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The future of public health
A horizon scan

Molly Morgan Jones, Alexandra Hall, Daniel Brooker, Sophie Castle-Clarke, Eleanor Winpenny, Deepa Jahagirdar, Josephine Exley, Joanna Chataway
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The research described in this document was prepared for Public Health England.
Public Health England (PHE) commissioned RAND Europe to undertake a horizon scanning study exploring the future of public health and related scientific services. This work was intended to help inform thinking at the strategic level within PHE, firstly in relation to the wider vision of the Agency (which was only established in April 2013) and, secondly, in relation to the proposals for the creation of an integrated public health science hub.

The report is based on a literature review, a brief Delphi exercise using the ExpertLens platform and key informant interviews with a range of PHE staff and external experts. It focuses on the different future public health science needs and the extent to which an integrated science hub could serve PHE as it evolves over the next twenty years. Thus, the report considers PHE’s future remit and objectives in order that decisions about an integrated and co-located science hub be made in context and with reference to expert perceptions about the future.

The report will be of interest to PHE, policymakers in public health and the wider academic community who are interested in future scientific and technological trends in public health science.

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Summary

This report is the synthesis of the findings of a horizon scanning study on the future of public health and its related scientific and laboratory capabilities and services. The work was intended to help inform thinking at the strategic level within Public Health England (PHE), firstly in relation to the wider vision of the Agency (which was only established in April 2013) and, secondly, in relation to the proposals for the creation of an integrated public health science hub within a network of facilities across the country. PHE is responsible for a broad range of health improvement, protection and surveillance activities. Research and science are core to the organisation’s function and success. As the organisation evolves, the capabilities it needs to address future public health science will also evolve. This report contributes to that endeavour and sheds some light on the extent to which an integrated science hub and network of facilities could serve PHE in the future.

The concept of a public health science hub had been under consideration by the Health Protection Agency (HPA) before it became part of PHE earlier this year. HPA’s Chrysalis Programme had considered the possible co-location of many of the existing microbiological services on a new site and PHE has inherited this programme of work and continues to explore further the possible benefits and challenges associated with the hub and network concept. The study was commissioned by PHE and carried out by RAND Europe in a short timeframe during July-August 2013. It involved a contextual overview including a review of international public health models and co-location literature, a series of key informant interviews, a structured literature review, and a brief Delphi exercise using the ExpertLens platform. Each activity and its main findings are discussed in turn.

Contextual overview

We reviewed organisational and management structures for international health models in Canada, France, Germany, the Netherlands, Sweden and the United States and highlighted national-level agencies which appear to be most relevant as comparators for the future PHE. We found that many of the comparator countries have a central agency or department to undertake data collection and surveillance, but that the agency’s responsibility for wider public health functions varied. In addition, there are a range of organisational models for public health systems, and, moreover, for the role of a national public health agency within these systems. In particular, the national public health agency of any country is usually part of a wider infrastructure that includes other national and sub-national organisations. In many cases, whether under a centralised or decentralised public health system, a central institute works to collect surveillance information, conduct research and provide resources to national and local government.
The countries reviewed benefit from centralising their public health efforts and expertise within a single organisation or network of collaborating institutions in order to provide effective, coordinated leadership of public health. However, there is little precedent for a fully integrated national public health agency. Where they do exist, the institutes have limited capacities and capabilities relative to need across all areas of public health responsibility. Regardless of the specific model, the international examples suggest a consensus for a national level institute or agency to deliver population health surveillance functions and coordination of research evidence for health improvement activities.

The literature on co-location and clustering of different scientific and technological capabilities was reviewed and we summarise the benefits, challenges and opportunities of co-location and clustering policies. The benefits of co-location include: enabling the exchange of tacit knowledge; helping to build trust and social capital; creation of a 'local buzz' and an atmosphere of collegiality and collaboration; outcomes of localised learning; the potential for economic externalities and knowledge spillovers to occur; and enhanced absorptive capacity.

However, all of these benefits are contingent upon appropriate policies and conditions for clustering, both nationally and organisationally. The conditions which must be considered include: the presence of factor conditions (human, physical, knowledge, capital and infrastructure resources); the need for demand conditions in the public health research 'market'; the presence of supporting industries; the role of a clear strategy and structure; and the importance of chance events. The interplay between these conditions is not always straightforward to determine, which has led to a backlash against clustering and engineered co-location in recent years. Clearly, careful consideration is needed in order to maximise the opportunities and benefits co-location can provide.

**Insights from stakeholder interview and workshops**

We conducted interviews with 26 stakeholders both internal and external to PHE, and facilitated a session at an internal PHE workshop in order to determine what the collective views of experts in the field were about future public health science needs and trends. The discussions covered: technological and research trends; the challenges facing public health; important capabilities for the future; the role of PHE in the future; the characteristics of a hub; and uncertainties about the future.

On the question of those technological and research trends that would be influential in future public health, genomics featured prominently, as did informatics and 'big data'. Challenges facing public health discussed included the involvement and regulation of the private sector's activities within this traditionally public sector-dominated field. Also considered challenging were various organisational issues pertaining, in particular, to internal integration and continuity issues within PHE itself.

The capabilities that were regarded as being important for future public health needs spanned wet lab disciplines (epidemiology, microbiology, virology, genetics, etc) and 'dry lab' capabilities (including statistics, economics, mathematics, behavioural science and bioinformatics and other IT-related disciplines). These were perceived by interviewees as important to allow PHE to deliver on its role, which they considered to involve: integration and co-ordination (nationally and internationally); the exercise of leadership in the public health field; surveillance and response; provision of advice to effect demonstrable positive outcomes for the health of the public; and making the transition from a primarily 'responsive' stance to a primarily 'preventive' posture.
The greatest diversity of views emerged, perhaps unsurprisingly, in relation to the issue of the possible creation of a hub and how it would work with a range of other facilities within and outside PHE. There was broad consensus on the strategic-level prerequisites for the establishment of a hub (eg robust leadership, common narrative, careful design and so on). Equally, the possible advantages offered by standardisation, cross-fertilisation and economies of scale were also widely recognised. The greatest disparity of views was in relation to the question of whether the establishment of a physical hub would be necessary or beneficial or whether a virtual hub could be just as effective. The question of 'where' (as well as 'whether') was particularly prominent as many respondents could see the merits of physical location, but only providing that the geographical location was appropriate (ie collocated with other relevant bodies and with easy access to other organisations and governmental partners).

The final discussion area related to uncertainties and those issues that were considered core areas of concern by interviewees. These included: the emergence of new pathogens; the continuing rise of antimicrobial resistance; organisational challenges; the influence of short-termist policies and the vulnerability of PHE to changeability in national politics; health inequalities; and economic constraints.

**Horizon scanning the literature for future scientific and technology trends**

The literature review allows us to understand the wider empirical and conceptual developments in the field that will impact upon the co-location of laboratory and other public health services. We derived a number of areas from an initial rapid search and early-stage interviews which resulted in eight ‘deep dive’ areas presented in this chapter. These cover both broad areas of scientific and technological capability, and public health challenges in which those capabilities would be utilised. Due to limitations of resource and time, we do not claim these are fully representative of all areas, but they do provide insight in several capabilities which are likely to be needed in some way in the future.

A number of implications for PHE and a series of themes emerge across these areas. The challenges for public health over the next 20 years will be multi-faceted and affect the population at many levels. **Integration of data** will play a significant role. The future will be dominated by many different kinds of data and these will all need to be collected, mined, fused, integrated and managed in order to maximise positive outcomes for public health. Finally, there is no single technology or capability that dominates the field. Multiple platforms will be required, and need to be brought together across both wet and dry laboratory spaces in order to make the most of the data and knowledge that emerge from each space. Each ‘deep dive’ area is summarised in turn below.

**Behavioural science** is important to the future of public health science because the most prominent contributors to death and disease in the UK and globally are related to behavioural factors and non-communicable diseases, particularly tobacco use, diet and activity patterns, alcohol consumption and sexual behaviour. In synthesising the diverse literature, the following future trends stand out: policy planning and design; behavioural nudging; design of intervention trials; ecological modelling; populomics; and data collection, mining and management. The key challenge in mobilising behavioural sciences for PHE rests on the use of inter-disciplinary, locally sensitive and multi-level approaches to solve clinical, high-risk and population-based public health problems.

**Public health informatics** is the systematic application of information and computer science and technology to public health practice, research, and learning. Some of the future trends which will feature include:
bioinformatics and biomedical informatics; privacy and data management; user-led information networking and sharing; and the management of electronic health records. There are two main reasons for the importance of informatics to public health: the availability of new kinds of data and the potential new ways to use the data. In the future not only will scientific data drive public health, but so will patient, clinical and social data. PHE must be able to utilise this in so-called dry lab facilities, which will draw on more traditional wet lab data as well as various other kinds, and there will be corresponding requirements for supporting IT infrastructures.

**Simulation and modelling** provide public health science with means for testing and experimenting with potential improvements and future scenarios. Several types of models might be used in the future, including: models for accountability and management; population effects models; prevalence models; and systems dynamics models. Public health agencies will look to modelling and simulation techniques to understand the ‘future state’ of public health conditions under alternative demographic, economic and technological assumptions.

**Genomics and genetic technologies** can further our understanding of disease risk in the future, support diagnosis and prognosis, enable prioritising preventative or therapeutic options, and develop targeted vaccines or antimicrobials. Genomics can help support the shift to a more predictive and preventive paradigm in public health. The following areas will help to drive the field: stratified medicine and preventative medicine; pathogen genomics, as it continues to track and identify infectious disease; and enhanced technological tools and capacity. The effective application of genetic technologies to public health involves disciplines will range from computer to wet lab scientists, social scientists and public health practitioners.

**Infectious disease** coupled with the rise of antimicrobial resistance (AMR) has been identified as a key public health concern for the UK by the Chief Medical Officer. In order for infectious disease surveillance programmes to be successful, they will need to be comprehensive, integrating data from a wide range of heterogeneous sources and employing advanced technological developments including: improved diagnostic tests; intelligent sensor networks; data mining and fusion; and biosensors and biomarkers. Interventions in the healthcare setting will be important in responding to AMR, such as antimicrobial stewardship, rapid diagnostic tests and aggressive infection control.

**Health improvement** will become an increasingly important area of focus for public health agencies as there are growing health inequalities in England, both in terms of life expectancy and quality of life. Tackling these challenges will require cross-disciplinary methodologies (eg behavioural sciences, informatics, genetic technologies) and a holistic view of how to promote healthy environments and wellbeing.

**Public health emergency preparedness** (PHEP) focuses on ensuring that public health agencies anticipate, assess, prevent and prepare for any major event that has the potential to overwhelm routine capabilities. It is thus both a capability and a future public health challenge that PHE will need to address. The following capabilities will be needed: surveillance; epidemiological and microbiological capabilities; data monitoring using geographical information systems; and risk awareness. PHEP is a holistic capability that cuts across a number of the literature reviews identified above including behavioural science, informatics, modelling and simulation, infectious diseases and AMR.
The ExpertLens

ExpertLens is an online variant of the Delphi approach to stakeholder engagement. The purpose of the ExpertLens was to understand the perspective of a diverse group of stakeholders regarding the relative importance of different public health scientific and laboratory capabilities which might be required in the future.

The central role of integrating different types of knowledge in any future configuration of public health services is clear. Underpinning this knowledge is the different kinds of data that future public health scientists will need to grapple with. Putting in place effective mechanisms for collecting, managing, mining, integrating and translating data into new knowledge will be of central importance. Participants in the ExpertLens confirmed this in their repeated stress on the need to focus not only on centralisation in a physical way, but more crucially, on integration of different kinds of capabilities and knowledge going forward.

Interestingly, given its focal role in the literature review and, to a certain extent in the interviews, there were mixed views on the role of genetic sequencing across different areas of public health. In particular, there was less certainty about its potential importance in relation to health improvement. This sits in contrast to some of the insights from the literature review, which pointed to the role, in some cases the central role, of genetic technologies in the future across many areas.

The exercise also allowed for a set of issues around the hub itself to emerge. In the discussions these issues were less related to the nature of the capabilities a hub might enable, and more about the characteristics which would enable success. Here, participants highlighted the need for a strong vision for PHE, which in turn would inform the nature of the hub, as well as the importance of continued discussions about how a hub would be implemented. Participants felt that one should not precede the other, but rather the two must go forward hand-in-hand.

Cross-cutting themes and findings

During the course of the study it became clear that there are a series of both strategic enablers and operational platforms which will allow for PHE to deliver across the three domains of public health: health protection, health improvement and health services. The strategic enablers which emerged comprise different, often overlapping component parts, and may be loosely defined as follows:

- **Integrated knowledge flows.** This relates to the flow of information, skills and best practice between individuals and groups, underpinned by various different types of data, its storage, integration, interrogation, analysis and sharing.

- **Leadership and management.** This relates to the provision of strong, committed direction which embodies the corporate mission, motivates and guides PHE’s people, and makes and delivers on long-term strategy to meet emerging needs.

- **Scientific capabilities.** This relates to the various disciplines and domains that allow the Agency to prosecute its mission and to their integration in a multi-disciplinary, collegiate context.

For PHE to be successful, all three strategic enablers will be required, to a greater or lesser extent, at all times. Under differing circumstances, though, the various elements will, naturally, assume greater or lesser
importance, or may require particular attention or enhancement. In any case, the relative extent of each enabler is less important than the interplay between them.

In reality the balance may shift in a dynamic way in relation to a broader set of contextual conditions in which PHE operates. To this end, a set of operational platforms are also required which can be called upon and utilised in various ways depending on the demands placed upon PHE and the public health infrastructure in the future. These operational platforms will provide the capabilities, capacity, methodologies/techniques, technologies and resources for this task. These capabilities and supporting elements are drawn from across all the activities of this horizon scan and are summarised in full in the final chapter of this report.

The three strategic enablers, the operational platforms and the elements which support all of it are critical factors in the successful establishment of a hub. The interplay between these three areas will represent the core constituents of PHE's future success, as shown in the figure here.

However, one of the most important take-away messages of our study relates to the question of a hub: interdisciplinary efforts will drive the future, and just as these interdisciplinary efforts will manifest in different ways, so too will the concept of co-location. Co-location is itself multi-faceted. It can be virtual, networked or physical; centralised, decentralised or interconnected. Each one of these facets will be important in some way for PHE to consider. Integrated knowledge flows, the ability to draw on the supporting scientific capabilities and the constant, guiding role of strategic leadership and operational management will be crucial, whatever kind of co-location is sought.

In this sense, co-location is not about physical centralisation of capabilities so much as it is about the integration of all of PHE’s collective resources. PHE will need to consider the need to conduct and provide public health science activities itself, alongside its role in enabling others to conduct public health science activities and helping to shape the future. It must, crucially, integrate both aspects together. These considerations and the balance between them will drive many of the future decisions which are necessary.

This also suggests that there is a wider role public health science alongside PHE in the future. Not only will PHE have to consider the right balance of its activities, but the field as a whole could collectively consider where capabilities are overlapping, mutually supporting, complementary, or duplicative. To this end, a wider system mapping might be beneficial in order to understand where expertise, capacity and capability already exist, and therefore where synergies might be maximised and duplicative efforts removed.

Protecting and improving the public’s health and wellbeing are substantial, multifaceted tasks, and ones which require not only national, but international perspectives and cooperation. PHE must balance its
role in enabling, doing and integrating public health science. It must consider where it makes sense to act on its own versus leading a more networked approach. The individual scientific capabilities, techniques, tools and associated elements identified in this report can help to enable this. They will cut across each other and intersect in various ways and their overlap and interplay will vary depending on the type of public health challenges faced. All capabilities will support different operational platforms, which will require strategic integration of knowledge flows in order to optimise the efforts. Strong leadership must guide the efforts. The subtle interplay of all of this should be considered together in any future decisions.
Acknowledgements

The authors would like to thank Julian Brookes and his team at Public Health England for facilitating various aspects of the data collection stages. We would also like to thank all the interviewees and participants in the ExpertLens exercise for their time and insights. Dmitry Khodyakov provided invaluable support and guidance on conducting the ExpertLens exercise.

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<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>AMR</td>
<td>Antimicrobial Resistance</td>
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<tr>
<td>ARS</td>
<td>Agences Regionales de Santé</td>
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<tr>
<td>ASTA</td>
<td>Applied Science and Technology Abstracts</td>
</tr>
<tr>
<td>BSE</td>
<td>Bovine Spongiform Encephalopathy</td>
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<tr>
<td>CIRE</td>
<td>Network of Regional Epidemiology Units (Cellules interregionales d’épidémiologie)</td>
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<tr>
<td>CDC</td>
<td>US Center for Disease Control</td>
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<tr>
<td>EHR</td>
<td>Electronic Health Records</td>
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<tr>
<td>EL&amp;I</td>
<td>Dutch Ministry of Economic Affairs, Agriculture and Innovation</td>
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<tr>
<td>EPRR</td>
<td>Emergency Preparedness, Resilience and Response</td>
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<tr>
<td>GGD</td>
<td>Dutch Municipal Health Services (Gemeenschappelijke Gezondheidsdienst)</td>
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<td>GIS</td>
<td>Geographical Information Systems</td>
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<td>HPA</td>
<td>Health Protection Agency</td>
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<td>HHS</td>
<td>US Federal Department of Health and Human Services</td>
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<tr>
<td>I&amp;M</td>
<td>Dutch Ministry of Infrastructure and the Environment</td>
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<td>ICT</td>
<td>Information and Communications Technology</td>
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<tr>
<td>INPES</td>
<td>National Institute for Prevention and Health Education (Institut national de prévention et d’éducation pour la santé)</td>
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<tr>
<td>InVS</td>
<td>Institute for Public Health Surveillance (Institut de Veille Sanitaire)</td>
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<td>ISN</td>
<td>Intelligent sensor networks</td>
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<tr>
<td>MHRA</td>
<td>Medicines and Healthcare Products Regulatory Agency</td>
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<td>MSB</td>
<td>Swedish Civil Contingencies Agency</td>
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<tr>
<td>NHS</td>
<td>National Health Service</td>
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<td>NICE</td>
<td>National Institute for Health and Care Excellence</td>
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<td>Acronym</td>
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<tr>
<td>NIPH</td>
<td>Swedish National Institute for Public Health</td>
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<td>PHAC</td>
<td>Public Health Agency of Canada</td>
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<td>PHE</td>
<td>Public Health England</td>
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<td>PHEP</td>
<td>Public Health Emergency Preparedness</td>
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<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
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<tr>
<td>RDA</td>
<td>Regional Development Agency</td>
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<td>RHA</td>
<td>Regional Health Administrator</td>
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<td>RIVM</td>
<td>National Institute for Public Health and the Environment</td>
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<td>RKI</td>
<td>Robert Koch Institute</td>
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<td>SMS</td>
<td>Specialist Microbiology Services</td>
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<td>VWS</td>
<td>Dutch Ministry of Health, Welfare and Sport</td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<td>ZBS</td>
<td>Centre for Biological Threats and Special Pathogens (Zentrum für Biologische Gefahren und Spezielle Pathogene)</td>
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1. Introduction

**Chapter summary**

This report is the synthesis of the findings of a horizon scanning study on the future of public health and its related scientific and laboratory capabilities and services.

This work was intended to help inform thinking at the strategic level within Public Health England (PHE), firstly in relation to the wider vision of the Agency (which was only established in April 2013) and, secondly, in relation to the proposals for the creation of an integrated public health science hub within a network of facilities across the country. PHE is responsible for a broad range of health promotion, protection and surveillance activities and research and science are core to the organisation’s function and success. As the organisation’s activities evolve it needs to address future public health science needs. This chapter explains how this report contributes to that endeavour and sheds light on the extent to which an integrated science hub could serve PHE as it evolves. The concept of a public health science hub and network had been under consideration by the Health Protection Agency (HPA) before it became part of PHE earlier this year. HPA’s Chrysalis Programme had considered the possible co-location of microbiological services on a new site and PHE has inherited this programme of work and continues to explore further the possible benefits and challenges associated with the hub and network concept.

The study was commissioned by PHE and carried out by RAND Europe in July 2013. It involved a structured literature review, a series of key informant interviews and a brief Delphi exercise using the ExpertLens platform.

1.1. Background to the study

The science and technology associated with health protection, promotion and services is constantly changing. It follows that the organisational structures and physical facilities used by researchers and professionals working in this area require periodic updating and adaptation.

This report is based on RAND Europe’s response to a request from Public Health England (PHE) for a horizon scanning exercise on future public health scientific and laboratory capabilities and services. This would help to inform thinking at the strategic level within PHE, both in relation to its wider vision and to proposals to create an integrated public health science hub and network of facilities around the country. The report is based on a literature review and key informant interviews with a range of PHE staff and external experts on the different future public health science needs and the extent to which an integrated science hub could serve PHE as it evolves over the next twenty years. Thus, the report looks at PHE’s future remit and objectives in order that decisions about an integrated and co-located science hub be made in context and with reference to expert perceptions about the future.

PHE’s future vision is evolving and in some respects this complicated the task of thinking about how an integrated science hub would serve the agency in the future. From another perspective, however, carrying
out this work at this juncture is timely, as the findings highlighted in this report can feed into future development of PHE’s vision and mission.

1.1.1. An introduction to Public Health England and background to our study

PHE is an Executive Agency of the Department of Health, tasked with protecting and improving the nation’s health and wellbeing, and reducing health inequalities. The organisation was established in April 2013 as a result of the Health and Social Care Act 2012. This is the first time that responsibilities for public health in all its many forms have been brought together within a national organisation.

PHE is responsible for a wide range of activities. These include:

- improving the health of the public;
- supporting the public to improve their own health;
- protecting the nation’s health through the national health protection service, and preparing for public health emergencies;
- researching, collecting and analysing data to improve an understanding of health;
- reporting on improvements in the public’s health so everyone can understand the challenges and the next steps;
- sharing information with key partners such as local authorities, industry and the NHS.

On 26 April 2013, PHE published its priorities for 2013/14. Within this document PHE identified the importance of taking forward the business case for the creation of an integrated national science centre. This strategic business case is an internal programme, which builds on the existing work inherited from the Health Protection Agency (HPA) – the Chrysalis Programme – but in doing so, ensures that the wider remit of PHE is properly considered. The Chrysalis Programme looked at the co-location of microbiological services on a new site and its findings were summarised in a due diligence report (the Griffin Report).

Given the initial focus on microbiological services as a driver for an integrated science hub, it is worth briefly reflecting on their particular role in achieving PHE’s remit of public health protection. PHE operates eight specialist clinical laboratories across England that provide Specialist Microbiology Services (SMS). These laboratories deliver a comprehensive range of clinical diagnostic and public health microbiology tests and services to the NHS and allied healthcare providers sector. A lead public health laboratory is designated for each of the English regions where they act as collaborative hubs effecting comprehensive geographic coverage in pursuit of core public health objectives. Microbiology services are now part of the Operations Directorate at Public Health England, based both at Colindale and Porton Down.

As part of its health protection responsibilities, PHE is responsible for overseeing the upgrade of Containment Level 4 Laboratories in England. In the course of this process, a case was made for relocating two current SMS facilities in Porton Down and Colindale to a single site, thus creating an integrated public health science hub. Traditionally, Colindale has focused on preparing for and responding to health threats by providing specialist and reference microbiology services and high containment microbiological research and reference capabilities. Porton’s remit includes specialist and
reference microbiology services for high containment pathogens, translational research programmes and the manufacture of biopharmaceutical products. Manufacturing facilities are expected to remain at Porton Down whatever the eventual decision about an integrated science hub and network of facilities.¹

1.1.2. Study Scope

Our horizon scanning work expands beyond the focus on microbiological services to consider the broader remit and public health functions of PHE, including health improvement and delivery of public health services. In doing this, it brings to the surface a series of questions about broader benefits, challenges and opportunities that might be associated with co-location in light of scientific and public health trends and developments. These questions need to be considered not only in relation to present challenges and opportunities, but also in light of the future evolution of the wider science and technology landscape, socio-political context, and organisational and management practices and strategies. For instance, it is possible that new scientific and technological developments could alter what constitutes excellent practice and the social and organisational arrangements needed to maximise the potential of new science and IT related to microbiological and other public-health services. Similarly PHE is actively developing new disease and health management strategies which may necessitate the broader developments of networks, novel management strategies and organisational reconfigurations. Furthermore, the development of new approaches to managing the relationship between infectious and non-communicable diseases may require PHE to amend its working practice and structures to enable it to deliver on its broader aims, objectives and ambitions. Throughout, PHE needs to be flexible enough to respond to enduring elements of its mandate, eg protecting the linkages between national and field microbiological services, while demonstrating the ability to adapt to new developments. Our study sought to understand these types of issues in the context of what the future might require of public health science and related laboratory facilities.

The study methodology is described in detail below but revolved around three key activities: literature review; interviews with ‘key informants’; and the ExpertLens Delphi-based exercise, and the report provides a synthesis of key findings in each area. Although the various elements of the study were undertaken simultaneously, the primary source activities are covered first with the synopsis of the literature review provided subsequently to add depth and context to stakeholder views. The debate surrounding co-location as well as the international dimension (a necessarily brief and schematic overview of what similar public health services look like in other countries, including the US, Canada and other European countries) are also covered. Finally the report seeks to signpost some of the key themes for consideration and attempts to capture important aspects of the future interplay of science/technology on the one hand and organisational/management factors on the other. The report makes no attempt to suggest how PHE should be best configured to respond to future needs and developments, nor should it be considered as a substitute for a wider consultation exercise with those potentially affected by organisational change. Rather, it is intended as a forward-looking ‘think piece’ aimed at stimulating

informed discussion regarding both the future of PHE and the possible ways in which the public health domain may evolve.

1.2. Methodology

Our research was carried out to a very tight timeframe. The initial meeting took place on 26 June 2013, with the report being due in the week commencing 12 August. In the light of the time constraints we worked to identify priority issues and cover the fundamental aspects of a horizon scanning exercise. We worked closely with PHE in organising and scoping the research so that it focussed most closely on those areas which would be of use and interest however it was not possible to treat the topic comprehensively in the way that a fuller, longer study might permit.

1.2.1. Science and technology trends assessment and review of associated organisational and management issues

This phase of work involved an adapted horizon scanning exercise, including a structured literature review and key informant interviews. Horizon scanning is a technique for detecting early signs of potentially important developments through a systematic examination of potential threats and opportunities, with emphasis on new technology and its effects on the issue at hand. It explores novel and unexpected issues as well as persistent problems and trends, including matters at the margins of current thinking that challenge past assumptions.

In thinking about the creation of an integrated science hub, horizon scanning provided the basis for understanding the key issues related to the evolution of public health needs on the one hand and science, technology and services on the other. A brief overview of the different research techniques that underpinned this report is provided below. Horizon scanning exercises can be done on a much wider scale, but due to the constraints of this exercise the work we did was tightly focused, whilst still drawing on the core principles of a more traditional exercise. Thus, we refer to the work involved in this report as an adapted horizon scanning exercise simply due to the timescales involved and the need for rapid reporting.

Literature review

Following a broad search of relevant literature and drawing on the initial interviews, the study team identified several bodies of literature that were particularly relevant to PHE’s evolving remit and decision making around a co-located scientific hub. As a prelude to the more detailed literature searches, we constructed a matrix with PHE directorates and core areas of responsibility set along the vertical axis, with PHE areas of delivery activity depicted along the horizontal axis. This matrix (included in Appendix D) allowed us to identify key areas of both public health need and scientific activity for PHE.

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2 The data gathering for the literature review took place throughout July 2013. The first interview was conducted on 3 July with all but one of the interviews having been completed by 31 July. The ExpertLens process began on 29 July and completed on 5 August 2013.

3 See Chapter 2 for a more detailed description of the literature review methodology.
After sharing this initial matrix with PHE, we clustered these issues around key domains and focussed our literature review efforts on so-called ‘deep dives’. These involved more structured literature searches of peer-reviewed and grey literature in the following domains: health improvement, behavioural sciences, informatics, simulation and modeling, infectious disease, antimicrobial resistance, genetic technologies, and public health emergency preparedness.

**Phase 1: Interviews**

The study team conducted semi-structured telephone interviews with 26 experts. Of these, 15 were from PHE and the remaining 11 from various universities, NHS Foundation Trusts, Institutes, the Department of Health and the Medicines and Healthcare Products Regulatory Agency (MHRA). We asked PHE for recommendations for interviewees from within and outside the Agency. Several additional interviewees were suggested by members of the RAND Europe team.

An interview protocol (see Appendix B) guided interviews, which usually lasted between 30 and 45 minutes. The protocol gave us the basis for ensuring that interviewees were asked a standard set of questions but we took a flexible approach so that interviewees were able to focus on their particular areas of expertise or concern. Interviews were transcribed and key extracts/insights are provided at Appendix A.

**Phase 2: ExpertLens**

ExpertLens is a modified Delphi technique that allows participants to interact with each other online around a structured set of questions and discussion topics. The process allows relatively large groups of geographically dispersed individuals to engage with each other around particular issues and questions. The process is structured in the sense that participants are asked a set of common questions but the discussion phase of the exercise allows for a more open dialogue. Figure 1-1 below provides an overview of the ExpertLens process:

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Figure 1-1 Description of the ExpertLens process

Study team members drew on the interviews and literature review to compile the set of ExpertLens questions (see Appendix C). Participants were notified that all contributions would be made in anonymity. Because of the tight timeframe of the project, the ExpertLens was run over the course of a week (the process is usually run over two or three weeks). In total, 118 PHE and external stakeholders were invited to participate in the exercise. A total of 51 participants completed Round 1. In Round 2, 50 comments and 7 threads were posted by 27 participants in (and a further 3 participants logged in to view the discussion). Round 3 was completed by 39 participants.

1.3. Structure of the report

The report is structured around the data we have collected and designed to capture qualitative feedback and results from the ExpertLens. Chapter 2 provides some contextual insight into the way in which a) public health services are organised in other countries and b) recent debates in the literature on the issue of co-location of research and services. Chapter 3 provides feedback from the interviews and is structured around the key themes that emerged. Chapter 4 details results of the ‘deep dive’ literature search and provides insight into key aspects of future science, technology and organisational/institutional features in relation to each theme. Chapter 5 documents the results of the ExpertLens (which drew on both the interviews and literature reviews). Chapter 6 pulls together key themes that have emerged out of the study and draws out the intersections.
2. Insights in context

Summary of chapter insights
This chapter sets the horizon scanning study in context. We first present a study of international comparator public health agencies in Europe and North America. We review organisational and management structures for international health models in Canada, France, Germany, the Netherlands, Sweden and the United States and highlight national level agencies which appear to be most relevant as comparators for the future PHE. Four primary insights emerged from this review:

- Several comparator countries have a central agency or department to undertake data collection and surveillance, but their responsibility for wider public health functions varied. There are a range of organisational models for public health systems, and, moreover, for the role of a national public health agency within these systems.
- While the countries reviewed benefit from centralising their public health efforts and expertise within a single organisation or network of collaborating institutions in order to provide effective, coordinated leadership of public health, there is little precedent for a fully integrated national public health agency. Where they do exist, the institutes have limited capacities and capabilities relative to the need across all areas of public health responsibility.
- The national public health agency of any country is usually part of a wider infrastructure that includes other national and sub-national organisations. In many cases, whether under a centralised or decentralised public health system, a central institute works to collect surveillance information, conduct research and provide resources to national and local government.
- Regardless of the specific model, the international examples suggest a consensus for a national level institute or agency to deliver population health surveillance functions and coordination of research evidence for health promotion activities.

Second, we reviewed the literature on co-location and clustering of different scientific and technological capabilities. The review summarises the benefits, challenges and opportunities of co-location and clustering policies. The benefits of co-location include: enabling the exchange of tacit knowledge; helping to build trust and social capital; creation of a ‘local buzz’ and an atmosphere of collegiality and collaboration; outcomes of localised learning; the potential for economic externalities and knowledge spillovers to occur; and enhanced absorptive capacity.

However, all of these benefits are contingent upon appropriate policies and conditions for clustering, both nationally and organisationally. The conditions which must be considered include: the presence of factor conditions (human, physical, knowledge, capital and infrastructure resources); the need for demand conditions in the public health research ‘market’; the presence of supporting industries; the role of a clear strategy and structure; and the importance of chance events. The interplay between these conditions is not always straightforward to determine, which has led to a backlash against clustering and engineered co-location in recent years. Clearly careful consideration is needed in order to maximise the opportunities and benefits co-location can provide.
2.1. Contextualising the co-location debate

In order to contextualise the horizon scanning exercise and to illuminate the rationale for an integrated public health science hub we undertook wider research activities in conjunction with reviewing literature on public health science. Firstly, we studied country comparators in Europe and North America to examine the organisational and management structure of public health organisations outside the UK. Secondly, we undertook a literature review on the rationale for the co-location of organisational, management and research functions. The purpose of the review was to provide a conceptual context for co-location debates and broadly to understand the benefits of co-location, clustering and agglomeration activities through a reading of academic literature and relevant case studies.

2.2. Comparison of international public health models

To position PHE in a wider context we looked across six European and North American countries to understand the organisation of national public health agencies. These countries were chosen to present a spread across more centralised and more decentralised health systems, looking at how the public health function is distributed at a national and local level and what national level support functions are available. Our comparison exercise drew upon online material from different public health organisations, policy documents, academic literature and discussions with key informants in the field of public health science.

For each country we provide an overview of the public health system, and provide further information on the one or two national level agencies or departments which appear to be most relevant for the future PHE. The evidence collated shows that several comparator countries have a central agency or department to undertake data collection and surveillance, but their responsibility for wider public health functions varied. To ensure a consistent approach to our analysis we have categorised the functions performed by a central agency on the basis of five core Essential Public Health Operations, as defined by the World Health Organisation European office:

- Surveillance of population health and wellbeing
- Monitoring and response to health hazards and emergencies
- Health protection including environmental, occupational, food safety and others
- Health promotion including action to address social determinants and health inequity
- Disease prevention, including early detection of illness

An overview of the functions provided by each agency or department is provided in Table 2-1.\(^5\)

\(^5\) Note that this is an illustrative table and the distinctions between responsibilities are indicative and are not always clear-cut in the documentation we reviewed.
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Table 2-1 Overview of national agencies and departments with public health responsibilities

<table>
<thead>
<tr>
<th>Country</th>
<th>Agency</th>
<th>Population health surveillance</th>
<th>Emergency response</th>
<th>Health protection</th>
<th>Health improvement/promotion</th>
<th>Disease prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Public Health Agency of Canada (PHAC)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>France</td>
<td>Institute for Public Health Surveillance (InVS)</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>National Institute for Prevention and Health Education (INPES)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>Robert Koch Institute (RKI)</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>National Institute for Public Health and the Environment (RIVM)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>Swedish National Institute of Public Health</td>
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<tr>
<td></td>
<td>Swedish Institute for Communicable Disease Control</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>The Centers for Disease Control and Prevention</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

The following sections provide further information and background about each organisational structure of comparator agencies in other countries and the way in which they deliver the responsibilities outlined above.

2.2.1. Canada

Responsibility for public health is split between provincial and national governments. The federal government provides a broad range of public health services principally through the Public Health Agency of Canada (PHAC) (see below for further details). Meanwhile, federal/provincial/territorial governments all appoint a chief public or medical health officer to lead their public health efforts in their respective jurisdictions and provincial ministries of health all have public health branches (some even have a separate public health agency or department) with responsibility for the six discrete functions of public health. All provincial and territorial ministries of health devote resources to infectious disease control, including immunization planning and programming, as well as screening for chronic conditions, such as cancer screening. However, given the geographical reach of infectious diseases and the rapidity with which they spread, the federal government has begun to play a larger role in both control and surveillance.  

Public Health Agency of Canada

The PHAC coordinates, at least in part, the six public health functions:

- population health assessment

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7 Ibid.
• health promotion
• disease and injury control and prevention
• health protection
• surveillance and emergency preparedness
• epidemic response.

The primary mission of PHAC is to strengthen Canada’s capacity to protect and improve the health of the national population and to help reduce pressures on the healthcare system. As part of this mandate, PHAC’s role is to promote health; prevent and control chronic diseases and injuries; ensure that Canada is adequately prepared to respond effectively to public health emergencies; service as a central point for sharing Canada’s expertise with the rest of the world; apply international research and development to Canada’s public health programmes; and strengthen intergovernmental collaboration on public health and facilitate national approaches to public health policy and planning. PHAC is also committed to reducing health disparities between the most advantaged and disadvantaged Canadians.

PHAC is responsible for reporting back to the WHO and other relevant international bodies on disease surveillance activities. PHAC also administers a network of disease-control laboratory services such as the National Microbiology Laboratory. PHAC is responsible for funding and administering a number of public health programmes, some of which emphasise the social determinants of health, including the Aboriginal Head Start Program, the Canada Prenatal Nutrition Program and the Healthy Living Strategy, and illness prevention programmes for AIDS and tobacco reduction.8

PHAC is one of six departments and agencies that make up the federal government’s Health Portfolio and reports to Parliament through the Minister of Health. PHAC is managed by the Chief Public Health Officer of Canada and is made up of three main branches, each led by an Assistant Deputy Minister: Infectious Disease Prevention and Control; Health Promotion and Chronic Disease Prevention; and Emergency Management and Corporate Affairs. PHAC’s headquarters are organised in two locations: one is in Ottawa, and the other is the National Microbiology Laboratory in Winnipeg, Manitoba. This is also the location of Canada’s only Level 4 microbiology laboratory for human health. PHAC has approximately 2,700 employees working across Canada.

PHAC was created in 2004 following a series of reports critical of the country’s response to the 2002–2003 outbreak of SARS. The government presented the PHAC as a pro-active pan-Canadian public health agency that would provide a robust response to emerging outbreaks of infectious disease and other public health threats. Administrative functions related to setting standards and regulation remained with Health Canada, whereas evaluation and response to both infectious and non-infectious problems were consolidated into PHAC.

2.2.2. France

The Ministry of Health (Ministère des Affaires sociales et de la Santé) is responsible for providing overall guidance on health-related issues on the basis of governmental policies. It is responsible for defining

8 Ibid.
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health policies and for assessing the 100 objectives defined by law in August 2004. The Secrétariat Général des Ministères Sociaux, based in the Ministry of Health coordinates the Regional health agencies (Agences Regionales de Santé (ARS)), decentralised agencies in each of the 24 French regions which are responsible for implementation of the national public health policies at regional and local level. The ARS participate in regional assessment as well as protection and promotion of population health.

Institute for Public Health Surveillance

The French Institute for Public Health Surveillance (Institut de veille sanitaire (InVS)), a governmental institution reporting to the Ministry of Health, is responsible for surveillance and alert in all domains of public health. Created on 1 July 1998, to reinforce health surveillance and the safety of products intended for human use, its mandate was enlarged by the Public Health Policy Act of 2004, in order to meet the new challenges highlighted by recent health and emerging risks. InVS is headquartered in Saint-Maurice Cedex, and is made up of five scientific departments, focusing on infectious diseases, environmental health, occupational health, chronic diseases and injuries and international and tropical diseases. InVS’s activities include:

- continuous monitoring of the population’s health status. Collecting and analysing population health data for epidemiologic purposes, working with the public and private partners who make up the national public health network
- health surveillance, collecting, analysing, and updating knowledge about health risks and threats
- informing the Minister of Health as soon as possible of any threat to the health of the population or any population group, whatever the origin of this threat, and recommending appropriate measures or actions to prevent it or reduce its impact
- managing emergency health situations.

The institute gathers information from various sources, including national monitoring systems that rely on networks of professionals, mandatory reports of some diseases by health professionals, as well as a network of regional epidemiology units (cellules interregionales d’épidémiologie (CIRE)) which are located within the ARS. In addition to coordinating regional health surveillance, the CIRE provide methodological support to the decentralised state agencies. There are 17 CIRE, 15 in metropolitan France and two overseas.

National Institute for Prevention and Health Education (Institut national de prévention et d’éducation pour la santé (INPES))

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13 Ibid.
INPES is a public health institute created in 2002. The core mission of INPES includes provision of expertise and advice on prevention and health promotion; development of health education; and implementation of prevention programmes.

2.2.3. Germany

The responsibility for public health services in Germany rests mainly with the federal states (Länder). The Länder are supported at the national level by The Federal Ministry of Health and supporting agencies specialising in communicable disease, health education and environmental health:

- Federal Institute for Pharmaceuticals and Medical Products
- The Institute for Communicable and Non-communicable Diseases (The Robert Koch Institute)
- The Federal Centre for Health Education
- The German Institute for Medical Documentation and Information
- Advisory Council for Concerted Action in Health Care.

The Robert Koch Institute

The Robert Koch Institute (RKI) is the central federal institution responsible for disease control and prevention and is therefore the central federal reference institution for both applied and response-orientated research as well as for the Public Health Sector.

The tasks of the Robert Koch Institute comprise:

- the identification of politically important health problems and associated scientific issues
- applied and response-orientated research to resolve these issues
- the assessment of scientific results through analysis of current international developments in the respective scientific areas
- informing and the advising political decision makers and the scientific sector
- executive tasks defined by special laws, in particular with regard to protection from infection, legislation on stem cell research, and attacks using biological agents
- the topical realisation and coordination of federal health reporting.

The RKI is made up of three main departments covering 1) Infectious Diseases, 2) Epidemiology and Health Monitoring, 3) Infectious Disease Epidemiology, together with the ZBS: Centre for Biological Threats and Special Pathogens and additional project and research groups. There are about 990 employees of the RKI, including 390 scientists (including graduate students and trainees). In addition, there are numerous undergraduate students. In addition, all German National Reference Centers for monitoring important disease pathogens are administered by the RKI.

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2.2.4. The Netherlands

Public health activities in the Netherlands are predominantly carried out at the municipality level. Disease prevention, health promotion and health protection fall under the responsibility of municipalities. There are 29 municipal health services (GGDs) that carry out these tasks for the 443 municipalities. The services covered differ between GGDs, since each municipality gives its own directions to the local GGD; however all GGDs also have a number of uniform tasks, which include:

- child health care
- environmental health
- socio-medical advice
- periodic sanitary inspections
- public health for asylum seekers
- medical screening
- epidemiology
- health education
- community mental health.

At a national level, the Ministry of Health, Welfare and Sport enacts legislation and offers guidance to municipalities. In 2001, the National Contract for Public Health Care was signed by the Minister of Health Welfare and Sport, the Minister of the Interior and Kingdom Relations, the municipalities and GGD Nederland (the Association of Municipal Health Services) and sets the main priorities to strengthen public health infrastructure, to reduce health inequalities and to encourage healthy lifestyles.

Public health efforts are supported by several agencies:

- The Council of Public Health makes recommendations for public health programmes.
- The National Institute for Health Promotion and Disease Prevention develops preventive measures and methodology.
- The National Institute for Public Health and Environmental Issues (RIVM) conducts research and monitoring of health indicators and environmental indicators.

The National Institute for Public Health and Environmental Issues (RIVM)

The RIVM conducts research and provides scientific oversight in the area of public health, the environment and nature. The institute is an independent branch of the Ministry of Health, Welfare and Sport (VWS). It also works on behalf of the Ministry of Infrastructure and the Environment (I&M) and the Ministry of Economic Affairs, Agriculture and Innovation (EL&I).

RIVM has about 30 separate units (laboratories, teams and centres) each of which has a specific research task. These units are grouped within four divisions, each of which has a division director. RIVM has

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18 Allin et al., Op Cit.
approximately 1,500 staff in total. RIVM is responsible for providing impartial and reliable information to support the Dutch government in formulating its policy, as well as to members of the public and professionals who work in the fields of healthcare, infectious diseases, medicine, the environment, and nutrition and safety.

2.2.5. Sweden

In Sweden the county councils (independent regional government bodies) are responsible for public health provision. The department of public health within each county council plans services, based on epidemiological data. At a national level, the Ministry of Health and Welfare is responsible for regulation and setting policy frameworks.

Public health efforts are supported by a number of national agencies:

- The National Institute for Public Health (NIPH) is responsible for health promotion, disease prevention and reducing inequalities.
- The National Public health Committee assists in developing national strategies.
- The Commission on National Targets guides the formation of health targets.
- The National Board of Health and Social Welfare publishes a national public health report every 3 years, describing patterns of health and disease, living conditions and risk factors, and the distribution of health resources.
- Swedish Institute for Infectious Disease Control monitors the epidemiological situation of communicable disease and promotes protection against such disease.
- Swedish Civil Contingencies Agency (MSB) enhances and supports societal capacities for preparedness and prevention of emergencies and crises.

The Swedish National Institute for Public Health, Sweden

The Swedish National Institute for Public Health is a state agency, under the Ministry of Health and Social Affairs, tasked with promoting health and preventing disease and injury. An emphasis is placed on groups that are vulnerable for the most significant health risks. The three main tasks of the Institute are:

- To monitor and coordinate the implementation of the national public health policy.
- To be a national expert agency for the development and dissemination of methods and strategies in the field of public health, based on scientific evidence.
- To exercise supervision in the areas of alcohol and tobacco.

These functions include analysis and research on health risk factors, health promotion and health economics, and dissemination of this research to municipalities, county councils, and the non-profit sector.20

The Swedish National Institute of Public Health is located in Östersund, a city situated about 600km northwest of Stockholm. The Institute has about 160 employees and is headed by Director-General Sarah Wamala.

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The Swedish Institute for Communicable Disease Control

The Swedish Institute for Communicable Disease Control is a government expert authority whose mission is to monitor the epidemiology of infectious disease and promote control and prevention of these diseases. The Swedish Institute for Communicable Disease Control gives expert advice and support to local, regional and central authorities with operative or political responsibilities for infectious disease control. In 2010, The Swedish Institute for Infectious Disease Control took responsibility for the day-to-day operational work of planning, coordinating, evaluating and monitoring the preventive efforts against HIV and other Sexually Transmitted Infections.

2.2.6. United States of America (US)

The public health infrastructure of the US is comprised of many different organisations. Although there is some responsibility for public health functions at all levels of government (federal, state and local), primary authority for regulation and oversight of public health in the US rests with individual states. This activity can be influenced by the federal government through funding decision and setting of national policy, and states can delegate authority for some functions to local governments.

The following entities comprise the public health infrastructure in the US:

- About 3,000 county and city health departments and local boards of health
- 59 state, territorial, and island nation health departments
- Various U.S. Public Health Service agencies in the Department of Health and Human Services
- Tribal health agencies, coordinated at the Department of Health and Human Services by the Indian Health Service
- More than 160,000 public and private laboratories
- Hospitals and other private-sector healthcare providers
- Volunteer organizations, such as the American Red Cross, American Diabetes Association, American Cancer Society, and others.

At a national level, HHS is the US government’s principal agency for protecting the health of all Americans. Within HHS, the primary agencies responsible for public health are:

- the Centers for Disease Control and Prevention
- the Health Resources and Services Administration
- the National Institutes of Health
- the Food and Drug Administration
- the Agency for Healthcare Research and Quality.

Primary leadership for public health policy within the Department of Health and Human Services rests with the US Surgeon General (the head of the US Public Health Service) and the Centers for Disease Control (CDC). The Department of Health and Human Services works closely with state and local

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22 Ibid.
governments, and many HHS-funded services are provided at the local level by state or county agencies, or through private sector grantees.

Regional Health Administrators performs essential functions for the Department of Health and Human Services in three major areas: prevention, preparedness and agency-wide coordination. These functions directly and indirectly support the work of the Department and the individual federal agencies. The Regional Health Administrators promote real-world implementation of the Department of Health and Human Services’ broad prevention mission and specific prevention initiatives in the field.

The Centers for Disease Control and Prevention

The Centers for Disease Control and Prevention (CDC) is a federal agency of the Department of Health and Human Services which provides national leadership on many public health matters. The CDC’s main functions include provision of a system of health surveillance to monitor and prevent disease outbreaks (including bioterrorism), implementation of disease prevention strategies, and maintenance of national health statistics. In addition, it has responsibility for health promotion, developing public health policies and providing leadership, education and training. In order to deliver on its mission, the CDC collaborates with a diverse set of local, state and international partners to prevent, monitor, investigate and resolve the wide range of complex health issues facing the US and global communities. CDC has also provided the leadership and technical expertise to build the Ministry of Health to a capacity that can establish and maintain key public health infrastructure, such as national laboratory networks, which are essential to any health system, enabling disease detection and response to numerous diseases and emerging health threats.

The CDC was founded in 1946 and is headquartered in Atlanta, Georgia. CDC has more than 15,000 employees in nearly 170 occupations. Field staff are assigned to all 50 states and more than 50 countries. CDC’s FY 2012 Operating Budget is approximately $6.9 billion.

2.2.7. Organisational models of public health agencies

As demonstrated in the international examples set out above, there are a range of organisational models for public health systems, and the role of a national public health agency within these systems. While we found that many of the agencies or institutes studied provided public health research and information, there were differences in the range of functions provided, the degree to which the institution operated within or on behalf of the national government, and the degree of collaboration with local government.

First, we found that national public health agencies elsewhere are science and research-based agencies, which may be within or outside of national governments, who are responsible for directing and managing a nation’s public health efforts as well as providing a critical component of global disease prevention and response systems. The core functions include: surveillance for diseases and injuries, including risk factors; epidemiological investigations of health problems; public health research; and response to public health emergencies and outbreaks. These agencies typically act as a centre of public health leadership and coordination in a country. They are responsible for developing science-based policies, monitoring and


24 Ibid.
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responding to changing patterns and determinants of health and disease, and (in countries with low resources) coordinating the use of donor funds to meet national public health priorities. They are often critical to countries’ efforts to address major public health challenges both within and beyond their borders. They work in partnership with other agencies, sub-national levels of government, academic institutions and non-profit organisations; and they coordinate with other national and multilateral organisations to address global or regional threats.

Second, it seems that many countries benefit from centralising their public health efforts and expertise within a single organisation or network of collaborating institutions in order to provide effective, coordinated leadership of public health. In order to be effective, public health agencies must have adequate human, financial, and infrastructure support and good links with key organisations within the country and internationally. Given the nature and scope of their activities, public health agencies are a vital asset to health development and protection. Many countries, however, still do not have an integrated national public health agency or have institutes with severely limiting capacities and capabilities relative to the need. Even in countries with a strong centralised public health agency, unpredictable and rapidly evolving health threats can quickly overwhelm capacity and inhibit a timely and complete response.

Third, in many cases, whether under a centralised or decentralised public health system, we see that a central agency or institute usually works to collect together surveillance information, conduct research and provide resources to national and local government. The degree to which information and analysis is provided to policymakers solely at a national level, or also to regional and local government offices appears to depend upon the degree of centralisation of the public health system. Within this, it is also useful to consider the advantages and disadvantages of placing the leadership for epidemiologic and laboratory investigation of outbreaks in a single organisation, having a single agency focus on both infectious and non-communicable conditions, and maintaining routine or reference laboratory services in a national institute of public health. For example, based on the experience in Canada, where the creation of the Public Health Agency of Canada has manifestly improved the country’s ability to monitor and manage threats to public health, and other nations where similar models have greatly improved national resilience to health problems, it would appear that a strong, consolidated national agency and institutes has the potential for more effective and efficient performance of such public health functions.

Finally, the national public health agency of any country is usually part of a wider infrastructure that includes other national and sub-national organisations. However, there is no single model and the organisational structure, functions, and remit of any national public health agency can vary greatly from country to country. While institutes such as the Robert Koch Institute in Germany provide information primarily at a national level to the federal government, other agencies such as the CDC in the US and the Public Health Agency of Canada work more closely with local public health players to help implement health promotion and disease protection programmes. In France and Sweden, a separate organisation from that conducting surveillance is responsible for health promotion. Therefore, in some cases, there is a large agency that leads national efforts in disease surveillance, outbreak investigation, research, and policy work for infectious and chronic diseases. Some national public health agencies focus only on a core mission of surveillance, laboratory science and applied research while others work as part of an in-country network of public health agencies.
These international examples suggest a strong consensus for a national level institute or agency to deliver population health surveillance functions and coordination of research evidence for health promotion activities, while other functions were less consistently provided by the agencies considered.

2.3. Co-location: reviewing the evidence

This section summarises evidence on the benefits of co-location; that is the advantages firms, organisations and individuals receive from the agglomeration of specific activities in proximity to one another. The review draws primarily upon academic literature from peer reviewed international academic literature. The literature is drawn from a variety of disciplines including business studies, management, organisation studies, economic geography, regional development and economics. The review also covers ‘grey’ policy literature including cluster strategy and policy plans developed by international agencies, central government departments, regional and local development agencies.

There is a considerable body of academic research exploring the benefits and competitive advantages from co-location for firms, regions and nations. The literature is vast in scope, tracing back to Alfred Marshall’s book *Principles of Economics*. Marshall observed that specific kinds of industries tended to agglomerate in specific places. This co-location of specialised activities created specific advantages in the ready availability of skilled labour; the growth of supporting and ancillary trade; and the specialisation of firms in different stages and branches of production.

More recently scholars have mobilised Marshallian ideas on industrial districts to explore the benefits of clustering economic activities for creating knowledge spillovers, building trust, absorbing knowledge, and better networks between firms and individuals. Much of the recent literature falls into two general categories. Firstly, case studies of how clusters originated and how they develop highlighting successful example of co-location (eg Silicon Valley, Hollywood, ‘Third Italy’). Secondly, more conceptual research papers about the proposed benefits of co-location to firms and organisations. The review here synthesises both categories of literature.

The review seeks to focus primarily on the benefits of co-location to a public sector organisation rather than to firms. This is challenging because much of the literature examines the economic benefits that can be gained from co-location in terms of enhanced capacity for innovation, productivity, economic externalities and competitive advantages. The main unit of analysis for much of the literature is the firm, and research unpacks the advantages that firms can gain from co-location. The review here seeks to draw out findings from this research and understand more broadly the benefits of co-location for both public and private sector organisations.

2.4. Benefits of co-location

In terms of definition, in the literature the term co-location is rarely mentioned explicitly. Often co-location is described through the language of proximity, agglomeration and the ‘clustering’ of business, management and organisational activities. The vocabulary used to describe co-location and its benefits

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varies across disciplines with economic geographers mobilising terms of ‘agglomeration’, ‘sticky places’, and ‘spillovers’, while business and management thinkers articulate concepts of ‘absorptive capacity’ and ‘untraded dependencies’.

There are a number of spaces designed and planned to reap the benefits of co-location of particular industries or knowledge activities and these appear under various names including business park, research park, science park, technology park, and innovation center and technopoles. These spaces vary in nature and scope, ranging from simple real estate development clustering activities to university science parks with an organisational programme of activities for technology transfer to formalised partnerships between academic institutions, government, and the private sector which are co-located.

There is an extensive literature on science and technology parks which is beyond the focus of the review. The main purpose of the review here is to provide a summary of the benefits of co-locating knowledge activities rather than to explore in depth the pros and cons of different mechanisms through which co-location can occur (e.g., an industrial estate, science park or business park). The literature identifies and discusses a range of benefits of proximity and co-location and each is discussed in turn below.

2.4.1. Exchange of tacit knowledge

Innovation can be broadly understood as an interactive process where different actors possessing different types of knowledge and competencies come together and exchange information with the aim to solve some—technical, organisational, commercial or intellectual—problems. Types of knowledge involved in this exchange can be different. Codified knowledge describes knowledge that is less space sensitive and can be communicated through data, documents, and reports. Tacit knowledge is higher-value knowledge that is embedded in experts who have accumulated the knowledge through years of experience (‘knowledge-by-doing’). Whereas codified knowledge can be communicated at a distance through ICTs and transmitted by emails, the exchange of tacit knowledge is dependent on spatial proximity between the actors involved.

Co-location enables the exchange of tacit knowledge to happen. The exchange of more subtle forms of information is possible only by actors being in the same location and meeting repeatedly in person. This

has been proposed as the main mechanism that makes it beneficial for a firm to be located in a spatial cluster, surrounded by other similar and related firms.

The need for proximity has persisted despite improvement in telecommunication and the potential of the internet to enable communication at a distance at anytime and from anywhere. While there was a wave of futurology in the mid-1990s speculating how the internet would create new possibilities for ‘tele-work’ and ‘tele-presence’ through cyberspace, such predictions have failed to materialise. Talk of the ‘death of distance’ or ‘end of geography’ has proved to be premature. Although telecommunications have changed the way we live and work they have not reduced the need for proximity and co-location. If anything with the advent of an interconnected, networked society and digitised economy the need for proximity has become more important to build networks of trust, reciprocity and social capital. This is borne out by evidence from the literature which suggests ICTs affirm the importance of proximity and co-location rather than making them redundant.

2.4.2. Trust and social capital

Co-location and the ability to communicate and exchange tacit knowledge with individuals face-to-face helps to build trust and social capital between actors. The frequent exchange of information between actors in a specific location can enhance social cohesion and facilitate better trust and openness among individuals. For firms, this can help to encourage the sharing of information, encourage agreements to be honoured and help to place negotiators on the same wavelength.

Creating a climate of trust can facilitate what Storper labels ‘untraded dependencies’. These are the form of conventions, informal rules, and habits that coordinate economic actors under conditions of uncertainty. Co-location and proximity is key to enable values of trust, reciprocity and cooperation to flourish in ways that would not be possible when actors are communicating with each other at a distance. Storper argues these interdependencies are vital to economic and organisational learning and co-ordination. They are based on collective tacit knowledge that cannot be removed from its human, cultural and social context.

Storper views untraded dependencies as the most significant form of scarcity in contemporary capitalism, largely because they are non-codifiable. Soft externalities such as trust-based interactions are the glue that holds local economies and actors together. They are likely to be highly differentiated from place to place and not easily duplicated, transferred, or imitated.

2.4.3. Local ‘buzz’

Co-location can create an atmosphere that encourages collegiality, entrepreneurship and creativity. With origins in the work of Marshall, a number of scholars have observed that co-location can encourage and stimulate innovation.\(^{38}\) Their argument is that co-location creates a local ‘buzz’ because there are a number of activities going on that are concentrated in a specific place. As a consequence, individuals can transmit and receive information and co-location encourages inspiration and entrepreneurialism amongst all actors.

The local buzz is akin to an ‘information ecology’ created by face-to-face contacts, co-presence and co-location of people and firms within the same industry and place or region. As Bathlet et al\(^ {39}\) argue, this buzz:

\[\text{consists of specific information and continuous updates of this information, intended and unanticipated learning processes in organized and accidental meetings, the application of the same interpretative schemes and mutual understanding of new knowledge and technologies, as well as shared cultural traditions and habits within a particular technology field, which stimulate the establishment of conventions and other institutional arrangements.}\]

Through co-location various actors are able to continuously contribute to and benefit from the diffusion of information, gossip and news by just ‘being there’\(^ {40}\). Participating in this local buzz does not require specific investments because information will be received by more or less all of the actors located in the cluster who are co-located in proximity to one another.

For an organisation or an individual it becomes almost unavoidable to receive information through both formal and informal exchanges. Formal exchanges may include participation in formal meetings, networking events or conferences. Informal exchange describes how information may be spread through chance encounters by simply bumping into somebody in a corridor or overhearing conversations in a pub over after-work drinks. Both are important mechanisms through which knowledge is exchanged and the local buzz is sustained.

2.4.4. Localised learning

Three distinct localised learning processes have been identified as an outcome of co-location.\(^ {41}\) All three relate to the fact that spatial proximity makes face-to-face interaction easier (less costly, time consuming, tiresome) and that it tends to carry with it an element of social, cultural, and not least cognitive, proximity. The three different types of localised learning are mainly relevant to firms co-locating.

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Firstly, *learning by interacting* describes a vertical process of learning. Firms specialising in different stages of a production process carried out along the vertical axis of a production chain require some kind of coordination as the output of one firm may be the input of another. Vertically related firms are linked through input/output relations. They possess knowledge, experience or skills useful for undertaking dissimilar but complementary activities. Innovation and learning may come through interactions with firms connected to one another vertically in the production chain.

Secondly, *learning by monitoring* describes a horizontal learning process occurring when firms are spatially agglomerations to other firms operating in the same industry. Being horizontally integrated through proximity enables firms to observe the behaviour of firms that are located nearby. Co-location also enables firms to compare their performance against other firms close by. The sharing of common conditions, opportunities and threats makes the strengths and weaknesses of each individual firm apparent to anyone who cares to take an interest.

Lastly, co-location offers the possibility for *social learning through interactions* that take place between individuals in the same place. These processes of information exchange going on that need not be related to the conscious undertakings of firms, but are rather to be seen as side effects of such undertakings.\(^{42}\)

The key argument here is that spatial proximity enables localised learning to happen. Learning is enhanced because proximity brings interacting parties together not only in space but also in perception via a shared social, cultural setting. In addition, localised learning may involve ‘spillover effects’ that work their way through more-or-less automatic processes of observation, monitoring, benchmarking and informal information exchange such as buzz.

### 2.4.5. Economic externalities

Much of the literature on co-location has considered agglomeration externalities as the key force behind clustering. Externalities involve a diversity of supplier, information and knowledge spillovers on market conditions and technology transfer, which resonate with the original Marshallian model. Put simply, models of dynamic externalities argue that clusters grow because they allow people to interact and learn from one another, and this is promoted by physical proximity. Moreover, the co-location also provides cost-saving benefits through shared infrastructure that can create comparative advantages. The economic externalities view of clusters identifies a number of benefits from co-location of economic activity within clusters (see below).

#### Table 2-2 Demand side and supply side benefits

<table>
<thead>
<tr>
<th>Demand side</th>
<th>Supply side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximity to customer</td>
<td>Knowledge spillovers</td>
</tr>
<tr>
<td>Reduced costs for customers</td>
<td>Access to specialised labour</td>
</tr>
<tr>
<td>Information externalities</td>
<td>Infrastructure benefits</td>
</tr>
<tr>
<td>Enhanced reputation from ‘being there’</td>
<td>Informal externalities</td>
</tr>
</tbody>
</table>

2.4.6. Knowledge spillovers

One of the major benefits from co-location is that of knowledge spillovers that can boost innovation capacity and growth of firms.\textsuperscript{43} Co-location facilitates knowledge spillovers by providing opportunities for both planned and serendipitous interactions. Knowledge acquired through such spillovers is, moreover, often less costly than knowledge produced internally, or sourced externally from greater distance or through contractual agreements.

These spillovers, resulting from contact with other firms or institutions, do not simply influence technological innovation and productivity. They also have a wider range of effects, such as altering the financing, marketing, managerial and organisational practices of the beneficiaries; and by affecting firm growth and changing the nature of market structure. As Kuah\textsuperscript{44} argues:

\begin{quote}
knowledge spillovers arise from everyday contact, networking through geographical proximity, as well as from formal arrangements such as joint-ventures and joint research work with universities.
\end{quote}

In short, spillovers are a broader concept than traditional agglomeration externalities. This is because a spillover such as that of information and knowledge is not necessarily spatially bound and can diffuse locally, regionally, nationally or globally.

2.4.7. Absorptive capacity

The notion of ‘absorptive capacity’ is linked to knowledge spillovers.\textsuperscript{45} The literature suggests a benefit for co-location is enhanced absorptive capacity that comes from exposure to a large pool and flow of ideas. The ability of a cluster of activities to absorb knowledge depends on two interrelated aspects: (a) the formation of linkages with extra-cluster sources of knowledge (i.e. the extra-cluster knowledge system); and (b) the structural characteristics of the intra-cluster knowledge system. The more a hub or cluster is networked both internally and externally the more capacity the hub will develop to absorb and put knowledge to use through time.

2.5. Co-location policy

From the mid-1990s onwards, clusters gained coverage in both academic literature and this interest was translated to policymakers. As a number of influential scholars\textsuperscript{46} sought to highlight the benefits of


clustering they found policymakers an audience willing to listen and implement the cluster ‘model’. Policymakers influenced by these debates – in particular those of Harvard’s Michael Porter and Princeton’s Paul Krugman – began to see co-location and the clustering of economic, business and organisational activities as a miracle cure for achieving external economies of scale, boosting innovation, enhancing competitiveness vis-à-vis globalisation and to help firms to develop products, services and production and distribution systems that engender competitive advantage.

The work of Michael Porter has been particularly influential in popularising clusters and providing a ‘template’ for cluster development policy. Porter’s paper in *Harvard Business Review* set out a persuasive argument on the importance of clusters for growth. 47 In this seminal article Porter provided the following definition of clusters:

> Clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions—such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations—that provide specialized training, education, information, research, and technical support.

In the article, Porter concluded that clusters broadly affect competition and create competitive advantage in three ways: (a) by increasing the productivity of companies based in the cluster; (b) by driving the direction and pace of innovation, which underpins future productivity growth; and (c) by stimulating the formation of new businesses. Porter was clear in placing responsibility for cluster development with the state. His argument was that government had a key role to play in creating the conditions where clusters could grow and consolidate their competitive advantages. Rather than seeking to develop new clusters, governments were instructed to work with the private sector to develop existing clusters and maximise advantages from existing specialisation within nations and regions. In so doing, governments were to be guided by a diamond model, which identified the conditions for successful co-location strategies based on Porter’s mapping exercise of existing clusters. Within his model a number of factors need to be considered for successful cluster development:

- **Factor conditions** are the first determinant of competitiveness. They are human resources, physical resources, knowledge resources, capital resources and infrastructure. Specialised resources are often specific for an industry and important for its competitiveness. Specific resources can be created to compensate for factor disadvantages.
- **Demand conditions** are the second determinant of competitiveness. In the home market, they can help companies create a competitive advantage, when sophisticated home market buyers pressure firms to innovate faster and to create more advanced products than those of competitor.

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• **Related and supporting industries** are the third determinant of competitiveness. They can produce inputs which are important for innovation and internationalization. These industries provide cost-effective inputs, but they also participate in the upgrading process, thus stimulating other companies in the chain to innovate.

• **Firm strategy, structure and rivalry** constitute the fourth determinant of competitiveness. The way in which companies are created, set goals and are managed is important for success. But the presence of intense rivalry in the home base is also important; it creates pressure to innovate in order to upgrade competitiveness.

• **Government** can influence each of the above four determinants of competitiveness. Clearly government can influence the supply conditions of key production factors, demand conditions in the home market, and competition between firms. Government interventions can occur at local, regional, national or supranational level.

• **Chance** events are occurrences that are outside of control of a firm. They are important because they create discontinuities in which some gain competitive positions and some lose.

The persuasiveness of Porter’s model contributed to clustering and co-location becoming hegemonic in economic development policy discourse and practice. In response, a significant body of research was developed to examine clusters in operation and the benefits of co-location. These case studies became exemplars utilised by academics to interrogate clusters and by policymakers to justify cluster development policies. Silicon Valley is the leading example of successful co-location to which all others aspired, but a number of cluster exemplars were explored in the academic literature:

- High-technology cluster, Silicon Valley, California\(^{48}\)
- High-tech cluster, Boston’s Route 128, Massachusetts\(^{49}\)
- Film and media cluster, Hollywood, California\(^{50}\)
- New media cluster, San Francisco, California\(^{51}\)
- Outsourcing and shared services cluster, Bangalore, India\(^{52}\)
- Financial services cluster, City of London, UK.\(^{53}\)


Cluster policies have been adopted by the Organisation for Economic Co-operation and Development, EU, national and local governments the world over and manifested in variety of forms including science park and technology park developments, innovation centres, and technopoles of various forms. Each development represented a means by which policymakers tried to engineer and create a locality where related industries of knowledge activities could be clustered and co-located. Invariably, cluster policies were manifested through real estate development, and served to showcase local and regional expertise and provide an engine for economic and social development. There are numerous examples of such physical developments in the UK which formed part of regional and local cluster policies: Newcastle International Centre for Life; Exeter Science Park; Cambridge Science Park; Media City UK in Manchester; and St John’s Innovation Centre in Cambridge.

Policy makers have looked to both the academic literature and case studies when developing co-location policies to foster regional economic growth. These arguments were persuasive partly because they presented generic ideas and set out a flexible approach to clustering and agglomeration that could be applied to a range of contexts. For example, Porter’s notion of co-location was universalistic offering a vision for how people, firms and organisation working together to create competitive advantages. Moreover, clusters were attractive because:

…they came with a ready-made methodological tool box. The methods, case studies and exemplars contained in Porter’s books offered provided apparent 'off-the-peg' examples of how this could be done.\(^{56}\)

For policymakers, understanding the benefits of co-location has been achieved through different stages. Firstly, there is an understanding that the factors identified by Porter (1998) are achieved through cluster-mapping exercises, which form the first stage of any cluster development strategy, and are designed to identify existing and potential clusters. Secondly, once a potential cluster has been identified, its strengths and weaknesses are determined, before more tailored interventions can be developed.

In the UK context, clusters were a key component of New Labour’s regional competitiveness strategy in the 1990s/2000s. The government’s vision for the future of the UK economy was published in the 1998 white paper, *Our Competitive Future: Building the Knowledge-driven Economy*.\(^{57}\) The paper identified the importance of regional competitiveness and the role of clusters in driving grow at the regional scale citing the examples of Silicon Valley and Porter’s cluster theory. Following this, in 1999 the DTI commissioned a nationwide cluster mapping exercise, Regional Development Agencies (RDAs) were operationalised and

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the DTI established the Cluster Policy Steering Group to bring together ministers with experts from academia and the public and private sectors.

With a groundswell of policy focus towards regional development and clusters the DTI published *A Practical Guide to Cluster Development*.

This document reiterated the government’s commitment to cluster-led regional economic development, and provided strategic, methodological and practical tools for cluster policy, reproducing the arguments made by Porter and the growing number of cluster theorists in academia and policy circles. The benefits of co-location according the DTI report were:

- Increased levels of expertise. This provides sourcing companies with a greater depth to their supply chain and allows for the potential of inter-firm learning and co-operation.
- The ability of firms to draw together complementary skills in order to bid for large pieces of work that as individual units they would be unable to compete for.
- The potential for economies of scale to be realised by further specialising production within each firm, by joint purchasing of common raw materials to attract bulk discounts or by joint marketing.
- Strengthening social and other informal links, leading to the creation of new ideas and new businesses.
- Improved information flows within a cluster, for example, enabling finance providers to judge who the good entrepreneurs are and business people to find who provides good support services.
- Enabling the development of an infrastructure of professional, legal, financial and other specialist services.

2.6. Disadvantages of co-location

While considerable comparative advantages can be gained from co-location it is important to recognise that the benefits from clustering specific activities are not guaranteed. Despite the pervasiveness of Porter’s hypothesis and the volume of literature unpacking co-location and its potential advantages there has been a move away from cluster policies in recent years. In academia in particular there was a growing backlash against Porter’s thinking with scholars describing the concept as ‘fuzzy’, ‘chaotic’, and a ‘conceptual headache’. The major critique was the lack of robust evidence for co-location benefits beyond a small number of case studies, the conceptual elasticity of clusters and the focus of cluster literature on soft factors (eg social capital, trust) that were hard to measure.

Indeed, cluster policy and attempts to engineer co-location through the planning and development of science parks, technology parks, innovation centres have produced mixed results. As such, clusters and the mechanisms for co-location are neither a policy panacea nor a miracle cure for economic growth, organisational efficiency and increased research and development productivities. Once seen as a “fashion

label for aspiring regions and localities clusters are now reviewed more reflexively and there is a body of research critical of engineered attempts at co-location.

The major critique is that cluster policies have been mobilised in an overly deterministic way based on the premise that a science park type development can create a conducive environment for knowledge sharing, collaboration, entrepreneurialism and in turn enhance the capacity to innovate. Science parks have often been mobilised in a highly ecological deterministic manner which assumes that environments for innovation can simply be engineered and if people are co-located in a sanitised, campus-styled landscape they will be able to think more clearly, talk more often, be more productive, with a higher propensity for creativity. Such assumptions are based on a simplistic reading of Porter’s cluster ‘model’ and the premise that the lessons learned by the successes of the Silicon Valley/Stanford Science Park approach are universally applicable to other contexts.

In sum, Porter’s cluster ‘model’ should not be considered an ‘off the peg’ policy and science parks do not represent a planning template which can be inserted into different contexts to create range of pre-determined effects. Rather than the ‘if you build it, they will come’ attitude, approaches to engineering co-location need to be highly sensitive to context and take into account the unique political, economic, social and cultural characteristics of the locality in which they are being implemented. The examples of unsuccessful attempts to engineer co-location should function as a cautionary note against overly deterministic cluster policies. These include New York’s Silicon Alley, Seville’s Cartuja 98 Technology Park, Russia’s Akademgorodok Technology Park, Scotland’s Silicon Glen, and various cluster initiatives implemented by England’s now obsolete Regional Development Agencies (eg East of England Enterprise Hubs, West Midlands Medical Technologies Cluster). The reasons for failure are diverse but include the lack of a shared vision amongst stakeholders, difficulties in creating an entrepreneurial culture, deficiencies in local labour markets, external economic pressures, and a lack of support from the private sector.

In the UK context, cluster policy has waned reflecting the move away from spatial economic development strategies at the local and regional level since the Conservative-Liberal Democrat coalition came to power.

More widely there has been some scepticism about the scope for cluster, hub and co-location policies to provide a ‘one-size-fits-all’ solution to innovation, growth and development questions. As Martin and Sunley argue, though there is some evidence that clusters work in some contexts, in order to enable the development of more effective policymaking we need additional research.  

This research should focus on organisational and institutional learning, particularly in relation to innovation in clusters. In particular, Martin and Sunley suggest that cluster policies should seek to stimulate innovation flows and learning mechanisms by encouraging institutional developments, often involving collaboration between public and private agencies.

2.7. Conclusion

In summary, the diverse literature on clustering and agglomeration identifies a number of important benefits to co-location. These are the exchange of tacit knowledge, trust and social capital, localised learning, externalities, knowledge spillovers and absorptive capacity. The majority of the literature reviewed examines the benefits of co-location for firms and takes the firm as the main unit of. Case studies on co-location identify the benefits of co-location to firms and the localities in which cluster and agglomeration economies are evident. These studies focus on small number of exemplars which have gained much currency in academic and policy debates (eg Silicon Valley, Third Italy).

Influenced by research, and prominent case studies, clusters gained currency within policy circles from the early 1990s onwards. Policymakers at international, national and regional scales attempted to create benefits of co-location through strategies for clustering and agglomeration. A number of these strategies were mobilised through real estate development and included the construction of science parks, business parks, innovation centres, etc. The paradigmatic shift resulted in cluster policy becoming a central pillar in the architecture of regional development policy in the UK and elsewhere during the past twenty years. More recently however the appetite for clusters has waned and governments are playing a less active role in engineering co-location through cluster policy.

3. Insights from stakeholders

Summary of chapter insights

The interviews with key stakeholders covered a broad spectrum of topics and a diversity of views which are summarised in the pages which follow. These covered technological and research trends; the challenges facing public health; important capabilities for the future; the role of PHE in the future; the characteristics of a hub; and uncertainties about the future.

On the question of those technological and research trends that would be influential in future public health, genomics featured prominently, as did informatics and ‘big data’. As regards the challenges facing public health, the involvement and regulation of the private sector’s activities within this traditionally public sector-dominated field was considered challenging, as were various organisational issues pertaining, in particular, to internal integration and continuity issues within the Agency itself.

The capabilities that were regarded as being important for future public health needs spanned wet lab disciplines (epidemiology, microbiology, virology, genetics, etc) and dry lab capabilities (including statistics, economics, mathematics, behavioural science, and bioinformatics and other IT-related disciplines). These were perceived by interviewees as important to allow PHE to deliver on its role which they considered to involve: integration and co-ordination (nationally and internationally); the exercise of leadership in the public health field; surveillance and response; provision of advice to effect demonstrable positive outcomes for the health of the public; and making the transition from a primarily ‘responsive’ stance to a primarily ‘preventive’ posture.

The greatest diversity of views emerged, perhaps unsurprisingly, in relation to the issue of the possible creation of a hub. There was broad consensus on the strategic-level prerequisites for the establishment of a hub (eg robust leadership, common narrative, careful design and so on). Equally, the possible advantages offered by standardisation, cross-fertilisation and economies of scale were also widely recognised. The greatest disparity of views was in relation to the question of whether the establishment of a physical hub would be necessary or beneficial or whether a virtual hub could be just as effective. The question of ‘where’ (as well as ‘whether’) was particularly prominent as many respondents could see the merits of physical location, but only providing that the geographical location was appropriate (ie collocated with other relevant bodies and with easy access to other organisations and governmental partners).

The final area related to uncertainties and those issues that were considered core areas of concern by interviewees. These included: the emergence of new pathogens; the continuing rise of antimicrobial resistance; organisational challenges; the influence of short-termist policies and the vulnerability of PHE to changeability in national politics; health inequalities; and economic constraints.

3.1. Interview approach

The study team conducted semi-structured interviews with 26 experts. Of these, 15 were from PHE and the remaining 11 from various universities, NHS Foundation Trusts, Institutes, the Department of Health and the Medicines and Healthcare Products Regulatory Agency (MHRA).

An interview protocol (see Appendix B) guided interviews which usually lasted between 30 and 45 minutes. The protocol gave us the basis for ensuring that interviewees were asked a standard set of
questions but we took a flexible approach so that interviewees were able to focus on their particular areas of expertise or concern. After each interview, a transcript was created and key extracts/insights are provided at Appendix A. The insights shown below were drawn from the transcripts of the 24 interviews conducted with senior PHE and external stakeholders. Each interviewee has been assigned a letter. The insights are grouped by theme and are not intended to be comprehensive but rather to give a flavour of the respondents’ views on different topics. Each section begins with a ‘wordle’ diagram of the key themes coming out of that interview topic.

3.2. Trends

![Figure 3-1 Wordle diagram for interview responses about research, technology and other trends](image)

When asked about the research, technology or other trends that would drive the field of public health in the future, 16 interviewees (out of 26) mentioned genomics, with the majority of the opinion that developments in this area will have significant potential for responding to future public health needs. Several interviewees pointed to specific areas including epigenomics (the study of the set of epigenetic modifications of the genetic material of a cell, known as the epigenome), metagenomics (the study of genetic material taken directly from environmental samples) and proteomics (the study of proteins, their structures and functions) as having particular potential (interviewees H, O, T, W and Y). Two (O and P) challenged the view that genomics would be a key driver in the field of public health or queried its utility within the public health domain.

Eleven interviewees mentioned informatics, big IT and data analytics as being key future drivers of trends in public health, with interviewee Y emphasising the growing significance of dry labs (ie for data
manipulation and bio-informatics and surveillance-related disciplines) along with wet labs (ie for microbiology and other bench-based sciences) for the future of public health.

Increasing Antimicrobial Resistance (AMR) was identified by five interviewees as a key challenge which would drive public health needs and responses in the future. The continuing emergence of new infectious agents was cited by interviewees G, N, R and U as being an enduring trend for which the public health community would need to be prepared.

Two interviewees (C and G) expressed the view that public health initiatives would be directed increasingly at preventive rather than curative action. The relevance of social determinants and public health inequalities was flagged by six interviewees and behavioural science was identified as an increasingly important research area by interviewees J, T, U and V. The need for cost transparency and demonstrable value in the delivery of public health services were flagged by interviewees E and F as being important future drivers.

### 3.3. Issues and challenges facing public health

When asked to identify the issues and challenges facing those responsible for responding to future health needs, interviewees described a number of institutional factors. Five interviewees expressed concerns over the involvement of the private (industrial) sector within public health. These concerns revolved around: loss of control, eg in the pathology field (A); the loss of interoperability (eg with the sale by private companies of proprietary vertical systems which are not compatible with existing public systems) (B); the impact of possible failure to send samples (eg for cost purposes) on national surveillance (J); and the quality of methods used (L). Interviewee C expressed the view that there was scope for industry to derail
the public health system. Other interviewees expressed concerns regarding the role of academia in public health. Interviewee B considered heavy reliance on academia to be a failing in the public health system, while Interviewee R expressed concern regarding the continuing change in the funding landscape which was described as having been diverted by the academic route.

Interviewee X voiced concerns relating to wider environmental phenomena and the implications for public health. Resource scarcity, climate change and the increase in the number of places which will become unfit for human habitation were all cited as posing potentially severe challenges for public health in the future, not least as a result of large-scale migration.

In addition, eight interviewees described what can be broadly thought of as organisational challenges. These included:

- the risks relating to silos of funds and capabilities (C, F and T)
- the need for a better vision for PHE (D)
- the uncertainty introduced by regular re-structuring and re-branding activities (E and U)
- the difficulties associated with recruitment and retention (K)
- issues relating to integration challenges at a strategic level within PHE (R).

3.4. Capabilities

![Figure 3-3 Wordle diagram for interview responses about public health capabilities](image)

When interviewees were asked to identify the capabilities that would be required in order to meet the future demands of public health, three areas were particularly prominent. These were the need for laboratory and/or medical and related sciences including:
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- epidemiologists (H, K, S)
- microbiologists (H, I, J, K, R)
- virologists (I)
- clinicians (I)
- geneticists (J, S)

Many interviewees also emphasised the importance of non-laboratory-based scientific capabilities including:

- behavioural scientists including sociologists, anthropologists and psychologists (D, E, F, I, K, N, O, S, T, U, V)
- statisticians (D, Y)
- mathematicians (I, Y)
- modellers (I, Y)
- economists (D, Y)
- emergency response experts (I).

Data informatics capabilities also featured prominently. A few interviewees mentioned the need to be able to link and interpret information and analysis across multiple methodologies for the creation of databases and the management and sharing of information (I and L). There were differing views regarding the extent to which those involved in informatics will need to understand the biological elements of the data with which they are working.

Several interviewees mentioned the need for 'hybrid' individuals who were capable of understanding differing disciplines and methodologies and working across multifunctional areas (H, I, M). There was also much coverage of the need for integration: between public health and clinicians (D); within the public health community so as to configure scientific interventions to be fit for purpose in meeting existing and future needs (S); and in relation to the distribution of resources disciplines across PHE, with particular emphasis on smoothing out any imbalances across any particular field (S).
3.5. Role of PHE

When asked what the role of PHE should be, interviewees emphasised eight inter-related areas. Nine interviewees saw integration as being a key element of PHE’s remit, however they varied on the extent to which this should be its sole remit. Interviewee C expressed the view that PHE should be ‘a supporting agency rather than a doing one’. This view was not shared by interviewee M, who was of the view that ‘it is fundamental that PHE acts both as an integrator and as a scientific lead because you can’t do the first very well unless you’re doing the second.’ Interviewee N’s view fell somewhere between these two positions: ‘PHE’s capability in science needs to be of the highest standards but it doesn’t need to do everything. It should do those things that are not possible elsewhere.’ Interviewee X agreed, expressing the view that ‘PHE shouldn’t necessarily be doing the science but should be looking for the gaps and filling them.’ Interviewee N saw PHE as being in an ideal position to ‘pull together the expertise and to act as a knowledge integrator and disseminator’.

Co-ordination was also widely perceived as being central to PHE’s role. Interviewees mentioned:

- good internal co-ordination across the PHE organisation (L, M)
- co-ordination with NHS partners (D)
- co-ordination with Local Authorities (D, E, O). Interviewee D emphasised this point in particular given that public health needs and inequalities are often bespoke to the region
- co-ordination with the ‘What Works’ centres (P)
- co-ordination with academic partners (G, Y)
• clarification of responsibilities for cutting-edge fundamental research and for applied public health research (O)
• the cultivation of a collaborative culture within the public health community (T).

The need for PHE to assume a co-ordination role with other international public health bodies was also identified by a few of those interviewed (D, G and O) both in the context of engendering a greater awareness of and exploiting the opportunities presented by international partnership (D, O) and in relation to the need to monitor national and international developments in relation to outbreaks that could impact upon public health (G).

The exercise of leadership was also identified as an essential component of PHE’s role by interviewees. Interviewees spoke of the need: to demonstrate leadership and best practice (E); to maintain the authoritative science voice (H); to demonstrate scientific advances within a high-quality research environment (M); to be a national voice and champion with clear messages (S); to undertake a leadership and advocacy role for health, putting health and the public’s health on the agenda and making the environment more supportive for individual health (V); and to continue to exert international leadership in the field of public health (W).

Surveillance and response featured prominently in interviewees’ responses. Most were of the view that a robust surveillance capability was key, with interviewee W stating the view that PHE ‘needs to develop an increasing capability for high-level public health surveillance and epidemiological data analysis in order to deliver prevention and protection.’ Interviewee H urged ‘a focus on structured surveillance which defines the question then applies appropriate surveillance techniques’ and counselled against ‘stamp-collecting’ and the routine sequencing or surveillance of things which were not necessary. Allied to this was the need for robust response and advice capabilities which would allow the organisation to deliver demonstrable outcomes. Interviewee F expressed the belief that PHE ‘must be able demonstrably to influence public behaviour and demonstrate public health benefits.’ One interviewee (V) described the potential for PHE to play an important role in ‘effecting a posture change from responsive to preventive across the public health domain.’

Interviewee U summarised their view regarding the role of PHE as follows: PHE is well-placed to develop a strategy for managing disease which takes the longer view and is science-based. It should marshal three broad sets of competencies: laboratory science in which it is strong and has a rich legacy; behavioural science, which revolves around establishing the right links between the academic and practitioner base; and informatics. Since PHE’s responsibility for population health covers a broad canvas and represents a multi-faceted challenge, it should span these three domains.
3.6. Views on an integrated public health science hub

Discussion on the merits and demerits of establishing an integrated public science hub provoked some diverse views from interviewees particularly in relation to the question of whether a hub required a physical rather than virtual presence. There was broad agreement that in the establishment of a hub there would be a need for: ‘robust commitment and leadership’ (E); very careful organisation and a lot of design work in the knowledge that subsequent reconfiguring would probably be required (G); clear indication as to organisational objectives in establishing the hub, moving from transition to transformation (H); and the generation of a coherent vision which would win hearts and minds (Q) and provide a common narrative for PHE employees (V).

Several interviewees identified functions which they believed would be particularly pertinent to the establishment of a hub. These included: a common informatics infrastructure (B); the capability to undertake resistance and reference-typing (B); the standardisation of techniques in particular areas (B); the generation of information flows, processes and policies (F); mechanisms for the introduction of new high-potential technologies (H); and the maintenance of repositories of strain collections and bio-banks (I). Some were keen to discuss organisational structure including the establishment of multi-disciplinary groups to avoid the partition of expertise, the creation of a ‘big data’ centre with high-speed links to national and international stakeholders, and flexibility in staff organisation and deployment to allow the creation of a ‘surge’ capacity (all H). Interviewee R felt that a hub organisation would allow resource duplication to be avoided and would be slick and efficient. Interviewee V agreed that a hub could help reduce overlaps within the field.

On the question of the need for physical co-location as opposed to a virtual hub, views were split. Those who felt that physical co-location would be beneficial expressed views including, *inter alia*:
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- ‘Physical presence is important for organisational potency’ (C).
- ‘I would love my epidemiology colleagues to be across the corridor rather than across the town’ (K).
- ‘Establishing and maintaining good relationships is underpinned by working on the same site. It is easier to discuss things and there are differences in the relationship between teams when they’re working in different locations from when they’re co-located’ (M).
- ‘Bringing multi-disciplinary people together with a common endeavour enables them to spark off one another. Physical co-location makes these chance encounters/sparks more likely.’ (V)
- ‘The creation of a physical hub could help engender a feeling of excitement both within and beyond PHE’ (V).

Those who did not see physical co-location as being important expressed views including, inter alia:

- ‘In reality, those who want to integrate and work in a multi-disciplinary context will do so anyway regardless of physical location. Those who do not, will not. There are examples of facilities which may be located 200 miles apart but which run their centres effectively as an integrated entity’ (N).
- ‘It is impossible to put all resources in one location and so it is necessary to try and network existing resources’ (O).
- ‘There is no particular virtue in a physical presence rather than a virtual presence’ (P).
- ‘We should avoid getting too fixated on bricks and mortar which is a dead weight. The important thing is to bring disciplines together in a networked fashion rather than necessarily bringing them together in one place. Given the swiftly changing nature of the public health agenda, the environment must be fluid and networked’ (U).
- ‘While you get good interactions when you co-locate scientists from different disciplines (eg biology and physics), when you co-locate scientists who do similar things, you don’t get that much synergy. With real-time virtual contact you can talk to anyone whenever you like. Linkages with appropriate groups matters much more than being on the same site’ (W).
- ‘A single physical hub may not be the best approach since the local is the important thing for public health.’ (X).

The criteria regarding the geographical location of a physical hub was mentioned by several interviewees. Some felt that there was value in having a science ‘federation’, but only if there are other organisations on site with whom to integrate, eg if the hub was placed with the Sanger Centre at Hixton (J). Interviewee M expressed the belief that ‘a successful hub would need to exist not in isolation but to have good links and to be close to other institutes or science partners or an academic institute. Easy access to central London is also important.’ Interviewee Q stated the view that ‘geographical proximity does matter. Colindale interactions are facilitated by the fact that lab colleagues are onsite and by the close proximity to London. A great deal of the most effective interaction arises from the ability to meet physically.’ interviewee Y suggested that ‘ideally the co-location site would be on a university campus.’

Interviewees’ concerns regarding the establishment of a hub included the following:

- ‘What is going to happen in the hub that isn’t already happening at Colindale and Porton Down?’ (A)
- ‘Constant reorganisation stands in the way of work’ (E).
- ‘How are you going to stop people behaving dysfunctionally? To co-locate three dysfunctional areas will be detrimental and only cause further fragmentation’ (J).
• ‘Moving people around is not always a good thing and tends to create a year or two of interference with operational efficiency. You would need a really good case to bring together Porton Down and Colindale to warrant that level of disruption.’ (O)

• Potentially, in establishing a co-located hub, you’d be putting all your eggs in one basket so that if something went wrong in one of those labs, you could stand to lose everything.’ (R), and ‘You’d be putting all your eggs in one basket and contamination caused, for example, by flooding, would mean that you couldn’t use the laboratories.’ (X)

• ‘The challenges of creating a hub include physically getting people there, creating a culture of encouraging people to talk to each other, both formally and informally, and getting everyone to realise that they’re in the same game even though the field is extremely broad.’ (V).

3.7. Concerns and uncertainties for the future of public health

Figure 3-6 Wordle diagram for interview responses about concerns and uncertainties for the future of public health

When asked to describe what ‘keeps you awake at night’ in relation to the future of public health, interviewees cited the following threats, challenges and uncertainties:

• The influence of politics on the public health agenda: participants were sensitive to decisions arising from ‘the politics of the day’ (G) and the dangers of political whim (N), citing politics as ‘having caused the most amazing upheaval of the health landscape in the last few years’ (I).
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• The emergence of a novel infectious disease or pandemic: four of those interviewed raised the issue of new pandemics, questioning whether public health will be able to rise to the challenge such an outbreak would pose (G, O, S, U). There was a concern that ‘dry runs’ such as swine flu and H1N1 might induce complacency in both the public health sphere and in the population.
• The loss of control to the private and academic sectors of certain elements of the public health domain, eg in relation to the storage and sharing of surveillance data (H and M).
• Organisational challenges for PHE: these included personality clashes at a senior level, the need for a change process mechanism to integrate the multiple different components of PHE and concerns associated with PHE’s wider remit (H, J, M, P).
• Issues relating to recruitment and retention for PHE: in particular the loss of talented young individuals as a result of poor workforce planning and policy (I) and the risks associated with high staff turnover (R).
• A failure to take account of emerging evidence: two interviewees mentioned the evidence base (O and P) and a perceived absence of value placed on evidence synthesis.
• Health inequalities: interviewees S, T and V commented on social inequalities with particular concern being expressed in relation to the lack of an integrated approach to tackling them and the prospect that inequalities were likely to get worse because the factors driving them are economic and social.
• Economic constraints: resources were deemed essential to allow PHE to ‘carve out the unique voice of advocacy, leadership and truth that will allow us to get the job done’ (S). In addition, interviewee T considered the economy to ‘represent a major challenge to public health.
• Antimicrobial resistance: the threat posed by AMR to current treatment policies was highlighted by interviewee O with W citing emerging antibiotic resistance as a major threat to public health. Interviewee U suggested that ‘the talk about the ending of the days of safe surgery may not be a massive exaggeration’.

3.8. Internal PHE Workshop

In addition to the key informant interviews, the study team was also able to capture insights from stakeholders at a PHE event on 10 July which was concerned with the strategic case for the establishment of a hub. At this ‘Expert Advisory Session’, the team facilitated a session which was designed to elicit the views of the 60 stakeholders present.

We opened the session with a broad discussion of the factors which contributed to each individual’s decision to work in the public health sphere/for PHE. Stakeholder views encompassed: a desire to work for the greater public good and to make a difference; a passion for their subject; a wish to be involved in applied science with demonstrable public benefit; the opportunity to work with like-minded colleagues in a research-driven environment; and an attraction to the diversity and intellectual stimulation of the work.

We then asked stakeholders to discuss their individual aspirations for PHE as this would help to drive the future vision for the organisation. They indicated the hopes that PHE would be: a recognisable brand and acknowledged centre of excellence; trusted by the public with a reputation for the rigour and quality of its work; a ‘one-stop-shop’ for public health; a partner of choice for academia; a joined-up global leader in the field of public health; at the forefront of innovation and technology; demonstrably good value and effective; and resourced by happy, committed, high-quality staff.
PHE’s values, stakeholders believed, should embody: integrity, trust, honesty and fairness; independence; respect for the workforce; professionalism; invulnerability to political expediency; collaboration; and a focus on outcomes.

Following from the vision and values, stakeholders were asked to describe the core components of the role that PHE should undertake in the future. This list was expanded as follows:

- Playing an outward-facing leadership role for public health, building on strong leadership within/for the Agency.
- Providing a publically recognised authoritative voice within the field which is future-focused and outward-looking.
- Embodying honesty, impartiality, integrity and scientific independence.
- Supporting front-line deliverers in demonstrably improving the health of the public, including reducing disease and health inequalities.
- Focusing on the early identification and adoption of effective new laboratory and information technologies.
- Keeping abreast of possible future issues and influential trends.
- Assuming a co-ordination function for the public health community and ensuring more effective integration of the ‘hub and spokes’.
- Working with universities, other partners and the NHS to deliver the most economic, efficient and effective service possible.
- Sharing evidence with other public health bodies both nationally and internationally.
- Recruiting promising graduates and young scientists who will represent the future of the organisation.

We also asked participants to consider the future, and how this looks against PHE’s current role and its core activities. Current activities were identified as the delivery of public health benefits and outcomes; the provision of advice; the synthesis of different scientific disciplines; the provision and integration of information; the development of interventions; and research and development, including into the spread and containment of infectious disease. There are clear overlaps, then, between PHE’s current role and future activities, although stakeholders were slightly broader in their thinking about the different nature of these activities going forward.

Stakeholders identified a range of capabilities that will be required by PHE in order to deliver today and in the future. The following were emphasised:

- Visionary, capable and sustainable leadership and a coherent, supporting organisational structure.
- The ability to deploy a surge capacity in times of heightened need.
- State of the art laboratories, both wet and dry to include informatics capabilities.
- Robust data protection and information governance procedures.
- Good internal and external knowledge management processes.
- Effective non-bureaucratic support systems spanning HR, Finance, IT, etc.
- A trained, motivated and skilled workforce with defined career paths spanning generalist and specialist public health domains.
- The ability to work in partnership with other public, private and academic sector organisations.

In addition, areas requiring special focus for PHE in the future were considered to be: the behavioural sciences; the impacts of environmental factors on public health; data-mining and interpretation; gene-
environment interaction; non-antibiotic means to reducing infectious disease; securing easy access to national decision makers; focusing on recruitment and retention; and undertaking more research on delivering effective interventions.

Delivering these capabilities will come with a set of challenges and opportunities and stakeholders reflected on the challenges PHE faces both internally and externally:

- the recruitment and retention of the best people.
- the need to prove its organisational effectiveness quickly.
- the vulnerability of its funding streams.
- the need to maintain academic independence.
- the challenges of data collection, integration and interpretation.
- the difficulties associated with the breaking down of silos and multi-disciplinary working.
- the loss of research funding to the universities and other organisations.
- the influence of ‘legacy’ approaches.
- the challenges of an ageing workforce.
- the need for a clear organisational vision and remit.
- the health impacts of economic austerity.
- the reduction of internal corporate challenges.

When asked about the benefits of co-location on a single site, attendees cited:

- the bringing together of multidisciplinary experts and the creation of formal and informal networks within a ‘centre of excellence’ environment.
- the ability to co-ordinate cross-laboratory activities, eg a front-line laboratory with a reference laboratory.
- the cost-sharing and efficiency savings including capital receipts from disposal of vacated sites.
- the improved use of IT and technology infrastructure and centralised procurement and support structures.
- the introduction of cultural change and more efficient ways of working.
- the scope to act as a hub for training and career development.
- the potential for brand enhancement and the scope to establish PHE as more than an expanded HPA.
- the potential to enhance PHE’s international reputation.
- the fact that it acts as a strong focal point.
- the smaller carbon footprint.

The disadvantages identified by attendees included:

- the continuing risk of ‘stove-piped’ working and the possibility that existing dysfunction will continue
- the threat to retention posed by the requirement to relocate, particularly in relation to specialist posts
- remoteness from the population
- the likely separation from government
- loss of current geographical interaction and relationships
- risks associated with business continuity
- risk to service continuity in the transition phase
- threats to the brand associated with current locations
- costs of relocation.
In addition to the synthesis presented here, the workshop outputs have fed into our wider synthesis for the horizon scanning study as a whole and are therefore reflected in the findings of this report. The event was particularly valuable for the fact that it brought so many different PHE staff together and allowed them to hear and reflect on each other’s views about the future of the organisation.

3.9. Summary of key themes

The interviews and workshop with key stakeholders covered a range of topics. These encompassed:

- potentially influential technology and research trends for the future of public health, in which genomics, informatics and ‘big data’ were emphasised by interviewees as significant trends;
- the challenges for public health which prompted participants to raise concerns regarding the role of the private and academics sectors in the delivery of public health and regarding organisational challenges internal to PHE;
- the capabilities that would be required to respond to future public health needs for which interviewees listed multiple ‘wet’ and ‘dry’ lab disciplines spanning epidemiology, microbiology, genetics, economics, behavioural sciences, bioinformatics and information technology;
- the future role of PHE which respondents considered to include robust surveillance; integration; co-ordination; leadership; dispensation of advice; and effecting culture change to transition from responsive to preventive interventions;
- the merits and demerits in relation to the creation of an integrated public health science hub where the debate revolved principally around whether physical co-location would, on balance, offer greater benefits than virtual co-location and, if a physical hub were created, whether co-location with organisations external to PHE would be a pre-requisite for the hub to function effectively;
- the uncertainties in the future of public health which prompted interviewees to mention: the emergence of new diseases; the continuing rise of AMR; health inequalities; economic constraints at both an organisational and individual level; the vulnerability of the Agency to ‘buffeting’ on the seas of political change; and organisational challenges within PHE.

During the interview phase, no new topics were introduced that were not already being considered in the literature review. This gave the study team confidence that the majority of the major issues had been incorporated within the study approach.
4. Horizon scanning future scientific and technological trends: literature review

## Summary of chapter insights

The literature review allows us to understand the wider empirical and conceptual developments in the field that will impact upon the co-location of laboratory and other public health services. We derived a number of areas from an initial rapid search and early-stage interviews which resulted in eight ‘deep dive’ areas presented in this chapter. These cover both broad areas of scientific and technological capability, and public health challenges in which those capabilities would be utilised.

Each area is summarised below and a number of implications for PHE and a series of themes emerge across them. **Interdisciplinary approaches** will cut across many areas. The challenges for public health over the next 20 years will be multi-faceted and affect the population at many levels. **Integration of data** will play a significant role. The future will be dominated by many different kinds of data and these will all need to be collected, mined, fused, integrated and managed in order to maximise positive outcomes for public health. Finally, there is no single technology or capability that dominates the field. Multiple platforms will be required, and need to be brought together across both ‘wet’ and ‘dry’ laboratory spaces in order to make the most of the data and knowledge that emerge from each space.

### The Deep Dives

**Behavioural science** is important to the future of public health science because the most prominent contributors to death and disease in the UK and globally are related to behavioural factors and non-communicable diseases, particularly tobacco use, diet and activity patterns, alcohol consumption and sexual behaviour. In synthesising the diverse literature, the following future trends stand out: policy planning and design; behavioural nudging; design of intervention trials; ecological modelling; populomics; and data collection, mining and management.

The key challenge in mobilising behavioural sciences for PHE rests on the use of inter-disciplinary, locally sensitive and multi-level approaches to solve clinical, high-risk and population-based public health problems.

**Public health informatics** is the systematic application of information and computer science and technology to public health practice, research, and learning. Some of the future trends which will feature include: bioinformatics and biomedical informatics; privacy and data management; user-led information networking and sharing; and the management of electronic health records. There are two main reasons for the importance of informatics to public health: the availability of new kinds of data and the potential new ways to use the data. In the future not only will scientific data drive public health, but so will patient, clinical and social data. PHE must be able to utilise this in dry lab facilities.

**Simulation and modelling** provide public health science with means for testing and experimenting with potential improvements and future scenarios. Several types of models might be used in the future, including: models for accountability and management; population effects models; prevalence models; and systems dynamics models. Public health agencies will look to modelling and simulation techniques to understand the ‘future state’ of public health conditions under alternative demographic, economic and technological assumptions.
4.1. Literature review approach

The literature review was a key component of our horizon scanning exercise to understand the wider empirical and conceptual developments in the fields of science, organisation and management that will impact upon the co-location of laboratory and other public health services. The purpose of the literature was twofold. Firstly, to horizon scan broadly to understand the key future developments in public health science. Secondly, to examine in more detail key scientific and technological capabilities required by PHE to prepare for future developments and respond to future challenges.

In the first instance our approach was to map PHE’s strategic priorities and areas of activities. From this we undertook a broad review of future developments in public health. From our wider reading regarding future trends in public health science, we derived a number of areas which appeared to merit closer examination in eight literature review ‘deep dives’:

- Behavioural sciences
- Informatics
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- Simulation and modelling
- Genetic technologies
- Infectious disease
- Antimicrobial resistance
- Health improvement
- Emergency preparedness

The selection of these deep dive areas was based on our assessment of the capabilities required to deliver the public health functions identified within the PHE documentation and an understanding of future scientific and technological trends. Each ‘deep dive’ encompassed an extensive review of relevant literature in scientific peer-reviewed journals, technical reports, lay press, market newsletters and other ‘grey’ literature. The literature gathering approach consisted of selecting appropriate and relevant keyword searches applied to targeted databases, including:

- Pubmed/MEDLINE
- Google Scholar
- Web of Science
- PubMed
- ABI/INFORM
- Lexis/Nexis Academic
- Applied Science and Technology Abstracts (ASTA)
- Business and Management Practices (from OCLC/Firstsearch)
- EconLit (from OCLC/Firstsearch)
- Wilson Business Abstracts (from OCLC/Firstsearch)
- Wilson Select Plus (from OCLC/Firstsearch)

The searches were carried out first within a limit of the past five years to try to obtain the most recent literature on technology trends. If these limits did not provide a great deal of literature, the scope was expanded to ten years.

The objective of each ‘deep dive’ literature review was to identify relevant trends both external to and within the deep dive areas; explores areas of synergy; consider major areas of uncertainty; and consider potential implications for PHE. Each review followed a specified structure to ensure a consistent approach was adopted by RAND researchers:

- an overview of the area
- an examination of future scientific and technological trends suggested by the literature
- a discussion of potential, synergies with PHE’s remit determined on the basis of researcher analysis.

The remainder of the chapter presents the key findings from each literature review and the potential implications for co-locating services in an integrated public health science hub are drawn out at the end of the chapter.
4.2. Behavioural Sciences

4.2.1. Overview of the area

There has been a growing focus from academic researchers, policymakers and government health agencies in understanding the role of behavioural sciences in public health science in the 21st century. In a broad sense, health behaviour refers to ‘the actions of individuals, groups, and organizations, as well as their determinants, correlates, and consequences, including social change, policy development and implementation, improved coping skills, and enhanced quality of life’. The importance of behavioural science for the future of public health science can be explained by the fact that the most prominent contributors to death and disease, in the UK and globally, are behavioural factors, particularly tobacco use, diet and activity patterns, alcohol consumption and sexual behaviour. Allied to these factors, changing lifestyle patterns, expanding food portion size, prevalent internet culture, car-dependent community designs, availability of cheap foods high in fat and sugar and ubiquitous fast food have further contributed to the deterioration in public health.

In this context, public health programmes to help people maintain and improve health, reduce disease risks, and manage illness usually require behaviour change at many levels (e.g. individual, organisational and community). There is a growing body of research unpacking what influences behaviour and the relationship between behavioural science and health. Behavioural sciences in public health research have thus come to embody both a conceptual framework for explaining health inequalities and a methodological approach for designing new health interventions.

4.2.2. Future scientific and technology trends

While the importance of behavioural sciences in informing public health policy is agreed upon in the literature, there is limited consensus on what the future trends will be. It is our assessment that the lack of a coherent future vision for behavioural sciences in public health is related to both the relative newness of the behavioural science capability in policy terms, and the broad areas of health improvement targeted by health agencies (e.g. smoking, diet and weight, pregnancy, alcohol, diabetes, and food hygiene). In synthesising the diverse literature, the following future trends stand out: policy planning and design; behavioural nudging; design of intervention trials; ecological modelling; populomics; and data collection and management.

Policy planning and design

A central challenge for policymakers and government public health agencies is planning and designing public health interventions that are attentive to behavioural change. Traditionally, behavioural interventions have emphasised acute change via the assumption an individual, group or community could be behaviourally correct and live more healthily as a result of a brief programme over a short timescale. These approaches have had limited success and there is a need for models of behaviour change that address sustained efforts in the context of changing personal, social, and environmental circumstances. For example, ‘pathway characterisations’ which integrate information from the molecular and cellular level with psychosocial and community information present an opportunity for better understanding of disease etiology.

Interventions can take place at different scales and incorporate policies (legislative), education (teaching or media campaigns), technologies (eg seat belts, food labelling) or resources (access to sports facilities, free condoms). Whereas previous public health science interventions tended to focus narrowly on the individual, future policy approaches may seek to effect behavioural change at the population level.

**Behavioural nudging**

The concept of ‘behavioural nudging’ is related to policy planning. Research suggests that policy approaches to identify population level factors that influence rates of disease, and target those for intervention, have the biggest potential to engender health outcomes even if they fail the test of causality at the individual level. The Behavioural Insights Team at the cabinet office has emphasised the effectiveness of behavioural nudging as a means to steer people towards making healthier choices (see also Section 4.8).

Nudging refers to the practice of ‘altering social or physical environments to make certain behaviours more likely’ and excludes legislation, regulation and interventions that alter economic incentives. As Marteau et al. explain, ‘it draws on behavioural economics and social psychology to explain why people behave in ways that deviate from rationality as defined by classical economics’. Moreover ‘it is embedded in libertarian paternalism, a political philosophy in which people’s choices are actively guided in their best interests but they remain at liberty to behave differently.

**Designing trials**

Related to the above there are future methodological challenges in evaluating behavioural science public health interventions. The literature stresses the importance in robust tests of theory-based interventions, including measurement and analyses of mediator and moderators, to build a more solid evidence base of health behavioural change. Evidence gathering for policymakers may involve decisions about whether to use a group-randomised controlled clinical trial or a quasi-experimental design. Evaluations should not be

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83 Ibid., p. 263.
limited to trials of efficacy but should also be informed by planning and evaluation frameworks utilised by public health practitioners such as the RE-AIM\textsuperscript{84} (Reach, Efficacy, Adoption, Implementation, and Maintenance) and PRECEDE (Predisposing, Reinforcing, and Enabling Constructs in Educational/Environmental Diagnosis and Evaluation)/PROCEED (Policy, Regulatory, and Organisational Constructs in Educational and Environmental Development) approaches.\textsuperscript{85,86}

**Ecological modelling**

The future of behavioural science in public health might also be grounded in a wider ecological perspective that recognises the multiple causes of behaviour. This means that the most effective interventions also should operate at multiple levels. For example, diet and physical activity interventions that build knowledge, motivation, and behaviour change skills in individuals without changing the environments in which they live are unlikely to be effective.\textsuperscript{87} Similarly, just altering the physical activity or the environment may not be sufficient for a substantial change in behaviour. Thus, future interventions for public health improvement will need to operate on multiple levels considering the behavioural and environmental contexts that influence health choices for individuals and populations.

**Populomics**

The next generation of behavioural public health science may also need to build synergies with research in genetics, informatics, computer sciences, measurement, methods and multilevel analyses.\textsuperscript{88} The former chief executive of the Medical Research Council, Professor Blakemore, coined the term ‘populomics’ to describe the crossover between ‘the study of the genetic and phenotypic diversity of human populations, and how they interact with their environments and how their behaviour influences their health and disease patterns’.\textsuperscript{89} According to his report, future research in populomics will examine two main areas: gene-environment interactions and biopsychosocial stress markers. Studies of gene-environment interactions will address questions such as: how are genetic traits and early life experiences linked to physical and emotional health later in life? What role does personality play in the expression of psychosocial risk factors under varying environmental conditions? How are epigenetics and gene expression related to inter- and trans-generational transmission of behaviour and emotion? What impact does the transmission of behaviour patterns have on DNA? Studies of biopsychosocial stress markers, in turn, will address questions such as: what are the biological sequelae of stress, and how do they relate to long-term cognitive and affective reactions? How can these findings be used to understand group


\textsuperscript{89} Op cit. p. 22
behaviour in the context of trauma such as natural or man-made disasters and in phenomena such as premature chronic disease, neurodegeneration with aging? How do poverty and adverse living conditions interact with variation in DNA in disease etiology and progression?

In order to enable all of this, advancements in information technologies have contributed to methodological advances in the biological, molecular and clinical sciences (e.g., DNA chip technology and microarray analysis) which have expanded the scope for populomics to integrate knowledge from the molecular and biological sciences. Therefore, populomics will have a potentially important role to play for future public health science in understanding the complex interplay of socio-behavioural, community and biological factors within the context of the current healthcare system.

Data collection and management

There are significant future challenges for how behavioural data is collected and managed to inform public health science interventions. Future developments will be dependent on progression with biometrics, and the maintenance and widespread use of databases containing genomic information as well as biological, social and behavioural data. Specifically, there are challenges in adopting more scientific approaches to measurement in order to shift focus away from modelling individual trajectories of change, to ones that focus on modelling dynamic systems comprised of interlocking and nested subsystems. National public health agencies and institutes will have a key role to play in driving these areas of research.

More widely, there are opportunities to optimise information and communication technologies to encourage individuals to create ‘digital health identities’ which could be used to inform policy through large-scale data harvesting. As one example of this, the Institute for Future Studies envisages a ‘personal health ecology’ to describe the way new technologies and media could be used by individuals to manage their health and the health of their family.90

4.2.3. Synergies with PHE context

A summary of the main behavioural science capabilities for PHE is shown in Figure 4-1 below.

PHE has already recognised the need to create environments where individuals, families and communities can feel informed, empowered, healthier and happier. For PHE, a key challenge will be how to coordinate policy at different levels. Although the literature on behavioural sciences is diverse, there is a consensus that health improvement interventions at the individual level need to be reinforced at the organisational and societal level if they are to succeed.\textsuperscript{91,92} Similarly, it is unlikely that many organizational and societal campaigns will be fully effective unless reinforced by behaviour change strategies directed at the individual and interpersonal level. This means that decentralisation and localism will also help to shape the way behavioural sciences inform public health science.\textsuperscript{93,94} This is because behavioural science approaches are inherently local and require understanding of different components of the environment.\textsuperscript{95} In this context,

\begin{itemize}
  \item \textsuperscript{93} Glanz and Bishop, \textit{Op. Cit.}.
  \item \textsuperscript{95} Glanz and Bishop, \textit{Op. Cit.}
\end{itemize}
health improvement interventions will need to be locally tailored, implemented and sensitive to social and cultural contexts.\(^{96,97}\)

To this end, behavioural sciences will have an influential role in shaping health improvement strategies (see Section 4.8) and, to some extent, the integration of behavioural science researchers with PHE policymakers may create benefits in terms of knowledge sharing and facilitating multi-disciplinary approaches. However, much of the evidence reviewed suggests that PHE will need to shift away from working at a particular level of intervention (such as changing organisational or individual health behaviours) or employing a specific type of behaviour change strategy (such as group interventions or individual counselling), because, as suggested by the literature, multiple interventions at multiple levels are often needed to initiate and sustain behaviour change effectively. Thus the key challenge in mobilising behavioural sciences for PHE rests on the use of inter-disciplinary, locally sensitive and multi-level approaches to solve clinical, high-risk and population-based public health problems.

### 4.3. Informatics

#### 4.3.1. Overview of the area

The mobilisation of informatics in health policy, research and practice is relatively new, and has led to the emergence of a new field of public health science termed ‘public health informatics’.\(^{98}\) Public health informatics is the systematic application of information and computer science and technology to public health practice, research and learning.\(^{99}\) The scope of public health informatics includes the conceptualisation, design, development, deployment, refinement, maintenance, and evaluation of communication, surveillance, and information systems relevant to public health. It requires the application of knowledge from numerous disciplines, particularly information science, computer science, management, organisational theory, psychology, communications, political science, and law. The practical application of informatics may also involve synergies with other capabilities that contribute to public health (eg epidemiology, microbiology, toxicology, statistics, etc).

Although public health informatics is an evolving capability that is influenced by emerging technologies within public health science, current use falls into three categories. First is the study and description of complex systems (eg models of disease transmission or public health nursing work flow). Second is the identification of opportunities to improve the efficiency and effectiveness of public health systems through innovative data collection or use of information. Third is the implementation and maintenance of processes and systems to achieve such improvements.\(^{100}\)

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\(^{99}\) Ibid.

The importance of an informatics capability has already been recognised by the Department of Health in the strategy on the future of informatics for the UK healthcare system. The strategy predicts a ‘seismic shift in the way information can improve the experience, quality and outcomes of health and care services’. Effective use of information is therefore expected to facilitate and drive integration across care settings and inform health and wellbeing strategies that best meet the needs of local communities.

4.3.2. Future scientific and technological trends

It is generally agreed that healthcare is becoming saturated with data in ways that it never has been before: from biological data such as gene expression, next-generation DNA sequence data, proteomics and metabolomics, to clinical data and health outcomes data contained in ever more prevalent electronic health records (EHRs) and longitudinal drug and medical claims. There are two main reasons for the importance of informatics to public health: the availability of new kinds of data and the potential new ways to use the data. Of the latter, how the data can be used effectively to generate health outcomes is generally to be defined and many of the future trends outlined in the literature are speculative. However, the trends and areas below are some of the issues highlighted in the literature to date.

Bioinformatics and Biomedical Informatics

Scientific advancements in the collection of new genetic and proteomic data have given rise to the possibility of developing new targets and therapies based on new data. Bioinformatics describes the capacity to deal with the large amount of data generated in the laboratory by functional genomics and proteomics and is sometimes referred to as computational biology. Biomedical informatics is more expansive as it also includes clinical and health data. Thus, the scope of biomedical informatics will be a future scientific capability as it requires mobilising tools and techniques to correlate clinical information (eg electronic health records, clinical decision systems, image- and signal-processing) with genotypic information and expressed phenotypic information. One of the potential impacts of bioinformatics and biomedical informatics will be a broader understanding of how minute variations in DNA sequences, protein synthesis and subsequent protein function affect the evolution of diseases at the molecular, individual and potentially population level. This will require integration across a number of areas:

- **Individualised Healthcare.** Biomedical informatics will play a key role in acquiring, representing, analysing and integrating data, eg real integration of genetic data of the patients in clinical information systems.
- **Genomic Medicine.** Bioinformatics capacity will facilitate integrated approaches oriented towards analysing the knowledge of diseases or the personalization of clinical solutions using information coming from the different levels (molecular, clinical or environmental) that take part in disease development. Biomedical informatics can enable multi-level information from bioinformatics to be collated and managed.

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• **Enabling Technologies.** Both types of informatics experts will play an important role in shaping computing, information and communication platform needed to collate data through a variety of analytical devices (see section below on user-led information and networks).

• **Clinical Trials.** Biomedical databases are needed to provide a sound scientific basis for what kind of genetic tests make sense and which tests make healthy people anxious about their future.

### Privacy and data management

A significant future challenge will exist around effective data management in public health science. These challenges are relevant to a number of the capabilities examined in the chapter including behavioural science, informatics, simulation and modelling. Data management refers to ‘the development, implementation, and maintenance of plans, policies, and programmes that control, protect, and enhance the value of data’.\(^{104}\) While the data exists the future will require better ways of knowing how to integrate it, including how to collate and prepare high quality data which can inform public health research analysis and policy formulation. Expertise and technical infrastructures will be needed by public health agencies to clean and manipulate data to ensure data accurately reflect the true nature of what has been measured.

There are reasonable concerns about how to secure data on clinical profiles and genomic/proteomic profiles and the need for informed consent from individuals to use the data. It is our assessment that there is a need for wider public debate between public health agencies and the public to engage with concerns about privacy and the management of personal data.

### User-led information networking and sharing

While there has been much focus on the capacity of the internet to share information and connect individuals and communities via online social networks less attention has been given to its potential to improve health outcomes. The internet has been utilised in innovative ways seeing the establishment of websites for virtual patient networks enabling health users to share and exchange information. Health social networks now are some of the largest patient communities. As of August 2013, PatientsLikeMe has over 195,000 patients in 500 different condition groups; ACOR has over 100,000 patients in 127 cancer support groups; 23andMe has over 100,000 members in its genomic database; and diabetes health social network SugarStats has over 10,000 members.\(^{105}\) While these are the numbers for larger communities, thousands of small communities are created around rare diseases, or even uncommon experiences with common diseases. All of these communities are generating data that they voluntarily share with each other and the world.

ICTs are also transforming how data is collected and managed. The proliferation of smart devices has enhanced the capacity to collect and collate personal health data. There are mobile apps for taking your pulse, and an iPhone attachment for measuring your glucose. The next generation of mobile applications may have the potential to constantly listen to a patient’s speech and detect changes that might be the precursor for a stroke, or would use the device’s accelerometer to report falls. There is significant, yet unrealised potential to link personalised data to doctors’ offices, labs, hospitals, and insurers into a data

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\(^{104}\) H. Rolka et al., *Analytical Challenges for Emerging Public Health Surveillance*, Atlanta, GA: Centers for Disease Control and Prevention, 2012, p.36.

\(^{105}\) O’Reilly et al., *Op. Cit.*
network, so that all patient data is immediately stored in a data centre: every prescription, every procedure and whether or not treatment was effective.  

**Electronic health records (EHR)**

Utilising the informatics capability, public health systems will be able to capture, collect, and integrate standardised data from individual citizens who move within the healthcare domain from outpatient/ambulatory care to inpatient care, enable individuals to add additional health data, and thus provide an interoperable infrastructure for all.  

A future outcome of this data will be the design and use of an electronic health record (EHR) for each individual. The record will provide a point of interface for medical care and has wider applications when aggregated for real-time surveillance (to detect bioterrorism and natural disasters), and providing individualised prevention and health improvement strategies. For example, an integrated system could send timely notices of individualised preventive screening schedules, reminders to improve medication compliance given the regimen of a particular patient, links to community services and resources based on need detected from patient-level health data, and links to connect with other people who share similar health needs and interests.

4.3.3. Synergies with PHE context

A summary of the main informatics capabilities for PHE is shown in Figure 4-2 below.

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106 Ibid.

Figure 4-2: Summary of informatics capabilities

With the rising costs of healthcare there is a growing need for public health agencies to better understand treatment effectiveness. Managing data, integrating and using biological and health data in more effective ways through an informatics capability will be vital to both the healthcare system and to the health and sustainability of the economy overall. This will require the building of dry laboratory capabilities which can serve as a focal point for the storage and integration activities (including mining and data fusion activities, see Section 4.6, on infectious disease). For example, PHE will face a challenge to adapt and integrate biomedical informatics into the healthcare system due to the sheer scope and scale of different kinds of data which might be available in the future. Moreover, new technologies are much more expensive than old ones and biomedical informatics capability needs to be realised incrementally. Rather than being pushed by market forces, healthcare providers should be prepared to carefully select technologies and standardised platforms. Moreover, the adoption of public health informatics will change the way PHE interacts with health users and could enable a culture of shared decision making in which individuals can make better and informed choices about their healthcare system.

However, an advanced informatics capability will require the development of a some form of centralised arrangement that can integrate technological infrastructures needed to manage and analyse large amounts
of data. National standards will ensure that information can flow safely and effectively around the system. PHE will require a local presence to collect data from local populations and to develop health interventions locally. These localised infrastructures will feed into a centralised hub that coordinate and manage ‘big data’ from public health.

4.4. Simulation and Modelling

4.4.1. Overview of the area

Modelling and simulation are capabilities that provide public health science with means for testing and experimenting with potential improvements and future scenarios. They are techniques for understanding current and potential impacts of interventions and identifying unforeseen impacts of interventions. Modelling and simulation techniques have been used in public health science to explore control schemes and to predict future incidence, prevalence and mortality for these diseases as well as monitor their progress for assistance in deciding on public health outcomes.

In public health science, modelling and simulation approaches have been adopted for a variety of reasons:

- To estimate missing data (eg What is the prevalence of dementia in a PCT?).
- To predict the future (eg What will the demand for renal dialysis be in 10 years’ time? How will cost of treating hypertension change over next 10 years?).
- To explore the effect of interventions (eg How will a 10% reduction in smoking affect incidence of lung cancer?)
- To explore how systems might work (eg How could lifestyle change and medical treatment interact to produce a fall in coronary heart disease mortality? Which variables will have the largest effect on the use of emergency departments?).

Although modelling has been undertaken in some areas of healthcare, the use and value of these models remain unclear, as the robustness of models and the extent to which findings have been translated into policy is not routinely evaluated.

4.4.2. Future scientific and technological trends

Accountability and resource management

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Public health agencies are increasingly open to scrutiny from the public and need to show evidence that resource management decisions and interventions are based on robust evidence. Modelling and simulation can provide an alternative to empirical evidence and help public health agencies to manage and plan interventions. For healthcare providers, modelling techniques have been utilised to provide evidence of healthcare expenditures and utilisation. In the US context, health economists have mobilised models to produce national and regional estimates of the impact of changes in financing, health insurance coverage, and reimbursement policy, as well as estimates of who benefits and who bears the cost of a change in policy.

**Population effect models**

As personal health data becomes more widely available, modelling approaches can be used to simulate the life histories of individuals and then estimate the population effect from the sum of the individual effects. Individuals within a population can be included in a simulation model and tracked through a network of options. At each decision point a variety of choices are available, and the outcome will depend on, for example, the characteristics of the entity being modelled and available resources, previous movement through the model, and the choices other entities have made.¹¹² Public health models of the future will be able to inform the development of programmes to improve the population’s health, and consider contextual influences (such as public policies, culture, and the natural environment) and community influences (such as material resources, collective lifestyles and health practices, social interactions, the built environment, health services and biological characteristics) in models. Models of population health can also enrich public health practice by providing evaluative frameworks for programme design and implementation.

**Prevalence modelling**

Prevalence modelling is a specific modelling technique to estimate the number of people with a particular condition or risk factor in a population when direct evidence is not available.¹¹³ Direct evidence may be lacking because surveys or data collection have not been undertaken, are technically impractical or are unreliable. Methods for generating synthetic or modelled estimates range in complexity from simple to highly sophisticated. For example, crude estimates of the number of cases can be generated by applying known prevalence rates to a different population, for example applying national rates measured in a large survey to a local population; or applying local rates for a recent year to a projected future population. However, many factors such as age, gender, deprivation and ethnicity can influence the prevalence of a behaviour, risk factor or disease and more complex epidemiological modelling techniques are required in order to take such factors into account.

**Systems dynamics modelling**

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A further technique that public health science will draw upon for modelling and simulation is systems dynamics modelling. Systems dynamics modelling is a tool for modelling multiple interacting diseases and risks, the interaction of delivery systems and diseased populations and matters of national and state policy. The approach is linked to the ecological approaches in behavioural sciences and is broad in nature to encompass analysis disease, health and risk behaviours, environmental factors, and resources that provide health and social services or are involved in health-related social transformation. Models combining delivery systems and risk and disease epidemiology could help policymakers and healthcare providers understand the nature of coordination required to put ambitious public health and risk reduction programmes in place without overwhelming delivery capacities.

**4.4.3. Synergies with PHE context**

A summary of the main simulation and modelling capabilities for PHE is shown in Figure 4-3 below.

![Figure 4-3: Summary of simulation and modelling capabilities](image)

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Public health agencies will look to modelling and simulation techniques to understand the ‘future state’ of public health conditions under alternative demographic, economic and technological assumptions, which are subject to the greater levels of uncertainty traditionally associated with sampling and non-sampling error.115 With advancements in ICT infrastructure and enhanced data collection, modelling approaches will be better placed to assess the impacts of revisions to existing public health approaches. For example, modelling and simulation can help inform public health emergency planning and responses. Overall, the evidence from the literature review suggests that modelling and simulation capabilities will have an increasingly important role in informing public health science and policy in the future.

4.5. Genomics and genetic technologies

4.5.1. Overview of the area

Genetic sciences have expanded over the last two decades and promises to support public health initiatives to be more cost-effective, precise and ultimately be better able to improve people’s health. Using genetic technologies can further our understanding of disease risk in the future, support diagnosis and prognosis, enable prioritising preventative or therapeutic options and develop targeted vaccines or antimicrobials.116 Advances in bioinformatics (discussed above) will help analyse the mass volumes of data being generated using high throughput techniques such as microassays. The UK is well positioned to be a leader in adopting genetic technology innovation because foundations in this area of research were built in this country and we have increasing partnerships between the NHS, academia and industry enabling us to embed innovation at different levels.117

In the past two decades genetic science’s applicability to investigate the relationship between human genes and health has evolved and continues to expand. Genetic technologies are now being used to identify conditions resulting from specific mutations such as cystic fibrosis and currently there are tests available through the UK Genetic Testing Network for 519 diseases based on the network’s assessment of valid and useful tests.118

However, the literature suggests that progress is stalling as we try to understand the genetic complexity underlying common chronic disease over monogenic conditions.119,120 More recent genetics research is expanding to tackle this problem and bring genetics up to speed for today’s diseases. For example, epigenetics is a rapidly expanding field, but one which relies on more than just molecular understanding of the genetic code. Epigenetics relates to changes in gene expression and phenotype rather than the

117 Ibid.
genetic code itself. Here, gene expression may be modified by environmental factors, requiring a more integrated understanding and analysis of what factors might cause modifications and why. Epigenetics are thought to be significant in diseases such as cancer that may not be caused by a known mutation, but rather by an interplay between genetic and environmental factors. Such increased understanding of the relationship between genotype, gene expression and phenotype has given way to rapidly expanding fields of stratified and predictive medicine.

4.5.2. **Future Scientific and Technological Trends**

Advances in genetics have been exponential in the past two decades, and genetic technologies underpin future approaches to individual and population health. However, currently most genetics research is still in the basic pre-clinical phase and not ready for application. Regardless, there are predictions for a paradigm shift in healthcare from the current reactionary paradigm to one of prediction and prevention. This shift will support individual health and, moreover, it is anticipated that the genomics era will support health systems by helping to manage and allocate resources most effectively. Stratified medicine and preventative medicine are two areas that may enable more accurate predictions of disease risk, prognosis and the benefits of therapies, allowing for more effective and efficient resource use. Pathogen genomics continues to be significant in tracking and identifying infectious disease and will play an increasingly prominent role in an era of antimicrobial resistance. Enhanced technological tools and capacity continue to determine advances in genetics and act as an essential catalyst for future development. Each area is discussed in turn below.

**Stratified and predictive medicine**

Stratified medicine involves identifying strata in which to group patients with a particular condition based on disease mechanisms. Traditionally most disease treatment is prescribed based on an average effectiveness response calculated from large clinical trials. In contrast, within stratified medicine studies continue to identify many genetic variations underlying disease so that we are better able to predict an individual’s response which may deviate from the average. Knowing the genetic variations underlying a disease will help to identify those who are likely to benefit the most or the least from particular treatments. There are plans in the UK to increase research in this area. For example, the Medical Research Council plans to set aside £60 million over the next four years for research on stratified medicine and Cancer Research UK has an ongoing stratified medicine programme that ultimately aims to make

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125 Stratified Medicine: Medical Research Council, 2013. As of 14 August 2013: [http://www.mrc.ac.uk/Fundingopportunities/Highlightnotices/stratmed/MRC008933](http://www.mrc.ac.uk/Fundingopportunities/Highlightnotices/stratmed/MRC008933).
stratified medicine routine in NHS practice.\textsuperscript{127} Future research will continue to understand genetic and molecular bases of diseases and there is opportunity to identify biomarkers to stratify patients in more conditions, for example, in depression.\textsuperscript{128}

Predictive medicine, which overlaps with stratified medicine, involves ascertaining individuals’ risk for particular diseases based on genetic profile. Both rely on identification of clinical biomarkers. These biomarkers are biological measurements that are used to assess disease risk, detect disease early, and classify patients for treatment as in stratified medicine.\textsuperscript{129} For example, there are advances in identifying the individual risk of obesity using this approach.\textsuperscript{130} However, the utility of predictive medicine in this way is still uncertain. Moreover, there is evidence that communicating risk information to individuals might not necessarily result in the altered behaviours, such as increased exercise, that are required to mitigate the risk.\textsuperscript{131}

Pathogen genomics

Alongside advances in human genotyping have been advances in genotyping other organisms to support human health. Identifying genomic sequences of pathogens is becoming more important to study infectious disease, pathogens and patterns in disease transmission,\textsuperscript{132} particularly in infectious diseases that pose widespread risks to population health. For example, DNA fingerprinting to genotype bacteria causing TB was crucial on public health efforts involving detecting TB outbreaks and classifying ill patients according to TB strains.\textsuperscript{133} Knowing genetic sequences of both pathogens and hosts has resulted in an increase in the number of potential vaccine and drug targets to control infectious disease; using genetic approaches over conventional empirical approaches enables 10–100 times more candidates over 1–2 years.\textsuperscript{134} Genomics can also be used to detect variants in viruses with few genes, enabling faster detection of mutations and development of therapies.\textsuperscript{135} This potential application is especially pertinent in an era where antimicrobial resistance is becoming more prominent; sequencing organisms enables a

\begin{thebibliography}{9}
\bibitem{135} Ibid.
\end{thebibliography}
better understanding of particular genes that have mutated to result in resistance and the spread of mobile genetic elements conferring resistance. In the future, genomics will be the first line of defence to identify antigens, develop diagnostic tests and characterise causative agents for emerging infectious diseases.

Technology

Technological capacity underpins genomics and has made the advances to date possible. More computational and analytical tools will be required to support future research and emerging genetics disciplines. The decreasing cost of sequencing organisms and bioinformatics advances are resulting in the generation of huge amounts of data. High throughput genetic sequencing technologies continue to evolve, and become even faster by sequencing millions of DNA fragments in parallel. Understanding functional pathways and the interplay between environmental influences and genetic factors particularly will require further development of robust approaches to analyse complex data sets through enhanced computational abilities. At the same time as technology develops to support emerging trends in genetics such as populomics, which incorporates behavioural sciences and genetics at a population level, specific skill sets are also required to make the data useful. For example, within stratified medicine there is a foreseeable need for more sophisticated and powerful informatics technology and training of bioinformaticians with large dataset analysis skills. Within predictive medicine, predictive health IT systems are already in development, which analyse information from a range of genomic information systems and other health assessment tools.

4.5.3. Synergies with PHE context

A summary of the main genetic technology capabilities for PHE is shown in Figure 4-4 below.

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137 Seib, Dougan and Rappuoli, Op. Cit.


141 The Academy of Medical Sciences, Op. Cit.


143 The Academy of Medical Sciences, Op. Cit.
Figure 4-4: Summary of genetic technology capabilities

Genetic sciences have an important role to play in providing population data to inform public health initiatives and ultimately be better able to improve people’s health. Continuing to build capacity in this area, including technical understand to enable cross-sector working, will be important for PHE to better understand disease risk in the future, support diagnosis and prognosis, enable prioritising preventative or therapeutic options and develop targeted vaccines or antimicrobials. The effective application of genetic technologies to public health involves disciplines will range from computer scientists to wet lab scientists, social scientists, and public health practitioners. Hard sciences, including computer science, will be required to continue to study genetic pathways themselves, develop techniques and tools, analytic methods, and to give meaning to genetic data. Furthermore, epidemiological skills are required to apply genetics to surveillance and disease tracking. At the same time social scientists including sociologists and psychologists are vital to apply genetics research to patients and population health, and overcome challenges in transferring genetic technologies into an everyday tools used in clinics and hospitals, including facilitating the cultural change that must accompany a shift away from the biomedical paradigm.

4.6. Infectious diseases

4.6.1. Overview of the area

While the previous areas discussed in this literature review have been focused around specific capabilities that PHE will need in the future, the final areas concentrate on the question of how some of these different capabilities will help to address pressing public health issues for the future. While there are many public health issues which could be addressed, we have focused here on three cross-cutting challenges, two of which are inter-related: infectious disease and antimicrobial resistance (AMR) and health improvement.

Infectious disease coupled with the rise of antimicrobial resistance has been identified as a key public health concern for the UK by the Chief Medical Officer. Infectious diseases are driven by a large and diverse range of social, environmental and ecological factors. For example, changes in land use and agriculture (such as increased human contact with previously remote areas) may enable the transmission of novel pathogens. Similarly, zoonotic diseases may emerge through increased trade in animals and animal products (particularly illegal trade which is not regulated or monitored). Climate change may lead to extreme weather events, such as flooding which may increase the likelihood of infection; it may also increase the diversity and longevity of disease vectors. Sexually transmitted infections will also be affected by societal and demographic change as well as changes in sexual behaviour. Other potential drivers of infectious disease include international travel and trade, intensification of agriculture and livestock-keeping, misuse, over-use and abuse of antimicrobial drugs and bioterrorism to name a few. The most recent Foresight report on infectious diseases found that the three sources of greatest future threat for human, animal and plant diseases in the UK are:

- New pathogens, or new strains of existing pathogens, arising through natural genetic change
- Geographical extension of pathogens from within or outside the UK
- Increased pathogen resistance (eg to microbicides)

The report also identified two key trends which are seen as important drivers of future disease threats:

- Emergence of resistance to current disease control, that is, the use of drugs in animal and human disease and pesticides for plant (see also Section 4.7).
- A change in global temperature by 0.5–2°C, affecting conditions for disease emergence or spread.

Infectious diseases are a major threat to public health, given their ability to rapidly incapacitate whole populations. They present a particular hazard, because new infectious diseases often appear without warning and precedent (eg HIV and BSE). With that in mind, infectious disease and its drivers must be comprehensively monitored both nationally and internationally. The rest of this review focuses on

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147 Ibid.
148 Ibid.
surveillance and required capabilities, although it is important to note that aggressive infection control and vaccinology programmes will also be important in responding to the threat of infectious disease.

4.6.2. Future scientific and technological trends

In order for infectious disease surveillance programmes to be successful, they will need to be comprehensive, integrating data from a wide range of heterogeneous sources. For example, hospital admissions data should be linked with surveillance of outcomes, lifestyle risk factors, potentially remediable risks from environmental tracking (e.g. water quality monitoring reports), electronic medical records, veterinary health records, and data external to healthcare such as satellite images, CCTV images, blogs and wikis. This will draw on a range of future technological developments, which are summarised below.

Improved diagnostic tests (including self-diagnostic devices)

Improvements in molecular testing as well as whole genome sequencing will aid in monitoring infectious diseases as well as antimicrobial resistance (this is explored in further detail in the antimicrobial resistance literature review). This technology is likely to become standard in the near future and ‘advances in the techniques and hardware will drive the increases in throughput, automation and miniaturisation that will enable these technologies to be used and interconnected at all levels from the laboratory to the field.’

Self-diagnostic tests are also currently in development and this raises issues in terms of surveillance and regulation more generally. Firstly, healthcare professionals must maintain access to diagnostic information. This could be achieved by insisting on professional consultation for treatment, or by producing devices which automatically relay diagnostic information by radio link. Secondly, it would be useful if interoperability and open standards were developed across diagnostic tests. These technologies will need to be validated and regulated, and provision of information, advice and support will be required.

Intelligent sensor networks (ISNs)

Intelligent sensor networks ‘perform the collection of reliable and timely information which in turn enables early warning, supports decision making and helps provide rapid and co-ordinated responses to potential threats’. This technology is required in order to provide real-time monitoring, which is then processed and analysed through interconnected computer systems. Sensor networks will be important to a range of areas relevant to public health such as climate change, flood warning, drinking water distribution systems and syndromic reporting. A current example of intelligent sensor networks in

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151 Foresight, ibid, p. 3.


practice is FloodNet which is a flood warning system that uses a set of sensor nodes to collect readings of water level, which it then communicates via an ‘asynchronous reliable messaging infrastructure to a grid-based flood predictor model’.\textsuperscript{155}

There are several issues to consider in the future development of ISNs. In terms of technological advances, developments in silicon technology will enable entire systems to be produced on a single chip, and smaller, lower-cost sensors are being developed which will lead to their wide deployment. However, as sensors continue to be developed, it will be essential to ensure interoperability, which will be achieved through standards for describing devices, services and data.\textsuperscript{156} A second issue to consider is that of trust. It is unclear at this stage how much reliance should be placed on information provided by ISNs.\textsuperscript{157}

Data mining and data fusion

Data mining and data fusion operate at the next stage of the pipeline from intelligent sensor networks. It refers to a set of techniques that ‘enables data from a wide range of heterogeneous sources to be used in applications such as anomaly detection, hypothesis testing and epidemiological model calibration for the detection and identification of infectious diseases in plants, animals and humans’.\textsuperscript{158} It draws on grid computing, a term for ‘sharing heterogeneous resources which are under different ownership or control, over a network using open standards’.\textsuperscript{159} Data used may be structured (such as electronic medical records, satellite images or CCTV images) or unstructured (such as blogs, wikis and other measures of personal communication).\textsuperscript{160} Novel techniques have been developed to mine unstructured data such as Google searches using smart analytics. In the United States, web search queries were analysed to track influenza-like illness in different regions of the country. There was found to be a high correlation of influenza related Google queries with the percentage of physician visits in patients with influenza-like symptoms.\textsuperscript{161}

There are several issues which should be acknowledged in exploring the future of data mining and data fusion in public health. The need for such comprehensive surveillance raises issues such as ethics, sovereignty, data protection and freedom of information which will require substantial regulation. Secondly, new methodologies and processes will need to be developed to ensure confidence in the results. Moreover, semantic data integration is required, which can only be addressed through distributed (ie networked) processing, analysis and knowledge management techniques. These are all relevant issues in considering co-location.

Biosensors and biomarkers

\textsuperscript{156} Foresight, \textit{Op. Cit.}
\textsuperscript{157} Ibid.
\textsuperscript{158} Ibid.
\textsuperscript{159} Ibid.
\textsuperscript{160} Ibid.
According to the 2006 Foresight report, two major technology trends are likely to have the biggest impact on biosensors of infectious disease diagnosis and monitoring.\textsuperscript{162} The first is nanotechnology, which will have an impact on diagnostics (specifically lateral-flow diagnostics). Rather than using dyes to display the read-out system on immunodiagnostic platforms, developments in nanotechnology have ‘led to the introduction of new materials based on metal nanoparticles, where light is absorbed or reflected through interactions with surface plasmons in the metal’.\textsuperscript{163} This allows for a numerical readout which can be captured in digital form, and therefore stored and archived. The second is the increasing interconnectedness of electronic devices. However, as outlined above in relation to data fusion, this raises issues beyond the technological which will first need to be addressed.

4.6.3. Synergies with the Public Health England (PHE) context

A summary of the capabilities needed for PHE to address infectious diseases is shown in Figure 4-5 below.

![Figure 4-5: Summary of infectious disease capabilities](image)

Responding to infectious diseases falls under a key component of PHE’s remit in protecting the country’s health. The primary emphasis in responding to infectious disease through surveillance is on the

\textsuperscript{162} Foresight, \textit{Op. Cit.}

\textsuperscript{163} Ibid., p. 16.
The Foresight report states that surveillance technologies need to be both generic and flexible, meaning that traditional divides between virology, bacteriology, mycology and parasitology, or between medicine, veterinary medicine and plant science need to be bridged. This means that technological developments need to be integrated, for example by combining handheld diagnostic devices with wireless internet links. In terms of skills, interdisciplinary approaches to training are needed as well as close collaborative working. This may be enhanced through effective communication.

4.7. Antimicrobial Resistance (AMR)

4.7.1. Overview of the area

Antimicrobial Resistance (AMR) refers to a bacterium’s ability to survive and replicate during a course of treatment with a specific antibiotic. AMR is driven by a wide range of factors, one of which is the over-use, misuse and abuse of antibiotic drugs (where over-use refers to the prescription of antibiotics when they are not necessary, misuse refers to the prescription of antibiotics when they are likely to be ineffective, such as the failure to adjust antibiotic prescriptions based on culture data and abuse refers to a physician preferentially prescribing one antibiotic drug over all others, for example due to financial reasons). Both over-use and misuse are exacerbated by diagnostic uncertainty. Antibiotics have also been over-used in animals and the agricultural setting. This has resulted in the spread of antimicrobial resistance through the food chain, revealing the need for an integrated response between health agencies and veterinary healthcare providers.

Aside from the use of antimicrobials, there are a variety of social drivers which could shape the future of AMR. Firstly, population characteristics could determine national trends. An increase in immune compromised patients, growing life expectancy and the susceptibility of older persons to infections ‘could indirectly contribute to greater antimicrobial drug use and dissemination of resistant microbes’. Secondly, health beliefs and antimicrobial drug demand may impact on the way in which AMR develops in given populations (although few studies exist on this subject). This could be addressed through educational campaigns aimed at the general population in order to inform them of inappropriate antibiotic drug use and its contribution to AMR. Thirdly, international travel and globalisation may play a significant role in AMR’s development. More specifically, ‘global mixing, increased population density and decreased travel times’ may ‘facilitate the spread of a variety of antimicrobial resistant pathogens such as fluoroquinolene-resistant pneumococci and enteric microbes’. To some extent, AMR

164 Ibid., p. 32.
169 Ibid., p. 796.
will also be driven by drivers of infectious disease, such as climate change, the increased use of medical devices and gene therapies, infection control and behaviour change.

Antimicrobial resistance is a significant concern for public health. It is responsible for an excess duration of hospital stay of 6.4 to 12.7 days\(^{170}\) and antibiotic resistant infections are associated with a 1.3–2-fold increase in mortality compared to susceptible infections.\(^{171}\) Moreover, antimicrobial resistance is responsible for significant economic burdens, although the real cost is difficult to quantify. Smith and Coast point out that AMR is responsible for increased costs of care associated with: ‘additional investigations such as laboratory tests and X-ray examinations; additional or alternative treatments, often much more expensive than drugs used to treat infections caused by sensitive organisms; additional side-effects from more toxic treatments, which have to be managed; longer hospital stay; longer time off work; reduced quality of life and productivity; greater likelihood of death due to inadequate or delayed treatment, hence reducing the workforce; increased burden on family of infected individual; increases in private insurance coverage; additional cost for hospital when hospital-acquired infection occurs and infection control procedures required; increased costs of disease surveillance; increased costs to firms of absenteeism, possibly leading to increased product prices; and so forth’.\(^{172}\) Smith et al. took costs external to healthcare into account when developing a computable general equilibrium to estimate the cost of MRSA in the UK. In assessing the economy-wide impact they found that MRSA is responsible for a 0.4%–1.6% reduction in GDP and a 0.3%, 0.35% and 2% reduction in household income, government tax revenues and total national savings respectively.\(^{173}\) Household income, government tax revenues and total national savings in the UK were estimated to fall by at least 0.3%, 0.35% and 2% respectively, due to MRSA alone.\(^{174}\) Interventions in the healthcare setting will be important in responding to AMR, such as antimicrobial stewardship, rapid diagnostic tests and aggressive infection control. However, complex diagnostic testing alongside a comprehensive surveillance system will be essential public health functions in addressing the threat from antimicrobial resistance.

### 4.7.2. Future scientific and technological trends

There are a number of scientific and technological developments which are likely to impact on how antimicrobial resistance is addressed in the future. These trends are summarised below, along with their relevance to a public health response to AMR.

**Development of antimicrobial drugs**

There is a general consensus in the literature that the key to addressing AMR will be in the development of new antibiotics. Ridge et al. (2011) state that ‘while better diagnostics and strengthening stewardship...
are critical, they are likely only to buy time while new antimicrobials are developed.\textsuperscript{175} It has been suggested that this could be encouraged through push incentives to reduce the marginal cost of R&D, pull incentives to foster R&D through financial rewards, legal-regulatory incentives such as adjusting pricing and reimbursement, and hybrid push-pull incentives such as product development partnerships. However, the assumption of the feasibility of new drug development has been recently challenged by Cormican and Vellinga (2012), who suggest that the existing classes of antibiotics may be the best there will ever be and warn against ‘creating an expectation that economic incentives can generate a pipeline to compensate for our squandering of this non-renewable resource.’\textsuperscript{176} As such, it is unclear whether new antimicrobial drugs will be developed in the future, and therefore public health responses utilising technological developments may be of even more significance.

**Improved diagnostic tests**

As technology advances, diagnostic tests are becoming increasingly sophisticated and this is something which is likely to continue. This is particularly important in addressing AMR given that the development of molecular diagnostics may increase diagnostic accuracy and aid physicians in the appropriate prescription of antimicrobials. Not only this, but molecular methods are also contributing to the rapid identification of pathogen and resistances, such as gene detection for specific pathogens.\textsuperscript{177} Of these, whole-genome sequencing may be of most importance to public health, given that it can be used ‘to support the investigation and control of outbreaks, such as those that occur following the ingestion of food or drink contaminated by a pathogenic bacterium.’\textsuperscript{178} With the use of appropriate bio-informatics, this technique allows for specific pathogens isolated in diagnostic laboratories to be sequenced and this information could be collated and compared over time to track disease trends. This capability is linked to public health surveillance, explored further below.

However, there are several barriers to the widespread implementation of this method. At present there are no detailed assessments of the feasibility, utility or cost-effectiveness of rapid whole bacterial genome sequencing.\textsuperscript{179} Moreover, there is a lack of automated tools that ‘interpret sequence data and that provide clinically relevant information in a format that can be acted upon by people with no specialist informatics expertise’.\textsuperscript{180} In order to fully benefit from bioinformatics and improved diagnostic testing, all public health staff will need training in specialist microbiology and virology.\textsuperscript{181}

**Surveillance**

Surveillance is a key public health function and is of primary importance in addressing AMR and infectious diseases more broadly. In order to be successful, surveillance efforts will need to integrate data

\textsuperscript{175} Walker, Fowler and Murphy, eds., *Op. Cit.*, p. 82.

\textsuperscript{176} M. Cormican and A. Vellinga, 'Existing Classes of Antibiotics are Probably the Best we will Ever Have', *British Medical Journal*, Vol. 344 No. e3369, 2012.

\textsuperscript{177} Walker, Fowler and Murphy, eds., *Op. Cit.*, p. 82.

\textsuperscript{178} Ibid, p. 132.

\textsuperscript{179} Ibid.

\textsuperscript{180} Ibid.

\textsuperscript{181} Ibid.
from a large amount of sources. Surveillance should also exploit genomic and molecular data from new diagnostic tests as outlined above.

In order to integrate data from such a wide variety of sources it will be necessary to draw on technological developments in data mining and data fusion, intelligence sensor networks, grid computing, genomics and bioinformatics and biosensors and biomarkers. It will also be necessary to ensure regulations are in place to allow the free sharing of data across a wide range of bodies. Surveillance is explored further in relation to infectious diseases (see above).

**Vaccinology**

The development of new vaccines is likely to contribute to the ‘decreased transmission and impact of antimicrobial-resistant bacteria in the near future’.\(^\text{182}\) In order to select the most appropriate vaccines, there will be a need to draw upon ‘first class disease surveillance, economic analysis of cost effectiveness and mathematical modelling’.\(^\text{183}\) In addition, new innovation models for stimulating vaccine development will be required, which may require multiple actors in the innovation system to come together. For example, demand-side measures such as procurement signalling, value-based pricing and prizes will all require multiple research institutions, industry representatives and government bodies to come together. There is a clear role a public health body could play in both informing and helping to set the direction for future vaccine development efforts were the right measures in place. Finally, amidst public concerns around vaccine safety it may also be necessary to run education campaigns (drawing on other capabilities like behavioural science as discussed below) in order to assure the public of a vaccine’s safety, alongside new diagnostic technologies for rapid detection of adverse side effects.\(^\text{184}\)

**Educational campaigns**

Health beliefs and AMR drug demand, as we have outlined, could influence physician prescribing habits and the widespread use of antimicrobial drugs. In order to address this, educational campaigns aimed at the general population may be necessary, in order to educate them about the harms of antimicrobial overuse. Such campaigns would draw on behavioural science capabilities.

**4.7.3. Synergies with the PHE context**

A summary of the capabilities needed for PHE to address antimicrobial resistance is shown in Figure 4-6 below.
Responding to antimicrobial resistance is a key part of PHE’s responsibilities in protecting the country’s health. It also has synergies with PHE’s responsibility for vaccination and screening programmes. In utilizing the techniques and methodologies outlined above, a range of capabilities will be required. It is clear that the response to antimicrobial resistance will require a broad range of capabilities from a number of disciplines. Capabilities in bioinformatics, genomics and microbiology will be required to exploit developments in diagnostic testing and surveillance. In relation to surveillance more generally, a range of technological capabilities will be needed such as data mining and data fusion, the use of intelligence sensor networks, grid computing and biosensor and biomarkers. Big data capacity will also be required, particularly in the use of smart analytics and integrating data in surveillance links with informatics and modelling. In implementing vaccinology programmes and educational campaigns it will be important to utilise modelling and behavioural science (in addition to capabilities already outlined elsewhere).
4.8. Health and wellbeing: health improvement

4.8.1. Overview of the area

The most recent Public Health white paper, *Healthy Lives, Healthy People*,\(^{185}\) takes a broad approach to health and wellbeing, recognising that it encompasses wellness as well as the absence or presence of disease (whether that is mental or physical). Inherent to health and wellbeing improvement is lifestyle choice. *Our Health and Wellbeing Today* suggests that many deaths and illnesses could be avoided by adopting healthier lifestyles.\(^ {186}\) It estimates a substantial proportion of cancers, around one-third of circulatory diseases and a large proportion of vascular dementia could be avoided through a combination of reducing smoking rates, improving diet and increasing physical activity.\(^ {187}\) Britain is now the most obese nation in Europe, has the worst rates of recorded sexually transmitted infections, a relatively large population of problem drug users and rising levels of harm from alcohol.\(^ {188}\)

There are growing health inequalities in England, both in terms of life expectancy and quality of life. *The Marmot Review* found that there is a systematic pattern of declining health linked to declining socioeconomic status in England.\(^ {189}\) The review also found a gap of seven years in life expectancy between the richest and poorest neighbourhoods, and a gap in disability-free life expectancy of up to 17 years. The cause of these inequalities is linked to road traffic accidents, emotional and behavioural problems and anxiety and depression.\(^ {190}\) In terms of behaviour, ‘harm from alcohol, illicit drugs and smoking is concentrated in people from lower socioeconomic groups, with 30% of men and 20% of women in the most disadvantaged groups having at least two or three high-risk behaviours compared with less than 10% (men) and less than 5% (women) in the least disadvantaged groups’.\(^ {191}\)

In this context health and wellbeing will become an increasingly important area of focus for public health agencies. The area has been defined by the 1986 WHO Ottawa Charter as the process of ‘enabling people to increase control over, and to improve, their health’.\(^ {192}\) The charter clearly identifies a link between health improvement and behaviour change. Firstly, it states that supportive environments should be created in which the ‘overall guiding principle for the world, nations, regions and communities alike, is the need to encourage reciprocal maintenance – to take care of each other, our communities and our natural environment’.\(^ {193}\) Secondly, it states that community action should be strengthened drawing on ‘existing human and material resources in the community to enhance self-help and social support, and to


\(^{188}\) Ibid.


\(^{191}\) Ibid., p. 18


\(^{193}\) Ibid., p. 2
develop flexible systems for strengthening public participation and direction of health matters. Finally, it outlines the connection between health improvement and personal development, stating that ‘health promotion supports personal and social development through providing information, education for health and enhancing life skills’.

The capabilities needed to design and inform health improvement promotion strategies are explored in the following literature reviews (in particular behavioural science and simulation and modelling). The purpose of this overview here is to provide a review of the area of health improvement and to identify key developments.

4.8.2. Future scientific and technological trends

From April 2013 a number of health improvement responsibilities were passed to local authorities, including tackling campaigns such as encouraging the public to quit smoking, eat healthily and be more physically active. The National Institute for Clinical Excellence (NICE) has produced public health briefings for local government on areas such as tobacco, workplace health, physical activity and alcohol, among others.

In order to address these areas, a range of different health improvement strategies are likely to be required. While many of them are highlighted in the sections below, the concept of behavioural nudging is one which can be thought of as an overarching conceptual approach for tying them together. Nudging refers to the practice of ‘altering social or physical environments to make certain behaviours more likely’ and excludes legislation, regulation and interventions that alter economic incentives. As Marteau et al. explain, ‘it draws on behavioural economics and social psychology to explain why people behave in ways that deviate from rationality as defined by classical economics’. Moreover ‘it is embedded in libertarian paternalism, a political philosophy in which people’s choices are actively guided in their best interests but they remain at liberty to behave differently.’ As a conceptual and methodological approach for health improvement, then, behavioural nudging will draw upon scientific and technological developments in areas such as behavioural science, modelling and informatics, and will be informed by different types of data generation and integration strategies. In particular, behavioural data, ecological models and the ‘populomics’ approach will be important for informing the design of health improvement strategies which can lead to better health prevention in the population.

4.8.3. Synergies with PHE context

A summary of the main health improvement capabilities for PHE is shown in Figure 4-7 below.

194 Ibid., p. 3
195 Ibid., p. 3
197 Ibid., p. 263
198 Ibid., p. 263
Health improvement and wellbeing were previously the responsibility of Primary Care Trusts, overseen and supported by Strategic Health Authorities, informed by evidence from NICE and led by priorities set by the Department of Health. However, now this remit has now been subsumed into PHE. Health improvement is a key component of PHE’s mission to save lives, enhance wellbeing, and create environments where individuals, families and communities can feel informed, empowered, healthier and happier. PHE advocates an integrated approach to improving health and wellbeing and has identified five key areas of focus: wellbeing and mental health; diet, obesity and physical exercise; smoking; alcohol and Drugs; and HIV and sexual health. Tackling these areas will require cross-disciplinary methodologies (e.g., behavioural sciences, informatics, genetic technologies) and a holistic view of the ways to promote healthy environments and wellbeing. The capabilities which may be required for health improvement in the future are discussed below.


4.9.1. Overview of the area

The final area we reviewed was Public Health Emergency Preparedness (PHEP). PHEP focuses on the pre-emergency phase, with the aim of ensuring that public health agencies anticipate, assess, prevent and
prepare for any major event that has the potential to overwhelm routine capabilities. It is thus both a capability and a future public health challenge that PHE will need to address.

Incidents such as the heatwave in the summer of 2003, the flooding of Boscastle in Cornwall on 16 August 2004, the London Bombings 7 July 2005 and the avian influenza outbreak at the Bernard Matthews site 2 February 2007 illustrate the diverse and complex nature of threats to public health. Threats can also originate outside of our borders, for example the 2009 swine flu pandemic which was first identified in Mexico and the Icelandic ash cloud in 2010, which caused the largest closure of air-traffic space since World War II.

When a major event such as these happens it can put considerable strain on the system. It can disrupt the infrastructure needed to deliver relief, services can become overwhelmed by the potential scale of casualties and panic can impede the ability to act quickly and efficiently. However, the severity of impact does not solely correspond to the size of the event but also upon the level of exposure and vulnerability of the affected community. Adequate preparedness, through risk assessment, capacity planning and event management capabilities can do much to prevent and mitigate risk, and strengthen the response of vulnerable communities. An emergency response strategy should be a flexible and adaptable arrangement that can be scaled accordingly to respond to any event regardless of cause.

PHE is responsible for strengthening health protection systems, gathering data to support emergency plans, carrying out risk assessments, and providing specialist advice and support to the emergency services and NHS. Its role has been outlined in the Health and Social Care Act 2012 as follows:

Public Health England will be responsible for providing public health Emergency Preparedness, Resilience and Response (EPRR) leadership and scientific and technical advice at all levels, co-ordinating its activities closely with the NHS and Directors of Public Health. It will deliver specialist public health services to national and local government, the NHS and the public, working in partnership to protect the public against infectious diseases and minimise the health impact from

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201 Major Incident Plans. As of 14 August 2013: [http://www.patient.co.uk/doctor/Major-Incident-Plans.htm](http://www.patient.co.uk/doctor/Major-Incident-Plans.htm)


210 Ibid.
hazards. PHE will also be responsible for assuring itself that its systems are fit for purpose to respond to incidents and emergencies.\textsuperscript{211}

To deliver this PHE will work with local government who are responsible for ensuring that plans are in place to protect the health of their local population.\textsuperscript{212}

\subsection*{4.9.2. Future scientific and technological trends}

The risks that the UK faces are continually changing. The National Risk Register provides a comprehensive overview of the risks posed to the UK and the future likelihood of such events.\textsuperscript{213} Overall, the number, scale and cost of disasters is increasing. For example natural events as a consequence of climate change are becoming more frequent, while human exposure and vulnerability to hazards is increasing due to a growing and ageing population, and increasing assets.\textsuperscript{214} A RAND report looking at PHEP in the US found that standards and best practice for PHEP have been developed without a strong empirical evidence base owing to the relatively few opportunities to learn from real-life responses to large scale public health emergencies.\textsuperscript{215} PHE, through partners such as Environmental Hazards and Emergencies, has the responsibility for continuing to develop the evidence base for the public health impacts of extreme events in England.\textsuperscript{216}

\section*{Surveillance}

Emergency preparedness is an ongoing process that requires continual surveillance of the public’s health and related factors to be able to detect even the smallest changes that might be indicative of an adverse event, for example a localised increase in the incidences of influenza might be the first signs of a wider influenza pandemic. It entails the systematic collection, recording, analysis, interpretation and dissemination of data reflecting the current health status of a population. Epidemiological surveillance is particularly relevant for monitoring the risk posed by new and re-emerging disease outbreaks,\textsuperscript{217} and consequently has been covered extensively in the literature reviews for AMR and infectious diseases. Surveillance requires improved data handling across PHE. Implementing a national strategy to ensure that data are collected and reported, using common tools to help streamline reporting with the goal of achieving near-real-time reporting systems, could help to coordinate the necessary data handling requirements. Maintaining such a robust system will require a specialised workforce, which is responsible

\begin{thebibliography}{9}
\bibitem{212} Baxter, \textit{Op. Cit.}
\end{thebibliography}

79
for collecting, analysing, interpreting and disseminating data to the relevant bodies (eg epidemiologists, microbiologists).\textsuperscript{218} Data gathered should be freely available, so that it can be shared and fed into public information and health warning systems, and used by local authorities as the baseline for risk assessment and resource gap analysis.\textsuperscript{219}

**Extreme weather events and health protection**

Extreme weather events (flooding, drought, cold, heat) warrant further attention, given that they are not covered by any of the other capabilities presented here, and the frequency of such events is predicted to increase as a result of climate change.\textsuperscript{220} The UK experiences a large health burden from extreme weather with many thousands of avoidable deaths occurring annually. Currently periods of cold weather account for the greatest number of excess deaths, estimated to be around 24,000 in 2011–12,\textsuperscript{221} although, with changing weather patterns the number of heat related deaths is likely to increase.\textsuperscript{222} The elderly are the most vulnerable, so as the population demographic shifts future health burdens will be intensified.\textsuperscript{223}

Emergency response plans to reduce the harmful effects of extreme events are in place, such as the heatwave and cold weather plan.\textsuperscript{224} However there is a need for a more consolidated effort in this area, since the overall approach is currently fragmented and uncoordinated across different government departments.

Information on the likely future health impacts of projected climate changes (impact of air pollution and changing vector-borne diseases, as well as changing temperatures) is needed in order to inform UK public health policy. Central to this is the characterisation of the direct health impacts associated with current climate events and the identification of those subgroups of the population most at risk. This information could be used to create a single national ‘at-risk’ register that would identify households as high, medium or low risk. Death rates within each group could be quantified, enabling local authorities to assess the vulnerability of their local population and take the appropriate action. Future projections could be estimated by epidemiological analysis of weather and health related.\textsuperscript{225} PHE would be well placed to coordinate such activities.\textsuperscript{226}

**Epidemiological and microbiological capabilities**


\textsuperscript{219} Ibid.


\textsuperscript{223} S. Vardoulakis and C. Headviside, eds., *Health Effects of Climate Change in the UK 2012: Current Evidence, Recommendations and Research gaps*, Oxfordshire: Centre for Radiation, Chemical and Environmental Hazards, Health Protection Agency, 2012


\textsuperscript{225} Vardoulakis and Headviside, *Op. Cit.*

\textsuperscript{226} Lloyd *Op. Cit.*
Epidemiological and microbiological capabilities are needed to maintain and improve the systems to monitor, detect, and investigate potential hazards particularly those that are environmental, radiological, toxic or infectious.\textsuperscript{227} In the event of an emergency situation these services need the capacity to mobilise quickly in order to rapidly detect, characterise and confirm threat agents, as well as to support on-going situational awareness and decision making.\textsuperscript{228}

**Data monitoring and Geographical Information Systems (GIS)**

In the short term, research could seek to support the development of more robust data monitoring techniques to monitor environmental conditions, including better tests for airborne contaminants and surveillance. Coverage needs to be increased, requiring the promotion of greater collaboration between different services, for example better integration of veterinary data and meteorological data analysis for health into current surveillance systems.\textsuperscript{229} The latter is particularly pertinent given the predicted increase in extreme weather events as a result of climate change.\textsuperscript{230} In the longer term, research is needed to define the requirements of a universally applicable outbreak management information system.\textsuperscript{231}

To this end, Geographical Information Systems (GIS) can be utilised to map those potential risks identified by National Risk Register, against population distribution, population health, and critical infrastructure, for example power stations and hospitals. A technological GIS capability will enable PHE to assess community exposure and vulnerability, to contextualise the risks of public health emergencies and to determine appropriate mitigation requirements. Furthermore, as identified in the modelling and simulation review above, better techniques will help to understand likelihood and impact of future events.

**Risk awareness**

There is a growing awareness of the need to better understand how individuals, whether civilians or those in a leadership or decision making role, approach risk and behave in an emergency situation.\textsuperscript{232} The behavioural science capability identified above will have relevance for emergency planners to understand how populations respond to emergencies at different scales and across multiple geographies.

**Strengthening scientific and technical support**

Finally, PHEP is a relatively new field and as a consequence there is an unmet demand for data, tools, methods and guidance on implementing emergency preparedness strategies (risk assessment and reduction), and a shortage of specialists, educated and trained for the task. All parties involved in


\textsuperscript{228} Acosta et al., *Op. Cit.*


\textsuperscript{231} Acosta et al., *Op. Cit.*

emergency preparedness (individuals, businesses, local authorities, emergency services, central government, etc) need access to information, both scientific and technical, that is readily understood and usable. Furthermore, citizens need to be informed and assisted in making practical use of available data, including through information and communication technologies. A role exists for PHE to ensure the effective dissemination and communication of findings, particularly around projections and uncertainties.\textsuperscript{233,234}

4.9.3. Synergies with PHE context

A summary of the capabilities needed for PHE in relation to public health emergency preparedness are in Figure 4-8 below.

Figure 4-8 Summary of public health emergency preparedness capabilities

PHEP interlinks with all of PHE’s areas of activity but is especially relevant to health improvement. This is because PHEP is a holistic capability that cuts across a number of the literature reviews identified above including behavioural science, informatics, modelling and simulation, infectious diseases and AMR.

\textsuperscript{233} PHE, Extreme Events, Op. Cit.

The structure of emergency preparedness is currently decentralised and is likely to remain so given the localised nature of most emergencies. The initial response – first-aid, search and rescue, etc – will be provided by the civilians caught up in the event, before the arrival of response personnel.\cite{235} This requires the promotion of more resilient communities who have the knowledge and practical skills to be able to respond to a variety of threats.\cite{236,237} The majority of emergency incidents will be managed by the Local Resilience Forums (multiagency partnerships made up of representatives from local public services) without significant input from central government, though there is a role for PHE in running the Scientific and Technical Advisory Cell for emergency preparedness.

However, this is not to say centralisation is not needed. The role of centralised government, and by association its agencies, is to provide additional, often technical, support.\cite{238} For PHE there could be scope for a public health science hub to integrate surveillance, informatics and modelling capabilities that will be required for more effective PHEP.

Emergency preparedness requires the collective effort of multiple stakeholders. The strength of the response is characterised by the number of connections between these different services, with a more collaborative approach resulting in a more effective response. These difficult organisational challenges require sustained attention and resources to build organisational and leadership capacity for public health.

4.10. Summary

In this chapter we reviewed the evidence across eight ‘deep dive’ areas in order to determine where there were future capabilities which would be important for delivering public health science and where there were key public health challenges which would need to be addressed through these capabilities. Ours is not an exhaustive summary of the field, but given the resource and time constraints of this study we attempted to cover both depth and breadth of different areas.

In doing so, we highlighted a range of public health science capabilities which will be important for PHE to sustain, develop and integrate in the future, including: behavioural sciences, informatics, simulation and modelling, and genetic technologies. When we began to apply these ideas to the public health challenges of infectious disease, AMR, health prevention/promotion, and public health emergency preparedness, enhanced technological surveillance and microbiological laboratory capabilities also emerged as underpinning capabilities.

We will be drawing out cross-cutting themes in the final chapter of this report, but we can highlight a few themes and implications for the future of public health from the review of the literature. First, it is clear that integration and interdisciplinary approaches will cut across many areas. The challenges for public health over the next 20 years will be multi-faceted and affect the population at many levels. Any future composition of PHE will need flexible and adaptable mechanisms in place to respond accordingly.

\cite{235} Nelson et al., Op. Cit.
\cite{237} Lurie et al., Op. Cit.
\cite{238} O’Brien and Read Op. Cit.
Second, integration of data will play a significant role. The future will be dominated by many different kinds of data and these will all need to be collected, mined, fused, integrated and managed in order to maximise positive outcomes for public health. The role of informatics, simulation, modelling and the need to integrate different kinds of data, including scientific, patient and social means that we will need dry laboratories to sit alongside more traditional wet laboratories. We will address this in more detail in the conclusion. Finally, there is no single technology that seems to dominate the field. While genomics and the so-called genetic revolution will clearly play an important role, our ability to make the most of that data will only be realised if many other technologies and capabilities evolve and emerge alongside it.
5. ExpertLens

Summary of chapter insights

ExpertLens is an online variant of the Delphi approach to stakeholder engagement. The purpose of the ExpertLens was to understand the perspective of a diverse group of stakeholders regarding the relative importance of different public health scientific and laboratory capabilities which might be required in the future.

A total of 61 participants engaged in the ExpertLens process from across PHE, and though participation rates varied across the rounds, we were able to draw some conclusions from the process.

The central role of integrating different types of knowledge in any future configuration of public health services is clear. Indeed capabilities which enable data integration were seen as the most important across all capabilities and there was strong agreement amongst participants about this.

Therefore, putting in place effective mechanisms for collecting, managing, mining, integrating and translating data into new knowledge will be of central importance. Participants in the ExpertLens confirmed this in their repeated stress on the need not only focus on centralisation, but crucially on integration of different kinds of capabilities and knowledge.

There were mixed views on the role of genetic sequencing across different areas of public health. In particular, there was less certainty about its potential importance in relation to health promotion. This sits in contrast to some of the insights from the literature review, which pointed to the role, in some cases the central role, of genetic technologies in the future across many areas. We believe this finding from the ExpertLens may reflect a lack of consensus or awareness of the potential of genomics as a platform technology for public health.

The exercise highlighted shared views on the characteristics of a hub which would enable success. Participants believed there was a need for a strong vision for PHE, which in turn would inform the nature of the hub, as well as the importance of continued discussions about how a hub would be implemented. Participants believed the two must go forward hand-in-hand.

5.1. Introduction

The purpose of undertaking a Delphi-based, ExpertLens exercise was to understand the perspective of a diverse group of stakeholders regarding public health scientific and laboratory capabilities which might be required in the future and the implications of this on co-location of different scientific and laboratory facilities in a central public health science hub.

ExpertLens is an online variant of the Delphi approach, which was developed over 60 years ago. In a traditional Delphi process, participants respond to a survey anonymously, the results of which are combined and fed back to the group. Participants discuss the combined group results and compare them to their own individual responses. After discussion, the participants have the opportunity to refine their


responses through a second survey. This process can be repeated until a conclusion is reached.\textsuperscript{241} The Delphi process can be used to achieve consensus, and can also yield insight into where the major points of agreement and disagreement lie.

The usual recommended number of participants for the Delphi is 5–20, but the ExpertLens can incorporate more than 100 participants, who may be geographically dispersed. Thus, for this exercise we could engage a diverse, multi-disciplinary panel of leading experts in the field of public health in a meaningful and productive way. ExpertLens therefore allowed for both a structured way to find out what the experts in our study thought about the relative importance of different public health capabilities and how they may be suited to co-location, as well as why they thought about things in the way they did. It is their expertise and the diversity of their opinions which drove the analysis and emergent insights into their views.

In this chapter we will briefly outline the ExpertLens process and describe how this approach was used in the context of the broader horizon scanning exercise. We then discuss the findings and insights gained from the ExpertLens and draw out the implications for the project as a whole.

5.2. ExpertLens methodology

5.2.1. Overview of ExpertLens approach

ExpertLens proceeds over three rounds (Figure 5-1). In Round 1 participants respond to a set of predetermined questions. In Round 2 participants familiarise themselves with the answers given by others and discuss the group responses via anonymous online discussion boards. Finally, in Round 3 participants respond to the questions again, and have the opportunity to modify their original answers in light of the group discussion. The group’s final answer is determined statistically by analysing the last set of responses provided by each individual.\textsuperscript{242}


\textsuperscript{242} Please note, if a participant provided more complete answers in round 1 than round 3, round 1 answers were used.
The future of public health: A horizon scan

Figure 5-1: The ExpertLens process

For this project, the aim of Round 1 was to elicit the individual views of the experts on the future of public health and the type of capabilities which are likely to be most important in addressing this future. It also attempted to ascertain what the implications of such conclusions may be on laboratory co-location, as well as solicit views on any necessary prerequisites for co-location to be successful. Experts were given two days to complete Round 1.243

There are two broad sets of questions participants were asked to answer. In the first section participants were asked to rank the importance of eight public health capabilities in relation to each of the three areas of public health, health improvement, health protection and improved health services, as well as in relation to overall public health needs. The public health capabilities were drawn from insights gained in the ‘deep dive’ literature reviews and interviews in order to provide consistency between the phases. We also determined that a full list of detailed public health scientific and laboratory capabilities could be unwieldy for this kind of exercise and so made a conscious decision to ask about capabilities at a purposely broad level. We solicited views in the discussion section (Round 2) on additional, more specific capabilities that participants felt would be important to discuss in the future. For the ExpertLens question set, the public health capabilities participants were asked to consider were defined as follows:

- **Behavioural science**: a multi-disciplinary science drawing on psychology, sociology, and anthropology, seeking to understand human actions at the individual and societal level. Within public health behavioural science has been mobilised to examine the relationship between behaviour and health outcomes. The approach has become an important capability for public health because a number of the most prominent contributors to death and disease in the UK and globally are behavioural factors, particularly tobacco use, diet and activity patterns, alcohol consumption and sexual behaviour.

- **Informatics**: an information science about the processing, management and manipulation of data. In public health informatics has involved the systematic application of information and computer science and technology to public health practice, research, and learning. The scope of public health informatics includes the conceptualisation, design, development, deployment, refinement, maintenance, and

243 The very short timelines for the ExpertLens process were necessitated by Public Health England’s needs and were not ideal for ensuring an optimum response.
evaluation of communication, surveillance, and information systems relevant to public health. It requires the application of knowledge from numerous disciplines, particularly information science, computer science, management, organisational theory, psychology, communications, political science and law.

- **Modelling and simulation**: capabilities that provide public health science with means for testing and experimenting with potential improvements and future scenarios. They are techniques for understanding current and potential impacts of interventions and identifying potentially unforeseen impacts of interventions. Modelling and simulation techniques have been used in public health science to explore control schemes, predict future incidence, prevalence and mortality for these diseases as well as monitor their progress for assistance in deciding on public health outcomes.

- **Genomics**: high-throughput technologies for DNA sequencing that have enabled us to begin deciphering human and pathogen genomes, linking them to health and disease and generating significant volumes of genomic data. Future trends suggest increasing application of genetics, formerly rooted in pure and lab-based sciences, to several areas of public health including, but not limited to: sequencing and analysing genetics of pathogens to enable faster and more accurate diagnosis, prediction of virulence, mechanisms of drug resistance, transmission and targeted therapy; greater application of personalised and stratified medicine to enable genetic profiling and identification of individual risk factors; and association of patients with specific therapies based on clinical biomarkers.

- **Robust evaluation methodologies**: evaluation methods to test theory-based interventions, such as measurement and analyses of mediator and moderators. These are necessary to build a more solid evidence base of health behavioural change. Evidence gathering for policymakers may involve decisions about whether to use a group-randomised controlled clinical trial or a quasi-experimental design. Evaluations should not be limited to trials of efficacy but should also be tied to planning and evaluation frameworks.

- **Integrated laboratory science capabilities from virologists, micro-biologists, etc**: integration and collaborative working across a range of areas such as microbiology, virology and bioinformatics. This is particularly necessary given developments in diagnostic testing and integrated surveillance, and may require enhanced specialist training across the whole public health workforce.

- **Epidemiology**: a methodological approach to understand and explain the frequency of disease occurrence in different groups. Evidence from epidemiological studies is useful for public health science to help plan more effective strategies for illness prevention and monitoring populations where diseases are evident.

- **Data integration**: the integration of data from a vast range of heterogeneous data sources into one data set or network. This could include electronic health records, hospital admissions, environmental tracking (such as water quality monitoring reports) and veterinary healthcare data. It may also be necessary to draw on unstructured data such as blogs and wikis, for example. Data integration is likely to draw on a range of technological advances such as data mining and data fusion and grid computing. In terms of gathering data in the first instance, intelligent sensor networks and automated laboratory reporting may also be important.

In the second section of questions, participants were asked to focus specifically on co-location and identify key characteristics necessary for a successful integrated public health science hub, as well as the public health areas for which an integrated hub would be most useful. Here, participants were provided with a broad definition of a public health science hub so that we could allow for their own views on the issue to emerge. The definition provided was:
• An ‘integrated’ public health science hub is a place that provides a common geographical location for a range of facilities, capabilities and skills. The physical form of an integrated public health science hub may vary according to organisation needs and context but could be a science park, science campus or multi-disciplinary complex.

Again, the options participants were given were drawn from insights from the literature review and the interviews. They included issues such as strong centralised leadership; good organisational structure; co-location with other leading scientific and laboratory services; efficiency savings; and mechanisms for exchange of tacit knowledge.

For each set of questions in each section, participants were asked to rate the importance of the capability or the characteristic in relation to the question at hand. For example, for the first set of questions participants were asked:

*On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following scientific capabilities in addressing all public health needs in the future.*

While for the second set of questions, participants were asked questions such as the following:

*Please rate the importance on a scale from 1 (not very important) to 10 (very important) of the following factors in contributing to the success of a future public health science hub.*

The full question set is provided in Annex C.

In Round 2, experts were provided with a summary comparing their own answers with those of the entire group. Over a period of 48 hours, they could engage in anonymous online discussions about the questions with the entire group of experts. The project team monitored and facilitated the discussion during this round. The discussion in Round 2 allowed participants to explore issues in a way that is not possible within a structured question set. For example, divergent views on the importance of public health capabilities were identified in real time, and by directing attention to points of divergence within the group, we were able to explore the reasons behind particular views.

Finally, in Round 3, lasting five days (this period initially lasted over a weekend and then was extended by 36 hours due to low response rates), experts were asked to answer the same set of questions as those in Round 1, but this time they were free to amend any responses in light of discussions or further reflections made during Round 3. 118 participants consisting of experts in a wide range of public health fields such as epidemiology, microbiology, virology, emergency preparedness and infectious diseases were invited to participate in the process.

**5.2.2. ExpertLens analysis**

Before discussing the findings from the ExpertLens survey it is worth summarising the different types of analysis that will be presented in the subsequent pages. We used both ‘median’ and ‘average’ ratings and rankings to understand what the overall group thought. We calculated median scores for the entire group for each question and reported back to everyone at the end of Round 1. Respondents could then reflect on the group’s median score in relation to the score they provided as individuals. This helped them to
contribute to discussions in Round 2. We also displayed quartile ranges, so the group could see what the relative spread of answers was like around the mean.

When we discuss the results of the survey we refer to levels of ‘agreement’ or ‘disagreement’ among the group. This is the extent to which participants respond with similar answers, indicating agreement, or give a range of different answers with none emerging more frequently than another, indicating disagreement. To display this relative agreement or disagreement, we focused on identifying areas of relative agreement among participants. Agreement was defined as more than 66% (2/3) of participants answering a question within the same ‘band’. These bands were defined as follows:

1. Participants rated the capability either 1, 2 or 3: classified as not very important
2. Participants rated the capability either 4, 5, 6 or 7: classified as somewhat important
3. Participants rated the capability either 8, 9 or 10: classified as very important.

For ease of analysis below, we refer to the scoring in relation to these three bands. The tables set out in the analysis sections below summarise responses for each section of the process, highlighting areas of convergence in red. They also detail the number of respondents for each question, the median, the upper and lower quartiles and the interquartile range, providing a sense of the distribution of answers.

The quantitative summary for each question is accompanied by a brief qualitative analysis which aims to highlight key issues of importance raised in the discussion round. This analysis is supported by quotations from discussion threads where appropriate.

5.3. ExpertLens results across the three areas of public health

5.3.1. Brief overview of participation rates

Before summarising the findings of the ExpertLens, we provide a brief overview of the participation rates and any significance between rounds.

A total of 118 individuals were asked to participate in the ExpertLens, and of these, 17 were external to PHE. After being invited to participate, 61 participants engaged in some way during the entire ExpertLens exercise. Due to limitations of time, however, not everyone was able to participate in all rounds. Sixteen participants gave feedback about the process along the lines of these participants:

> I wasn’t able to participate in rounds 1 (absent from work) and 2 (pressure of work on my return) which limits any input. I am sure this is true for many given a) holiday season and b) the limited time the rounds were open for. (Participant 08)

> Overall a good tool. I understand the time pressures for the study but I believe a longer step 2 would have been of value. I had issues I wanted to raise but because of other priorities the timing was not good for me and I missed the opportunity. (Participant 02)

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244 Thus the distribution of the responses was uni-modal, with one unique score, or mode, emerging from the responses.
245 This is indicated by a uniform or bimodal distribution.
Four participants reflected some concern that the questions were too high-level and did not allow for enough granularity of capabilities to be reflected.\(^{246}\) The extent to which participants found this difficult varied, with some simply saying ‘it was a little high level at times’ (Participant 103), and others commenting along the lines of ‘there were many gaps and areas of PHE functions that were not considered’ (Participant 30). A related concern, expressed by five participants, was that there were not enough specific questions about a science hub, although one person commented that the real challenge was that ‘a lot of the questions were around whether a science hub would assist with realising PHE’s objectives in the future. We don’t really know what these objectives are yet, which made it hard to answer some questions’ (Participant 45). Interestingly, a small set of participants expressed concern that the findings would be biased towards one group of stakeholders, although these concerns worked in both directions with one participant commenting ‘I don’t think we had the right mix of people participating; you will have somewhat skewed results in favour of labs, sequencing,’ (Participant 30) while another commented ‘The largest part of the workforce is in SMS and it appears that this group were effectively forgotten in this study’ (Participant 33).

In total, 51 participants logged on and completed questions in Round 1. A further 27 participants logged on and made comments or began new discussion threads in Round 2. In Round 3, 39 participants logged on and answered the questions. Some of these were new participants who did not answer questions in Round 1.

We performed a standard T-test on the whole sample across round 1 and round 3 which showed that the difference between the two samples was not statistically significant at the normal 5% confidence level. However this assumed that the responses from two rounds were independent from each other which is not the case given that there were overlapping respondents between the two rounds. We then performed a paired sample T-test (ie using data from participants who answered both rounds 1 and 3) which revealed that there was a significant difference across the rounds for 5 questions. However, this test did not reveal whether the overall responses from these five questions were significantly different from the two rounds as the responses left out of the matched sample were not included. In order to explore this further, we performed a modified T-test which took into account the correlation between the two samples. This showed that there was not a significant difference at the 5% confidence level across the rounds for any question which meant that we were able to combine all the data from Rounds 1 and Round 3 into the main dataset on which the analysis presented below is based.\(^{247}\) Though most questions had a total respondent rate of 61 (100%), for some questions we did not have answers from all respondents. Thus we also note in the analysis tables below what the number of respondents were for each question.

5.3.2. Health protection

Table 5-1 below summarises the results of the first question of the ExpertLens process, whereby participants were asked to rate the importance of eight public health capabilities in delivering on PHE’s health protection remit in the next 20 years.

\(^{246}\) We acknowledge and discuss this limitation later in this chapter.

\(^{247}\) This approach has been used in previous studies where there has either been a low response rate in Round 3 or a lack of statistical significance between responses.
On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following in addressing the PHE priority of **health protection** in the next 20 years:

<table>
<thead>
<tr>
<th></th>
<th>Number of respondents (N)</th>
<th>Lower quartile</th>
<th>Median</th>
<th>Upper quartile</th>
<th>Interquartile range</th>
<th>% of participants who rated capability 1, 2 or 3</th>
<th>% of participants who rated capability 4, 5, 6 or 7</th>
<th>% of participants who rated capability 8, 9 or 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Behavioural science</td>
<td>61</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>13</td>
<td>48</td>
<td>39</td>
</tr>
<tr>
<td>b) Informatics</td>
<td>61</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>23</td>
<td>72</td>
</tr>
<tr>
<td>c) Modelling</td>
<td>61</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>2</td>
<td>3</td>
<td>46</td>
<td>51</td>
</tr>
<tr>
<td>d) Genetic sequencing</td>
<td>59</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>e) Robust evaluation methodologies</td>
<td>60</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>3</td>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>f) Integrated laboratory science capabilities from virologists, micro-biologists, etc</td>
<td>60</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>18</td>
<td>82</td>
</tr>
<tr>
<td>g) Epidemiology</td>
<td>61</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>16</td>
<td>82</td>
</tr>
<tr>
<td>h) Data integration</td>
<td>60</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>3</td>
<td>2</td>
<td>32</td>
<td>67</td>
</tr>
</tbody>
</table>

**Table 5-1: Health protection and the importance of public health capabilities**
The results show strong agreement that informatics, genetic sequencing, integrated laboratory capabilities and, though to a lesser extent, data integration were all very important capabilities for delivering on this remit. The capability which invoked most disagreement among participants was behavioural science, with a high concentration of respondents rating the capability as only somewhat important (48%), 39% rating it as very important, and 13% scoring it as not very important. This capability had the most divergent views of any capability under this area of public health remit.

Despite this, the median scores reveal that all capabilities were thought to be very important to health protection, though behavioural science was at the low end of this band with a median score of 7. There was also some disagreement in rating the importance of modelling and robust evaluation methodologies, although the majority of participants agreed they were either somewhat or very important. Despite the lack of agreement around one band, the interquartile range was relatively low for all capabilities, again supporting the assertion that there was a good degree of consensus around the relative importance of all capabilities for achieving public health protection in the future.

Though there were not many comments on this particular question, when asked to reflect on the different types of capabilities in Round 2, some participants commented that they struggled to identify with the capabilities because they were not specific enough.

I found the questionnaire difficult to complete. Here is an analogy to try to illustrate. ‘As a car driver how important are the following to you? Halfords; MOT centre; petrol station; etc’ However, what if I am a Formula 1 racing driver? What I need to be successful is a team of highly skilled mechanics; sponsors; specialist fuel, etc. So the capabilities offered for rating do not include the most important things I need to be successful as an F1 driver. (Participant 56)

As someone involved in the HPA Chrysalis project from its inception I found the questions a bit too ‘high end’ to give really meaningful answers. (Participant 115)

However, one participant commented that they felt the questions were written at the correct level and went on to comment on additional areas of capability which might be needed.

I think that the eight areas are sensible ones to assess and I think the scores reflect my personal view of their relative importance. My only concern looking forward in infectious disease is that we may continue to focus on the ‘bug’ rather than the host and interactions with the pathogen. Human genetics may indicate predisposition but links with immunology might be beneficial. (Participant 61)

It is also worth noting here that participants began their own discussion thread about the importance of having an integrated science hub for PHE’s role in health protection. While the full extent of this thread will be covered below, there were comments raised about the importance of integrated laboratory facilities for health protection.

Integrated laboratory science capabilities are essential for health protection, but this does not mean that everything needs centralising in a central hub. (Participant 05)

Many participants agreed with this assessment and the discussion went on to discuss the different merits of ‘integration’ vs. physical ‘centralisation’ (see below).
5.3.3. Health improvement

The results in Table 5-2 below show how participants rated the importance of the eight public health areas in delivering health improvement services in the next 20 years.

As shown in the table, there was the most agreement (78%) amongst participants that behavioural science will be of key importance to health improvement in the future. Other capabilities where there was strong agreement were in respect of the high importance (8, 9 or 10) of robust evaluation methodologies, epidemiology, and data integration. Few participants rated these capabilities as either 1, 2 or 3.

There was the most disagreement about the importance of integrated laboratory services and, though to a lesser extent, genetic sequencing. This distribution is demonstrated by a relatively high interquartile range of 3 in comparison to the other capabilities. In addition to having higher disagreement, these capabilities were also thought to be the least important of the eight capabilities for health improvement, as evidenced by a median score of 5 for each, the lowest of all the capabilities.

When asked to discuss if there were any other capabilities which should be considered under health improvement, two participants responded. One raised the need to address health inequalities as this was a statutory function of PHE. The other commented that a range of functions would be required:

There is a need to identify the disease, understand the morbidity/pathology, intervention opportunities and windows. This requires the underpinning sciences such as pathology, disease models, immunology, multiple influences on why the body does not get ill, exposure routes and dose rates, etc. (Participant 70)

One participant raised an interesting discussion thread which generated several (10) responses about the relationship between genetic sequencing and health improvement. The thread asked, ‘Won’t advances in genetic sequencing tell us much more about how we can better promote good health in the coming years?’ (Participant 101). Respondents became engaged in a discussion which had two distinct strands. One concerned the relative merits of genetic sequencing in addressing health improvement, while the other was about how PHE should make the best use of genetic sequencing expertise. In relation to the first strand, there was some shared agreement that genetic sequencing could play a role in helping to understand ‘the influence our genetic makeup has on human behaviour or a disposition to disease; not the behaviour itself but some of the drivers’ (Participant 33). Reflecting a similar belief, another participant asked ‘If we knew individual risk profiles, could we better target behavioural interventions to the relevant risk factors?’ (Participant 94).

The second strand yielded much more discussion. Here, the question was raised as whether PHE needed to have its own genetic sequencing expertise in-house, or whether it needed to focus more on strengthening its links to other leading international centres. The issues at play were neatly summarised by one respondent:

Gene sequencing has a huge role to play in disease prevention. In the field of infectious diseases it is highly advantageous to look at the variability of human populations to explain why some are susceptible and some more resistant to particular diseases. In addition identification of genes of both the host and the infectious agent that are either expressed or suppressed during infection is vital in designing and strategizing vaccines and therapeutic interventions. I agree with the comment that this is a fast moving field and that forming strong links with centres of excellence such as the Sanger is the best way of utilising this technology. (Participant 115).
Most people agreed with the assertion that better and stronger links with other leading centres was important, however, the ways in which this should happen were not always as clear, as illustrated by the comment from the participant below.

I agree that we need formal closer ties with centres of sequencing expertise but we need to look at the needs of the PHE and develop internal and external capacity as appropriate. We need to be able to respond quickly in some situations and we need to be self-determining in how we use these approaches. My sense of NGS is that it is here to stay and will become a widely used method at all levels. It reminds me of the emergence of PCR where similar discussions took place, it was initially a specialist technique done by molecular biology labs and now it is pretty much everywhere. But there are challenges and I think there has been a lot of oversimplification regarding how quickly and in what form these technologies reach primary diagnostic labs. This may well depend on the level of interest from sequencing platform commercial companies in infectious disease diagnostics I suspect. (Participant 61)

The fact that one of the points which generated the most discussion about health improvement, was related to one of the capabilities that was rated as the least important of all the capabilities, and a capability which had the most disagreement, may speak to the benefits of the ExpertLens method. It allows participants’ views and insights to emerge in a grounded fashion where there is interest and insight to be gained. Given the nature of the discussion, though it is interesting to note that there was little discussion around other kinds of capabilities which themselves might need to be integrated with genetic technologies as well, such as informatics and modelling of data, in order to make the most of the insights for health improvement. We will pick this up in the final discussion sections below.
On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following in addressing the PHE priority of **health improvement** in the next 20 years:

<table>
<thead>
<tr>
<th></th>
<th>Number of respondents (N)</th>
<th>Lower quartile</th>
<th>Median</th>
<th>Upper quartile</th>
<th>Interquartile range</th>
<th>% of participants who rated capability 1, 2 or 3</th>
<th>% of participants who rated capability 4, 5, 6 or 7</th>
<th>% of participants who rated capability 8, 9 or 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)  Behavioural science</td>
<td>59</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>19</td>
<td>78</td>
</tr>
<tr>
<td>b)  Informatics</td>
<td>58</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>52</td>
<td>47</td>
</tr>
<tr>
<td>c)  Modelling</td>
<td>57</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>46</td>
<td>53</td>
</tr>
<tr>
<td>d)  Genetic sequencing</td>
<td>57</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>3</td>
<td>18</td>
<td>60</td>
<td>23</td>
</tr>
<tr>
<td>e)  Robust evaluation methodologies</td>
<td>58</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>33</td>
<td>66</td>
</tr>
<tr>
<td>f)  Integrated laboratory science capabilities from virologists, micro-biologists, etc</td>
<td>57</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>35</td>
<td>46</td>
<td>19</td>
</tr>
<tr>
<td>g)  Epidemiology</td>
<td>58</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>29</td>
<td>69</td>
</tr>
<tr>
<td>h)  Data integration</td>
<td>57</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>28</td>
<td>72</td>
</tr>
</tbody>
</table>

**Table 5-2: Health improvement and the importance of public health capabilities**
5.3.4. Improved health services

Table 5-3 below summarises the results of the third section of the ExpertLens process, in which participants were asked to rate the importance of eight public health capabilities in delivering improved health services.

As shown below, there the strongest consensus was that data integration will be of great importance for improving health services in the future. Other capabilities which were agreed to be very important were informatics, robust evaluation methodologies, and epidemiology. However, as with health improvement, there was disagreement between participants in ranking the importance of genetic sequencing and integrated laboratory capabilities, as demonstrated by high interquartile ranges of 5.75 and 4.75 respectively. These capabilities also had the highest concentrations of ratings in the ‘not very important’ band. All participants considered behavioural science to be either somewhat (40%) or very important (60%).

When asked in Round 2 if there were other capabilities which were important, some participants expressed surprise that integrated laboratory services had such disagreement and had a low median. One commented:

> It is important to note that around 80% of a lab’s activity is in provision of a clinically-led microbiology service to the NHS. It is important to maintain this activity as it provides significant public health and epidemiological data. In the near future the genetic sequencing and modelling will have a role but will only account for a very small amount of the routine labs clinical and technical service. (Participant 30)
On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following in addressing the PHE priority of **improved health services** in the next 20 years:

<table>
<thead>
<tr>
<th></th>
<th>Number of respondents (N)</th>
<th>Lower quartile</th>
<th>Median</th>
<th>Upper quartile</th>
<th>Interquartile range</th>
<th>% of participants who rated capability 1, 2 or 3</th>
<th>% of participants who rated capability 4, 5, 6 or 7</th>
<th>% of participants who rated capability 8, 9 or 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Behavioural science</td>
<td>58</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>b) Informatics</td>
<td>58</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>29</td>
<td>69</td>
</tr>
<tr>
<td>c) Modelling</td>
<td>57</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>49</td>
<td>47</td>
</tr>
<tr>
<td>d) Genetic sequencing</td>
<td>58</td>
<td>3.25</td>
<td>6</td>
<td>9</td>
<td>5.75</td>
<td>26</td>
<td>41</td>
<td>33</td>
</tr>
<tr>
<td>e) Robust evaluation methodologies</td>
<td>57</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>30</td>
<td>68</td>
</tr>
<tr>
<td>f) Integrated laboratory science capabilities from virologists, micro-biologists, etc</td>
<td>58</td>
<td>4</td>
<td>6</td>
<td>8.75</td>
<td>4.75</td>
<td>21</td>
<td>47</td>
<td>33</td>
</tr>
<tr>
<td>g) Epidemiology</td>
<td>58</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>31</td>
<td>67</td>
</tr>
<tr>
<td>h) Data integration</td>
<td>57</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>18</td>
<td>82</td>
</tr>
</tbody>
</table>

Table 5-3: Improved health services and the importance of public health capabilities
5.3.5. All public health needs

This question asked participants to rate the importance of the public health capabilities in relation to all public health needs. The results are summarised in Table 5-4. There was particularly strong agreement that data integration is of importance to public health needs, with 93% of participants rating it as 8, 9 or 10 and 7% rating it as either 4, 5, 6 or 7. This is also evidenced in the median score of 9. Epidemiology was also considered to be very important by a strong majority (79%), followed by informatics (72%), robust evaluation methodologies (71%) and behavioural science (71%). There was relative disagreement from participants in rating integrated laboratory science capabilities as evidenced through an interquartile range of 2.75, and this capability also has the lowest median score.

When asked if there were other capabilities which would be important, three respondents commented. One asserted that behavioural science and evaluation were critical to all three domains, while the other two commented on the importance of health services and on the role of networks in delivering across all three areas.
On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following in addressing **all public health needs** in the next 20 years:

<table>
<thead>
<tr>
<th>Capability</th>
<th>Number of respondents (N)</th>
<th>Lower quartile</th>
<th>Median</th>
<th>Upper quartile</th>
<th>Interquartile range</th>
<th>% of participants who rated capability 1, 2 or 3</th>
<th>% of participants who rated capability 4, 5, 6 or 7</th>
<th>% of participants who rated capability 8, 9 or 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Behavioural science</td>
<td>58</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>b) Informatics</td>
<td>58</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>c) Modelling</td>
<td>58</td>
<td>6.25</td>
<td>8</td>
<td>8</td>
<td>1.75</td>
<td>0</td>
<td>43</td>
<td>57</td>
</tr>
<tr>
<td>d) Genetic sequencing</td>
<td>58</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>5</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>e) Robust evaluation methodologies</td>
<td>56</td>
<td>7</td>
<td>8.5</td>
<td>9.25</td>
<td>2.25</td>
<td>2</td>
<td>27</td>
<td>71</td>
</tr>
<tr>
<td>f) Integrated laboratory science capabilities</td>
<td>58</td>
<td>6.25</td>
<td>7</td>
<td>9</td>
<td>2.75</td>
<td>9</td>
<td>43</td>
<td>48</td>
</tr>
<tr>
<td>g) Epidemiology</td>
<td>58</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>19</td>
<td>79</td>
</tr>
<tr>
<td>h) Data integration</td>
<td>57</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>93</td>
</tr>
</tbody>
</table>

Table 5-4: All public health needs and the importance of public health capabilities
5.3.6. Capabilities across all areas

Before moving to the results of the second set of questions, about the creation of a science hub specifically, let us compare the relative importance of capabilities across all the areas of public health (and for public health needs overall).

![Figure 5-2 Comparison of median scores across all domains of public health](image)

As can be seen from the graph above, the greatest difference in perceived relative importance is in genetic sequencing technologies and integrated laboratory science capabilities across the different areas of public health. There is the most similarity in the assessment of data integration capabilities for all areas, and indeed there was strong agreement for all areas of public health that this capability would be very important. The same is also true for epidemiology, although the median scores were not as high for this capability across all areas.

5.4. Characteristics and implications of a future public health science hub

5.4.1. The characteristics of success and importance of a future public health science hub

The second set of questions in the ExpertLens asked participants to rate the importance of a number of characteristics to ensuring a successful future public health science hub and to discuss the relative importance of a hub for realising success in relation to PHE’s broad aims. We will first discuss responses to each set of questions, before moving to the additional insights gained by the discussion in relation to these sets of issues.

First, as shown in Table 5-5 below, the clearest agreement was that strong centralised leadership, a good organisation structure, harnessing organisation collaborative culture and exchange of tacit knowledge amongst organisational leaders were very important characteristics for success of a future public health science hub. Co-location with other laboratory services and efficiency savings through a shared infrastructure were considered to
be relatively less important and there was more disagreement around both of these characteristics. The provision of social mechanisms to enhance integration was only considered to be somewhat important by the majority of participants. These results perhaps suggest that effective collaboration between existing services, as well as the exchange of tacit knowledge, would be more successful than the physical or virtual co-location of public health laboratories.

The final question of the ExpertLens asked participants to rate how important an integrated public health science hub would be for achieving success in a range of PHE’s activities. As can be seen in Table 5-6, there was little agreement across all of the questions, revealing a lack of consensus around how useful an integrated public health science hub would be for any of PHE’s future roles. The only area of consensus was that an integrated science hub would be somewhat important to PHE’s role in health improvement.
On a scale from 1 (not very important) to 10 (very important), rate the importance of the following factors in contributing to the success of a future public health science hub:

<table>
<thead>
<tr>
<th>a) Strong centralised leadership</th>
<th>Number of respondents (N)</th>
<th>Lower quartile</th>
<th>Median</th>
<th>Upper quartile</th>
<th>Interquartile range</th>
<th>% of participants who rated capability 1, 2 or 3</th>
<th>% of participants who rated capability 4, 5, 6 or 7</th>
<th>% of participants who rated capability 8, 9 or 10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>22</td>
<td>78</td>
</tr>
<tr>
<td>b) Good organisational structure</td>
<td>59</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>88</td>
</tr>
<tr>
<td>c) Co-location with other leading laboratory and scientific services</td>
<td>59</td>
<td>5</td>
<td>7</td>
<td>8.5</td>
<td>3.5</td>
<td>10</td>
<td>46</td>
<td>44</td>
</tr>
<tr>
<td>d) Provision of social mechanisms to enhance integration</td>
<td>58</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>59</td>
<td>38</td>
</tr>
<tr>
<td>e) Efficiency savings through shared infrastructure</td>
<td>58</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>9</td>
<td>53</td>
<td>38</td>
</tr>
<tr>
<td>f) Harnessing collaborative organisational culture</td>
<td>57</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>3</td>
<td>4</td>
<td>23</td>
<td>74</td>
</tr>
<tr>
<td>g) Exchange of tacit knowledge amongst organisational leaders</td>
<td>55</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>87</td>
</tr>
</tbody>
</table>

Table 5-5: The success of a future public health science hub
On a scale from 1 (not very important) to 10 (very important), rate the importance of having an integrated public health science hub to:

<table>
<thead>
<tr>
<th></th>
<th>Number of respondents (N)</th>
<th>Lower quartile</th>
<th>Median</th>
<th>Upper quartile</th>
<th>Interquartile range</th>
<th>% of participants who rated capability 1, 2 or 3</th>
<th>% of participants who rated capability 4, 5, 6 or 7</th>
<th>% of participants who rated capability 8, 9 or 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Help PHE realise its future objectives?</td>
<td>58</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>10</td>
<td>53</td>
<td>36</td>
</tr>
<tr>
<td>b) PHE’s role in health protection?</td>
<td>58</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>4</td>
<td>10</td>
<td>47</td>
<td>43</td>
</tr>
<tr>
<td>c) PHE’s role in health improvement/prevention?</td>
<td>58</td>
<td>4.25</td>
<td>5.5</td>
<td>7</td>
<td>2.75</td>
<td>12</td>
<td>74</td>
<td>14</td>
</tr>
<tr>
<td>d) PHE’s role in emergency preparedness?</td>
<td>58</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>4</td>
<td>21</td>
<td>41</td>
<td>38</td>
</tr>
<tr>
<td>e) PHE’s role in improving health services?</td>
<td>57</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>21</td>
<td>60</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 5-6: The importance of a public health science hub
5.4.2. Insights and views

The discussions around the final set of questions which were most specific about the science park generated the most discussion threads and debates amongst respondents. There were several strands which emerged from the discussions, including: the definition of what was meant by a science hub, the importance of having an integrated science hub for PHE's role in health protection, and the question of how the science hub would actually work. Insights from each are addressed in turn.

When discussing what could be meant by a science hub, there were two distinct views. One was that integrated facilities need only apply to administration and governance functions, thereby allowing laboratory services to remain at the ‘frontline’ and for existing capabilities and regional collaborations to stay intact. This was expressed in the following ways:

> The science hub should be a central point for the whole PHE organisation, and include a training centre, HR, payroll, purchasing, finance, core safety team, etc. It should be where PHE employees visit regularly for updated learning and training and to promote interaction. For laboratory science, it is well accepted that collaboration with others is essential instead of working in isolation. Therefore, whilst centralised/routine functions can be part of the hub - some of the other work should be continued to be performed elsewhere to allow PHE to reach/exert an influence and presence over more regions of England. (Participant 05)

> I also agree that for laboratory science PHE has inherited some world class resources and expertise that have been built up over many decades and that important collaborations have a considerable region-based perspective that has served to strengthen the capabilities and reputation of these laboratories, which in turn leads to more successful funding. As long as there is strong leadership that provides a clear focus and direction on the science then there is an obvious advantage to not disrupting well-established capabilities. (Participant 115)

> I think that a lot of the benefits of integration could be realised without co-location (a ‘virtual hub’). Also, I think there are significant risks that we will throw the baby out with the bath water during the process of relocating existing services. There is a real danger that current capabilities will be lost during the transition, and these may be very hard to replace. (Participant 45)

However, others disagreed and expressed the view that some microbiology and laboratory services needed to be integrated in order to maximise synergies.

> I’m not an epidemiologist, but I would think that in the era of ‘big data’, some kind of centralised data resource, that could inform both regional and national research (ie used by the regional lab ‘spokes’ not just the ‘hub’) would be critically important. (Participant 45)

> Where there is a common process thread of microbiological diagnosis-surveillance-epidemiology, then co-location may be beneficial to some extent if this is balanced with the local needs, and strong localism agenda. But be careful about relocating capabilities which are not part of this process thread - the capabilities could be lost. (Participant 56)

> Laboratory-based services and research, in-vivo and associated training need to be in a physical hub. Everything else could be a ‘virtual hub’. […] Others have argued against co-location but how otherwise
do we build the 'critical mass' of expertise to drive improvements and prevent the development of silos? (Participant 76)

Despite the opposing views, what did seem to emerge from the discussion was agreement that clear ways of communicating and collaborating so as to maximise synergies was important. Whether this should happen in a single hub, or through more coordinated leadership, was to a certain extent a follow-on discussion from this. As stated by one participant, ‘Would co-location in itself make for better science, or is that down to improved communication/management and a sense of common purpose?’ (Participant 45).

Many of these discussions seemed to focus on laboratory services in particular, perhaps not surprisingly given the origins of this project in the Chrysalis project. While we will pick up on this point in the final discussion, it is important to consider the different views raised about the implications of a hub for PHE’s role in health protection, especially considering two distinct discussion threads were raised by participants about this element. As highlighted earlier, one participant was especially interested to know why, ‘In the first set of answers on Health Protection, Integrated laboratory science capabilities from virologists, microbiologists, etc scored very highly. However, the importance of having an integrated science hub for PHE’s role in health protection the results seemed more mixed.’ (Participant 101). As with the discussion about the definition of a science hub, there was a common theme about the need for better leadership and coordination internally to make this work.

Instead of centralisation of capabilities, what perhaps is needed is better communication and collaboration between PHE scientists to make the most of what is on offer internally. (Participant 05)

What is needed is strong leadership that providers a clear direction on what science is required through themes or programmes but that allows flexibility and freedom to form collaborations and seek funding both within the UK and internationally. (Participant 115)

Within this discussion a distinction began to be made between co-location in a physical location, and ‘integration’ of different PHE functions.

Co-location at a hub does not deliver integration guaranteed, and integration of many functions (especially those not requiring rare/expensive equipment, ie lab science) could be achieved without co-location. Perhaps we should be considering the advantages of integration (within PHE and with key others) and of co-location/centralisation as separate issues? (Participant 55)

This point seemed to resonate with many people. One participant commented that ‘genuinely beneficial collaborations depend on a shared goal, willing participants, complementary capabilities and adequate resources. Geographical co-location is far less important’ (Participant 56). Another stated that ‘it makes more sense for some to integrate/link with other subject matter experts in the same or a related field in the UK, across the EU or wider to share methods, reagents, knowledge, expertise and training’ (Participant 18). However, in a related discussion thread concerning the importance of health protection services being located together, it was raised that the broadening of scope of health protection under PHE meant that some of these issues would need to be examined more closely:

The broadening of the scope in terms of ‘health protection’ in PHE means that co-location needs to be re-examined in terms of this new landscape. Thus, it may be more cost-effective and productive to consider co-locating some of the Public Health observatories and cancer registries with the 'infectious
disease’ epidemiology, surveillance and modelling groups from HPA in order to generate new ‘synergies’ within PHE. (Participant 20)

All of this feeds into an overarching concern which was not discussed in great length, but which does seem to us, in analysing the exercise, to cut through the other areas. This is in relation to how an integrated science hub would actually work and how it would help PHE realise its objectives. One participant raised a set of issues in relation to this which garnered some positive responses from other respondents. The initial thread is paraphrased below:

I think there is something missing from this exercise. We are being asked good questions about the importance of various science disciplines for the domains of PH. […] But what we are not talking about is HOW the science hub will work. […] (Do) we want/need to have this expertise and knowledge in house or could we find smart ways of working with experts elsewhere, building on, and working with the expertise where it already sits? What does PHE want to be? A centre of excellence itself with the experts employed by PHE, or a centre of excellence in collaborating with experts wherever they are, offering exchange of ideas, exchange of employment etc etc? I hope we are not creating a science hub that might become another silo. It seems to me that we need to explore where capability is already, in the wider system, when making decisions about what our science hub should be, and scope particularly for those areas where there isn’t any ‘competing’ capability out there that we could work with, draw on etc, to bring into PHE and build capacity and capability. (Participant 33)

Two others agreed strongly with this statement, and in fact elements of the initial posting resonate with issues discussed above. One commented ‘I hope that the Science Hub will regain its focus. Concentrating on its strengths in high containment microbiology, rapid diagnostics and emergency preparedness seems sensible.’ (Participant 05). Another commented, in a different but related thread:

The model seems to be CDC but CDC has many centres of excellence including Atlanta, Research Triangle, Cincinnati and Montana. I think the issue is perhaps changing the way we work through effective leadership and not changing where we work. (Participant 103)

5.5. Summary of the ExpertLens

The purpose of the ExpertLens was to understand the perspective of a diverse group of stakeholders regarding the relative importance of different public health scientific and laboratory capabilities which might be required in the future. Moreover, we sought to understand the implications of these capabilities on the co-location of different scientific and laboratory facilities in a central public health science hub. Before summarising the findings from the ExpertLens, it is important to highlight a few of its limitations. First, due to the short timescales of the study as a whole, participation in the ExpertLens was not as consistent as might have been the case had there been more time for it. Many participants commented that they felt it was a valuable exercise, but they were concerned there was not enough time to engage in the discussion and consider the issues more fully. Second, and related, the majority of participants in the ExpertLens were internal PHE staff across a range of offices and divisions. Though we did invite external stakeholders to participate, it is likely that the timescales of the study made it less likely for them to engage. However, we did have two external participants in the ExpertLens exercise itself. Third, the fact there was not any statistical significance between questions means we could not conduct the analysis in
such a way as to explore convergence over time during the exercise, as one might usually do. However, this is not a prohibiting factor in making use of the responses and discussions that were provided, it simply means that we were not able to explore convergence or divergence in views over the course of the study. Rather, we focussed on highlighting areas of agreement/disagreement as they emerged over the course of the study as a whole.

Nevertheless, despite these limitations a range of issues did emerge from across the analysis. The central role of integrating different types of knowledge in any future configuration of public health services is clear. Underpinning this knowledge is the different kinds of data that future public health scientists will need to grapple with. Putting in place effective mechanisms for collecting, managing, mining, integrating and translating data into new knowledge will be of central importance. Participants in the ExpertLens confirmed this in their repeated stress on the need to focus not only on centralisation in a physical way, but more crucially on integration of different kinds of capabilities and knowledge going forward.

Interestingly, given its focal role in the literature review and, to a certain extent in the interviews, there were mixed views on the role of genetic sequencing across different areas of public health. In particular, there was less certainty about its potential importance in relation to health improvement. This sits in contrast to some of the insights from the literature review, which pointed to the role, in some cases the central role, of genetic technologies in the future across many areas.

The exercise also allowed for a set of issues around the hub itself to emerge. In the discussions these were less related to the nature of the capabilities a hub might enable, and more about the characteristics which would enable success. Here, participants highlighted the need for a strong vision for PHE, which in turn would inform the nature of the hub, as well as the importance of continued discussions about how a hub would be implemented. Participants felt like one could not necessarily precede the other, but rather the two must go forward hand-in-hand.
6. Cross-cutting themes and findings

Summary of chapter insights

During the course of the study it became clear that there are a series of both strategic enablers and operational platforms which will allow for PHE to deliver across the three domains of public health: health promotion, health improvement, and health services. The strategic enablers which emerged comprise different, often overlapping component parts, and may be loosely defined as follows:

- **Integrated knowledge flows.** This relates to the flow of information, skills and best practice between individuals and groups, underpinned by various different types of data, its storage, integration, interrogation, analysis and sharing.

- **Leadership and management.** This relates to the provision of strong, committed direction which embodies the corporate mission, motivates and guides PHE’s people, and makes and delivers on long-term strategy to meet emerging needs.

- **Scientific capabilities.** This relates to the various disciplines and domains that allow the Agency to prosecute its mission and to their integration in a multi-disciplinary, collegiate context.

For PHE to be successful, all three strategic enablers will be required, to a greater or lesser extent, at all times. Under differing circumstances, though, the various elements will, naturally, assume greater or lesser importance, or may require particular attention or enhancement. In any case, the relative extent of each enabler is less important than the interplay between them.

In reality the balance may shift in a dynamic way in relation to a broader set of contextual conditions in which PHE operates. To this end, a set of operational platforms are also required which can be called upon and utilised in various ways depending on the demands placed upon PHE and the public health infrastructure in the future. These operational platforms will provide the capabilities, capacity, methodologies/techniques, technologies, and resources for this task. These capabilities and supporting elements are drawn from across all the activities of this horizon scan.

The three strategic enablers, the operational platforms and the elements which support all of it are critical determining elements to the successful establishment of a hub. The interplay between these three areas will represent the core constituents of PHE’s future success.

One of the most important take-away messages of our study relates to the question of a hub: interdisciplinary efforts will drive the future, and just as these interdisciplinary efforts will manifest in different ways, so too will the concept of co-location. Co-location is itself multi-faceted. It can be virtual, networked or physical; centralised, decentralised or interconnected. Each one of these facets will be important in some way for PHE to consider. Integrated knowledge flows, the ability to draw on the supporting scientific capabilities and the constant, guiding role of strategic leadership and operational management will be crucial, whatever kind of co-location is sought. PHE will need to consider the need to **conduct** and **provide** public health science activities itself, alongside its role in **enabling others** to conduct public health science activities and **helping to shape** the future. It must, crucially, **integrate** both aspects together. In this sense, co-location is not about physical centralisation of capabilities so much as it is about the integration of all of PHE’s collective resources. These considerations will drive many of the future decisions which are necessary.
6.1. Introduction

This study was undertaken in response to a request by PHE for RAND Europe to carry out a horizon scan looking at the future of public health science and the various trends and developments by which it may be driven and shaped over the next few decades. While it was not a consultation exercise, the study did involve extensive engagement with stakeholders, both through the conduct of interviews with key informants and through the ExpertLens Delphi process. The time-constrained nature of the study prevented a forensic examination across all current and emerging dimensions of public health and rather permitted only a relatively limited horizon scan of possible developments in significant areas. That said, in the course of the ExpertLens, informant interview, workshop, and literature review activities, we did not encounter any major ‘game-changing’ capabilities that are not addressed in some way in the pages of this report. Hence, we have cautious confidence that many relevant areas are covered within the study and have been reflected in our thinking both in relation to public health science in the future and specifically to the possible creation of an integrated public health science hub.

Moreover, the study was undertaken between late June and early August 2013 at the same time that PHE was undertaking a refresh of the Agency’s strategic vision and remit. This represented both a challenge and a potential opportunity. On the one hand, the fact that PHE’s organisational vision had not been confirmed made thinking about how a hub could potentially enhance or detract from the Agency’s ability to deliver on its mission more complex. On the other, it was hoped that the simultaneous conduct of the horizon scan could feed into the strategic alignment exercise and potentially enhance the in-house work in that area. In this spirit we offer concluding thoughts which attempt to synthesise across the spectrum of our horizon scan activities.

6.2. Critically determinant elements

During the course of the study it became clear that there are a series of both strategic- and operational-level enablers which will allow PHE to deliver across the three domains of public health: health protection, health improvement, and health services. These domains are not mutually exclusive, and though the diagram below is simplistic (Figure 6-1), it is important to bear in mind.
Building out from this, and looking across the findings from each of the principal activities of our horizon scan, three strategic enablers for PHE clearly emerged: integrated knowledge flows; leadership and management; and scientific capabilities. These elements comprise different, often overlapping component parts, and may be loosely defined as follows:

- **Integrated knowledge flows.** This relates to the flow of information, skills and best practice between individuals and groups, underpinned by various different types of data, its storage, integration, interrogation, analysis and sharing.

- **Leadership and management.** This relates to the provision of strong, committed direction which embodies the corporate mission, motivates and guides PHE’s people, and makes and delivers on long-term strategy to meet emerging needs.

- **Scientific capabilities.** This relates to the various disciplines and domains that allow the Agency to prosecute its mission and to their integration in a multi-disciplinary, collegiate context.

For PHE to be successful, all three strategic enablers will be required, to a greater or lesser extent, at all times. Under differing circumstances, though, the various elements will, naturally, assume greater or lesser importance, or may require particular attention or enhancement. In any case, the relative extent of each enabler is less important than the interplay between them. This interplay must be coterminous and reflective of PHE’s broader strategic aims as they relate to the three pillars of public health (see Figure 6-2). While a perfectly balanced interplay is depicted in the figure below, in reality the balance may shift in a dynamic way depending on the nature of the public health challenge, the types of capabilities required to address it, the organisational demands and infrastructure and, of course, the broader contextual conditions in which PHE operates.
To this end, a set of operational platforms are also required which can be called upon and utilised in various ways depending on the demands placed upon PHE and the public health infrastructure in the future. These operational platforms will provide the capabilities, capacity, methodologies/techniques, technologies, and resources for this task and can be grouped under the following broad headings: surveillance; simulation and modelling; behavioural science; informatics; genetic technologies; and data. They cut across both wet and dry laboratory capabilities, and each has many different supporting elements (specific capabilities, technologies, methods, resources, etc) as shown in Figure 6-3 below.

It is worth noting one caveat to this immediately before proceeding further with our description of the figure. This is that we are aware specialist microbiological services are not included as a broad grouping and we have instead reflected the role it plays as a consistent supporting element across each heading. We fully recognise the critical role these services will play in enabling PHE to perform many of its health protection and health improvement functions. However, within the activities of this horizon scanning study, developments within this area did not themselves emerge as drivers of future capabilities, but rather as a consistent part of the picture of any future, regardless of other drivers which help to shape it.

With this in mind, and due to the limitations of this exercise, we do not claim that the operational platforms and supporting elements are comprehensive in nature, but they do cover many of the macro-capabilities which PHE will require in the future. They are drawn from across the findings of the study and in some cases directly correspond with areas already described in detail, eg behavioural sciences as presented in the ‘deep dive’ literature review, but in other cases draw across activities. In this latter case, we found that some capabilities emerged in an iterative way as we conducted the study. For example, the critical role of data mining and management, together with data integration (eg data fusion) is relevant to many areas of future need. Equally, the technologies, tools and specialist microbiological services required for future surveillance activities also emerged. Figure 6-3 shows how these operational enablers might be depicted in relation to the critical element ‘picture’ we have been building.
Figure 6-3 Strategic enablers and operational platforms for PHE
In considering this figure, there are several important considerations. The figure is not meant to be static, but rather should be imagined as a dynamic, shifting series of co-centric circles which are fluid and responsive to different demands on the system. In addition, many components of the operational platforms are repeated, and indeed some platforms may appear as elements of other platforms. This again relates to the fact that none of these areas are static, nor the lines between them black and white. The nature of the strategic requirement for integrated knowledge flows demands the recognition that it is the interconnectedness between the platforms which will be a critical determinant of PHE’s ability to maximise the resources and capabilities it has to hand. Finally, this picture is one which was built on a horizon scan into the future, and not necessarily one which is reflective of today’s challenges. Both should be borne in mind in order to build a resilient public health agency for the future.

6.3. Taking PHE into the future

The three strategic enablers, the operational platforms and the elements which support them are critical determining elements for the future of PHE: the interplay between them will represent the core constituents of the Agency’s future success. However, this does raise the question of how this interplay is determined and what the implications are for an integrated public health science hub.

The answer to this question is not straightforward. In the first instance, one of the most important take-away messages of our study is that the issue of co-location is multi-faceted. Co-location can be virtual, networked or physical: centralised, decentralised or interconnected. Each one of these facets will be important in some way for PHE to consider. This is where the role of the strategic enablers come into their own. No matter what kind of co-location is sought, integrated knowledge flows, the ability to draw on the supporting scientific capabilities, and the constant application of strategic leadership and operational management will be crucial. In this sense, co-location is not about physical centralisation of capabilities so much as it is about the integration of all of PHE’s collective resources and physical locale is just one part of the wider integrative efforts.

To this end, the question is raised as to the extent to which PHE is able to provide all of the operational platforms and associated capabilities itself, or whether it should outsource some of them. Our findings suggest that many highly technical areas may require expensive technologies which may not be feasible for PHE to maintain. In these cases, there may be a need to outsource the requisite functions (eg high throughput screening of the human genome), but this does not preclude PHE from retaining the ability to be an ‘intelligent customer’ of those functions and effectively integrate them into other areas. PHE will need to consider the need to conduct and provide public health science activities itself, alongside its role in enabling others to conduct public health science activities and helping to shape the future. It must, crucially, integrate both aspects together. These considerations will drive many of the future decisions which are necessary.

This conclusion also suggests that there is a wider role public health science alongside PHE in the future. Not only will PHE have to consider the right balance of its activities, but the field as a whole could collectively consider where capabilities are overlapping, mutually supporting, complementary or duplicative. To this end, a wider system mapping might be beneficial in order to understand where
expertise, capacity and capability already exist, and therefore where synergies might be maximised and duplicative efforts removed.

If we take as given that all of the enablers, platforms and elements described above are present in some form within PHE, or that PHE has the capacity to call on them as needed, then we believe there could be advantages to physically co-locating some, if not many, of these capabilities in some way. This is strongly predicated on the assumption that a number of key criteria (drawn from our study findings) have been satisfied:

- the suitability of the geographical location (to include proximity to other relevant organisations for ‘cross-fertilisation’ purposes)
- the availability of appropriate, flexible facilities
- the availability of integrated funding streams
- the involvement of the right people at all levels.

These assumptions are not insignificant. Given this, we believe there would be merit in undertaking a broader consultation exercise with internal and external public health stakeholders on the question of the functions and organisation of the hub. This would enable PHE to capture the widest possible spectrum of views in respect of the optimisation of capabilities, knowledge and leadership and would give those potentially affected the opportunity to share their views and contribute to the wider debate, thereby assisting with securing buy-in. Equally, since geographical location as well as physical co-location was identified by study participants as being a critical success factor, the relative merits and constraints of any proposed site should be examined both in quantitative terms (eg the scope and adaptability of the facilities available) and in qualitative terms (eg the proximity to other relevant organisations and the ability to maximise many of the benefits identified in relation to co-location as set out in Chapter 2).

In any case, it is important, going forward, to stress the significance of the requirements for knowledge, leadership and capabilities, and the associated components which underpin them. Were PHE to decide to establish a physical hub, for instance, the organisational configuration of the facility would be key to the integration of capabilities and the optimisation of knowledge flows. Similarly securing the buy-in of those staff who would be affected by the changes would represent a major endeavour for those leading the initiative and would require significant leadership at all levels. Key questions that would have to be addressed in respect of all three areas might include: how should the hub be configured to allow people of different disciplines and skill-sets to ‘spark’ off one another?; how can dysfunctional behaviours be eliminated?; what local ties would be needed?; and what capabilities can be more broadly networked and how do we effectively draw them in?

By way of illustration, the case of the operational platform related to data may constitute a useful example. Data may be a particular issue that highlights the importance of the three key elements of leadership, capabilities and knowledge for PHE and how they might interplay in the future. The scope of data relating to public health is expanding and diversifying and this is a source of challenges and opportunities for PHE in general, and in particular, with regard to the establishment of an integrated and co-located hub. There are three different kinds of data which might be relied upon: scientific data; patient/clinician data; and social data. Scientific data will come from many areas, including genetic sequencing. Genomics has been highlighted in this report as an area of importance. Although there is a lack of consensus
amongst PHE and external stakeholders on the impact that genomics will have on public health, it is clearly an area that will generate a huge amount of new science. In addition to laboratory based scientific data, increasing use of electronic health records will also mean that health data available from clinicians will multiply. Patient data from websites such as PatientsLikeMe represent another avenue which has potential to contribute to health improvement, protection and to surveillance. Finally, social data about our environments, experiences and interactions may also begin to have an effect on the way we understand, interpret and deliver public health science.

Making the most of each kind of data by finding ways to understand the links between them will be a core challenge for health services. More broadly, data mining and fusion of various kinds will likely be used in a wide variety of ways (for example, the transmission of ‘flu can be traced by analysing the number of hits of ‘flu information websites for example) and will underscore the importance of innovative and excellent data management. In this context, management and the capacity to use knowledge to effect improvements in health will be a key area for PHE. The extent to which an integrated hub will contribute to the ability to manage and use data effectively and creatively is widely seen by participants in this study and through our assessment of the literature as depending on the nature and quality of various types of capabilities, leadership and knowledge rather than being singly dependent on co-location per se. Thus, as just this one example highlights, there are a number of interplays that the future horizon requires us to consider.

6.4. Conclusion

PHE finds itself presented with a large set of challenges and opportunities. Protecting and improving the public’s health and wellbeing are substantial, multifaceted tasks, and ones which require not only national, but international perspectives and cooperation. Returning to the idea that PHE must balance its role in enabling, integrating and furthering public health science may prove a useful way forward. It can be a leader across all three aspects, but it must think about how to do this and where it makes sense to act on its own versus leading a more networked approach.

Here is where the final thought of our study leaves us. The individual scientific capabilities, techniques, tools and associated elements identified above cut across each other and intersect in various ways. Their overlap and interplay will vary depending on the type of public health challenges faced. Clearly all capabilities will support different operational platforms, which will require strategic integration of knowledge flows in order to optimise the efforts. This, in turn, will require strong leadership to help manage and guide. All of this will feed into PHE’s three central remits of public health, and so the extent to which intersecting capabilities and integrated knowledge will benefit from co-location is itself dependent upon PHE’s own strategic leadership, vision and goals. The subtle interplay of all three should be considered together in any future decisions.


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## Appendix A: Insights from key informant interviews

<table>
<thead>
<tr>
<th>TRENDS</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migration and climate change will change the scale and types of diseases and test our capacity to respond.</td>
<td>A</td>
</tr>
<tr>
<td>Genomics will be a significant technology trend.</td>
<td>A</td>
</tr>
<tr>
<td>Big IT and data analytics are key</td>
<td>A</td>
</tr>
<tr>
<td>There is scope for genomic sequencing to be done routinely in a hospital environment (though the barriers are cost and a lack of expertise/common look-up table.</td>
<td>B</td>
</tr>
<tr>
<td>The international exchange of data will become more important.</td>
<td>B</td>
</tr>
<tr>
<td>The future of microbiology is likely to be informatics-based.</td>
<td>B</td>
</tr>
<tr>
<td>There will be an increasing focus on prevention rather than cure in the future.</td>
<td>C</td>
</tr>
<tr>
<td>Personal choice will be a key element of future public health.</td>
<td>C</td>
</tr>
<tr>
<td>There will need to be greater awareness of science as an investigation of social phenomena.</td>
<td>D</td>
</tr>
<tr>
<td>Genomics trend will be significant.</td>
<td>E</td>
</tr>
<tr>
<td>There will be increasing need for transparency of cost-effectiveness.</td>
<td>E</td>
</tr>
<tr>
<td>There will be a need for greater flexibility within the public health system.</td>
<td>E</td>
</tr>
<tr>
<td>Need to demonstrate value-add on the public health front-line.</td>
<td>F</td>
</tr>
<tr>
<td>Genomics is a key development area.</td>
<td>F</td>
</tr>
<tr>
<td>Proteomics also a key emergent area.</td>
<td>F</td>
</tr>
<tr>
<td>Info and data becoming increasingly important.</td>
<td>F</td>
</tr>
<tr>
<td>Microbial genomics (sequencing could replace diagnostic reference functions)</td>
<td>G</td>
</tr>
<tr>
<td>Stratified medicine using genomics to understand how to treat individual patients or conditions</td>
<td>G</td>
</tr>
<tr>
<td>Emergence of new infectious agents and the change in the nature of infectious agents</td>
<td>G</td>
</tr>
<tr>
<td>Issue of AMR and spread of drug resistance which represents one of the biggest challenges to the health of the world</td>
<td>G</td>
</tr>
</tbody>
</table>
### Continuing trend towards prevention rather than cure

**G**

Sequencing is going to impact and is going to impact on everyday science both within the public and private sectors (particularly in relation to front-line diagnostics).

**H**

Proteomics may also be revolutionary because of its development through commercial companies.

**H**

Epigenomics – environmental factors will influence how an individual with a genetic predisposition will respond in certain sets of circumstances

**H**

Metagenomics – looking at genetic sequences directly in a sample rather than culturing – may confuse us as will probably find multiple pathogens in a sample and will not know which is causing the disease.

**H**

Developments in genomics (host genome and ability to analyse micro-organisms) mean there will be a trend towards doing more sequence-based analysis and replacement of older fingerprinting schemes for determining relationships between micro-organisms. Shifting from partial genetic analysis to full genetic analysis. Underlying this trend are the developments that have taken place in human genome sequencing work which enables you to look at host susceptibility

**I**

Linked to the developments in genomics are developments happening in informatics generally: ability to interrogate and link together large data-sets which will speed the way in which we may identify linkages between different places in the health service and in our ability to identify populations at risk or hotspots for particular incident or provide more predictive data that will help GPs identify what is the most common cause of the respiratory diseases you are seeing in their surgeries at any one time. Improves forecasting capability

**I**

Miniaturisation and robotics. More centralisation – concentration of warehouses for analytical activities linked to the idea of databases and genomics. Mechanical delivery.

**I**

Consequences of the genomics-related trends is that in microbiology or virology itself, all of these trends take us away from handling micro-organisms and this will mean an increasing dependency on unique capabilities at national level. This is important in relation to the PH science hub that is under consideration. The clear future here is that you will stop doing a lot of microorganism culture activates throughout the health service but you need to retain the capability as a whole at national level. You will see greater need to handle and maintain micro-organisms at national level. E.g. 6 years ago, all laboratories, more or less, within the public laboratories regional network, had the ability to culture the influenza virus. In the last 6 years, with the advent of molecular detection capability, it is now the case that none of these labs do culture work on influenza so you need that work to be done centrally. Genomics does not replace all that is necessary.

**I**

Applications linked to smart technology – personalised medicine and point of care testing. E.g. HIV testing: if you were smart enough to link what you know about host
The future of public health: A horizon scan

<table>
<thead>
<tr>
<th>Susceptibility, you could make linkages between diagnosis and prognosis of HIV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintaining public health will require more and more behavioural psychology</td>
</tr>
<tr>
<td>Whole Genome Sequencing will have a profound effect on microbiology and will reshape what we do. We need the capability to know far more about how infections are transmitted and transmission routes. There is enough will and excitement at a senior political level and interest from many academic centres so this will not remain just in Public Health which provides more energy.</td>
</tr>
<tr>
<td>Whole Genome Sequencing is going to have an effect but the question will remain 'what are we looking for'?</td>
</tr>
<tr>
<td>The travel and mingling of populations and the continuing mingle of micro-organisms represents a significant trend as does poor antibiotic use. The incredible mutability of so many micro-organisms means some will flourish.</td>
</tr>
<tr>
<td>Whole Genome Sequencing will change microbiology profoundly. For example the kind of bacteria typing methods currently in use will be swept away by WGS.</td>
</tr>
<tr>
<td>Changing public perceptions of infectious disease – genuinely ill vs worried well</td>
</tr>
<tr>
<td>The more people move into new environments, the more they push animals out of their own environments and greater prevalence of rare diseases</td>
</tr>
<tr>
<td>Changing patterns of bird migration have also changed infectious disease patterns</td>
</tr>
<tr>
<td>Big data – using large databases to assess impact of Public Health and healthcare policies</td>
</tr>
<tr>
<td>Genomics agenda though difficult to see how much impact that will have on Public Health. Epigenetics may be more important than genomics.</td>
</tr>
<tr>
<td>You now need obligatory approaches to drive people to improve their health</td>
</tr>
<tr>
<td>Social, Demographic and Environmental factors assuming same importance as technologies</td>
</tr>
<tr>
<td>Big data and evidence synthesis to allow for spotting of novel patterns that might offer useful insights into people’s behaviour</td>
</tr>
<tr>
<td>Genetic technologies will not drive the field of public health</td>
</tr>
<tr>
<td>Move towards ‘Population Health Science’ rather than ‘Public Health Science’</td>
</tr>
<tr>
<td>Commercial determinants of health (e.g. tobacco industry)</td>
</tr>
<tr>
<td>The way in which we work will be driven even more by the access to the cutting edge of information technology.</td>
</tr>
<tr>
<td>There will be a major change in the way that laboratory science is done over the next 20 years, underpinned by things like WGS. Greater consolidation and rationalisation of laboratory services are likely to result from a greater recognition of the possibility of sharing approaches.</td>
</tr>
<tr>
<td>Statement</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>New pathogens will continue to emerge (at a rate of 1 every year on average)</td>
</tr>
<tr>
<td>New threats will increasingly challenge our diagnostic capabilities</td>
</tr>
<tr>
<td>The democratisation of information through digital and social media, ie the engagement of the public in health and science and public health – will be a key driver</td>
</tr>
<tr>
<td>The democratisation of the ownership of individual health information, its governance and the way data moves between interested parties will drive greater engagement</td>
</tr>
<tr>
<td>There will be a movement towards becoming more granular in focusing on genomics and understanding the role of genomics and health and also looking outwards, eg looking at social determinants, etc.</td>
</tr>
<tr>
<td>There may be changes to the contract between the people and the government in relation to PH, eg increasing scepticism or increasing reliance.</td>
</tr>
<tr>
<td>There will be increased emphasis on the need to push the population to take responsibility for their own health – this can’t be left to emerge organically and naturally.</td>
</tr>
<tr>
<td>More capability and research required to deal with health inequalities at the local level, particularly in relation to why some communities do well and others do not. A more holistic approach is required for understanding spatial inequalities and the role of behavioural and environmental factors. Should look to understand impact of factors like social capital in communities, eg do communities with more social capital have better health?</td>
</tr>
<tr>
<td>Potential for the use of new forms of data collection devices, eg handheld devices to collect health data but also to improve health promotion information and messages</td>
</tr>
<tr>
<td>Epigenetics will be an important trend in bringing together genetic and ecological approaches</td>
</tr>
<tr>
<td>Increasing importance of behavioural sciences – large volume of chronic diseases have strong environmental and behavioural basis. Now have a much more precise understanding over the last 20 years through epidemiology of the factors for illness – now see in conditions like diabetes that they are the composite result of multiple factors and there are clear determinants of risk. When people talk about the demographic timebomb, they’re actually talking about the accumulated burden of chronic disease. Public Health is already starting to think with an additional skillset which is not the biomedical model and to look at behaviour, communication and behavioural modelling. Because of the successes in hard biological sciences have tended to overlook the advances made in behavioural sciences</td>
</tr>
<tr>
<td>Importance of AMR – keep seeing emergence of new human pathogens and of AMR which is more than just a passing concern. The ability for pathogens and resistance patterns to change and move around the world is increasing and will have profound implications.</td>
</tr>
<tr>
<td>Modern genomic technology should allow us to know more about the ability of pathogens</td>
</tr>
</tbody>
</table>
and viruses to transmit from one species to another and to identify what features of its genome would determine its fatality rate.

| Increasing importance of behavioural science and individual resilience – research to understand what makes one community/group ‘invest’ in themselves and another not. This will take us far beyond realm of traditionally-defined public health science. | V |
| Increasing emphasis on genetic science both in terms of the genetic underpinnings of disease and genetic analysis of diseases and pathogens. | V |
| Rise of AMR | V |
| Increasing prominence of smart computing within a networked world. | V |
| Continuing increase in new biological medicines which will become increasingly complex. | W |
| AMR as a key public health risk. | W |
| Complete analysis of the genomes of pathogenic bacteria will lead to a better understanding of immunogenicity, their virulence and the emergence of pharmacological targets for the emergence of new antibiotic drugs. | W |
| Increasing tie-up between new medicines and diagnostic techniques. Will lead increasingly to stratified medicines (groups that will receive a particular medicine and those that won’t) and the increased use of companion diagnostics enabled by genetic profiling. | W |
| There will be a much more sophisticated and intelligent approach to datasets and data storage which will be generic to all public health. | W |
| Globalisation of the production of medicines and the complexity of supply chains, sourcing and market competition. Not that easy to regulate a medicine over such a long supply chain. This increases the complexity of the challenge. | W |
| The development of much more sophisticated analytical technology and the use of large throughput ‘-omic’ technology will be key across a number of PH areas. | W |
| There will be wet lab work which will need to be state of the art and be responsive to the move within the NHS towards Point of Care diagnostics. There will also be dry lab work which relates to research manipulating data and surveillance activities. | Y |
## ISSUES AND CHALLENGES FACING PUBLIC HEALTH

<table>
<thead>
<tr>
<th>Issue</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are risks associated with the increasing involvement of private companies in pathology, eg loss of control.</td>
<td>A</td>
</tr>
<tr>
<td>There is a risk that companies will attempt to sell proprietary vertical systems which will not be interoperable.</td>
<td>B</td>
</tr>
<tr>
<td>Heavy reliance on academia has been a failing in the Public Health system.</td>
<td>B</td>
</tr>
<tr>
<td>There is scope for industry to derail public health.</td>
<td>C</td>
</tr>
<tr>
<td>There are risks relating to silos of funds and capabilities.</td>
<td>C</td>
</tr>
<tr>
<td>There is a need for greater emphasis on individual responsibility for health.</td>
<td>D</td>
</tr>
<tr>
<td>PHE needs a better vision of what it is trying to achieve.</td>
<td>D</td>
</tr>
<tr>
<td>The creation of PHE feels like a barrier because of the uncertainty it has introduced.</td>
<td>E</td>
</tr>
<tr>
<td>Trend towards local commissioning prompts the need for the issue of Terms and Conditions or other controls by PHE.</td>
<td>F</td>
</tr>
<tr>
<td>It has been a failing of PHE to only see the silo and not the human.</td>
<td>F</td>
</tr>
<tr>
<td>Storing large datasets – not just dumping them in servers but how they are accessed and interacted with. All techs associated with high-performance computing.</td>
<td>H</td>
</tr>
<tr>
<td>The independent sector is going to be a nuisance for public service microbiology – they can’t even afford to send samples through for national surveillance.</td>
<td>J</td>
</tr>
<tr>
<td>Recruitment and retention issues – training is much more rigid than it used to be and lots of younger microbiologists have only limited experience of emergency response and much less training. There are not the opportunities to ‘have a go’ at doing public health microbiology as would have existed 20 years ago.</td>
<td>K</td>
</tr>
<tr>
<td>Interviewee too well aware of having to tender for services moving from current providers within an NHS envelope to private providers with all sorts of methods of delivery. Surveillance information may become unstable due to involvement of commercial providers who are not doing the tests they were doing before or providing the information they were providing before.</td>
<td>L</td>
</tr>
<tr>
<td>Ageing population with pressures on the NHS budget and the continuing growth of chronic disease</td>
<td>O</td>
</tr>
<tr>
<td>Huge public health inequalities across the country</td>
<td>P</td>
</tr>
<tr>
<td>The funding landscape will continue to change, having been diverted by the academic route.</td>
<td>R</td>
</tr>
<tr>
<td>There are major integration issues, both internally and externally. Colindale and PD work together at a local level but not at a strategic level where there are obstacles.</td>
<td>R</td>
</tr>
</tbody>
</table>
A challenge associated with the creation of a PH science hub is the risk that it becomes just another academic silo which does not share knowledge outside the organisation.

Needs to establish its credentials and capability to try and protect itself from the political winds of change which may threaten it unless it is quick to establish itself. Needs to be seen as authoritative and not at the whim of a general election or as a result of a select committee.

We are in debt to the planet due to unsustainable behaviour in relation to natural resources and climate change: the question becomes how can we improve the public’s health while subsequently abusing the planet? We know that by using too much, there is less for people who are more vulnerable. We know that the world is heating and, as a result, a lot of the earth is no longer a sustainable place to live. This may prompt massive migration which has huge public health challenges associated with it.
<table>
<thead>
<tr>
<th>CAPABILITIES</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is a requirement for better integration between public health and clinicians.</td>
<td>D</td>
</tr>
<tr>
<td>Statisticians will be required.</td>
<td>D</td>
</tr>
<tr>
<td>Sociologists will be required.</td>
<td>D</td>
</tr>
<tr>
<td>Economists will be required.</td>
<td>D</td>
</tr>
<tr>
<td>Psychologists will be required.</td>
<td>D</td>
</tr>
<tr>
<td>The behavioural sciences are currently considered an external discipline and shouldn’t be.</td>
<td>E</td>
</tr>
<tr>
<td>Needs to retain ability to conduct high-throughput precision-testing in case of emergency outbreak.</td>
<td>F</td>
</tr>
<tr>
<td>No need for the public sector to duplicate work in the private sector. You need people who can use software not design it.</td>
<td>F</td>
</tr>
<tr>
<td>Need to maintain focus on the international dimensions as public health is global.</td>
<td>F</td>
</tr>
<tr>
<td>Behavioural science skills will be required.</td>
<td>F</td>
</tr>
<tr>
<td>Must move towards the use of already analysed centralised data rather than rely on doing the analysis oneself.</td>
<td>F</td>
</tr>
<tr>
<td>Will require Informatics and bio-informatics capabilities (a much overdue boost to resourcing in this area)</td>
<td>H</td>
</tr>
<tr>
<td>Need epidemiologists</td>
<td>H</td>
</tr>
<tr>
<td>Need laboratory scientists</td>
<td>H</td>
</tr>
<tr>
<td>Need hybrid scientists that understand laboratory and bioinformatics</td>
<td>H</td>
</tr>
<tr>
<td>Need data managers and data administrators</td>
<td>H</td>
</tr>
<tr>
<td>Labs are recruiting bioinformaticans to work in their departments. What isn’t going on yet is that the number people who used to do a lot of traditional microbiological typing techniques will probably have to be reduced. Over a couple of years, lab workforces likely to change at the regional level.</td>
<td>H</td>
</tr>
<tr>
<td>Need people who retain expertise in handling micro-organisms – this is a highly-specialised skill. This is particularly relevant when dealing with nasty micro-organisms.</td>
<td>I</td>
</tr>
<tr>
<td>Bioinformatics in two categories; the underlying mathematical/statistical skillset which revolves around the mathematical interrogation of large data-sets which gives you the capability to infer biological information from large data sets; and the biologist who looks at the data-sets and makes inferences about biology from that data (you will need statisticians, mathematicians and modellers who can apply their skillset across the spectrum of public health);</td>
<td>I</td>
</tr>
<tr>
<td>Micro-biologists and virologists working closely with epidemiologists as part of an</td>
<td>I</td>
</tr>
<tr>
<td>Integrated Team</td>
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<tr>
<td>-----------------</td>
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</tr>
<tr>
<td>Ability to link the information and analysis to methodologies for creation of databases and sharing of information (making information available within a system);</td>
<td></td>
</tr>
<tr>
<td>Informatics analysis – ability to link across databases and different forms of information to create intelligent analyses</td>
<td></td>
</tr>
<tr>
<td>Wet laboratory skills, some of which are generic, some of which are organism-specific, including taking in PhD scientists from academia</td>
<td></td>
</tr>
<tr>
<td>Medical skillsets: medical leadership (ability to lead a multi-disciplinary organisation, work across boundaries, apply knowledge for infection-control or risk-management assessment); technical medical expertise at the level of infectious control (vaccines, technical areas of public health); lead emergency responses (generic medical responses)</td>
<td></td>
</tr>
<tr>
<td>Technical staff including the bringing on of graduates</td>
<td></td>
</tr>
<tr>
<td>Possible increase in behavioural psychology input which could be useful in enhancing risk communication and understanding of individual responses in emergencies but may not be a major trend in public health work.</td>
<td></td>
</tr>
<tr>
<td>Continuing need for microbiology services – targeting the intervention, helping the intervention, giving analytical support to patterns of infectious disease.</td>
<td></td>
</tr>
<tr>
<td>Will require outlook, broad leadership, collaboration and synergy. Will need to develop and share technology.</td>
<td></td>
</tr>
<tr>
<td>Need to continue to capture and retain good scientists – good clinicians who are good scientists and good scientists who are good clinicians. These are few and far between.</td>
<td></td>
</tr>
<tr>
<td>Need to have people who will understand and interpret the sequencing outputs.</td>
<td></td>
</tr>
<tr>
<td>Need careful assembly of the analytical pipeline so that the microbiologists and the epidemiologists work together.</td>
<td></td>
</tr>
<tr>
<td>Will need great expansion in the bioinformatics sphere but the balance of skillsets is likely to shift over time.</td>
<td></td>
</tr>
<tr>
<td>Behavioural sciences might well be a priority given the remit of science.</td>
<td></td>
</tr>
<tr>
<td>Need to make optimal use of existing data within the system.</td>
<td></td>
</tr>
<tr>
<td>Need people with expertise of particular pathogens as well with people with bioinformatics skills who are at ease with microbiology. As things stand, you have microbiologists and bioinformaticians. What you need is hybrid individuals.</td>
<td></td>
</tr>
<tr>
<td>Recognition that what’s done in the lab currently probably won’t be in the future – a key capability will be managing the knowledge base</td>
<td></td>
</tr>
<tr>
<td>Given public perceptions of infectious diseases, the behavioural sciences will have a large part to play in the future both in terms of treating people and in relation to the messaging of risk.</td>
<td></td>
</tr>
<tr>
<td>Statement</td>
<td>Rating</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Will be using algorithms to interpret ordinary hospital indicators</td>
<td>N</td>
</tr>
<tr>
<td>Whole Genome Sequencing will be part of the equation – it is a good way</td>
<td>N</td>
</tr>
<tr>
<td>of looking at different organisms, however it also presents you with an</td>
<td></td>
</tr>
<tr>
<td>issue in relation to information of which you have no or only limited</td>
<td></td>
</tr>
<tr>
<td>understanding.</td>
<td></td>
</tr>
<tr>
<td>Need a multi-disciplinary approach including social sciences to help</td>
<td>O</td>
</tr>
<tr>
<td>effect behavioural change and inter-disciplinarity linking health with</td>
<td></td>
</tr>
<tr>
<td>other sectors.</td>
<td></td>
</tr>
<tr>
<td>Bioinformaticians (or at least IT people – they don’t necessarily need</td>
<td>P</td>
</tr>
<tr>
<td>to know about biochemistry.</td>
<td></td>
</tr>
<tr>
<td>Integration as the highest science – must pull together what we know</td>
<td>P</td>
</tr>
<tr>
<td>already.</td>
<td></td>
</tr>
<tr>
<td>Will need to retain the ability to undertake testing of specialised</td>
<td>R</td>
</tr>
<tr>
<td>pathogens, ie will continue to require high-containment microbiology</td>
<td></td>
</tr>
<tr>
<td>Centre of Excellence.</td>
<td></td>
</tr>
<tr>
<td>Need to configure scientific interventions to be fit for purpose to meet</td>
<td>S</td>
</tr>
<tr>
<td>both existing and future need rather than to make yesterday perfect. Need</td>
<td></td>
</tr>
<tr>
<td>to think more creatively and be more than just epidemiologists and</td>
<td></td>
</tr>
<tr>
<td>laboratory staff but also to include geneticists, social scientists, etc.</td>
<td></td>
</tr>
<tr>
<td>The workforce will need to be more flexible than in the past in order to</td>
<td>S</td>
</tr>
<tr>
<td>respond to the working patterns of today, eg employments likely to be</td>
<td></td>
</tr>
<tr>
<td>3 – 5 years rather than 30 – 40 years.</td>
<td></td>
</tr>
<tr>
<td>Need to understand and change current approaches to scientific enquiry</td>
<td>S</td>
</tr>
<tr>
<td>and planning which currently result in a 20 year delay between the</td>
<td></td>
</tr>
<tr>
<td>creation of a new technique and its rolling out to the population.</td>
<td></td>
</tr>
<tr>
<td>PHE needs to ask questions about the relative distribution of resources.</td>
<td>S</td>
</tr>
<tr>
<td>The majority come from the Health Protection field and it may be necessary</td>
<td></td>
</tr>
<tr>
<td>to ‘right the ship’ in order to take account of the challenges.</td>
<td></td>
</tr>
<tr>
<td>Needs to be a process of rethinking research and a trend towards more</td>
<td>T</td>
</tr>
<tr>
<td>cross-disciplinary research, especially across the social sciences, eg</td>
<td></td>
</tr>
<tr>
<td>bringing together anthropologists, sociologists and psychologists to</td>
<td></td>
</tr>
<tr>
<td>explore the role of behavioural science for health promotion and public</td>
<td></td>
</tr>
<tr>
<td>health.</td>
<td></td>
</tr>
<tr>
<td>There will be a requirement to integrate data in a strategic and efficient</td>
<td>T</td>
</tr>
<tr>
<td>way and to maximise the use of medical, clinical, genetic and behavioural</td>
<td></td>
</tr>
<tr>
<td>data.</td>
<td></td>
</tr>
<tr>
<td>The ability to genotype organisms will require a strong laboratory base</td>
<td>U</td>
</tr>
<tr>
<td>in molecular biology in order to determine the relationship between</td>
<td></td>
</tr>
<tr>
<td>microbial genetics and disease.</td>
<td></td>
</tr>
<tr>
<td>Increasing requirement for behavioural science capabilities.</td>
<td>U</td>
</tr>
<tr>
<td>Requirement for molecular biology capabilities including high-throughput</td>
<td>U</td>
</tr>
<tr>
<td>screening.</td>
<td></td>
</tr>
<tr>
<td>The increasing prominence of health informatics, ie the ability to get</td>
<td>U</td>
</tr>
<tr>
<td>information about populations. A large commercial organisation would have</td>
<td></td>
</tr>
<tr>
<td>a much more joined-up picture of its business than the NHS has and this</td>
<td></td>
</tr>
<tr>
<td>should be tackled over the next ten years via an</td>
<td></td>
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</tbody>
</table>
integrating function within the delivery of PH.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need to work on enhancing the credible evidence in relation to non-communicable disease (eg through the social sciences, etc.)</td>
<td>V</td>
</tr>
<tr>
<td>Need close integration and networking of capabilities</td>
<td>V</td>
</tr>
<tr>
<td>Need world-class people in scientific teams and very high quality laboratory facilities</td>
<td>W</td>
</tr>
<tr>
<td>Need access to new sophisticated equipment that will be evolving</td>
<td>W</td>
</tr>
<tr>
<td>Need for strong, healthy links with the key academic centres</td>
<td>W</td>
</tr>
<tr>
<td>Need for good links with international regulatory bodies</td>
<td>W</td>
</tr>
<tr>
<td>Need high-level capability for data collection, integration and use</td>
<td>W</td>
</tr>
<tr>
<td>Both wet and dry labs will be necessary.</td>
<td>Y</td>
</tr>
<tr>
<td>It may not be affordable for PHE to do human genome sequencing but it may be possible to undertake the bug genome sequencing in-house.</td>
<td>Y</td>
</tr>
<tr>
<td>Cat 4 laboratories will still be required.</td>
<td>Y</td>
</tr>
</tbody>
</table>
**ROLE OF PHE**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHE should be a supporting agency rather than a doing one.</td>
<td>C</td>
</tr>
<tr>
<td>PHE involves programmes not strategies at the moment. This should change.</td>
<td>D</td>
</tr>
<tr>
<td>PHE needs integration within NHS structures.</td>
<td>D</td>
</tr>
<tr>
<td>The regional structure is key as public health needs to be bespoke to the region.</td>
<td>D</td>
</tr>
<tr>
<td>PHE should have a greater awareness of and role in exploiting the opportunities present by international partnership,</td>
<td>D</td>
</tr>
<tr>
<td>The role of PHE should be to demonstrate leadership and best practice.</td>
<td>E</td>
</tr>
<tr>
<td>PHE should have responsibility for the maintenance of relationships with the Local Authorities.</td>
<td>E</td>
</tr>
<tr>
<td>PHE must be capable of robust surveillance and response.</td>
<td>E</td>
</tr>
<tr>
<td>PHE must be able to demonstrable influence public behaviour and demonstrate public health benefits.</td>
<td>E</td>
</tr>
<tr>
<td>PHE should be responsible for the provision of advice and strategies for prevention and protection.</td>
<td>F</td>
</tr>
<tr>
<td>PHE will require a framework for growth.</td>
<td>F</td>
</tr>
<tr>
<td>Monitoring national and international developments in relation to outbreaks that could affect public health</td>
<td>G</td>
</tr>
<tr>
<td>Surveillance and outbreak detection capabilities</td>
<td>G</td>
</tr>
<tr>
<td>Reference service as a co-ordinated centre in which tests can be done in reference facility</td>
<td>G</td>
</tr>
<tr>
<td>Education of the public – keeping them informed.</td>
<td>G</td>
</tr>
<tr>
<td>PHE can’s do all the academic work that underpins new discoveries. The most important thing is for them to see how to capture the information and discoveries and translate them into their own practice.</td>
<td>G</td>
</tr>
<tr>
<td>Co-ordination function with other academic partners.</td>
<td>G</td>
</tr>
<tr>
<td>Concern is that will have the BBC effect – so big that the managers could no longer be corporate as they couldn’t understand what the other elements were doing.</td>
<td>H</td>
</tr>
<tr>
<td>Need to be the authoritative voice on PH infectious disease. May be international things that happen and PHE must be the authoritative organisation if not the first. Must maintain the authoritative science voice.</td>
<td>H</td>
</tr>
<tr>
<td>Must genuinely impact on public health outcomes. Challenge is how you evaluate outcomes.</td>
<td>H</td>
</tr>
<tr>
<td>Some of the microbial collection that has gone on over the years has been stamp-collecting and while you could hypothesise how that might impact a condition, it might not have withstood economic scrutiny as to whether it is reducing the burden of disease in hospitals.</td>
<td>H</td>
</tr>
</tbody>
</table>
An example of this would be the routine sequence of things which didn’t need doing. Should focus on structured surveillance which defines the question then applies appropriate surveillance techniques. E.g. Don’t monitor immunity to polio viruses continuously, you should do it once every three to five years.

Function of PHE to not only report on evidence but to make the raw data available for other people to analyse as well.

Continuation of its current role as its core activity – will still need to deliver health protection, responding to outbreaks and events

Would hope to see a much better linkage across the public health landscape so there is better opportunity to link, for example, what we know about cancers with what we know about preventive strategies. The compartmentalisation of liver cancer and Hep B vaccination strategies (at the moment they are completely compartmentalised but you would hope to be able to link aspects of preventive medicine to bring those together to reduce occurrence).

Much more centralisation of what is currently done in diverse locations.

Lots of issues in relation to medical workforce and planning – no longer so easy to have people who are generalists compared to people who are specialists.

If public health is not woven into your role in a laboratory, it is difficult to see it as a priority at the time. People need to own and sign up to it within the context of a stable network where people know each other.

It is essential that people work together and PHE must try to fit in with the existing good network of collaborative relationships and not seek to reinvent the wheel.

It will be up to PHE to ensure the communication between bioinformaticians and microbiologists and the bridging of the gap. PHE must encourage people to embrace the new and emerging technological developments. As things stand, bioinformaticians and epidemiologists talk and microbiologists get left out which leaves you without the pathogen-related expertise. Also need to incorporate behavioural scientists, particularly on the host side of things.

PHE needs to be demonstrating scientific advances within a high-quality research environment.

It is fundamental that PHE acts both as an integrator and as a scientific lead. You can’t do the first very well unless you’re doing the second. You may not be doing blue skies research (and that is maybe what the academic partnership should be doing (hence the importance of the relationship) but the value of the work done within PHE must be evident.

PHE as a knowledge integrator and disseminator
<table>
<thead>
<tr>
<th><strong>PHE in an ideal position to pull together the expertise.</strong></th>
<th><strong>N</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHE’s capability in science needs to be of the highest standards but it doesn’t need to do everything. It should do those things that are not possible elsewhere like collate and integrate data from the whole of the country. It should not be duplicating areas which are already covered elsewhere. A traditional role of reference laboratories has been to do typing but in 5 – 10 years the diagnostic techniques will be available in hospitals everywhere.</strong></td>
<td><strong>N</strong></td>
</tr>
<tr>
<td><strong>Disease Surveillance</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td><strong>Consider environmental threats</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td><strong>Provide linkages between the laboratory and epidemiological resources</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td><strong>Looking at the spread of AMR</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td><strong>Linking promotion and protection with broader issues</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td><strong>Need clarity on who is doing cutting-edge fundamental research and who is more about applied public health research.</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td><strong>How Public Health and Local Authorities interact with PHE will be crucial given that the latter is a central repository and focus of excellence. Crucial for carrying forward the public health agenda over the next decade and relationships key.</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td><strong>Role in leading international collaboration including across European Communicable Disease Centre and other agencies.</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td><strong>PHE needs to have intelligent links into ‘what works’ centres which could be virtual</strong></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td><strong>PHE will be expected to pull together the information that they get from surveillance, pull together and if necessary conduct research and bring that together in the form of evidence that can be used to develop policy in those areas.</strong></td>
<td><strong>Q</strong></td>
</tr>
<tr>
<td><strong>PHE role is principally about obtaining and laying out and providing advice based on the evidence in relation to public health issues. Greater role in health promotion.</strong></td>
<td><strong>Q</strong></td>
</tr>
<tr>
<td><strong>PHE will be required to identify the problems, analyse the root cause, work out how to solve the problems (behaviour, immunisation, surveillance if we don’t know about it). Must be able to respond rapidly and have the appropriate mechanisms in place.</strong></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td><strong>Should assume a leadership role and be a national voice and champion with clear messages and leadership.</strong></td>
<td><strong>S</strong></td>
</tr>
<tr>
<td><strong>Role as an honest broker, connector and networker</strong></td>
<td><strong>S</strong></td>
</tr>
<tr>
<td><strong>Should be configured for the creative deployment of assets and the employment of innovative models</strong></td>
<td><strong>S</strong></td>
</tr>
<tr>
<td><strong>Needs to be a robust, dynamic, evidence-based organisation in terms of programme, policy and other activities.</strong></td>
<td><strong>S</strong></td>
</tr>
<tr>
<td><strong>Needs to map capabilities and expertise in order to understand what already exists so as not</strong></td>
<td><strong>T</strong></td>
</tr>
</tbody>
</table>
The future of public health: A horizon scan

to replicate what has already been done.

Should maximise a collaborative culture within the community and encourage knowledge spillover to/from PHE.

T

Should play an influencing role, look to build trust and work more closely with local government. The key thing for PHE will be to communicate PH messages up and down scales to different organisations and communities from local to regional to global.

T

The PHE role should be less about research, data collection and scientific advancement and more about influencing and communicating.

T

Should have the freedom to develop its agenda in a way that responds to the problems with which it is faced.

U

PHE is well-placed to develop a strategy for disease which takes the longer view and is science based. It should marshal three broad sets of competencies: laboratory science in which it is strong and has a rich legacy; behavioural science which revolves around establishing the right links between the academic and practitioner base; and informatics. Since PHE’s responsibility for population health covers a broad canvas and represents a multi-faceted challenge, it should span these three domains.

U

PHE should undertake a leadership and advocacy role for health, putting health and the public’s health on the agenda and making the environment more supportive for individual health.

V

PHE’s role is to avoid falling into the ‘too difficult’ trap but to build a coalition to meet the challenges it faces, promoting cultural change and building momentum.

V

PHE could play an important role in effecting a posture change from responsive to preventive across the public health domain.

V

Needs to develop an increasing capability for high-level public health surveillance and epidemiological data analysis in order to deliver prevention and protection.

W

PHE should take the lead in the monitoring of microbial research including AMR.

W

PHE should maintain and develop further a world-class capability to respond to a serious PH threat – pandemics, deliberate or accidental release of pathogens, etc.

W

Intelligent use of large data should fall into the remit of PHE in the PH domain.

W

Should continue to exert international leadership in the field of PH.

W

PHE shouldn’t necessarily be doing the science but should be looking for the gaps and filling them in its role as an enabler and an integrator.

X

PHE should be the leading agency in improving the health and wellbeing of the public. It should deliver the service needed in the UK drawing on high-quality delivery science.

Y
<table>
<thead>
<tr>
<th><strong>HUB</strong></th>
<th><strong>Interviewee</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>What is going to happen in the hub that isn’t already happening at Porton Down and Colindale? What you need is a centre that feeds a network of hubs.</td>
<td>A</td>
</tr>
<tr>
<td>The hub should maintain collections of unusual things.</td>
<td>B</td>
</tr>
<tr>
<td>The hub should provide a common informatics infrastructure.</td>
<td>B</td>
</tr>
<tr>
<td>The hub should undertake resistance and reference-typing</td>
<td>B</td>
</tr>
<tr>
<td>The hub should have some responsibility for social science and behavioural elements</td>
<td>B</td>
</tr>
<tr>
<td>The hub should deal with common techniques in a common way.</td>
<td>B</td>
</tr>
<tr>
<td>Physical presence is important for organisational potency.</td>
<td>C</td>
</tr>
<tr>
<td>Constant reorganisation stands in the way of work.</td>
<td>E</td>
</tr>
<tr>
<td>There is a need for robust commitment and leadership.</td>
<td>E</td>
</tr>
<tr>
<td>Hub should focus on information flows, political process, policies and decision making. Local centres should be bespoke to the local need with a powerful, centralised organisation in the middle.</td>
<td>F</td>
</tr>
<tr>
<td>Dialogue is essential to a co-ordinated system of surveillance. Relocation could help reconfigure and co-location will be important.</td>
<td>G</td>
</tr>
<tr>
<td>Will need very careful organisation and a lot of design work. Could potentially established and then reconfigured at a later stage. Will require cultural change.</td>
<td>G</td>
</tr>
<tr>
<td>Barriers to the establishment of a successful hub come down to people and money. You need to get the right people in the job, you need to have the right amount of money and you need to avoid being over-bureaucratic but rather must be nimble.</td>
<td>G</td>
</tr>
<tr>
<td>Would need clear indication within the organisational structure as to what we’re trying to achieve (PHE moving from transition to transformation)</td>
<td>H</td>
</tr>
<tr>
<td>Would need disease scenario-focused multi-disciplinary groups rather than partition of expertise</td>
<td>H</td>
</tr>
<tr>
<td>Would need Big data centre with high-speed links to the world at large and big stakeholders like the sanger institute</td>
<td>H</td>
</tr>
<tr>
<td>Staff organised in such a way that they can be flexible and not attached to a particular organism but can be used for surge capacity and response</td>
<td>H</td>
</tr>
<tr>
<td>Social facilities to enhance working relationships and build up trust between individuals</td>
<td>H</td>
</tr>
<tr>
<td>Mechanisms for introducing new high-potential technologies</td>
<td>H</td>
</tr>
<tr>
<td>Philosophically, the only way we can modernise and meet the need is through the establishment of a scientific hub and that relates to organisational structure as much as location.</td>
<td>H</td>
</tr>
<tr>
<td>Centre of excellence – scientific hub and repository of strain collection, bio-banks and</td>
<td>I</td>
</tr>
</tbody>
</table>
unique capabilities.

<table>
<thead>
<tr>
<th>There is merit in having an integrated hub but the question is, how are you going to stop people being dysfunctional? To co-locate three dysfunctional areas will be detrimental and will only cause further fragmentation.</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is value in having a science federation but only if there are other organisations on site with whom to integrate. E.g. no-one would baulk if the hub was placed with the Sanger Centre at Hixton.</td>
<td>J</td>
</tr>
<tr>
<td>Not sure whether there would need to be wet lab provision in a hub – rather you could build surge provision into your dispersed service.</td>
<td>K</td>
</tr>
<tr>
<td>I would love my epidemiologist colleagues to be across the corridor rather than across the town.</td>
<td>K</td>
</tr>
<tr>
<td>Establishing and maintaining good relationships is underpinned by working on the same site. It is easier to discuss things and there are differences in the relationship between teams when they’re working in different locations from when they’re co-located.</td>
<td>M</td>
</tr>
<tr>
<td>A successful hub would need to exist not in isolation but would have to have good links and be close to other institutes or science partners or an academic institute. Needs to have easy access to central London – this was key to a previous emergency response.</td>
<td>M</td>
</tr>
<tr>
<td>Physical co-location might yield a slight increase in PHE’s ability to pull together all the relevant expertise. In reality, those who want to integrate and work in a multi-disciplinary context will do so anyway. Those who do not, will not. There are examples of facilities which may be geographically located 200 miles apart but which run their centres effectively as an integrated entity.</td>
<td>N</td>
</tr>
<tr>
<td>Impossible to put all resources in one location so need to try and network existing resources.</td>
<td>O</td>
</tr>
<tr>
<td>Would be a mistake to take all the cutting-edge laboratory science out of PHE. Can’t just be seen as a low-level storage facility.</td>
<td>O</td>
</tr>
<tr>
<td>Represents an opportunity to align PHE more closely with academic sector through joint appointments, etc.</td>
<td>O</td>
</tr>
<tr>
<td>Moving people around is not always a good thing and tends to create a year or two of interference with operational efficiency. Would need to be a really good case to bring together PD and Colindale to warrant that level of disruption.</td>
<td>O</td>
</tr>
<tr>
<td>No particular virtue in a physical presence rather than a virtual presence.</td>
<td>P</td>
</tr>
<tr>
<td>Should consider that geographical proximity does matter. Colindale interactions are facilitated by the fact that lab colleagues are onsite and by the proximity to London. A great deal of the most effective interaction arises from the ability to meet physically.</td>
<td>Q</td>
</tr>
<tr>
<td>It would be unrealistic to imagine that you could achieve full integration across all the elements of PHE but if you could bring together the expertise in the various areas in a</td>
<td>Q</td>
</tr>
</tbody>
</table>
National Centre, it could have lots of potential benefits, provided that it was not at the expense of those groups’ ability to interact with others outside of the group.

| Q | The business of getting a coherent vision for the science hub and for PHE is going to be really important for being able to go forward and win hearts and minds and be persuasive. |
| R | A potential benefit is that in theory you wouldn’t get duplication of resources and would be slick and efficient. |
| R | Potentially, in establishing a hub you’d be putting all your eggs in one basket so that if something went wrong in one of those labs, you could lose everything. |
| T | An integrated PH science hub would help break down silos, make synergies happen and create a shared culture within PH science. It should be dynamic with secondments from different organisations and a constant flow of people from outside PHE sharing knowledge and ideas. |

| U | We should avoid getting too fixated on bricks and mortar which is a dead weight. The important thing is to bring disciplines together in a networked fashion rather than necessarily bringing them together in one place. Given the swiftly changing nature of the PH agenda, the environment must be fluid and networked. |
| U | It will be important for PHE to have inter-organisational network links and to be involved with academics and practitioners rather than become isolated. |
| U | You can do v high quality work in a distributed fashion. The HPA was working on 50 or 70 sites anyway so the challenge of networked working was one they were already dealing with. |

| V | A hub would enable a common story or narrative and bring people together under a shared vision. |
| V | The creation of a hub could help reduce overlaps. |
| V | Bringing multi-disciplinary people together with a common endeavour enables them to spark off one another. Physical co-location makes these chance encounters/sparks more likely. |
| V | The creation of a hub could help engender a feeling of excitement in relation to PHE. |

| V | The challenges of creating a hub include physically getting people there, creating a culture of making people talk to each other both formally and informally and getting everyone to realise that they’re in the same game although the field is very broad. |
| W | While you get good interactions when you co-locate scientists from different disciplines (eg biology and physics), when you co-locate scientists who do similar things, you don’t get that much synergy. With real-time virtual contact you can talk to anyone whenever you like. Linkages with appropriate groups matters much more than being on the same site. |
| W | In terms of geographic location, not being near several large universities would be a demerit. |
A single physical hub may not be the right approach since the local is the most important thing in public health.

To create a single physical hub might represent an ‘eggs in one basket’ risk – contamination might mean that you couldn’t use the laboratories.

Ideally the co-location site would be on a university campus. Working with the universities will be one of the answers and interaction with them will be key.
## UNCERTAINTIES

<table>
<thead>
<tr>
<th>Question</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will PHE have to sway in the wind according to the politics of the day?</td>
<td>G</td>
</tr>
<tr>
<td>Something will come along eventually that will wipe ¼ of the world’s population off the face of the earth. Will PHE be up to the job of dealing with it?</td>
<td>G</td>
</tr>
<tr>
<td>Links with academic groups are important but one of the recent concerns through certain initiatives of engaging with academic groups is that some of the initiatives are much lauded at CMO level actually potentially undermine PHE in the longer-term because ac grps are proposing to take on national surveillance functions, etc. Not appropriate. This needs to be the remit of PHE – danger is that they get outsourced to academic grps who are only interested in it while its interesting. Could lead to a disassembling and there’s no way back to reassembling. So naïve as many of these individuals are dismissive of PHE and motivated by need to bring funding into the University.</td>
<td>H</td>
</tr>
<tr>
<td>Microbiology services seem to be treading water and have been for some time and need to get the management team sorted and the transformation underway. Seem to be at an impasse and have been for some time. HPA colleagues have organised themselves well. MS not so much perhaps.</td>
<td>H</td>
</tr>
<tr>
<td>Politics (UK government in the health sector) has led to the most amazing upheaval of the health landscape in the last few years. Linked to this economic austerity.</td>
<td>I</td>
</tr>
<tr>
<td>In danger of losing some of the most skilled and gifted people because of bad workforce planning and policy.</td>
<td>I</td>
</tr>
<tr>
<td>Difficulty attracting most gifted graduates into civil service framework – major threat to the future of science hub because without them, there is no lifeblood.</td>
<td>I</td>
</tr>
<tr>
<td>Internal problems including personality clashes between senior individuals mean that the organisation will continue to bleed good people.</td>
<td>J</td>
</tr>
<tr>
<td>There are so many organisations within PHE that it is impossible to know where they could start to work together. A proper change process/mechanism will be needed.</td>
<td>M</td>
</tr>
<tr>
<td>Transformation of pathology will impact on microbiology and may interfere with ability to obtain surveillance data of infectious diseases. There is a requirement to look forward and plan. There may be a requirement to pay to ensure labs send samples.</td>
<td>M</td>
</tr>
<tr>
<td>In the future, people may be sending whole genome information rather than individual bacterial isolets so the microbiologists may not be receiving the data they need and the value of the information they’ve currently got will not be a reflection of what’s actually happening.</td>
<td>M</td>
</tr>
<tr>
<td>If PHE is properly configured, it has huge potential. The danger in government-controlled public health is whim. Politicians change their ideas based on whim. To change the trend on whether we should eat chips or not forgets the unexciting and mundane things that need to be kept going. Councils are not legally obliged to provide public toilets and people will eventually resort to relieving themselves in the street. This</td>
<td>N</td>
</tr>
</tbody>
</table>
The future of public health: A horizon scan

<table>
<thead>
<tr>
<th>Issue</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will have public health repercussions.</td>
<td>N</td>
</tr>
<tr>
<td>A key danger is an utter and total lack of understanding on how to do data mining, extraction and interpretation and provide the infrastructure for it across the whole of PHE. There has been no attempt to build the multi-disciplinary techniques you need to do it and we are so far behind the automotive and space industry, we will end up with a lot of data we’re not able to use.</td>
<td>N</td>
</tr>
<tr>
<td>Concerns regarding ideological basis for some decisions coming out of government. Evidence needs to play a more prominent role.</td>
<td>O</td>
</tr>
<tr>
<td>Don’t have the right policies in place to prepare people for healthy old age so the burdens on the NHS are significant and growing.</td>
<td>O</td>
</tr>
<tr>
<td>Possibilities of a zoo pandemic.</td>
<td>O</td>
</tr>
<tr>
<td>Continued growth of AMR may threaten current treatment policies.</td>
<td>O</td>
</tr>
<tr>
<td>Public Health interventions are heavily influenced by political agendas</td>
<td>O</td>
</tr>
<tr>
<td>Absence of value attached to evidence synthesis – failure to take account of where the evidence is telling you not to go</td>
<td>P</td>
</tr>
<tr>
<td>Concern that PHE is doing everything and nothing</td>
<td>P</td>
</tr>
<tr>
<td>A big challenge in the medium term will be to win hearts and minds and getting people to sign up to and be part of the new arrangement. There is a big risk that people will say that the move to a hub is too much of an upheaval and that there isn’t enough in it for them to make a big change. To mitigate this, you make sure it is not too distant and you also make it more about hearts and minds.</td>
<td>Q</td>
</tr>
<tr>
<td>There is a risk associated with high staff turnover. Staff are not that easy to find.</td>
<td>R</td>
</tr>
<tr>
<td>Inequalities look likely to get worse because the principal factors driving them are in the economic and social domain and without an integrated approach to tackling them which involves politics, public health will fail.</td>
<td>S</td>
</tr>
<tr>
<td>Concerned re dropping the ball in relation to the safety net – rapid response, identifying new diseases and ensuring robust research to ensure effective policies.</td>
<td>S</td>
</tr>
<tr>
<td>Need resources if going to be able to carve out the unique voice of advocacy, leadership and truth that helps get the job done.</td>
<td>S</td>
</tr>
<tr>
<td>The public health gap in the UK continues to increase.</td>
<td>T</td>
</tr>
<tr>
<td>The economy represents a major challenge to PH.</td>
<td>T</td>
</tr>
<tr>
<td>Population change, food security, global warming and other global health challenges will impact on the UK.</td>
<td>T</td>
</tr>
<tr>
<td>AMR represents a major threat – the talk about the ending of the days of safe surgery may not be a massive exaggeration.</td>
<td>U</td>
</tr>
<tr>
<td>Novel infectious diseases will continue to emerge and ’dry runs’ such as the swine flu</td>
<td>U</td>
</tr>
<tr>
<td>Issue</td>
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<td>----------------------------------------------------------------------</td>
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<tr>
<td>epidemic may induce complacency.</td>
<td></td>
</tr>
<tr>
<td>The issue of obesity has the potential to become a chronic generational problem.</td>
<td>U</td>
</tr>
<tr>
<td>Inequalities – we need to understand why they're there and what to do about them.</td>
<td>V</td>
</tr>
<tr>
<td>Emerging antibiotic resistance.</td>
<td>W</td>
</tr>
<tr>
<td>The accidental or deliberate release of pathogens</td>
<td>W</td>
</tr>
<tr>
<td>We may be on the cusp of a wonderful new era in health and if we get it wrong at the beginning could set it back decades.</td>
<td>W</td>
</tr>
<tr>
<td>The resourcing of some emergency preparedness activities eg responses to extreme weather events and other natural hazards is minimal and often run on a shoestring.</td>
<td>X</td>
</tr>
</tbody>
</table>
Appendix B: Interview Protocol

PHE – Phase 1 – Key Informants Interview Protocol

Introduction

Public Health England has commissioned RAND Europe to undertake a horizon scanning study exploring the future of public health and related scientific and laboratory services. This work is intended to inform thinking at the strategic level within PHE, both in relation to the wider vision and remit of the Agency and in relation to the potential creation of an ‘integrated public health science hub’ comprising co-located elements of different laboratory and public health facilities. RAND Europe is an independent, not-for-profit research organisation whose mission is to improve policy and decision making through research and analysis.

In this interview we will ask you a series of questions about different drivers for the field of public health science over the next 20 years, as they relate to your discipline and area of expertise. We encourage you to be as open-minded and ‘blue skies’ in your thinking as possible – we need both a healthy dose of creative thinking as well as grounding practical elements. Though part of the remit of our study is to consider the implications of these drivers for co-location, we want to try and tackle each element separately and then bring them together.

As a key stakeholder, your views and feedback on the issue identified above are highly valued. The interview should last approximately 30-45 minutes.

1) To start, what is your ‘day job’ like? What kind of areas are you investigating/researching?

2) What are the main research/technology trends that are going to drive the field of public health? (try for up to three trends and follow-up questions should try to get at the potential of each trend to improve public health)
   a. What capabilities (skills, capacity, expertise) are going to be needed? What’s the scale of investment required?
   b. What are the challenges/opportunities associated with each of these?

3) What external drivers, eg migration, environmental change, socio-political/socio-economic issues, might change the requirements for public health scientific and laboratory service capabilities in the future?
4) Given these broad technology, research and socio-political/socio-economic trends, what kind of scientific and research capabilities and facilities will be needed and how might they best be organised?

5) Considering future developments, are there any synergies between public health disciplines and capabilities that will need to be realised for things to reach full potential?
   a. Where are the overlaps between methodologies (eg infrastructure, laboratories)
   b. How do you think capabilities and capacities can best be organised and located in light of future trends

6) What are the major uncertainties which ‘keep you up at night’ when you think about the future of the public health and all the trends and factors we just spoke about?

7) Looking ahead 10 years, what do you see as the main characteristics of Public Health England’s role nationally in public health science? Does this role change when you think internationally?

8) [Ask only if you have time] Can you think of any examples of successful integration of multi-disciplinary scientific capabilities? Are there any useful comparators to understand what similar Public Health services look like in other countries (eg US, Canada and other European countries)?

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Appendix C: ExpertLens Protocol

Elicitation name: The future of public health and implications for an integrated public health science hub

Subgroup 1: Overview of the project

Public Health England (PHE) has commissioned RAND Europe, an independent, not-for-profit research organisation whose mission is to improve policy and decision making through research and analysis, to undertake a horizon scanning study exploring the future of public health and related scientific and laboratory services. This work is intended to inform thinking at the strategic level within PHE, both in relation to the wider vision and remit of the Agency, as well as in relation to the potential creation of an ‘integrated public health science hub’ – defined as a place that provides a common geographical location for a range of facilities, capabilities and skills (also referred to as co-location). The physical form of an integrated public health science hub may vary according to organisation needs and context but could be a science park, science campus or multi-disciplinary complex.

Our study has two phases. In Phase 1, a literature review and series of key informant interviews were undertaken to understand the wider empirical and conceptual developments in the fields of science, organisation and management that will impact the co-location of laboratory and other public health services. Phase 2 is the ExpertLens process, which enable us to broaden and deepen our understanding of future technological and scientific trends related to public health science and to examine views on an integrated public health science hub. As such, the ExpertLens process will give participants a chance to:

- contribute to the debate over co-location, including discussion of potential synergies
- discuss the relative importance of different scientific capabilities in relation to future public health needs
- discuss the relative importance of different facets of co-location
- reflect on the issues in ‘real-time’ with other internal and external PHE stakeholders.

The final output of both phases of this targeted, rapid review horizon scanning exercise will be a report which will feed into PHE’s wider strategic thinking about its future.

Subgroup 2: Online Expert Panel Process

To reach the goals of Phase 2 of our study, we are asking for input from a broad group of stakeholders. You have been invited to participate in this unique, online community due to your knowledge, experience, and individual perspective on the future of public health and related scientific and laboratory services.
This panel process will occur in three rounds, over a period of one week. Rounds One and Two will last two days, while Round Three will last for three days.

- In Round One, you will be asked to answer a set of close-ended questions about a broad set of scientific and technological capabilities and their relative importance in addressing future public health needs. As you go through Round One, you may want to jot down a few notes on issues you would like to discuss in Round Two.

- In Round Two, you will have the opportunity to engage in an anonymous online discussion with the Round One respondents. This will give you the chance to reflect on how your answers in Round One compared to the group, but more importantly the opportunity to delve deeper into the issues and discuss in more detail the different kinds of capabilities which might be needed, how they relate to public health needs and future trends, and whether any capabilities are more suited to different types of co-location than others.

- In Round Three, you will revisit the same question set from Round One and be able to change the answers you provided in Round One if you wish to do so. At the end of Round Three, we will ask you to complete a brief questionnaire about your experience with our online programme.

Round One Instructions

Round One questions ask you to rate the importance of eight different scientific or technological capabilities as well as considering the role of an integrated public health hub in addressing various PHE domains. The eight capabilities include:

- **Behavioural science**: a multi-disciplinary science drawing on psychology, sociology, and anthropology to understand human actions at the individual and societal level. Within public health, behavioural science has been mobilised to examine the relationship between behaviour and health outcomes. The approach has become an important capability for public health because a number of the most prominent contributors to death and disease in the UK and globally are behavioural factors, particularly tobacco use, diet and activity patterns, alcohol consumption and sexual behaviour.

- **Informatics**: an information science about the processing, management and manipulation of data. In public health informatics has involved the systematic application of information and computer science and technology to public health practice, research, and learning. The scope of public health informatics includes the conceptualisation, design, development, deployment, refinement, maintenance, and evaluation of communication, surveillance, and information systems relevant to public health. It requires the application of knowledge from numerous disciplines, particularly information science, computer science, management, organisational theory, psychology, communications, political science, and law.

- **Modelling and simulation**: capabilities that provide public health science with means for testing and experimenting with potential improvements and future scenarios. They are techniques for understanding current and potential impacts of interventions and identifying potentially unforeseen impacts of interventions. Modelling and simulation techniques have been used in public health science to explore control schemes, predict future incidence, prevalence and mortality for these diseases as well as monitor their progress for assistance in deciding on public health outcomes.
• **Genomics (includes genetic sequencing technologies):** high-throughput technologies for DNA sequencing that have enabled us to begin deciphering human and pathogen genomes, linking them to health and disease and generating significant volumes of genomic data. Future trends suggest increasing application of genetics, formerly rooted in pure and lab-based sciences, to several areas of public health including, but not limited to: sequencing and analysing genetics of pathogens to enable faster and more accurate diagnosis, prediction of virulence, mechanisms of drug resistance, transmission and targeted therapy; greater application of personalised and stratified medicine to enable genetic profiling and identification of individual risk factors; and association of patients with specific therapies based on clinical biomarkers.

• **Robust evaluation methodologies:** evaluation methods to test theory-based interventions, such as measurement and analyses of mediator and moderators. These are necessary to build a more solid evidence base of health behavioural change. Evidence gathering for policymakers may involve decisions about whether to use a group-randomised controlled clinical trial or a quasi-experimental design. Evaluations should not be limited to trials of efficacy but should also be tied to planning and evaluation frameworks.

• **Integrated laboratory science capabilities from virologists, micro-biologists, etc.:** integration and collaborative working across a range of areas such as microbiology, virology and bioinformatics. This is particularly necessary given developments in diagnostic testing and integrated surveillance, and may require enhanced specialist training across the whole public health workforce.

• **Epidemiology:** a methodological approach to understand and explain the frequency of disease occurrence in different groups. Evidence from epidemiological studies is useful for public health science to help plan more effective strategies for illness prevention and monitoring populations where diseases are evident.

• **Data integration:** the integration of data from a vast range of heterogeneous data sources into one data set or network. This could include electronic health records, hospital admissions, environmental tracking (such as water-quality monitoring reports) and veterinary healthcare data. It may also be necessary to draw on unstructured data such as blogs and wikis for example. Data integration is likely to draw on a range of technological advances such as data mining and data fusion and grid computing. In terms of gathering data in the first instance, intelligent sensor networks and automated laboratory reporting may also be important.

We have selected these capabilities and domains of public health through our literature review and series of semi-structured interviews, which have occurred in Phase 1 of the project. We recognise that there are many more capabilities and domains of public health needs, which you will be able to discuss with other study participants in Round Two. To facilitate this discussion, however, we would like you to answer a series of close-ended questions on capabilities, public health needs, and the implications for co-location of these capabilities and laboratory services in Round One.

Please print and have available this handout, which explains the meaning of scientific or technological capabilities, PHE domains, and an integrated public health hub used in this study.

We ask that you answer all the questions by 11:59pm (BST) on Tuesday, 30 July 2013.
Subgroup 3: Health Protection

The first domain of public health is health protection, which refers to and encompasses PHE’s responsibility for health protection services, including establishing and maintaining internationally benchmarked best practice. Areas of public health risk and hazard PHE is to safeguard against include infectious diseases, chemicals and poisons, radiation, public emergencies and environmental health hazards. Scientific and technological capabilities (as they relate to PHE’s priorities) which may be needed include, but are not limited to:

- Reversing the current trends so that we reduce the rates of tuberculosis infections.
- Leading the gold standards for current vaccination and screening programmes.
- Tackling antimicrobial resistance (AMR).
- Developing and implementing a national surveillance strategy to ensure the public health system responds rapidly to new and unexpected threats.  

Question(s)

1. On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following scientific capabilities in addressing the PHE priority of health protection:

- Behavioural science
- Informatics
- Modelling
- Genetic sequencing/technologies
- Robust evaluation methodologies
- Integrated laboratory science capabilities from virologists, micro-biologists, etc
- Epidemiology
- Data integration

Subgroup 4: Health Improvement

The second domain of public health is health improvement, which refers to and encompasses the responsibilities of PHE’s health improvement and population health directorate, which will be responsible for the development of a 21st century health and wellbeing service. Areas of practice include inequalities, education, housing, employment, family/community, lifestyles, and surveillance and monitoring of specific diseases and risk factors. Scientific and technological capabilities (as they relate to PHE’s priorities) which may be needed include, but are not limited to:

- Reducing preventable deaths, for example by accelerating efforts to promote tobacco control and reducing the prevalence of smoking.

• Reducing the burden of disease, for example reducing the incidence and impact of dementia and improving recovery rates from drug dependency.
• Giving children and young people the best start in life, for example by launching a national programme promoting healthy weight and tackling childhood obesity.
• Improving health in the workplace, for example by supporting employers to establish the business case for supporting a healthy workforce.

**Question(s)**

2. On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following scientific capabilities in addressing the PHE priority of health promotion:

- Behavioural science
- Informatics
- Modelling
- Genetic sequencing/technologies
- Robust evaluation methodologies
- Integrated laboratory science capabilities from virologists, micro-biologists, etc
- Epidemiology
- Data integration.

**Subgroup 5: Improved Health Services**

The third domain of public health is improved health services, which refers to and encompasses the responsibilities across PHE’s directorates, in particular the operations directorate which will be responsible for the delivery of consistent, high-quality services across the PHE delivery chain. Areas of practice include clinical effectiveness, efficiency, service planning, audit and evaluation, clinical governance, and equity. Scientific and technological capabilities (as they relate to PHE’s priorities) which may be needed include, but are not limited to:

• Supporting people to live healthier lives by implementing NHS Healthchecks.
• Enabling improved integration of care to support local innovations to find alternatives to hospital-based care.
• Improving sexual health and reducing the burden of sexually transmitted infections by improving the coordination, effectiveness and impact of HIV and sexual health services.
• Promoting place-based public health systems, including implementing the public health workforce strategy and developing the PHE workforce.

**Question(s)**

3. On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following scientific capabilities in addressing the PHE priority of improved health services:
• Behavioural science
• Informatics
• Modelling
• Genetic sequencing/technologies
• Robust evaluation methodologies
• Integrated laboratory science capabilities from virologists, micro-biologists, etc
• Epidemiology
• Data integration

Subgroup 6: Overall Public Health Needs

Public health needs describes the broad health needs of a population in the future. The definition includes both physical, social and mental health needs.

Question(s)

4. On a scale from 1 (not very important and will not impact on my field) to 10 (very important and will have an impact on my field), rate the importance of the following scientific capabilities in addressing all public health needs in the future:

• Behavioural science
• Informatics
• Modelling
• Genetic sequencing/technologies
• Robust evaluation methodologies
• Integrated laboratory science capabilities from virologists, micro-biologists, etc
• Epidemiology
• Data integration

Subgroup 7: Understanding Capabilities in Relation to Integrated Facilities

For this exercise, we consider an ‘integrated’ public health science hub to be a place that provides a common geographical location for a range of facilities, capabilities and skills. The physical form of an integrated public health science hub may vary according to organisation needs and context but could be a science park, science campus or multi-disciplinary complex.

Question(s)

5. Please rate the importance on a scale from 1 (not very important) to 10 (very important) of the following factors in contributing to the success of a future public health science hub. These factors have been identified from academic and policy literatures as benefits from clustering organisational, management and research functions at the same geographical location:

• Strong centralised leadership
• Good organisational structure
• Co-location with other leading laboratory and scientific services
The future of public health: A horizon scan

• Provision of social mechanisms to enhance integration
• Efficiency savings through shared infrastructure
• Harnessing collaborative organisational culture
• Exchange of tacit knowledge amongst organisational leaders

6. On a scale from 1 to 10 (1=not very important, 10 = very important), rate the importance of having an integrated public health science hub to:
   • Delivering on PHE’s future vision?
   • PHE’s role in health protection?
   • PHE’s role in health improvement/prevention?
   • PHE’s role in emergency preparedness?
   • PHE’s role in improving health services?

Subgroup 8: Demographic Information

Question(s)

7. Gender (Male/Female)

8. Highest degree (Undergraduate, Masters, PhD)

9. Type of degree(s) (open answer)

10. Field of public health science expertise (open answer)

11. Number of years in profession (numeric open answer)
## Appendix D: PHE Areas of Activity and Directorates

<table>
<thead>
<tr>
<th>Areas of Activity</th>
<th>PHE Directorates</th>
<th>Health Protection and Medical Directorate</th>
<th>Health and Wellbeing Directorate</th>
<th>Nursing Directorate</th>
<th>Chief Knowledge Officer’s Directorate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing preventable deaths</td>
<td>Tobacco Control</td>
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<td></td>
<td>High blood pressure</td>
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<tr>
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<td>Obesity &amp; poor diet</td>
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<td>Reducing the burden of disease</td>
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<td>Chronic diseases (incl cancer)</td>
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<td>Rates of TB infection</td>
<td>Vaccination and screening progs</td>
<td>Chemicals &amp; poisons</td>
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<td>Giving children and young people the best start in life</td>
<td>Childhood obesity</td>
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<td>Health Improvement</td>
<td>Workplace/ Employment</td>
<td>Inequalities</td>
<td>Education</td>
<td>Housing</td>
<td>Family/Community</td>
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