.html
Fuel3D	Chinnor	Visualisation Image analysis	A developer of advanced 3D scanning systems and solutions for the medical imaging sector and the broader 3D market including consumers	http://www.fuel3dtech.com
GeneFirst Ltd	Culham	Diagnostics Genomic medicine	A molecular diagnostics company working predominantly in the fields of infectious disease, cancer diagnostics and personalised medicine	http://www.genefirst.com
Genomics	Oxford Centre	Genomic medicine Big data	Developing cutting edge software applications that uncover the relationships between genetic variation and human disease	http://www.genomicsplc.com
GFC Diagnostics	Chipping Warden	Interactive healthcare Diagnostics	Specialists in point of care detection of smoking and cotinine measurements, and treatment adherence in TB	http://www.gfcdiagnostics.com/index.html
Global Initiative		Media development Mobile technology	Web, UX and software development company with experience of developing health-related apps	http://www.global-initiative.com
GP-Update	Reading science centre	Education	Provide on-line CPD courses for health-care professionals	http://www.gp-update.co.uk
Hospital in Hand	Oxford	Logistics Education	An easily accessible and user-friendly smartphone app that helps (junior) doctors to efficiently start work at new hospital trusts	http://www.hospitalinhand.com/

Name	Location	Descriptors	Summary	Website
Intelligent Ultrasound Limited	Innovation Centre	Image analysis Visualisation	Develops software that significantly improves the quality, reliability and diagnostic power of medical ultrasound scans	http://www.intelligentultrasound.com
iWantGreatCare	Witney	Patient experience	Collects and distributes patient feedback on healthcare practitioners, institutions and drugs	https://www.iwantgreatcare.org
Message Dynamics	Chertsey	Telecare Interactive healthcare	Provider of telehealth services using a range of communications media including automated voice, SMS, email and a smartphone app	http://www.messagedynamics.co.uk
Mykrobe	Old Road Campus	Genomic medicine Big data	Mykrobe Predictor analyses the whole genome of a bacterial sample and predicts which drugs the infection is resistant to	http://www.mykrobe.com
Natural Motion	Oxford		Leading games and technology company based on tools that create the most hyper-realistic, intelligent animation in the industry	http://www.naturalmotion.com
Oncascan	Innovation centre	Genomic medicine Diagnostics	Developing a unique type of blood test for cancer based on analysing lymphocyte population genomics	http://www.oncascan.com
OxCEPT	London	Logistics Connectivity	A team of security and communication experts creating military-grade authentication security products for business teams	http://oxcept.com
Oxehealth	Oxford City	Image analysis Vital signs monitoring	Developing a new technology for measurement of vital signs such as pulse and respiratory rates using video cameras and ambient light	http://www.oxehealth.com/
Oxford Biodynamics	Oxford Centre	Diagnostics Genomic medicine	The epigenetic biomarker platform offers an affordable means of non-invasive screening, early detection, monitoring and prognosis of disease	oxford biodynamics
Oxford Consultants for Social Inclusion	Brighton	Care pathways Social context	Committed to improving social and economic outcomes by providing high quality research, analysis and software.	http://ocsi.uk

Name	Location	Descriptors	Summary	Website
Oxford Medical Diagnostics Ltd	Begbroke Science Park	Diagnostics Sensors	Developing breath tests as a rapid, accurate and low-cost approach to diagnostics - initially focused on diabetic ketoacidosis	http://www.omdiagnostics.com
Oxford MediStress	Birmingham	Interactive healthcare Diagnostics	Commercialised a novel in vitro blood test device which provides the first objective, rapid, quantitative measurement of stress	http://www.oxford-medistress.com
OxSyBio	London	Tissue engineering	Developing 3D printing techniques to produce a range of tissue-like and functional tissues for medical research and clinical applications	http://www.oxsybio.com
Oxtox	Stockport	Diagnostics Sensors	Developing a device that uses novel and cost-effective technology based on electroschemistry to rapidly detect specific drugs	http://www.oxtox.com
Patients Know Best	Cambridge	EHR Interactive healthcare	Developing a secure EHR which is owned by the patient and allows them to manage their condition more effectively and conveniently	https://www.patientsknowbest.com
Perspectum diagnostics	Oxford Centre	Diagnostics	Focus on the non-invasive detection and quantitative measurement of liver, gallbladder and pancreatic disease, including precancerous states	http://perspectum-diagnostics.com
Rowan analytics	Oxford	Big data	Putting complex analytics in the hands of those that need them through mobile applications	http://rowanalytics.com
Run3D	Cassington	Biomechanics Visualisation Image analysis	Use a state-of-the art 3D motion capture system and biomechanical database to offer rigorous assessment of running or walking injury	http://www.run3d.co.uk
Sentimoto	Thame	Social context Care pathways Interactive healthcare Telecare	Wearable devices and applications that connect and monitor the elderly to protect against social isolation	http://sentimoto.com
Smartcare Sleep	Oxford	Interactive healthcare Mobile technology Sensors	Takes obstructive sleep apnoea screening out of the clinic and into the home using a mobile pulse oximeter	http://www.smartcaresleep.com

Name	Location	Descriptors	Summary	Website
SmartSensor telemed	Harwell	Sensors Diagnostics Interactive healthcare	Developing a diagnostic platform based on wireless biosensor test devices; initially targeting diabetes control	http://www.smartsensortelemed.com/
Spacelabs Healthcare Ltd	Hertford	Vital signs monitoring Connectivity	US-based medtech company working in a wide variety of medical technologies including patient monitoring and connectivity	http://www.spacelabshealthcare.com
VA-ST	John Radcliffe Hospital	Visualisation	Developing 3D visualisation and analysis tools to provide computer vision applications (Smart Specs) for personal real-world applications	http://www.va-st.com
Vision Factory		Artificial intelligence Image analysis Visualisation	World-class, scientifically-proven object recognition and text recognition systems based on deep learning; acquired by DeepMind in 2014	https://www.linkedin.com/company/vision-factory-ai
Wild Knowledge	Oxford Centre	Education Interactive healthcare	Developed an educational app targeted at logging field data that is increasingly being for rapid assessment, patient feedback and monitoring	http://www.wildknowledge.co.uk

Networking organisations and consortia

Name	Location	Summary	Website
Berkshire Healthcare Research and Development Department	Bracknell	Support and manage all aspects of research within Berkshire Healthcare, including mental health and community health	http://www.berkshirehealthcare.nhs.uk/ServiceCatInfo.asp?id=23
Buckinhamshire Healthcare NHS Trust Research and Development Department	Aylesbury	Offers advice and support to health professionals wishing to carry out research on Trust property, or using staff, patients or their data	http://www.buckshealthcare.nhs.uk/For%20health%20professionals/research-and-innovation.htm
Centre for RRIO	Windmill Road	Collaborative research into the rehabilitation of acute musculoskeletal injuries or chronic conditions such as RA or persistent back pain	http://rehabresearch.ndorms.ox.ac.uk
ChemBio Hub	Old Road Campus	Makes life easier for chemical biology researchers in Oxford by providing better tools and more opportunities for collaboration	https://chembiohub.ox.ac.uk
Collaboration for Leadership in Applied Health Research and Care (NIHR CLAHRC) Oxford	Radcliffe site	Thames Valley partnership that carries out novel applied health research that will have a direct impact on patient health and well-being	http://www.clahrc-oxford.nihr.ac.uk
Connect Thames Valley Tech	Reading	Social networking site for technologists and entrepreneurs working in the Thames Valley area	http://www.connecttvt.co.uk/ecosystem
Continua Alliance		Setting global technology industry standards to develop plug-and-play connectivity for personal connected health	http://www.continuaalliance.org/about-continua
COSSAC	Oxford	IRC focused on advanced computing and artificial intelligence techniques and technologies to help in solving biomedical problems	http://www.cossac.org
Digital Health Oxford	Oxford centre	A cross-disciplinary, cross-sector group that promotes and supports digital health in Oxford and beyond	http://www.dhox.org
Digital Oxford	Web presence	Promoting Oxford as a world leading centre for the development of new digital technologies	http://digitaloxford.com

Name	Location	Summary	Website
Doctors.net.uk	Milton Park	A trusted channel for information, communication and education used by more than 40,000 doctors every day	http://www.doctors.net.uk
Earthwatch Institute	Summertown	An international charity that brings individuals from all walks of life together with scientists to work for the good of the planet	http://eu.earthwatch.org
Equator Network	Windmill Road	Improves the reliability and value of medical research by promoting transparent and accurate reporting of research studies	http://www.equator-network.org
Handi	Droitwich	Not-for-profit venture to promote the transformational power of digital technology to improve people's health and well-being	http://handihealth.org/
Health Education England		Supports the delivery of excellent healthcare and health improvement to the patients and public of the Thames Valley	http://www.hee.nhs.uk/hee-your-area/thames-valley
HELIX	London	A multi-disciplinary design team embedded in a hospital developing new approaches to complex healthcare issues	http://www.helixcentre.com
InstructHub	Old Road Campus	A pan-European Research Infrastructure providing expertise and access to high quality instruments for structural cell biology researchers	http://www.structuralbiology.eu
NIHR Diagnostic Evidence Co-operative Oxford	Radcliffe site	Horizon scans and produces rapid reviews to identify new and emerging in vitro diagnostics	http://www.clahrc-oxford.nihr.ac.uk
Oxbridge Biotech Roundtable	Oxford	A global organization of innovators founded in 2011 to connect industry and academia in order to move ideas forward	http://oxbridgebiotech.com
Oxford Academic Health Science Network	Oxford Science Park	Brings together universities, industry and the NHS to improve the health and prosperity in our region through rapid clinical innovation	http://www.oxfordahsn.org
Oxford Biomedical Research Centre	Old Road Campus	Based at the University NHS Trust, the BRC was awarded another 5 years funding in 2012 in recognition of its excellent healthcare research	http://oxfordbrc.nihr.ac.uk
Oxford Innovation	Oxford	Helps businesses reach their full potential by providing mentoring and access to investment networks	http://oxfordinnovationservices.co.uk
Oxford Strategic Partnership	Oxford Centre	Partnership promoting shared resources, access to funds and other joined-up approaches for improving quality of life in the city	http://www.oxfordpartnership.org.uk

Name	Location	Summary	Website
Oxford Trust	Oxford centre	an independent charity that initiates and encourages the pursuit of science and enterprise across Oxfordshire and the surrounding region	http://www.theoxfordtrust.co.uk
Oxford University Hospitals Research and Development Department	Churchill Hospital	Supports research by acting as sponsor for certain studies, providing NHS Permission and provision of GCP compliant training	http://www.ouh.nhs.uk/researchers/
Oxfordshire Local Enterprise Partnership	Oxford Centre	Works with businesses, academia and the public sector to drive economic development across the county	http://www.oxfordshirelep.org.uk
Oxfordshire Social Entrepreneurship Partnership	Oxford	Set up as a one stop shop to support social enterprises and help social entrepreneurs plan, develop and grow their businesses in the county	https://www.osep.org.uk/about
OXION	Science area	Wellcome Trust funded initiative to promote integrative physiology centred on ion channel research	http://www.dpag.ox.ac.uk/research/oxion/
Research in Adult Dyslexia	Buckingham	A forum for researchers and practitioners to submit their research on experiences of adults with dyslexia	http://www.buckingham.ac.uk/research/read
Royal Berkshire NHS Research and Development Department	Reading	Promotes, co-ordinates and supports R&D within the Royal Berkshire NHS Foundation Trust	http://www.royalberkshire.nhs.uk/research_and_development
Science Oxford	Oxford Centre	Aims to bring you the very best in live science events and deliver inspiring science and careers activities for schools	http://www.scienceoxford.com
Smart Oxford	Oxford Centre	An initiative by Oxfordshire Partners to develop efficient and effective use of data and technology for the benefit of its citizens	http://oxfordsmartcity.uk/cgi-bin/index.pl
Structural Genomics Consortium (SGC)	Old Road Campus	Catalyses research in new areas of human biology and drug discovery by focusing explicitly on less well-studied areas of the human genome	http://www.thesgc.org/scientists/groups/oxford/
The Global Health Network	Old Road Campus	Streamlines global health research through an innovative digital platform for facilitating collaboration and resource sharing	https://tghn.org
The Hill	Headington	A healthcare ideas lab, situated at the heart of Oxford's medical, academic, digital and entrepreneurial communities	http://thehill.co/#

Name	Location	Summary	Website
The Oxford Rare Disease Initiative (OUDI)	Old Road Campus	Facilitates relationships between Oxford's researchers, clinicians, and the wider rare disease community	http://www.rarediseases.ox.ac.uk/home
UK Cochrane Tobacco Addiction Group	Radcliffe site	Produce and help others to produce systematic reviews and meta-analyses of interventions to prevent and treat tobacco addiction	http://www.phc.ox.ac.uk/research/cochrane
Vitalsix	Reading science centre	Group of consultants providing practical advice to small businesses wishing to grow	http://vitalsix.co.uk
VPH-Share	Milton Keynes	The Knowledge Media Institute provides the IT infrastructure to support an international programme to develop a model of human physiology	http://projects.kmi.open.ac.uk/vph-share/
Worldwide Antimalarial Resistance Network (WWARN)	John Radcliffe Hospital	A collaborative platform generating innovative resources and reliable evidence to inform the malaria community on antimalarial medicines	http://www.wwarn.org

Projects, proposals and apps

Name	Location	Summary	Website
Care4today Heart Health	High Wycombe	Programme of remote and continued support for patients with heart failure based on the Janssen platform	https://www.care4today.com/real-world/heart-health
CARRE	Milton Keynes	The KMI provides the semantic "glue" for an EU project developing better technologies to support patients with multiple co-morbidities	http://kmi.open.ac.uk/projects/name/carre
diabetesprofile	Oxford	Widely used and standardised tool for profiling diabetes patients, their management and outcomes	http://www.diabetesprofile.com
Dynamic Consent Open Framework	Web presence	Project to develop open interoperability standards for the management of Dynamic Consent and the exchange of data under that consent	http://dynamic-consent.info
GD-m Health	Oxford	Mobile blood glucose monitoring system to improve detection and control of gestational diabetes via telecare	http://www.oxfordahsn.org/our-work/wealth-creation/partnerships-with-industry/digital-healthcare/digital-health-case-study-gestational-diabetes/
Inquire	Oxford	NIHR funded project to find out how the NHS should best interpret and act on patient experiences as extracted from online patient feedback	http://www.phc.ox.ac.uk/research/health-experiences/research-projects/improving-nhs-quality-using-internet-ratings-and-experiences-inquire
Internet Patient Experiences	ND Primary Health Care Services	An NIHR funded programme to investigate the impact of disseminating patient experiences	http://ipexonline.org
Lighthouse diagnostics	Oxford	Early stage cancer diagnosis by sequencing of tumour DNA from blood	https://www.youtube.com/watch?v=vy8Bsa0Q24E
OARS	Oxford	An acute referrals system to document and manage acute, specialist referrals between different healthcare organisations in Oxford UHT	http://www.medsci.ox.ac.uk/news/innovation-in-good-health-at-oxford-university-hospital
OpenClinical	Oxford	Open source framework for developing and sharing clinical pathways and applications to improve health care worldwide	http://www.openclinical.net
Oxford Programme for the Future of Cities	Oxford	Rethinking the city, in theory and practice, as a flexible and evolving space that better responds to contemporary urban challenges.	http://www.futureofcities.ox.ac.uk

Name	Location	Summary	Website
Prolific Academic	Oxford	Online platform for managing clinical trial volunteering and identification of participants	https://www.prolific.ac
SEND	Oxford	Electronic observation chart developed by the Oxford University Hospitals NHS trust to improve patient safety	http://www.send-system.co.uk/index.html#
Support HF	Oxford	Project evaluating an integrated home monitoring system for the better management of heart failure	http://supporthf.org
Telehealth	Oxford	Mobile technology is used to transmit blood glucose test results and diary data to a central server with real time feedback of blood glucose	http://oxfordbrc.nihr.ac.uk/biomedical/biomedical-research/telehealth-for-type-2-diabetes/
Total Mama	Oxford	TOTAL MAMA is a new health service concept that helps women before, during, and after pregnancy	http://totalmama.com
Trial Spark	Oxford	Web-based clinical trial recruiting tool based at the Jenner Institute	https://www.trialspark.com
True Colours	Oxford	A versatile online self-management system that allows patients to monitor symptoms and experiences using text, email and the internet	https://oxfordhealth.truecolours.nhs.uk/www/en/

Academic institutions

Name	Location	Summary	Website
Buckinghamshire New University: Care and Health Alliance	High Wycombe	Supports workforce development across health and social care, facilitates networks and promotes career progression and vocational learning	http://bucks.ac.uk/research/research_institutes/care_health_alliance
Buckinghamshire New University: Centre for Health Communications Research & Excellence	High Wycombe	Focuses on the communication dilemmas, challenges, issues and problems faced by organisations in the health sector	http://bucks.ac.uk/research/research_institutes/CHCR/
Buckinghamshire New University: Centre of Excellence for Telehealth and Assisted Living (CETAL)	High Wycombe	CETAL develops Telehealth packages based on proven clinical models and assessed technology to meet specific clinical needs	http://cetal.co.uk/index.html
Buckinghamshire New University: Faculty of Society and Health	High Wycombe	Offers a variety of programmes geared towards needs of NHS and health workers in independent sector	http://bucks.ac.uk/about_us/how_we_are_structured/faculties/
Buckinghamshire New University: Institute of Integrated Care	High Wycombe	Forum for stakeholders within the NHS, Academia and Commerce interested in improving care within the Health and Social Care sector	http://bucks.ac.uk/research/research_institutes/institute-of-integrated-care/
Bucks Living Lab	Aylesbury	A place where assisted living technology is being exhibited, researched and developed for educational and commercial purposes	http://buckslivinglab.co.uk/index.html
Cranfield University: School of Energy, Environmental Technology and Agrifood	Cranfield	Recognised for its multi-disciplinary approach to research and teaching in environmental science and technology, manufacturing and materials	https://www.cranfield.ac.uk/About/People-and-Resources/Schools-institutes-and-research-centres
Open University: Computing & ICT	Milton Keynes	Research is interdisciplinary and human-centred, considering technological developments in the context of broader socio-technical systems	http://mct-research.open.ac.uk/research/computingandict

Name	Location	Summary	Website
Open University: Digital Society	Milton Keynes	Research in development, adoption and consequences of innovative healthcare solutions across a wide range of technologies	http://mct-research.open.ac.uk/research/digital_society
Open University: Faculty of Health & Social Care	Milton Keynes	UK's largest provider of health and social care education, specific expertise in developing work-based learning programmes	http://www.open.ac.uk/research/main/our-research/faculties-institutes/health-and-social-care
Open University: Faculty of Mathematics, Computing & Technology	Milton Keynes	Focus on real-world problems that require technological advances, behavioural transformation and enhancements in policy and practice	http://www.open.ac.uk/research/main/our-research/faculties-institutes/mct
Open University: Faculty of Science	Milton Keynes	One of Europe's premier research centres in Space Sciences, noted for its contribution to space missions such as ROSETTA	http://www.open.ac.uk/research/main/our-research/faculties-institutes/science
Open University: International Development	Milton Keynes	Focuses on aspects such as new health technologies in driving international development in the early 21st Century	http://mct-research.open.ac.uk/research/international_development
Open University: Knowledge Media Institute	Milton Keynes	Centre of excellence for R&D in the fields of cognitive and learning sciences, artificial intelligence, semantic Technologies and multimedia	http://kmi.open.ac.uk
Open University: Milton Keynes Campus	Milton Keynes	Newest facility houses dedicated laboratories for pervasive computing and deployment of ambient and ubiquitous technologies	http://www.open.ac.uk/about/main/faculties-centres/milton-keynes-campus
Oxford Brookes University: Advanced Reliable Computer Systems Group	Oxford Brookes	Carries out leading research in design, test, and verification of reliable computer systems	http://cct.brookes.ac.uk/research/dsec/arcos/index.html
Oxford Brookes University: Applied Software Engineering Research Group	Oxford Brookes	Takes an empirical and experimental approach to software engineering, studying software systems to characterize and improve the systems	http://cct.brookes.ac.uk/research/dsec/applied-software-engineering/index.html

Name	Location	Summary	Website
Oxford Brookes University: Artificial Intelligence and Vision Research Group	Oxford Brookes	Research in vision applications such as gesture recognition, identity recognition, machine learning, robotics and autonomous navigation	http://cct.brookes.ac.uk/research/isec/artificial-intelligence/themes/computer-vision/index.html
Oxford Brookes University: Cognitive Robotics Group	Oxford Brookes	Undertakes research into human-robot interaction, autonomous vehicles and bio-inspired robotics	http://cct.brookes.ac.uk/research/isec/cognitive-robotics/index.html
Oxford Brookes University: Communications, Media and Electronic Technologies Research Group	Oxford Brookes	Interdisciplinary approach to develop novel solutions or identify new applications and opportunitites in media and communications	http://cct.brookes.ac.uk/research/isec/comet/index.html
Oxford Brookes University: Department of Applied Health and Professional Development	Oxford Brookes	Provides healthcare courses focused on specific areas of clinical expertise and professional practice underpinned by research activities	http://ahpd.brookes.ac.uk
Oxford Brookes University: Department of Biological and Medical Sciences	Oxford Brookes	Research opportunities across plant and animal biology, biomedical science, cell/molecular biology, conservation and the environment	http://bms.brookes.ac.uk
Oxford Brookes University: Department of Computing and Communication Technologies	Oxford Brookes	Blends excellence in teaching and knowledge transfer with world-leading research in areas that spans Computer Science and Communications	http://cct.brookes.ac.uk
Oxford Brookes University: Department of Mechanical Engineering and Mathematical Sciences	Oxford Brookes	Research organised into the cross-cutting themes of sustainable engineering, advanced propulsion and simulation, modelling and integration	http://mems.brookes.ac.uk

Name	Location	Summary	Website
Oxford Brookes University: Department of Psychology, Social Work and Public Health	Oxford Brookes	Works with health and education professionals and industry to develop knowledge and understanding that informs policy and improves lives	http://pswph.brookes.ac.uk
Oxford Brookes University: Department of Sports and Health Science	Oxford Brookes	Research opportunities across occupational therapy, physiotherapy, rehabilitation, nutrition, exercise science and sports coaching	http://www.shs.brookes.ac.uk
Oxford Brookes University: Dependable Systems Engineering Research Centre	Oxford Brookes	Encompasses the Applied Formal Methods, Applied Software Engineering Research and Advanced Reliable Computer Systems groups	http://cct.brookes.ac.uk/research/
Oxford Brookes University: Faculty of Health and Life Sciences	Oxford Brookes	Working for evidence-based public care, helping to improve quality/ service impact in health, social care, education, housing and welfare	http://www.hls.brookes.ac.uk
Oxford Brookes University: Faculty of Humanities and Social Sciences	Oxford Brookes	Schools of Education; English and Modern Languages; History, Philosophy and Religion; Social Sciences; Law and the Institute of Public Care	https://www.brookes.ac.uk/about-brookes/faculties-and-departments/faculty-of-humanities-and-social-sciences/
Oxford Brookes University: Faculty of Technology, Design and Environment	Oxford Brookes	Home to five Schools and Departments providing specialist and interdisciplinary teaching, research and knowledge transfer activities	https://www.brookes.ac.uk/about-brookes/faculties-and-departments/faculty-of-technology-design-and-environment/
Oxford Brookes University: Institute of Public Care	Oxford Brookes	Leads the way in thinking and practice on commissioning and market development, service improvement and improving practice quality	http://ipc.brookes.ac.uk
Oxford Brookes University: Intelligent Systems Engineering Research Centre	Oxford Brookes	ISERC operates as umbrella Research Centre covering work of Computer Vision and Artificial Intelligence research groups	http://cct.brookes.ac.uk/research/

Name	Location	Summary	Website
Oxford Brookes University: Movement Science Group	Oxford Brookes	Uses fundamental and applied research to evaluate factors affecting optimal human performance in health and disease	http://www.shs.brookes.ac.uk/research/movement-science
Oxford Brookes University: The Applied Formal Methods Research Group	Oxford Brookes	Focuses on applying mathematical theories and methods to a wide range of fundamental problems in software development	http://cct.brookes.ac.uk/research/dsec/applied-formal-methods/index.html
Oxford University: Acute Vascular Imaging Centre (AVIC)	John Radcliffe Hospital	Imaging facility dedicated to clinical research in acute coronary syndromes (heart attack and unstable angina) and stroke and TIA	http://www.avic.ox.ac.uk/home
Oxford University: Advanced Microscopy Unit	Science area	Developing and applying new and emerging advanced microscopy technologies to facilitate important discoveries in basic biomedical research	http://www.micron.ox.ac.uk/home.php
Oxford University: Arthritis Research UK Centre for Osteoarthritis Pathogenesis	Old Road Campus	Training centre that also aims to develop novel disease markers and therapies for patients with osteoarthritis	http://oacentre.kennedy.ox.ac.uk
Oxford University: Big Data Institute	Old Road Campus	An institute directed at obtaining and characterising large datasets to improve our understanding of human disease	http://www.ndmrb.ox.ac.uk/the-li-ka-shing-centre
Oxford University: Bioimaging Facility	Science area	Provides students and researchers with state-of-the-art preparation, imaging and analysis instrumentation to facilitate their research	http://web.path.ox.ac.uk/~bioimaging//bioimaginghome.html
Oxford University: Botnar Research Centre	Windmill Road	Enabling and encouraging research and education into the causes of musculoskeletal diseases and their treatment	http://www.ndorms.ox.ac.uk/botnar.php
Oxford University: British Heart Foundation Centre on Population Approaches for Non-Communicable Disease Prevention	Old Road Campus	Research into population approaches for the prevention of non-communicable disease like cardiovascular diseases, diabetes, cancer and COPD	http://www.ndph.ox.ac.uk/bhfcpnp/

Name	Location	Summary	Website
Oxford University: Cancer Epidemiology Unit (CEU)	Old Road Campus	Providing large-scale reliable evidence on the relationship between common exposures and conditions of public health importance	http://www.ceu.ox.ac.uk
Oxford University: Cancer Research UK and Medical Research Council Oxford Institute for Radiation Oncology	Old Road Campus	World-leading centre exploring aspects of radiation biology research that could yield new advances in the treatment of cancer	http://www.radiationoncology.ox.ac.uk
Oxford University: Centre for Cellular and Molecular Physiology (CCMP)	Old Road Campus	Research led by clinician scientists working in kidney medicine and non-clinical groups with expertise in proteomics and structural biology	http://www.ccmp.ox.ac.uk/home
Oxford University: Centre for Genomics & Global Health	Old Road Campus	This core team acts a hub for our wider network of collaborators and data-sharing initiatives with active projects in more than 20 countries	http://www.cggh.org
Oxford University: Centre for Health Service Economics and Organisation	Radcliffe site	An innovative research unit focused on whole-system analysis of the health and social care sector and selected local health economies	http://www.chseo.org.uk
Oxford University: Centre for Health, Law and Emerging Technologies (HeLEX)	Summertown	investigating the relationships between law, ethics, and practice in new health technologies to facilitate effective translational outcomes	http://www.ndph.ox.ac.uk/research/centre-for-health-law-and-emerging-technologies-helex
Oxford University: Centre for Neural Circuits & Behaviour	Mansfield Road	Aim is to understand how intelligence emerges from the physical interaction of nerve cells by studying the brain from the top down	http://www.cncb.ox.ac.uk
Oxford University: Centre for Personalised Medicine	Oxford Centre	Facilitates new programmes of research that will contribute to an integrative and more individualised approach to healthcare	http://www.well.ox.ac.uk/cpm/home
Oxford University: Centre for Statistics in Medicine	Windmill Road	Collaborates in health care research, conducts applied statistical research, and runs courses for health care workers and statisticians	http://www.csm-oxford.org.uk

Name	Location	Summary	Website
Oxford University: Centre for the Advancement of Sustainable Medical Innovation (CASMI)	Headington	A partnership between Oxford University and UCL, created to develop new models for medical innovation	http://casmi.org.uk/about-casmi/
Oxford University: Centre for tropical medicine and global health	Oxford	A collection of research groups who are permanently based in Africa and Asia as well as a growing number of groups in Oxford	http://www.tropicalmedicine.ox.ac.uk/home
Oxford University: Clinical Trial Service Unit & Epidemiological Studies Unit (CTSU)	Old Road Campus	Large-scale population health studies into the causes and treatment of chronic diseases such as cancer, heart attack and stroke	http://www.ctsu.ox.ac.uk
Oxford University: Department of Biochemistry	Science area	Research covers all aspects of modern molecular and cellular biochemistry, from atomic resolution biophysics to cell biology and imaging	http://www.bioch.ox.ac.uk
Oxford University: Department of Computer Science	Science area	Research includes computational biology, quantum computing, linguistics, information systems, software verification and engineering	http://www.cs.ox.ac.uk
Oxford University: Department of Engineering Science	Science area	The only unified department in the UK which offers accredited courses in all the major branches of engineering	http://www.eng.ox.ac.uk
Oxford University: Department of Experimental Psychology	Science area	Research in behavioural neuroscience, cognitive neuroscience, developmental psychology, social psychology, and psychological disorders	http://www.psy.ox.ac.uk
Oxford University: Department of Oncology	Old Road Campus	Enhancing clinical and basic cancer research through multidisciplinary collaboration with the ultimate goal of increasing cancer cure rates	http://www.oncology.ox.ac.uk
Oxford University: Department of Paediatrics	John Radcliffe Hospital	A world leader in child health research from fundamental biology all the way up to its application in clinical settings	http://www.paediatrics.ox.ac.uk

Name	Location	Summary	Website
Oxford University: Department of Pharmacology	Science area	Priority areas include molecular pharmacology, cardiac pharmacology, neuropharmacology, cell signalling, and pharmacogenetics	http://www.pharm.ox.ac.uk
Oxford University: Department of Physiology, Anatomy and Genetics	Science area	Home to a large number of internationally-renowned teams of scientists addressing major questions in biomedicine	http://www.dpag.ox.ac.uk
Oxford University: Department of Psychiatry	Warneford Hospital	World-class psychiatric research and teaching facility involved in the development of innovative clinical services	http://www.psych.ox.ac.uk
Oxford University: Diabetes Trial Unit (DTU)	Old Road Campus	A fully registered UKCRC Clinical Trials Unit, specialising in performing national and multinational clinical trials related to diabetes	http://www.dtu.ox.ac.uk
Oxford University: Division of Cardiovascular Medicine	John Radcliffe Hospital	Home to an internationally leading academic programme in cardiology and cardiovascular medicine with a focus on translational research	http://www.cardiov.ox.ac.uk/home
Oxford University: Division of Clinical Neurology	John Radcliffe Hospital	Carrying out research that improves understanding of the nervous system in health and disease alongside teaching clinical neurology	http://www.ndcn.ox.ac.uk/divisions/dcn/
Oxford University: Division of Structural Biology (STRUBI)	Old Road Campus	Applies the techniques of structural biology to the study of biomedically important processes	https://www.strubi.ox.ac.uk
Oxford University: Ethox Centre	Old Road Campus	Improving ethical standards in healthcare practice and medical research through education, research, and the provision of ethics support	http://www.ndph.ox.ac.uk/research/ethox-centre
Oxford University: Experimental Medicine Division (EXPMED)	John Radcliffe Hospital	Research spans fundamental basic science to translational and experimental medicine approaches including clinical trials	http://www.expmedndm.ox.ac.uk/home

Name	Location	Summary	Website
Oxford University: George Institute for Global Health (GIGH)	Oxford Centre	A health and medical research institute whose mission is to improve the health of millions of people worldwide	http://www.georgeinstitute.org.uk
Oxford University: Health Economics Research Centre (HERC)	Old Road Campus	The economics of health and disease, the costs and benefits of prevention and treatment, and the design and evaluation of health systems	http://www.herc.ox.ac.uk
Oxford University: Health Experiences Institute	Oxford Centre	Uses interdisciplinary research into patient experiences to transform care through influencing policy, practice and education	http://hexi.gtc.ox.ac.uk
Oxford University: Health Services Research Unit (HSRU)	Old Road Campus	Supports a programme of research into health outcomes that informs the development of a more effective Health Service	http://www.ndph.ox.ac.uk/research/health-services-research-unit-hsru
Oxford University: Healthcare innovation and evaluation unit	Oxford Centre	Conduct high impact research into chronic diseases and how their management at individual and population level could be further improved	http://www.georgeinstitute.org.uk/units/healthcare-innovation-and-evaluation
Oxford University: Institute for Science, Innovation and Society	Oxford Centre	Research that informs the key processes of social and technological innovation critical to business, governments and civil society	http://www.insis.ox.ac.uk
Oxford University: Institute of Biomedical Engineering	Old Road Campus	Engineers and clinicians work together on unmet needs in the prevention, early diagnosis and treatment of major diseases and conditions	http://www.ibme.ox.ac.uk
Oxford University: Investigative Medicine Division (IMD)	John Radcliffe Hospital	Carries out translational research across the themes of acute stroke, behavioural science, geratology, and immunology	http://www.imd.ox.ac.uk/home
Oxford University: ISIS Innovation	Summertown	Manages technology transfer for the University and provides consultancy services to clients around the world	http://isis-innovation.com
Oxford University: Kennedy Institute of Rheumatology	Old Road Campus	Adopt a multidisciplinary approach to inflammatory disease, from basic biology through to the testing of novel therapies in the clinic	http://www.kennedy.ox.ac.uk

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Oxford University: Ludwig Institute for Cancer Research Oxford Branch (LICR)	Old Road Campus	Translating basic discoveries into the clinic for early diagnosis and the design of more effective, individualised treatments for patients	http://www.ludwig.ox.ac.uk/home
Oxford University: Mathematical Physical and Life Sciences Division	Science area	Provides leadership for the natural and physical sciences at Oxford, and acts as an advocate within and outside of the University	http://www.mpls.ox.ac.uk
Oxford University: Medical Sciences Division	Headington	The largest of the four academic divisions and an international centre of excellence for biomedical and clinical research and teaching	http://www.medsci.ox.ac.uk
Oxford University: MRC Brain Network Dynamics Unit	Mansfield Road	Aim to develop and deliver novel therapies that specifically target the disturbed brain circuit interactions arising in disease	http://www.mrcbndu.ox.ac.uk
Oxford University: MRC Functional Genomics Unit	Science area	Uses genomic information to determine mechanisms of disease and to develop novel therapeutic approaches focused on neurological conditions	http://www.dpag.ox.ac.uk/research/mrcfgu/
Oxford University: National Perinatal Epidemiology Unit (NPEU)	Old Road Campus	Research to improve the care provided to women and their families during pregnancy, childbirth, the newborn period and early childhood	https://www.npeu.ox.ac.uk
Oxford University: NDM Research Building	Old Road Campus	Allows for development of the Target Discovery Institute and expansion of existing research groups of NDM with research synergies	http://www.ndmrb.ox.ac.uk/home
Oxford University: NDM Strategic (Offices of the Nuffield Professor of Medicine)	Old Road Campus	Manages the department of clinical medicine, one of the largest groups of Biomedical Researchers in the University Sector	http://www.ndm.ox.ac.uk/home
Oxford University: NIHR Oxford Musculoskeletal Biomedical Research Unit	Windmill Road	NIHR funded interdisciplinary research initiative which brings together research and clinical departments studying rheumatological disease	http://www.oxford.msk.bru.nihr.ac.uk

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Oxford University: NIHR School for Primary Care Research	Radcliffe site	Mission is to increase the evidence base for primary care practice, and to increase research capacity in primary care	http://www.spcr.nihr.ac.uk
Oxford University: Nuffield Department of Clinical Medicine	Old Road Campus	Linking high quality clinical research with medical application for positive impact on the health and wellbeing of the global community	http://www.ndm.ox.ac.uk/home
Oxford University: Nuffield Department of Clinical Neurosciences	John Radcliffe Hospital	Pursues research in pain and consciousness, respiration and hypoxia, intensive care, simulation and human factors training	http://www.ndcn.ox.ac.uk
Oxford University: Nuffield Department of Obstetrics and Gynaecology	John Radcliffe Hospital	Focus on fundamental research and clinical studies in women's health and pregnancy, growth and development for the first 1000 days of life	http://www.obs-gyn.ox.ac.uk
Oxford University: Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences	Windmill Road	Focus is the cause of musculoskeletal conditions and delivery of innovative translational research that improves people's quality of life	http://www.ndorms.ox.ac.uk
Oxford University: Nuffield Department of Population Health	Old Road Campus	Undertakes research and trains scientists to answer the important questions about the causes, prevention and treatment of disease	http://www.ndph.ox.ac.uk
Oxford University: Nuffield Department of Primary Care Health Sciences	Oxford University	Research, engagement and training that advances primary care, influences policy and develops skills for the delivery of better health care	http://www.phc.ox.ac.uk/about
Oxford University: Nuffield Department of Surgical Sciences	John Radcliffe Hospital	Academic department hosting a team of senior clinical academic surgeons, senior scientists, junior clinicians and scientists in training	http://www.nds.ox.ac.uk
Oxford University: Nuffield Division of Anaesthetics	John Radcliffe Hospital	Run research programmes in pain and consciousness, respiration and hypoxia, intensive care, simulation and human factors training	http://www.ndcn.ox.ac.uk/divisions/nda/

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Oxford University: Nuffield Division of Clinical Laboratory Sciences (NDCLS)	John Radcliffe Hospital	The integration of clinical laboratory-based disciplines contributes to a coherent strategy for translational and experimental medicine	http://www.ndcls.ox.ac.uk/home
Oxford University: Nuffield Laboratory of Ophthalmology	John Radcliffe Hospital	Research covers the dual function of the eye as both the receptor organ for vision and for the regulation of sleep and circadian systems	http://www.ndcn.ox.ac.uk/divisions/nlo/
Oxford University: Oxford Cardiovascular Clinical Research Facility (CCRF)	John Radcliffe Hospital	One of the core clinical research facilities in Oxford, CCRF is focused on facilitating high-quality cardiovascular clinical research	http://www.ccrf.ox.ac.uk/home
Oxford University: Oxford Cardiovascular Science	John Radcliffe Hospital	Brings together two BHF funded research centres focusing on cardiovascular disease and regenerative medicine	http://www.cardioscience.ox.ac.uk/home
Oxford University: Oxford Centre for Clinical Magnetic Resonance Research (OCMR)	John Radcliffe Hospital	A world-leading multidisciplinary centre for clinical research in heart and brain magnetic resonance imaging and spectroscopy	http://www.ocmr.ox.ac.uk/home
Oxford University: Oxford Centre for Diabetes, Endocrinology & Metabolism (OCDEM)	Old Road Campus	Combines clinical care, research and education in diabetes, endocrine and metabolic diseases to accelerate the search for new treatments	http://www.ocdem.ox.ac.uk/home
Oxford University: Oxford Centre for Evidence Based Medicine	Radcliffe site	Non-profit organisation dedicated to the practice, teaching and dissemination of high quality evidence based medicine to improve healthcare	http://www.cebm.net
Oxford University: Oxford Centre for Functional MRI of the Brain	John Radcliffe Hospital	Focuses on the use of Magnetic Resonance Imaging, along with related technologies such as EEG and non-invasive brain stimulation	http://www.ndcn.ox.ac.uk/divisions/fmrib/

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Oxford University: Oxford Centre for Human Brain Activity (OHBA)	Warneford Hospital	Use the latest neuroimaging technologies and novel analysis methods to research how the functioning human brain works	http://www.ohba.ox.ac.uk
Oxford University: Oxford Clinical Trials Research Unit	Old Road Campus	OCTRU is a fully registered Clinical Trials Unit and leads and co-ordinates strategy, operations and systems across all of the trial groups	http://www.octru.ox.ac.uk
Oxford University: Oxford Dementia and Ageing Research (OxDARE)	Warneford Hospital	Vision is to translate the very best basic science into patient care across a range of neurodegenerative conditions	http://www.oxdare.ox.ac.uk/home
Oxford University: Oxford Genomics Centre	Old Road Campus	Brings together genomics and analysis services to support scientists wanting to exploit the latest in high-throughput genomics techniques	http://www.well.ox.ac.uk/ogc/home
Oxford University: Oxford Institute for Digital Health	Warneford Hospital	Centre of excellence which provides all the elements necessary to design, build and deploy successful digital health interventions	http://oidh.medsci.ox.ac.uk
Oxford University: Oxford Internet Institute	Oxford Centre	Develop cutting edge methods to understand digital life, such as experiments, social network analysis and big data approaches	http://www.oii.ox.ac.uk
Oxford University: Oxford Neuroscience	John Radcliffe Hospital	Brings together neuroscience research at Oxford, which is performed in departments and multidisciplinary units across four sites	http://www.neuroscience.ox.ac.uk
Oxford University: Oxford Parkinson's Disease Centre	Science area	Focused on understanding the earliest events in the development of Parkinson's and creating animal models with greater relevance	http://opdc.medsci.ox.ac.uk/home
Oxford University: Oxford Vaccine Group	Old Road Campus	Independent clinical trials and epidemiology group developing new vaccines for the prevention of infection in adults and children	http://www.ovg.ox.ac.uk

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Oxford University: Primary Care and Vaccines Collaborative Clinical Trials Unit (PCVC-CTU)	Oxford Centre	Consortium of individually accredited research units carrying out high-quality, academically-led trials and translational research	http://www.pcvcctu.org
Oxford University: Radcliffe Department of Medicine	John Radcliffe Hospital	Broad interests and strengths in translating molecular and cellular research across multiple disease areas through to clinical application	http://www.rdm.ox.ac.uk/home
Oxford University: Research Support	Oxford Centre	Provide comprehensive support to researchers across the research lifecycle in partnership with other University departments	https://www.admin.ox.ac.uk/researchsupport/
Oxford University: Sir William Dunn School of Pathology	Science area	World-class biomedical research department aiming to discover the molecular and cellular mechanisms that underlie human health and disease	http://www.path.ox.ac.uk
Oxford University: Sleep & Circadian Neuroscience Institute	John Radcliffe Hospital	Interdepartmental group of researchers working to understand the relationships between sleep, circadian physiology and health	http://www.ndcn.ox.ac.uk/research/sleep-circadian-neuroscience-institute
Oxford University: Surgical Trials Intervention Unit (SITU)	Windmill Road	A training and development hub for UK surgical trialists and centre of excellence for the design and management of surgical trials	http://www.situ.ox.ac.uk
Oxford University: The Jenner Institute (JENNER)	Old Road Campus	Develops innovative vaccines against major global diseases of both humans and livestock	http://www.jenner.ac.uk/home
Oxford University: The Peter Medawar Building for Pathogen Research	Science area	Interdisciplinary research consortium investigating pathogen diversity through molecular characterisation and theoretical analysis	http://www.medawar.ox.ac.uk/home
Oxford University: The Target Discovery Institute (TDI)	Old Road Campus	A collaborative research initiative centred on a high throughput screening capability, medicinal chemistry and allied technologies	http://www.tdi.ox.ac.uk/home

Name	Location	Summary	Website
Oxford University: Tropical Medicine and Global Health (TROPMED)	Old Road Campus	A collection of research groups permanently based in Africa and Asia as well as in Oxford with a focus on tropical disease	http://www.tropicalmedicine.ox.ac.uk/home
Oxford University: Unit of Health-Care Epidemiology (UHCE)	Old Road Campus	Carries out epidemiological and health services research using medical statistics and linked data	http://www.uhce.ox.ac.uk/uhce/
Oxford University: Weatherall Institute of Molecular Medicine (WIMM)	John Radcliffe Hospital	Internationally competitive research to understand disease processes better and translate these insights into improvements in human health	http://www.imm.ox.ac.uk/home
Oxford University: Wellcome Trust Centre for Human Genetics (WTCHG)	Old Road Campus	International leader in applying genetics, genomics and structural biology to gain clearer insights into mechanisms of health and disease	http://www.well.ox.ac.uk/home
University of Bedfordshire: Department of Computer Science and Technology	Luton	Has expanding research profile and range of vocationally-relevant courses, including a BSc in Biomedical Science	http://www.beds.ac.uk/howtoapply/departments/computing
University of Bedfordshire: Faculty of Creative Arts, Technologies & Science	Luton	Comprises the Institute for Media, Arts and Performance, Department of Computing and Information Systems and the Division of Science	http://www.beds.ac.uk/howtoapply/departments/cats
University of Bedfordshire: Faculty of Health and Social Sciences	Luton	Comprised of Applied Social Studies, Clinical Education and Leadership, Healthcare Practice, Psychology, Sports Therapy and Rehabilitation	http://www.beds.ac.uk/howtoapply/departments/healthsciences
University of Bedfordshire: Institute for Health Research	Luton	Focused on the three main themes of health inequalities, public health and commissioning	http://www.beds.ac.uk/research-ref/ihr

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University of Bedfordshire: Institute of Applied Social Research	Luton	Two distinct but cross cutting strands of work: 'Social Work and Social Care Research' and 'Research with and for Young People'	http://www.beds.ac.uk/research-ref/iasr
University of Bedfordshire: Institute of Biomedical and Environmental Science and Technology	Luton	Applied biomedical and environmental research and product development in association with other academic groups and industrial collaboration	http://www.beds.ac.uk/research-ref/ibest
University of Bedfordshire: Research Centre for Applied Psychology	Luton	Applying psychology to real-world contexts: work, health, social care, the criminal justice system, mobile communications and education	http://www.beds.ac.uk/howtoapply/departments/psychology/rcap
University of Bedfordshire: The Institute of Diabetes for Older People	Luton	Non-profit institution dedicated to enhancing the health and well-being of older people with diabetes and related metabolic illness	http://www.idop.adc-online.co.uk/the-development-of-idop/#
University of Buckingham: Buckingham Centre for Astrobiology	Buckingham	Combining the expertise of astronomers, biochemists and microbiologists to generate cutting edge science	http://www.buckingham.ac.uk/research/bcab/
University of Buckingham: Buckingham Institute for Translational Medicine	Buckingham	Preclinical research informing drug development and enhance underlying biological understanding in diabetes, obesity and metabolic disease	http://www.buckingham.ac.uk/bitm
University of Buckingham: Buckingham University Department of Applied Computing	Buckingham	Main research areas are feature detection in biomedical images, image processing, wireless networks and biometric aunthentication	http://www.buckingham.ac.uk/appliedcomputing

Name	Location	Summary	Website
University of Buckingham: Buckingham University Psychology Department	Buckingham	Main research areas are performance psychology, psychology of emotion, heath psychology and the psychology of religion.	http://www.buckingham.ac.uk/psychology
University of Buckingham: School of Science	Buckingham	Comprises the Departments of Applied Computing, Psychology and Diabetes, Obesity and Metabolic Disease	http://www.buckingham.ac.uk/sciences
University of Buckingham: University of Buckingham Medical School	Buckingham	A GMC approved sponsor for full registration with the GMC	http://www.buckingham.ac.uk/medicine

Investment organisations

Name	Location	Summary	Website
2023 Challenge	Oxford	Competition tapping into the appetite for innovation among trainee doctors and nurses within the NHS in the region	http://www.tvwleadershipacademy.nhs.uk/2023-innovation-challenge
Longwall Venture Partners	Harwell	£70m fund investing in innovative start up and early stage businesses in the healthcare, science and engineering sectors	http://www.longwallventures.com
NHS Innovations Southeast	Harwell	Helps NHS organisations with intellectual property and and technology transfer	http://www.innovationssoutheast.nhs.uk
Nominet Trust	Oxford Science Park	A source of seed funding for projects that harness the power of the internet to tackle social challenges	http://www.nominettrust.org.uk
Oxford Capital	Cumnor Hill	Provide growth capital and infrastructure investment to small companies from a range of industries	http://www.oxcp.com
Oxford Investment Opportunity Network	Oxford	Business angel network for companies with patented technology requiring investment between £200k and £2m	http://www.oion.co.uk
Oxford Sciences Innovation plc	Oxford	Fund with £300m capital and scaling expertise to support businesses emerging from Oxford's MPLS and Medical Sciences Divisions	http://isis-innovation.com/news/launch-of-300m-partnership-to-boost-development-of-science-and-technology-businesses/
Oxford Spin Out Equity Management	Magdalen Centre	Offers strategic, tactical and procedural support along with access to funding to companies emerging from Oxford University	http://www.osem.ox.ac.uk
Oxford Technology	Magdalen Centre	Fund specialising in making and managing investments in start-up and early stage technology-based businesses with high growth prospects	http://www.oxfordtechnology.com
Oxford University Endowment Management	Oxford	OU Endowment Management invests over £2bn for collegiate investors attracted by our long term approach to global investing	http://ouem.co.uk
University Challenge Seed Fund	Oxford	Seed fund managed by ISIS for high risk early stage financing of ideas coming from University researchers with between £2,500 to £250,000	http://isis-innovation.com/award-details/university-challenge-seed-fund-ucsf/

Name	Location	Summary	Website
Woodford Investment Management	Oxford	Private fund management company with an equity income fund and a capital trust fund	https://woodfordfunds.com