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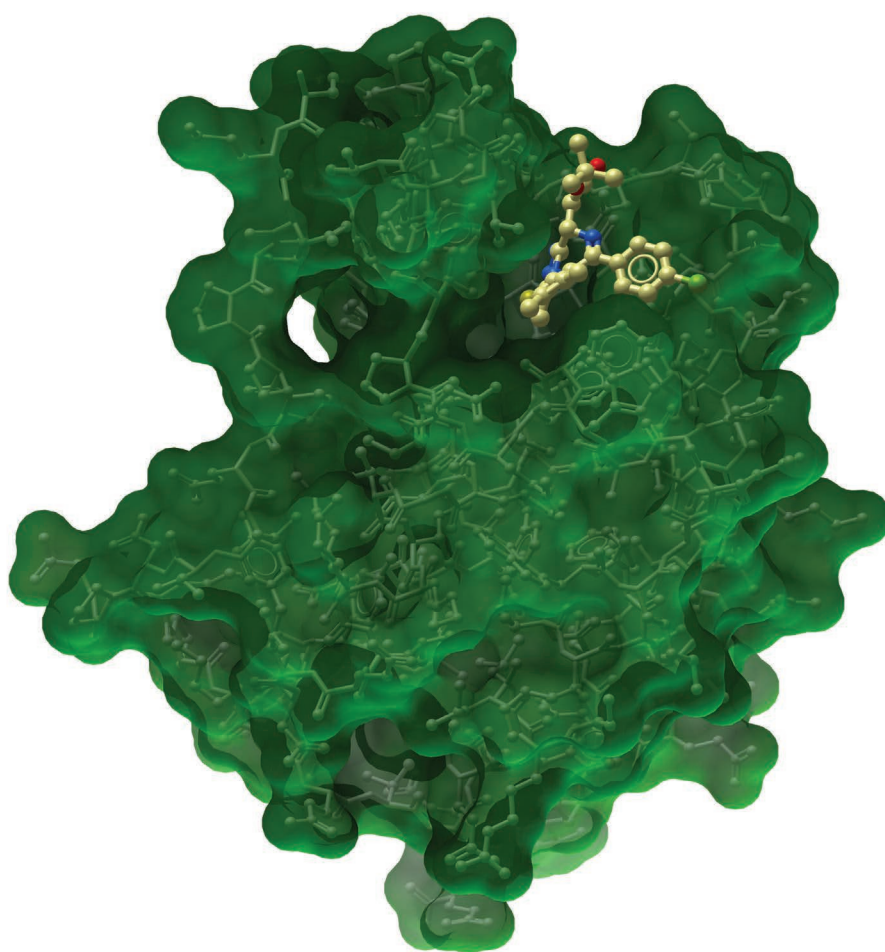
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The Structural Genomics Consortium

A knowledge platform for drug discovery



Molly Morgan Jones, Sophie Castle-Clarke, Daniel Brooker,
Eddy Nason, Farah Huzair and Joanna Chataway



EUROPE

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Preface

Since its establishment as a not-for-profit, multinational public-private partnership in 2004, the Structural Genomics Consortium (SGC) has been supporting drug discovery efforts through a unique, open access model of public-private collaboration. Its primary focus has been and continues to be on pre-competitive structural biology research, namely determining the 3D protein structures of biomedical importance on a large scale and cost-effectively. Over time, though, its portfolio has expanded to include chemical probes and antibodies, branching out to research studies that aim to deliver open access reagents for epigenetics research.

The SGC is currently in its third phase (which ends June 2015), yet little systematic and rigorous analysis has been done to understand the nature and diversity of the benefits gained, both for the partnering organisations and for the wider research community. In light of this and to determine a potential next phase for the consortium, the SGC commissioned an evaluation of its current model of operation. A competitive tendering process resulted in RAND Europe and The Institute on Governance being asked to carry out this evaluation. The scope of work was extended as a result of a parallel grant from the Department of Health (England), Policy Research Programme, who provided extra resource for additional literature review related research. The INNOGEN Institute also contributed by enabling the participation of Farah Huzair as part of the research team.

This report constitutes a completely independent assessment and has not been subject to content review by the SGC or others associated with the SGC. The report is intended for a broad audience of those with direct and indirect interests in the SGC. Its main objective is to answer the following questions:

- What are the most convincing arguments in favour of current funding of the SGC?
- What are relative merits of the SGC open access model as opposed to alternative models of funding R&D in this space?
- What judgements can be made about the SGC's past and current performance track record in light of achievements and expectations?
- Are there important trade-offs or limitations that need to be addressed looking towards a Phase IV or reasons against funding the SGC?
- In considering a potential Phase IV are funders anticipating changes internal to the SGC or in the wider PPP landscape in this field?
- What are the key trends and opportunities in the external environment that could influence a Phase IV, and can the SGC benefit from or have influence over these trends?

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including governments, communities, business, charities and public organisations.

For more information about RAND Europe, the Institute on Governance or this document, please contact:

Joanna Chataway
RAND Europe
Westbrook Centre
Milton Road
Cambridge CB4 1YG
United Kingdom
Tel. +44 (1223) 353 329
chataway@rand.org

or

Eddy Nason
Institute on Governance
150 Bloor St West
Suite 200
Toronto, ON M5S 2X9
Canada
Tel./Tél: 647 295-8506
enason@iog.ca

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Summary

This report presents the results of an independent evaluation of the Structural Genomics Consortium (SGC), conducted by RAND Europe with the Institute on Governance. The SGC is an open access public-private partnership (PPP) with a primary focus on pre-competitive structural biology research (namely determining the 3D protein structures) and an emerging secondary focus on chemical probes and antibodies, and epigenetics research. The SGC's current funding phase ends in June 2015 and this evaluation was commissioned to feed into discussions regarding the next stage of funding.

The evaluation had a number of objectives. Firstly, by drawing on a literature review, it aimed to establish the role of the SGC within the wider drug discovery and PPP landscape, assessing the merits of the SGC open access model relative to alternative models of funding R&D in this space, as well as the key trends and opportunities in the external environment that may impact on the future of the SGC. Secondly, the evaluation turned to key informant interviews with SGC researchers, past and present funders and external stakeholders, and a survey of SGC researchers. The objective was to establish – as the SGC nears the end of its current funding phase – the incentives and disincentives for investment, strengths and weaknesses of the SGC's model, and the opportunities and threats the SGC will face in the future. This process enabled us to assess the most convincing arguments for funding the SGC at present; important trade-offs or limitations that should be addressed in moving towards the next funding phase; and whether funders are anticipating changes either to the SGC or the wider PPP landscape. Finally, we undertook a quantitative analysis to ascertain what judgements can be made about the SGC's past and current performance track record, before unpacking the role of the external environment

and particular actors within the SGC in developing scenarios for the future.

Literature review

The literature review covers the conceptual background to open innovation, intellectual property and PPPs. In reviewing academic and grey literature a number of key findings can be identified. Firstly, the review found a vibrant critique of the status quo from a number of angles on the possible dangers of the 'anti-commons' and the potential benefits of a more collaborative approach to research and innovation. With regards to the question of whether there are initiatives that are comparable to the SGC, it is clear that the SGC is unique although it shares characteristics with a wide range of other 'open innovation' partnerships and collaborations; meaning that whilst it has unique characteristics, it is a part of a trend. Much of the grey and peer-reviewed literature suggests that this trend exists because there is a widely acknowledged crisis in pharmaceutical R&D. There seem to be two distinct trends emerging in pharmaceutical R&D. One is based on biotechnology, venture capital and intellectual property rights, and the other is based on more openness and collaboration at pre-competitive stage. There are grey areas where these two trends converge but the logic behind each of them is distinct. Finally, there are broad system level issues to do with the nature of the way science is funded and incentives in public and private sectors and different perspectives on what works.

To contextualise the conceptual arguments, the literature review included analysis of PPPs in the health sector and in other sectors. There are some initiatives which have similarities to the SGC both in terms of overall aims associated with contributing to drug development and in trying to foster more openness and collaboration in pre-

competitive research. There is also a set of initiatives that have a focus on structural genomics such as Japan's RIKEN research institution, the USA's Protein Structures Initiative (PSI), and Europe's Structural Proteomics in Europe (SPINE) initiative. Each of these groups is organised to deliver structural genomics information in different ways. We reviewed aspects of both with a particular aim of identifying any evaluations of these organisations that might help to inform both the evaluation and the nature of our findings and insights.

In considering comparators from other sectors we found a variety of PPPs including formal organisational models, informal networking mechanisms and different platforms geared towards facilitating innovation and knowledge production to the benefit of different sectors. A large number of initiatives are reviewed and summarised before a more detailed analysis of three selected 'case studies' are given for the Linux, Sematech and EU Technology Platforms initiatives. Our review found that PPPs from other sectors are mobilised in multiple ways and that their characteristics differ according to their geographical coverage, funding, sector, position in the value chain, innovation model and organisational focus. Most PPPs are evolving and transform over time; their characteristics depend on the maturity of the sector, the characteristics of industry and firms therein and wider political, economic, technological and scientific factors influencing innovation.

The SGC as a platform for knowledge

We drew on survey and key informant interview data as well as quantitative analysis to focus on three, interrelated yet conceptually distinct spheres of knowledge which emerge from the SGC's efforts:

- *The SGC as a model for investing in knowledge:* this sphere relates to what the motivations and rationale for investing in the SGC are from the perspective of those who are engaged in it, including funders, SGC researchers and external collaborators/stakeholders.
- *The SGC as a model for generating knowledge:* this domain relates to perceived strengths and weaknesses of the SGC model as it operates in practice.
- *The SGC as a model for extracting value from knowledge:* this domain relates to the value that

comes from both the investment and generation of knowledge.

We present our findings in relation to these spheres of knowledge in order to draw out a more nuanced discussion about the role of the SGC as a unique model for the production of scientific knowledge. We hope this framing moves the discussion away from the question of how the SGC might be funded in future, to that of how best to maximise the different ways stakeholders find the SGC model to be of value for them.

First, viewing the SGC as a model for investing in knowledge resulted in identifying incentives and disincentives for investing in the SGC model from the point of view of SGC researchers, past and present funders and external stakeholders in the wider chemical and biological science landscape. Incentives which were discussed across the groups covered a range of topics, including: open access, collaborative research and networks, 'de-risking' of new areas of science, the 'industrial' focus of the SGC and rapid and efficient research.

Open access makes the SGC unique as a PPP in this field and creates a number of desirable knock-on effects, including wider societal benefits, maximising the opportunities and efficiencies of further research, improving the competitiveness of the field, proving the feasibility of open access, enabling funding to be secured and enabling the efficient establishment of diverse collaborations. This latter point is particularly aided by the SGC's ability to overcome institutional regulations and restrictions about intellectual property due to its open access nature. Several examples of efficiency in the research process, improved research outputs, and new areas for drug discovery, were highlighted across the collaborators, funders and researchers we spoke with and all attributed this in part to the open access philosophy of the SGC.

The collaborative research opportunities and access to a global network in core areas of structural biology expertise were cited as key reasons for investment in the SGC by most researchers, the majority of the funders and some external stakeholders. One reason that the SGC's collaborative network is particularly appealing and, therefore, is an incentive for investment, is that one can easily make the most of the SGC's collaborative network because of the open access format. Several interviewees commented that this format means that it

is very easy to set up collaborations without worrying about contracts and legal issues. In particular, the majority of private sector funders stated that links to a global network of expertise in the area of epigenetics was especially important.

Many private sector funders highlighted the importance of the SGC model in helping to ‘de-risk’ new areas of science as a reason for investment. In particular, the majority of pharmaceutical funders used the epigenetics programme as an example of this ‘de-risking’ effort, and it was clear that the SGC’s decision to conduct epigenetics research was a significant factor in their decision to invest in the SGC. Epigenetics is a new and developing area of biology and joining a consortium offered gains in this area at relatively little cost. Closely linked to the incentive of de-risking new areas of science is an incentive around the alignment with ongoing strategic initiatives within a company, public funder or collaborating organisation.

Many stakeholders cited as an incentive the fact that *the SGC enabled rapid and efficient research processes*. There are two elements to this incentive. The first is that the majority of interviewees felt that research happened more quickly in the SGC than in either academia or industry, and this was a significant strength of the SGC. The speed and volume of SGC research is enabled at least in part through open access, the collaborative nature of the model and the ability to collectively de-risk new areas. The second, related, element, was expressed by several funders, who reported the SGC’s approach to using an ‘*industrial model*’ for research was an important factor in their decision to invest in the SGC. The SGC possesses several characteristics of an industrial model, with milestones and targets determining the scientific outputs and a commitment to ensuring that findings can be reproduced by others. Not only this, but it operates on a large scale, accessing a wide range of expertise and resources which would not be available to a small laboratory. This is perceived to have a considerable impact on the efficiency and volume of SGC research.

Disincentives for investment as identified by SGC researchers, funders and external stakeholders included *unprotected intellectual property* of work conducted by the SGC and a *perception of limited spillover effects for the wider community*. Such regional and national spillover effects of the SGC are important to public sector funders in

particular who see these as linked to the SGC’s physical location. However, it is important to note that a lack of economic and societal spillover effects was not cited as a weakness or a disincentive by all public sector funders and this difference in views demonstrates the difficulty the SGC has in meeting the needs of each individual funder.

The second reason for our approach is that viewing the SGC as a model for generating knowledge allows us to set out the strengths, opportunities, weaknesses and challenges of the SGC. These areas are interwoven with incentives and disincentives for investment to a certain extent; however in deliberately separating the two we hope to understand how far perceptions of the model prior to investment align with how the SGC operates in practice. Across the different perspectives in the evaluation a number of interrelated strengths and opportunities for the SGC were highlighted, including the role it plays in enabling collaboration and maintaining strong research networks; providing rapid and efficient research outputs and processes for the field; having an industrially oriented, flexible research model with strong leadership; and being able to produce strong, world-class science.

Along with world-class scientific expertise, the *extensive collaborations between academia and industry* were the most frequently mentioned strength of the SGC, across the three stakeholder groups. Indeed, it was a specific aim of the founders of the SGC to ensure that the benefits of public and private sector research were brought together in the most productive ways. In this, the SGC considered how the private sector could benefit from the consortium without involving intellectual property, as well as where the private sector could add value to the consortium aside from the provision of funding. This included their expertise in designing molecules or assays for target validation, their commercial focus which would help to drive drug discovery, and their need for reproducible science. Moreover, close collaboration and networks help to prevent the duplication of effort among pharmaceutical companies. If the SGC did not exist, these organisations might be more likely to pursue the same lines of discovery independently, underscoring the efficiency afforded by the SGC. Though we were not able to quantify this in this evaluation due to resource constraints, one can likely conclude that at least in some instances,

overall costs to both public and private innovation efforts would be higher in the absence of the SGC and thus there would be a negative impact on drug discovery.

Providing rapid and efficient research outputs was cited as a strength of the SGC across all stakeholder groups. Eighty-two per cent of surveyed researchers (N=17) believed their research had come to fruition more quickly through the SGC than it would have done if it had been supported by traditional academic approaches. The most frequently cited reasons for accelerated research translation were high quality collaborations and an integrated approach, the lack of a need to spend time writing grant proposals, and the efficiency of SGC processes. Other reasons which emerged from the interviews as to why people thought the SGC may be faster and more efficient at research were related to the lack of intellectual property, the importance of a highly interactive research process which is accelerated through open access, and the fact that the SGC is streamlined and narrowly focused, with a strong ‘company ethos’ and industrialised research processes.

One of the reasons that many stakeholders felt the SGC was able to operate more efficiently than other research models was its *industrially oriented, flexible model of research which is well managed with a clear focus* (unlike some academic research which may be more curiosity driven). The SGC’s flexible approach to collaborators enables a large range of diverse networks and collaborations, which in turn affords the SGC the chance to be flexible in approaching new scientific areas. The flexibility coupled with the focused nature of the science allows the SGC to exploit economies of scale and networks in exploring new scientific areas. Moreover, the leadership of the SGC was thought to be essential to making the SGC a success in practice. Related to this, is the fact that the SGC is able to conduct ‘reproducible science’ – that is, the SGC can be relied upon to produce results which can be reproduced by others. Although this may not be highly valued by academia (given that experiments in academia are rarely replicated), it is of particular importance to industry given that they cannot build technologies that work properly without it.

With these strengths come many opportunities. *The SGC is part of a wider trend which seems to be forging the way in pre-competitive research in the drug discovery landscape.* There is a real oppor-

tunity to expand the pre-competitive boundaries of drug discovery in the future. Not only are there broader changes in the field which mean that pre-competitive research is seen as more likely in future by stakeholders, but there is also a view that the SGC’s open innovation model is particularly appropriate given the structural biology focus of the SGC. In addition, several interviewees were explicit in their view that it was the role of the public sector to help ensure the future of open innovation and drive pre-competitive research boundaries as the private sector itself was not likely to provide a catalyst in and of itself. This is clearly a complex issue which will be shaped by a series of external factors, including price pressures, trends towards outsourcing innovation, openness to flexible approaches, the intellectual property regime and future downsizing in the economic climate.

These features of the SGC mean that it has a wide range of opportunities in terms of scientific areas of focus and *there was a degree of divergence among interviewees regarding how the SGC should exploit these opportunities in the future.* Some wanted the SGC to narrow their focus back onto structural biology, while others were of the view the SGC should continue to push into areas such as epigenetics. Ultimately the scientific direction of the SGC will be determined to a certain extent by available funding. However one of the most frequently cited weaknesses of the SGC was the fact that its mission had become much more diffuse in recent years.

Alongside the strengths and opportunities for the SGC, a number of weaknesses and challenges for the future were identified. These included: a view that there were too many collaborators, which inhibited the ability to do the science; a perceived lack of professional development opportunities for SGC researchers; too much movement away from the SGC ‘core’; and a lack of resources to support future growth. As above, we first present weaknesses in the model before discussing the challenges for the future.

The single most significant challenge mentioned across interviewees was *the need to maintain a substantial level of funding for the future.* Public sector funding has diminished significantly since the SGC’s inception and has been replaced with private sector funding, leaving a one to five ratio of public to private funding. However, there was considerable divergence among interviewees

regarding the importance of the source of funding. There was a shared view among all funders that the public sector/private sector mix was important. However, a public sector or 'non-industrial' presence was considered to be important by private sector funders for two main reasons. First, the presence of non-private funds would keep the SGC research open and in the public domain. Second, it would keep SGC research innovative and safeguard against SGC becoming too closely aligned solely with the needs and interests of the private sector. Non-private funds are seen as protecting the SGC from becoming more like a contract research organisation, which would result in its losing its competitive and innovative edge. Although the role of the public and private sectors were generally considered to be important, the role the two different funding types might play was debated. The role of each sector within the SGC is particularly important in understanding the consequences of public sector withdrawal, and this is built upon in more detail through scenarios in Chapter six and the overall conclusion.

Finally, viewing the SGC as a model for extracting value from knowledge, we provide a more quantitative analysis to ascertain what judgements can be made about the SGC's past and current performance track record. The quantitative outputs of the SGC range from the main outputs of SGC work (such as publications, structures and sequences), through to broader economic outcomes (including monetised outcomes) that are the result of SGC involvement in research. We identify a number of SGC's scientific knowledge outputs. Firstly, since 2004, the SGC has developed and deposited the structures of 1195 proteins in the Protein Data Bank (PDB). Secondly, from 2004 to 2011, this has led to 83 new sequences deposited in Uniprot – the protein sequence database. Thirdly, the SGC has produced 452 peer-reviewed journal publications (and eight books) up to August 2013. Finally, in terms of dissemination SGC scientists attended and presented at over 250 conferences from 2007 to 2011, including 38 poster presentations and 87 invited talks as a direct result of scientist involvement in the SGC.

In terms of economic outcomes our quantitative analysis shows that the average cost per structure identified for the SGC over the 2004/5–2012 period was \$289,000 CAD which suggests, compared to other structural genomics organisations,

the SGC is able to provide competitive cost per structure for the protein structures it does develop (especially bearing in mind the other outputs that the SGC produces in terms of clones, probes and vectors). When we compare this to other structural genomics organisations in the same time period, we can see that the SGC is considerably more efficient than RIKEN (\$712,000 CAD per structure – based on 2006–2011 funding for RIKEN as a whole), while the cost per structure for PSI (in its first two phases, 2000–2005 and 2005–2010) was \$104,000 CAD. The quantitative outputs do not account for other economic benefits arising from SGC activities (such as the patents and sales of products developed by industry partners downstream from their involvement in SGC research), which would provide an even higher likely monetary return on investment.

In undertaking an analysis of the quantitative outputs of SGC work it is important to recognise the context in which SGC operates the value of impacts arising from the SGC's work. Specifically, the SGC have set a specific task to deliver protein structures that go beyond those already developed in the scientific literature. This means that the SGC specifically targets proteins that are considered more difficult to work with, and therefore any consideration of the outcomes of SGC research should take into account the relative difficulty of the task the consortium has set itself.

The possible futures for the SGC

To inform how the SGC might look in the future we developed a set of the scenarios for the SGC to consider, which form the basis of Chapter six. For our scenarios analysis exercise we used a simple scenario development process rather than a more formal approach. This meant that we thought about the SGC in light of future decisions it may need to take about its funding strategy, scientific direction and the external context in which these decisions would need to be made. In order to do this, we first identified contextual certainties and uncertainties which would play a role in the future which included the nature of R&D in the pharmaceutical sector, the direction of drug discovery science, and wider political economic conditions. Allied to these contextual conditions we then identified a list of critical success factors for the SGC, permutations of which are likely to be particularly important to the SGC's future. These

factors included the SGC's scientific vision, business model, funders, role of open access, role of networks, spillover effects, location and consideration of wider scientific and political-economic developments.

When it came to developing the scenarios, we considered both the contextual elements and the implications of them for the success factors. We developed narratives around four scenarios, each of which was underpinned by the assumption that the SGC continues to function as a knowledge platform in the future with different drivers for generating knowledge, investing in knowledge and extracting value from knowledge. In the first scenario of *'Maximising the science'*, the main driver is about generating new scientific knowledge. Extracting value from that knowledge is of least importance, and the investment incentives derive from the open generation of publicly accessible scientific data. In the second scenario *'Maximising returns for industry'*, the main driver in the future concerns extracting value from knowledge, with the generation of knowledge playing the lesser role. Funders support the SGC to facilitate industrial development and competitiveness so that the value of SGC science can be maximised. In the third scenario, *'Maximising the good news story'* the main driver for the SGC is to lead to greater patient benefit and improving health outcomes. The main incentive in this scenario is not so much about value, but about generating knowledge that can catalyse direct returns for patients. The value of the SGC in scenario three is in the targeted nature of knowledge outputs in different disease areas. Finally, in the fourth scenario *'Maximising the benefits to nations'* we see the main driver being extracting value from knowledge as countries seek to invest in the SGC so that they can see a return on investment for industry through the creation of knowledge spillovers and economic growth. In this scenario SGC is supported by the public sector as a platform to create knowledge that will lead to economic benefits in terms of jobs and gross value added.

Each of these scenarios has its own merits, challenges and opportunities. They are presented as distinct, but in reality there are many overlaps between them to be further explored and examined. What will be crucial for the SGC going forward is the balance between the different elements in each model, and the extent to which different drivers serve as the motivating element. It

is important to note that in developing scenarios we sought to create a narrative and in many cases often exaggerated what the future might look like for the purposes of illustration. We fully recognise, and in fact would likely argue, that SGC's future strategy is going to encompass a mix of these scenarios, but it is the process of determining that mix which is important. In order to do this, we must understand what each scenario looks like independently.

In conclusion, our evaluation suggests that in order to understand the added value of the SGC, it is important not only to appreciate what the role of open access is, but also how both public sector and private sector actors within the SGC benefit and help to maintain it. Therefore, we argue that there is a finely nuanced role of the public and private sector presence in the SGC in relation to the added value it brings. The public sector plays a fundamental role in relation to maintaining open access, while the private sector helps to maintain the SGC's industrial quality and reproducible science. Both contribute to a form of innovation and related benefits that come out of the SGC and spill over to the wider field. Therefore, without each element, the SGC ceases to exist in its current form, and its added value to the field is reduced. We believe this goes to the core of some of the current tensions in the SGC model and its future. Therefore, by working through the role each plays, the benefits which accrue, and the broader questions and insights this leads us to, we hope to shed light on a possible way forward.

All of this serves to demonstrate that each set of funders, and the public sector in particular in relation to open innovation, needs to be fully aware of the role it is currently fulfilling and the losses that would be incurred if each were to withdraw from the SGC. These losses should be considered against the backdrop of the changing nature of drug development and innovation which poses wider challenges to the field.

The report ends with a list of recommendations for the SGC to consider in moving forwards. These are to:

- *Maintain the SGC in something akin to its current form*
- *Develop a high level strategy that provides a broad plan for operations over the next five to ten years*
- *Incentivise the public sector to (re)invest*

- *Develop a strategic approach for identifying potential philanthropic and charitable funders who may be interested in investing in the SGC as a platform for knowledge*
- *Consider ways to enhance the sustainability of the SGC's leadership, potentially through recruiting deputy leaders*
- *Provide more support for scientists to aid career progression and develop transferable research skills*
- *Improve monitoring and evaluation processes to more effectively capture knowledge and disseminate positive impacts where they arise*
- *Build on the successful examples of the few small biotechnology firms which have arisen out of partnering with the SGC to focus more on possibilities for engaging small firms in its generating knowledge and extracting value models*
- *Undertake a more comprehensive assessment of the comparative costs and merits of the different trajectories to drug development.*

We are conscious that some of the recommendations presented may not be in line with the SGC vision, but they arise from our understanding of the evidence gathered in this report, the different challenges and opportunities facing the SGC and how it may need to respond. These are important considerations for the question of how the SGC can attract more funding, generate knowledge more efficiently, and extract more value from the knowledge it creates in both the scientific and wider socio-economic sense and address the pressing issue of how the consortium can be sustainable in the future.

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Abbreviations

BRDs	Bromodomains
CMS	Course Management System
CONRAD	Contraceptive Research And Development Program
DNDi	Drugs for Neglected Diseases Initiative
ETP	European Technology Platform
EVI	European Vaccine Initiative
FIND	Foundation for Innovative New Diagnostics
Gaelf	Global Alliance To Eliminate Lymphatic Filariasis
GAIN	Global Alliance for Improved Nutrition
GAVI	Global Alliance for Vaccines and Immunisation
GBC Health	Global Business Coalition on Health
GPEI	Global Polio Eradication Initiative
GRI	Global Reporting Initiative
GVA	Gross Value Added
HTP	High-throughput
IAVI	International AIDS Vaccine Initiative
ICH	International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use
IDRI	Infectious Disease Research Institute
IMI	Innovative Medicines Initiative
IOWH	Institute For Oneworld Health
IP	Intellectual Property
IPCS	International Programme on Chemical Safety
IPM	International Partnership For Microbicides
IPR	Intellectual Property Rights
ITI	International Trachoma Initiative
LMS	Learning Management System
MDP	Microbicides Development Programme
MDR-TB	Lilly Multi-Drug Resistant Tuberculosis Partnership
MI	Micronutrient Initiative
MIM	Multilateral Initiative On Malaria
MMV	Medicines for Malaria Venture
MTAs	Material transfer agreements
MVI	Malaria Vaccine Initiative
MVP	Meningitis Vaccine Project
NIGMS	National Institute of General Medical Sciences
NIH	National Institutes of Health
NIHR	National Institute of Health Research
PDB	Protein Data Bank
PDPs	Product development partnerships

Pdvi	Pediatric Dengue Vaccine Initiative
PPP	Public-Private partnership
PPPHW	Public-Private Partnership for Handwashing with soap
PSI	Pharmaceutical Security Institute
PSI	Protein Structures Initiative
R&D	Research and development
RBM	Roll Back Malaria Partnership
RTLAs	Reach Through Licence Agreements
SABs	Scientific advisory boards
SCI	Schistosomiasis Control Initiative
SGC	Structural Genomics Consortium
SIGN	Safe Injection Global Network
SME	Small Medium Enterprise
SMIP	Stratified Medicine Innovation Platform
SNP Consortium	The Structural Nucleotide Polymorphism
SPINE	Structural Proteomics in Europe
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
STOP TB	Stop TB Partnership
VLEs	Virtual learning environments

Chapter 1 Introduction

The Structural Genomics Consortium

The Structural Genomics Consortium (SGC) breaks new ground in health innovation. In a sector characterised by widespread concern with patenting, direct appropriations and returns from investment in science and technology, the SGC offers a unique public-private, open access approach to pre-competitive research. Established in 2004 as a not-for-profit organisation, its original core mandate was to determine 3D protein structures on a large scale and cost-effectively. This allowed research to target human proteins of biomedical importance and proteins from human parasites that represent potential drug targets. Since then, the SGC's research activities have expanded, covering chemical probes to support drug discovery and antibodies, though the core focus is still to support pre-competitive research in drug discovery. Today, the overarching aim of the SGC is to contribute to improved human health by delivering open access research that is characterised as basic but is nevertheless focused on drug development.

When it began, one of the primary rationales behind establishing the SGC was a 'motivation to accelerate the flow of human protein structures into the public database. This will benefit biological research in general and particularly within the pharmaceutical area' (Williamson, 2000). In particular, it was recognised that at the current rate of development of 3D protein structures it could take over 1,000 years to generate structures for all human proteins (*ibid*). This desire to develop an 'industrial-scale drive to develop the high throughput determination of thousands of protein structures' (Butler, 2000), rather than rely on the efforts of individual researcher studying one molecule at a time also drew on the (then recent) suc-

cess of The Structural Nucleotide Polymorphism (SNP) Consortium.

Since this time, the rationale for the SGC has further developed to address the need to better coordinate genomic efforts taking place across the globe at pre-competitive research stages, and to avoid duplication of efforts. The private sector role in the SGC (going beyond just funding and involving active collaboration) follows a novel model, especially given the focus on pre-competitive research and open access Intellectual Property (IP) policy. To this end the SGC has three distinguishing features:

- First, it releases outputs to the public domain without IP restriction on use until later stages of clinical trials.
- Second, it has a distinctive way of engaging public and private actors and organising research activity. For a certain level of investment, a funding organisation gains the rights to influence the direction of research to a degree: for example, it can nominate targets to a target list for researching; nominate a member to the scientific community and board of directors of the SGC; and place scientists to work within the SGC laboratories.
- Third, it represents a large-scale, long-term, and multiple-funder initiative which has provided stability to the field.

As an open access model of public-private collaboration, the SGC has found and released the structures of over 1,200 proteins which may assist in the development of more targeted therapies for cancer, diabetes, obesity and other conditions (although the consortium in itself is 'disease agnostic'). The SGC also reports that the consortium is now responsible for more than 25% of all the biomedically important human proteins, and more than 50% of all the proteins from human

Table 1-1:
SGC research groups

Research group by SGC site	Brief description
Toronto	
Chromatin Structural Biology and Epigenetics	Aims to characterise chromatin proteins by X-ray crystallography in combination with other biochemical and biophysical techniques
Ubiquitin Biology	Focuses on understanding the structure, function, specificity, and enzymatic mechanism of HECT-type E3 ubiquitin ligases and deubiquitinases
Structural Parasitology	Works on structural biology of proteins from malaria pathogens as well as other protozoan parasites
Biophysics	Focuses on developing new high throughput biophysical and biochemical characterization and screening methods
Epigenetic Chemical Probes	Identifies small molecules which interact with epigenetic targets
Cell Biology	Collaborates with medicinal chemists in pharmaceutical companies and academia to create potent, selective and cell-active inhibitors
Biotechnology	Performs high-throughput cloning in 96-well format, typically 10 constructs per target, into a range of vectors for expression in different hosts (primarily E.coli and insect cells) and with different tags
Research Informatics	Focuses on the structural and chemical bioinformatics of chromatin-mediated signalling
Oxford	
Epigenetics and Inflammation	Focuses on understanding structural and functional features of a protein, as well as applying chemical biology to inflammation and stem cell biology with respect to regenerative medicine approaches
Chemical Biology	Focuses on a molecular mechanism that regulates signalling molecules and in the exploration of such a mechanism for the rational design of inhibitors
Epigenetics and Cellular Biology	Aims to generate well characterised tool compounds against key enzymes and recognition domains involved in histone regulation of transcription
Genome Integrity and Repair	Focuses on the structural biology of human disease, with a loose focus on two areas: DNA damage recognition and repair, and the impact of genetic variation on human disease
Bromodomains	Seeks to structurally characterise all human bromodomains (BRDs)
Integral Membrane Proteins	Aims to solve structures of some of the most challenging proteins in the human genome, proteins that are embedded in the lipid bilayers of cells
Growth Factor Signalling	Addresses how growth factor signals are propagated inside the cell by phosphorylation
Metabolic & Rare Diseases	Combines structural, biochemical, and chemical biology approaches to explore how genetic defects lead to disease at a protein molecular level
Biotechnology	Generates the pipeline of clones targeted by the SGC in Oxford and determines, using high-throughput (HTP) screening methods, which proteins are expressed in a soluble and stable form suitable for structural and functional studies
Medicinal Chemistry and Chemical Biology	Utilises high-throughput and fragment-based screening to discover chemical leads
Research Informatics	Responsible for the maintenance and upkeep of the SGC Oxford target list
Protein Crystallography	Scientific focus is how crystallography can truly transform cost and efficiency in protein-targeted chemistry

parasites that represent potential drug targets deposited into the Protein Data Bank (PDB). The PDB is a repository for 3D structural data on proteins and nucleic acids, to which scientists from any and every country may submit data and which is accessible, free of charge, for use by all (that is, it is in the public domain).

The SGC is currently funded by a mix of public and private funders who contribute a fixed annual sum over the phase of research activity in return for membership of the SGC Board and a voice in determining the focus of research efforts. Current public funders are situated in the UK and Canada, and the SGC has a site at both Oxford and Toronto, in affiliation with the universities. At the time of inception, the SGC also had a physical presence in Stockholm, Sweden (in affiliation with Karolinska Institutet) and received public funding from a number of Swedish sources. However, SGC Stockholm ceased operation in 2011. Funding decisions are not based on conventional peer review but rather on a determination of priority areas within the consortium. The SGC's scientific approach is self-described as a 'family-based' approach (Lee, et al., 2009) which helps to ensure that 'comparative analysis' and 'blanket' methods can be applied to members of same family groups.

In order to work across all the different areas, the SGC has several different research groups, listed in the table opposite.

The SGC has also evolved across its three funding phases. The key characteristics of each phase are summarised below.

An independent evaluation of the SGC

Despite the unique approach of the SGC, little systematic analysis has been done to understand the nature and diversity of the benefits gained, both for the partnering organisations and for the wider research community. This evaluation will help address the gap. Our primary focus is on the SGC approach, although a degree of comparative enquiry inevitably emerged over the course of the evaluation and may help to shed some light on relative merits and potential trade-offs of the SGC approach vis-à-vis other models of organising and collaborating in R&D in this space. Given the consortium is now eight years into existence and is also expanding the scope and scale of its portfolio, this is a particularly timely stage to capture, reflect on and learn from 'work to date' and to help to inform 'work to come' and future strategic direction. This document constitutes the first independent evaluation of the SGC. The main objectives of the evaluation were to answer the following questions:

- What are the most convincing arguments in favour of current funding of the SGC?
- What are the relative merits of the SGC open access model as opposed to alternative models of funding R&D in this space?
- What judgements can be made about the SGC's past and current performance track record in light of achievements and expectations?

Table 1-2:
Summary of SGC funding phases

Phase of the SGC	Overview
Phase I	In Phase I the primary objective of the SGC was to determine the 3-dimensional structures of 350 human proteins and release them into the public domain via public databases
Phase II	In Phase II the SGC planned to dedicate 80% of its effort to produce ~660 structures from proteins on the SGC target list, and 20% to determining three human integral membrane proteins. These numbers would have risen to 1070 and ten respectively if full funding had been received
Phase III	Phase III saw a marked change from Phases I and II with a diversification of SGC aims. It proposed 40% of resources should maintain the critical mass necessary for the protein science based platform to support the structural genomics programme and create the foundations for add on activities. In addition ~25% of resource should provide minimum support for the parasitology, chemical probes and biological probes programs and 35% was unallocated and open for funder prioritisation

- Are there important trade-offs or limitations that need to be addressed looking towards a Phase IV or reasons against funding the SGC?
- In considering a potential Phase IV are funders anticipating changes internal to the SGC or in the wider PPP landscape in this field?
- What are the key trends and opportunities in the external environment which could influence a Phase IV, and can the SGC benefit from or have influence over these trends?

This evaluation, therefore, captures the SGC's past achievements and current performance track; helps it to learn about what has worked well, how and why to date; identifies where challenges and scope for adaptation might reside; and enriches insights on the potential of this model *vis a vis* alternatives.

Methodology

Evaluation of research funding has multiple purposes, including demonstrating achievements, accountability and learning (Morgan Jones and Grant, 2013). Selection of appropriate evaluation methodologies depends on understanding not only what the objectives of the research being funded is (eg the purpose of the SGC), but also the rationale behind the evaluation itself. As stated above the objectives are multi-faceted and so a multi method evaluation approach was warranted that provides qualitative and quantitative data on SGC's performance to date and synthesises views about its perceived contributions to innovation in both the wider field and the drug discovery R&D value chain.

Our evaluation proceeded in several stages. We summarise below the main phases and the methodologies employed. Further detail on the methodology across all work packages is presented in Appendix C.

The first phase of the project entailed detailed project planning and the inception meeting (Work Package 0) which established the foundation for a fit-for-purpose evaluation and the methodological approach and also clarified expectations for the project. The second phase was to establish the background and context to inform further evaluation enquiries through a literature and document review of biomedical R&D models and future trends in the research landscape (Work Package 1). Upon establishing a robust project plan and con-

textual evidence base, the third phase of the project involved primary research through interviews with scientists, funders and external stakeholders, an impact survey with a sample of scientists and quantitative analysis of SGC outputs through data mining and light touch economic analysis (Work Packages 2,3,4,5). Qualitative methodologies were engaged to garner perspectives on the evolution of the SGC, performance, effectiveness of the SGC model, future potential and influences. Phase 4 of the project involved the development of future scenarios for the SGC (Work Package 6) and cross analysis, synthesis and drawing out of lessons learnt across the previous work packages, methodologies and stakeholder perspectives, and final reporting (Work Package 7).

The key methodological approaches employed in the study were:

- A document review of relevant SGC documents (eg strategic plans, any prior performance evidence).
- A literature review of conceptual debates and recent developments concerning open innovation, intellectual property and public-private partnerships.
- A literature review of open innovation public-private partnerships across different sectors.
- Semi-structured interviews with eighteen SGC researchers and collaborators, seventeen current and former SGC funders, and a selection of nine external stakeholders including potential funders, industry experts and research collaborators.
- An online survey of SGC principal investigative researchers to identify the diversity of research outputs and impacts. All of the SGC researchers who were interviewed were invited to undertake this survey.
- A quantitative assessment of SGC outputs and an assessment of economic impact.
- An internal workshop on future scenarios for the SGC.

Structure of the evaluation report

The report is structured to deliver key insights from the research and the different chapters condense findings from different strands of the evaluation. Chapter 2 sets the context for the SGC and the evaluation by providing an overview of

a relevant subset of the literature on biomedical innovation in relation to both open innovation and PPPs. Chapter 3 reflects on the principles behind the SGC as a model for *investing in knowledge development*. We present feedback from stakeholders on the attributes that attract investors to the SGC, and organisations like it, and reflect on their perceptions of the major barriers, challenges and opportunities associated with the SGC. Chapter 4 builds on Chapter 3 and assesses how the SGC, specifically, operates and performs as a model of *generating knowledge*. We look at the range of achievements, strengths and weaknesses as perceived by funders, researchers and external observers to the SGC, drawing on interviews and the survey that we carried out with researchers.

Chapter 5 considers the SGC in relation to its ability to effectively and efficiently *extract knowledge* for wider use in the field. Here, we focus primarily on the major knowledge outputs and outcomes from SGC and draws primarily on quantitative assessments. The quantitative analysis is further complemented by feedback from inter-

views and survey results. The chapter presents data about how the SGC adds value to the knowledge created by researchers and collaborators in the form of protein structures deposited, publications, capacity built, and a range of other indicators. The chapter also provides some insight into the SGC's performance relative to other initiatives that represent different models of creating value from knowledge. While our focus in this evaluation was primarily on the SGC and we had limited resource to undertake a comprehensive comparative analysis we have indicated where we think the SGC's contribution is particularly noteworthy and where further comparison might be likely to yield interesting results.

Chapter 6 presents the results of our scenarios-based analysis of a set of potential futures for the SGC. We paint several pictures of different scenarios within which the SGC might develop in the future and the implications of this for its future direction and strategy. Finally, in Chapter 7 we return to the central questions of the evaluation and draw out cross-cutting syntheses.

Chapter 2 The SGC in context: A review of relevant literature

The literature helped in setting the context for the evaluation

The SGC is distinctive for a number of reasons and we felt it important to review academic and grey literature so that we were able to situate this evaluation in the context of broader debates and other relevant analysis. Health research and innovation is a very broad terrain and is accompanied by a diverse literature providing data, analysis and commentary from management, economic, policy and social perspectives amongst others. Given the wide-ranging nature of all possible literatures, our approach to undertaking a review of the literature was not to endeavour to be comprehensive or systematic. Rather we aimed to create boundaries relevant to the evaluation tasks at hand and to search selectively for representative articles that offered valuable empirical or conceptual insights.

In order to review the conceptual debates and recent developments concerning open innovation, intellectual property and public-private partnerships, we conducted a targeted literature review of both the academic and the grey literature. The academic literature search was conducted in JSTOR, EBSCO and Google Scholar databases, while additional documents were retrieved through a general internet search (Google) and on the basis of our existing knowledge of health research and innovation. For both searches, we used the following search strategy: ‘public good’, ‘tragedy of the commons’ and ‘anti-commons’.¹ These search terms were used singularly and then with all permutations in combination with ‘innovation’ and

‘intellectual property’ to narrow the search and prioritise relevant literature. A snowball method was also used by scanning the references of papers that were highly relevant to our topic. In our final selection we retained documents that, according to our expertise, were significantly contributing to the theory of innovation and helped contextualise and understand the role of the SGC. Our final selection includes peer-review articles, editorials, as well newspaper articles and reports.

The literature review is structured around important features of the SGC model. These include its open access policy, its incorporation of public and private sectors into a public-private partnership (PPP), and the funding model of the SGC itself, that is, that funding for the SGC is provided on the basis of block grants rather than on peer review. The relative importance of these features emerged iteratively over the course of the study, so while we anticipated initially that the first two areas would be crucial to the study, we came to realise that the third area also raised some relevant considerations which the literature might help shed some light on. The approach was driven by asking hypothesis-driven research questions:

- What are the relevant insights about the rationale for open innovation in health innovation and research? In particular, what are some of the relevant debates about intellectual property rights (IPR) in health innovation and research?
- What are the alternative (or additional) models of funding biomedical R&D through PPPs or other collaborative mechanisms, particularly in light of the open innovation agenda?
- Are there comparable PPPs to SGC and if so have relevant evaluations been undertaken? Related, what are the alternative models of open innovation in other sectors and do they suggest any comparative insights in relation to

¹ Murray and Stern (2007) explain the ‘anti-commons perspective’ as the belief that the expansion of IPR (in the form of patents and/or copyrights) is ‘privatising’ the scientific commons and limiting scientific progress.

the development of ‘platforms’ in pre-competitive spaces?

- Are there implications of peer review as a mechanism for funding health research?

Though the review references some literature from SGC itself, the majority of the evidence about SGC specifically is used in later chapters. We begin with the first set of questions about the relationship between IP and open innovation. This is the largest section and reflects the very considerable literature on this question.

What are the relevant insights about the rationale for open innovation in health innovation and research?

Open innovation is a term used to describe a range of collaborations and ways of sharing knowledge and research activity and results. In the context of innovation systems, the concept is understood through the work of Chesborough (2006). He describes open innovation as a paradigm where firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as firms look to advance their technology. In terms of the pharmaceutical sector, SGC represents a more radical approach than many because it is committed to open access, as well as open innovation, meaning that it has adopted and had success with innovation which has no intellectual property rights associated with it.²

However, open innovation does not mean entirely open access at all stages of the research value chain. Chas Bountra, the SGC Oxford Chief Scientist, argues that conducting research on the basis of open access makes sense from a cost of research perspective and will actually make patenting more effective. In a recent interview about the SGC he said:

Since all data is freely shared, any company is free to exploit it, which is when competition kicks in. This is the only way to reduce the current duplication wastage and needless exposure

of patients to molecules destined for failure. [...] Currently drug companies have to apply a patent as soon as they develop a new molecule – years before it can be tested and developed. The patent can be close to running out by the time the finished drug gets to market – which opens them up to generic competition and diminishes their returns. [...] Under this new model [of the SGC] we do the research together by pooling our expertise, often much more cheaply than any one company can do it, and then the drug companies take it on, create a proprietary molecule that they can advance quickly through clinical trials. (*The Daily Telegraph* 23 June 2013)

Since the SGC is walking a line between open access, open innovation and the role of intellectual property as a market force, it is worth first considering some of the history of the debate about the role of intellectual property rights in health research and innovation.

Changing trends and on-going debates in the funding landscape

Intellectual property rights have a complex history in the field of health research and innovation, and debates about the impact of patenting, especially on research, are polarised. The debate about Intellectual Property Rights (IPR) is intimately connected to the fact that significant amounts of both public and private funds support health innovation. This is because historically, a common justification for public spending on health research has been that the lack of mechanisms to appropriate the rewards of investment has led to ‘market failure’ and a scarcity of private funding for basic research (Arrow, 1962; Nelson, 1959; Chataway et al., 2011). Changes in IPR regulation over recent decades have allowed for patenting further upstream and the sector has witnessed a huge increase in patenting activity in life science (Mowery and Sampat, 2005a). Patenting has been seen as a requisite to stimulating investment and securing payback on the rising public and private costs of investment (Teece, 1986).

Moreover, there has been widespread recognition that knowledge is cumulative and complex to acquire. It does not flow as freely as some – those who worried about how the private sector would appropriate returns – feared, and this has given

² Crowdsourcing experiments such as those hosted by DREAM and Sage (*Nature*, 2013) represent other initiatives that are very different to SGC but have also had success in the context of non-IPR based approaches.

the private sector confidence to invest (Nelson 2011; Chataway et al., 2011). On the one hand, then, the range of IPR-based activity has expanded further upstream, while on the other hand, it is widely acknowledged that patent regulation is only one method of appropriation and allocating benefits from research (Teece, 1998; Grootendorst et al., 2010). However, just as we see that the private sector has increasingly invested upstream, so too has IPR led to changes in the nature of public sector funding. Public sector funds are now increasingly deployed across a broad spectrum of health research and product development activities. Thus, it would seem that the changing nature of both private and public sector funding would partially seem to undermine the market failure argument constructed around the need for public investment in basic health research, whilst also necessitating a different theoretical justification for, and understanding of, public sector funding (Chataway et al., 2011).

Whilst the patterns of investment may have changed over the decades, health research and innovation is such a politically and socially important area that public sector funding has always been used to underpin and maximise the impact of private sector funds. The two are thus intertwined. It is unlikely that 'market failure' would ever be corrected in such a way as to replace public sector funding entirely (Mazzucato, 2013), and indeed it is becoming more evident that public sector investment is needed across the basic, applied and product development spectrum as well as in the continuing vital area of providing skilled researchers to work with and in the private sector.

The nature of 'public' versus 'private' goods

The existence of substantial public funding for health research and innovation, is one factor in the debate about the degree to which health research and knowledge should be considered as a collective or public good (Samuelson, 1954; Ostrom and Ostrom, 1977). This means that public funding is also part of the context underlying a question about how intellectual property can be granted so as to generate maximum efficiency and payback to investment from both public and private sector perspectives.

The issue of the extent to which patents should be granted on early stage research has been debated

by scholars from a number of perspectives. Stiglitz (1999) and many others have recommended that in cases where market failure is impossible to overcome, taxes and subsidies be deployed so that public funds underpin private investment. The market failure argument is further used to argue for the extension of patent rights on research (institutionalised by the Bayh Doyle act in the US) as a way to incentivise investment (Stiglitz, 1999).

Intellectual property rights clearly can be used to generate returns to investors and therefore to structure incentives (Arrow, 1962). Recent writings have stressed the role that patents play on early stage discoveries in bringing public and private sectors together (Mowery and Sampat, 2005b). For example, proponents of strong IPR regimes and the granting of patents on early research point to the increasing reliance of the pharmaceutical industry on the biotech sector, which itself is linked closely to academia but also heavily dependent on venture capital and IPR for its survival. In fact, in a 2011 editorial criticising public investment in the Innovative Medicines Initiative (IMI) for of its poor track record in engaging biotech-based SMEs, *Nature Biotechnology* highlights the importance of intellectual property to biotech firms, and the whole sector:

One reason for the poor engagement of biotechs [in IMI] is intellectual property (IP). Although the Commission drew up extensive explanatory documentation distinguishing background (pre-consortium) and foreground (during consortium) IP and defining the various rights of participants to its access, use or dissemination, the fact is that IP is the most important tangible asset for most venture-backed biotech firms. (*Nature*, 2011).

In part the reason that the *Nature Biotechnology* editor feels so strongly about biotechnology-based SMEs is that he considers that they can play a potentially vital role in moving the pharmaceutical industry in novel and much needed directions. They can be 'disrupters' to technological and industrial trajectories that have become unproductive (*Nature*, reply to IMI, 2011).

However, this point is disputed. Whilst there is evidence that biotech firms are increasingly important to innovative activity in the pharmaceutical sector (Galambos and Sturchio, 1998; Munos, 2009; Kneller, 2010; Martin, Nightin-

gale, Hopkins et al., 2006,7; Hopkins et al., 2013) researchers point out that the evidence behind the assertion that biotechnology-based SMEs play this disruptive role is weak. The financial basis of biotech SMEs, constrained as it is by reliance on VC means that biotechnology companies complement rather than challenge existing industrial structures.

[...] biotech firms significantly compressed their life cycles and changed their business models to support, rather than attempt to displace, large pharmaceutical firms and reduce the need to access stock market funding. [...] [F]irms funded solely by VC have had less likelihood of contributing to projects that pass Phase II trials. (Hopkins et al, 2013).

Apart from the debate about importance of IPR to biotechnology-based SMEs and the importance of biotechnology firms to drug discovery and development, there is some evidence to suggest that research itself is enhanced by strong IPR because it requires disclosure of the knowledge underlying the patent. This contributes to the broader knowledge base on which future research is based. Any immediate increased costs to researchers can be avoided by Reach Through Licence Agreements (RTLAs) which allow researchers with limited funds to use patented research tolls right away and defer payment until research yields valuable result (Heller and Eisenberg, 1998).

Though the debates are diverse and wide-ranging, in the opinion of many analysts health innovation in particular is not being served well by early patenting (eg Mazzoleni and Nelson, 1997). This concern coincides with a pronounced interest from both companies and analysts in open innovation in various guises. Open innovation can be based on IPR agreements or on increasing non-patentable pre-competitive research collaboration. However, the best institutional environment for more open collaboration is the topic of much debate. That debate of course is directly related to the issue of whether open access represents a valuable option in health research and innovation. Before discussing the value of open innovation, though, we turn to a strand of argument that focuses more on the negative consequences of patenting on the research environment.

Perspectives on the impact of patents on research on the research environment

There are numerous perspectives on the impact of patents on research and the research environment and these are explored by different scholars in the literature. Nelson (2004) argues that technological advance is an evolutionary process, and as such, benefits from the development of knowledge via multiple paths by a number of different actors. It is also cumulative, as bodies of knowledge build on previous understanding of practice. Further, outputs of scientific research are almost never themselves final products but are used in further research.

The scientific community, Nelson claims, should not be hindered in working freely with and from new scientific findings because of the long run and public good benefits that come to society from government support of basic research. Nelson emphasises that keeping the body of scientific knowledge largely open for all to use, and preserving the commons, is extremely important. The scientific commons has however, and is, being undermined by patenting and the Bayh-Dole act of 1980, which encourages universities to take out patents on their research. Patenting can theoretically create the problem of needing to assemble a number of permissions or licenses before going forward; RTLAs can pose a problem rather than a solution as they give the right for each upstream participant to be present at the bargaining table as a research project moves downstream toward product development (Heller and Eisenberg, 1998).

However in practice this was found not to be the case in a number of studies (see Walsh, Arora and Cohen (2002), Cited by Nelson, 2004). A problem that was found to impede research, however, was that a holder of a patent on an input or pathway, sometimes did not widely license, and in some cases sought to preserve a monopoly on use of rights. Others, such as Mowery and Sampat (2005a), have highlighted the negative impacts that patents can have on the creation of a collection collective knowledge base. Murray and Stern (2005) note an impact of patenting on knowledge accumulation but make it clear that the relationships are complex and that the 'anti-commons' effect from patenting is very likely not uniform across all areas. Exploring the debate further, Dosi et al. suggest that the effect of IPR regimes will be dependent on the nature of the technol-

ogy, information or innovation (Dosi et al., 2007). Where an innovation is 'standalone' or 'discrete', the effects will be less deleterious than patenting innovation in a sector that is strongly cumulative such as biotechnology or drug development (Dosi et al., 2007).

Patenting is of course one feature of the complex organisational and institutional landscape in the pharmaceutical industry and its relevance and importance needs to be seen in the context of the broader market structure. An article by Malerba and Orsenigo (2002) highlights the importance of a broader set of relationships between science, technological and institutional environments. In the article, which tries to develop a 'history friendly' model (a model based on an understanding of the markets, organisations and science and technology), the authors are attentive to the impact of biotechnology and molecular biology and the rise of biotech companies on the structure of the pharmaceutical industry as a whole. A major finding is that while collaboration between big pharmaceutical and new biotechnology firms is positive because collaboration generates more innovation, biotechnology firms do not have a significant impact on the structure of the industry overall (concentration levels of companies remain the same). These findings add to the argument, referred to earlier, by Hopkins et al. (2007) that small biotech companies are unlikely to be engines of new technological and innovation trajectories. Moreover an increase in patent protection does nothing to offset the decrease in demand for drugs (a consequence of more accurate targeting and stratified medicine amongst other possible factors).

Various and alternative arrangements to IP on research

Nelson (2004) proposes several solutions to preserve the scientific commons and so address the anti-commons dangers that he and others have identified. First he urges more care so that patents are not granted on natural phenomena and that a strong case be made for 'substantial transformation'. Second he suggests that a relatively strict meaning of 'utility' or 'usefulness' be adopted by patent law. Third he argues that patent offices and courts should take care not to grant patents too broadly. Universities and non-profit organisations should be immune from prosecution if the materials they need to use are not available

on 'reasonable terms' and that the university or other research organisation agrees not to patent anything that comes out of the research (or to do so on a royalty free basis). He concludes that to defend the scientific commons, universities need to come to the rescue by laying research results open and institutionalising this through their own policies. This point is made all the more salient if we consider that the biomedical and biotechnology industry is advanced more significantly and directly by university research advances than other sectors (Mowery and Sampat, 2005a).

Akoi and Schiff (2008) review patent pools (a consortium of at least two companies agreeing to cross-license patents relating to a particular technology) and IP clearinghouses (including copyright collectives) as systems that promote access to IP. These promote downstream uses of IP such as cumulative innovation and the development of products based on multiple innovations by reducing search and transaction costs, helping to solve the tragedy of the anti-commons that occurs with complementary IP. Patent pools for example, are ideal in situations where a bundle of complementary patents must be combined to produce a new product or innovation and the essential patents are easy to identify (Akoi and Schiff, 2008).

Davies and Withers (2006) suggest that the 'best' model of IPR cannot be based on economics alone. The economic, the political and the moral are closely connected in this policy problem. These authors advocate a public interest IP regime that seeks to balance: the economic incentive to innovate; the economic value of public domain; the civic value of access and inclusion; and preservation and heritage. Such an IP policy would place knowledge as a public resource first and private asset second.

In the view of some authors, society as a whole will suffer from the legally sanctioned restraints placed on access to bodies of knowledge and information goods. The privatisation of knowledge may result in a less efficient resource allocation (David, 2000) compared to an alternative scenario in which the dynamics of collective action in the management and use of a body of knowledge result in a greater good (Hess and Ostrom, 2007). Many fields of research (including health and medicine) rely on the collection, management and analysis of large volumes of observational data and the conduct of open, collaborative science (David 2000).

Open innovation as a model for drug discovery

The closed innovation model is built around the benefits of self-reliance in development, manufacturing, marketing and distribution and the idea that successful innovation requires control over these processes. Towards the end of the 20th century, a number of factors began to challenge closed innovation systems including a rise in the number and mobility of knowledge workers and the growing availability of private venture capital, which helped to finance new firms and their efforts to commercialise ideas that have spilled outside the silos of corporate research labs. Whilst partnerships, collaborations and shared agendas have always existed to some extent, academics, analysts and managers began to think about how collaboration and openness could be placed at the core of business models.

A more open model has resulted from a changing landscape as knowledge becomes more available, but open innovation itself affects change within firms and within sectors. In the open model, human capital and knowledge can be accessed from both inside and outside the boundaries of the organisation. It requires firms to be adept at screening ideas and opportunities that come from outside the firm. Business models based on open innovation face the challenge of sustainability. 'Open strategies' address this challenge by balancing value capture and value creation (Chesborough and Appleyard, 2007).

Not all industries will migrate to open innovation, but pharmaceuticals and biotechnology are thought to be amongst those that will. It has been assumed that consumers will benefit from low prices and increased transparency, making it easier to judge the quality of both existing and proposed products (Maurer, 2008). It is now recognised that the life science industry is based on a cumulative model of innovation. Alongside the recognition that biological knowledge is complex with genomes representing complex interacting systems, has grown the idea that we are in a systems paradigm; the patent system needs to reflect that this excessive privatisation will increase the transactions costs associated with procuring licenses to required knowledge (Allarakhia et al., 2007). The current patent system in biomedical innovation is vulnerable to two particular problems according to Grootendorst, 2010). Firstly there have been increased drug discovery costs related to secrecy

and unwillingness to share information about attrition in early research and in clinical trials leading to costly duplication of effort. Secondly, decreased sales revenues from discovery and drug approval consuming much of a molecule's patent life and 'raiders' (parallel traders, counterfeiters), who appropriate these margins.

The literature on changes in the pharmaceutical R&D model and the increasing use of knowledge produced from outside the firm is significant and spans peer-reviewed literature (Powell, Koput et al., 1996; Lane and Lubatkin, 1998; Mathews, 2003; Nicholls, Nixon and Woo, 2003; Athreye and Godley, 2009) and grey literature from consultancy companies (PricewaterhouseCoopers, 2008, 2009a, 2009b, 2009c; Ernst&Young, 2009a, 2009b, 2010a, 2010b; McKinsey&Company 2010a, 2010b, 2010c 2010d).

The drivers behind the change are complex but were in part catalysed by substantial advances in physiology, pharmacology, enzymology, cell biology and the ability of firms to take advantage of publically generated knowledge (Malerba and Orsenigo, 2002). It would be nearly impossible for any single firm to develop in-house the detailed subject-specific expertise needed for modern drug development. The open innovation paradigm can see firms taking on some of the properties of 'knowledge integrator' (Hopkins et al., 2007) to co-ordinate and direct activity towards innovation. The emphasis then is placed on large firms maintaining sufficient 'absorptive capacity' (Cohen and Levinthal, 1990) to be able to use knowledge that comes from outside.

The drop in productivity of pharmaceutical R&D (Kola and Landis, 2004) and rising costs of innovation (DiMasi et al., 2003), the demise of the blockbuster model (Deloitte, 2008b; Owens, 2007) and the emergence of personalised medicine (Deloitte, 2008b) as a framework for drug development are also factors that have prompted moves towards open innovation (Chesborough and Crowther, 2006). This move towards more open forms of innovation is now widely reflected in company strategy and in government policy, for example, the UK's Health and Wealth and Life Science strategies (Department of Health, 2011; BIS, 2012). Open innovation strategies are deployed for a number of reasons and include attempts to try to reduce costs of R&D for individual investors (Golightly et al, 2012: 35).

One area that may be a focus for future open innovation in the pharmaceutical sector is open source drug discovery. Open source drug discovery is underpinned by open source networks, in turn defined as defined voluntary or social as opposed to organised by price incentives (eg the market) or hierarchical commands (eg by laboratories or firms). Maurer reflects that open source drug discovery has not yet been achieved, though some types of collaboration in the life sciences can be described as having some open source characteristics. There are examples of collaborations in the life science that are relatively open, though are not by a stricter definition 'open source drug development', such as: biology software design and development, community-wide big science projects designed to acquire key data for an entire community, databases, use of stem cell lines, etc). Maurer (2008) suggests that any analysis to find where open source would be useful and feasible would involve looking for niches in the drug discovery process.

Open discovery initiatives being used by the biopharmaceutical sector include, for example, open knowledge networks and other cooperative strategies. The objective of cooperative strategic alliances is to preserve downstream technological opportunities for multiple firms. The ability to join an open source initiative is tempered by informal and formal rules of participation. Entrance fees for example not only facilitate research and development activities but also signals cooperation and commitment to the initiative. Participation rules can also create trust for example through committing resources in advance, including paying monetary fees, reassures other participants including future participants of a researcher's cooperative intentions.

Whether these open source drug discovery initiatives will succeed is open to debate. In contrast to open source software development, validation of biological knowledge often necessitates laboratory expenses and expensive clinical trials, often with long time scales (Munos, 2006). In software development there is no 'discovery phase', but drug discovery cannot flourish until a certain amount of knowledge about the target disease has been accumulated. In contrast to drug developers, software publishers are lightly regulated (Munos, 2006). Furthermore, underlying knowledge structures have changed in the new genomic paradigm,

with increased complementarity between biological knowledge standing to impact downstream product development. And so across different sectors, incentives to participate and also the rules of participation will differ. From game models and analysis of consortia, Allarakhia et al. (2010) also show that funding agencies enable the creation of large-scale collaborative projects. By supporting such collaborations, funding agencies indirectly encourage the norm of disclosure. Many consortia use rules and binding agreements to defer appropriation until the characteristics of knowledge warrant patenting, in order to ensure that downstream products are developed. Consortia differentiate between disembodied knowledge in the form of raw data and embodied knowledge created by consortium members in the form of tools, biomaterials and reagents. Data that are high in complementarity and applicability but low in substitutability are usually released immediately. Tools, biomaterials and reagents that are high in complementarity and applicability, as well as in substitutability, may be appropriated and licensed to consortium members and the public.

A comparison of the SGC and other PPPs

There are no exact comparators for the SGC but there are some initiatives which have similarities both in terms of overall aims associated with contributing to drug development and in trying to foster more openness and collaboration in pre-competitive research. There is also a set of initiatives that have a focus on structural genomics. We reviewed aspects of both with a particular aim of identifying any evaluations of these organisations that might help to inform both the evaluation and the nature of our findings and insights.

Beginning with organisations that have a similar focus on structural genomics, the SGC is not the only structural genomics group that is producing data for the scientific community. A number of other large research groups are also heavily involved in providing structural genomics data. The three main organisations involved in this work are Japan's *RIKEN* research institution, the USA's *Protein Structures Initiative* (PSI), and Europe's *Structural Proteomics in Europe* (SPINE) initiative. Each of these groups is organised to deliver structural genomics information in different ways.

RIKEN is a single comprehensive research institution in Japan, and they have had a structural genomics component to their work since 1998 in the form of the Protein Structures Group. RIKEN is predominantly funded by the Japanese government, but additional partnerships with the private sector allow RIKEN to translate their outputs beyond academia. RIKEN cite the examples of the RIBA II healthcare robot for nursing care, and a strain of disease-resistant rice as ways that their private sector links lead to public impacts.

PSI is the US National Institute of General Medical Sciences (NIGMS) funding stream dedicated to structural biology. PSI is a US national effort in place since 2000 to assemble a large collection of protein structures in a high-throughput operation. It has three main aims: to cut the costs and time it takes to produce proteins for study; to determine their three-dimensional structures; and to make the atomic level structures of most proteins easily obtainable from their corresponding DNA sequences.³ Initially, from 2000–2005, PSI addressed this through the funding of nine pilot projects across the US, each bringing together multiple academic centres to form consortia.⁴ This pilot phase was funded predominantly through public sector funders. In 2005, PSI transferred to a ‘production phase’ in which centres started to provide more structures based on the methodology and technology advancements of the first phase of PSI.

In Europe, SPINE was the main structural genomics funding provided by the European Commission’s Framework Research and Technological Development Programme. Funded from 2002–2006, and coordinated by the University of Oxford, SPINE brought together 19 research groups across Europe and Israel to address the development and rollout of new technologies for structural biology, to determine protein structures

and to build on previous structural genomics work conducted in Europe. Phase two of SPINE from 2006–2010 also used a multi-centre approach, but focused on protein complex structures related to signalling pathways. This was a deliberate attempt to focus on the more complicated protein complexes, where other structural biology groups were focused only on individual proteins.

While none of the other ‘big three’ structural groups are funded or structured in the same way as the SGC (having mainly public funders rather than a large proportion of private funding), they each work towards the same goal: to develop protein structures that can be used in future biological and biomedical research and development. As such, understanding that the SGC is not alone in this field is an important context in which to place any assessment of outputs and impacts.

As well as other structural groups, we looked more broadly at a variety of health innovation PPPs and the majority of this work can be found in Appendix A. A longlist of global health PPPs was compiled by selecting all active PPPs included in the Health Partnerships Database.⁵ Table 2-1 maps where these health innovation PPPs operate in the drug discovery value chain, with green shading highlighting those that are explicitly open access to enable product access for patients and blue shading revealing those that are explicitly open access for product development. We discounted PPPs that were entirely focused on supply and distribution and those that were not involved in the value chain at all, and explored the latter category in more detail, the results of which exploration are outlined below. We also include some details about product development partnerships (PDPs) for neglected diseases in the appendices. PDPs share some organisational characteristics with the SGC but they predominantly operate further downstream on the research and product development value chain and focus on clinical rather than basic research (Chataway and Smith, 2006; Chataway et al., 2010).

³ National Institute of General Medical Sciences website: Protein Structure Initiative Mission Statement. Available at: <http://www.nigms.nih.gov/Research/FeaturedPrograms/PSI/Background/MissionStatement.htm> [Last accessed 4th November 2013].

⁴ Pilot Centres were: Berkeley Structural Genomics Center; Center for Eukaryotic Structural Genomics; Joint Center for Structural Genomics; Midwest Center for Structural Genomics; New York Structural Genomics Research Consortium; Northeast Structural Genomics Consortium; The Southeast Collaboratory for Structural Genomics; Structural Genomics of Pathogenic Protozoa Consortium; and TB Structural Genomics Consortium.

⁵ Health Partnerships Database. Available at: <http://www.open.ac.uk/researchprojects/health-partnerships/> [Last accessed 4th November 2013].

Table 2-1:
Mapping of global health Public-Private Partnerships

Operation within the drug development value chain					
Name of PPP	Pre-competitive	Development	Supply and distribution	All stages of value chain	Not involved in value chain
Aeras Global TB Vaccine Foundation				X	
Biomarkers consortium	X				
Concept Foundation				X	
Contraceptive Research And Development Program (CONRAD)				X	
Corporate Council on Africa					X
DNDi				X	
European Vaccine Initiative (EVI)		X			
Foundation for Innovative New Diagnostics (FIND)				X	
GALVmed PL/SHL-1 programme				X	
Global Alliance for Improved Nutrition (GAIN)					X
Global Alliance for Vaccines and Immunisation (GAVI)					X
Global Alliance To Eliminate Lymphatic Filariasis (Gaelf)					X
Global Business Coalition on Health (GBC Health)					X
Global Campaign for Microbicides					X
Global Fund To Fight Aids, Tuberculosis And Malaria (Global Fund)					X
Global Polio Eradication Initiative (GPEI)					X
Global Reporting Initiative (GRI)					X
Human Hookworm Vaccine Initiative		X			
IAVI				X	
Infectious Disease Research Institute (IDRI)				X	
Innovative Medicines Initiative (IMI)	X				
Institute For Oneworld Health (IOWH)				X	
International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH)					X

Operation within the drug development value chain					
Name of PPP	Pre-competitive	Development	Supply and distribution	All stages of value chain	Not involved in value chain
International Programme on Chemical Safety (IPCS)					
International Trachoma Initiative (ITI)			X		
Lilly Multi-Drug Resistant Tuberculosis Partnership (MDR-TB)				X	
Mectizan Donation Program			X		
Microbicides Development Programme (MDP)		X			
Micronutrient Initiative (MI)			X		
MMV				X	
Multilateral Initiative On Malaria (MIM)					
MVI				X	
MVP				X	
Oncotrack consortium	X				
Pediatric Dengue Vaccine Initiative (Pdvi)					X
Pharmaceutical Security Institute (PSI)					X
PREDICT consortium		X			
Public-Private Partnership for Handwashing with soap (PPPHW)					X
Roll Back Malaria Partnership (RBM)					X
Safe Injection Global Network (SIGN)			X		
Schistosomiasis Control Initiative (SCI)			X		
Secure the future			X		
Stop TB Partnership (STOP TB)				X	
Stratified Medicine Innovation Platform (SMIP)					X
Structural Genomics Consortium	X				
TB Alliance				X	
The Alliance for Health Policy and Systems Research					X
Vision 2020					X

Our review shows that there are initiatives that share features and characteristics with the SGC, including public and private initiatives that operate in the area of protein research, but that there are no direct comparators. Moreover, there are very few independent evaluations which could provide useful benchmarks. The scarcity of evaluation data in individual initiatives is matched by a lack of sector-wide thinking and *ex ante* evaluation about how public and private sectors can best work together in pre-competitive and open innovation spaces (Chataway et al., 2011). This exacerbates risks for both public and private sectors and is a theme that we will return to later in the report.

The literature on innovation in the pharmaceutical sector more generally, and on PDPs specifically, shares a concern with trying to understand the need for public and private partnerships. Both literatures consider the nature of market failure (for example Dosi et al., 2007; Malerba and Orsenigo, 2002; Towse and Kettler, 2002). Moreover, a set of authors writing in both strands of the literature share common perspectives that the market failure ‘lens’ is insufficient for understanding the trends and diversity of arrangements in public and private collaboration and that this perspective needs complementing or replacing in understanding the nature of capabilities that different actors are able to bring to innovation (Chataway et al., 2010).

Are there lessons to be learnt from open access initiatives in other sectors?

In a growing number of industrial sectors, development models that are characterised by individual, firm-based R&D procedures, including IPR protection, are challenged by innovative technology development models. The modes of collaboration are varied and multiple avenues for creativity are being explored. There is no universal approach and a number of public-private partnerships (PPPs) have been established with an open innovation ethos to facilitate better knowledge and exchange across different communities. Many of these PPPs are evolving, experimental and operate uniquely within the context of the industrial sectors they inhabit.

This review of the literature on other open access initiatives is summarised in full in Appendix A. We identify a range of examples from dif-

ferent industrial sectors which have adopted an open innovation ethos through public and private partnerships. These were identified through a web-based search of academic and policy literature. The form of these partnerships varies but includes formal organisational models, informal networking mechanisms and different platforms geared towards facilitating innovation and knowledge production to the benefit of different sectors. A number of initiatives are reviewed and summarised before a more detailed analysis of three selected ‘case studies’ are given for the Linux, Sematech, and EU Technology Platforms initiatives.

As the analysis in Appendix A shows, there are considerable difficulties in establishing any kind of collaborative PPP for research and development. Partnerships often take a number of years to become established and face significant obstacles around antitrust, mistrust amongst members and often a lack of consensus among the industry to get the initiative off the ground. Once established, partnerships need to balance the needs of the public and private sector and manage the tension of inter-firm rivalries that may threaten the sustainability of the partnership. Moreover, the internal conditions amongst partners may alter and the external environment is subject to shocks, which put the model for collaboration in jeopardy or make it considerably less attractive than when it was first established.

Although difficulties exist there are a small number of partnerships from other sectors that have been established with positive impacts. These partnerships take different forms and their success is dependent on specific conditions being in place and clear boundaries being drawn on the scope and scale of initiatives. Within the scope of this short review it is has not been possible to delve deeply into each PPP and undertake a comprehensive review of evidence on impacts on each individual sector. Based on our brief review of comparator PPPs from other sectors a number of different modes of collaboration have been mobilised, these are, *inter alia*:

- **Domestic versus international.** Restricting collaborations to firms of the same nationality (eg Sunshot) or a geographical region (EU) (eg European Technology Platforms). Or adopting an open access platform which has no geographical boundaries or immediate barriers of access (eg Linux).

- **Public versus private.** Collaborations are likely to be funded differently depending on the scope and rationale of the initiative. Funding is also likely to change over time as the priorities of funders change or external conditions alter. For example Sematech was conceived as a state-sponsored public-private partnership but is now supported mainly by the private sector.
- **Narrow or broad sectoral focus.** Collaborations may have a broad sectoral focus and a wide remit to facilitate knowledge exchange and technologies (eg Sustainable Process Industry through Resource and Energy Efficiency (SPIRE)). Others may be organised narrowly around a specific sector area or a strategically important technology (European Joint Technology Initiatives).
- **Horizontal versus vertical.** Collaboration between a horizontal group of competing firms (eg Sematech and ETPs) or collaborating vertically in the supply chain with firms in a sector (eg National Alliance for Advanced Technology Batteries). Of these two modes horizontal forms of collaboration tend to be more common and are often organised to overcome a technological or scientific obstacle (eg ETPs) or emerge in the face of external pressures (Sematech).
- **Firm-to-firm, consortium-to-firm, consortium-to-consortium.** Different modes of collaboration can take place at different levels. This can involve firms collaborating with one another or a consortium collaborating with a firm.
- **Competitive versus pre-competitive.** Competition between firms in the partnership or pre-competitive research on technologies or tools to benefit all.
- **Organisations versus networks versus platforms.** Partnerships can be managed through complex organisational structures and hierarchies (eg European PPPs) or less formalised, more organic bottom-up networks (Linux). Other PPPs may take the form of a simple platform that provides the mechanisms for different actors to network as desired (eg Moodle).

From these different modes of collaboration we can develop a crude typology based on the PPPs surveyed. Firstly, there are a number of *open source platforms*, mainly from the software sector, that promote user-led innovation by making research and development pre-competitive and non-profit.

A number of these platforms have been utilised by a community of enthusiasts who have devoted a considerable amount of time and energy to developing open access software. As a consequence, platforms have been highly successful and challenged the dominant position of market incumbents like Microsoft who are able to mobilise considerable resources and expertise on their own competing platforms. The classic examples of open source platforms are those of Apache, Linux and Eclipse and are included in the Appendix A.

Secondly, there are *collaborative innovation webspaces* these are essentially websites that enable different communities to exchange ideas and transfer knowledge. In its simplest form collaborative innovation webspaces can take the form of a Wiki, which is a webspace in which people can add, modify or delete content in collaboration with others. More complex forms can encompass webspaces that have the functionality of virtual learning environments (VLEs) or a Learning Management System (LMS). The main example from our longlist is Moodle, which is an open source Course Management System (CMS) that functions as a tool for creating online dynamic web sites for educational use.

Thirdly, *PPPs for research and development* are more formalised mechanisms for knowledge exchange and technology transfer in different sectors. These can be driven by industry in the case of Sematech to enhance competitiveness of firms or driven by government institutions to maintain the competitiveness of a region (eg European Technology Platforms). Due to these varying motivations, PPPs for R&D tend to be diverse in organisation, scope and scale. Some PPPs have a broad sectoral focus while others are centred on specific key enabling technologies that are anticipated to drive growth in a sector and beyond.

In conclusion, PPPs from other sectors are mobilised in multiple ways and their characteristics differ according to their geographical coverage, funding, sector, position in the value chain, innovation model and organisational focus. Most PPPs are evolving and transform over time; their characteristics depend on the maturity of the sector, the characteristics of industry and firms therein and wider political, economic, technological and scientific factors influencing innovation. The examples identified provide a useful context for the way in which the SGC is operationalised

Table 2-2:
Summary of peer review in health research criticisms

Evaluation question	General critique	Particular criticism(s)	Is the criticism valid?	Strength of the evidence base (1=weak; 5=strong)
Is peer review an efficient system for awarding grants?	Peer review is an inefficient way of distributing research funding	High bureaucratic burden on individuals	Unclear	2
		High cost	Yes	4
		Doubtful long-term sustainability	Unclear	2
Is peer review an effective system for awarding grants?	Peer review does not fund the best science	It is anti-innovation	Unclear	2
		It does not reward interdisciplinary work	Unclear	2
		It does not reward translational/applied research	Unclear	2
	Peer review is unreliable	Ratings vary considerable between reviewers	Yes	4
	Peer review is unfair	It is gender-biased	Unclear	3
		It is age-biased	No	4
		It is biased by cognitive particularism	Unclear	3
		It is open to cronyism	Unclear	3
	Peer review is not accountable	Review anonymity reduces transparency	Yes	4
	Peer review is not timely	It slows down the grant award process	Unclear	2
	Peer review does not have the confidence of key stakeholders		No	4

but direct comparison is difficult because each PPP operates uniquely in different sectors.

Are there implications of peer review as a mechanism for funding health research?

More than 95% of the approximately £2 billion of public funding for health research in the UK is allocated by peer review (Ismail, 2009). The same percentage is likely to be true in the US, Canada and many other countries that allocate significant funding to health research. It is widely regarded as the gold standard as a funding mechanism. However, it has been criticised as there is a growing interest in the limitations of peer review and a burgeoning of literature on alternatives to this

model. While we have not addressed the so-called ‘alternatives to peer review’ in this review, we do seek to understand some of the reasons for the perception that it may be inadequate.⁶ Ismail’s 2009 review of the literature on peer review in health research summarised criticisms and findings are summarised in the table above:

An article in *Nature* by Amgen researchers on the low quality of scientific studies in cancer points to failures in peer review for publication and grant giving. Grants are awarded on the basis of track record but track record is established on the basis of publication and publication, even in

⁶ For a review of different models of allocating research funding in a competitive way, see Guthrie, et al, 2012 and 2013.

highly regarded journals, does not signify good quality science. The authors argue ‘the academic system and peer-review process tolerates and perhaps even inadvertently encourages such conduct. To obtain funding, a job, promotion or tenure, researchers need a strong publication record, often including a first-authored high-impact publication. Journal editors, reviewers and grant-review committees often look for a scientific finding that is simple, clear and complete — a “perfect” story. It is therefore tempting for investigators to submit selected data sets for publication, or even to massage data to fit the underlying hypothesis.’ (Begley and Ellis, 2012).

The reason that this type of critique is important relates to the idea that the quality of basic science is considered to be key to the overall cost of innovation. A review of the literature on pharmaceutical innovation indicates that the literature regards upstream (early drug discovery) as a firm’s ultimate driver of competitive advantage and significant attention is given to changes geared towards improving research earlier in the discovery process (Wamae et al., 2011). As pointed out by one author on the subject, ‘it is important that the mindset of reducing attrition in development should be in place from the earliest stages of discovery.[...]Scientific and technological innovations that affect efficacy and safety (factors that most significantly contribute to attrition in the clinic) will have to be addressed’ (KolaKolís and Landis, 2004, pp. 713–14).

Indeed, this flaw has been highlighted by SGC researchers themselves. In a commentary piece in *Nature*, Edwards introduces, and provides bibliometric evidence for the idea that peer review is a contributing factor to a conservatism in science that may contribute to a lack of more radical and untraditional approaches to science (Edwards et al., 2011). As will be documented later in this report, the SGC has had success in broadening the scope of research on proteins. This could be attributable to the SGC’s ability to allocate funds on the basis of a non-peer-reviewed process, although this remains an open question, subject to evaluation. Indeed, it is an apt place to conclude this literature review and lead us directly into the evaluation data collected.

Conclusion

Before moving to the findings of the evaluation and our analysis, it is worth reflecting on the insights of this review of the literature as they relate to our original questions. First, we discussed some of the key debates about IPR as revolving around the question of whether granting IP rights on early research fosters or inhibits research and innovation. A different but not unrelated issue is whether the trade-off of ‘openness’ in research is made up for by the success of small biotechnology companies in developing new technology. There is significant literature on the alternatives to patenting and the basis upon which patenting regimes should be constructed. In particular, open innovation, broadly defined, has now become acknowledged as an important feature of the pharmaceutical innovation landscape. What this discussion demonstrates is that although there is no definitive consensus amongst authors about the role of patenting on health research and innovation, there is a vibrant critique from a number of angles on the possible dangers of ‘anti-commons’ and the potential benefits of a more collaborative approach to research and innovation.

With regards to the question of whether there are initiatives that are comparable to the SGC it is clear that the SGC is unique, although it shares characteristics with a wide range of other ‘open innovation’ partnerships and collaborations. While it is unique, then, it is a part of a trend. Much of the grey and peer-reviewed literature suggests that this trend exists because there is a widely acknowledged crisis in pharmaceutical R&D.

There seem to be two distinct trends emerging in pharmaceutical R&D. One is based on biotechnology, venture capital and IPR, and the other on more openness and collaboration at pre-competitive stage. There are grey areas where these two trends converge but the logic behind each of them is distinct. The exchange between IMI and *Nature Biotechnology* referred to earlier in this chapter is indicative of the tension between these two models. Finally, there are broad system level issues concerning the nature of the way science is funded and incentives in public and private sectors and there are different perspectives on what works. With this background in the literature now in place, we move to presenting the findings of data collection element of this evaluation and the different perspectives of a range of stakeholders on the SGC.

Chapter 3 The SGC as a model for investing in knowledge: Perspectives on the approach

Three spheres of knowledge

The next three chapters aim to distinguish between the different ways in which we found ‘knowledge’ to be produced and further utilised by the scientific and research efforts of the SGC. Our analysis points to three interrelated yet conceptually distinct spheres of knowledge which emerge from the SGC’s efforts:

- *The SGC as model for investing in knowledge:* this sphere relates to what the motivations and rationale for investing in the SGC are from the perspective of those who are engaged in it, including funders, SGC researchers and external collaborators/stakeholders.
- *The SGC as a model for generating knowledge:* this sphere relates to perceived strengths and weaknesses of the SGC model as it operates in practice
- *The SGC as a model for extracting value from knowledge:* this sphere relates to the value which comes from both the investment and generation of knowledge.

In presenting our findings in relation to these spheres of knowledge, we hope to draw out a more nuanced discussion about the role of the SGC as a unique model for the production of scientific knowledge. We hope this framing moves the discussion away from the question of how the SGC might be funded in future, to that of how best to maximise the different ways varied actors find the SGC model to be of value for them. Indeed, once these perspectives are set out, one can begin to consider what their intersections might mean for the future of the SGC. This synthesis is taken forward in Chapters 6 and 7.

This chapter about investing in knowledge aims to set out incentives and disincentives for investing in the SGC model from the point of

view of SGC researchers, past and present funders and external stakeholders in the wider chemical and biological science landscape. It draws on key informant interviews with these groups, as well as a survey of SGC researchers. This chapter is particularly concerned with the SGC as an open innovation research model and focuses on how the characteristics of an open access, public-private partnership may influence decisions to invest in or become a part of the SGC as a collaborator. The strengths and weaknesses of the SGC more specifically, as well as opportunities and challenges, will be explored in the following chapter on knowledge generation.

Incentives for investment

This section explores the motivations that different groups of stakeholders have for investing in the SGC. These include both public and private sector funders, potential funders, and SGC researchers. Incentives which were discussed across the groups covered a range of topics from which the following central themes emerged: open access, collaborative research and networks, ‘de-risking’ of new areas of science, ‘industrial’ focus and rapid and efficient research.

Open access has many desirable knock-on effects

Fundamental to the SGC model is a strict open access policy, whereby all research findings are made publicly available before publication and none of the work is patented (should a patentable product arise). This aspect of the model makes the SGC unique as a public-private partnership in this field and creates a number of desirable knock-on effects, including fostering wider societal benefits, maximising the opportunities and efficiencies of further research, improving the competitiveness of

the field, proving the feasibility of open access and enabling funding to be secured. Each is discussed in turn.

Open access was considered to be a strength of the SGC by four researchers and five funders who felt it helped to create wider societal benefits and maximised the opportunities for further research (which builds on research conducted by the SGC). This could occur either through the pharmaceutical sector taking the research forward in-house to explore new targets, through enabling further research in the academic community, or through facilitating and speeding up new collaborations,⁷ which themselves would lead to new research. One stakeholder put it this way:

It is one of only a few public-private partnerships that operate in pharma with an open access capacity. The capacity of SGC to engage pharma in this way is a real strength. It is an exemplar of business and academia working together (F7).⁸

There are many examples throughout the SGC research portfolio that were reported by interviewees in which the research conducted by the SGC was taken forward quickly and more efficiently as a result of the open access policy (see also Chapter 5). One example involved the SGC research group in Oxford publishing a structure, in *Science*, which another academic research group used to conduct research on a yeast protein. This sharing of information saved the group months of time on research and led to better scientific outputs (R7).

In another case, the SGC's work on the JQ1 probe catalysed further research in the field. As additional data were gathered about this probe and related protein families, further research areas were developed. In addition, though it is difficult to make any specific determinations of proportional attribution, the initial research did play a role in the establishment of Tensha Therapeu-

tics, which is now building on the JQ1 research to develop clinical targets. In another example of further research opportunities being realised, a researcher told us that Constellation Pharmaceuticals and The Leukemia & Lymphoma Society Partnership plan to develop a novel BET inhibitor for the treatment of hematologic malignancies.⁹ The researcher pointed out that again attribution would be difficult to quantify, but they felt there was a clear contribution of SGC research and that it was an interesting example of work being taken forward in a field the SGC (arguably) helped to catalyse (R17). Another collaborator also felt assured of the clear contribution, reflecting on the fact that working with the SGC had led to tangible, specific benefits for his research lab, including contributing to their ability to win further funding. The researcher attributed this in large part to the open access approach.

Without SGC support it would have taken years to achieve the results and get the enzyme. SGC's open access policy meant knowledge and outputs could be shared to further the science in my laboratory, which in turn helped me to secure further funding for my laboratory (E3).

These kinds of contributions are difficult to quantify in part because of the nature of scientific research, which builds cumulatively and often on many different findings. It is also difficult to identify any counter-factual data. Nevertheless, several examples of efficiency in the research process, improved research outputs, and new areas for drug discovery, were highlighted across the collaborators, funders and researchers we spoke with and all attributed this in part to the open access philosophy of the SGC. Indeed, five researchers, nine funders and four external stakeholders explicitly mentioned the importance of generating publicly available structures for the field in relation to the SGC's work.

Related to this, five private sector funders explicitly stated that they viewed open access to be important for science, writ large. One pointed out

⁷ Collaborations are discussed further on pages 23 and 29.

⁸ All examples given in Chapters 3–4 are illustrative and paraphrased. All interviewees were given assurances of anonymity and that no directly attributable quotations would be used in this report. We will not provide any identifiable information other than designating whether a stakeholder was representative of external stakeholder views (E), was an SGC researcher (R), or was a funder, past or present (F) of the SGC. The numbers represent the unique code given to that individual.

⁹ <http://www.constellationpharma.com/2012/09/constellation-pharmaceuticals-and-the-leukemia-lymphoma-society-partner-to-develop-novel-bet-inhibitor-for-the-treatment-of-hematologic-malignancies/>

that open access policies mean the whole field can be more competitive (F16), while another used the analogy of trying to get from point A to point B and pointed out that in his view everyone would get to point B faster if they pooled their money and travelled halfway together (F10). A third believed that open innovation was the future and commented on the fact that in his company there was a wider internal philosophy about the need to engage in open innovation and use it as a way to develop chemical probes and validate targets (F5).

The SGC model, then, goes some way towards proving the feasibility of open access collaborations between large pharmaceutical organisations and the public sector in the pre-competitive space. Twenty interviewees across the three stakeholder groups stated that an important system-level impact of the SGC was that it showed that this new model of R&D can work. This in and of itself was stated as a reason to invest in, or be a part of, the SGC. Moreover, the fact that the SGC is unique was cited as a reason for investment by eight funders; particularly the way in which open access and the partnership enables collaborations across the public and private sector, allows access to public and private funding and permits the release of data into the public domain. It is important to note that open access is fundamental to these benefits, and the pre-competitive, open access model may become more important in the future (see Chapter 6).

Finally, many stakeholders also thought open access was particularly important to the ability to secure public funding and to incentivise the private sector to invest. One researcher (R2) commented that ‘the public funding allows us to focus on societal impact rather than private benefit’, and another (R3) stated that without public sector funding, people would not believe that the SGC was truly open access. However, this view was not equally expressed across all interviewees, in particular the public funders, and may suggest that the connection between the public sector, open access and the SGC contributing to the ‘public good’ may not be enough to incentivise sustained public sector funding in the future. This is explored in much greater detail in Chapter 4.

Collaborative research is enhanced and access to a global network provided

The collaborative research opportunities and access to a global network in core areas of structural biology expertise were cited as key reasons for investment in the SGC by most researchers, the majority of the funders and some external stakeholders. One funder pointed out that a broad collaborative network is important because it widens the pool of expertise (F4). Indeed the extensive range of collaborations the SGC facilitates and draws upon produces a number of benefits for the SGC and its associates. These collaborations and resulting benefits are explored further in Chapters 4 and 5.

One reason that the SGC’s collaborative network is particularly appealing and, therefore, is an incentive for investment, is that one can easily make the most of the SGC’s collaborative network because of the open access format. This format means that it is very easy to set up collaborations without worrying about contracts and legal issues, as one funder remarked (F15). In particular, the majority of private sector funders stated that links to a global network of expertise in the area of epigenetics was especially important. For the majority of pharmaceutical funders, in-house epigenetic capabilities were relatively underdeveloped prior to joining the SGC. Therefore, the ability to draw on world-class expertise in this area through the SGC’s networks, as well as benefit from knowledge exchange between other funders, has allowed them to develop this area more quickly than would have been possible if they were dependent on their own resources and skills. However, it is important to note that this is just one area in which networks and collaborative relationships were particularly valued and the benefits of a networked model extend beyond this. The view of one private sector funder is representative of many of the others in this respect:

We [...] recognised that we needed [...] a lot more infrastructure in epigenetics which we didn’t have here. In order for us to get up to speed with other pharma companies we needed to join the SGC. We are now forming an epigenetics area with expertise. Another benefit of joining the SGC was [...] the network one buys into beyond the SGC that allows us to look at [the wider] probe community in academia (F15).

New areas of science are de-risked and readily linked to strategic initiatives

Many private sector funders highlighted the importance of the SGC model in helping to ‘de-risk’ new areas of science as a reason for investment. In particular, the majority of pharmaceutical funders used the epigenetics programme as an example of this ‘de-risking’ effort, and it was clear that the SGC’s decision to conduct epigenetics research was a significant factor in their decision to invest in the SGC. The reason given for this was that epigenetics is a new and developing area of biology and joining a consortium offered gains in this area at relatively little cost.

One funder commented that they had been trying to move into epigenetics and the SGC involvement represented a way to get started on the research more quickly than would be possible by conducting the research alone (F4). Another expressed a similar view when stating that epigenetics was one of two main reasons to invest in the SGC (the other being open innovation). The fact that the scientific area was underdeveloped meant that the idea of ‘a pre-competitive forum joining together to research in this area seemed like a good idea’ (F5). Yet another funder commented that epigenetics research would have been difficult to ‘start from scratch’ and by joining the SGC they had ready access to that area of work (F10).

Although researchers did not specifically comment on the benefit for funders in exploring epigenetics through the SGC, they did outline what they thought were the considerable cost savings for pharmaceutical companies. One researcher stated:

It would take them [pharmaceutical companies] six months to do the same job, which can add up to hundreds and thousands of dollars. They benefit from our capabilities and often we simply can’t complete all our requests for work (R8).

These examples demonstrate the kind of advantage that a pre-competitive consortium like the SGC can have as it obtains public and private funding, which enables shared risks when exploring new and complex areas of research. The SGC model in particular is useful for industry in this regard given that funders are all represented on the SGC board. Therefore if new areas emerge that are of interest to them, they are able to express the

desire for a new scientific direction at the board level, thereby not only enabling scientific advances but also determining where these advances should be made.¹⁰ Thus, the way in which the SGC model operates provides potential gains for industrial partners.

However, what is less clear, and potentially problematic for the SGC, is the fact that public funders may see the private sector’s interest and investment as a sign that the area in which the SGC is operating in is being de-risked and subsequently signal their intention to leave (as classical market forces might suggest). Although the concept of de-risking was only highlighted in relation to the private sector in our evaluation, we believe that the public sector could also view the SGC as a means to de-risk new scientific areas it believes are of strategic importance and that it wants to engage the private sector in (in situations where market forces may be failing). This analytical point is picked up further in Chapter 6, when we consider potential futures for the SGC, and in our conclusions.

Closely linked to the incentive of de-risking new areas of science is an incentive around the alignment with ongoing strategic initiatives within a company, public funder or collaborating organisation. As discussed above, some funders commented that open innovation was part of a new strategic initiative within their companies and so joining the SGC aligned well with that. Others commented that the SGC, particularly at the beginning, was directly aligned with ongoing major initiatives in the wake of the human genome project. In particular, the SNP Consortium and the Human Genome Project itself were seen as immediate precursors to the SGC and that the SGC was the ‘natural next step’ in making use of all the data coming out of human genetics (F14). It was also seen as aligned with major infrastructure projects, including the Diamond Synchrotron, which was being built near Oxford. This philosophy also applied to external collaborators. Many said they were drawn to working with the SGC because they shared a similar ‘scientific philosophy’ and approach (E4).

¹⁰ However, this flexibility in scope also has its weaknesses, which are discussed further in Chapter 4.

The SGC enables rapid and efficient research processes

Many stakeholders cited as an incentive the fact that the SGC enabled rapid and efficient research processes. There are two elements to this incentive. First is that the majority of interviewees felt that research happened more quickly in the SGC than in either academia or industry, and this was a significant strength of the SGC. The speed and volume of SGC research is enabled at least in part through open access, the collaborative nature of the model and the ability to collectively de-risk new areas as outlined in the sections above. Indeed the contribution of the model in this regard was highlighted by an external stakeholder who stated that the model educates people more rapidly and allows innovation to occur more quickly than it otherwise would (with regard to epigenetics and making tools for target analysis and then disseminating them into a wide academic population) (E8). Therefore, potential commercialisation is accelerated and enhanced. This may act as an incentive for investment (or for re-investment) and will also be explored in relation to knowledge generation in Chapter 4.

The second, related, element is that several funders also reported the SGC's approach to using an 'industrial model' for research was an important factor in their decision to invest in the SGC. Though this incentive is a specific feature of the SGC open access model and so will also emerge as a strength of the SGC to be discussed in Chapter 4, it was mentioned specifically in several interviews in relation to an investment incentive. This means that the SGC possesses several characteristics of an industrial model, with milestones and targets determining the scientific outputs. One funder member commented that it has a 'company ethos' (F6), and not only this, but it operates on a large scale, accessing a wide range of expertise and resources which would not be available to a small laboratory. This is perceived to have a considerable impact on the efficiency and volume of SGC research, resulting in outputs which could not be produced in academia alone (F13, F14). Another funder highlighted the link in funding the SGC to the organisation's commitment to investing in scientific capacity development in the funder's country. Their assessment was that the SGC had real potential to make an important contribution to scientific infrastructure and resources both nationally and globally (F12).

Disincentives for investment

This section is concerned with potential disincentives for investment as identified by SGC researchers, funders and external stakeholders. These include the flip side of open access, which results in unprotected intellectual property from any findings and a perception of limited spillover effects for the wider scientific community.

Unprotected intellectual property as a disincentive

The issue of unprotected intellectual property was raised as a disincentive for investment by five private sector funders of the SGC. This was primarily due to problems open access causes in creating 'buy-in' within the wider organisation as well as a shared sense of fear over losing a competitive advantage. Others pointed out that though the SGC's open access policies were not currently prohibiting their full engagement with the SGC, it was something they 'constantly' had to discuss with their legal teams (F15).

In addition, three researchers raised the issue of unprotected IP prohibiting external engagement with the SGC, although this was primarily in reference to working with small biotechnology companies that rely heavily on the ability to claim intellectual property. However, one funder commented that at the time of funding the SGC, there had already been a shift within the pharmaceutical sector toward pre-competitive research and the sharing of findings. It was only a matter of time before the industry was moving towards more open access further downstream (F8). Another posited that in the near future there would be a model of drug discovery in which there was no intellectual property claimed until phase two clinical trials (F15).

Intellectual property restrictions were not only considered to be a concern for the private sector. One public sector interviewee noted that in recent times there has been a trend for universities and academics to be more protective of their intellectual property and more aggressive patenting, which may hinder the establishment of productive collaborations (F6). However, this view was not reflected in interviews with academic collaborators and the majority of SGC researchers who were interviewed commented that open access was a positive aspect of the SGC from all angles. This

apparent contradiction may reflect a divergence in the experiences of university researchers, and research managers, including those in the public sector.

Despite the challenges of unprotected intellectual property, the continued investment of pharmaceutical companies in the SGC does suggest that the challenge of unprotected intellectual property is outweighed by the benefits afforded by joining the SGC. One researcher (R12) provided an example to illustrate this involving a young researcher who approached the SGC to pursue a drug discovery project. Upon hearing that all parts of the research project – including potential products and research findings – must remain open access the researcher hesitated before stating that they would happily forego patent protection and potential commercial exploitation for an opportunity to work with the SGC. This resonates with statements made by funders and external stakeholders (as outlined above) who stated that open innovation was a likely part of any future drug discovery model.

A perception of limited economic spillover effects for publicly funded science

Public funding of the SGC has been decreasing in recent years. Two of the five public funders we interviewed (who represented both previous and current funders) cited limited economic and societal spillover effects as a disincentive to fund (or continue funding) the SGC. Such regional and national effects of the SGC are important to public sector funders, who see these effects as particularly linked to the SGC's physical location. Thus, although impacts on the scientific community were acknowledged as important elements by these public funders, and indeed as an incentive for funding the SGC, they also expressed a desire to see impacts on innovation and the economy to justify sustained funding of the SGC.

However, it is important to note that a lack of economic and societal spillover effects was not cited as a weakness or a disincentive by all public sector funders. Indeed, one funder acknowledged that there was likely to be a significant time lag between SGC discoveries and the development of therapeutic products, which in turn would stimulate innovation and have wider health impacts. Equally, some public sector funders pointed out

that they valued spillover effects to the wider scientific community, with or without economic spillovers. This difference in views simply demonstrates the difficulty the SGC has in meeting the needs of each individual funder. Though there are some common features across the incentives and disincentives, ultimately a balance will need to be sought between the individual strategies of different funders and the broader needs of the field.

A range of success criteria were identified

A final element of the perspectives related to investing in knowledge relates to a question we asked current and past funders of the SGC about the success criteria for SGC investment and engagement. A range of issues emerged with the most frequently cited success criterion being the development of a new research project or internal research programme emerging for the organisation as a result of the investment. It is interesting to note that within this some funders stated this did not necessarily mean a new drug was eventually developed, but rather that there was enough interesting science to merit a new programme of work or a new target that could be pursued.

If we don't have any projects running based around what came out of the SGC but we can guide our future research much more effectively because that knowledge/research is in the public domain, that would be the case I could make (F10).

This applied equally to private and public sector funders, with public sector funders commenting that it would be nice to see the SGC stimulating new ideas or other programmes in the field, in addition to meeting the milestones it had agreed. One funder commented that seeing new collaborations within their organisation as a result of working with SGC researchers was already showing that some degree of success had been achieved (F10). Related to this were success criteria about demonstrating spillover effects and benefits. Two funders wanted to see evidence that the SGC was contributing to the building of localised 'clusters' of knowledge and innovation, which may lead to economic growth and contribute to building world class expertise in particular geographical locations (F1 and F2).

The next most frequently cited criteria were about international prestige and maintaining the benefits of the collaborative network, including continued access to high quality probes and structures and building epigenetics capacity (although only one funder specifically mentioned this as a success criteria). Here, many stakeholders commented that, in general, 'success' criteria for the SGC were rather 'soft'. One commented that it was difficult to answer the question and value the investment as a business case because the real benefits are 'softer in nature and are about personal connections, networking and pushing forward a new model of collaboration' in the field (F3). Finally, some funders mentioned scientific outputs such as publications, structures and research capacity, but these did not

feature as central criteria, and certainly not those which seemed to make people the most excited about the potential of the SGC.

Summary of perspectives of the SGC as a model for investing in knowledge

The table below provides a summary of the findings presented above. We have indicated the relative 'strength' of the perspective across the interview categories using a simple Low (L – less than 1/3 respondents), Medium (M – 1/3 to 2/3 respondents), High (H – more than 2/3 respondents) scale. Shading is used to represent slightly higher or lower strength within the three main bands.

Table 3-1:
Summary of perspectives on investments in the SGC

Perspective on the SGC as a model for investing in knowledge		Strength of perspective across interview groups		
		SGC Researcher (R)	SGC Funder (F)	SGC External Collaborator (E)
Incentives for investment	Ability to participate in open innovation initiative	H	M	H
	Collaborative research and networks	H	H	M
	De-risking new areas of science and linking to strategic priorities	–	M	–
	Ability to enable rapid scientific progress	M	H	L
Disincentives for investment	Unprotected intellectual property	L	M	–
	Limited spillover effects (scientific and economic)	–	L	–
Success criteria for investment	Develop a new research project	–	L	L
	Demonstrated spillover effects	–	L	–
	International prestige and maintaining the network	–	L	–

Chapter 4 The SGC as a model for generating knowledge: The model in practice

While the previous chapter outlined incentives and disincentives for investment in the SGC, this chapter aims to set out the strengths, opportunities, weaknesses and challenges specifically in relation to the SGC as a model which generates knowledge for the field. These areas are interwoven with incentives and disincentives for investment in the SGC. However in deliberately separating our discussion of the two into discrete chapters, we hope to understand how far perceptions of the model prior to investment align with the way in which the SGC operates in practice. Importantly, in this chapter we provide an extended discussion about the sustainability of future funding for the SGC and the perceived benefits that both private sector and public sector funders bring to the SGC's model of generating knowledge for the field (see page 35).

Strengths of the SGC model and opportunities for the future

Across the different perspectives in the evaluation a number of interrelated strengths and opportunities for the SGC were highlighted, including the role it plays in enabling collaboration and maintaining strong research networks; providing rapid and efficient research outputs and processes for the field; having an industrially oriented, flexible research model with strong leadership; and being able to produce strong, world-class science. Strengths are discussed first before we move to the opportunities, though there is some overlap between the two categories.

The SGC enables collaboration and has strong research networks

Along with world-class scientific expertise, the extensive collaborations between academia and industry were the most frequently mentioned

strength of the SGC across the three stakeholder groups (34 out of 44 interviewees, including 17 researchers, 10 funders and 4 external stakeholders). One external collaborator summed it up very simply, stating that 'SGC has an amazing consortium of world class expertise' (E7). One funder (F10) recalled that it was their understanding that the integration of the public and private sector was carefully considered when the SGC was established. More specifically, the SGC considered how the private sector could benefit from the consortium without involving intellectual property, as well as where the private sector could add value to the consortium aside from the provision of funding. This included their expertise in designing molecules or assays for target validation, their commercial focus which would help to drive drug discovery, and their need for reproducible science. Both researchers and private sector funders found the collaborations and networks to be one of the biggest benefits of the SGC.

SGC's open access model has big advantages for research. It makes it easier for collaboration between laboratories, industry and biotech. It is just easier to do everything; all partners need to do to get these benefits is comply with the open access model (R15).

The main benefit is knowledge transfer and fantastic links to academics. All of the academic collaborators have been [...] of the highest order. [...] Academics have acted as the glue which brings scientists together externally and internally. Without the open access ethos this depth of collaboration would have been impossible to mobilise. There is world-class expertise available en masse (F5).

Not only are the collaborations of high quality, but many attributed the breadth and depth of the networks to the open access model. More spe-

cifically, open access enables collaborators to circumvent restrictions imposed by protecting intellectual property, allowing them to occur quickly and easily without long delays caused by internal restrictions. Several interviewees told us that outside of the SGC, there are often delays of at least six months (for simple cases) in establishing collaborative working relationships between research groups. We were told that these negotiations can involve multiple manpower days involving legal teams, researchers and administrators, and could potentially result in lost time spent on the science. By contrast, collaborations which occur through the SGC have a very small and in some cases no lag time. A good example of this was provided by an SGC researcher who stated that the SGC was sent 32 clones of targets by a pharmaceutical company, and all it required was one signature on a simple document, after which the clones were sent within a week. This is not only an example of a short time lag, but also of a very rare sharing of materials between the pharmaceutical industry and an external body which would not ordinarily take place. An external collaborator and funder of the SGC both had similar views, with each stating, respectively,

Open access is great so we have lots of easy collaboration. No MTA [is great]. Very free flowing [knowledge and resource exchange] and low overhead in terms of managerial expenses (E4).

Another intangible benefit is the connection to academic institutions which is down to the charity aspect of the SGC. AI can set up research agreements with a handshake to the SGC and we get access to this information as a part of the SGC. If [our company] tried to do it, it would take 9 months of legal agreements. So actually despite the open access plan, we have really benefitted being a part of the SGC as a member (F11).

Moreover, two interviewees specifically stated that their organisation had become more collaborative as a whole as result of the successful and valuable collaborations facilitated through the SGC (F3 and F10). The speed of sharing and collaboration is attributed, then, to both the open access and specific model and reputation of the SGC, thereby underscoring the unique nature of the SGC model.

These collaborations provide access to a vast range of different kinds of expertise. Though it is becoming more commonplace for academia to collaborate with industry, there are difficulties in doing so, despite the benefits of collaborating being appreciated by both sets of stakeholders. One researcher commented that academics are particularly good at focusing on their own study systems and the type of expertise they possess takes years of work and practice, which can be drawn upon by the SGC (R4). Similarly, a private sector funder stated that academic collaborations through the SGC have been of the highest quality and the organisation has benefitted through crowdsourcing academic knowledge (F5). Similarly, an external interviewee made the point that diverse perspectives and expertise were critical to the successful generation of new ideas for science.

When tackling fundamental scientific questions we need a diverse array and range of views. Science is facilitated when we bring diverse views together. We generate much more innovation this way (E9).

Following on from this, collaborations mean that work can be undertaken which could not be carried out by either industry or academia alone. For example, in the area of epigenetic probes, the SGC relies on academia to validate targets – which is an essential step in declaring they have a probe. This draws on the narrow expertise and experience of academia, enabling its practical application. Another example relayed by two different SGC researchers is the partnership between the SGC and Discover X, a biotech company. Here, the SGC works with Discover X to support assay development and Discover X goes on to develop compounds and use the assays for testing. This results in quick and efficient results, co-publication and validation of the assay system. Several other interviews revealed further examples, in particular with biotechnology companies, where the collaboration between the SGC, academia, and the industry partner resulted in much more efficient and targeted research for the company, leading directly to improved commercial products.

Another aspect of the strength of the SGC's networks and collaborations, which was particularly valued by SGC researchers, is that they can facilitate dissemination, and potentially wider

impacts, of SGC research. One researcher stated that the importance of engaging with academics was two-fold: first it helped them to draw on expertise for particular structures and second, once the structures were publicly available, those structures can be quickly disseminated through the academic networks and used by leading experts in the field (R3). Another researcher made a similar point regarding industry collaborations. When asked if it would be desirable for more expertise to be brought in house, they responded that maximum impact occurs through links with industry and therefore collaborations serve as an important dissemination tool (R1).

Aside from those outlined above in terms of access to expertise, there are significant benefits for collaborating organisations themselves. According to our survey of SGC researchers, benefits include easier access to research materials which would have been difficult to obtain if working outside of the SGC network (88%, $n=17$), improved efficiency and/or reduced costs (76%, $n=17$), increased reputational benefits ($n=76\%$, $n=17$) and expanded R&D activity (71%, $n=17$). It is important to note that not one respondent suggested that collaborating organisations had not received any benefits as a result of collaborating with the SGC, and the number of respondents identifying a range of benefits was relatively large.

Finally, close collaboration and networks help to prevent the duplication of effort among pharmaceutical companies. In fact, this was one of the original aims of the SGC: to reduce duplication and improve the efficiency of the science. One researcher stated that a pharmaceutical organisation took the decision not to work on a drug target after learning that another organisation was pursuing work on that target with the SGC. Instead, the organisation is waiting for the SGC to produce the chemical probe before they start work on it (R12). If the SGC did not exist, these organisations would be more likely to pursue the same lines of discovery independently, underscoring the efficiency afforded by the SGC. Though we were not able to quantify this in this evaluation due to resource constraints, one can safely conclude that at least in some instances, overall costs to both public and private innovation efforts would likely be higher in the absence of the SGC and thus there would be a negative impact on drug discovery.

The SGC produces high quality, rapid and efficient research outputs

Following directly on from the point above, eleven researchers, four funders and three external stakeholders believed that research in the SGC is more rapid and efficient than in other research settings. Our survey of SGC researchers yielded similar results, with 82% of respondents stating that they believed their research had come to fruition more quickly than it would have done if it had been supported by traditional academic approaches. The most frequently cited reasons for accelerated research translation in the researcher survey were high quality collaborations and an integrated approach, the lack of need to spend time writing grant proposals, and the efficiency of SGC processes. Other reasons which emerged from the interviews as to why people thought the SGC may be faster and more efficient at research were related to the lack of IP, the importance of a highly interactive research process which is accelerated through open access, and the fact that the SGC is streamlined and narrowly focused, with a strong 'company ethos' and industrialised research processes (see below for further discussion of this latter point). Included in this latter point is the issue of 'reproducibility'. The high level of quality science produced by the SGC was thought to be an important element of the SGC by a wide range of stakeholders – a key element of which is the 'reproducibility' of SGC research. The ability to re-produce experiments conducted by the SGC and obtain the same results is particularly important for the pharmaceutical sector given that it enables them to incorporate SGC research into their existing programmes with relative ease.

When discussing the importance of this efficiency, there were multiple views expressed about why it was an important element. One external stakeholder commented that the emphasis should not be on relative 'speed', but rather on the fact that the SGC model, and other open innovation or public-private partnership initiatives like it, enabled a 'more efficient use of knowledge' (E9). Another stated that the model 'educates people [about tools to go with target analysis] faster and innovation comes out quicker. The potential commercialisation is accelerated and enhanced' (E8).

More efficient use of knowledge can also result in cost-savings for pharmaceutical partners (see

also discussion in Chapter 5). Indeed value for money was highlighted as a strength of the SGC by two researchers and five funders. One pharmaceutical funder outlined the value for money for their organisation as follows:

We can do things because we are part of the SGC that we can't do on our own or simultaneously. It's cost-effective when you think of how much effort and expertise we're buying for the money we put in. We couldn't invest that much internally and get so much out of it (F10).

With this in mind, the SGC model of drug discovery may become more prominent in the future. According to one public sector representative the individual mode of research (whereby pharmaceutical companies pursue their own research internally and run the risk of duplicating efforts) is a 'waste of money'. As such, it was felt that the SGC model is likely to continue for the next five years, and will become increasingly popular from an economic point of view (F6), particularly as one recalls that not only are costs shared through the SGC model, but the 'rewards' of the research findings are too, and not just with the board members, but all members of the wider scientific community. Moreover, the speed at which research findings are made available in the public domain means that potential commercialisation is accelerated and enhanced, as outlined above.

It is worth noting, though, that when it came to discussing speed and efficiency, not everyone felt this was a strength. One funder commented that for the amount they put into the SGC, and when considering the specific areas of disease they were interested in, they could determine the protein structures much faster and more efficiently on their own. However, when it became apparent that the SGC were also going to work in probes and epigenetics, this became much more appealing to them because they did not have that expertise in house and needed to 'catch up' with the rest of the field (F15).

The SGC is an industrially oriented, flexible model with good management and effective leadership

One of the reasons that many stakeholders felt the SGC was able to be more efficient than other research models were because of its industrially

oriented, flexible model of research which was well managed and led. All three elements are related, but will be discussed in turn. First, the industrially oriented model of research was considered to be a strength of the SGC's model by five researchers, five funders and two external stakeholders. One external stakeholder commented:

The SGC model is all about scale and speed. They look at thousands of proteins and may be successful in exploring hundreds. They have an industrialised approach to research which means everything happens quickly (E5).

Similarly, a public sector funder felt that it was able to drive forward research and develop links with industry because of this 'industrial perspective' where 'the advantage is discussions and work are not purely academic and there is a clear industrial edge' (F2). Another stated that 'research happens quicker through SGC because researchers are pragmatic, hard-working and very able. The research is similar to industrial research with a clear focus' (F3).

Related to this is the SGC's oft-commented-on ability to consistently produce high quality science. One funder went so far as to claim that the role of the SGC in bringing an industrial perspective to research was to decrease 'scientific pollution' in the field:

The majority of experiments [published in the scientific literature] are not reproducible and the quality of presented findings is often lacking in quality and rigour. Mostly this does not impact negatively on the individual academics but has quite profound implications for the advance of science and drug discovery overall (F9).

This is directly linked to the fact that the SGC is able to produce 'reproducible science'. Two funders explicitly stated that a clear advantage of the SGC was that their science is 'reproducible' and so could easily be incorporated into a company's drug development process (F9, F11).

The second aspect of the research model is flexibility. Given the scale, resources and large number of collaborations the SGC has, it is afforded a high level of flexibility, which was outlined as both a strength and an opportunity to exploit by nine researchers, six funders and three external stakeholders. One researcher highlighted that these characteristics allow the SGC to adapt to new sci-

entific areas – such as drug discovery, protein production and structure determination – with ease (R16). Another pointed out the flexibility coupled with the focused nature of the science allows the SGC to exploit economies of scale and networks in exploring new scientific areas (R18).

While the intellectual and scientific flexibility the SGC has in moving into new areas is clear, several researchers also highlighted the flexibility of the SGC as helping them to engaged and work with a range of diverse collaborators. One researcher stated: ‘The SGC tries to work with academics in the same way academics work with academics. We have to be flexible and understand the constraints there are as a consequence of that’ (R3).

Another researcher stated that the SGC was unique in being able to engage with industry and academia in a way that would not be possible in any other setting (R17). The SGC’s flexible approach to collaborators enables a large range of diverse networks and collaborations, which in turn affords the SGC the chance to be flexible in approaching new scientific areas.

Finally, of those interviewed, good management and effective leadership were considered to be core strengths of the SGC by nine researchers, thirteen funders and two external stakeholders, and 65% of SGC researchers who undertook the survey highlighted effective leadership as an important aspect of the SGC. Whilst the SGC model was considered to have a large number of strengths, which alone provides incentives for investment, the leadership was thought to be essential to making the SGC a success in practice. As one funder put it: ‘although the model is good and effective you need the people in place to lead and make it happen’ (F3). The diversity in the backgrounds and strengths of the SGC’s three leaders were particularly valued and the ability and drive to secure such large amounts of funding from the consortium was highlighted as an important skill for the SGC. The majority of researchers were also particularly positive about the management structure with one head of the SGC overall, and a site leader at both Oxford and Toronto.

The SGC has strong science and access to shared resources

It is difficult to make a cause and effect link between the strengths above and the simple strength of the SGC’s scientific capabilities and outputs, but it is

clear that all are closely intertwined. The majority of all stakeholders commented that it has both within its own researcher pool and through its networks a proven track record in world-class structural biology. As one funder put it, the ‘SGC has a record of excellence in science. Linking to a high quality scientific network is a key strength’ (F3). This track record that it has built up is borne out in the number of publications it has and the volume of proteins and probes it deposits in public databases. These outputs are all discussed in Chapter 5.

However, it is also important to note that most stakeholders were quick to point out that the SGC’s real strengths were in relation to structural biology, but not as much in other areas they were currently working in (probes and epigenetics). It was felt by several stakeholders that the SGC would be missing an opportunity if they moved too far away from the core work of structural biology. ‘As a consortium they are the best structural biologists in the world. They are not the best chemical biologists in the world although they are very good’ (F10). This issue was raised by many stakeholders and is explored further on page 38.

The SGC has an opportunity to help expand pre-competitive research horizons

The SGC is part of a wider trend which seems to be forging the way in pre-competitive research in the drug discovery landscape. In order to build on this, ten interviewees from across all three stakeholder groups believed that the SGC could further exploit the opportunity to expand the pre-competitive boundaries of drug discovery in the future. Eight funders believed that the nature of science is such that it was inevitable to have a greater shift towards pre-competitive models in drug discovery, and one researcher noted that the SGC has only ‘scratched the surface’ in terms of pre-competitive research. This was not only due to the changing nature of collaborative research but also because of the growing complexity of the biology.

SGC has played a valuable service in pushing the boundaries of pre-competitive research through its own activities and also the open access pre-clinical trials they advocate. Pushing back the boundaries is desirable. These

kinds of public-private models will become more usual and the pre-clinical model will further move down the drug discovery pipeline [...] the sheer complexity of biology research [makes this inevitable]. It is becoming increasingly difficult for the researcher working in a lab to really make progress (F7).

Others echoed the views that pre-competitive boundaries should shift, with one funder stating that they should shift as far as the end of phase two clinical trials given that that is where most drugs fail (F15), and another external stakeholder commenting that all clinical trial data should become publicly available (E8). Not only were there broader changes in the field which meant that pre-competitive research was more likely, but there was also a view that the SGC's open innovation model was particularly appropriate given the structural biology focus of the SGC. It was felt this area was particularly important to have companies involved in openly working together.

This is a big change in the way companies are generating data. Companies have previously held on to information in the past, then would embark on drug discovery programmes without a sound foundation. With the SGC, it makes the foundation for drug discovery much stronger (E9).

However, although many interviewees felt that pushing pre-competitive boundaries would be desirable, several were explicit in their view that this was the role of the public sector to help ensure. In other words, the private sector itself was not likely to provide the catalyst for pushing the boundaries. Similarly, and in relation to this point, one interviewee stated that the development of pre-competitive models depends on public sector support – otherwise they will 'wither' (F4). Moreover, a number of external stakeholders and funders stated that defining the pre-competitive boundary is a difficult issue and a definition of it was itself, a 'moving target' (F3).

Thus, while the mega-trend was towards more collaboration (and this was mentioned by several interviewees), there was a question as to what the limits of the boundary were. Some were concerned that if the boundary is pushed too far, then the competitive edge may be lost and one funder commented that the SGC currently has the pre-com-

petitive boundary in the right place. This is clearly a complex issue which will be shaped by a series of external factors, including price pressures, trends towards outsourcing innovation, openness to flexible approaches, and future downsizing in the economic climate.

The SGC has an opportunity to revisit its scientific direction

The way in which the SGC can quickly adapt to new areas of research, and the ability of pharmaceutical partners to shape the direction of the SGC have both been outlined above. These features of the SGC mean that it has a wide range of opportunities in terms of scientific areas of focus, and there was a degree of divergence among interviewees regarding how the SGC should exploit these opportunities in the future.

Three researchers and three funders stated that they believed significant opportunities for the SGC lay in the area of epigenetics. Expansion into more cellular assays and systems, particularly in epigenetics around chromatin biology, was specifically outlined by one researcher, while others were more general about the need to increase the focus on epigenetics in the future.

However, one researcher and five funders felt that the SGC should consolidate its expertise in the area of structural biology. One public sector funder commented that due to the SGC's diversification, they were concerned that the 'next big thing' in structural biology was not being looked for (F13). A private sector funder commented that although the SGC could deliver chemical biology it would miss an opportunity if it did so because as a consortium they are the best structural biologists in the world (F10).

Other scientific opportunities suggested by a minority of interviewees included molecular probe design, membrane research and the need to take a more systemic look at the heterogeneous nature of disease. In regards to the latter, these comments were not intended to imply that the SGC should do this kind of work on its own, but rather that collectively it could help to push a system-level understanding about how structures worked in relation to disease. Some interviewees also mentioned that the SGC should be researching and investing in big technological breakthroughs in structural biology, and that it should do more to attract philanthropic funders from more research charities.

Ultimately the scientific direction of the SGC will be determined to a certain extent by available funding. However, it is important to note that a tightly focussed mission may be an advantage for the SGC. As one researcher outlined:

At the beginning SGC was clearly defined. The narrow focus was a real advantage. Now SGC is much less well defined and there needs to be a balance amongst the partners. It depends on SGC and it depends on the partners. SGC needs to adapt and be flexible going forward (R16).

Concerns about the extent to which the SGC mission has become more diffuse in the past few years are explored in further detail below.

Weaknesses of the SGC model and challenges for the future

Alongside the strengths and opportunities for the SGC, there were also weaknesses and challenges for the future that were identified. These included a view there were too many collaborators which inhibited the ability to do the science, a perceived lack of professional development opportunities for SGC researchers, too much movement away from the SGC 'core' and a lack of resources to support future growth. As above, we first present weaknesses in the model before discussing the challenges for the future.

There may be too many collaborators

The SGC depends on a wide range of diverse collaborations and the value of these has already been outlined. However, ten researchers and two funders expressed concern about the volume of collaborations, and suggested that the optimum number of collaborations for the SGC may have already been surpassed. These concerns primarily centred on the lack of support staff and resources to manage these collaborations. Indeed seven researchers and two funders commented on the lack of resources in the SGC to support growth. The vast majority of those concerned about the number of collaborations felt that this could be addressed if the SGC employed more staff and acquired the facilities necessary to support them. In these conditions, continued collaborations would be welcomed.

However, it is worth noting that a minority of researchers had more fundamental concerns about

the SGC's growth. One commented that the continued expansion of the SGC was dangerous and another stated that it could contribute to a lack of focus.

Improve the professional development of its researchers

Given the unique nature of the SGC, there was concern among some interviewees that SGC researchers had limited opportunities for career progression within the SGC, and their narrow research focus coupled with a lack of experience in writing grant proposals also meant that they were less competitive in the job market upon leaving the SGC. Worries about the lack of career progression were outlined by three researchers, one funder and one external stakeholder. As one researcher outlined:

The SGC model can also be a barrier for academic career development and continuity funding. For example, it can be a barrier for application of future grant funding because the SGC outputs are less recognised by academic funders or because the researchers are less experienced for academic outputs (R15).

This may present a challenge for the SGC in the longer term, particularly if it results in an inability to attract world-leading scientists or a high staff turnover. If this was the case, the high quality of science produced by the SGC may be affected and this could have reputational repercussions which may go on to affect the collaborative relationships the SGC relies upon.

The greatest challenge is the need for sustained funding

Across the majority of interviewees the single most significant challenge mentioned was the need to maintain a substantial level of funding for the future. Public sector funding has diminished significantly since the SGC's inception and has been replaced with private sector funding, leaving a 1:5 ratio of public to private funding. However, there was considerable divergence among interviewees regarding the importance of the source of funding. Some interviewees believed that a public sector presence was essential to the future of the SGC, while others felt that the funding portfolio could and should be diversified and philanthropic organisations, in particular, could be important

fundors of the SGC. Indeed four funders and two external stakeholders suggested that a significant opportunity for the SGC lay in attracting philanthropic funding. However, several interviewees cautioned against attracting charitable organisations which have their own agenda – thereby serving to further complicate the SGC’s mission, which to date has been disease agnostic (see section below).

Since the main distinction which is made in relation to SGC funding is in reference to ‘public’ versus ‘private’, it is worth reflecting on what our findings revealed about the importance of each in the view of each type of SGC funder and external stakeholders.¹¹

First and foremost, there was a shared view among all funders that the public sector/private sector mix was important. No one felt that one type of funder should provide all the funding. However, a public sector or ‘non-industrial’ presence was considered to be important by private sector funders for two main reasons: first, the presence of non-private funds would keep the SGC research open and in the public domain and second, it would keep SGC research innovative and from becoming too closely aligned solely with the needs and interests of the private sector.

In relation to the first point, funders commented variously that public funders ‘enabled’ the open innovation policy, they created a ‘purifying effect’ and ‘validation’ for the open access model, without it there would be no ‘incentive’ to put research into the public domain, and the public-presence ‘pushes’ the idea that all research is in the public domain (F3, F5, F9, F15). Another believed that without the public sector funding, the scientific community would not believe that everything was being undertaken openly rather than behind closed doors in a ‘smoky room’ (F4). This would damage the reputation of the SGC and it was believed it would make people less likely to want to collaborate with the SGC, which in turn would harm one of the central pillars of the SGC’s model and strengths. This view was also echoed by

some external stakeholders, with one commenting that the public sector funding presence ‘reassured’ people that all the science was open to the public (E5).

Perhaps more interestingly, though, was the second point in relation to keeping the SGC innovative. Here, many felt that without a balance with the private sector interests, the SGC would lose its competitive and innovative edge. This was reflected by funders and external stakeholders in various ways (examples are taken from both public and private sector funders):

If SGC migrates to becoming a pharma consortium with limited public sector involvement it will become more target driven. [...] However, target chasing restricts the capacity to do really cutting edge science because there is less scope for risk. [...] There is a threat the science will become more conservative [...] The involvement of public funders in this sense guarantees a level of innovation. This would be at risk if it were a pure pharma consortium (F7).

Maybe when the industry becomes enlightened and understands the value of participating in the consortium for knowledge building then public funding won’t be necessary (F10).

There is important research and an element of risk which works under the platform. Only private [sources of funding] would lead to lots of arguments and disagreements with a clash of interests, leading to the destruction of the SGC. Public money acts as the referee (F6).

The more private funders become involved the more SGC will get closer to the needs of pharma. SGC needs to make a choice about whether it wants to lead or follow (F8).

We need a collective effort and public/private collaboration across all sectors at a personal level and molecular level. This will all require much more investment than we currently put in (E9).

In addition to these points, it was also believed that public sector funding made it slightly easier to make the case internally within private sector companies to invest, and thereby to secure funds across the consortium.

Public sector involvement is also important for leverage. It is important for an internal fund-

¹¹ Though the Wellcome Trust is, technically, a philanthropic funder, they are commonly grouped into a ‘public sector funder’ category by all interviewees. Conversely, when ‘philanthropic’ funders were mentioned, this typically referred to research charities which had a particular disease or patient focus.

ing argument to show for every dollar of [our] money that one dollar will come from the public sector. This creates a convincing argument (F5).

The funding model is important because it makes it easier to sell to the management. For example, for every dollar of company funding the public sector may provide two [dollars]. The ratio is attractive and it is easy to do. The most important thing is not if the money comes from the public sector or the charitable sector. The major issue is that the funding is 'non-industrial' and from a 'non-profit' (F9).

Similarly, others commented that their organisation did not predict the decrease of public funds which was currently happening, and if it continued it may affect decisions to invest again.

When reflecting on the role of public sector funders, a few expressed concerns about the relative length of time the public sector was expected to invest in the SGC. This relates to the idea discussed in Chapter 3 about 'de-risking' new areas of science, but also reflects the difficulty public sector funders face in sustaining long-term strategic investments. Classically, the role of the public sector is to invest in an area until the private sector feels the area is 'safe' to move into. At this point the public sector moves out as the 'market failure' has been addressed.

It is not much of an incentive to a government organisation that the seed funding is leading to value for private industry. The open access model has been adopted between companies so they would uphold it if they were to take over the SGC (F13).

The old reason that pharma doesn't get the money without public funders coming in isn't valid. Frankly nobody believes it. Pharma must see the value to put in money. All the new funders have put in the money without asking for public funders to come in, so there must be value for them to do so (F7).

Compared to the views on the role of the public sector there was much less reflection on the role of the private sector. This is perhaps because it was generally agreed that the private sector role was to keep the SGC focussed on targets that had potential for further drug development and, thus, economic value. To this end, there was an interest-

ing theme which emerged around the question of whether the public and private sector funds might be conceptualised in different ways. One funder commented that the public sector should fund the structural biology side of the SGC, while the private sector funds the epigenetics program (F1). This would make it clear that the role of one was to fund the science that was more akin to an infrastructure or resource for the field, while that of the other was to fund things more applicable to industry. However, this kind of 'splitting' of the SGC funds does not align with its current model and was not necessarily how private sector funders saw their own role. In addition, some felt it missed the point: 'The public versus private funding debate is less important. It is more about the effort from both parties in realising the goals of the SGC' (F3).

The point here is that open access and the pursuit of open knowledge are incentives for investing in the SGC and the open access initiative was something many interviewees felt was a public good in and of itself.

In addition to these views, there were both positive and negative views about bringing additional funders into the mix. Some feared that bringing in additional funders would be problematic and further complicate the dynamic within the SGC, while others felt that it was a useful way forward:

Expanding the number or type of organisations or funders involved in SGC is not really needed because it adds complexity. If you add charitable organisations to the mix then it adds another dimension to be balanced. You need a broad mix of people with a broad mix of objectives needed from the collaboration (F7).

The way to solve the funding issue would be an endowment. The notion of a rich charitable organisation or individual coming in would be great because it would solve the funding issue and remove the uncertainty (F9).

Finally, although consistent funding is required to maintain the SGC's activities, SGC researchers did note that belonging to an organisation which receives significant amounts of funding can have the unintended consequence of making it very difficult to obtain external grants:

When looking to get funding externally, funders wonder why an SGC researcher would need it (R6).

We get the sense that people assume we have far more research and funding than we do which means that we can't deal with all our collaboration requests. If we do want to supplement a piece of work outside SGC then we are forced to attract other grants and if people feel like we don't need it then they are likely to cut our funding if they need to cut their budget (R1).

With this in mind, the SGC needs to take care to outline that although it requires a significant amount of funding, this does not mean that it has the luxury of conducting experimental research, and would benefit from additional grant funding in certain areas.

It does seem that there are no simple answers to this issue, but it does merit further reflection and thought. It cuts to the core of why different actors invest in the SGC, what they get from it, and how it could be sustained. There are ways to build out these different views and arguments and we develop this thinking further in Chapter 6 when we consider different future scenarios the SGC might pursue and help to shape and in Chapter 7 when we draw together the elements of the evaluation and make recommendations for the future.

Dilution of the SGC mission

The benefits afforded by an open access public-private partnership in relation to de-risking exploratory research have been outlined on page 24. However, although this aspect of the model provides a large incentive for pharmaceutical investment, it was not necessarily reflected as such by public sector funders. Many people noted that the current SGC model is vulnerable to continued diversification, given that it offers funders the opportunity to shape its direction. One public sector funder commented that the 'main weakness' of the SGC is 'too many offshoot activities' which prevent the SGC from focusing on its core strengths. Another public sector representative

was concerned that the SGC may just follow scientific fashions. Indeed aside from public sector concerns, the model may mean that the SGC itself cannot decide its own area of focus, and the private sector may too be concerned about continued diversification if it is not in line with its own requirements.

Underlying this concern is the SGC's funding structure. Although the SGC requires continued funding (and to some extent may need to be pragmatic in securing future funding through a range of sources) it may become necessary for funders to adopt a passive role in allowing the SGC to focus on its core strengths. The ability for funders to shape the direction of the SGC has already been outlined above, in conjunction with the private sector's particular interest in epigenetics. It may be that the epigenetics programme has more tangible impacts for industry (particularly in terms of targets) and so are more appealing for the pharmaceutical sector than basic structural biology. Indeed, in responding to our survey five SGC researchers believed that their SGC research was likely to be involved in further knowledge translation in the coming 6–12 months, primarily due to the nature of work in exploring probes. This suggests a tension between the SGC's core strengths in structural biology and the route to more immediate, tangible impacts.

Summary of perspectives on the SGC as a model for generating knowledge

The table opposite provides a summary of the findings presented above. We have indicated the relative 'strength' of the perspective across the interview categories using a simple Low (L – less than 1/3 respondents), Medium (M – 1/3 to 2/3 respondents), High (H – more than 2/3 respondents) scale. Shading is used to represent slightly higher or lower strength within the three main bands.

Table 4-1:
Summary table of perspectives on SGC as a model for generating knowledge

Perspective on the SGC as a model for generating knowledge		Strength of perspective across interview groups		
		SGC Researcher (R)	SGC Funder (F)	SGC External Collaborator (E)
Strengths	Collaborative research and networks	H	H	M
	Rapid and efficient research	M	H	L
	Industrial model	L	L	L
	Flexible approach	M	M	L
	Good management and effective leadership	M	H	L
	Quality of science	L	M	M
	Access to shared resources	L	L	–
Opportunities	Expand pre-competitive research horizons	L	M	–
	Re-visit its scientific direction	L	M	L
Weaknesses	Too many collaborations	M	L	–
	Limited development opportunities	L	L	L
Challenges	Maintaining funding levels	L	M	L
	Dilution of the SGC mission	L	M	L

Chapter 5 Extracting the value of knowledge: Outputs, outcomes and impacts of the SGC

Understanding the context for SGC knowledge

In addition to the variety of impacts that have been identified through the survey and interviews with SGC stakeholders, there are a variety of impacts that can be quantified to provide some sense of the scope of the SGC's activities. These impacts range from the main outputs of SGC work (such as publications, structures and sequences), through to broader economic outcomes (including monetised outcomes) that are the result of SGC involvement in research.

When considering SGC quantitative outputs and outcomes, there are a number of contextual factors to take into account. These are important since the SGC does not operate in a 'sterile environment' where only the SGC activities relate to the value of impacts arising from SGC work.

As mentioned earlier in this report, the SGC have set a specific task to deliver protein structures that go beyond those already developed in the scientific literature. This means that the SGC specifically targets proteins that are considered more difficult to work with, and therefore any consideration of the outcomes of SGC research should take into account the relative difficulty of the task the consortium has set itself. For example, the SGC's work on human protein kinase structures has delivered structures for proteins that have been systematically under-studied, rather than just focussing on proteins that have existing literature to support structural analysis. The green bars in Figure 5-1¹² show where the SGC has identified protein structures for the kinases shown along the x-axis. This shows how the SGC has developed structures for human protein kinases, regardless of their existing scientific body of evidence (illustrated by number

of citations and publications along the y-axis). This is supported also by the increase in publications around kinases that have had genetic and structural data developed since 2012.

In addition to the stated aim to deliver structures that represent under-studied proteins, the SGC also intends to provide structures that are significantly different from data already maintained in the Protein Databank (PDB), thus moving beyond the determination of homologs to existing proteins. This is important to consider when investigating the quantity of structures produced by the SGC and other structural genomics groups.

Combined with the need to develop novel protein structures, the SGC also work predominantly on eukaryotic (human and parasite), rather than prokaryotic (bacterial) proteins. The data on structures of eukaryotic proteins has proven more difficult to develop than that for prokaryotic proteins. This is shown starkly in the numbers of protein structures identified over time for prokaryotes versus eukaryotes – where the rate of prokaryotes structure identification far outstrips that for eukaryotes (Bill et al., 2011).

While the SGC has set itself difficult tasks, they also work within a complex research environment that affects the outputs and outcomes of the consortium. For example, as noted in Chapter 2, the SGC is not alone in developing protein structures. This means that there is a delicate dynamic to maintain whereby the SGC can work collaboratively with other groups working on protein structures, whilst also working competitively to secure funding to deliver upon their stated goals. This balance is important to maintain if the SGC and funding model are to produce outputs that can inform future research and healthcare. In addition to the competition issue, the SGC and its collaborators/competitors also alter the scientific environment in which they work. This is seen most pertinently

¹² Figure 5-1 was provided by the SGC.

Figure 5-1:
Human protein kinase research and structure analysis by the SGC.



through the development and improvements in technology and methods that allows for more efficient analysis of proteins. By improving the efficiency of structural analysis, the SGC can alter the rate at which it can deliver new structures, and thus the value for money that it can deliver to its funders.

Inputs: Knowing how knowledge is built

The SGC has been in place for nearly ten years now, and in that time has been through multiple funding rounds to receive research funds from the public and private sectors. From its inception in 2004 to its current funding request, the SGC has experienced three phases of funding worth a combined \$425,024,876 based on the budgets submitted by the SGC (Figure 5-2).¹³

This funding has been relatively evenly spread across the three phases of the SGC, although

Phase I included more infrastructure funding than Phases II and III. The funding amounts for 2004–05 in the figure contain the full funding envelopes for Phase I of the SGC from Oxford and Sweden, since there is no data on the distribution of that funding across Phase I by year.

As noted in the introduction, funding for the SGC comes from both public and private funders. While there is information on the location of funding for most of the funds attributed to the SGC, in both Phases I and II there are some funds that cannot be easily attributed to either public or private funders alone. Data for Phase III on the breakdown of where funding comes from was not available to the research team (Table 5-1).

Table 5-1:
Distribution of funders by phase of SGC

	Phase I	Phase II	Phase III
Public	\$59.8m	\$100m	–
Private	\$15m	\$16m	–
Public and Private	\$67.5m	\$55.6m*	\$127.3m
Total	\$142.3m	\$171.6m	\$127.3m

* Phase II contains funding from a Swedish private foundation.

¹³ The total funding in CAD is based on the current exchange rates for GBP:CAD (1:1.63) and SEK:CAD (1:0.16) – exchange rates identified on 20 August, 2013 – where there was no original exchange rate identified for non-CAD figure.

Figure 5-2:
Funding in Canadian Dollars by year of SGC.

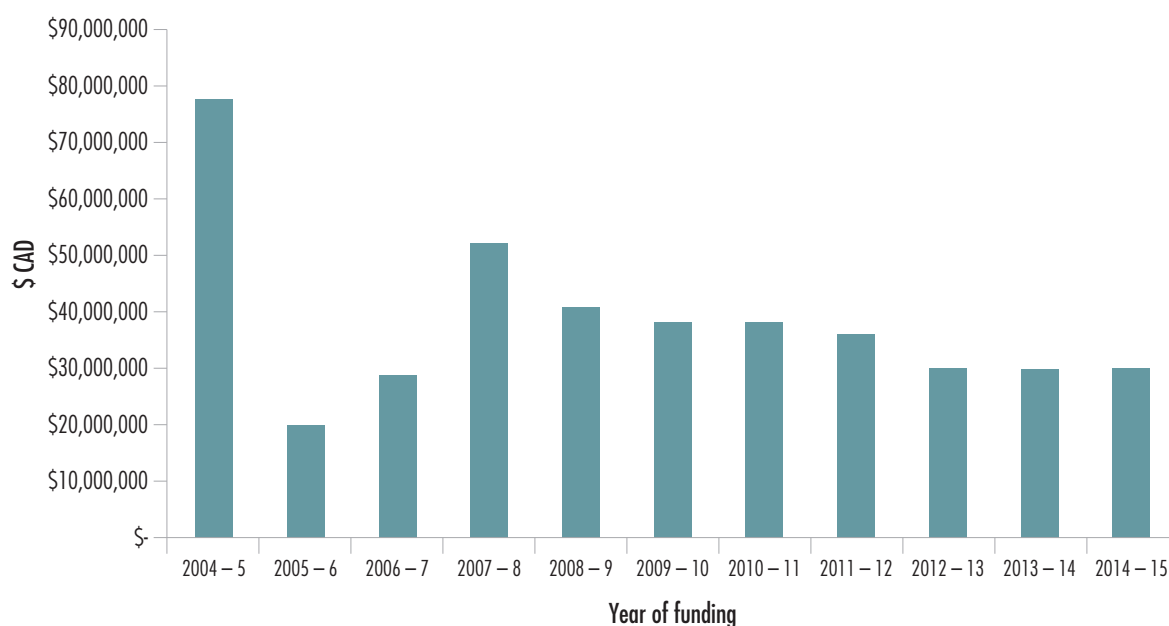


Table 5-2:
Distribution of funding by intended expenditure area

Phase I		Phase II	Phase III	
Enabling Technology Group	\$12,798,800	Information not available to the project team	Chemical Probes	\$11,704,094
Biology Group	\$18,932,302		Biological Probes	\$6,688,054
Structural Biology Group	\$12,061,900		Funder prioritization	\$37,341,643
Core Support Group	\$10,012,600		SGC Company	\$5,069,533
Infrastructure	\$16,850,000		CapEx	\$20,804,316
Operations Support Group	\$4,255,952		Structural Genomics	\$45,701,701
Unidentified	\$67,500,000			
TOTAL	\$142,411,554	\$170,590,000		\$127,309,341

It is also possible to monitor where SGC intended inputs to be spent through the budgeting process.¹⁴ Each phase of the SGC identified different ways to break the budget down dependent on the necessary tasks in the phase, although the Phase II budget contained no breakdown of expenditures (Table 5-2).

¹⁴ Intended areas of expenditure are used, as actual areas of expenditure were unavailable to the research team.

In addition to funding directly linked to the SGC, the consortium have also been successful in securing funding from other sources for specific pieces of research, and in terms of cash and in-kind support from SGC member organisations. Existing data on this funding provides a figure of over \$25.5m CAD. However, secured funds may actually be higher than the reported funding due to research projects that have enhanced the SGC's reputation, science and scientists without reporting it to the SGC for inclusion in official documentation.

Outputs: Knowledge production at the SGC

The SGC has three main streams of work: determining structures and sequences; developing chemical probes; and developing biological probes (or antibodies). Each of these streams has been productive through the life of the SGC, with initial work focusing on structures and sequences, and more recent work looking at the development of probes.

One of the main areas of scientific output for the SGC is protein structures. Since 2004, the SGC has developed and deposited the structures of 1195 proteins in the Protein Data Bank (PDB).¹⁵ The majority, 1184, of these are eukaryote structures (human and parasite). The SGC also produces a significant proportion of new structures submitted to the PDB – over 10% of new structures in any year, and over 25% and 50% of medically relevant human and parasite structures yearly.¹⁶

In addition, the SGC has also been responsible for the publication of sequence data for proteins it works on. From 2004 to 2011, this has led to 83 new sequences¹⁷ deposited in Uniprot – the protein sequence database. SGC has developed 15 epigenetic chemical probes to date, with an additional two compound tools. It has also developed and submitted 98 antibodies (biological probes) up to March 2013.¹⁸ Outside of the structures, sequences and probes produced by the SGC other scientific outputs relevant to quantifying the impact of the consortium include the probes and the SGC clones (578) and vectors (17).¹⁹

In terms of scientific publications, the SGC has produced 452 peer-reviewed journal publications

Table 5-3:
SGC main outputs

SGC output	Number of outputs (date range)
Protein structures	1195 (2004–August 2013)
Protein sequences	83 (2004–2011)
Chemical probes and compound tools	17 (2004–March 2013)
Antibodies (biological probes)	98 (2004–March 2013)

(and eight books) up to August 2013.²⁰ These span the full lifespan of the SGC so far, with a peak in publications in 2010 (Figure 5-3).²¹ It is unclear, without a full bibliometric analysis, why the publications appear to have peaked in 2010, but one possibility is the delivery of articles on science supported by the increased funding available through Phase II of the SGC. Over 130 journals are covered by SGC publications, with the main eight journals in which the SGC publishes in shown in Table 5-4. In addition to these journals, the SGC has also published 19 papers in *Nature* or its subsidiary journals (such as *Nature Genetics*).

Table 5-4:
Top 8 journals that SGC publishes in

Journal	Number SGC papers
Journal of Biological Chemistry	56
PLoS One	27
Journal of Medicinal Chemistry	22
Proceedings of the National Academy of Science	20
Journal of Molecular Biology	19
Proteins: Structure, Function and Bioinformatics	18
Structure	12
Biochemistry Journal	10

¹⁵ This data was extracted from the protein data bank website (<http://www.rcsb.org/pdb/home/home.do>) [Last accessed 18th August 2013].

¹⁶ Taken from: http://www.thesgc.org/about/our_science [Last accessed August 16th 2013].

¹⁷ Based on sequence data provided to the RAND Europe/IOG project team by the SGC.

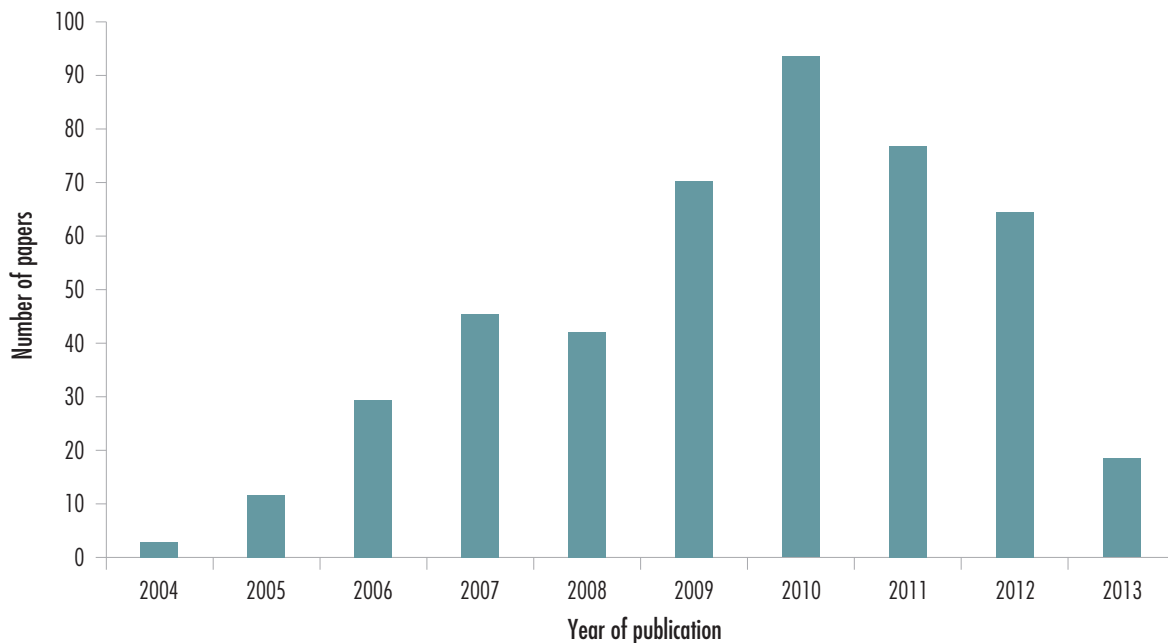
¹⁸ Data provided by the SGC.

¹⁹ Data taken from Source Bioscience (<http://www.lifesciences.sourcebioscience.com/clone-products/structural-genomics-consortium-expression-clones.aspx>) [Last accessed 4th November 2013]

²⁰ In comparison, over the 2004–2013 period RIKEN produced 796 publications (see: http://www.rsgi.riken.go.jp/rsgi_e/ResearchResult/index.html), and PSI produced 795 publications (see: <http://olenka.med.virginia.edu/psi/publications/viewcenter/All>). It is worth noting that RIKEN and PSI both were predominantly publicly funded and more likely to prioritize publications than the SGC.

²¹ Data provided by the SGC.

Figure 5-3:
Peer reviewed publications from the SGC by year



Other academic dissemination of results is also a key output for the SGC, with scientists attending and presenting at conferences (over 250 conferences 2007–2011), including 38 poster presentations and 87 invited talks as a direct result of scientist involvement in the SGC (2007–2011). In addition, one SGC researcher won two Canadian academic awards as a result of their work with SGC.²² Public outreach has also been an important output of the SGC, with SGC engaging in outreach to schools (716 school and college students engaged at SGC between 2009–2011).²³ In 2012, the SGC was involved in 10 public outreach approaches, and also engaged the media through TV and interviews (7) and press articles (12).²⁴

The public dissemination of SGC scientific outputs was also identified as a positive impact in interview feedback and survey results. The majority of SGC researchers were active in the public dissemination of scientific research through different channels. Of the scientists surveyed 94% had

given an oral presentation (including in conferences, academic departments and seminar series), 71% had given a keynote or invited presentation and 65% had given a poster presentation and participated in workshops.

In addition, and as summarised in Chapters 3 and 4, scientists asserted that the open access SGC model allowed for a larger volume of knowledge translation and greater number of publications in high impact journals. Survey evidence was supported by interviewees who suggested SGC was active in translating knowledge into the public domain through publications and conference papers alongside SGC's publicly accessible scientific outputs.

Outcomes: Using SGC knowledge to change the world

While outputs represent the products and knowledge developed through the SGC, outcomes represent the utility of those outputs in delivering additional impacts. For example, outcomes would include the reach of SGC research, the influence expressed by researchers as a result of their engagement in the SGC or the monetary impact of SGC developments.

²² SGC Phase II final report, 2011.

²³ SGC Phase II performance measures, 2011.

²⁴ SGC data from MRC eVal., 2012.

Contribution not attribution

When considering the outcomes of scientific research, it is important to ensure that there is sufficient understanding of the causality involved in outcomes arising. Where traditional evaluations have concentrated on attributing outcomes to particular inputs, research evaluations have now moved to an understanding that outcomes arise as part of a complex network of interactions that cannot be easily compartmentalised to provide levels of attribution. As such, the research evaluation field has settled on assessing contribution (could this outcome have happened without the research under evaluation) rather than attribution (this proportion of the outcome is related to the research under evaluation) (Donavan, 2011). This caveat should be borne in mind when considering the outcomes below and was a limitation of the research team in terms of how far it could take forward the analysis in a robust way.

Showing the value – defining monetary outcomes

For monetary outcomes related to the SGC, there are three main areas where it is possible to easily identify quantitative data:

- Costs of new products (unit costs);
- Financing or valuation of new companies; and
- Cost-savings attributable to new technological improvements from the SGC.

These areas relate to two standard categories of health research evaluation: gains related to product development; and gains related to cost-savings (Buxton et al., 2004). It is worth noting that monetary outcomes from medical research are not instantaneous. Recent studies suggest that the monetary payback on academic health research is in the region of 17 years (Slote Morris, 2011; Buxton et al., 2008). Each part of the chain that leads to that payback can vary, but estimates from the SGC suggest that the time lag from the discovery of new structures to the first human clinical testing of therapeutics is somewhere between three and six years.²⁵ The anticipated time lag from research funding to research outputs (in terms of structures and publications) is in the one to three years range, depending on the structures under

study. This suggests that time lags from investment are likely to be in the range of 1-3 years for SGC outputs, 3-6 years for pharmaceutical clinical testing, and around 17 years (or potentially quicker) for financial returns on new medicines. In addition, as monetary outcomes occur further away from the research in time, the more difficult it is to directly attribute outcomes to specific SGC research (another reason to consider contribution over attribution).

Financial returns on research investment come with multiple caveats that need to be clarified. Firstly, while it is often possible to identify revenues related to research outputs, it is difficult to develop an understanding of the additional costs needed to develop the revenue (eg industry costs to develop patentable diagnostic tests). Also, while the sale value of goods may be easily identified, industry rarely provides information on the total revenues or sales of products. When considering company valuations, the financial value may be easily defensible, but the link of the company to the initial research (attribution) can be complex to unravel. Cost-savings are also complex to analyse, since the figures rely on estimated efficiency savings where money is not spent on one type of resource, freeing it up to be spent elsewhere (essentially an opportunity cost-saving). In reality, cost-savings are rarely due to lower spending, but to reorganised spending.

SGC Reach and Influence

In terms of reach, the SGC's international network of researchers has enabled to over 500 scientists to co-publish with the SGC,²⁶ and these represent 17 different countries. In addition, since 2007, the SGC has distributed over 1200 clones to a wide variety of academic researchers and over 200 to industry.²⁷ Figures from 2006 show clones were sent to both the public (37) and private (9) sectors in multiple countries (eight countries) even in Phase I.²⁸ Recent figures for one chemical probe suggest that over 250 groups worldwide requested the probe.²⁹ SGC also has international reach

²⁵ Taken from data provided by the SGC to the evaluation team.

²⁶ SGC Final Report, 15 December 2011 (provided to the project team by the SGC).

²⁷ Data provided by the SGC to the project team (SGC Phase II final report).

²⁸ Data taken from the SGC's Phase II application.

²⁹ Data provided by the SGC.

Table 5-5:
Reach and Influence of SGC

Reach of SGC	Influence of SGC
500 scientists working with SGC across 17 countries	50+ meetings with Industry in 2012 alone; 24 policy maker discussions in 2011–12
Clones provided to private (200+) and academic (1200+) sectors since 2007	In 2012, SAB membership for 5 biotech companies; 3 research consortia; 2 funding agencies
One chemical probe requested by 250+ research groups internationally	20+ workshops by the SGC between 2009–12
200+ scientists and 100+ students trained at SGC	Staff movement to academia (65); industry (33) and business schools (4)

through its training of students and researchers. For example, the SGC has trained over 200 external scientists and over 100 co-op students.³⁰

Influence is a complex concept, with influence from SGC scientists seen in terms of their roles related to industry, policy and the academic sector. For industry influence, the SGC has clear links to the private sector funders engaged (with over 50 face-to-face meetings with industry in 2012 alone), but also has scientists that serve on scientific advisory boards (SABs) of five biotech companies. For policy, it is unclear the quantity of policy interactions, but SGC researchers are involved in advising policy makers on approaches to drug discovery and research funding (discussions with 24 policy makers in 2011–12).³¹ For the academic sector, SGC scientists serve on three research consortia and two funding agencies SABs, as well as hosting and presenting at conferences. SGC also has staff move from the SGC to academia (65 – 13 of which are in leadership), industry (33) and business schools (4).³²

Evidence from the survey and interview research also pointed to the wider influence of the SGC on different communities. Over half (59%) of scientists surveyed stated their research had led to improved public understanding of science and had led to improved public engagement with science. Different routes to impact were identified and included public lectures, teaching activities, public engagement activities including present-

ing on a national Canadian radio show, museum exhibits, podcasts, interviews, workshops, newsletters and educational activities.

While SGC is active in academic dissemination and public engagement activities there was less evidence of dissemination activities aimed specifically at policymakers. The majority of respondents to the survey were either not aware of a policy influence (47%) or did not believe their research had had a policy influence (18%). Examples of SGC policy engagement activities included preparing briefing for government ministries or agencies, providing evidence to international panels on specific policy areas, briefings to non-government organisations, impact assessment of existing policies and participation in reviews of public administration processes.

SGC economic outcomes

Identifiable monetary outcomes from the SGC fall broadly into three categories: sales of products, valuations of companies, and cost-savings due to SGC technology. Due to SGC's open access business model, there are no patent values to consider as monetary returns, but products that can be sold do have clear unit values (Table 5-6).

SGC has spun out two companies, in *Harbinger Biotech* (by SGC researchers) and *Biohub Online*, which is now *1DegreeBio* (by a former SGC administrator). While neither of these two companies have available valuations or finance information, another spin out company that built on SGC research on bromodomains – Tensha Therapeutics (see also discussion in Chapter 3 above) – was the subject of a \$15million (USD) financing in 2011 (Tensha Therapeutics 2011). Biohub, meanwhile, has estimated that its approach to identifying

³⁰ Data from SGC Phase II review documents: Open access research to promote drug discovery. 2011.

³¹ SGC data for MRC eVal tool, 2011–12.

³² *Ibid.*

Table 5-6:
Unit values of SGC products

SGC product	Product description	Mean unit value (size of unit)	Data source
Antibodies	High quality, renewable antibodies to proteins implicated in epigenetic and chromatin biology.	\$347 (per 100µg)	Invitrogen.com
Clone library	Collection of DNA sequences corresponding to SGC proteins.	\$950 (per library)	Source Bioscience
Individual clone	Single DNA sequences corresponding to SGC proteins.	\$87 (per clone)	Source Bioscience
Individual vector	Tool to enable the introduction of DNA into bacteria for protein expression.	\$45 (per vector)	Source Bioscience
Individual chemical probe	Potent, selective and cell-permeable inhibitors of protein function.	\$199 (per 10mg)	Tocris
Lex system	An ultra high-throughput bench-top bioreactor system.	\$30,000 (per system)	Harbinger Biotech
Stargazer System	A plate reader for studying the thermal stability of 384 protein samples in parallel.	\$90,000 (per system)	Harbinger Biotech

which antibodies available for purchase are actually effective, will save up to \$1bn (CAD) of research expenditures (PR Newswire Europe 2010).³³

In addition to these measurable financial impacts, there are a number of areas of potential financial impact that have been identified in this review. While we are not able to provide quantitative data on these, it is worth taking into account the additional likely economic benefits of SGC activities.

There are a number of characteristics of the SGC model of scientific research and innovation that create economic benefits to different stakeholders. These benefits were mentioned in the survey and in interview feedback but are difficult to quantify and analyse in a robust way. In a number of cases funders and scientists could identify how and why SGC creates economic benefits but unable to measure exactly what the benefit may be to different stakeholders.

The majority of stakeholders interviewed (28 interviewees across all stakeholder groups) were

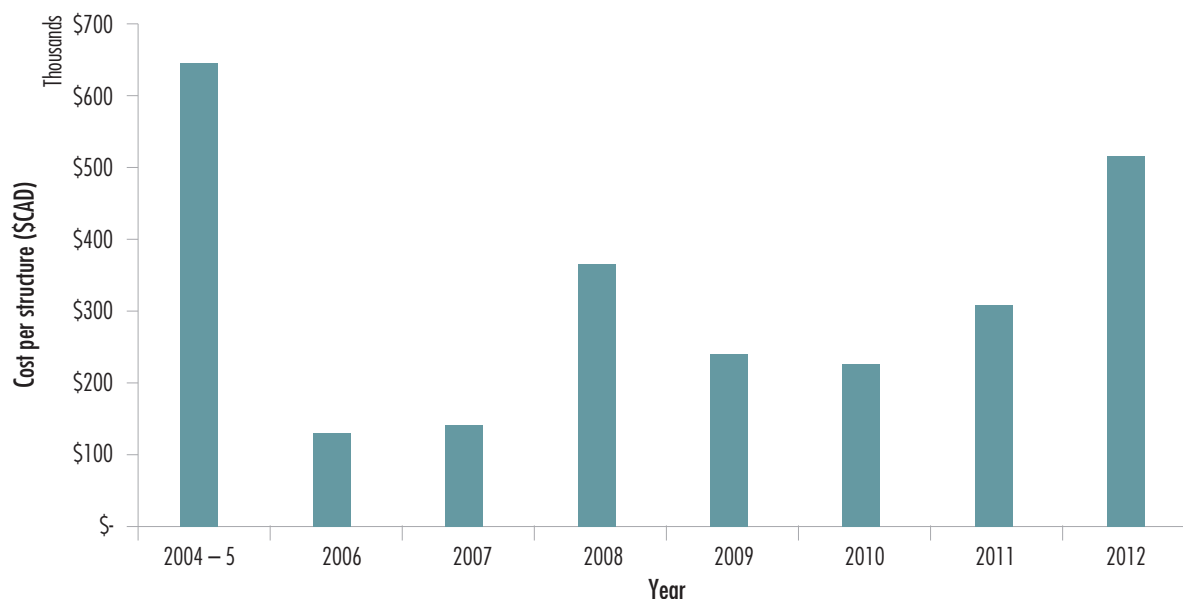
in agreement that a key benefit of SGC is how it enables this type of research to occur in a rapid and efficient way. The efficiency of SGC's open access model for research has economic benefits for funders in avoiding the costs and time entailed in establishing material transfer agreements (MTAs) normally required to facilitate the transfer of materials in support of research and formal research collaborations between organisations.

Aside from saved costs on the bureaucracy associated with R&D activity, SGC creates economic advantages in pooling resources and sharing expertise. This was an economic benefit identified particularly by private sector funders who highlighted the advantage of the SGC approach in avoiding replication of research within the pharmaceutical industry. Although difficult to quantify, companies were in agreement that SGC saves time and money by adopting a more strategic and targeted approach to scientific research.

From our survey results, three quarters of scientists surveyed highlighted the benefit of reduced costs to organisations collaborating with the SGC through more efficient research processes. The research network is able to mobilise people and resource in a highly efficient way that saves costs both for academia and industry.

³³ This figure is based on the global market in antibodies being a \$2bn market where 50% of antibodies are in fact not of adequate quality to use effectively in research.

Figure 5-5:
Cost per structure for SGC structures deposited in the PDB (2004/5–2012).



missions to the PDB. For example, in Phase I, the SGC provided data showing the cost per structure at \$225,730, but this was decreasing as the SGC gained more experience and improved its production. Looking at the total funding for the SGC over the time frame 2004/5–2012, and the productivity in terms of structures submitted to the PDB, we can see that the cost per structure has varied between \$130,000 in 2006 to over \$500,000 in 2012 (Figure 5-5). These numbers are based on the full expenditure of the SGC, rather than just the expenditure on protein structures – which at just over \$12m CAD in Phase I identifies a cost per structure for the investment in the structural biology group of just over \$25,000 CAD. In our opinion, the ‘correct’ cost per structure is likely to be somewhere in between the total expenditure and structural group expenditure figures, since structure determination relies on infrastructure and operations as well as research funds for structural biology, but the SGC performs a number of other functions outside structure development that use funds from the full funding pot.

When we compare the average cost per structure identified for the SGC over the 2004/5–2012 (\$289,000 CAD) with those for other structural genomics organisations in the same time period, we can see that the SGC is considerably more efficient than RIKEN (\$712k per structure, based

on 2006–2011 funding for RIKEN as a whole), while the cost per structure for PSI (in its first two phases, 2000–2005/2005–2010) was \$104,000 CAD.³⁴ While comparisons of the cost per structure are difficult without comparable data on the funding allocated to each group, the data does suggest that the SGC is able to provide competitive cost per structure for the protein structures it does develop (especially bearing in mind the other outputs that the SGC produces in terms of clones, probes and vectors).

The figure for 2004–5 is inflated by the lack of information on the breakdown of funding across years for the UK and Swedish parts of the Phase I SGC.

In addition to identifying the cost per structure of the SGC, we can also assess the cost per publication (\$727,000 CAD), the cost per submitted antibody (\$3.4m CAD), the cost per clone (\$580,000 CAD) and the cost per probe (\$19.6m CAD). While all of these per-unit costs are interesting, they all assume that all funds are spent on producing the output identified. In reality, all of the outputs rely on the same funding pot, and so a generalised cost per output for the SGC would

³⁴ Taken from the PSI Fact Sheets: <http://www.nigms.nih.gov/Research/FeaturedPrograms/PSI/Background/>

be in the region of \$145,000 CAD for the outputs identified above.³⁵

Attempting to provide a total value of identifiable and quantifiable SGC impacts is an important tool for identifying the return on investment that SGC funders receive. In this case, the total input to the SGC up to 2013 is \$364.5m CAD, and the economic impacts related to the SGC that we are able to quantify include the \$15m financing of an SGC spin-out company, the potential \$1bn cost-savings associated with a different SGC spin-out, and the numerous per-unit costs for SGC-related products. If we assume that 500 units of each product related to the SGC have been sold over the lifetime of the consortium, that accounts for over \$60m CAD in sales. This does not account for other economic benefits arising from SGC activities (such as the patents and sales of products developed by industry partners downstream from their involvement in SGC research), which would provide an even higher likely monetary return on investment.

As noted earlier, there is an issue over when investments can reap benefits. In the case of the SGC, it appears clear that the benefits in terms of outputs from the research are fast (1-3 years), while the likely economic returns on those benefits will take longer (depending upon the type of benefit being assessed) and these economic benefits may be difficult to quantify when related to private sector returns. However, as a fast throughput structural genomics group, the SGC does seem to provide a fast return on research investment in terms of its outputs. Although there are numerous caveats to developing any assessment of return on investment, providing an understanding of likely costs (inputs) and impacts (outputs and outcomes) can help to establish a shared understanding of what type of return will be seen from the SGC, both monetary and knowledge.

³⁵ It is worth noting that the information on the full outputs from the other structural genomics groups is not openly available so developing a comparator 'total cost per output' is not possible in this project.

Chapter 6 Learning from the past to inform the future

Introduction to scenarios

A scenario is a logical and consistent picture of the future that is credible and challenging to stakeholders. Scenarios are not predictions of the future, but can provide insight into future trajectories and logics governing development. The analysis of scenarios enables us to identify the potential implications of decisions made today and think through and prepare for the consequences and implications of those decisions and choices. The scenarios analysis presented in this chapter highlight linkages among different aspects of the future which might not otherwise be apparent and so can be a useful tool in considering different options and trade-offs for the future of the SGC.

In developing scenarios for the SGC we used a simple scenario development process rather than a more formal approach (Bishop et al., 2007). We

adapted an approach called ‘visioning’, which is defined in the following way:

The systematic creation of images of desirable futures for the organisation of interest. Kicking off with a review of historic and current trends, consequently envisioning desirable futures, and finishing with the identification of strategies to achieve the desired future (Ling and Villalba Van Dijk, eds., 2009).

This approach to scenarios analysis meant that we thought about the SGC in light of future decisions it may need to take about its funding strategy, scientific direction and the external context in which these decisions would need to be made. In order to do this, we first identified contextual certainties and uncertainties which would play a role in the future. These are summarised in the table below.

Table 6-1:
Contextual elements of the scenarios: Future ‘knowns’ and ‘unknowns’ for the SGC

What we know (certainties)	What we do not know (uncertainties)
The pharmaceutical model of drug discovery is changing and uncertain. The era of the blockbuster drug is over.	The extent to which this new era means that pharmaceutical companies will focus on both R&D, or just ‘D’.
Drug discovery is becoming more expensive.	The availability of finance for biotechnology-based companies, and the role of IPR in the future of health research and innovation in order to recoup costs.
Not all proteins and potential drug targets are being explored and this appears to be related, in part at least, to peer review.	The shape of pharmaceutical sector industry and market structures.
The economic downturn means that resources are closely monitored within the pharmaceutical industry and effective and efficient leveraging of funds is of critical importance.	The extent to which open innovation and collaboration drives drug discovery, or whether there is a proliferation of closed collaborative loops.
There will be a continuing need for new drugs and treatments and both public and private sector will need to contribute to health research and innovation.	The precise roles that public and private sectors, and within that small and large firms, will play in health research and innovation to provide the needed drugs and treatments.

We then identified a list of critical success factors for the SGC, permutations of which are likely to be particularly important to the SGC's future. The factors were identified collaboratively within the team and were drawn from the data collected from the survey, interviews, and the literature review. We included the following factors in our analysis:

- Principal motivation for engaging with, or funding, the SGC
- SGC's scientific vision
- SGC's business model
- The main funders of the SGC
- The role of open access/IP within the SGC
- Political will in the external environment
- The role of networks and collaborations for the SGC
- The trends in drug discovery R&D
- Competition from another model
- Nature of scientific and economic spillovers produced by the SGC
- SGC's location.

When it came to developing the scenarios, we considered both the contextual elements and the implications of them for the success factors above. Those factors which have greater degrees of uncertainty or which might be reasonably expected to play out differently because of their dependence on other variables were used to differentiate between the scenarios. We then developed narratives around each of these futures and the result is the following four scenarios presented below. What is important to note is that we have deliberately highlighted a number of prominent characteristics in each scenario and, in many cases, often exaggerated what the future might look like for the purposes of illustration. We fully recognise, and in fact would likely argue, that SGC's future strategy is going to be informed by a mix of elements presented in these scenarios, but it is the process of determining that mix which is important. In order to do this, we must understand what each scenario looks like independently.

Scenario 1: Maximising the science

Rationale/context of the scenario

In this scenario the primary motive of the SGC is scientific knowledge discovery which is driven by intellectual curiosity rather than market need. Open access is fundamental to the model, and

the SGC aims to provide world-leading scientific structures, tools, techniques and methods for the field of structural biology to build upon. The model of the SGC as a vehicle for cutting edge scientific exploration is particularly endorsed by the public sector, as there is strong political support for open access initiatives, as well as an agreement that the high quality outputs of the SGC are working to improve the public good. In this scenario there is recognition that the SGC needs support from the public sector in order to undertake world-class science that will benefit society through improved health outcomes. This results in the engagement of research councils and continued public sector funding, meaning that public sector involvement becomes essential to the SGC.

This has implications for the SGC's location, given that it requires a physical presence in the countries it can secure public sector funding from, although the science could be conducted elsewhere. Public sector funders are eager to reap the benefits of the SGC both in terms of public interest science in their 'home' countries but also possible knowledge spillovers to the indigenous scientific community. Effects from the later helps to maintain the case for continued public sector funding because the presence of the SGC helps to maintain the competitiveness of scientific research and development (R&D).

The private sector has moved towards a model of in-house research in order to keep full control of new exploratory areas and is not wholly open to pre-competitive collaboration. Although it continues to engage with the SGC, it does so peripherally.

How the SGC model works

Due to public sector funding, the SGC has the freedom to explore all areas of scientific inquiry as it wishes, with an underlying assumption that the SGC is best placed to choose new areas for research. This sees a return to basic science, and the SGC becomes tightly focussed around its core strengths in structural biology. In this model, the SGC has the space and time to innovate on new methods, which subsequently results in innovative science. With this in mind, its business model is akin with that of an academic laboratory, rather than an industrial operation. SGC scientists have complete intellectual autonomy to develop their research interests and push the boundaries of scientific exploration.

Given this, the SGC is not influenced by the wishes of industry, and this causes the private sector to question the value of the SGC for them. The inability to nominate targets or shape the scientific direction of the SGC means that the private sector is only marginally involved. It continues to invest small amounts given that it sees the value of the high quality scientific outputs and the collaborative links, although a shift away from pre-competitive collaboration towards in-house research further reduces the value of continued engagement. As such private sector engagement is minimal compared to before; it does not engage in collaborative basic science with SGC scientists but adopts the view that the SGC is useful for keeping abreast of scientific developments and fostering closer ties to academic research groups working in areas of interest.

The open access aspect of the model means that the SGC has a large network of stakeholders who benefit from their research. However, the SGC is less reliant on collaborations to actually carry out the science, and they undertake most scientific operations in-house. Nevertheless, the network is important for knowledge sharing, validation and dissemination of scientific tools.

Implications, risks, opportunities and spillovers

Due to the entirely open dissemination of SGC outputs without delays, there are significant benefits to the scientific community. Knowledge spillovers mean that small scientific operations are able to sustain their own laboratories, which may in turn lead to knowledge breakthroughs. Although not primary objective of the SGC in this scenario, knowledge spillovers may lead to economic benefits given that jobs are created and small biotech start-ups may be able to grow by accessing SGC knowledge outputs.

The pharmaceutical sector may also benefit from SGC outputs, although its lack of engagement with the SGC means that the direct benefits for industry are not entirely clear. The pharmaceutical sector is able to access SGC outputs but these outputs are less targeted to the specific needs of industry. A knock-on effect of this is that the translation of SGC's research is delayed, given that the SGC's research focus is more academic and less industrial and it has no hand in how its outputs are used once they enter the public domain.

The SGC's primary competition comes from other open access initiatives, which may win the support and funding of the public sector over the SGC. As such, the challenge for the SGC is to remain the world-leading structural biology group, thus ensuring continued funding.

Scenario 2: Maximising the return for industry

Rationale/context of scenario

In this future, a challenging economic climate means that the pharmaceutical and biotechnology industries are continually exploring avenues for leverage funding, different models of collaboration and research in order to keep the research pipeline open. In more austere times, pharmaceutical companies adopt a more cost-effective approach to research including flexible arrangements with biotechnology firms and outsourcing arrangements being more common. Less research takes place 'in-house', and so pharmaceutical companies in particular are more mobile in the location of research and development activities. This is worrying for politicians, and so the political will to keep these industries in a given country is a strong driver for this scenario. There is a desire from government to keep industry afloat and provide incentives for the SGC to stay in the countries in which it is currently based (eg the UK and Canada).

In this scenario, then, the principal motivation behind the existence of the SGC is that it can provide the tools, techniques, skills and personnel that the pharmaceutical and biotechnology industries need for drug discovery. In this sense, it is responsive to the needs of a diverse set of actors within the industry, yet because it provides things in an open way all can benefit at some point. The SGC provides the foundation for drug discovery, and its location is crucial to maximising economic and knowledge spillovers for science and industry.

Since the SGC is driven by the needs of industry, there is clear value for the private sector. Reflecting this the majority of funding and comes from the private sector, both a combination of pharmaceutical and biotechnology companies. The political will to support the pharmaceutical and biotechnology industries mean that public sector funders are involved to try and keep the industries in their country. In this scenario the public sector is in

effect providing locational incentives in the form of funding – but incentives could also include tax-breaks or ease of sourcing labour – to these industries to persuade them to stay and do business in their countries.

How the SGC model works

Within this scenario the scientific focus of the SGC is diffuse. Structural, chemical and systems biology are all pursued. The SGC pursues scientific opportunities that are suggested by industry and it is target driven. In this sense, it represents a continued evolution along the trajectory that some felt the SGC is currently on in that it is more like a contract research organisation.

Open access under this scenario does feature, but it is not a principal driver behind the SGC's work. This means that there may be more of a shift towards late publishing of targets and/or a shift to open collaboration within the consortium before things are released to the public. In order to support this, most collaborations are with pharmaceutical and biotechnology researchers in the consortium so that the focus stays on applied drug discovery. There are still networks and collaborations with academics, but only on those targets that have already been made public. The SGC is not a leader for the field in this way, but rather functions as a scientific platform for drug discovery within industry.

Implications, risks, opportunities and spillovers

Since the scientific remit of the SGC is broader, the SGC experiences greater competition because it is working across many fields. The SGC is more of a follower than a leader of scientific trends and is highly responsive to the needs of industry. The risk in this is that it is not able to maintain world-leading expertise in all fields and it must attain high quality research through the nature of its collaborations with industry. Because the drug discovery R&D model is reliant upon collaborative working in the early phases of drug discovery, the pre-competitive boundary shifts more upstream, but is only accessible to those who can be at the table. Knowledge spillovers accrue mostly to industry, economic spillovers accrue to countries that have SGC researchers within them and where SGC partners from the pharmaceutical sector are present. This opens the opportunities for the SGC

to work in new countries which would like to access their expertise, but it also further stretches the SGC as it has to work across different countries in addition to different areas of science.

This scenario would help to address one of the risks that was expressed to us in relation to the SGC's current operating model and the concern that what it produces goes out into the wider world and there is little control over what actually is done with the knowledge it produces.

The main weakness is that SGC produces 'tools' that are publicly available. The use of the tools is not in the hands of SGC but dependent on the external environment. [...] SGC is in danger of information overload because so much information is produced; there comes a point when that can be considered a weakness (F6).

In fact, several external stakeholders also discussed a need for the SGC to focus more on 'break-through structures' and on developing and facilitating deeper understanding of those structures at a system level (E4 and E5). In this scenario, then, the SGC would play a greater role in enabling different kinds of insights and networks to be developed, rather than just solely focussing on meeting as many milestones as possible. The SGC is thus more strategically focused in exploring areas of science that are aligned to industrial interests, and in doing so, articulates more effectively with the external political-economic context.

Scenario 3: Maximising the 'good news' story

Rationale and background context of scenario

As with other scenarios, the economic future continues to be challenging for drug development. There is a collective drive within the industry to leverage and pool resources effectively and efficiently. But in this scenario the impetus to collaborate comes from a desire to improve patient lives and wellbeing as quickly as possible. In other words, the focus is on the patient and disease and this is driven from the top down (politicians) and bottom up (patient groups and charities). This means that the principal motivation behind the SGC is that it can bring its full set of resources to both identifying the structures which underpin

human disease and advancing our understanding of these structures at a system level.

How the SGC model works

In this future, the scientific focus of the SGC is around different disease states and is driven by a combination of both scientists and pharmaceutical/biotechnology companies who are looking to explore the causes and consequences of disease in a holistic way and in relation to the heterogeneous nature of disease. Here, the SGC produces structures which can be explored at a systems level by collaborators and in this sense they provide a critical platform for knowledge production that can be accessed by scientists from anywhere at any time who share SGC's ethos to improve patient lives and wellbeing. The SGC is pursuing incredibly complex and challenging areas of science and there is a need for a much broader pool of collaborators to provide SGC with the requisite expertise across a broader range of disease areas. This means the SGC must play a leading role in catalysing the field and bringing these networks together.

Open access is central to achieving this and all structures are made immediately available to the field, as are the broader implications of those structures so that knowledge can be translated rapidly. Location of the SGC is not as important as in other scenarios in relation to spillovers, but it is important to maintain public sector funding and to this end there may be a need to focus on diseases important to different political interests.

There is a diverse funding portfolio which enables all of this to happen which comes from government, industry and patient-centred charitable foundations. In particular, the strong political drive to address patient needs and the SGC's role in catalysing progress makes it almost impossible for research charities not to fund the SGC. This, in turn, puts pressure on the pharmaceutical sector to take it forward and deliver results. In short, there are many different interests and players at the table, but all work in concert with clear roles and responsibilities in driving both research and development for the greater public good.

Implications, risks, opportunities and spillovers

The implications of this scenario for patients are also its biggest opportunity. There is a greater likelihood that the front-page news story is: 'SGC

helps cure cancer!' While this may be an exaggeration, the reality is more likely to be that more good news stories emerge from the SGC, which helps to reinforce and sustain its funding sources. In any case, it is easier for everyone, public and private, to see how the SGC helps to drive science. The economic and knowledge spillovers are similar to other scenarios, but there are much greater spillovers to health and healthcare.

There are also implications for drug discovery R&D as the model shifts to much broader collaborative networks and an inevitable shifting of the pre-competitive boundary, if funders can agree that open access helps everyone get there faster. Partners start to see it in their interest to collaborate much further down the chain and there is a growing recognition that drugs are discovered more quickly and patient lives improved through a collective effort and shared vision.

However, the risks of this scenario are starting to become clear. With so many vested interests it will be important that the SGC plays the role of a referee and does not allow itself to become too diffuse in its scope. It may start with exploring just a few disease areas to see if the principle can work. It cannot allow itself to become even more dispersed because each funder has his own agenda. Strong leadership will be required to balance interests in the SGC and to select areas of scientific focus with the greatest potential for a 'good news story'.

In terms of competition, there will be a need to compete with academic groups who may have been working on specific disease states for much longer. The SGC will have to carefully consider its role in facilitating and managing networks in order to stand out as a superior model.

Scenario 4: Maximising the benefit to the UK/Canada

Rationale/context of scenario

In the future challenging economic conditions persist meaning there is less funding available for R&D and a concomitant need to maximise the impact of publicly supported initiatives. In this context the SGC continues to produce high-class scientific research but has a specific remit to maximise wider socio-economic returns from scientific outputs. The SGC works in the 'public good' from an economic sense and research investments and scientific areas

of focus are selected to maximise impact measured using a number of potential indicators. Economic indicators would potentially include: the number of jobs created, number of jobs safeguarded, number of firms created, upskilling opportunities, net increases in employee salaries, and net increases in business turnover. At the macro level the SGC's success is evaluated according to its Gross Value Added (GVA)³⁶ contribution to the UK or Canadian economy. In contrast, social indicators would potentially include: long-term health improvements; changes to life expectancy, morbidity or mortality; and improvements in socio-economic status for regions in which the SGC works. At the micro level, the SGC's success could be considered using new indices of well-being or social progress.

In this scenario the government of the day argues that research and scientific communities have a responsibility to maximise economic spillovers and social outcomes. The demand for economic impact dominates the agenda during times of a recession as British and Canadian governments want to support science that can create jobs. As a consequence industrial policy has influenced public funders to 'pick winners' and support areas of science that have the greatest potential for economic returns. The SGC is viewed by government as a potential enabler of economic growth and thus attracts support from a range of funders (in the UK context this may include the Wellcome Trust, the Department for Business, Innovation and Skills, the Technology Strategy Board, local authorities, and other development agencies).

As the SGC has a remit to support industrial development and competitiveness, there is clear value for the private sector. Pharmaceutical companies are engaged although providing less funding than the public sector. Pharmaceutical companies have a more direct role in working with biotechnology companies and creating potential avenues for spin-outs to commercialise SGC science. The public sector contributes by seeding funding into the private sector to support entrepreneurial activity and enable SMEs to grow.

³⁶ For an explanation on GVA see Office of National Statistics website 'The relationship between Gross Value Added (GVA) and Gross Domestic Product (GDP)' Available at: <http://www.ons.gov.uk/ons/guide-method/method-quality/specific/economy/national-accounts/gva/relationship-gva-and-gdp/gross-value-added-and-gross-domestic-product.html> [Last accessed 4th November 2013].

How the SGC model works

The scientific focus of SGC is diverse and its approach is flexible responding to scientific trends and external political economic conditions. SGC's leadership and management board comprises representatives from industry, trade associations and development agencies who work closely with public funders to identify areas of strategic focus.

The SGC 'model' is to provide a platform for scientific outputs that others (eg pharmaceutical, biotechnology, and other spin-out companies) can take forward in a productive way to create new programmes, products that will bring opportunities for jobs, entrepreneurship and profitability. Scientific exploration will be driven by a broad range of industry interests not just those of large pharmaceutical companies. The science will be attentive to areas with low start-up costs that can provide easy access for SMEs that need to create IP in a cost-effective way.

The SGC continues to be highly collaborative and engages with a range of stakeholders from government, academic and scientific communities. These networks are more geographically concentrated and embedded as the focus of the SGC is to create economic opportunities in particular localities and nations within which spillover benefits are concentrated. It retains a commitment for open access science but only within the boundaries of the consortium of funders and industry partners who seek to create IP and value from scientific outputs for the greater economic good.

Implications, risks, opportunities and spillovers

The SGC's economic paradigm shift is a risk and opportunity. The major risk is that the scientific remit of the SGC becomes too broad and fragmented according to the priorities of different stakeholders. As a consequence there is a risk that the SGC struggles to retain its world-class expertise of scientists, who become disillusioned with the move away from a scientifically driven open access model to a consortium reactive to the needs of industry and the caprices of political decisionmakers.

There are considerable opportunities in using SGC's science to create tangible economic benefits in the form of jobs and GVA for the UK and Canada. There may be greater possibilities for 'good news stories' to emerge from the SGC if industrial partners can show evidence of new eco-

conomic activities emerging from the cutting edge science. If SGC can demonstrate it has stimulated the development of a globally competitive economic cluster or the creation of hundreds of jobs it will help to reinforce and sustain funding sources.

The challenge will be in illustrating evidence of economic spillovers and to attribute impact to the SGC. In the absence of a counter-factual it will be difficult for public funders to fully justify whether funding a scientific consortium is the best means for achieving economic impact. The obvious critique will be that interventions with more direct economic returns would be a wiser use of public money than funding the SGC.

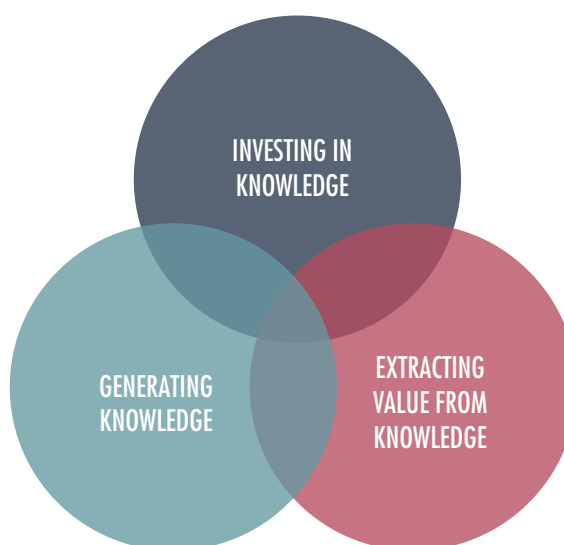
Conclusion

Each of these scenarios has its own merits, challenges and opportunities. They are presented here as distinct, but in reality there are many overlaps between them to be further explored and examined. We draw these out further below. What will be crucial for the SGC going forward is the balance between the different elements in each model, and the extent to which different drivers serve as the motivating element. One framework for thinking about this uses the knowledge platform analogy as a guide and it is worth revisiting the three spheres again:

- *The SGC as a model for investing in knowledge:* this sphere relates to what the motivations and rationale for investing in the SGC are from the perspective of those who are engaged in it, including funders, SGC researchers and external collaborators/stakeholders.
- *The SGC as a model for generating knowledge:* this sphere relates to perceived strengths and weaknesses of the SGC model as it operates in practice.
- *The SGC as a model for extracting value from knowledge:* this sphere relates to the value which comes from both the investment and generation of knowledge.

With the permutations of the the SGC under different future scenarios set out, one can begin to consider what the intersections of these spheres might mean for the future of the SGC. That is, in considering its role as a knowledge platform, it may be worth reflecting on how these different models could or should intersect depending on what the

Figure 6-1:
The SGC as a knowledge platform



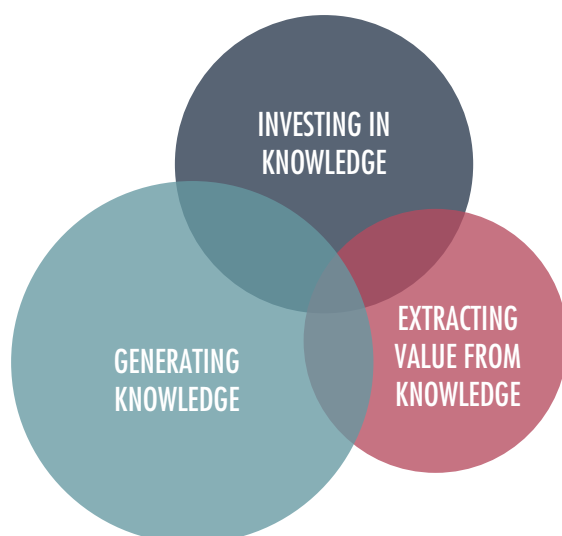
SGC would like its future vision to be. Consider, for example the figure above, which depicts an even balance between the three spheres (Figure 6-1). Here, a perfectly balanced knowledge platform is presented and the intersections between them are even. In practice, what this might mean is that each is an equal driver of a future model of the SGC.

However, each scenario presented above has a different set of drivers, contexts, models and assumptions which sit behind it. The intersections of the different spheres of knowledge will be different in each and one way for the SGC to take the scenarios forward is to consider what kind of balance they would like to see across each sphere. Put another way, in considering the findings of this evaluation and the different perspectives on the SGC, it may be that the SGC is able to see ways in which different incentives can be strengthened, opportunities maximised and challenges overcome.

For example, in the first scenario of ‘Maximising the science’, the main driver is the generation of new scientific knowledge. Extracting value from that knowledge is of least importance, and the investment incentives derive from the generation of publicly accessible scientific data. Here, the balance of the knowledge spheres might look like those in Figure 6-2.

Equally, in the second scenario of ‘Maximising returns for industry’, the main driver is the extraction of value from knowledge, with the generation of knowledge playing the lesser role (Figure 6-3). Funders support the SGC to facilitate industrial

Figure 6-2:
Maximising the science

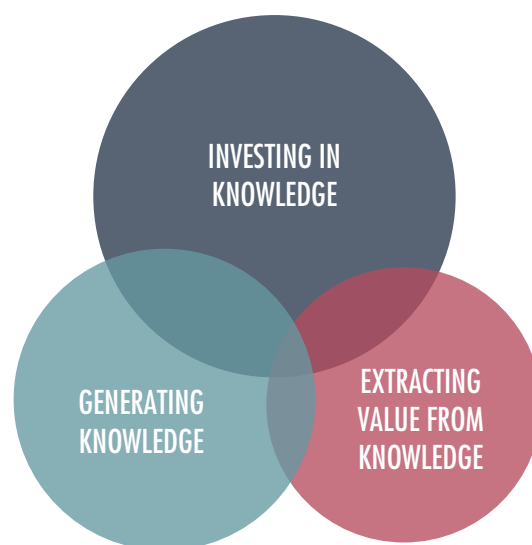


development and competitiveness so that the value of SGC science can be maximised.

In the third scenario investing in knowledge to lead to greater patient benefit plays a strong role, followed by the generation of knowledge. The outputs are not so much about value, but about generating knowledge that can catalyse direct returns for patients (Figure 6-4). The value of the SGC in scenario three is through the targeted nature of knowledge outputs in different disease areas.

Finally, in the fourth scenario we again see the main driver being the extraction of value from knowledge (Figure 6-5) as countries seek to invest

Figure 6-4:
Maximising the 'good news' story



in the SGC so that they can see a return on investment for industry through the creation of knowledge spillovers and economic growth. SGC is supported by the public sector as a platform to create knowledge that will lead to economic benefits in terms of jobs and gross value added. Again, the point is not to belabour the different permutations, but rather to illustrate how the SGC can begin to use this thinking to reframe its role and the drivers behind it in light of the changing R&D landscape around it. The final chapter offers concluding thoughts and recommendations to this end.

Figure 6-3:
Maximising the return for industry

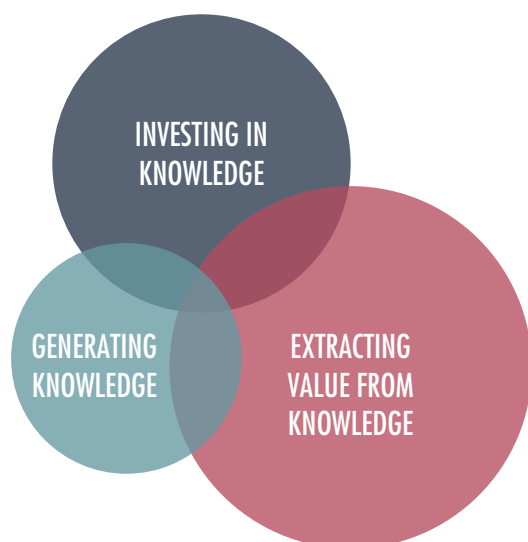
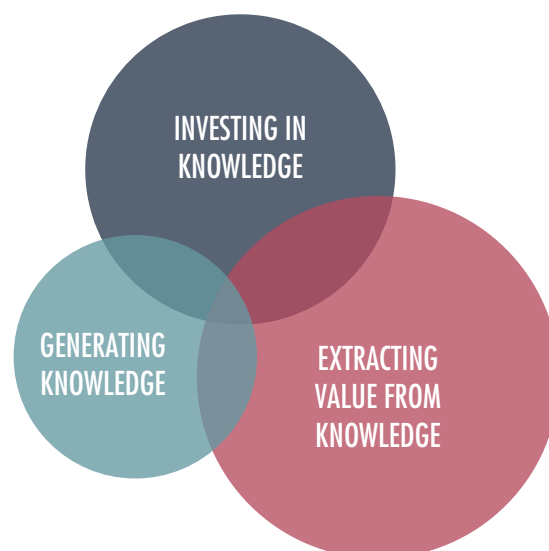


Figure 6-5:
Maximising the returns for a country's 'plc'



Chapter 7 What comes next for the knowledge platform?

The knowledge platform is an infrastructural resource for the field

Our primary conclusion is that the SGC constitutes a new approach to investigating, developing, producing and sharing knowledge because it provides a knowledge platform akin to an *infrastructural resource for drug discovery*. As a resource, it enables others to further science and technology, so it makes contributions across industry, academia, the public sector and biomedical research stakeholders. On the basis of our evaluation findings, we believe it should be continued as an open access, public-private partnership.

We conclude by drawing out the distinction between SGC as a group of scientists, and the SGC as a knowledge platform, which provides a resource for research. We first summarise the different kinds of benefits we have found the SGC to be making, and to which stakeholder groups, as well as the perceived weaknesses. We then consider the added value of the SGC as a unique open access, public-private partnership, and make recommendations for the future.

Benefits of the SGC

Our findings indicate that the SGC delivers a range of benefits for a diverse range of stakeholders, including industry, academia, the public sector and research stakeholders. Firstly, our findings indicate a widely held view that the SGC produces high quality and efficient science. This is of benefit for anyone wishing to build on SGC research. The high quality stems from the SGC's proven track record (contributing to the prestige of the organisation) and extensive network of collaborators. The efficiency stems from this as well, but also from the very way it does research. By employing a more 'industrial' approach to research, it is

able not only to stay focussed on particular targets and goals, but also to produce highly *reproducible* research findings. The point about reproducibility was particularly noted by private sector stakeholders. Reproducible scientific outputs meant that the work could be easily incorporated into a company's drug development process. When this insight from the evaluation is considered in the light of the wider literature in the field about the productivity of science and the wider spillover benefits good science can bring (Begley and Ellis, 2012),³⁷ we believe this in itself is a crucial finding.

Secondly, a range of interviewees noted that the vast collaborative network on which the SGC is built allows flexibility not only in the way it adapts to new areas of science, but also in the way it collaborates with a diverse set of stakeholders. Ultimately, this flexibility affords the SGC a range of scientific opportunities, and enhances successful collaborations.

Thirdly, the SGC is thought to benefit from good management and effective leadership by a significant number of stakeholders. The importance of a successful and productive team should not be underestimated. In fact, there is a small, underdeveloped body of literature which points to the importance of effective leadership in productive, high quality research. Dedicated leadership programmes and efforts within organisations like the National Institute of Health Research (NIHR) and National Institutes of Health (NIH) provide

³⁷ The Economist 'How Sciences Goes Wrong' 19th October 2013. Available at: <http://www.economist.com/news/leaders/21588069-scientific-research-has-changed-world-now-it-needs-change-itself-how-science-goes-wrong> [Last Accessed 4th November 2013].

Table 7-1
Summary of benefits of the SGC model by stakeholder group

Stakeholder group	Benefits of the SGC model
Industry	Large range of collaborations and networks (see pages 23 and 29) Securing funding and de-risking emergent areas (see page 24) Rapid research and the efficient use of knowledge (see pages 25 and 31) Demonstrable feasibility of a new model of R&D to underpin drug discovery (see page 32) An industrial edge (see page 32)
Academia	Large range of collaborations and networks (see pages 23 and 29) REF and RAE
The public sector	Knowledge spillovers facilitated through open access (see page 21)
All stakeholders	High quality science (see pages 32 and 33) The flexibility of the SGC (see page 32) Good management and effective leadership (see page 32)

evidence of this.³⁸ Thus, this element of the SGC constitutes a distinctive benefit of the SGC.

There are also a range of benefits which are specific to certain fields. For *industry*, the wide range of collaborations and networks provide a large pool of expertise to draw upon, increasing efficiency and allowing industrial partners to explore new areas in which they do not possess skills and expertise. This combined with the securing of funding from a number of public and private sources serves to ‘de-risk’ new and emerging areas. Moreover, de-risking is enhanced because funders of the SGC have representation at the board level. This allows pharmaceutical partners to determine areas of exploration through the SGC. This efficiency through knowledge sharing inevitably results in cost savings at some stage in the value chain, though we were not able to quantify this through our evaluation.

The real system level impact is larger than making processes more efficient, however. As outlined in Chapter 2, there is a widely held view that the current model of drug discovery is not as productive as it once was. It is in need of reform as the pharmaceutical sector is being forced to invest increasingly larger amounts for a smaller return. The SGC, then, does not simply reduce costs, it provides an alternative model of R&D which is

prolific in its outputs and has proven to work in practice. In the context of a struggling pharmaceutical sector, this is of fundamental importance.

The benefits of the SGC for *academia* are also diverse. For individual academics, the benefits accrued through the SGC’s open access policy are particularly important given that they facilitate further academic research. This benefit is enhanced for collaborating academics, who also benefit from the SGC’s vast networks across academia and industry, thereby widening the possibilities for further research and collaboration. In particular, the SGC facilitates knowledge sharing across diverse settings, allowing industry and academia to benefit from a wide range of perspectives. In the context of what many perceive to be a stranglehold of excessive IPR enforcement and litigation, the importance of the open access nature should not be understated.

For the *public*, benefits from the scientific advances enabled through the SGC’s open access policy are important. Interviewees perceived that research that builds upon SGC findings facilitates research advances for those in the field. Essentially, open access increases the number of potential beneficiaries of SGC findings in an environment where intellectual property regimes are widely considered to be excessively enforced. These benefits are summarised in Table 7-1 above.

Weaknesses of the SGC

Interviewees perceived fewer weaknesses of the SGC than strengths and benefits. However, the evaluation highlighted a number of concerns which are important particularly in light of the

³⁸ See for example Morgan Jones, M, Wamae, W., Fry, C., Kennie, T. and Chataway, J. (2012) *The National Institute of Health Research Leadership Programme: An evaluation of programme delivery and progress*. RAND Europe: Cambridge, UK. http://www.rand.org/pubs/technical_reports/TR1162.html and

SGC's future. First, although the positive aspects of the SGC's large range of collaborations and networks have been outlined above, it may be that the SGC has become too diverse. It subsequently may become too reliant on an ever-growing network. Too many collaborative relationships can create an unmanageable administrative burden and a number of stakeholders expressed concern regarding the resources and support staff available to manage them. Second, and related, a key challenge for the SGC concerns bounding the scope of its scientific focus. Some interviewees were of the view that SGC needed time and space to consolidate structural biology expertise rather than continually diversifying into new areas. Indeed this is something which must be determined by funders of the SGC to an extent, and may represent an opportunity for the public sector to provide means for the development of continued core expertise. This possibility is explored further below in relation to the role of the public sector within the SGC. Third, a minority of interviewees noted there was a lack of opportunities for career progression for researchers at the SGC, and their narrow research focus coupled with a lack of experience in writing grant proposals may also mean that they are less competitive in the academic job market upon leaving the SGC. However, stakeholder views and a strong assessment of SGC's outputs, underpin our conclusion that SGC's strengths are considerable. With the exception of the concerns about the diffuse focus of the SGC in the most current phase of funding, the weaknesses largely do not appear to have had a material adverse impact on performance or appeal. However, this expansion of focus into areas like epigenetics, antibodies and chemical probes was also seen as necessary to sustain the funding of the SGC. Therefore, one must consider the way in which the SGC is seen as a platform for investing in the basic resources and tools needed for drug discovery alongside this weakness.

The added value of the SGC: Beyond risk sharing

Though the SGC has many benefits, an important question to ask is whether any of these benefits are unique to the SGC as opposed to benefits which might emerge from any public-private partnership. Our rapid review of other public-private partnerships suggests that there are some benefits

that are common to the majority of drug discovery PPPs. For example, the establishment of a network of collaborations and efforts to share and distribute risk are to be expected of any PPP. In addition, the representation of both the public and private sector in leveraging funds and de-risking new areas for the private sector is thought to provide good 'value for money'.

However, we have found a number of benefits that are distinct to the SGC's PPP model. The SGC's collaborative network serves to ensure its findings are not only produced in an efficient manner, and disseminated quickly, but the nature of its science means it is readily reproducible and usable. The shared risk in an area which is a resource for the field means that a variety of actors can and do build on the SGC's findings. We believe that many of these 'added' benefits can be significantly attributed to the role of open access as it is perceived, maintained and benefitted from by the public and private sectors.

Our evaluation points to the conclusion, then, that in order to understand the added value of the SGC, it is important not only to appreciate what the role of open access is, but also how both public sector and private sector actors within the SGC benefit and help to maintain it. Therefore, we argue below that there is a much more finely nuanced role of the public and private sector presence in the SGC in relation to the added value it brings. The public sector plays a fundamental role in relation to maintaining open access, while the private sector helps to maintain the SGC's industrial quality and reproducible science. Both contribute to a form of innovation and related benefits that come out of the SGC and spill over to the wider field. Therefore, without each element, the SGC ceases to exist in its current form, and its added value to the field is reduced. We believe this goes to the core of some of the current tensions in the SGC model and its future. Therefore, by working through the role each plays, the benefits which accrue, and the broader questions and insights this leads us to, we hope to shed light on a possible way forward.

The public sector presence in the SGC helps to ensure that the 'rules' of open access and joint decisionmaking are maintained. Although the public sector need not always play this role, a range of stakeholders believed that the SGC in its current form could not maintain its open access philosophy without a public sector presence. Open access

itself is seen as underpinning a large range of benefits for the SGC, including enabling efficient and effective collaborations between academia and industry thereby facilitating direct knowledge sharing across the sectors. Therefore, it is important that this element of the SGC is maintained.

Moreover, the SGC's open access approach generates knowledge that creates 'spillover effects' for science and its supporting infrastructure. Knowledge spillovers occur directly through the dissemination of chemical structures and probes which are published openly and used by scientists and indirectly through formal and informal mechanisms for exchanging tacit knowledge (eg board meetings, conferences and personal relationships). Evidence from this evaluation suggests that these knowledge spillovers have system level impacts on structural biology, the pharmaceutical industry, and the science research system which are important but hard to measure or quantify. In addition, knowledge spillovers are of particular importance to the public sector because they maximise benefits and reach a wider range of beneficiaries than those directly involved with the SGC. Therefore codified and tacit knowledge produced by the SGC does permeate through the system, although it would require further research, such as bibliometrics or access to private sector investment data, to quantify how the knowledge is used by a vast array of different actors, and how it subsequently generates tangible benefits for them.

These benefits of open access are important because our evaluation findings suggest that the public sector may be one of the few ways to maintain open access of the SGC in the future. In the absence of their presence, there may be defensive behaviour from private sector investors and a pressure to reduce the open access component. Therefore, the open access philosophy as well as all of the benefits which directly arise from it can be said to be related to the public sector presence in the SGC. Moreover, it is the benefits that accrue from this open access which are of great importance to public, as opposed to private sector funders.

The private sector, whether involved in the SGC or not, also benefits from open access, but in a different way. We found examples of pharmaceutical companies and biotechnology firms which are not even involved in the SGC gaining from the substantial volume of structures and proteins which the SGC produces. However, those

which fund the SGC directly gain even more from their participation. They benefit from sharing in the processes undertaken in conducting the research and report benefits for their companies such as improved internal collaboration, greater efficiency, and improved access to collaborations through the SGC. In addition, the private sector is responsible for helping the SGC to maintain its industrial edge. The industrial model of the SGC was thought by stakeholders to be responsible for the speed, volume and overall efficiency of SGC research, as well as the high quality and reproducibility of science produced. This is borne out by the data, too. When we compare the average cost per structure identified for the SGC over 2004/5–2012 (\$289,000 CAD) with those for other structural genomics organisations in the same time period, we can see that the SGC is more efficient than RIKEN (\$712,000 CAD per structure, based on 2006–2011 funding for RIKEN as a whole), while the cost per structure for PSI (in its first two phases, 2000–2005/2005–2010) was \$104,000 CAD. As noted in Chapter 5, the SGC also works on other aspects of structural genomics, including chemical and biological probes, and, to some extent, new methods and tools, which are not captured in the analysis of structures alone, so the cost comparison should be interpreted with this in mind. Moreover, the way in which the SGC has drawn on the private sector is notable. Indeed one private sector funder acknowledged that from the beginning the SGC was aware of where and how it could extract most value from the private sector, aside from financial input. With this philosophy in mind, the SGC drew on the technical expertise of the private sector in allowing it to design assays and validate targets.

All of this serves to demonstrate that one of the main reasons it seems the public sector funds the SGC is in order to reap the wider scientific benefits of SGC research, which benefit both the public and private sector, but may cease to exist if the public sector were to withdraw funding. The private sector benefits from the industrial, reproducible model which it helps to maintain, and also benefits from the broader networks and flexibility the open access approach provides. It was the view of a number of interviewees that the SGC as currently constituted provides benefits to the public and private sector that may cease to exist if the public sector were to withdraw funding.

What this calls our attention to is an important and fundamental question: how does the SGC model contribute to innovation in relation to drug discovery? The question prompts the consideration of alternative routes to drug discovery. The 'productivity gap' in the pharmaceutical industry has received significant attention in scientific literature (Pammolli et al., 2011). It is widely acknowledged that investment in pharmaceutical research and development has increased substantially in recent decades, although during this time there has been a reduction in the number of medicines entering the market on a year-by-year basis (Carney, 2005). As a result, the cost of developing new medicines has risen (Carney, 2005; DiMasi et al., 2003). Pammolli et al. have shown that this can be explained through an increasing concentration of R&D investments in areas in which the risk of failure is high, which correspond to 'unmet therapeutic needs and unexploited biological mechanisms' (Pammolli et al., p. 428). This has led many to begin to point to alternative routes to drug discovery, most prominently the biotechnology sector as the main alternative model of drug discovery. In the absence of a rigorous empirical study that considers the benefits and costs associated with different alternative routes, it is to some extent an open question, but one to which the literature and our insights from this study does offer some different perspectives on this question. We consider some views on this here.

While open access provides numerous benefits to the scientific community, it may inhibit the opportunity for the establishment of biotechnology firms which rely on intellectual property in order to exist. If the SGC was to allow patenting at an early stage, it could encourage the spin out of a number of biotechnology firms. Biotechnology firms have often been equated with successful exploitation of life sciences and indicate the capacity of science to stimulate economic growth. It is an obvious expression of the capacity of entrepreneurs to engage in commercial development of new treatments and drugs (*Nature*, 2011a; 2011b). A counter argument to this, though, is that, because a large number of targets developed in biotechnology firms will fail, this model may serve to reap large economic rewards for the investors but may not be an efficient route to the production of new a drug (Hopkins et al., 2013).

The argument becomes more complex and more nuanced if we consider the nature of inno-

vation in the SGC as opposed to biotechnology firms. The open access approach offers a way of diffusing research without contracts and delays. The SGC approach and in particular a strong public sector presence in the SGC also enhance the nature of the research. The governance structure and the combination of public and private sector representatives on the board, protects the SGC from a narrow and perhaps short term perspective in selecting the focus of study. This allows the SGC to concentrate on novel targets and mechanisms, which are beyond the scope of biotechnology firms, and in many cases pharmaceutical firms as well.

This raises other questions for the role of the public sector and what it can hope to achieve in funding the SGC. If it maintains open access, it is unlikely that it will see immediate and direct economic payback in the form of new spin-outs. While a change in open access policy may lead to more economic activity through the spinning out of biotechnology firms, some of the knowledge spillovers may become lost. Moreover, the way in which the SGC is able to innovate may be lost because open access cuts across and contributes to its model in so many ways.

The current crisis in pharmaceutical innovation therefore raises the stakes of how to address this, particularly with regard to decisions about a change in direction in the SGC and in relation to the diminishing role of the public sector. Due consideration must be given to the broad costs to innovation in the pharmaceutical sector that may result if the SGC and other initiatives which depart from more traditional public and private sector approaches are abandoned. For example, scenario two illustrates one future for the SGC that might yield a range of benefits and opportunities, but that too may lead to the SGC becoming an entity which primarily serves to benefit the private sector.

In conclusion, the SGC provides benefits which are greater than the sum of its parts. The public sector plays an important role in ensuring open access and all of the accompanying benefits are maintained, as well as in keeping the SGC innovative and relevant. Without the public sector, the benefits of the SGC would be quite different, and indeed could be reduced. However, there are trade-offs between enabling innovative research designed to have impact in the medium

or long term, and turning the SGC into a body which fuels the establishment of biotechnology firms in the short term, but which could then lose its world-class expertise in structural biology and ability to produce innovative targets and mechanisms. In turn, the benefits the public sector gets from the SGC are reliant on the private sector's influence to produce high quality, useful outputs in a quick and cost-effective manner, which it has so far done. Both public and private sectors are needed in order to continue to provide the resources for the field which the SGC provides.

Taking forward the SGC

Our evaluation has shown that the public and private sectors do bring different perspectives and carry out distinct roles which are fundamental to the SGC model's operation. The source of funding is perhaps not important in and of itself, although the role that each fulfils would likely need to be maintained by other bodies and this role would need to be explicit. Specifically, complete public sector withdrawal may lead to the disbandment of the SGC. This could result in a loss of productivity for the academic community as a result of not having the benefits of the SGC's open access structures; a backlash in the pharmaceutical community as companies re-invest their resources internally, or collaboratively with each other, but not back into the scientific communities in the public domain; and an overall decline in efficiency in the drug discovery process. Moreover, the SGC in its current form has the potential to create a clustering effect, given that it will attract companies and skills to its locations. Indeed, we heard through our evaluation that this is already happening.

All of this serves to demonstrate that the public sector needs to be fully aware of the role it is currently fulfilling, and the losses that would be incurred by a wide range of stakeholders if it withdrew from the SGC. These losses should be considered against the backdrop of the traditional model of drug development and innovation and the productivity gap discussed above. The ability of the SGC to de-risk new areas for pharmaceutical companies is hugely important, as is the current ability of the SGC to produce novel targets and mechanisms. The SGC has proven itself to be a model of drug discovery which is efficient

in terms of outputs in relation to financial inputs, prolific in terms of tangible outputs and beneficial to a wide range of stakeholders. Overall then, it is a success managed by a motivated team who complement each other's talents and expertise – and in the age of a pharmaceutical productivity crisis the value of such an enterprise cannot be understated.

We conclude with these thoughts and a succinct set of recommendations for the SGC and its stakeholders:

- **The SGC should be maintained.** The evaluation findings suggest that it is contributing scientifically in relation to knowledge production and in catalysing further knowledge development and growth in other areas. It serves as a knowledge platform, and more importantly a scientific resource for research. It adds value to the scientific and industrial communities.
- **Consider producing a high level strategic policy that provides a broad plan for operations over the next 5–10 years.** This should aid the exploration of issues such as the limits of scientific diversification, geographical base, risks and risk management strategies and so on. Such an exercise could also serve as a good way to engage existing and new funders in a conversation about sustainability and the scenarios in this report may provide a good starting point for this.
- **The public sector should be incentivised to (re)invest.** This could happen in a number of ways drawing on this evaluation and other data. Some suggestions include:
 - Maximising the promotion of benefits of the SGC to the wider public. This could be achieved through giving a bigger profile to the knowledge and scientific spillovers the SGC generates, including helping researchers outside the SGC obtain additional funding for their own laboratories in more cost effective and scientifically efficient ways than they would be able to do through other collaborations.
 - Creating opportunities for public funders to demarcate what their contributions to the SGC are. Sponsored or branded fellowships or conferences could raise the profile of funders and may attract new collaborators.
 - Ensuring efficient monitoring and evaluation processes are in place to help identify

and demonstrate value for the public sector funders (this is elaborated on below).

- **Develop a strategic approach for identifying potential philanthropic and charitable funders who may be interested in investing in the SGC as a platform for knowledge.**

This would need to be done in a way which did not stifle innovation within the SGC or overly narrow the focus, but it could be done in a way and in specific areas which sat within a broader strategic vision.

- **Consider ways to enhance the sustainability of the SGC's leadership, potentially through recruiting deputy leaders.** The evidence presented in the report is unanimous that the SGC leadership is dynamic and entrepreneurial in driving the SGC forward. This is both a strength and weakness; on the one hand the leadership is integral to the SGC's strength as an organisation and on the other any loss of key personnel could jeopardise the support of funders and effectiveness of the SGC in the future.
- **Provide additional support for scientists to aid career progression and develop transferable research skills.** This could be achieved by establishing a mentoring programme for junior scientists by senior scientists, encouraging exploration of scientific ideas by working across research groups and providing PhD opportunities for the recruitment of promising postgraduate scientists.
- **Improve monitoring and evaluation processes to more effectively capture knowledge and disseminate positive impacts where they arise.** More effective monitoring and evaluation will enable the SGC to improve activities in the future, have internal and external accountability, take more informed decisions about the future and empower beneficiaries of the SGC.
- **Enhance engagement with SMEs.** Build on the successful examples of the few small biotechnology firms which have arisen out of partnering with the SGC to focus more on possibilities for engaging small firms in its generating

knowledge and extracting value models. There are several ways this could be done:

- Extend the non-board member 'buy-in' route for small firms, akin to that provided to Life Biotech in the antibodies programme.
- Recruit knowledge transfer managers with expertise in biotech and relevant industrial sectors to work more closely with SMEs.
- Utilise economies of scale and scope more effectively which in turn would enhance the SGC's capacity to create more knowledge.
- Develop mechanisms to enhance support for SMEs and take a more active role as a 'social venture capitalist', supporting clusters of firms aligned to SGC activities.
- **Understand the comparative value of the SGC model.** Undertake a more comprehensive assessment of the comparative costs and merits of the different trajectories to drug development. This could focus perhaps on the two emerging models of biotechnology and venture capital on the one hand and pre-competitive open innovation/open access on the other.

Our recommendations acknowledge that the SGC undertakes excellent science that has considerable system-level benefits for academia, scientific exploration (eg structural biology, epigenetics, antibodies) and the pharmaceutical industry. We are aware, though, that the recommendations need to be considered in the light of how the SGC articulates itself with the wider funding landscape that surrounds it. We are conscious that some of the recommendations presented may not be in line with the SGC vision, but they arise from the evidence gathered in this evaluation and from our understanding of the different challenges and opportunities facing the SGC and how it may need to respond. These are important considerations for how the SGC can attract more funding, generate knowledge more efficiently, and extract more value from the knowledge it creates in both the scientific and wider socio-economic sense and address the pressing issue of how the consortium can be sustainable in the future.

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Appendix A: Literature review material

Public-Private Partnerships for Innovation from other sectors

In a growing number of industrial sectors, development models characterised by ‘traditional’ R&D procedures, including ‘traditional’ IPR protection, are challenged by innovative technology development models. The modes of collaboration are varied and multiple avenues for creativity are being explored. There is no universal approach and a number of public-private partnerships (PPPs) have been established with an open innovation ethos to facilitate better knowledge and exchange across different communities. Many of these PPPs are evolving, experimental and operate uniquely within the context of the industrial sectors they inhabit.

This annex identifies a range of examples from different industrial sectors which have adopted an open innovation ethos through public and private partnerships. These have been identified through a web-based search of academic and policy literature. The forms of these partnerships vary but include formal organisational models, informal networking mechanisms and different platforms geared towards facilitating innovation and knowledge production to the benefit of different sectors. After introducing a ‘longlist’ of examples identified across a range of different sectors a number of case studies are discussed before a closing summary that examines a typology of public and private partnerships.

Case studies

Linux

Linux is a Unix-like computer operating system assembled under the model of free and open source software development and distribution. Its underlying source code may be used, modi-

fied, and distributed — commercially or non-commercially — by anyone under licenses such as the GNU General Public License. Distribution is largely driven by its developer and user communities. Some vendors develop and fund their distributions on a volunteer basis, Debian is one such example.

Linux cannot be considered a PPP in the conventional sense; the system has developed organically and has evolved into an informal self-organising community. It operates without a particular market audience and there is no clear hierarchy to its organisation and management (West and Gallagher, 2006). The system is developed not only on a non-profit basis but also no money is exchanged and developers work voluntarily on the system. Despite the lack of financial incentivisation for developers Linux has a reputation as one of the best operating systems available in terms of functionality and use (Gruber and Henkel, 2006).

The impact of Linux on the software and internet-based industries has been considerable. Firstly, Linux has offered a way for corporations, government and others to cut costs and avoid lock-in to proprietary operating systems (Waring and Maddox, 2005). Secondly, and more importantly, the flexible open source approach gives Linux flexibility in design that enables the system to be more innovative than competitors. The growth and popularity of Linux has reached a point where Linux may challenge the hegemony of Microsoft in the future (Henkel, 2006). In sum, the impact of Linux in revolutionising product development models and transforming the culture of innovation in software and internet industries has been profound.

Sematech

Sematech (Semiconductor Manufacturing Technology Consortium) was established in 1987 as a

Table A-1:
List of comparator PPPs from other sectors

Name	Description
Apache	Apache is a web-based server. It is an open source platform enabling users to download, use, and modify and further develop it.
Linux	Linux is a Unix-like computer operating system assembled under the model of free and open source software development and distribution. Its underlying source code may be used, modified and distributed —commercially or non-commercially — by anyone under licenses such as the GNU General Public License. Distribution is largely driven by its developer and user communities. Some vendors develop and fund their distributions on a volunteer basis.
Eclipse SDK	Eclipse is a multi-language Integrated development environment (IDE) comprising a base workspace and an extensible plug-in system for customizing the environment. It can be used to develop applications in Java and, by means of various plug-ins, other programming languages
Moodle	Moodle is an Open Source Course Management System (CMS), also known as a Learning Management System (LMS) or a Virtual Learning Environment (VLE). It has gained popularity amongst educators as a tool for creating online web sites for educational purposes.
Creative Commons	Creative Commons (CC) is a non-profit organisation headquartered in the United States. Its aim is to expand the range of creative works available for others to build upon legally and to share. The organisation has released several copyright-licenses known as Creative Commons licenses free of charge to the public. These licenses allow creators to communicate which rights they reserve, and which rights they waive for the benefit of recipients or other creators.
Sunshot	Sunshot is an initiative sponsored by the the U.S. Department of Energy (DOE) Solar Energy Technologies Office. The office issues competitive solicitations that fund selective research projects aimed at transforming the ways the United States generates, stores, and utilizes solar energy. The emphasis is on collaboration between public and private sectors to make solar energy cost-competitive with other forms of electricity by the end of the decade. The SunShot Initiative drives research, manufacturing, and market solutions to make the abundant solar energy resources in the United States more affordable and accessible for Americans.
National Alliance for Advanced Technology Batteries	The National Alliance for Advanced Technology Batteries (NAATBatt) is a not-for-profit trade association of foreign and domestic corporations, associations and research institutions focused on the manufacture of large format advanced batteries for use in transportation and large scale energy storage applications in the United States. Members include advanced battery and electrode manufacturers, materials suppliers, vehicle makers, electric utilities, equipment vendors, service providers, universities and national laboratories.
European Technology Platforms	European Technology Platforms (ETPs) were set up as industry-led stakeholder forums with the aim of defining medium to long-term research and technological objectives and developing roadmaps to achieve them. Their aim was to contribute to increasing synergies between different research actors, ultimately enhancing European competitiveness.
EU Joint Technology Initiatives	Joint Technology Initiatives (JTIs) are a means to implement the Strategic Research Agendas (SRAs) of a limited number of European Technology Platforms (ETPs). In these few ETPs, the scale and scope of the objectives is such that loose co-ordination through ETPs and support through the regular instruments of the Framework Programme for Research and Development are not sufficient. To meet the needs of this small number of ETPs, the concept of "Joint Technology Initiatives" has been developed.
Sustainable Process Industry through Resource and Energy Efficiency (SPIRE)	Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) is a European Public-Private Partnership (PPP) dedicated to innovation in resource and energy efficiency and enabled by the process industries. Sectors such as steel, chemicals, minerals, water, nonferrous metals, glass, representing big and small companies, have set up common aspirations for innovations in resource and energy efficiency in their sectors and beyond. SPIRE intends to develop a practical roadmap, to help ensure that EU innovation projects address the right needs and achieve optimal impact from 2014 to 2020.
Sematech	Sematech (Semiconductor Manufacturing Technology Consortium) is a public-private partnership for innovation and research in semiconductor industry. Sematech's mission statement is to address critical challenges in advanced technology and manufacturing effectiveness, and to find ways to speed development, reduce costs, share risks and increase productivity. The organisation was founded in 1987 as a national PPP for U.S. chipmakers but is now a global organisation.
Open Hardware Repository	The Open Hardware Repository ohwr.org is a place on the web for electronics designers at experimental physics facilities to collaborate on open hardware designs, much in the philosophy of the free software movement.

Sector	Geographical Coverage	Type of PPP	Link
Software	Global	Open source software platform	http://httpd.apache.org/
Software	Global	Open source software platform	http://www.linux.org/
Software	Global	Open source software platform	http://www.eclipse.org/eclipse4/
Education	Global	Collaborative innovation webspace	https://moodle.org/about/
Arts	Global	Open source platform	http://creativecommons.org/
Renewable energy	United States of America (U.S.A)	PPP for research and development	http://www1.eere.energy.gov/solar/sunshot/
Advanced Manufacturing	United States of America	PPP for research and development	http://naatbatt.org/
Bio-based economy, Energy, Environment, ICT, Production, and Transport	Europe	PPP for research and development	http://cordis.europa.eu/technology-platforms/home_en.html
Health, Transport, Energy, ICT, Space	Europe	PPP for research and development	http://ec.europa.eu/research/jti/index_en.cfm?pg=about
Energy	Europe	PPP for research and development	http://www.spire2030.eu/
Semiconductor	Global (previously U.S. only)	PPP for research and development	http://www.sematech.org/
Electronics	Global	Collaborative innovation webspace	http://www.ohwr.org/projects/ohr-meta/wiki

not-for-profit partnership between the semiconductor industry, academia and government. The original consortium consisted of 14 semiconductor firms (including IBM, HP, Intel) in the United States of America (US) with the objective to maintain the competitiveness of the US semiconductor industry by pooling resources more effectively to retain a comparative advantage vis-à-vis competitors in East Asia (Browning et al., 1995).

The partnership was originally subsidised by the US Department of Defence but now is funded mainly by industry and has a larger international focus representing about half of the world's chip makers. Although the partnership is still active it receives less funding support than during its zenith from the mid-1980s to mid-1990s (Carayannis and Alexander, 2004). In the early 1990s Sematech focused a great deal of R&D funding on strengthening the suppliers of its members companies. Now Sematech functions more as a forum to develop strategies and influence industry rather than direct interventions into the electronics industry. Sematech draws extensively on industrial expertise and follows a 'crowdsourcing' model of deciding what should be the next technologies to pursue and where the sector should focus its resources. Although Sematech has not eliminated competition it has created a space in which rival firms can cooperate towards specific goals and within certain boundaries (Hoff, 2011).

Sematech is perceived to have generally a positive impact on the US semiconductor industry (Carayannis and Alexander, 2004). The partnership has been credited with a role in maintaining the global competitiveness of the US semiconductor industry. Before the establishment of Sematech it took 30 per cent more research and development dollars to bring about each new generation of chip miniaturisation. The figure dropped to 12.5 per cent shortly after the advent of Sematech and has since fallen to the low single digits (Hoff, 2011). While Sematech created a number of benefits for the sector in encouraging collaboration, pooling expertise, creating a shared strategic vision it is difficult to isolate the mechanisms by which the partnership may have directly contributed to the success of the US semiconductor industry at large.

More broadly, Sematech has become a model for how industry and government can work together to keep manufacturing industries competitive. A number of other US technology devel-

opment consortia funded by public and private sectors have been influenced by Sematech (eg National Alliance for Advanced Technology Batteries). Despite these successes Sematech has not been without problems. It has needed to balance the competing interest of its members and adjust priorities to the rapidly changing environment of electronic technologies. It has also been criticised for being an exclusive club of large chip makers who are not always willing to share technologies with smaller firms and spillover benefits to the wider electronics community.

EU Technology Platforms

European Technology Platforms (ETPs) were established in 2002 as industry-led stakeholder forums with the aim of defining medium to long-term research and technological objectives and developing roadmaps to achieve them. Their goal is to provide a framework for addressing major technological challenges. These challenges are to be addressed and led primarily by industry. However, to ensure that European Technology Platforms achieve optimum results and reflect wider community interests, public authorities and all other relevant stakeholders should also be actively involved (European Commission, 2005). ETPs are implemented through Joint Technology Initiatives (JTIs) (European Commission, 2007).

JTIs have been implemented across 34 diverse research areas, including road transport, space technology, wind energy, hydrogen and fuel cell technology, nanotechnologies for medical applications, robotics and water supply and sanitation technology, to name a few. Each initiative strives to adopt a unique approach due to the varied nature of the technological challenges, the different relationships between partners in the sector and the need for bespoke funding arrangements. While remaining sensitive to industrial context the overall guiding principles for ETPs are to ensure efficiency and durability, to support long-term stakeholder commitment and to promote openness, transparency and cooperation.³⁹

The ETPs were evaluated by the European Commission in 2008. The evaluation identified

³⁹ European Technology Platforms. As of 13th August: http://ec.europa.eu/research/jti/index_en.cfm?pg=about

obstacles facing ETPs in making research results more easily translatable into new products and services. The evaluation recommended ETPs ‘move beyond scientific and technological challenges’ and instead start focusing on the application of research results European Commission (2008). Those platforms which are more advanced and have already developed their SRAs should focus on ‘the regulations and standards that affect the commercialisation of research.’ In addition, the evaluation concludes that the platforms have ‘underachieved’ regarding the identification of future education and training needs and recommends the introduction of more initiatives in this field in the near future.

Generally it is difficult to evaluate the success of ETPs and their JTIs due to the relative newness of the initiatives and also because their objectives are forward looking. JTIs seek to horizon scan for future technological and scientific developments across different sectors and promote collaboration between public and private sectors over the long term to maximize future opportunities thus enhancing European competitiveness.

Summary

There are considerable difficulties in establishing any kind of collaborative PPP for R&D. Partnerships often take a number of years to become established and face significant obstacles around antitrust, mistrust amongst members and often a lack of consensus among industry to get the initiative off the ground. Once established partnerships need to balance the needs of the public and private sector and manage the tension of inter-firm rivalries which may threaten the sustainability of the partnership. Moreover, the internal conditions amongst partners may alter and the external environment is subject to shocks which put the model for collaboration in jeopardy or make it considerably less attractive than when it was first established.

Although difficulties exist there are a small number of partnerships from other sectors that have been established with positive impacts. These partnerships take different forms and the success of these is dependent on specific conditions being in place and clear boundaries being drawn on the scope and scale of initiatives. Within the scope of this short review it has not been possible to

delve deeply into each PPP and undertake a comprehensive review of evidence on impacts on each individual sector. Based on our brief review of comparator PPPs from other sectors a number of different modes of collaboration have been mobilised, these are, *inter alia*:

- **Domestic versus international.** Restricting collaborations to firms of the same nationality (eg Sunshot) or a geographical region (EU) (eg ETPs). Or adopting an open access platform which has no geographical boundaries or immediate barriers of access (eg Linux).
- **Narrow or broad sectoral focus.** Collaborations may have a broad sectoral focus and a wide remit to facilitate knowledge exchange and technologies (eg Sustainable Process Industry through Resource and Energy Efficiency (SPIRE)). Others may be organised narrowly around a specific sector area or a strategically important technology (European Joint Technology Initiatives).
- **Horizontal versus vertical.** Collaboration between a horizontal group of competing firms (eg Sematech and ETPs) or collaborating vertically in the supply chain with firms in a sector (eg National Alliance for Advanced Technology Batteries). Of these two modes horizontal forms of collaboration tend to be more common and are often organised to overcome a technological or scientific obstacle (eg ETPs) or emerge in the face of external pressures (Sematech).
- **Firm-to-firm, consortium-to-firm, consortium-to-consortium.** Different modes of collaboration can take place at different levels. This can involve firms collaborating with one another or a consortium collaborating with a firm.
- **Competitive versus pre-competitive.** Competition between firms in the partnership or pre-competitive research on technologies or tools to benefit all.
- **Organisations versus networks versus platforms.** Partnerships can be managed through complex organisational structures and hierarchies (eg European PPPs) or less formalised, more organic bottom-up networks (Linux). Other PPPs may take the form of a simple platform that provides the mechanisms for different actors to network as desired (eg Moodle).

From these different modes of collaboration we can develop a crude typology based on the PPPs surveyed. Firstly, there are a number of *open source platforms* mainly from the software sector that promote user-led innovation by making research and development pre-competitive and non-profit. A number of these platforms have been utilised by a community of enthusiasts who have devoted a considerable amount of time and energy to developing open access software. As a consequence, platforms have been highly successful and challenged the dominant position of market incumbents like Microsoft who are able to mobilise considerable resources and expertise on their own competing platforms. The classic examples of open source platforms are those of Apache, Linux and Eclipse and are included in our longlist.

Secondly, there are *collaborative innovation webspaces*. These are essentially websites that enable different communities to exchange ideas and transfer knowledge. In their simplest form collaborative innovation webspaces can take the form of a Wiki: webspaces in which people can add, modify or delete content in collaboration with others. More complex forms can encom-

pass webspaces that have the functionality of virtual learning environments (VLEs) or a Learning Management System (LMS). The main example from our longlist is Moodle which is an Open Source Course Management System (CMS) that functions as a tool for creating online dynamic web sites for educational use.

Thirdly, *PPPs for research and development* are more formalised mechanisms for knowledge exchange and technology transfer in different sectors. These can be driven by industry in the case of Sematech to enhance competitiveness of firms or driven by government institutions to maintain the competitiveness of a region (eg European Technology Platforms). Due to these varying motivations PPPs for research and development tend to be diverse in organisation, scope and scale. Some PPPs have a broad sectoral focus while others are centred on specific key enabling technologies that are anticipated to drive growth in a sector and beyond. Most PPPs are evolving and transform over time; their characteristics depending on the maturity of the sector, the characteristics of industry and firms therein and wider political, economic, technological and scientific factors influencing innovation.

Appendix B: SGC Researcher Survey Analysis

Introduction

The Structural Genomics Consortium (SGC) is currently assessing its approach, activities and actions in order to help improve outcomes from its work in the future. As part of this work, the SGC have commissioned RAND Europe and the Institute on Governance (IOG) to provide a report on the work undertaken by SGC so far.

As part of the methodological approach a survey was conducted with SGC researchers to provide feedback on the impacts that they have seen from their work within the SGC. The survey asked about the impacts that have occurred from any SGC research programme or research project for SGC which researchers had been a PI during any phase of SGC operation. The survey examined in a holistic way the benefits and impacts to researchers from all research they had undertaken during their involvement with SGC.

The survey complimented the e-Val impact tool used by SGC, by requesting additional information about downstream impacts, emerging impacts (that will soon be realised) and the role the SGC has played in these impacts. The survey was conducted online and each participant was contacted by email with an introduction about the survey and a URL link for access to the survey.

The following annex provides a summary of the main findings from the survey. The analysis is conducted in a linear fashion reflecting the order in which the questions were completed by researchers. A total of 17 of 23 SGC researchers completed the online survey, although in some cases questions were skipped. Therefore total numbers are given in the text where percentages are provided.

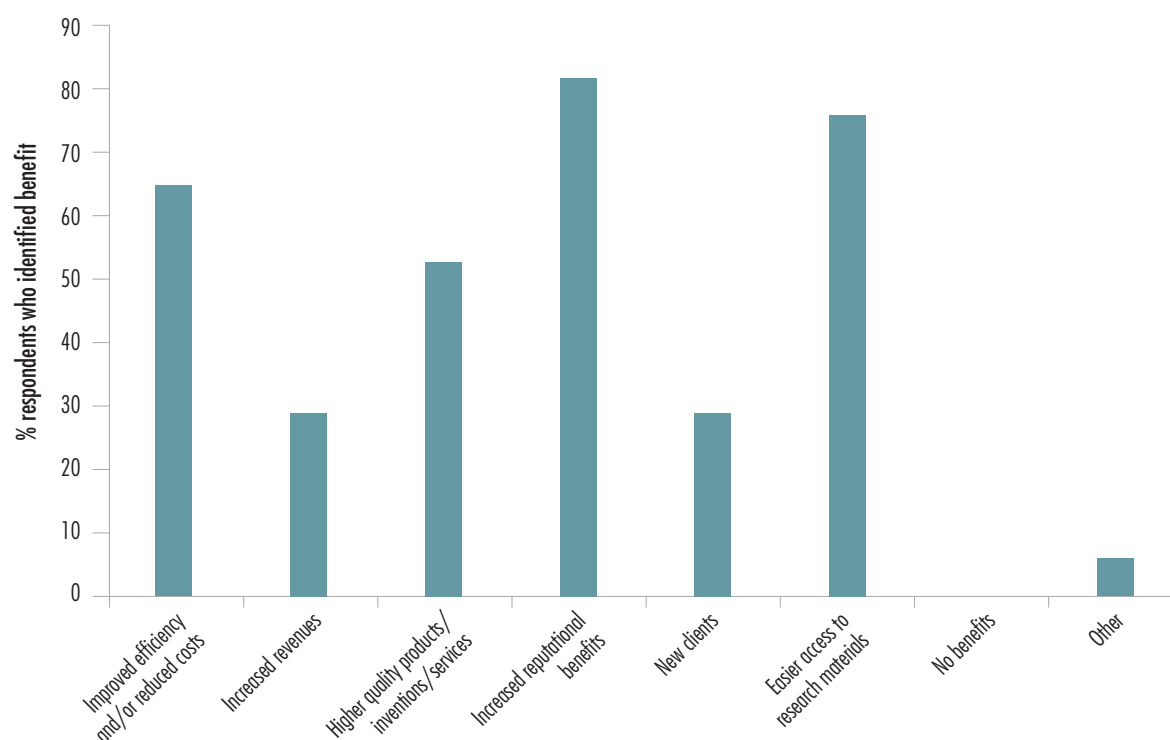
Impacts on Research Capacity

The first section of the survey examined the impacts of the SGC on research capacity. Researchers were asked a series of open and closed questions about impacts on human capital, research culture, research infrastructure, research funding and research priorities.

Question one asked respondents if their involvement in the SGC had played a role in any scientific awards they have received. Relatively few had received awards during their time at the SGC, with 7% (n=15) receiving a scientific achievement award, 20% (n=15) receiving a research support award and 7% (n=15) receiving an unspecified award.

The SGC draws on a highly collaborative research network and a series of questions were posed to researchers to understand the impact of collaborations on research capacity – for researchers directly employed by the SGC, for research capacity within the University of Oxford and the University of Toronto and for external collaborators with no financial ties with the SGC. The first question in this series asked researchers to identify the benefits for the SGC where SGC research has led to agreements to form research collaborations or similar arrangements, by selecting answers from a pre-defined list. They identified increased reputation benefits (82%, n=17) and easier access to research materials (76%, n=17) as major benefits for the SGC. Other benefits which were identified to a lesser extent were higher quality products, inventions or services (53%, n=17), increased revenues (29%, n=17) and new clients (29%, n=17) (see Figure B-1).

Figure B-1:
Benefits for the SGC as a result of collaborations



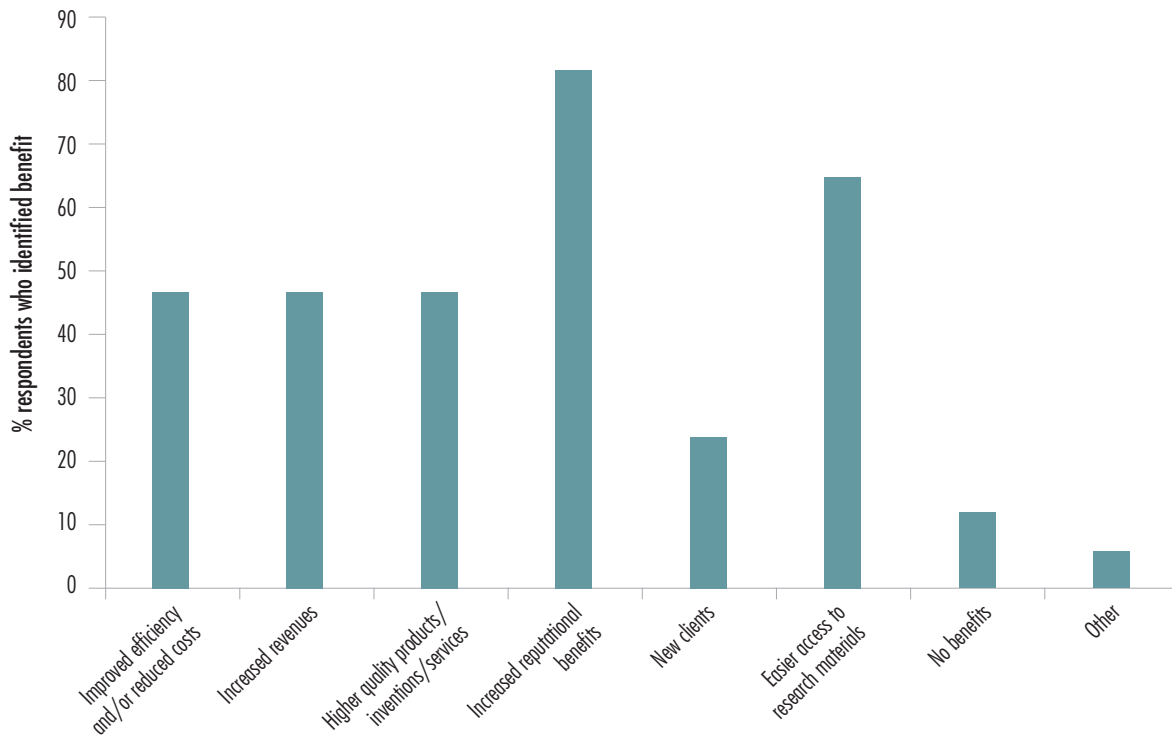
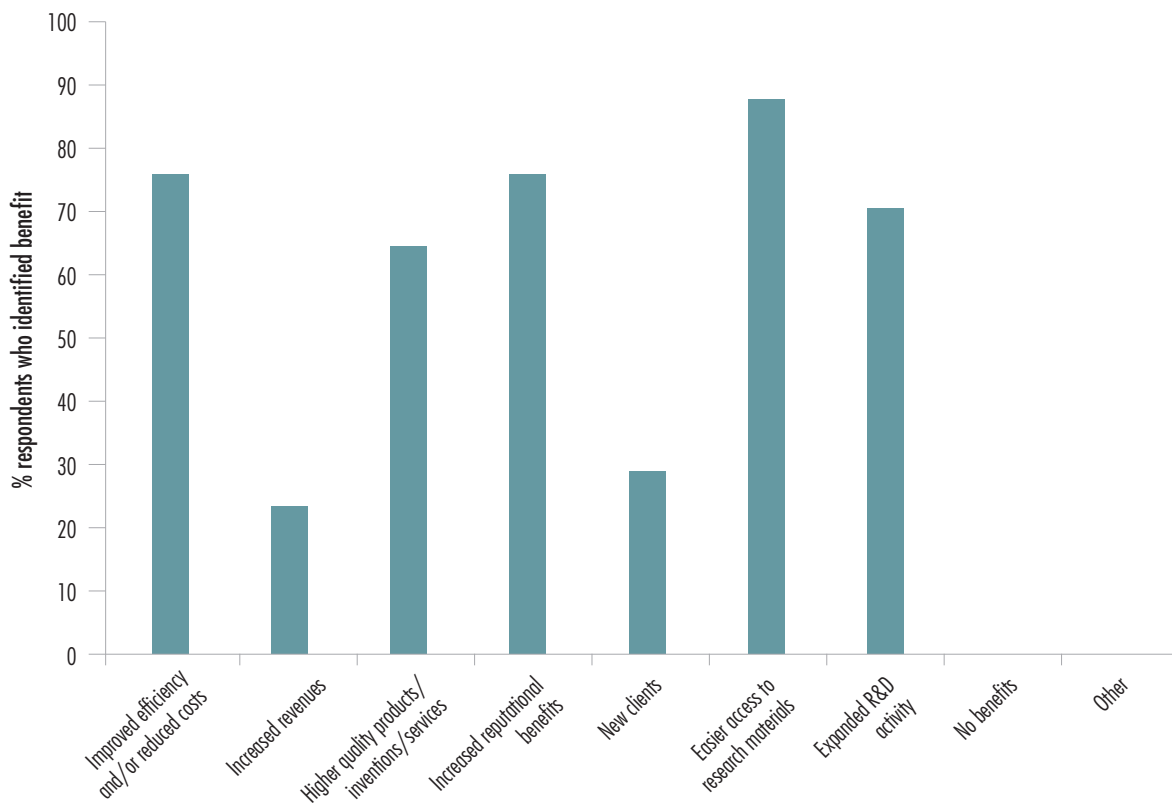
Following questions examined benefits to affiliated universities (University of Toronto and University of Oxford) and benefits to the collaborating organisation, using the same pre-defined list for respondents to choose from. Major benefits to universities involved in the SGC were increased reputational benefits (82%, n=17) and easier access to research materials which would have been difficult to obtain working outside the network (65%, n=17). Other benefits to universities included improved efficiency and/or reduced costs (47%, n=17), increased revenues (47%, n=17) and higher quality products, inventions, services (47%, n=17) (see Figure B-2).

In reference to benefits obtained by collaborating organisations, the benefit identified by most respondents was easier access to research materials which would have been difficult to obtain if working outside of the SGC network (88%, n=17), followed by improved efficiency and/or reduced costs (76%, n=17), increased reputational benefits (n=76%, n=17) and expanded R&D activity (71%, n=17). Not one respondent suggested that collaborating organisations had not received any benefits as a result of collaborating with the SGC, and the

number of respondents identifying a range of benefits was relatively large (see Figure B-3).

When asked specifically about the role of the SGC in building research capacity, 94% (n=17) of respondents stated that they believe working with the SGC has impacted on research capacity in a way that would not have occurred outside of the SGC (ie within a different research structure or environment). Those respondents were then asked to provide up to three important impacts on research capacity in an open-ended manner, which can be categorised into four major areas.

The first of these relates to the collaborative opportunities offered through the SGC and the impacts of people more generally. This encompasses both collaborations within the SGC and those external to the organisation. The importance of internal collaboration was mentioned by 31% (n=16) of respondents. One researcher stated that the ability to combine the key expertise of different labs – allowing for cross-disciplinary research and the production of novel data that would not be possible to produce in one lab alone – was important, while two others commented that projects were completed faster and more efficiently as a

Figure B-2:**Benefits for affiliated universities as a result of collaborating with the SGC****Figure B-3:****Benefits for organisations collaborating with the SGC**

result of working within the SGC, considering a broad range of angles which would otherwise not have been explored. However, more importance was placed on external collaboration which was mentioned by 50% (n=16) of respondents. This referred to collaboration with the pharmaceutical industry, academia and SMEs (although collaboration with pharmaceutical companies was mentioned most frequently (44%, n=16)). Another respondent noted the importance of external collaboration more generally and yet another mentioned collaboration without specifying whether it related to internal or external collaboration. Related to attracting external collaborators was the ability to attract visiting scholars, which act as a resource for the SGC and bring new skills and expertise. This was specifically mentioned by 19% (n=16) of respondents.

The second major area was mentioned by 50% (n=16) of respondents and was related to funding. This included funding from the SGC itself, the receipt of grants/research money received due to SGC research, the funding of industrial collaborators and access to more leveraged funding through collaborations with the pharmaceutical industry. One researcher also stated that the fact funding is achieved through a common effort for the whole of the SGC site gives economic safety and creates beneficial teamwork.

The third category of responses relates to the high quality of infrastructure offered by the SGC, which was mentioned by 31% (n=16) of researchers. One respondent particularly noted the importance of genomic libraries, automation and tools; although for the most part the importance of infrastructure was referred to in general terms.

The fourth major area was mentioned by 13% (n=16) of respondents and is concerned with the benefits of an open access model. One researcher commented that open access research has pooled resource and enabled goals to be reached more quickly while another stated that the 'open access concept' has 'resulted in numerous publications in high impact journals, providing data to the scientific community without restriction'. Other impacts on research capacity referred to specific scientific achievements (13%, n=16) and the ability to host conferences (6.25%, n=15).

When asked about future impacts 76% (n=13) believed their SGC research would have further impacts on research capacity within the next 6–12

months. Respondents were asked to provide the details of these impacts in open-ended responses which included the attraction of new collaborators and funders, the ability to conduct multidisciplinary research due to the high productivity of the research programme, the development of a university-wide chemical biology database driven by the SGC, the development of a prototype drug which may attract new research collaborations and funding, and various scientific advances. One respondent also referred to the external political environment and noted that the UK government's growing interest in open access models may provide the opportunity to engage with UK government agencies.

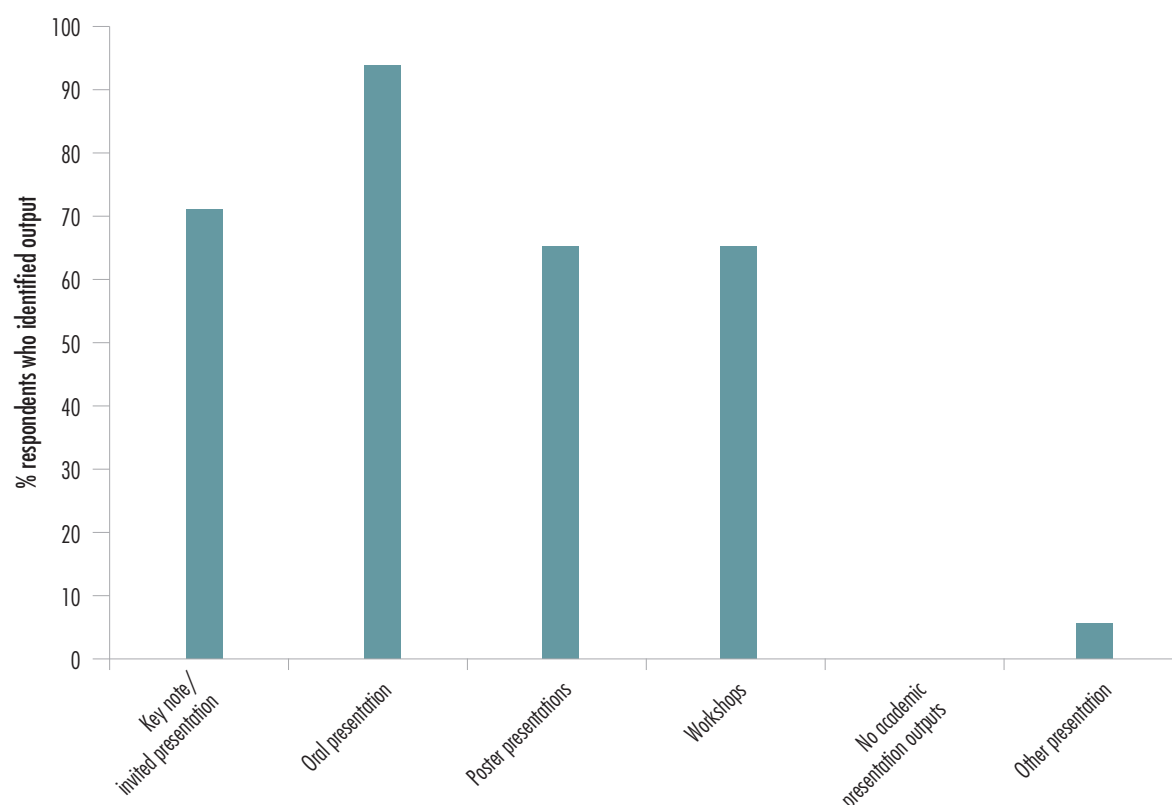
Overall, the survey response suggests that working with the SGC has led to significant impacts on research capacity – not just for the SGC, but also for the affiliated universities and the collaborating organisations. It has done so through a variety of ways – particularly in enabling collaboration and the pooling of resources, securing funding and providing a superior research infrastructure. Not only this, but it is expected to continue to impact on research capacity through expanding its activities and networks.

Impacts on Knowledge

This section aimed to ascertain how far knowledge production has been affected through working with the SGC. It primarily consisted of a series of closed questions, although in certain cases respondents were invited to provide details of their responses in open-ended text boxes. The number of academic dissemination activities of SGC research was high. 94% (n=17) of researchers had given an oral presentation (including in conferences, academic departments and seminar series), 71% (n=17) had given a key note or invited presentation and 65% (n=17) had given a poster presentation and participated in workshops. One respondent also stated that they had participated in a symposium (see Figure B-4).

When asked about whether working in the SGC impacts on the type of networks, collaborative opportunities, and other engagements with the research community in comparison to other types of research environments, 88% (n=17) believed it did, while 12% (n=17) did not know. In elaborating on the value of the SGC in this area,

Figure B-4:
Academic presentation outputs of SGC research



the SGC's link with both academia and the pharmaceutical industry was particularly highly valued – with the link to either academia, pharmaceutical companies or both being mentioned by 67% (n=15) of respondents. The ability to work across labs and various biomedical research groups was also mentioned by 13% (n=15), and the opportunity to reach a wide audience due to the SGC's superior dissemination of scientific data through the open access model was cited by 13% (n=15) of researchers.

Researchers were also asked if they believed working through the SGC had allowed their research to come to fruition more quickly than if it had been supported by traditional academic approaches, to which 82% (n=17) believed it had and 18% (n=17) did not know. The most frequently cited reasons for accelerated research translation were high quality collaborations and an integrated approach, the lack of need to spend time writing grant proposals and efficient SGC processes. One respondent also suggested that the lack of patents increased efficiency. In relation to the direction and rate of future knowledge pro-

duction, 41% (n=17) believed it would change in the next 6–12 months, 41% (n=17) did not believe it would change in the next 6–12 months and 18% (n=17) did not know.

Respondents were asked to rank how important they perceived different aspects of the SGC model to be in enabling them to produce high quality research and knowledge outputs, from very important, important, neutral, somewhat important and not at all important. The aspect which the largest number of researchers considered to be very important was the established prestige and reputation of the SGC (76%, n=17), followed by effective leadership (65%, n=17) and open access (65%, n=17) (see Table B-2). As Table 1 shows, many aspects of the SGC were considered to be either important or very important by the majority of researchers, suggesting that there is not one single element which is responsible for the SGC's success. Rather, numerous aspects across the model play a key role. Other important elements provided by researchers in an open-ended way constituted a common funding model which enhances teamwork, quality of research colleagues, a diverse network of exter-

Table B-2:
Ranking of various aspects of the SGC model

	Very important	Important	Neutral	Somewhat important	Not at all important	Response total
Open access	64.7% (11)	35.29% (6)	0% (0)	0% (0)	0% (0)	17
Direct contact with pharma	52.94% (9)	35.29% (6)	5.88% (1)	5.88% (1)	0% (0)	17
The SGC PPP funding model	52.94% (9)	35.29% (6)	11.76% (2)	0% (0)	0% (0)	17
Direct contact with different user groups	41.18% (7)	47.06% (8)	11.76% (2)	0% (0)	0% (0)	17
Established prestige and reputation of the SGC	76.47% (13)	23.53% (4)	0% (0)	0% (0)	0% (0)	17
Effective leadership	64.71% (11)	23.53% (4)	11.76% (2)	0% (0)	0% (0)	17
Effective governance	43.75% (7)	43.75% (7)	6.25% (1)	6.25% (1)	0% (0)	16
Strong links to local university communities	47.06% (8)	41.18% (7)	11.76% (2)	0% (0)	0% (0)	17
Basic research focused on facilitating drug discovery	58.82% (10)	41.18% (7)	0% (0)	0% (0)	0% (0)	17
A paperless operating environment	11.76% (2)	47.06% (8)	35.29% (6)	0% (0)	5.88% (1)	17
The diverse geographical distribution of research partners within the SGC	5.88% (1)	35.29% (6)	41.18% (7)	11.76% (2)	5.88% (1)	17
The diverse geographic distribution of funding partners	17.65% (3)	23.53% (4)	35.29% (6)	23.53% (4)	0% (0)	17
Other important element of the model not mentioned	66.67% (4)	0% (0)	16.67% (1)	0% (0)	16.67% (1)	6

nal collaborators, effective scientific steering from the scientific committee and a pragmatic approach to exploring unknown areas.

A total of 11 respondents believed their SGC research would have further impact on knowledge production in the coming 6–12 months, largely through the development of new chemical probes, epigenetic probes, epigenetic proteins and novel protein structures (mentioned by six researchers).

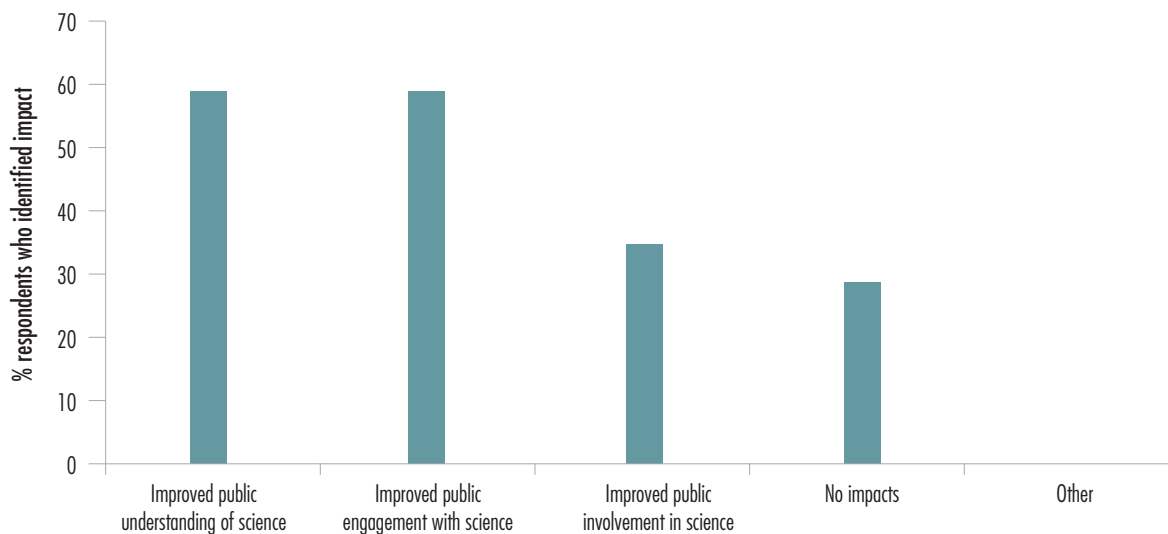
Overall, respondents were very positive about the impact of working with the SGC on knowledge production – from its impact on enabling productive collaborative relationships to enabling the efficient translation of their research. Moreover, researchers highly valued a high number of aspects of the SGC model, rather than one key element such as open access for example.

Knowledge Translation

This section aimed to ascertain how far SGC research has been translated outside academia in relatively general terms. It primarily focused on the process of translation (rather than the specific impacts of translation) and whether or not the process is more efficient within the SGC as opposed to more traditional academic approaches.

The first question asked researchers to select the impacts their SGC research has had on the general public from a pre-defined list. They were asked to select all that apply. Seventeen respondents answered the question and the results are shown in Figure B-5. Only five respondents stated that their research had not had any impact. Moreover, ten respondents stated their research had

Figure B-5:
Impacts of SGC research on the general public



led to improved public understanding of science, ten respondents stated their research had led to improved public engagement with science and six respondents stated their research had led to improved public involvement in science, revealing that where impacts had occurred they had done so in several areas. However, it is important to note that these responses could refer to several different research projects. When asked to identify the routes to these public impacts, respondents identified public lectures (6), teaching and activities with students (3), public engagement activities including presenting on a national Canadian radio show, museum exhibits, podcasts, interviews, workshops, newsletters and educational activities (7).

When probed about the process of translation, 53% (n=17) believed that the SGC model allowed for a larger volume of knowledge translation, 76% (n=17) believed it allowed for a greater speed of knowledge translation and 47% (n=17) believed it allowed for more effective knowledge translation, when compared to more traditional academic approaches. The primary reason given for this was SGC's open access model and pre-publication information sharing, which was mentioned by six respondents. A secondary reason was the volume of research outputs generated by the SGC due to its organisational structure – specifically large numbers of staff and collaborations.

When asked whether they considered the diverse geographical distribution of research part-

ners to be important in enabling knowledge translation of high quality research into benefits for different research users, the majority of respondents answered that they did not know (53%, n=17), while 24% (n=17) thought it was important and 24% (n=17) thought it was not.

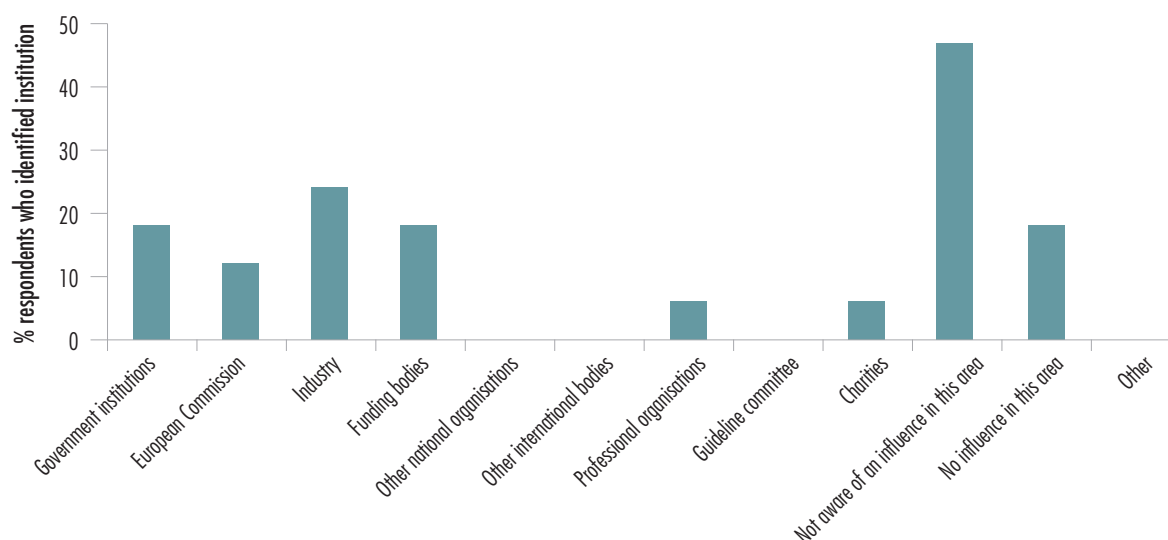
In terms of future knowledge translation, five respondents thought their SGC research was likely to be involved in further knowledge translation in the coming 6–12 months, primarily due to the nature of the work in exploring probes.

Overall, the key message is that the open access model and continuous information sharing along with the SGC's highly collaborative approach enables a very high level of knowledge translation, and indeed this is fundamental to the way in which the SGC operates. This may lead to direct impacts outside of academia, or allow further research to be conducted which may also have significant impacts. The following sections of the survey aim to identify and explore the kinds of impact SGC research has had outside of academia.

Impacts on policy

This section aimed to identify and explore any impacts SGC research may have had on the policymaking process. It primarily consisted of closed questions, although respondents were invited to provide more detail to particular answers in open-ended text boxes.

Figure B-6:
Policymaking institutions affected by SGC research



The first question asked respondents to select institutions that their research had had a policy impact on from a pre-defined list. Seventeen respondents answered the question and the results are shown in Figure B-6.

The results show that the majority of respondents were either not aware of a policy influence (47%) or did not believe their research had had a policy influence (18%). However, four respondents (24%) had had an impact on policymaking in industry and three respondents (18%) were aware of a policy impact on government institutions and funding bodies.

While academic dissemination activities were particularly high, dissemination activities aimed at policymakers were low. Respondents were asked to select all the ways in which their SGC research had been communicated to policymakers from a pre-defined list. Nine respondents answered the question and the results are shown in Figure B-7. The 'other' category consisted of dissemination through the MP patron of FOP Action UK where promotion on rare diseases is promoted by the researcher, and an answer of not known.

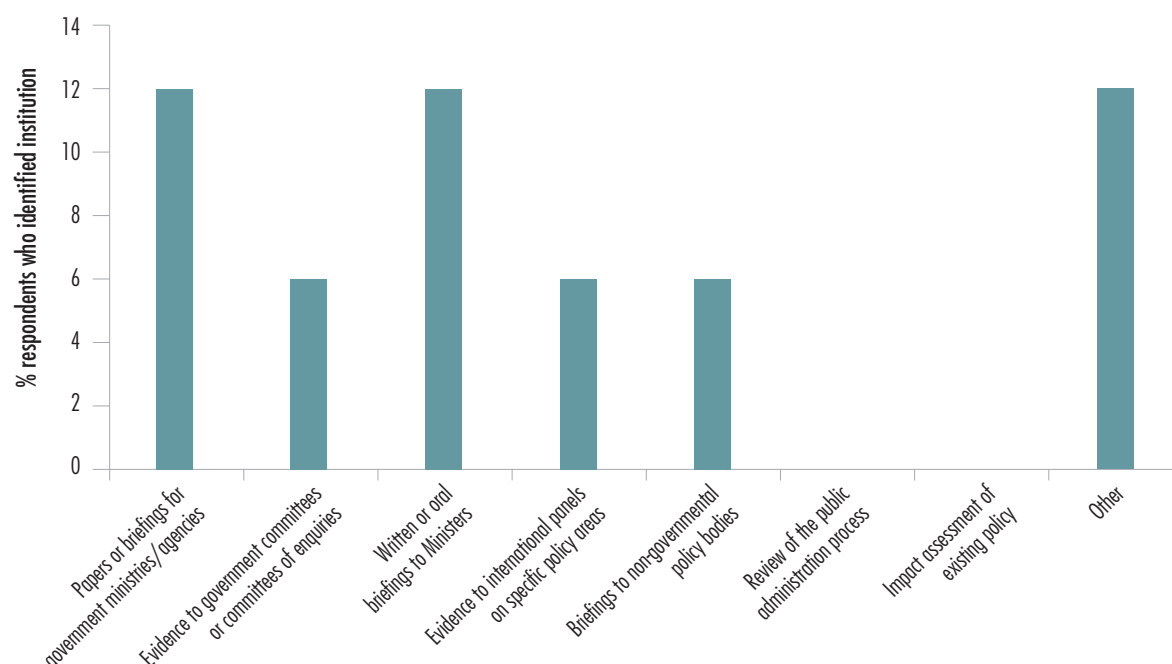
When asked if any policy contributions resulted in changes to the policy process, 7 of 13 respondents stated that it had not. However, two answered it improved the knowledge base for policy development, one answered it provided new resources or reference material to inform the policy process and one stated that it was used for

consultancies for private or public activities. Two respondents also selected 'other', one of which stated that their model has been cited by government agencies and that they are being approached by various bodies by recommendation. The second 'other' respondent stated they did not know. Similarly, very few respondents believed their SGC research had led to a particular policy outcome. Eight respondents (47%) stated that there was no evidence of a policy outcome, while one respondent stated their research provided relevant, high quality evidence that has been cited in a policy document, one stated their research provided high quality evidence that informed the content of a resulting policy, one believed their research that resulted in altered barriers to obtaining research materials and one believed their research altered focus on capacity building initiatives.

Given the distinct lack of policy impacts arising from SGC research, it is not surprising that 81% (n=16) of respondents did not know whether the SGC model of support for research led to greater impact in informing policy than if it had been supported through traditional academic approaches. However, 19% believed it did and the primary reason for this was the interconnectivity of the SGC allowing the message to be communicated effectively and the SGC's leadership's continued interaction with policymakers.

Overall, there have been very few impacts on policy through SGC research. Although various

Figure B-7:
Dissemination activities to policymakers



policy contributions have been reported in very low numbers, and one respondent stated that their interaction with policymakers is increasing, in general impact on this area is weak.

Impacts on health research and innovation

This section specifically examined how SGC research has translated into technologies and/or products within health research and innovation. Questions in this section were primarily closed.

In the first question respondents were asked to select whether their SGC research involved or led to the development or trialing of technologies and/or products from a pre-defined list. Respondents could select all those that applied. Sixteen respondents answered the question and the results are shown in Figure B-8. The most common development was of probes (13), followed by construct clones (10). Two respondents selected 'other' which consisted of antibodies, clinical candidate molecules, cellular assays and antibodies.

The sixteen respondents who answered the above question were then asked to identify the stage of development or use these products are at. Again, respondents selected all that applied from a pre-defined list. Ten respondents selected wide-

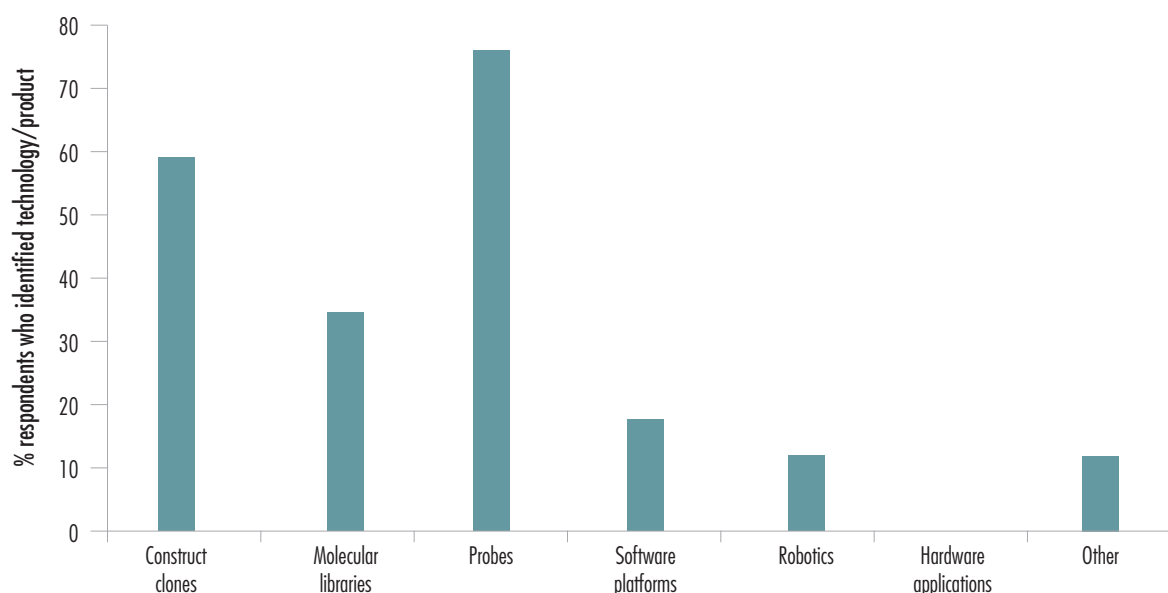
spread distribution, nine selected proof of concept, nine selected 'in use or further development by another company' and 5 selected regional or sector-specific distribution.

The majority of researchers thought that their research would lead to the development or trialing of a therapeutic pharmaceutical product in the future (47%, n=17), while 24% (n=17) stated that their research had not led to this and 12% (n=2) did not know whether their research had led to it or not. However, three respondents noted that their research had already had this outcome, and the products were all either in the identification of drug target phase, phase one clinical trials or phase two clinical trials.

Similarly, three respondents believed their SGC research would lead to the development or trialing of a diagnostic test in the future, whereas eleven respondents stated their research had not led to this and three respondents did not know whether their research had led to it or not.

Four respondents (24%) noted that their research had led to pharmaceutical innovations/processes that are cited by patents or other intellectual property arising, whereas three respondents believed this would happen in the future and ten respondents either did not know whether this had happened or stated it had not. All four respondents

Figure B-8:
Technologies and products produced through SGC research



who had seen this impact stated that a patent had been applied for/filed.

Ten of seventeen respondents believed that the SGC model of support for their research allowed for greater health research and innovation than if it had been supported through traditional academic approaches (seven did not know). The primary reason for this was the revelation of new target areas for exploration along with comprehensive target validation, which was cited by six of eight respondents. Secondary reasons included the benefits of collaboration and teamwork.

When asked about the impact of SGC research on health or healthcare (including healthcare delivery and the training of healthcare professionals), 18% (n=17) believed their research was having an impact in this area, while 24% (n=17) did not and 59% (n=17) did not know. However, none of the respondents believed that their SGC research had let to any direct quantifiable impacts on public or patients' health. In looking to the future, a total of seven respondents believed that their SGC research will have further impact on health research or innovation in the coming 6–12 months. One respondent stated that this may be in the area of antibodies which are already in use in health research and another suggested this may be related to cancer genomics of chromatin signaling. Other respondents spoke in general terms.

Overall, impacts on health research and innovation have been considerable. In large part this is believed to be due to the SGC's approach to gene families, revealing target areas which may otherwise have been ignored. Not only this, but the SGC is able to exclude chemical probes against epigenetic targets.

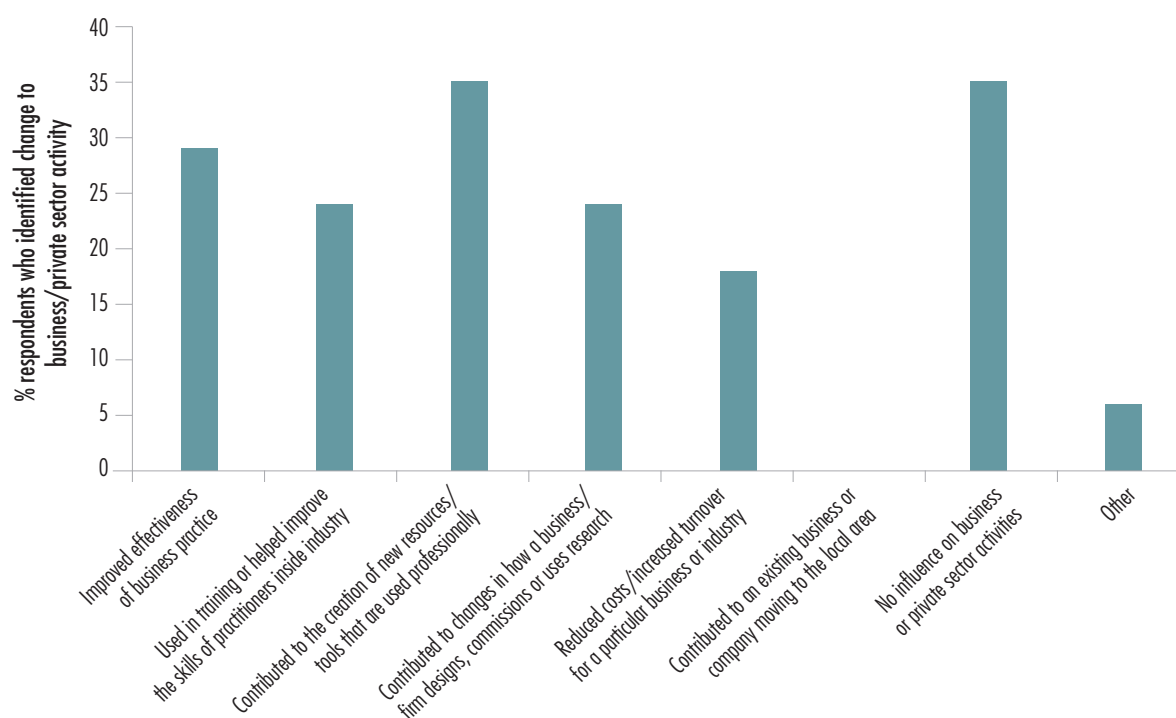
Impacts on the economy

This section aimed to ascertain how SGC research has impacted on business and the private sector.

The first question asked respondents to select all the ways in which SGC research has influenced business or private sector activities from a pre-defined list. Researchers could select all those that applied. Sixteen respondents answered the question and the results are shown in Figure B-9.

Wider economic impacts were also noted by 13 of 16 respondents. The most frequently cited impact was securing external funding which was mentioned by 12 respondents (71%, n=17). Others included the generation of revenue for related universities/colleges and communities by attracting students (41%, n=17), and contribution to employment in the pharmaceutical or other industry (29%, n=17). Moreover, five respondents believed that SGC support for their research has allowed for greater economic impact than if it

Figure B-9:
Impacts of SGC research on business or private sector activities



had been supported through traditional academic approaches, although eleven reported that they did not know whether this was the case or not.

Seven respondents believed that their SGC research would have further economic impact in the coming 6–12 months, one noting that they are currently in the process of setting up a new company branch in Oxford.

Overall, economic impacts are relatively high, with only six respondents stating that their SGC research has not impacted on business or the private sector and three that it has not brought wider economic impacts. Moreover, these economic impacts are expected to continue for seven researchers.

Opportunities and challenges for the SGC

In this section participants were asked to provide the three main opportunities and the three main challenges for the SGC over the next 3–5 years.

Opportunities were provided by 15 respondents, and the majority of them were specifically concerned with furthering the SGC's scientific achievements and reputation. These included the

consolidation of structural biology capabilities, helping the scientific community to identify new drug targets, using chemical probes to prioritise targets, the development of particular molecules towards clinical use to directly benefit patients, deciphering the role of disease-linked genes and mutations and being a continuous, major contributor to the structural biology of human technologies and related technologies, among others.

A secondary opportunity identified by several respondents was the SGC's link between industry and academia. Other than continuing to fulfil this role, which was mentioned by three respondents, it was also noted that the SGC should try to feed structural and chemical biology efforts into academic and industrial entities. The opportunity to further the open access model was also noted by four recipients – specifically to encourage more research organisations (both academic and industrial) to adopt the model, to grow the model of open access beyond pre-clinical research as well as to lead the way in more open access research.

The main barriers offered by respondents were slightly more diverse and were less concerned with the scientific work of the SGC. A key theme amongst the cited barriers to the SGC was related

to the funding of the organisation— although this encompassed several different elements. The first concerned maintaining steady and sustainable funding which was mentioned by five respondents. The second centred on maintaining public funding in order to maintain the neutral status of the SGC as well as open access. Others mentioned funding generally along with balancing funder expectations with resources and getting funding to take novel molecules into clinical trials without patents.

A third theme within the suggested barriers to the SGC was concerned with the organisation's evolution. Four respondents commented that the SGC will need to renew and remain relevant while maintaining focus. A fifth respondent stated that it is important for the SGC to maintain common goals as the organisation becomes more diverse.

The fourth area was concerned with managing collaborations and diverse research groups as the

SGC network continues to grow, which was mentioned by eight respondents. Linked to that notion was the fifth area which constituted the management of a large number of complex projects.

Overall, the majority of opportunities mentioned by researchers related to scientific achievements. Several of these were concerned with consolidating the work of the SGC. However, others mentioned diversifying and moving into new areas which may bring a new set of barriers. Several respondents stated that the SGC needs to be able to renew as an organisation and remain relevant – although the ability to manage a growing number of collaborations and complex projects were also thought to be a key barrier as the SGC continues to grow. Therefore the renewal and growth of the SGC needs to be carefully considered and cannot simply be approached through increasing the number of collaborative networks.

Appendix C: Methodology

Evaluation Approach

Our approach to the evaluation needed to be both fit-for-purpose and focused, while simultaneously providing the analytical rigour which will allow for policy learning to occur both within and outside the SGC. We adopted a staged approach which incrementally enriched the evidence base through the duration of the research project.

Figure C-1 summarises the way in which our evaluation approach was implemented.

WP0. Inception meeting

An inception meeting with the SGC Secretariat and representatives of both public and private partners was the first task in this project.

The purpose of the inception meeting was to:

- Further develop a shared understanding of expectations from the study as a foundation for a productive relationship looking forward.
- Further specify and discuss the data gathering and analyses processes, including access to source documentation, areas of prioritisation in the study, deliverables and deadlines.
- Provide a forum for discussion and refinement of our understanding of SGC's vision of what constitutes success; strategic approach to the programme and portfolio of projects over time; assumptions driving the approach and key areas of uncertainty; and early considerations and questions regarding the future.

Together with background desk-based research (see WP1), the inception meeting was to ensure the underpinning for a suitable implementation protocol for the evaluation.

WP1. Biomedical R&D models and the future context

The work package entailed a focussed literature and document review on:

- alternative models of funding biomedical R&D in the field of SGC activity
- insights on key future trends in the environment which frames SGC activity
- a review of relevant SGC documents (e.g. strategic plans, any prior performance evidence).

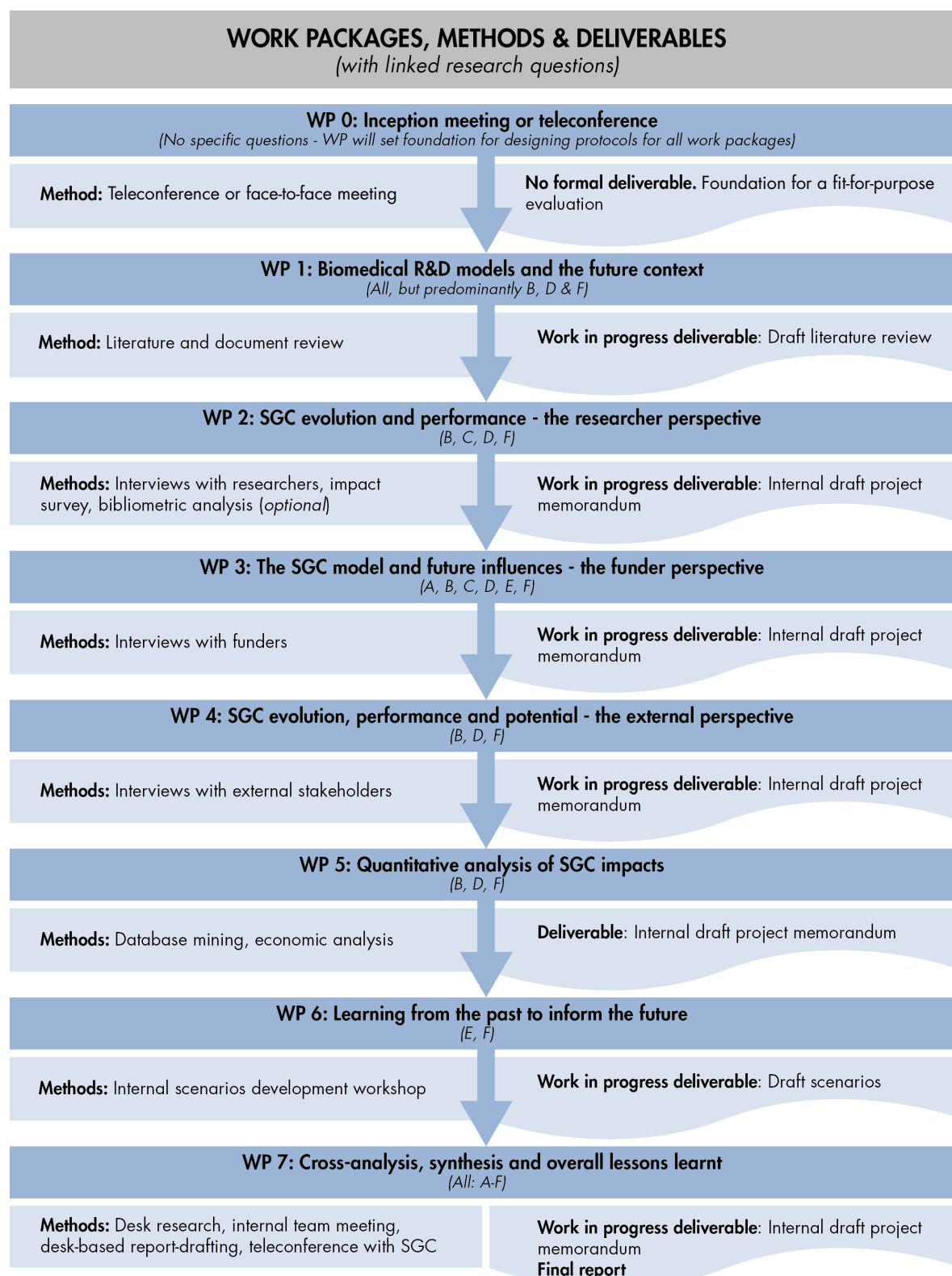
The purpose of the work package was to help map the landscape for the evaluation of SGC, by identifying key factors to examine in more detail when implementing the evaluation through primary research (ie through stakeholder consultation). It also helped to facilitate the interpretation of the evaluation findings in the context of the wider biomedical R&D collaborative landscape at later stages of the evaluation.

The literature review examined key governance and management, scientific and technological, regulatory and political, socioeconomic, and cultural/relational aspects in different biomedical R&D models and their influences on performance. The review helped to analyse the environment in which public-private collaboration in biomedical R&D takes place, including key anticipated features of this environment looking into the future. The review drew insights from literature on both 'closed' and open innovation and public-private partnership models. For example, this included funding of a single organisation or researcher, outsourcing-based collaborations, alliances and joint ventures where IP exists, and collaborations where various levels of open access principles are followed.

Workflow and methods

Figure C-1

An overview of the workflow



WP 2: SGC Evolution and performance – the researcher perspective

It was important for the evaluation to solicit evidence from multiple stakeholders in SGC. In this work package, we focussed on gaining evidence from researchers involved in projects in the SGC portfolio, across Phases I, II and III (to date) of the programme. Given that researchers are key stakeholders, we sought to harness their views and front-line experience of implementing the SGC vision.

We first gathered evidence on the outputs and impacts, including tangible and softer benefits from SGC to date. We then solicited researcher perspectives on key merits and limitations of the SGC model; enablers and barriers or challenges to achieving project objectives; prospects for the future (including opportunities to maximise impact from prior activities); and anticipated future influences in the external environment that will shape SGC operations (eg scientific, financial and regulatory).

WP1 involved two core tasks:

- Task 1 was a survey to identify the diversity of research outputs and impacts
- Task 2 was a series of semi-structured interviews to explore in greater depth the relationships between activities and impacts suggested by the survey

Each is described in further detail.

Task 1. The diversity of research outputs and impacts: evidence from researchers through the impact survey: A bespoke impact survey was designed to capture the outputs and impacts from SGC funded projects and to solicit the views of a broad range of researchers. SGC previously indicated that there are several outputs and impacts from its activity to date – including cost-savings, accelerated science, job creation, saving patients (eg preventing unnecessary dosing with drugs in trials) and publications. The survey set out to explore a diversity of potential benefits in a more comprehensive and organised way and to gather sufficient evidence in support of impact claims.

The survey was structured in a way that allowed subsequent analysis of the findings according to the three main streams of SGC activity (structural biology, binders project, chemical probes). Evidence from the survey was to provide an *initial* comparison of the outputs emerging across these three key areas of the scientific programme over

time (of course, this needs to be examined further and interpreted in the context of the relative investment size and duration of the research portfolio in each key area).

The survey was administered in the format of a web-based questionnaire. It was designed to place a comparatively low burden on respondents, in order to maximise responsiveness. We piloted the survey questions through cognitive interviews on a small sample of respondents to ensure clarity of questions. The survey included a mix of closed focused questions with multiple choice and Likert scale answers to capture the diversity of evolving outputs and impacts from the programme, and to get an indication of their scope and strength. The number of open-ended questions was limited to strike the appropriate balance between response rates, breadth and depth. More in-depth analysis was obtained through interviews.

Task 2. Gaining in-depth insights about SGC performance and the potential of the model: interviews with a sample of researchers. We interviewed 18 researchers representing:

- A range of different projects across geographical areas (eg PIs and Oxford and Toronto Centre Directors, as well as potentially from the former Karolinska Institute site)
- Public and private sector scientists
- Representatives across the research themes of biomarkers, chemical probes and antibodies

Interviews were semi-structured, and explored a range of complementary issues:

- Firstly and primarily, they allowed us to focus on more in-depth qualitative analysis and learning about the SGC's progress, to explore information gaps from the survey, strengthen the evaluation narratives, and begin to explore causal mechanisms at play as perceived by researchers.⁴⁰
- Secondly, the interviews prompted respondents to reflect on what has materialised *vis a vis* what outputs/impacts they would consider to be feasible for this point in time, and on any downstream impacts which are likely to accrue in the future. We solicited evidence on sig-

⁴⁰ ie to tease out the processes in the SGC model which are leading to achieving desired outputs and impacts (eg organisational-model related, science related, cultural/relational, etc)

nals of potential future impacts, required supportive conditions, and what would have happened (or not happened) to their specific area of research and impacts from it, had it not been for the SGC. The evidence was used to provide foresight on prospects for future impact as well as to learning about key conditions for success in this partnership model and its value added.

- Thirdly, to further explore the value added of the SGC model, we solicited researcher views on the merits and trade-offs or limitations of the SGC approach compared to other models of collaboration in biomedical R&D.⁴¹ This element of the interviews was to gauge how the distinguishing features of the SGC model relate to achievements and to impacts.
- Fourthly, we solicited researcher views on what they perceive to be major changes which could take place in the scientific and technological, regulatory, socioeconomic and political environments which might impact on future SGC activity looking towards 2015–2020 (assuming a Phase IV).

The findings were anonymised. This principle applies to the engagement of all study participants across work packages.

WP3. The SGC model and future influences – the funder perspective

Clearly, the buy-in and commitment of diverse funders is central for the sustainability and impact from SGC activity. Understanding their perspectives on the achievements, benefits, limitations and future prospects for the SGC model and activities was therefore crucial, particularly as different partners may have a mix of common, unique, complementary or divergent perspectives and reasons for engaging with the consortium. In light of this, we conducted 17 interviews with representatives of each funder organisation across Phases I, II and III).

The design of the interview protocol was informed by the findings from WP0-2, and associated tasks. The interviews focussed on examin-

ing funder insights on the following key evaluation issues:

- What were the convincing arguments for funding the SGC when decisions to fund Phase III were being made and what was the source evidence to funders for these arguments?
- Related to the above, what were the *expected* outputs and impacts (tangible and softer benefits) for the scientific and funder community when decisions to fund Phase III were being made (as perceived by funders)?
- The relative importance of the three key areas of the SGC scientific programme for funders, and exploring any changes in their perceived relative importance over time.
 - Reactions to ‘headline findings’ from the researcher impact survey and interviews, and the funder’s own and additional views on the consortium’s past and current performance track, and on enablers and barriers to date. This was to provide insights on funder perspectives on SGC’s past and present performance track.
 - Whether and why it is beneficial to invest in SGC as opposed to alternatives – ie their experience of the merits and trade-offs of the SGC model in comparison with alternatives.
 - What they would have happened (or not happened) to each of the three key areas of the scientific programme and impacts from it, had it not been for the SGC (and why). Examples in support of their claims (eg such as experience from other relevant efforts)⁴² were sought.
 - The limitations and risks they foresee in future rounds of SGC funding and how they might like to see these addressed.
 - Key changes in the external and internal context they envisage affecting SGC activity in the future looking to 2015–2020. This included scientific and technological, regulatory, political and socioeconomic environments, and the wider research and PPP landscape.⁴³

⁴¹ This is as opposed to more traditional models such as in-house R&D funding, funding individual PIs and IP-based institutional or collaborative arrangements including those involving both public and private actors in relevant fields of activity.

⁴² ie efforts aiming to achieve similar objectives and from initiatives with different external, governance and operational contexts.

⁴³ We suggest following the PESTEL framework as a guiding structure.

WP4. Evolution, performance and potential – the external perspective

In order for evaluation findings to have legitimacy and credibility, it was important to validate, test and triangulate the emerging insights informed by SGC researchers and funding partners, with the perceptions and insights from external stakeholders.⁴⁴ We conducted nine interviews with a sample of external stakeholders in the research, PPP and funding communities in biomedical R&D space relevant for SGC activity (eg structural biology, chemical probes, binders). Suitable interviewees were identified depending on emerging insights from earlier phases of a staged evaluation and in discussion with the SGC.

The interviews solicited external stakeholder views on:

- The relative strengths /merits and limitations of the SGC model *vis a vis* other forms of organising research in this space.
- Future trends, opportunities, challenges in external context conditions which could impact on the SGC model and activity in a Phase IV, and on the general landscape within which this type of research takes place.

WP5. Quantitative analysis of SGC impacts

In this work package, we assessed some of the major quantitative data available on the impacts of SGC (and compared them to the impacts of competing approaches in structural genomics). We assessed the volume of production of SGC and other organisations against funding commitments (from SGC documentation and other organisations annual reports), to provide quantitative data on one measure of productivity within SGC. This measure of productivity (outputs per dollar input) is a useful tool for discussion in future funding rounds, since it speaks to the investment capacity in SGC.

WP6. Learning from the past to inform the future

Drawing on insights from previous work packages, we held an internal evaluation team workshop, in which four scenarios were developed regarding the likely future world in which SGC will operate in Phase IV. Factors which are likely to be particularly important or certain were included in all scenarios, where those of potentially secondary importance or greater degrees of uncertainty were used to differentiate between the scenarios. We developed coherent narratives around each of these futures as outputs. The objectives of scenarios were to be useful for SGC when exploring the different directions possible for the next phase of the consortium.

WP7. Cross analysis, synthesis and overall lessons learnt

In this work package we cross analysed and synthesised evidence from the SGC research, funder and external stakeholder community and across all work packages to provide a rigorous, stakeholder inclusive analysis of evidence on the six key research issues.

⁴⁴ [We acknowledge there is always the possibility of inherent biases or internal interests influencing interviews, but nevertheless expect them to provide a useful additional lens on the consortium model. In addition, we will design the interview protocol to solicit evidence in support of interviewee claims, and interpret evidence in context and against views of other study participants].